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Industrial Surface Impoundments in the United States

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Office of Solid Waste
U.S. Environmental Protection Agency
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In memory of the late Oliver Fordham,
who performed the field sampling for this study.

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Executive Summary

EPA's study, *Industrial Surface Impoundments in the United States*, originates from the Land Disposal Program Flexibility Act (LDPFA), an amendment to the Resource Conservation and Recovery Act (RCRA) enacted in 1996. The LDPFA exempts certain decharacterized wastes from provisions of the RCRA land disposal restrictions. "Decharacterized" wastes are hazardous wastes that have had their hazardous characteristics–that is, ignitability, corrosivity, reactivity, or toxicity–removed through dilution or other treatment. The LDPFA exemption allows decharacterized wastes to be either: (1) placed in surface impoundments that are part of wastewater treatment systems whose ultimate discharge is regulated under the Clean Water Act (CWA), or (2) disposed of in Class 1 nonhazardous injection wells regulated under the Safe Drinking Water Act. Because of concerns regarding constituents that might remain in the wastes after removal of the characteristic, Congress required, in the LDPFA, that the Environmental Protection Agency (EPA) conduct a study "to characterize the risks to human health or the environment associated with managing decharacterized wastes in CWA treatment systems" and to "evaluate the extent to which risks are adequately addressed under existing State or Federal programs and whether unaddressed risks could be better addressed under such laws or programs."[1]

Additionally, in 1997 EPA agreed to an amendment to an existing consent decree, *Environmental Defense Fund vs. Whitman,* D.C. Circuit, 89-0598 (EDF consent decree), to include a requirement for a study of air risks from surface impoundments. The amended consent decree required a study of air risks from several different kinds of waste management units and an evaluation of gaps in regulatory controls for air risks posed by waste management practices. The specific part of the air risk consent decree requirement pertaining to surface impoundments in essence became a complementary study for the LDPFA study, since its time frame for completion matched the LDPFA study and it imposed similar requirements on EPA–a risk assessment and evaluation of regulatory coverage. Two of the major differences between the consent decree requirements and the LDPFA study were the consent decree requirement's focus on a single route of human exposure to pollutants–the air inhalation route–and the regulatory status of the wastes required to be studied. While the LDPFA requires a study of nonhazardous wastes that, at some point in time, exhibited a characteristic of hazardous waste, the consent decree requires EPA to study nonhazardous wastes that have never been classified as hazardous wastes. The consent decree also requires EPA to identify potential regulatory gaps in the current RCRA hazardous waste characteristics and the Clean Air Act (CAA) programs.

This report summarizes EPA's study. It begins by describing the nature and variety of industrial surface impoundments and the wastewaters they manage. In 1996, when EPA began

[1] Congress, in the LDPFA, also required that EPA conduct a study of nonhazardous injection wells. The results and findings of that study are reported in U.S. EPA, Office of Groundwater and Drinking Water, 2001, *Class I Underground Injection Control Program: Study of the Risks Associated with Class I Underground Injection Wells,* Washington, DC.

this study, there was limited information on industrial impoundment sizes, designs, and operating characteristics, and there was limited information on the wastewaters managed in industrial impoundments. This report, comprising an analysis of survey data, risk analysis, and regulatory coverage findings, is the result of EPA efforts over the past 5 years to fill information gaps and meet legislative and consent decree obligations. The report quantifies and describes the potential risks to human health and the environment posed by chemical constituents present in the wastewaters managed by industrial surface impoundments. It also identifies existing regulatory controls and nonregulatory programs that can be used to address potential risks.

Overview of Survey and Risk Assessment Findings

Methodology

EPA estimates that, in the 1990s, there were approximately 18,000 industrial surface impoundments in use throughout the United States. These surface impoundments were present at about 7,500 facilities located primarily east of the Mississippi River and in Pacific Coast states. Because of the scope of the universe, EPA conducted the study focusing on a sample of U.S. facilities that use impoundments to manage industrial nonhazardous waste. Most of the facilities selected for the study were chosen randomly to ensure that the sample facilities would be representative of the facilities in the study population. EPA sent surveys to 221 facilities to collect information on their impoundments and the wastes managed in them. EPA requested information on the presence and quantities of 256 chemical constituents in the impoundments, as well as on the impoundments' design and operation. EPA used these data to characterize the potential risks that may be posed by managing the wastes in impoundments. The survey responses on the presence and concentrations of specific chemical constituents were particularly central to EPA's analysis. EPA also collected and analyzed wastewater and sludge from impoundments at 12 facilities in the study and used that information to illuminate the completeness and accuracy of the survey data. EPA also used data from a variety of other sources such as facility permit files, U.S. Census data, and technical references.

In the first part of this report, EPA presents the survey findings, then the risk assessment findings. The survey data provide information on the sizes and nature of the industrial impoundment population, the impoundments' environmental settings, historical summaries of liner failure and overtopping events, and the impoundments' designs and operating practices. EPA conducted a risk assessment using the survey data and other sources of data. The risk assessment consisted of a risk analysis in which EPA developed estimates of the chronic risks that are potentially posed by three pathways (air, groundwater, and groundwater to surface water) and a risk screening in which EPA considered the potential for other indirect pathway and ecological hazards.

EPA conducted the risk analysis and risk screening in stages in order to screen the thousands of possible data points, focus the analysis where most warranted, and, ultimately, characterize the potential risks associated with industrial surface impoundments. In the first stage, EPA applied precautionary exposure assumptions to screen out impoundments of no concern and identify those that merited additional analysis. In subsequent stages, EPA used data on actual exposure and used various fate and transport modeling tools to estimate potential risks.

EPA's risk screening of the other indirect pathways and ecological hazards was similar to the initial stages of the risk analysis. Thus, the characterization of the other indirect pathway hazards and ecological hazards developed in this study is less certain than the characterization of risks via air, groundwater, and groundwater to surface water.

In the risk analysis, EPA used several chronic risk and hazard measures to evaluate potential threats to human and ecological receptors from chemical constituents managed in surface impoundments. EPA developed estimates of the excess individual lifetime cancer risk posed to humans by exposure to carcinogenic chemicals. Chemicals with noncancer health effects were evaluated using threshold measures of hazard. EPA developed hazard quotients (HQs), which are the ratio of the dose of contaminant expected at an exposure point to an appropriate safe reference dose. Other risk measures were also developed for the risk screening to examine the threats associated with consumption of contaminated fish and with ecological hazards. In determining what risks were of concern at each stage of the analysis, EPA generally used a cancer risk of 1 or more in 100,000 and an HQ of 1 or more as the criteria for deciding whether to retain an impoundment for the next stage of evaluation.

Characterization of Surface Impoundments

In the United States, industrial surface impoundments are an important and widely used industrial materials management unit. Surface impoundments serve a variety of beneficial uses in a number of industrial processes. Industrial facilities that produce wastewaters often use surface impoundments to perform necessary wastewater treatment prior to discharge into surface waters. In other cases, industrial facilities may need to control wastewater flows and use surface impoundments for storing excess wastewater. In still other cases, industrial facilities may use surface impoundments to manage their excess wastewaters through evaporation or seepage into the ground.

EPA's best estimate is that two-thirds of the 18,000 industrial impoundments in the United States, or about 11,900 impoundments located at 4,500 facilities, contain at least one of the 256 chemical constituents that were of interest for this study or contain high (11 to 12.5) or low (2 to 3) pH wastewater. Surface impoundments are used by many industrial sectors, such as manufacturing, bulk petroleum storage, air and truck transportation, waste management, and national security. The wastewaters managed in these surface impoundments are primarily from manufacturing and washing processes and certain contaminated stormwaters. More than half of the impoundments with chemical constituents or pH of interest are in the chemical, concrete, paper, and petroleum industries.

Industrial impoundments vary greatly in size, from less than a quarter of a hectare (1/3 of an acre) to several hundred hectares. The larger impoundments provide the bulk of the total national industrial impoundment capacity. On a volume basis, the paper and allied products sector manages roughly two-thirds of the total quantity of wastewater, more waste in impoundments than all of the other industry categories combined.

Industrial impoundments frequently use management techniques that increase the potential for chemical releases and frequently are found in environmental settings that increase the potential for impacts to humans or ecosystems in the event of a chemical release. In this study, EPA found that most industrial impoundments are located only a few meters above groundwater and that, in most cases, shallow groundwater discharges to a nearby surface waterbody. More than half of the impoundments do not have liner systems to prevent the release of wastes to soil or groundwater. In addition, about 20 percent of impoundments are located within 150 meters of a fishable waterbody, so migration through the subsurface to the nearby surface water is possible. Finally, while aeration can have certain benefits, it also increases volatilization and the potential for airborne contaminant migration. EPA found that about 45 percent of the total wastewater quantity managed in impoundments is aerated.

There is potential for people to be exposed to chemical constituents released from industrial impoundments. EPA estimates that more than 20 million people live within 2 kilometers (or about 1.2 miles) of an industrial impoundment that was in operation during the 1990s, and about 10 percent of the impoundments have a domestic drinking water well located within 150 meters of the impoundment's edge.

After evaluating impoundment settings and operations and confirming there was potential for releases, EPA went a step further and conducted a risk assessment to examine the degree to which the chemicals found in impoundments were likely to be released from impoundments and ultimately expose people to harmful chemicals.

The results of the survey are presented in Chapter 2. Appendix A outlines the survey methodology and quality assurance procedures. Appendix B presents more comprehensive and detailed reporting of results. Appendix E discusses the field sampling effort.

Risk Analysis Findings

EPA is basing its conclusions on two sets of risk results. The first set of risk results are those calculated using reported survey values for specified constituent concentrations present in the impoundments. These risk results, therefore, reflect model results from reported concentrations. The second set of risk results are those calculated either using imputed values, where survey respondents reported constituents as being present but did not provide quantities, or using detection limit levels when constituents were reported at less than a limit of detection. Consequently, the second set of risk results are considerably more uncertain.

On a national scale across all pathways in the risk analysis, EPA found that only 5 percent of the estimated 4,500 in-scope facilities and 2 percent of the estimated 11,900 impoundments may pose **risks** to human health. However, EPA also found that 21 percent of facilities nationally, corresponding to 24 percent of impoundments, have the potential for **environmental releases** to occur from impoundments. While these releases do not appear to pose risk to human health, they do indicate that selected contaminants in excess of health-based levels have the potential to move beyond the surface impoundment confines and into the environment.

In the risk analysis, in addition to the national aggregated results, EPA developed risk estimates for three pathways of potential exposure by which chemical constituents could move from an impoundment, through the environment, and be available to be inhaled or ingested by people nearby:

- Direct inhalation risks can occur if a constituent of concern evaporates from the impoundment's water surface, is carried by air dispersion to nearby residences, and then is inhaled by residents. EPA developed risk estimates for the closest residences, based on locations reported in the surveys or identified through census information, and generated national estimates.

  About 92 percent of impoundments were found to pose no air inhalation risk of concern. About 1 percent of impoundments are estimated to have a risk of concern from the inhalation of airborne contaminants. In addition, an estimated additional 3 percent of impoundments do not pose air inhalation risks to people nearby, but do generate releases to the air that exceed health-based levels at a distance of 25 meters from the impoundments. The remaining 4 percent of impoundments could not be evaluated conclusively because of the use of detection limits or inferred data due to incomplete reporting.

- Groundwater risks can occur if impoundments release a constituent of concern through the bottom or sides of the impoundment and these chemicals enter groundwater and move through the subsurface to a drinking water well. EPA estimated risks that could occur due to consumption of water from the closest drinking water wells reported in the surveys or identified through census information, and then generated national estimates. Groundwater contaminant migration depends on many factors, but migration can be slow. EPA's modeling did not examine the speed of contaminant movement, so some of the reported risks may occur in the future.

  Groundwater risks also appear low; 67 percent of impoundments have no evidence of risk. Less than 1 percent of impoundments are estimated to have the potential for risk exceedances. In addition, 11 percent of impoundments have the potential to generate contaminated groundwater plumes that may extend 150 meters or more beyond the unit boundary. The remaining 22 percent of impoundments, while not estimated to cause a risk, could not be evaluated conclusively for their potential to result in a release to the environment because of incomplete reporting of concentration information.

- Groundwater to surface water risks can occur if constituents in an impoundment migrate through groundwater, discharge into nearby surface water, and contaminate fish and make drinking the surface water a concern. From the survey data, EPA generated national risk estimates that identified situations where human health ambient water quality criteria (HH-AWQC) might be exceeded in surface waterbodies.

EPA estimates that less than 1 percent of impoundments contribute to exceedances of HH-AWQC in nearby surface waters. EPA estimates 19 percent of impoundments, while not causing exceedances of HH-AWQC once dilution has occurred in the surface water, are estimated to generate releases that could cause groundwater to exceed the HH-AWQC at the point of groundwater discharge into the surface water.

Risk Screening Findings

EPA also screened for potential risks to human health through indirect pathways that were not considered in the risk analysis and for potential risks to ecological receptors. The objective of the screening was to determine the worst case potential for wastes of concern to cause harm.

- Indirect pathway hazards can occur when humans ingest foods that have been contaminated indirectly by surface impoundment releases. For example, constituents can evaporate, move by dispersion through air, and then deposit on nearby crops and contaminate food sources. EPA's methodology resulted in estimates of potential indirect pathway hazards that were ranked categorically. Approximately 6 percent of the facilities fell into the highest category, indicating that this group of facilities has the greatest potential to result in an indirect risk of concern. However, this analysis does not confirm that facilities in this group actually have indirect risks of concern.

- Industrial wastes managed in surface impoundments may potentially cause adverse effects on nonhuman organisms and natural systems. Many impoundments are located near waterbodies and are freely accessible to wildlife. For this study, EPA assessed the potential for impoundments to pose risks to populations and communities of ecological receptors that live in and near surface impoundments both during their operation and in the event that the impoundments were closed with exposed wastes remaining in place. EPA estimates that approximately 29 percent of facilities may have localized ecological impact during their operation or after closure if ecological receptors inhabit the impoundment area or the nearby areas affected by undiluted impoundment runoff.

The results of the risk analysis and risk screening are presented in Chapter 3 of this report. Appendix C describes the methodology and more detailed findings.

Evaluation of Existing Federal and State Programs

Methodology

The LDPFA requires EPA to assess the various federal and state regulatory and nonregulatory programs that address potential risks from surface impoundments and evaluate the adequacy of such programs. In addition, the EDF consent decree requires us to determine the

need for a RCRA air characteristic to address potential air pathway risks from the studied surface impoundments.

Our general approach for the regulatory coverage analysis included a detailed review of applicable federal and state regulatory and nonregulatory programs. The regulatory coverage analysis and identification of gaps in this coverage focused on the potential for risks as determined by our human health and ecological risk screening analyses. The regulatory analysis addresses each of the health pathways of concern and potential risks to ecological receptors. We divided our analysis into two parts: (1) regulatory coverage of direct air inhalation risks, and (2) regulatory coverage of all other "nonair" risks.

To evaluate regulatory coverage and potential gaps for direct air inhalation risks, we reviewed two federal statutes: RCRA, that is, the hazardous and nonhazardous waste programs under this act, and the CAA. The CAA analysis involved three interrelated elements: (1) a waste management unit analysis to identify CAA provisions that can address surface impoundments; (2) a constituent coverage analysis, which focused on the constituents of concern from the risk assessment; and (3) an industry coverage analysis, which focused on the industry categories that were within the scope of this study. We then evaluated possible regulatory coverage by state programs. For potential nonair pathway risks posed by nonhazardous wastes in surface impoundments, we (1) identified constituents of concern from the groundwater and groundwater to surface water pathways, (2) identified federal regulations and programs that may address such risks, and (3) assessed coverage by state programs.

Regulatory Analysis Findings

Overall, the study shows that regulatory and nonregulatory coverage of potential air risks is extensive and that any gaps in coverage appear to be limited to specific industry sectors, individual facilities that meet certain CAA exemptions, or specific air pollutants. The primary regulatory program that addresses potential air risks from industrial surface impoundments is the CAA National Emission Standards for Hazardous Air Pollutants program. Pursuant to section 112 of the CAA, all source categories that emit hazardous air pollutants and pose risks to human health should be regulated when the maximum achievable control technology program is fully implemented. There also are several other existing regulatory and nonregulatory programs that, to varying degrees, address air releases from industrial surface impoundments. These programs include the RCRA Corrective Action Program, the CAA Criteria Air Pollutant Program, state regulations pursuant to State Implementation Plans, the Voluntary Industrial Waste Management Guidance Program, and federal and state waste minimization programs.

For groundwater, the study shows that regulatory and nonregulatory coverage of potential groundwater risks is extensive, but may still have some limited gaps. Potential groundwater risks from industrial surface impoundments, including the groundwater to surface water pathway, are addressed primarily through state regulatory and nonregulatory programs. Based on our available information, most states have one or more programs that include provisions for controlling or addressing groundwater releases from industrial nonhazardous waste surface impoundments. The level of regulatory control or ability to address these releases, however, varies from state to state. These state regulations may be implemented under either general solid and industrial waste

management authority or under water program authority, for example, a state National Pollutant Discharge Elimination System (NPDES) program. Additionally, there are RCRA, CWA, and Safe Drinking Water Act (SDWA) programs that also, to varying degrees, address groundwater releases or assess the susceptibility of drinking water sources to contamination. These programs, for example, include the SDWA Source Water Assessment Program, SDWA Wellhead Protection Programs, RCRA Corrective Action Program, the Voluntary Industrial Waste Management Guidance Program, NPDES program, and federal or state waste minimization programs.

The results of EPA's regulatory analysis are presented in Chapter 4 of this report. In addition to identification of potential regulatory "gaps," EPA discusses the limitations of the analysis and existing and future regulatory or nonregulatory tools that may be used to address identified gaps.

Study Conclusions

Today's study satisfies both the requirements of the EDF consent decree and the LDPFA with regard to evaluating the risks and regulatory programs for surface impoundments receiving "decharacterized" wastewaters and never characteristic wastewaters. In both cases, EPA has conducted an extensive analysis of the impoundment universe to understand the risks that may be posed and the extent to which risks are addressed by current and emerging federal and state programs.

In conducting the study pursuant to the EDF consent decree, EPA obtained the information necessary to determine whether a rulemaking to promulgate a hazardous waste characteristic should be initiated. Specifically, EPA examined the universe of impoundments that manage nonhazardous wastewaters. In addition, EPA characterized the pollutants of concern, likely releases, and pathways from these impoundments and assessed potential risks to human health and environment. Little risk has been found, and any risk found is not widespread, but may exist at a facility-specific level. Further, EPA examined the regulations that may apply to impoundments under a variety of federal and state authorities and found that coverage is extensive, but may not be complete in all cases. EPA identified a number of tools (for example, CAA, RCRA, state programs) that can be used effectively to mitigate risks as alternatives to a new hazardous waste characteristic.

In conducting the study pursuant to the LDPFA, EPA completed a study of "decharacterized" wastewater that characterizes the risks to human health or the environment associated with such management. The completed surface impoundment risk study will be undergoing a formal peer review process by EPA's Science Advisory Board expected to begin in early summer. In light of the planned peer review, any technical data in the report should be used with appropriate caveats and cautions. Further, EPA examined existing federal and state programs to evaluate the extent to which risks are adequately addressed under those programs and looked at whether the risks could be better addressed under such laws or programs. EPA concluded that there are some limited gaps in regulatory coverage, but did not find any serious risks that are unaddressed by existing programs. The Agency has not yet determined whether any specific regulatory actions are appropriate to mitigate the potential risks identified in the study.

Chapter 1

Study Background

This chapter explains the legal framework and issues that form the Surface Impoundment study's background, the previous studies of industrial surface impoundments, and the specific purpose and scope of this study. A brief overview of the technical part of the study methodology is included. Further explanations of the technical and program coverage methodologies are found in Chapters 3 and 4.

1.0 Introduction

In the late 1970s to mid-1980s, the U.S. Environmental Protection Agency (EPA) conducted research on industrial surface impoundments. Between 1990 and 1997, certain issues arose concerning industrial impoundments, the nonhazardous (or formerly hazardous) wastes managed in them, the potential risks posed by managing those wastes in impoundments, and how existing regulations address potential risks. These issues were identified in the Land Disposal Program Flexibility Act (LDPFA) legislation that amended the Resource Conservation and Recovery Act (RCRA) and also in a consent decree (*EDF v. Whitman*). Both the legislation and the consent decree required EPA to study the issues. To resolve these issues, EPA needed specific information that was not available from previous research.

1.1 Previous Studies Defining and Characterizing Surface Impoundments

EPA performed a comprehensive census of agricultural, mining, industrial and municipal surface impoundments in the late 1970s and early 1980s (U.S. EPA, 1983b). In this census, the investigators located and categorized approximately 30,000 industrial surface impoundments (SIs). The census included information on these impoundments' geographic distribution, sizes,

industry categories, functions, and potential for groundwater contamination. The data identifying the facilities and their locations were not available to be used to help design this study.

At the time this census was performed, the federal RCRA hazardous waste regulations were just beginning to be implemented. These regulations included requirements for surface impoundment design and operation; the original requirements for hazardous waste surface impoundments were tightened in the mid-1980s. These requirements caused many facility owners and operators to change their waste management practices for hazardous wastes and manage more of their wastes in tanks rather than in surface impoundments.

In 1985, EPA conducted a telephone screening survey (U.S. EPA, 1987) of facilities that managed nonhazardous waste in onsite waste management units, including surface impoundments. The definition of surface impoundment used in the telephone screening survey was slightly different from the definition used in the 1983 census, and the telephone screening survey study involved selected industry sectors rather than the broader range of industry sectors covered in the 1983 census. The 1985 telephone screening survey results indicated that approximately 15,000 surface impoundments were being used to manage nonhazardous waste.

During this study, EPA conducted a literature search to determine whether other organizations had performed either national or regional studies of surface impoundments. There was limited information in the public domain, and many of the published references on surface impoundments that EPA found were journal articles describing topics relating to a single impoundment or a single facility's impoundments. EPA found very few published risk assessments of human or ecological effects posed by managing wastes in surface impoundments.

1.2 Legal Framework and Issues

1.2.1 Resource Conservation and Recovery Act - Background

RCRA establishes "a 'cradle-to-grave' regulatory structure overseeing the safe treatment, storage, and disposal of hazardous waste."[1] The first step in the cradle-to-grave process is determining which wastes are hazardous. The statute delineates two types of hazardous wastes: those wastes listed specifically by EPA as hazardous, and those that are hazardous because they exhibit some objectively quantifiable property or characteristic (such as ignitability, corrosivity, reactivity, or toxicity) identified by EPA. This study concerns the latter type: so-called "characteristic" hazardous wastes.

In 1984, Congress amended RCRA to prohibit land disposal of hazardous wastes unless hazardous constituents in the wastes are substantially destroyed, removed, or immobilized so that threats to human health and to the environment posed by the wastes' land disposal are minimized. Normally, this land disposal restrictions (LDR) requirement is satisfied by pretreating hazardous wastes before they are land disposed. Implementing this requirement for characteristic hazardous wastes, however, raises significant issues about the extent to which

[1] *United Technologies Corp. v. EPA*, 821 F. 2d 714, 716 (D.C. Cir. 1987).

pretreatment can be required. This is because, under RCRA regulations, characteristic wastes are no longer identified as hazardous wastes once they no longer clearly exhibit a hazardous waste characteristic. For example, a waste acid with pH less than 2 no longer exhibits the corrosivity characteristic when its pH is greater than 2 and, thus, is no longer a hazardous waste (assuming corrosivity is the only reason this waste was classified as hazardous).

The issue raised for purposes of the LDR program was whether EPA could require further treatment of characteristic wastes even if they no longer exhibited a characteristic. Such treatment could be needed to minimize threats posed by the wastes' land disposal (the overall standard for assessing when land disposal is permissible) because characteristic hazardous wastes may pose hazards for reasons in addition to the characteristic property they exhibit. For example, characteristic hazardous wastes can contain problematic concentrations of hazardous constituents. In its rule of June 1, 1990, EPA imposed further treatment of characteristic hazardous wastes even when the wastes no longer exhibited a characteristic. Such treatment was intended to minimize threats posed by land disposal.

Because the statute requires that hazardous constituents must be destroyed, removed, or immobilized in order for threats to be minimized, this means, ordinarily, that hazardous constituent levels cannot be reduced by means of dilution. EPA's LDR rules thus contain a prohibition on dilution being used as a substitute for treatment that destroys, removes, or immobilizes hazardous constituents. Applied to characteristic hazardous wastes, this means that merely removing a characteristic property by dilution is inadequate treatment if the waste also contains hazardous constituents (as most characteristic wastes do), since the hazardous constituents would not be immobilized or destroyed, and, consequently, threats posed by land disposal would not be minimized.

The most difficult issue presented by the question of dilution of characteristic wastes, and the one that (eventually) occasioned this study, arises when wastewaters exhibit a characteristic, become decharacterized as a result of dilution, and are then land disposed in waste management units affected by either the Clean Water Act (CWA) or the Safe Drinking Water Act (SDWA). The chief example is where a manufacturing plant's wastewaters, some of which exhibit a characteristic, are commingled—resulting in decharacterization by dilution— and then treated in a surface impoundment, a land disposal unit. The ultimate discharge of wastewaters from the impoundment to navigable waters, or to publicly owned treatment works (POTW), is regulated by the Clean Water Act.

Although in such a case the wastewater would be land disposed (i.e., placed in the impoundment) without hazardous constituents in the characteristic wastes being destroyed, removed, or immobilized (i.e., they would be merely diluted), EPA chose, in the June 1, 1990, rulemaking, not to require treatment in advance of land disposal because of the likelihood of substantial disruption of CWA treatment programs. Subsequently the D.C. Circuit Court agreed with EPA only partially, holding that such dilution was permissible only to the extent treatment in the impoundment removed the same amount of hazardous constituent before ultimate discharge as would otherwise be required by the treatment standard. (*Chemical Waste Management, Inc. et al. v. EPA.*)

It is this aspect of the Court's opinion that Congress addressed in the 1996 Land Disposal Program Flexibility Act (Public Law 104-119). Instead of immediately requiring the equivalent treatment requirement adopted by the D.C. Circuit Court, Congress amended the statute to allow most characteristic wastes to be decharacterized by any means (including dilution) and managed in surface impoundments whose ultimate discharge is regulated under the Clean Water Act[2] or managed in underground injection wells regulated under the Safe Drinking Water Act. Congress further required EPA to study risks to human health and to the environment posed by managing decharacterized hazardous wastes in surface impoundments whose ultimate discharge is regulated by the CWA or by managing decharacterized hazardous wastes in underground injection wells regulated under the Safe Drinking Water Act. For risks found, EPA is required by the LDPFA to evaluate the extent to which those risks are adequately addressed under existing regulatory or nonregulatory programs. If risks are found that are not adequately addressed, then EPA may "impose additional requirements" or rely on other state or federal programs to address risks found (RCRA section 3004(g)(10)).

EPA's Office of Solid Waste (OSW) conducted this study on surface impoundments, and EPA's Office of Groundwater and Drinking Water (OGWDW) separately conducted the study on underground injection wells (U.S. EPA, 2001).

In 1997, as part of negotiations over the terms of a consent decree in U.S. District Court,[3] EPA agreed to study human health risks from air inhalation posed by the nonhazardous wastes managed in surface impoundments that were not part of the LDPFA study. These consent decree nonhazardous wastes are called **never characteristic** wastes in the rest of this report. The LDPFA study wastes are called **decharacterized** wastes in the rest of this report.

1.2.2 Clean Water Act - Background

The Clean Water Act establishes a program that controls the discharge of pollutants into the waters of the United States. When facilities use water for some purpose and contaminate it through use, or channelize precipitation that runs off into surface water, they generally direct the flow

- Toward or into surface water
- Into a municipal wastewater collection system (where it is treated in a POTW)
- Into a topographic depression (low-lying area) where it either evaporates or percolates into the ground.

[2] RCRA sections 3004(g)(7) and (8). Decharacterized wastes for which EPA specified a method of treatment remain prohibited from land disposal, as do reactive cyanide wastes (RCRA section 3004(g)(8)).

[3] *Environmental Defense Fund, Inc. vs. Christine Todd Whitman, Administrator, United States Environmental Protection Agency, et al., Defendants, and American Petroleum Institute, et al., Intervenor-Defendants*, Civ. No. 89-0598, in the United States District Court for the District of Columbia.

The first way of handling the excess water is called **direct discharge**. At the point where the excess water enters the surface water, a CWA National Pollutant Discharge Elimination System (NPDES) permit, or an equivalent permit issued by an authorized state environmental agency, specifies the amount of pollutants that may enter the surface water without degrading the surface water quality.

The second way of handling excess water is called **indirect discharge**. The facility that generates the excess water directs it into a publicly owned treatment works that includes both a collection system and a treatment plant. In the POTW collection/treatment system, the excess waters typically mix with the wastewaters from many other collection/treatment system users. Once the wastewaters are treated, the discharge from the treatment system goes directly into surface water, and that discharge is a direct discharge. The discharge from the treatment system requires a Clean Water Act permit.

The third way of handling excess water, by directing or allowing it to flow into a low-lying area, then recycling it back into facility processes or waiting for it to evaporate or drain (infiltrate) into the ground, is called **zero discharge** because the excess water does not go into surface water—at least not in a rapid or visually observable way. The term "zero discharge" refers to the fact that there is no intended discharge into surface water or to a POTW.

For the direct dischargers, EPA or the authorized state environmental agency receives permit applications and writes the permits. For indirect dischargers, pretreatment standard regulations and/or a POTW collection/treatment system sets treatment levels for indirect discharger users. Zero dischargers sometimes are regulated under the CWA and sometimes are not. In general terms, an authorized state's environmental laws and their implementation determine whether that state issues permits for zero dischargers. In many states, the authorized state agency does not issue NPDES permits for zero dischargers.

1.2.3 Clean Air Act - Background

Section 112 of the Clean Air Act (CAA) requires EPA to regulate emissions of the most potent air pollutants: those that are known or suspected to cause serious health problems such as cancer or birth defects. The Clean Air Act refers to these pollutants as hazardous air pollutants (HAPs).

When amending the CAA in 1990, Congress directed EPA to use a technology-based approach to significantly reduce emissions of air toxics from major sources of air pollution,[4] followed by a risk-based approach to address any remaining, or residual, risks. Under the technology-based approach, EPA develops standards for controlling the emissions of air toxics from each major source of HAPs. The standards are to result in the maximum reduction in emissions of hazardous air pollutants achievable and cannot be any less stringent than the average emission limitation achieved by the best performing 12 percent of existing sources

[4] Major sources are defined as sources that emit 10 tons per year of any of the listed toxic air pollutants or 25 tons per year of a mixture of air toxics.

within a source category for which EPA has emission information.[5] Standards may be more stringent than this base level of control (typically called a floor) after EPA considers cost, energy, and nonair quality health and environmental impacts of potentially more stringent standards**.** Standards thus typically reflect the performance of the maximum achievable control technology (MACT). Eight years after each MACT standard is issued, EPA must assess the remaining health risks from source categories. If necessary, EPA must implement additional standards that address any significant remaining risk.

1.2.4 Interaction of RCRA, CWA, and CAA

The CWA and CAA were enacted to control and minimize water and air pollution, respectively. These two laws caused facilities to collect and manage pollutants that previously had been discharged into the nation's waterways and into its air. RCRA was enacted in recognition of the need to manage these collected pollutants appropriately so that they would not become waterborne or airborne again (RCRA section 1002(b)). This section discusses how these three laws interact with respect to the particular issue of risks to human health and the environment posed by managing nonhazardous wastes in surface impoundments.

A traditional focus of the RCRA hazardous waste program has been on risks posed by collected wastes, such as air and water pollution control residues, and protecting groundwater resources from contamination from those residues. The RCRA hazardous waste program exempts from RCRA substantive and permitting requirements tank systems that are part of CWA treatment systems. CWA NPDES permits issued by states, using state environmental statutes, occasionally contain prohibitions on groundwater contamination. Because the CWA program's traditional focus has been on protecting surface water rather than groundwater, however, questions have arisen about whether wastes managed in CWA-regulated treatment systems, but exempt from RCRA requirements, might contaminate groundwater. An example is one part of the controversy that the LDPFA addressed: the potential for groundwater contamination from decharacterized wastes managed in CWA treatment systems. In a CWA treatment system in which wastewater flows first through a tank system and then into surface impoundments, the wastewater treatment unit exemption from RCRA substantive and permitting requirements would apply to the tank system part of the wastewater treatment system. Thus, characteristic hazardous wastes could be introduced into the RCRA-exempt tank system part of the treatment train, become diluted during treatment, and no longer exhibit the hazardous characteristic by the time they reach a surface impoundment. This situation gave rise to the concern that hazardous constituents present in the wastewater could still be present and available to contaminate groundwater.

Historically, EPA's rules implementing the CWA have not addressed pollution from air emissions emanating from wastewater collection and treatment systems. In some instances, the RCRA hazardous waste program does address air emissions from wastewater collection and treatment, and, in other instances, the CAA hazardous air pollutant (air toxics) program addresses certain emissions from wastewater collection and treatment. However, there could be situations

[5] For new sources, the standard is the level of emission reduction achieved by the best performing single source within a source category.

in which wastewaters containing volatile HAPs are not regulated under either the RCRA hazardous waste program or the CAA air toxics program. The consent decree sought to have EPA investigate such situations and requires that EPA explicitly include certain facilities and impoundments with a particular CAA section 112 status. EPA must assess whether these facilities and impoundments, and the chemicals managed in them, pose risks by the direct air inhalation pathway.

1.2.5 Requirements To Conduct This Study

1.2.5.1 LDPFA Requirements. Section 3004(g)(10) of the LDPFA requires the Administrator of EPA to complete a study of wastes that: (1) no longer exhibits a hazardous characteristic prior to management in any land-based solid waste management unit; and (2) is treated in a treatment system that subsequently discharges to waters of the United States pursuant to a permit issued under section 402 of the Federal Water Pollution Control Act, treated for the purposes of the pretreatment requirements of section 307 of the Clean Water Act, or treated in a zero discharge system that, prior to any permanent land disposal, engages in treatment that is equivalent to treatment required under section 402 of the CWA for discharges to waters of the United States.

Not later than 5 years after the date of enactment of the LDPFA (i.e., by March 26, 2001), EPA must complete a study of these wastes to characterize the risks to human health or the environment associated with such management. In conducting the study, EPA must evaluate the extent to which risks are adequately addressed under existing state or federal programs and whether unaddressed risks could be better addressed under such laws or programs. Upon receipt of additional information or upon completion of such study and as necessary to protect human health and the environment, EPA may impose additional requirements under existing federal laws, including subsection 3004(m)(1) or rely on other state or federal programs or authorities to address such risks.

1.2.5.2 EDF Consent Decree Requirements. Paragraph 11.1 of the consent decree requires EPA to perform two studies on gaps in the hazardous waste characteristics. The studies must also evaluate the resulting potential risks to human health posed by the inhalation of gaseous and nongaseous air emissions from wastes managed in tanks, surface impoundments, landfills, wastepiles, and land treatment units. For surface impoundments, the consent decree specifically excludes those surface impoundments receiving decharacterized wastewaters that are being studied under the LDPFA. With respect to the consent decree studies, at a minimum, EPA is required to address releases from waste management units that: (1) are at facilities that are not within source categories subject to the scope of the CAA NESHAP program, (2) are at facilities that are not major sources under the CAA, and (3) are excluded under a specific NESHAP MACT rule due to unit or chemical type. For the surface impoundments, EPA is required to evaluate those impoundments receiving wastewaters that never exhibited a hazardous waste characteristic.

The purpose of these studies is "to obtain such information as the Administrator may require to determine whether a rulemaking to promulgate a hazardous waste characteristic that addresses potential risk to human health through the direct inhalation pathway should be

initiated." In May 1998, EPA released the first of the two required studies covering the waste management units other than surface impoundments. (See *Air Characteristic Study,* U.S. EPA 1998, subsequently revised November 1999a.) The Consent Decree calls for completion and public release of the surface impoundment study by March 26, 2001.

1.3 Study Purpose

This study's purpose is to fulfill, in a single place, the separate requirements posed by the LDPFA and the consent decree, which are

> "to characterize the risks to human health or the environment associated with [managing decharacterized wastes in CWA treatment systems]" and to "evaluate the extent to which risks are adequately addressed under existing State or Federal programs and whether unaddressed risks could be better addressed under such laws or programs." (RCRA section 3004(g)(10))

and

> The Administrator shall...perform [a] stud[y] on gaps in the hazardous waste characteristics and relevant Clean Air Act ("CAA") controls, and the resulting potential risks to human health, posed by the inhalation of gaseous and non-gaseous air emissions from wastes managed in...surface impoundments (excluding those impoundments receiving decharacterized wastewaters that the Agency is obliged to study pursuant to section 3004(g)(10) of RCRA, 42 U.S.C. S 6924(g)(10))....[6]

Both the statute and the consent decree require a risk assessment and then an evaluation of existing mechanisms that address risks posed by this waste management practice. There are differences between the statutory requirement and the consent decree requirement. EPA chose to conduct a multimedia[7] risk assessment, which satisfies the statutory requirement and goes beyond what is required in the consent decree. EPA also performed an evaluation of existing programs, both regulatory and nonregulatory, which satisfies the statutory requirement and goes beyond what is required in the consent decree.

As a result, the study has two primary objectives: (1) to assess risks posed by the waste management practices described in the statute and consent decree, and (2) to describe how existing regulatory and nonregulatory programs address any risks that may be present.

[6] Civ. No. 89-0958, *Environmental Defense Fund, Inc. vs. Whitman et al.* June 12, 1997.

[7] In this context, "multimedia" refers to multiple environmental media— air, water, soil, and biota.

1.4 Study Scope

1.4.1 Definition of Surface Impoundment

In the RCRA hazardous waste regulations, the definition of "surface impoundment" at 40 CFR 260.10 is

> . . . a facility or part of a facility which is a natural topographic depression, man-made excavation, or diked area formed primarily of earthen materials (although it may be lined with man-made materials), which is designed to hold an accumulation of liquid wastes or wastes containing free liquids, and which is not an injection well. Examples of surface impoundments are holding, storage, settling, and aeration pits, ponds, and lagoons.

Historically, there have been some difficulties in interpreting this definition related to distinguishing between surface impoundments and tanks for purposes of interpreting whether the hazardous waste regulations do or do not apply to a particular waste management unit. In a 1983 memorandum, EPA distinguished between tanks and impoundments (U.S. EPA, 1983a) by an engineering test of a wastewater holding unit's structural integrity and interpreted the unit to be either a tank (if it can withstand the forces applied during the engineering test) or a surface impoundment (if it cannot withstand the applied forces).

In this study, EPA considered using this definition, but was concerned that the difficulties in distinguishing between tanks and impoundments would pose problems with the screening survey, which was intended to identify a sample of facilities with impoundments. EPA reviewed the definitions used in the 1983 census and the 1985 telephone screening survey and chose to use a modified version of the definition in the 1983 census. The definition OSW finally used in its surveys for this study (U.S. EPA, 1999b, 1999c) used both text and graphics and is shown in Figure 1-1)

1.4.2 Other Scope Decisions

EPA faced several decisions on scoping the study on matters that were not specified in the legislation. EPA received and considered public comments on many of the scope decisions. (EPA's strategy for involving the public in the study design and implementation is described in Section 1.5.) These specific decisions are described as follows.

Economic Sectors To Include in the Study. EPA chose to focus the study on those sectors most likely to generate characteristic hazardous waste and, thus, to potentially have decharacterized waste that might be managed in impoundments. The sectors included were the manufacturing industries (including food processing; textiles; paper and allied products; stone, clay and glass; chemicals and allied products; petroleum and allied products; and primary metals), bulk chemical and petroleum storage, sewerage and refuse systems, scrap and waste materials, airport terminals, truck transportation terminals, and national security. EPA generally excluded the economic sectors that had already been studied in considerable detail under the various statutory RCRA exclusions for large-volume wastes (the so-called "Bevill exclusions"

A surface impoundment is a natural topographic depression, artificial excavation, or dike arrangement for storing, treating, or disposing of wastewater (i.e., liquid or semi-solid waste with less than 5% solids by weight). A surface impoundment may be constructed above the ground, below the ground, or partly above the ground and partly below the ground. A surface impoundment's length or width is greater than its depth (for example, it is not an injection well). Here are some examples (side view):

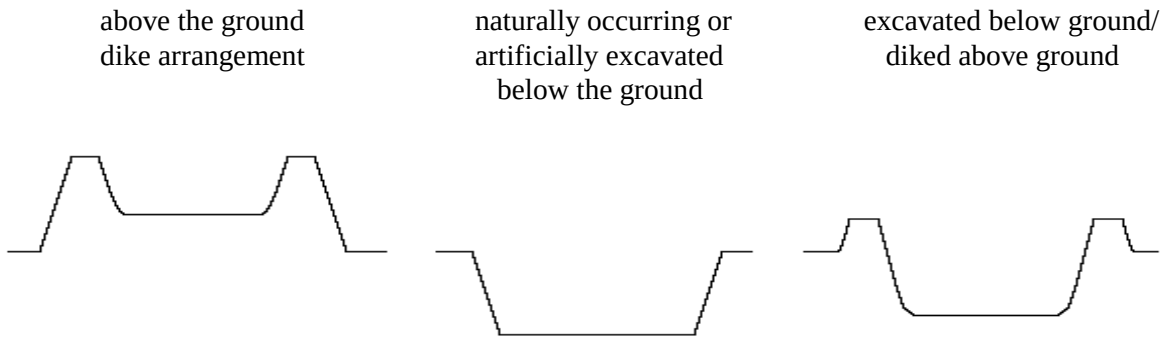

Figure 1-1. Definition of surface impoundments used in this study.

found at RCRA section 3001(b)(3)). However, some facilities whose wastes are excluded under these statutory exclusions inadvertently were included in the study population because it was not possible to separate them from facilities in the economic sectors of interest.

Time Frame in Which Impoundments Operate. Because impoundments sometimes operate for many decades, EPA needed to define practical boundaries for the operating period time frames this study would review. EPA did not believe that facility owners would have information readily available concerning old impoundments that had closed many years ago. EPA decided that, since the original LDPFA issue came about due to the so-called "third third" 1990 land disposal restrictions, it was appropriate to focus attention on only those impoundments that were potentially affected by those regulations (promulgated on June 1, 1990). Thus, EPA limited the study's scope to impoundments that had received waste on or after June 1, 1990.

Geographic Range. In RCRA, the term "state" refers to the 50 states, the District of Columbia, Puerto Rico, the Virgin Islands, Guam, American Samoa, and the Commonwealth of the Northern Mariana Islands. The study's geographic range includes all of these areas.

Whether To Include both Wastewater and Sludge. For this study, EPA defined wastewater as "liquid or semi-solid waste with less than 5% solids by weight" and sludge as "any solid, semi-solid, or liquid waste containing 5 weight percent or more solids, that is generated in the course of treating or managing wastewater." Initially, EPA proposed including sludge and sludge management practices in the study's scope. However, the issue of sludge management after removal from the impoundment (or sludge management in impoundments, where the impoundment is the final disposal unit for the sludge) was not part of the original LDPFA issue.

In addition, the complexity of the ongoing nature of sludge management (with such diverse practices as dewatering, land application, landfilling, and beneficial reuse) would have complicated the data collection. Thus, EPA decided to limit the study to wastewater and sludge present in an impoundment and not to study risks posed by sludges after they are intentionally removed from an impoundment.

Chemical Constituents of Concern. The legal issues that prompted the study revolved around hazardous constituents in these wastes remaining after the characteristic property is removed (in the case of the LDPFA) and around a list of 105 specific constituents that the consent decree required EPA to study. EPA combined the list of 105 specific constituents with a list of constituents that had been identified previously as being of concern in the LDR program (certain so-called "universal treatment standards" constituents), or more broadly in the RCRA hazardous waste program (additional constituents that were being considered under the Hazardous Waste Identification Rule [HWIR] proposal in early 1997). The combined list consisted of 256 chemicals (or, in some cases, classes of chemicals) that were the subject of the study.

1.5 Overview of Methodology

1.5.1 Public Involvement in Study Design and Identification of Data Needs

Soon after the Land Disposal Program Flexibility Act was enacted, EPA placed a notice in the *Federal Register* about the legislation's requirement to conduct the study, requested public comments on the "data collection, quality assurance/quality control of data, development of risk assessment methods, establishment of a peer-review structure for the study, and assessment of current State/Federal/Tribal regulations or programs that address risks"[8] and invited stakeholders to submit ideas for the study design. The general nature of the comments submitted was that EPA would need to collect detailed, site-specific information from a representative sample of facilities to be able to assess potential risks accurately. EPA chose to design the study using many of the public comments received. EPA also sought a consultation from a committee of EPA's Science Advisory Board (SAB) to gain expert scientific input on the design of the risk assessment portion of the study.

Based on the public comments and expert scientific input, EPA identified three broad categories of data needs:

- Data on chemical constituents' health effects and physical/chemical properties
- Information on federal and state regulatory and nonregulatory programs
- Data on sources and wastes including
  - Environmental settings in which impoundments are found

[8] Vol. 61, *Federal Register*, pp. 38684-38687, July 25, 1996.

- Impoundment design features
- Impoundment operating and closure practices
- Wastes managed in impoundments (quantity of the waste matrix and its chemical composition—presence, identification and quantities of chemical constituents)
- Presence, location, and activities of people and nonhuman organisms.

The data in the first category are available in the scientific literature. For the information in the second category, EPA used various public data sources. For the data in the third category, although some data were readily available in public data sources, EPA had no way to judge their representativeness. Thus, a major challenge EPA faced in performing the study was how to identify facilities that used surface impoundments meeting the criteria spelled out in the legislation and consent decree in order to select a representative sample of facilities with impoundments and how to collect from them the data in the third category.

1.5.2 Overall Framework of Risk Assessment

The basic framework for the risk assessment portion of the study can be summarized in five steps:

1. Characterize the target population of facilities and impoundments and draw a probability sample
2. Develop the risk assessment framework
3. Conduct a pilot study
4. Collect and process data for the risk assessment
5. Perform the risk assessment.

The first step consisted of targeting impoundments that were likely to manage the kinds of wastes the legislation and consent decree required to be studied and that were likely to manage the hazardous constituents that were at issue in both the legislation and the consent decree. Because impoundments are sometimes used to manage stormwater that is merely precipitation runoff and potentially contains very few, if any, of these constituents, EPA was not interested in including impoundments holding stormwater only. However, many facilities use impoundments to hold stormwater and some process wastewater, and some facilities use impoundments to hold cooling water (which could be combined with stormwater, process wastewater, or both). The wide variety of situations led EPA to decide on a list of wastewater attributes to use as criteria for screening out impoundments that were unlikely to have constituents of concern. The criteria were included in a "screening" survey that was used to target the study's focus on impoundments most likely to be of interest.

The second step was to develop the risk assessment framework. During the study period, both computing technology and risk assessment "state of the science" developed rapidly, and EPA continually revised its approach for conducting the risk assessment to take advantage of these developments. Using guidance from EPA's Science Advisory Board and technical expertise in risk assessment, EPA developed a series of data analysis protocols to apply to the information identified as necessary for the risk assessment.

The third step was to conduct a pilot study to test the data collection, data processing, and risk assessment framework on a limited number of facilities. EPA used the results from the data collection test to improve the survey used to collect the detailed data necessary for the risk assessment. EPA also gauged the level of effort, both for the pilot study facilities to complete the survey and for EPA to process and analyze the data, and made adjustments in the study's scope and the risk assessment framework to improve the data collection and analysis efficiency.

The fourth step, collecting and processing the data, took the largest amount of time. For situations such as this study, the Paperwork Reduction Act requires federal agencies to publish draft surveys and accept public comments in two separate *Federal Register* notices before receiving Office of Management and Budget (OMB) approval for sending out surveys. EPA designed the data collection as a two-stage sample: the first stage was necessary to identify facilities with impoundments meeting the study criteria, and the second stage was necessary to collect the detailed information needed for the risk assessment. EPA used the screener survey for the first stage and a long survey for the detailed information in the second stage. At the end of the second stage, EPA also performed "field sampling" of wastewater and sludge samples taken from impoundments at some of the study facilities. The total elapsed time for conducting the pilot and completing the data collection part of the second stage survey was 3 years (see Figure 1-2 for study timeline showing key milestones).

The fifth step, performing the risk assessment, was altered from the pilot study approach due to the advances in computing technology, the availability of environmental fate and transport models, and the need to perform further screening to remove from consideration those facilities, impoundments, and constituents that present very little or no risk. EPA prepared a technical plan for conducting the risk assessment and obtained input from independent peer reviewers before embarking on the task of analyzing the survey and field sampling data. In performing the risk assessment, EPA encountered certain situations not anticipated, so the final risk assessment approach differed somewhat from the approach outlined in the technical plan. The approach used is described in Chapter 3 and in Appendix C.

1.5.3 Representativeness of Facilities in This Study

Section 2 of the LDPFA described the three types of CWA facilities: direct, zero, and indirect dischargers. Facilities that are one of these three types of dischargers and use surface impoundments are the population the LDPFA directed EPA to study. At the beginning of this study, EPA did not have a list of facilities in the United States with impoundments meeting the criteria described in the statute or the consent decree. For direct dischargers, EPA had a database, called the Permit Compliance System (PCS), that had some facility name and address information, but did not identify very many facilities that used impoundments. For zero

Date	Activity
March 1996	Land Disposal Program Flexibility Act (LDPFA) enacted
July 1996	*Federal Register* notice requesting comment on study methodology
September 1996	Preliminary consultation on methodology with Science Advisory Board
October 1996 to April 1997	Prepare methodology for Science Advisory Board peer review
April 30/May 1, 1997	Science Advisory Board peer review of proposed methodology
July 1997	Begin pilot study
February 1998	Draw random sample of facilities to receive screener surveys First Paperwork Reduction Act *Federal Register* notice
April to June 1998	Revise surveys based on public comments
July 1998	Complete pilot study report; Second Paperwork Reduction Act *Federal Register* notice; Submit Information Collection Request to Office of Management and Budget (OMB)
August 1998	Science Advisory Board peer review report on proposed methodology
December 1998	OMB approves Information Collection Request
February to September 1999	Send out screener surveys, process data from returned surveys; draw random sample of facilities to receive long survey
November 1999 to July 2000	Long survey data collection
February to March 2000	Peer review of technical plan for risk assessment
May to August 2000	EPA “field sampling”
May 2000 to January 2001	Human health and ecological risk assessment
September 2000 to March 2001	Review of existing regulatory requirements and nonregulatory programs
February to March 2001	Final Agency review

Figure 1-2. Study timeline.

dischargers and indirect dischargers, there was no corresponding database that listed facility names and addresses.

After extensive research, EPA concluded that the three subpopulations (direct, zero, and indirect dischargers) presented different challenges for conducting the study. EPA was able to use PCS as the data source to locate direct dischargers with impoundments. EPA constructed an essentially complete list of the direct dischargers and drew a stratified random sample from that list. For the direct dischargers, EPA believes that the sample is a representative one. EPA constructed a new national list of zero dischargers from data supplied by state environmental agencies and certain other sources. This list reflects the known zero discharger subpopulation, but may not accurately reflect the entire national zero discharger subpopulation. However, it is the most complete national list of zero dischargers that was possible to construct under this study's constraints. Thus, EPA believes the sample of zero dischargers is representative of the facilities on the list but may not be representative of all zero dischargers in the study population. For the indirect dischargers, EPA concluded that, of the many thousands of indirect dischargers across the country, it was likely that, at most, several hundred used impoundments. As a result, EPA concluded that it was infeasible to locate a representative sample of this small subpopulation. Instead, EPA chose to identify a nonrepresentative sample of the indirect dischargers, selected to represent the known range of industries, and simply compare the results for this group with the results for the direct and zero dischargers.

Figure 1-3 illustrates the steps taken to identify a representative sample of direct and known zero dischargers and to identify the sample of indirect dischargers for this study.

In the rest of this report, EPA presents the survey data and risk assessment results for the direct and zero dischargers. Although EPA included some indirect dischargers in the study and performed the same risk assessment steps for those indirect dischargers, none were found to pose risks at levels of concern. For simplicity, the indirect dischargers are omitted from the descriptions in the rest of the report (although the data on their impoundments and wastes are included in the appendixes and other supporting materials).

1.5.4 Peer Review of Study Components

EPA has a policy that requires peer review of major scientific and technically based work products (U.S. EPA, 1994). One group that performs peer reviews of selected EPA work products is the Science Advisory Board. EPA requested a SAB peer review of the proposed study methodology. SAB agreed to review the proposed methodology, and convened a special subcommittee of its Environmental Engineering Committee to perform the peer review. EPA presented the proposed study design to the subcommittee in April 1997. The Science Advisory Board's report for this peer review is available at http://www.epa.gov/sab/eec9809.pdf. (U.S. EPA, 1998).

EPA made use of many of the SAB recommendations during the study's implementation. One topic on which EPA requested advice was the question of obtaining peer review at different points in the study's implementation. SAB's advice on this topic was that EPA should consider, plan for, and seek "...the peer review for minimum disciplinary acceptability of the

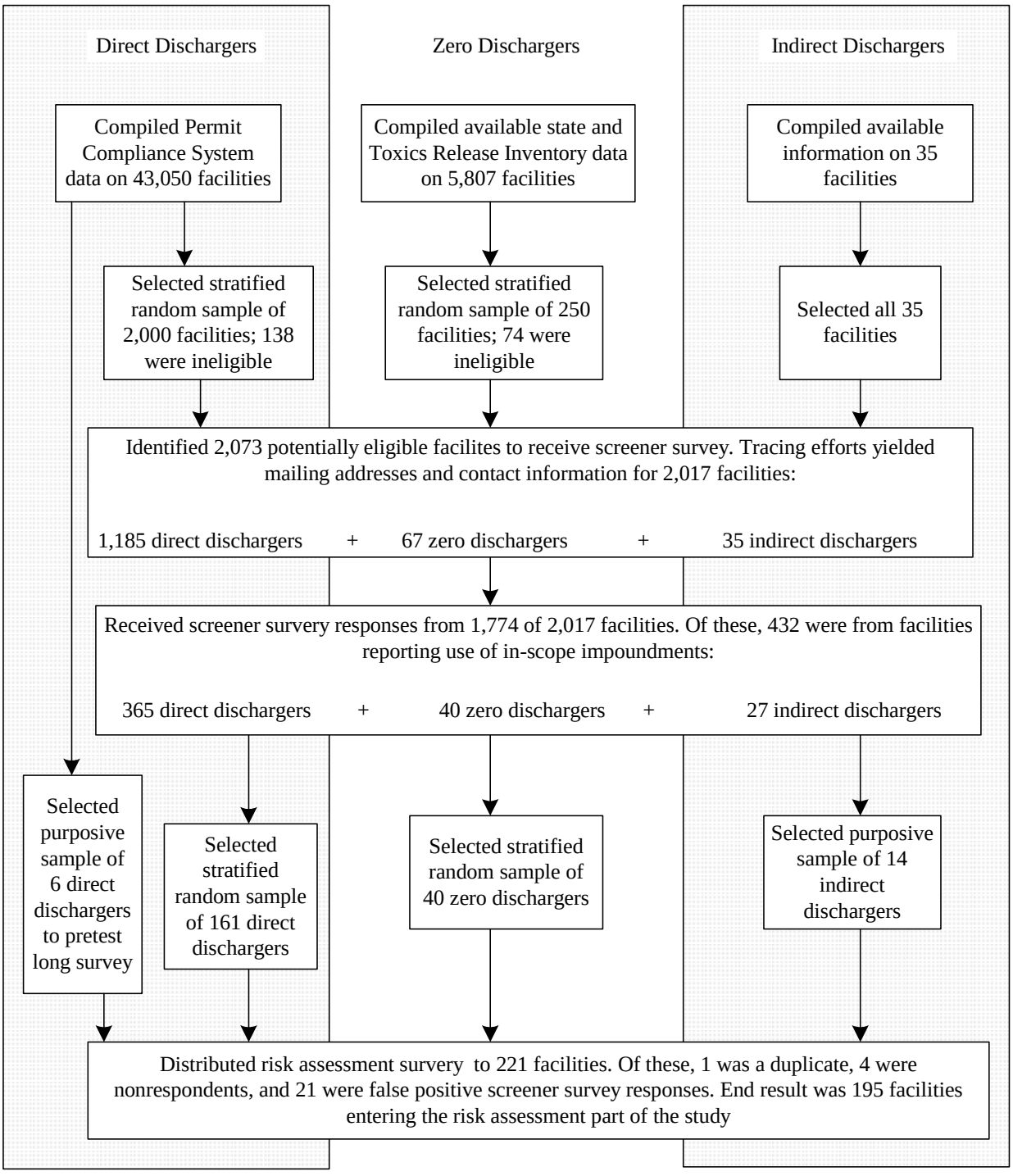

Figure 1-3. Selection of facilities for study.

information...the validity of the technical interpretation, and...the relevance of the technical data and interpretation to a policy decision..." while suggesting that there should be flexibility in exactly which parties perform these three functions (U.S. EPA, 1998). EPA chose to follow this advice using already existing mechanisms in place for obtaining public input and to seek formal peer review by independent scientific experts at two points: a review of the technical plan for the risk assessment prior to implementing it, and a review of the final risk characterization results. The review of the technical plan for the risk assessment is described in more detail in Appendix C. An SAB peer review of the risk characterization results will occur after completion of the study.

1.6 Organization of This Report

The rest of this report describes the methodology, results, and conclusions of the risk portion of the study and the corresponding analysis of regulatory and nonregulatory program coverage of potential risks found. The risk portion of the study is described in Chapters 2 and 3, the existing program coverage portion of the study is described in Chapter 4, and the risk conclusions and the program coverage conclusions are summarized in Chapter 5.

Chapter 2 explains the long survey data that were used to develop the bulk of the study's conclusions about potential risks. It also includes a discussion of the field sampling results and how they illustrate the strengths and weaknesses of the long survey data on waste characterization. The survey data are a critical component of the overall risk portion of the study because they provide the context for the formal risk assessment results.

Chapter 3 presents the two parts of the formal risk assessment: the risk analysis, which yielded numerical estimates of risks potentially posed via three human health "pathways," and a risk screening, which did not yield numerical estimates of risks. The risk analysis consists of

- Estimates of potential risks to actual current, or likely future, receptors
- An assessment of environmental releases that are occurring and would cause potential risks if people or ecological receptors were present at certain locations.

Chapter 4 presents the evaluation of the extent to which existing regulatory and non-regulatory programs address the potential risks found and described in Chapter 3. For human health risks from the direct air inhalation pathway, EPA identified provisions in both RCRA and CAA programs that address surface impoundments, the extent to which any of the 256 constituents are specifically addressed by such programs, and the extent to which the industry categories covered by the SI Study are addressed by the programs. For "non-air risks," EPA identified federal and state regulations and programs that may address such risks and identified the constituents of concern and assessed their coverage by these regulations and programs.

Chapter 5 summarizes the important findings from the survey data, summarizes the results from the risk assessment, and summarizes the overall assessment of how well the existing programs address the potential risks found.

Appendix A explains the statistical study design, the survey implementation, and data processing steps.

Appendix B provides a detailed profile of the study population. The particular attributes of impoundments, and the wastes managed in them, which can contribute to their probability of causing environmental releases and/or human or ecological risks are described in considerable detail. These data are important for understanding the context of the risk assessment results and conclusions.

Appendix C provides a detailed description of the risk assessment methodology and more details about the risk assessment results.

Appendix D provides a detailed description of the "existing program" analysis methodology and more details about the coverage found.

Appendix E provides an overall summary of the field sampling waste characterization data and the detailed information underlying the Chapter 2 description of how the field sampling data illustrate the strengths and weaknesses of the long survey waste characterization data.

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Chapter 2

Characterization of Industrial Surface Impoundments

This chapter presents the survey findings of EPA's 5-year study of the population of surface impoundments that manage industrial nonhazardous wastewaters. This presentation accompanies the risk assessment results discussed in Chapter 3 and the regulatory gap findings addressed in Chapter 4. Main findings are discussed under the following sections:

For background information on EPA's study, including the sampling methodology and survey instrument, see Chapter 1 and Appendix A. A more detailed presentation of the data from the survey is provided in Appendix B of this report.

2.1 Overview of Surface Impoundment Population

This section provides an overview of surface impoundment population characteristics, such as impoundment age, location, industrial classification, and size.[1] The data presented here portray a snapshot in time and, therefore, cannot account for changes in given industrial sectors that have already taken place since the survey or may take place at some point in the future.

[1] Throughout this chapter, rounded figures on the number of facilities, number of impoundments, and total wastewater volume are presented in the text. Estimates of these variables shown in tables and figures are left unrounded. Due to differing patterns of missing data, the weight adjustments for missing data lead to slightly different estimates presented for the same variable in some tables/figures. See Appendix B for the standard errors associated with these estimates.

2.1.1 Population of Surface Impoundments

EPA estimates that there are approximately 18,000 industrial nonhazardous surface impoundments[2] located at 7,500 facilities that received waste between June 1990 and June 2000 and met the other criteria for being in this study. Of these nonhazardous industrial impoundments, approximately 11,900 manage wastewaters that contain one or more chemicals of concern and/or have either high or low pH (see Table 2-1). These impoundments are located at an estimated 4,500 facilities and account for roughly 650 million metric tons (t) of wastewater quantity managed. Although only 15 percent of these facilities manage any decharacterized wastes, the volumes of decharacterized wastewater managed make up 70 percent of the entire wastewater quantity. This study presents results for these 11,900 impoundments that contain wastewaters with chemicals/pH of concern.[3]

Management of wastewaters in impoundments can include storage, treatment, and, in some cases, disposal. Approximately two-thirds of all facilities have more than one impoundment onsite and roughly 5 percent have more than 10 impoundments onsite that manage wastewaters. Usually, storage and treatment functions are performed before the wastewater is discharged to a surface waterbody under a National Pollutant Discharge Elimination System (NPDES) permit; facilities employing this approach are often referred to as "direct dischargers." As shown in Table 2-1, there are 3,940 facilities and 10,990 surface impoundments that manage approximately 618,000,000 metric tons of wastewater through direct discharge.[4]

Impoundments used for disposal of wastewater are referred to as "zero discharge" impoundments. The practice of wastewater disposal in impoundments is less common than storage and treatment of wastewater in impoundments. Disposal is usually achieved by allowing the wastewater to evaporate or to percolate into the ground and does not include discharge to a surface waterbody. EPA estimates that there are 510 zero discharge facilities, or 880 impoundments, that manage approximately 27,000,000 metric tons.

In the economic sectors that are the subject of this study, surface impoundments are used for the management of wastewater, stormwater, and cooling water. As shown in Figure 2-1, the majority of impoundments were constructed within the past 30 years. Furthermore, 40 percent of impoundments came on line in the 1970s, probably in response to environmental programs promulgated early in that decade requiring greater treatment of industrial wastewaters. The impoundments that were in operation before 1970, approximately one-quarter of the population, were likely employed in some aspect of water supply management associated with the industrial processes at these facilities.

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[2] Actual estimates of the number of industrial nonhazardous waste impoundments vary from 16,700 (based on the long survey) to 18,400 (based on the screener survey). See Appendix A for a detailed discussion of these estimates.

[3] In comparison, in the United States today, there are just under 50 facilities with roughly 200 surface impoundments that are used to manage hazardous waste. These hazardous waste surface impoundment figures are based on data extracted from EPA's RCRAInfo in January 2001.

[4] Number for facilities, impoundments, and quantities of wastewater managed are rounded in this chapter.

Table 2-1. Overview of Facility, Impoundment, and Wastewater Quantity Estimates

Characteristic	Direct Dischargers	Zero Dischargers	Total Population
Estimated number of facilities	3,944	512	4,457
Estimated number of impoundments	10,987	876	11,863
Total quantity of wastewaters managed (metric tons)[a]	627,218,336	27,250,309	654,468,645

[a] The estimate of the wastewater quantity for the total population differs from the estimates shown in Tables 2-2 and 2-15. This is due to missing data associated with this variable. Refer to Appendix A on missing data and Appendix B for the standard error associated with this variable.

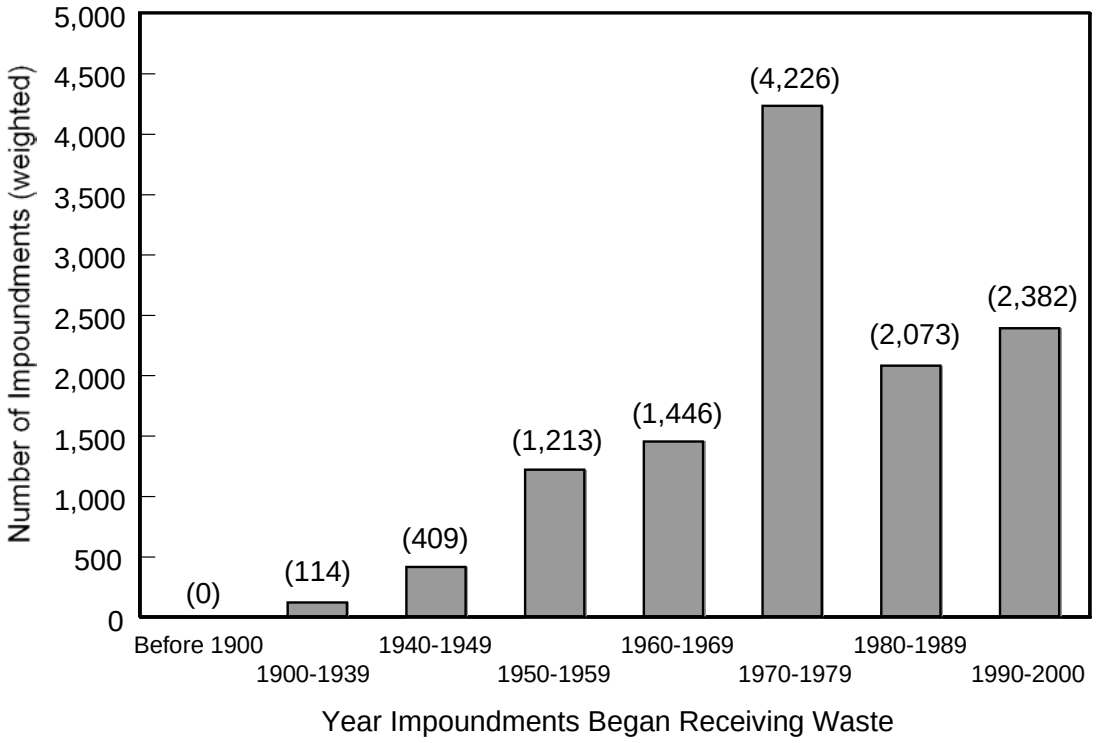


Figure 2-1. Distribution of 11,863 impoundments by year unit began receiving waste.

2.1.2 Location of Surface Impoundments

Generally, surface impoundments are located in areas with fairly significant precipitation levels and availability of water. Figure 2-2 shows the breakdown of the 11,900 impoundments from the survey by EPA Region across the United States. The greatest proportion of impoundments are located in Gulf Coast states and along the East Coast. EPA's Region 3 has the greatest density of impoundments per 100 square miles; EPA Region 4 has the highest number of impoundments. Zero discharge facilities are generally distributed across the regions evenly, with the exception of EPA Regions 1 and 8, which have none.

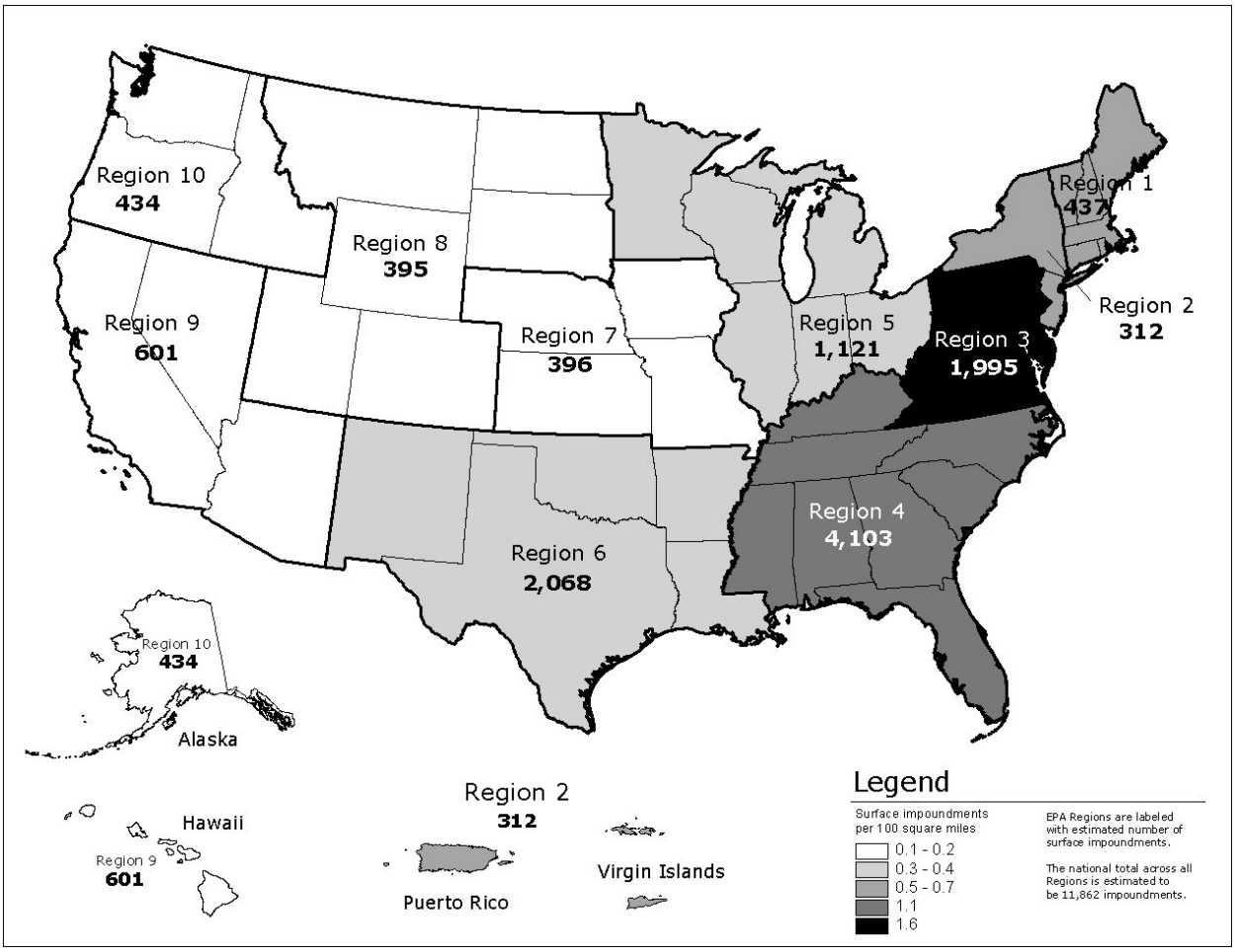


Figure 2-2. Regional distribution of surface impoundments.

2.1.3 Breakdown of Surface Impoundments by Industry

Surface impoundments have been and continue to be used widely in the management of industrial wastewaters. For this study, EPA chose a scope of economic activities that generally matched the "industrial" categories of the December 1983 *Surface Impoundment Assessment National Report*, focusing on the manufacturing sector, along with certain other economic sectors that were likely to have surface impoundments with wastes containing chemical constituents. The nonmanufacturing sectors included were trucking, motor freight terminal maintenance, airports, the waste management and sanitary services sector, industrial supplies, chemical and allied product bulk storage, petroleum bulk stations, national security, and miscellaneous services. (See Chapter 1 and Appendix A for a discussion of the industry coverage in the sample selection for the study.)

According to the survey data, approximately two-thirds of the total wastewater quantity managed in the 11,900 impoundments is managed at paper and allied product sector facilities (see Table 2-2). This industrial sector, however, represents only 6 percent of the population of facilities and just over 10 percent of all impoundments. Furthermore, an analysis at the 4-digit

Table 2-2. Breakdown by 2-Digit SIC Code of Surface Impoundments that Manage Chemicals/pH of Concern and of Quantities of Wastewater Managed

SIC Code Descriptor	Percent of 4,457 Facilities	Percent of 11,863 Impoundments	Percent of 653,314,426 [a] Metric Tons Wastewater
Chemical and Allied Products (SIC 28)	19	23	9
Stone, Clay, Glass, Concrete Products (SIC 32)	15	13	1
Wholesale Trade-Nondurable Goods (SIC 51)	12	10	4
Primary Metals Industry (SIC 33)	10	8	7
Food and Kindred Products (SIC 20)	8	8	5
Petroleum and Coal Products (SIC 29)	7	11	6
Paper and Allied Products (SIC 26)	6	12	66
All Other SIC Codes	23	15	2

SIC = Standard Industrial Classification.

[a] The estimate of the wastewater quantity for the total population differs from the estimates shown in Tables 2-1 and 2-15. This is due to missing data associated with this variable. Refer to Appendix A on missing data and Appendix B for the standard error associated with this variable.

Standard Industrial Classification (SIC) code level reveals that roughly 40 percent of the total wastewater quantity falls in the pulp mills industry (SIC 2611), a subsector of the paper and allied products industry.

Examining the data in Table 2-2 regarding the overall industrial coverage, the top four sectors account for 56 percent of the population of facilities; these sectors are chemical and allied products; stone, clay, glass, concrete products; wholesale trade-nondurable goods; and primary metals. These sectors manage only 20 percent of the total wastewater volume. The breakdown of industries differs at the impoundment level. The chemical and allied product sector and the stone, clay, glass, concrete products sector represent an estimated 36 percent of the population of impoundments. However, the next highest sectors in impoundment representation are the petroleum and coal product sector and the paper and allied products sector, with a total of 23 percent of the impoundments in the population.

2.1.4 Surface Impoundment Size and Appearance Characteristics

Impoundments vary considerably in surface area and depth. A size breakdown of impoundment surface area for the impoundment population is shown in Table 2-3. The depth of the impoundment can fluctuate, especially with larger units. These factors determine the overall volume of wastewater managed in any given impoundment. The relationship of impoundment surface area and wastewater volume is discussed in Section 2.2.3.

Table 2-3. Breakdown of Impoundment Surface Area

Size Range (hectares)	Impoundment Surface Area (Percent of 11,863 Total)
0 to 1/4 hectares	6,013 (51%)
1/4 to 1 hectares	2,953 (25%)
1 to 5 hectares	1,989 (17%)
5 to 10 hectares	456 (4%)
10 to 500 hectares	452 (4%)

As shown in Table 2-3, 51 percent of all impoundments have a surface area of 1/4 hectare or less. The medium size range of impoundments, from 1/4 to 5 hectares, constitutes 42 percent of the total population. The upper 8 percent of impoundments range from 5 to 500 hectares in size. The direct and zero discharge populations each have roughly the same size breakdown as that shown in Table 2-3 for the total population of impoundments.

Figures 2-3 through 2-5 show three pictures of impoundments taken during EPA's field sampling (see Appendix E for details on field sampling). Surface impoundments range from engineered structures that have the appearance of being man-made to marsh-like areas that an observer might not realize were used for wastewater management. Some have vegetation growing in the impoundments; many have vegetation growing along the edges. For impoundments with "liner" systems (one or more layers of material placed on the sides and bottom to prevent the wastewater from seeping into the ground), the aboveground part of the liner may be visible. Frequently, equipment such as pumps, flow control devices, and aeration equipment is present. There can be vehicle access roads constructed on top of the berms that form the sides. The color of the wastewater can be many different hues, and the wastewater can have a floating layer of oil or grease, a frothy appearance from foam, and/or a distinct odor. Impoundments can be located immediately adjacent to agricultural or residential areas or in areas of heavy industrial concentration.

2.2 Chemicals and Management Practices at Surface Impoundments

Surface impoundments provide a relatively low-maintenance/low-cost method of effectively managing nonhazardous wastewater, and thus serve a useful purpose in protecting waterbodies from receiving highly contaminated industrial wastes. However, impoundments can have an impact on the environment: chemicals can volatilize from the wastewater surface, contamination of the groundwater can occur if wastewater leaches from the impoundment, and nearby surface waterbodies can become polluted. Additionally, impoundments can experience overtopping releases through significant precipitation events or berm failure.

Figure 2-3. Surface impoundment located at a fruit processing facility.

Figure 2-4. Surface impoundment at a petroleum refinery.

Figure 2-5. Surface impoundment at a nylon manufacturing plant.

This section describes the sources for the chemical data used in this study, discusses the chemicals that can be present in wastewater and sludge in impoundments, identifies impoundment size and wastewater volume characteristics of the population of impoundments, and examines the management practices employed at surface impoundments.

2.2.1 Data Sources for Chemical Data

In this study, EPA is using two sources of data to identify the chemicals present in the impoundments and to quantify the amounts of those chemicals that are present: survey data and field sampling data.

2.2.1.1 Survey Data. In the SI survey, EPA requested that respondents identify the chemicals of concern present in their impoundments and, if known, state the average quantity of each chemical present

- In the preceding 3-year period, or
- In any 3-year period since 1990, if no data were available for the most recent 3-year period.

EPA encouraged respondents to conduct analytical tests to produce their answers, but allowed respondents to report estimates based on their knowledge of their wastes and processes. If data were unavailable, the survey respondents were not required to provide information. However, many survey respondents conducted sampling in order to respond to the survey.

Based on the survey data, methanol, fluoride, acetone, manganese, zinc, barium, and nickel are present in the greatest quantity in wastewater. See Section 2.2.2 for a more detailed discussion of frequently occurring chemicals.

2.2.1.2 Field Sampling Data. Of the major industry categories represented in the survey sample, EPA selected 12 facilities and, based on the survey responses and general knowledge of each industry, identified chemicals likely to be present in those facilities' impoundments. EPA then visited the facilities to obtain wastewater and sludge samples, analyzed those samples, and used the field sampling data for comparison with the survey data.[6] For more information on the field sampling, see Appendix E of this report. EPA performed the field sampling to accomplish two primary objectives. The risk assessment relies on the survey data regarding the presence and quantities of constituents. If the survey data on constituent quantities do not reflect the actual quantities of constituents in an impoundment (that is, are inaccurate), then the risk assessment results based on those data will be inaccurate as well. Similarly, if survey respondents did not report all the constituents present in an impoundment, then the survey data on the presence of constituents will be incomplete and the risk assessment results will likewise be incomplete. The field sampling effort provided an independent check, or verification, of the survey data on constituent presence and quantities. Thus, the field sampling objectives were

- To evaluate the degree to which the concentrations of constituents reported in the survey agree with the concentrations measured in the field
- To evaluate the degree to which the field sampling results revealed omissions in the reported survey data on presence and quantities of constituents.

For those constituents reported in the survey data and for which the field sampling confirmed their presence at the particular facilities and impoundments, the reported survey data values of chemical quantity agree, in most instances, within an order of magnitude of the corresponding field sampling quantity (see Figure 2-6). Furthermore, in almost all instances, the reported survey values agree within 2 orders of magnitude of the corresponding field sampling values. This finding indicates that, where chemical constituents were reported by survey respondents, EPA's field sampling did not find evidence of underreporting.

One limitation of this comparison is the fact that the survey requested average values over a 3-year period, while the field sampling data were obtained on a 1- or 2-day visit. Another limitation is that, because the facilities selected for field sampling were not chosen randomly, the results cannot be statistically extrapolated. However, EPA believes that the comparisons provide useful insights into the overall quality of the survey data and into certain critical areas of uncertainty in the risk assessment.

[6] For more information on the field sampling, see Appendix E of this report.

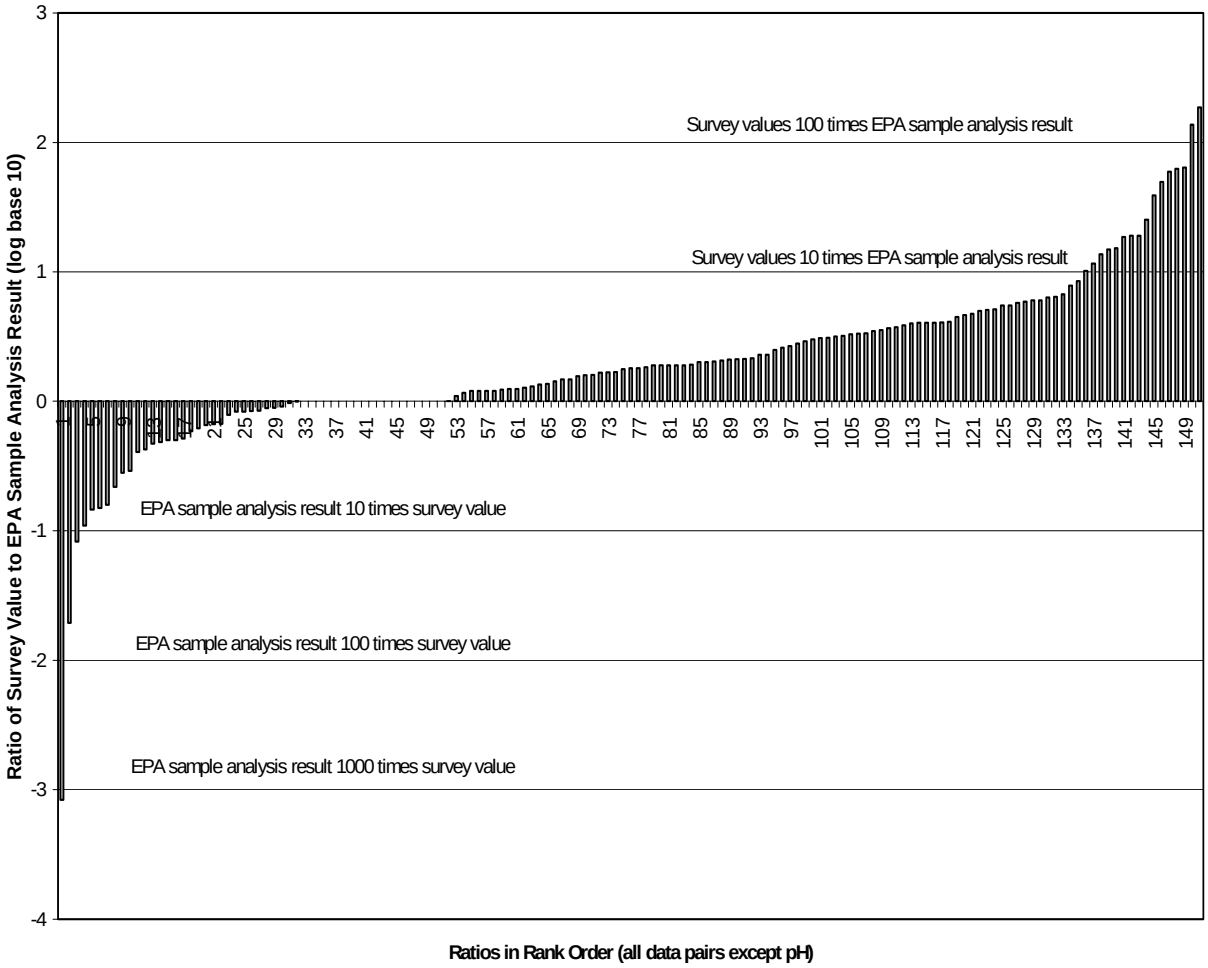


Figure 2-6. Relationship between survey values and corresponding EPA measurements.

As an indication of whether constituents might tend to be present that were not reported in the survey, EPA compared the number of constituents reported by each of the 12 field sampling facilities with the number of constituents found in the field sampling. Table 2-4 presents the results of this comparison.

Table 2-4 suggests that the reported survey data on the presence of chemical constituents may be incomplete. At each of the 12 facilities visited for sampling, EPA found unreported constituents above a limit of detection. The number of unreported constituents found at a facility ranged from 3 to 30.

Based on the agreement between the concentrations reported in the survey and those measured during EPA's field study, EPA has concluded that there is no reason to question the concentration data provided in the facility survey. However, based on the discrepancies observed as to the presence of some constituents in the impoundments sampled, there is evidence to suggest that facility operators do not necessarily have comprehensive knowledge of all the individual constituents contained in their impoundments.

Table 2-4. Constituents Confirmed with Field Sampling and Unreported Constituents

Facility SIC Code	SIC Description	No. Of Constituents Reported in Survey[a]	No. Of Same Constituents Detected in Corresponding EPA Sample	No. Of Additional Constituents Detected by EPA and Not Reported by Facility
2037	Fruit processing	0	0	11
2621	Paper mill	15	8	18
2611	Pulp mill	11	10	30
2821	Nylon manufacturing	8	6	18
2819	Inorganic chemicals	6	4	13
2911	Petroleum refinery #1	55	17	7
2911	Petroleum refinery #2	11	11	13
3087	Rubber mixing	10	5	3
3273	Ready mix concrete	0	0	10
3313	Electrometallurgical products	17	15	13
3353	Aluminum manufacturing	7	7	11
3674	Semiconductors	4	4	9

SIC = Standard Industrial Classification.

[a] Includes concentration values reported as "<", and constituents reported as "present but quantity unknown."

There are a variety of possible reasons for these discrepancies. For example, EPA used high-quality analytical procedures enabling the quantification of constituents that are present at low levels. In addition, impoundment operators may only be required to monitor for a limited number of indicator chemicals and, as a consequence, may only track and therefore report one chemical among a larger class of chemical constituents.

Where chemical data are discussed in the remainder of this chapter, data from the survey database are used. For a more complete discussion of the field sampling data, please see Appendix E of this report.

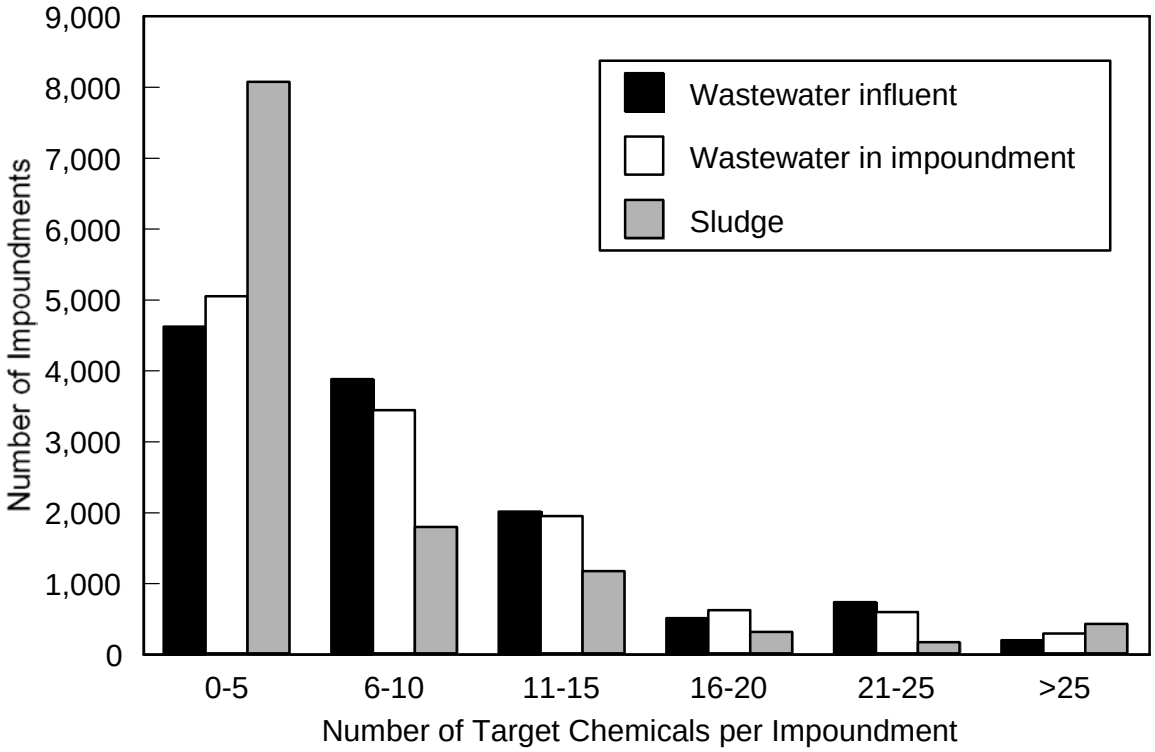
2.2.2 Chemicals Managed in Surface Impoundments

As stated in Section 2.1.1, the impoundments addressed in this study are those that manage wastewaters that contain chemicals or pH of concern. Of the 11,900 impoundments that meet this criterion, just over 90 percent had chemicals of concern and roughly 10 percent had pH

of concern. According to the survey data, approximately half of all facilities (15 percent of wastewater quantity managed) employ impoundments to manage five or fewer chemicals. Figure 2-7 shows the distribution of chemicals present on a per impoundment basis for wastewater influent, wastewater in impoundment, and sludge. The industry sectors that employ impoundments to manage more than 20 chemicals are chemical and allied products, paper and allied products, petroleum and coal products, and primary metals. A more detailed examination of the chemicals found in impoundments across SIC codes is provided in Appendix B.

A breakdown of chemicals present, by chemical category, for wastewaters and sludges is shown in Table 2-5. This table displays chemical presence based on "influent," "in impoundment," and "effluent" sampling points. The figures in this table represent the number of impoundments that contain chemicals from the given chemical category (shown under "# Imps"), and the percentage of the total volume of wastewater that contains chemicals from the given chemical category (shown under "% Vol").

As shown in Table 2-5, metals are the most prevalent chemical category found in wastewaters across the population of impoundments, present in 9,970 impoundments at influent and 7,760 impoundments at effluent sampling points. Furthermore, approximately 85 percent of



Note: For a detailed examination of the number of chemicals found in impoundments by SIC code, see Appendix B.

Figure 2-7. Number of chemicals in wastewater and sludge managed in impoundments.

Table 2-5. Breakdown of Chemical Categories for Wastewater and Sludge (at Different Sampling Points) on Impoundment and Volume Basis

Chemical Categories	Wastewater						Sludge					
	Influent		In Impoundment		Effluent		Influent		In Impoundment		Effluent	
	# Imps	% Vol	# Imps	% Vol	# Imps	% Vol	# Imps	% Vol	# Imps	% Vol	# Imps	% Vol
VOCs	5,866	76	5,412	76	4,815	72	1,690	4	2,006	21	1,311	14
SVOCs	3,824	75	3,786	75	3,508	69	863	7	1,261	24	605	3
Metals	9,966	84	9,982	83	7,762	85	3,925	42	5,551	98	3,078	88
Dioxin-like compounds	291	24	218	21	346	22	247	10	861	35	412	41
Mercury	2,483	27	2,479	30	2,235	31	1,061	0.9	1,745	66	826	6
Any chemicals	10,745	96	10,766	97	8,187	92	4,101	45	5,759	100	3,230	89

Imps = number of impoundments.
% Vol = percent of total volume.
SVOCs = Semivolatile organic compounds.
VOCs = Volatile organic compounds.

wastewater volumes contain metals. Dioxin-like compounds are the least common category of chemicals found in wastewaters across the population of impoundments, present in 290 impoundments at influent and 350 impoundments at effluent sampling points. However, just over 20 percent (between 21 and 24 percent) of wastewater volume contains dioxin-like compounds.

Metals are also the most common chemicals present in sludges across the population of impoundments, showing up in 3,930 impoundments at influent and 3,080 impoundments at effluent sampling points. A comparatively higher number of impoundments contain metals in sludge at the "in impoundment" sampling point, approximately 5,500 impoundments. Dioxin-like compounds are the least common category of chemicals in sludge managed in impoundments, present at between 250 impoundments at influent and 410 impoundments at effluent sampling points. There is also a comparatively higher number of units, 860 impoundments, with dioxin-like compounds at the "in impoundment" sampling point.

The most common constituents (by volume) in each chemical category are

- VOCs: methanol, acetone, methyl ethyl ketone, and acetaldehyde
- SVOCs: ethylene glycol, phenol, cresols, and aniline
- Metals: manganese, zinc, barium, and nickel.

In addition, two inorganic chemicals, sulfides and fluoride, are commonly present in wastewater volumes. These data are provided in Appendix B, along with presence and volume estimates for all SIS chemicals.

The pH criteria (pH between 2 and 3 or pH between 11 and 12.5) was not a significant issue at the impoundments addressed in this report. Approximately 3 percent of impoundments were in the acidic range, almost all of which managed never characteristic wastewaters. Roughly 8 percent of impoundments were in the basic range, the vast majority of which never managed characteristic wastes.

Table 2-6 presents data on the wastewater influent concentrations for 11 toxicity characteristic (TC) constituents that are managed in impoundments (see 40 CFR 261.124, Table 1). These 11 constituents are among the most frequently occurring across the population of impoundments, with all but cresol being in the top 25 chemicals; cresol is ranked 35th by presence. Appendix B, Table B-19a shows a complete breakdown of chemicals by presence and by wastewater quantity.

As the data show, arsenic, benzene, and cadmium have 50th percentile concentrations for never characteristic, decharacterized, or all impoundments that are above a screening factor health benchmark for cancer or noncancer effects. For the 90th percentile concentrations, selenium is added to that list. Barium, chloroform, chromium, mercury, and methyl ethyl ketone have 90th percentile concentrations that are within an order of magnitude of a human health screening factor. Benzene is the lone chemical to have 90th percentile wastewater influent concentrations for never characteristic and for all impoundments above the TC level. Arsenic, barium, benzene, cadmium, chloroform, chromium, lead, and selenium show concentrations that are above the TC level at a few impoundments (see Appendix B for histograms of the full concentration distributions for these TC chemicals). The never characteristic and decharacterized concentration breakdowns do not reveal any clear trends regarding chemical concentration.

In Table 2-7, EPA presents data on the facility-level co-occurrence of chemicals in wastewater by human health effect. Facility-level co-occurrence is defined as two or more chemicals with a common target health effect occurring within or across impoundments at a single facility. These figures on co-occurrence of chemicals with a common target health effect do not account for the potential variance of the effects that may result within the same target health effect category, nor does this evaluation consider chemical concentration with regard to co-occurrence. However, EPA did consider chemical concentration and co-occurrence in the risk analysis. Specifically, EPA's risk analysis examined the risks caused by exposure to multiple contaminants from the same impoundment and facility and found only a single instance where co-occurrence led to a risk of concern. (See Appendix C, Section C.1, which provides information on the assessment of cumulative risks.) The evaluation of chemical co-occurrence was specifically called for as a part of the consent decree (*EDF v. Whitman*).

As the data show, the top five target health effect categories for facilities with two or more chemical co-occurrences in wastewater are kidney, liver, neurological, cancer, and hematological. The target health effect categories that have facilities with co-occurrences of

Table 2-6. Comparison of 50th and 90th Percentile Influent Wastewater Concentrations with Toxicity Characteristic (TC) Limits and Health-Based Screening Factors for Selected Chemicals

Chemical	Screening Factor[a] (mg/L)		TC Limit [b] (mg/L)	Influent Wastewater Concentrations (mg/L)					
				50th Percentile			90th Percentile		
	Carc.	Noncarc.		Never Charac-teristic	Decharac-terized	All Impound-ments	Never Charac-teristic	Decharac-terized	All Impound-ents
Arsenic (7440-38-2)	6.6E-04	6.9E-03	5.0	9.0E-03	6.9E-03	9.0E-03	1.3E-02	2.1E-02	2.1E-02
Barium (7440-39-3)	NA	1.6E+00	100.0	1.3E-01	1.0E-01	1.3E-01	3.2E-01	4.5E-01	3.5E-01
Benzene (71-43-2)	1.8E-02	NA	0.5	8.0E-01	1.6E-02	2.1E-02	1.1E+00	9.0E-02	8.0E-01
Cadmium (7440-43-9)	NA	1.2E-02	1.0	1.8E-02	3.1E-03	3.1E-03	7.9E+00	7.0E-03	1.5E-01
Chloroform (67-66-3)	1.6E-01	2.3E-01	6.0	4.0E-03	1.9E-02	4.0E-03	1.1E-02	1.1E-01	3.0E-02
Chromium (7440-47-3)	NA	6.9E-02	5.0	6.0E-03	6.4E-03	6.4E-03	2.5E-02	2.7E-02	2.7E-02
Cresol (1319-77-3)	NA	1.2E+00	200.0	NA	4.1E-02	3.1E-02	NA	1.1E-01	1.1E-01
Lead (7439-92-1)	NA	NA	5.0	2.0E-02	5.7E-03	1.0E-02	2.0E-02	2.0E-02	2.0E-02
Mercury (7439-97-6)	NA	6.9E-03	0.2	6.0E-05	5.9E-04	3.0E-04	6.0E-04	7.5E-03	3.8E-03
Methyl Ethyl Ketone (MEK) (78-93-3)	NA	1.4E+01	200.0	0.0E+00	7.4E-01	6.1E-01	2.5E-02	5.9E+00	5.9E+00
Selenium (7782-49-2)	NA	1.2E-01	1.0	2.0E-03	8.0E-03	5.3E-03	1.4E-01	4.8E-02	1.4E-01

NA = Not available.

[a] Human health screening factors for carcinogens (carc.) and noncarcinogens (noncarc.) in drinking water. See Appendix C, Attachment C-3.

[b] Source: RCRA §261.24, Table 1 – Maximum Concentration of Contaminants for the Toxicity Characteristic

between 11 and 20 chemicals in wastewater within/across impoundments are liver, cancer, kidney, and neurological; liver has the most facilities within this range, at 221. Additional evaluation of the co-occurrence of chemicals in wastewaters and in sludge is shown in Appendix B.

Table 2-7. Co-occurrence of Chemicals in Wastewater by Human Health Effect

Target Health Effect[a]	Estimated Number of Facilities with Co-occurrences[b] in Wastewater				
	Number of Chemicals Co-occurring Within/ Across Impoundments[c]				All Facilities with Two or More Co-ocurrences
	2-3	4-6	7-10	11-20	
Cancer	621	328	390	30	1,369
Adrenal	0	0	0	0	0
Bladder	0	0	0	0	0
Body weight	984	193	13	0	1,191
Brain	0	0	0	0	0
Cardiovascular	0	0	0	0	0
Death	0	0	0	0	0
Developmental	635	11	0	0	646
Eyes	13	0	0	0	13
Forestomach	0	0	0	0	0
Gastrointestinal	0	0	0	0	0
General	0	0	0	0	0
Hematological	1,246	76	11	0	1,334
Kidney	1,099	799	111	11	2,020
Leukemia	0	0	0	0	0
Liver	972	339	212	221	1,743
Lung	766	64	0	0	830
Mammary	0	0	0	0	0
Nasal cavity	0	0	0	0	0
Neurological	873	696	73	10	1,653
Organ weight	13	0	0	0	13
Reproductive	123	0	0	0	123
Respiratory	832	131	0	0	962
Respiratory tract	0	0	0	0	0
Skin	238	0	0	0	238
Spleen	0	0	0	0	0

(continued)

Table 2-7. (continued)

Target Health Effect[a]	Estimated Number of Facilities with Co-occurrences[b] in Wastewater				
	Number of Chemicals Co-occurring Within/ Across Impoundments[c]				All Facilities with Two or More Co-ocurrences
	2-3	4-6	7-10	11-20	
Stomach	0	0	0	0	0
Thyroid	0	0	0	0	0
Vascular	6	0	0	0	6

[a] For noncarcinogenic chemicals, target organ on which health benchmark (e.g., RfD) is based. Cancer or leukemia for carcinogenic chemicals. See Appendix C for discussion of health benchmarks.

[b] A facility-level co-occurrence is defined as when two or more chemicals with a common target health effect occur within or across impoundments at a single facility.

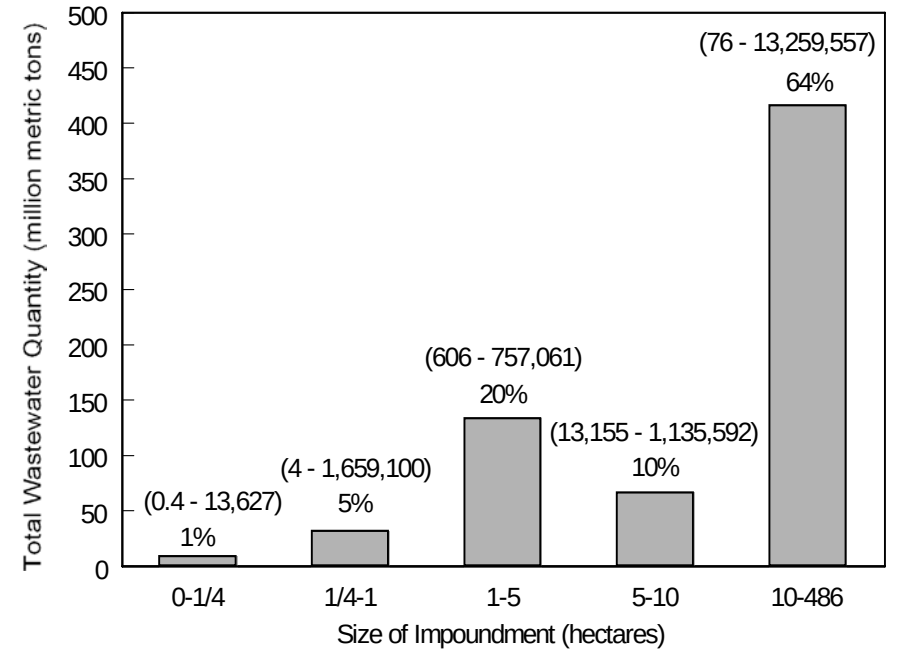
[c] Lists of the co-occurring chemicals at each facility in the sample are provided in Appendix B.

2.2.3 Surface Impoundment Size and Wastewater Volume Characteristics

Impoundment size is an important variable in the assessment of wastewater volumes and the potential for environmental releases. As shown in Figure 2-8, approximately 75 percent of the total wastewater quantity for all impoundments exists at roughly 10 percent of the impoundments; these impoundments have surface areas that range from 5 to 500 hectares. Alternatively, approximately half of all impoundments have surface areas under 1/4 hectare; these 6,000 impoundments have a combined total of roughly 1 percent of the wastewater quantity managed in all impoundments.

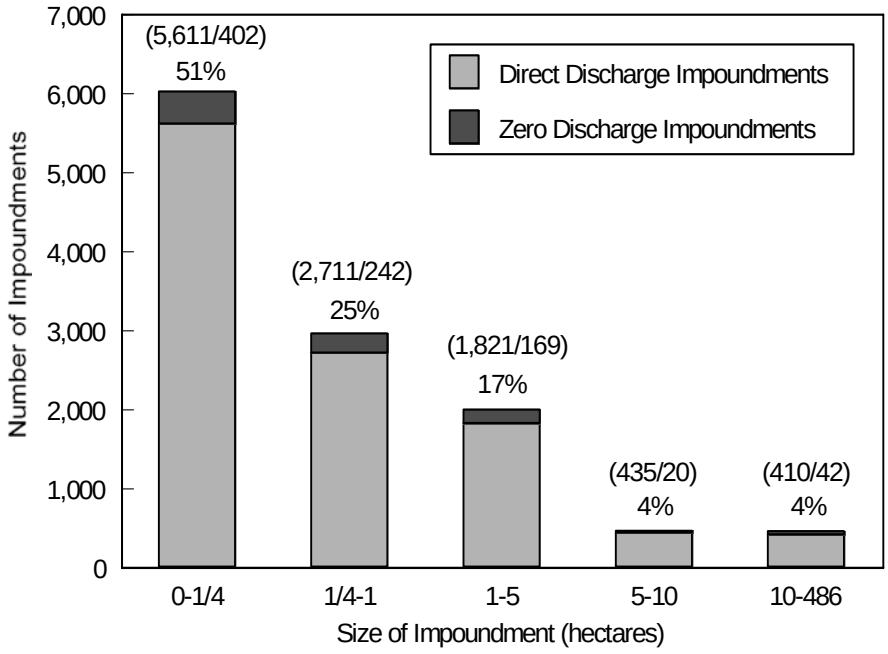
For a given impoundment surface area, the wastewater quantity in that impoundment will, of course, vary based on depth of the impoundment as well as the potential for partial impoundment dryness on a seasonal basis. Above each bar in the top histogram in Figure 2-8 is the range of wastewater quantities in impoundments in the given size class. A clear example of variance in wastewater quantities is seen for the 1/4- to 1-hectare size range. The wastewater quantity for this group of impoundments varies from roughly 4 metric tons to over 1 million metric tons.

The lower histogram in Figure 2-8 displays the number of impoundments broken out by direct or zero discharge status above each bar. While zero discharge impoundments are present at just over 10 percent of all facilities and make up approximately 7 percent of all impoundments, they represent under 5 percent of the total wastewater quantity. Just over 400 zero discharge impoundments (almost half of the 876 total zero dischargers) are under 1/4 hectare, while just 7 percent of the zero discharge impoundments are over 5 hectares in size.



% = percent of total wastewater managed

(A - B) = range of lowest (A) to highest (B) wastewater quantity (metric tons) per impoundment



% = percent of the total number of impoundments

(A/B) = number of direct discharge impoundments (A)/number of zero discharge impoundments (B)

Figure 2-8. Total wastewater quantity and number of impoundments by impoundment size.

Table 2-8. Facility Breakdown of Treatment Process (Used by at Least One Impoundment)

Facility Status	Treatment Process							
	Aeration		Sedimentation		Other		No Treatment	
	Number of Impoundments	%	Number of Impoundments	%	Number of Impoundments	%	Number of Impoundments	%
Direct dischargers (3,944 facilities)	920	23	1,780	45	1,745	44	2,091	53
Zero dischargers (512 facilities)	160	31	217	42	92	18	232	45
All facilities (4,457 facilities)	1,081	24	1,997	45	1,837	41	2,323	52

% = percent of discharge category.
Several treatment processes may be used at the same facility. Therefore, the sum of the percentages for "all facilities" does not total 100%.

Impoundment size is an important factor in assessing the potential for human exposure to chemicals managed at these facilities. For the air pathway, volatilization potential can increase at larger impoundments due to the increase in surface area exposed to the atmosphere at these impoundments. Alternatively, greater impoundment size can allow for greater dilution of chemicals and thus lower concentrations and reduced emissions (see Section 2.3.1). Similarly, for the groundwater pathway, larger impoundments are less likely to be lined than are smaller impoundments. Additionally, chemical releases to groundwater may be more difficult to detect at larger impoundments due to the greater demand for monitoring well coverage. However, the greater dilution of chemicals that often occurs in larger impoundments is again a mitigating factor, reducing the potential that releases from the unit will be at high concentrations (see Section 2.3.2).

2.2.4 Management Practices at Surface Impoundments

Management practices at impoundments can be broadly classified as aeration, sedimentation, and other (including flocculation, coagulation, precipitation, filtration, biotreatment, denitrification, disinfection, ion exchange, adsorption, and chemical oxidation). Table 2-8 shows a breakdown of management methods at facilities by discharge type. Approximately one-quarter of all facilities performed aeration in at least one impoundment, with a slightly greater percentage of zero dischargers than direct dischargers conducting aeration. Roughly 45 percent of all facilities have sedimentation occurring in an impoundment, while approximately 40 percent of facilities employed some other treatment method. At half of all facilities, no treatment was conducted. See Appendix B, Table B-10, for a detailed list of all treatment types used in the survey.

Many facilities manage wastewaters in multiple impoundments, allowing different methods of treatment to be conducted in different impoundments that are linked in the process (e.g., aeration, biotreatment, and sedimentation). EPA did not assess the occurrence of staged treatment at these facilities. This issue is discussed briefly with regard to transport of chemicals in the atmosphere in Section 2.3.1.

2.3 Factors Related to Transport of Chemicals from Surface Impoundments

This section presents data on factors associated with the transport of chemicals in wastewater from source to receptor via environmental media: air, groundwater, and surface water. The presence of volatile organic compounds (VOCs), the use of aeration, and the size of the impoundment are discussed for the air pathway. The depth to groundwater and presence of liners are discussed for the groundwater pathway. The surface water pathway is treated as a special case of groundwater transport. Therefore, the hydrogeological connectivity of groundwater to surface water is discussed in this section; the possibility of surface water contamination from occurrence of overtopping events is also briefly discussed.

2.3.1 Factors Related to Transport of Chemicals in Air

The uncontrolled release of VOCs from wastewaters is an area of concern. There are many factors that affect the volatilization of a chemical from the water surface of an impoundment and its subsequent transport in the atmosphere. These factors include the properties of the chemical (e.g., its chemical-specific tendency to partition between water and air), the temperature of the air above the impoundment and the wastewater in the impoundment, the local meteorological conditions including wind speed and atmospheric stability class, and the characteristics of the impoundment such as its surface area and aeration level.[7] Additionally, the mass of VOC present in the wastewater has an important influence on the overall emissions from a given unit. The data on VOCs in wastewater, impoundment size, and aeration are discussed below as they relate to potential air contamination.

Approximately 50 percent of impoundments manage wastewaters that contain VOCs (see Table 2-9). However, roughly 75 percent of wastewaters by volume contain VOCs. Additionally, 55 percent of direct dischargers have VOCs present in wastewaters, compared to an estimated 20 percent of zero dischargers. As discussed in Section 2.2.2, the most common VOCs (by volume) present in wastewaters are methanol, acetone, methyl ethyl ketone, and acetaldehyde.

Impoundment size is an important factor influencing the atmospheric contaminant concentration at a receptor point. EPA therefore examined the presence of VOCs by impoundment size in a separate analysis. Approximately 70 percent of the very large impoundments (those in the 5- to 500-hectare category) contain VOCs, while 50 percent of the small impoundments (under 1 hectare) contain VOCs.

[7] Surface impoundments are generally designed as open-air units. Relatively few are known to have a cover or be under a roofed structure.

Table 2-9. VOC/Aeration Status for Impoundments

VOCs/Aeration Treatment	Number of Impoundments	Wastewater Quantity (metric tons)	Percent of Total Wastewater Quantity
No VOCs / aeration	804	44,276,182	6
VOCs / aeration	939	306,608,296	40
VOCs / no aeration	5,350	253,540,050	33
No VOCs / no aeration	4,770	154,075,362	20
All impoundments[a]	11,863	758,499,891	100

[a] The total wastewater quantity shown here for all impoundments does not equal the total wastewater quantity shown in Table 2-1. This is due to the missing data associated with this variable. Please refer to Appendix A for a discussion of how missing data were handled, and Appendix B for information on the standard error associated with the wastewater quantity estimate.

Aeration is a fairly common management practice for these impoundments and is performed for various reasons to improve the efficiency of wastewater treatment. As discussed in Section 2.2.4, aeration is performed at approximately 25 percent of all facilities. Using the figures shown in Table 2-9, EPA estimates that approximately 45 percent of the total wastewater volume is aerated. However, according to the same table, of the 1,743 impoundments where aeration is conducted, 804, or almost half, show no presence of VOCs in wastewater. This is understandable given that aeration may be employed for reasons other than treatment of volatiles, such as for mixing coagulants in the wastewater or promoting aerobic biodegradation (Metcalf and Eddy, 1991).

Of those impoundments conducting aeration, approximately 50 percent are under 1 hectare in size. However, almost 40 percent of impoundments in the 5- to 500-hectare size range are employing aeration practices. These very large impoundments are likely aerated only in particular areas of the impoundment.

As discussed in Section 2.2.4, facilities may employ more than one impoundment in the process of managing industrial wastewaters. Approximately two-thirds of all facilities have more than one impoundment onsite; roughly 5 percent have more than 10 impoundments onsite. In such cases, a facility may have one aerated impoundment in conjunction with an impoundment for sedimentation purposes or some other purpose. Information on the sequencing of impoundments in multistage treatment processes at these facilities was not analyzed in this report. However, any time wastewater containing VOCs experiences turbulence (as when it is pumped from one unit to another), flows through a channel from one unit to another, or at any discharge points in the process, releases to the atmosphere are likely (Metcalf and Eddy, 1991). Therefore, the roughly 5,300 impoundments that contain volatiles but are not performing aeration may still produce air emissions.

2.3.2 Factors Related to Transport of Chemicals in Groundwater

Moderate release of chemicals to the subsurface is a design feature of many zero discharge impoundments, which make up just under 10 percent of the population of impoundments addressed in this study. However, releases of chemicals at high enough concentrations can, over time, result in contamination of drinking water supplies or of fishable waterbodies, and thus potential risk to humans. Many factors influence the release and migration of chemicals in groundwater. This section examines depth to groundwater and presence of an impoundment liner for the population of impoundments addressed in this report. In addition, EPA also addresses the discharge of groundwater to surface water, overtopping events, and the data on monitoring wells used to detect releases to groundwater.

2.3.2.1 Depth to Groundwater. The distribution of the depths to groundwater relative to the bottom of the impoundment is shown in Figure 2-9. Approximately 75 percent of impoundments are located in areas where groundwater depth is within 4 meters of the bottom of the impoundment, and almost 90 percent of impoundment bottoms are within 8 meters of groundwater. There are no notable differences in depth to groundwater for the direct and zero discharge subpopulations.

Given that over 90 percent of impoundments in the population are direct dischargers and are located near surface waterbodies, it is not surprising to find that the impoundments are located over relatively shallow groundwater. In fact, as Figure 2-9 shows, almost 20 percent of impoundments have impoundment bottoms that are below the groundwater surface. Given their proximity to surface water, many of these groundwater levels are likely to fluctuate seasonally or with significant precipitation events.

Although the presence of generally shallow groundwater conditions is significant in terms of the potential for groundwater transport of chemical from impoundments, not all shallow groundwater is potable; thus, it is less significant in terms of risk to humans. Approximately one-third of these groundwaters are not potable according to the survey respondents reporting potability status.

2.3.2.2 Presence of Liner. Use of liners is an important method of preventing releases from impoundments to the subsurface. The survey defined the term "liner" as

> a continuous layer of natural or man-made materials, emplaced beneath and/or on the sides of a surface impoundment, that restricts the downward and/or lateral release of waste, waste constituents, or leachate from the surface impoundment. The liner does not include naturally occurring materials (such as a naturally occurring clay layer) that, although effective in controlling the release of leachate from the surface impoundment, were not emplaced intentionally for that purpose.

EPA collected data on the presence of liners at impoundments, as well as the age and type of liner and whether liner failure had occurred. Figure 2-10 displays information on liner usage by impoundment, impoundment size, and wastewater volume. EPA estimates that approximately 5,000 impoundments, or approximately 40 percent of the population, are lined. However, just

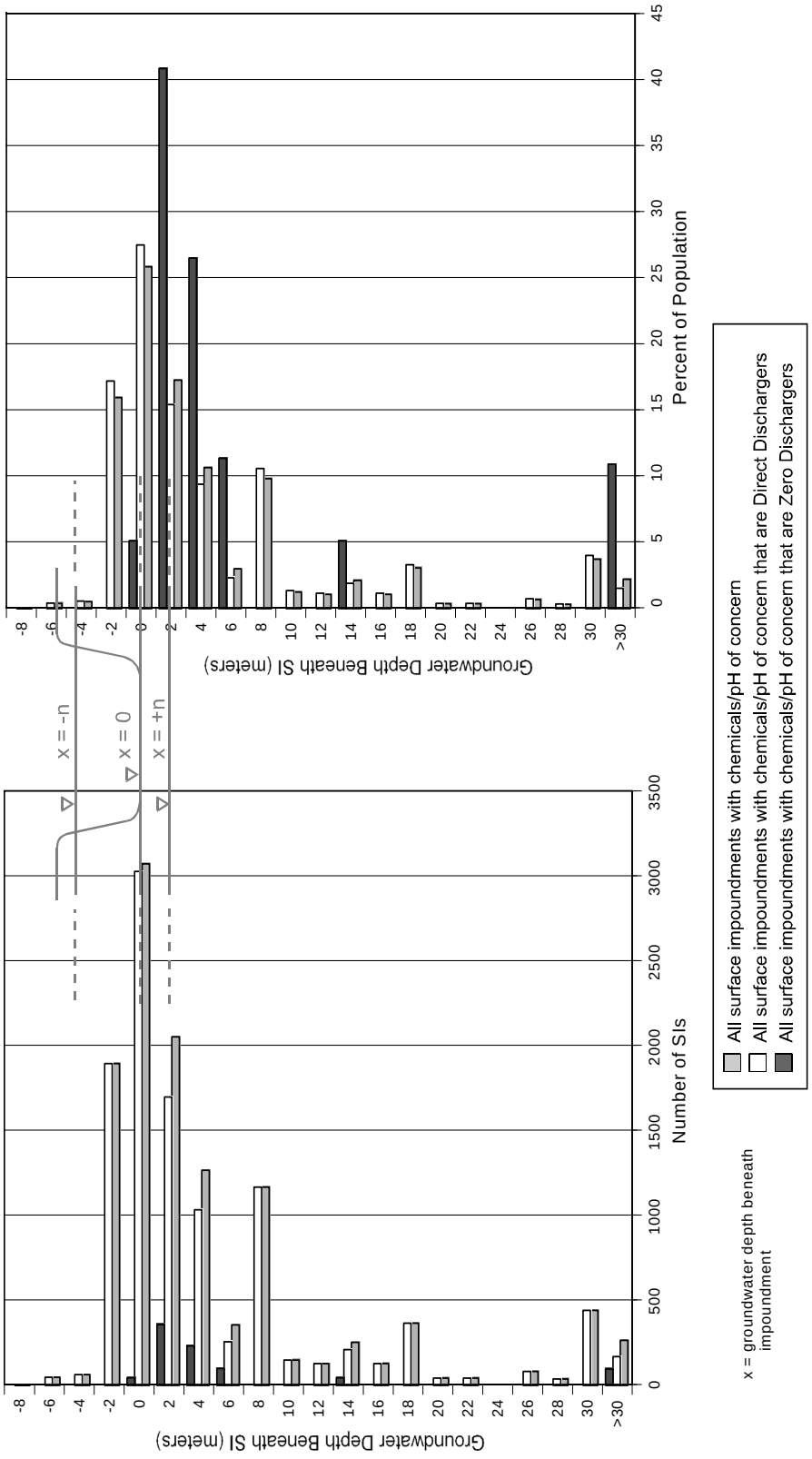
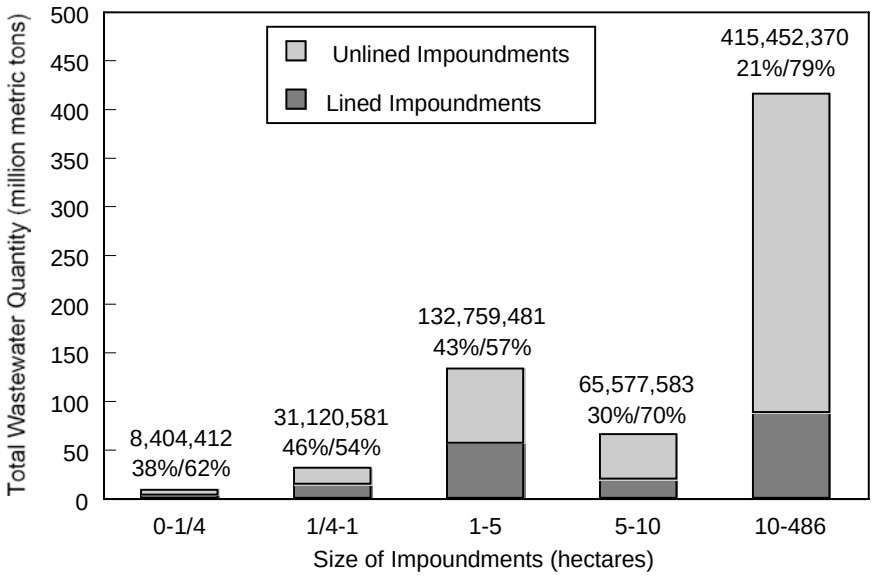


Figure 2-9. Depth to groundwater beneath impoundment by impoundment discharge status.



Total wastewater quantity (from lined and unlined impoundments) is presented above each bar

(A%/B%) = percent of wastewater managed in lined impoundments (A)/percent managed in unlined impoundments (B)

Size of Impoundment (hectares)	0-1/4	1/4-1	1-5	5-10	10-486	All Impoundments
Number of Impoundments	6,013	2,953	1,989	456	452	11,863
Number of Lined Impoundments	2,043	1,878	796	99	139	4,955
Number of Unlined Impoundments	3,970	1,075	1,193	356	314	6,908
Depth to Groundwater (m): median (lowest, highest)	1.1 (-3.8, 64)	1.2 (-6.1, 44)	2.9 (-8.2, 122)	2.9 (-8, 27)	1.2 (-4.6, 41)	1.5 (-8.2, 122)

Figure 2-10. Number of impoundments and wastewater volumes by liner status.

under 25 percent of wastewater volumes are managed in lined units. This difference in the percentage of lined impoundments and the percentage of wastewater quantities managed in lined impoundments is attributable to the fact that larger units are lined less frequently. Just over 40 percent of impoundments under 1 hectare are lined, and 25 percent of those over 5 hectares are lined. One-third of those impoundments with liners were from the chemical and allied products industry sector.

There are a number of possible reasons why liners are used more frequently at smaller units. Obviously, it is more economical and practical to line a smaller unit than to line a larger unit. Additionally, many of the larger impoundments are likely older and were built to provide access to large water supplies that were critical to the manufacturing process at these facilities. They were, therefore, probably constructed in areas that would effectively contain water naturally rather than built to rely on more modern liner technologies.

As engineered structures, liners are susceptible to design and operating flaws and to routine wear and tear that can eventually reduce their ability to restrict flow. However, liner failure can occur in just one layer of the liner at impoundments with multiliner systems or occur in a place in the liner that is above the water surface, which would not necessarily result in a release to groundwater. In addition, liner failure can occur in the freeboard area or next to conveyances, making detection and repair relatively simple. EPA estimates that approximately 12 percent of the impoundments with liners experienced liner failure. Roughly 10 percent of all wastewater volumes are managed in impoundments that have had a liner failure.

The effectiveness of a liner system depends in part on the type of liner installed. The data on liner types are shown in Table 2-10. Almost 80 percent of the lined units have clay, flexible membrane, or composite (flexible membrane and clay) liners. Forty-four percent of the units lined have flexible membrane or composite liners, which are generally more effective than alternative liner types. Asphalt was the least common liner type, employed at less than 1 percent of lined impoundments.

2.3.2.3 Groundwater Discharge to Surface Water. Transport of chemicals from surface impoundments to fishable waterbodies can occur through discharge of groundwater to surface water. In cases where there is a direct hydrogeological connection between groundwater and surface water, contaminant transport in groundwater can impact fishable waterbodies.

Survey data suggest that roughly 80 percent of all impoundments are above groundwater systems that discharge to surface water. In addition, approximately 95 percent of impoundments with a surface area over 5 hectares are above groundwater that discharges to surface water. These larger impoundments constitute only 10 percent of the total impoundment population. In addition, the size of these larger impoundments may allow for greater dilution of chemicals than in smaller impoundments. However, given that only 40 percent of all impoundments are lined, and that these larger impoundments are less likely to be lined than the smaller ones, they may present a greater potential, at the impoundment level, for contamination of adjacent fishable waterbodies.

Table 2-10. Number and Percentage of Impoundments by Liner Status

Liner Status	Number of Impoundments	Percentage of Impoundments
Compacted clay	1,680	14
Flexible membrane (FML)	1,584	13
Composite (FML and clay)	536	5
Concrete	629	5
Asphalt	55	< 1
Other	363	3
Unlined[a]	7,017	59
Total	11,863	100

[a] This estimate differs from the estimate of outlined impoundments shown in Table 2-12. This is due to missing data associated with this variable. Refer to Appendix A on missing data and Appendix B for the standard error associated with this variable.

2.3.2.4 Overtopping Events. Overtopping of impoundments can result in contamination of adjacent surface waterbodies through overland transport of wastewaters. EPA estimates that one-quarter of all facilities had an overtopping event, which occurs where there is significant precipitation, or dike or berm failure. An estimated 20 percent of the population of impoundments have fishable waterbodies within 150 meters of the impoundment. And approximately 20 percent of impoundments with fishable waterbodies within 150 meters experienced an overtopping event. EPA did not analyze data on the magnitude of these overtopping events due to concerns with their reliability. Therefore, the potential for impacts to nearby aquatic systems from overtopping is unknown.

2.3.2.5 Monitoring Wells. Monitoring wells are installed to detect releases of chemicals from impoundments to groundwater. One-third of the population of impoundments and roughly the same percentage of facilities reported the presence of a monitoring well intended to detect releases. Of these impoundments, 5 percent (189 units) detected a release of chemicals to groundwater, as shown in Table 2-11.

Almost 50 percent of the impoundments with monitoring wells are solid waste management units (SWMUs) at RCRA treatment, storage, and disposal (TSD) facilities (see Section 2.5 for information on SWMUs). However, only one-third of the total population of impoundments are SWMUs at RCRA TSDs. This increased attention to potential releases, evidenced by the greater use of monitoring wells at these SWMUs, is not surprising given the RCRA corrective action program's oversight at these facilities.

Table 2-11. Monitoring Well/Detection of Releases by Discharger Type

Discharger Type	Monitoring Well Present				No Monitoring Well to Detect Release		All Impoundments	
	Detected Release	Did Not Detect Release	Total					
			Number	%	Number	%	Number	%
Direct dischargers	189	3,257	3,446	31	7,541	69	10,987	100
Zero dischargers	0	411	411	47	465	53	876	100
All impoundments	189	3,668	3,856	33	8,007	67	11,863	100

2.4 Proximity of Humans to Surface Impoundments

In this section, EPA examines the potential for human exposure to the chemicals managed in impoundments. First, the general proximity of humans and human activities to surface impoundments is addressed. Then, EPA focuses on the proximity of humans to potential exposure points for air, groundwater, and surface water.

The industrial facilities that employ surface impoundments to manage nonhazardous wastewater are located throughout the United States in a wide array of settings. Some facilities are located in rural areas adjacent to agricultural land use, while other facilities are in heavily populated residential areas or are part of a concentration of industrial activity (see Figures 2-3 and 2-4).

Within this diversity of settings, the potential for human exposure to chemicals managed in these impoundments does exist. EPA estimates that roughly 20 million people (approximately 10 million residences) are located within 2 kilometers of an impoundment (see Table 2-12). Of this population, roughly 50,000 people live within 150 meters of an impoundment. Additionally, an estimated 540 schools are located within 500 meters of an impoundment.

Another indicator of potential exposure is the human activity that occurs near these facilities. EPA's data suggest that farming occurs within 2 km of an impoundment at approximately 40 percent of all facilities. Roughly half of all facilities have fishing within 2 km of an impoundment, and two-thirds of all facilities identified swimming as occurring within 2 km of an impoundment. Hunting is estimated to occur within 2 km of an impoundment at approximately one in five facilities. Each of these activities represents a means by which an exposure pathway could be completed (e.g., indirect exposure through ingestion of produce grown at farms with significant air deposition of chemicals from an adjacent impoundment).

This overview of humans and human activities near surface impoundments suggests that exposure is possible, given the potential for release of contaminants to air, groundwater, or surface water. Section 2.3 of this report discusses several factors related to the possibility of such environmental transport of chemicals from wastewater. In this section, these transport

Table 2-12. Proximity of Surface Impoundments to People, Residences, Drinking Water Wells, and Schools

Distance from Impoundment (m)	People Living within a Given Distance	Residences within a Given Distance	Drinking Water Wells within a Given Distance	Schools within a Given Distance
0 - 150 m	51,579	21,227	888	0
151 - 500 m	663,380	285,411	13,728	541
501 - 1,000 m	3,284,378	1,341,834	56,146	2,390
1,001 - 2,000 m	14,414,175	5,898,810	204,984	8,990

GW= Groundwater.

factors are linked with the human proximity data to provide a closer look at the potential for exposure.

2.4.1 Proximity of Humans to Surface Impoundments by Pathway

EPA has generally observed a significant decline in the concentration of airborne chemicals in a plume as the distance from the source increases. Therefore, in assessing potential exposure to chemicals through the air pathway, EPA examined the proximity of humans within a 150-meter radius of surface impoundments that manage VOCs. EPA estimates that just under 10 percent of all impoundments manage VOCs and have residences within a 150-meter radius (see Table 2-13). Roughly half of these impoundments manage VOCs through aeration.

As discussed in Section 2.3.2 of this chapter, movement of a contaminant plume in groundwater is influenced by a host of factors. These factors must be assessed at the facility level for an accurate determination of the potential for human exposure through groundwater. For the purposes of this chapter, EPA examined the proximity of wells and of fishable waterbodies to impoundments in order to provide an overall picture of the potential for human exposure through groundwater. Approximately 10 percent of all facilities (or 6 percent of all impoundments) are estimated to have a drinking water well within 150 m of an impoundment (see Table 2-14). Fifteen percent of those impoundments (approximately 100) are lined impoundments. At a 2,000-meter radius from the impoundment, the proportion of impoundments with wells jumps to 50 percent (approximately 6,000 out of 11,900), 45 percent (approximately 2,700) of which are lined units.

EPA considered the potential for surface water contamination through groundwater at a 150-meter radius also. As discussed in Section 2.3.2, just over 80 percent of all impoundments are located above groundwater systems that discharge to a fishable waterbody. Furthermore, approximately 20 percent of all impoundments have a fishable waterbody within a 150-meter radius.

Table 2-13. Proximity of Residences to Impoundments Based on Presence of VOCs and Aeration Status

VOC/Aeration Status of Impoundments[a]	Proximity of Nearest Residences to Surface Impoundments (m)				
	0 - 150	151-1,000	1,001-2,000	No Residences within 2,000	Total
No VOCs in wastewater					
Number of impoundments	3,439	2,173	236	101	5,947
Percent of total wastewater quantity	14%	8%	3%	< 1%	25%
VOCs present in wastewater/no aeration					
Number of impoundments	458	4,123	338	44	4,963
Percent of total wastewater quantity	8	24%	1%	< 1%	33%
VOCs present in wastewater/aeration					
Number of impoundments	406	433	96	18	953
Percent of total wastewater quantity	8%	29%	3%	2%	41%
Total					
Number of impoundments	4,303	6,729	670	162	11,863
Percent of total wastewater quantity	30%	60%	8%	2%	100%

[a] The estimates of the number of impoundments and the percent of total wastewater quantity shown in this table do not agree with those shown in Table 2-9. This is due to the missing data associated with these variables. Please refer to Appendix A for a discussion of how missing data were handled, and Appendix B for information on the standard error associated with these variables.

EPA believes that the data discussed above on the proximity of humans to impoundments with respect to the air, groundwater, and surface water pathways suggest that the potential exists for human exposure to chemicals from these impoundments. The risk assessment work discussed in Chapter 3 of this report evaluates this potential for human exposure.

2.5 Regulatory, Exemption/Exclusion, and Operating Status of Surface Impoundments

The 4,500 facilities examined in this study operate within an overall regulatory context. This context may include permits requiring regular onsite activities, such as periodic sampling of wastewater or routine contacts with regulators, or operational conditions calling for occasional adjustments to treatment processes or monitoring of various aspects of facility operations and monthly flow rates. At any given facility, this regulatory context is made up of federal, state, or local regulations. For example, survey data show that approximately 80 percent of all impoundments are under some level of regulatory oversight, either by virtue of a state or local permit or as an SWMU at a RCRA TSD. Similarly, this regulatory context may include exemptions or exclusions from such regulations. Survey data show that roughly 15 percent of

Table 2-14. Proximity of Nearest Wells to Impoundments Based on Liner Status

Liner Status of Impoundments	Proximity of Nearest Wells to Surface Impoundments (m)				
	0-150	151-500	501-2,000	No Well within 2,000	Total
Lined impoundments—no liner failures					
Number of impoundments	54	541	1,661	1,809	4,065
Percent of total wastewater quantity	2%	5%	8%	4%	18%
Lined impoundments—with liner failures					
Number of impoundments	40	95	311	38	484
Percent of total wastewater quantity	<1%	<1%	5%	<1%	6%
Unlined impoundments[a]					
Number of impoundments	569	546	2,173	4,026	7,314
Percent of total wastewater quantity	6%	25%	28%	17 %	75%
Total					
Number of impoundments	663	1,182	4,145	5,873	11,863
Percent of total wastewater quantity	8%	30%	41%	21%	100%

[a] The estimates of the number of unlined impoundments shown in this table do not agree with the number shown in Table 2-10. This is due to the missing data associated with these variables. Refer to Appendix A for a discussion of how missing data were handled, and Appendix B for information on the standard error associated with this variable.

impoundments are used to manage wastewaters that are excluded or exempt from RCRA regulations.

EPA collected data on the state, local, and federal regulations that apply at these facilities. Additionally, any exemptions or exclusions that apply at the facility were identified. The survey also requested information on the operating status of the impoundments at the facility. This section presents the main findings from these data.

EPA first examined the data on whether impoundments had a state or local permit for any wastewater or sludge management, groundwater protection activities, and/or air emissions associated with the particular impoundment. As shown in Table 2-15, there are an estimated 3,600 facilities, or 80 percent of all facilities, with at least one impoundment that is under a state or local permit. These 3,600 facilities represent over 95 percent of the wastewater quantities managed in impoundments and are almost entirely NPDES permits for direct discharge to a surface waterbody. Of the facilities that identified permits, 25 percent were chemical and allied product facilities and roughly 15 percent were stone, clay, glass, and concrete product facilities.

The paper and allied product sector and the wholesale trade-nondurable goods sector each accounted for just under 15 percent of these facilities.

Some impoundments examined in this study are solid waste management units at a RCRA TSD facility and are, therefore, subject to federal requirements for remediation of environmental contamination at the facility (40 CFR 264.101). Approximately one-quarter of all facilities (one-third of all impoundments) are RCRA TSD facilities with SWMUs onsite that have been through a RCRA Facility Assessment (RFA), as shown in Table 2-15.[8] Of those impoundments in this group, two-thirds are chemical and allied product impoundments and one-quarter are petroleum and coal product impoundments.

EPA gathered information on the management of exempt/excluded wastewaters in impoundments. As shown in Table 2-15, approximately 15 percent (1,700 impoundments) of the population manage some exempted or excluded wastewaters. Of those impoundments in this group, roughly 35 percent are paper and allied product impoundments, 35 percent are chemical and allied product impoundments, and 20 percent are petroleum and coal product impoundments. These wastewaters are identified as being exempt or excluded from RCRA Subtitle C regulation under a number of possible exemption/exclusion categories. This volume, approximately 98,800,000 metric tons, represents 15 percent of the total wastewater quantity managed in impoundments. As shown in Table 2-16, the exclusions and exemptions cited include those for point source discharges (40 CFR 261.4(a)(2)), mixtures of solid waste and characteristic-only hazardous waste (40 CFR 261.3(a)(2)(iii)), Bevill wastes (40 CFR 261.4(b)(7) and 3001(b)(3)(A)(ii)), coal and fossil fuel combustion wastes (40 CFR 261.4(b)(4) and 3001(b)(3)(A)(i)), and mixtures of solid waste and hazardous waste discharging to Clean Water Act systems (40 CFR 261.3(a)(2)(iv)). For more details on these exclusions and exemptions, please see Appendix A, which contains the survey appendix with the definitions that were provided to survey respondents. Also see Appendix B, which provides a more detailed breakdown of the exempt/excluded wastewaters.

EPA collected data on the operating status of the impoundments in the study. Most impoundments were built more than 20 years ago (see Figure 2-1). Nearly 40 percent of the impoundments operating in the 1990s were constructed in the 1970s and were presumably built in response to environmental programs seeking improved wastewater treatment. The impoundments that were in operation before 1970, approximately one-quarter of the population, were likely employed in some aspect of water supply management associated with the industrial processes at these facilities.

Eventually, impoundments stopped being used for waste management and were closed, with varying degrees of waste removal. As shown in Table 2-15, EPA estimates that, during the 1990s, 16 percent of the industrial impoundments permanently stopped receiving waste. This closure rate is in sharp contrast to the previous decade when a significant percentage of

[8] During an RFA, an overseeing agency typically compiles existing information on environmental conditions at a given facility and, as necessary, gathers additional facility-specific information on solid waste management units and other areas of concern, releases, potential releases, release pathways, and receptors. Information gathered during an RFA usually forms the basis for initiating full-scale site characterization.

Table 2-15. Regulatory, Exempt/Excluded, and Operating Status of Impoundments

	(1) SWMU RCRA Assessment	(2) Manage Excluded/ Exempt Wastewater	(3) Ceased Receiving Waste since June 1, 1990	(4) Are under State/Local Regulations	(5) Meet All (1-4)	(6) Meet None (1-4)
Percent of impoundments (out of 11,863)	33	15	16	86	0.9	5
Percent of facilities with at least one unit in category (out of 4,457)	25	14	22	81	0	7
Percent of total wastewater quantity managed at impoundments (out of 653,796,340 metric tons)[a]	14	15	4	97	0.5	2

[a] The estimate of the wastewater quantity for the total population differs from the estimates shown in Tables 2-1 and 2-2. This is due to missing data associated with this variable. Refer to Appendix A on missing data and Appendix B for the standard error associated with this variable.

Table 2-16. Breakdown of Exempt/Excluded Wastewaters

Exemption/Exclusion Category	Estimated Volume (and Percentage) of Wastewater	
Other (not on specific list of exclusions/exemptions)	40,444,366	(41%)
Mixtures of solid waste and characteristic hazardous waste listed solely because it exhibits a characteristic	16,731,865	(17%)
Point source discharges	13,366,523	(14%)
Bevill wastes	12,537,291	(13%)
Coal and fossil fuel combustion wastes	7,836,906	(8%)
Mixtures of solid waste and hazardous waste discharging to CWA system		
Lab wastes mixed with solid waste	1,852,033	(2%)
De minimis quantities of commercial chemical products mixed with solid waste	1,175,821	(1%)
Heat exchanger bundle cleaning sludge from petroleum refining industry and solvent waste mixtures	105,767	(0.1%)
Domestic sewage and mixtures of domestic sewage	1,606,185	(2%)
Reclaimed pulping liquor	2,016,833	(2%)
Wastes excluded from definition of solid waste	1,000,407	(1%)
Total Volume of Exempt/Excluded Wastewaters	98,768,548	(100%)

hazardous waste impoundments were closed and replaced with tanks. One-quarter of the impoundments that ceased receiving wastes are from the wholesale trade-nondurable goods industry sector. Roughly 35 percent of these impoundments were between 15 and 20 years old and 20 percent were between 35 and 55 years old. These impoundments were predominantly smaller units and account for under 5 percent of the total wastewater quantity.

The data examined above provide a picture of the regulatory and operating status of the population of facilities addressed in this study. As Table 2-15 shows, only 7 percent of the population of facilities fall under none of the regulatory/operating status categories. Furthermore, based on analyses not shown in the table, almost half of the impoundments in the overall population either ceased receiving waste during the 1990s or are at a RCRA TSD facility and are therefore subject to facility-wide corrective action remedial requirements to address potential releases. In addition, approximately 80 percent of all impoundments are under some level of regulatory oversight, either by virtue of a state or local permit or as an SWMU at a RCRA TSD. These facts, to some degree, mitigate the concerns stated in Section 2.4 concerning the potential for human exposure to chemicals from impoundments. Chapter 4 of this report, which investigates the potential gaps that exist in the regulation of surface impoundments, covers these issues in much greater detail.

2.6 Conclusions

Surface impoundments continue to be a prominent feature in the industrial landscape. The overall picture of the U.S. industrial surface impoundment population shows approximately 18,000 impoundments operating in the 1990s; an estimated 11,900 contain at least one or more of the chemical constituents of concern for this study or have high or low pH. The geographic distribution of these impoundments reflects areas with generally higher precipitation levels; that is, they tend to be located in the areas east of the Mississippi River, mainly in Gulf Coast states and along the East Coast. Fewer appear to be located in the more arid states west of the Mississippi. Approximately 90 percent of impoundments are direct dischargers and 10 percent are zero dischargers.

These impoundments serve a variety of beneficial uses. Many facilities employ impoundments to perform necessary wastewater treatment prior to discharge into surface waters. In other cases, industrial facilities may need to control wastewater flows and use impoundments for storing excess wastewater. In still other cases, facilities use impoundments to manage excess wastewaters through evaporation or seepage into the subsurface.

Industrial impoundments vary greatly in size and physical characteristics. Just under 50 percent of impoundments are 1/4 hectare or smaller in size, and, almost 10 percent of the population of impoundments are over 5 hectares in size. These larger impoundments form the bulk of the total national industrial impoundment capacity. Approximately 75 percent of the total wastewater quantity managed exists at only 10 percent of the impoundments. Additionally, about one-third of the facilities that fall into the study population have only one nonhazardous impoundment onsite. Just under 5 percent of facilities have over 10 impoundments for nonhazardous industrial waste management.

The paper and allied products sector accounts for two-thirds of the entire volume of wastewater managed in these impoundments, although representing only 6 percent of the facilities in the population. Over 50 percent of the facilities in the population fall into four industrial sectors: chemical and allied products; stone, clay, glass, and concrete products; wholesale trade-nondurable goods; and primary metals industry. Almost one in four impoundments is located at a chemical and allied products facility.

Although only 15 percent of all facilities manage any decharacterized wastes, the impoundments with decharacterized wastes account for 70 percent of the total industrial wastewater quantity. Approximately 85 percent of impoundments have metals present in the wastewater, and roughly half have volatile organic chemicals present. Approximately half of all facilities use impoundments to manage between one and five chemicals of concern.

Most impoundments were built more than 20 years ago. Nearly 40 percent of the impoundments operating in the 1990s were constructed in the 1970s; presumably in response to environmental programs seeking improved wastewater treatment. Approximately 25 percent of impoundments were in operation before 1970, suggesting that water supply was a critical component of their process.

Impoundments, consistent with their intended purpose, are frequently found in vulnerable environmental settings or use management techniques that increase the potential for chemical releases to the environment. For example, although aeration can have certain benefits, it also increases the potential for airborne contaminant migration. Furthermore, most impoundments are located above shallow groundwater that is located within a few meters of the impoundment bottom, and more than half of the impoundments do not have a liner system to retain the wastes inside the impoundment. Four-fifths of industrial impoundments are located above groundwater that discharges to a fishable waterbody, and approximately one out of five impoundments is within 150 meters of a fishable waterbody. Approximately 20 percent of impoundments with fishable waterbodies within 150 meters had overtopping events.

Regarding the potential for human exposure to constituents of concern, EPA estimates that roughly 20 million people live within 2 kilometers of an industrial impoundment that operated during the 1990s. Approximately one-tenth of the facilities have drinking water wells within 150 meters of at least one of their impoundments. Further, approximately 75 percent of all wastewaters contain volatile organic chemical constituents, which to varying degrees will escape from the impoundments as air emissions (depending on physical properties of the specific constituent and on meteorological conditions). Roughly one-third of impoundments have residences within 150 meters of the impoundment.

Eventually, impoundments cease receiving waste and are closed with varying degrees of waste removal. During the 1990s, EPA estimates that about 15 percent of the industrial impoundments permanently stopped receiving waste. This is in sharp contrast to the previous decade when the majority of hazardous waste impoundments were converted to tanks. Furthermore, EPA estimates that more than three-quarters of industrial impoundments are located at a RCRA permitted interim status facility and, as a result, are within RCRA jurisdiction

for corrective action as solid waste management units or operate under a state or local permit such as a wastewater discharge permit.

The figures presented above on the chemicals managed in impoundments, the potential for transport of chemicals in environmental media, and the proximity of residences to impoundments provide an overall picture of the surface impoundment universe. Impoundments are used to manage a host of chemicals of concern. The conditions that exist at these units allow for the possibility of chemical transport from wastewaters. These conditions include the presence of VOCs in aerated impoundments and the absence of liners at units that are located above relatively shallow groundwater. In many cases, there are residences near these units, allowing for the potential of residents' exposure to chemicals. Given these facts, EPA performed an assessment of the risks posed by the population of impoundments. The results of this risk assessment are presented in Chapter 3.

2.7 Reference

Metcalf and Eddy, Inc. 1991. *Wastewater Engineering Treatment, Disposal, and Reuse*. *Third Edition*. Revised by G. Tchobanoglous and F. L. Burton. McGraw-Hill, Inc.

Chapter 3

Human and Ecological Risk Analysis

3.0 Summary of Chapter

The purpose of this chapter is to describe the methodology and provide the results for the screening and assessment of potential risks to human and ecological receptors that may be attributable to surface impoundments managing industrial wastewaters. The methodology and results are summarized for each major pathway assessed, as outlined below. Additional detail on this analysis is provided in Appendix C.

3.1 Introduction and Overview

EPA has conducted the risk analysis for surface impoundments in several stages, with the basic objectives of screening all the reported surface impoundments and chemicals, ranking those that warrant additional analysis, and developing risk estimates for chemicals and surface impoundments that may be of higher concern due to concentrations and environmental settings. Throughout this process, the findings reported in the November 1999 survey have been used to identify factors that may contribute to environmental releases or potential chronic risks posed by surface impoundments.

3.1.1 Overview of Methodology

3.1.1.1 Tiered Approach to Risk Assessment Methodology. This analysis has been conducted according to the technical plan submitted for peer review in February 2000, with several additional refinements to the risk screening, ranking, and modeling steps. In general, EPA used a sequential approach to rank facilities to progress through each step of the analysis:

1. **Preliminary Screen:** Conduct direct exposure pathway screenings of all the survey facilities using health-based and ecological screening factors based on precautionary exposure assumptions.

2. **Release Assessment:** Conduct screening-level modeling for direct pathways using health-based screening factors.

3. **Risk Modeling:** Conduct site-based modeling to further refine the initial risk estimates according to the environmental setting described in the survey data.

In essence, the methodology was designed to progress from a very precautionary exposure/risk analysis for all facilities to a more realistic, site-based assessment that takes full advantage of survey and site-specific information on facilities in the final stages of analysis. For each major exposure pathway, EPA used the most appropriate approaches available to screen and rank facilities, impoundments, and constituents for further analysis.

EPA used several different measures of chronic risk and hazard in the risk assessment. Cancer risks were expressed as individual lifetime excess probability of cancer; a threshold of 1 in 100,000 was used as the criteria for determining whether a constituent posed a risk of concern. The hazard associated with exposure to noncancer constituents was measured using a hazard quotient (HQ). The HQ is the ratio of the estimated exposure concentration to an EPA reference dose (RfD) for ingestion or reference concentration (RfC) for inhalation. RfDs and RfCs are threshold measures of hazard that are set at a level that EPA has estimated will not result in adverse effects in humans. The human health threats associated with surface water contamination were evaluated using ratios of estimated surface water concentrations to ambient water quality criteria for human health (HH-AWQC).

The final risk results for the statistically representative sample were extrapolated to generate national estimates of the number and proportion of facilities and impoundments with potential risks. Throughout this chapter facility proportions are expressed as a percentage of the estimated 4,500 facilities, and surface impoundment proportions are expressed as a percentage of the estimated 11,900 in-scope surface impoundments.

3.1.1.2 Relevant Exposure Pathways. EPA structured its risk analysis methodology to identify potential risks posed to people by direct pathways and indirect pathways and to ecological receptors. A pathway is the route a chemical takes from the impoundment to the person or to ecological receptors after release of a chemical from a surface impoundment.

As suggested in Figure 3-1, chemicals may be released from an impoundment by volatilizing from the wastewater into the air, by leaching through the bottom of the impoundment into groundwater, or by erosion/runoff of contaminated sludge particles from an impoundment that has closed.[1] Once released into the environment, chemicals may pose direct exposures, migrate through the groundwater to reach the surface water, or be deposited onto the soil in areas that are close to the facility. Plants and animals that are exposed to these media may accumulate chemicals in their tissues, and human and ecological exposures may occur through the food chain.

People may be exposed to chemicals by many pathways. In **direct** pathways, the person is exposed to the medium, such as air or groundwater, to which the chemical was released. In

[1] Chemicals may also be released through direct discharge to surface water (currently regulated under the Clean Water Act) or through overtopping events. However, these releases were not evaluated in this analysis.

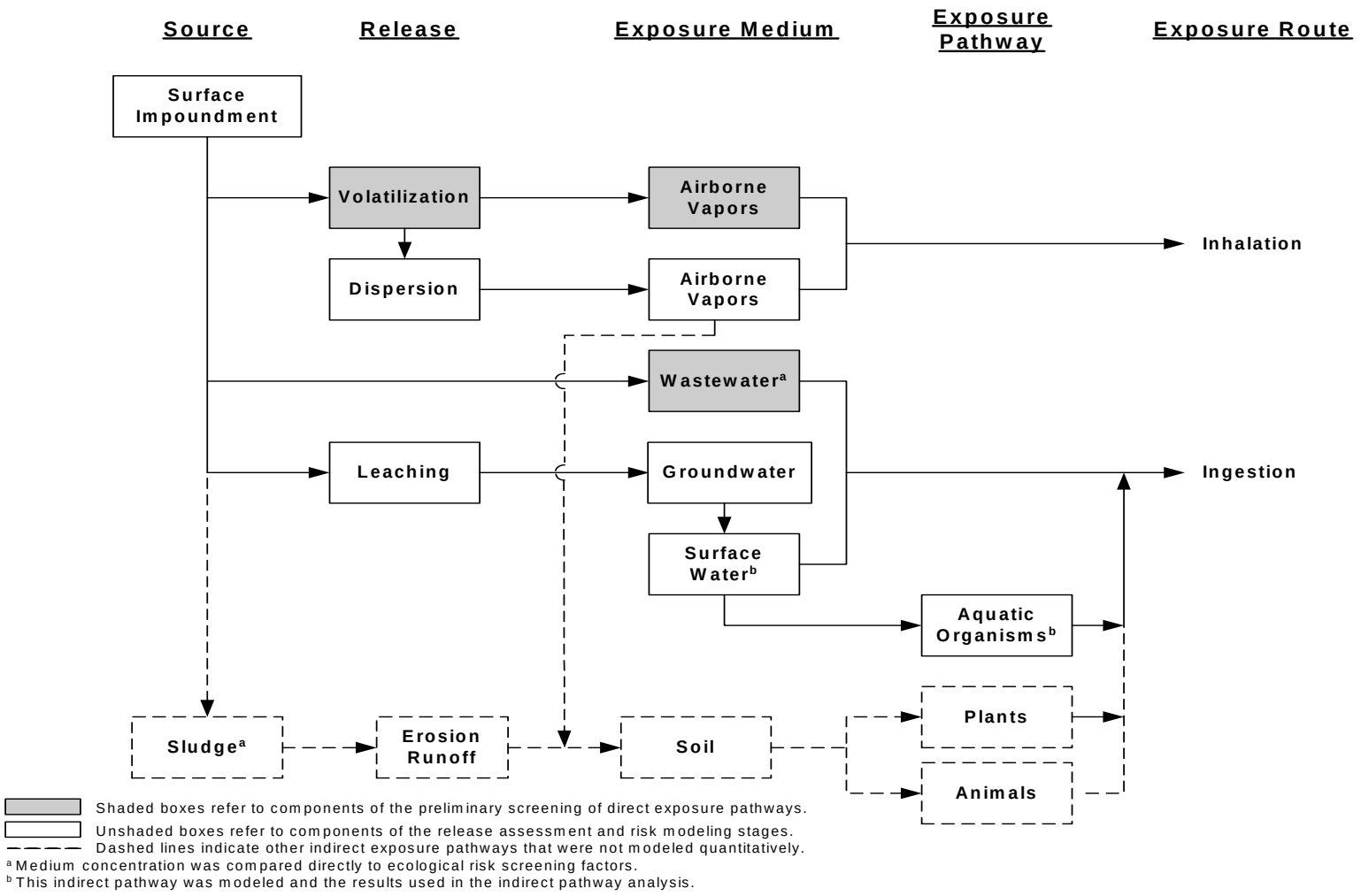


Figure 3-1. Exposure pathways for active surface impoundments considered for human and ecological receptors.

indirect pathways, the person is exposed to a different medium than the one to which the chemical was released. For example, chemicals may be released into the groundwater aquifer and transported to an adjacent surface waterbody by subsurface transport. If the chemical is bioaccumulative, people who eat fish from that waterbody may be exposed to contaminants in their diet.

This study develops quantitative risk estimates for the direct pathways of air inhalation and groundwater ingestion and the indirect pathway of groundwater to surface water. In addition, a screening was conducted of other indirect pathways, such as air deposition or erosion and transport of chemicals across soil, to provide insight into the potential for food chain risks attributable to these types of exposures. The direct discharge of chemicals to surface waters is not considered because this pathway is already regulated by EPA. This study also includes a screening-level assessment of potential ecological risks.

The following sections summarize the methodology and present the risk results for each of the pathways in the human health risk analysis and for the ecological risk screening. For each area of analysis, the screening and ranking stages were based on clear science decision rules related to threshold concentrations of potential concern and the likelihood of exposures. The modeling stages used peer-reviewed modeling tools available for use by the Agency. Appendix C provides a detailed discussion of the methodologies used, including a listing of health-based screening factors, ecological screening factors, and relevant data sources. In addition, Appendix C presents the full analytical results of the assessment.

3.1.2 Overview of Results

Tables 3-1 and 3-2 present the overall results for each of the pathways in the human health risk analysis and for the screening analyses of indirect pathways and potential ecological risks. Sections 3.2 through 3.5 provide more detailed results and discussion for each analysis and pathway. The complete results of the risk analysis are provided in Appendix C. The results for each analytic question are given as the number or percent of facilities or impoundments having the attribute in question. These numbers and percents are weighted national estimates derived from the risk results for the sample population.

The results for the risk analysis are presented in two distinct sets depending on the nature of the information provided in the surveys on chemical concentrations. Chemical concentration data were central to EPA's risk screening and risk analysis of surface impoundments. EPA provided considerable flexibility to survey respondents in submitting concentration data for use in this study. This affects the certainty of the results. Some respondents provided analytical reports; some used professional judgment to identify chemicals likely to be present; some estimated concentrations based on averaged sampling events or other methods; some reported chemicals to be present but did not report a concentration value; and some indicated that concentrations were below detection limits. Survey respondents used many different reporting conventions for detection limits. Sometimes chemicals were reported with very high detection limits, possibly because of analytical interferences. In other cases constituents were reported with very low detection limits. In still other cases facilities that did not expect certain chemicals to be present would report higher detection limits, possibly not wanting to exert the additional

Table 3-1. Overview of Modeling-Level Results

Pathway	Route	Facilities That Have Environmental Releases[a, c]		Facilities That May Exceed Risk Criterion[b, c]		Numbers of Chemicals and Impoundments That May Exceed Risk Criterion	
		RV	S/DL	RV	S/DL	Chemicals	Impoundments
Groundwater	Ingestion	641 (14%)	846 (19%)	27 (0.6%)	23 (0.5%)	15 chemicals: 1 inorganic 2 metals 3 SVOCs 9 VOCs	126 impoundments: 114 dechar waste 12 never char waste
Air	Inhalation	173 (4%)	165 (4%)	171 (4%)	55 (1%)	11 chemicals: 1 dioxin-like 5 SVOCs 5 VOCs	236 impoundments: 85 dechar waste 151 never char waste
Groundwater to surface water	Ingestion	790 (18%)	1,079 (24%)	44 (1%)	31 (0.7%)	35 chemicals: 1 dioxin-like 3 metals 24 SVOCs 7 VOCs	142 impoundments: 100 dechar waste 42 never char waste

RV = Reported values.
S/DL = Surrogate values/detection limits.

[a] An impoundment was determined to have an environmental release when there was evidence that contaminants had the potential to migrate from the impoundment into the media of concern at concentrations above health-based levels. The specific definitions vary by media.

[b] A facility was determined to exceed a risk criterion if individual constituents had concentrations in excess of 10^{-5} for cancer, an HQ greater than 1 for noncancer effects, or concentrations in excess of the ambient water quality criteria in the case of surface water. EPA also summed risk across constituents where appropriate to identify any cases where, even though a particular constituent might not exceed a risk criterion, all of the constituents together might exceed a risk level.

[c] Number of facilities (percentages are of the total number of facilities, approximately 4,500).

analytical effort that would be needed to establish a much lower detection limit. EPA observed several cases where facilities reported a rather high limit of detection when, in fact, the chemicals are very unlikely in a particular industrial sector and are probably not present at levels anywhere near the detection limit. When chemicals were reported to be present but the quantity was unknown or when chemicals were reported as being below a detection limit but the respondent did not provide the detection limit, EPA inferred a value for use in the risk analysis as described in Appendix B. When a value was reported to be less than a detection limit and that detection limit was provided, EPA used the reported detection limit in the analysis.

EPA is most confident in those data where repondents reported a value above a limit of detection and far less confident in other values, such as values less than detection limits. EPA took great care to present the results separately based on concentrations actually reported in the surveys because: (1) these values are based on survey respondents' knowledge or estimates of

Table 3-2. Overview of Screening-Level Results

Pathway	Route	Facilities That Are of Lower Concern[a]	Facilities That Are of Potential Concern[a]	Number of Chemicals and Impoundments That Have a Potential Concern	
				Chemicals	Impoundments
Indirect	Ingestion	2,620 (59%)	285 (6%)	37 chemicals: 8 dioxin-like 1 mercury 2 metals 26 SVOCs	NA[b]
Ecological	Ingestion	2,359 (53%)	1,310 (29%)	34 chemicals: 1 dioxin-like 1 mercury 14 metals 7 SVOCs 11 VOCs	2,355 impoundments: 675 dechar waste 1,680 never char waste

[a] Number of facilities (percentages are of the total number of facilities, approximately 4,500).
[b] Not applicable; the indirect pathway analysis evaluates potential exposures for the entire facility.

chemical concentrations and (2) EPA considers these data to have a reasonable degree of certainty. The results based on concentrations that EPA inferred or on detection limits are presented separately, because the Agency believes that these span a greater range of potential uncertainty. These results, nonetheless, may provide an indication of the range of possible environmental releases or exposures for the significant number of surface impoundments for which we lack concentration data.[2] Where concentrations are reported below detection limits, the use of detection limits for risk screening served two purposes: to screen out cases of no concern, and to identify cases where, even at detection limits, there could be exposures of concern depending on environmental settings and management conditions. Some survey respondents who provided a response in the context of detection limits may have intended their responses to represent negligible concentrations or may have intended to convey that the chemical is not present. In these cases, the corresponding risks may be negligible and the risk estimates based on detection limits would clearly be overestimates of potential risk. In summary, the results based on surrogate data and detection limits span a range from negligible risk and no environmental releases of concern to potential risk exceedances and environmental releases. These are all accompanied by a greater level of uncertainty than results based on reported concentrations.

[2] EPA's field sampling provides additional insights concerning the concentration data reported in the surveys. While generally confirming the range of reported concentration values, the field sampling identified many cases where chemicals were not reported and other cases where chemicals were reported that EPA did not detect in its sampling. This suggests that some facility operators do not have full knowledge of the chemicals contained in their impoundments. The EPA field sampling results are discussed further in Chapter 2 and in Appendices C and E.

The results presented for the risk analysis are the national number and percent of all facilities or impoundments that occur in the following categories:

- **Negligible concern:** These are facilities or impoundments for which no pathway exceedances are predicted and/or environmental characteristics prevent the completion of any exposure pathway. Based on the data made available, EPA believes that these facilities or impoundments do not present any concern.

- **Environmental releases:** These are facilities or impoundments at which environmental releases may be occurring because of the concentrations present in the impoundments, and also because of operating conditions such as the presence or absence of liners, the use of aeration, or other factors. However, taking into account actual residential exposures, risks are not anticipated.

- **Potential risk exceedances:** These are facilities and impoundments that potentially pose risks, taking into account actual residential exposures. These tend to be high-end estimates because they are developed for the closest residential exposures.

EPA identified potential environmental releases and risk exceedances, and separately presented results based on reported concentration values, for three pathways: direct inhalation, direct groundwater ingestion, and groundwater discharges to surface water with potential exceedances of HH-AWQC. Tables 3-3 and 3-4 portray the overall results of the risk analysis for these three pathways. Table 3-3 distinguishes results between never characteristic and decharacterized wastes, and Table 3-4 distinguishes results according to the facilities' discharge status under the Clean Water Act. These questions were examined because of the statutory intent, expressed in the 1996 Land Disposal Program Flexibility Act, that decharacterized wastewaters managed in surface impoundments under the scope of the Clean Water Act be assessed in this study. Notable findings are that most facilities do not seem to pose risks or exposures of concern. Twenty-one percent of facilities may have significant environmental releases for at least one of the pathways examined, although not exceeding risk criteria. Five percent of facilities (corresponding to 2 percent of impoundments) may pose potential risk exceedances. Up to 23 percent of facilities may have releases or exposures for at least one of the pathways examined based on surrogate data or detection limits, although the extent to which this may actually be occurring is uncertain due to the lack of concentration data.

The results of EPA's screening level assessments for other indirect pathways and for potential ecological concerns are described in Sections 3.4 and 3.5.

3.2 Direct Pathways (Inhalation and Groundwater Ingestion)

3.2.1 Methodology

Table 3-5 provides an overview of the tiered methodology used to assess potential risks from direct ingestion of groundwater, and Table 3-6 provides an overview of the methodology to assess direct inhalation risks. Appendix C provides complete details on the methodologies used.

Table 3-3. Facility-Level Overview of Human Health Results by Decharacterization Status[a]

Facility Status	Environmental Release[b]	May Exceed Risk Criteria[b]
Risk results based on reported waste concentrations		
Never characteristic	598 (13%)	196 (4%)
Decharacterized	330 (7%)	41 (0.9%)
All facilities with reported values	928 (21%)	237 (5%)
Risk results based on surrogate/DL waste concentrations		
Never characteristic	812 (18%)	0 (0%)
Decharacterized	169 (4%)	66 (1%)
All facilities with surrogate/DL values	981 (22%)	66 (1%)

DL = Detection limit.

[a] Results are for groundwater, air, and groundwater to surface water pathways.
[b] Number of facilities (percentages are of the total number of facilities, approximately 4,500).

Table 3-4. Facility-Level Overview of Human Health Results by Discharge Status[a]

Facility Status	Environmental Release[b]	May Exceed Risk Criteria[b]
Risk results based on reported concentrations		
Direct dischargers	716 (16%)	191 (4%)
Zero dischargers	150 (3%)	27 (0.6%)
All facilities with reported values[c]	865 (19%)	218 (5%)
Risk results based on surrogate/DL concentrations		
Direct dischargers	1,111 (25%)	66 (1%)
Zero dischargers	76 (2%)	0 (0%)
All facilities with surrogate/DL values[c]	1,187 (27%)	66 (1%)

DL = Detection limit.

[a] Results are for groundwater, air, and groundwater to surface water pathways.
[b] Number of facilities (percentages are of the total number of facilities, approximately 4,500).
[c] Note that the facility total for Table 3-4 does not equal the facility total for Table 3-3. This is because the patterns of missing data are different for each of the tables, and the weight adjustments for missing data lead to slightly different estimates.

Table 3-5. Overview of Tiered Risk Assessment Methodology for Direct Ingestion of Groundwater

Analysis Stage	Risk Assessment Methodology - Groundwater/Direct Ingestion Human Health Chronic Risk Measures: (1) Lifetime excess risk of cancer greater than 10^{-5} and (2) Exposure in excess of a reference dose		
	Approach	**Receptor Exposure**	**Key Variables**
Preliminary screen	■ Precautionary screen ■ Eliminate impoundments with no evidence of risk from further evaluation	■ Direct consumption of impoundment water	■ Impoundment chemical concentrations ■ Exposure factors
Release assessment	■ Evaluate facilities, impoundments, and constituents not eliminated in the preliminary screen ■ Use Industrial D Tier I groundwater model lookup tables ■ Impoundments not screened out have release potential; evaluate for risk modeling	■ Drinking water well located at 150 m from unit boundary	■ Liner type ■ Impoundment chemical concentrations ■ Exposure factors
Risk modeling	■ Review site-specific data for all facilities with release potential ■ Select facilities with the greatest potential for risk ■ Conduct site-specific modeling using EPACMTP ■ Conduct Monte Carlo analysis of exposure/risk to capture within-site variability	■ Nearest actual household with a reported domestic well in the direction a plume would migrate ■ Actual exposure to receptor could occur in the future depending on transport time	■ Surface impoundment dimensions ■ Impoundment chemical concentrations ■ Presence and distance to receptor well ■ Subsurface characteristics ■ Infiltration/liner type ■ Groundwater flow direction ■ Exposure factors

EPACMTP = EPA's Composite Model for Leachate Migration with Transformation Products.

Table 3-6. Overview of Tiered Risk Assessment Methodology for the Direct Inhalation of Air

Analysis Stage	Risk Assessment Methodology - Air / Direct Inhalation Human Health Chronic Risk Measures: (1) Lifetime excess risk of cancer greater than 10^{-5} and (2) Exposure in excess of a reference concentration		
	Approach	**Receptor Exposure**	**Key Variables**
Preliminary screen	■ Precautionary screen ■ Eliminate impoundments with no evidence of risk from further evaluation ■ Required reporting of emissions data—few impoundments screened out ■ Promoted impoundments lacking sufficient data to screen to the next tier	■ Direct inhalation of impoundment emissions with zero dispersion	■ Impoundment chemical concentrations ■ Exposure factors
Release assessment	■ Evaluate facilities, impoundments, and constituents not eliminated in the preliminary screen ■ Apply Industrial D air model with a combination of default assumptions and site-specific data	■ Direct inhalation by hypothetical receptor exposed at a fixed distance of 25 m along the centerline of the plume	■ Impoundment chemical concentrations ■ Meteorological conditions ■ Impoundment characteristics such as surface area, aeration status
Risk modeling	■ Review site-specific data for all facilities with release potential, including aerial photographs to identify nearest residence ■ Apply Industrial D air model with a combination of default assumptions and site-specific data	■ Direct inhalation by actual closest resident, assumed to be along the centerline of the plume	■ Impoundment chemical concentrations ■ Meteorological conditions ■ Receptor distance ■ Impoundment characteristics such as surface area, aeration status

In the initial screening stage, EPA compared the reported concentration data (in impoundment water and emissions) collected from the facility survey with threshold concentrations that are protective of human health (residential exposures). EPA made full use of all survey data available to derive concentrations in wastewater and leachate in surface impoundments where values were not reported by respondents. The textbox summarizes the surrogate data protocol used by EPA to infer concentrations when necessary from other reported values. See Appendix B for more discussion on the protocol for inferring concentrations.

EPA Surrogate Data Protocol

EPA relied on the surveys to identify the presence or absence of particular constituents and used the reported concentration data when available. When chemicals were reported present, but concentrations or emission data were not reported, EPA used a number of approaches to derive surrogate values for screening purposes. These included using data from other impoundments at the same facility, using data from other facilities in the same industrial category, or modeling and backcalculating to infer concentrations. In a number of cases, EPA's own sampling identified additional constituents not reported. These data provide an important QA step.

Impoundments with concentrations below the screening factors were below risk criteria for that particular chemical or pathway. Those units that screen out remain an important component of the overall risk profile for the surface impoundment universe. This screening was precautionary because it was based on direct ingestion of the surface impoundment influent and direct inhalation of the emissions.

To remain under consideration at this stage for additional risk screening, a facility must either have at least one constituent in one impoundment that exceeds a risk criterion or present cumulative risks from several constituents and/or impoundments that exceed the risk criteria. Appendix C, Section C.1, provides additional detail on the methodology used for assessing cumulative risks.

In the first modeling stage, EPA used screening-level fate and transport models developed for use under the Industrial D guidance in situations where the major routes of exposure were direct ingestion of drinking water or direct inhalation. These models used some key site-specific data such as unit size, presence or absence of liners, and whether the unit is aerated. Because some chemicals and units were to be screened from further analysis, EPA used precautionary modeling approaches, such as assessing risks for close-in receptors (150 m for groundwater and 25 m for inhalation).[3] Most impoundments reporting volatile constituents did not report emissions data, so the reported wastewater concentrations were used to model emission levels for the air pathway.

Based on the results of the screening-level modeling, EPA identified those chemicals, impoundments, and facilities for which risks could not be ruled out and that, therefore, required

[3] The Industrial D air model (U.S. EPA, 1998) is based on CHEMDAT8 and ISCST3 models for emissions and dispersion factors, respectively. This model uses emissions data from the survey or, if no data are available, estimates emissions from concentration and other site-specific data from the survey. The Industrial D groundwater model is based on the EPACMTP. In this analysis, the Tier I approach was used (U.S. EPA, 1999a, b), using dilution attenuation factors that correspond to a receptor well distance of 150 m.

further analysis. The second modeling stage consisted of site-based modeling of exposures and potential risks to human receptors using more site-based data such as actual receptor locations.

With respect to inhalation, the risk analysis was repeated using the Industrial D air model (U.S. EPA, 1998) and site-specific data were used as before; however, the receptor was placed at the actual distance to the nearest residence for each impoundment (taken from the survey and checked for accuracy against census data and aerial photos). This was typically more than the default distance of 25 m used in the previous step, and, as a result, predicted air risks were almost always lower in this stage.

With respect to groundwater ingestion, EPA reviewed the risk distribution of groundwater ingestion risks after the first two stages of analysis within the context of the site-specific details for those facilities at the high end of that distribution. The conclusions from that review were that EPA could only properly characterize the risk through a more site-specific modeling process. EPA developed numeric ranking criteria based on the potential for receptor well chemical concentrations to exceed risk-based levels of concern. These criteria included site-specific characteristics relevant to completing the groundwater pathway, such as the presence of a confining clay layer in the subsurface. EPA selected 10 facilities with the greatest potential for exposures that could lead to risk and modeled these 10 facilities using more sophisticated tools.

Monte Carlo model simulations were executed using EPA's Composite Model for Leachate Migration with Transformation Products (EPACMTP, U.S. EPA, 1997) for the top-ranked facilities to predict the 90^{th} and 50^{th} percentile risk levels.[4] The simulation varied parameters from site-specific, regional, and national data sources, as appropriate. The groundwater concentrations predicted by EPACMTP were then used to conduct a Monte Carlo simulation of the exposure to contaminated drinking water to generate risk distributions. This assessment focused on chronic cancer risk and noncancer hazard resulting from tap water ingestion. Consequently, the exposure assessment combined modeled residential well concentrations with tap water ingestion rates and exposure durations to predict average daily dose estimates for noncarcinogens and lifetime-averaged daily dose estimates for carcinogens.

At each stage (i.e., screening or modeling), EPA used the same risk criteria to determine when risks to an individual are considered significant:

- For carcinogens: excess lifetime cancer risk = 10^{-5}
- For noncarcinogens: hazard index (HI) = 1.

These criteria were applied to potential risks posed by a specific constituent, unit, and pathway, as well as to summations of risks for a constituent, an impoundment, or a facility.

Once final risk results were generated based on the sample facilities, these were extrapolated using the appropriate facility weights to generate a national estimate of the proportions of facilities and surface impoundments that may pose potential risks.

[4] The full risk distribution was calculated in the groundwater pathway analysis. This chapter presents results at the 90^{th} and 50^{th} percentiles; the full risk results are presented in Attachment C-11 of Appendix C.

Appendix C provides further discussion of the methodologies and data used for risk analysis, including a listing of the human health and ecological benchmarks used to derive screening factors, the derivation of provisional benchmarks in some cases, the methodologies for deriving surrogate concentration data, and the methodology for representing cumulative risks for constituents, surface impoundments, and facilities. Appendix C also discusses uncertainties associated with the analysis.

3.2.2 Screening Results and Proportions of Facilities that May Pose Risks

Table 3-7 shows the number of facilities and chemicals in the survey sample that were evaluated for potential air and groundwater risks at each stage of the analysis. This table illustrates that, with each stage of the analysis, progressively fewer facilities and constituents continued to the next analytic stage.

3.2.3 Results for Groundwater Ingestion

Based on the precautionary screening stages described above, EPA ranked the facilities that showed risk criteria exceedances in the release assessment phase according to their potential for groundwater concentrations to occur at levels of concern. For each facility that passed an initial decision criterion for potential groundwater flow in the direction of receptor wells, EPA conducted an additional review using data in technical materials submitted by the survey respondents. This review focused on criteria relevant to the completion of the groundwater pathway (e.g., well depth), and was used to determine whether to conduct detailed fate and transport modeling. A narrative was prepared for each facility summarizing all pertinent information according to a series of technical and risk-based criteria. Although the quantitative risk estimates generated in the release assessment were above levels of concern, the review of technical data indicated that, for some facilities, the potential for groundwater contamination at receptor wells was insignificant relative to levels of concern. To ensure consistency during this technical review process, EPA quantified these criteria and adopted a numeric framework to rank the facilities for groundwater contamination potential (see Attachment C-8 of Appendix C). Based on this numeric ranking and the supporting narratives, EPA selected the 10 highest ranked facilities to model for the groundwater pathway. Table 3-8 presents the maximum hazard and risk exceedances for the seven facilities that showed potential risk exceedances; the results based on reported concentrations are distinguished from those based on surrogate data and/or detection

Example of a Site-Specific Narrative

The site is underlain by 260 feet of lacustrine clay. The thickness of the formation, combined with the characteristic low conductivity of clay, suggests that leachate emanating from a surface impoundment would likely not impact drinking water resources. The facility did not indicate that drinking water wells were present within 2 km of the site. This is supported by the fact that the clay formation is not a producing aquifer (i.e., insufficient yield to provide water). Furthermore, the area surrounding the facility is structured in city blocks, suggesting that the populace is supplied with municipal water.

The release assessment indicates that there are seven chemicals of concern at this site. Although the screening suggests that maximum cancer and noncancer risks could be 1.9E-01 and 4.28, respectively, it is highly unlikely that the surrounding populace is at risk from ingestion of groundwater. EPA did not model this facility any further.

Table 3-7. Summary of Screening Process and Risk Analysis Results for Direct Pathways: Groundwater Ingestion and Air Inhalation

Category	Number of Sample Facilities[a]	Number of Chemicals	Number of Impoundment/ Chemical Combinations
Reported in Survey	195	215	
Entered screening assessment (Facilities that reported chemicals to be present)	133	193	8,117
Entered release assessment (Facilities that did not screen out)	116	147	4,097
Considered for risk modeling (Facilities that did not screen out)	75	92[b]	795
Modeled	37	65	359
Evaluated but not modeled	38	66	436
Final Analytic Results[c]			
Results based on reported concentrations			
Environmental release	36	53	202
May exceed risk criteria	8	6	16
Results based on surrogate/DL concentrations			
Environmental release	24	68	519
May exceed risk criteria	7	20	59

DL = Detection limit.

[a] The number of actual facility responses analyzed in the study that were used to perform the national extrapolations presented throughout this report. There are no nationally extrapolated estimates in this table.

[b] Some chemicals were modeled for only one of the two direct pathways; in addition, some chemicals were modeled for several impoundments at the same facility. Therefore, the number of chemicals in subsequent stages does not add to 92.

[c] These results were subdivided according to whether the concentration data used were reported values or were based on surrogate data and detection limits.

Table 3-8. Summary of Chemicals and their Maximum of Hazard and Risk Exceedances for Groundwater Pathway[a]

Summary of HQ Exceedances 90th Percentile (50th Percentile)[a]	Summary of Risk Exceedances 90th Percentile (50th Percentile)[a]
Risk exceedances based on reported concentrations	
Acetone - 13 (0.02) **Fluoride** - 59 (12)	
Risk exceedances based on surrogate/DL chemical concentrations	
Allyl alcohol - 26 (0.06) Chloroform[b] - 50 (0.09) Pyridine - 1.7 (0.003) Methanol - 1.7 (0.004) Methylene chloride[b] - 8.2 (0.01) Thallium - 4.5 (0.03) Toluene - 1.8 (0.004)	Acrylonitrile - 2.5E-5 (1E-6) Arsenic - 1.6E-5 (8E-9) Benzidine - 1.6E-03 (3E-4) Chloroform[b] - 1.5E-4 (2E-7) Methylene chloride[b] - 1.8E-4 (3E-7) N-Nitrosodi-n-propylamine - 4.5E-5 (1E-5) N-Nitrosodimethylamine - 3.3E-4 (7E-5) Vinyl chloride - 1.1E-5 (2E-6)

DL = Detection limit.

[a] Risk estimates and HQ values at the 90th percentile are shown first, and those at the 50th percentile are shown in parentheses.

[b] Agency had both cancer and noncancer endpoints for these constituents.

limits. Several of these facilities showed potential exceedances at more than one impoundment. The complete impoundment level results are presented in Appendix Table C-3-20.

Table 3-9 portrays the groundwater ingestion risk analysis results for decharacterized and never characteristic wastes and further distinguishes these according to whether the results derive from reported concentrations or from surrogate data and detection limits. For each category of interest, Table 3-9 portrays the proportion of the surface impoundment universe that may exceed risk criteria because of the direct ingestion of groundwater and those that may have environmental releases to groundwater that do not exceed risk criteria.

3.2.3.1 Quantitative Risk Estimation for the Groundwater Pathway. Notable findings in Table 3-9 are that very few facilities seem to show risks due to groundwater ingestion, less than 1 percent of reported concentrations. The majority of potential risk exceedances may be associated with decharacterized wastes, although the total numbers are too small to generalize with confidence. Fourteen percent of facilities (based on reported concentration data) may have environmental releases, that is, the potential to generate groundwater plumes that extend 150 meters or more beyond the impoundment boundary. These releases are evenly split between decharacterized and never characteristic wastes. As described in Attachment C-12 to Appendix C, the rates of potential risk exceedances and environmental releases are higher for decharacterized wastes than for never characteristic wastes. About 20 percent of facilities cannot be assessed with confidence because the results are based on surrogate concentration data and

Table 3-9. Facility-Level Results for Groundwater Pathway by Decharacterization Status

Facility Status	Environmental Release[a]	May Exceed Risk Criteria[a]
Risk results based on reported concentrations		
Never characteristic	341 (8%)	9 (0.2%)
Decharacterized	300 (7%)	18 (0.4%)
All facilities with reported values	641 (14%)	27 (0.6%)
Risk results based on surrogate/DL concentrations		
Never characteristic	714 (16%)	0 (0%)
Decharacterized	132 (3%)	23 (0.5%)
All facilities with surrogate/DL values	846 (19%)	23 (0.5%)

DL = Detection limit.

[a] Number of facilities (percentages are of the total number of facilities, approximately 4,500).

detection limits. Some of these facilities may have negligible concentrations and others may have environmental releases or risk exceedances.

Not surprisingly, the highest risks for the groundwater pathway on an impoundment basis correlate strongly with the absence of a liner. The liner status reported in the survey responses provided the necessary data to make this determination, and, as shown in Table 3-10, the number of risk criteria exceedances observed in unlined impoundments is twice the number for those that are lined. Similarly, the number of unlined impoundments that indicate the potential for environmental releases is almost three times the number for lined impoundments. These results strongly suggest that (1) the modeling is sensitive to the presence and type of liner, and (2) the contaminant release into the environment tends to be much higher for unlined impoundments.

Two chemical constituents with reported concentrations exceeded the risk criteria for the groundwater ingestion pathway: acetone and fluoride.

Acetone is a non-cancer-causing chemical that has been associated with increased liver and kidney weights and nephrotoxicity in rats via oral administration. The RfD of 0.1 mg/kg-d for ingestion was identified in IRIS and used in the risk modeling. This benchmark represents a health benchmark suitable for evaluating chronic exposures.

Fluoride is a noncarcinogen that, at elevated doses, may cause objectionable dental fluorosis in children. The RfD of 0.06 mg/kg-d used in the risk modeling was based on fluorine, as soluble fluoride, currently found in IRIS. EPA has determined that dental fluorosis is a cosmetic effect, not a toxic or adverse health effect. However, it is important to note that, at somewhat higher levels of exposure, the endpoint of concern is crippling skeletal fluorosis. Although an RfD for skeletal fluorosis is not available, EPA has determined that a safe exposure level for this more severe endpoint in adults is twice the RfD for dental fluorosis, or 0.12 mg/kd-d.

Table 3-10. Impoundment-Level Results for Groundwater Pathway by Liner Status

Impoundment Status	Environmental Release[a]	May Exceed Risk Criteria[a]
Risk results based on reported concentrations		
Lined	449 (4%)	8 (0.07%)
Not lined	850 (7%)	36 (0.3%)
All impoundments with reported values	1,299 (11%)	44 (0.4%)
Risk results based on surrogate/DL concentrations		
Lined	461 (4%)	32 (0.3%)
Not lined	1,939 (16%)	47 (0.4%)
All impoundments with surrogate/DL values	2,400 (20%)	79 (0.7%)

DL = Detection limit.

[a] Number of impoundments (percentages are of the total number of in scope impoundments, approximately 11,900).

3.2.3.2 Discussion of Uncertainties Associated with Groundwater Analysis. In its assessment of the groundwater pathway, EPA relied on modeling tools that have been peer-reviewed and used in previous analyses, as much site-specific data as possible from the surveys, and standard EPA sources for important data such as exposure factors and health benchmarks. All of these factors contributed to a relatively robust analysis that met the study objectives of the Surface Impoundment Study. This section identifies the primary sources of uncertainty and qualitatively describes how each may influence the results of the risk assessment. Additional details on these uncertainties are presented in Appendix C of this report.

***Parameter Uncertainties*.** The critical parameters required for the screening of groundwater pathway included the distribution coefficients (K_d) and model parameter inputs.

- **Distribution Coefficients.** Empirical data were used to characterize partitioning of chemical contaminants between the aqueous phase and soil and aquifer materials. The K_d values used in the SI Study are based on values found in the literature. Uncertainty associated with these values could result in either an underestimation or an overestimation of risk.

- **Model Input Parameters.** Application of the EPACMTP model requires input values for the source-specific, chemical-specific, unsaturated zone-specific, and saturated zone-specific model parameters. For this analysis, facility-specific values for impoundment location and waste, soil, and aquifer characteristics were used to the extent possible. Where facility-specific data were not available, regional databases were used to obtain the parameter values for soil and aquifer

conditions. The use of facility-specific data reduces but does not eliminate uncertainty. Use of regional databases may result in a greater spread of risks in Monte Carlo analyses.

Model Uncertainties. Model uncertainty is associated with all models used in all phases of a risk assessment because models and their mathematical expressions are simplifications of reality that are used to approximate real-world conditions, processes, and their relationships. These simplifications generally rely on precautionary assumptions and, as a result, the modeling approach tends to overpredict the potential effects on water quality.

- **Model Simplifications.** In modeling the fate and transport of chemicals in groundwater, complex hydrogeology such as karst or highly fractured aquifers was not directly assessed. A small fraction of the groundwater settings in this analysis are located in hydrogeologic environments where fracturing is likely. EPACMTP also does not model colloidal transport nor does it model possible geochemical interactions among different contaminants in the leachate and the subsurface environment. In addition, some precautionary assumptions are made that allow for the saturated zone to be modeled as having a uniform thickness. The use of these simplifications may result in a greater spread of concentrations in the groundwater in the Monte Carlo analysis.

- **Recharge Rates.** The recharge rates used in this analysis rely on regionalized climatic data and generalized soils types. These are not site-specific data, but are intended to represent the range of conditions expected in the area. Although the model accounts for uncertainty using a probabilistic simulation, the recharge rates are not site-specific and may over- or underpredict the contaminant flux to groundwater.

- **Timeframe of Exposure.** There is uncertainty in predicting the movement of contaminants over long periods of time. The risk to receptors for the groundwater pathway was evaluated over a time period of 10,000 years. There are significant uncertainties concerning how exposure and environmental assumptions will change over time, and the modeling methodology does not change these assumptions over this 10,000-year period.

Uncertainty in Results. It is important to consider several key uncertainties in interpreting the significance of the groundwater pathway results. The greatest uncertainty relates to assumptions made in defining the geometric configuration of the modeled system, specifically concerning the groundwater flow direction, well construction, and aquifer mounding.

- **Groundwater Flow Direction.** The direction of groundwater flow was not provided in the survey responses. Because the exact direction of the groundwater flow was unknown, the actual receptor well locations in the general the direction of the groundwater flow, as well as the physiography of the site were used to define the angle "THETA." For each surface impoundment, THETA sets the bounds for the true direction of groundwater flow and, therefore, captures the

uncertainty in centerline for groundwater flow and contaminant movement relative to the nearest receptor well to the impoundment. The error margin for THETA was based on professional judgement, and was set to 5 degrees for all facilities evaluated in the risk modeling. The impact of this geometrical inexactitude is considered to be small compared to several other uncertainties in the groundwater pathway analysis.

- **Well Construction.** The aquifer from which receptor wells drew water was not consistently reported in survey results. In the absence of technical information from the survey respondents indicating a site-specific well depth, it was assumed that the receptor wells considered in this analysis drew water from the uppermost unconfined saturated zone. This is a protective assumption and would tend to overestimate risk.

3.2.4 Results for Direct Inhalation Pathway

Table 3-11 identifies the chemicals that showed potential risk exceedances for the direct inhalation pathway. The more reliable findings based on reported values are distinguished in the table from those based on use of surrogate values and detection limits as modeling inputs. Eleven chemicals show a potential risk of 1E-5 or more or an HQ of 1 or more. Two of these chemicals show potential risks based on reported values.

Table 3-12 provides national estimates of the number of facilities that may have risk exceedances by the direct inhalation pathway, distinguishing those results in which we have more confidence because they are based on reported concentration data from those less reliable results based on inferred concentrations or detection limits. Table 3-12 further distinguishes results for decharacterized wastewaters and for never characteristic wastewaters.

Two chemical constituents with reported concentrations exceeded the risk criteria for the air inhalation pathway: alpha-hexachlorocyclohexane and chlorodibromomethane.

alpha-Hexachlorocyclohexane is considered a probable human carcinogen (Class B2) and has been shown to cause hepatic nodules and hepatocellular carcinomas in male mice when administered orally. The cancer slope factor for inhalation of $6.3\ (mg/kg\text{-}d)^{-1}$ was identified in IRIS and used in the risk modeling. The inhalation CSF found in IRIS is based on the oral ingestion study on male mice.

Chlorodibromomethane is considered a possible human carcinogen (Class C); oral administration to female mice resulted in an increased incidence of hepatocellular adenomas and carcinomas. The CSF for inhalation of $8.4E\text{-}02\ (mg/kg\text{-}d)^{-1}$ was extrapolated from the CSF for ingestion identified in IRIS and used in the risk modeling. This provisional inhalation benchmark was derived from the oral ingestion study described in IRIS; however, this benchmark has not undergone EPA-wide review.

Table 3-13 shows the proportion of impoundments by aeration status. Aeration greatly facilitates emissions to air. The majority (86 percent) of impoundments are not aerated, thus most of the exceedances are for nonaerated impoundments.

3.2.4.1 Quantitative Risk Estimation for Air Pathway. Table 3-12 shows that 4 percent of facilities potentially exceed risk criteria (based on reported wastewater concentrations.) Most

Table 3-11. Maximum Hazard and Risk Exceedances for Air Pathway

Summary of HQ Exceedance	Summary of Risk Exceedance
Risk exceedances based on reported concentrations	
	Chlorodibromomethane - 1E-05 **alpha-Hexachlorocyclohexane** - 3E-05
Risk exceedances based on surrogate/DL chemical concentrations	
Acetonitrile - 57 Acrolein[b] - 11 Chloroform - 2 Hexachlorocyclopentadiene - 1.5	Bis (chloromethyl) ether - 4E-01 n-Nitrosodiethylamine[b]- 5 E-05 n-Nitrosodi-n-butylamine[b] - 2 E-05 Tetrachlorodibenzofurans - 3 E-05 Toxaphene - 4E-03
Risk exceedances based on summed risks for the facility	
	Facility level sum - 1.5E-05 **Acetaldehyde**[a] - 6 E-06 Tetrachlorodibenzodioxins - 9E-06

DL = Detection limit.

[a] Constituent risk was based on a reported value. However, the individual risk did not exceed the risk criterion.

[b] Industry representatives, subsequent to completion of the survey, have indicated that this constituent is not expected to be present at the facility. These constituents were reported to EPA in response to the Survey of Surface Impoundments in November 1999 as less than a specified limit of detection. When this constituent was evaluated in our risk analysis at the reported detection limit the concentrations were high enough to predict the indicated risk/hazard of concern. EPA included the results in this table because of the methodology used throughout the study to evaluate less than detection limit data.

Table 3-12. Facility-Level Results for Air Pathway by Decharacterization Status

Facility Status	Environmental Release[a]	May Exceed Risk Criteria[a]
Risk results based on reported concentrations		
Never characteristic	105 (2%)	158 (4%)
Decharacterized	69 (2%)	13 (0.3%)
All facilities with reported values	173 (4%)	171 (4%)
Risk results based on surrogate/DL concentrations		
Never characteristic	31 (0.7%)	0 (0%)
Decharacterized	134 (3%)	55 (1%)
All facilities with surrogate/DL values	165 (4%)	55 (1%)

DL = Detection limit.

[a] Number of facilities (percentages are of the total number of facilities, approximately 4,500).

Facility-Level Risk Summation

The risks presented in the exceedance tables in this section reflect risks for individual chemicals in individual impoundments. However, an aggregate facility-level risk was also calculated and was used to determine whether a facility exceeded the risk criterion or not.

- For carcinogens, the aggregate risk for a facility was calculated by taking the maximum risk for each chemical across all impoundments at the facility and summing these.
- For noncarcinogens, the aggregate risk for a facility was calculated by taking the maximum hazard index for each chemical across all impoundments at the facility, summing those that act on the same target organ, and taking the maximum of the target organ-specific sums.

In only one case did a facility have an aggregate risk that exceeded the risk criterion and no individual impoundment-chemical results that exceeded the risk criterion. This was via the air pathway. This aggregate, however, is a combination of reported data and less reliable surrogate or detection limit data. That exceedance is listed in Table 3-11 with all the individual impoundment chemical components as well as the aggregate facility-level risk.

See Attachment C-6 in Appendix C for the full impoundment-level results that were used to generate facility-level risk summations.

Table 3-13. Impoundment-Level Results for Air Pathway by Aeration Status

Impoundment Status	Environmental Release[a]	May Exceed Risk Criteria[a]
Risk results based on reported concentrations		
Aerated	78 (0.7%)	8 (0.06%)
Not aerated	297 (3%)	154 (1%)
All impoundments with reported values	375 (3%)	161 (1%)
Risk results based on surrogate/DL concentrations		
Aerated	195 (2%)	60 (0.5%)
Not aerated	207 (2%)	26 (0.2%)
All impoundments with surrogate/DL values	402 (3%)	85 (0.7%)

DL = Detection limit.

[a] Number of facilities (percentages are of the total number of facilities, approximately 4,500).

of these manage never characteristic wastes. The trend is reversed for facilities and impoundments that show environmental releases, with a higher rate of these releases associated with decharacterized wastes. From an impoundment standpoint, Table 3-13 shows that a significantly higher number of impoundments that may exceed risk criteria are not aerated. These data are somewhat misleading because the number of non-aerated impoundments (10,193) far exceeds the number of aerated impoundments (1,670). The relative proportion of aerated impoundments that are classified as "may exceed risk criteria" is much higher than the relative proportion of not aerated impoundments classified as "may exceed risk criteria." Approximately one-third of the total risk exceedances are attributable to aerated impoundments even though less than one-fifth of the sample population consists of aerated impoundments. (See Attachment C-7 to Appendix C for additional detail.) Chemicals of interest included primarily volatile organic compounds (VOCs), although several semivolatile organic compounds (SVOCs) and one dioxin-like chemical showed potential risk exceedances; both cancer risks and noncancer risks were predicted.

Table 3-12 also shows that 4 percent of facilities may have environmental releases, i.e., exposures of potential concern at a distance of 25 meters from the facility boundary. An additional 5 percent of facilities cannot be assessed with certainty because of lack of information on concentrations. Some of these facilities may have negligible concentrations, and others may have environmental releases or risk exceedances.

3.2.4.2 Discussion of Uncertainties for Air Analysis. In its assessment of the air pathway, EPA relied on modeling tools that have been peer-reviewed and used in previous analyses, as much site-specific data as possible from the surveys, and standard EPA sources for important data such as exposure factors and health benchmarks. All of these factors contribute to

an analysis that met the study objectives of precautionary screening at earlier stages for the many impoundments and constituents and more robust modeling at the final stages of analysis. However, there are several key uncertainties that should be considered in interpreting the results of the air analysis. These are grouped under parameter uncertainties, modeling uncertainties, and results uncertainties. This section identifies these sources of uncertainty and qualitatively describes how each may influence the results. Additional details on these uncertainties are presented in Appendix C.

***Parameter Uncertainties*.** The key parameters required for the air pathway modeling included impoundment characteristics, receptor location, and exposure parameters.

- **Impoundment Characteristics.** Impoundment characteristics needed for the modeling were taken from the survey responses whenever possible; however, when this was not possible, assumptions or estimates were made that introduce uncertainty into the results. Assumptions and estimates were generally chosen to be somewhat conservative (i.e., to overpredict risk).

- **Receptor Location.** To the extent that receptor locations were based on old or inaccurate maps, there is some uncertainty introduced in the risk estimates, which could be either over- or underestimated. However, conclusions regarding whether or not the risk may exceed the risk criteria are more robust, because, in cases where this conclusion was sensitive to receptor location, the location was verified using recent aerial photos.

- **Exposure Parameters.** The air model used in this analysis, is called the IWAIR, the Industrial Waste Air Model (IWAIR) (U.S. EPA, 1998) and was developed for EPA's draft industrial nonhazardous waste guidelines and used standard EPA exposure factors, such as inhalation rate, body weight, and exposure duration. Exposure factors have been chosen to be somewhat conservative; therefore, this uncertainty will typically result in an overestimate of risk.

- **Volatilization.** Our evaluation of the groundwater pathway was focused only on the ingestion of contaminated groundwater. We did not address volatlization of chemical constituents in groundwater that may result in inhalation exposures during showering. Because the inhalation pathway associated with shower exposure was not modeled, the groundwater pathway risk results may underestimate the total risk from leaching to groundwater. This contributes to the uncertainty in the risk estimates in the direction of underprotection.

***Modeling Uncertainties*.** The modeling for the air pathway simplifies the fate and transport of chemicals from an impoundment through air to a receptor. Many of these simplifications could result in either over- or underprediction of risk.

- **Hydrolysis.** IWAIR cannot model hydrolysis. To the extent that constituents modeled do hydrolyze, IWAIR will overpredict risks. For constituents that hydrolyze quickly, this could be significant. For others, it will be less significant.

- **Biodegradation Losses.** IWAIR models biodegradation losses using conservative biodegradation rate constants. However, biodegradation is heavily influenced by site-specific factors. Therefore, the emissions estimates are uncertain. This uncertainty could result in either over- or underprediction of emissions and risks.

- **Receptor Location Relative to Plume.** The receptor is assumed to be located at the centerline of the plume, where air concentrations are highest. Depending on site-specific meteorology, particularly prevailing wind directions, the nearest receptor may not be located in the centerline of the plume. This uncertainty tends to overpredict air concentration at the nearest receptor, and thus the risk.

- **Coverage of Meteorological Data in IWAIR**. The version of IWAIR used for this study uses dispersion factors for 41 meteorological stations. Use of these meteorological stations introduces uncertainty to the extent that they may not fully represent all possible impoundment locations. However, this uncertainty is believed to be small. The direction of this uncertainty is not known.

- **Interpolation of Dispersion Factors in IWAIR Based on Impoundment Area.** IWAIR uses dispersion factors generated for a fixed set of impoundment areas and interpolates results for other areas. This will result in the underprediction of risk; however, this underprediction is expected to be modest.

***Results Uncertainites*.** As with any risk assessment, there is uncertainty in the risk results associated with simplifying assumptions and data limitations. Several key uncertainties to consider in interpreting the risk results are presented below.

- **Chemical-Physical Properties.** Adequate chemical-physical properties to run IWAIR were not available for 12 constituents of interest in this study for the air pathway. To the extent that these constituents pose risks, this results in an underestimate of risk.

- **Health Benchmarks.** It was not possible to assess inhalation risks for many constituents in the scope of this study becasue they do not have health benchmarks for inhalation. If inhalation health benchmarks were available for all constituents of interest, a few more might be found to pose risks; therefore, this uncertainty tends to result in an underestimate of risk.

3.3 Indirect Pathways: Groundwater to Surface Water

Many impoundments are located near surface waterbodies and their direct discharges are subject to regulatory standards. However, there is the potential for indirect discharge to surface waters when chemicals are released through the bottom of the impoundment, travel through the subsurface, and impact nearby waterbodies. The intersection of groundwater flow with surface water is often referred to as groundwater discharge to surface water. Through this pathway, contaminant discharge into a pond or stream has the potential to affect water quality adversely.

For chemicals that are bioaccumulative, chemical concentrations in fish may approach or exceed levels of concern for the segment of the population that ingests fish from the nearby waterbody. For convenience, we will refer to the release, transport, and accumulation of chemicals in fish and other aquatic organisms as the groundwater to surface water (gw-sw) pathway.

3.3.1 Methodology for Groundwater to Surface Water Pathway

Table 3-14 provides an overview of the methodology for assessing the groundwater to surface water pathway. The basic approach to evaluating the potential for risks by this pathway was first to identify candidate sites through a screening process that considered groundwater concentrations, proximity to surface waterbodies, and the magnitude of potential dilution. For these candidate sites, screening-level modeling was conducted to generate flux rates from the surface impoundments, estimate groundwater concentrations that might contaminate the surface waterbody, and estimate the ensuing dilution. This analysis was conducted on all facilities that reported the presence of in-scope constituents. The basic steps in the screening process were to

- Identify sites near (within 1 km) one or more fishable waterbodies
- Screen out some sites based on a comparison of wastewater concentrations to the human health ambient water quality criteria for the ingestion of surface water and aquatic organisms (HH-AWQC)
- For those that did not screen out, estimate groundwater concentrations (from dilution attenuation factors [DAFs]) and compare these to the HH-AWQC. The DAFs used were intended to provide conservative estimates of groundwater concentrations
- Using site-specific data (such as surface impoundment area) and reviewing topographical maps, identify sites with a potential to impact surface water. Typically, this was based on a low probability of dilution by the surface waterbody based on flow data for the closest waterbody.

After the screening process, EPA conducted screening-level modeling to generate more refined estimates of chemical concentrations in the receiving waterbody and compared the resulting values to the HH-AWQC.[5]

[5] In cases in which the receiving waterbody was brackish (e.g., in an estuary), the HH-AWQC for ingestion of contaminated aquatic biota only was used (i.e., no drinking water ingestion).

Table 3-14. Overview of Tiered Risk Assessment Methodology for Potential for Adverse Effects on Surface Water Quality

Analysis Stage	Risk Assessment Methodology—Groundwater to Surface Water Human Health Chronic Risk Measure: Surface water concentrations in excess of AWQC for protection of human health for ingestion of aquatic organisms and surface water		
	Approach	**Receptor Exposure**	**Driving Variables**
Preliminary Screen	■ Precautionary screen ■ Determine potential for a groundwater to surface water pathway as a function of distance (surface waterbody within 1 km) ■ Eliminate impoundments with wastewater concentrations below HH-AWQC from further evaluation	Ingestion of aquatic organisms and surface water (as defined by the HH-AWQC)	■ Wastewater leachate concentrations
Release Assessment	■ Evaluate facilities, impoundments, and constituents not eliminated in the preliminary screen ■ Use Industrial D Tier I groundwater model lookup tables to estimate groundwater concentrations ■ Eliminate impoundments with leachate concentrations below HH-AWQC from further evaluation ■ Impoundments not screened out have release potential and are evaluated for screening risk modeling	Ingestion of aquatic organisms and surface water (as defined by the HH-AWQC)	■ Impoundment wastewater concentrations ■ Liner type ■ Distance to surface waterbody (groundwater concentration was not diluted if waterbody was within 150 km of impoundment)

(continued)

Table 3-14. (continued)

Analysis Stage	Risk Assessment Methodology—Groundwater to Surface Water Human Health Chronic Risk Measures: Surface water concentrations in excess of AWQC for protection of human health for ingestion of aquatic organisms and surface water		
	Approach	**Receptor Exposure**	**Driving Variables**
Risk modeling (screening)	■ Evaluate characteristics of impoundments (e.g., surface area) and receiving waterbodies (e.g., flow rate) that drive this pathway ■ Develop numeric ranking scheme to identify impoundments with potential to adversely affect surface water quality ■ Using EPACMTP, calculate infiltration rate and contaminant flux from impoundment to surface water ■ Determine surface water concentrations using instantaneous dilution and full mixing assumptions ■ Compare surface water concentrations with HH-AWQC for the impoundments modeled	Ingestion of aquatic organisms and surface water (as defined by the HH- AWQC)	■ Impoundment leachate concentrations ■ Surface area of surface impoundment ■ Meteorological conditions that affect infiltration (e.g., precipitation) ■ Type of receiving waterbody (flowing versus quiescent) ■ Flow rate ■ Liner type ■ Distance to surface waterbody

EPACMTP = EPA's Composite Model for Leachate Transformation Products.
HH-AWQC = Human health ambient water quality criteria.

3.3.2 Results for Indirect Pathway—Surface Water

After completion of this screening-level modeling, EPA found 158 potential risk exceedances (35 constituents) at 27 impoundments at nine facilities in the survey sample. In summary, EPA found

- 30 exceedances of the HH-AWQC by a factor of over 100—of these 30 exceedances, 7 are based on reported values for arsenic at a single facility.
- 38 exceedances of the HH-AWQC by a factor between 10 and 100—none are based on reported values.
- 90 exceedances of the HH-AWQC by a factor between 1 and 10—of these 90 exceedances, only thallium and arsenic are based on reported values.

Table 3-15 identifies the maximum exceedances for reported values at each of the nine facilities with respect to the ratio of the surface water concentration to the HH-AWQC. Where a reported value was not identified, the maximum exceedance based on a surrogate/detection limit (DL) value, in which there is less confidence, is presented.

Tables 3-16 and 3-17 illustrate the proportion of the surface impoundment universe that show potential exceedances of HH-AWQC and those that show potential environmental release to surface water. Table 3-16 shows the proportion of facilities by decharacterization status; Table 3-17 shows the proportion of impoundments by liner status.

3.3.2.1 Quantitative Risk Estimation for Surface Water Pathway. Based on screening level modeling, Table 3-16 shows that very few facilities—about 1 percent—may exceed risk criteria using reported concentration data. Eighteen percent of facilities may have environmental releases into surface water that are higher than HH-AWQC at the point of discharge before dilution occurs. An additional 25 percent of facilities cannot be assessed with certainty because of incomplete information on concentrations; some of these facilities may have negligible concentrations, and others may have environmental releases or risk exceedances. The number of potential risk exceedances is roughly similar for decharacterized and never characteristic wastes; however, the rate of potential risk exceedance is higher for decharacterized wastes. (See Attachment C-15 of Appendix C.) Table 3-18 shows the risk results by discharge status. For the groundwater pathway, no zero discharge facilities exceeded the risk criteria; however, for the surface water pathway, it can be inferred that roughly 37 percent[6] of all facilities that exceeded the risk criteria were zero dischargers. The value of liners for protecting the surface water pathway was pronounced (see Table 3-17); no impoundments with liners show potential exceedances of the human health ambient water quality criteria, whereas unlined impoundments do show potential risk exceedances.

[6] There are approximately 73 total facilities with 27 zero dischargers listed as "May Exceed Risk Criteria." The complete analytical results for this pathway are shown in Attachment C-15 in Appendix C.

Table 3-15. Maximum Exceedances for Groundwater to Surface Water Pathway

Constituent of Concern	C_{leach}[a] (mg/L)	C_{gw}[b] (mg/L)	C_{river}[c] (mg/L)	HH-AWQC (mg/L)	C_{river}/ HH-AWQC[d]
Risk exceedances based on reported chemical concentrations					
Thallium	2.40E-01	3.29E-03	3.29E-03	1.70E-03	1.93E+00
Arsenic	1.95E-01	1.95E-01	1.95E-01	1.80E-05	1.08E+04
Risk exceedances based on surrogate/dl chemical concentrations					
Antimony	6.00E-02	6.00E-02	3.74E-04	1.40E-04	2.67E+00
3,3'Dichlorobenzidine	2.00E-02	2.00E-02	9.02E-05	4.00E-05	2.26E+00
4,4-DDD	3.67E-04	3.67E-04	1.65E-06	8.30E-07	1.99E+00
4,4-DDE	3.67E-04	3.67E-04	1.65E-06	5.90E-07	2.80E+00
4,4-DDT	3.67E-04	3.67E-04	1.65E-06	5.90E-07	2.80E+00
Heptachlor epoxide	2.93E-03	2.93E-03	1.32E-05	1.00E-07	1.32E+02
Hexachlorobenzene	1.00E-02	1.00E-02	4.51E-05	7.50E-07	6.02E+01
PCBs	1.65E-02	1.65E-02	7.45E-05	1.70E-07	4.38E+02
Benzo(a)anthracene	1.00E-02	1.00E-02	1.44E-04	4.40E-06	3.28E+01
Benzo(a)pyrene	1.00E-02	1.00E-02	1.44E-04	4.40E-06	3.28E+01
Benzo(b)fluoranthene	1.00E-02	1.00E-02	1.44E-04	4.40E-06	3.28E+01
Chrysene	1.00E-02	1.00E-02	1.44E-04	4.40E-06	3.28E+01
Dibenzo(a,h)anthracene	1.00E-02	1.00E-02	1.44E-04	4.40E-06	3.28E+01
Ideno 1,2,3-cd pyrene	1.00E-02	1.00E-02	1.44E-04	4.40E-06	3.28E+01
1,1,2,2-Tetrachloroethane	5.00E-03	5.00E-03	4.87E-04	1.70E-04	2.86E+00
1,1-Dichloroethylene	5.00E-03	5.00E-03	4.87E-04	5.70E-05	8.54E+00
1,2-Dichloroethane	5.00E-03	5.00E-03	4.87E-04	3.80E-04	1.28E+00
1,2-Diphenylhydrazine	1.00E-02	1.00E-02	9.73E-04	4.00E-05	2.43E+01
2,4-Dinitrotoluene	1.00E-02	1.00E-02	9.73E-04	1.10E-04	8.85E+00
Acrylonitrile	1.00E-02	1.00E-02	9.73E-04	5.90E-05	1.65E+01
Aldrin	5.00E-05	5.00E-05	4.87E-06	1.30E-07	3.74E+01
Benzidine	1.00E-02	1.00E-02	9.73E-04	1.20E-07	8.11E+03
Bis(2-chloroethyl) ether	1.00E-02	1.00E-02	9.73E-04	3.10E-05	3.14E+01
Carbon tetrachloride	5.00E-03	5.00E-03	4.87E-04	2.50E-04	1.95E+00
Chlordane	5.00E-05	5.00E-05	4.87E-06	2.10E-06	2.32E+00

(continued)

Table 3-15. (continued)

Constituent of Concern	C_{leach}[a] (mg/L)	C_{gw}[b] (mg/L)	C_{river}[c] (mg/L)	HH-AWQC (mg/L)	C_{river}/ HH-AWQC[d]
Chlorodibromomethane	5.00E-03	5.00E-03	4.87E-04	4.10E-04	1.19E+00
Dieldrin	2.00E-04	2.00E-04	1.95E-05	1.40E-07	1.39E+02
Heptachlor	5.00E-05	5.00E-05	4.87E-06	2.10E-07	2.32E+01
Hexachlorobutadiene	1.00E-02	1.00E-02	9.73E-04	4.40E-04	2.21E+00
N-Nitrosodimethylamine	1.00E-02	1.00E-02	9.73E-04	6.90E-07	1.41E+03
N-Nitrosodi-n-propylamine	1.00E-02	1.00E-02	9.73E-04	5.00E-06	1.95E+02
Pentachlorophenol	1.00E-02	1.00E-02	9.73E-04	2.80E-04	3.48E+00
Toxaphene	5.00E-03	5.00E-03	4.87E-04	7.30E-07	6.67E+02

HH-AWQC = Ambient Water Quality Criteria for human health.

[a] The estimated concentration in the leachate as it leaves the unit boundary.
[b] The estimated concentration in the groundwater as it enters the surface water; if this value exceeds a HH-AWQC then the facility is considered to have the potential for an environmental release.
[c] The estimated concentration in the surface water after complete mixing.
[d] The ratio of the surface water concentration to the HH-AWQC; if this ratio exceeds 1, then the facility is considered to pose a potential risk to surface water quality.

Table 3-16. Facility-Level Results for Groundwater to Surface Water Pathway by Decharacterization Status

Facility Status	Environmental Release[a]	May Exceed Risk Criteria[a]
Risk results based on reported concentrations		
Never characteristic	479 (11%)	29 (0.7%)
Decharacterized	311 (7%)	14 (0.3%)
All facilities with reported values	790 (18%)	44 (1.0%)
Risk results based on surrogate/DL concentrations		
Never characteristic	918 (21%)	9 (0.2%)
Decharacterized	161 (4%)	22 (0.5%)
All facilities with surrogate/DL values	1,079 (24%)	31 (0.7%)

DL = Detection limit.

[a] Number of facilities (percentages are of the total number of facilities, approximately 4,500).

Table 3-17. Impoundment-Level Results for Groundwater to Surface Water Pathway by Liner Status

Impoundment Status	Environmental Release[a]	May Exceed Risk Criteria[a]
Risk results based on reported concentrations		
Lined	1,123 (9%)	0 (0%)
Not lined	1,028 (9%)	64 (0.5%)
All impoundments with reported values	2,150 (18%)	64 (0.5%)
Risk results based on surrogate/DL concentrations		
Lined	426 (4%)	0 (0%)
Not lined	1,121 (9%)	74 (0.6%)
All impoundments with surrogate/DL values	1,547 (13%)	74 (0.6%)

DL = Detection limit.

[a] Number of impoundments (percentages are of the total number of in scope impoundments, approximately 11,900).

Table 3-18. Facility-Level Results for Groundwater to Surface Water Pathway by Discharge Status[a]

Facility Status	Environmental Release[a]	May Exceed Risk Criteria[a]
Risk results based on reported concentrations		
Direct dischargers	622 (14%)	14 (0.3%)
Zero dischargers	115 (3%)	27 (0.6%)
All facilities with reported values[b]	738 (17%)	42 (0.9%)
Risk results based on surrogate/DL concentrations		
Direct dischargers	906 (20%)	31 (0.7%)
Zero dischargers	76 (2%)	0 (0%)
All facilities with surrogate/DL values[b]	982 (22%)	31 (0.7%)

DL = Detection limit.

[a] Number of facilities (percentages are of the total number of facilities, approximately 4,500).

[b] Note that the facility totals for Tables 3-16 through 3-18 do not match. This is because the patterns of missing data are different for each of the tables, and the weight adjustments for missing data lead to slightly different estimates.

3.3.3 Discussion of Uncertainties

There are several key uncertainties that should be considered in interpreting the results of the surface water quality screening assessment. These are grouped under parameter uncertainties, modeling uncertainties, and results uncertainties. This section identifies these sources of uncertainty and qualitatively describes how each may influence the results. Additional details on these uncertainties are presented in Appendix C to this report.

3.3.3.1 Parameter Uncertainties. The critical parameters required for the screening modeling of surface waterbodies included flow rates and dilution/attenuation factors.

- **Flow Rates.** Flow rates were a potentially significant source of uncertainty; the low flow rate (7Q10) was often greater than the average flow rate, suggesting that the data sources were highly variable. In addition, many flow rate estimates are based on end-of-stream locations, which could be a substantial distance from the point at which the groundwater could reasonably be expected to intersect with the surface waterbody. Consequently, the river dilution factor calculated from the flow rate may be highly uncertain.

- **Dilution/Attenuation Factors.** For surface waterbodies within 150 meters, a default DAF of 1.0 was chosen. This value tends to overestimate the contaminant flux in groundwater that reaches the surface waterbody. The DAFs in Industrial Waste Evaluation Model (IWEM) were used for waterbodies beyond 150 meters and, as with the default DAF, these were developed for a groundwater screening tool. The resulting groundwater concentrations will generally lead to an overprediction of the contaminant concentration in the surface waterbody.

3.3.3.2 Modeling Uncertainties. The screening modeling for the groundwater to surface water pathway simplifies the fate and transport of chemicals from groundwater to surface water and is based on several assumptions. These simplifications generally rely on precautionary assumptions and, as a result, the modeling approach tends to overpredict the potential effects on water quality.

- **Groundwater Flow Direction.** For the surface water screening, groundwater flow direction was inferred from the topography and a plausible groundwater flow direction was established perpendicular to the receiving waterbody—either a flowing waterbody or a quiescent system such as a small pond. In addition, the plume was assumed to completely intersect with the waterbody so that the groundwater would exert the maximum impact on the surface waterbody. The combination of these assumptions creates a bias toward higher surface water concentrations.

- **Designation of Fishable Waterbody.** The closest fishable waterbody was identified for each impoundment based on both survey responses and simple decision rules. However, there may be substantial uncertainty in this selection because, in many instances, survey responses were not useful in identifying the closest fishable waterbody.

- **Infiltration Rates.** The infiltration rates used in this analysis were developed with the EPACMTP model using generalized soils data. These are not site-specific data but are intended to represent the conditions expected in the area. The infiltration rates are not site-specific and may over- or underpredict the contaminant flux to groundwater.

3.3.3.3 *Results Uncertainties*. It is important to consider several key uncertainties in interpreting the significance of the surface water pathway results. The modeling approach is based on the assumption of instantaneous and thorough dilution throughout the surface waterbody, which would create a constant exposure profile for human usage throughout the entire receiving waterbody. In reality, contaminant release into the surface waterbody through this pathway would likely be associated with a concentration gradient that would vary the exposure pattern throughout the length of the waterbody. In many instances, only a small portion of the receiving waters may actually maintain chemical concentrations above the HH-AWQC. For the highest area of contamination (perhaps a "favorite" fishing spot), the dilution may mask potentially adverse impacts on surface water quality. Nevertheless, the results of this analysis suggested that, despite the proximity of receiving waterbodies to surface impoundments, the risks from adverse effects to surface water quality are generally low nationwide.

- **Data Gaps.** The screening criteria (HH-AWQC) selected for this analysis were identified in EPA's compilation of national recommended water quality criteria developed pursuant to section 304(a) of the Clean Water Act. An HH-AWQC was not available for all of the constituents that failed the preliminary screen; therefore, the results may not capture impacts from all chemicals that may be released through this pathway.

- **Additive/Synergistic Effects.** The screening modeling does not address the possibility that other contaminant sources may be releasing similar chemical constituents into the same waterbody. For waterbodies that are already receiving significant contaminant loads of similar chemicals (or synergistic chemicals), the chemical release from an impoundment may be a significant contributor to water quality degradation.

- **Surface Water as a Drinking Water Source.** Some facilities were located next to freshwater systems and others were located adjacent to saline estuarine systems. In freshwater systems EPA used HH-AWQC that assume both fish consumption and use of the waterbody as a drinking water source without treatment. Because few people use untreated surface water as a source of drinking water, some of the results are overestimates of the potential groundwater to surface water risk. In estuarine systems, EPA assumed the water would not be used as a source of drinking water and only used the HH-AWQC that are based on fish consumption.

3.4 Other Indirect Pathways

3.4.1 Methodology

The potential for industrial sites with surface impoundments to pose a risk to surrounding populations through indirect exposure pathways was evaluated using a screening analysis that was implemented in two stages. Table 3-19 provides an overview of the methodology used.

In reviewing the indirect pathway methodology and results it is important to consider the limited nature and explicit purpose of this risk screening. This analysis ranks and orders facilities and impoundments based on whether they have the potential to generate an indirect risk. Unlike the previous risk analysis of groundwater, air and groundwater to surface water this analysis does not use models to predict the movement of chemicals through indirect pathways and therefore this analysis never measures the actual degree of indirect risk, this analysis only identifies the potential for risk. It is likely that many of the facilities in this screening analysis that are indicated to have the potential for an indirect risk would not actually indicate a risk of concern if modeling were conducted. This was certainly observed in the risk analysis of groundwater, air, and groundwater to surface water. Since indirect pathways often involve even more complex and highly site specific movement of contaminants through several different environmental compartments (e.g., sludge to wind blown dust to crops to cattle to humans) it is even more likely that many potential indirect exposure pathways would not be completed and as a result the proportion of facilities with actual indirect risk are likely to be far less than those with only the potential for risk.

In the first stage of the indirect screening, EPA reviewed the constituents reported in the surveys to identify a short list of constituents of focused concern for indirect exposure. The tendency to bioaccumulate is a chemical property that is considered especially relevant for indirect pathways of exposure where accumulation occurs in food chains and humans ingest these foods. This screening-level assessment of indirect pathways focused on those chemicals having a significant potential to bioaccumulate. The first step was to rank order all the constituents reported in the surveys, irrespective of their concentrations, according to their potential to bioaccumulate considering chemical-specific data on bioaccumulation. Based on this rank ordering, 37 constituents were included in our assessment of indirect exposure pathways. These chemicals are shown in Table 3-20.

The second stage of the screening analysis was to identify all facilities that reported managing these constituents and to screen these facilities according to their potential for indirect exposures. This potential was evaluated by examining facility-specific data and environmental settings, including probable proximity to receptors such as residents, farmers, and fishers. The release scenarios considered were volatilization of constituents from wastewater, particulate entrainment or erosion of constituents from exposed sludge, and leaching of constituents from wastewater into groundwater with subsequent transport and release to surface water.

The criteria considered in the ranking process included size of the surface impoundment, distance from the impoundment to the nearest receptor, slope of the terrain in the vicinity of the site (which impacts the degree of erosion/runoff that may occur in some cases after closure), size

Table 3-19. Overview of Tiered Risk Assessment Methodology for Indirect Pathway Assessment

Analysis Stage	Risk Assessment Methodology—Indirect Pathway Human Health Chronic Risk Measure: Numeric ranking scheme for potential completion of indirect pathways		
	Approach	**Receptor Exposure**	**Key Variables**
Preliminary screen	■ Precautionary screen for indirect exposure potential conducted at the facility-level ■ Focus on bioaccumulative chemical constituents that may pose risk via indirect exposures ■ Eliminate facilities from further evaluation that do not manage bioaccumulative chemicals	■ Indirect exposures (e.g., food chain) are considered to be a function of the presence or absence of bioaccumulative chemicals	■ Source concentration data indicating that the facility manages bioaccumulative chemicals
Release Assessment	■ Take full advantage of site-specific information on physiography, residences, presence of farms, location of nearest waterbody ■ Consider potential from exposures associated with active impoundments as well as for postclosure scenario ■ Scoring criteria include impoundment characteristics such as surface area, proximity to receptors, and groundwater-surface water modeling results ■ Use the numeric ranking criteria to identify facilities with the highest potential to complete indirect pathways	■ Ingestion of fruits and vegetables grown in local gardens or on local farms ■ Ingestion of animals and animal products raised on local farms ■ Ingestion of fish caught in fishable waterbodies located near the facility ■ Receptors and farms located at actual distances reported in the survey responses or identified using GIS tools	■ Impoundment characteristics (e.g., size) ■ Distance to farms, residences ■ Distance to fishable waterbodies ■ Results from gw-sw pathway screening modeling ■ Impoundment characteristics ■ Physiographical characteristics indicating potential for erosion/runoff of soil particles

GIS = Geographic information system.

Table 3-20. Chemicals Selected for Inclusion in Indirect Exposure Pathway Ranking Analysis

p,p'-DDT	Fluorene	Polychlorinated biphenyls
Dibenz[a,h]anthracene	Hexachloro-1,3-butadiene	2,3,7,8-TCDD
3-Methylcholanthrene	1,2,4,5-Tetrachlorobenzene	Lead
Chlordane, alpha & gamma isomers	2,4,5-Trichlorophenol	Mercury
7,12-Trimethylbenz[a]anthracene	Endosulfan	Cadmium
Lindane	Hexachlorobenzene	Toxaphene
Dieldrin	1,2,4-Trichlorobenzene	Pentachlorodibenzofurans
Endrin	Kepone	Hexachlorodibenzo-p-dioxins
Methoxychlor	Indeno(1,2,3-cd) pyrene	Pentachlorodibenzo-p-dioxins
p,p'-DDD	Benzo(b)fluoranthene	Tetrachlorodibenzo-p-dioxins
p,p'-DDE	Aldrin	Hexachlorodibenzofurans
Heptachlor	Pentachlorobenzene	Tetrachlorodibenzofurans
	Heptachlor epoxide, alpha, beta, and gamma isomers	

of the waterbody (which can influence the degree of dilution following deposition of bioaccumulative chemicals into waterbodies such as lakes, rivers, or creeks). These criteria were quantified and integrated into a numerical ranking framework designed to provide a consistent protocol to determine the potential for complete exposure pathways. The decision to list a facility as potential concern, lower concern, or least concern is based on the outcome of the numeric scheme.

The rankings assigned to facilities are based exclusively on an assessment of current site-conditions, including both impoundment status and environmental setting criteria in the vicinity of the facilities. However, a future closure scenario was also included in the analysis to address potential risks following impoundment closure. The future closure scenario is based on the precautionary assumption that all impoundments close without taking action to mitigate environmental releases such as dredging of residual sludge and capping to prevent erosion/runoff. Because of the precautionary assumptions underlying the future closure scenario, the results of this portion of the analysis are used to qualify the overall rankings given to individual facilities, but are not considered explicitly in assigning those rankings. Appendix C provides additional detail on the methodology, and Attachment 17 of Appendix C presents the full ranking results.

Once the screening had been completed to identify facilities where indirect pathways are of potential concern, EPA generated national estimates of the proportion of facilities that could pose concerns due to indirect pathway exposures. The measures used to portray the results in Tables 3-1 and 3-2 (overview of results) and in the tables described below, are as follows:

- Potential Concern: This risk metric is an indicator of the potential for completion of more than one indirect exposure pathway at the facility.

- Lower Concern: This risk metric is an indicator of the potential for completion of one indirect exposure pathway at the facility and, therefore, of relatively lower concern.

- Least Concern: This risk metric is an indicator of low potential to complete even one indirect exposure pathway at the facility.

3.4.2 *Results*

The screening analysis generated a number of results that provide a different perspective on whether facilities have the potential to pose indirect exposures of concern to surrounding populations. These include: (1) overall rankings, which summarize the overall facility-rankings across the entire set of facilities that manage bioaccumulative chemicals, (2) results presented according to which receptor population and exposure pathways are of concern. Appendix C provides additional detail on these results and additional perspectives of potential interest.

3.4.2.1 Overall Results. Table 3-21[7] summarizes the overall results by characterization status of the indirect pathway screening analysis, expressed as national estimates. Six percent of facilities fall into the potential concern category for indirect exposure. Table 3-22 presents the overall results by regulatory status, also expressed as national estimates, and indicates that all facilities classified as of potential concern are direct dischargers.

3.4.3 Discussion of Uncertainties

The qualitative character of the indirect exposure pathway analysis leads to several major areas of uncertainty that affect interpretation of the results. These are grouped under parameter uncertainties, modeling uncertainties, and results uncertainties. Additional details on these uncertainties are presented in Appendix C to this report.

Table 3-21. Facility-Level Results for Indirect Pathways by Decharacterization Status

Facility Status	Lower Concern[a]	Potential Concern[a]
Never characteristic	2,153 (48%)	116 (3%)
Decharacterized	466 (10%)	169 (4%)
All facilities	2,620 (59%)	285 (6%)

[a] Number of facilities (percentages are of the total number of facilities, approximately 4,500).

[7] Because specific chemical concentrations are not used in the indirect assessment, these results are not divided into reported vs. surrogate DL as other results are.

Table 3-22. Facility-Level Results for Indirect Pathways by Discharge Status[a]

Facility Status	Lower Concern[a]	Potential Concern[a]
Direct dischargers	2,487 (56%)	272 (6%)
Zero dischargers	181 (4%)	0 (0%)
All facilities[b]	2,668 (60%)	272 (6%)

[a] Number of facilities (percentages are of the total number of facilities, approximately 4,500).
[b] The facility total for Table 3-22 does not equal the facility total for Table 3-21 because the patterns of missing data are different for each of the tables, and the weight adjustments for missing data lead to slightly different estimates.

3.4.3.1 Parameter Uncertainties. Key parameters required for this analysis fall into one of two broad categories, including facility performance parameters and environmental setting parameters. Various sources of uncertainty can impact each of these parameters. The following parameter uncertainties are believed to have the greatest potential impact on the indirect exposure pathway screening assessments.

- **Distance to Nearest Receptor.** The distance between specific impoundments and the nearest receptor (i.e., residential areas, farms, or fishable waterbodies) was estimated using a combination of aerial photos and topographic maps. Although these measurements were made using the most up to-date photos and maps available, some of the photos and maps were somewhat dated and possibly inaccurate. This introduces uncertainty in the distance-to-nearest-receptor measurements because land use change could result in a receptor either being added to or removed from a given study area. This is less of an issue in identifying fishable waterbodies.

- **Assessment of Potential for Erosion/Runoff.** Topographic maps used to assess slope and the potential for sheet versus channel flow may not be current, in which case significant changes in land use (which would not show up on older maps) could introduce uncertainty into the characterization of this parameter.

3.4.3.2 Modeling Uncertainties. The indirect exposure pathway screening assessment is a facility-level evaluation intended to rank facilities according to their potential for complete indirect exposure pathways. This analysis uses a ranking algorithm together with facility-specific and environmental setting criteria to generate overall ranking scores for individual exposure pathways. The criteria used in this analysis were selected as surrogates for key factors related to human health risk (e.g., impoundment surface area was used as a surrogate for level of chemical emissions, distance to receptor was used as a surrogate for level of dispersion following source release). The use of these surrogate parameters as criteria in the ranking algorithms for individual exposure pathways, while appropriate given the screening nature of the analysis, does

introduce modeling uncertainty into the analysis. In addition, there are uncertainties associated with the ranking algorithms used in the analysis.

- **Use of ranking algorithms.** The ranking algorithm used in this analysis assumes an additive relationship between the criteria that are considered. However, in relation to actual risk, these criteria may have multiplicative or other nonlinear relationships to each other, in which case the overall importance of individual criteria could be misrepresented in the ranking algorithm.

- **Use of surface area as a surrogate parameter.** Total aggregated impoundment surface area for a given facility was used as a surrogate for the level of constituent emissions from that facility. However, a wide range of factors can influence the degree of source emissions from an impoundment including chemical composition of the wastewater/sludge and other environmental setting/impoundment characteristics. Consequently, use of surface area as a surrogate for emissions levels does introduce uncertainty into the analysis.

- **Use of distance to receptor as a surrogate parameter.** The shortest distance from any of the impoundments at a facility to the nearest offsite receptor (i.e., resident, farmer, or fisher) was used as a surrogate for the degree of chemical dispersion that would occur following release. However, a wide range of factors in addition to distance-to-receptor can impact dispersion including meteorology, topography, and the specific characteristics of the source release.

3.4.3.3 Results Uncertainties. The indirect exposure screening analysis is designed to identify which facilities have the potential to pose an indirect exposure pathway risk to surrounding populations. Given this scope, the analytical framework for the screening analysis uses a combination of surrogate criteria and simple additive ranking algorithms in place of a formal site-specific risk assessment framework to generate ranking results. While this semi-quantitative approach does support ranking of facilities with regard to the potential for indirect exposure pathway risk, care should be taken not to overextend conclusions drawn from the analysis. A similar issue applies to results produced for the current status scenario versus future closure scenario.

- **Drawing Conclusions from the Analysis.** Because the indirect exposure screening analysis uses surrogate criteria combined with simple additive algorithms to rank facilities, there is significant uncertainty associated with the overall analysis that should be considered in interpreting results. While this degree of uncertainty is considered acceptable for a first-pass assessment as to whether individual facilities have the potential for indirect exposure pathway risk, it precludes drawing any conclusions regarding the potential magnitude of risk that these facilities could pose.

- **Current Status Scenario Versus Future Closure Scenario Results.** There is significantly greater uncertainty associated with results generated for the future closure scenario than for the current status scenario. This discrepancy results

from the fact that the current status scenario is based on best available data regarding the current status of modeled facilities, while the future closure scenario is not intended as a "best guess" of future closure conditions at sites, but rather as a precautionary analysis of the potential for indirect exposure pathway risk should impoundments close without sufficient postclosure actions being taken to limit constituent mobility. Reflecting this discrepancy in uncertainty, overall rankings for the indirect exposure screening analysis are based only on results for current status scenario—results from the future closure scenario are not considered in assigning these rankings. However, the results of the future closure scenario could be used to qualify the results of the current status scenario since they provide perspective on how many facilities could pose an indirect exposure pathway risk should impoundment closure occur without remediation.

3.5 Ecological Risk Screening

Industrial wastes managed in surface impoundments can potentially cause adverse effects on flora and fauna in natural systems. Many impoundments are located near rivers and waterbodies and are freely accessible to wildlife. Moreover, some chemicals are more toxic to wildlife than to humans; wildlife species generally have higher metabolic rates than humans and, therefore, eat, drink, and breathe proportionately more contaminants than humans. In addition, nonhuman organisms live in closer association with their immediate environment and often cannot avoid contamination or replace destroyed food sources as humans can. For this study, EPA assessed the potential for impoundments to pose risks to populations and communities of ecological receptors that live in and near surface impoundments.

3.5.1 Methodology

Table 3-23 provides an overview of the methodology used to assess potential ecological risks. The ecological risk screening was similar to the first screening stage of the human health risk analysis, but did not go beyond that stage to consider actual exposures and did not rely on fate and transport modeling. The assessment strategy is intended to represent only the potential for adverse ecological effects, not the actual risk posed to wildlife.

In reviewing the ecological risk screening methodology and results it is important to consider the limited nature and explicit purpose of this evaluation. This analysis ranks and orders facilities and impoundments based on their potential to generate an ecological threat. Unlike the previous risk analysis of groundwater, air, and groundwater to surface water, this analysis does not use models to predict the movement of chemicals through the environment and actual exposure through the food chain. In this way the ecological risk screening analysis never measures the actual degree of ecological risk; this analysis only identifies the potential for risk. It is likely that many of the facilities in this analysis that are indicated to have the potential for an ecological risk would not actually indicate a risk of concern if modeling were conducted. This was certainly observed in the risk analysis of groundwater, air, and groundwater to surface water. Because the ecological pathways often involve even more complex and highly site-specific movement of contaminants through several different environmental compartments and food chains (e.g., sludge to windblown dust to flora to fauna to other fauna), it is even more likely that

Table 3-23. Overview of Tiered Risk Assessment Methodology for Screening Ecological Risk Assessment

Analysis Stage	Risk Assessment Methodology Ecological Receptors Chronic Risk Measures: (1) Media concentrations in excess threshold concentration and (2) Exposure in excess of a reference dose		
	Approach	**Receptor Exposure**	**Key Variables**
Preliminary Screen	■ Screen using protective ecological screening factors for range of taxa ■ Use endpoints relevant to population sustainability and community structure/function ■ Eliminate impoundments with no evidence of risk from further evaluation ■ Ascertain potential for adverse ecological effects across habitats ■ Divide facilities into two categories based on the number of receptor exceedances: potential concern or lower concern ■ Identify sensitive and protected ecosystems in the proximity of facilities with chemicals that exceed risk criteria	■ Direct consumption of impoundment water ■ Direct contact with contaminants in sludge and impoundment water ■ Direct ingestion of sludge and plant/animals in contact with the sludge ■ Receptors presumed to have complete access to impoundment and rely on immediate area as major food source	■ Impoundment chemical concentrations ■ Ecological benchmarks including NOAELs ■ Ecological exposure factors

NOAEL = No observed adverse effect level.

many potential ecological pathways would not be completed; as a result, the proportion of facilities with actual ecological risk is likely to be far smaller than the proportion with only the potential for risk.

A screening assessment was performed to estimate the potential risk for a wide variety of plants and animals. EPA assigned receptors to each facility based on regional data sources and land use characteristics at each facility. EPA screened for ecological risk in a manner similar to that used in the preliminary screening stage for noncancer risks for humans. The assessment compares chemical concentrations in surface impoundment water and sludge to concentrations that are considered protective of animals and plants. When this ratio, or hazard quotient, exceeds 1, there is the potential for adverse effects; if the result is less than 1, adverse effects are not expected for a particular ecological receptor. The ecological screening assessment is precautionary because it is based on direct ingestion or uptake of the surface impoundment influent. Risk was assessed for birds, mammals, and amphibians as well as for organisms that live in the soil, water, and sediment (e.g., worms, fish, and insect larvae). Plants that grow in water and those that grow on land were also assessed. By including many different types of

ecological receptors, EPA can infer a degree of protection to ecosystems as a whole.[8] An additional element of the ecological screening considered whether surface impoundments are located near sensitive ecosystems such as wetlands, wildlife refuges, or national forests.

The final stage of the screening-level assessment was to compare the number of each facility's risk exceedances[9] to the median number of exceedances (38 exceedances) for all the facilities that did not screen out. Using this standard, facilities were placed in two categories:

- Potential concern: Facilities having at least the median number of exceedances for ecological receptors (i.e., 38 or more exceedances).

- Lower concern: Facilities having fewer than the median number of exceedances for ecological receptors.

Note that the selection of the median number of exceedances does not guarantee that an equal number of facilities will be assigned to the two risk categories. The risk results from the sample population are weighted-up to produce the national risk estimates; therefore, the percentages for each risk category reflect the weights and missing data patterns as well as the exceedance rate.

3.5.2 Results

Based on the comparison with screening factors, a total of 34 chemicals exceeded the risk criteria for at least one receptor at one impoundment, and 54 of the more than 62 ecological receptors considered in this assessment showed potential risk exceedances. These receptor taxa include mammals, birds, and plants, as well as organisms living in the soil, water, and sediment. Wildlife species for which potential risks were indicated cover a variety of taxa and feeding strategies, from species that depend on aquatic systems for food (e.g., mink, river otter, kingfisher, great blue heron) to those typical of terrestrial systems (e.g., terrestrial plants, coyote, white tailed deer, cerulean warbler). These results were not based on modeling; they represent a screening-level exposure assessment that implies direct usage of the impoundment by wildlife. EPA recognizes that, although direct usage is possible, surface impoundments are not designed to provide habitat and it is highly unlikely that many receptors would rely on an impoundment exclusively to provide shelter, food sources, and other attributes of functioning habitats. Nevertheless, these results do measure the potential ecological impacts at a national level.

[8] Regionally unique species occurring in coastal areas of the southeastern United States (e.g., Florida manatee) and other species listed as threatened and endangered were not evaluated in the analysis. However, the precautionary nature of the screening factors, which are based on standards such as EPA ambient water quality criteria and no observed effects levels, implies some degree of protection for species already considered to be under stress.

[9] Risk exceedances are defined as the ratio of the chemical concentration in the medium of interest to the ecological screening factors for surface water, sludge, and soil, as appropriate.

Figure 3-2 presents the nationally weighted facility results correlated with potentially sensitive ecosystems such as wetlands and managed areas (e.g., national wildlife refuges, national forests). Approximately 25 percent of all facilities that show screening-level risk exceedances are located within 1 km of a permanently flooded wetland or 3 km of a managed area. Figure 3-2 illustrates the relative level of exceedances for lower concern (light shading) and potential concern (dark shading). At facilities identified as of potential concern, 19 percent are located within 1 km of a wetland and 7 percent are located within 3 km of a managed area. At facilities listed as lower concern, 19 percent are located within 1 km of a wetland and 14 percent are located within 3 km of a managed area. Slightly more than 3 percent of these facilities have both a wetland within 1 km and a managed area within 3 km.

3.5.2.1 Quantitative Risk Estimation for Ecological Risk Screening. Tables 3-24 and 3-25 summarize the ecological screening results. Because of the screening nature of the assessment and the precautionary exposure assumptions used, these results are associated with a high level of uncertainty. As shown in Table 3-24, 29 percent of facilities may pose potential concern for ecological receptors. Table 3-24 distinguishes the facilities according to whether they manage decharacterized wastes, and Table 3-25 distinguishes facilities according to their discharge status. Most of the facilities of potential concern manage never characteristic wastes and are direct dischargers. This is consistent with the fact that 80 percent of facilities manage never characteristic wastes and the vast majority of facilities are direct dischargers.

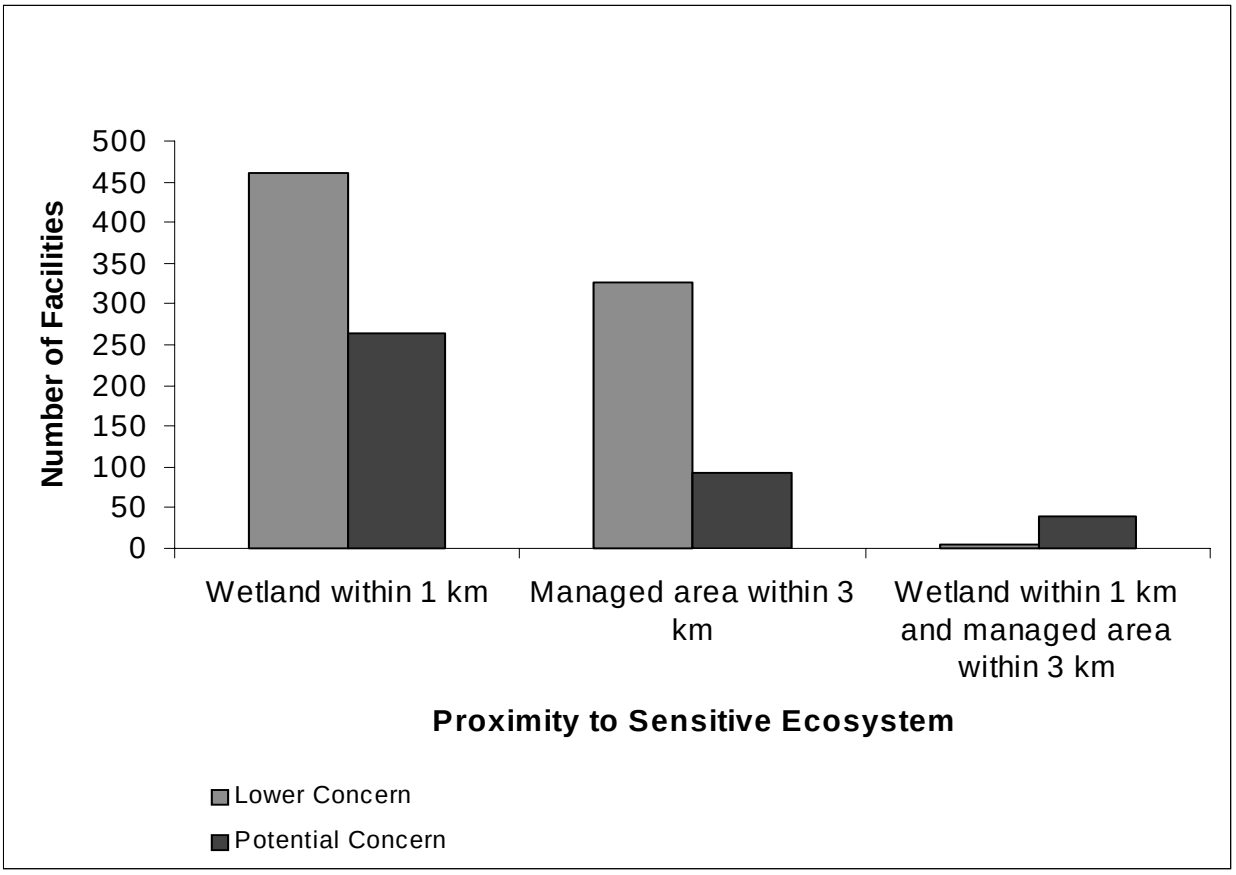


Figure 3-2. Summary of sensitive ecosystem analysis.

Table 3-24. Facility-Level Results for Ecological Risk by Decharacterization Status

Facility Status	Lower Concern[a]	Potential Concern[a]
Never characteristic	2,007 (45%)	1,037 (23%)
Decharacterized	352 (8%)	273 (6%)
All facilities	2,359 (53%)	1,310 (29%)

[a] Number of facilities (percentages are of the total number of facilities, approximately 4,500).

Table 3-25. Facility-Level Results for Ecological Risk by Discharge Status[a]

Facility Status	Lower Concern[a]	Potential Concern[a]
Direct dischargers	2,058 (46%)	1,072 (24%)
Zero dischargers	101 (2%)	160 (4%)
All facilities[b]	2,160 (48%)	1,232 (28%)

[a] Number of facilities (percentages are of the total number of facilities, approximately 4,500).
[b] The facility total for Table 3-25 does not equal the facility total for Table 3-24 because the patterns of missing data are different for each of the tables, and the weight adjustments for missing data lead to slightly different estimates.

3.5.3 Discussion of Uncertainties Associated with Screening Ecological Risk Analysis

The screening nature of the analysis leads to several major areas of uncertainty that affect interpretation of the results. These are grouped under parameter uncertainties, modeling uncertainties, and results uncertainties. Additional details on these uncertainties are presented in Appendix C to this report.

3.5.3.1 Parameter Uncertainties. The key parameters required for the ecological risk screening include the list of ecological receptors assigned to each facility, dietary assumptions, and ecological screening factors. As appropriate for screening-level analyses, the selection of parameter values tends to support a precautionary assessment.

- **Ecological Receptor Assignments.** Ecological receptors were assigned at each facility as a function of the land use patterns and presence of wetlands and/or fishable waterbodies. This adds to the protective nature of the screening assessment because not all facilities are located in areas of sufficient ecological quality to sustain those receptors.

- **Assumptions on Dietary Exposure.** Screening-level assessments typically assume exclusive intake of contaminated prey in the diets of primary and secondary consumers (i.e., 100 percent of the diet originates from the contaminated area), providing a very conservative estimate of potential risks.

- **Conservatism of Screening Factors.** Because the screening factors were generally based on benchmarks for very low levels of effect for sensitive endpoints, these factors tend to be precautionary of wildlife species and natural communities.

3.5.3.2 Modeling Uncertainties. The screening ecological risk assessment did not involve fate and transport modeling of chemical movement and uptake into plants and prey items. Consequently, this direct exposure approach is precautionary in the sense that it implies actual usage of the impoundment as habitat.

- **Spatial Scale of Exposure.** The screening level of resolution does not provide insight into the scope/size of ecological impacts. The size of the contaminated area is a critical determinant of the risk results because larger areas dilute chemical concentrations. Restricting the area to the impoundment tends to bias the results toward an overestimate of risk.

- **Temporal Scale of Exposure.** The timing is assumed to include the entire life stage of the wildlife species evaluated or, in the case of community-type receptors (e.g., soil biota), a period that is relevant to the structure and function of the community. The chronic, low-level exposure that this implies may be underprotective of some species during sensitive lifestages or of short-lived species.

- **Constant Chemical Concentration.** The chemical concentration was assumed to be constant for the screening analysis when, in reality, the chemical concentrations in plants, prey, and media will vary over time and space. A constant chemical concentration will tend to overpredict the potential risks to wildlife.

- **Chemical Behavior.** For screening purposes, all forms of a constituent are assumed to be equally bioavailable and toxic. This assumption may either overestimate or underestimate the actual exposures, depending on the environmental characteristics. For example, the form of arsenic (i.e., elemental, ionic, and methylated) has been shown to influence toxicity profoundly.

- **Single Chemical Exposures.** The risk of each constituent is considered separately in this analysis, and this may overlook possible synergistic effects. This is one example of a potential underestimation of adverse effects.

3.5.3.3 Results Uncertainties. As with any screening ecological risk assessment, there is considerable uncertainty in the risk results associated with simplifying assumptions and data limitations such as ecological benchmarks. Moreover, the screening analysis does not address

the potential significance of predicted ecological impacts. Although the ecological risk results indicate that the potential for adverse ecological effects exists at these facilities, it is not possible to quantify that potential within the broader context of ecological health and sustainability. Key uncertainties to consider in interpreting the risk results are as follows:

- **Concentration Data Source.** A portion of the risk findings are based on surrogate data and detection limits, rather than on reported concentrations, which contributes to the overall uncertainty in the results.

- **Data Gaps.** Protective ecological screening factors were developed for constituents when sufficient data were available, which, for this analysis, included 41 chemicals. The absence of benchmarks may lead to the underestimation of risks associated with stressors for those chemicals that could not be evaluated.

- **No Additional Stressors.** The only stressor assumed in the screening analysis is the introduction of chemicals into the environment. In the field, wildlife may be exposed to a variety of stressors (e.g., habitat alteration) and, therefore, the risk results may underestimate the potential for adverse effects.

- **Threatened/Endangered Species.** Only common species were evaluated in this analysis. The sensitivity of endangered species that are already under substantial stress is not accounted for explicitly. Although the selection of screening approach and parameters is inherently precautionary, it is possible that the results do not capture the risks to sensitive species and habitats.

3.6 Summary and Conclusions

This section summarizes several key findings of the risk assessment and highlights findings that address the statutory requirements for the scope of the study.

The assessment of potential risks posed by surface impoundments was based on a tiered approach designed to address comments from EPA's Science Advisory Board and external peer review comments on the technical plan. The first stage of this tiered approach was an initial screening based on precautionary exposure assumptions. Subsequent stages increased the level of realism through the use of increasing levels of facility-specific data, screening-level models, and site-based models. At each stage in the analysis, EPA was able to identify chemicals at particular surface impoundments and facilities that did not require further analysis. Given the design of the overall approach, which proceeds from precautionary exposure scenarios to realistic exposure scenarios, and based on the data available to EPA, the Agency has concluded that those constituents and impoundments do not pose significant risks to human health or the environment.

The risk estimates developed in this study for human health and the screening conducted for indirect exposures and ecological risks are based on an extensive analysis of the survey data reported for a wide array of chemicals and impoundments of potential concern. EPA acknowledges the uncertainties in the predicted risks and considers the following findings to be representative of the population of industrial surface impoundments managing wastewaters.

3.6.1 Summary of Major Risk Analysis Findings

- Most facilities and impoundments nationally do not appear to pose risks to human health through environmental releases. Two percent of impoundments and 5 percent of facilities show potential risk exceedances for at least one pathway, based on reported concentration data.

- Twenty-four percent of impoundments (21 percent of facilities) have the potential for environmental releases to occur from impoundments by at least one pathway, considering the chemical concentrations present in the impoundments and site-specific attributes such as the presence or absence of liners and proximity to surface water. These releases do not appear to pose risks to human health; however, some degradation of the environment is possible.

- For 23 percent of facilities and impoundments overall, EPA was not able to estimate potential risks with any confidence due to lack of chemical concentration data. This study portrays a range of possible findings, limited to the extent they are based on inferred data and detection limits, that may provide insights into potential risks or environmental releases for some portion of these facilities.

3.6.2 Findings by Pathway Based on Risk Analysis

- **Direct inhalation** risks can occur if a toxic chemical volatilizes from the impoundment's water surface, is carried by air dispersion to nearby residences, and then is inhaled by residents. EPA developed risk estimates for the closest residences, based on locations reported in the surveys or identified through census information, and generated national estimates of the proportion and number of facilities and impoundments exceeding levels of concern. Most facilities (87 percent) and impoundments (92 percent) appear to pose no concern. Four percent of facilities and three percent of impoundments do not pose risks, but do show releases that exceed levels of concern within 25 meters from impoundments. Four percent of facilities and one percent of impoundments are estimated to have a potential for risk exceedances to occur. Five percent of facilities and 4 percent of impoundments cannot be assessed with confidence due to incomplete reporting of concentration data. For those chemicals with reported concentration values, only chlorodibromomethane and alpha-hexachlorocyclohexane exceeded risk criteria and only acetaldehyde contributed to a calculated facility risk of potential concern.

- **Groundwater** ingestion risks can occur if impoundments release toxic chemicals through the bottom or sides of the impoundment and these chemicals enter groundwater and move through the subsurface to a drinking water well. EPA developed risk estimates that could occur at the closest drinking water wells reported in the surveys. If survey data were not available, EPA used census information and assigned the receptor well to the nearest residence identified with a census block that reports drinking water well usage. The majority of facilities and impoundments appear to pose no concerns. A very small percentage of

facilities and impoundments have the potential for risk exceedances to occur at the time the impacted groundwater reaches the closest well. Fourteen percent of facilities and eleven percent of impoundments do not appear to pose risks but are predicted to generate groundwater releases that will exceed levels of concern at or beyond 150 meters of the unit boundary. About 19 percent of facilities and 22 percent of impoundments cannot be assessed with confidence due to the lack of concentration data.

- **Groundwater to surface water** risks can occur if impoundments release toxic chemicals through the bottom or sides of the impoundment and these chemicals migrate through groundwater, discharge into nearby surface water, and contaminate fish and drinking water supplies. EPA identified exceedances of human health ambient water quality that could occur to surface waterbodies that were reported in the surveys and generated national estimates. Fifty-six percent of facilities do not appear to pose concerns by this pathway. About 18 percent of facilities may produce contaminated groundwater concentrations that exceed the HH-AWQC at the point of entry into the surface waterbody. One percent of facilities may contribute to exceedances of EPA's HH-AWQC by this pathway. About 25 percent of facilities could not be assessed with confidence because of the lack of concentration data.

3.6.3 Findings Based on Risk Screening

EPA also screened for potential risks to human health through other indirect pathways and screened for potential risks to ecological receptors.

- **Indirect pathway** risks can occur when humans ingest food sources that have been contaminated indirectly by surface impoundment releases. For example, toxic chemicals can evaporate, move by dispersion through air, and then deposit on nearby crops and contaminate food sources. Another example may occur when impoundments close with sludge left in place; chemicals present in those sludges can move with stormwater, or by erosion, onto nearby soil and crops or can be dispersed as dust. Based on a screening analysis and precautionary assumptions, an estimated 6 percent of facilities nationally may pose the greatest potential concern through indirect pathways.

- **Ecological** risks are possible for flora and fauna in natural systems located near impoundments. Many impoundments are located near rivers and waterbodies and are freely accessible to wildlife. The objective of the ecological screening was to characterize the national potential for adverse ecological effects associated with the management of chemicals in impoundments considered within the scope of this study. Although the screening methods imply that the impoundment is used directly as habitat, the intent of the screen is to characterize the potential for adverse ecological effects at the site, not simply from direct use of the impoundment. The measure of this potential was based on ecotoxicological endpoints relevant to the sustainability of wildlife populations (e.g., reproductive

effects) and the structure and function of communities (e.g., growth and survival of key species). Based only on this initial screening level analysis and using precautionary assumptions, no more than 29 percent of facilities nationally may pose potential concerns to ecological receptors that live near, or make direct use of, surface impoundments.

3.6.4 Additional Findings of Interest

EPA examined potential risks for decharacterized wastes separately from never characteristic wastes and also examined potential risks depending on discharge status. This was to address the statutory intent in the 1996 Land Disposal Program Flexibility Act that the study assess decharacterized wastewaters managed in surface impoundments subject to the Clean Water Act.

- The results suggest that impoundments managing decharacterized waste may be associated with higher risks than those managing never characteristic waste for two pathways of concern. For one pathway, direct inhalation, the trend is reversed, with never characteristic waste representing two-thirds of the overall risk. This is largely because most impoundments (about 80 percent) manage never characteristic wastes. However, for all pathways, including direct inhalation, the rates of risk exceedances for decharacterized wastes were higher than for never characterized wastes.

- The bulk of facilities are direct dischargers; consequently, most of the potential risk exceedances and environmental releases are associated with direct dischargers. For the groundwater to surface water pathway, the rates of potential HH-AWQC exceedances are much higher for zero dischargers even though the national numbers in that group are relatively small.

Reference

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Chapter 4

Regulatory/Program Coverage and Gaps Analysis

4.0 Introduction and Background

This chapter presents EPA's regulatory/program coverage and gaps analysis in support of the Surface Impoundment Study. The regulatory/program coverage and gaps analysis was conducted to satisfy provisions of (1) the Land Disposal Program Flexibility Act of 1996 and (2) a consent decree in the matter of *EDF v. Whitman*. The methodology and regulatory coverage findings are summarized under the following sections:

4.1 Regulatory/Program Analysis Methodology

4.2 Coverage and Potential Gaps in Existing Programs and Regulations Addressing Air Risks

4.3 Coverage and Potential Gaps in Existing Programs and Regulations Addressing Nonair Risks

4.4 The Role of EPA's Multimedia Strategy for PBT Pollutants in Reducing Risks from Surface Impoundments.

4.1 Regulatory/Program Analysis Methodology

The general approach for conducting the regulatory coverage and gaps analysis for this study required a detailed review of provisions in applicable federal and state programs that address surface impoundments, an evaluation of the extent to which the constituents of concern are specifically addressed by such programs, and the extent to which the industry categories covered by this study are addressed by the programs. The regulatory coverage and gaps were identified and evaluated based on potential risks found by the human health and ecological risk screening analyses, as described in Chapter 3. The regulatory gaps analysis addresses coverage for each of the two human direct exposure pathways of concern (i.e., air and groundwater), indirect pathways including groundwater releases to surface water, and other indirect pathways. The information reflects risk results with varying levels of certainty. The level of certainty depends, in part, on the extent to which the results were based on (1) reported concentration values, and (2) surrogate data (including detection limit values). Regulatory gaps identified based on this information thus carry the same level of varying certainty.

4.1.1 Approach for Conducting Regulatory/Program Coverage and Gaps Analysis for Air Risks

To evaluate regulatory coverage and potential gaps in regulations addressing air releases from surface impoundments, EPA identified existing federal and state programs that potentially address such releases. Federal programs evaluated included RCRA hazardous and nonhazardous waste programs and the Clean Air Act. The specific activities and related analyses are summarized below. The detailed analysis is presented in Section 4.2.

Existing RCRA Regulations/Programs That Can Address Air Risks from Non-Hazardous Surface Impoundments. EPA evaluated existing RCRA regulations and programs that address air emissions from nonhazardous waste surface impoundments. RCRA programs (both federal and state) are included in this part of the analysis primarily to address the requirement of the LDPFA to evaluate the extent to which existing federal and state programs address risks posed by decharacterized wastes in surface impoundments. The coverage analysis also applies to never characteristic wastes managed in surface impoundments, thereby providing additional information to support EPA's obligations under the EDF consent decree. Programs evaluated were:

- RCRA Subtitle C corrective action program (and the authority under RCRA section 3005) to address air risks from nonhazardous surface impoundments located at RCRA interim status and permitted facilities,
- RCRA Subtitle D (nonhazardous) waste regulations and state programs that address air emissions from nonhazardous waste surface impoundments,
- EPA's draft *Guide for Industrial Waste Management* (U.S. EPA, 1999a),
- Toxicity characteristic (TC) (to assess whether the management of impoundment wastewaters not classified as hazardous by the TC could still result in environmental air releases), and
- Other nonregulatory programs including the use of Supplemental Environmental Projects (SEPs) and EPA's Multimedia Strategy for Persistent, Bioaccumulative, and Toxic Pollutants.

Existing RCRA Subtitle C Hazardous Waste Regulations and Programs That Address Air Emissions from Hazardous Waste Surface Impoundments. Even though the focus of the surface impoundment study is on nonhazardous wastes, hazardous waste requirements were included in this part of the analysis to address the extent to which regulations can address air risks from wastes in impoundments if these wastes were newly characterized or listed as hazardous wastes. If a waste were classified as hazardous, then it would be subject to current Subtitle C requirements.

The following provisions within the Subtitle C program were evaluated to determine the extent to which these programs can address potential air risks: requirements for hazardous waste

management units (e.g., Subpart K, Surface Impoundments), RCRA air emission control standards (e.g., Subpart CC—Air Emission Standards for Tanks, Surface Impoundments, and Containers), land disposal restrictions, the omnibus permitting authority under RCRA section 3005(c)(3), and the RCRA corrective action program.

This discussion assumes these wastes will continue to be managed in surface impoundments even if they became subject to the Subtitle C requirements. It is perhaps more realistic to assume that these wastes would be managed in tanks if they became subject to the Subtitle C requirements (such that the LDR requirements would not apply). The tank management scenario was evaluated as part of EPA's Air Characteristics Study (U.S. EPA, 1998, 1999b).

Existing Clean Air Act Programs. The primary focus of the air pathway analysis was the CAA requirements. Identifying potential gaps in current CAA regulations was required to fulfill one of the obligations in the EDF consent decree. The analysis also provided information needed to satisfy the requirements of the LDPFA. The analysis involved three interrelated elements: (1) a waste management unit analysis to identify provisions within the CAA that can address surface impoundments, (2) a constituent coverage analysis that focused on the constituents of concern from the risk assessment, and (3) an industry coverage analysis that focused on the industry categories within the scope of this study.

The outputs of the waste management unit, constituent, and industry analyses were integrated with the findings of the risk assessment to identify those constituents and industry categories for which regulations or programs may not adequately address potential risks.

4.1.2 Approach for Conducting Regulatory Program Coverage and Gaps Analysis for Nonair Risks Found from Managing Nonhazardous Waste in Surface Impoundments

In addition to examining potential air risks, EPA investigated risks to other media as well. In this portion of the analysis, EPA assessed program coverage of (1) risks resulting from consumption of groundwater containing constituents released from surface impoundments, (2) risks resulting from the contamination of surface water (from the groundwater pathway), (3) risks posed via other indirect pathways (e.g., erosion runoff and deposition), and (4) ecological risks, collectively identified as "nonair risks." EPA evaluated the extent to which these predicted risks are adequately addressed under existing federal and state programs.

4.1.2.1 Approach for Conducting Regulatory/Program Coverage and Gaps Analysis for Groundwater and Surface Water Risks Found from Managing Nonhazardous Waste in Surface Impoundments

. Leachate from a nonhazardous waste surface impoundment can potentially migrate through the subsurface and affect groundwater and surface water quality. Therefore, it was necessary to identify existing regulations and programs that address the release of constituents from nonhazardous waste surface impoundments to groundwater and surface water.

The general approach for identifying regulatory coverage by federal and state programs comprises four general steps:

1. Use the risk analysis results to identify constituents posing potential risks to groundwater.

2. Identify federal regulations and programs that address releases to groundwater from nonhazardous waste surface impoundments.

3. Identify state regulations and programs that address releases to groundwater from nonhazardous waste surface impoundments.

4. Determine if gap exists.

4.1.2.2 Approach for Conducting Regulatory Program Coverage and Gaps Analysis for Risks Associated with Other Indirect Pathways. As discussed in Chapter 3, EPA evaluated potential risk scenarios from indirect pathways, including air deposition to surrounding crops and exposures resulting from runoff and erosion of contaminated sludge particles onto local farms and gardens. Runoff and erosion of contaminated sludge was assumed to occur after closure; therefore, EPA evaluated regulations and programs addressing industrial runoff, corrective action, and postclosure care. EPA did not evaluate regulatory coverage of indirect risk posed by air deposition separately; it is included in the air pathway coverage analysis.

4.1.2.3 Approach for Conducting Regulatory Program Coverage and Gaps Analysis for Ecological Risks. The approach for evaluating regulatory coverage and gaps for any ecological risks focused on reviewing regulations, programs, and guidance on location standards for new units and other provisions in federal and state programs designed to protect endangered and threatened species and habitats.

4.2 Coverage and Potential Gaps in Existing Programs and Regulations Addressing Air Risks

The intent of this chapter is to identify existing programs/regulations that are used to address risks from surface impoundments and to identify possible gaps in them based on the results of the risk assessment. If EPA determines these gaps must be addressed, then the Agency may either: (1) use existing programs as tools to address the gaps or (2) propose changes to existing regulations or propose new regulations to address the gaps, such as new LDR requirements, a new hazardous waste characteristic, a new hazardous waste listing, or perhaps investigate the protectiveness of some of the hazardous waste exclusions/exemptions.

One of the primary objectives of the surface impoundment study was to investigate gaps in the current hazardous waste characteristics and CAA programs for air risks associated with managing never characteristic wastes in surface impoundments. A related objective was to address the requirements of section 3004(g)(10) of RCRA, as amended by the LDPFA, which required EPA to evaluate the extent to which risks posed from decharacterized wastes in surface impoundments are adequately addressed under existing state and federal programs. This part of the study, which in part fulfills EPA's obligation under both the EDF consent decree and the LDPFA, describes the Agency's analysis of coverage by regulations that address air risks posed by wastes managed in surface impoundments.

The regulatory coverage and gaps analysis for the air pathway addresses relevant RCRA, CAA, and state regulations and programs; however, emphasis is placed on those constituents that did not screen out of the study upon completion of the risk assessment for the air pathway. The direct inhalation risk assessment determined that air emissions from surface impoundments can, in some cases, potentially exceed the specified risk threshold. Specifically, the risk assessment identified the possibility of risks associated with 13 chemicals. Refer to Chapter 3 for more detailed information on the risk assessment findings.

4.2.1 Existing RCRA Rules and Programs That Address Air Risks

Existing RCRA Subtitle C and Subtitle D programs include various provisions that, when implemented, can limit air emissions from nonhazardous waste surface impoundments. This section includes the following:

- An analysis of the ability of the RCRA Subtitle C corrective action program (and the authority under RCRA section 3005) to address air risks from nonhazardous surface impoundments located at RCRA interim status and permitted facilities (Section 4.2.1.1).

- An analysis of Subtitle D (nonhazardous) RCRA waste regulations and state programs that address air emissions from nonhazardous waste surface impoundments (Section 4.2.1.2).

- An analysis of coverage by EPA's draft *Guide for Industrial Waste Management* (Section 4.2.1.3).

- An analysis of the TC regulatory levels to determine if the management of impoundment wastewaters not classified as hazardous by the TC (e.g., decharacterized wastewaters or wastewaters that have never been hazardous waste) could still result in environmental air releases (Section 4.2.1.4).

- A description of EPA's enforcement program for SEPs and how it may be used to address risks posed by nonhazardous waste surface impoundments. Note that the use of SEPs is discretionary, and their potential application for addressing risks posed by surface impoundments would be determined on a case-specific basis (Section 4.2.1.5).

Finally, EPA's Multimedia Strategy for Persistent, Bioaccumulative, and Toxic (PBT) Pollutants (PBT Strategy) has the goal of reducing risks to human health and the environment from current and future exposure to priority PBT pollutants. See Section 4.4 for an evaluation of how the PBT initiative may affect constituents that may be found in surface impoundments.

4.2.1.1 RCRA Corrective Action Program, Permitting Authority under RCRA 3005, and RCRA 7003. Facilities that treat, store, or dispose of hazardous waste (TSDFs) must apply for a RCRA Subtitle C permit. Under RCRA 3004(u), RCRA permits must require corrective action for releases of hazardous waste or constituents from any solid waste management units

(SWMUs) as necessary to protect human health and the environment. TSDFs that have not yet received permits and have been authorized to operate under interim status may be compelled to conduct corrective action under section 3008(h). Under the RCRA corrective action program, a surface impoundment containing nonhazardous waste located at a TSDF is considered an SWMU. Therefore, releases from these impoundments, including air emissions, are subject to corrective action requirements on a site-specific basis.[1] EPA can incorporate specific corrective action requirements into the permit during the permitting process or when a permit is already in place. Corrective action requirements could include interim measures (e.g., use of a temporary cover), institutional controls (such as deed restrictions or access controls), and application of remediation technologies designed to contain, remove, and/or destroy contamination.

The survey indicates that about 33 percent of the surface impoundments nationwide that fall within the scope of this study have been designated as SWMUs pursuant to the RCRA corrective action RCRA Facility Assessment (RFA) process (see also Chapter 2, Section 2.5, for additional information on the permit and corrective action status of impoundments within the scope of this study). This indicates that a significant number of nonhazardous surface impoundments are located at RCRA TSD facilities; these impoundments are being addressed by EPA and the states on a priority basis, and thus no regulatory gaps should exist for these impoundments.

RCRA contains various additional permitting requirements for facilities. The omnibus permitting authority at RCRA section 3005(c)(3) requires EPA to include in permits any requirements necessary to protect human health and the environment. For impoundments containing nonhazardous waste, permit writers may use their omnibus permitting authority under RCRA 3005(c)(3) to impose additional standards to achieve the health-based requirements of RCRA 3004(n).

RCRA section 3005(h) mandates, as a permit condition, that TSDFs that are also generators must have a program in place to reduce the volume and toxicity of the waste they generate. These waste minimization requirements, to the extent they are used to minimize concentrations of constituents of concern that might be released to the air pathway, provide some potential for control of air emissions.

Note that the imminent and substantial endangerment provision of RCRA section 7003 allows EPA, upon evidence of past or present handling of solid or hazardous waste, to require any action necessary if a situation presents an imminent and substantial endangerment to health or the environment. This authority applies to all facilities that manage solid waste, whether or not they have a RCRA permit, and could be used at any impoundment that is within the scope of this study if the situation meets the statutory threshold.

4.2.1.2 Coverage by State Waste Programs. Historically, regulation of nonhazardous waste has been provided by the states; however, state nonhazardous waste regulations typically

[1] See also EPA's policy on integrating RCRA corrective action with requirements imposed in permits issued pursuant to other environmental laws at 55 FR 30798, 30808 (July 27, 1990), and 61 FR 19423, 19442 (May 1, 1996).

do not include provisions that address inhalation risks from nonhazardous waste surface impoundments. Previous studies summarizing state nonhazardous waste regulations, including ASTSWMO (1996), ICF (1993), and U.S. EPA (1995a, 1995b), provide limited information on programs for controlling air emissions from industrial nonhazardous waste surface impoundments.

EPA's own analysis for this study indicates that, of the 50 states, only six have waste regulations or other waste programs in place that address, to some degree, air emissions from industrial nonhazardous waste surface impoundments. These states are California, Colorado, Delaware, Louisiana, Maryland, and Pennsylvania (see also Appendix D, Section D-1, Summary of State Regulations and Programs Covering Nonhazardous Industrial Waste Surface Impoundments). The type of regulatory coverage varies considerably among these states. For example, some states require monitoring and reporting of emissions and some require permits. Another state regulates both fugitive dust and gas emissions. Note that this program coverage discussion applies to waste programs (i.e., RCRA) and not air programs. State air regulations should provide more extensive coverage for air releases from surface impoundments.

Note that EPA's analysis of state waste regulations and programs in Appendix D is based on publicly available information rather than a survey of state regulators. EPA did not review state air programs. Therefore, the analysis may not have identified all state regulations and programs that address nonhazardous waste industrial surface impoundments. Furthermore, the state regulatory coverage may change in the future.

Federal regulations for solid waste disposal facilities (including nonhazardous waste surface impoundments) are given in 40 CFR Part 257, Criteria for Classification of Solid Waste Disposal Facilities and Practices. Regulations that specifically address potential impacts to air are identified in 40 CFR 257.3-7. However, the Part 257 applicability to air emissions from surface impoundments of this study is limited to restrictions on open burning and referencing applicable State Implementation Plan (SIP) requirements (see Part 257.3-7(a) and (b)). The regulatory coverage of the Part 257 requirements does not provide additional restrictions beyond those provided by the SIPs. Due to the complexity and potential for change, as noted above, SIPs were not evaluated as part of this study.

4.2.1.3 Coverage by EPA's Draft Guide for Industrial Waste Management. In 1999, EPA's Office of Solid Waste, in collaboration with states, industry, and environmental groups, published the draft *Guide for Industrial Waste Management* (U.S. EPA, 1999a). The document, which is voluntary and commonly referred to as the "Industrial D Guidance," evaluates all aspects of the design and operation of industrial waste management facilities to enable these facilities to protect human health and the environment. It is designed primarily for new units and can be used by state regulatory programs to evaluate their existing programs. The approach taken in the guide is site-specific to help communities and facility managers identify a protective facility site, design, and operation that fits their needs.

The draft guide recommends a three-part strategy for addressing potential air risks from waste management units (including surface impoundments). First, the guide helps the user determine whether the waste management unit(s) is already subject to requirements under the

Clean Air Act. Second, the guide provides a tool (the IWAIR model software) to assess risks associated with toxic air emissions. Third, the guide suggests the user implement pollution prevention, treatment, or controls to reduce risks, if appropriate. For the protection of air, 95 constituents are addressed in the draft guide.

The extent to which risk assessment constituents of concern are addressed by this guide is discussed in Section 4.2.3.2.

4.2.1.4 Toxicity Characteristic Regulatory Levels. Under RCRA regulations, a solid waste is defined as a hazardous waste if it either is listed as a hazardous waste or exhibits one of the four characteristics of a hazardous waste (i.e., toxicity, ignitability, corrosivity, or reactivity). Wastes are listed as hazardous based on the criteria set forth in 40 CFR 261.11. Once listed, the waste is presumed hazardous regardless of the concentration of hazardous constituents present (unless the generator has successfully petitioned EPA to delist the waste) and must be managed in accordance with Subtitle C standards. In contrast to hazardous waste listings, the toxicity characteristic provides concentration-based regulatory thresholds used to identify wastes that present significant hazard and therefore should be managed under Subtitle C. The regulations defining the other three characteristics (ignitability, corrosivity, and reactivity) do not generally address specific constituents and are not addressed in this analysis.

The TC was designed to protect against human health risks from exposure to hazardous waste constituents released to groundwater. EPA's current definition of toxicity was promulgated in 1990, replacing the Extraction Procedure (EP) leach test with the Toxicity Characteristic Leaching Procedure (TCLP). The final TC rule added 25 organic chemicals to the eight metals and six pesticides on the existing list and established regulatory levels for these constituents. All 39 TC constituents (40 including total cresols) are also on the list of 256 constituents of interest for this study.

Wastewaters with TC constituent concentrations meeting or exceeding the TC regulatory levels would be hazardous, subject to the protective measures required under RCRA Subtitle C regulations (unless exempted or excluded from regulation), and thus are not within the scope of this study. To determine if wastewater concentrations at or below TC levels could still result in environmental releases to the air pathway, a direct comparison was made between the milligram/liter TC levels in the regulations (40 CFR 261.24) and waste concentrations in surface impoundments predicted to cause environmental air releases. For purposes of this analysis, environmental air releases are defined as air releases from surface impoundments that result in predicted risks as indicated by the screening-level Industrial D risk model for receptors at a default distance of 25 meters rather than site-specific distances to receptors. This comparison is presented in Appendix D, Section D-2.

The wastewater concentrations (presented as ranges in Appendix D) are divided into three categories: concentrations with predicted inhalation risks less than the risk criteria, concentrations with predicted risks in the range of 10E-5 to 10E-4 or HI of 1 to 10, and concentrations with predicted risks greater than 10E-4 or HI greater than 10. It is appropriate to report a range of concentration values because risk results for a given constituent varied

significantly due to factors such as the concentration of the constituent in the wastewater, the size of the impoundment, where it is located, and whether it is aerated.

The comparison indicates that concentrations of 10 TC constituents in surface impoundment wastewater may result in environmental air releases at concentrations less than their respective TC regulatory levels. As mentioned above, this conclusion is based on the use of a screening-level risk model employing conservative assumptions (i.e., chronic exposure at 25 meters). The 10 constituents include nine volatile organics plus mercury. For the remaining nine volatiles on the TC list, there were no concentration data that yielded predicted environmental releases. This does not mean, however, that the TC regulatory levels for these constituents prevent environmental air releases (we did not evaluate whether environmental air releases would occur if concentrations of these constituents increased). The remaining 21 non-volatiles on the TC list are constituents that would not likely cause environmental air releases, and risk estimates were not conducted for these constituents.

The TC constituents that show the potential for environmental air releases in Appendix D-2 reflect risk results with varying levels of certainty. The level of certainty depends, in part, on the extent to which the results were based on (1) reported concentration values and (2) surrogate data (including detection limit values). For this analysis, we did not determine the extent to which predicted environmental air releases were based on reported or surrogate data.

4.2.1.5 Use of Supplemental Environmental Projects to Address Risk from Surface Impoundments. If EPA or a state believes that an individual or company has failed to comply with federal environmental laws, it may initiate an enforcement action. Enforcement actions are taken to require an individual or company to return to compliance and deter others from violating these laws. Enforcement settlements may also include Supplemental Environmental Projects (U.S. EPA, 2001). EPA's SEP Policy encourages the use of environmentally beneficial projects as part of the settlement of an enforcement action. Through SEPs, the settlement of an enforcement action can result in environmental and public health protections beyond that specifically required by law. There must be some connection between the SEP and the kinds of concerns addressed by the statute or statutes that were violated (EPA SEP Policy, May 1, 1998). The SEP Policy provides criteria to guide when and how SEPs may be included as part of a settlement. SEPs may not be appropriate in the settlement of all cases, but they are an important part of EPA's enforcement program.

SEPs are actions taken by an individual or company that are in addition to what is required to return to compliance with environmental laws. A SEP is an environmentally beneficial project that a violator voluntarily agrees to perform. When volunteering to perform a SEP, a company must show that it can and will complete the project and must provide all funds used to finance the project. EPA provides oversight to ensure that the company does what it promises to do. EPA, however, does not manage or control the funds.

EPA has seven specific categories of projects that can be acceptable SEPs. These include Pollution Prevention, Pollution Reduction, Public Health, Environmental Restoration and Protection, Assessments and Audits, Environmental Compliance Promotion, and Emergency

Planning and Preparedness. Other acceptable SEPs would be those that have environmental merit but do not fit within the categories above (U.S. EPA, 2000b).

In the context of a nonhazardous waste surface impoundment, a violation of existing regulations affecting a facility could result in an enforcement action and then, as a condition of the settlement, EPA and the defendant could agree upon a SEP that is related to reducing the risks posed by a surface impoundment at the facility. A SEP related to a surface impoundment could include closure, installation of a liner, or implementation of some other measure that would eliminate or reduce risk to the environment and/or public health.

4.2.2 Extent to Which Current RCRA Subtitle C Regulations Address Risks from Wastes Newly Classified as Hazardous

Subtitle C of RCRA established management practices to safely control hazardous wastes from the point of generation to final disposal. If a waste stream that is within the scope of this study was newly classified as hazardous based on a new characteristic or listing, then it would be subject to current Subtitle C requirements for hazardous waste surface impoundments (assuming the waste stream continued to be managed in a surface impoundment). Therefore, the RCRA hazardous waste regulations relevant to the regulatory analysis include those that limit air emissions from surface impoundments. Several RCRA Subtitle C regulations and RCRA statutory provisions have this effect, including

- Requirements for hazardous waste management units (e.g., Subpart K—Surface Impoundments)
- RCRA air emission control standards (e.g., Subpart CC—Air Emission Standards for Tanks, Surface Impoundments, and Containers)
- Land disposal restrictions
- Omnibus permitting authority under RCRA section 3005(c)(3)
- RCRA corrective action program.

These regulations and provisions are discussed in Sections 4.2.2.1 through 4.2.2.5.

4.2.2.1 Subpart K—Surface Impoundments. RCRA standards for hazardous waste TSDFs include specific requirements for surface impoundments. Because a new characteristic or listing could subject additional wastes to RCRA Subtitle C standards, it would also subject surface impoundments managing the waste to Subtitle C standards and permitting as well, if such units do not currently manage hazardous wastes (and the wastes are continued to be managed in the impoundments). Thus, affected surface impoundments would be subject to the requirements at 40 CFR Parts 264 and 265, Subpart K. These requirements include the use of double liners, leachate collection, leak detection, inspection, waste analysis, financial responsibility, closure, and postclosure. In addition, there are special requirements restricting the placement of ignitable and reactive wastes in surface impoundments. To control air emissions, Subpart K requires the

owner or operator to manage all hazardous waste placed in a surface impoundment in accordance with the requirements of Subparts CC—Air Emission Standards for Tanks, Surface Impoundments, and Containers.

4.2.2.2 Subpart CC—Air Emission Standards for Tanks, Surface Impoundments, and Containers. Section 3004(n) of RCRA authorizes EPA to regulate air emissions from hazardous waste TSDFs. Under this authority, EPA issued air emission standards under 40 CFR Part 264 and 265, Subpart CC—Air Emission Standards for Tanks, Surface Impoundments, and Containers. Subpart CC applies to tanks, surface impoundments, containers, and certain miscellaneous units that

- Are not expressly exempted from the rule.
- Are subject to permit standards (40 CFR 264) or interim status standards (40 CFR 265)
- Manage hazardous wastes that have an average volatile organic concentration at the point of waste origination equal to or greater than 500 parts per million by weight (ppmw).

These requirements do not apply to surface impoundments in which all the hazardous waste entering the surface impoundment meets one of the following (40 CFR 264.1082(c) and 265.1083(c)):

- The average volatile organic concentration of the hazardous waste at the point of waste origination is less than 500 ppmw (as noted above)
- The organic content of the hazardous waste has been reduced by an organic destruction or removal process. For example, organic destruction can be achieved by waste incineration or biodegradation. Organic removal must achieve the treatment level specified for the process.
- The waste meets the treatment standards for hazardous waste as specified in 40 CFR 268.40 or has been treated by the treatment technology established by EPA for the waste in 268.42(a) or by an equivalent method.

To control air emissions from a surface impoundment managing a hazardous waste with a volatile organic concentration greater than 500 ppmw, an owner or operator must install and operate either a floating membrane cover or a cover that is vented through a closed-vent system to a control device. The floating membrane cover must meet certain design and inspection requirements including use of materials that meet standards for organic permeability and compatibility with the waste, weather conditions, and operating conditions. The facility must also perform periodic (once per year) inspections for membrane defects.

The technical requirements for the RCRA air rules in Subpart CC as amended are essentially the same as those adopted by EPA under the MACT program (e.g., requirements in

Subparts OO, PP, and QQ of Part 63). A unit controlled under one or the other set of requirements would achieve the same emission reduction and performance level; the various requirements thus provide the same level of protection (61 FR 59939, November 25, 1996).

Due to the exclusion for wastes below the 500-ppmw threshold for volatile organic content, any wastes subject to the Subpart CC requirements that potentially pose air risks at concentrations less than 500 ppmw might not be controlled by the Subpart CC air emission standards for surface impoundments.

4.2.2.3 Land Disposal Restrictions Treatment Requirements. RCRA LDRs limit the placement of untreated hazardous waste in all land-based waste management units, including landfills, wastepiles, land application units, and surface impoundments. Under 40 CFR 268.1, characteristic wastes may not be land disposed unless (1) the wastes are treated in a Clean Water Act or equivalent treatment system, and (2) the wastes no longer exhibit the characteristic at the point of land disposal. Listed waste must meet treatment standards defined in 40 CFR Part 268, Subpart D, prior to land disposal.

Note that RCRA section 3005(j)(11) and 40 CFR Part 268.4 (which implements that provision) provide an exclusion allowing treatment of otherwise prohibited wastes (i.e., listed or characteristic hazardous wastes that do not meet the otherwise applicable treatment standard) in surface impoundments provided that treatment occurs in the impoundment, the treated residues are removed at least annually, sampling and testing and recordkeeping requirements are met, and evaporation of hazardous constituents is not used as a means of treatment. Because the LDR treatment requirements would not apply to these wastes, the LDR treatment requirements would not mitigate risks to the air pathway. Nonetheless, such surface impoundments must meet the Subpart K and Subpart CC design and operating requirements for hazardous waste surface impoundments.

The LDR treatment standards—when they apply—are based on the performance of best demonstrated available technology (BDAT) and are deemed sufficient to minimize threats to human health and the environment posed by land disposal of the waste. In fact, the standards for most organics reflect the performance of combustion technology, which destroys organics to nondetectable levels, so that the treatment standard is actually the analytical detection limit for the organic chemical times a factor that reflects technological variability. Consequently, EPA has found that units receiving wastes that satisfy these standards for organics need not be controlled further, since the organics in the wastes are already reduced to levels at which threats posed by release of the organics have been minimized (see 61 FR 59941, November 25, 1996).

4.2.2.4 EPA's Permitting Authority under RCRA 3005. If a waste is newly subject to Subtitle C, then EPA's permitting authority under RCRA 3005 is another statutory control that could be used to address air risks posed by surface impoundments. See Section 4.2.1.1 for a detailed explanation of EPA's omnibus permitting authority at RCRA section 3005(c)(3).

4.2.2.5 RCRA Corrective Action Program. If a waste is newly subject to Subtitle C, then EPA's corrective action authority is another control that could be used to address air risks posed by surface impoundments. See Section 4.2.1.1 for a detailed explanation of EPA's corrective

action authority under RCRA section 3004(u) for permitted facilities and under section 3008(h) for interim status facilities.

4.2.3 Analysis of Coverage and Potential Gaps in CAA Requirements

This section focuses on relevant federal programs under the Clean Air Act to determine the extent of coverage of air emissions from surface impoundments. This analysis was conducted in four steps. First, a general analysis of relevant CAA programs was conducted (Section 4.2.3.1). Second, an evaluation of the risk assessment constituents of concern was conducted to determine the extent to which they are covered by existing programs (Section 4.2.3.2). The third part of the analysis focused on the CAA NESHAP program since it was identified as the primary program to address air releases from industrial surface impoundments (Section 4.2.3.3). This section provides a list of NESHAP requirements that may apply to surface impoundments and industry sectors that are within the scope of this study. The fourth part of the analysis focuses on the Criteria Air Pollutant Program, which may, to a lesser extent, also address air releases from surface impoundments (Section 4.2.3.4).

4.2.3.1 Overview of Relevant Clean Air Act Programs. The 1990 Amendments to the CAA substantially enhanced existing air quality programs. These enhancements include new attainment provisions for National Ambient Air Quality Standards (NAAQS) and substantial changes to the NESHAP program including control of HAPs using MACT standards. These programs can, to varying degrees, address air emissions from industrial surface impoundments.

Most of the CAA programs regulate significant sources of air pollution; these sources are defined as major sources of air pollution. A major source generally includes all of the individual emission points within a plant complex or facility; emissions from the source would be the sum of emissions from all the individual emission points. Typical sources include petroleum refineries, power plants, and manufacturing facilities. Whether a source meets the definition of major depends on the type and amount of air pollutants it emits.[2]

The following subsections summarize the relevant CAA programs that address air emissions from industrial surface impoundments.

Regulation of Hazardous Air Pollutants

Air Toxics Program. Prior to the 1990 CAA amendments, a few HAPs were regulated using risk-based standards under the NESHAP program. These NESHAPs appear at 40 CFR Part 61. Section 112 of the 1990 amendments to the CAA authorized EPA to set technology-based standards to reduce HAP emissions. While both the risk-based standards (i.e., those enacted prior to 1990) and the technology-based standards (i.e., those enacted after 1990) are all considered NESHAPs, the risk-based standards are generally referred to as original NESHAPs and the technology-based standards are referred to as MACT standards.

[2] As discussed later, the definition of major source differs for the NESHAP and Criteria Air Pollutant Program.

The following is a brief overview of the pertinent subsections of section 112 applicable to this study:

- List of Hazardous Air Pollutants
- MACT Emissions Standards
- Residual Risk Program
- Area Source Standards
- Urban Air Toxics Program.

List of Hazardous Air Pollutants. Section 112(b)(1) established the list of HAPs to which the air toxics program applies. Currently EPA is required to regulate 188 HAPs.[3] While broad in nature, the statutory list may be modified by adding or deleting pollutants. The CAA also allows outside parties to request an addition or deletion to the list of HAPs. EPA may, after notice and comment, add or delete a pollutant. Section 112(b)(3)(B) lists the following criteria for adding a pollutant to the list:

> ...determination that the substance is an air pollutant and that emissions, ambient concentrations, bioaccumulation or deposition of the substance are known to cause or may reasonably be anticipated to cause adverse effects to human health or adverse environmental effects.

MACT Standards. The technology-based MACT program and the related residual risk program are key elements of the CAA air toxics provisions. Under section 112, EPA is required to list all categories of major sources emitting HAPs and such area sources warranting regulation and to promulgate MACT standards to control, reduce, or otherwise limit the emissions of HAPs from these categories. To the extent possible, this list of source categories is consistent with the list of source categories listed pursuant to New Source Performance Standard (NSPS) requirements. EPA has identified 83 source categories requiring MACT standards and has promulgated 47 MACT standards to date. The remaining standards are in various stages from proposal to under development. As discussed in Section 4.2.3.3, many industry categories that are within the scope of this surface impoundment study are, or will be, covered by a MACT rule.

A major source is defined as a facility with the potential to emit 10 tons per year or more of any one HAP or 25 tons per year or more of a combination of HAPs. Under section 112(a)(1), EPA is authorized to reduce the 10-ton/yr threshold upon a demonstration that a lesser quantity cutoff is warranted.

MACT standards must require the maximum degree of emission reduction that EPA determines to be achievable by each particular source category. Different criteria for MACT standards apply for new and existing sources. In setting MACT standards, EPA does not generally prescribe a specific control technology. Instead, whenever feasible, EPA sets a performance level based on the performance of technology or other practices already used by the

[3] The original list contained 189 chemicals; however, EPA removed caprolactam from the list in 1996 after a review of the most current scientific information.

industry. Facilities are free to achieve these performance levels in whatever way is most cost-effective for them. Eight years after each MACT standard is issued, EPA must assess the remaining health risks from source categories through the residual risk program.

Residual Risk Program. To ensure that MACT regulations protect public health and the environment, Congress included section 112(f) in the 1990 CAA Amendments, which requires a human health risk-based and adverse environmental effects-based "needs test" in the second regulatory phase of the air toxics program. In this phase, referred to as residual risk standard setting, EPA is required to promulgate additional standards for those source categories that, after imposition of MACT standards, are emitting HAPs at levels that present a potential unacceptable risk to the public or the environment. Congress directed that such residual risk standards should "provide an ample margin of safety to protect public health."

Section 112(f) specifically gives EPA the mandate to consider environmental health assessment. Although not very explicit as to how this should be done, Congress does say that EPA shall promulgate standards to provide an ample margin of safety to protect public health unless the Administrator determines that a more stringent standard is necessary to prevent "an adverse environmental effect." The statute directs that consideration of adverse environmental effects must take into account "costs, energy, safety, and other relevant factors" in deciding what level is protective. Adverse environmental effect is defined in section 112(a)(7) as "any significant and widespread adverse effect, which may reasonably be anticipated to wildlife, aquatic life, or other natural resources, including adverse impacts on populations of endangered or threatened species or significant degradation of environmental quality over broad areas."

EPA has developed the residual risk strategy to implement the requirements of CAA sections 112(f)(2) through (6). Goals of the residual risk strategy include (1) assessing any risks remaining after MACT standard compliance, (2) determining if additional emission reductions are necessary and, if so, for which source categories, (3) setting a standard that protects the public with an "ample margin of safety," and (4) setting a more stringent standard, if necessary, to protect the environment. (See U.S. EPA, 1999c, *Residual Risk, Report to Congress*, EPA-453/R-99-001, for a more detailed description of the residual risk program.)

Area Source Standards. Area sources are smaller sources, such as dry cleaners and gas stations, that release smaller amounts of toxic pollutants into the air than major sources. Area sources are defined as sources that emit less than 10 tons per year of a single air toxic and less than 25 tons per year of a mixture of air toxics. Though emissions from individual area sources are often relatively small, collectively their emissions can be of concern. The CAA provides EPA with broad authority to control HAP emissions from area sources. EPA is authorized to develop technology-based standards for area sources when such sources present a threat of adverse effects to health or the environment (this is often referred to as a "positive area source finding" that is issued pursuant to CAA 112(c)(3)). These technology-based standards are to be based either on MACT or generally achievable control technology (GACT). For example, hazardous waste incinerators, cement kilns, and lightweight aggregate kilns are required to comply with MACT standards, regardless of whether they are major or area sources.

Urban Air Toxics Program. The National Urban Air Toxics Strategy aims to reduce the health risks associated with air toxics exposures affecting populations in urban areas (metropolitan areas with population greater than 250,000) by developing a number of national standards for stationary and mobile sources to reduce HAP risks. The strategy includes a description of risk reduction goals; a list of 33 HAPs judged to pose the greatest potential threat to public health in the largest number of urban areas, including 30 HAPs specifically identified as being emitted from area sources; and a list of area source categories that emit a substantial portion of these HAPs and that are being considered for regulation under section 112(d). The goal of the strategy is to attain a 75 percent reduction in incidence of cancer attributable to exposure to HAPs emitted by stationary sources. This is relevant to all HAPs from both major and area stationary sources in all urban areas nationwide.

The list of area source categories includes 29 categories: 13 new categories being listed for regulation and 16 categories already subject to standards or for which standards are under development. The area source categories include industrial organic and industrial inorganic chemical manufacturing.

Section 112(k)(3)(b) of the CAA requires that the Urban Air Toxics program ensure that area sources that account for 90 percent of the aggregate emissions for each of the 30 area source HAPs are subject to standards. The program has developed MACT standards for these 30 area source HAPs for those area sources whose emissions pose the greatest threat to urban areas under section 112(k). Section 112(k) requires that area source categories be subject to standards under section 112(d). Section 112(d) standards are national standards that generally apply everywhere in the country. Consistent with this approach, EPA expects to apply section 112(k) standards nationally. This approach may also result in reductions of emissions from facilities with surface impoundments not located in urban areas.

Additionally, if further analyses reveal that an area source category that is currently unregulated or unlisted poses a public health risk, the Urban Air Toxics program will list that source category under authority of section 112(c) and develop the necessary regulation under 112(d), or they may address it through other activities like pollution prevention or voluntary programs. Similarly, if a specific source is contributing to a local risk problem, then it may be more appropriate for the state, local, or tribal program to address it.

Regulation of Volatile Organic Compounds

Criteria Air Pollutant Program. The CAA authorizes EPA to protect human health and the environment from criteria air pollutants, including ozone, lead, sulfur dioxide (SO_2), nitrogen oxides (NO_x), particulate matter, and carbon monoxide (CO). Few sources emit ozone directly; rather ozone is formed in the atmosphere through the reaction of VOCs and NO_x. To attain the ozone standard, EPA typically requires VOC and NO_x emission reductions. The definition of VOCs according to the CAA regulations (40 CFR Part 51.100), while complex, is basically any compound of carbon (excluding CO, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium) that participates in atmospheric photochemical reactions. Essentially all organic compounds are considered VOCs except those with negligible photochemical reactivity. The definition specifically excludes methane, ethane, methyl chloride,

methyl chloroform, and many chlorofluorocarbons (CFCs), and hydrochlorofluorocarbons (HCFCs). Most of these are halogenated compounds (i.e., refrigerants) and do not take part in the photochemical reactions that cause ozone formation. CAA provisions that reduce VOCs to address ozone formation thus have the potential to limit VOC emissions from surface impoundments.

As required by the CAA, EPA established NAAQS for the criteria air pollutants. NAAQS are ambient concentrations above which the air is deemed unhealthy. Geographic areas (e.g., counties and urban areas) in which ambient concentrations exceed the NAAQS are referred to as nonattainment areas, and areas in which ambient concentrations are below the NAAQS are called attainment areas.

Under the Criteria Air Pollutant Program, major sources are stationary facilities that emit 100 tons or more per year of a criteria air pollutant. For purposes of this study, this would mean any source that emits greater than 100 ton/yr VOCs. Two of the major components of criteria air pollutant control programs are New Source Review (NSR) and control programs under State Implementation Plans that require reasonably available control technology (RACT) on existing sources. In attainment areas, new and modified major sources must install best available control technology (BACT) under the Prevention of Significant Deterioration (PSD) permit program, which is an NSR program. Within nonattainment areas, states must require emissions reductions beyond those called for in attainment areas to bring the area back into attainment. New and modified major sources in nonattainment areas must be equipped with technology representing lowest achievable emissions rate (LAER) as part of NSR permitting.

As previously discussed, existing sources in nonattainment areas must be equipped with technology representing RACT. Although EPA publishes guidance for RACT, SIPs are designed to meet local and regional problems and vary substantially between states. Smaller sources are considered major in areas that are not meeting the NAAQS for a particular pollutant. For example, VOC sources emitting 50 ton/yr are considered major for SIP and NSR programs in areas in serious ozone nonattainment areas. The amount goes down to 25 ton/yr in severe nonattainment areas and to 10 ton/yr in extreme nonattainment areas.

A federal program requiring emission reductions in both attainment and nonattainment areas is the NSPS program. This program, as authorized by section 111 of the Clean Air Act, requires EPA to identify source categories emitting criteria pollutants or their precursors and to establish emissions limits for new, modified, and reconstructed sources of emissions. Emissions limits must be based on the best demonstrated technology. To date, EPA has promulgated 77 NSPSs. As discussed in Section 4.2.3.4, several industry categories that fall within the scope of this study have applicable VOC NSPS requirements; sources in these industry sectors would thus be subject to the requirements if they met the definition of new, modified, or reconstructed source.

4.2.3.2 Constituent Coverage Analysis. Under the CAA, constituents could be regulated under the Air Toxics Program as HAPs or under the Criteria Air Pollutant Program pursuant to NAAQS. For the purposes of evaluating emissions from surface impoundments, the relevant criteria pollutants are VOCs. Note that some coverage may be provided by the draft *Guide for*

Industrial Waste Management (U.S. EPA, 1999a) as discussed in Section 4.2.1.3. This section thus evaluates whether the risk assessment constituents of concern in this study are HAPs or VOCs or are covered by the draft *Guide for Industrial Waste Management*.

The risk assessment identified 13 constituents of concern for the air pathway based on reported data as well as surrogate data. Table 4-1 lists the 13 constituents and indicates if they are CAA HAPs or VOCs.[4] Table 4-1 also indicates whether the constituent is addressed in EPA's draft *Guide for Industrial Waste Management* and the companion Industrial Waste Air Model.

As explained earlier, the constituents of concern listed in Table 4-1 reflect risk results with varying levels of certainty. The level of certainty depends, in part, on the extent to which the results were based on (1) reported concentration values and (2) surrogate data (including DL values). Constituents of possible concern that were reported at specific concentration values (above the detection limit) are identified in the table. Of the 13 constituents, only 3 represent reported values. The 10 surrogate values were not detected, and, if present in the samples, were at levels less than the detection limits. For these 10 constituents, modeling risk at the detection limit provided a conservative and protective basis for analysis of regulatory gaps.

HAP Constituents. Of the 13 constituents of concern that show potentially elevated risk, four are not HAPs. These four constituents cannot be directly controlled by MACT standards unless they are added to the list of HAPs pursuant to section 112 (b)(3)(B). These constituents may, however, be indirectly co-controlled by MACT standards if control of other, perhaps similar, regulated constituents also results in control of the non-HAP (see discussion below on draft *Guide for Industrial Waste Management* constituents for additional details on co-control). Instances where non-HAPs pose risk can thus be considered a limitation of current CAA requirements.

Nine of the 13 risk assessment constituents are CAA HAPs. These nine HAPs thus fall within the jurisdiction of the MACT program. A HAP-emitting facility, however, must first be subject to a specific MACT standard in order to be regulated under section 112 under the CAA. Section 4.2.3.3 discusses the extent to which surface impoundments and industry sectors that are within the scope of this study are, or will be, covered by MACT rules.

VOC Constituents. Table 4-1 identifies all 13 constituents of concern as VOCs under the CAA. VOC regulations may fill regulatory gaps for those constituents not regulated as HAPs. For example, NSPS Subpart QQQ regulates wastewater for petroleum refineries. Constituents that are not HAPs but are VOCs could be controlled by oil/water separators or other NSPS requirements under this subpart. One disadvantage of NSPS requirements is that they apply to new and modified sources. This leaves a potential gap because the control requirements are not applied to "grandfathered" sources. The same issue occurs with NSR program requirements. Although BACT is applied to major modifications and new sources, grandfathered sources may remain uncontrolled.

[4] This risk assessment differentiated between volatile and semivolatile organic compounds as a result of different analytical methods. 40 CFR Part 51.100 defines VOCs differently for the Criteria Air Pollutant Program. Table 4-1 reflects the Part 51.100 definition.

Table 4-1. Extent That Constituents Exceeding Risk Criteria for Air Pathway Are HAPs, VOCs, or Covered by Draft *Guide for Industrial Waste Management*

Chemical Name	CAA HAP	Criteria Pollutant (VOC)	Addressed by *Guide for Industrial Waste Management*
alpha-Hexachlorocyclohexane [alpha-BHC][b]		•	
Acetaldehyde [b, c]	•	•	•
Chlorodibromomethane [dibromochloromethane][b]		•	•
Acetonitrile [methyl cyanide] [a]	•	•	•
Acrolein [2-propenal] [a]	•	•	•
Bis(chloromethyl) ether [sym-dichloromethyl ether] [a]	•	•	
Chloroform [trichloromethane] [a]	•	•	•
Hexachlorocyclopentadiene [a]	•	•	•
N-Nitrosodi-n-butylamine [a]		•	•
N-Nitrosodiethylamine [a]		•	•
Tetrachlorodibenzodioxins [TCDDs] [a, c]	•	•	•
Tetrachlorodibenzofurans [TCDFs] [a]	•	•	•
Toxaphene [chlorinated camphene] [a]	•	•	
Totals	**9**	**13**	**10**

CAA = Clean Air Act.
HAP = Hazardous air pollutant.
VOC = Volatile organic compound as defined by criteria air pollutant program.
[a] Indicates risk estimate was based on surrogate or detection limit value.
[b] Indicates risk estimate was based on reported concentrations.
[c] Indicates no individual chemical combination exceeds the risk criteria, but the aggregate facility-level risk does.

It is not clear to what extent SIP regulations will provide coverage. Although state regulations may reduce emissions from surface impoundments, the regulations are likely to apply only to major sources located in urban areas with photochemical smog problems. Because of this, SIP programs were not included as a potential mechanism for gap filling even though they may regulate surface impoundment emissions in some areas.

Draft *Guide for Industrial Waste Management Constituents*. The draft *Guide for Industrial Waste Management* identifies 95 constituents for the protection of air (see Section 4.2.1.3). Ten of the 13 compounds that showed the potential for risk are addressed by the guide. These 10 constituents included three of the four non-HAPs (chlorodibromethane, N-nitrosodi-n-butylamine, and N-nitrosodiethylamine).

The three non-HAP, draft *Guide for Industrial Waste Management* constituents are also considered VOCs, and any source emitting them would be subject to applicable VOC regulations. If a source emits one of these three compounds along with any HAP, there could be a co-control benefit. Co-control occurs when measures taken to reduce HAP emissions under the MACT standards also reduce emissions of non-HAPs. Co-control is likely to occur at facilities that are major HAP sources and that also emit non-HAP chemicals. Most of the technology-based controls prescribed for HAPs will reduce emissions of all organic chemicals, including

non-HAPs. Similarly, most MACT requirements to reduce emissions of specific HAPs, or to reduce total HAP emissions by specific amounts, imply or identify control technologies that are also effective for non-HAP pollutants. Thus, co-emitted HAPs and non-HAPs could receive roughly equivalent levels of control. For example, if a source generates wastewater containing both chlorodibromomethane and a regulated HAP and is required to meet wastewater concentration limitations pursuant to MACT, then the source's efforts to reduce the wastewater HAP concentration could also reduce chlorodibromomethane concentrations. Lower chlorodibromomethane wastewater levels would subsequently reduce chlorodibromomethane emissions from any impoundment that receives that wastewater.

4.2.3.3 NESHAP Program Coverage. The primary regulatory program that addresses air releases from industrial surface impoundments is the CAA NESHAP program. Under this third step of this analysis, specific NESHAP regulations were examined to determine the extent to which these requirements address air releases from surface impoundments.

Waste Management Unit Coverage. NESHAP rules that directly regulate surface impoundments were examined. CAA regulations are not typically adopted for waste management units such as surface impoundments—instead the emission limits are targeted at specific source categories that may include surface impoundments as a regulated emission unit. Generally speaking, most NESHAP standards tend to focus on HAP levels in wastewater generated in the production process, which eventually could be treated/stored in the surface impoundment unit (e.g., MACT standards may control HAP levels in wastewater as opposed to requiring emission controls, such as a cover, on surface impoundments). However, there are some NESHAP regulations that specifically address surface impoundments. Table 4-2 lists these regulations.

Although there is a MACT standard for surface impoundments (40 CFR 63, Subpart QQ), it is only applicable to facilities subject to other MACT or NESHAP requirements that also reference subpart QQ. This subpart is listed only as an administrative convenience. The requirements include standards for floating membrane covers and closed-vent systems venting to a control device. The subpart also includes requirements for test methods, inspection procedures, monitoring, recordkeeping, and reporting.

Industry Coverage. As previously discussed, MACT standards are typically issued for specific industries. Table 4-3 lists the in-scope industry categories (by four-digit SIC code) and the extent to which they are, or will be, covered by MACT standards (e.g., proposed, completed, and upcoming). The table also notes if there is no existing, proposed, or scheduled MACT standard for the industry sector. The four-digit SICs are ranked by estimated wastewater volume managed in descending order. For example, Table 4-3 indicates that pulp mills (1) manage the highest estimated volume of wastewater and (2) have an applicable MACT standard.

Table 4-3 shows that MACT requirements exist, or will exist, for the majority of the SIC codes that manage the largest wastewater volume in surface impoundments. For example, the paper and allied products industry, which EPA estimates manages roughly 67 percent of the wastewater capacity, is subject to the Pulp and Paper Cluster rule (see Chapter 2, Table 2-2).

Table 4-2. Potential MACT and NESHAP Requirements Applicable to Surface Impoundments

MACT/NESHAP	Regulatory Citation	Waste Streams Covered
National Emission Standard for Benzene Waste Operations	40 CFR Part 61 Subpart FF	Benzene-containing waste from chemical manufacturing plants, coke byproduct recovery plants, and petroleum refineries, individual drain systems, wastewater treatment system
National Emission Standard for Organic Hazardous Air Pollutants from the Synthetic Organic Chemical Manufacturing Industry for Process Vents, Storage Vessels, Transfer Operations, and Wastewater Operations	40 CFR Part 63 Subpart G	Wastewater streams
National Emission Standard for Hazardous Air Pollutants from Off-Site Waste and Recovery Operations	40 CFR 63 Subpart DD, including 10 CFR 63 Subpart QQ	Waste and recoverable materials from offsite for treatment, storage, disposal, recovery, or recycling
National Emission Standards for Pharmaceuticals Production	40 CFR Part 63 Subpart GGG	Wastewater
National Emission Standards for Pesticide Active Ingredient Production	40 CFR Part 63 Subpart MMM	Wastewater
National Emission Standards for Polyether Polyols Production	40 CFR Part 63 Subpart PPP	Wastewater

Table 4-3. List of In-Scope 4-Digit SICs and Extent to Which They are Covered by MACT

SIC (Ranked by Estimated Wastewater Volume Managed)	SIC Title	Potentially Applicable MACT Standard	Regulatory Citation	Completed/ Proposed/ Upcoming
2611	Pulp mills	Pulp and Paper Cluster Rule	40 CFR Part 63 Subparts S and MM	Completed
2631	Paperboard mills			
2621	Paper mills			
2911	Petroleum refining	Petroleum Refineries	40 CFR 63 Subpart CC	Completed
		Petroleum Refineries- Catalytic Cracking, Catalytic Reforming & Sulfur Plant Unit	40 CFR Part 63 Subpart UUU	Proposed
5171	Petroleum bulk stations and terminals	Gasoline Distribution	40 CFR Part 63 Subpart R	Completed

(continued)

Table 4-3. (continued)

SIC (Ranked by Estimated Wastewater Volume Managed)	SIC Title	Potentially Applicable MACT Standard	Regulatory Citation	Completed/ Proposed/ Upcoming
3313	Electrometallurgical products	Wool Fiberglass Manufacturing	40 CFR Part 63 Subpart NNN	Completed
		Ferroalloys Production	40 CFR Part 63 Subpart XXX	Completed
		Metal Coil (Surface Coating)	40 CFR Part 63 Subpart SSSS	Proposed
3312	Blast furnaces and steel mills	Integrated Iron & Steel	40 CFR Part 63 Subpart FFFFF	Upcoming
		Steel Pickling-HCl Process	40 CFR Part 63 Subpart CCC	Completed
		Metal Coil (Surface Coating)	40 CFR Part 63 Subpart SSSS	Proposed
		Coke Oven Batteries	40 CFR Part 63 Subpart L	Completed
		Coke Oven Batteries: Pushing, Quenching and Battery Stacks	40 CFR Part 63 Subpart CCCCC	Upcoming
2821	Plastics materials and resins	Polymers and Resins I	40 CFR Part 63 Subpart U	Completed
		Polymers and Resins II	40 CFR Part 63 Subpart W	Completed
		Polymers and Resins III	40 CFR Part 63 Subpart OOO	Completed
		Polymers and Resins IV	40 CFR Part 63 Subpart JJJ	Completed
		Generic MACT	40 CFR Part 63 Subpart YY	Proposed
		Amino/Phenolic Resins Production	40 CFR Part 63 Subpart OOO	Completed
		Miscellaneous Organic Chemical Production and Processes (MON)	40 CFR Part 63 Subpart FFFF	Upcoming
		Polyvinyl Chloride and Copolymers Production	40 CFR Part 63 Subpart J	Proposed
		Cellulose Product Manufacture	40 CFR Part 63 Subpart UUUU	Proposed

(continued)

Table 4-3. (continued)

SIC (Ranked by Estimated Wastewater Volume Managed)	SIC Title	Potentially Applicable MACT Standard	Regulatory Citation	Completed/ Proposed/ Upcoming
2819	Industrial inorganic chemicals, not elsewhere classified	Hydrochloric Acid Production Industry	Rules not yet proposed or promulgated	Upcoming
		Generic MACT	40 CFR Part 63 Subpart YY	Proposed
		Cellulose Product Manufacture	40 CFR Part 63 Subpart UUUU	Proposed
		Uranium Hexafluoride Production	Rules not yet proposed or promulgated	Upcoming
2092	Food and kindred products (fish)	No existing, proposed, or scheduled MACT standard		
2874	Phosphatic fertilizers	Phosphoric Acid Manufacturing Plants/ Phosphate Fertilizer Plants	40 CFR Part 63 Subpart AA and BB	Completed
2436	Softwood veneer & plywood	Plywood & Composite Wood Products	40 CFR Part 63 Subpart ZZZ	Upcoming
		Wood Building Products	40 CFR Part 63 Subpart QQQQ	Upcoming
2063	Food and kindred products (beet sugar)	No existing, proposed, or scheduled MACT standard		
3273	Ready-mixed concrete	No existing, proposed, or scheduled MACT standard		
2022	Food and kindred products (cheese)	No existing, proposed, or scheduled MACT standard		
2873	Nitrogenous fertilizers	No existing, proposed, or scheduled MACT standard		
2035	Food and kindred products (pickles, sauces, salad dressing)	No existing, proposed, or scheduled MACT standard		
4953	Refuse systems	MSW Landfills	40 CFR Part 63 Subpart AAAA	Proposed
2869	Industrial organic chemicals, not elsewhere classified	Synthetic Organic Chemical Manufacturing Industry (SOCMI) Manufacture	40 CFR Part 63 Subpart F	Completed
		SOCMI for Process Vents, Storage Vessels, Transfer Operations, and Wastewater	40 CFR Part 63 Subpart G	Completed

(continued)

Table 4-3. (continued)

SIC (Ranked by Estimated Wastewater Volume Managed)	SIC Title	Potentially Applicable MACT Standard	Regulatory Citation	Completed/ Proposed/ Upcoming
2869 (cont.)		SOCMI for Equipment Leaks	40 CFR Part 63 Subpart H	Completed
		SOCMI for Negotiated Regulation for Equipment Leaks	40 CFR Part 63 Subpart I	Completed
		Generic MACT	40 CFR Part 63 Subpart YY	Proposed
		Polyether Polyols Production	40 CFR Part 63 Subpart PPP	Completed
		Cellulose Product Manufacture	40 CFR Part 63 Subpart UUUU	Proposed
3353	Aluminum sheet, plate, and foil	Metal Coil (Surface Coating)	40 CFR Part 63 Subpart SSSS	Proposed
2653	Corrugated and solid fiber boxes	No existing, proposed, or scheduled MACT standard		
3339	Primary nonferrous metals, not elsewhere classified	Wool Fiberglass Manufacturing	40 CFR Part 63 Subpart NNN	Completed
		Primary Magnesium Refining	Rules not yet proposed or promulgated	Upcoming
3351	Copper rolling and drawing	No existing, proposed, or scheduled MACT standard		
3334	Primary aluminum	Primary Aluminum Production	40 CFR Part 63 Subpart LL	Completed
		Metal Coil (Surface Coating)	40 CFR Part 63 Subpart SSSS	Proposed
2824	Organic fibers, noncellulosic	Generic MACT	40 CFR Part 63 Subpart YY	Proposed
		Miscellaneous Organic Chemical Production and Processes (MON)	40 CFR Part 63 Subpart FFFF	Upcoming
2899	Chemical preparations, not elsewhere classified	Misc. Organic Chemical Production & Processes (MON)	40 CFR Part 63 Subpart FFFF	Upcoming
2833	Medicinals and botanicals	No existing, proposed, or scheduled MACT standard		
3229	Pressed and blown glass, not elsewhere classified	Wet Formed Fiberglass Mat Production	40 CFR Part 63 Subpart HHHH	Proposed

(continued)

Table 4-3. (continued)

SIC (Ranked by Estimated Wastewater Volume Managed)	SIC Title	Potentially Applicable MACT Standard	Regulatory Citation	Completed/ Proposed/ Upcoming
3624	Carbon and graphite products	No existing, proposed, or scheduled MACT standard		
2435	Hardwood veneer & plywood	Plywood & Composite Wood Products	40 CFR Part 63 Subpart ZZZ	Upcoming
		Wood Building Products	40 CFR Part 63 Subpart QQQQ	Upcoming
2843	Surface active agents	Polyether Polyols Production	40 CFR Part 63 Subpart PPP	Completed
4952	Sewerage systems	Publicly Owned Treatment Works (POTW)	40 CFR Part 63 Subpart VVV	Completed
		Sewage Sludge Incinerators	Rules pending	Upcoming
2251	Women's hosiery, except socks	Fabric, Printing, Coating and Dyeing	40 CFR Part 63 Subpart OOOO	Upcoming
2834	Pharmaceutical preparations	Pharmaceuticals Production	40 CFR Part 63 Subpart GGG	Completed
3011	Tires and inner tubes	Tire Manufacturing	40 CFR Part 63 Subpart XXXX	Proposed
3341	Secondary nonferrous metals	Secondary Lead	40 CFR Part 63 Subpart RRR	Completed
		Secondary Brass and Bronze	40 CFR Part 63 Subpart SSSS	Proposed
3761	Guided missiles and space vehicles	Aerospace Industry	40 CFR Part 63 Part GG	Completed
		Rocket Engine Test	Rules not yet proposed or promulgated	Upcoming
2865	Cyclic crudes and intermediates, and organic dyes and pigments	Miscellaneous Organic Chemical Production and Processes (MON)	40 CFR Part 63 Subpart FFFF	Upcoming
		Fabric, Printing, Coating and Dyeing	40 CFR Part 63 Subpart OOOO	Upcoming
3399	Primary metal products, not elsewhere classified	Taconite Iron Ore Processing	Rules not yet proposed or promulgated	Upcoming
9711	National security	No existing, proposed, or scheduled MACT standard		
2211	Broadwoven fabric mills, cotton	No existing, proposed, or scheduled MACT standard		
3321	Gray and ductile iron foundries	Iron & Steel Foundries	40 CFR Part 63 Subpart EEEEE	Upcoming

(continued)

Table 4-3. (continued)

SIC (Ranked by Estimated Wastewater Volume Managed)	SIC Title	Potentially Applicable MACT Standard	Regulatory Citation	Completed/ Proposed/ Upcoming
3087	Custom compound purchased resins	No existing, proposed, or scheduled MACT standard		
3674	Semiconductors and related devices	Semiconductor Production	40 CFR Part 63 Subpart BBBB	Upcoming
3462	Iron and steel forgings	No existing, proposed, or scheduled MACT standard		
3317	Steel pipe and tubes	Metal Coil (Surface Coating)	40 CFR Part 63 Subpart SSSS	Proposed
		Steel Pickling-HCl Process	40 CFR Part 63 Subpart CCC	Completed
2011	Food and kindred products (meat packing)	No existing, proposed, or scheduled MACT standard		
3324	Steel investment foundries	Iron & Steel Foundries	40 CFR Part 63 Subpart EEEEE	Upcoming
2679	Converted paper products, not elsewhere classified	No existing, proposed, or scheduled MACT standard		
3316	Cold finishing of steel shapes	Metal Coil (Surface Coating)	40 CFR Part 63 Subpart SSSS	Proposed
3499	Fabricating metal products, not elsewhere classified	Metal Coil (Surface Coating)	40 CFR Part 63 Subpart SSSS	Proposed
		Metal Furniture (Surface Coating)	40 CFR Part 63 Subpart RRRR	Upcoming
		Misc. Metal Parts & Products (surface coating)	40 CFR Part 63 Subpart MMMM	Upcoming
3069	Fabricated rubber products, not elsewhere classified	No existing, proposed, or scheduled MACT standard		
3089	Plastics products, not elsewhere classified	Plastic Parts (surface coating)	40 CFR Part 63 Subpart PPPP	Upcoming
		Reinforced Plastics Components Production	40 CFR Part 63 Subpart WWWW	Upcoming
3731	Shipbuilding and repairing	Shipbuilding & Ship repair	40CFR Part 63 Subpart II	Completed
		Boat Manufacturing	40 CFR Part 63 Subpart VVVV	Proposed

(continued)

Table 4-3. (continued)

SIC (Ranked by Estimated Wastewater Volume Managed)	SIC Title	Potentially Applicable MACT Standard	Regulatory Citation	Completed/ Proposed/ Upcoming
3357	Nonferrous wiredrawing & insulating	No existing, proposed, or scheduled MACT standard		
3398	Metal heat treating	No existing, proposed, or scheduled MACT standard		
2952[a]	Asphalt felts and coatings	Asphalt Roofing and Processing	40 CFR Part 63 Subpart LLLLL	Upcoming
3052[a]	Rubber & plastics hose and belting	Plastic Parts (surface coating)	40 CFR Part 63 Subpart PPPP	Upcoming
3081[a]	Unsupported plastics film & sheet	Metal Coil (Surface Coating)	40 CFR Part 63 Subpart SSSS	Proposed
		Plastic Parts (surface coating)	40 CFR Part 63 Subpart PPPP	Upcoming

[a] Survey data not available to adequately quantify wastewater volumes for ranking purposes.

This set of rules is an innovative regulatory effort to address both air and water releases from pulp and paper mills. The air rule covers MACT I emissions (noncombustion sources from pulping and bleaching operations at chemical and semichemical wood pulping mills); MACT II emissions (chemical recovery combustion areas of mills); and MACT III emissions (noncombustion sources from mills that mechanically pulp wood, pulp secondary fibers, or pulp nonwood materials and those that use paper machine additives and solvents). The final water rule applies to mills in Subpart B (Bleached Papergrade Kraft and Soda) and Subpart E (Papergrade Sulfite) Subcategories and includes best available technology (BAT) limitations and Best Management Practice (BMP) requirements. The implementation of the cluster rule will eliminate the use of chlorine or hypochlorite in the pulp bleaching process or require the facility to meet the revised effluent limitation guidelines and standards. This rulemaking will also achieve 99 percent reduction in chloroform in the wastewater discharged.

It is important to note that this industry coverage analysis did not focus on the industry types that showed potential risks. There were not enough risk exceedances in any one industry sector that warranted a more detailed industry-specific regulatory analysis. A review of those industry sectors that did show the potential for risk, however, indicated that the majority of those industry sectors are, or will be, covered by MACT regulations.

A HAP-emitting facility must first be part of a source category that is subject to a specific MACT standard in order to be regulated under section 112 of the CAA. If a surface impoundment emits a HAP but is not part of a listed source category for which there is an applicable MACT standard, then it is not an affected source subject to MACT requirements. Situations where nonaffected HAP-emitting sources pose unacceptable risk could thus also be

considered a limitation in current MACT requirements, since these types of sources should be regulated pursuant to section 112. This could potentially occur in two different scenarios.

First, MACT standards may not exist for a source category that emits HAPs (and are not on the list of upcoming MACT rules). As noted previously, a review of industry sectors that showed the potential for risk indicated that the majority (but not all) of those industry sectors are, or will be, covered by MACT regulations. Second, a source category that is covered by an existing MACT rule may not be considered an affected source if it does not meet the definition of a major source. A facility emitting HAPs is considered a major source if it emits or has the potential to emit 10 tons per year or more of any listed HAP or a combination of listed HAPs of 25 tons or more. This study did not investigate what fraction of the facilities that were within the scope of this study would meet the definition of a major source.

In addition, MACT regulations for each source category do not always address all the HAPs listed in section 112 of the CAA. For example, the Petroleum Refinery MACT (40 CFR 63 Subpart CC) is limited to organic HAPs as defined by the regulation. The regulation includes only 28 of the 188 HAPs. In some cases, this occurs because the source category emits only a subset of CAA HAPs. In other cases, this may have occurred because the best performing sources were uncontrolled and EPA therefore concluded that the MACT standard for that pollutant was no control. A recent court decision (National Lime Association v. *EPA*, 99-1325 (DC Cir)) clarifies that, even if no controls are found to be in use, other means of reduction must also be evaluated and that MACT represents the performance level of lowest emitting facilities and a MACT standard must address all HAPs emitted by the industrial category. For the instances where an unacceptable risk is identified as a result of a constituent of concern in this study being a HAP but not addressed in an existing MACT regulation, it is assumed that this will be addressed by the residual risk program. Therefore, for those constituents that are HAPs, there is not a regulatory gap because the Air Toxics Program should, in time, address HAPs that pose unacceptable threats to human health.

Other air toxics regulations may achieve some emissions reductions for HAPs. Section 112(j) contains the MACT "hammer" requirement. This requires facilities and states to establish MACT equivalent standards should EPA fail to meet congressionally mandated MACT schedule deadlines. Prior to the 1990 CAA and MACT programs, individual states had a variety of air toxics programs. Although these programs may control emissions from industrial surface impoundments, they have not been included in this regulatory/program analyses because these provisions vary significantly from state to state.

4.2.3.4 Other CAA Coverage—Criteria Air Pollutant Program. We also evaluated applicability of VOC regulations. All of the 13 constituents of potential concern in this study are VOCs. As VOCs, the constituents of concern may be regulated indirectly as part of a national program to reduce ozone. Although VOC regulations have resulted in substantial reductions in emissions of air toxics, it is important to note that NSPS requirements apply only to new and newly modified sources. This means that older "grandfathered" sources may not be required to comply with the standards.

NSPS Waste Management Unit and Industry Coverage. There are no NSPS requirements that directly regulate surface impoundments. However, NSPS regulations that control, for example, VOCs generated in the manufacturing process and ultimately in the wastewater generated can serve to limit VOC emissions from surface impoundments that manage such wastewaters. For example, NSPS Subpart QQQ regulates VOC emissions from petroleum refinery wastewater systems. Appendix D, Section D-3, lists the in-scope industry sectors and potentially applicable NSPS VOC standards. The appendix lists several NSPS regulations that can potentially limit VOC emissions from surface impoundments within the scope of this study (provided the source has been modified as defined by the NSPS requirements).

Many ozone problems are regional in nature; thus additional VOC requirements may be in place pursuant to SIPs at the state and local level. There are SIP programs that specifically regulate surface impoundments; however, control of criteria pollutants under the CAA is based on local, state, and regional air quality programs and regulations. A detailed analysis of SIPs was not conducted for this study. EPA may issue guidance, such as control technology guidelines (CTGs) and alternative control technique guidance (ACTs) for VOC sources, to assist states in designing control programs to meet local air quality needs. The Office of Air Quality Planning and Standards developed a CTG in 1993 and released an ACT guidance in 1994 for VOCs in industrial wastewater.

4.2.3.5 Summary of Potential Regulatory Program Coverage and Gaps in CAA Regulations. The analysis of potential regulatory gaps under the Clean Air Act examined constituents of concern and the regulatory applicability under Air Toxics and Criteria Pollutant Control programs. The analysis looked at regulations that directly control constituents of concern (e.g., MACT regulations) as well as regulations that indirectly control constituents of concern (e.g., VOC regulations). This subsection outlines the nature and extent of potential regulatory/program gaps.

The analysis showed that MACT requirements exist, or will exist, for the majority of the SIC codes that manage the largest wastewater volume in surface impoundments. The analysis also indicates that the majority of industry categories that showed the potential for risk were covered by MACT standards. However, potential exists for a particular source category not to be covered by a MACT rule. Under the CAA, MACT categories are supposed to include all source categories that emit HAPs and pose risks to human health. Thus, source categories that emit HAPs at levels of concern but are not currently regulated, regardless whether they are major or area sources, are supposed to be regulated when MACT is fully implemented. Section 112(c) of the CAA gives EPA the authority to list additional source categories that emit HAPs but are not currently subject to existing or proposed MACT standards.

Another type of gap under this analysis may occur when a MACT standard exists for an industrial category that exceeds the risk threshold, but does not specifically address surface impoundments or the constituents of concern that are HAPs. A review of the industry sectors that showed the potential for risk found two instances in which an industry category was covered by MACT standards, but the MACT standard did not directly address the HAP constituent of concern. It must be noted, however, that both of these risk estimates were based on DL values as opposed to reported concentration values, and both of these constituents would have benefitted

from co-control of similar HAPs that are covered by the MACT standard. Thus, it is not clear that the risks are real, and, if they are, they may well be addressed by the MACT standard. Regardless, gaps associated with unaddressed HAPs at sources that are covered by MACT standards should be addressed by the Residual Risk Program.

It must be noted, however, that MACT typically applies only to major sources. Although major sources account for most of the pollution (e.g., traditionally less than 20 percent of the sources are considered to emit over 80 percent of the pollution), there is still the potential for elevated exposure from small sources. The area source program for HAPs is designed to address this issue. EPA is authorized to develop technology-based standards for area sources when such sources present a threat of adverse health effects. One important qualification for coverage under the area source program is that the residual risk program cannot address area sources unless they have been listed in accordance with section 112(c)(3) and have been included in regulations under section 112(d).[5] This study did not investigate what fraction of the facilities that were within the scope of this study would meet the definition of a major source.

These limitations are supposed to be addressed when MACT is fully implemented. For those constituents of concern that are non-HAPs, there are still potential regulatory gaps. Table 4-1 lists the four constituents of concern that are not regulated as HAPs and show the potential for elevated risks. They are

- Alpha-hexachlorocyclohexane
- N-Nitrosodi-n-butylamine
- N-Nitrosodiethylamine
- Chlorodibromomethane.

Non-HAP constituents were evaluated to determine if they are regulated as VOCs. Alpha-hexachlorocyclohexane, chlorodibromomethane, N-nitrosodi-n-butylamine, and N-nitrosodiethylamine are VOCs and would potentially be subject to VOC requirements for wastewater treatment for some NSPS industrial categories. NSPS standards for VOCs only address new or newly modified sources in certain industrial categories and would not apply to "grandfathered" sources that had not made modifications that triggered NSPS requirements. Because the NSPS requirements do not address "grandfathered" sources, there is no certainty that a regulatory gap would be closed. However, as previously discussed, additional VOC requirements may be in place pursuant to SIPs at the state and local level.

The likelihood of these four constituents presenting a problem should also be considered. Risk results for both N-nitrosodi-n-butylamine and N-nitrosodiethylamine were not based on reported values. This means that concentration values used in the risk assessment were a function of the detection levels. Both chlorodibromomethane and alpha-hexachlorocyclohexane were only detected at one facility each. The limited verification of the hazard posed by these constituents suggests that any gap is likely to be small.

[5] The Residual Risk Program is not required to cover area sources that are subject to GACT rather than MACT.

4.3 Coverage and Potential Gaps in Existing Programs and Regulations Addressing Nonair Risks

Although the EDF consent decree was limited to examining the air risks from never characteristic wastes in surface impoundments, EPA investigated risks associated with other media as well in response to the requirements of the LDPFA. In this portion of the analysis, EPA assessed program and regulatory coverage for

- Risks resulting from consumption of groundwater containing constituents released from surface impoundments (Section 4.3.1)
- Indirect risks resulting from contaminated groundwater leaching into surface waterbodies (Section 4.3.2)
- Risks posed via other indirect pathways (Section 4.3.3)
- Ecological risks (Section 4.3.4).

EPA evaluated the extent to which these predicted risks are adequately addressed under existing federal and state programs.

4.3.1 Groundwater Risks Found from Managing Nonhazardous Waste in Surface Impoundments

Leachate from a nonhazardous waste surface impoundment can potentially migrate through the subsurface and affect groundwater quality. Therefore, EPA identified existing federal and state regulations and programs that address the release of constituents from nonhazardous waste surface impoundments to groundwater.

In this part of the analysis, EPA used the results of the groundwater risk assessment to illustrate regulatory coverage and potential gaps. The risk assessment evaluated risks from specific facilities, constituents, and impoundments resulting from ingestion of groundwater that had been contaminated with impoundment leachate. The results of the risk assessment indicate that groundwater contamination from surface impoundments may potentially pose a risk (see also Section 3.2 for a discussion of groundwater risks). Specifically, the risk assessment identified 15 constituents that potentially exceed the specified risk threshold of this study for the groundwater pathway.

4.3.1.1 Existing Federal RCRA Regulations and Programs that Control Releases to Groundwater from Nonhazardous Industrial Waste Surface Impoundments. This section describes the federal solid waste regulations and programs that may address potential risks to groundwater posed by the management of nonhazardous wastes in surface impoundments. State programs are described in Section 4.3.1.2. Federal regulations and programs that address groundwater risks at nonhazardous waste impoundments include the following:

- RCRA Subtitle C—Corrective Action Program

- Omnibus permitting authority under RCRA section 3005(c)(3)
- SEPs conducted in connection with an enforcement action
- RCRA Subtitle D Regulations
- EPA's draft *Guide for Industrial Waste Management*.

In addition, EPA's multimedia strategy for persistent, bioaccumulative, and toxic (PBT) pollutants could potentially reduce risks to groundwater from surface impoundments in the future. EPA's PBT strategy is described in detail in Section 4.4.

Potential regulatory coverage and gaps in these programs, as they pertain to protection of groundwater at nonhazardous waste surface impoundments, are discussed below.

Potential Coverage by RCRA 7003 and Subtitle C Corrective Action Program. As described in Section 4.2.1.1, releases from SWMUs can be addressed under the RCRA corrective action program if a facility has a RCRA permit or is an interim status facility. For facilities with RCRA permits, the RCRA corrective action program provides extensive regulatory and program coverage to address any releases to groundwater from nonhazardous waste surface impoundments that pose unacceptable risks.

Also, as previously discussed, the imminent and substantial endangerment provision of RCRA section 7003 allows EPA, upon evidence of past or present handling of solid or hazardous waste, to require any action necessary when a situation may present an imminent and substantial endangerment to health or the environment.

The survey indicates that about 33 percent of the surface impoundments nationwide that fall within the scope of this study have been designated as solid waste management units pursuant to the RCRA corrective action RFA process (see also Chapter 2, Section 2.5 for additional information on the permit and corrective action status of impoundments within the scope of this study). This indicates that a significant number of nonhazardous surface impoundments are located at RCRA TSD facilities; these impoundments are being addressed by EPA and the states on a priority basis, and thus no regulatory gaps should exist for these impoundments.

EPA's Permitting Authority under RCRA 3005. EPA's permitting authority under RCRA 3005 is another statutory control that could be used to address groundwater risks posed by surface impoundments if they are located at a RCRA TSD facility. See Section 4.3.1.1 for a detailed explanation of EPA's omnibus permitting authority at RCRA section 3005(c)(3).

Use of SEPs to Address Surface Impoundments at Facilities Subject to Enforcement Actions. As discussed in Section 4.2.1.5, a SEP is one program that could be used to address contamination problems found at a nonhazardous waste surface impoundment if the facility is subject to a related enforcement action. As a condition of the settlement, EPA and the defendant could agree upon a SEP that is related to reducing groundwater risks posed by a surface impoundment at the facility. A SEP related to a surface impoundment could include closure, installation of a liner, or implementation of some other measure that would eliminate or reduce risk to the environment and/or public health.

Coverage by RCRA Subtitle D Regulations. RCRA sections 1008(a)(3) and 4004(a) required EPA to develop criteria for states to use in determining which facilities would be classified as open dumps and thus be required to be closed or upgraded. EPA promulgated 40 CFR Parts 256 and 257 to partially fulfill the Agency's obligations under the Act. Part 256 establishes guidelines for the states to use in the development and implementation of their solid waste management plans and includes provisions related to the scope of the plan, the identification of the responsibilities for state and substate agencies, the requirements for state legal and regulatory authorities, and planning and implementation. The federal regulations at Part 257 were EPA's primary mechanism for controlling open dumps prior to promulgation of municipal solid waste landfill regulations at Part 258. The Part 257 standards provide siting restrictions, limited performance standards, and references to other applicable federal programs (e.g., CWA). Table 4-4 is provided in this report for completeness; the regulations have limited ability to address potential risks, as identified in our study, posed by surface impoundments. Although the Part 257 regulations typically are administered and enforced by the states, and state regulations generally are more stringent than the Part 257 regulations, the federal Part 257 regulations may still apply to surface impoundments that are in the scope of this study.

Table 4-4 describes the Part 257 criteria that potentially apply to industrial surface impoundments.

The regulations that specifically address potential impacts to groundwater are identified in 40 CFR 257.3-4. This regulation identifies a list of contaminants (appearing at 40 CFR 257 Appendix I) and maximum concentration limits (MCLs) that cannot be exceeded in groundwater. Table 4-5 compares the risk assessment constituents of concern for the groundwater pathway to the Part 257 constituent list. Note that the information in the table reflects risk results with varying levels of certainty. The level of certainty depends, in part, on the extent to which the results were based on (1) reported concentration values and (2) surrogate data (including DL values). (See discussion in Chapter 3.) Constituents of possible concern that were reported at specific concentration values (above the detection limit) are identified in the table. Regulatory gaps identified based on this information thus carry the same level of varying certainty.

Table 4-5 indicates that only 3 of the 15 constituents potentially exceeding the risk criteria (flouride, arsenic, and vinyl chloride) are covered under 40 CFR Part 257.3-4. Thus, coverage of the constituents of potential concern for groundwater risks must be provided by other programs such as state programs (see Section 4.3.1.2) or EPA's voluntary draft *Guide for Industrial Waste Management*. Two of the potential constituents of concern (allyl alcohol and flouride) are not covered by the draft guidance. Allyl alcohol is not covered by either 40 CFR Part 257.3-4 or the draft guidance. The groundwater tool in the draft guidance allows the user to enter additional constituents that are not specifically listed in the guidance. Because the guidance is in draft form, the constituent list may change in the future.

Description of EPA's Draft *Guide for Industrial Waste Management* as It Relates to Coverage of the Groundwater Pathway. EPA's draft *Guide for Industrial Waste Management* (U.S. EPA, 1999a) includes three categories of groundwater protection guidelines: risk assessment, liner design and installation, and long-term operations. See Section 4.2.1.3 for a more generalized description of the draft guide.

Table 4-4. Summary of 40 CFR Part 257 Criteria That Potentially Apply to Surface Impoundments

Regulatory Citation	Summary of Requirement
§257.3-1 Floodplains	Facilities located in the 100-year floodplain must not restrict the flow of the flood, reduce water storage of the floodplain, or result in a washout of solid waste.
§257.3-2 Endangered or Threatened Species	Facilities must not cause or contribute to the taking of endangered or threatened species nor destroy or adversely modify their critical habitat.
§257.3-3 Surface Water	Facilities must not cause a discharge of pollutants or dredged or fill material in violation of the requirements of the Clean Water Act or cause nonpoint source pollution that violates an area or statewide water quality management plan under the Clean Water Act.
§257.3-4 Groundwater Protection	Facilities must not contaminate underground drinking water sources beyond the solid waste boundary unless it can be shown that an alternative boundary would not result in the contamination of water that may be needed for human consumption.
§257.3-7 Air	Facilities must not engage in the open burning of waste unless it is the infrequent burning of agricultural wastes in the field, silvicultural wastes for forest management purposes, land-clearing debris, diseased trees, debris from emergency cleanup operations, and ordinance and must not violate requirements developed under a State Implementation Plan under the Clean Air Act.
§257.3-8 Safety	Facilities must not generate high concentrations of explosive gases, pose a fire hazard, be located within 10,000 feet of a jet aircraft runway or 5,000 feet of a piston-type aircraft runway, or allow uncontrolled public access.

- ***Assessing Risk.*** Chapter 7a of the draft guide provides a tool for assessing risks associated with waste management practices and for tailoring management controls accordingly. The guidance employs a three-tiered evaluation approach to determine recommended liner systems and whether land application is appropriate. The chapter is intended for use at new units.

- ***Designing and Installing Liners.*** Chapter 7b of the draft guide discusses different types of liner systems that can be used to protect groundwater from contamination. Liner recommendations may include clay liners, synthetic liners, composite liners, leachate collection systems, and leak detection systems as appropriate. The chapter is intended for use at new units.

- ***Long-Term Operation.*** Chapter 9 of the draft guide includes recommendations for groundwater monitoring, Chapter 10 includes guidance on taking corrective action, and Chapter 11 provides guidance on closure/postclosure care. While the draft guide focuses primarily on new units, information in these chapters can be applied to existing industrial waste units.

Table 4-5. Federal Regulatory or Program Coverage of Constituents with Predicted Risks Exceeding Risk Criteria for Groundwater Pathway

CAS Number	Constituent	40 CFR Part 257 Constituent	*Guide for Industrial Waste Management* Constituent
107-13-1	Acrylonitrile [a]		•
107-18-6	**Allyl alcohol** [a]		
110-86-1	Pyridine [a]		•
16984-48-8	Fluoride [a,b]	•	
621-64-7	N-Nitrosodi-n-propylamine [di-n-propylnitrosamine] [a]		•
62-75-9	N-Nitrosodimethylamine [a]		•
67-56-1	Methanol [a]		•
67-64-1	Acetone [2-propanone] [a,b]		•
67-66-3	Chloroform [trichloromethane] [a]		•
7440-28-0	Thallium [a]		•
7440-38-2	Arsenic [a]	•	•
75-09-2	Methylene chloride [dichloromethane] [a]		•
75-01-4	Vinyl chloride [a]	•	•
8001-35-2	Toluene [a]		•
92-87-5	Benzidine [a]		•

[a] Risk estimate was based on surrogate or detection limit value.
[b] Risk estimate was based on a reported waste concentration.
Note: **Bold** indicates the constituent is not specifically addressed by either program.

Corrective action can include use of interim measures, institutional controls (such as deed restrictions or access controls), and application of remedial technologies designed to contain, remove, and/or destroy contamination.

4.3.1.2 Existing State Regulations and Programs that Control Releases to Groundwater at Nonhazardous Waste Surface Impoundments. States typically regulate nonhazardous waste surface impoundments under their more general solid and industrial waste management regulations for nonhazardous waste or pursuant to their water programs. This section provides an overview of state regulations that are applicable to nonhazardous waste management in general or nonhazardous waste surface impoundments in particular. The following types of state programs and regulations may address potential groundwater risks from in-scope surface impoundments:

- States may have regulations or programs addressing the groundwater pathway, such as monitoring or unit design requirements.

- A facility may have a permit for the surface impoundment issued by the state that addresses potential groundwater risks.

- States may make specific exclusions to their requirements for certain facilities. Such facilities, therefore, would not be subject to otherwise stricter state requirements.

Key Components of State Regulations and Programs that Address Releases to Groundwater at Nonhazardous Waste Surface Impoundments. Based on available information, most states have a program that includes provisions for controlling or addressing releases to groundwater from industrial nonhazardous waste surface impoundments (see Appendix D, Section D-1). The level of controls, however, varies across states. Many provisions are not formally adopted regulations; rather, they are imposed through permits, on a case-by-case basis at the discretion of the regulators, or via nonmandatory guidance. Note that EPA's analysis of state waste regulations and programs in Appendix D is based on publicly available information rather than on a survey of state regulators. Therefore, the analysis may not have identified all state waste regulations and programs that address nonhazardous waste industrial surface impoundments.

State programs may include some or all of the following key components, many of which are for the protection of groundwater:

- ***Location standards.*** Location standards generally address both potential effects a waste management unit may have on the surrounding environments and the effect that natural and man-made conditions may have on the performance of the unit. Location standards may include provisions such as airport safety; restrictions on placement of a unit in flood plains and wetlands; and design, construction, or siting requirements for placement in a fault area, seismic impact zone, or unstable areas. Note that the federal Part 257 location restrictions apply in all states and territories, even if such restrictions are not covered by state regulations.

- ***Design criteria***. Design criteria typically include design standards for liners and leachate collection or performance standards for maintaining contaminant concentrations in groundwater at protective levels at a point of compliance.

- ***Operating criteria.*** State programs for nonhazardous waste surface impoundments may include criteria pertaining to routine operation, management, and environmental monitoring. Operating criteria may include provisions for preventing disposal of hazardous or special waste, access and security, stormwater runon/runoff controls, freeboard requirements, nuisance controls, inspection, and reporting and recordkeeping.

- ***Monitoring.*** Monitoring programs may be required to evaluate whether a unit meets performance objectives and whether there are releases of constituents to and impacts on the surrounding environment that need to be corrected. Monitoring

requirements typically emphasize groundwater monitoring; however, states may require monitoring of air, surface water, and sludge or soil.

- ***Corrective action.*** If monitoring indicates that performance objectives are not being met, then a state program may require corrective measures. Under a remedial program, a facility may be required to assess the nature and extent of the releases of waste or constituents; to evaluate unit characteristics; and to identify, evaluate, and implement an appropriate corrective measure or measures to protect human health.

- ***Closure and postclosure care.*** A state may have requirements for unit closure to minimize or eliminate potential threats and the need for future corrective action at a site. Closure measures may include removal of wastewater, treatment of wastes, and/or containment. For postclosure care, the overall goal is to minimize the infiltration of water into a unit after closure by providing maintenance of the final cover until such time as it is determined that care is no longer necessary.

Figure 4-1 summarizes the number of states that have various programs in place for the protection of groundwater at nonhazardous industrial waste surface impoundments. A comprehensive summary of state waste regulations applicable to nonhazardous waste surface impoundments is included in Appendix D, Section D-1.

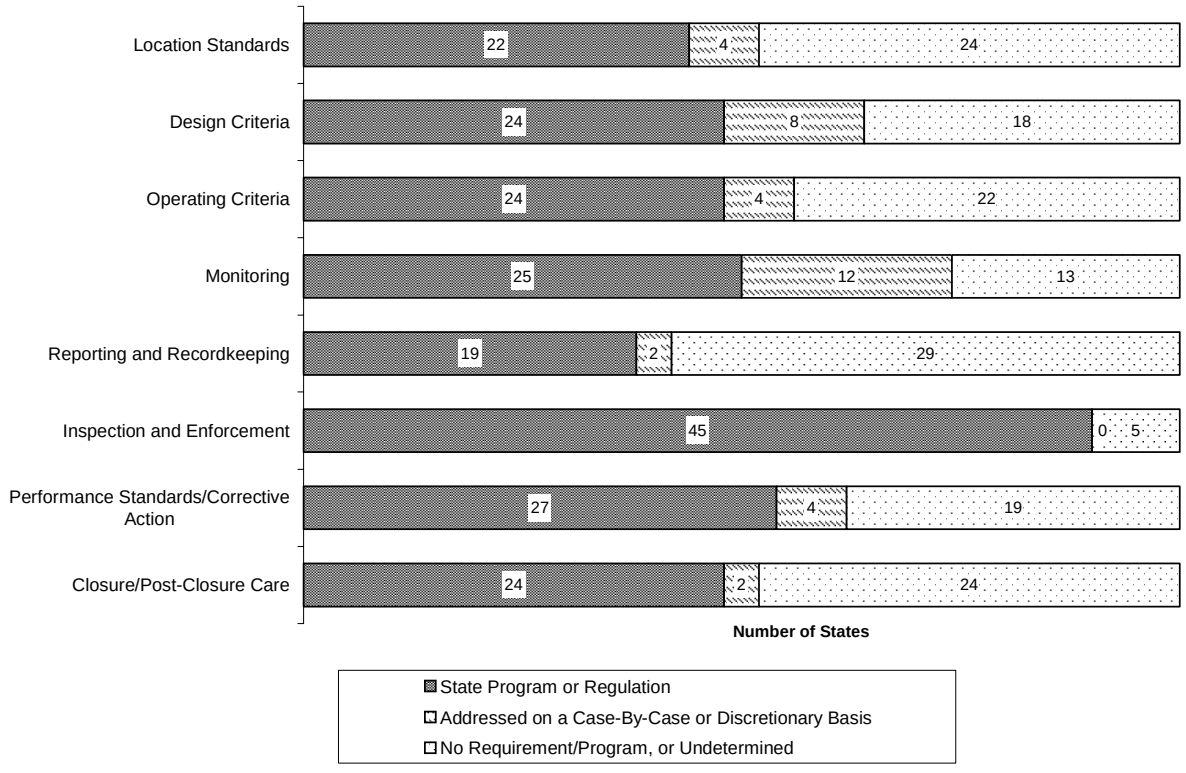

Figure 4-1. State programs or regulations for the protection of groundwater at nonhazardous waste surface impoundments.

In conclusion, many, but not all, states have regulatory or other programs in place designed to address groundwater risks posed by nonhazardous waste surface impoundments. While these programs provide an important level of protection, they do not, at least by regulation, address all potential releases of concern.

4.3.1.3 Existing Programs Under the Safe Drinking Water Act that Address Releases to Groundwater from Surface Impoundments. Programs under the SDWA Amendments of 1996 also provide coverage at the national level and state level.

To determine the susceptibility of all public water supplies in the nation through source water assessments, EPA published guidance for state source water assessment and protection programs in 1997, under section 1453 of the SDWA. Each state, using the national guidance and funding under the Drinking Water State Revolving Fund (SRF) (section 1452 of the SDWA), developed and has started to implement a Source Water Assessment Program (SWAP) approved by EPA. Each SWAP includes delineation or mapping of the areas around drinking water sources, an inventory of potential contamination sources (such as Class 5 wells, landfills, surface impoundments), assessment of risks or likelihood of contamination, and reports to the public. While SWAPs do not control releases to groundwater or provide for remediation of any releases, they are part of EPA's overall strategy, Source Water Contamination Prevention.

Nationally, by the end of 2003, all 170,000 public water systems should have a completed assessment showing their relative susceptibility to potential sources of contamination, including surface impoundments. To the extent a surface impoundment is in a delineated source water protection area geospatially mapped by a state, it will be part of an assessment. Whether or not an impoundment is mapped and determined to be a significant potential source of contamination for a water supply depends on the factual situation for any such water supply and the approved state methodology for determining a public water system's susceptibility.

In addition, 49 states are implementing EPA-approved Wellhead Protection Programs (WHP) under section 1428 of the Safe Drinking Water Act to protect public water wells from identified potential sources of contamination. While many states do not require local governments and public water systems to develop and implement these programs, about 6,000 public water systems as of September 30, 1999, are in communities where some management measures have been implemented to protect the systems (measures could be nonregulatory or regulatory).

Also, the Groundwater Report to Congress in October 1999 (U.S. EPA, 1999e), required by section 1429 of the SDWA, reported that every state is "undertaking some component of a comprehensive groundwater protection program, including enacting protection legislation and regulations, coordinating activities of various agencies responsible for groundwater management, performing groundwater mapping and classification, monitoring ambient quality, developing data management systems, and implementing remediation and prevention programs." Although the report pointed out that there are many sources threatening groundwater contamination, there were no national data ranking sources from more to less threatening.

In the *1998 National Water Quality Inventory, Report to Congress* (U.S. EPA, 2000c) requested by Clean Water Act section 305(b), states report the major sources of groundwater contamination in their states. Nineteen states reported that surface impoundments ranked only ninth as a contamination source of groundwater. Potential sources of contamination that were reported to be more prevalent than surface impoundments were underground storage tanks, septic systems, landfills, large industrial facilities, fertilizer applications, spills, pesticide applications, and hazardous waste sites.

4.3.2 Risks to Surface Water from Releases of Contaminated Groundwater to Surface Water

EPA evaluated the potential for risks and performed an indirect exposure pathway screening analysis and quantitative modeling to estimate risks from surface water contaminated by releases from groundwater to surface water (see also Section 3.3).

By design, surface impoundments are often located near receiving waterbodies. Impoundments designed for final treatment are intended to produce effluent that meets regulatory standards (e.g., NPDES) and, therefore, discharges directly into the waterbody. Many impoundments, however, are designed as part of a treatment train and are not intended to produce effluent of sufficient quality to meet regulatory standards. Although these impoundments do not discharge directly to surface water, chemicals may be released through the bottom or sides of the impoundment, travel through the subsurface, and adversely impact the quality of nearby waterbodies.

The risk analysis identified 35 constituents of concern for the groundwater to surface water pathway. Of the 35 constituents estimated to pose potential risks to surface water from groundwater releases, five are regulated under 40 CFR Part 257 as constituents whose concentrations must not exceed MCLs in groundwater. Thirty-one of the constituents are addressed in EPA's draft *Guide for Industrial Waste Management*. Only two constituents of concern are not addressed by either program. These constituents are dibenz[a,h]anthracene and 1,2-diphenylhydrazine. The 35 constituents and their program coverage by 40 CFR Part 257 regulations and EPA draft *Guide for Industrial Waste Management* are presented in Table 4-6.

Note that the information in the table reflects risk results with varying levels of certainty. The level of certainty depends, in part, on the extent to which the results were based on (1) reported concentration values and (2) surrogate data (including DL values). (See discussion in Chapter 3.) Constituents of possible concern that were reported at specific concentration values (above the detection limit) are identified in the table. Regulatory gaps identified based on this information thus carry the same level of varying certainty.

Regulations and programs designed to control releases to groundwater or to address groundwater contamination at or near a unit's boundary (as discussed previously in Section 4.3.1) should, in turn, control any potential releases from groundwater to downgradient surface water. Based on research of federal and state regulations, there do not appear to be any programs or requirements specifically intended to control releases from groundwater to surface water. EPA's longstanding interpretation of the Clean Water Act, however, is that the discharge of a pollutant from a point source to a navigable water via groundwater that has a direct

Table 4-6. Federal Regulatory or Program Coverage of Constituents with Predicted Risks Exceeding the Risk Criteria for Groundwater to Surface Water Releases

Constituent	40 CFR Part 257 Constituent	*Guide for Industrial Waste Management* Constituent
Arsenic [a,b]	•	•
Thallium [a,b]		•
Acrylonitrile [a]		•
Aldrin [a]		•
Antimony [a]		•
Benzidine [a]		•
Benzo(a)anthracene [benz[a]anthracene] [a]		•
Benzo(a)pyrene [a]		•
Benzo(b)fluoranthene [a]		•
Bis(2-chlororethyl)ether [a]		•
Carbon tetrachloride [a]	•	•
Chlordane [a]		•
Chlorodibromomethane [a]		•
Chrysene [a]		•
4,4-DDD [a]		•
4,4-DDE [a]		•
4,4-DDT [a]		•
Dibenz[a,h]anthracene [a]		
3,3-Dichlorobenzidine [a]		•
1,2-Dichloroethane [a]	•	
1,1-Dichloroethylene [a]	•	
Dieldrin [a]		•
2,4-Dinitrotoluene [a]		•
1,2-Diphenylhydrazine [a]		
Heptachlor [a]		•
Heptachlor epoxide [a]		•
Hexachlorobenzene [a]		•
Hexachlorobutadiene [hexachloro-1,3-butadiene] [a]		•
Ideno (1,2,3-cd) pyrene [a]		•
Pentachlorophenol [a]		•
PCBs [a]		•
1,1,2,2-Tetrachloroethane [a]		•
Toxaphene [a]	•	•
N-Nitrosodimethylamine [a]		•
N-Nitrosodi-n-propylamine [a]		•

[a] Risk estimate was based on surrogate or detection limit value.

[b] Risk estimate was based on a reported waste concentration.

Note: **Bold** indicates the constituent is not specifically addressed by either program.

hydrologic connection to that water is subject to regulation under the NPDES. EPA and states with authorized NPDES programs have issued permits addressing the discharge or potential discharge of pollutants to surface water via hydrologically connected groundwater to a number of facilities including those involved in

- Concentrated animal feeding operations (CAFOs)
- Waste disposal
- Site remediation
- Mining
- Petroleum refining
- Aircraft production.

In those cases where these facilities may impact a waterbody not meeting state water quality standards, their impacts could be addressed through the Total Maximum Daily Load (TMDL) program.

Also, EPA has recently proposed that CAFOs that discharge or have the potential to discharge wastes to navigable waters via groundwater with a direct hydrologic connection must apply for an NPDES permit. See, generally, 66 FR 2960, 3015-3020, 3138, and 3144 (January 12, 2001).

4.3.3 Risks Associated with Other Indirect Pathways

The risk assessment evaluated indirect pathways other than the groundwater to surface water pathway. This involved numerically ranking facilities that manage bioaccumulative chemicals based on criteria relevant to release, transport, and exposure to farmers, home gardeners, and fishers (see also Section 3.4 in Chapter 3). The release scenarios considered included volatilization of constituents from wastewater and particulate entrainment or erosion of constituents from exposed sludge. In addition, the possibility that postclosure exposures could occur through any of these release scenarios was also considered.

To address postclosure exposure to sludge, the regulatory/program coverage and gaps analysis focused on federal and state programs and regulations that address closure and post-closure care requirements for nonhazardous waste surface impoundments (see Section 4.3.3.1). The analysis also evaluated CWA programs that can address erosion and runoff (see Section 4.3.3.2). Program coverage for air deposition indirect pathway risks is identical to programs discussed in Section 4.2.

4.3.3.1 Programs That Address Closure and Postclosure Care of Nonhazardous Waste Surface Impoundments. The RCRA corrective action program and EPA's draft *Guide for Industrial Waste Management* (U.S. EPA, 1999a) are two federal programs that may be used to address closure and postclosure care of nonhazardous waste surface impoundments. Note that the Subtitle D regulations at 40 CFR Part 257 (Subpart A) addressing solid waste disposal units do not address closure and postclosure care. In addition, closure of nonhazardous waste impoundments also could be addressed under various state programs, as voluntary actions, or

under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), commonly known as Superfund.

RCRA Corrective Action. As discussed previously, the RCRA corrective action program provides authorized states or the EPA Regions with the authority to address potential risks from nonhazardous waste surface impoundments located at TSDFs. This provides a regulatory mechanism to address any risks that may be posed by sludge left in place after closure.

Draft *Guide for Industrial Waste Management*. As discussed previously, EPA has developed the draft *Guide for Industrial Waste Management* (U.S. EPA, 1999a) to address multiple aspects of industrial waste management in land-based units. The guide, as currently drafted, includes detailed information on closure and postclosure care of nonhazardous waste surface impoundments. The document currently includes guidance on

- Developing a closure plan
- Selecting a closure method
- Closure by use of a final cover system
- Closure by waste removal
- Postclosure care monitoring and financial assurance.

Implementation of the practices recommended in the guidance, when finalized, would provide substantial reduction in potential risks associated with sludges left in place after closure of a nonhazardous waste surface impoundment.

State Programs. State regulations and programs relevant to closure and postclosure care typically address potential risks posed by exposure to sludge after closure of an impoundment. Based on available information, approximately 26 states have regulations that address closure and postclosure care of nonhazardous waste surface impoundments.

4.3.3.2 CWA Coverage of Erosion/Runoff of Sludges. Once a surface impoundment is closed, the sludge left in the impoundment may contain significant concentrations of chemical contaminants. In some cases, impoundments may be completely filled (or nearly so) with sludge upon closure. If the impoundment sludge is not capped following closure (perhaps pursuant to the previously discussed programs), the potential for runoff and erosion of contaminated sludge particles exists.

EPA's NPDES Program for Storm Water Discharges Associated with Industrial Activity may provide a regulatory mechanism by which erosion/runoff of contaminated sludge particles can be controlled. Under 40 CFR Part 122.26, EPA or authorized states regulate storm water discharges associated with a variety of industrial activities, including discharges associated with those activities from the portions of such "sites used for residual treatment, storage, or disposal" including surface impoundments.

4.3.4 Ecological Risks

Federal regulations applicable to nonhazardous waste surface impoundments that may reduce risks posed to ecological receptors include the provisions at 40 CFR Part 257.3-2 for the protection of endangered or threatened species and critical habitats at nonhazardous waste disposal facilities. For facilities that have or are seeking RCRA permits, clearly identified ecological risks may be addressed under the RCRA corrective action program. In addition, the imminent and substantial endangerment provision of RCRA section 7003, allows EPA, upon evidence of past or present handling of solid or hazardous waste, to require any action necessary when a situation may present an imminent and substantial endangerment to health or the environment. This authority applies to all facilities, whether or not they have a RCRA permit, in those specific situations where the statutory threshold is met.

Approximately 26 of 50 states have siting requirements to prevent adverse effects on endangered or threatened species from surface impoundments.

In addition, EPA's draft *Guide for Industrial Waste Management* suggests buffer zones to help prevent the destruction or adverse modification of a critical habitat and minimize harm to endangered or threatened species. The guidance also indicates the need to check with state and local officials in the area to determine if buffer zones are required for industrial waste management units.

4.4 Role of EPA's Multimedia Strategy for PBT Pollutants in Reducing Risks from Surface Impoundments

EPA has a multimedia strategy in place to address the challenges associated with priority persistent, bioaccumulative, and toxic pollutants in the environment. The purpose is to create a mechanism that will enable EPA to better address the cross-media issues associated with reducing priority PBT pollutants in the environment. PBT chemicals pose risks because they are toxic, persist in ecosystems, and accumulate in fish and other organisms.

A set of 12 chemicals is the initial focus of EPA's PBT Strategy. These pollutants are the Level 1 chemicals identified in the United States - Canada Binational Toxicity Strategy (BNS). It is these chemicals, listed in Table 4-7, that are the subject of national action plans, currently in various stages of development. When priority PBTs are selected for the development of national action plans, a comprehensive analysis is conducted to identify, among other things, chemical characteristics, release patterns, uses, sources, multimedia fate and transport, geographic hot spots, sensitive populations, and impacts to human health and the environment. A pesticide action plan will cover aldrin/dieldrin, chlordane, DDT (DDE, DDD), mirex, and toxaphene.

Table 4-7 indicates that, out of the 12 priority PBT chemicals, eight showed the potential for risk for one or more pathways. No groundwater risks were predicted for any of the PBT chemicals listed in the table. Note that all predicted risks for these listed chemicals were based on detection limit/surrogate data, not reported concentrations.

Table 4-7. List of Priority PBT Chemicals and Extent to Which They Showed Potential for Risk

Level 1 PBT Chemicals		Potential Risk Predicted for One or More Pathways?
CAS Number	**Chemical Name**	
309-00-2/60-57-1	Aldrin/dieldrin [b]	Yes (gw-sw)[a]
	Alkyl-lead	Not evaluated
50-32-8	Benzo(a)pyrene	Yes (gw-sw)
57-74-9	Chlordane	Yes (gw-sw)
50-29-3 (72-54-8 & 72-55-9)	DDT (DDD & DDE)[b]	Yes (gw-sw)
110-00-9	Dioxins and furans	Yes (gw-sw, air)[a]
118-74-1	Hexachlorobenzene	Yes (gw-sw)
7439-97-6	Mercury and its compounds	No
2385-85-5	Mirex	Not evaluated
29082-74-4	Octochlorostyrene	Not evaluated
1336-36-3	PCBs	Yes (gw-sw)
8001-35-2	Toxaphene	Yes (gw-sw, air)

[a] "Air" and "gw-sw" (groundwater to surface water) indicate the pathways for which risks were predicted for the identified PBT chemical.

[b] PBT chemicals listed together, such as aldrin/dieldrin and DDT (DDD&DDE), are listed separately on the Surface Impoundment Study list of constituents.

The Surface Impoundment Study seeks to evaluate the risks posed by managing wastewaters in surface impoundments and to determine whether existing state or federal programs adequately address those risks. If, through the action plan development process, EPA decides to address PBT risks through any of the various regulatory and nonregulatory mechanisms that are appropriate, any subsequent reductions to the generation of PBT pollutants can, in turn, reduce the quantity of PBT chemicals sent to surface impoundment units, thereby indirectly reducing risk from this source.

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Chapter 5

Summary and Conclusions

5.1 Scope of Surface Impoundment Study

This study is of industrial surface impoundments located in the United States that operated during the 1990s and managed nonhazardous wastes. This study does not address management of hazardous wastes in surface impoundments. For this study, the term "industrial" refers to manufacturing, chemical and petroleum storage, waste management, transportation, and national security activities. The term “surface impoundment” means a natural topographic depression, artificial excavation, or diked arrangement for storing, treating, or disposing of wastewater. It may be constructed above ground, below ground, or partly above and partly below ground.

5.2 SIS Requirements

EPA undertook this study to satisfy two separate requirements: (1) a consent decree between EPA and the Environmental Defense Fund (EDF) resulting from EDF vs. Whitman, D.C. Circuit, 89-0598; and (2) the March 26, 1996, amendment to the Solid Waste Disposal Act (see section 3004(g)(10)), also known as the Land Disposal Program Flexibility Act of 1996 (LDPFA). These requirements are described in detail in Chapter 1.

5.3 Survey and Risk Assessment Findings

5.3.1 Survey of Industrial Impoundments

Chapter 2 of this report discusses the findings of the survey of industrial impoundments. EPA’s best estimate is that no more than two-thirds of the 18,000 industrial impoundments in the United States contain one or more of the chemical constituents that were of interest for this study or contain either high (11-12.5) or low (2-3) pH wastewater. More than half of the impoundments with chemical constituents or pH of interest are in the chemical, concrete, paper, and petroleum industries.

Industrial impoundments vary greatly in size, from less than a quarter hectare to several hundred hectares. The larger impoundments form the bulk of the total national industrial impoundment capacity. On a volume basis, the paper and allied products sector manages roughly two-thirds of the total quantity of wastewater—this represents more wastewater than all categories combined.

Industrial impoundments frequently use management techniques that increase the potential for chemical releases and frequently are found in environmental settings that increase

the potential for impacts to humans or ecosystems in the event of a chemical release. For example, in this study, EPA found that most industrial impoundments are located only a few meters above groundwater and that, in most cases, shallow groundwater discharges to a nearby surface waterbody. More than half of the impoundments do not have liner systems to prevent releases of wastes to soil or groundwater.

There is also significant potential for people to be exposed to chemical constituents released from industrial impoundments. EPA estimates that 20 million people live within 2 kilometers (about 1.2 miles) of an industrial impoundment that was in operation during the 1990s. Additionally, about 10 percent of impoundments have a drinking water well located within 150 meters of the impoundment's edge.

5.3.2 Risk Assessment

This section summarizes key findings of the risk assessment, which included a risk analysis quantifying risks associated with exposure to contaminated groundwater, air, and surface water and a risk screening ranking the risks associated with indirect pathways and ecological threats. This discussion also highlights findings that address the statutory requirements for the scope of the study. A detailed discussion of the risk screening and risk analysis is included in Chapter 3 of this report.

The analysis to characterize potential risks posed by surface impoundments was based on a tiered approach designed to screen the large number of constituents and impoundments in order to focus subsequent analysis. The first stage of this tiered approach was an initial screening based on very protective exposure assumptions; subsequent stages increased the level of realism through the use of increasing levels of facility-specific data, screening-level models, and site-based models. At each stage in the analysis, EPA was able to identify combinations of facility, impoundment, and chemical that did not require further analysis. Given the design of the overall approach–proceeding from a very protective exposure scenario to a realistic exposure scenario–EPA is confident that combinations that were omitted from further consideration, or screened out, do not pose significant risks to human health or the environment.

The risk estimates developed in this study for human health and the screening conducted for ecological risks are based on an extensive analysis of the survey data reported for a wide array of chemicals and impoundments of potential concern. While there are elements of uncertainty in this analysis, EPA has increased confidence in the results by emphasizing those risk findings that are based on concentration data reported in the survey as being above a limit of detection.

Our major risk analysis findings, as they apply to the 11,900 surface impoundments containing constituents or exhibiting a pH within the scope of this study, can be summarized as follows:

- Most facilities and impoundments nationally do not appear to pose risks to human health or environmental releases of concern.

- Twenty-one percent of facilities nationally—corresponding to 24 percent of impoundments—have the potential for environmental releases above health-based levels to occur from impoundments. While these releases do not appear to pose risk to human health (because of limited exposure), the results do indicate that, at these facilities, selected contaminants have the potential to move beyond the surface impoundment confines and through the environment in excess of health-based levels.

- Five percent of facilities nationally, corresponding to 2 percent of impoundments, may pose potential risks by at least one pathway.

- For 23 percent of impoundments and facilities, EPA was not able to estimate potential risks with confidence because the chemical concentration data were based on inferred or detection-limit data.

Our major risk screening findings for the in-scope surface impoundments can be summarized as follows:

- Based on a screening analysis and protective assumptions, 6 percent of facilities nationally may pose potential concerns through indirect pathways such as contamination of croplands.

- Based on a screening analysis and protective assumptions, 29 percent of facilities nationally may pose potential localized ecological impacts to receptors that inhabit the impoundment area or the nearby areas affected by undiluted impoundment runoff.

EPA also examined potential risks according to whether wastewaters are decharacterized or never characterized and according to their discharge status. This examination was to address the requirement of the 1996 LDPFA that EPA assess decharacterized wastewaters that are managed in surface impoundments under the scope of the Clean Water Act. The findings may be summarized as follows:

- Only about 20 percent of impoundments manage decharacterized wastewaters. Because of this, a relatively small number of the total potential risk exceedances or environmental releases are attributable to decharacterized wastes. However, the rates of risk exceedances and releases generally are higher for decharacterized than for never characterized wastes.

- There are relatively few zero dischargers compared to direct dischargers. For certain pathways, notably the groundwater to surface water pathway, the zero dischargers have a higher rate of potential risk exceedances and environmental releases.

5.4 Regulatory Analysis Findings

As is discussed in detail in Chapter 4, EPA performed a regulatory and program analysis specific to each risk pathway. For the air pathway, EPA conducted a generic program analysis and then a more detailed analysis based on the constituents that showed the potential for risk. Programs that were analyzed include: Clean Air Act (e.g., MACT, residual risk, NSPS), RCRA (e.g., corrective action, permitting, solid waste program), and state regulations and programs. Similarly, for the groundwater and surface water pathways, EPA conducted a RCRA coverage analysis, a review of state programs, and a review of the Clean Water Act and Safe Drinking Water Act.

5.4.1 Air Pathway Regulatory Analysis

5.4.1.1 Summary of Clean Air Act Coverage. As discussed in previous chapters, the risk analysis showed with that, with relatively few exceptions, the impoundments in the scope of the study do not pose risks from air emissions.

The primary regulatory program that addresses potential air risks from industrial surface impoundments is the CAA NESHAP program. Our regulatory analysis found that MACT requirements exist, or will exist, for the majority of industries managing the largest estimated wastewater volume in surface impoundments. Also, a review of the industry sectors that showed the potential for risk did show that the majority, but not all, of the industry sectors are covered by MACT regulations or will be covered by upcoming MACT standards. Further, most of the pollutants that may cause concern are hazardous air pollutants. EPA recognizes that some of these NESHAP rules have not yet reached their compliance dates, so some releases identified in these findings reflect the preregulatory status. Also, the NESHAPs issued after 1990 CAA (commonly referred to as MACT standards) are technology based and, therefore, may not completely restrict releases to levels below the EPA identified risk level. However, under the Clean Air Act, sources subject to MACT standards must be evaluated to determine if "residual risk" remains; if so, additional controls may be imposed.

The study also found that most industry-level NESHAPs do not directly address surface impoundments. A few industry NESHAPs require covers on surface impoundments only if wastewater exceeds a certain threshold concentration value for particular constituents (e.g., benzene loading, total organic concentration). Generally, however, most NESHAP standards tend to focus on HAP levels in the wastewater generated in the production process, which eventually could be treated/stored in the surface impoundment unit (e.g., MACT standards may control wastewater concentration HAP levels as opposed to requiring emission controls, such as a cover, on surface impoundments). However, when a technology standard addresses and reduces or removes pollutants upstream of the surface impoundment, this reduces the load entering the impoundment and, ultimately, emitted to the environment.

5.4.1.2 Possible Limitations in Air Regulatory Coverage. Even though coverage of the air pathway is fairly complete, coverage may not address all surface impoundments in all situations (i.e., in different industries or with different pollutants of concern). Current limitations

in regulatory coverage may include situations in which a source category is not covered and, therefore, is not subject to a NESHAP. If an industry is not listed as a source category under section 112 of the CAA, the source would not be subject to a NESHAP or, therefore, a residual risk analysis. As explained previously, this situation is the exception based on the results of this survey and risk analysis.

Another potential gap in coverage is the limited situation in which pollutants of concern are not HAPs. As discussed in Chapter 3, this study suggested only four non-HAP constituents that potentially exceed risk thresholds. It should be noted that there are uncertainties with the identification of a regulatory gap for these four constituents. Risk results for two of the four constituents were not based on reported values; that is, the concentration values used in the risk assessment were a function of the detection levels. Clearly, the other two constituents were detected at only one facility each. The limited verification of the hazard posed by these constituents suggests that any gap is likely to be small. Furthermore, non-HAPs that cannot be addressed directly with NESHAPs and subsequent residual risk determinations still may be indirectly "co-controlled" through use of pollution abatement technologies for other, similar HAPs.

Another type of existing CAA limitation may occur when a MACT rule exists for an industrial category that exceeds the risk threshold, but the MACT rule does not directly address surface impoundment emissions or the risky constituents of concern that are HAPs. As discussed previously, MACT rules typically address the emissions of HAPs generated facility-wide; therefore, few MACT rules require air emission controls specifically for the surface impoundment. Also, based on a review of the industry sectors that showed the potential for risk, EPA found two instances suggestive of industry categories covered by MACT standards, but where the MACT standard did not directly address the HAP constituent of potential concern. Because both of these risk estimates were based on detection limit values as opposed to reported concentration values, and both of these constituents would benefit from co-control of similar HAPs that are covered by the MACT standard, it is not clear that a regulatory gap, in fact, exists.

It should be noted that the NESHAP program only automatically applies to facilities that are considered "major sources," as determined by quantitative measure of the facilities' HAP emissions. Facilities that release less than 10 tons per year of a single HAP or less than 25 tons of more than one HAP are not major sources, and are defined as "area sources." Area sources have special designation under the NESHAP program and their emissions may not be controlled to the same degree as major sources or they may not be controlled at all. To issue equivalent controls for area sources, EPA must either: (1) find that the source presents a threat to human health or the environment warranting regulation, which may or may not be as stringent as major source regulations;[1] or (2) determine that MACT standards are necessary to fulfill the requirements of the Urban Air Toxics Program pursuant to CAA 112(c)(3) and 112(k). One important aspect of the area source program is that the residual risk program cannot address area sources unless they have been listed in accordance with section 112(c)(3) and have been included

[1] "Positive area source determinations" are rarely made and, if not made, area sources are not subject to the MACT controls that apply to major sources for the same source category.

in regulations under section 112(d). EPA did not evaluate the extent to which surface impoundments are located at facilities that meet the definition of a NESHAP major source.

5.4.1.3 Whether Unaddressed Risks Could Be Better Addressed under Existing Programs. Overall, the study shows that coverage of potential air risks is fairly complete, and any gaps in coverage appear, at most, to be limited to specific industry sectors, individual facilities that meet certain exemptions in the NESHAP program, or specific HAPs. This regulatory analysis has determined that, for the air risks that may be present from impoundments, EPA and states have the following tools that could be used more expansively to better address the few risks identified. Most of these tools are currently available, without any regulatory or statutory changes. Voluntary and site-specific tools are included on this list because the potential risks are not widespread.

- Clean Air Act NESHAPs: The CAA requires air emission standards for certain source categories under section 112, i.e., Hazardous Air Pollutants. Additionally, the CAA has residual risk evaluations associated with the 112 MACT standard.

- Clean Air Act Criteria Air Pollutant Program: New or modified sources may be subject to NSPS requirements that could limit VOC emissions from surface impoundments.

- RCRA: For those facilities that are subject to permitting under Section 3005, EPA has the authority to address releases from nonhazardous waste impoundments under the corrective action provisions of section 3008(h) and 3004(u). The "omnibus" permit provision of section 3005 also requires that any RCRA permit issued be protective of human health and the environment and, therefore, can be used to address any identified risks. Further, EPA retains authority to address any solid waste unit, including nonhazardous waste impoundments, under RCRA section 7003 to the extent that "an imminent and substantial endangerment" to human health and the environment may exist.

- State regulation programs: This study determined that a few state solid waste programs address, to varying degrees, air releases from surface impoundments. States also may have additional authorities they can bring to bear at the site-specific level (e.g., through the state's Air Toxics Program or State Implementation Plan). Such programs may be able to target facilities that have the potential to exceed risk thresholds for the air pathway. EPA also has issued draft guidance for state Industrial D programs that identify ways air risks can be evaluated and addressed.

- Voluntary Waste Minimization Programs: Federal and state agencies have a number of waste minimization programs that may address the pollutants of concern. Process changes made upstream of impoundments may reduce or eliminate the pollutants of concern to prevent them from even reaching the impoundments. These programs generally rely on voluntary actions by private parties.

- Supplemental Environmental Programs: When enforcement actions are taken under RCRA or other authorities at facilities with impoundments, EPA or the states may negotiate supplemental agreements or compliance orders to address releases from impoundments.

- New controls: Under RCRA, EPA has considerable authority to develop new regulations that would address possible gaps. These regulations might identify additional wastes as hazardous under 40 CFR Part 261, either through additional waste listings or characteristics. Wastes identified as hazardous would then be subjected to all Subtitle C requirements, which include controls on air emissions. Also, for the decharacterized waste, EPA can issue additional rules under the Land Disposal Restrictions (see 40 CFR Part 268). These controls may require treatment of the pollutants of concern prior to placement in the impoundment so that the pollutants would either be eliminated or reduced to levels that minimize threats to human health and the environment.

- New controls: The CAA provides the ability to add industrial source categories and HAPs to the section 112 and 129 evaluations. (See sections 112 (c)(5) and (b)(3)(B), respectively.)

In summary, a number of tools exist to better address any risks that may be present from impoundment air emissions. Some of the tools are already being used as a matter of course to address impoundments and pollutants of concern.

5.4.2 Groundwater and Surface Water Pathway Analysis

5.4.2.1 Summary of State and Federal Coverage. For the groundwater pathway, several metal and organic constituents were identified as potentially posing risks above the EPA threshold at 1E-05 cancer risk or 1 HQ noncancer risk. As discussed above, in general, releases to groundwater from nonhazardous surface impoundments are controlled under state programs. This study found that regulatory and nonregulatory coverage of potential groundwater risks is fairly complete, but may still have some limited gaps. Based on available information, most states have a program(s) that includes provisions for controlling or addressing groundwater releases from industrial nonhazardous waste surface impoundments. The level of regulatory control or ability to address these releases, however, varies from state to state. These state regulations may be implemented under either general solid and industrial waste management authority or under water program authority. Note that EPA's analysis of state regulations and programs is based on publicly available information rather than on a survey of state regulators. Therefore, the analysis may not have identified all state regulations and programs that address nonhazardous waste industrial surface impoundments.

Additionally, there are RCRA, CWA, and SWDA programs that also, to varying degrees, address groundwater releases or assess the susceptibility of drinking water sources to contamination. These programs, for example, include the SDWA Source Water Assessment Program (SWAP), SDWA Wellhead Protection Programs, RCRA corrective action, reliance on the voluntary Guide for Industrial Waste Management as it is being developed, NPDES program

(including the Program for Storm Water Discharges Associated with Industrial Activity), and federal or state waste minimization programs. Where these facilities may impact a waterbody not meeting state water quality standards, their impacts could be addressed through the total maximum daily load program.

5.4.2.2 Limitations in State and Federal Coverage. As noted in Chapter 4, coverage under the various state programs varies, and some impoundments posing potential risks may not currently be addressed. Further, as discussed elsewhere in this report, should land use patterns change and populations increase around impoundments, additional impoundments could pose risks in the future that are not currently addressed by state programs.

5.4.2.3 Whether Unaddressed Risks Could Be Better Addressed under Existing Programs. Many of the same RCRA and state tools described for the air pathway are also applicable to the groundwater and surface water pathways:

- RCRA: The same RCRA tools that exist for the air pathway also exist for the groundwater and surface water pathway.
- State non-RCRA regulations: State NPDES programs and solid waste programs may be able to target facilities that have the potential to exceed risk thresholds for the groundwater and surface water pathway. EPA also has issued draft guidance for State Industrial D programs that identify ways groundwater and surface water risks can be evaluated and addressed.
- Voluntary Waste Minimization Programs: Same as discussed for the air pathway.
- Supplemental Environmental Programs: Same as discussed for the air pathway.
- New RCRA Controls: Same as discussed for the air pathway.

In summary, a number of tools exist to better address any risks that may be present from impoundment groundwater releases. Some of the tools are already being used as a matter of course to address impoundments and pollutants of concern.

5.5 Surface Impoundment Study Conclusions

5.5.1 Our General Findings

This study satisfies both the requirements of the consent decree and the LDPFA with regard to evaluating the risks and regulatory programs for surface impoundments receiving "decharacterized" wastewaters and never characteristic wastewaters. In both cases, EPA has conducted an extensive analysis of the in-scope surface impoundment universe to better understand the risks that may be posed, and the extent that risks are addressed by current and emerging federal and state programs.

5.5.2 Specific Findings to Satisfy Consent Decree Resulting from EDF v. Whitman

In conducting the study pursuant to the EDF consent decree, EPA has obtained the information necessary to determine whether a rulemaking to promulgate a hazardous waste characteristic should be initiated. Specifically, EPA examined the universe of impoundments that manage nonhazardous wastewaters; characterized the pollutants of concern, likely releases, and pathways from these impoundments; and assessed potential risks to human health and the environment. Little risk was found and, such as it is, any risk is not widespread. However, risks may, at most, exist in certain industrial sectors or at a facility-specific level, which needs to be verified more specifically. Further, EPA examined the regulations that may apply to impoundments under the variety of federal and state authorities and found that coverage is extensive, but may not be complete in all cases. EPA also identified a number of tools that may be used more expansively to better address risks.

5.5.3 Specific Findings to Satisfy LDPFA—RCRA Section 3004 (g)(10)

In conducting the study pursuant to the LDPFA, EPA has completed a study of "decharacterized" wastewaters that characterizes the risks to human health or the environment associated with such management. The findings of the risk assessment, and its limitations, are discussed at length in Chapter 3 of this study. Further, EPA examined existing federal and state programs to evaluate the extent that risks are adequately addressed under those programs. EPA also looked at whether the risks could be better addressed under such laws or programs. These analyses, including a "gap analysis," are discussed in detail in Chapter 4 of this study. EPA concluded that there are some limited gaps in regulatory coverage, but did not find any serious risks that are not addressed by existing programs.

5.5.4 Study Conclusion

The completed surface impoundment study will undergo a formal peer review process similar to the one EPA conducted after completion of the first phase of the consent decree study. Consequently, any technical data in the report should be used with appropriate caveats and cautions. The Agency has not yet determined whether any specific regulatory actions are appropriate to mitigate the potential risks identified in the study.

Appendix A

Study Design and Survey Data Collection and Processing

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Appendix A

Study Design and Survey Data Collection and Processing

This appendix describes the overall study design, implementation of the survey data collection, and the preparation of these data for the analyses described in Chapters 2 and 3 of this document. Section A.1 explains the statistical study design and the development of the original sampling frame, or list of facilities from which EPA selected facilities for the study. It also provides details on the design and implementation of the screener and long surveys developed to collect study data.

The remainder of this appendix provides details on the creation of electronic long survey databases and their use in providing data for data exploration (Chapter 2) and the risk assessment (Chapter 3). This includes how the long survey data were entered and archived in electronic formats (A.2); how facility-specific data supplemental to the survey were collected (A.3); how the data were processed for consistency and to provide inputs for modeling and data analysis (A.4); and a description of the statistical methodology used to weight up survey data and risk assessment results to estimates applicable to the entire population of surface impoundments with constituents or pH of concern (A.5).

A.1 Statistical Study Design and Survey Implementation

As described in Chapter 1, the Surface Impoundment Study is directed towards identifying and characterizing certain nonhazardous surface impoundments. An eligible impoundment is one that meets the criteria in the legislation or consent decree, regarding the wastes managed, and meets additional scope criteria described in Chapter 1, notably extreme pH conditions (i.e., less than 3 or greater than 11) or that one or more of 256 chemicals are present. In order to identify a representative sample of facilities with impoundments meeting the study criteria, EPA developed a two-phase or double-sampling design. In the two-phase design EPA collected some information on a relatively large sample of facilities through a screener survey and then used this information to select a second-phase subsample of facilities for which detailed facility and impoundment data were collected using a longer survey questionnaire.

EPA decided to collect data in the long survey for all eligible impoundments at the facilities in the sample. This decision meant that EPA would obtain an approximately equal probability sample of impoundments within primary sampling strata because facilities were selected with approximately equal probabilities within primary sampling strata (direct discharge facilities with high priority SICs, direct discharge facilities with low priority SICs, and zero discharge facilities). In addition, by collecting data for all eligible impoundments at sample facilities, EPA could overlay risk estimates for the separate impoundments to produce an integrated assessment of risk at the facility level. Facility-level risk estimates are important if a facility's nearby residents can be exposed to emissions from multiple sources (impoundments).

A.1.1 Sampling Frame and Stratification

The sampling frame for nonhazardous industrial surface impoundments was based on available data identifying and listing facilities with surface impoundments that might meet the study criteria. Three primary sampling strata were defined for selection of facilities for the screener survey based on the facility's regulatory status under the Clean Water Act:

- **Direct discharge (Section 402) impoundments** treat waste in systems that ultimately discharge directly into surface waters. This subpopulation is regulated under CWA Section 402, which requires National Pollution Discharge Elimination System (NPDES) permits for all facilities that discharge to "waters of the United States."

- **"Zero discharge" impoundments** are not designed to discharge waste into the environment except through infiltration into soil or evaporation. Facilities that use infiltration or evaporation ponds for waste treatment or disposal may be regulated under a variety of state laws addressing both waste handling and groundwater protection. Specific regulations regarding these impoundments vary by State.

- **Indirect discharge (Section 307) impoundments** treat or hold waste prior to discharging to a publicly owned treatment works (POTW). Facilities that discharge significant waste flows to POTWs must comply with federal and local standards for pretreatment of waste in order to prevent adverse impacts on the public treatment plants. Local POTWs are the principal permitting authorities for CWA Section 307 facilities.

There are major differences in the sources and availability of data for defining the sampling frame for each of these subpopulations, and this affected the sampling frame and stratification for each. For the direct and zero discharger subpopulations, sampling frame data were adequate to use a stratified simple random sampling design, in which facilities were randomly selected from strata without replacement, and data were collected for all eligible impoundments at the facilities in the sample. For the indirect discharger subpopulation, limited sampling frame data led to a purposive (non-random) sample of facilities identified using anecdotal information. The chosen designs mean that the direct discharger and zero discharger samples are representative (although the sample is less representative for zero dischargers because their sampling frame was incomplete for some states). However, the non-random indirect discharger sample may not be representative.

A.1.1.1 Direct Discharge Facilities and Impoundments. The Permit Compliance System database (PCS) contains all facilities releasing waste to surface water, including those operating surface impoundments. EPA used this database as the sampling frame for the direct discharger subpopulation. EPA took the records in this database, as of late 1997, for facilities having SIC codes that were defined as the study's scope.

Each PCS record related to a given discharge point, so a facility with multiple discharge points had multiple records. In addition, facilities with multiple permits were listed more than once. EPA combined multiple records for a given facility into one record only when it was quite clear that the records were for the same facility. EPA merged up to three different permits into a single facility-level record. The final count of records for facilities with SIC codes in the study's scope was 43,050.

EPA partitioned the sampling frame into three primary sampling strata, defined as:

1. Facilities in high-priority SICs (26, 2819, 2824, 2834, 2869, 2897, 2911, 30, 33, or 36)
2. All other facilities with in-scope SICs
3. Six pilot study facilities

Stratum 1, the high-priority SICs, were expected to contain a higher proportion of facilities that use surface impoundments to manage decharacterized wastewaters. Hence, this stratum was sampled at a much higher rate than Stratum 2, the remainder of the in-scope SICs, to ensure that the screener survey would include an adequate number of facilities using surface impoundments to manage decharacterized wastewaters. Each of these strata was then partitioned into substrata based on SIC codes, and the substrata were all sampled at the same rate within each primary sampling stratum. Hence, a stratified simple random sample of 2,000 facilities was selected from 15 sampling strata plus all six pilot study facilities.

A.1.1.2 Zero Discharge Impoundments. In this study, EPA defined zero discharge impoundments as those that are neither permitted under Section 402 of the Clean Water Act to release to surface water, nor permitted under Section 307 to pretreat waste before releasing it to a publicly owned treatment works (POTW). Because states are the primary regulators of zero discharge impoundments, state databases were the principal source of information on these impoundments. In addition, EPA identified some zero discharge impoundments in the Toxics Release Inventory (TRI) and the Aerometric Informational Retrieval System (AIRS) Facility Subsystem (AFS) databases. By assembling information from TRI, AFS, and available state data, EPA developed a list of 5,807 zero discharger facilities. EPA stratified the sampling frame according to general categories of completeness for the different state and federal data sources, and according to high and low priority SIC codes. A stratified random sample of 250 facilities was selected in the first stage using the same sampling rate for all strata except for the Oklahoma database of private sewage treatment facilities. EPA expected this group of facilities to be mostly out-of-scope, and if in-scope, to be relatively homogeneous. Hence, EPA sampled them at one-half the rate used for the other strata.

A.1.1.3 Indirect Discharge Impoundments. Section 307 of the Clean Water Act regulates indirect discharger facilities, which "pretreat" or hold waste prior to discharging it to a POTW. The total population of facilities required to pretreat their waste prior to discharge to a POTW is over 30,000; they are regulated and tracked by the approximately 2,000 POTWs that receive this pretreated waste. However, the POTWs do not routinely collect data on surface impoundment use by their pretreating customers, so there is no consistent data source from which to identify indirect dischargers that use surface impoundments. In addition to the 30,000 pretreaters, there

are an unknown number of other indirect dischargers who are not required to pretreat their waste (and who discharge to POTWs outside the national pretreatment programs). Theoretically, any of these indirect dischargers could potentially use surface impoundments to store wastewater before discharging it. Based on information from EPA Regional pretreatment coordinators, it appears that only a very small proportion of these indirect discharger facilities are likely to use surface impoundments. From this information, EPA assembled a group of 35 facilities likely to operate indirect discharge impoundments and used this as a purposive sample to characterize the indirect discharger subpopulation.

A.1.2 Screener Survey Implementation

The sampling frame and stratification scheme led to a total of 2,285 facilities being selected for the screener survey, a short questionnaire designed to identify facilities and impoundments that meet the study criteria and thereby provide the sampling frame data for the long survey (see Attachment A1). These facilities included 2000 direct dischargers, 250 zero dischargers, and 35 indirect dischargers. Implementing the screener survey involved identifying and removing ineligible facilities from this sample, identifying and locating survey respondents to obtain the highest possible response rate, adjusting facility weights to account for survey nonresponse, and data entry, quality control, and processing.

A.1.2.1 Removal of Ineligible Facilities from Sample. The facilities chosen for the direct and zero discharger samples included a number of facilities that were outside the scope of the study. In many cases, the facilities selected in the sample were private residences or retail businesses that did not have activities in the SIC code range defined for the study, even though they were listed on the sample frame as having eligible SIC codes. EPA confirmed these sample members' status as "ineligible" using other data sources, and removed them from the sample. For the direct discharger sample, EPA determined that 138 facilities among the 2,000 direct dischargers were ineligible, and 74 facilities among the 250 zero dischargers were ineligible, resulting in 2,038 direct and zero discharger facilities in the sample.

A.1.2.2 Identifying Screener Survey Respondents. Once eligible facilities were identified, EPA needed to identify and locate the survey respondents. EPA found that the PCS data and the zero discharger frame data were frequently missing mailing address, location, and contact information. Of the 2,038 direct and zero discharger facilities, EPA found mailing addresses for 1,982. EPA found mailing addresses for all 35 indirect dischargers. Thus, the screener survey was mailed to 2,017 facilities.

The screener survey was mailed in February 1999. A large proportion of the surveys went to the appropriate individuals and were returned within the requested 45-day time frame with adequate information. EPA found that a significant proportion of the sample facilities had either changed ownership or names, or had ceased to exist during the period between 1990 and 1999, and required further tracing to locate individuals who were knowledgeable about those facilities' impoundments. Thus the screener survey data collection extended over a six-month period.

EPA also needed to address the sampling frame multiplicity problem described in Section A.1.1.1. Any facilities with multiple permits that did not get merged into a single facility-level record on the sampling frame had multiple chances to be selected into the sample. Because being listed on the sampling frame more than once increases a facility's probability of selection, EPA needed to correct for this multiplicity, or being present on the sample frame more than once. EPA listed on the screener survey all wastewater permits that had been used to define the facility on the sampling frame, and asked each facility (on the screener survey) to list any additional permits that had been active for the facility at any time since June 1, 1990. In addition, EPA set up a computer-assisted telephone interviewing (CATI) application to call the screener survey respondents and probe for any additional permits that had not been listed on their screener survey responses. EPA then used both the responses to the original screener survey question and the responses to the supplemental CATI interviews to make weight adjustments for frame multiplicity (described in Section A.5).

EPA also used a CATI version of the mail survey to increase the response rate for approximately 100 of the mail screening survey recipients who did not provide their responses in a timely manner.

A.1.2.3 Screener Survey Weight Adjustments. For each of the 1,982 direct and zero discharge facilities mailed a screener, an initial sampling weight was computed by dividing the total number of facilities in the stratum (frame count) by the number of facilities selected into the sample from the stratum. Frame counts, sample sizes, and initial sampling weights for each stratum are provided in Section A.5, along with the detailed statistical methodologies. Sampling weights were not computed for the sample of 35 indirect discharger facilities because the sample was purposively selected and the survey results cannot be statistically extrapolated to any larger population.

Next, EPA needed to adjust these initial sampling weights for the sampling frame multiplicity described in Section A.1.1.1. After considerable data cleaning, multiplicity (number of linkages to the sampling frame) was determined for each facility that responded to the screening questionnaire. Because frame multiplicity must be known for every sample facility, not just the responding facilities, EPA computed, for each direct discharger sampling stratum, the average multiplicity among the respondents and used this value to impute multiplicity for each nonresponding facility. These multiplicity estimates were then used to adjust weights as described in Section A.5.

Weight adjustments to minimize bias due to survey nonresponse are based on models for the probability of not responding, using data that are available for both the respondents and the nonrespondents. For nonresponding facilities, EPA knew only the sampling stratum, and thus, EPA used sample-based ratio adjustments based on the sampling strata (Kalton and Maligalig, 1991). The nonresponse adjustments were defined only for the direct and zero discharge facilities because the indirect discharger sample was not a probability-based sample. Statistical details on facility weights and weight adjustments, including item-specific adjustments made during data analysis, can be found in Section A.5.

A.1.2.4 Screener Survey Data Processing. In the screener survey (U.S. EPA, 1999b), EPA collected data on the facility's use of surface impoundments, and on the activities that were the source of the waste in the impoundment(s). For those facilities that reported using impoundments that met the criteria for being in the study, EPA also collected data on the facility's status as a hazardous waste generator, whether any impoundments contained decharacterized waste, whether the impoundments were used to treat waste biologically, and whether the impoundments had permanently stopped receiving waste.

When the screener surveys were returned, a coding clerk assigned codes for the closed-ended questions, according to a predetermined code list for the various response options. The surveys were then grouped into batches for tracking the hard copy survey forms and to subdivide the overall data entry task into more manageable segments. Double-extraction/double-entry was used to minimize data entry errors. Each coded response was entered into the data file twice, by different data entry staff, the files were electronically compared, and any differences were resolved by referring to the hard-copy forms.

EPA also performed a check on the responses indicating that there was no impoundment at the facility that met the study criteria. To perform the check, EPA drew a systematic random sample of every tenth response that indicated an absence of impoundments meeting the study criteria. For these responses, EPA obtained independent data (generally, state environmental agency files such as inspection reports) to verify these respondents' answers that no impoundments meeting the study criteria existed at these facilities. This check did not turn up any false negative responses.

Some facilities claimed their screening survey responses as Confidential Business Information (CBI), and EPA handled those facilities' screening survey responses data separately, in accordance with RCRA CBI procedures, but challenged all CBI claims. One screener survey response remains CBI.

EPA conducted a final edit of the screening survey data for all 1,787 completed screening surveys. This edit cleaned the data and ensured consistent formatting of responses and coded standardized responses for subsequent analyses. The cleaned data includes all screening survey data items, plus additional data needed for statistical analyses, and are available in electronic format (U.S. EPA, 1999b).

A.1.3 Long Survey (Second-Phase Sample)

For all facilities in the second phase sample, EPA prepared a long survey questionnaire requesting detailed information on the impoundments' design, operation, and closure practices as well as data on the wastewater and sludge composition and quantity. This three-part survey (U.S. EPA, 1999d) was developed by EPA to characterize the sample facilities with in-scope nonhazardous industrial surface impoundments and is the primary source of data for the Surface Impoundment Study (SIS), including the risk assessment, regulatory coverage, and other analyses presented in this report. EPA developed the sampling frame for this long survey from the screener survey data, as described in the following section.

A.1.3.1 Long Survey Sampling Frame Development. While screener survey data collection was continuing through the summer of 1999, EPA needed to proceed with developing the sampling frame for the second phase sample of facilities that were to receive the long survey. The study's schedule required the long surveys to be mailed in the fall of 1999 so that the long survey data could be processed and analyzed for both the risk assessment and the regulatory coverage analysis. EPA chose to draw the second phase sample in two parts: a June 1999 sample, using the screener survey responses that had been received and processed by June 14, 1999, and a September 1999 supplementary sample to complete the sample with the facilities whose screener survey responses were processed after June 14, 1999, along with those that had claimed CBI status for all or part of their screener survey responses. The reason for this timing was so that EPA could collect publicly available data for most of the second phase sample facilities from state environmental agencies, along with the publicly available data being used to perform the false negative quality assurance check on the systematic random sample of screener survey responses.

After developing the complete set of non-CBI screeners, and reducing them to one record per facility, EPA determined which facilities were eligible for the second phase sample (long survey). The June sampling frame was developed from 1,597 completed screeners. Some facilities had more than one record in the combined hard-copy and CATI, non-CBI database. If there were screener surveys from both former and current owners, for the same facility, EPA kept the record for the current owner and deleted the record for the former owner. The resulting file contained 1,684 unique facilities with completed screeners.

The next step was to identify the facilities that were eligible for the second phase sample, according to their screener survey responses for the questions about the existence of an impoundment at the facility, meeting the criteria necessary for being in the study. Not all facilities answered the question about their facility's SIC code. In these cases, EPA obtained SIC codes from EPA databases or from descriptions of the facility's products or processes.

The file of facilities with a completed screener survey that were determined to be eligible for the second phase was the sampling frame for the second phase sample. The June 1999 sampling frame for the second phase sample consisted of 380 facilities; the non-CBI September 1999 sampling frame consisted of 43 facilities, and the CBI September 1999 sampling frame consisted of 9 facilities. EPA's objective was to obtain an overall sample of approximately 200 facilities, with approximately half of the facilities having at least one impoundment with decharacterized waste (to satisfy the requirements in the LDPFA), and approximately half of the facilities having never characteristic waste (to satisfy the requirements of the consent decree). In addition, EPA needed to balance the study resources so that direct and zero dischargers, and a few indirect dischargers, were included in the sample. With these general criteria, EPA selected sampling rates from the various strata that achieved the overall objectives, and resulted in the sample drawn as shown in Table A-1.

The final result was a sample of 216 facilities, plus the six pilot study facilities. However, one of the 222 facilities was included in both the June and September sample frames. Thus, the second phase sample consisted of 221 facilities, six of which were pilot study facilities.

A.1.3.2 Weight Adjustments for Ineligible Facilities and Nonresponses. Theoretically, all facilities selected into the sample to receive the long survey should have been eligible for this phase of the study. That is, they should all have had at least one surface impoundment that satisfied the eligibility conditions in the screener survey. However, after they received the long survey, 21 facilities reported no eligible impoundments. By using extensive followup contacts, EPA determined the eligibility status of all facilities selected into the sample for the long survey. Hence, nonresponse adjustments were confined to adjustment for nonresponse among the sample facilities that were determined to be eligible for the survey.

For the full sample, there were only four eligible facilities that did not respond to the long survey, and one of those was an indirect discharge facility. Hence, for the weight adjustments for direct and zero discharge facilities, there were only three nonresponding facilities. Moreover, all three were direct discharge facilities whose screener data indicated that they did not handle any formerly characteristic waste.

The statistical analysis weights for the remaining 195 long survey respondents then were computed by adjusting the calibrated sampling weights for nonresponse among the eligible sample facilities. The weight adjustment process and results is described in detail in Section A.5. Because data were collected for all eligible impoundments at each responding facility (i.e., there was no subsampling of impoundments), these facility-level analysis weights also are appropriate for analysis of the impoundment-level data collected for the responding facilities.

A.1.3.3 Long Survey Implementation. The long survey questionnaire (U.S. EPA, 1999d) is a three-part form designed to collect the detailed information necessary for the risk assessment and regulatory gaps analysis as well as general characteristics of the study population. This information includes each facility's environmental setting (including receptor locations) and details on the design, operation, and history of each eligible surface impoundment, including the chemical composition of wastewater and sludge managed within these impoundments. The three parts include: Part A, basic facility identification information; Part B, an overview of the wastewater treatment system and environmental setting at the facility; and Part C, details about the design and operation of each in-scope impoundment. Part C also requested, for a list of 256 chemicals, chemical concentration data for wastewater, sludge, air, and leachate. Attachment A.1 includes electronic copies of the Part A, Part B, and Part C long survey forms.

The detailed information in the long survey required considerable effort to enter into an electronic format, standardize to consistent units and format, clean to correct skip pattern errors and other inconsistent responses, and process for data exploration and risk analyses. This was accomplished by creating and populating a series of relational databases, described in the subsequent sections, that hold the raw and processed survey data. Statistical methods were then applied (as described in Section A.5) to weight and analyze variables derived from the screener and long surveys (including risk assessment results) to characterize the population of nonhazardous industrial surface impoundments that meet the study criteria.

Table A-1. Second Phase (Long Survey) Strata and Sample Sizes

Stage 2 Stratum	Type of Facility	Decharacterized Waste	SIC Priority	Frame Count	Sample Size
Non-CBI Stage 2 Strata and June Sample Sizes					
1	Direct Dischargers (DISCHARG=1)	Yes (Q16=1)	High (SIC_STR=1)	69	69
2			Low (SIC_STR=2)	7	4
3		Other (Q16=2 or missing)	High (SIC_STR=1)	183	61
4			Low (SIC_STR=2)	72	12
5	Zero Dischargers (DISCHARG=2)	Yes (Q16=1)	High (SIC_STR=1)	2	2
6			Low (SIC_STR=2)	4	4
7		Other (Q16=2 or missing)	High (SIC_STR=1)	13	13
8			Low (SIC_STR=2)	20	20
9	Preselected Indirect Dischargers (DISCHARG=3 and PREINDIR=1)	Yes (Q16=1)	High (SIC_STR=1)	2	2
10			Low (SIC_STR=2)	0	0
11		Other (Q16=2 or missing)	High (SIC_STR=1)	4	4
12			Low (SIC_STR=2)	4	4
13	Other Indirect Dischargers (DISCHARG=3 and PREINDIR=2)	Yes (Q16=1)	High (SIC_STR=1)	0	0
14			Low (SIC_STR=2)	0	0
15		Other (Q16=2 or missing)	High (SIC_STR=1)	0	0
16			Low (SIC_STR=2)	0	0
Total				380	195

(continued)

Table A-1. (continued)

Stage 2 Stratum	Type of Facility	Decharacterized Waste	SIC Priority	Frame Count	Sample Size
Non-CBI Stage 2 Strata and September Sample Sizes					
1	Direct Dischargers (DISCHARG=1)	Yes (Q16=1)	High (SIC_STR=1)	4	4
2			Low (SIC_STR=2)	0	0
3		Other (Q16=2 or missing)	High (SIC_STR=1)	17	6
4			Low (SIC_STR=2)	4	1
5	Zero Dischargers (DISCHARG=2)	Yes (Q16=1)	High (SIC_STR=1)	0	0
6			Low (SIC_STR=2)	0	0
7		Other (Q16=2 or missing)	High (SIC_STR=1)	1	1
8			Low (SIC_STR=2)	0	0
9	Preselected Indirect Dischargers (DISCHARG=3 and PREINDIR=1)	Yes (Q16=1)	High (SIC_STR=1)	0	0
10			Low (SIC_STR=2)	0	0
11		Other (Q16=2 or missing)	High (SIC_STR=1)	2	2
12			Low (SIC_STR=2)	1	1
13	Other Indirect Dischargers (DISCHARG=3 and PREINDIR=2)	Yes (Q16=1)	High (SIC_STR=1)	2	0
14			Low (SIC_STR=2)	1	0
15		Other (Q16=2 or missing)	High (SIC_STR=1)	3	1
16			Low (SIC_STR=2)	8	0
Total				43	16

(continued)

Table A-1. (continued)

Stage 2 Stratum	Type of Facility	Decharacterized Waste	SIC Priority	Frame Count	Sample Size
CBI Stage 2 Strata and Sample Sizes					
1	Direct Dischargers (DISCHARG=1)	Yes (Q16=1)	High (SIC_STR=1)	3	3
2			Low (SIC_STR=2)	0	0
3		Other (Q16=2 or missing)	High (SIC_STR=1)	4	1
4			Low (SIC_STR=2)	2	1
Total				9	5

A.2 Long Survey Data Entry

The goals of the data entry effort for the long survey were 1) to archive as complete a dataset as possible, in order to increase statistical confidence and 2) to maintain the integrity of the dataset through entry, processing, and analysis. This required rigorous quality assurance/quality control (QA/QC) procedures at every step of the process. The general QA/QC plan was to check all manually entered data 100 percent and to manually confirm that each data processing or analysis program was functioning correctly. Details on the data entry methodology and associated QC measures follow. This required entry of almost 200 Part A and Part B forms and, because many facilities had multiple eligible impoundments, over 500 Part C forms.

A.2.1 Data Entry Objectives

The overall objective of long survey data entry was to record and preserve, in an electronic format, exactly what the survey respondents reported on their returned forms. Although obvious typographical errors were corrected, entry staff were instructed not to judge how reasonable or consistent responses were, but to record them exactly as written. Database fields for margin notes from the long survey were included in for practically every question; this also enabled for typographic or other corrections to be recorded in the data entry database.

A.2.2 Data Entry Database

The data entry database for the long survey mirrors the design of the survey forms shown in Attachment A1. Data tables were indexed at the facility level (questions in Parts A and B), facility and impoundment level (Part C), and at a third level, by chemical for chemical data and by layer for liner and subsurface layer data. To help ensure consistent entry, coding tables were used for units and other repeated data elements. Duplicate tables were included in the entry database to allow for double extraction and double entry. Once double extraction/double entry

comparisons were complete, these tables were removed from the database, resulting in the design described in this section. Although created and maintained in Microsoft Access, data design conventions include compatibility with *.dbf format, and programs are available to automatically export the database tables as .dbf or ASCII text files.

Data entry forms were developed that replicate the survey's appearance as closely as possible. This provided almost immediate familiarity with the entry screen for the data entry staff. Buttons were used to open text fields to record margin notes and comments. Drop-down boxes included standardized selections for units and other repeated data responses. EPA designed the survey to allow respondents to choose units for numeric values, resulting in a number of units being used for each numeric variable. As new units were encountered during data entry, the standard list of units was expanded to help ensure consistent and correct entry of each response.

Attachment A2 includes data entry database design documentation which describes the data table structure, linkages, codes, and the content of the various data fields. The database design is fully documented three parts, described briefly below.

A.2.2.1 Entity Relationship Diagram. Attachment A2-1 contains entity relationship diagrams that picture how the various tables that make up the data entry database are linked together using key fields. Links in this diagram are shown as one-to-many (where a table is related to several tables of the same structure) or one-to-one (where a table is linked to a single table). Tables are linked using one, two, or three key fields, depending on the number of tables linked and the position of the tables in the database. For example, because there can be multiple surface impoundments at a facility, there can be many surface impoundment data tables for each facility, with these multiple tables linked to the Surf_Imps table by the key fields FAC_ID and IMP_ID.

The first figure in Attachment A2-1 shows the overall database structure along with table structures for Part A and Part B of the long survey questionnaire. The remaining figures show the table structures and relationships for the Form C tables connected to the SURF_IMPS table. Survey questions corresponding to the data tables are listed at the top of each diagram.

A.2.2.2 Data Dictionary. Attachment A2-2 contains the data dictionary for the database tables shown in the entity relationship diagram (Attachment A2-1). This dictionary provides data type, size, and description (including long survey question number) for each field (column) in each database table, which are listed in the order of the survey questions and as they appear in the entity relationship diagrams. Data dictionaries for the coding tables are provided in alphabetical order at the end of this attachment.

A.2.2.3 Coding Tables. Attachment A2-3 contains the coding tables from the data entry database. In the SI survey database, coding tables serve the same function as a data entry code book: to ensure consistent responses for questions with answers that can be standardized, such as units or chemical names, or for questions with multiple choice responses (e.g., yes, no, don't know, or other). These tables were adapted from coding tables developed during survey design. Standardization (i.e., use of a table for multiple questions) was used wherever practical to minimize the number of tables and increase consistency within the database. During data entry,

codes and their definitions are presented as drop-down boxes in the data entry forms to ensure correct and consistent data entry. The coding tables appearing in this document supercede those in the previous version in that they include additional rows for new values encountered during data entry. For example, the codes for concentration units expanded from 20 to over 40 possible entries during the course of data entry.

A.2.3 Data Entry Protocols

Data entry protocols were developed for and followed by data entry staff, and serve as a record of how data were entered. As new situations were encountered during data entry, the protocols were modified. The final protocol is included in Attachment A3.

Data entry protocols were developed to ensure consistent treatment of potentially inconsistent or incomplete data, and thereby minimize the double-entry comparison task and ensure a higher quality dataset. Perhaps the most important protocol was to record exactly, word-for-word, what was recorded in the survey, including the margin notes entered by the survey respondents. Another was to record a comment for every change made to correct obvious errors, resulting in a note wherever the database differs from the original survey.

Chemical data conventions were needed to ensure consistent treatment of nonstandard responses. Examples include: enter "cyanide" and "reactive cyanide" as total cyanide and "amenable" cyanide as free cyanide; sum individual alachlor values and enter total under "PCBs," including individual values in margin note; enter "chromium" values as total chromium. In each of these cases, notes were included in the database describing what was done. These and other data entry conventions are detailed in the data entry protocol in Attachment A3.

A.2.4 Digitizing Map Data

A geographic information system (GIS) was used to digitize residence and well locations from the marked topographic maps returned as question B3 of the Part B of the survey. Question B3 asked the survey respondents to mark wells, residences, and schools within a 2-kilometer radius of their surface impoundments on a U.S. Geological Survey (USGS) topographic map that was included with the survey form (see Attachment A1).

Survey response data for question B3 maps were used to develop a series of GIS map layers. The goals of these procedures were (1) to develop a series of GIS map and data layers that could be used to analyze spatial relationships among surface impoundment ponds, receptors, schools, and wells; and (2) to process and extract data to serve as inputs to risk assessment models. The coordinate locations of impoundment boundaries, individual residences, residential areas, schools and wells were entered into a GIS through "heads-up digitizing," a process whereby a GIS technician uses a mouse to enter the locations of features by pointing to them on a digitized image displayed on screen. A series of programs were written in Arc Macro Language (AML) to automate the data preparation and digitizing processes.

A.2.4.1 Map Preparation and Registration. Map preparation and registration consisted of three main steps:

1. Obtain the necessary documents, including the map, image files of the map, and any additional annotation.
2. Assess the overall quality of the scanned image.
3. Create a registered image from the scanned image.

Obtain documents and images. Spatial data were acquired by physically searching the file of documents returned by each survey respondent in response to question B3. For most sites, these documents consisted of one or more hardcopy maps, which were usually annotated by the survey respondent to show the features to be digitized. In some most cases, these maps were the USGS topographic maps originally supplied to the respondent. In many cases, however, the respondent provided an alternate map or maps. These included other USGS topographic maps, photocopies of USGS maps, and a variety of non-USGS maps including site plan drawings and as-built diagrams.

Question 3B maps were labeled with preprinted labels containing a text ID and barcode. These maps were then scanned and converted to TIFF multiband ("composite") images.

Assess image quality. GIS technicians assessed the usability of each scanned image by displaying the map on the screen and viewing it to confirm that:

- all features shown on the map could be seen clearly on the image;
- registration marks and site ID label were clearly visible;
- there was no apparent distortion of the image;
- the image covered all of the area within 2km of the impoundments; and
- features and annotation added by the respondent were clearly visible.

The AML program epa_scanmap.aml prompted the user with a checklist and ensured consistency during this procedure. If the map was not usable and/or areas within the 2km buffer were missing, USGS Digital Raster Graphic (DRG) images of 1:24,000 Quads were downloaded via the internet and stored in the respective site directory as TIFF files.

Register image. The original maps provided to survey respondents were standard USGS 7.5-foot topographic quadrangles (1:24,000 scale). These maps contain registration marks for NAD 83 geographic coordinates near the four corners of the map area. Some of the maps returned by survey respondents were not standard USGS 7.5-foot topographic quadrangles. Although some of these maps contained registration marks labeled with geographic coordinates, others contained grid lines or registration marks based on arbitrary or unidentified coordinate systems. In some cases, no coordinate system or grid was shown on the map.

Prior to digitizing, each image was registered to a real world coordinate system so that subsequent measurements of distance and area could be expresses in real world units (as opposed to scanner inches). In most cases, the appropriate State Plane coordinate system was used. In this case, "appropriate" means the State Plane coordinate system zone specified on the map. Although the standard units of the State Plane coordinate system are generally feet, meters were used throughout this project.

For maps with registration marks for NAD 83 geographic coordinates (primarily standard USGS topographic quadrangles), the program epa_box.aml was used to create a file containing the geographic coordinates of the four registration marks. The program then used this file to generate a map layer whose corners were coincident with the tic marks at the corners of the 7.5-foot topographic quadrangle and project this to the user-specified State Plane coordinate system zone.

A series of other programs, links.aml, register_image.aml, register_grayscale.aml and register_pseudocolor.aml, utilized Arc/Info's GRIDWARP command to identify registration marks and transform images to the appropriate State Plane coordinate system.

A.2.4.2 Digitizing Procedures. Features from all maps were digitized using the menu-driven digitize.aml program. Scanned images were displayed in the background and features were captured from these images using the cursor as the input device. Each feature type was stored as a separate map layer, or coverage, and a set of digitizing guidelines was developed (see Attachment A4-1). The coverage names, their contents and associated map symbols are shown in Table A-2.

All coverages contained fields for feature-specific margin notes, i.e. information that was noted on the map by the respondent, and digitizer's comments. Feature-specific margin notes and comments were added to individual features as they were digitized. Attachment A4-2 contains a list of standard digitizer's comments. Margin notes and comments that were not specific to one or more features were inserted into a text file specific to that site and image, i.e., 1234a.txt.

Because all coverages and all of their contained data items were created with the digitize.aml program, all coverages containing the same feature types have identically defined attribute tables. This ensures that coverages can be appended at some point in the future after they are projected to a common coordinate system.

A.2.4.3 QA/QC of Digitized Coverages. QA procedures were incorporated into the digitizing process and QC checks were carried out throughout the data development process through the use of computer programs that ensured standardization of data development.

The *digitize.aml* program was initiated at the command line and required a single parameter, the image ID of the image to be used for the current digitizing session. The menu interface to this program, displayed in Figure A-1, contained a large number of buttons which allowed the user to select the coverage to be edited (the "edit coverage"), add or delete features, assign impoundment ids, margin notes, or digitizer comments to feature databases ("feature attribute tables"), and perform all of the other normally-required processes. Also included was a button to allow the user to temporarily suspend menu input so that commands could be entered directly on the ArcEdit command line.

Most attributes were assigned to the feature attribute tables automatically, including the facility ID and map letter, type of source map, feature "origin" (preprinted or handdrawn), and attributes that controlled the symbolization of features in the graphic display.

Table A-2. GIS Coverage Name, Type, and Content

Coverage	Type	Contents	Map Symbol
BOX_siteid	Line	Topographic map limits	
BUFF_2KM	Line	A system-generated 2-km buffer around impoundments	Thick red line
PONDS_PNT	Point	Impoundments represented by points	Blue dot
PONDS_POLY	Polygon	Impoundment boundaries of ponds with areas	Blue line
PROPERTY	Line	Site property boundary	Dashed red line
RECP_PNT	Point	Receptor locations – Individual buildings known or believed to be residences	Green dot
RECP_POLY	Polygon	Receptor locations – Urban or residential areas	Green line
RESP_2KM	Line	The 2-km radius as drawn by the survey respondent	Thick red line
SCHL_PNT	Point	Schools represented by point symbols and individual school buildings	Red dot
WELLS	Point	Wells (generally groundwater supply wells)	Hollow blue triangle with cross

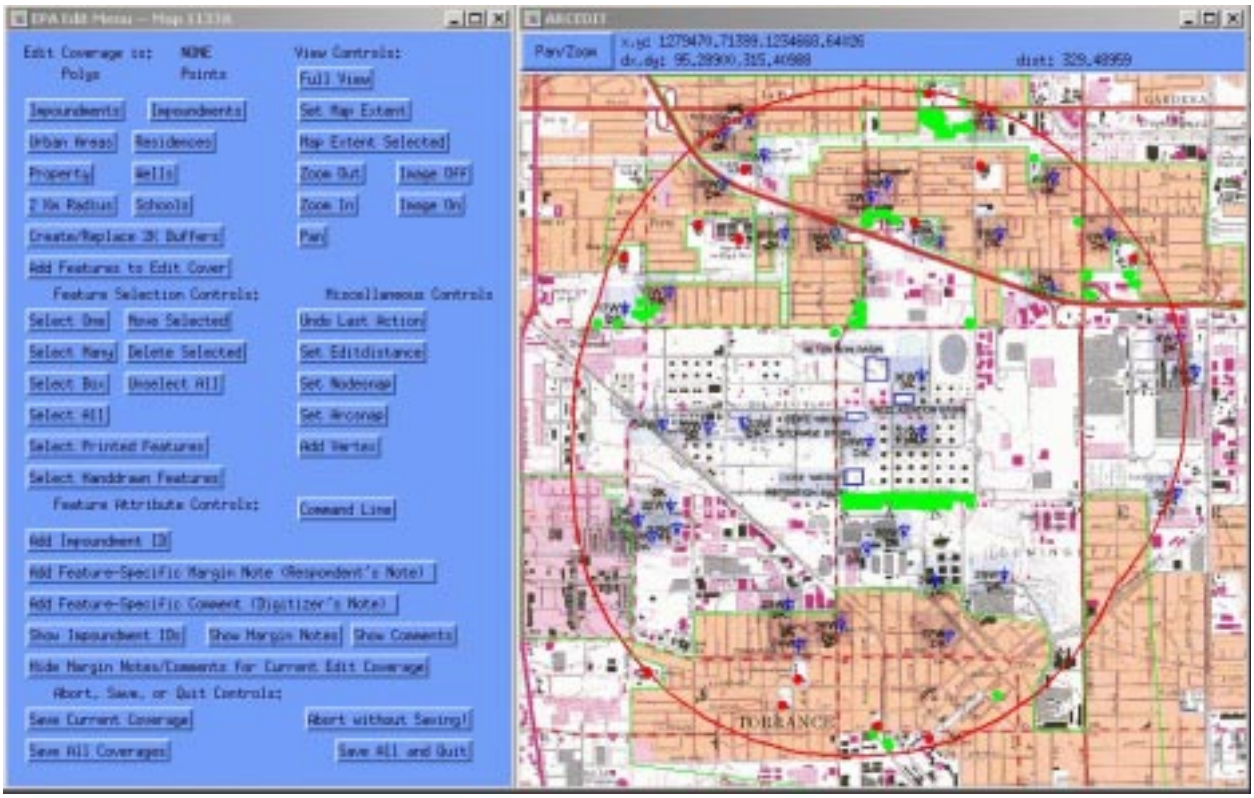

Figure A-1. Digitizing menu used in *digitize.aml* program.

This interface was flexible enough to be used by both experienced GIS personnel and others without significant prior GIS experience. The program behind the interface was also designed to prevent or at least limit the inadvertent assignment of incorrect attributes. In other words, QA was integrated into the program wherever practical.

When all features had been digitized using the digitize.aml program, a program, qc_site.aml, was run to perform a series of automated QC checks on all coverages created for that site. These checks ensured that

- All the required coverages had been created
- All items in each feature attribute tables were present and correctly defined
- All standardized items (e.g. site, map, symbol, etc.) had correct values
- All lines in coverages containing polygon features formed closed polygons
- Lines did not intersect except at nodes (a requirement of lines that would be used to build polygon features).

The results of the program were written to a text file containing two types of messages. A warning message was issued if a coverage lacked features (e.g., the coverage containing residences lacked any points). Error messages were issued if any of the situations described in the above list dictated (e.g., the program found an incorrectly-defined item or an unclosed polygon). Corrections were made to the respective coverages, when necessary.

A second QC process involved the generation of large (24" x 36") checkplots of each image for examination by a quality control reviewer. The reviewer was a GIS analyst who had not been involved in that site's digitizing process. The checkplot displayed the map image and each of the digitized features drawn with its corresponding symbol (see Table A-2). The review process consisted of comparing the original map with both the checkplot and the digital coverages and carrying out the following steps:

- Determine whether all features had been digitized
- Determine whether all margin notes had been entered with feature data
- Determine whether appropriate digitizer's comments had been entered
- Determine whether non-feature-specific margin notes had been inserted into a text file.

The reviewer also examined receptor features to determine whether questionable residences should remain in the coverage. Ancillary data, such as Digital Ortho Quarter Quads, viewable via a web browser, were used in this determination. In the event that additional digitizing or revisions were needed, the map original was returned to the digitizer. Corrections were made and the review process was repeated.

A.2.4.4 Additional Data Modifications. Prior to final analyses of in-scope surface impoundments (described below), modifications were made to some features to improve the accuracy of analyses. Three types of modifications were made:

- Many wells of WELLTYPE 7 or 14 (unknown or unspecified) were reclassified, based on ancillary data, such as documentation included with the survey.

- An examination of aerial photographs for specific ponds during the analysis of sites showing air risks revealed residences that had not been digitized. These were located in subdivisions that were developed after the USGS topographic quad was produced. In these cases, the additional residences were digitized.

- The assumption was made that all private drinking water wells should have residences associated with them. Residences were added to many sites to correspond with these wells.

A.2.5 Diagram Data, Elevation Data

Survey respondents were asked to supply diagrams containing information for three sets of questions in the survey. These diagrams contained information on facility wastewater treatment information (survey question B1), plan and elevation diagrams (question C10), and liner diagrams (question C11). Respondents often combined some or all of this information into a single diagram and or sent diagrams that combined different impoundments on a single diagram. To avoid making multiple scanned image files of these large format diagrams for each question, it was decided that each diagram should be scanned only once and then linked to the appropriate questions.

A.2.5.1 Database for Diagram Tracking and Linkages. A database system was developed to link each diagram to one or more facilities, impoundments, and uses. Tables A-3 and A-4 provide dictionaries for the two data tables in this database. Adhesive stickers were printed that contained a unique number printed in both Code 39 barcode and text. One sticker was placed on each diagram and its number was used as a "diagram number" to track and link the diagrams. The diagram number contained a checkdigit, which was used to detect and prevent data entry errors. Database tables were created in an Microsoft Access database to store linkage information. Simple data entry forms were created to permit linking the diagrams to their use(s) with simultaneous entry of plan and elevation data extracted from the diagrams.

Diagrams could be linked either to a facility (survey question B1, wastewater treatment diagrams) or to an impoundment (survey question C10, plan and elevation diagrams; survey question C11, liner diagrams). Wastewater treatment diagrams were linked to a facility by entering a record containing the diagram number and the facility ID in the table DIAG_WWT. Other diagrams were linked to an impoundment by entering a record containing the diagram number, the facility ID, and the impoundment ID in the table DIAG_IMP. In this way, a single diagram could be linked to a facility and one or more impoundments.

After linkage, the diagrams were scanned into TIFF format, which was converted to the more highly compressed (i.e., smaller files) GIF format for archiving. The resulting diagram files were titled with their diagram number (and .gif) as their file name. A simple report program was written in Microsoft Access that produced listings of documents by facility, impoundment, and use. This report was printed to an Adobe Acrobat (pdf) file for reference and use in retrieving the

Table A-3. Structure of DIAG_WWT Database Table for Wastewater Treatment Diagrams (Question B1)

Field Name	Type	Size	Description
FAC_ID	Text	5	Facility ID - Linked to Table FAC_INFO
DIAG_ID	Text	15	Unique ID for diagram (from diagram sticker)

Table A-4. Structure of DIAG_IMP Database Table for Impoundment Diagrams (Question C10, plan and elevation views; Question C11, liner cross sections)

Field Name	Type	Size	Description
FAC_ID	Text	5	Facility ID - Linked with IMP_ID to table SURF_IMP
IMP_ID	Text	50	Impoundment ID - unique ID for impoundment at Facility
DIAG_ID	Text	15	Diagram ID - unique ID for diagram
C10_PLN	Boolean	1	True if diagram is a plan view of impoundment
C10_XST	Boolean	1	True if diagram is a elevation (cross section) view
C11_LNR	Boolean	1	True if diagram is a liner cross section

desired files for review. A copy of this report is included in Attachment A-5. The GIF format survey diagrams are archived and available on CD-ROM.

A.2.5.2 Processing of Elevation Data from Diagrams. In survey question C-10, Respondents were asked to supply plan and elevation diagrams for each surface impoundment. These diagrams were used to obtain the following elevation data:

- Ground elevation,
- Water table elevation,
- Base (bottom surface of the impoundment) elevation,
- Elevation of liquid level in the impoundment.

Maximum, minimum, and typical values (if supplied) were recorded for all elevation data, except for ground elevation, where an average value was recorded (if supplied). From this data, the following information was calculated:

- Distance of base from the water table,
- Distance of liquid level from the water table, and
- Height of liquid in the impoundment (i.e., distance of liquid level from base).

Table A-5. Structure of IMP_ELEV Database Table for Impoundment Elevation Data (Question C-10)

Field Name	Type	Size	Description
FAC_ID	Text	5	Unique ID for each facility
IMP_ID	Text	50	Unique ID for impoundment at that facility
GR_EL	Double	8	Ground (reference) elevation - 0 when referenced to ground
GRELUTS	Long Integer	4	Units code for ground elevation
WT_MIN	Double	8	Minimum water table distance from ground
WT_MAX	Double	8	Maximum water table distance from ground
WT_TYP	Double	8	Typical water table distance from ground
WT_UTS	Long Integer	4	Units code for water table distances
B_MIN	Double	8	Minimum distance from ground to base of impoundment
B_MAX	Double	8	Maximum distance from ground to base of impoundment
B_TYP	Double	8	Typical distance from ground to base of impoundment
B_UTS	Long Integer	4	Units code for base distances
LH_MIN	Double	8	Minimum distance from ground to top of liquid surface
LH_MAX	Double	8	Maximum distance from ground to top of liquid surface
LH_TYP	Double	8	Typical distance from ground to top of liquid surface
LH_UTS	Long Integer	4	Units code for liquid distances
Comment	Text	250	Comment

A database table (IMP_ELEV) was created to store impoundment plan and elevation data extracted from diagrams. The structure of the database table (IMP_ELEV) is shown in Table A-5. The data entry form for the plan and elevation data was combined with the impoundment linkage form (mentioned above).

Because of the wide variety of diagrams supplied by participants, extraction of elevation data required some interpretation. In some instances, the needed elevation data was clearly noted on the diagram. In other cases, the needed data could be measured from scale drawings. For quality control, a second person compared all diagrams to their extracted values (i.e., 100 percent of all data was checked).

Upon completion of data entry and comparison, a senior review was conducted that focused on extreme data points including:

- Facilities with the greatest differences between high and low water table values
- Impoundments with the greatest depth to the water table
- Impoundments with the water table at or above the base of the impoundment
- Impoundments with water table aboveground elevation
- Impoundments with base aboveground elevation
- Impoundments with the water table above the impoundment liquid level
- Facilities with the greatest distance between impoundment liquid level and water table
- Inconsistencies between elevation data and depth to saturated zone in survey question B-10.

This review considered approximately 15 percent of the facilities. The facility diagrams, surveys, and published data, such as USGS maps, were used in the review. Changes were made for 10 facilities based on review of elevation data. Corrections were made for three additional facilities based on the comparison of elevation data with question B-10. Additional corrections were made for three impoundments with unusually large distances between the water table and their impoundment liquid levels.

A.2.6 Quality Assurance/Quality Control

Extensive and rigorous QA/QC procedures were developed and followed throughout the data entry process. QA/QC procedures for map and diagram data have been described in the sections above. To achieve a 100-percent check for data entry, all survey data that were manually entered into the survey entry database from the hard-copy surveys were double-extracted and entered independently by two different staff members. To accommodate double-extraction/ double-entry, the data entry database contained duplicate tables for every data element as well as duplicate entry forms. Once both entries were complete, the two files were electronically compared, and, using the hard copy survey, a third staff member reconciled any differences. Other manually entered data were checked 100 percent.

For automated data processing, the data extraction/processing system was thoroughly validated before use. This involved manually checking enough of the data (usually 5 percent to 10 percent) to ensure that the system functioned properly. When conducting such checks, the QC procedures required that each unique calculation or data combination be checked at least once. In addition, a version control system was employed to ensure data integrity and that each analysis conducted with the most recent dataset. Detailed records were kept of every QC check, and these were reviewed during a final QA audit of the data entry process.

A.3 Collection of Supplementary Data

Secondary data sources included U.S. Census GIS data (used to supplement survey information on the number and location of people living around the site), GIS coverages of soils and aquifer data, USGS topographic maps, and river flow data from EPA's Basins database. These data were collected and used to provide more consistency and completeness for key data elements, or to provide data not directly available from the survey (e.g., population data).

A.3.1 Development of Supplementary Spatial Data

A geographic information system was used to digitize residence and well locations from the marked topographic maps requested in question B3 of the Part B of the long survey. Question B3 asked the survey respondents to mark wells, residences, and schools within a 2-kilometer radius of their surface impoundments on a USGS topographic map that was included with the survey form (see Attachment B1). Because these maps were returned unmarked (or not returned) by a significant number of respondents and because the survey did not ask for population data, the GIS was used to supplement these data with U.S. Census data. In addition, the GIS was used to collect spatial data on the presence of waterbodies, wetlands, and managed areas with 2 km for the ecological risk assessment.

A.3.1.2 Data Processing and Spatial Analysis. Out of the total 157 facility sites with impoundments in-scope for the long survey (i.e., those with chemicals or pH of concern), a total of 153 returned maps with the survey, including 150 sites in the continental U.S., 2 sites in Alaska, and 1 site in Puerto Rico (four sites were determined to have missing geographic data). The geographic analysis was carried out for these sites to develop the sample data necessary to develop the following statistics about the distribution of wells, residences, population, and schools for impoundments with chemicals or pH of concern:

- Estimated number of groundwater supply wells, broken out by distance (0-150, 151-500, 501-1000, and 1001-2000 meters) from the impoundments, and cross tabbed by use (public, private drinking water, irrigation, livestock watering, don't know, other).

- Estimated number of residences, broken out by distance (0-150, 151-500, 501-1000, and 1001-2000 meters) from the impoundments.

- Estimated number of schools, broken out by distance (0-150, 151-500, 501-1000, and 1001-2000 meters) from the impoundments.

- Estimated number of people, broken out by distance (0-150, 151-500, 501-1000, and 1001-2000 meters) from the impoundments.

A simple Arc/Info distance function was used to process the school data, but the remaining questions required pre-processing of the digitized survey data and the 1990 U.S. Census data.

Overlay Processing of In-Scope Impoundments. To develop the best estimate of wells, residences (households), and population surrounding the impoundments with constituents used census coverages and data were used to: (1) provide an indicator of average household size; (2) estimate the number of private drinking water wells, and (3) provide population data for population estimates. Census coverages and corresponding data were obtained via ftp download from the EPA server in Research Triangle Park. Additional processing was carried out to link block and block group variables with block coverages. Census data were not available for Puerto Rico, so the wells and residence analyses utilized only feature data on the map supplied by the survey respondent and no population data could be estimated.

The most critical data processing steps for census/feature data analyses for each of the in-scope surface impoundment (excluding Puerto Rico) were as follows:

- Step 1. Create a set of buffers at distances of 150, 500, 1000 and 2000 meters, respectively, from the impoundment boundary.

- Step 2. Overlay buffers on census block group coverages to create new coverage of census blocks split by distance buffers, retaining the value of the original area of the census block for later analysis. Steps 1 and 2 were carried out using procbloc.aml. The resulting coverages were named BLR<Site ID><Impoundment Index>, e.g. BLR12341.

- Step 3. Overlay BLR coverage with RECP_PTS coverage and summarize number of receptor points per polygon, using rcp_over.aml.

- Step 4. Overlay BLR coverage with WELLS coverage and summarize number of wells per polygon, by welltype, using well_over.aml.

- Step 5. Populate new overlay coverages with census, receptor and well data, using linkwells.aml and blrprep.aml.

Figure A-2 shows an example of a BLR coverage, with surface impoundments, receptors and wells.

A.3.1.2 Dasymetric Mapping and Analysis Procedures for Human Receptor Data. As previously noted, the computation of distances for schools was straightforward because no census data were required. A GIS distance function (Arc/Info's NEAR command) was utilized to compute the distance of each school from each surface impoundment at the respective site. Distance were then categorized as belonging to Ring 1 (0 – 150m), Ring 2 (150.1 – 500m), Ring 3 (500.1 – 1000m) or Ring 4 (1000.1 – 2000m). Data were compiled in a file with the data structure shown in Table A-6.

A similar procedure was used to compute distances to marked wells, except that wells were broken out by well type. An additional analysis of wells was conducted, utilizing census data to provide supplemental data on the number of drinking water wells in the vicinity of a surface impoundment. The initial well distance file that was generated contained information about the distance of each marked well to each surface impoundment. The structure of this file is shown in Table A-7.

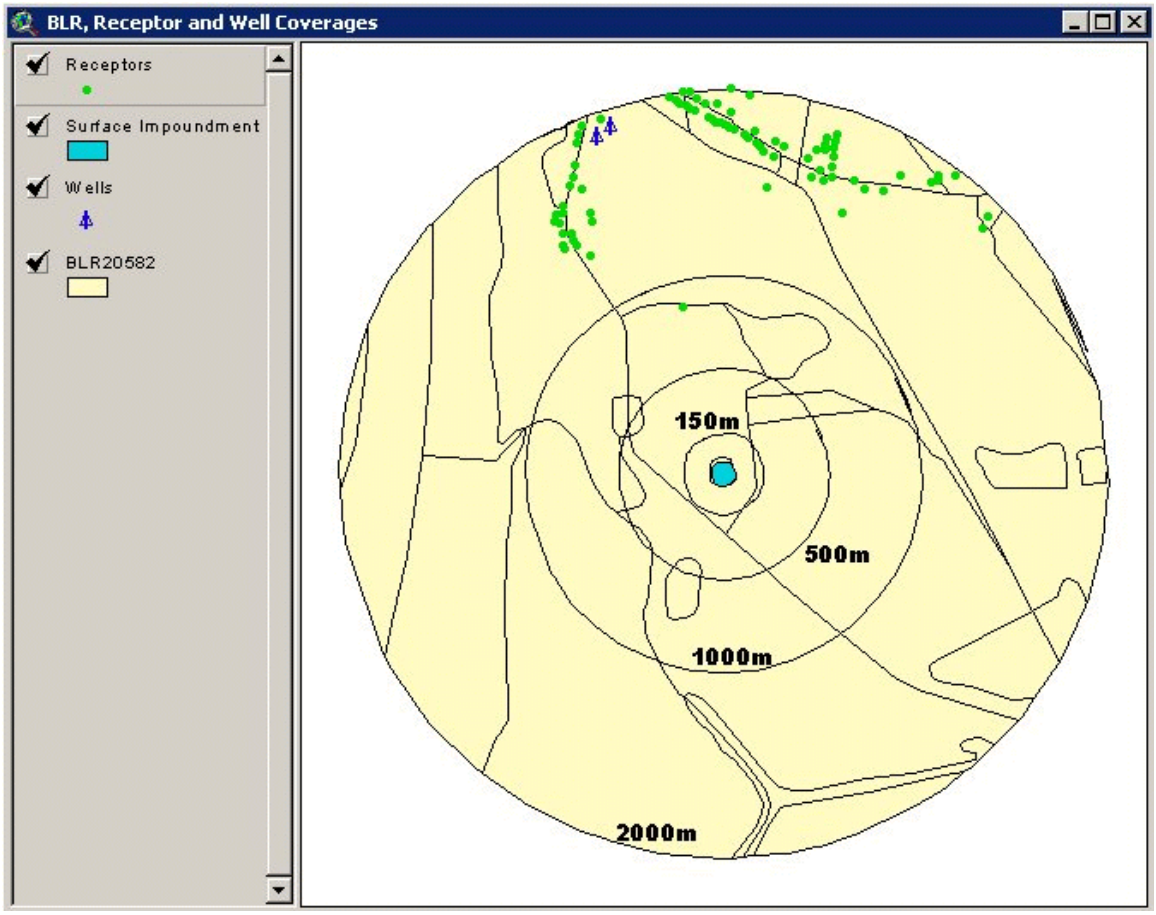

Figure A-2. Overlay of census blocks and distance rings with wells and receptors.

Table A-6. Table Structure for School Data

Variable Name	Description	Data Type
FAC_ID	Unique facility ID	Text
IMP_ID	Unique impoundment ID	Integer
RING_ID	Ring 1, 2, 3 or 4	Integer
RINGDIST	Ring distance of 150, 500, 1000 or 2000	Integer
AREAUNIT	Meters	Text
NMSCHOOL	Number of schools within specified ring	Integer

Table A-7. Table Structure for Well Distance Data

Variable Name	Description	Data Type
FAC_ID	Unique facility ID	Text
IMP_ID	Unique impoundment ID	Integer
WELL_ID	Unique well ID: FAC_ID plus coverage ID	Integer
DIST	Distance from surface impoundment boundary	Float
XCOORD	X-coordinate in jState Plane meters	Float
YCOORD	Y-coordinate in State Plane meters	Float
WELLTYPE	Type of well	Integer

Census data were used to develop estimates of population and number of residences for each geographic unit that fell within the 2-km range of each eligible surface impoundment. The geographic unit of analysis was the result of a geographic overlay of census blocks and distance rings (at distances of 150 m, 500 m, 1,000 m, and 2,000 m from the surface impoundment, respectively). In some cases, the unit of analysis was an entire census block; in other cases, where a distance ring bisected it, the unit of analysis was a partial census block.

Dasymetric Mapping. Dasymetric mapping techniques were used to obtain a more accurate estimate of population and residence numbers than are possible by more traditional methods. Although the census block is the smallest geographic unit used by the U.S. Census, it is sufficiently large enough that variations in the numbers of people and residences within the block are obscured. This does not pose a problem when the entire block is the unit of analysis. With partial blocks, however, population and residence numbers for the entire census block must be reassigned to the partial block, keeping the block totals constant. Normally, this is done by prorating the block variables (such as population) by the area of the new, or partial block unit, that is, if the partial block was 75 percent of the size of the original, then 75 percent of the population would be assigned to that unit. The problem with this method is that, especially in rural areas, residences may be widely scattered and there may be large areas that are assigned a population when, in fact, they have none. The reverse is also possible, population undercounts in densely populated areas.

Dasymetric mapping uses supporting information about the distribution of a phenomenon to provide a more accurate representation of a (map) surface than that provided by standard data collection units, such as census blocks or block groups. In this case, the supporting information comes from the residences that were digitized from maps returned by the survey respondents. This information can be used to provide a better characterization of high and low density areas within the census block and to develop more accurate counts for enumeration units split by the 150, 500, 1,000 and 2,000 m rings. In other words, the presence of digitized points, and decisions made about their accuracy and currency, were used to weight the population and residence number estimations.

Assumptions. Three different methods of geoprocessing and computation were developed, using assumptions based on the date of the map and the accuracy of the maps provided by the survey respondents. Assumptions:

- If map predates 1990 **and** no residences were marked on the map by respondent, then the 1990 census is the most accurate source of population and residence data.

- If the map predates 1990 and residences **were** marked on the map by respondent, the digitized map data represents the most accurate source of population and residence data in non-urban areas.

- If the map date is later than 1990, the digitized map data represents the most accurate source of population and residence data in non-urban areas, whether or not residences were marked on the map by respondent.

- Since individual receptor points are not present in urban areas, 1990 census data provide the most accurate source of population and residence data in those areas.

Decision Rules. Using the assumptions stated above, a decision tree, based on (1) presence of urban areas on map, (2) date of source map, and (3) whether respondent had marked residences on the map was used to determine which one of three processing and analysis routines would be used to most accurately estimate the population and number of residences within the 2-km surface impoundment buffer area. This decision tree is reflected in the Figure A-3.

Before implementing the decision tree, the map for each surface impoundment (n=517), was checked for: (1) presence of urban polygons, (2) map date, and (3) marked residences on map. Based on this check, one of the following three routines was implemented.

Routine A

This routine was used when no urban areas were contained in the geographic data and the map data were assumed to be more accurate than the census data. It is the simplest of the three routines. The number of receptor points in each geographic unit were counted. This provided the value for estimated number of residences. This value was then multiplied by the average number of people per housing unit, at the block group level (hereafter referred to as the block group housing unit size), to obtain the estimated number of persons.

Routine B

This routine was used when the map from which receptor points were digitized predated the 1990 census and there were no residences marked on the map by the respondent. Census data were assumed to be the most accurate source of information and census population totals for each block were held constant. However, the distribution of digitized points was used to weight population and residence numbers for partial blocks.

For census blocks that were not split by a distance ring (hereafter referred to as whole blocks), the estimated number of persons was simply the census population value for that block.

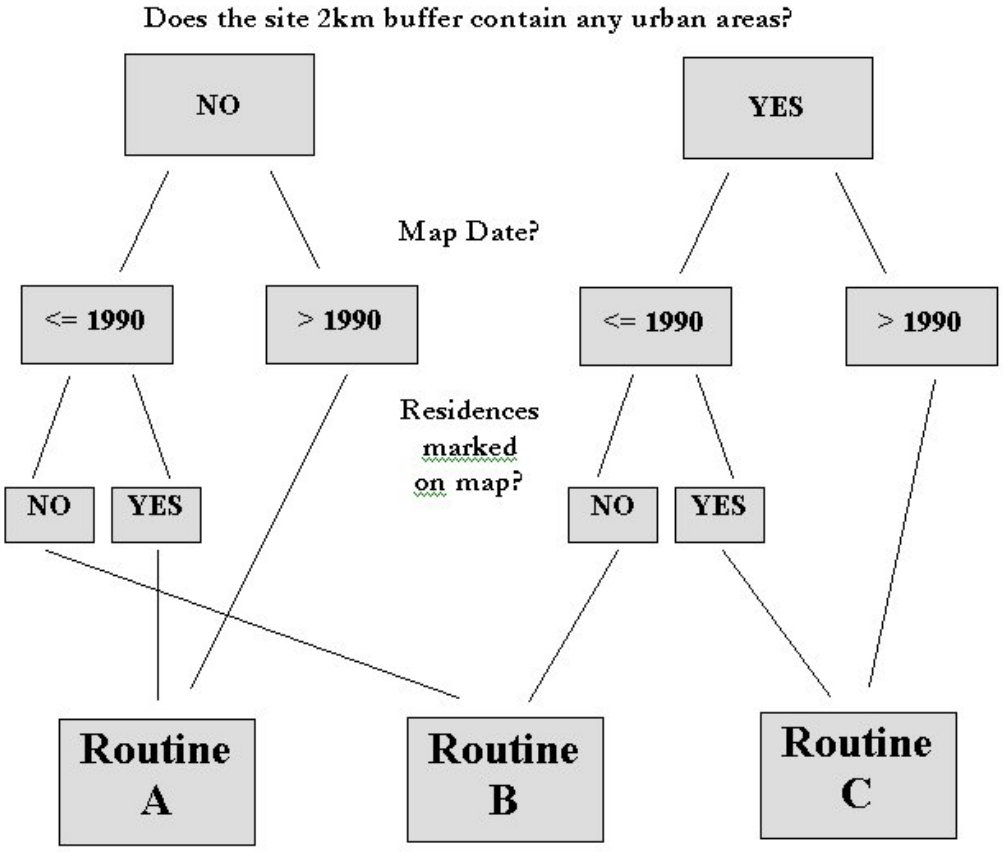

Figure A-3. Dasymetric procedure for integrating survey and U.S. Census data.

The estimated number of residences was computed by dividing the estimated number of persons by the block group housing unit size.

For census blocks that were split by a distance ring (hereafter referred to as partial blocks), the number of digitized receptor points was counted. If the partial block contained no receptor points, the block population was multiplied by the area proportion, and a percentage value was obtained by dividing the area of the partial census block by the area of the whole census block. The resulting value was the estimated number of persons for that partial block. The estimated number of residences was computed by dividing the estimated number of persons by the block group housing unit size.

For partial blocks that contained digitized receptor points, a revised block population value was obtained by multiplying the block population by the area proportion. Then, the total number of receptor points in the whole block was multiplied by the block group housing unit size. If that value exceeded the revised block population, the revised block population was divided by the number of receptor points in the block to come up with an estimated block housing unit size. This value was then multiplied by the number of receptor points in the partial

block to determine the estimated number of persons. The estimated number of residences was equal to the number of digitized receptor points.

If the product of the number of receptor points in the whole block and block group housing unit size was less than the revised block population, the ratio of partial block receptor points to whole block receptor points was multiplied by block population to get the estimated number of persons. This value was divided by block group housing unit size to obtain the estimated number of residences.

Routine C

Routine C was used when the geographic data contained urban areas (with the exception of pre-1990 map dates with no residences marked on the map). The digitized receptor data were assumed to be accurate. However, census data were used in polygons with no digitized receptor points because areas delineated urban on topographic maps do not show individual residences.

For partial and whole blocks with digitized points, the number of receptor points were counted to estimate the number of residences. This value was then multiplied by the block group housing unit size to estimate population.

For whole blocks with no digitized receptor points, the estimated number of persons was the census population value for that block. The estimated number of residences was computed by dividing the estimated number of persons by the block group housing unit size. For partial blocks, the population value was the product of the area proportion and census block population. This value was divided by the census block group housing unit size to obtain estimated number of residences.

Routines A, B and C were incorporated into the program dasyprog.aml. After this program was run, the estimated number of residences was used to obtain an estimate of the number of drinking water wells, based on census data (census wells). Where the ratio of drinking water wells to housing units at the census block-group level was greater than 0.5, this ratio was multiplied by the estimated number of residences to obtain this value. Because those data were more complete (many respondents did not mark drinking water wells), the census wells were used in subsequent analyses in all cases except where marked private wells drinking-water wells were greater than the census well count.

The data obtained from the overlay analysis and dasymetric mapping procedures was compiled in a table with the structure shown in Table A-8.

A.3.1.3 Screening for Ecological Risk Modeling. GIS screening of sites with in-scope surface impoundments was conducted to determine the level and type of ecological risk assessment modeling. A series of GIS overlay procedures was developed and employed to examine spatial relationships between each surface impoundment site and (1) managed areas (such as parks and wildlife preserves), (2) land use categories, (3) permanently flooded woodlands, (4) Bailey's ecoregions, (5) fishable water bodies, (6) soils, and (7) groundwater geology. Attachment B4-3 contains a more detailed description of ecological screening overlay procedures.

Table A-8. Table Structure for Population, Residence, and Well Data

Variable Name	Description	Data Type
FAC_ID	Unique facility ID	Text
IMP_ID	Unique impoundment ID	Integer
PUBW_1	No. public GW wells 0 - 150m	Float
PUBW_2	No. public GW wells 151 - 500m	Float
PUBW_3	No. public GW wells 501 - 1000m	Float
PUBW_4	No. public GW wells 1001 - 2000m	Float
PRIDW_1	No. private DW GW wells 0 - 150m	Float
PRIDW_2	No. private DW GW wells 151 - 500m	Float
PRIDW_3	No. private DW GW wells 501 - 1000m	Float
PRIDW_4	No. private DW GW wells 1001 - 2000m	Float
IRRW_1	NO. irrigation GW wells 0 - 150m	Float
IRRW_2	No. irrigation GW wells 151 - 500m	Float
IRRW_3	No. irrigation GW wells 501 - 1000m	Float
IRRW_4	No. irrigation GW wells 1001 - 2000m	Float
COWW_1	No. livestock GW wells 0 - 150m	Float
COWW_2	No. livestock GW wells 151 - 500m	Float
COWW_3	No. livestock GW wells 501 - 1000m	Float
COWW_4	No. livestock GW wells 1001 - 2000m	Float
DKW_1	No. DK GW wells 0 - 150m	Float
KW_2	No. DK GW wells 151 - 500m	Float
DKW_3	No. DK GW wells 501 - 1000m	Float
DKW_4	No. DK GW wells 1001 - 2000m	Float
OTHERW_1	No. other GW wells 0 - 150m	Float
OTHERW_2	No. other GW wells 151 - 500m	Float
OTHERW_3	No. other GW wells 501 - 1000m	Float
OTHERW_4	No. other GW wells 1001 - 2000m	Float
CENPRW_1	No. 1990 census private GW wells 0 - 150m	Float
CENPRW_2	No. 1990 census private GW wells 151-500m	Float
CENPRW_3	No. 1990 census private GW wells 501 - 1000m	Float
CENPRW_4	No. 1990 census private GW wells 1001 - 2000m	Float
RES_1	Estimated residences 0 - 150m	Float
RES_2	Estimated residences 151 - 500m	Float
RES_3	Estimated residences 501 – 1000m	Float
RES_4	Estimated residences 1001 – 2000m	Float
POP_1	Estimated population 0 – 150 m	Float
POP_2	Estimated population 151 – 500m	Float
POP_3	Estimated population 501 – 1000m	Float
POP_4	Estimated population 1001 – 2000m	Float

A.3.2 Surface Water Distances and Flow Data

Because the distance to surface water responses (survey question B12) were incomplete and did not include surface water flow data needed for the risk assessment, it was necessary to supplement these data with data collected from other sources. This data collection effort included largely a manual review of topographic maps and gathering of flow data from EPA's BASINS database.

A.3.2.1 Distance to Nearest/Nearest Waterbody and Ground Water Flow. The nearest fishable waterbody (FWB) in any direction and the nearest, downslope FWB (stream, lake, or pond) were identified using survey responses, site maps, atlases, topographical maps, and aerial photographs. FWBs were selected based on the following criteria:

- Lakes beyond the facility boundary but within 2 kilometers of the SI
- Streams that extended beyond the property boundary
- Streams that were order 3 or larger (The order of the stream was determined by tracing the convergence of tributaries with order 1 assigned to the furthest upstream segment indicated on the 1:24,000 topographic map (both ephemeral and perennial steams were assigned order 1). The streams were traced also using state atlases, hydrologic unit maps, and basin maps on the EPA "Know Your Watershed" web pages
- Waterbodies that did not meet the above criteria, but were closer to the SI than other waterbodies and were specifically mentioned by the respondent in Part B of the survey.

To determine the potential for a groundwater migration pathway from the SI to the FWB the following criteria were used:

- Respondent's geology summary from the B-form of the survey
- Regional geology information
- Topography as indicated on 1:24,000 or other available topographic maps.

In most cases the topography and stream flow were used as an indication of shallow groundwater flow to evaluate the potential contamination pathway to the FWB. In areas where there was the potential for fracture flow in shallow, hard-rock aquifers or in karst formations, it was automatically assumed that transport to the FWB was possible. Regional geology also was considered. Additional information was obtained from the following sources if supplemental information was required:

- DRASTIC: *A Standard System for Evaluating Ground Water Pollution Potential Using Hydrogeologic Settings*, Kerr ERL, Table 8, p.9 (Aller et al. 1987).

- Hunt, 1974, *Natural Regions of the United States and Canada*, map of surface deposits, p. 122.
- USGS, 1984. Geologic Map of the United States
- USDA, state soil surveys as available
- Professional judgment.

Distances from the SI to the FWBs were typically measured using USGS 1:24,000 topographic maps. A 1:24,000 scaled rule was used for measurements, eliminating the need for conversions. Some facility packages did not include USGS maps, and a calculated scale was used.

Later analysis using generally newer aerial photography data (1977, 1997, 1998) than the USGS topographical maps indicated that some streams and lakes had been missed or were no longer present. The table was corrected based on this information. Independent, duplicate analysis was performed using the original assessment results for each facility as a 100 percent quality control check.

A.3.2.2 Collection of Surface Water Flow Data. Flow data were collected for all identified non-quiescent water-bodies (i.e., streams and rivers). Surface area was obtained for quiescent water-bodies (i.e., ponds and lakes). Stream attribute data included mean flow, 7Q10 flow, and stream width. The 7Q10 flow is representative of drought/low-flow conditions. No data were obtained for bay or ocean areas.

Three data sources were used to obtain stream data:

- EPA Office of Water. May 1996a. Database for *Better Assessment Science Integrating Point and Nonpoint Sources* (BASINS). EPA-823-R-96-001.
- Web pages: USGS, January 26 through 28, 2001. *United States NWIS-W Water Data Retrieval* Internet Site: http://waterdata.usgs.gov/nwis-w/us/
- van der Leeden et al., 1990. *The Water Encyclopedia - Second Edition*: Table 3-6 Flowing Water Resources of the United States, Data Source: Keup, L.E., 1985. Lewis Publishers, Inc., pp. 176.

EPA's BASINS model was the primary data source for 7Q10 and mean stream flow data for approximately 219 streams. The streams were found by searching the data tables and using GIS techniques to compare the site's latitude and longitude with the gaging station's coordinates. This search yielded all gages within 10 miles of the facility and a manual search was performed to narrow the list to modeled streams. The distance between the gage and the facility was calculated from the coordinate data using a spreadsheet. This calculation was validated for two facilities (in the Northwest and Southeast) using hand calculations and map comparisons.

The USGS's NWIS-W water data and associated state geological survey web pages were used to obtain flow data for 56 streams that did not have appropriate data in the BASINS database. Typically, annual mean flow data were available from this source; however, only daily mean values were available for several streams. A relative annual mean was calculated from the daily mean values based on the data collected over the last 5 years or the available period of record. Generally, there was not enough data to obtain a 7Q10 value, and most of the data were not available in a format that could be downloaded into a digital file. As a result, a representative annual 7Q10 flow for streams was not calculated using the USGS gage data.

The distance along lines of latitude and longitude from the facility to gage stations was also provided in the tabulated results. Flow data webpages for the streams were printed and used to check the inputs of the original data table. A quality control check was performed on approximately six of the mean flows calculated from daily averages.

Table 3-6 Flowing Water Resources of the United States by Keup (van der Leeden et al., 1990) was used to estimate flow data for approximately 115 streams that were not listed in BASINS or on the USGS websites. The table correlates the stream's measured width and its estimated mean flow. Estimates based on the Keup's data are from end-of-stream locations. If actual data existed even many miles away (usually for large rivers) from the facility, the mean for the gage data was also presented along with the estimated Keup flow. Interpolations from the Keup data were independently verified.

The width of every stream was measured. At the end of the data collection activities, all data were queried to compare measured stream widths and flows to the estimated flows from the Keup's table. The query results showed that interpolations from the Keup data for mean annual flow compared well with actual gage information obtained from BASINS and the USGS sources. The estimates of the mean flow data appeared congruous for the set of streams to be modeled.

The surface areas for most of the lakes, ponds, and river inlets were measured on USGS 1:24,000 topographic maps using a planimeter. Some maps were of a different scale, and the planimeter was calibrated accordingly. Some waterbodies had areas below the limit of the planimeter. The areas of these waterbodies were estimated by multiplying the measuring length and width to find the square area. Some inlet areas were considered lake-like and areas were also determined for these waterbodies. The areas of approximately six, randomly selected waterbodies were independently checked for accuracy.

A.4 Data Processing

Data processing includes the calculations, conversions, and transformations necessary to prepare the basic survey data in the data entry database (described in Section A.2), for additional exploration and analysis. Data processing activities produced three primary products:

- Consolidated database, which is similar in basic structure and content as the data entry database except that units have been standardized and initial data cleaning (e.g., correction of skip pattern errors) has been conducted.

- Risk assessment input database, which contains the chemical concentrations and associated surface impoundment characteristics necessary for modeling risks from surface impoundments.

- Derived variables, which were developed from survey data, risk assessment results, or combinations of these for estimating population characteristics using the statistical methodologies described in Section A.5.

Each of these processing activities is described in greater detail below.

The automated programs developed to create each of these data products were subjected to rigorous and complete QA/QC protocols. For all automated data processing, the data extraction/processing system was thoroughly validated before use. This involved manually checking enough of the data (usually 5 percent to 10 percent) to ensure that the system functioned properly. When conducting such checks, the QC protocol required that each unique calculation or data combination be checked at least once. In addition, a version control system was employed to ensure data integrity and that each analysis conducted with the most recent dataset.

A.4.1 Consolidated Database

The consolidated database is intended to serve as the final archive of survey data and contains the data in a form that makes it makes it useable for future analyses. To achieve these objectives, the consolidated database was designed to be consistent with the following criteria.

- Accurate reflection of survey responses, including margin notes as possible.

- Cleaning of conflicting responses and correction of skip pattern errors by respondents completing the survey.

- Conversion of quantitative data to standard units to enable meaningful analyses to be conducted.

- Collapse of chemical data from 8 tables in the data entry database into a single table in the consolidated database to allow easy comparison between the different sampling points (influent, effluent, and within the impoundment) and media (wastewater, sludge, leachate, air) requested by the survey.

Processing of the survey data in accordance with the last two criteria presented the biggest challenge, both from a programming and QA perspective. The chemical data from survey questions C23 and C24, required the most complex processing to convert units, calculate concentrations and mass per unit time values when possible, average different sampling periods, and, for wastewater influent only, combine data across multiple influent points. Over 40 different units used by survey respondents had to be converted to standard units for wastewater, leachate, sludge, and air. To document this process, Attachment A6 provides the data processing algorithms and unit conversions used for processing the chemical data. Each of these algorithms

was checked manually during QC for correct program functioning. Records of these checks are available and archived and were subjected to a final GA audit.

To find conflicting data and skip pattern errors, SQL queries were performed based on the structure of the original survey form. For example survey question C2a asks if the impoundment has ceased receiving wastes since June 1, 1990, based on the response to this question the respondent should have or should not have responded to questions C2b, C2c, and C27a. By searching for instances that the response to question C2a was "no" or "don't know", but any one of C2b, C2c, or C27a is answered, or conversely if the response to question C2a was "yes", but there were no responses for C2b, C2c and C27a, problems were identified and rectified by looking at the responses to the questions as well as any margin notes made by the respondent. If the respondent clearly indicated that the impoundment was closed, but failed to answer the follow up questions, then non response codes could be entered as appropriate. In a couple of cases, the response to C2a was "yes", but the margin note for C27a clearly indicated that the impoundment was not closed. In this case the C2a response was rectified with the C27a margin note, and the change was noted in the C2a margin note. There also were instances when respondents answered all questions in some manner even if a response was not required. These spurious responses remain in the original data entry database, but were not transferred to the consolidated database.

Values for any survey response that could result in values reported with varying units were converted to a standard set of units. The only exception to this is the liner thickness response to question C12. Because liner thicknesses can vary greatly in magnitude by liner type, the values were transferred as provided with the actual survey units listed in the field provided. Similarly the chemical concentration data required conversion to a standard set of units as well as calculating concentrations and mass per unit time values, and combining data across multiple influent points for survey question C24a. Processing of the chemical data would also vary based on the type of data provided. Processing for concentration values, mass per unit time values, chemicals present with quantity unknown, non-detects, etc all required slightly different processing. A6-1 is an algorithm for the processing of each type of chemical data by survey question. This algorithm was used to document the processing as well as being used for quality control. The conversion functions written to convert survey data to a standard set of units are provided in A6-2.

Attachment A7 provides the basic design documents for the consolidated database. As described in section A.2 for the data entry database, these include entity relationship diagrams, a data dictionary, and copies of each coding table.

A.4.2 Risk Assessment Input Data

The risk assessment input database includes all of the chemical concentration data needed to run the risk assessment models. Design documents for this database, including a data dictionary and coding tables, are provided in Attachment A8. The risk assessment input database was populated in accordance with the risk assessment Technical Plan (see Appendix C), and included the following conventions developed to help reduce missing data and to ensure that the screening analysis was adequately protective.

- Values below detection limits were entered at the detection limit given in the survey. Where the detection limit was not specified, a lookup table of default detection limits was used to fill a detection limit value in the risk assessment database.

- A nearest neighbor imputation methodology was applied to develop surrogate concentration data were chemicals are expected to be present, but quantities are unknown.

- Where sludge data were not available, partition coefficients were used to estimate sludge concentrations from wastewater concentrations

Each of these procedures is discussed in more detail in the following sections.

A.4.2.1 Detection Limits. Where the survey respondent entered a concentration value as less than a detection limit, for example "< 0.05 mg/L", a value at the detection limit (i.e., 0.05 mg/L) was placed in the risk assessment input database. This protective convention was adopted for the screening risk assessment to ensure broad coverage in cases where a chemical could be just below the detection limit. To ensure that this assumption is not overly conservative, chemical concentrations still exceeding risk criteria after the final phase of the risk analysis were examined as to their source (i.e., detection limit, surrogate) (see Section 3 and Appendix C).

For cases where the survey did not provide a detection limit (e.g., specified "not detected" or "ND"), a lookup table of default detection limits was developed considering analytical methods likely to be used for wastewater samples. The primary sources are summarizes as follows.

- **Wastewater.** EPA method 1624 and 1625 were selected because the methods are designed to meet the requirements of NPDES under 40 CFR parts 136.1 and 136.5. For inorganics (metals) standard methods for inductively coupled plasma (ICP) and cold-vapor atomic adsorption (CVAA) analyses were used. When detection limits for organic constituents were not available from these methods, the EPA 600 series for municipal and industrial wastewater was used. For any remaining constituents without detection limits, SW-846 EPA 8000 series was used. Finally, if no method was available, then a detection limit was pulled from the available detection limits in the survey database.

- **Sludge.** For the organics SW-846 EPA 8000 series was used. For method 8021, the method provided an estimated quantitation limit (EQL) of 0.1 mg/kg, and this value was used for applicable constituents. For 8081, a factor for sludge was calculated into the detection limit as noted in the spreadsheet. Finally, if no method is referenced, then the detection limit was pulled from the available detection limits in the survey database.

- **Air.** Detection limits in air were taken from the EPA report Ambient Measurement Methods and Properties of the 189 Clean Air Act Hazardous Air

Pollutants. When a method is not referenced, then the detection limit was based on best professional judgment.

All detection limits were multiplied by a factor of ten to account for interferences. The final 1x and 10x values for wastewater, sludge, and air are provided in Attachment A-9 (Tables A-9-1, A-9-2, and A-9-3).

A.4.2.2 Surrogate Values. The Surface Impoundment Study Technical Plan for Human Health and Ecological Risk Assessment (Attachment C) specifies that in cases where the presence of a chemical in an impoundment can be inferred, but it is not possible to quantify a value, a value from a similar impoundment will be used to represent a likely concentration. These surrogate values were developed using a nearest neighbor imputation method which made it possible to maximize the use of presence information in the survey. Presence was inferred, and surrogate concentrations were sought, in three cases: (1) where the respondent had checked the "present but quantity unknown" (PQU) flag, (2) where the respondent had entered a chemical but provided no value (and did not check PQU), and (3) where chemicals were reported in wastewater effluent (to infer presence within the impoundment).

The imputation methodology is picture in Figure A-4 and described in the following text. Note that because detection limits were decided to be valid representations of concentrations in the impoundments for this risk analysis, the detection limit values described in Section A.4.2.1 were available and used for surrogates. All surrogate data processing was done on the constituent level and the maximum of the surrogate data gets filled into the CHEM_CONC Table in the risk assessment database with "Surrogate" marked as true.

The imputation methodology employed a decision framework that was programmed into a data processing system to implement the methodology. The theme throughout the process is to find the most similar impoundment possible within the survey database that had data for the chemicals without values. Steps in the process include answering the following questions:

1. Are there any other impoundments at the same facility with data for the constituent?
   Yes
   1a. Are there any impoundments with the exact same treatment processes?
      Yes - fill surrogate data - finished
   1b. If the impoundment requiring surrogate data is aerated, are there any other impoundments which are aerated?
      Yes - fill surrogate data - finished
   1c. Are there any impoundments which perform the same function (treatment or non-treatment only)?
      Yes - fill surrogate data - finished

2. Are there any other impoundments with the same 6 digit SIC code with data for the constituent?
   Yes
   2a. Are there any impoundments with the exact same treatment processes?
      Yes - fill surrogate data - finished

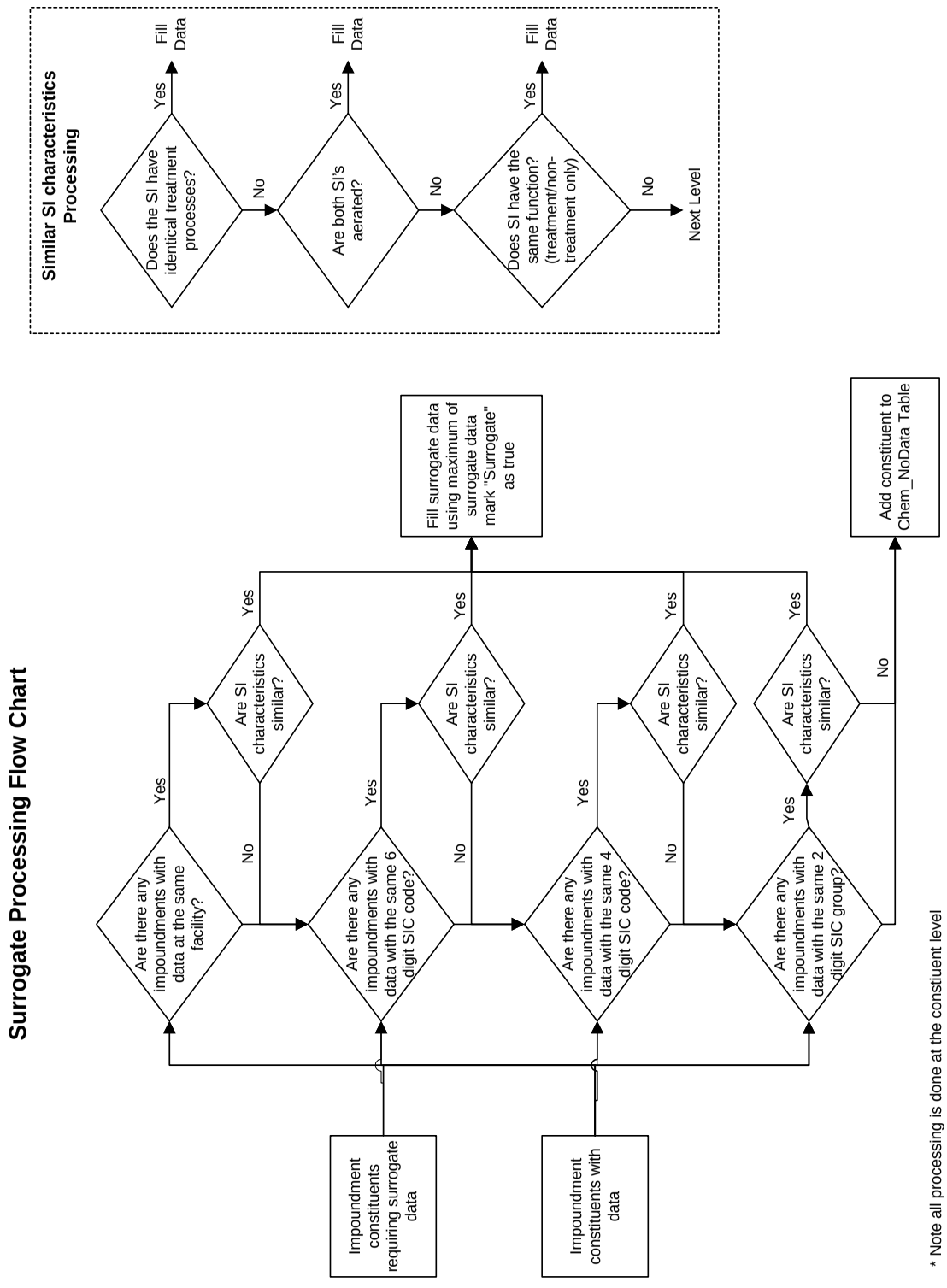

Figure A-4. Decision tree for identifying surrogate data for risk assessment

2b. If the impoundment requiring surrogate data is aerated, are there any other impoundments which are aerated?
Yes - fill surrogate data - finished
2c. Are there any impoundments which perform the same function (treatment or non-treatment only)?
Yes - fill surrogate data - finished

3. Are there any other impoundments with the same 4 digit SIC code with data for the constituent?
Yes
3a. Are there any impoundments with the exact same treatment processes?
Yes - fill surrogate data - finished
3b. If the impoundment requiring surrogate data is aerated, are there any other impoundments which are aerated?
Yes - fill surrogate data - finished
3c. Are there any impoundments which perform the same function (treatment or non-treatment only)?
Yes - fill surrogate data - finished

4. Are there any other impoundments with the same 2 digit industry group with data for the constituent?
Yes
4a. Are there any impoundments with the exact same treatment processes?
Yes - fill surrogate data - finished
4b. If the impoundment requiring surrogate data is aerated, are there any other impoundments which are aerated?
Yes - fill surrogate data - finished
4c. Are there any impoundments which perform the same function (treatment or non-treatment only)?
Yes - fill surrogate data - finished

5. If there are still constituents requiring surrogates which can not be matched in steps 1 to 4, then add the constituents to the Chem_NoData table.

A.4.2.3 Estimating Sludge Concentrations from Wastewater Concentrations. When there is not a sludge concentration provided in the survey, but there is sludge within the impoundment, a sludge concentration was estimated from using waste-water partition coefficients (Kdw) for metals and a soil organic carbon-water partition coefficient (Koc) for organic constituents, along with total suspended solids (TSS) data pulled from the study survey. This approach accounts for contaminants sorbed to TSS, which is necessary when using total wastewater concentrations (versus dissolved).

The equations to be used are.

Kd (metals):

Sludge_Conc = WW_Conc*([Kdw_L/kg]/(1+([Kd_L/kg]*([TSS_WW]/1000000))))

where:

WW_Conc is the wastewater concentration within the SI in mg/L
Kdw_L/kg is the 50th percentile waste-water Kdw value in L/kg
TSS_WW is the TSS value in mg/L.

Koc (organics):

Sludge_Conc = WW_Conc*(([Koc]*foc)/(1+(([Koc]*foc)*([TSS_WW]/1000000))))

where:

WW_Conc = wastewater concentration within the SI in mg/L
Koc = soil organic carbon / water partition coefficient in L/kg
foc = fraction organic carbon (waste solids)
TSS_WW = TSS value for wastewater in mg/L.

These two equations were derived from the following equation:

C_sol (mg/kg) = C_ww (mg/L) * { Kdw/ (1+Kdw [TSS]) }

where:

C_sol = solids concentration (sorbed, mg/kg)
C_ww = measured wastewater sample contaminant concentration (total, mg/L)
Kdw = waste-water partitioning coefficient = Koc*foc for organics (L/kg)
TSS = total suspended solids concentration (kg/L = g/cm3).

Total Suspended Solids (TSS). TSS values were obtained from the SI survey database (question C15) using the following hierarchy:

1. Use wastewater within the impoundment TSS value (WW_TSSV)
2. Use wastewater within the impoundment Total Solids value (WW_TSOLV)
3. Use wastewater within the impoundment MLSS value (WW_MLSSV)
4. Use wastewater within the impoundment MLVSS value (WW_MLVSS)
5. Use wastewater within the impoundment Biomass Concentration value (WW_BIOV)
6. Use wastewater influent TSS value (INF_TSSV)
7. Use wastewater influent Total Solids value (INF_TSOLV)
8. Use wastewater influent MLSS value (INF_MLSSV)
9. If still no data, use IWAIR default of 0.2 g/L (200 mg/L)

Fraction Organic Carbon (foc). With respect to foc, some correlations developed for biomass sludge in activated sludge systems suggest that an foc around 0.7 would be reasonable. Given that MLVSS is a measure of solids that volatilize at about 550 degrees centigrade, it is also reasonable to estimate fraction organic carbon (foc) in wastewater solids using the following equation:

foc = MLVSS / (TSS or MLSS)

SI Survey data (MLVSS/TSS) that can be used to estimate foc for wastewater solids are limited to 99 pairs of MLVSS/TSS or MLVSS/MLSS data for influent, effluent, and wastewater in the impoundment (Table A-9). Review of these data shows little difference between the different sampling points and limited variability (overall coefficient of variation = 0.3). Based on these data the median fraction organic carbon (foc) value of 0.7 (70 percent organic carbon) was used as a typical value.

Table A-9. Summary Statistics: MLVSS/TSS

Medium	n	mean	StdDev	CV	min	10th %ile	median	90th %ile	max
wastewater	37	0.68	0.16	0.24	0.20	0.46	0.71	0.82	0.88
influent	30	0.61	0.28	0.46	0.03	0.12	0.71	0.89	0.93
effluent	32	0.71	0.15	0.20	0.32	0.51	0.70	0.88	1.00
all	99	0.67	0.20	0.31	0.03	0.32	0.70	0.86	1.00

StdDev = Standard deviation.
CV = Coefficient of variation (StdDev/mean).

Partition Coefficients for Organics (Koc). Soil organic carbon-water partition coefficients (Koc values) were extracted from the following readily available sources (listed in order or preference):

- IWEM model datafiles (178 values). This will ensure consistent Koc values with the groundwater modeling results described in Appendix C. IWEM Koc values are reported to be collected from Kollig et al. (1993).

- Kollig et al. (1993; 2 values), the EPA ORD reference containing peer-reviewed Koc values used in EPACMTP and IWEM.

- Superfund Chemical Data Matrix (SCDM; 29 values). Well-referenced EPA Superfund values used in Hazard Ranking System (HRS) (U.S. EPA, 1996b). Available online.

Values were found from these sources for most of the study organic chemicals. Koc values for nine study constituents were developed as follows:

- Extract log octanol / water partition coefficient (log Kow) from Hansch et al. (1995).

- Use following equation to calculate log Koc values from log Kow :

  log Koc = log Kow + 0.32.

This equation was used in HWIR and in Kollig et al. (1993) to calculate Koc values.

The final Koc values used for sludge estimatation methodology as well as for the groundwater pathway exposure modeling are provided in Attachment A9. As shown above, Koc x foc was used to estimate waste-water partition coefficients (Kdw values) for organic constituents in the sludge estimation methodology. The two most significant uncertainties in this assumption are:

- the accuracy of applying soil Koc values to wastes
- limited data on waste organic carbon content.

Depending on waste streams, organic carbon content could contribute up to about a two-order of magnitude uncertainty factor to the Kdw value. The magnitude and impact of uncertainty introduced by the the applicability question is unknown.

Wastewater Partition Coefficients for Metals (Kdw). Waste solids / water Kdw values for metals were obtained from the HWIR modeling effort (U.S. EPA, 1999c). HWIR developed distributions from collected literature values for soil, sediment, suspended matter, and wastes. For wastes managed in surface impoundments, HWIR uses metal partition coefficients (Kd values) collected for suspended matter in surface water bodies. The distributions were based on collected data or, for metals where data were inadequate, using a regression equation relating soil and suspended matter log Kd values collected for other metals. These data show that suspended matter tends to have 2 to 3 times the affinity for metals than soil. This has been attributed to the higher surface area and organic carbon content of suspended particulate matter, which are also characteristics of solids in many industrial surface impoundments. The distributions for metals are provided in Attachment A9.

Significant uncertainties associated with the wastewater partition coefficients for metals include:

- Literature values are not a random, nonbiased sample and thus may not adequately represent the true distribution of partition coefficients.

- The accuracy of applying soil data to suspended solids; r^2 for the HWIR soil / supended matter regression equation is 0.37. However, the calculated values appear to be roughly in line with the measurements collected from published literature for other metals.

- The accuracy of applying surface water suspended solids data to waste solids.

The magnitude and impact of these uncertainties are uncertain in themselves, but, given the variability in partition coefficients, could be several orders of magnitude for a particular metal in a particular impoundment.

A.4.3 Derived Variables for Exploration and Analysis

Both the survey findings presented in Chapter 2 and section A.5.2 of this attachment, and the risk results provided in Chapter 3 required weighting up to the entire population of facilities represented by the survey so that national level observations and conclusions could be made about nonhazardous industrial surface impoundments. This required development of derived variables and populating them from the surface impoundment database and the risk results. As with the other database discussed above, this was accomplished using automated data processing programs that were subjected to rigorous, complete QA/QC protocols to ensure that the programs are functioning as designed (i.e., all algorithms and calculations were hand-checked for each unique data situation).

Attachment A10 includes detailed specifications, by report question and variable, used to develop and check these derived variables. In each case, the source and destination of each variable is included in these tables, which are organized by section Chapter 2, Appendix B, and Appendix C) and variable level (facility or impoundment).

A.5 Data Analysis Methods

This section describes the statistical methodology underlying the population estimates computed using screener and long survey data. It is divided into two sections. The first section discusses how the statistical analysis weights were computed to account for the sampling design and to reduce the bias due to nonresponse. The second section discusses how these weights and features of the sampling design were used to compute robust, design-consistent estimates of sampling variances, standard errors, and confidence interval estimates of population parameters.

A.5.1 Statistical Analysis Weights

The statistical analysis weights for the observational units in any probability-based sample survey are the initial sampling weights adjusted to reduce the potential for bias due to survey nonresponse. The initial sampling weight for each unit is the reciprocal of the probability that the unit was selected into the sample. If each unit could have more than one linkage to the sampling frame (or list) from which the sample was selected, the initial sampling weights must be adjusted to compensate for this multiplicity. Finally, a model-based estimate of the probability of responding is usually used to reduce the bias due to nonresponse. The following sections discuss each of these steps for computing the statistical analysis weights for the Surface Impoundment Study.

A.5.1.1 Initial Sampling Weights. As described in Section A.1.1, major differences in the sources and availability of sampling frame data led to the definition of three primary sampling strata based on the facility's regulatory status under the Clean Water Act:

For direct discharge facilities, EPA constructed an essentially complete sampling frame of 43,050 facilities from the NPDES permits in the EPA's Permit Compliance System (PCS) database. EPA partitioned the sampling frame into three primary sampling strata, defined as follows:

1. Facilities in high-priority SICs (26, 2819, 2824, 2834, 2869, 2897, 2911, 30, 33, or 36)
2. All other facilities with in-scope SICs
3. The six pilot study facilities.

Substrata were defined based on SIC codes resulting in a total of 15 sampling strata. A stratified simple random sample of 2,000 facilities was selected from the 15 sampling strata, and the six pilot study facilities were retained with certainty.

For zero discharge facilities, a sampling frame of 5,807 facilities was constructed from available state data and two federal databases: EPA's Toxics Release Inventory (TRI) and the Aerometric Information Retrieval System, Facility Subsystem (AFS). The sampling frame was stratified into 15 sampling strata based on general categories of completeness for the different state and federal data sources, and according to high and low priority SIC codes. A stratified random sample of 250 facilities was selected using the same sampling rate for all but one stratum.

Because local POTWs are the principal permitting authorities for indirect discharge facilities, anecdotal information collected from EPA, state and local personnel, and database information from EPA Region 7 was used to construct a sampling frame from which 35 facilities were purposively selected.

Subsequent to selection of this sample for the screener survey, EPA determined that some of the sample facilities were ineligible for Phase 2 of the study, and those facilities were removed from the sample before mailing the screener surveys. For each of the 1,984 direct and zero discharge facilities mailed a screener survey, the initial sampling weight was computed for the j-th facility in stratum r as follows:

$$w1(j) = N1(r) / n1(r) ,$$

where

N1(r) = Total number of facilities in stratum r, and
n1(r) = Number of facilities selected into the sample from stratum r.

The frame count, N1(r), sample size, n1(r), and initial sampling weight, w1(j), are shown for each stratum in Table A-10. Sampling weights were not computed for the sample of 35 indirect discharger facilities because the sample was purposively selected and the survey results cannot be statistically extrapolated to any larger population.

A.5.1.2 Multiplicity Adjustments. The PCS data used to construct the sampling frame for the direct discharger sample were outfall- or pipe-level records. The first step was to collapsed the pipe-level records to the permit level by permit ID (NPID). Permits were then combined to the facility level. Because there was no unique facility ID to guide this process, permits were

Table A-10. Initial Sampling Weights for the Screener Survey

Sampling Stratum	Frame Count	Sample Size	Initial Weight
Direct Discharge Facilities			
High-priority SICs:			
■ SIC 26	927	142	6.528
■ SIC 28	1019	156	6.532
■ SIC 29	440	67	6.567
■ SIC 30	1478	226	6.540
■ SIC 33	1752	268	6.537
■ SIC 36	919	141	6.518
Low-priority SICs:			
■ SIC 20-23	5169	141	36.660
■ SIC 24-27	3442	95	36.232
■ SIC 28-31	3000	82	36.585
■ SIC 32	3212	88	36.500
■ SIC 34	2680	73	36.712
■ SIC 35-39	3642	100	36.420
■ SIC 42-45[a]	2688	74	36.324
■ SIC 49[b]	9276	254	36.520
■ SIC 50-76[c]	3400	93	36.559
Pilot study facilities (certainty selections)	6	6	1.000
Direct discharger subtotal	43,050	2,006	NA
Zero Discharge Facilities			
States with complete databases:			
■ In TRI or AFS	228	13	17.539
■ High-priority SICs[d]	61	5	12.200
■ Low-priority SICs[d]	301	13	23.154
■ Unknown SIC[d]	1155	55	21.000

(continued)

Table A-10. (continued)

Sampling Stratum	Frame Count	Sample Size	Initial Weight
■ SIC 4952[d]	891	22	40.500
States with general databases: ■ In TRI or AFS	128	6	21.333
■ High-priority SICs	127	6	21.167
■ Low-priority SICs	543	25	21.720
■ Unknown SIC	1592	74	21.514
■ SIC 4952	95	3	31.667
States with partial databases: ■ In TRI or AFS	116	4	29.000
■ With target SICs	121	6	20.167
■ Unknown SICs	117	4	29.250
■ SIC 4952	138	8	17.250
States with no relevant databases ■ In TRI or AFS	194	6	32.333
Zero discharger subtotal	5,807	250	NA

TRI = EPA's Toxic Release Inventory.
AFS = EPA's Aerometric Information Retrieval System, Facility Subsystem.
[a]SICs 4212, 4213, 4231, and 4581
[b]SICs 4952 (excluding Publicly Owned Treatment Works), 4953, and 4959
[c]SICs 5085, 5093, 5169, 5171, and 7699 (transportation equipment cleaners only)
[d]Not in TRI or AFS.

merged to the facility level only when it was quite clear that there were multiple permits for the same facility. Up to 3 different permits were merged into a single facility-level record. Any facilities that had multiple permits that did not get merged into a single facility-level record on the sampling frame had multiple chances of being selected into the sample.

The screener survey listed all permits that had been used to define the facility on the sampling frame, and asked each facility to list any additional permits that had been active for the facility at any time since June 1, 1990. After considerable data cleaning, the multiplicity (number of linkages to the sampling frame) was determined for each facility that responded to the screener survey.

However, the frame multiplicity must be known for every sample facility, not just the responding facilities. Therefore, for each direct discharger sampling stratum, the average

multiplicity was computed among the respondents and the multiplicity was imputed for each nonresponding facility within each sampling stratum to be the average multiplicity for that stratum. After having computed or imputed the multiplicity, m(j), for each direct discharge sample facility, the multiplicity-adjustment to the sampling weight was computed for the j-th facility as follows:

w2 (j) = 1 / m(j)	for direct discharge facilities
w2 (j) = 1	for zero discharge facilities.

Lessler and Kalsbeek (1992, Section 5.2.2) show how this using this multiplicity adjustment produces survey estimates that are design-unbiased.

A.5.1.3 Adjustment for Nonresponse to the Screener Survery. Weight adjustments to reduce the bias due to survey nonresponse are based on models for the probability of responding, using data that are available for both respondents and nonrespondents. Since the sampling stratum was the only thing we knew about the nonresponding facilities, we used sample-based ratio adjustments based on the sampling strata (see Brick and Kalton, 1996). The nonresponse adjustments were defined only for the direct and zero discharge facilities because the indirect discharger sample was not a probability-based sample.

The weight adjustment for nonresponse is simply the reciprocal of the weighted response rate in each weighting class. Therefore, strata for which the number of respondents was small (e.g., less than 20) were collapsed with similar strata to form weighting classes. However, assigning strata with dissimilar response rates to different weighting classes is necessary to reduce nonresponse bias.

Hence, after reviewing the pattern of study eligibility and survey response by sampling strata, it was decided that each of the 15 sampling strata for the direct discharger sample contained sufficient numbers of respondents to be a separate weighting class, and they are the first 15 weighting classes. However, because of the smaller sample size for the zero discharger sample, strata were combined to form weighting classes as follows:

- Weighting class 16 consists of zero discharger strata 1 through 4: the facilities from the TRI or AFS portion of the sampling frame;
- Weighting class 17 consists of zero discharger strata 5, 6, and 9: the facilities with high-priority SICs; and
- Weighting class 18 consists of the remainder of the zero discharger facilities.

Having defined the weighting classes for nonresponse adjustment, the weight adjustments were implemented for nonresponse in two stages. First, an adjustment was made for inability to determine whether or not a facility was eligible for the screener survey (i.e., was in operation at any time since June 1, 1990). The second stage of nonresponse adjustment was an adjustment for nonresponse among the facilities known to be eligible for the screener survey.

The weight adjustment factor for inability to determine eligibility for the screener survey was computed for the *c*-th weighting class follows:

$$w_3(c) = \frac{\sum_{j \in c} w_1(j)\, w_2(j)}{\sum_{j \in c} w_1(j)\, w_2(j)\, I_k(j)} \quad ,$$

where $I_k(j)$ is an indicator that the eligibility status or the *j*-th facility is known, i.e.,

$I_k(j) = 1$ if the eligibility status of the *j*-th facility is known
$I_r(j) = 0$ otherwise.

This adjustment is equivalent to assuming that the proportion of sample facilities that are eligible for the screener survey (i.e., in operation at any time since June 1, 1990) is the same for facilities both with known and unknown eligibility status.

Similarly, the weight adjustment factor for survey nonresponse was defined for the *c*-th weighting class as follows:

$$w_4(c) = \frac{\sum_{j \in c} w_1(j)\, w_2(j)\, w_3(j)\, I_e(j)}{\sum_{j \in c} w_1(j)\, w_2(j)\, w_3\, I_r(j)} \quad ,$$

where I_r and I_e are indicators of response and eligibility status, respectively, i.e.,

$I_r(j) = 1$ if the *j*-th facility was a screener respondent
$I_r(j) = 0$ otherwise, and
$I_e(j) = 1$ if the *j*-th facility was eligible for Phase 1
$I_e(j) = 0$ otherwise.

These nonresponse adjustments are shown for each of the 18 weighting classes in Table A-11.

The final statistical analysis weight for the screener survey was defined for the *j*-th facility in the *c*-th weighting class as the product of the various weight components, as follows:

$w_5(j) = w_1(j)\, w_2(j)\, w_3(c)\, w_4(c)\, I_r(j)$.

A.5.1.4 <u>*Adjustment for Subsampling for the Long Survey*</u>. Respondents to the screener survey were eligible for selection into the subsample to receive the long survey if their screener survey data indicated that they satisfied the following conditions:

- Had an in-scope SIC[1]

[1] Major groups 20-39 and 97 plus codes 4212, 4213, 4231, 4581, 4952 (except Publicly Owned Treatment Works), 4953, 4959, 5085, 5093, 5169, 5171, and 7699 (transportation equipment cleaners only).

- Were in operation at any time since June 1, 1990, and the time of the survey in the summer of 1999

- Used at least one direct- or zero-discharge surface impoundment to manage only nonhazardous waste.

A stratified random sample of 201 of the screener respondents, plus the six pilot study facilities, were selected to receive the long survey. The weight component for selection of this subsample was the reciprocal of the probability of selection. It was computed for the *j*-th facility in stratum *s* as

$$w_6(j) = N_2(s) / n_2(s) ,$$

where

$N_2(s)$ = Total number of facilities in stratum *s* eligible to be selected for the long survey sample, and
$n_2(s)$ = Number of facilities selected from stratum *s* to receive the long survey.

The frame count, $N_2(s)$, sample count, $n_2(s)$, and weight component, $w_6(j)$ are shown in Table A-12 for each sampling stratum.

A.5.1.5 <u>*Calibration to Screener Survey Weight Totals*</u>. The estimated number of facilities in the survey population using the long survey weights is not identical to the estimate based on the screener analysis weights (7,459 facilities) because the screener weights were not all the same within each stratum from which facilities were selected for the long survey. The screener sample weights provide a more reliable estimate of the size of the population because of the larger number of screener respondents, relative to the long survey subsample. Therefore, the long survey weights were calibrated to sum to the screener totals within each stratum used to select facilities for the long survey. In particular, the calibration weight factor was computed for the *j*-th facility in stratum *s* as follows:

$$w_7(j) = \frac{\sum_{i=1}^{N_2(s)} w_5(i)}{\sum_{i=1}^{N_2(s)} w_5(i)\, w_6(i)\, I_{S_2}(i)} ,$$

where I_{S_2} is a (0,1) indicator of inclusion in the long survey sample. These calibration adjustment factors also are shown in Table A-12.

Table A-11. Weighting Class Adjustments for Screener Survey Nonresponse

Weighting Class	Adjustment for Inability to Determine Eligibility	Adjustment for Nonresponse Among Eligible Facilities
Direct Discharge Facilities		
High-priority SICs: ■ SIC 26	1.035	1.000
■ SIC 28	1.096	1.000
■ SIC 29	1.159	1.000
■ SIC 30	1.071	1.010
■ SIC 33	1.058	1.008
■ SIC 36	1.109	1.016
Low-priority SICs: ■ SIC 20-23	1.126	1.008
■ SIC 24-27	1.044	1.023
■ SIC 28-31	1.052	1.000
■ SIC 32	1.098	1.000
■ SIC 34	1.105	1.000
■ SIC 35-39	1.074	1.033
■ SIC 42-45[a]	1.119	1.000
■ SIC 49[b]	1.315	1.038
■ SIC 50-76[c]	1.105	1.012
Pilot study facilities (certainty selections)	1.000	1.000
Zero Discharge Facilities		
In TRI or AFS	1.105	1.000
High-priority SICs[d]	1.290	1.000
All other facilities[d]	1.154	1.012

TRI = EPA's Toxic Release Inventory.

AFS = EPA's Aerometric Information Retrieval System, Facility Subsystem.

[a]SICs 4212, 4213, 4231, and 4581

[b]SICs 4952 (excluding Publicly Owned Treatment Works), 4953, and 4959

[c]SICs 5085, 5093, 5169, 5171, and 7699 (transportation equipment cleaners only)

[d]Not in TRI or AFS.

Table A-12. Subsampling and Calibration Weights for the Long Survey

Sampling Stratum[a]	Frame Count	Sample Size	Subsampling Weight	Calibration Weight
Direct Discharge Facilities				
Handles formerly characteristic waste and high-priority SIC	75	75	1.000	1.000
Handles formerly characteristic waste and low-priority SIC	7	4	1.750	0.894
Does not handle formerly characteristic waste and high-priority SIC	204	68	3.000	1.003
Does not handle formerly characteristic waste and low-priority SIC	78	14	5.571	0.938
Pilot study facilities (certainty selections)	6	6	1.000	1.000
Direct discharger subtotal	370	167	NA	NA
Zero Discharge Facilities				
Handles formerly characteristic waste and high-priority SIC	2	2	1.000	1.000
Handles formerly characteristic waste and low-priority SIC	4	4	1.000	1.000
Does not handle formerly characteristic waste and high-priority SIC	14	14	1.000	1.000
Does not handle formerly characteristic waste and low-priority SIC	20	20	1.000	1.000
Zero discharger subtotal	40	40	NA	NA

[a]Based on the screener survey data.

A.5.1.6 Adjustment for Nonresponse to the Long Survey. Theoretically, all facilities selected into the sample to receive the long survey should have been eligible for this phase of the study. That is, they should all have had at least one surface impoundment that satisfied the eligibility conditions in the screener survey. However, several facilities reported that they had no eligible impoundments and had completed the screener survey incorrectly. Using extensive follow-up contacts, the eligibility status was determined for all facilities selected into the sample for the long survey. Hence, nonresponse adjustments were confined to adjustment for nonresponse among the sample facilities that were determined to be eligible for the survey.

For the full sample, there were only four eligible facilities that did not respond to the long survey, and one of those was an indirect discharge facility. Hence, for the weight adjustments for direct and zero discharge facilities, there were only three nonresponding facilities. Moreover, all three were direct discharge facilities whose screening data indicated that they did not handle any formerly characteristic waste. Therefore, the weighting classes for nonresponse to the long survey will be defined as shown in Table A-13.

Table A-13. Weighting Class Adjustments for Long Survey Nonresponse

Weighting Class[a]	Eligible Facilities	Responding Facilities	Nonresponse Adjustment
Direct Discharge Facilities			
Facility does not handle formerly characteristic waste	33	30	1.084
Facility and its impoundment(s) handle formerly characteristic waste	75	75	1.000
Facility handles formerly characteristic waste, but not its impoundment(s)	38	38	1.000
Direct discharger subtotal	146	143	NA
Zero Discharge Facilities			
All	35	35	1.000

[a]Based on the screener survey data.

The statistical analysis weights for the long survey respondents then were computed by adjusting the calibrated sampling weights, $w_5 * w_6 * w_7$, for nonresponse among the eligible sample facilities. Hence, the weight adjustment factor for nonresponse to the long survey was defined for the *k*-th weighting class as follows:

$$w_8(k) = \frac{\sum_{i \in k} w_5(i)\, w_6(i)\, w_7(i)\, I_e(i)}{\sum_{i \in k} w_5(i)\, w_6(i)\, w_7(i)\, I_r(i)} \quad ,$$

where I_r and I_e are indicators of long survey response and eligibility status, respectively, i.e.,

$I_r(i) = 1$ if the *i*-th facility was a long survey respondent
$I_r(i) = 0$ otherwise, and

$I_e(i) = 1$ if the *i*-th facility was eligible to receive the long survey
$I_e(i) = 0$ otherwise.

The final statistical analysis weight for the long survey then was defined for the *i*-th facility in the *c*-th weighting class as the product of the various weight components, as follows:

$$w_9(i) = w_5(i)\, w_6(i)\, w_7(i)\, w_8(k)\, I_r(i) \, .$$

Because data were collected for *all* eligible impoundments at each responding facility (i.e., there was no subsampling of impoundments), these facility-level analysis weights also are appropriate for analysis of the impoundment-level data collected for the responding facilities.

A.5.1.7 *Adjustment for Item Nonresponse*. Using the final statistical analysis weights, w_5 and w_9, for the 1,774 screener survey and 195 long survey respondents, respectively, reduces the potential for bias due to nonresponse of eligible facilities selected for these surveys. However, some survey items have additional missing data among these survey respondents. Failure to adjust for nonresponse to individual data items again leads to nonresponse bias. In particular, all population totals will be underestimated if item nonresponse is ignored. Statistical imputation procedures are often used to replace missing data items because they result in simpler, more consistent, analyses. However, they also have the potential to distort relationships between variables (see Brick and Kalton, 1996).

Because of concern regarding the potential distortions that can result from using imputed data, weight adjustments were used to reduce the potential for bias due to item nonresponse, exactly as they were used to compensate for total survey nonresponse. In particular, if an analysis was based on *m* variables that were constructed from long survey data, the data used in the analysis were those belonging to the facilities (or impoundments) that had complete data for all *m* variables. The weight adjustment for item nonresponse was developed as a SAS macro so that it could easily be implemented for each individual data analysis for which complete data were not available for all long survey respondents. The adjustment was a standard weighting class adjustment. Because some analyses had high levels of missing data, the weighting classes used to adjust for long survey nonresponse were collapsed to the following three weighting clases:

- Direct discharge facilities that do not manage decharacterized waste (based on the screener survey data).
- Direct discharge facilities that do manage decharacterized waste (based on the screener survey data).
- Zero discharge facilities.

Hence, the weight adjustment factor for item nonresponse to the long survey was defined for the *l*-th weighting class as follows:

$$w_{10}(l) = \frac{\sum_{i \in l} w_9(i)\, I_e(i)}{\sum_{i \in l} w_9(i)\, I_r(i)} \quad ,$$

where I_r is an indicator of respondents with data for all *m* items used in a particular analysis and I_e is an indicator of the full set of long survey respondents, i.e.,

$I_r(i) = 1$	if the *i*-th facility or impoundment has data for all *m* variables used in the particular analysis
$I_r(i) = 0$	otherwise, and
$I_e(i) = 1$	if the *i*-th facility or impoundment was a long survey respondent
$I_e(i) = 0$	otherwise.

The final statistical analysis weight, adjusted for item nonresponse, then was defined for the *i*-th facility in the *l*-th weighting class as follows:

$$w_{11}(i) = w_9(i)\, w_{10}(l)\, I_r(i) .$$

Hence, each analysis was based on complete data cases with a statistical adjustment for nonresponse to the set of data items used in each particular analysis. This ensures that the estimated numbers of facilities and impoundments in the survey population are consistent across all analyses.

Nevertheless, estimates of population totals for other population characteristics (e.g., the total number of impoundments with liners) may be somewhat inconsistent from one analysis to the next because of different missing data patterns. However, when the extent of missing data is low (e.g., 10 percent or less), the inconsistencies will be small.

A.5.1.8 Analysis Domains. Statistical analyses were performed primarily for two populations of facilities and the surface impoundments used to manage non-hazardous wastes at those facilities. This section describes and briefly characterizes each of these populations.

The first population of particular interest consists of those facilities in the screener survey population that had at least one eligible impoundment, as defined for that survey. The specific characteristics of that population of facilities are as follows: facilities with in-scope SICs[2] in the United States that were in operation at any time between June 1, 1990, and the summer of 1999 that used at least one direct- or zero-discharge surface impoundment to manage only nonhazardous wastes resulting from any one of the following processes:

- A manufacturing process other than heat transfer
- A direct-contact heat transfer process
- Equipment washing, product washing, or washing surfaces (e.g., buildings or floors)
- Spill cleanup
- Air pollution control
- Materials handling (e.g., valve/pump drips collected in a sump and mixed with rainwater)
- Boiler blowdown
- Laundering
- Leachate (liquid percolated through or drained from a waste management unit).

Because of many false positive responses to the screener survey, the best estimate of the size of this population is based on the long survey responses. The estimated number of such facilities is 7,459, based on 184 such facilities that responded to the long survey. The estimated number of surface impoundments at these facilities that meet these same eligibility conditions is 16,782, based on 562 such impoundments reported in the long survey.

[2] Major groups 20-39 and 97 plus codes 4212, 4213, 4231, 4581, 4952 (except Publicly Owned Treatment Works), 4953, 4959, 5085, 5093, 5169, 5171, and 7699 (transportation equipment cleaners only).

The second population of particular interest consists of those facilities in the first population that used at least one eligible surface impoundment to manage at least one of the target chemicals identified in the long survey or had an extreme pH in an eligible impoundment . The specific characteristics of this population of facilities are as follows: facilities in the first population whose direct- and zero-discharge impoundments were used only to manage non-hazardous waste for which *any* of the following were true:

- 30-day average pH was less than 3
- 30-day average pH was greater than 11
- at least one target chemical was managed in the surface impoundment.

The estimated number of such facilities is 4,457, based on 157 such facilities that responded to the long survey. The estimated number of surface impoundments at these facilities that meet these same eligibility conditions is 11,863, based on 531 such impoundments reported in the long survey.

A.5.2 Estimation Procedures

This section discusses the statistical analysis procedures used to compute point estimates of population totals, means, and proportions for the populations of facilities and impoundments discussed above. In addition, it describes how standard errors were computed for these population estimates, how estimates with poor precision were identified, and how confidence interval estimates can be generated. All the standard errors were produced using RTI's SUDAAN software for analysis of data from complex sample surveys (Shah et al, 1997).

A.5.2.1 Point Estimates. If Y_i denotes a measured quantity for the *i*-th facility or impoundment (e.g., number of eligible impoundments or presence of a liner), then the population total for characteristic Y_i was estimated as

$$\hat{Y} = \Sigma\, w_i Y_i \quad ,$$

where w_i denotes the statistical analysis weight and Σ denotes summation over either all facilities in the sample or over all impoundments at these facilities (depending on whether the outcome, Y_i, is a facility-level or impoundment-level outcome). In the same manner, the population mean for characteristic Y_i was a ratio estimate computed as follows:

$$\bar{Y} = \Sigma\, w_i Y_i / \Sigma\, w_i \quad ,$$

Likewise, population proportions were ratio estimates, computed as follows:

$$\hat{P}_x = \Sigma\, w_i X_i / \Sigma w_i \quad ,$$

where X_i =1 for those facilities or impoundments with the characteristic of interest (e.g., ever managed RCRA characteristic hazardous waste) and X_i = 0 otherwise.

In addition, estimates of population totals, means, and proportions were generated for various subpopulations, or analysis domains (e.g., states or SIC codes). In these cases, the estimators of the population totals, means, and proportions were generated by substituting the product $d_i w_i$ for w_i in the above formulas, where $d_i = 1$ if the facility or impoundment is a member of the analysis domain and $d_i = 0$ otherwise.

A.5.2.2 *Standard Errors*. The standard error of an estimate is a common statistical measure of its precision. It is the standard deviation of the sampling distribution of the estimate or, alternatively, is the square root of the variance of the estimate. That is, if one were to replicate the sample selection and data collection procedures many times in exactly the same way and with exactly the same population, the standard error of the estimate is the standard deviation of the values of that estimate that would be generated by those samples.

Estimates of variances and standard errors of survey statistics were computed using RTI's SUDAAN software. For nonlinear survey statistics, such as estimated means and proportions, SUDAAN uses the classical first-order Taylor Series linearization method (Wölter, 1985).

Because the number of facilities and impoundments in the target population is much greater than the number included in the sample, calculation of standard errors was simplified by treating the initial sample of facilities selected for the screener survey as having been selected with replacement. Hence, computation of standard errors only required identifying the analysis strata and primary sampling units (PSUs) used at the first stage of sample selection. Because facilities were selected directly in the initial sample for the screener survey, they are the PSUs. Because each analysis stratum must contain at least two responding facilities in order to calculate standard errors, some of the sampling strata shown in Table A-10 were collapsed to form analysis strata as shown in Table A-14. In addition, when the number of facilities with complete data for the set of items entering a particular analysis was low, adjacent analysis strata were sometimes collapsed, but strata representing direct discharge facilities were never collapsed with strata representing zero discharge facilities.

The procedures used by SUDAAN to estimate variances and standard errors can best be explained by introducing some mathematical notation to represent the statistical analysis strata, facilities, impoundments, and observations. Hence, let

$h = 1, 2, ..., 15$ denote the 15 statistical analysis strata shown in Table A-14
$i = 1, 2, ..., n_h$ denote the sample facilities in stratum h and
$j = 1, 2, ..., m_{hi}$ denote the impoundments at the i-th facility in stratum h.

If Y represents an impoundment-level characteristic (e.g., concentration of a target analyte), then let

Y_{hij} = the value of the outcome, Y, for the j-th impoundment at the i-th facility in stratum h

and

$$Y_{hi} = \sum_{j=1}^{m_{hi}} Y_{hij} \quad .$$

However, if *Y* represents a facility-level characteristic (e.g., number of years of operation), then let

Y_{hi} = the value of the outcome, *Y*, for the *i*-th facility in stratum *h*.

Using this notation, whether *Y* represents an impoundment-level characteristic or a facility-level characteristic, Y_{hi} is a facility-level outcome, and it is helpful to further let

$$Z_{hi} = w_{hi} Y_{hi} \quad .$$

Then, the estimated population total for characteristic *Y* can be represented as

$$\hat{Y} = \sum_{h=1}^{15} \sum_{i=1}^{n_h} Z_{hi} \quad .$$

Sampling variances for estimated totals were then estimated as

$$\hat{V}(\hat{Y}) = \sum_{h=1}^{15} n_h S_h^2 \quad ,$$

where

$$S_h^2 = \frac{n_h}{n_h - 1} \sum_{i=1}^{n_h} (Z_{hi} - \bar{Z}_h)^2 \quad ,$$

and

$$\bar{Z}_h = \frac{1}{n_h} \sum_{i=1}^{n_h} Z_{hi} \quad .$$

In order to illustrate how SUDAAN computed sampling variances for estimates means and totals, it is helpful to represent these ratio estimates as

$$\hat{R} = \frac{\sum_{h=1}^{15} \sum_{i=1}^{n_h} w_{hi} Y_{hi}}{\sum_{h=1}^{15} \sum_{i=1}^{n_h} w_{hi}} \quad .$$

The estimated variance of the ratio was then based on the following "linearized value:"

$$Z_{hi}^* = \frac{w_{hi} (Y_{hi} - \hat{R})}{\sum_{h=1}^{15} \sum_{i=1}^{n_h} w_{hi}} \quad .$$

The variance of the estimated mean or proportion was then computed as the estimated variance for the population total of the linearized values, Z_{hi}^*, i.e,

$$\hat{V}(\hat{R}) = \hat{V}(Z_{hi}^*) \quad ,$$

where the latter variance is computed using the formula presented above for estimating the variance of a population total.

The standard errors computed in this manner account only for the uncertainty resulting from random errors, primarily those due to making inferences from a sample, rather than from a census of all facilities in the population. They do not account for potential sources of systematic error (or bias), such as the incomplete nature of the sampling frame for zero dischargers (see Table A-10), response errors, data entry errors, etc.

When a cell sample size (i.e., the number of observations upon which a total, mean, or the denominator of a proportion is based) is small (e.g., less than 30), the standard error calculated by SUDAAN often is underestimated. In that case, the survey design effect, which typically exceeds one (1), may be estimated to be less than one, suggesting that the survey achieved greater precision than a simple random sample. Hence, if $\hat{\theta}$ represents an estimated total, mean, or proportion and $SE(\hat{\theta})$ represents its standard error calculated by SUDAAN, the standard error

used for that estimate was calculated as

$$se(\hat{\theta}) = Max\left[SE(\hat{\theta}), \frac{SE(\hat{\theta})}{\sqrt{DEFF(\hat{\theta})}}\right] \qquad \text{when } n < 30$$

$$se(\hat{\theta}) = SE(\hat{\theta}) \qquad \text{when } n \geq 30,$$

where DEFF is the Type 1 survey design effect calculated by SUDAAN and n is the cell sample size. Hence, the standard error calculated by SUDAAN was inflated to compensate for underestimation when the cell sample size was small (<30) and the survey design effect was less than one (1).

Estimates with Poor Reliability

When cell sample sizes are small, weighted population estimates may not be reliable, and their standard errors may not be accurately estimated. Therefore, estimated totals and means are flagged in the report as being unreliable when the relative standard error (RSE) of the estimate is 50 percent or more. That is, if $\hat{\theta}$ represents an estimated total or mean, then that estimate is flagged as unreliable if

$$\frac{se(\hat{\theta})}{\hat{\theta}} > 0.50 \quad .$$

RSEs do not work as well as measures of precision for estimated proportions because an estimate, $\hat{P}$, and its complement, $(1 - \hat{P})$, have the same variance but quite different RSEs. Therefore, the statistic used to flag estimates of proportions as unreliable is the RSE of the natural logarithm of $\hat{P}$. In particular, the estimate, $\hat{P}$, of a population proportion is flagged as unreliable if

$$\frac{se(\hat{P}) / \hat{P}}{-\ln(\hat{P})} > 0.275 \qquad \text{when } \hat{P} < 0.50$$

or

$$\frac{se(\hat{P}) / (1 - \hat{P})}{-\ln(1 - \hat{P})} > 0.275 \qquad \text{when } \hat{P} \geq 0.50 \quad .$$

The upper bound, 0.275, is an *ad hoc* bound that has been found to produce reasonable results.

Table A-14. Analysis Strata Used for Variance Estimation

Analysis Stratum	Number of Long Survey Respondents
Direct Discharge Facilities	
■ SIC 26	27
■ SIC 28	29
■ SIC 29	21
■ SIC 30	6
■ SIC 33	20
■ SIC 34-39	6
■ SIC 20-23	6
■ SIC 24-27	6
■ SIC 28-31	9
■ SIC 32	6
■ SIC 49-76[a]	7
Pilot study facilities (certainty selections)	6
Direct discharger subtotal	149
Zero Discharge Facilities	
In TRI or AFS	5
High priority SICs[b]	6
All other facilities[b]	24
Zero discharger subtotal	35

TRI = EPA's Toxic Release Inventory.
AFS = EPA's Aerometric Information Retrieval System, Facility Subsystem.
[a]SICs 4952 (excluding Publicly Owned Treatment Works), 4953, and 4959, 5085, 5093, 5169, 5171, and 7699 (transportation equipment cleaners only)
[b]Not in TRI or AFS.

A.5.2.3 <u>*Confidence Intervals*</u>. The reported standard errors also can be used to compute confidence interval estimates of population totals, means, and proportions. If $\hat{\theta}$ represents an estimated total, mean, or proportion, an approximate 100(1-α) percent confidence interval estimate of that parameter can be calculated as

$$\hat{\theta} \pm t_{df,1-\alpha/2}\, SE(\hat{\theta}) \quad ,$$

where t is the 100(1-α/2) percentile of the Student's t distribution with df degrees of freedom and $SE(\hat{\theta})$ is the standard error of the estimate. The appropriate degrees of freedom is

$$df = \sum_{h=1}^{H} (r_h - 1) \quad ,$$

where h represents the analysis strata (see Table A-14) and r_h is the number of responding facilities in analysis stratum h.

These confidence intervals are valid so long as the number of facilities contributing to the estimated total, mean, or proportion is large enough that the sampling distribution of the sample total, mean, or proportion is approximately a Student's t distribution.

Because of the relatively large number of facilities in the sample for the surface impoundment study, the resulting degrees of freedom usually are greater than 30, and the appropriate value to use from the Student's t distribution is actually the 100(1-α/2) percentile of the standard normal distribution. In that case, the approximate 95 percent confidence interval estimate of a population parameter (total, mean, or proportion) becomes

$$\hat{\theta} \pm 1.96\, SE(\hat{\theta}) \quad .$$

Confidence interval estimates are reported only when the cell sample size is sufficiently large to support a reasonably precise estimate. Therefore, confidence interval estimates are not reported for those estimates that are flagged as unreliable based on the criteria discussed above.

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Appendix B

Database Tables

Appendix B: Database Tables

This Appendix supplements Chapter 2 with additional estimates of the characteristics of the surface impoundment sampling frame. The first section of the appendix presents tables of various data elements from the survey database, with standard errors where appropriate. All of the data presented are extrapolated estimates; no sample-level data are shown. The tables in this first section are Table B-2 through Table B-18. The second section of the appendix focuses on the chemical data, and presents comparisons of the chemical data in the survey (consolidated) database to the chemical data in the risk input database, as well as other chemical data comparisons relevant to the Study. This section includes Table B-19 through Table B-30, and Figures B-1 through B-33.

Table B-1 lists all of the tables and figures in this appendix, and provides for each the survey question or other data source used, along with references to relevant sections of this report that describe data processing methods, protocols, and specifications used to create the data displayed in the tables. The primary section referenced is Appendix A and its attachments, which provide background on the sampling methodology, survey, and database development, including the consolidated survey and risk input databases. For example, Attachment A1 is the actual three-part survey forms, which have the questions (number and text) referred to in Table B-1. The information in Appendix A and its attachments provides the context for understanding the data provided in the tables in this appendix.

How to read and interpret the tables and the standard errors. Most of the tables in this appendix include the standard errors for each population estimate, usually in parentheses but sometimes as separate tables (e.g., Tables B-19b and B-20b). Estimates that may be unreliable because of a high relative standard error are indicated with an asterisk. The standard error is a common statistical measure of the precision of an estimate. It is the standard deviation of the sampling distribution of the estimate. That is, if one were to replicate the sample selection and data collection procedures many times in exactly the same way and with exactly the same population, the standard error of the estimate is the standard deviation of the values of that estimate generated by the samples. Section A.5.2 (Appendix A) explains how standard errors were calculated for the surface impoundment study.

Two common applications of standard errors are for computing relative standard errors, which are unit-free measures of precision, and for computing confidence interval estimates of population parameters. Both these uses of standard errors are summarized briefly below.

If $se(\hat{\theta})$ represents the standard error of the estimate, θ, then the relative standard error is the ratio of the standard error divided by the estimate itself, i.e.,

$$RSE(\hat{\theta}) = \frac{se(\hat{\theta})}{\hat{\theta}} \quad .$$

Estimates in Tables B-1 through B-30 that have relative standard errors exceeding 50 percent have been flagged (with an asterisk) as possibly being unreliable.

Because the estimates in Tables B-1 through B-30 are all based on a large sample of facilities, a 95 percent confidence interval estimate of the population total, mean, or proportion is the point estimate, $\hat{\theta}$, plus or minus two standard errors, i.e.,

$$\hat{\theta} \pm 2\, se(\hat{\theta}) \quad .$$

Additional details on the calculation of standard errors and confidence intervals may be found in section A.5.2 of Appendix A.

Table B-1. Description of Tables and Figures

Table Number	Description: Survey Question, Data Sources
Table B-1. List of Tables and Figures	(This table) Summarizes content and data sources for Appendix B tables and figures, including long survey question number and relevant Appendix A sections.
Table B-2. Characteristics of Industrial Impoundments	Number of all impoundments, number of impoundments with chemicals and pH of concern: B2; impoundment level characteristics: C6 to C9a; wastewater quantities: C16 or from impoundment areas and depths: from diagrams/maps provided in response to B3 and C10 (see section A.2.5)
Table B-3. Estimated Number of Facilities with Chemicals/pH of Concern by EPA Region	Facility location (address, city, state): A2
Table B-4. Estimated Number of Impoundments with Chemicals/pH of Concern by EPA Region	
Table B-5. Estimated Number of Facilities with Chemicals/pH of Concern by 2-Digit Standard Industrial Classification (SIC) Code	SIC code: screener data or, if missing, obtained from other sources (see section A.1.2)
Table B-6. Estimated Number of Impoundments with Chemicals/pH of Concern by 2-Digit Standard Industrial Classification (SIC) Code	
Table B-7. Estimated Quantity of Wastewater (metric tons) Managed in Impoundments with Chemicals/pH of Concern, by 2-Digit Standard Industrial Classification (SIC) Code	Wastewater quantities: C16 or from impoundment areas and depths: from diagrams/maps provided in response to B3 and C10 (see section A.2.5)
Table B-8. Distribution of Ages of Impoundments with Chemicals/pH of Concern in Operation in Year 2000	Ages of impoundments: C1 (midpoint of year range), C2a (operating status in 2000)
Table B-9. Distribution of Lifetimes of Impoundments with Chemicals/pH of Concern that have Permanently Ceased Receiving Wastes	Impoundment lifetimes: C1 (midpoint of year range), C2a (closure status); Year impoundment ceased receiving wastes: C2b
Table B-10. Estimated Number of Facilities with Chemicals/pH of Concern by Treatment Type	Treatment types: C18 (treatment, storage, disposal status); C20:types of treatment being performed.
Table B-11. Estimated Number of Lined Impoundments with Chemicals/pH of Concern by 2-Digit Standard Industrial Classification (SIC) Code	Liner status: standardized data based on C12 (see liner tables in consolidated database, section A.4.1 and Attachment A7).

(continued)

Table B-1. (continued)

Table Number	Description: Survey Question, Data Sources
Table B-12. Frequency of Liner Usage for Impoundments by Age of Impoundment	Time when impoundments began receiving wastes: C1, C2; liner status: standardized data based on C12 (see liner tables in consolidated database, section A.4.1 and Attachment A7); liner failure determination: C14a (oldest failure event)
Table B-13. Estimated Number of Overtopping Events at Impoundments with Chemicals/pH of Concern by Duration	Number and duration of overtopping events : C25
Table B-14. Estimated Number of People, Residences, Drinking Water Wells, and Schools within Distance Ranges of the Population of Impoundments with Chemicals/pH of Concern	Estimates for the number of residences, drinking water wells, and schools: B3 maps, U.S. Census data, GIS analysis (see section A.3.1)
Table B-15. Estimated Number of Impoundments with Chemicals/pH of Concern that had a State or Local Permit for Wastewater, Sludge Management, Groundwater Protection, or Air Emissions by 2-Digit SIC Code	Determination of whether impoundment is under a state or local permit: C8a
Table B-16. Estimated Number of Impoundments with Chemicals/pH of Concern which are Solid Waste Management Units at RCRA Treatment, Storage, and Disposal Facilities (TSDs) Evaluated During a RCRA Facility Assessment, or Similar Action by 2-Digit SIC Code	Determination of whether impoundment was evaluated during a RCRA Facility Assessment: C9a
Table B-17. Estimated Number of Impoundments with Chemicals/pH of Concern which Received Any Waste Exempt or Excluded from Regulation by 2-Digit SIC Code	Determination of whether impoundment received exempt/excluded waste and exemption/exclusion type: C7a (see Attachment A2.3, coding table EX_LIST for a listing of exemptions/exclusions by regulatory code).
Table B-18. Estimated Quantity (metric tons) of Wastewater Managed in Impoundments with Chemicals/pH of Concern that is Exempt or Excluded from Regulation	Determination of whether impoundment received exempt/excluded waste and exemption/exclusion type: C7a; estimated quantity: C7b (midpoint of the percentage range), C16 (typical wastewater quantity) (see Attachment A2.3, coding table EX_LIST for a listing of exemptions/exclusions by regulatory code)
Table B-19a. Chemicals: Presence and Volume in Wastewater (for Impoundments with Chemicals/pH of Concern)	Chemical presence in wastewater: C23a, C24a, or C24c (mark as present but quantity unknown or reported concentration or flux detection); wastewater quantities: C23a, C24a, and C24c (concentration or mass per unit time), (consolidated database - see section A.4.1 and Attachments A6, A7); C16 (wastewater quantity)
Table B-19b. Standard Errors for Chemicals: Presence and Volume in Wastewater (for Impoundments with Chemicals/pH of Concern)	

(continued)

Table B-1. (continued)

Table Number	Description: Survey Question, Data Sources
Table B-20a. Chemicals: Presence and Volume in Sludge (for Impoundments With Chemicals/pH of Concern)	Chemical presence in sludge: C23b, C24b, or C24d (mark as present but quantity unknown or reported concentration or flux detection); sludge chemical quantities: C23b, C24b, and C24d (concentration or mass per unit time), (consolidated database - see section A.4.1 and Attachments A6, A7); C16 (sludge quantity)
Table B-20b Standard Errors for Chemicals: Presence and Volume in Sludge (for Impoundments With Chemicals/pH of Concern)	
Table B-21. Comparison of Survey Data and Risk Input Data: Chemical Categories for Wastewater and Sludge at Influent, In Impoundment, and Effluent Sampling Points	Chemical presence in wastewater, sludge: C23, C24 (consolidated database - see section A.4.1 and Attachments A6, A7; risk input database - see section A.4.2 and Attachment A8); C16 (wastewater and sludge quantity)
Table B-22. Chemical Presence in Wastewater Influent by SIC Code (Survey Database)	Chemicals presence in influent: C24a (mark as present but quantity unknown or reported concentration or flux detection) (consolidated database - see section A.4.1 and Attachments A6, A7)
Table B-23. Chemical Presence in Wastewater In Impoundment by SIC Code (Survey Database)	Chemical presence in wastewater in impoundment: C23a (mark as present but quantity unknown or reported concentration or flux detection) (consolidated database - see section A.4.1 and Attachments A6, A7)
Table B-24. Chemical Presence in Wastewater Effluent by SIC Code (Survey Database)	Chemical presence in effluent: C24c (mark as present but quantity unknown or reported concentration or flux detection) (consolidated database - see section A.4.1 and Attachments A6, A7)
Table B-25. Chemical Presence in Sludge by SIC Code (Survey Database)	Chemical presence in sludge: C23b, C24b, or C24d (mark as present but quantity unknown or reported concentration or flux detection) (consolidated database - see section A.4.1 and Attachments A6, A7)
Table B-26. Chemical Presence in Wastewater Influent by SIC Code (Risk Input Database)	Chemical presence in influent: all chemicals listed in the risk input data for wastewater influent (risk input database - see section A.4.2 and Attachment A8)
Table B-27. Chemical Presence in Wastewater In Impoundment by SIC Code (Risk Input Database)	Chemical presence in wastewater in impoundment: all chemicals listed in the input risk data set for wastewater in impoundment (risk input database - see section A.4.2 and Attachment A8)
Table B-28. Chemical Presence in Sludge by SIC Code (Risk Input Database)	Chemical presence in sludge: all chemicals listed in the risk input data for sludge (risk input database - see section A.4.2 and Attachment A8)
Table B-29. Chemicals Cooccurring in Wastewater by Human Health Effect, Number of Cooccurring Chemicals, and Facility at which they Cooccur	If the number of chemicals in wastewater (C23a, C24a, or C24c) across all impoundments at a facility for a particular target human health effect was greater than 2, then the number and list cooccurring chemicals were reported by target health effect, number of cooccurrences, and facility (consolidated database - see section A.4.1 and Attachments A6, A7)

(continued)

Table B-1. (continued)

Table Number	Description: Survey Question, Data Sources
Table B-30. Facility-Level Cooccurrence of Chemicals in Wastewater by Human Health Effect (Survey Database)	Query based on chemical presence in wastewater: C23a, C24a, C24c (consolidated database: PQU or reported detection - see section A.4.1 and Attachments A6, A7)
Table B-31. Facility-Level Cooccurrence of Chemicals in Sludge by Human Health Effect (Survey Database)	Query based on chemical presence in sludge: C23b, C24b, C24d (consolidated database: PQU or reported detection - see section A.4.1 and Attachments A6, A7)
Table B-32. Impoundment-Level Cooccurrence of Chemicals in Wastewater by Human Health Effect (Survey Database)	Query based on chemical presence in wastewater: C23a, C24a, C24c (consolidated database: PQU or reported detection - see section A.4.1 and Attachments A6, A7)
Table B-33. Impoundment-Level Cooccurrence of Chemicals in Sludge by Human Health Effect (Survey Database)	Query based on chemical presence in sludge: C23b, C24b, C24d (consolidated database: PQU or reported detection - see section A.4.1 and Attachments A6, A7)
Table B-34. Facility-Level Cooccurrence of Chemicals in Wastewater by Human Health Effect (Risk Input Database)	Query based on chemical presence in wastewater: C23a, C24a, C24c (risk database: PQU, reported detection, or reported below detection - see section A.4.2 and Attachment A8)
Table B-35. Facility-Level Cooccurrence of Chemicals in Sludge by Human Health Effect (Risk Input Database)	Query based on chemical presence in sludge: C23b, C24b, C24d (risk database: PQU, reported detection, or reported below detection - see section A.4.2 and Attachment A8)
Table B-36. Impoundment-Level Cooccurrence of Chemicals in Wastewater by Human Health Effect (Risk Input Database)	Query based on chemical presence in wastewater: C23a, C24a, C24c (risk database: PQU, reported detection, or reported below detection - see section A.4.2 and Attachment A8)
Table B-37. Impoundment-Level Cooccurrence of Chemicals in Sludge by Human Health Effect (Risk Input Database)	Query based on chemical presence in sludge: C23b, C24b, C24d (risk database: PQU, reported detection, or reported below detection - see section A.4.2 and Attachment A8)
Table B-38. 50^{th} and 90^{th} Percentile Wastewater Concentrations in Impoundment for Selected Chemicals	For selected Toxicity Characteristic (TC) chemicals: concentration percentiles from C23a (consolidated database - see section A.4.1 and Attachments A6, A7)
Figure B-1. Arsenic influent and effluent wastewater concentrations.	For arsenic: influent (C24a) and effluent (C24c) concentrations, PQU flags, BDLs (consolidated database - see section A.4.1 and Attachments A6, A7)
Figure B-2. Arsenic influent wastewater concentrations by decharacterization status.	For arsenic: influent (C24a) concentrations, PQU flags, BDLs (consolidated database - see section A.4.1 and Attachments A6, A7); decharacterization status: C6
Figure B-3. Arsenic wastewater concentrations in impoundment (survey data versus risk input data).	For arsenic: wastewater in impoundment (C23a) concentrations, PQU flags, BDLs (consolidated database - see section A.4.1 and Attachments A6, A7); concentrations (risk input database - see section A.4.2 and Attachment A8)

(continued)

Table B-1. (continued)

Table Number	Description: Survey Question, Data Sources
Figure B-4. Barium influent and effluent wastewater concentrations.	For barium: influent (C24a) and effluent (C24c) concentrations, PQU flags, BDLs (consolidated database - see section A.4.1 and Attachments A6, A7)
Figure B-5. Barium influent wastewater concentrations by decharacterization status.	For barium: influent (C24a) concentrations, PQU flags, BDLs (consolidated database - see section A.4.1 and Attachments A6, A7); decharacterization status: C6
Figure B-6. Barium wastewater concentrations in impoundment (survey data versus risk input data).	For barium: wastewater in impoundment (C23a) concentrations, PQU flags, BDLs (consolidated database - see section A.4.1 and Attachments A6, A7); concentrations (risk input database - see section A.4.2 and Attachment A8)
Figure B-7. Benzene influent and effluent wastewater concentrations.	For benzene: influent (C24a) and effluent (C24c) concentrations, PQU flags, BDLs (consolidated database - see section A.4.1 and Attachments A6, A7)
Figure B-8. Benzene influent wastewater concentrations by decharacterization status.	For benzene: influent (C24a) concentrations, PQU flags, BDLs (consolidated database - see section A.4.1 and Attachments A6, A7); decharacterization status: C6
Figure B-9. Benzene wastewater concentrations in impoundment (survey data versus risk input data).	For benzene: wastewater in impoundment (C23a) concentrations, PQU flags, BDLs (consolidated database - see section A.4.1 and Attachments A6, A7); concentrations (risk input database - see section A.4.2 and Attachment A8)
Figure B-10. Cadmium influent and effluent wastewater concentrations.	For cadmium: influent (C24a) and effluent (C24c) concentrations, PQU flags, BDLs (consolidated database - see section A.4.1 and Attachments A6, A7)
Figure B-11. Cadmium influent wastewater concentrations by decharacterization status.	For cadmium: influent (C24a) concentrations, PQU flags, BDLs (consolidated database - see section A.4.1 and Attachments A6, A7); decharacterization status: C6
Figure B-12. Cadmium wastewater concentrations in impoundment (survey data versus risk input data).	For cadmium: wastewater in impoundment (C23a) concentrations, PQU flags, BDLs (consolidated database - see section A.4.1 and Attachments A6, A7); concentrations (risk input database - see section A.4.2 and Attachment A8)
Figure B-13. Chloroform influent and effluent wastewater concentrations.	For chloroform: influent (C24a) and effluent (C24c) concentrations, PQU flags, BDLs (consolidated database - see section A.4.1 and Attachments A6, A7)
Figure B-14. Chloroform influent wastewater concentrations by decharacterization status.	For chloroform: influent (C24a) concentrations, PQU flags, BDLs (consolidated database - see section A.4.1 and Attachments A6, A7); decharacterization status: C6
Figure B-15. Chloroform wastewater concentrations in impoundment (survey data versus risk input data).	For chloroform: wastewater in impoundment (C23a) concentrations, PQU flags, BDLs (consolidated database - see section A.4.1 and Attachments A6, A7); concentrations (risk input database - see section A.4.2 and Attachment A8)

(continued)

Table B-1. (continued)

Table Number	Description: Survey Question, Data Sources
Figure B-16. Chromium influent and effluent wastewater concentrations.	For chromium: influent (C24a) and effluent (C24c) concentrations, PQU flags, BDLs (consolidated database - see section A.4.1 and Attachments A6, A7)
Figure B-17. Chromium influent wastewater concentrations by decharacterization status.	For chromium: influent (C24a) concentrations, PQU flags, BDLs (consolidated database - see section A.4.1 and Attachments A6, A7); decharacterization status: C6
Figure B-18. Chromium wastewater concentrations in impoundment (survey data versus risk input data).	For chromium: wastewater in impoundment (C23a) concentrations, PQU flags, BDLs (consolidated database - see section A.4.1 and Attachments A6, A7); concentrations (risk input database - see section A.4.2 and Attachment A8)
Figure B-19. Cresol influent and effluent wastewater concentrations.	For cresols: influent (C24a) and effluent (C24c) concentrations, PQU flags, BDLs (consolidated database - see section A.4.1 and Attachments A6, A7)
Figure B-20. Cresol influent wastewater concentrations by decharacterization status.	For cresols: influent (C24a) concentrations, PQU flags, BDLs (consolidated database - see section A.4.1 and Attachments A6, A7); decharacterization status: C6
Figure B-21. Cresol wastewater concentrations in impoundment (survey data versus risk input data).	For cresols: wastewater in impoundment (C23a) concentrations, PQU flags, BDLs (consolidated database - see section A.4.1 and Attachments A6, A7); concentrations (risk input database - see section A.4.2 and Attachment A8)
Figure B-22. Lead influent and effluent wastewater concentrations.	For lead: influent (C24a) and effluent (C24c) concentrations, PQU flags, BDLs (consolidated database - see section A.4.1 and Attachments A6, A7)
Figure B-23. Lead influent wastewater concentrations by decharacterization status.	For lead: influent (C24a) concentrations, PQU flags, BDLs (consolidated database - see section A.4.1 and Attachments A6, A7); decharacterization status: C6
Figure B-24. Lead wastewater concentrations in impoundment (survey data versus risk input data).	For lead: wastewater in impoundment (C23a) concentrations, PQU flags, BDLs (consolidated database - see section A.4.1 and Attachments A6, A7); concentrations (risk input database - see section A.4.2 and Attachment A8)
Figure B-25. Mercury influent and effluent wastewater concentrations.	For mercury: influent (C24a) and effluent (C24c) concentrations, PQU flags, BDLs (consolidated database - see section A.4.1 and Attachments A6, A7)
Figure B-26. Mercury influent wastewater concentrations by decharacterization status.	For mercury: influent (C24a) concentrations, PQU flags, BDLs (consolidated database - see section A.4.1 and Attachments A6, A7); decharacterization status: C6
Figure B-27. Mercury wastewater concentrations in impoundment (survey data versus risk input data).	For mercury: wastewater in impoundment (C23a) concentrations, PQU flags, BDLs (consolidated database - see section A.4.1 and Attachments A6, A7); concentrations (risk input database - see section A.4.2 and Attachment A8)

(continued)

Table B-1. (continued)

Table Number	Description: Survey Question, Data Sources
Figure B-28. Methyl ethyl ketone (MEK) influent and effluent wastewater concentrations.	For MEK: influent (C24a) and effluent (C24c) concentrations, PQU flags, BDLs (consolidated database - see section A.4.1 and Attachments A6, A7)
Figure B-29. Methyl ethyl ketone (MEK) influent wastewater concentrations by decharacterization status.	For MEK: influent (C24a) concentrations, PQU flags, BDLs (consolidated database - see section A.4.1 and Attachments A6, A7); decharacterization status: C6
Figure B-30. Methyl ethyl ketone (MEK) wastewater concentrations in impoundment (survey data versus risk input data).	For MEK: wastewater in impoundment (C23a) concentrations, PQU flags, BDLs (consolidated database - see section A.4.1 and Attachments A6, A7); concentrations (risk input database - see section A.4.2 and Attachment A8)
Figure B-31. Selenium influent and effluent wastewater concentrations.	For selenium: influent (C24a) and effluent (C24c) concentrations, PQU flags, BDLs (consolidated database - see section A.4.1 and Attachments A6, A7)
Figure B-32. Selenium influent wastewater concentrations by decharacterization status.	For selenium: influent (C24a) concentrations, PQU flags, BDLs (consolidated database - see section A.4.1 and Attachments A6, A7); decharacterization status: C6
Figure B-33. Selenium wastewater concentrations in impoundment (survey data versus risk input data).	For selenium: wastewater in impoundment (C23a) concentrations, PQU flags, BDLs (consolidated database - see section A.4.1 and Attachments A6, A7); concentrations (risk input database - see section A.4.2 and Attachment A8)

Table B-2. Characteristics of Industrial Impoundments

Characteristic	Direct Dischargers	Zero Dischargers	Total
Estimates for All Nonhazardous Industrial Impoundments			
Number of facilities	6,575 (384)	884 (178)	7,459 (385)
Number of impoundments (based on screener survey)	15,992 (2,038)	1,705 (240)	17,697 (2,048)
Number of impoundments (based on long survey)	16,701 (1,756)	1,717 (421)	18,417 (1,764)
Estimates for Impoundments with Constituents/pH of Concern			
Number of facilities	3,944 (518)	512 (139)	4,457 (522)
Number of impoundments	10,987 (1,896)	876 (165)	11,863 (1,903)
Total volume of wastewater managed (metric tons)	627,218,336* (334,849,400)	27,250,309* (14,903,337)	654,468,645* (334,824,107)
Number of facilities that manage decharacterized wastes	605 (128)	62* (45)	667 (133)
Number of facilities that manage never characteristic wastes	3,339 (440)	450 (112)	3,789 (441)
Number of impoundments that manage decharacterized wastes	2,167 (454)	140* (115)	2,306 (468)
Number of impoundments that manage never characteristic wastes	8,821 (1,715)	736 (137)	9,557 (1,720)
Quantity (metric tons) of wastewater managed in impoundments that manage decharacterized wastes	481,135,509 (202,260,427)	532,435* (463,972)	481,667,944 (202,257,984)
Quantity (metric tons) of wastewater managed in impoundments that manage never characteristic wastes	156,398,430 (43,847,438)	27,084,601 (12,580,135)	183,483,030 (45,616,418)
Number of facilities with pH of concern pH<3	302* (206)	28* (31)	330* (208)
pH>11	565 (271)	144 (68)	709 (276)
Number of impoundments with pH of concern pH<3	295* (196)	54* (54)	349* (204)
pH>11	758 (352)	164 (67)	921 (358)
Number of facilities that manage any waste exempt or excluded from RCRA regulations	541 (171)	83* (52)	625 (178)
Number of impoundments that manage any waste exempt or excluded from RCRA regulations	1,587 (537)	183* (122)	1,770 (551)
Number of impoundments with state/local permits	9,538 (1,777)	682 (136)	10,220 (1,783)
Number of impoundments that have RFAs conducted	3,761 (1,320)	185* (113)	3,946 (1,325)

Table B-3. Estimated Number of Facilities with Chemicals/pH of Concern by EPA Region

EPA Region	Direct Dischargers	Zero Dischargers	Total
All Facilities	3,944 (348)	512 (116)	4,457 (348)
1	87* (50)	0 (0)	87* (50)
2	100* (66)	83* (49)	183 (76)
3	585 (210)	75* (47)	661 (213)
4	1,705 (390)	103* (55)	1,808 (393)
5	391 (130)	28* (29)	419 (133)
6	434* (233)	89* (51)	524 (237)
7	165* (132)	28* (29)	193* (135)
8	219* (165)	0 (0)	219* (165)
9	114* (58)	46* (37)	159 (68)
10	145* (117)	59* (42)	205* (125)

Table B-4. Estimated Number of Impoundments with Chemicals/pH of Concern by EPA Region

EPA Region	Direct Dischargers	Zero Dischargers	Total
All impoundments	10,987 (1,704)	876 (137)	11,863 (1,706)
1	437* (351)	0 (0)	437* (351)
2	229* (138)	83* (44)	312 (143)
3	1,895* (1,168)	100* (56)	1,995* (1,169)
4	3,975 (991)	128 (63)	4,103 (993)
5	1,064 (329)	56* (56)	1,121 (333)
6	1,900* (1,161)	168* (91)	2,068* (1,165)
7	368* (278)	28* (28)	396* (279)
8	395* (207)	0 (0)	395* (207)
9	418* (228)	184* (140)	601 (268)
10	307* (238)	128* (105)	434* (260)

Table B-5. Estimated Number of Facilities with Chemicals/pH of Concern by 2-Digit Standard Industrial Classification (SIC) Code

2-Digit SIC Code	Direct Dischargers	Zero Dischargers	Total
All Facilities	3,944 (348)	512 (116)	4,457 (348)
20	236* (236)	101* (54)	336* (241)
22	157* (127)	0 (0)	157* (127)
24	243* (122)	0 (0)	243* (122)
26	244 (83)	25* (27)	270 (87)
28	819 (141)	28* (29)	847 (143)
29	263 (86)	62* (44)	325 (95)
30	96* (53)	19* (23)	114* (58)
32	517 (165)	149 (66)	666 (172)
33	401 (127)	27* (28)	429 (130)
34	7* (14)	24* (26)	31* (30)
36	15* (21)	0 (0)	15* (21)
37	0 (0)	50* (39)	50* (39)
49	333* (199)	0 (0)	333* (199)
51	491 (243)	28* (29)	519 (244)
97	122* (122)	0 (0)	122* (122)

Table B-6. Estimated Number of Impoundments with Chemicals/pH of Concern by 2-Digit Standard Industrial Classification (SIC) Code

2-Digit SIC Code	Direct Dischargers	Zero Dischargers	Total
All Impoundments	10,987 (1,704)	876 (137)	11,863 (1,706)
20	708* (708)	267* (153)	974* (724)
22	157* (127)	0 (0)	157* (127)
24	486* (243)	0 (0)	486* (243)
26	1,340 (400)	25* (25)	1,365 (400)
28	2,734 (1,022)	28* (28)	2,762 (1,022)
29	1,230 (252)	130* (106)	1,361 (273)
30	119 (52)	74* (74)	193 (80)
32	1,426* (1,001)	174 (63)	1,600* (1,003)
33	884 (229)	27* (27)	912 (230)
34	7* (13)	47* (47)	54* (48)
36	37* (29)	0 (0)	37* (29)
37	0 (0)	75* (54)	75* (54)
49	419* (220)	0 (0)	419* (220)
51	1,197* (636)	28* (28)	1,225* (637)
97	244* (244)	0 (0)	244* (244)

Table B-7. Estimated Quantity of Wastewater (metric tons) Managed in Impoundments with Chemicals/pH of Concern, by 2-Digit Standard Industrial Classification (SIC) Code

2-Digit SIC Code	Direct Dischargers	Zero Dischargers	Total
All Impoundments	626,495,468 (200,068,968)	26,818,959 (11,992,958)	653,314,426 (200,145,906)
20	13,296,807* (13,296,807)	18,714,576* (11,627,671)	32,011,382* (17,663,742)
22	388,459* (293,594)	0 (0)	388,459* (293,594)
24	10,042,479* (9,372,635)	0 (0)	10,042,479* (9,372,635)
26	426,454,295 (195,842,259)	1,774,657* (1,774,657)	428,228,953 (195,841,439)
28	60,443,443 (24,132,932)	139,799* (139,799)	60,583,241 (24,132,547)
29	36,028,791* (21,167,383)	443,535* (443,535)	36,472,326* (21,166,930)
30	67,914* (61,270)	337,517* (337,517)	405,432* (342,900)
32	619,108* (609,131)	5,118,566* (4,941,102)	5,737,674* (4,940,840)
33	46,970,517* (30,868,752)	86,284* (86,284)	47,056,801* (30,868,586)
34	7,038* (12,912)	48,265* (48,265)	55,303* (48,775)
36	502,008* (661,349)	0 (0)	502,008* (661,349)
37	0 (0)	144,692* (143,530)	144,692* (143,530)
49	4,259,858* (3,851,949)	0 (0)	4,259,858* (3,851,949)
51	27,345,022* (26,311,362)	11,067* (11,067)	27,356,090* (26,311,364)
97	69,729* (69,729)	0 (0)	69,729* (69,729)

Table B-8. Distribution of Ages of Impoundments with Chemicals/pH of Concern in Operation in Year 2000

Age of Impoundment	Direct Dischargers	Zero Dischargers	Total
All Impoundments In Operation in 2000	9,083 (1,751)	849 (137)	9,932 (1,753)
5 years	1,970 (905)	205 (78)	2,175 (908)
15 years	1,371 (414)	100 (49)	1,471 (416)
25 years	3,325 (1,095)	331 (94)	3,656 (1,099)
35 years	1,144 (359)	188* (142)	1,332 (386)
45 years	1,122 (389)	25* (25)	1,147 (389)
55 years	110* (60)	0 (0)	110* (60)
65 years	34* (28)	0 (0)	34* (28)
101 years	7* (13)	0 (0)	7* (13)

Table B-9. Distribution of Lifetimes of Impoundments with Chemicals/pH of Concern that have Permanently Ceased Receiving Wastes

Age Range	Direct Dischargers	Zero Dischargers	Total
All Closed Impoundments	1,630 (533)	25* (25)	1,655 (534)
0-5 years	93* (52)	0 (0)	93* (52)
6-10 years	29* (26)	0 (0)	29* (26)
11-15 years	798* (453)	25* (25)	823* (454)
16-20 years	143* (76)	0 (0)	143* (76)
21-25 years	116 (55)	0 (0)	116 (55)
26-30 years	37* (29)	0 (0)	37* (29)
31-35 years	31* (27)	0 (0)	31* (27)
36-40 years	22* (22)	0 (0)	22* (22)
41-45 years	28* (26)	0 (0)	28* (26)
46-50 years	262* (241)	0 (0)	262* (241)
51-55 years	47* (47)	0 (0)	47* (47)
56-60 years	24* (24)	0 (0)	24* (24)

Table B-10. Estimated Number of Facilities with Chemicals/pH of Concern by Treatment Type

Treatment Type	Direct Dischargers	Zero Dischargers	Total
Aeration	920 (221)	160 (69)	1,081 (226)
Flocculation	239* (232)	0 (0)	239* (232)
Sedimentation	1,780 (278)	217 (80)	1,997 (285)
Filtration	38* (34)	0 (0)	38* (34)
Coagulation	156* (130)	0 (0)	156* (130)
Disinfection	7* (15)	0 (0)	7* (15)
Precipitation	200* (133)	0 (0)	200* (133)
Ion exchange	0 (0)	0 (0)	0 (0)
Adsorption	7* (15)	0 (0)	7* (15)
Chemical oxidation	76* (49)	36* (36)	112* (60)
Nitrification	97* (55)	29* (30)	127 (62)
Denitrification	63* (44)	29* (30)	92* (53)
Carbonaceous biochemical oxygen demand (CBOD) removal	122* (61)	65* (46)	187 (75)
Anaerobic biological treatment process	399* (266)	0 (0)	399* (266)
Aerobic biological treatment process	612 (268)	36* (36)	647 (271)
Facultative treatment process	150 (68)	29* (30)	180 (74)
pH adjustment	795 (307)	0 (0)	795 (307)
Temperature adjustment	449 (182)	0 (0)	449 (182)
Other	498 (181)	26* (29)	525 (183)
No treatment	2,091 (273)	232 (83)	2,323 (280)

Table B-11. Estimated Number of Lined Impoundments with Chemicals/pH of Concern by 2-Digit Standard Industrial Classification (SIC) Code

2-Digit SIC Code	Direct Dischargers	Zero Dischargers	Total
All Impoundments	4,444 (1,148)	403 (126)	4,847 (1,155)
20	708* (708)	110* (78)	818* (712)
22	21* (22)	0 (0)	21* (22)
24	233* (233)	0 (0)	233* (233)
26	544 (229)	0 (0)	544 (229)
28	1,466* (790)	28* (28)	1,494* (791)
29	290 (88)	102* (102)	392 (135)
30	44* (32)	37* (37)	81* (46)
32	0 (0)	25* (25)	25* (25)
33	460 (166)	0 (0)	460 (166)
34	7* (13)	47* (47)	54* (48)
36	37* (29)	0 (0)	37* (29)
37	0 (0)	25* (25)	25* (25)
49	177* (163)	0 (0)	177* (163)
51	214* (214)	28* (28)	242* (216)
97	244* (244)	0 (0)	244* (244)

Table B-12. Frequency of Liner Usage for Impoundments by Age of Impoundment

Year Impoundment Began Receiving Waste	Before 1900	1900-1939	1940-1949	1950-1959	1960-1969	1970-1979	1980-1989	1990-2000	Total
Number of Impoundments	0	114	409	1,213	1,446	4,226	2,073	2,382	11,863
% of Total Impoundments	0	1	3	10	12	36	17	20	100
Impoundments with Liners									
Number of Lined Impoundments	0	79	267	95	356	1,887	631	1,440	4,755
% of Lined Impoundments for Given Year Range	0	68	65	8	25	45	30	60	40
% of Total Lined Impoundments	0	2	6	2	7	40	13	30	100
% of Lined Impoundments with No Liner Failure	0	2	6	2	8	35	13	34	100
% of Lined Impoundments with Liner Failure	0	0	0	1	4	73	17	4	100
Impoundments without Liners									
Number of Unlined Impoundments	0	35	142	1,118	1,090	2,339	1,442	942	7,108
% of Unlined Impoundments for Given Year Range	0	31	35	92	75	55	70	40	60
% of Total Unlined Impoundments	0	0.5	2	16	15	33	20	13	100

Table B-13. Estimated Number of Overtopping Events at Impoundments with Chemicals/pH of Concern by Duration

Duration	Direct Dischargers	Zero Dischargers	Total
All Overtopping Events	2,040 (761)	61* (44)	2,101 (763)
1 Day	932 (428)	61* (44)	992 (430)
2 Days	96* (79)	0 (0)	96* (79)
4 Days	116* (116)	0 (0)	116* (116)
1 Month	4* (9)	0 (0)	4* (9)
2 Months	3* (9)	0 (0)	3* (9)
5 Months	7* (13)	0 (0)	7* (13)
Cannot Be Determined	882* (538)	0 (0)	882* (538)

Table B-14. Estimated Number of People, Residences, Drinking Water Wells, and Schools within Distance Ranges

Distance from Impoundment	Direct Dischargers	Zero Dischargers	Total
Number of people within 0-150m	47,979 (14,524)	3,600 (1,079)	51,579 (14,564)
151-500m	580,127 (162,685)	83,253 (36,390)	663,380 (166,705)
501-1000m	2,938,328 (964,251)	346,050* (184,390)	3,284,378 (981,722)
1001-2000m	12,434,974 (2,899,926)	1,979,202 (946,061)	14,414,175 (3,050,344)
Number of residences within 0-150m	19,687 (5,836)	1,540 (453)	21,227 (5,854)
151-500m	249,429 (72,408)	35,983 (15,495)	285,411 (74,047)
501-1000m	1,202,653 (379,787)	139,182* (69,912)	1,341,834 (386,168)
1001-2000m	5,072,366 (1,135,606)	826,444 (390,984)	5,898,810 (1,201,029)
Number of drinking water wells within 0-150m	567* (317)	321* (200)	888 (379)
151-500m	12,064* (6,342)	1,663* (1,317)	13,728 (6,476)
501-1000m	53,528 (22,575)	2,618* (1,557)	56,146 (22,622)
1001-2000m	195,041 (55,029)	9,944* (5,097)	204,984 (55,165)
Number of schools within 0-150m	0 (N/A)	0 (N/A)	0 (N/A)
151-500m	541* (321)	0 (N/A)	541* (321)
501-1000m	2,146 (1,032)	243* (163)	2,390 (1,044)
1001-2000m	8,116 (2,069)	874 (387)	8,990 (2,104)

Table B-15. Estimated Number of Surface Impoundments with Chemicals/pH of Concern That Had a State or Local Permit for Wastewater, Sludge Management, Groundwater Protection, or Air Emissions by 2-Digit Standard Industrial Classification (SIC) Code

2-Digit SIC	Direct Dischargers	Zero Dischargers	All Impoundments
All Industries	9,159	643	9,802
20 (Food and Kindred Products)	708	267	974
22 (Textile Mill Products)	21	0	21
24 (Lumber and Wood Products)	233	0	233
26 (Paper and Allied Products)	1,222	25	1,247
28 (Chemicals and Allied Products)	2,515	28	2,543
29 (Petroleum and Coal Products)	965	28	993
30 (Rubber and Miscellaneous Plastic Products)	98	37	135
32 (Stone, Clay, and Glass Products)	1,199	103	1,302
33 (Primary Metal Industries)	488	27	516
34 (Fabricated Metal Products)	7	24	31
36 (Electronic and Other Electrical Equipment)	7	0	7
37 (Transportation Equipment)	0	75	75
49 (Electric, Gas, and Sanitary Services)	256	0	256
51 (Wholesale Trade, Nondurable Goods)	1,197	28	1,225
97 (National Security and International Affairs)	244	0	244

Table B-16. Estimated Number of Impoundments in Population B Which Were Solid Waste Management Units at RCRA Treatment, Storage, and Disposal Facilities (TSDs)Evaluated During a RCRA Facility Assessment or Similar Action, by 2-Digit Standard Industrial Classification (SIC) Code

2-Digit SIC	Direct Dischargers	Zero Dischargers	All Impoundments
All Industries	3,288	146	3,433
26 (Paper and Allied Products)	20	0	20
28 (Chemicals and Allied Products)	2,171	0	2,171
29 (Petroleum and Coal Products)	778	68	846
33 (Primary Metal Industries)	240	27	267
37 (Transportation Equipment)	0	50	50
49 (Electric, Gas, and Sanitary Services)	79	0	79

Table B-17. Estimated Number of Impoundments with Chemicals/pH of Concern that Received Any Waste Exempt or Excluded from RCRA Regulations, by 2-Digit Standard Industrial Classification (SIC) Code

2-Digit SIC (Industry)	Direct Dischargers	Zero Dischargers	All Impoundments
All Industries	1,534	173	1,706
22 (Textile Mill Products)	21	0	21
26 (Paper and Allied Products)	641	0	641
28 (Chemicals and Allied Products)	588	0	588
29 (Petroleum and Coal Products)	206	102	308
32 (Stone, Clay, and Glass Products)	0	20	20
33 (Primary Metal Industries)	28	0	28
34 (Fabricated Metal Products)	7	0	7
36 (Electronic and Other Electrical Equipment)	22	0	22
37 (Transportation Equipment)	0	50	50
49 (Electric, Gas, and Sanitary Services)	22	0	22

Table B-18. Estimated Quantity (Metric Tons) of Wastewater Managed in Impoundments with Chemicals/pH of Concern That is Exempt or Excluded from Regulation

Regulation	Direct Dischargers	Zero Dischargers	Total
All Regulations	94,472,856	4,295,692	98,768,548
§260.22 and §3001(f)	0	0	0
§261.3(a)(2)(i)	0	0	0
§261.3(a)(2)(iii)	16,731,865	0	16,731,865
§261.3(a)(2)(iv)	86,328	0	86,328
§261.3(a)(2)(iv)(A)	8,221	0	8,221
§261.3(a)(2)(iv)(B)	0	0	0
§261.3(a)(2)(iv)(C)	95,669	10,098	105,767
§261.3(a)(2)(iv)(D)	1,168,963	6,859	1,175,821
§261.3(a)(2)(iv)(E)	1,845,175	6,859	1,852,033
§261.3(a)(2)(iv)(F)	0	0	0
§261.3(a)(2)(iv)(G)	0	0	0
§261.3(c)(2)(ii)	0	0	0
§261.3(c)(2)(ii)(A)	0	0	0
§261.3(c)(2)(ii)(B)	0	0	0
§261.3(c)(2)(ii)(C)	0	0	0
§261.3(c)(2)(ii)(D)	0	0	0
§261.4(a)	1,000,407	0	1,000,407
§261.4(a)(1)	1,606,185	0	1,606,185
§261.4(a)(2)	13,366,523	0	13,366,523
§261.4(a)(3)	0	0	0
§261.4(a)(4)	0	0	0
§261.4(a)(5)	0	0	0
§261.4(a)(6)	2,016,833	0	2,016,833
§261.4(a)(7)	0	0	0
§261.4(a)(9)	0	0	0
§261.4(b)	0	0	0
§261.4(b)(1)	0	0	0
§261.4(b)(2)	0	0	0
§261.4(b)(3)	0	0	0
§261.4(b)(4) and §3001(b)(3)(A)(i)	7,836,906	0	7,836,906
§261.4(b)(5) and §3001(b)(12)(A)	0	0	0
§261.4(b)(6)	0	0	0
§261.4(b)(7) and §3001(b)(3)(A)(ii)	8,265,414	4,271,877	12,537,291
§261.4(b)(8) and §3001(b)(3)(A)(iii)	0	0	0
§261.4(b)(10)	0	0	0
§268.4 and §3005(j)(11)	0	0	0
§268.5 and §3004(h)	0	0	0
§268.6 and §3004(d)	0	0	0
§3004(h)	0	0	0
Other	40,444,366	0	40,444,366

Table B-19a. Chemicals: Presence and Volume in Wastewater (for Impoundments with Chemicals/pH of Concern)

Chemical	Number of Impoundments with Chemical Present in Wastewater [1]	Reported Quantity of Chemical in Wastewater (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
Barium	5,609	86,867*	4,045,548*	334,235,652*
Zinc	5,537	42,413	44,137,843*	26,175,024*
Copper	4,435	6,690*	232,239	1,197,404*
Nickel	4,332	743,304*	232,559*	709,369*
Lead	4,187	1,288*	81,436*	325,629*
Chromium	3,840	2,340*	72,702*	921,257*
Manganese	2,672	273,073*	17,537,976*	697,272,315*
Arsenic	2,163	1,993*	39,721	335,748*
Selenium	2,101	1,395*	30,767*	1,039,495*
Mercury	1,943	138*	10,977*	15,523*
Toluene	1,933	190*	6,450*	6,348*
Fluoride	1,640	881,320*	655,872,641*	709,804,880*
Xylenes, mixed isomers [Xyenes]	1,591	35*	4,672*	3,294*
Chloroform [Trichloromethane]	1,570	3,000*	149,528*	80,860*
Phenol	1,434	2,505*	449,842*	2,539,884*
Cadmium	1,325	125*	5,756*	10,984*
Ethyl benzene	1,176*	11*	4,965*	3,207*
Benzene	1,108*	51*	4,164*	2,262*
Vanadium	1,086	5,519*	32,666*	25,233*
Molybdenum	1,062	471*	19,499*	35,317*
Acetone [2-Propanone]	1,047*	385,119*	48,558,027*	24,103,457*
Carbon disulfide	1,023*	130*	14,416*	939,914*
Sulfide	915	62,403*	7,273,444*	5,472,858*
Antimony	907	47*	2,530*	2,450*
Methyl ethyl ketone [2-Butanone][MEK]	903	25,812*	1,554,826*	11,445,363*
Naphthalene	884*	267*	7,890*	1,594,276*

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table B-19a. (continued)

Chemical	Number of Impoundments with Chemical Present in Wastewater [1]	Reported Quantity of Chemical in Wastewater (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
Methanol [methyl alcohol]	807	6,147,194*	636,494,373	3,994,144,150*
Silver	748	72*	2,749*	2,658*
Chromium VI [Hexavalent Chromium]	745	40*	5,559*	9,790*
Beryllium	722	101*	618*	1,158*
Ethylene glycol	710*	23,303*	9,488,441*	17,246*
Cyanide	653	377*	173,996*	91,663*
Formaldehyde	626*	479*	3,739,508*	1,604,584*
Acetaldehyde [Ethanal]	621*	14,858*	5,854,234*	237,461*
Cresols	535*	437*	65,631*	2,908,262*
2,4,5-Trichlorophenol	484*	16*	0	0
Methylene chloride [Dichloromethane]	481*	254*	6,348*	9,658*
Cobalt	470	18*	868*	945*
Bis(2-ethylhexyl) phthalate [Dioctyl phthalate]	451*	16*	9*	6,193*
Methyl isobutyl ketone [Hexone] [4-Methyl-2-pentanone] [MIBK]	392*	0	0	0
Bromodichloromethane [Dichlorobromomethane]	379*	1,823*	169*	28,669*
Chloromethane [Methyl chloride]	373*	209*	17,009*	4,459*
Formic Acid	360*	0	8,804,297*	1,580*
Bromoform [Tribromomethane]	336*	29,772*	301*	468,223*
Thallium	309*	5*	1,931*	1,693*
Chlorodibromomethane [Dibromochloromethane]	291*	9,464*	54*	148,767*
n-Dioctyl phthalate	280*	7*	0	302*
Chloroethane [Ethyl chloride]	253*	29*	0	456*
o-Xylene	252*	5*	427*	427*
Bromomethane [Methyl bromide]	232*	664*	0	10,430*
Carbon tetrachloride	232*	13*	0	203*

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table B-19a. (continued)

Chemical	Number of Impoundments with Chemical Present in Wastewater [1]	Reported Quantity of Chemical in Wastewater (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
Heptachlor epoxide, alpha, beta, and gamma isomers	230*	0*	49*	31*
p-Cresol [4-Methyl phenol]	229*	16*	150*	276*
Benzyl alcohol	207*	473*	87,068*	41,424*
Pyrene	194	8*	1,259*	2*
Aniline	190*	699*	75,635*	64,560*
2,4,6-Trichlorophenol	188*	16*	0	0
Methyl tert-butyl ether [MTBE]	187*	412*	0	0*
o-Cresol [2-Methyl phenol]	184*	16*	86*	0
Tetrachlorodibenzofurans [TCDFs]	182*	0*	1*	4*
m-Cresol [3-Methyl phenol]	159*	16*	0	0
Methoxychlor	156*	5*	222*	0
Tetrachloroethylene [Perchloroethylene]	152*	2*	53*	53*
1,4-Dichlorobenzene [p-Dichlorobenzene]	143*	16*	0	0
Cyanide, amenable	142*	14*	8,514*	1,776*
2,4-D [2,4-Dichlorophenoxyacetic acid]	136*	2*	0	0
2,4-Dinitrotoluene	136*	16*	0	0
Chlordane, alpha & gamma isomers	136*	1*	0	0
Endrin	136*	0*	0	0
Heptachlor	136*	0*	0	0
Lindane [gamma-Hexachlorocyclohexane] [gamma-BHC]	136*	0*	0	0
Silvex [2,4,5-Trichlorophenoxypropionic acid]	136*	0*	0	0
Toxaphene [Chlorinated camphene]	136*	8*	0	0
Chrysene	136	10*	197*	12*

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table B-19a. (continued)

Chemical	Number of Impoundments with Chemical Present in Wastewater [1]	Reported Quantity of Chemical in Wastewater (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
Styrene	129*	52*	69,572*	28,460*
2,3,7,8-TCDD [2,3,7,8-Tetrachlorodibenzo-p-dioxin]	121*	0	0*	0*
alpha-Hexachlorocyclohexane [alpha-BHC]	115*	1*	106*	49*
Di-n-butyl phthalate	114*	0	0*	0
Acenaphthene	106*	0	109*	0
Benzo(a)pyrene	103*	0*	102*	1*
Fluoranthene	100*	0*	178*	9*
Tetrachlorodibenzo-p-dioxins [TCDDs]	91*	0	0	0
Benzo[a]anthracene	85*	0*	23*	2*
Anthracene	85*	0	28*	0
Fluorene	66*	0	41*	5*
1,1-Dichloroethylene [Vinylidene chloride]	57*	0*	79*	79*
Polychlorinated biphenyls [Aroclors]	55*	1*	2,907*	6,061*
N,N-Dimethyl formamide [DMF]	52*	0	0	0
2,4-Dichlorophenol	52*	0	0	0
2-Chlorophenol [o-Chlorophenol]	52*	0	0	0
Hexachlorodibenzofurans [HxCDFs]	51*	0*	0*	0*
1,2-Dichloropropane [Propylene dichloride]	50*	18*	20,848*	10,039*
1,2-Dichloroethane [Ethylene dichloride]	49*	0*	332*	21*
Ethylene thiourea	46*	0	0	0
Thiram [Thiuram]	46*	0	0	0
N-Nitrosodiphenylamine [Diphenylnitrosamine]	46*	0	0	0
Cumene [Isopropyl benzene]	44*	0	0	0

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table B-19a. (continued)

Chemical	Number of Impoundments with Chemical Present in Wastewater [1]	Reported Quantity of Chemical in Wastewater (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
n-Hexane	44*	0	0	0
Acrylonitrile	43*	3*	1,360*	1,380*
1,1,1-Trichloroethane [Methyl chloroform]	43*	3*	0*	0
Epichlorohydrin [1-Chloro-2,3-epoxypropane]	42*	0	0	0
2,4-Dimethylphenol	42*	14*	3,487*	379*
Hexachlorodibenzo-p-dioxins [HxCDDs]	41*	0	0	0*
Pentachlorodibenzofurans [PeCDFs]	41*	0	0	0*
1,4-Dioxane [1,4-Diethyleneoxide]	40*	107*	32,468*	4,811*
Benzo(b)fluoranthene	40*	0*	34*	1*
Bis(2-chloroisopropyl) ether [2,2 -Dichloroisopropyl ether]	36*	53*	46,503*	29,530*
Cyclohexanone	35*	88*	20,485*	5,051*
Pentachlorophenol [PCP]	35*	0	0	9*
Indeno(1,2,3-cd) pyrene	33*	0	25*	2*
Acrolein [2-propenal]	32*	18*	0	0
Allyl alcohol	31*	5,128*	1,636,554*	471,788*
Dibenz[a,h]anthracene	29*	0	10*	1*
Ethylidene dichloride [1,1-Dichloroethane]	29*	1*	0	0
Pyridine	24*	0	191*	0
Chlorobenzene	22*	0	0*	0
Diethyl phthalate [DEP]	22*	0	3*	0
Vinyl acetate	22*	0	0	0
Chloroprene [2-Chloro-1,3-butadiene]	22*	0	0	0
1,2,4-Trichlorobenzene	21*	0	1*	0
m-Xylene	21*	0*	123*	123*
p-Xylene	21*	0*	123*	123*

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table B-19a. (continued)

Chemical	Number of Impoundments with Chemical Present in Wastewater [1]	Reported Quantity of Chemical in Wastewater (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
Ethyl acetate	16*	0	187,466*	0
Ethyl ether [Diethyl ether]	16*	0	898*	0
Methyl methacrylate	15*	242*	124,055*	17,782*
Ethylene dibromide [1,2-Dibromoethane]	15*	0	0	0
1,2-Dichlorobenzene [o-Dichlorobenzene]	15*	0	0	0
Trichloroethylene [TCE]	15*	2*	0	0
1,1,2-Trichloroethane [Vinyl trichloride]	14*	0	0*	0
2,6-Dinitrotoluene	14*	0	0	1,034*
Allyl chloride	14*	100*	46,234*	9,484*
Bis(2-chloroethyl) ether [sym-Dichloroethyl ether]	14*	0	0	54*
Triethylamine	14*	0	0	0
Vinyl chloride [chloroethylene]	14*	0	0*	0
2,3,4,6-Tetrachlorophenol	14*	0	0	0
n-Butyl alcohol [n-Butanol]	11*	0	388,258*	247*
Hexachlorobenzene	11*	0	0	0
2,4-Dinitrophenol	8*	0	0	0
Dimethyl phthalate [DMP]	8*	0	0	0
Acrylic acid [propenoic acid]	8*	3*	769,840*	2,307*
Acetonitrile [Methyl cyanide]	7*	0	0	0
beta-Hexachlorocyclohexane [beta-BHC]	7*	3*	168*	168*
Ethylene oxide	6*	76*	42,880*	58*
Furfural	5*	0	7,266*	0
Propylene oxide [1,2-Epoxypropane]	4*	30*	11,052*	0
Cyclohexanol	1*	0	0	0
Isobutyl alcohol [Isobutanol]	1*	0	0	0

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table B-19a. (continued)

Chemical	Number of Impoundments with Chemical Present in Wastewater [1]	Reported Quantity of Chemical in Wastewater (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
1,1,1,2-Tetrachloroethane	Not Present or Not Reported	0	0	0
1,1,2,2-Tetrachloroethane	Not Present or Not Reported	0	0	0
1,1,2-Trichloro-1,2,2-trifluoroethane [Freon 113]	Not Present or Not Reported	0	0	0
1,2,3-Trichloropropane	Not Present or Not Reported	0	0	0
1,2,4,5-Tetrachlorobenzene	Not Present or Not Reported	0	0	0
1,2-Dibromo-3-chloropropane	Not Present or Not Reported	0	0	0
1,2-Diphenylhydrazine	Not Present or Not Reported	0	0	0
1,2-Epoxybutane [1,2-Butylene oxide]	Not Present or Not Reported	0	0	0
1,3,5-Trinitrobenzene [sym-Trinitrobenzene]	Not Present or Not Reported	0	0	0
1,3-Butadiene	Not Present or Not Reported	0	0	0
1,3-Dinitrobenzene [m-Dinitrobenzene]	Not Present or Not Reported	0	0	0
1,3-Phenylenediamine [m-Phenylenediamine]	Not Present or Not Reported	0	0	0
2,4,5-Trichlorophenoxyacetic acid [2,4,5,-T]	Not Present or Not Reported	0	0	0
2,4-Toluenediamine [2,4-Diaminotoluene]	Not Present or Not Reported	0	0	0
2-Chloronaphthalene [beta-Chloronaphthalene]	Not Present or Not Reported	0	0	0
2-Ethoxyethanol [Ethylene glycol monoethyl ether]	Not Present or Not Reported	0	0	0
2-Ethoxyethanol acetate [2-EEA]	Not Present or Not Reported	0	0	0
2-Methoxyethanol [methyl cellosolve]	Not Present or Not Reported	0	0	0

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table B-19a. (continued)

Chemical	Number of Impoundments with Chemical Present in Wastewater [1]	Reported Quantity of Chemical in Wastewater (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
2-Methoxyethanol acetate [2-MEA] [methyl cellosolve acetate]	Not Present or Not Reported	0	0	0
2-Nitropropane	Not Present or Not Reported	0	0	0
3,3 -Dichlorobenzidine	Not Present or Not Reported	0	0	0
3,3 -Dimethoxybenzidine	Not Present or Not Reported	0	0	0
3,3 -Dimethylbenzidine	Not Present or Not Reported	0	0	0
3,4-Dimethylphenol	Not Present or Not Reported	0	0	0
3-Methylcholanthrene	Not Present or Not Reported	0	0	0
4,4 -Methylene bis(2-chloroaniline)	Not Present or Not Reported	0	0	0
4-Chloroaniline [p-aminochlorobenzene]	Not Present or Not Reported	0	0	0
7,12-Dimethylbenz[a]anthracene	Not Present or Not Reported	0	0	0
Acetophenone	Not Present or Not Reported	0	0	0
Acrylamide	Not Present or Not Reported	0	0	0
Aldicarb	Not Present or Not Reported	0	0	0
Aldrin	Not Present or Not Reported	0	0	0
Ammonium vanadate	Not Present or Not Reported	0	0	0
Amonium perchlorate	Not Present or Not Reported	0	0	0
Aramite	Not Present or Not Reported	0	0	0
Benzidine	Not Present or Not Reported	0	0	0

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table B-19a. (continued)

Chemical	Number of Impoundments with Chemical Present in Wastewater [1]	Reported Quantity of Chemical in Wastewater (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
Benzyl chloride	Not Present or Not Reported	0	0	0
Bis(chloromethyl) ether [sym-Dichloromethyl ether]	Not Present or Not Reported	0	0	0
Butyl benzyl phthalate	Not Present or Not Reported	0	0	0
Chloral [Trichloroacetaldehyde]	Not Present or Not Reported	0	0	0
Chloral hydrate [Trichloroacetaldehyde hydrate]	Not Present or Not Reported	0	0	0
Chlorobenzilate	Not Present or Not Reported	0	0	0
Chloromethyl Methyl Ether	Not Present or Not Reported	0	0	0
cis-1,2-Dichloroethylene	Not Present or Not Reported	0	0	0
cis-1,3-Dichloropropylene	Not Present or Not Reported	0	0	0
Cyanogen bromide [Bromine cyanide]	Not Present or Not Reported	0	0	0
Cyanogen chloride [Chlorine cyanide]	Not Present or Not Reported	0	0	0
Diallate	Not Present or Not Reported	0	0	0
Dichlorodifluoromethane [CFC-12]	Not Present or Not Reported	0	0	0
Dieldrin	Not Present or Not Reported	0	0	0
Diethylstilbestrol [DES]	Not Present or Not Reported	0	0	0
Dimethoate	Not Present or Not Reported	0	0	0
Dinoseb [2-sec-Butyl-4,6-dinitrophenol]	Not Present or Not Reported	0	0	0
Diphenylamine	Not Present or Not Reported	0	0	0

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table B-19a. (continued)

Chemical	Number of Impoundments with Chemical Present in Wastewater [1]	Reported Quantity of Chemical in Wastewater (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
Direct Black 38	Not Present or Not Reported	0	0	0
Direct Blue 6	Not Present or Not Reported	0	0	0
Direct Brown 95	Not Present or Not Reported	0	0	0
Disulfoton	Not Present or Not Reported	0	0	0
Endosulfan	Not Present or Not Reported	0	0	0
Endothall	Not Present or Not Reported	0	0	0
Ethyl methacrylate	Not Present or Not Reported	0	0	0
Ethyl methanesulfonate	Not Present or Not Reported	0	0	0
Furan	Not Present or Not Reported	0	0	0
Glycidylaldehyde	Not Present or Not Reported	0	0	0
Hexachloro-1,3-butadiene [Hexachlorobutadiene]	Not Present or Not Reported	0	0	0
Hexachlorocyclopentadiene	Not Present or Not Reported	0	0	0
Hexachloroethane	Not Present or Not Reported	0	0	0
Hexachlorophene	Not Present or Not Reported	0	0	0
Hydrazine	Not Present or Not Reported	0	0	0
Isophorone	Not Present or Not Reported	0	0	0
Kepone	Not Present or Not Reported	0	0	0
Maleic anhydride	Not Present or Not Reported	0	0	0

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table B-19a. (continued)

Chemical	Number of Impoundments with Chemical Present in Wastewater [1]	Reported Quantity of Chemical in Wastewater (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
Maleic hydrazide	Not Present or Not Reported	0	0	0
Methacrylonitrile	Not Present or Not Reported	0	0	0
Methomyl	Not Present or Not Reported	0	0	0
Methyl parathion	Not Present or Not Reported	0	0	0
Methylene bromide [Dibromomethane]	Not Present or Not Reported	0	0	0
Nickel Subsulfide	Not Present or Not Reported	0	0	0
Nitrobenzene	Not Present or Not Reported	0	0	0
N-Nitrosodiethylamine	Not Present or Not Reported	0	0	0
N-Nitrosodimethylamine	Not Present or Not Reported	0	0	0
N-Nitrosodi-n-butylamine	Not Present or Not Reported	0	0	0
N-Nitrosodi-n-propylamine [Di-n-propylnitrosamine]	Not Present or Not Reported	0	0	0
N-Nitroso-N-methylethylamine	Not Present or Not Reported	0	0	0
N-Nitrosopiperidine	Not Present or Not Reported	0	0	0
N-Nitrosopyrrolidine	Not Present or Not Reported	0	0	0
Octamethylpyrophosphoramide	Not Present or Not Reported	0	0	0
o-Toluidine	Not Present or Not Reported	0	0	0
p,p -DDD	Not Present or Not Reported	0	0	0
p,p -DDE	Not Present or Not Reported	0	0	0

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table B-19a. (continued)

Chemical	Number of Impoundments with Chemical Present in Wastewater [1]	Reported Quantity of Chemical in Wastewater (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
p,p -DDT	Not Present or Not Reported	0	0	0
Parathion	Not Present or Not Reported	0	0	0
Pentachlorobenzene	Not Present or Not Reported	0	0	0
Pentachlorodibenzo-p-dioxins [PeCDDs]	Not Present or Not Reported	0	0	0
Pentachloronitrobenzene [PCNB] [Quintobenzene] [Quintozene]	Not Present or Not Reported	0	0	0
Perchlorate	Not Present or Not Reported	0	0	0
Phorate	Not Present or Not Reported	0	0	0
Phthalic anhydride	Not Present or Not Reported	0	0	0
Pronamide	Not Present or Not Reported	0	0	0
p-Toluidine	Not Present or Not Reported	0	0	0
Safrole	Not Present or Not Reported	0	0	0
Strychnine	Not Present or Not Reported	0	0	0
Styrene oxide	Not Present or Not Reported	0	0	0
Tetraethyldithiopyrophosphate [Sulfotepp]	Not Present or Not Reported	0	0	0
trans-1,2-Dichloroethylene	Not Present or Not Reported	0	0	0
trans-1,3-Dichloropropylene	Not Present or Not Reported	0	0	0
Trichlorofluoromethane [Trichloromonofluoromethane] [CFC-11]	Not Present or Not Reported	0	0	0
Tris(2,3-dibromopropyl) phosphate	Not Present or Not Reported	0	0	0
Warfarin	Not Present or Not Reported	0	0	0

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table B-19b. Standard Errors for Chemicals: Presence and Volume in Wastewater (For Impoundments with Chemicals/pH of Concern)

Chemical	Number of Impoundments with Chemical Present in Wastewater [1]	Reported Quantity of Chemical in Wastewater (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
Barium	1,616	92,570*	3,359,085*	601,022,558*
Zinc	1,319	19,623	69,191,620*	41,154,732*
Copper	1,029	4,694*	98,639	1,758,524*
Nickel	1,360	735,781*	137,148*	954,657*
Lead	1,218	1,161*	68,854*	472,479*
Chromium	905	1,468*	42,265*	1,474,002*
Manganese	736	198,223*	9,291,106*	1,217,759,748*
Arsenic	692	1,087*	19,008	458,257*
Selenium	989	1,485*	18,329*	1,805,473*
Mercury	704	126*	10,071*	14,620*
Toluene	869	293*	8,252*	8,050*
Fluoride	535	932,880*	652,297,404*	645,992,631*
Xylenes, mixed isomers [Xyenes]	776	22*	6,637*	5,440*
Chloroform [Trichloromethane]	620	2,376*	120,208*	63,104*
Phenol	330	1,945*	305,642*	4,323,561*
Cadmium	361	90*	4,270*	8,405*
Ethyl benzene	665*	7*	4,228*	4,204*
Benzene	665*	71*	3,496*	2,205*
Vanadium	433	5,016*	32,051*	30,889*
Molybdenum	373	306*	13,414*	18,996*
Acetone [2-Propanone]	601*	511,381*	64,548,719*	40,066,547*
Carbon disulfide	678*	140*	17,303*	2,306,653*
Sulfide	381	94,198*	7,911,353*	5,481,577*
Antimony	333	31*	2,745*	2,405*
Methyl ethyl ketone [2-Butanone][MEK]	398	23,992*	1,130,593*	18,400,064*
Naphthalene	647*	448*	6,804*	2,893,890*

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table B-19b. (continued)

Chemical	Number of Impoundments with Chemical Present in Wastewater [1]	Reported Quantity of Chemical in Wastewater (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
Methanol [methyl alcohol]	362	5,208,393*	289,572,696	6,024,051,004*
Silver	289	50*	2,408*	2,392*
Chromium VI [Hexavalent Chromium]	317	22*	3,947*	9,878*
Beryllium	291	84*	585*	779*
Ethylene glycol	373*	22,348*	27,583,115*	23,388*
Cyanide	239	473*	191,511*	108,534*
Formaldehyde	359*	584*	8,209,467*	1,451,442*
Acetaldehyde [Ethanal]	357*	14,707*	5,117,810*	210,533*
Cresols	356*	404*	58,808*	4,970,921*
2,4,5-Trichlorophenol	374*	16*	N/A	N/A
Methylene chloride [Dichloromethane]	244*	184*	7,566*	9,224*
Cobalt	233	16*	1,407*	1,415*
Bis(2-ethylhexyl) phthalate [Dioctyl phthalate]	260*	12*	8*	9,681*
Methyl isobutyl ketone [Hexone] [4-Methyl-2-pentanone] [MIBK]	350*	N/A	N/A	N/A
Bromodichloromethane [Dichlorobromomethane]	234*	1,822*	206*	28,633*
Chloromethane [Methyl chloride]	234*	180*	28,116*	3,056*
Formic Acid	275*	N/A	10,828,275*	4,442*
Bromoform [Tribromomethane]	242*	29,770*	284*	467,897*
Thallium	203*	5*	3,488*	3,020*
Chlorodibromomethane [Dibromochloromethane]	234*	9,464*	40*	148,750*
n-Dioctyl phthalate	236*	9*	N/A	796*
Chloroethane [Ethyl chloride]	233*	29*	N/A	450*
o-Xylene	232*	4*	715*	715*
Bromomethane [Methyl bromide]	232*	664*	N/A	10,430*

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table B-19b. (continued)

Chemical	Number of Impoundments with Chemical Present in Wastewater [1]	Reported Quantity of Chemical in Wastewater (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
Carbon tetrachloride	232*	13*	N/A	203*
Heptachlor epoxide, alpha, beta, and gamma isomers	166*	0.08*	56*	52*
p-Cresol [4-Methyl phenol]	145*	16*	508*	277*
Benzyl alcohol	154*	468*	84,668*	49,993*
Pyrene	72	7*	1,677*	3*
Aniline	136*	699*	75,635*	64,560*
2,4,6-Trichlorophenol	142*	16*	N/A	N/A
Methyl tert-butyl ether [MTBE]	106*	412*	N/A	0.4*
o-Cresol [2-Methyl phenol]	139*	16*	290*	N/A
Tetrachlorodibenzofurans [TCDFs]	95*	0.000*	1*	6*
m-Cresol [3-Methyl phenol]	137*	16*	N/A	N/A
Methoxychlor	137*	5*	326*	N/A
Tetrachloroethylene [Perchloroethylene]	137*	2*	53*	53*
1,4-Dichlorobenzene [p-Dichlorobenzene]	136*	16*	N/A	N/A
Cyanide, amenable	106*	57*	36,182*	3,700*
2,4-D [2,4-Dichlorophenoxyacetic acid]	136*	2*	N/A	N/A
2,4-Dinitrotoluene	136*	16*	N/A	N/A
Chlordane, alpha & gamma isomers	136*	0.8*	N/A	N/A
Endrin	136*	0.2*	N/A	N/A
Heptachlor	136*	0.08*	N/A	N/A
Lindane [gamma-Hexachlorocyclohexane] [gamma-BHC]	136*	0.08*	N/A	N/A
Silvex [2,4,5-Trichlorophenoxypropionic acid]	136*	0.2*	N/A	N/A
Toxaphene [Chlorinated camphene]	136*	8*	N/A	N/A

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table B-19b. (continued)

Chemical	Number of Impoundments with Chemical Present in Wastewater [1]	Reported Quantity of Chemical in Wastewater (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
Chrysene	67	10*	148*	14*
Styrene	66*	74*	80,509*	50,226*
2,3,7,8-TCDD [2,3,7,8-Tetrachlorodibenzo-p-dioxin]	82*	N/A	0.002*	0.002*
alpha-Hexachlorocyclohexane [alpha-BHC]	115*	0.8*	106*	81*
Di-n-butyl phthalate	67*	N/A	0.04*	N/A
Acenaphthene	54*	N/A	516*	N/A
Benzo(a)pyrene	55*	0.02*	83*	2*
Fluoranthene	53*	0.09*	352*	14*
Tetrachlorodibenzo-p-dioxins [TCDDs]	55*	N/A	N/A	N/A
Benzo[a]anthracene	51*	0.08*	37*	2*
Anthracene	50*	N/A	55*	N/A
Fluorene	39*	N/A	42*	10*
1,1-Dichloroethylene [Vinylidene chloride]	57*	0.3*	79*	79*
Polychlorinated biphenyls [Aroclors]	39*	1*	3,767*	6,545*
N,N-Dimethyl formamide [DMF]	41*	N/A	N/A	N/A
2,4-Dichlorophenol	41*	N/A	N/A	N/A
2-Chlorophenol [o-Chlorophenol]	41*	N/A	N/A	N/A
Hexachlorodibenzofurans [HxCDFs]	42*	0.000*	0.02*	0.002*
1,2-Dichloropropane [Propylene dichloride]	38*	24*	23,714*	16,607*
1,2-Dichloroethane [Ethylene dichloride]	34*	0.1*	1,082*	54*
Ethylene thiourea	46*	N/A	N/A	N/A
Thiram [Thiuram]	46*	N/A	N/A	N/A
N-Nitrosodiphenylamine [Diphenylnitrosamine]	46*	N/A	N/A	N/A

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table B-19b. (continued)

Chemical	Number of Impoundments with Chemical Present in Wastewater [1]	Reported Quantity of Chemical in Wastewater (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
Cumene [Isopropyl benzene]	33*	N/A	N/A	N/A
n-Hexane	33*	N/A	N/A	N/A
Acrylonitrile	36*	4*	1,758*	2,439*
1,1,1-Trichloroethane [Methyl chloroform]	31*	3*	0.3*	N/A
Epichlorohydrin [1-Chloro-2,3-epoxypropane]	31*	N/A	N/A	N/A
2,4-Dimethylphenol	31*	24*	8,145*	659*
Hexachlorodibenzo-p-dioxins [HxCDDs]	41*	N/A	N/A	0.001*
Pentachlorodibenzofurans [PeCDFs]	41*	N/A	N/A	0.000*
1,4-Dioxane [1,4-Diethyleneoxide]	38*	362*	109,950*	16,292*
Benzo(b)fluoranthene	30*	0.008*	57*	2*
Bis(2-chloroisopropyl) ether [2,2 -Dichloroisopropyl ether]	36*	76*	48,605*	51,713*
Cyclohexanone	34*	128*	73,865*	6,622*
Pentachlorophenol [PCP]	28*	N/A	N/A	9*
Indeno(1,2,3-cd) pyrene	27*	N/A	39*	3*
Acrolein [2-propenal]	27*	32*	N/A	N/A
Allyl alcohol	27*	9,203*	2,041,911*	843,892*
Dibenz[a,h]anthracene	26*	N/A	19*	2*
Ethylidene dichloride [1,1-Dichloroethane]	26*	0.9*	N/A	N/A
Pyridine	24*	N/A	646*	N/A
Chlorobenzene	22*	N/A	0.02*	N/A
Diethyl phthalate [DEP]	22*	N/A	4*	N/A
Vinyl acetate	22*	N/A	N/A	N/A
Chloroprene [2-Chloro-1,3-butadiene]	22*	N/A	N/A	N/A
1,2,4-Trichlorobenzene	22*	N/A	2*	N/A
m-Xylene	22*	0.4*	206*	206*

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table B-19b. (continued)

Chemical	Number of Impoundments with Chemical Present in Wastewater [1]	Reported Quantity of Chemical in Wastewater (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
p-Xylene	22*	0.4*	206*	206*
Ethyl acetate	19*	N/A	635,951*	N/A
Ethyl ether [Diethyl ether]	19*	N/A	3,045*	N/A
Methyl methacrylate	19*	314*	282,462*	31,885*
Ethylene dibromide [1,2-Dibromoethane]	19*	N/A	N/A	N/A
1,2-Dichlorobenzene [o-Dichlorobenzene]	18*	N/A	N/A	N/A
Trichloroethylene [TCE]	18*	4*	N/A	N/A
1,1,2-Trichloroethane [Vinyl trichloride]	18*	N/A	0.05*	N/A
2,6-Dinitrotoluene	18*	N/A	N/A	1,336*
Allyl chloride	18*	180*	68,044*	17,005*
Bis(2-chloroethyl) ether [sym-Dichloroethyl ether]	18*	N/A	N/A	70*
Triethylamine	18*	N/A	N/A	N/A
Vinyl chloride [chloroethylene]	18*	N/A	0.2*	N/A
2,3,4,6-Tetrachlorophenol	18*	N/A	N/A	N/A
n-Butyl alcohol [n-Butanol]	16*	N/A	1,195,884*	839*
Hexachlorobenzene	16*	N/A	N/A	N/A
2,4-Dinitrophenol	13*	N/A	N/A	N/A
Dimethyl phthalate [DMP]	13*	N/A	N/A	N/A
Acrylic acid [propenoic acid]	13*	8*	2,612,547*	7,832*
Acetonitrile [Methyl cyanide]	13*	N/A	N/A	N/A
beta-Hexachlorocyclohexane [beta-BHC]	12*	6*	310*	310*
Ethylene oxide	11*	192*	87,103*	197*
Furfural	11*	N/A	25,588*	N/A
Propylene oxide [1,2-Epoxypropane]	9*	77*	28,031*	N/A
Cyclohexanol	5*	N/A	N/A	N/A

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table B-19b. (continued)

Chemical	Number of Impoundments with Chemical Present in Wastewater [1]	Reported Quantity of Chemical in Wastewater (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
Isobutyl alcohol [Isobutanol]	5*	N/A	N/A	N/A
1,1,1,2-Tetrachloroethane	Not Present or Not Reported	N/A	N/A	N/A
1,1,2,2-Tetrachloroethane	Not Present or Not Reported	N/A	N/A	N/A
1,1,2-Trichloro-1,2,2-trifluoroethane [Freon 113]	Not Present or Not Reported	N/A	N/A	N/A
1,2,3-Trichloropropane	Not Present or Not Reported	N/A	N/A	N/A
1,2,4,5-Tetrachlorobenzene	Not Present or Not Reported	N/A	N/A	N/A
1,2-Dibromo-3-chloropropane	Not Present or Not Reported	N/A	N/A	N/A
1,2-Diphenylhydrazine	Not Present or Not Reported	N/A	N/A	N/A
1,2-Epoxybutane [1,2-Butylene oxide]	Not Present or Not Reported	N/A	N/A	N/A
1,3,5-Trinitrobenzene [sym-Trinitrobenzene]	Not Present or Not Reported	N/A	N/A	N/A
1,3-Butadiene	Not Present or Not Reported	N/A	N/A	N/A
1,3-Dinitrobenzene [m-Dinitrobenzene]	Not Present or Not Reported	N/A	N/A	N/A
1,3-Phenylenediamine [m-Phenylenediamine]	Not Present or Not Reported	N/A	N/A	N/A
2,4,5-Trichlorophenoxyacetic acid [2,4,5,-T]	Not Present or Not Reported	N/A	N/A	N/A
2,4-Toluenediamine [2,4-Diaminotoluene]	Not Present or Not Reported	N/A	N/A	N/A
2-Chloronaphthalene [beta-Chloronaphthalene]	Not Present or Not Reported	N/A	N/A	N/A
2-Ethoxyethanol [Ethylene glycol monoethyl ether]	Not Present or Not Reported	N/A	N/A	N/A
2-Ethoxyethanol acetate [2-EEA]	Not Present or Not Reported	N/A	N/A	N/A

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table B-19b. (continued)

Chemical	Number of Impoundments with Chemical Present in Wastewater [1]	Reported Quantity of Chemical in Wastewater (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
2-Methoxyethanol [methyl cellosolve]	Not Present or Not Reported	N/A	N/A	N/A
2-Methoxyethanol acetate [2-MEA] [methyl cellosolve acetate]	Not Present or Not Reported	N/A	N/A	N/A
2-Nitropropane	Not Present or Not Reported	N/A	N/A	N/A
3,3 -Dichlorobenzidine	Not Present or Not Reported	N/A	N/A	N/A
3,3 -Dimethoxybenzidine	Not Present or Not Reported	N/A	N/A	N/A
3,3 -Dimethylbenzidine	Not Present or Not Reported	N/A	N/A	N/A
3,4-Dimethylphenol	Not Present or Not Reported	N/A	N/A	N/A
3-Methylcholanthrene	Not Present or Not Reported	N/A	N/A	N/A
4,4 -Methylene bis(2-chloroaniline)	Not Present or Not Reported	N/A	N/A	N/A
4-Chloroaniline [p-aminochlorobenzene]	Not Present or Not Reported	N/A	N/A	N/A
7,12-Dimethylbenz[a]anthracene	Not Present or Not Reported	N/A	N/A	N/A
Acetophenone	Not Present or Not Reported	N/A	N/A	N/A
Acrylamide	Not Present or Not Reported	N/A	N/A	N/A
Aldicarb	Not Present or Not Reported	N/A	N/A	N/A
Aldrin	Not Present or Not Reported	N/A	N/A	N/A
Ammonium vanadate	Not Present or Not Reported	N/A	N/A	N/A
Amonium perchlorate	Not Present or Not Reported	N/A	N/A	N/A
Aramite	Not Present or Not Reported	N/A	N/A	N/A

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table B-19b. (continued)

Chemical	Number of Impoundments with Chemical Present in Wastewater [1]	Reported Quantity of Chemical in Wastewater (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
Benzidine	Not Present or Not Reported	N/A	N/A	N/A
Benzyl chloride	Not Present or Not Reported	N/A	N/A	N/A
Bis(chloromethyl) ether [sym-Dichloromethyl ether]	Not Present or Not Reported	N/A	N/A	N/A
Butyl benzyl phthalate	Not Present or Not Reported	N/A	N/A	N/A
Chloral [Trichloroacetaldehyde]	Not Present or Not Reported	N/A	N/A	N/A
Chloral hydrate [Trichloroacetaldehyde hydrate]	Not Present or Not Reported	N/A	N/A	N/A
Chlorobenzilate	Not Present or Not Reported	N/A	N/A	N/A
Chloromethyl Methyl Ether	Not Present or Not Reported	N/A	N/A	N/A
cis-1,2-Dichloroethylene	Not Present or Not Reported	N/A	N/A	N/A
cis-1,3-Dichloropropylene	Not Present or Not Reported	N/A	N/A	N/A
Cyanogen bromide [Bromine cyanide]	Not Present or Not Reported	N/A	N/A	N/A
Cyanogen chloride [Chlorine cyanide]	Not Present or Not Reported	N/A	N/A	N/A
Diallate	Not Present or Not Reported	N/A	N/A	N/A
Dichlorodifluoromethane [CFC-12]	Not Present or Not Reported	N/A	N/A	N/A
Dieldrin	Not Present or Not Reported	N/A	N/A	N/A
Diethylstilbestrol [DES]	Not Present or Not Reported	N/A	N/A	N/A
Dimethoate	Not Present or Not Reported	N/A	N/A	N/A
Dinoseb [2-sec-Butyl-4,6-dinitrophenol]	Not Present or Not Reported	N/A	N/A	N/A

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table B-19b. (continued)

Chemical	Number of Impoundments with Chemical Present in Wastewater [1]	Reported Quantity of Chemical in Wastewater (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
Diphenylamine	Not Present or Not Reported	N/A	N/A	N/A
Direct Black 38	Not Present or Not Reported	N/A	N/A	N/A
Direct Blue 6	Not Present or Not Reported	N/A	N/A	N/A
Direct Brown 95	Not Present or Not Reported	N/A	N/A	N/A
Disulfoton	Not Present or Not Reported	N/A	N/A	N/A
Endosulfan	Not Present or Not Reported	N/A	N/A	N/A
Endothall	Not Present or Not Reported	N/A	N/A	N/A
Ethyl methacrylate	Not Present or Not Reported	N/A	N/A	N/A
Ethyl methanesulfonate	Not Present or Not Reported	N/A	N/A	N/A
Furan	Not Present or Not Reported	N/A	N/A	N/A
Glycidylaldehyde	Not Present or Not Reported	N/A	N/A	N/A
Hexachloro-1,3-butadiene [Hexachlorobutadiene]	Not Present or Not Reported	N/A	N/A	N/A
Hexachlorocyclopentadiene	Not Present or Not Reported	N/A	N/A	N/A
Hexachloroethane	Not Present or Not Reported	N/A	N/A	N/A
Hexachlorophene	Not Present or Not Reported	N/A	N/A	N/A
Hydrazine	Not Present or Not Reported	N/A	N/A	N/A
Isophorone	Not Present or Not Reported	N/A	N/A	N/A
Kepone	Not Present or Not Reported	N/A	N/A	N/A

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table B-19b. (continued)

Chemical	Number of Impoundments with Chemical Present in Wastewater [1]	Reported Quantity of Chemical in Wastewater (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
Maleic anhydride	Not Present or Not Reported	N/A	N/A	N/A
Maleic hydrazide	Not Present or Not Reported	N/A	N/A	N/A
Methacrylonitrile	Not Present or Not Reported	N/A	N/A	N/A
Methomyl	Not Present or Not Reported	N/A	N/A	N/A
Methyl parathion	Not Present or Not Reported	N/A	N/A	N/A
Methylene bromide [Dibromomethane]	Not Present or Not Reported	N/A	N/A	N/A
Nickel Subsulfide	Not Present or Not Reported	N/A	N/A	N/A
Nitrobenzene	Not Present or Not Reported	N/A	N/A	N/A
N-Nitrosodiethylamine	Not Present or Not Reported	N/A	N/A	N/A
N-Nitrosodimethylamine	Not Present or Not Reported	N/A	N/A	N/A
N-Nitrosodi-n-butylamine	Not Present or Not Reported	N/A	N/A	N/A
N-Nitrosodi-n-propylamine [Di-n-propylnitrosamine]	Not Present or Not Reported	N/A	N/A	N/A
N-Nitroso-N-methylethylamine	Not Present or Not Reported	N/A	N/A	N/A
N-Nitrosopiperidine	Not Present or Not Reported	N/A	N/A	N/A
N-Nitrosopyrrolidine	Not Present or Not Reported	N/A	N/A	N/A
Octamethylpyrophosphoramide	Not Present or Not Reported	N/A	N/A	N/A
o-Toluidine	Not Present or Not Reported	N/A	N/A	N/A

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table B-19b. (continued)

Chemical	Number of Impoundments with Chemical Present in Wastewater [1]	Reported Quantity of Chemical in Wastewater (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
p,p -DDD	Not Present or Not Reported	N/A	N/A	N/A
p,p -DDE	Not Present or Not Reported	N/A	N/A	N/A
p,p -DDT	Not Present or Not Reported	N/A	N/A	N/A
Parathion	Not Present or Not Reported	N/A	N/A	N/A
Pentachlorobenzene	Not Present or Not Reported	N/A	N/A	N/A
Pentachlorodibenzo-p-dioxins [PeCDDs]	Not Present or Not Reported	N/A	N/A	N/A
Pentachloronitrobenzene [PCNB] [Quintobenzene] [Quintozene]	Not Present or Not Reported	N/A	N/A	N/A
Perchlorate	Not Present or Not Reported	N/A	N/A	N/A
Phorate	Not Present or Not Reported	N/A	N/A	N/A
Phthalic anhydride	Not Present or Not Reported	N/A	N/A	N/A
Pronamide	Not Present or Not Reported	N/A	N/A	N/A
p-Toluidine	Not Present or Not Reported	N/A	N/A	N/A
Safrole	Not Present or Not Reported	N/A	N/A	N/A
Strychnine	Not Present or Not Reported	N/A	N/A	N/A
Styrene oxide	Not Present or Not Reported	N/A	N/A	N/A
Tetraethyldithiopyrophosphate [Sulfotepp]	Not Present or Not Reported	N/A	N/A	N/A
trans-1,2-Dichloroethylene	Not Present or Not Reported	N/A	N/A	N/A

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table B-19b. (continued)

Chemical	Number of Impoundments with Chemical Present in Wastewater [1]	Reported Quantity of Chemical in Wastewater (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
trans-1,3-Dichloropropylene	Not Present or Not Reported	N/A	N/A	N/A
Trichlorofluoromethane [Trichloromonofluoromethane] [CFC-11]	Not Present or Not Reported	N/A	N/A	N/A
Tris(2,3-dibromopropyl) phosphate	Not Present or Not Reported	N/A	N/A	N/A
Warfarin	Not Present or Not Reported	N/A	N/A	N/A

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table B-20a. Chemicals: Presence and Volume in Sludge (for Impoundments with Chemicals/pH of Concern)

Chemical	Number of Impoundments with Chemical Present in Sludge [1]	Reported Quantity of Chemical in Sludge (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
Barium	4,269	15,229,003*	201,078*	156,990*
Lead	3,499	6,292,236*	10,960*	13,106*
Zinc	3,282	64,793,166*	1,746,200*	374,157*
Chromium	3,108	3,343,304*	51,779*	21,342*
Nickel	2,773	2,443,425*	53,698*	38,907*
Selenium	2,647	15,851*	0	0
Copper	2,399	21,112,774*	35,953*	31,103*
Arsenic	2,184	1,014,712*	5,546*	10,926*
Manganese	1,937	88,742,093*	542,791*	346,030*
Cadmium	1,921	187,321*	77*	1,265*
Mercury	1,538	10,394*	2*	25*
Vanadium	1,316	9,169*	0	468*
Toluene	1,287	2*	0	0
Cobalt	999	4,124*	0	0
Acetone [2-Propanone]	878*	7*	0	0
Molybdenum	848	651*	0	0
Xylenes, mixed isomers [Xyenes]	809	5,686*	0	51*
Carbon disulfide	787*	1*	0	0
Silver	709	13,527*	0	0
Antimony	670	0	0	0
Beryllium	660	3,246,766*	0	0
Chloroform [Trichloromethane]	632*	2*	0	1*
Ethyl benzene	617	1,004*	0	9*
Phenol	592	160*	273*	0
Benzene	581	0	0	0

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table 20a. (continued)

Chemical	Number of Impoundments with Chemical Present in Sludge [1]	Reported Quantity of Chemical in Sludge (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
Polychlorinated biphenyls [Aroclors]	533*	86,997*	0	5,354*
Methyl ethyl ketone [2-Butanone][MEK]	518	0	0	0
Sulfide	505	2,423,021*	0	0
Fluoride	433	54,793,440*	0	0
Bis(2-ethylhexyl) phthalate [Dioctyl phthalate]	427*	0	0	0
p-Cresol [4-Methyl phenol]	377*	0	0	0
Fluorene	367*	0	0	0
Pyrene	349	3,029*	0	0
Naphthalene	303	2,903*	0	0
Trichloroethylene [TCE]	292*	0	0	0
Chrysene	284	1,788*	0	0
Cyanide	278	30,127*	0	0
n-Dioctyl phthalate	278*	0	0	0
1,2-Dichloroethane [Ethylene dichloride]	273*	0	0	0
2,4-Dimethylphenol	270*	0	0	0
Fluoranthene	259	1,768*	0	0
Benzo(a)pyrene	257	83*	0	0
o-Xylene	253*	0	0	0
Benzo[a]anthracene	248	98*	0	0
Chromium VI [Hexavalent Chromium]	240*	0	2*	0
Thallium	238*	942*	0	0
Di-n-butyl phthalate	238*	0	0	0
n-Butyl alcohol [n-Butanol]	234*	0	4*	0
Aldrin	232*	0	0	0
beta-Hexachlorocyclohexane [beta-BHC]	232*	0	0	0

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table 20a. (continued)

Chemical	Number of Impoundments with Chemical Present in Sludge [1]	Reported Quantity of Chemical in Sludge (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
Butyl benzyl phthalate	232*	0	0	0
Chlordane, alpha & gamma isomers	232*	0	0	0
Dieldrin	232*	0	0	0
Endrin	232*	0	0	0
Heptachlor	232*	0	0	0
Heptachlor epoxide, alpha, beta, and gamma isomers	232*	0	0	0
Lindane [gamma-Hexachlorocyclohexane] [gamma-BHC]	232*	0	0	0
Methoxychlor	232*	0	0	0
p,p -DDD	232*	0	0	0
p,p -DDE	232*	0	0	0
p,p -DDT	232*	0	0	0
Anthracene	223	0	0	0
Tetrachlorodibenzofurans [TCDFs]	182*	0*	0*	0*
Methylene chloride [Dichloromethane]	173	0*	0	0*
Acenaphthene	165	0	0	0
Dibenz[a,h]anthracene	139	0	0	0
Benzo(b)fluoranthene	133	155*	0	0
2,3,7,8-TCDD [2,3,7,8-Tetrachlorodibenzo-p-dioxin]	128	0	0	0
Cyanide, amenable	126*	0	0	0
Indeno(1,2,3-cd) pyrene	119*	0	0	0
Formaldehyde	111	881*	5,234*	2,640*
Tetrachlorodibenzo-p-dioxins [TCDDs]	108*	0	0	0
Methanol [methyl alcohol]	104	0	1*	0
o-Cresol [2-Methyl phenol]	99*	0	0	0

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table 20a. (continued)

Chemical	Number of Impoundments with Chemical Present in Sludge [1]	Reported Quantity of Chemical in Sludge (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
Tetrachloroethylene [Perchloroethylene]	99*	0	0	0
1,2-Dichlorobenzene [o-Dichlorobenzene]	98*	0	0	0
Ethylene glycol	81*	0	487*	0
m-Cresol [3-Methyl phenol]	80*	0	0	0
Acetaldehyde [Ethanal]	80*	0	0*	0
1,4-Dichlorobenzene [p-Dichlorobenzene]	77*	0	0	0
Chloromethane [Methyl chloride]	62*	0	0	0*
Styrene	60*	0	0	0
Chlorobenzene	52*	0	0	0
Ethylene thiourea	46*	0	0	0
Thiram [Thiuram]	46*	0	0	0
2,4,6-Trichlorophenol	45*	0	0	0
2,4-Dichlorophenol	45*	0	0	0
2-Chlorophenol [o-Chlorophenol]	45*	0	0	0
Bromomethane [Methyl bromide]	42*	0	0	0
Cresols	41*	0	0	0
1,4-Dioxane [1,4-Diethyleneoxide]	40*	0	100*	0
Isophorone	38*	0	0	0
1,1,1-Trichloroethane [Methyl chloroform]	38*	0	0	0
2,4-Dinitrophenol	38*	0	0	0
Diethyl phthalate [DEP]	38*	0	0	0
Dimethyl phthalate [DMP]	38*	0	0	0
Ethylene dibromide [1,2-Dibromoethane]	38*	0	0	0
Ethylidene dichloride [1,1-Dichloroethane]	38*	0	0	0

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table 20a. (continued)

Chemical	Number of Impoundments with Chemical Present in Sludge [1]	Reported Quantity of Chemical in Sludge (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
Methyl tert-butyl ether [MTBE]	38*	0	0	0
N,N-Dimethyl formamide [DMF]	38*	0	0	0
N-Nitrosodiphenylamine [Diphenylnitrosamine]	38*	0	0	0
Pyridine	38*	0	0	0
Hexachlorodibenzofurans [HxCDFs]	38*	0*	0	0*
1,2-Dichloropropane [Propylene dichloride]	36*	0	0	0
Bromoform [Tribromomethane]	36*	1*	0	0
1,1-Dichloroethylene [Vinylidene chloride]	29*	0*	0	0
Hexachlorodibenzo-p-dioxins [HxCDDs]	27*	0	0	0
Methyl isobutyl ketone [Hexone] [4-Methyl-2-pentanone] [MIBK]	27*	0	0	0
Pentachlorodibenzofurans [PeCDFs]	27*	0	0	0
Pentachlorodibenzo-p-dioxins [PeCDDs]	27*	0	0	0
Vinyl chloride [chloroethylene]	22*	0	0	0
Bis(2-chloroisopropyl) ether [2,2 -Dichloroisopropyl ether]	21*	0	0	0
Cumene [Isopropyl benzene]	20*	0	0	0
n-Hexane	20*	0	0	0
Bis(2-chloroethyl) ether [sym-Dichloroethyl ether]	14*	0	0	0
Acrolein [2-propenal]	11*	0	0	0
Hexachlorobenzene	11*	0	0	0
1,2,4-Trichlorobenzene	7*	0	0	0
2,3,4,6-Tetrachlorophenol	7*	0	0	0
Pentachlorophenol [PCP]	7*	0	0	0

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table 20a. (continued)

Chemical	Number of Impoundments with Chemical Present in Sludge [1]	Reported Quantity of Chemical in Sludge (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
Acrylonitrile	4*	0	0	0
Acrylic acid [propenoic acid]	2*	0	17*	0
Allyl alcohol	2*	0	8*	0
Ethylene oxide	2*	0	0*	0
Formic Acid	2*	0	8*	0
1,1,1,2-Tetrachloroethane	Not Present or Not Reported	0	0	0
1,1,2,2-Tetrachloroethane	Not Present or Not Reported	0	0	0
1,1,2-Trichloro-1,2,2-trifluoroethane [Freon 113]	Not Present or Not Reported	0	0	0
1,1,2-Trichloroethane [Vinyl trichloride]	Not Present or Not Reported	0	0	0
1,2,3-Trichloropropane	Not Present or Not Reported	0	0	0
1,2,4,5-Tetrachlorobenzene	Not Present or Not Reported	0	0	0
1,2-Dibromo-3-chloropropane	Not Present or Not Reported	0	0	0
1,2-Diphenylhydrazine	Not Present or Not Reported	0	0	0
1,2-Epoxybutane [1,2-Butylene oxide]	Not Present or Not Reported	0	0	0
1,3,5-Trinitrobenzene [sym-Trinitrobenzene]	Not Present or Not Reported	0	0	0
1,3-Butadiene	Not Present or Not Reported	0	0	0
1,3-Dinitrobenzene [m-Dinitrobenzene]	Not Present or Not Reported	0	0	0
1,3-Phenylenediamine [m-Phenylenediamine]	Not Present or Not Reported	0	0	0
2,4,5-Trichlorophenol	Not Present or Not Reported	0	0	0

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table 20a. (continued)

Chemical	Number of Impoundments with Chemical Present in Sludge [1]	Reported Quantity of Chemical in Sludge (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
2,4,5-Trichlorophenoxyacetic acid [2,4,5,-T]	Not Present or Not Reported	0	0	0
2,4-D [2,4-Dichlorophenoxyacetic acid]	Not Present or Not Reported	0	0	0
2,4-Dinitrotoluene	Not Present or Not Reported	0	0	0
2,4-Toluenediamine [2,4-Diaminotoluene]	Not Present or Not Reported	0	0	0
2,6-Dinitrotoluene	Not Present or Not Reported	0	0	0
2-Chloronaphthalene [beta-Chloronaphthalene]	Not Present or Not Reported	0	0	0
2-Ethoxyethanol [Ethylene glycol monoethyl ether]	Not Present or Not Reported	0	0	0
2-Ethoxyethanol acetate [2-EEA]	Not Present or Not Reported	0	0	0
2-Methoxyethanol [methyl cellosolve]	Not Present or Not Reported	0	0	0
2-Methoxyethanol acetate [2-MEA] [methyl cellosolve acetate]	Not Present or Not Reported	0	0	0
2-Nitropropane	Not Present or Not Reported	0	0	0
3,3 -Dichlorobenzidine	Not Present or Not Reported	0	0	0
3,3 -Dimethoxybenzidine	Not Present or Not Reported	0	0	0
3,3 -Dimethylbenzidine	Not Present or Not Reported	0	0	0
3,4-Dimethylphenol	Not Present or Not Reported	0	0	0
3-Methylcholanthrene	Not Present or Not Reported	0	0	0
4,4 -Methylene bis(2-chloroaniline)	Not Present or Not Reported	0	0	0

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table 20a. (continued)

Chemical	Number of Impoundments with Chemical Present in Sludge [1]	Reported Quantity of Chemical in Sludge (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
4-Chloroaniline [p-aminochlorobenzene]	Not Present or Not Reported	0	0	0
7,12-Dimethylbenz[a]anthracene	Not Present or Not Reported	0	0	0
Acetonitrile [Methyl cyanide]	Not Present or Not Reported	0	0	0
Acetophenone	Not Present or Not Reported	0	0	0
Acrylamide	Not Present or Not Reported	0	0	0
Aldicarb	Not Present or Not Reported	0	0	0
Allyl chloride	Not Present or Not Reported	0	0	0
alpha-Hexachlorocyclohexane [alpha-BHC]	Not Present or Not Reported	0	0	0
Ammonium vanadate	Not Present or Not Reported	0	0	0
Amonium perchlorate	Not Present or Not Reported	0	0	0
Aniline	Not Present or Not Reported	0	0	0
Aramite	Not Present or Not Reported	0	0	0
Benzidine	Not Present or Not Reported	0	0	0
Benzyl alcohol	Not Present or Not Reported	0	0	0
Benzyl chloride	Not Present or Not Reported	0	0	0
Bis(chloromethyl) ether [sym-Dichloromethyl ether]	Not Present or Not Reported	0	0	0
Bromodichloromethane [Dichlorobromomethane]	Not Present or Not Reported	0	0	0

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table 20a. (continued)

Chemical	Number of Impoundments with Chemical Present in Sludge [1]	Reported Quantity of Chemical in Sludge (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
Carbon tetrachloride	Not Present or Not Reported	0	0	0
Chloral [Trichloroacetaldehyde]	Not Present or Not Reported	0	0	0
Chloral hydrate [Trichloroacetaldehyde hydrate]	Not Present or Not Reported	0	0	0
Chlorobenzilate	Not Present or Not Reported	0	0	0
Chlorodibromomethane [Dibromochloromethane]	Not Present or Not Reported	0	0	0
Chloroethane [Ethyl chloride]	Not Present or Not Reported	0	0	0
Chloromethyl Methyl Ether	Not Present or Not Reported	0	0	0
Chloroprene [2-Chloro-1,3-butadiene]	Not Present or Not Reported	0	0	0
cis-1,2-Dichloroethylene	Not Present or Not Reported	0	0	0
cis-1,3-Dichloropropylene	Not Present or Not Reported	0	0	0
Cyanogen bromide [Bromine cyanide]	Not Present or Not Reported	0	0	0
Cyanogen chloride [Chlorine cyanide]	Not Present or Not Reported	0	0	0
Cyclohexanol	Not Present or Not Reported	0	0	0
Cyclohexanone	Not Present or Not Reported	0	0	0
Diallate	Not Present or Not Reported	0	0	0
Dichlorodifluoromethane [CFC-12]	Not Present or Not Reported	0	0	0
Diethylstilbestrol [DES]	Not Present or Not Reported	0	0	0

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table 20a. (continued)

Chemical	Number of Impoundments with Chemical Present in Sludge [1]	Reported Quantity of Chemical in Sludge (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
Dimethoate	Not Present or Not Reported	0	0	0
Dinoseb [2-sec-Butyl-4,6-dinitrophenol]	Not Present or Not Reported	0	0	0
Diphenylamine	Not Present or Not Reported	0	0	0
Direct Black 38	Not Present or Not Reported	0	0	0
Direct Blue 6	Not Present or Not Reported	0	0	0
Direct Brown 95	Not Present or Not Reported	0	0	0
Disulfoton	Not Present or Not Reported	0	0	0
Endosulfan	Not Present or Not Reported	0	0	0
Endothall	Not Present or Not Reported	0	0	0
Epichlorohydrin [1-Chloro-2,3-epoxypropane]	Not Present or Not Reported	0	0	0
Ethyl acetate	Not Present or Not Reported	0	0	0
Ethyl ether [Diethyl ether]	Not Present or Not Reported	0	0	0
Ethyl methacrylate	Not Present or Not Reported	0	0	0
Ethyl methanesulfonate	Not Present or Not Reported	0	0	0
Furan	Not Present or Not Reported	0	0	0
Furfural	Not Present or Not Reported	0	0	0
Glycidylaldehyde	Not Present or Not Reported	0	0	0

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table 20a. (continued)

Chemical	Number of Impoundments with Chemical Present in Sludge [1]	Reported Quantity of Chemical in Sludge (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
Hexachloro-1,3-butadiene [Hexachlorobutadiene]	Not Present or Not Reported	0	0	0
Hexachlorocyclopentadiene	Not Present or Not Reported	0	0	0
Hexachloroethane	Not Present or Not Reported	0	0	0
Hexachlorophene	Not Present or Not Reported	0	0	0
Hydrazine	Not Present or Not Reported	0	0	0
Isobutyl alcohol [Isobutanol]	Not Present or Not Reported	0	0	0
Kepone	Not Present or Not Reported	0	0	0
Maleic anhydride	Not Present or Not Reported	0	0	0
Maleic hydrazide	Not Present or Not Reported	0	0	0
Methacrylonitrile	Not Present or Not Reported	0	0	0
Methomyl	Not Present or Not Reported	0	0	0
Methyl methacrylate	Not Present or Not Reported	0	0	0
Methyl parathion	Not Present or Not Reported	0	0	0
Methylene bromide [Dibromomethane]	Not Present or Not Reported	0	0	0
m-Xylene	Not Present or Not Reported	0	0	0
Nickel Subsulfide	Not Present or Not Reported	0	0	0
Nitrobenzene	Not Present or Not Reported	0	0	0

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table 20a. (continued)

Chemical	Number of Impoundments with Chemical Present in Sludge [1]	Reported Quantity of Chemical in Sludge (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
N-Nitrosodiethylamine	Not Present or Not Reported	0	0	0
N-Nitrosodimethylamine	Not Present or Not Reported	0	0	0
N-Nitrosodi-n-butylamine	Not Present or Not Reported	0	0	0
N-Nitrosodi-n-propylamine [Di-n-propylnitrosamine]	Not Present or Not Reported	0	0	0
N-Nitroso-N-methylethylamine	Not Present or Not Reported	0	0	0
N-Nitrosopiperidine	Not Present or Not Reported	0	0	0
N-Nitrosopyrrolidine	Not Present or Not Reported	0	0	0
Octamethylpyrophosphoramide	Not Present or Not Reported	0	0	0
o-Toluidine	Not Present or Not Reported	0	0	0
Parathion	Not Present or Not Reported	0	0	0
Pentachlorobenzene	Not Present or Not Reported	0	0	0
Pentachloronitrobenzene [PCNB] [Quintobenzene] [Quintozene]	Not Present or Not Reported	0	0	0
Perchlorate	Not Present or Not Reported	0	0	0
Phorate	Not Present or Not Reported	0	0	0
Phthalic anhydride	Not Present or Not Reported	0	0	0
Pronamide	Not Present or Not Reported	0	0	0
Propylene oxide [1,2-Epoxypropane]	Not Present or Not Reported	0	0	0

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table 20a. (continued)

Chemical	Number of Impoundments with Chemical Present in Sludge [1]	Reported Quantity of Chemical in Sludge (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
p-Toluidine	Not Present or Not Reported	0	0	0
p-Xylene	Not Present or Not Reported	0	0	0
Safrole	Not Present or Not Reported	0	0	0
Silvex [2,4,5-Trichlorophenoxypropionic acid]	Not Present or Not Reported	0	0	0
Strychnine	Not Present or Not Reported	0	0	0
Styrene oxide	Not Present or Not Reported	0	0	0
Tetraethyldithiopyrophosphate [Sulfotepp]	Not Present or Not Reported	0	0	0
Toxaphene [Chlorinated camphene]	Not Present or Not Reported	0	0	0
trans-1,2-Dichloroethylene	Not Present or Not Reported	0	0	0
trans-1,3-Dichloropropylene	Not Present or Not Reported	0	0	0
Trichlorofluoromethane [Trichloromonofluoromethane] [CFC-11]	Not Present or Not Reported	0	0	0
Triethylamine	Not Present or Not Reported	0	0	0
Tris(2,3-dibromopropyl) phosphate	Not Present or Not Reported	0	0	0
Vinyl acetate	Not Present or Not Reported	0	0	0
Warfarin	Not Present or Not Reported	0	0	0

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table B-20b. Standard Errors for Chemicals: Presence and Volume in Sludge (for Impoundments with Chemicals/pH of Concern)

Chemical	Number of Impoundments with Chemical Present in Sludge [1]	Reported Quantity of Chemical in Sludge (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
Barium	1,203	11,198,278*	204,414*	168,935*
Lead	1,035	7,557,758*	10,402*	9,563*
Zinc	644	69,522,056*	1,563,828*	245,664*
Chromium	801	3,930,014*	46,243*	23,369*
Nickel	634	1,622,692*	52,842*	31,510*
Selenium	1,036	19,857*	N/A	N/A
Copper	521	17,034,712*	27,576*	20,442*
Arsenic	494	943,882*	5,612*	8,898*
Manganese	467	78,768,980*	550,742*	408,023*
Cadmium	473	186,252*	77*	1,265*
Mercury	438	7,078*	2*	25*
Vanadium	425	7,611*	N/A	840*
Toluene	480	2*	N/A	N/A
Cobalt	373	4,124*	N/A	N/A
Acetone [2-Propanone]	486*	7*	N/A	N/A
Molybdenum	330	616*	N/A	N/A
Xylenes, mixed isomers [Xyenes]	305	9,885*	N/A	89*
Carbon disulfide	485*	0.5*	N/A	N/A
Silver	234	13,993*	N/A	N/A
Antimony	267	N/A	N/A	N/A
Beryllium	282	3,258,540*	N/A	N/A
Chloroform [Trichloromethane]	468*	2*	N/A	1*
Ethyl benzene	248	1,742*	N/A	16*
Phenol	164	165*	475*	N/A
Benzene	267	N/A	N/A	N/A

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table B-20b. (continued)

Chemical	Number of Impoundments with Chemical Present in Sludge [1]	Reported Quantity of Chemical in Sludge (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
Polychlorinated biphenyls [Aroclors]	338*	158,541*	N/A	9,899*
Methyl ethyl ketone [2-Butanone][MEK]	255	N/A	N/A	N/A
Sulfide	213	2,704,783*	N/A	N/A
Fluoride	131	55,465,247*	N/A	N/A
Bis(2-ethylhexyl) phthalate [Dioctyl phthalate]	242*	N/A	N/A	N/A
p-Cresol [4-Methyl phenol]	236*	N/A	N/A	N/A
Fluorene	234*	N/A	N/A	N/A
Pyrene	118	3,099*	N/A	N/A
Naphthalene	92	5,020*	N/A	N/A
Trichloroethylene [TCE]	236*	N/A	N/A	N/A
Chrysene	88	1,788*	N/A	N/A
Cyanide	121	36,371*	N/A	N/A
n-Dioctyl phthalate	236*	N/A	N/A	N/A
1,2-Dichloroethane [Ethylene dichloride]	235*	N/A	N/A	N/A
2,4-Dimethylphenol	235*	N/A	N/A	N/A
Fluoranthene	87	3,181*	N/A	N/A
Benzo(a)pyrene	114	151*	N/A	N/A
o-Xylene	233*	N/A	N/A	N/A
Benzo[a]anthracene	86	178*	N/A	N/A
Chromium VI [Hexavalent Chromium]	121*	N/A	4*	N/A
Thallium	129*	950*	N/A	N/A
Di-n-butyl phthalate	135*	N/A	N/A	N/A
n-Butyl alcohol [n-Butanol]	232*	N/A	14*	N/A
Aldrin	232*	N/A	N/A	N/A

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table B-20b. (continued)

Chemical	Number of Impoundments with Chemical Present in Sludge [1]	Reported Quantity of Chemical in Sludge (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
beta-Hexachlorocyclohexane [beta-BHC]	232*	N/A	N/A	N/A
Butyl benzyl phthalate	232*	N/A	N/A	N/A
Chlordane, alpha & gamma isomers	232*	N/A	N/A	N/A
Dieldrin	232*	N/A	N/A	N/A
Endrin	232*	N/A	N/A	N/A
Heptachlor	232*	N/A	N/A	N/A
Heptachlor epoxide, alpha, beta, and gamma isomers	232*	N/A	N/A	N/A
Lindane [gamma-Hexachlorocyclohexane] [gamma-BHC]	232*	N/A	N/A	N/A
Methoxychlor	232*	N/A	N/A	N/A
p,p -DDD	232*	N/A	N/A	N/A
p,p -DDE	232*	N/A	N/A	N/A
p,p -DDT	232*	N/A	N/A	N/A
Anthracene	79	N/A	N/A	N/A
Tetrachlorodibenzofurans [TCDFs]	93*	0.1*	0.04*	0.05*
Methylene chloride [Dichloromethane]	72	0.08*	N/A	0.005*
Acenaphthene	68	N/A	N/A	N/A
Dibenz[a,h]anthracene	67	N/A	N/A	N/A
Benzo(b)fluoranthene	65	282*	N/A	N/A
2,3,7,8-TCDD [2,3,7,8-Tetrachlorodibenzo-p-dioxin]	54	N/A	N/A	N/A
Cyanide, amenable	106*	N/A	N/A	N/A
Indeno(1,2,3-cd) pyrene	63*	N/A	N/A	N/A
Formaldehyde	50	1,560*	5,819*	3,849*

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table B-20b. (continued)

Chemical	Number of Impoundments with Chemical Present in Sludge [1]	Reported Quantity of Chemical in Sludge (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
Tetrachlorodibenzo-p-dioxins [TCDDs]	57*	N/A	N/A	N/A
Methanol [methyl alcohol]	49	N/A	2*	N/A
o-Cresol [2-Methyl phenol]	58*	N/A	N/A	N/A
Tetrachloroethylene [Perchloroethylene]	59*	N/A	N/A	N/A
1,2-Dichlorobenzene [o-Dichlorobenzene]	56*	N/A	N/A	N/A
Ethylene glycol	45*	N/A	1,651*	N/A
m-Cresol [3-Methyl phenol]	54*	N/A	N/A	N/A
Acetaldehyde [Ethanal]	43*	N/A	0.8*	N/A
1,4-Dichlorobenzene [p-Dichlorobenzene]	54*	N/A	N/A	N/A
Chloromethane [Methyl chloride]	45*	N/A	N/A	0.04*
Styrene	44*	N/A	N/A	N/A
Chlorobenzene	41*	N/A	N/A	N/A
Ethylene thiourea	46*	N/A	N/A	N/A
Thiram [Thiuram]	46*	N/A	N/A	N/A
2,4,6-Trichlorophenol	39*	N/A	N/A	N/A
2,4-Dichlorophenol	39*	N/A	N/A	N/A
2-Chlorophenol [o-Chlorophenol]	39*	N/A	N/A	N/A
Bromomethane [Methyl bromide]	42*	N/A	N/A	N/A
Cresols	31*	N/A	N/A	N/A
1,4-Dioxane [1,4-Diethyleneoxide]	38*	N/A	340*	N/A
Isophorone	38*	N/A	N/A	N/A
1,1,1-Trichloroethane [Methyl chloroform]	38*	N/A	N/A	N/A
2,4-Dinitrophenol	38*	N/A	N/A	N/A
Diethyl phthalate [DEP]	38*	N/A	N/A	N/A

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table B-20b. (continued)

Chemical	Number of Impoundments with Chemical Present in Sludge [1]	Reported Quantity of Chemical in Sludge (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
Dimethyl phthalate [DMP]	38*	N/A	N/A	N/A
Ethylene dibromide [1,2-Dibromoethane]	38*	N/A	N/A	N/A
Ethylidene dichloride [1,1-Dichloroethane]	38*	N/A	N/A	N/A
Methyl tert-butyl ether [MTBE]	38*	N/A	N/A	N/A
N,N-Dimethyl formamide [DMF]	38*	N/A	N/A	N/A
N-Nitrosodiphenylamine [Diphenylnitrosamine]	38*	N/A	N/A	N/A
Pyridine	38*	N/A	N/A	N/A
Hexachlorodibenzofurans [HxCDFs]	29*	0.007*	N/A	0.02*
1,2-Dichloropropane [Propylene dichloride]	36*	N/A	N/A	N/A
Bromoform [Tribromomethane]	36*	1*	N/A	N/A
1,1-Dichloroethylene [Vinylidene chloride]	29*	0.08*	N/A	N/A
Hexachlorodibenzo-p-dioxins [HxCDDs]	25*	N/A	N/A	N/A
Methyl isobutyl ketone [Hexone] [4-Methyl-2-pentanone] [MIBK]	25*	N/A	N/A	N/A
Pentachlorodibenzofurans [PeCDFs]	25*	N/A	N/A	N/A
Pentachlorodibenzo-p-dioxins [PeCDDs]	25*	N/A	N/A	N/A
Vinyl chloride [chloroethylene]	22*	N/A	N/A	N/A
Bis(2-chloroisopropyl) ether [2,2 -Dichloroisopropyl ether]	22*	N/A	N/A	N/A
Cumene [Isopropyl benzene]	22*	N/A	N/A	N/A
n-Hexane	22*	N/A	N/A	N/A
Bis(2-chloroethyl) ether [sym-Dichloroethyl ether]	18*	N/A	N/A	N/A
Acrolein [2-propenal]	16*	N/A	N/A	N/A

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table B-20b. (continued)

Chemical	Number of Impoundments with Chemical Present in Sludge [1]	Reported Quantity of Chemical in Sludge (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
Ethylene thiourea	46*	N/A	N/A	N/A
Thiram [Thiuram]	46*	N/A	N/A	N/A
2,4,6-Trichlorophenol	39*	N/A	N/A	N/A
2,4-Dichlorophenol	39*	N/A	N/A	N/A
2-Chlorophenol [o-Chlorophenol]	39*	N/A	N/A	N/A
Bromomethane [Methyl bromide]	42*	N/A	N/A	N/A
Cresols	31*	N/A	N/A	N/A
1,4-Dioxane [1,4-Diethyleneoxide]	38*	N/A	340*	N/A
Isophorone	38*	N/A	N/A	N/A
1,1,1-Trichloroethane [Methyl chloroform]	38*	N/A	N/A	N/A
2,4-Dinitrophenol	38*	N/A	N/A	N/A
Diethyl phthalate [DEP]	38*	N/A	N/A	N/A
Hexachlorobenzene	16*	N/A	N/A	N/A
1,2,4-Trichlorobenzene	12*	N/A	N/A	N/A
2,3,4,6-Tetrachlorophenol	12*	N/A	N/A	N/A
Pentachlorophenol [PCP]	12*	N/A	N/A	N/A
Acrylonitrile	9*	N/A	N/A	N/A
Acrylic acid [propenoic acid]	7*	N/A	58*	N/A
Allyl alcohol	7*	N/A	26*	N/A
Ethylene oxide	7*	N/A	0.2*	N/A
Formic Acid	7*	N/A	28*	N/A
1,1,1,2-Tetrachloroethane	Not Present or Not Reported	N/A	N/A	N/A
1,1,2,2-Tetrachloroethane	Not Present or Not Reported	N/A	N/A	N/A
1,1,2-Trichloro-1,2,2-trifluoroethane [Freon 113]	Not Present or Not Reported	N/A	N/A	N/A

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table B-20b. (continued)

Chemical	Number of Impoundments with Chemical Present in Sludge [1]	Reported Quantity of Chemical in Sludge (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
1,1,2-Trichloroethane [Vinyl trichloride]	Not Present or Not Reported	N/A	N/A	N/A
1,2,3-Trichloropropane	Not Present or Not Reported	N/A	N/A	N/A
1,2,4,5-Tetrachlorobenzene	Not Present or Not Reported	N/A	N/A	N/A
1,2-Dibromo-3-chloropropane	Not Present or Not Reported	N/A	N/A	N/A
1,2-Diphenylhydrazine	Not Present or Not Reported	N/A	N/A	N/A
1,2-Epoxybutane [1,2-Butylene oxide]	Not Present or Not Reported	N/A	N/A	N/A
1,3,5-Trinitrobenzene [sym-Trinitrobenzene]	Not Present or Not Reported	N/A	N/A	N/A
1,3-Butadiene	Not Present or Not Reported	N/A	N/A	N/A
1,3-Dinitrobenzene [m-Dinitrobenzene]	Not Present or Not Reported	N/A	N/A	N/A
1,3-Phenylenediamine [m-Phenylenediamine]	Not Present or Not Reported	N/A	N/A	N/A
2,4,5-Trichlorophenol	Not Present or Not Reported	N/A	N/A	N/A
2,4,5-Trichlorophenoxyacetic acid [2,4,5,-T]	Not Present or Not Reported	N/A	N/A	N/A
2,4-D [2,4-Dichlorophenoxyacetic acid]	Not Present or Not Reported	N/A	N/A	N/A
2,4-Dinitrotoluene	Not Present or Not Reported	N/A	N/A	N/A
2,4-Toluenediamine [2,4-Diaminotoluene]	Not Present or Not Reported	N/A	N/A	N/A
2,6-Dinitrotoluene	Not Present or Not Reported	N/A	N/A	N/A
2-Chloronaphthalene [beta-Chloronaphthalene]	Not Present or Not Reported	N/A	N/A	N/A

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table B-20b. (continued)

Chemical	Number of Impoundments with Chemical Present in Sludge [1]	Reported Quantity of Chemical in Sludge (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
2-Ethoxyethanol [Ethylene glycol monoethyl ether]	Not Present or Not Reported	N/A	N/A	N/A
2-Ethoxyethanol acetate [2-EEA]	Not Present or Not Reported	N/A	N/A	N/A
2-Methoxyethanol [methyl cellosolve]	Not Present or Not Reported	N/A	N/A	N/A
2-Methoxyethanol acetate [2-MEA] [methyl cellosolve acetate]	Not Present or Not Reported	N/A	N/A	N/A
2-Nitropropane	Not Present or Not Reported	N/A	N/A	N/A
3,3 -Dichlorobenzidine	Not Present or Not Reported	N/A	N/A	N/A
3,3 -Dimethoxybenzidine	Not Present or Not Reported	N/A	N/A	N/A
3,3 -Dimethylbenzidine	Not Present or Not Reported	N/A	N/A	N/A
3,4-Dimethylphenol	Not Present or Not Reported	N/A	N/A	N/A
3-Methylcholanthrene	Not Present or Not Reported	N/A	N/A	N/A
4,4 -Methylene bis(2-chloroaniline)	Not Present or Not Reported	N/A	N/A	N/A
4-Chloroaniline [p-aminochlorobenzene]	Not Present or Not Reported	N/A	N/A	N/A
7,12-Dimethylbenz[a]anthracene	Not Present or Not Reported	N/A	N/A	N/A
Acetonitrile [Methyl cyanide]	Not Present or Not Reported	N/A	N/A	N/A
Acetophenone	Not Present or Not Reported	N/A	N/A	N/A
Acrylamide	Not Present or Not Reported	N/A	N/A	N/A
Aldicarb	Not Present or Not Reported	N/A	N/A	N/A

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table B-20b. (continued)

Chemical	Number of Impoundments with Chemical Present in Sludge [1]	Reported Quantity of Chemical in Sludge (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
Allyl chloride	Not Present or Not Reported	N/A	N/A	N/A
alpha-Hexachlorocyclohexane [alpha-BHC]	Not Present or Not Reported	N/A	N/A	N/A
Ammonium vanadate	Not Present or Not Reported	N/A	N/A	N/A
Amonium perchlorate	Not Present or Not Reported	N/A	N/A	N/A
Aniline	Not Present or Not Reported	N/A	N/A	N/A
Aramite	Not Present or Not Reported	N/A	N/A	N/A
Benzidine	Not Present or Not Reported	N/A	N/A	N/A
Benzyl alcohol	Not Present or Not Reported	N/A	N/A	N/A
Benzyl chloride	Not Present or Not Reported	N/A	N/A	N/A
Bis(chloromethyl) ether [sym-Dichloromethyl ether]	Not Present or Not Reported	N/A	N/A	N/A
Bromodichloromethane [Dichlorobromomethane]	Not Present or Not Reported	N/A	N/A	N/A
Carbon tetrachloride	Not Present or Not Reported	N/A	N/A	N/A
Chloral [Trichloroacetaldehyde]	Not Present or Not Reported	N/A	N/A	N/A
Chloral hydrate [Trichloroacetaldehyde hydrate]	Not Present or Not Reported	N/A	N/A	N/A
Chlorobenzilate	Not Present or Not Reported	N/A	N/A	N/A
Chlorodibromomethane [Dibromochloromethane]	Not Present or Not Reported	N/A	N/A	N/A
Chloroethane [Ethyl chloride]	Not Present or Not Reported	N/A	N/A	N/A
Chloromethyl Methyl Ether	Not Present or Not Reported	N/A	N/A	N/A

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table B-20b. (continued)

Chemical	Number of Impoundments with Chemical Present in Sludge [1]	Reported Quantity of Chemical in Sludge (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
Chloroprene [2-Chloro-1,3-butadiene]	Not Present or Not Reported	N/A	N/A	N/A
cis-1,2-Dichloroethylene	Not Present or Not Reported	N/A	N/A	N/A
cis-1,3-Dichloropropylene	Not Present or Not Reported	N/A	N/A	N/A
Cyanogen bromide [Bromine cyanide]	Not Present or Not Reported	N/A	N/A	N/A
Cyanogen chloride [Chlorine cyanide]	Not Present or Not Reported	N/A	N/A	N/A
Cyclohexanol	Not Present or Not Reported	N/A	N/A	N/A
Cyclohexanone	Not Present or Not Reported	N/A	N/A	N/A
Diallate	Not Present or Not Reported	N/A	N/A	N/A
Dichlorodifluoromethane [CFC-12]	Not Present or Not Reported	N/A	N/A	N/A
Diethylstilbestrol [DES]	Not Present or Not Reported	N/A	N/A	N/A
Dimethoate	Not Present or Not Reported	N/A	N/A	N/A
Dinoseb [2-sec-Butyl-4,6-dinitrophenol]	Not Present or Not Reported	N/A	N/A	N/A
Diphenylamine	Not Present or Not Reported	N/A	N/A	N/A
Direct Black 38	Not Present or Not Reported	N/A	N/A	N/A
Direct Blue 6	Not Present or Not Reported	N/A	N/A	N/A
Direct Brown 95	Not Present or Not Reported	N/A	N/A	N/A
Disulfoton	Not Present or Not Reported	N/A	N/A	N/A

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table B-20b. (continued)

Chemical	Number of Impoundments with Chemical Present in Sludge [1]	Reported Quantity of Chemical in Sludge (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
Endosulfan	Not Present or Not Reported	N/A	N/A	N/A
Endothall	Not Present or Not Reported	N/A	N/A	N/A
Epichlorohydrin [1-Chloro-2,3-epoxypropane]	Not Present or Not Reported	N/A	N/A	N/A
Ethyl acetate	Not Present or Not Reported	N/A	N/A	N/A
Ethyl ether [Diethyl ether]	Not Present or Not Reported	N/A	N/A	N/A
Ethyl methacrylate	Not Present or Not Reported	N/A	N/A	N/A
Ethyl methanesulfonate	Not Present or Not Reported	N/A	N/A	N/A
Furan	Not Present or Not Reported	N/A	N/A	N/A
Furfural	Not Present or Not Reported	N/A	N/A	N/A
Glycidylaldehyde	Not Present or Not Reported	N/A	N/A	N/A
Hexachloro-1,3-butadiene [Hexachlorobutadiene]	Not Present or Not Reported	N/A	N/A	N/A
Hexachlorocyclopentadiene	Not Present or Not Reported	N/A	N/A	N/A
Hexachloroethane	Not Present or Not Reported	N/A	N/A	N/A
Hexachlorophene	Not Present or Not Reported	N/A	N/A	N/A
Hydrazine	Not Present or Not Reported	N/A	N/A	N/A
Isobutyl alcohol [Isobutanol]	Not Present or Not Reported	N/A	N/A	N/A
Kepone	Not Present or Not Reported	N/A	N/A	N/A
Maleic anhydride	Not Present or Not Reported	N/A	N/A	N/A

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table B-20b. (continued)

Chemical	Number of Impoundments with Chemical Present in Sludge [1]	Reported Quantity of Chemical in Sludge (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
Maleic hydrazide	Not Present or Not Reported	N/A	N/A	N/A
Methacrylonitrile	Not Present or Not Reported	N/A	N/A	N/A
Methomyl	Not Present or Not Reported	N/A	N/A	N/A
Methyl methacrylate	Not Present or Not Reported	N/A	N/A	N/A
Methyl parathion	Not Present or Not Reported	N/A	N/A	N/A
Methylene bromide [Dibromomethane]	Not Present or Not Reported	N/A	N/A	N/A
m-Xylene	Not Present or Not Reported	N/A	N/A	N/A
Nickel Subsulfide	Not Present or Not Reported	N/A	N/A	N/A
Nitrobenzene	Not Present or Not Reported	N/A	N/A	N/A
N-Nitrosodiethylamine	Not Present or Not Reported	N/A	N/A	N/A
N-Nitrosodimethylamine	Not Present or Not Reported	N/A	N/A	N/A
N-Nitrosodi-n-butylamine	Not Present or Not Reported	N/A	N/A	N/A
N-Nitrosodi-n-propylamine [Di-n-propylnitrosamine]	Not Present or Not Reported	N/A	N/A	N/A
N-Nitroso-N-methylethylamine	Not Present or Not Reported	N/A	N/A	N/A
N-Nitrosopiperidine	Not Present or Not Reported	N/A	N/A	N/A
N-Nitrosopyrrolidine	Not Present or Not Reported	N/A	N/A	N/A
Octamethylpyrophosphoramide	Not Present or Not Reported	N/A	N/A	N/A
o-Toluidine	Not Present or Not Reported	N/A	N/A	N/A

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table B-20b. (continued)

Chemical	Number of Impoundments with Chemical Present in Sludge [1]	Reported Quantity of Chemical in Sludge (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
Parathion	Not Present or Not Reported	N/A	N/A	N/A
Pentachlorobenzene	Not Present or Not Reported	N/A	N/A	N/A
Pentachloronitrobenzene [PCNB] [Quintobenzene] [Quintozene]	Not Present or Not Reported	N/A	N/A	N/A
Perchlorate	Not Present or Not Reported	N/A	N/A	N/A
Phorate	Not Present or Not Reported	N/A	N/A	N/A
Phthalic anhydride	Not Present or Not Reported	N/A	N/A	N/A
Pronamide	Not Present or Not Reported	N/A	N/A	N/A
Propylene oxide [1,2-Epoxypropane]	Not Present or Not Reported	N/A	N/A	N/A
p-Toluidine	Not Present or Not Reported	N/A	N/A	N/A
p-Xylene	Not Present or Not Reported	N/A	N/A	N/A
Safrole	Not Present or Not Reported	N/A	N/A	N/A
Silvex [2,4,5-Trichlorophenoxypropionic acid]	Not Present or Not Reported	N/A	N/A	N/A
Strychnine	Not Present or Not Reported	N/A	N/A	N/A
Styrene oxide	Not Present or Not Reported	N/A	N/A	N/A
Tetraethyldithiopyrophosphate [Sulfotepp]	Not Present or Not Reported	N/A	N/A	N/A
Toxaphene [Chlorinated camphene]	Not Present or Not Reported	N/A	N/A	N/A
trans-1,2-Dichloroethylene	Not Present or Not Reported	N/A	N/A	N/A

(continued)

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table B-20b. (continued)

Chemical	Number of Impoundments with Chemical Present in Sludge [1]	Reported Quantity of Chemical in Sludge (All Impoundments) [2]		
		Within Impoundment (kg)	Influent (kg/yr)	Effluent (kg/yr)
trans-1,3-Dichloropropylene	Not Present or Not Reported	N/A	N/A	N/A
Trichlorofluoromethane [Trichloromonofluoromethane] [CFC-11]	Not Present or Not Reported	N/A	N/A	N/A
Triethylamine	Not Present or Not Reported	N/A	N/A	N/A
Tris(2,3-dibromopropyl) phosphate	Not Present or Not Reported	N/A	N/A	N/A
Vinyl acetate	Not Present or Not Reported	N/A	N/A	N/A
Warfarin	Not Present or Not Reported	N/A	N/A	N/A

1. Chemical presence in influent, effluent, or within impoundment, as indicated by reported value or check for "present but quantity unknown."
2. Calculated from reported concentration or flux.

Table B-21. Comparison of Survey Data and Risk Input Data: Chemical Categories for Wastewater and Sludge at Influent, In Impoundment, and Effluent Sampling Points

Survey Database Chemical Data

Chemical Categories	Wastewater (< 5 weight percent solids)						Sludge (≥ 5 weight percent solids)					
	Influent		In Impoundment		Effluent		Influent		In Impoundment		Effluent	
	#	%	#	%	#	%	#	%	#	%	#	%
VOCs	5,866	76	5,412	76	4,815	72	1,690	4	2,006	21	1,311	14
SVOCs	3,824	75	3,786	75	3,508	69	863	7	1,261	24	605	3
Metals	9,966	84	9,982	83	7,762	85	3,925	42	5,551	98	3,078	88
Dioxin-like compounds	291	24	218	21	346	22	247	10	861	35	412	41
Mercury	2,483	27	2,479	30	2,235	31	1,061	0.9	1,745	66	826	6
PBTs	6,870	71	7,216	72	4,989	67	2,556	13	4,539	91	2,269	72
Any chemicals	10,745	96	10,766	97	8,187	92	4,101	45	5,759	100	3,230	89
Percent missing overall	16	42	24	24	16	34	30	63	21	47	19	36
Number nonmissing zero dischargers*	30	10	28	26	30	17	22	12	23	16	30	23

Risk Input Database Chemical Data

Chemical Categories	Wastewater (< 5 weight percent solids)						Sludge (≥ 5 weight percent solids)					
	Influent		In Impoundment		Effluent		Influent		In Impoundment		Effluent	
	#	%	#	%	#	%	#	%	#	%	#	%
VOCs	5,791	85	5,835	77	NA	NA	NA	NA	3,417	79	NA	NA
SVOCs	4,819	83	4,819	81	NA	NA	NA	NA	2,914	78	NA	NA
Metals	10,476	89	10,493	85	NA	NA	NA	NA	6,293	100	NA	NA
Dioxin-like compounds	811	41	811	33	NA	NA	NA	NA	1,343	64	NA	NA
Mercury	2,934	45	2,934	36	NA	NA	NA	NA	2,228	70	NA	NA
PBTs	8,648	80	8,676	83	NA	NA	NA	NA	5,302	97	NA	NA
Any chemicals	11,345	100	11,345	99	NA	NA	NA	NA	6,559	100	NA	NA
Percent missing overall	16	42	24	24	NA	NA	NA	NA	21	47	NA	NA
Number nonmissing zero dischargers*	30	10	28	26	NA	NA	NA	NA	23	16	NA	NA

For both tables: # = number of impoundments
% = percent of total volume
NA = not applicable
*Total number of Zero Dischargers = 36

Table B-22. Chemical Presence in Wastewater Influent by SIC Code (Survey Database)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
Acenaphthene					✔	✔			✔							
Acetaldehyde [Ethanal]				✔	✔											
Acetone [2-Propanone]				✔	✔	✔										
Acetonitrile [Methyl cyanide]																
Acetophenone																
Acrolein [2-propenal]					✔											
Acrylamide																
Acrylic acid [propenoic acid]					✔											
Acrylonitrile					✔											
Aldicarb																
Aldrin																
Allyl alcohol					✔											
Allyl chloride					✔											
Ammonium vanadate																
Ammonium perchlorate																
Aniline				✔	✔	✔										
Anthracene				✔	✔	✔			✔							
Antimony				✔	✔	✔		✔	✔	✔						
Aramite																
Arsenic				✔	✔	✔			✔	✔						
Barium		✔	✔	✔	✔	✔	✔	✔	✔	✔		✔			✔	
Benzene					✔	✔			✔						✔	
Benzidine																
Benzo(a)pyrene				✔		✔			✔							
Benzo(b)fluoranthene				✔		✔			✔							
Benzo[a]anthracene				✔		✔			✔							
Benzyl alcohol				✔	✔	✔										
Benzyl chloride																
Beryllium				✔	✔	✔		✔	✔							
beta-Hexachlorocyclohexane [beta-BHC]				✔												
Bis(2-chloroethyl) ether [sym-Dichloroethyl ether]																
Bis(2-chloroisopropyl) ether [2,2'-Dichloroisopropyl ether]					✔											
Bis(2-ethylhexyl) phthalate [Dioctyl phthalate]		✔		✔	✔	✔	✔									
Bis(chloromethyl) ether [sym-Dichloromethyl ether]																
Bromodichloromethane [Dichlorobromomethane]				✔	✔	✔	✔									
Bromoform [Tribromomethane]					✔	✔	✔									
Bromomethane [Methyl bromide]					✔											
1,3-Butadiene																
n-Butyl alcohol [n-Butanol]					✔											
Butyl benzyl phthalate																
Cadmium		✔		✔	✔	✔	✔	✔	✔	✔						
Carbon disulfide				✔	✔	✔										
Carbon tetrachloride					✔											
Chloral [Trichloroacetaldehyde]																

(continued)

Table B-22. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
Chloral hydrate [Trichloroacetaldehyde hydrate]																
Chlordane, alpha & gamma isomers																
4-Chloroaniline [p-aminochlorobenzene]																
Chlorobenzene					✔	✔										
Chlorobenzilate																
Chlorodibromomethane [Dibromochloromethane]				✔	✔	✔	✔									
Chloroethane [Ethyl chloride]					✔											
Chloroform [Trichloromethane]				✔	✔	✔	✔		✔							
Chloromethane [Methyl chloride]				✔	✔											
Chloromethyl methyl ether																
2-Chloronaphthalene [beta-Chloronaphthalene]																
2-Chlorophenol [o-Chlorophenol]				✔	✔											
Chloroprene [2-Chloro-1,3-butadiene]					✔											
Chromium		✔		✔	✔	✔		✔	✔	✔		✔			✔	
Chromium VI [Hexavalent Chromium]					✔	✔			✔							
Chrysene				✔		✔			✔							
Cobalt				✔	✔	✔										
Copper		✔		✔	✔	✔	✔		✔	✔		✔			✔	
m-Cresol [3-Methyl phenol]						✔										
o-Cresol [2-Methyl phenol]					✔	✔										
p-Cresol [4-Methyl phenol]					✔	✔										
Cresols				✔												
Cumene [Isopropyl benzene]				✔												
Cyanide		✔		✔	✔	✔			✔							
Cyanide, amenable					✔	✔			✔							
Cyanogen bromide [Bromine cyanide]																
Cyanogen chloride [Chlorine cyanide]																
Cyclohexanol					✔											
Cyclohexanone				✔	✔											
2,4-D [2,4-Dichlorophenoxyacetic acid]																
p,p'-DDD																
p,p'-DDE																
p,p'-DDT																
Di-n-butyl phthalate					✔	✔	✔									
Diallate																
Dibenz[a,h]anthracene						✔			✔							
1,2-Dibromo-3-chloropropane																
1,2-Dichlorobenzene [o-Dichlorobenzene]					✔	✔										
1,4-Dichlorobenzene [p-Dichlorobenzene]						✔										
3,3'-Dichlorobenzidine																
Dichlorodifluoromethane [CFC-12]																
1,2-Dichloroethane [Ethylene dichloride]					✔	✔										
1,1-Dichloroethylene [Vinylidene chloride]					✔											

(continued)

Table B-22. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
cis-1,2-Dichloroethylene																
trans-1,2-Dichloroethylene																
2,4-Dichlorophenol				✔	✔											
1,2-Dichloropropane [Propylene dichloride]					✔											
cis-1,3-Dichloropropylene																
trans-1,3-Dichloropropylene																
Dieldrin																
Diethyl phthalate [DEP]					✔	✔										
Diethylstilbestrol [DES]																
Dimethoate																
3,3'-Dimethoxybenzidine																
N,N-Dimethyl formamide [DMF]					✔	✔										
Dimethyl phthalate [DMP]						✔										
7,12-Dimethylbenz[a]anthracene																
3,3'-Dimethylbenzidine																
2,4-Dimethylphenol				✔		✔										
3,4-Dimethylphenol																
1,3-Dinitrobenzene [m-Dinitrobenzene]																
2,4-Dinitrophenol						✔										
2,4-Dinitrotoluene																
2,6-Dinitrotoluene																
Dinoseb [2-sec-Butyl-4,6-dinitrophenol]																
n-Dioctyl phthalate					✔		✔									
1,4-Dioxane [1,4-Diethyleneoxide]					✔	✔										
Diphenylamine																
1,2-Diphenylhydrazine																
Direct Black 38																
Direct Blue 6																
Direct Brown 95																
Disulfoton																
Endosulfan																
Endothall																
Endrin																
Epichlorohydrin [1-Chloro-2,3-epoxypropane]		✔			✔											
1,2-Epoxybutane [1,2-Butylene oxide]																
2-Ethoxyethanol acetate [2-EEA]																
2-Ethoxyethanol [Ethylene glycol monoethyl ether]																
Ethyl acetate					✔											
Ethyl benzene				✔	✔	✔									✔	
Ethyl ether [Diethyl ether]					✔											
Ethyl methacrylate																
Ethyl methanesulfonate																
Ethylene dibromide [1,2-Dibromoethane]						✔										
Ethylene glycol		✔		✔	✔	✔										
Ethylene oxide					✔											

(continued)

Table B-22. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
Ethylene thiourea							✔									
Ethylidene dichloride [1,1-Dichloroethane]						✔										
Fluoranthene				✔	✔	✔			✔							
Fluorene					✔	✔			✔							
Fluoride				✔	✔	✔			✔					✔	✔	
Formaldehyde		✔		✔	✔	✔						✔				
Formic Acid				✔	✔											
Furan																
Furfural				✔												
Glycidylaldehyde																
Heptachlor																
Heptachlor epoxide, alpha, beta, and gamma isomers				✔												
Hexachloro-1,3-butadiene [Hexachlorobutadiene]																
Hexachlorobenzene																
alpha-Hexachlorocyclohexane [alpha-BHC]				✔												
Hexachlorocyclopentadiene																
Hexachlorodibenzo-p-dioxins [HxCDDs]				✔												
Hexachlorodibenzofurans [HxCDFs]				✔	✔											
Hexachloroethane																
Hexachlorophene																
n-Hexane				✔												
Hydrazine																
Indeno(1,2,3-cd) pyrene				✔		✔			✔							
Isobutyl alcohol [Isobutanol]					✔											
Isophorone																
Kepone																
Lead		✔		✔	✔	✔	✔	✔	✔	✔					✔	
Lindane [gamma-Hexachlorocyclohexane] [gamma-BHC]																
Maleic anhydride																
Maleic hydrazide																
Manganese	✔			✔	✔	✔			✔	✔				✔		
Mercury				✔	✔	✔			✔	✔						
Methacrylonitrile																
Methanol [methyl alcohol]		✔		✔	✔	✔										
Methomyl																
Methoxychlor				✔												
2-Methoxyethanol acetate [2-MEA] [methyl cellosolve acetate]																
2-Methoxyethanol [methyl cellosolve]																
Methyl ethyl ketone [2-Butanone][MEK]				✔	✔	✔										
Methyl isobutyl ketone [Hexone] [4-Methyl-2-pentanone] [MIBK]				✔												
Methyl methacrylate					✔											
Methyl parathion																

(continued)

Table B-22. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
Methyl tert-butyl ether [MTBE]						✔										
3-Methylcholanthrene																
4,4'-Methylene bis(2-chloroaniline)																
Methylene bromide [Dibromomethane]																
Methylene chloride [Dichloromethane]				✔	✔	✔			✔							
Molybdenum				✔	✔	✔	✔		✔					✔		
Naphthalene				✔	✔	✔			✔						✔	
Nickel		✔	✔	✔	✔	✔	✔	✔	✔	✔		✔		✔	✔	
Nickel Subsulfide																
Nitrobenzene																
2-Nitropropane																
N-Nitroso-N-methylethylamine																
N-Nitrosodi-n-butylamine																
N-Nitrosodi-n-propylamine [Di-n-propylnitrosamine]																
N-Nitrosodiethylamine																
N-Nitrosodimethylamine																
N-Nitrosodiphenylamine [Diphenylnitrosamine]						✔										
N-Nitrosopiperidine																
N-Nitrosopyrrolidine																
Octamethylpyrophosphoramide																
Parathion																
Pentachlorobenzene																
Pentachlorodibenzo-p-dioxins [PeCDDs]																
Pentachlorodibenzofurans [PeCDFs]				✔												
Pentachloronitrobenzene [PCNB] [Quintobenzene] [Quintozene]																
Pentachlorophenol [PCP]				✔												
Perchlorate																
Phenol				✔	✔	✔			✔							
1,3-Phenylenediamine [m-Phenylenediamine]																
Phorate																
Phthalic anhydride																
Polychlorinated biphenyls [Aroclors]				✔					✔							
Pronamide																
Propylene oxide [1,2-Epoxypropane]					✔											
Pyrene				✔	✔	✔			✔							
Pyridine					✔	✔										
Safrole																
Selenium				✔	✔	✔		✔	✔	✔						
Silver				✔	✔	✔		✔	✔	✔						
Silvex [2,4,5-Trichlorophenoxypropionic acid]																
Strychnine																
Styrene				✔	✔	✔										
Styrene oxide																
Sulfide	✔	✔		✔	✔	✔			✔							

(continued)

Table B-22. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
2,3,7,8-TCDD [2,3,7,8-Tetrachlorodibenzo-p-dioxin]				✔												
1,2,4,5-Tetrachlorobenzene																
Tetrachlorodibenzo-p-dioxins [TCDDs]				✔												
Tetrachlorodibenzofurans [TCDFs]				✔												
1,1,1,2-Tetrachloroethane																
1,1,2,2-Tetrachloroethane																
Tetrachloroethylene [Perchloroethylene]						✔			✔							
2,3,4,6-Tetrachlorophenol				✔												
Tetraethyldithiopyrophosphate [Sulfotepp]																
Thallium				✔		✔		✔								
Thiram [Thiuram]							✔									
Toluene				✔	✔	✔									✔	
2,4-Toluenediamine [2,4-Diaminotoluene]																
o-Toluidine																
p-Toluidine																
Toxaphene [Chlorinated camphene]																
1,1,2-Trichloro-1,2,2-trifluoroethane [Freon 113]																
1,2,4-Trichlorobenzene				✔	✔											
1,1,1-Trichloroethane [Methyl chloroform]					✔	✔										
1,1,2-Trichloroethane [Vinyl trichloride]					✔											
Trichloroethylene [TCE]						✔										
Trichlorofluoromethane [Trichloromonofluoromethane] [CFC-11]																
2,4,5-Trichlorophenol				✔												
2,4,6-Trichlorophenol				✔	✔											
2,4,5-Trichlorophenoxyacetic acid [2,4,5,-T]																
1,2,3-Trichloropropane																
Triethylamine					✔											
1,3,5-Trinitrobenzene [sym-Trinitrobenzene]																
Tris(2,3-dibromopropyl) phosphate																
Vanadium				✔	✔	✔		✔						✔		
Vinyl acetate		✔			✔											
Vinyl chloride [chloroethylene]					✔											
Warfarin																
m-Xylene				✔	✔											
o-Xylene				✔	✔											
p-Xylene				✔	✔											
Xylenes, mixed isomers [Xylenes]				✔	✔	✔									✔	
Zinc	✔	✔		✔	✔	✔	✔	✔	✔	✔		✔		✔	✔	

Table B-23. Chemical Presence in Wastewater in Impoundment by SIC Code (Survey Database)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
Acenaphthene						✔										
Acetaldehyde [Ethanal]				✔	✔											
Acetone [2-Propanone]				✔	✔	✔			✔							
Acetonitrile [Methyl cyanide]					✔											
Acetophenone																
Acrolein [2-propenal]					✔											
Acrylamide																
Acrylic acid [propenoic acid]					✔											
Acrylonitrile					✔											
Aldicarb																
Aldrin																
Allyl alcohol					✔											
Allyl chloride					✔											
Ammonium vanadate																
Ammonium perchlorate																
Aniline				✔	✔											
Anthracene						✔										
Antimony				✔	✔	✔			✔	✔						
Aramite																
Arsenic				✔	✔	✔		✔	✔	✔				✔		
Barium		✔		✔	✔	✔	✔	✔	✔	✔		✔			✔	
Benzene					✔	✔			✔						✔	
Benzidine																
Benzo(a)pyrene						✔			✔							
Benzo(b)fluoranthene						✔			✔							
Benzo[a]anthracene						✔			✔							
Benzyl alcohol				✔	✔											
Benzyl chloride																
Beryllium				✔	✔	✔			✔					✔		
beta-Hexachlorocyclohexane [beta-BHC]				✔												
Bis(2-chloroethyl) ether [sym-Dichloroethyl ether]																
Bis(2-chloroisopropyl) ether [2,2'-Dichloroisopropyl ether]					✔											
Bis(2-ethylhexyl) phthalate [Dioctyl phthalate]		✔		✔	✔	✔	✔									
Bis(chloromethyl) ether [sym-Dichloromethyl ether]																
Bromodichloromethane [Dichlorobromomethane]					✔		✔		✔							
Bromoform [Tribromomethane]					✔		✔									
Bromomethane [Methyl bromide]					✔											
1,3-Butadiene																
n-Butyl alcohol [n-Butanol]					✔											
Butyl benzyl phthalate																
Cadmium		✔		✔	✔	✔	✔	✔	✔	✔				✔		
Carbon disulfide				✔	✔	✔										

(continued)

Table B-23. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
Carbon tetrachloride					✔											
Chloral [Trichloroacetaldehyde]																
Chloral hydrate [Trichloroacetaldehyde hydrate]																
Chlordane, alpha & gamma isomers		✔														
4-Chloroaniline [p-aminochlorobenzene]																
Chlorobenzene						✔										
Chlorobenzilate																
Chlorodibromomethane [Dibromochloromethane]				✔	✔		✔									
Chloroethane [Ethyl chloride]					✔											
Chloroform [Trichloromethane]				✔	✔	✔	✔		✔							
Chloromethane [Methyl chloride]				✔	✔											
Chloromethyl methyl ether																
2-Chloronaphthalene [beta-Chloronaphthalene]																
2-Chlorophenol [o-Chlorophenol]				✔												
Chloroprene [2-Chloro-1,3-butadiene]					✔											
Chromium		✔		✔	✔	✔		✔	✔	✔		✔		✔	✔	
Chromium VI [Hexavalent Chromium]					✔	✔			✔	✔						
Chrysene						✔										
Cobalt				✔	✔	✔										
Copper		✔		✔	✔	✔	✔		✔	✔		✔		✔	✔	
m-Cresol [3-Methyl phenol]		✔				✔										
o-Cresol [2-Methyl phenol]		✔				✔										
p-Cresol [4-Methyl phenol]		✔				✔										
Cresols				✔												
Cumene [Isopropyl benzene]				✔												
Cyanide		✔		✔	✔	✔			✔							
Cyanide, amenable					✔	✔			✔							
Cyanogen bromide [Bromine cyanide]																
Cyanogen chloride [Chlorine cyanide]																
Cyclohexanol																
Cyclohexanone				✔												
2,4-D [2,4-Dichlorophenoxyacetic acid]		✔														
p,p'-DDD																
p,p'-DDE																
p,p'-DDT																
Di-n-butyl phthalate						✔	✔									
Diallate																
Dibenz[a,h]anthracene						✔										
1,2-Dibromo-3-chloropropane																
1,2-Dichlorobenzene [o-Dichlorobenzene]					✔	✔										
1,4-Dichlorobenzene [p-Dichlorobenzene]		✔				✔										
3,3'-Dichlorobenzidine																
Dichlorodifluoromethane [CFC-12]																
1,2-Dichloroethane [Ethylene dichloride]					✔	✔										

(continued)

Table B-23. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
1,1-Dichloroethylene [Vinylidene chloride]					✔											
cis-1,2-Dichloroethylene																
trans-1,2-Dichloroethylene																
2,4-Dichlorophenol				✔												
1,2-Dichloropropane [Propylene dichloride]					✔											
cis-1,3-Dichloropropylene																
trans-1,3-Dichloropropylene																
Dieldrin																
Diethyl phthalate [DEP]					✔	✔										
Diethylstilbestrol [DES]																
Dimethoate																
3,3'-Dimethoxybenzidine																
N,N-Dimethyl formamide [DMF]					✔	✔										
Dimethyl phthalate [DMP]						✔										
7,12-Dimethylbenz[a]anthracene																
3,3'-Dimethylbenzidine																
2,4-Dimethylphenol						✔										
3,4-Dimethylphenol																
1,3-Dinitrobenzene [m-Dinitrobenzene]																
2,4-Dinitrophenol						✔										
2,4-Dinitrotoluene		✔														
2,6-Dinitrotoluene																
Dinoseb [2-sec-Butyl-4,6-dinitrophenol]																
n-Dioctyl phthalate					✔		✔									
1,4-Dioxane [1,4-Diethyleneoxide]					✔	✔										
Diphenylamine																
1,2-Diphenylhydrazine																
Direct Black 38																
Direct Blue 6																
Direct Brown 95																
Disulfoton																
Endosulfan																
Endothall																
Endrin		✔														
Epichlorohydrin [1-Chloro-2,3-epoxypropane]		✔			✔											
1,2-Epoxybutane [1,2-Butylene oxide]																
2-Ethoxyethanol acetate [2-EEA]																
2-Ethoxyethanol [Ethylene glycol monoethyl ether]																
Ethyl acetate					✔											
Ethyl benzene				✔	✔	✔									✔	
Ethyl ether [Diethyl ether]					✔											
Ethyl methacrylate																
Ethyl methanesulfonate																
Ethylene dibromide [1,2-Dibromoethane]						✔										

(continued)

Table B-23. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
Ethylene glycol		✔		✔	✔	✔										
Ethylene oxide					✔											
Ethylene thiourea							✔									
Ethylidene dichloride [1,1-Dichloroethane]						✔			✔							
Fluoranthene						✔			✔							
Fluorene						✔										
Fluoride				✔	✔	✔			✔					✔	✔	
Formaldehyde		✔		✔	✔	✔						✔				
Formic Acid				✔	✔											
Furan																
Furfural																
Glycidylaldehyde																
Heptachlor		✔														
Heptachlor epoxide, alpha, beta, and gamma isomers		✔		✔												
Hexachloro-1,3-butadiene [Hexachlorobutadiene]																
Hexachlorobenzene					✔											
alpha-Hexachlorocyclohexane [alpha-BHC]				✔												
Hexachlorocyclopentadiene																
Hexachlorodibenzo-p-dioxins [HxCDDs]																
Hexachlorodibenzofurans [HxCDFs]					✔											
Hexachloroethane																
Hexachlorophene																
n-Hexane				✔												
Hydrazine																
Indeno(1,2,3-cd) pyrene						✔										
Isobutyl alcohol [Isobutanol]																
Isophorone																
Kepone																
Lead		✔		✔	✔	✔	✔	✔	✔	✔				✔	✔	
Lindane [gamma-Hexachlorocyclohexane] [gamma-BHC]		✔														
Maleic anhydride																
Maleic hydrazide																
Manganese	✔			✔	✔	✔			✔	✔				✔		
Mercury				✔	✔	✔		✔	✔	✔						
Methacrylonitrile																
Methanol [methyl alcohol]		✔		✔	✔	✔										
Methomyl																
Methoxychlor		✔		✔												
2-Methoxyethanol acetate [2-MEA] [methyl cellosolve acetate]																
2-Methoxyethanol [methyl cellosolve]																
Methyl ethyl ketone [2-Butanone][MEK]				✔	✔	✔										
Methyl isobutyl ketone [Hexone] [4-Methyl-2-pentanone] [MIBK]				✔												

(continued)

Table B-23. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
Methyl methacrylate					✔											
Methyl parathion																
Methyl tert-butyl ether [MTBE]					✔	✔										
3-Methylcholanthrene																
4,4'-Methylene bis(2-chloroaniline)																
Methylene bromide [Dibromomethane]																
Methylene chloride [Dichloromethane]				✔	✔	✔			✔							
Molybdenum				✔	✔	✔	✔		✔					✔		
Naphthalene				✔	✔	✔			✔						✔	
Nickel		✔		✔	✔	✔	✔	✔	✔	✔		✔		✔	✔	
Nickel Subsulfide																
Nitrobenzene																
2-Nitropropane																
N-Nitroso-N-methylethylamine																
N-Nitrosodi-n-butylamine																
N-Nitrosodi-n-propylamine [Di-n-propylnitrosamine]																
N-Nitrosodiethylamine																
N-Nitrosodimethylamine																
N-Nitrosodiphenylamine [Diphenylnitrosamine]						✔										
N-Nitrosopiperidine																
N-Nitrosopyrrolidine																
Octamethylpyrophosphoramide																
Parathion																
Pentachlorobenzene																
Pentachlorodibenzo-p-dioxins [PeCDDs]																
Pentachlorodibenzofurans [PeCDFs]																
Pentachloronitrobenzene [PCNB] [Quintobenzene] [Quintozene]																
Pentachlorophenol [PCP]				✔												
Perchlorate																
Phenol				✔	✔	✔			✔							
1,3-Phenylenediamine [m-Phenylenediamine]																
Phorate																
Phthalic anhydride																
Polychlorinated biphenyls [Aroclors]				✔					✔							
Pronamide																
Propylene oxide [1,2-Epoxypropane]					✔											
Pyrene						✔			✔							
Pyridine					✔	✔										
Safrole																
Selenium				✔	✔	✔		✔	✔	✔						
Silver				✔	✔	✔		✔	✔	✔						
Silvex [2,4,5-Trichlorophenoxypropionic acid]		✔														

(continued)

Table B-23. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
Strychnine																
Styrene					✔	✔										
Styrene oxide																
Sulfide	✔	✔		✔	✔	✔			✔							
2,3,7,8-TCDD [2,3,7,8-Tetrachlorodibenzo-p-dioxin]				✔												
1,2,4,5-Tetrachlorobenzene																
Tetrachlorodibenzo-p-dioxins [TCDDs]				✔												
Tetrachlorodibenzofurans [TCDFs]				✔												
1,1,1,2-Tetrachloroethane																
1,1,2,2-Tetrachloroethane																
Tetrachloroethylene [Perchloroethylene]						✔			✔							
2,3,4,6-Tetrachlorophenol				✔												
Tetraethyldithiopyrophosphate [Sulfotepp]																
Thallium				✔		✔										
Thiram [Thiuram]							✔									
Toluene				✔	✔	✔									✔	
2,4-Toluenediamine [2,4-Diaminotoluene]																
o-Toluidine																
p-Toluidine																
Toxaphene [Chlorinated camphene]		✔														
1,1,2-Trichloro-1,2,2-trifluoroethane [Freon 113]																
1,2,4-Trichlorobenzene				✔												
1,1,1-Trichloroethane [Methyl chloroform]						✔			✔							
1,1,2-Trichloroethane [Vinyl trichloride]																
Trichloroethylene [TCE]						✔			✔							
Trichlorofluoromethane [Trichloromonofluoromethane] [CFC-11]																
2,4,5-Trichlorophenol		✔		✔												
2,4,6-Trichlorophenol		✔		✔												
2,4,5-Trichlorophenoxyacetic acid [2,4,5,-T]																
1,2,3-Trichloropropane																
Triethylamine					✔											
1,3,5-Trinitrobenzene [sym-Trinitrobenzene]																
Tris(2,3-dibromopropyl) phosphate																
Vanadium				✔	✔	✔		✔						✔		
Vinyl acetate		✔														
Vinyl chloride [chloroethylene]																
Warfarin																
m-Xylene				✔	✔											
o-Xylene				✔	✔											
p-Xylene				✔	✔											
Xylenes, mixed isomers [Xylenes]				✔	✔	✔									✔	
Zinc	✔	✔		✔	✔	✔	✔		✔	✔		✔		✔	✔	

Table B-24. Chemical Presence in Wastewater Effluent by SIC Code (Survey Database)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
Acenaphthene						✔			✔							
Acetaldehyde [Ethanal]				✔	✔											
Acetone [2-Propanone]				✔	✔	✔										
Acetonitrile [Methyl cyanide]																
Acetophenone																
Acrolein [2-propenal]					✔											
Acrylamide																
Acrylic acid [propenoic acid]					✔											
Acrylonitrile					✔											
Aldicarb																
Aldrin																
Allyl alcohol					✔											
Allyl chloride					✔											
Ammonium vanadate																
Ammonium perchlorate																
Aniline				✔												
Anthracene						✔			✔							
Antimony				✔	✔	✔			✔	✔						
Aramite																
Arsenic				✔	✔	✔			✔							
Barium		✔		✔	✔	✔	✔	✔	✔			✔		✔	✔	
Benzene					✔	✔			✔						✔	
Benzidine																
Benzo(a)pyrene						✔			✔							
Benzo(b)fluoranthene						✔			✔							
Benzo[a]anthracene						✔			✔							
Benzyl alcohol				✔	✔	✔										
Benzyl chloride																
Beryllium				✔		✔		✔	✔							
beta-Hexachlorocyclohexane [beta-BHC]				✔												
Bis(2-chloroethyl) ether [sym-Dichloroethyl ether]					✔											
Bis(2-chloroisopropyl) ether [2,2'-Dichloroisopropyl ether]					✔											
Bis(2-ethylhexyl) phthalate [Dioctyl phthalate]		✔		✔	✔	✔	✔									
Bis(chloromethyl) ether [sym-Dichloromethyl ether]																
Bromodichloromethane [Dichlorobromomethane]					✔		✔									

(continued)

Table B-24. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
Bromoform [Tribromomethane]					✔	✔										
Bromomethane [Methyl bromide]					✔											
1,3-Butadiene																
n-Butyl alcohol [n-Butanol]					✔											
Butyl benzyl phthalate																
Cadmium		✔		✔	✔	✔	✔	✔	✔							
Carbon disulfide				✔	✔	✔										
Carbon tetrachloride					✔											
Chloral [Trichloroacetaldehyde]																
Chloral hydrate [Trichloroacetaldehyde hydrate]																
Chlordane, alpha & gamma isomers																
4-Chloroaniline [p-aminochlorobenzene]																
Chlorobenzene						✔										
Chlorobenzilate																
Chlorodibromomethane [Dibromochloromethane]					✔		✔									
Chloroethane [Ethyl chloride]					✔											
Chloroform [Trichloromethane]				✔	✔	✔	✔		✔							
Chloromethane [Methyl chloride]				✔	✔				✔							
Chloromethyl methyl ether																
2-Chloronaphthalene [beta-Chloronaphthalene]																
2-Chlorophenol [o-Chlorophenol]				✔												
Chloroprene [2-Chloro-1,3-butadiene]					✔											
Chromium		✔		✔	✔	✔		✔	✔			✔		✔	✔	
Chromium VI [Hexavalent Chromium]					✔	✔			✔							
Chrysene						✔			✔							
Cobalt				✔	✔	✔										
Copper		✔		✔	✔	✔	✔		✔	✔		✔	✔	✔	✔	
m-Cresol [3-Methyl phenol]						✔										
o-Cresol [2-Methyl phenol]						✔										
p-Cresol [4-Methyl phenol]						✔										
Cresols				✔		✔										
Cumene [Isopropyl benzene]				✔												
Cyanide		✔		✔	✔	✔			✔					✔		
Cyanide, amenable					✔	✔			✔							
Cyanogen bromide [Bromine cyanide]																
Cyanogen chloride [Chlorine cyanide]																

(continued)

Table B-24. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
Cyclohexanol																
Cyclohexanone				✔												
2,4-D [2,4-Dichlorophenoxyacetic acid]																
p,p'-DDD																
p,p'-DDE																
p,p'-DDT																
Di-n-butyl phthalate						✔	✔									
Diallate																
Dibenz[a,h]anthracene						✔			✔							
1,2-Dibromo-3-chloropropane																
1,2-Dichlorobenzene [o-Dichlorobenzene]					✔	✔										
1,4-Dichlorobenzene [p-Dichlorobenzene]						✔										
3,3'-Dichlorobenzidine																
Dichlorodifluoromethane [CFC-12]																
1,2-Dichloroethane [Ethylene dichloride]					✔	✔										
1,1-Dichloroethylene [Vinylidene chloride]					✔											
cis-1,2-Dichloroethylene																
trans-1,2-Dichloroethylene																
2,4-Dichlorophenol				✔												
1,2-Dichloropropane [Propylene dichloride]					✔											
cis-1,3-Dichloropropylene																
trans-1,3-Dichloropropylene																
Dieldrin																
Diethyl phthalate [DEP]						✔										
Diethylstilbestrol [DES]																
Dimethoate																
3,3'-Dimethoxybenzidine																
N,N-Dimethyl formamide [DMF]						✔										
Dimethyl phthalate [DMP]						✔										
7,12-Dimethylbenz[a]anthracene																
3,3'-Dimethylbenzidine																
2,4-Dimethylphenol						✔										
3,4-Dimethylphenol																
1,3-Dinitrobenzene [m-Dinitrobenzene]																
2,4-Dinitrophenol						✔										

(continued)

Table B-24. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
2,4-Dinitrotoluene																
2,6-Dinitrotoluene					✔											
Dinoseb [2-sec-Butyl-4,6-dinitrophenol]																
n-Dioctyl phthalate					✔		✔									
1,4-Dioxane [1,4-Diethyleneoxide]					✔	✔										
Diphenylamine																
1,2-Diphenylhydrazine																
Direct Black 38																
Direct Blue 6																
Direct Brown 95																
Disulfoton																
Endosulfan																
Endothall																
Endrin																
Epichlorohydrin [1-Chloro-2,3-epoxypropane]		✔			✔											
1,2-Epoxybutane [1,2-Butylene oxide]																
2-Ethoxyethanol acetate [2-EEA]																
2-Ethoxyethanol [Ethylene glycol monoethyl ether]																
Ethyl acetate																
Ethyl benzene				✔	✔	✔									✔	
Ethyl ether [Diethyl ether]																
Ethyl methacrylate																
Ethyl methanesulfonate																
Ethylene dibromide [1,2-Dibromoethane]						✔										
Ethylene glycol		✔		✔	✔	✔										
Ethylene oxide					✔											
Ethylene thiourea							✔									
Ethylidene dichloride [1,1-Dichloroethane]						✔										
Fluoranthene						✔			✔							
Fluorene						✔			✔							
Fluoride				✔	✔	✔			✔			✔				
Formaldehyde		✔		✔	✔	✔										
Formic Acid				✔	✔											
Furan																
Furfural				✔												
Glycidylaldehyde																

(continued)

Table B-24. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
Heptachlor																
Heptachlor epoxide, alpha, beta, and gamma isomers				✔												
Hexachloro-1,3-butadiene [Hexachlorobutadiene]																
Hexachlorobenzene																
alpha-Hexachlorocyclohexane [alpha-BHC]				✔												
Hexachlorocyclopentadiene																
Hexachlorodibenzo-p-dioxins [HxCDDs]				✔												
Hexachlorodibenzofurans [HxCDFs]				✔	✔											
Hexachloroethane																
Hexachlorophene																
n-Hexane				✔												
Hydrazine																
Indeno(1,2,3-cd) pyrene						✔			✔							
Isobutyl alcohol [Isobutanol]																
Isophorone																
Kepone																
Lead		✔		✔	✔	✔	✔		✔	✔				✔	✔	
Lindane [gamma-Hexachlorocyclohexane] [gamma-BHC]																
Maleic anhydride																
Maleic hydrazide																
Manganese	✔			✔	✔	✔			✔	✔		✔		✔		
Mercury				✔	✔	✔			✔					✔		
Methacrylonitrile																
Methanol [methyl alcohol]		✔		✔	✔	✔										
Methomyl																
Methoxychlor																
2-Methoxyethanol acetate [2-MEA] [methyl cellosolve acetate]																
2-Methoxyethanol [methyl cellosolve]																
Methyl ethyl ketone [2-Butanone][MEK]				✔	✔	✔										
Methyl isobutyl ketone [Hexone] [4-Methyl-2-pentanone] [MIBK]				✔												
Methyl methacrylate					✔											
Methyl parathion																
Methyl tert-butyl ether [MTBE]						✔										
3-Methylcholanthrene																

(continued)

Table B-24. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
4,4'-Methylene bis(2-chloroaniline)																
Methylene bromide [Dibromomethane]																
Methylene chloride [Dichloromethane]				✔	✔	✔			✔							
Molybdenum				✔	✔	✔	✔		✔			✔				
Naphthalene				✔	✔	✔			✔						✔	
Nickel		✔		✔	✔	✔	✔	✔	✔			✔			✔	
Nickel Subsulfide																
Nitrobenzene																
2-Nitropropane																
N-Nitroso-N-methylethylamine																
N-Nitrosodi-n-butylamine																
N-Nitrosodi-n-propylamine [Di-n-propylnitrosamine]																
N-Nitrosodiethylamine																
N-Nitrosodimethylamine																
N-Nitrosodiphenylamine [Diphenylnitrosamine]						✔										
N-Nitrosopiperidine																
N-Nitrosopyrrolidine																
Octamethylpyrophosphoramide																
Parathion																
Pentachlorobenzene																
Pentachlorodibenzo-p-dioxins [PeCDDs]																
Pentachlorodibenzofurans [PeCDFs]				✔												
Pentachloronitrobenzene [PCNB] [Quintobenzene] [Quintozene]																
Pentachlorophenol [PCP]				✔					✔							
Perchlorate																
Phenol				✔	✔	✔			✔					✔		
1,3-Phenylenediamine [m-Phenylenediamine]																
Phorate																
Phthalic anhydride																
Polychlorinated biphenyls [Aroclors]				✔					✔							
Pronamide																
Propylene oxide [1,2-Epoxypropane]					✔											
Pyrene						✔			✔							
Pyridine						✔										
Safrole																

(continued)

Table B-24. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
Selenium				✔	✔	✔			✔							
Silver				✔		✔		✔	✔							
Silvex [2,4,5-Trichlorophenoxypropionic acid]																
Strychnine																
Styrene				✔	✔	✔										
Styrene oxide																
Sulfide		✔		✔	✔	✔			✔							
2,3,7,8-TCDD [2,3,7,8-Tetrachlorodibenzo-p-dioxin]				✔												
1,2,4,5-Tetrachlorobenzene																
Tetrachlorodibenzo-p-dioxins [TCDDs]				✔												
Tetrachlorodibenzofurans [TCDFs]				✔												
1,1,1,2-Tetrachloroethane																
1,1,2,2-Tetrachloroethane																
Tetrachloroethylene [Perchloroethylene]						✔			✔							
2,3,4,6-Tetrachlorophenol				✔												
Tetraethyldithiopyrophosphate [Sulfotepp]																
Thallium				✔		✔		✔								
Thiram [Thiuram]							✔									
Toluene				✔	✔	✔									✔	
2,4-Toluenediamine [2,4-Diaminotoluene]																
o-Toluidine																
p-Toluidine																
Toxaphene [Chlorinated camphene]																
1,1,2-Trichloro-1,2,2-trifluoroethane [Freon 113]																
1,2,4-Trichlorobenzene																
1,1,1-Trichloroethane [Methyl chloroform]						✔										
1,1,2-Trichloroethane [Vinyl trichloride]																
Trichloroethylene [TCE]						✔										
Trichlorofluoromethane [Trichloromonofluoromethane] [CFC-11]																
2,4,5-Trichlorophenol				✔												
2,4,6-Trichlorophenol				✔												
2,4,5-Trichlorophenoxyacetic acid [2,4,5,-T]																
1,2,3-Trichloropropane																

(continued)

Table B-24. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
Triethylamine																
1,3,5-Trinitrobenzene [sym-Trinitrobenzene]																
Tris(2,3-dibromopropyl) phosphate																
Vanadium				✔	✔	✔		✔								
Vinyl acetate		✔														
Vinyl chloride [chloroethylene]																
Warfarin																
m-Xylene				✔	✔											
o-Xylene				✔	✔											
p-Xylene				✔	✔											
Xylenes, mixed isomers [Xylenes]				✔	✔	✔									✔	
Zinc	✔	✔		✔	✔	✔	✔	✔	✔	✔		✔				

Table B-25. Chemical Presence in Sludge by SIC Code (Survey Database)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
Acenaphthene					✔	✔										
Acetaldehyde [Ethanal]				✔	✔											
Acetone [2-Propanone]				✔	✔	✔			✔							
Acetonitrile [Methyl cyanide]																
Acetophenone																
Acrolein [2-propenal]					✔											
Acrylamide																
Acrylic acid [propenoic acid]					✔											
Acrylonitrile					✔											
Aldicarb																
Aldrin					✔											
Allyl alcohol					✔											
Allyl chloride																
Ammonium vanadate																
Ammonium perchlorate																
Aniline																
Anthracene					✔	✔										
Antimony				✔	✔	✔		✔	✔	✔				✔		
Aramite																
Arsenic	✔			✔	✔	✔			✔					✔		✔
Barium	✔			✔	✔	✔	✔	✔	✔	✔		✔		✔		✔
Benzene					✔	✔			✔							
Benzidine																
Benzo(a)pyrene					✔	✔			✔							
Benzo(b)fluoranthene					✔	✔			✔							
Benzo[a]anthracene					✔	✔			✔							
Benzyl alcohol																
Benzyl chloride																
Beryllium				✔	✔	✔		✔	✔					✔		
beta-Hexachlorocyclohexane [beta-BHC]					✔											
Bis(2-chloroethyl) ether [sym-Dichloroethyl ether]					✔											
Bis(2-chloroisopropyl) ether [2,2'-Dichloroisopropyl ether]					✔											
Bis(2-ethylhexyl) phthalate [Dioctyl phthalate]					✔	✔	✔									
Bis(chloromethyl) ether [sym-Dichloromethyl ether]																
Bromodichloromethane [Dichlorobromomethane]																

(continued)

Table B-25. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
Bromoform [Tribromomethane]					✔											
Bromomethane [Methyl bromide]									✔							
1,3-Butadiene																
n-Butyl alcohol [n-Butanol]					✔											
Butyl benzyl phthalate					✔											
Cadmium	✔			✔	✔	✔	✔	✔	✔	✔				✔		✔
Carbon disulfide				✔	✔	✔			✔							
Carbon tetrachloride																
Chloral [Trichloroacetaldehyde]																
Chloral hydrate [Trichloroacetaldehyde hydrate]																
Chlordane, alpha & gamma isomers					✔											
4-Chloroaniline [p-aminochlorobenzene]																
Chlorobenzene					✔	✔										
Chlorobenzilate																
Chlorodibromomethane [Dibromochloromethane]																
Chloroethane [Ethyl chloride]																
Chloroform [Trichloromethane]				✔	✔	✔			✔							
Chloromethane [Methyl chloride]				✔					✔							
Chloromethyl methyl ether																
2-Chloronaphthalene [beta-Chloronaphthalene]																
2-Chlorophenol [o-Chlorophenol]				✔	✔											
Chloroprene [2-Chloro-1,3-butadiene]																
Chromium	✔	✔		✔	✔	✔		✔	✔	✔		✔		✔	✔	✔
Chromium VI [Hexavalent Chromium]					✔	✔			✔							
Chrysene					✔	✔			✔							
Cobalt				✔	✔	✔			✔							✔
Copper	✔	✔		✔	✔	✔	✔		✔	✔		✔		✔		✔
m-Cresol [3-Methyl phenol]				✔	✔	✔										
o-Cresol [2-Methyl phenol]					✔	✔										
p-Cresol [4-Methyl phenol]					✔	✔										
Cresols				✔												
Cumene [Isopropyl benzene]				✔												
Cyanide					✔	✔			✔							
Cyanide, amenable									✔							
Cyanogen bromide [Bromine cyanide]																

(continued)

Table B-25. (continued)

Industry Group / Chemical	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
Cyanogen chloride [Chlorine cyanide]																
Cyclohexanol																
Cyclohexanone																
2,4-D [2,4-Dichlorophenoxyacetic acid]																
p,p'-DDD					✔											
p,p'-DDE					✔											
p,p'-DDT					✔											
Di-n-butyl phthalate					✔	✔	✔									
Diallate																
Dibenz[a,h]anthracene						✔			✔							
1,2-Dibromo-3-chloropropane																
1,2-Dichlorobenzene [o-Dichlorobenzene]					✔	✔										
1,4-Dichlorobenzene [p-Dichlorobenzene]					✔	✔										
3,3'-Dichlorobenzidine																
Dichlorodifluoromethane [CFC-12]																
1,2-Dichloroethane [Ethylene dichloride]					✔	✔										
1,1-Dichloroethylene [Vinylidene chloride]					✔											
cis-1,2-Dichloroethylene																
trans-1,2-Dichloroethylene																
2,4-Dichlorophenol				✔	✔											
1,2-Dichloropropane [Propylene dichloride]					✔											
cis-1,3-Dichloropropylene																
trans-1,3-Dichloropropylene																
Dieldrin					✔											
Diethyl phthalate [DEP]						✔										
Diethylstilbestrol [DES]																
Dimethoate																
3,3'-Dimethoxybenzidine																
N,N-Dimethyl formamide [DMF]						✔										
Dimethyl phthalate [DMP]						✔										
7,12-Dimethylbenz[a]anthracene																
3,3'-Dimethylbenzidine																
2,4-Dimethylphenol					✔	✔										
3,4-Dimethylphenol																
1,3-Dinitrobenzene [m-Dinitrobenzene]																

(continued)

Table B-25. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
2,4-Dinitrophenol						✔										
2,4-Dinitrotoluene																
2,6-Dinitrotoluene																
Dinoseb [2-sec-Butyl-4,6-dinitrophenol]																
n-Dioctyl phthalate					✔		✔									
1,4-Dioxane [1,4-Diethyleneoxide]					✔	✔										
Diphenylamine																
1,2-Diphenylhydrazine																
Direct Black 38																
Direct Blue 6																
Direct Brown 95																
Disulfoton																
Endosulfan																
Endothall																
Endrin					✔											
Epichlorohydrin [1-Chloro-2,3-epoxypropane]																
1,2-Epoxybutane [1,2-Butylene oxide]																
2-Ethoxyethanol acetate [2-EEA]																
2-Ethoxyethanol [Ethylene glycol monoethyl ether]																
Ethyl acetate																
Ethyl benzene					✔	✔										
Ethyl ether [Diethyl ether]																
Ethyl methacrylate																
Ethyl methanesulfonate																
Ethylene dibromide [1,2-Dibromoethane]						✔										
Ethylene glycol				✔	✔	✔										
Ethylene oxide					✔											
Ethylene thiourea							✔									
Ethylidene dichloride [1,1-Dichloroethane]						✔										
Fluoranthene					✔	✔			✔							
Fluorene					✔	✔										
Fluoride				✔	✔	✔			✔					✔		
Formaldehyde				✔	✔	✔						✔				
Formic Acid					✔											
Furan																

(continued)

Table B-25. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
Furfural																
Glycidylaldehyde																
Heptachlor					✔											
Heptachlor epoxide, alpha, beta, and gamma isomers					✔											
Hexachloro-1,3-butadiene [Hexachlorobutadiene]																
Hexachlorobenzene					✔											
alpha-Hexachlorocyclohexane [alpha-BHC]																
Hexachlorocyclopentadiene																
Hexachlorodibenzo-p-dioxins [HxCDDs]				✔												
Hexachlorodibenzofurans [HxCDFs]				✔	✔											
Hexachloroethane																
Hexachlorophene																
n-Hexane				✔												
Hydrazine																
Indeno(1,2,3-cd) pyrene						✔			✔							
Isobutyl alcohol [Isobutanol]																
Isophorone					✔											
Kepone																
Lead	✔	✔		✔	✔	✔	✔	✔	✔	✔		✔		✔		
Lindane [gamma-Hexachlorocyclohexane] [gamma-BHC]					✔											
Maleic anhydride																
Maleic hydrazide																
Manganese				✔	✔	✔			✔	✔				✔		✔
Mercury				✔	✔	✔			✔					✔		
Methacrylonitrile																
Methanol [methyl alcohol]				✔	✔	✔										
Methomyl																
Methoxychlor					✔											
2-Methoxyethanol acetate [2-MEA] [methyl cellosolve acetate]																
2-Methoxyethanol [methyl cellosolve]																
Methyl ethyl ketone [2-Butanone][MEK]				✔	✔	✔			✔							
Methyl isobutyl ketone [Hexone] [4-Methyl-2-pentanone] [MIBK]				✔												
Methyl methacrylate																
Methyl parathion																

(continued)

Table B-25. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
Methyl tert-butyl ether [MTBE]						✔										
3-Methylcholanthrene																
4,4'-Methylene bis(2-chloroaniline)																
Methylene bromide [Dibromomethane]																
Methylene chloride [Dichloromethane]				✔	✔	✔			✔							
Molybdenum	✔			✔	✔	✔	✔		✔					✔		✔
Naphthalene				✔	✔	✔			✔							
Nickel	✔	✔		✔	✔	✔	✔	✔	✔			✔		✔		✔
Nickel Subsulfide																
Nitrobenzene																
2-Nitropropane																
N-Nitroso-N-methylethylamine																
N-Nitrosodi-n-butylamine																
N-Nitrosodi-n-propylamine [Di-n-propylnitrosamine]																
N-Nitrosodiethylamine																
N-Nitrosodimethylamine																
N-Nitrosodiphenylamine [Diphenylnitrosamine]						✔										
N-Nitrosopiperidine																
N-Nitrosopyrrolidine																
Octamethylpyrophosphoramide																
Parathion																
Pentachlorobenzene																
Pentachlorodibenzo-p-dioxins [PeCDDs]				✔												
Pentachlorodibenzofurans [PeCDFs]				✔												
Pentachloronitrobenzene [PCNB] [Quintobenzene] [Quintozene]																
Pentachlorophenol [PCP]				✔												
Perchlorate																
Phenol				✔	✔	✔			✔							
1,3-Phenylenediamine [m-Phenylenediamine]																
Phorate																
Phthalic anhydride																
Polychlorinated biphenyls [Aroclors]				✔	✔				✔							✔
Pronamide																
Propylene oxide [1,2-Epoxypropane]																
Pyrene					✔	✔			✔							

(continued)

Table B-25. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
Pyridine						✔										
Safrole																
Selenium		✔		✔	✔	✔		✔	✔					✔		✔
Silver				✔	✔	✔		✔	✔					✔		
Silvex [2,4,5-Trichlorophenoxypropionic acid]																
Strychnine																
Styrene					✔	✔										
Styrene oxide																
Sulfide				✔	✔	✔			✔			✔				
2,3,7,8-TCDD [2,3,7,8-Tetrachlorodibenzo-p-dioxin]				✔												
1,2,4,5-Tetrachlorobenzene																
Tetrachlorodibenzo-p-dioxins [TCDDs]				✔												
Tetrachlorodibenzofurans [TCDFs]				✔												
1,1,1,2-Tetrachloroethane																
1,1,2,2-Tetrachloroethane																
Tetrachloroethylene [Perchloroethylene]					✔	✔			✔							
2,3,4,6-Tetrachlorophenol				✔												
Tetraethyldithiopyrophosphate [Sulfotepp]																
Thallium				✔	✔	✔		✔								
Thiram [Thiuram]							✔									
Toluene				✔	✔	✔										
2,4-Toluenediamine [2,4-Diaminotoluene]																
o-Toluidine																
p-Toluidine																
Toxaphene [Chlorinated camphene]																
1,1,2-Trichloro-1,2,2-trifluoroethane [Freon 113]																
1,2,4-Trichlorobenzene				✔												
1,1,1-Trichloroethane [Methyl chloroform]						✔										
1,1,2-Trichloroethane [Vinyl trichloride]																
Trichloroethylene [TCE]					✔	✔			✔							
Trichlorofluoromethane [Trichloromonofluoromethane] [CFC-11]																
2,4,5-Trichlorophenol																
2,4,6-Trichlorophenol				✔	✔											

(continued)

Table B-25. (continued)

Industry Group / Chemical	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
2,4,5-Trichlorophenoxyacetic acid [2,4,5,-T]																
1,2,3-Trichloropropane																
Triethylamine																
1,3,5-Trinitrobenzene [sym-Trinitrobenzene]																
Tris(2,3-dibromopropyl) phosphate																
Vanadium				✔	✔	✔		✔	✔					✔		✔
Vinyl acetate																
Vinyl chloride [chloroethylene]					✔											
Warfarin																
m-Xylene																
o-Xylene					✔											
p-Xylene																
Xylenes, mixed isomers [Xylenes]					✔	✔										
Zinc	✔	✔		✔	✔	✔	✔	✔	✔	✔		✔		✔		✔

Table B-26.Chemical Presence in Wastewater Influent by SIC Code (Risk Input Database)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
Acenaphthene				✔	✔	✔			✔			✔				
Acetaldehyde [Ethanal]				✔	✔											
Acetone [2-Propanone]				✔	✔	✔			✔							
Acetonitrile [Methyl cyanide]					✔											
Acetophenone					✔											
Acrolein [2-propenal]				✔	✔	✔			✔							
Acrylamide																
Acrylic acid [propenoic acid]					✔											
Acrylonitrile				✔	✔	✔			✔							
Aldicarb																
Aldrin				✔	✔	✔			✔							
Allyl alcohol					✔											
Allyl chloride					✔											
Ammonium vanadate																
Ammonium perchlorate																
Aniline				✔	✔	✔										
Anthracene				✔	✔	✔			✔			✔				
Antimony				✔	✔	✔		✔	✔	✔			✔	✔		
Aramite																
Arsenic		✔		✔	✔	✔		✔	✔	✔		✔		✔		
Barium		✔	✔	✔	✔	✔	✔	✔	✔	✔		✔	✔	✔	✔	
Benzene				✔	✔	✔			✔			✔		✔	✔	
Benzidine				✔	✔	✔			✔							
Benzo(a)pyrene				✔	✔	✔			✔			✔				
Benzo(b)fluoranthene				✔	✔	✔			✔			✔				
Benzo[a]anthracene				✔	✔	✔			✔			✔				
Benzyl alcohol				✔	✔	✔										
Benzyl chloride					✔											
Beryllium				✔	✔	✔		✔	✔					✔		
beta-Hexachlorocyclohexane [beta-BHC]				✔	✔	✔			✔							
Bis(2-chloroethyl) ether [sym-Dichloroethyl ether]				✔	✔	✔			✔							
Bis(2-chloroisopropyl) ether [2,2'-Dichloroisopropyl ether]				✔	✔	✔			✔							
Bis(2-ethylhexyl) phthalate [Dioctyl phthalate]		✔	✔	✔	✔	✔	✔		✔							
Bis(chloromethyl) ether [sym-Dichloromethyl ether]				✔	✔											
Bromodichloromethane [Dichlorobromomethane]				✔	✔	✔	✔		✔							

(continued)

Table B-26. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
Bromoform [Tribromomethane]				✔	✔	✔	✔		✔							
Bromomethane [Methyl bromide]				✔	✔	✔			✔							
1,3-Butadiene																
n-Butyl alcohol [n-Butanol]					✔											
Butyl benzyl phthalate				✔	✔	✔			✔							
Cadmium		✔		✔	✔	✔	✔	✔	✔	✔		✔		✔		
Carbon disulfide				✔	✔	✔			✔							
Carbon tetrachloride				✔	✔	✔			✔							
Chloral [Trichloroacetaldehyde]																
Chloral hydrate [Trichloroacetaldehyde hydrate]																
Chlordane, alpha & gamma isomers		✔		✔	✔	✔			✔							
4-Chloroaniline [p-aminochlorobenzene]					✔	✔										
Chlorobenzene				✔	✔	✔			✔							
Chlorobenzilate					✔											
Chlorodibromomethane [Dibromochloromethane]				✔	✔	✔	✔		✔							
Chloroethane [Ethyl chloride]				✔	✔	✔			✔							
Chloroform [Trichloromethane]				✔	✔	✔	✔		✔							
Chloromethane [Methyl chloride]				✔	✔	✔			✔							
Chloromethyl methyl ether																
2-Chloronaphthalene [beta-Chloronaphthalene]				✔	✔	✔			✔							
2-Chlorophenol [o-Chlorophenol]				✔	✔	✔			✔							
Chloroprene [2-Chloro-1,3-butadiene]					✔											
Chromium		✔		✔	✔	✔		✔	✔	✔		✔	✔	✔	✔	
Chromium VI [Hexavalent Chromium]					✔	✔			✔	✔		✔				
Chrysene				✔	✔	✔			✔			✔				
Cobalt				✔	✔	✔						✔				
Copper		✔		✔	✔	✔	✔		✔	✔		✔	✔	✔	✔	
m-Cresol [3-Methyl phenol]		✔				✔										
o-Cresol [2-Methyl phenol]		✔			✔	✔										
p-Cresol [4-Methyl phenol]		✔			✔	✔										
Cresols				✔		✔										
Cumene [Isopropyl benzene]				✔	✔	✔										
Cyanide		✔		✔	✔	✔			✔				✔	✔		
Cyanide, amenable					✔	✔			✔							
Cyanogen bromide [Bromine cyanide]																

(continued)

Table B-26. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
Cyanogen chloride [Chlorine cyanide]																
Cyclohexanol					✔											
Cyclohexanone				✔	✔											
2,4-D [2,4-Dichlorophenoxyacetic acid]		✔		✔	✔											
p,p'-DDD				✔	✔	✔			✔							
p,p'-DDE				✔	✔	✔			✔							
p,p'-DDT				✔	✔	✔			✔							
Di-n-butyl phthalate				✔	✔	✔	✔		✔							
Diallate					✔											
Dibenz[a,h]anthracene				✔	✔	✔			✔			✔				
1,2-Dibromo-3-chloropropane				✔	✔											
1,2-Dichlorobenzene [o-Dichlorobenzene]				✔	✔	✔			✔							
1,4-Dichlorobenzene [p-Dichlorobenzene]		✔		✔	✔	✔			✔							
3,3'-Dichlorobenzidine				✔	✔	✔			✔							
Dichlorodifluoromethane [CFC-12]				✔	✔											
1,2-Dichloroethane [Ethylene dichloride]				✔	✔	✔			✔							
1,1-Dichloroethylene [Vinylidene chloride]				✔	✔	✔			✔							
cis-1,2-Dichloroethylene				✔	✔	✔										
trans-1,2-Dichloroethylene				✔	✔	✔			✔							
2,4-Dichlorophenol				✔	✔	✔			✔							
1,2-Dichloropropane [Propylene dichloride]				✔	✔	✔			✔							
cis-1,3-Dichloropropylene				✔	✔	✔			✔							
trans-1,3-Dichloropropylene				✔	✔	✔			✔							
Dieldrin				✔	✔	✔			✔							
Diethyl phthalate [DEP]				✔	✔	✔			✔							
Diethylstilbestrol [DES]																
Dimethoate				✔	✔											
3,3'-Dimethoxybenzidine					✔											
N,N-Dimethyl formamide [DMF]					✔	✔										
Dimethyl phthalate [DMP]				✔	✔	✔			✔							
7,12-Dimethylbenz[a]anthracene						✔										
3,3'-Dimethylbenzidine																
2,4-Dimethylphenol				✔	✔	✔			✔							
3,4-Dimethylphenol																
1,3-Dinitrobenzene [m-Dinitrobenzene]					✔											

(continued)

Table B-26. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
2,4-Dinitrophenol				✔	✔	✔			✔							
2,4-Dinitrotoluene		✔		✔	✔	✔			✔							
2,6-Dinitrotoluene				✔	✔	✔			✔							
Dinoseb [2-sec-Butyl-4,6-dinitrophenol]					✔											
n-Dioctyl phthalate				✔	✔	✔	✔		✔							
1,4-Dioxane [1,4-Diethyleneoxide]		✔			✔	✔										
Diphenylamine					✔											
1,2-Diphenylhydrazine				✔	✔	✔			✔							
Direct Black 38																
Direct Blue 6																
Direct Brown 95																
Disulfoton				✔	✔											
Endosulfan				✔	✔	✔			✔							
Endothall																
Endrin		✔		✔	✔	✔			✔							
Epichlorohydrin [1-Chloro-2,3-epoxypropane]		✔			✔											
1,2-Epoxybutane [1,2-Butylene oxide]																
2-Ethoxyethanol acetate [2-EEA]																
2-Ethoxyethanol [Ethylene glycol monoethyl ether]																
Ethyl acetate					✔											
Ethyl benzene				✔	✔	✔			✔			✔			✔	
Ethyl ether [Diethyl ether]					✔											
Ethyl methacrylate					✔											
Ethyl methanesulfonate																
Ethylene dibromide [1,2-Dibromoethane]					✔	✔										
Ethylene glycol		✔		✔	✔	✔								✔		
Ethylene oxide					✔											
Ethylene thiourea							✔									
Ethylidene dichloride [1,1-Dichloroethane]				✔	✔	✔			✔							
Fluoranthene				✔	✔	✔			✔			✔				
Fluorene				✔	✔	✔			✔			✔				
Fluoride				✔	✔	✔			✔			✔		✔	✔	
Formaldehyde		✔		✔	✔	✔						✔				
Formic Acid				✔	✔											
Furan					✔											

(continued)

Table B-26. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
Furfural				✔	✔											
Glycidylaldehyde																
Heptachlor		✔		✔	✔	✔			✔							
Heptachlor epoxide, alpha, beta, and gamma isomers		✔		✔	✔				✔							
Hexachloro-1,3-butadiene [Hexachlorobutadiene]				✔	✔	✔			✔							
Hexachlorobenzene				✔	✔	✔			✔							
alpha-Hexachlorocyclohexane [alpha-BHC]				✔	✔	✔			✔							
Hexachlorocyclopentadiene				✔	✔	✔			✔							
Hexachlorodibenzo-p-dioxins [HxCDDs]				✔												
Hexachlorodibenzofurans [HxCDFs]				✔	✔											
Hexachloroethane				✔	✔	✔			✔							
Hexachlorophene					✔											
n-Hexane				✔	✔											
Hydrazine					✔											
Indeno(1,2,3-cd) pyrene				✔	✔	✔			✔			✔				
Isobutyl alcohol [Isobutanol]																
Isophorone				✔	✔	✔			✔							
Kepone					✔											
Lead		✔		✔	✔	✔	✔	✔	✔	✔		✔	✔	✔	✔	
Lindane [gamma-Hexachlorocyclohexane] [gamma-BHC]		✔		✔	✔	✔			✔							
Maleic anhydride																
Maleic hydrazide																
Manganese	✔			✔	✔	✔			✔	✔		✔	✔	✔		
Mercury		✔		✔	✔	✔		✔	✔	✔				✔		
Methacrylonitrile					✔											
Methanol [methyl alcohol]		✔		✔	✔	✔										
Methomyl																
Methoxychlor		✔		✔	✔	✔			✔							
2-Methoxyethanol acetate [2-MEA] [methyl cellosolve acetate]																
2-Methoxyethanol [methyl cellosolve]																
Methyl ethyl ketone [2-Butanone][MEK]				✔	✔	✔			✔							
Methyl isobutyl ketone [Hexone] [4-Methyl-2-pentanone] [MIBK]				✔	✔	✔										
Methyl methacrylate					✔											
Methyl parathion				✔	✔											

(continued)

Table B-26. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
Methyl tert-butyl ether [MTBE]				✔	✔	✔									✔	
3-Methylcholanthrene					✔											
4,4'-Methylene bis(2-chloroaniline)					✔											
Methylene bromide [Dibromomethane]				✔	✔											
Methylene chloride [Dichloromethane]				✔	✔	✔			✔							
Molybdenum		✔		✔	✔	✔	✔		✔			✔		✔		
Naphthalene				✔	✔	✔			✔			✔			✔	
Nickel		✔	✔	✔	✔	✔	✔	✔	✔	✔		✔	✔	✔	✔	
Nickel Subsulfide																
Nitrobenzene				✔	✔	✔			✔							
2-Nitropropane																
N-Nitroso-N-methylethylamine					✔											
N-Nitrosodi-n-butylamine					✔											
N-Nitrosodi-n-propylamine [Di-n-propylnitrosamine]				✔	✔	✔			✔							
N-Nitrosodiethylamine					✔											
N-Nitrosodimethylamine				✔	✔	✔			✔							
N-Nitrosodiphenylamine [Diphenylnitrosamine]				✔	✔	✔			✔							
N-Nitrosopiperidine					✔											
N-Nitrosopyrrolidine					✔	✔										
Octamethylpyrophosphoramide																
Parathion				✔	✔											
Pentachlorobenzene					✔											
Pentachlorodibenzo-p-dioxins [PeCDDs]																
Pentachlorodibenzofurans [PeCDFs]				✔												
Pentachloronitrobenzene [PCNB] [Quintobenzene] [Quintozene]					✔											
Pentachlorophenol [PCP]				✔	✔	✔			✔							
Perchlorate																
Phenol				✔	✔	✔			✔			✔		✔		
1,3-Phenylenediamine [m-Phenylenediamine]					✔											
Phorate				✔	✔											
Phthalic anhydride																
Polychlorinated biphenyls [Aroclors]				✔	✔	✔			✔							
Pronamide																
Propylene oxide [1,2-Epoxypropane]					✔											
Pyrene				✔	✔	✔			✔			✔				

(continued)

Table B-26. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
Pyridine				✔	✔	✔										
Safrole					✔											
Selenium		✔		✔	✔	✔		✔	✔	✔			✔	✔		
Silver		✔		✔	✔	✔		✔	✔	✔				✔		
Silvex [2,4,5-Trichlorophenoxypropionic acid]		✔		✔	✔											
Strychnine																
Styrene				✔	✔	✔										
Styrene oxide																
Sulfide	✔	✔		✔	✔	✔			✔			✔				
2,3,7,8-TCDD [2,3,7,8-Tetrachlorodibenzo-p-dioxin]				✔		✔										
1,2,4,5-Tetrachlorobenzene					✔											
Tetrachlorodibenzo-p-dioxins [TCDDs]				✔												
Tetrachlorodibenzofurans [TCDFs]				✔												
1,1,1,2-Tetrachloroethane				✔	✔											
1,1,2,2-Tetrachloroethane				✔	✔	✔			✔							
Tetrachloroethylene [Perchloroethylene]				✔	✔	✔			✔					✔		
2,3,4,6-Tetrachlorophenol				✔	✔	✔										
Tetraethyldithiopyrophosphate [Sulfotepp]				✔												
Thallium				✔	✔	✔		✔								
Thiram [Thiuram]							✔									
Toluene				✔	✔	✔			✔			✔			✔	
2,4-Toluenediamine [2,4-Diaminotoluene]																
o-Toluidine																
p-Toluidine																
Toxaphene [Chlorinated camphene]		✔		✔	✔	✔			✔							
1,1,2-Trichloro-1,2,2-trifluoroethane [Freon 113]					✔	✔										
1,2,4-Trichlorobenzene				✔	✔	✔			✔							
1,1,1-Trichloroethane [Methyl chloroform]				✔	✔	✔			✔					✔		
1,1,2-Trichloroethane [Vinyl trichloride]				✔	✔	✔			✔							
Trichloroethylene [TCE]				✔	✔	✔			✔					✔		
Trichlorofluoromethane [Trichloromonofluoromethane] [CFC-11]				✔	✔	✔			✔							
2,4,5-Trichlorophenol		✔		✔	✔	✔										
2,4,6-Trichlorophenol		✔		✔	✔	✔			✔							

(continued)

Table B-26. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
2,4,5-Trichlorophenoxyacetic acid [2,4,5,-T]				✔												
1,2,3-Trichloropropane				✔	✔											
Triethylamine					✔											
1,3,5-Trinitrobenzene [sym-Trinitrobenzene]					✔											
Tris(2,3-dibromopropyl) phosphate																
Vanadium				✔	✔	✔		✔						✔		
Vinyl acetate		✔			✔											
Vinyl chloride [chloroethylene]				✔	✔	✔			✔							
Warfarin																
m-Xylene				✔	✔				✔							
o-Xylene				✔	✔	✔			✔							
p-Xylene				✔	✔				✔							
Xylenes, mixed isomers [Xylenes]				✔	✔	✔									✔	
Zinc	✔	✔		✔	✔	✔	✔	✔	✔	✔		✔	✔	✔	✔	

Table B-27. Chemical Presence in Wastewater in Impoundment by SIC Code (Risk Input Database)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
Acenaphthene				✔	✔	✔			✔			✔				
Acetaldehyde [Ethanal]				✔	✔											
Acetone [2-Propanone]				✔	✔	✔			✔							
Acetonitrile [Methyl cyanide]					✔											
Acetophenone					✔											
Acrolein [2-propenal]				✔	✔	✔			✔							
Acrylamide																
Acrylic acid [propenoic acid]					✔											
Acrylonitrile				✔	✔	✔			✔							
Aldicarb																
Aldrin				✔	✔	✔			✔							
Allyl alcohol					✔											
Allyl chloride					✔											
Ammonium vanadate																
Ammonium perchlorate																
Aniline				✔	✔	✔										
Anthracene				✔	✔	✔			✔			✔				
Antimony				✔	✔	✔		✔	✔	✔			✔	✔		
Aramite																
Arsenic		✔		✔	✔	✔		✔	✔	✔		✔		✔		
Barium		✔	✔	✔	✔	✔	✔	✔	✔	✔		✔	✔	✔	✔	
Benzene				✔	✔	✔			✔			✔		✔	✔	
Benzidine				✔	✔	✔			✔							
Benzo(a)pyrene				✔	✔	✔			✔			✔				
Benzo(b)fluoranthene				✔	✔	✔			✔			✔				
Benzo[a]anthracene				✔	✔	✔			✔			✔				
Benzyl alcohol				✔	✔	✔										
Benzyl chloride					✔											
Beryllium				✔	✔	✔		✔	✔					✔		
beta-Hexachlorocyclohexane [beta-BHC]				✔	✔	✔			✔							
Bis(2-chloroethyl) ether [sym-Dichloroethyl ether]				✔	✔	✔			✔							
Bis(2-chloroisopropyl) ether [2,2'-Dichloroisopropyl ether]				✔	✔	✔			✔							
Bis(2-ethylhexyl) phthalate [Dioctyl phthalate]		✔	✔	✔	✔	✔	✔		✔							
Bis(chloromethyl) ether [sym-Dichloromethyl ether]				✔	✔											

(continued)

Table B-27. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
Bromodichloromethane [Dichlorobromomethane]				✔	✔	✔	✔		✔							
Bromoform [Tribromomethane]				✔	✔	✔	✔		✔							
Bromomethane [Methyl bromide]				✔	✔	✔			✔							
1,3-Butadiene																
n-Butyl alcohol [n-Butanol]					✔											
Butyl benzyl phthalate				✔	✔	✔			✔							
Cadmium		✔		✔	✔	✔	✔	✔	✔	✔		✔		✔		
Carbon disulfide				✔	✔	✔			✔							
Carbon tetrachloride				✔	✔	✔			✔							
Chloral [Trichloroacetaldehyde]																
Chloral hydrate [Trichloroacetaldehyde hydrate]																
Chlordane, alpha & gamma isomers		✔		✔	✔	✔			✔							
4-Chloroaniline [p-aminochlorobenzene]					✔	✔										
Chlorobenzene				✔	✔	✔			✔							
Chlorobenzilate					✔											
Chlorodibromomethane [Dibromochloromethane]				✔	✔	✔	✔		✔							
Chloroethane [Ethyl chloride]				✔	✔	✔			✔							
Chloroform [Trichloromethane]				✔	✔	✔	✔		✔							
Chloromethane [Methyl chloride]				✔	✔	✔			✔							
Chloromethyl methyl ether																
2-Chloronaphthalene [beta-Chloronaphthalene]				✔	✔	✔			✔							
2-Chlorophenol [o-Chlorophenol]				✔	✔	✔			✔							
Chloroprene [2-Chloro-1,3-butadiene]					✔											
Chromium		✔		✔	✔	✔		✔	✔	✔		✔	✔	✔	✔	
Chromium VI [Hexavalent Chromium]					✔	✔			✔	✔		✔				
Chrysene				✔	✔	✔			✔			✔				
Cobalt				✔	✔	✔						✔				
Copper		✔		✔	✔	✔	✔		✔	✔		✔	✔	✔	✔	
m-Cresol [3-Methyl phenol]		✔				✔										
o-Cresol [2-Methyl phenol]		✔			✔	✔										
p-Cresol [4-Methyl phenol]		✔			✔	✔										
Cresols				✔		✔										
Cumene [Isopropyl benzene]				✔	✔	✔										
Cyanide		✔		✔	✔	✔			✔				✔	✔		
Cyanide, amenable					✔	✔			✔							

(continued)

Table B-27. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
Cyanogen bromide [Bromine cyanide]																
Cyanogen chloride [Chlorine cyanide]																
Cyclohexanol					✔											
Cyclohexanone				✔	✔											
2,4-D [2,4-Dichlorophenoxyacetic acid]		✔		✔	✔											
p,p'-DDD				✔	✔	✔			✔							
p,p'-DDE				✔	✔	✔			✔							
p,p'-DDT				✔	✔	✔			✔							
Di-n-butyl phthalate				✔	✔	✔	✔		✔							
Diallate					✔											
Dibenz[a,h]anthracene				✔	✔	✔			✔			✔				
1,2-Dibromo-3-chloropropane				✔	✔											
1,2-Dichlorobenzene [o-Dichlorobenzene]				✔	✔	✔			✔							
1,4-Dichlorobenzene [p-Dichlorobenzene]		✔		✔	✔	✔			✔							
3,3'-Dichlorobenzidine				✔	✔	✔			✔							
Dichlorodifluoromethane [CFC-12]				✔	✔											
1,2-Dichloroethane [Ethylene dichloride]				✔	✔	✔			✔							
1,1-Dichloroethylene [Vinylidene chloride]				✔	✔	✔			✔							
cis-1,2-Dichloroethylene				✔	✔	✔										
trans-1,2-Dichloroethylene				✔	✔	✔			✔							
2,4-Dichlorophenol				✔	✔	✔			✔							
1,2-Dichloropropane [Propylene dichloride]				✔	✔	✔			✔							
cis-1,3-Dichloropropylene				✔	✔	✔			✔							
trans-1,3-Dichloropropylene				✔	✔	✔			✔							
Dieldrin				✔	✔	✔			✔							
Diethyl phthalate [DEP]				✔	✔	✔			✔							
Diethylstilbestrol [DES]																
Dimethoate				✔	✔											
3,3'-Dimethoxybenzidine					✔											
N,N-Dimethyl formamide [DMF]					✔	✔										
Dimethyl phthalate [DMP]				✔	✔	✔			✔							
7,12-Dimethylbenz[a]anthracene						✔										
3,3'-Dimethylbenzidine																
2,4-Dimethylphenol				✔	✔	✔			✔							
3,4-Dimethylphenol																

(continued)

Table B-27. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
1,3-Dinitrobenzene [m-Dinitrobenzene]					✔											
2,4-Dinitrophenol				✔	✔	✔			✔							
2,4-Dinitrotoluene		✔		✔	✔	✔			✔							
2,6-Dinitrotoluene				✔	✔	✔			✔							
Dinoseb [2-sec-Butyl-4,6-dinitrophenol]					✔											
n-Dioctyl phthalate				✔	✔	✔	✔		✔							
1,4-Dioxane [1,4-Diethyleneoxide]		✔			✔	✔										
Diphenylamine					✔											
1,2-Diphenylhydrazine				✔	✔	✔			✔							
Direct Black 38																
Direct Blue 6																
Direct Brown 95																
Disulfoton				✔	✔											
Endosulfan				✔	✔	✔			✔							
Endothall																
Endrin		✔		✔	✔	✔			✔							
Epichlorohydrin [1-Chloro-2,3-epoxypropane]		✔			✔											
1,2-Epoxybutane [1,2-Butylene oxide]																
2-Ethoxyethanol acetate [2-EEA]																
2-Ethoxyethanol [Ethylene glycol monoethyl ether]																
Ethyl acetate					✔											
Ethyl benzene				✔	✔	✔			✔			✔			✔	
Ethyl ether [Diethyl ether]					✔											
Ethyl methacrylate					✔											
Ethyl methanesulfonate																
Ethylene dibromide [1,2-Dibromoethane]					✔	✔										
Ethylene glycol		✔		✔	✔	✔								✔		
Ethylene oxide					✔											
Ethylene thiourea							✔									
Ethylidene dichloride [1,1-Dichloroethane]				✔	✔	✔			✔							
Fluoranthene				✔	✔	✔			✔			✔				
Fluorene				✔	✔	✔			✔			✔				
Fluoride				✔	✔	✔			✔			✔		✔	✔	
Formaldehyde		✔		✔	✔	✔						✔				
Formic Acid				✔	✔											

(continued)

Table B-27. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
Furan					✔											
Furfural				✔	✔											
Glycidylaldehyde																
Heptachlor		✔		✔	✔	✔			✔							
Heptachlor epoxide, alpha, beta, and gamma isomers		✔		✔	✔				✔							
Hexachloro-1,3-butadiene [Hexachlorobutadiene]				✔	✔	✔			✔							
Hexachlorobenzene				✔	✔	✔			✔							
alpha-Hexachlorocyclohexane [alpha-BHC]				✔	✔	✔			✔							
Hexachlorocyclopentadiene				✔	✔	✔			✔							
Hexachlorodibenzo-p-dioxins [HxCDDs]				✔												
Hexachlorodibenzofurans [HxCDFs]				✔	✔											
Hexachloroethane				✔	✔	✔			✔							
Hexachlorophene					✔											
n-Hexane				✔	✔											
Hydrazine					✔											
Indeno(1,2,3-cd) pyrene				✔	✔	✔			✔			✔				
Isobutyl alcohol [Isobutanol]																
Isophorone				✔	✔	✔			✔							
Kepone					✔											
Lead		✔		✔	✔	✔	✔	✔	✔	✔		✔	✔	✔	✔	
Lindane [gamma-Hexachlorocyclohexane] [gamma-BHC]		✔		✔	✔	✔			✔							
Maleic anhydride																
Maleic hydrazide																
Manganese	✔			✔	✔	✔			✔	✔		✔	✔	✔		
Mercury		✔		✔	✔	✔		✔	✔	✔				✔		
Methacrylonitrile					✔											
Methanol [methyl alcohol]		✔		✔	✔	✔										
Methomyl																
Methoxychlor		✔		✔	✔	✔			✔							
2-Methoxyethanol acetate [2-MEA] [methyl cellosolve acetate]																
2-Methoxyethanol [methyl cellosolve]																
Methyl ethyl ketone [2-Butanone][MEK]				✔	✔	✔			✔							
Methyl isobutyl ketone [Hexone] [4-Methyl-2-pentanone] [MIBK]				✔	✔	✔										
Methyl methacrylate					✔											

(continued)

Table B-27. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
Methyl parathion				✔	✔											
Methyl tert-butyl ether [MTBE]				✔	✔	✔									✔	
3-Methylcholanthrene					✔											
4,4'-Methylene bis(2-chloroaniline)					✔											
Methylene bromide [Dibromomethane]				✔	✔											
Methylene chloride [Dichloromethane]				✔	✔	✔			✔							
Molybdenum		✔		✔	✔	✔	✔		✔			✔		✔		
Naphthalene				✔	✔	✔			✔			✔			✔	
Nickel		✔	✔	✔	✔	✔	✔	✔	✔	✔		✔	✔	✔	✔	
Nickel Subsulfide																
Nitrobenzene				✔	✔	✔			✔							
2-Nitropropane																
N-Nitroso-N-methylethylamine					✔											
N-Nitrosodi-n-butylamine					✔											
N-Nitrosodi-n-propylamine [Di-n-propylnitrosamine]				✔	✔	✔			✔							
N-Nitrosodiethylamine					✔											
N-Nitrosodimethylamine				✔	✔	✔			✔							
N-Nitrosodiphenylamine [Diphenylnitrosamine]				✔	✔	✔			✔							
N-Nitrosopiperidine					✔											
N-Nitrosopyrrolidine					✔	✔										
Octamethylpyrophosphoramide																
Parathion				✔	✔											
Pentachlorobenzene					✔											
Pentachlorodibenzo-p-dioxins [PeCDDs]																
Pentachlorodibenzofurans [PeCDFs]				✔												
Pentachloronitrobenzene [PCNB] [Quintobenzene] [Quintozene]					✔											
Pentachlorophenol [PCP]				✔	✔	✔			✔							
Perchlorate																
Phenol				✔	✔	✔			✔			✔		✔		
1,3-Phenylenediamine [m-Phenylenediamine]					✔											
Phorate				✔	✔											
Phthalic anhydride																
Polychlorinated biphenyls [Aroclors]				✔	✔	✔			✔							
Pronamide																

(continued)

Table B-27. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
Propylene oxide [1,2-Epoxypropane]					✔											
Pyrene				✔	✔	✔			✔			✔				
Pyridine				✔	✔	✔										
Safrole					✔											
Selenium		✔		✔	✔	✔		✔	✔	✔			✔	✔		
Silver		✔		✔	✔	✔		✔	✔	✔				✔		
Silvex [2,4,5-Trichlorophenoxypropionic acid]		✔		✔	✔											
Strychnine																
Styrene				✔	✔	✔										
Styrene oxide																
Sulfide	✔	✔		✔	✔	✔			✔			✔				
2,3,7,8-TCDD [2,3,7,8-Tetrachlorodibenzo-p-dioxin]				✔		✔										
1,2,4,5-Tetrachlorobenzene					✔											
Tetrachlorodibenzo-p-dioxins [TCDDs]				✔												
Tetrachlorodibenzofurans [TCDFs]				✔												
1,1,1,2-Tetrachloroethane				✔	✔											
1,1,2,2-Tetrachloroethane				✔	✔	✔			✔							
Tetrachloroethylene [Perchloroethylene]				✔	✔	✔			✔					✔		
2,3,4,6-Tetrachlorophenol				✔	✔	✔										
Tetraethyldithiopyrophosphate [Sulfotepp]				✔												
Thallium				✔	✔	✔		✔								
Thiram [Thiuram]							✔									
Toluene				✔	✔	✔			✔			✔			✔	
2,4-Toluenediamine [2,4-Diaminotoluene]																
o-Toluidine																
p-Toluidine																
Toxaphene [Chlorinated camphene]		✔		✔	✔	✔			✔							
1,1,2-Trichloro-1,2,2-trifluoroethane [Freon 113]					✔	✔										
1,2,4-Trichlorobenzene				✔	✔	✔			✔							
1,1,1-Trichloroethane [Methyl chloroform]				✔	✔	✔			✔					✔		
1,1,2-Trichloroethane [Vinyl trichloride]				✔	✔	✔			✔							
Trichloroethylene [TCE]				✔	✔	✔			✔					✔		
Trichlorofluoromethane [Trichloromonofluoromethane] [CFC-11]				✔	✔	✔			✔							

(continued)

Table B-27. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
2,4,5-Trichlorophenol		✔		✔	✔	✔										
2,4,6-Trichlorophenol		✔		✔	✔	✔			✔							
2,4,5-Trichlorophenoxyacetic acid [2,4,5,-T]				✔												
1,2,3-Trichloropropane				✔	✔											
Triethylamine					✔											
1,3,5-Trinitrobenzene [sym-Trinitrobenzene]					✔											
Tris(2,3-dibromopropyl) phosphate																
Vanadium				✔	✔	✔		✔						✔		
Vinyl acetate		✔			✔											
Vinyl chloride [chloroethylene]				✔	✔	✔			✔							
Warfarin																
m-Xylene				✔	✔				✔							
o-Xylene				✔	✔	✔			✔							
p-Xylene				✔	✔				✔							
Xylenes, mixed isomers [Xylenes]				✔	✔	✔									✔	
Zinc	✔	✔		✔	✔	✔	✔	✔	✔	✔		✔	✔	✔	✔	

Table B-28. Chemical Presence in Sludge by SIC Code (Risk Input Database)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
Acenaphthene				✔	✔	✔			✔			✔				
Acetaldehyde [Ethanal]				✔	✔											
Acetone [2-Propanone]				✔	✔	✔			✔							
Acetonitrile [Methyl cyanide]					✔											
Acetophenone					✔											
Acrolein [2-propenal]				✔	✔	✔			✔							
Acrylamide																
Acrylic acid [propenoic acid]					✔											
Acrylonitrile				✔	✔	✔			✔							
Aldicarb																
Aldrin				✔	✔	✔			✔							
Allyl alcohol					✔											
Allyl chloride					✔											
Ammonium vanadate																
Ammonium perchlorate																
Aniline				✔	✔	✔										
Anthracene				✔	✔	✔			✔			✔				
Antimony				✔	✔	✔		✔	✔	✔				✔		
Aramite																
Arsenic	✔	✔		✔	✔	✔		✔	✔	✔		✔		✔		✔
Barium	✔			✔	✔	✔	✔	✔	✔	✔		✔		✔		✔
Benzene	✔			✔	✔	✔			✔			✔		✔		
Benzidine				✔	✔	✔			✔							
Benzo(a)pyrene				✔	✔	✔			✔			✔				
Benzo(b)fluoranthene				✔	✔	✔			✔			✔				
Benzo[a]anthracene				✔	✔	✔			✔			✔				
Benzyl alcohol				✔	✔	✔										
Benzyl chloride					✔											
Beryllium				✔	✔	✔		✔	✔					✔		
beta-Hexachlorocyclohexane [beta-BHC]				✔	✔	✔			✔							
Bis(2-chloroethyl) ether [sym-Dichloroethyl ether]				✔	✔	✔			✔							
Bis(2-chloroisopropyl) ether [2,2'-Dichloroisopropyl ether]				✔	✔	✔			✔							
Bis(2-ethylhexyl) phthalate [Dioctyl phthalate]				✔	✔	✔	✔		✔							
Bis(chloromethyl) ether [sym-Dichloromethyl ether]				✔	✔											

(continued)

Table B-28. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
Bromodichloromethane [Dichlorobromomethane]				✔	✔	✔	✔		✔							
Bromoform [Tribromomethane]				✔	✔	✔	✔		✔							
Bromomethane [Methyl bromide]				✔	✔	✔			✔							
1,3-Butadiene																
n-Butyl alcohol [n-Butanol]					✔											
Butyl benzyl phthalate				✔	✔	✔			✔							
Cadmium	✔	✔		✔	✔	✔	✔	✔	✔	✔		✔		✔		✔
Carbon disulfide				✔	✔	✔			✔							
Carbon tetrachloride	✔			✔	✔	✔			✔							
Chloral [Trichloroacetaldehyde]																
Chloral hydrate [Trichloroacetaldehyde hydrate]																
Chlordane, alpha & gamma isomers	✔			✔	✔	✔			✔							
4-Chloroaniline [p-aminochlorobenzene]					✔	✔										
Chlorobenzene	✔			✔	✔	✔			✔							
Chlorobenzilate					✔											
Chlorodibromomethane [Dibromochloromethane]				✔	✔	✔	✔		✔							
Chloroethane [Ethyl chloride]				✔	✔	✔			✔							
Chloroform [Trichloromethane]	✔			✔	✔	✔	✔		✔							
Chloromethane [Methyl chloride]				✔	✔	✔			✔							
Chloromethyl methyl ether																
2-Chloronaphthalene [beta-Chloronaphthalene]				✔	✔	✔			✔							
2-Chlorophenol [o-Chlorophenol]				✔	✔	✔			✔							
Chloroprene [2-Chloro-1,3-butadiene]					✔											
Chromium	✔	✔		✔	✔	✔		✔	✔	✔		✔		✔	✔	✔
Chromium VI [Hexavalent Chromium]					✔	✔			✔			✔				
Chrysene				✔	✔	✔			✔			✔				
Cobalt				✔	✔	✔			✔			✔				✔
Copper	✔	✔		✔	✔	✔	✔		✔	✔		✔	✔	✔		✔
m-Cresol [3-Methyl phenol]	✔			✔	✔	✔										
o-Cresol [2-Methyl phenol]	✔			✔	✔	✔										
p-Cresol [4-Methyl phenol]	✔			✔	✔	✔										
Cresols				✔	✔	✔			✔							
Cumene [Isopropyl benzene]				✔	✔	✔										
Cyanide				✔	✔	✔			✔					✔		
Cyanide, amenable					✔	✔										

(continued)

Table B-28. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
Cyanogen bromide [Bromine cyanide]																
Cyanogen chloride [Chlorine cyanide]																
Cyclohexanol					✔											
Cyclohexanone				✔	✔											
2,4-D [2,4-Dichlorophenoxyacetic acid]	✔			✔	✔				✔							
p,p'-DDD				✔	✔	✔			✔							
p,p'-DDE				✔	✔	✔			✔							
p,p'-DDT				✔	✔	✔			✔							
Di-n-butyl phthalate				✔	✔	✔	✔		✔							
Diallate					✔											
Dibenz[a,h]anthracene				✔	✔	✔			✔			✔				
1,2-Dibromo-3-chloropropane					✔											
1,2-Dichlorobenzene [o-Dichlorobenzene]				✔	✔	✔			✔							
1,4-Dichlorobenzene [p-Dichlorobenzene]	✔			✔	✔	✔			✔							
3,3'-Dichlorobenzidine				✔	✔	✔			✔							
Dichlorodifluoromethane [CFC-12]				✔	✔											
1,2-Dichloroethane [Ethylene dichloride]	✔			✔	✔	✔			✔							
1,1-Dichloroethylene [Vinylidene chloride]	✔			✔	✔	✔			✔							
cis-1,2-Dichloroethylene				✔	✔	✔										
trans-1,2-Dichloroethylene				✔	✔	✔			✔							
2,4-Dichlorophenol				✔	✔	✔			✔							
1,2-Dichloropropane [Propylene dichloride]				✔	✔	✔			✔							
cis-1,3-Dichloropropylene				✔	✔	✔			✔							
trans-1,3-Dichloropropylene				✔	✔	✔			✔							
Dieldrin				✔	✔	✔			✔							
Diethyl phthalate [DEP]				✔	✔	✔			✔							
Diethylstilbestrol [DES]																
Dimethoate				✔	✔											
3,3'-Dimethoxybenzidine					✔											
N,N-Dimethyl formamide [DMF]					✔	✔										
Dimethyl phthalate [DMP]				✔	✔	✔			✔							
7,12-Dimethylbenz[a]anthracene						✔										
3,3'-Dimethylbenzidine																
2,4-Dimethylphenol				✔	✔	✔			✔							
3,4-Dimethylphenol																

(continued)

Table B-28. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
1,3-Dinitrobenzene [m-Dinitrobenzene]					✔											
2,4-Dinitrophenol				✔	✔	✔			✔							
2,4-Dinitrotoluene	✔			✔	✔	✔			✔							
2,6-Dinitrotoluene				✔	✔	✔			✔							
Dinoseb [2-sec-Butyl-4,6-dinitrophenol]					✔				✔							
n-Dioctyl phthalate				✔	✔	✔	✔		✔							
1,4-Dioxane [1,4-Diethyleneoxide]		✔			✔	✔										
Diphenylamine					✔											
1,2-Diphenylhydrazine				✔	✔	✔			✔							
Direct Black 38																
Direct Blue 6																
Direct Brown 95																
Disulfoton				✔	✔											
Endosulfan				✔	✔	✔			✔							
Endothall																
Endrin	✔			✔	✔	✔			✔							
Epichlorohydrin [1-Chloro-2,3-epoxypropane]					✔											
1,2-Epoxybutane [1,2-Butylene oxide]																
2-Ethoxyethanol acetate [2-EEA]																
2-Ethoxyethanol [Ethylene glycol monoethyl ether]																
Ethyl acetate					✔											
Ethyl benzene				✔	✔	✔			✔			✔				
Ethyl ether [Diethyl ether]					✔											
Ethyl methacrylate					✔											
Ethyl methanesulfonate																
Ethylene dibromide [1,2-Dibromoethane]					✔	✔										
Ethylene glycol		✔		✔	✔	✔								✔		
Ethylene oxide					✔											
Ethylene thiourea							✔									
Ethylidene dichloride [1,1-Dichloroethane]				✔	✔	✔			✔							
Fluoranthene				✔	✔	✔			✔			✔				
Fluorene				✔	✔	✔			✔			✔				
Fluoride					✔	✔			✔							
Formaldehyde		✔		✔	✔	✔						✔				
Formic Acid				✔	✔											

(continued)

Table B-28. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
Furan					✔											
Furfural				✔	✔	✔										
Glycidylaldehyde																
Heptachlor	✔			✔	✔	✔			✔							
Heptachlor epoxide, alpha, beta, and gamma isomers	✔			✔	✔				✔							
Hexachloro-1,3-butadiene [Hexachlorobutadiene]	✔			✔	✔	✔			✔							
Hexachlorobenzene	✔			✔	✔	✔			✔							
alpha-Hexachlorocyclohexane [alpha-BHC]				✔	✔	✔			✔							
Hexachlorocyclopentadiene				✔	✔	✔			✔							
Hexachlorodibenzo-p-dioxins [HxCDDs]				✔												
Hexachlorodibenzofurans [HxCDFs]				✔	✔											
Hexachloroethane	✔			✔	✔	✔			✔							
Hexachlorophene					✔											
n-Hexane				✔	✔											
Hydrazine					✔											
Indeno(1,2,3-cd) pyrene				✔	✔	✔			✔			✔				
Isobutyl alcohol [Isobutanol]																
Isophorone				✔	✔	✔			✔							
Kepone					✔											
Lead	✔	✔		✔	✔	✔	✔	✔	✔	✔		✔		✔	✔	
Lindane [gamma-Hexachlorocyclohexane] [gamma-BHC]	✔			✔	✔	✔			✔							
Maleic anhydride																
Maleic hydrazide																
Manganese	✔			✔	✔	✔			✔	✔				✔		✔
Mercury	✔	✔		✔	✔	✔		✔	✔	✔				✔		
Methacrylonitrile					✔											
Methanol [methyl alcohol]		✔		✔	✔	✔										
Methomyl																
Methoxychlor	✔			✔	✔	✔			✔							
2-Methoxyethanol acetate [2-MEA] [methyl cellosolve acetate]																
2-Methoxyethanol [methyl cellosolve]																
Methyl ethyl ketone [2-Butanone][MEK]	✔			✔	✔	✔			✔							
Methyl isobutyl ketone [Hexone] [4-Methyl-2-pentanone] [MIBK]				✔	✔	✔										
Methyl methacrylate					✔											

(continued)

Table B-28. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
Methyl parathion				✔	✔											
Methyl tert-butyl ether [MTBE]				✔	✔	✔									✔	
3-Methylcholanthrene					✔											
4,4'-Methylene bis(2-chloroaniline)					✔											
Methylene bromide [Dibromomethane]					✔											
Methylene chloride [Dichloromethane]				✔	✔	✔			✔							
Molybdenum	✔	✔		✔	✔	✔	✔		✔					✔		✔
Naphthalene				✔	✔	✔			✔			✔				
Nickel	✔	✔		✔	✔	✔	✔	✔	✔			✔		✔		✔
Nickel Subsulfide																
Nitrobenzene	✔			✔	✔	✔			✔							
2-Nitropropane																
N-Nitroso-N-methylethylamine					✔											
N-Nitrosodi-n-butylamine					✔											
N-Nitrosodi-n-propylamine [Di-n-propylnitrosamine]				✔	✔	✔			✔							
N-Nitrosodiethylamine					✔											
N-Nitrosodimethylamine				✔	✔	✔			✔							
N-Nitrosodiphenylamine [Diphenylnitrosamine]				✔	✔	✔			✔							
N-Nitrosopiperidine					✔											
N-Nitrosopyrrolidine					✔	✔										
Octamethylpyrophosphoramide																
Parathion				✔	✔											
Pentachlorobenzene					✔											
Pentachlorodibenzo-p-dioxins [PeCDDs]				✔												
Pentachlorodibenzofurans [PeCDFs]				✔												
Pentachloronitrobenzene [PCNB] [Quintobenzene] [Quintozene]					✔											
Pentachlorophenol [PCP]	✔			✔	✔	✔			✔							
Perchlorate																
Phenol				✔	✔	✔			✔			✔		✔		
1,3-Phenylenediamine [m-Phenylenediamine]					✔											
Phorate				✔	✔											
Phthalic anhydride																
Polychlorinated biphenyls [Aroclors]	✔			✔	✔	✔			✔							✔
Pronamide																
Propylene oxide [1,2-Epoxypropane]																

(continued)

Table B-28. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
Pyrene				✔	✔	✔			✔			✔				
Pyridine	✔			✔	✔	✔			✔							
Safrole					✔											
Selenium	✔	✔		✔	✔	✔		✔	✔	✔				✔		✔
Silver	✔	✔		✔	✔	✔		✔	✔	✔				✔		
Silvex [2,4,5-Trichlorophenoxypropionic acid]	✔			✔	✔				✔							
Strychnine																
Styrene				✔	✔	✔										
Styrene oxide																
Sulfide				✔	✔	✔			✔			✔				
2,3,7,8-TCDD [2,3,7,8-Tetrachlorodibenzo-p-dioxin]				✔		✔										
1,2,4,5-Tetrachlorobenzene					✔											
Tetrachlorodibenzo-p-dioxins [TCDDs]				✔												
Tetrachlorodibenzofurans [TCDFs]				✔												
1,1,1,2-Tetrachloroethane					✔											
1,1,2,2-Tetrachloroethane				✔	✔	✔			✔							
Tetrachloroethylene [Perchloroethylene]	✔			✔	✔	✔			✔					✔		
2,3,4,6-Tetrachlorophenol				✔	✔	✔										
Tetraethyldithiopyrophosphate [Sulfotepp]				✔												
Thallium				✔	✔	✔		✔	✔					✔		
Thiram [Thiuram]							✔									
Toluene				✔	✔	✔			✔			✔			✔	
2,4-Toluenediamine [2,4-Diaminotoluene]																
o-Toluidine																
p-Toluidine																
Toxaphene [Chlorinated camphene]	✔			✔	✔	✔			✔							
1,1,2-Trichloro-1,2,2-trifluoroethane [Freon 113]					✔	✔										
1,2,4-Trichlorobenzene				✔	✔	✔			✔							
1,1,1-Trichloroethane [Methyl chloroform]				✔	✔	✔			✔					✔		
1,1,2-Trichloroethane [Vinyl trichloride]				✔	✔	✔			✔							
Trichloroethylene [TCE]	✔			✔	✔	✔			✔					✔		
Trichlorofluoromethane [Trichloromonofluoromethane] [CFC-11]				✔	✔	✔			✔							
2,4,5-Trichlorophenol	✔			✔	✔	✔			✔							

(continued)

Table B-28. (continued)

Chemical / Industry Group	Food and kindred products	Textile mill products	Lumber and wood products	Paper and allied products	Chemicals and allied products	Petroleum and coal products	Rubber and miscellaneous plastic products	Stone, clay, and glass products	Primary metal industries	Fabricated metal products	Industrial machinery and equipment	Electronic and other electric equipment	Transportation equipment	Electric, gas, and sanitary services	Wholesale trade, nondurable goods	National security and international affairs
2,4,6-Trichlorophenol	✔			✔	✔	✔			✔							
2,4,5-Trichlorophenoxyacetic acid [2,4,5,-T]				✔					✔							
1,2,3-Trichloropropane					✔											
Triethylamine					✔											
1,3,5-Trinitrobenzene [sym-Trinitrobenzene]					✔											
Tris(2,3-dibromopropyl) phosphate																
Vanadium				✔	✔	✔		✔	✔					✔		✔
Vinyl acetate					✔											
Vinyl chloride [chloroethylene]	✔			✔	✔	✔			✔							
Warfarin																
m-Xylene				✔	✔				✔							
o-Xylene				✔	✔	✔			✔							
p-Xylene				✔	✔				✔							
Xylenes, mixed isomers [Xylenes]				✔	✔	✔										
Zinc	✔	✔		✔	✔	✔	✔	✔	✔	✔		✔	✔	✔		✔

Table B-29. Chemicals Co-occurring in Wastewater by Human Health Effect, Number of Co-occurring Chemicals, and Facility at which they Co-occur.

Cancer

Facilities having 16 chemicals with cancer effects

Facility 068
Arsenic
Benzene
Benzo(a)pyrene
Benzo(b)fluoranthene
Benzo[a]anthracene
Bis(2-ethylhexyl) phthalate [Dioctyl phthalate]
Chloroform [Trichloromethane]
Chrysene
Dibenz[a,h]anthracene
1,4-Dichlorobenzene [p-Dichlorobenzene]
1,2-Dichloroethane [Ethylene dichloride]
1,4-Dioxane [1,4-Diethyleneoxide]
Ethylene dibromide [1,2-Dibromoethane]
Indeno(1,2,3-cd) pyrene
Tetrachloroethylene [Perchloroethylene]
Trichloroethylene [TCE]

Facilities having 12 chemicals with cancer effects

Facility 103
Acetaldehyde [Ethanal]
Arsenic
Chloroform [Trichloromethane]
Chloromethane [Methyl chloride]
Formaldehyde
Methylene chloride [Dichloromethane]
Pentachlorophenol [PCP]
Polychlorinated biphenyls [Aroclors]
2,3,7,8-TCDD [2,3,7,8-Tetrachlorodibenzo-p-dioxin]
Tetrachlorodibenzo-p-dioxins [TCDDs]
Tetrachlorodibenzofurans [TCDFs]
2,4,6-Trichlorophenol

Facility 126
Arsenic
Benzo(a)pyrene
Benzo(b)fluoranthene
Benzo[a]anthracene
Bromodichloromethane [Dichlorobromomethane]
Chloroform [Trichloromethane]
Chrysene
Dibenz[a,h]anthracene
Indeno(1,2,3-cd) pyrene
Methylene chloride [Dichloromethane]
Polychlorinated biphenyls [Aroclors]
Trichloroethylene [TCE]

Facilities having 9 chemicals with cancer effects

Facility 085
Arsenic
Bis(2-ethylhexyl) phthalate [Dioctyl phthalate]
Bromodichloromethane [Dichlorobromomethane]

(continued)

Table B-29. (continued)

Bromoform [Tribromomethane]
Carbon tetrachloride
Chlorodibromomethane [Dibromochloromethane]
Chloroform [Trichloromethane]
Chloromethane [Methyl chloride]
Methylene chloride [Dichloromethane]

Facilities having 8 chemicals with cancer effects

Facility 148
Chlordane, alpha & gamma isomers
1,4-Dichlorobenzene [p-Dichlorobenzene]
2,4-Dinitrotoluene
Heptachlor
Heptachlor epoxide, alpha, beta, and gamma isomers
Lindane [gamma-Hexachlorocyclohexane] [gamma-BHC]
Toxaphene [Chlorinated camphene]
2,4,6-Trichlorophenol

Facilities having 7 chemicals with cancer effects

Facility 104
Benzene
Bis(2-ethylhexyl) phthalate [Dioctyl phthalate]
Chloroform [Trichloromethane]
1,2-Dichloroethane [Ethylene dichloride]
1,2-Dichloropropane [Propylene dichloride]
1,1,2-Trichloroethane [Vinyl trichloride]
Vinyl chloride [chloroethylene]

Facility 174
Arsenic
Benzene
Benzo[a]anthracene
Chrysene
Dibenz[a,h]anthracene
Indeno(1,2,3-cd) pyrene
Methylene chloride [Dichloromethane]

Facilities having 6 chemicals with cancer effects

Facility 021
Acetaldehyde [Ethanal]
Benzene
1,2-Dichloroethane [Ethylene dichloride]
1,4-Dioxane [1,4-Diethyleneoxide]
Ethylene oxide
Formaldehyde

Facility 046
Acrylonitrile
Benzene
Bis(2-chloroethyl) ether [sym-Dichloroethyl ether]
Bis(2-chloroisopropyl) ether [2,2'-Dichloroisopropyl ether]
Bis(2-ethylhexyl) phthalate [Dioctyl phthalate]
1,2-Dichloropropane [Propylene dichloride]

Facility 084
Benzo(a)pyrene
Benzo(b)fluoranthene

(continued)

Table B-29. (continued)

Benzo[a]anthracene
Chrysene
Formaldehyde
Indeno(1,2,3-cd) pyrene

Facility 118
Acetaldehyde [Ethanal]
Arsenic
Chloroform [Trichloromethane]
Formaldehyde
2,3,7,8-TCDD [2,3,7,8-Tetrachlorodibenzo-p-dioxin]
Tetrachlorodibenzofurans [TCDFs]

Facility 134
Chloroform [Trichloromethane]
1,2-Dichloroethane [Ethylene dichloride]
Ethylene oxide
Hexachlorobenzene
Hexachlorodibenzofurans [HxCDFs]
Propylene oxide [1,2-Epoxypropane]

Facility 157
Arsenic
Bromodichloromethane [Dichlorobromomethane]
Chlorodibromomethane [Dibromochloromethane]
Chloroform [Trichloromethane]
Formaldehyde
Methylene chloride [Dichloromethane]

Facilities having 5 chemicals with cancer effects

Facility 002
Benzo(a)pyrene
Bromodichloromethane [Dichlorobromomethane]
Chlorodibromomethane [Dibromochloromethane]
Chloroform [Trichloromethane]
Chrysene

Facility 012
Acrylonitrile
Arsenic
Bromodichloromethane [Dichlorobromomethane]
Bromoform [Tribromomethane]
Chloroform [Trichloromethane]

Facility 038
Acetaldehyde [Ethanal]
Chloroform [Trichloromethane]
Chloromethane [Methyl chloride]
Formaldehyde
2,3,7,8-TCDD [2,3,7,8-Tetrachlorodibenzo-p-dioxin]

Facility 041
Acetaldehyde [Ethanal]
Formaldehyde
Hexachlorodibenzo-p-dioxins [HxCDDs]
Hexachlorodibenzofurans [HxCDFs]
Pentachlorodibenzofurans [PeCDFs]

(continued)

Table B-29. (continued)

Facility 151
Aniline
beta-Hexachlorocyclohexane [beta-BHC]
Chloroform [Trichloromethane]
Heptachlor epoxide, alpha, beta, and gamma isomers
alpha-Hexachlorocyclohexane [alpha-BHC]

Facility 156
Acetaldehyde [Ethanal]
Formaldehyde
2,3,7,8-TCDD [2,3,7,8-Tetrachlorodibenzo-p-dioxin]
Tetrachlorodibenzo-p-dioxins [TCDDs]
Tetrachlorodibenzofurans [TCDFs]

Facility 160
Arsenic
Bromodichloromethane [Dichlorobromomethane]
Chloroform [Trichloromethane]
Methylene chloride [Dichloromethane]
2,4,6-Trichlorophenol

Facilities having 4 chemicals with cancer effects

Facility 035
Benzene
Benzo(a)pyrene
Benzo[a]anthracene
Chrysene

Facility 048
Bromodichloromethane [Dichlorobromomethane]
Bromoform [Tribromomethane]
Chlorodibromomethane [Dibromochloromethane]
Chloroform [Trichloromethane]

Facility 081
Bromoform [Tribromomethane]
Chloroform [Trichloromethane]
1,1-Dichloroethylene [Vinylidene chloride]
Methylene chloride [Dichloromethane]

Facility 115
Benzene
Chloroform [Trichloromethane]
Chloromethane [Methyl chloride]
Methylene chloride [Dichloromethane]

Facility 185
Chloroform [Trichloromethane]
1,2-Dichloroethane [Ethylene dichloride]
Formaldehyde
Methylene chloride [Dichloromethane]

Facilities having 3 chemicals with cancer effects

Facility 022
Acetaldehyde [Ethanal]
Chloroform [Trichloromethane]
Formaldehyde

(continued)

Table B-29. (continued)

Facility 023
Acetaldehyde [Ethanal]
Arsenic
Chloroform [Trichloromethane]

Facility 037
Arsenic
Benzene
Chrysene

Facility 071
Acetaldehyde [Ethanal]
Chloromethane [Methyl chloride]
Tetrachlorodibenzofurans [TCDFs]

Facility 128
Arsenic
Benzene
Bis(2-ethylhexyl) phthalate [Dioctyl phthalate]

Facility 159
Arsenic
Benzene
N-Nitrosodiphenylamine [Diphenylnitrosamine]

Facility 173
Acetaldehyde [Ethanal]
Arsenic
Chloroform [Trichloromethane]

Facilities having 2 chemicals with cancer effects

Facility 006
Chloroform [Trichloromethane]
Tetrachlorodibenzo-p-dioxins [TCDDs]

Facility 007
Arsenic
Benzene

Facility 053
Acetaldehyde [Ethanal]
Formaldehyde

Facility 088
Acetaldehyde [Ethanal]
Chloroform [Trichloromethane]

Facility 091
Aniline
Benzene

Facility 098
Acetaldehyde [Ethanal]
Chloroform [Trichloromethane]

Facility 107
Chloroform [Trichloromethane]
Methylene chloride [Dichloromethane]

(continued)

Table B-29. (continued)

Facility 127
Arsenic
Formaldehyde

Facility 180
Arsenic
Chloroform [Trichloromethane]

Facility 183
Aniline
Chloromethane [Methyl chloride]

Facility 187
Arsenic
Bromoform [Tribromomethane]

Facility 191
Bis(2-ethylhexyl) phthalate [Dioctyl phthalate]
Formaldehyde

Body weight

Facilities having 8 chemicals with body weight effects

Facility 068
m-Cresol [3-Methyl phenol]
o-Cresol [2-Methyl phenol]
Cyanide
1,2-Dichlorobenzene [o-Dichlorobenzene]
Diethyl phthalate [DEP]
Naphthalene
Nickel
Xylenes, mixed isomers [Xylenes]

Facilities having 7 chemicals with body weight effects

Facility 021
o-Cresol [2-Methyl phenol]
Ethyl acetate
Ethyl ether [Diethyl ether]
Formaldehyde
Formic Acid
Naphthalene
Xylenes, mixed isomers [Xylenes]

Facilities having 6 chemicals with body weight effects

Facility 118
Cresols
Cyanide
Formaldehyde
Formic Acid
Nickel
Xylenes, mixed isomers [Xylenes]

Facility 157
Cyanide

(continued)

Table B-29. (continued)

Formaldehyde
Nickel
m-Xylene
o-Xylene
p-Xylene

Facilities having 4 chemicals with body weight effects

Facility 023
Cyanide
Ethyl acetate
Ethyl ether [Diethyl ether]
Formic Acid

Facility 041
Cresols
Formaldehyde
Nickel
Xylenes, mixed isomers [Xylenes]

Facility 091
o-Cresol [2-Methyl phenol]
Naphthalene
Nickel
Xylenes, mixed isomers [Xylenes]

Facility 103
Cresols
Formaldehyde
Naphthalene
Nickel

Facility 105
Cyclohexanone
Naphthalene
Nickel
Vinyl acetate

Facility 137
Cyanide
Formaldehyde
Formic Acid
Nickel

Facility 158
Diethyl phthalate [DEP]
Ethyl acetate
Ethyl ether [Diethyl ether]
Nickel

Facility 179
Cyanide
m-Xylene
o-Xylene
p-Xylene

Facility 185
Cyanide
Formaldehyde
Formic Acid

(continued)

Table B-29. (continued)

Nickel

Facility 191
Cyanide
Formaldehyde
Nickel
Vinyl acetate

Facilities having 3 chemicals with body weight effects

Facility 018
Nickel
o-Xylene
Xylenes, mixed isomers [Xylenes]

Facility 032
Cyanide
Naphthalene
Nickel

Facility 037
Naphthalene
Nickel
Xylenes, mixed isomers [Xylenes]

Facility 104
Cyanide
Diethyl phthalate [DEP]
Naphthalene

Facility 127
Cresols
Formaldehyde
Nickel

Facility 130
m-Cresol [3-Methyl phenol]
o-Cresol [2-Methyl phenol]
Cresols

Facility 159
Cyanide
Nickel
Xylenes, mixed isomers [Xylenes]

Facility 193
Naphthalene
Nickel
Xylenes, mixed isomers [Xylenes]

Facilities having 2 chemicals with body weight effects

Facility 013
Chloroprene [2-Chloro-1,3-butadiene]
Xylenes, mixed isomers [Xylenes]

Facility 022
Formaldehyde
Nickel

(continued)

Table B-29. (continued)

Facility 029
Cyanide
Nickel

Facility 035
Naphthalene
Xylenes, mixed isomers [Xylenes]

Facility 036
Cyanide
Nickel

Facility 045
Cyclohexanone
Nickel

Facility 046
Naphthalene
Nickel

Facility 053
Formaldehyde
Nickel

Facility 058
Formaldehyde
Nickel

Facility 084
Formaldehyde
Nickel

Facility 088
Formic Acid
Nickel

Facility 114
Cyanide
Nickel

Facility 126
Cyanide
Naphthalene

Facility 135
Cyanide
Nickel

Facility 140
Formaldehyde
Nickel

Facility 148
m-Cresol [3-Methyl phenol]
o-Cresol [2-Methyl phenol]

Facility 156
Cresols
Formaldehyde

(continued)

Table B-29. (continued)

Facility 173
Cresols
Naphthalene

Developmental

Facilities having 4 chemicals with developmental effects

Facility 068
Carbon disulfide
Ethyl benzene
Methyl ethyl ketone [2-Butanone][MEK]
Phenol

Facilities having 3 chemicals with developmental effects

Facility 041
Carbon disulfide
Methyl ethyl ketone [2-Butanone][MEK]
Phenol

Facility 103
Carbon disulfide
Methyl ethyl ketone [2-Butanone][MEK]
Phenol

Facility 105
Ethyl benzene
Methyl ethyl ketone [2-Butanone][MEK]
Phenol

Facility 151
Carbon disulfide
Methyl ethyl ketone [2-Butanone][MEK]
Phenol

Facility 156
Carbon disulfide
Methyl ethyl ketone [2-Butanone][MEK]
Phenol

Facility 160
Ethyl benzene
Methyl ethyl ketone [2-Butanone][MEK]
Phenol

Facilities having 2 chemicals with developmental effects

Facility 018
Ethyl benzene
Phenol

Facility 021
Ethyl benzene
Phenol

(continued)

Table B-29. (continued)

Facility 046
Ethyl benzene
Methyl ethyl ketone [2-Butanone][MEK]

Facility 054
Methyl ethyl ketone [2-Butanone][MEK]
Phenol

Facility 071
Methyl ethyl ketone [2-Butanone][MEK]
Phenol

Facility 085
Chloroethane [Ethyl chloride]
Phenol

Facility 086
Methyl ethyl ketone [2-Butanone][MEK]
Phenol

Facility 091
Ethyl benzene
Phenol

Facility 118
Carbon disulfide
Methyl ethyl ketone [2-Butanone][MEK]

Facility 127
Methyl ethyl ketone [2-Butanone][MEK]
Phenol

Facility 159
Ethyl benzene
Phenol

Facility 173
Methyl ethyl ketone [2-Butanone][MEK]
Phenol

Facility 174
Ethyl benzene
Phenol

(continued)

Table B-29. (continued)

Hematological

Facilities having 7 chemicals with hematological effects

Facility 068
Antimony
2,4-Dimethylphenol
Fluoranthene
Fluorene
Mercury
Styrene
Zinc

Facilities having 5 chemicals with hematological effects

Facility 046
Bis(2-chloroisopropyl) ether [2,2'-Dichloroisopropyl ether]
2,6-Dinitrotoluene
Mercury
Styrene
Zinc

Facility 091
Antimony
2,4-Dimethylphenol
Fluorene
Mercury
Zinc

Facilities having 4 chemicals with hematological effects

Facility 104
Fluoranthene
Fluorene
1,1,2-Trichloroethane [Vinyl trichloride]
Zinc

Facility 126
Fluoranthene
Fluorene
Mercury
Zinc

Facility 159
Antimony
Fluoranthene
Mercury
Zinc

Facilities having 3 chemicals with hematological effects

Facility 037
Antimony
Mercury
Zinc

(continued)

Table B-29. (continued)

Facility 118
Antimony
Mercury
Zinc

Facility 160
Antimony
Mercury
Zinc

Facility 174
Fluoranthene
Mercury
Zinc

Facility 180
Antimony
Mercury
Zinc

Facility 187
Antimony
Mercury
Zinc

Facilities having 2 chemicals with hematological effects

Facility 005
Mercury
Zinc

Facility 006
Mercury
Zinc

Facility 012
Mercury
Zinc

Facility 014
Mercury
Zinc

Facility 019
Antimony
Zinc

Facility 021
Ethylene oxide
Styrene

Facility 022
2,4-Dimethylphenol
Zinc

Facility 028
Mercury
Zinc

(continued)

Table B-29. (continued)

Facility 036
Mercury
Zinc

Facility 041
Styrene
Zinc

Facility 044
Mercury
Zinc

Facility 045
Mercury
Zinc

Facility 050
Antimony
Zinc

Facility 080
Mercury
Zinc

Facility 084
Fluoranthene
Zinc

Facility 085
Mercury
Zinc

Facility 088
Mercury
Zinc

Facility 103
Antimony
Zinc

Facility 105
Styrene
Zinc

Facility 114
Fluorene
Zinc

Facility 123
Mercury
Zinc

Facility 128
Mercury
Zinc

Facility 135
Antimony
Zinc

(continued)

Table B-29. (continued)

Facility 148
2,4-D [2,4-Dichlorophenoxyacetic acid]
2,4-Dinitrotoluene

Facility 157
Mercury
Zinc

Facility 164
Mercury
Zinc

Facility 170
Antimony
Zinc

Facility 179
Mercury
Zinc

Facility 183
Styrene
Zinc

Kidney

Facilities having 11 chemicals with kidney effects

Facility 068
Barium
Cadmium
Chlorobenzene
Chloroform [Trichloromethane]
Ethyl benzene
Ethylene glycol
Ethylidene dichloride [1,1-Dichloroethane]
Fluoranthene
Methyl tert-butyl ether [MTBE]
Pyrene
Toluene

Facilities having 8 chemicals with kidney effects

Facility 103
Acetone [2-Propanone]
Barium
Cadmium
Chloroform [Trichloromethane]
Chloromethane [Methyl chloride]
Ethylene glycol
Methyl isobutyl ketone [Hexone] [4-Methyl-2-pentanone] [MIBK]
Pentachlorophenol [PCP]

Facilities having 7 chemicals with kidney effects

Facility 002
Acetone [2-Propanone]

(continued)

Table B-29. (continued)

Barium
Bromodichloromethane [Dichlorobromomethane]
Cadmium
Chloroform [Trichloromethane]
Methyl tert-butyl ether [MTBE]
Pyrene

Facility 021
Acetone [2-Propanone]
Allyl alcohol
Barium
n-Dioctyl phthalate
Ethyl benzene
Ethylene glycol
Toluene

Facility 126
Acetone [2-Propanone]
Barium
Bromodichloromethane [Dichlorobromomethane]
Cadmium
Chloroform [Trichloromethane]
Fluoranthene
Pyrene

Facility 160
Acetone [2-Propanone]
Barium
Bromodichloromethane [Dichlorobromomethane]
Cadmium
Chloroform [Trichloromethane]
Ethyl benzene
Toluene

Facilities having 6 chemicals with kidney effects

Facility 104
Chlorobenzene
Chloroform [Trichloromethane]
Ethyl benzene
Fluoranthene
Pyrene
Toluene

Facility 118
Barium
Cadmium
Chloroform [Trichloromethane]
Ethylene glycol
Methyl isobutyl ketone [Hexone] [4-Methyl-2-pentanone] [MIBK]
2,4,5-Trichlorophenol

Facility 157
Barium
Bromodichloromethane [Dichlorobromomethane]
Cadmium
Chloroform [Trichloromethane]
Ethyl benzene
Toluene

(continued)

Table B-29. (continued)

Facility 159
Barium
Cadmium
Ethyl benzene
Fluoranthene
Pyrene
Toluene

Facilities having 5 chemicals with kidney effects

Facility 012
Acetone [2-Propanone]
Barium
Bromodichloromethane [Dichlorobromomethane]
Cadmium
Chloroform [Trichloromethane]

Facility 023
Acetone [2-Propanone]
Allyl alcohol
Chloroform [Trichloromethane]
Ethylene glycol
Methyl tert-butyl ether [MTBE]

Facility 038
Acetone [2-Propanone]
Barium
Chloroform [Trichloromethane]
Chloromethane [Methyl chloride]
Ethylene glycol

Facility 046
Acetone [2-Propanone]
Barium
2,6-Dinitrotoluene
Ethyl benzene
Toluene

Facility 156
Acetone [2-Propanone]
Barium
Cumene [Isopropyl benzene]
Ethylene glycol
Methyl isobutyl ketone [Hexone] [4-Methyl-2-pentanone] [MIBK]

Facility 174
Barium
Ethyl benzene
Fluoranthene
Pyrene
Toluene

Facility 191
Barium
Cadmium
Epichlorohydrin [1-Chloro-2,3-epoxypropane]
Ethylene glycol
Vinyl acetate

(continued)

Table B-29. (continued)

Facilities having 4 chemicals with kidney effects

Facility 018
Barium
Ethyl benzene
Ethylene glycol
Toluene

Facility 022
Barium
Cadmium
Chloroform [Trichloromethane]
Ethylene glycol

Facility 084
Acetone [2-Propanone]
Barium
Fluoranthene
Pyrene

Facility 085
Bromodichloromethane [Dichlorobromomethane]
Chloroform [Trichloromethane]
Chloromethane [Methyl chloride]
n-Dioctyl phthalate

Facility 091
Barium
Ethyl benzene
Methyl tert-butyl ether [MTBE]
Toluene

Facility 105
Acetone [2-Propanone]
Ethyl benzene
Toluene
Vinyl acetate

Facility 115
Barium
Chloroform [Trichloromethane]
Chloromethane [Methyl chloride]
Ethylidene dichloride [1,1-Dichloroethane]

Facility 173
Barium
Chloroform [Trichloromethane]
Ethylene glycol
Toluene

Facility 180
Acetone [2-Propanone]
Barium
Chloroform [Trichloromethane]
Toluene

Facility 183
Chloromethane [Methyl chloride]
Ethyl benzene
Ethylene glycol

(continued)

Table B-29. (continued)

Toluene

Facilities having 3 chemicals with kidney effects

Facility 006
Barium
Chloroform [Trichloromethane]
Ethylene glycol

Facility 032
Barium
Cadmium
Pyrene

Facility 035
Ethyl benzene
Pyrene
Toluene

Facility 037
Cadmium
Pyrene
Toluene

Facility 041
Barium
Cumene [Isopropyl benzene]
Ethylene glycol

Facility 077
Acetone [2-Propanone]
Cadmium
Toluene

Facility 081
Barium
Chloroform [Trichloromethane]
1,1-Dichloroethylene [Vinylidene chloride]

Facility 148
2,4-D [2,4-Dichlorophenoxyacetic acid]
Lindane [gamma-Hexachlorocyclohexane] [gamma-BHC]
2,4,5-Trichlorophenol

Facility 151
Acetone [2-Propanone]
Barium
Chloroform [Trichloromethane]

Facility 172
Barium
Cadmium
n-Dioctyl phthalate

Facility 193
Barium
Ethyl benzene
Toluene

(continued)

Table B-29. (continued)

Facilities having 2 chemicals with kidney effects

Facility 004
Barium
Cadmium

Facility 005
Barium
Cadmium

Facility 013
Ethyl benzene
Toluene

Facility 014
Barium
Cadmium

Facility 036
Barium
Cadmium

Facility 039
Allyl alcohol
Chloromethane [Methyl chloride]

Facility 040
Barium
Cadmium

Facility 043
Barium
Toluene

Facility 048
Bromodichloromethane [Dichlorobromomethane]
Chloroform [Trichloromethane]

Facility 050
Barium
Cadmium

Facility 053
Acetone [2-Propanone]
Cadmium

Facility 080
Barium
Cadmium

Facility 086
Barium
Cadmium

Facility 088
Barium
Chloroform [Trichloromethane]

Facility 090
Barium

(continued)

Table B-29. (continued)

Cadmium

Facility 116
Barium
Pentachlorophenol [PCP]

Facility 123
Barium
Cadmium

Facility 128
Ethyl benzene
Toluene

Facility 134
Chloroform [Trichloromethane]
Ethylene glycol

Facility 135
Barium
Cadmium

Facility 164
Barium
Cadmium

Facility 167
Acetone [2-Propanone]
Toluene

Facility 176
Barium
Cadmium

Facility 185
Chloroform [Trichloromethane]
Epichlorohydrin [1-Chloro-2,3-epoxypropane]

Liver

Facilities having 14 chemicals with liver effects

Facility 068
Acenaphthene
Bis(2-ethylhexyl) phthalate [Dioctyl phthalate]
Chlorobenzene
Chloroform [Trichloromethane]
1,4-Dichlorobenzene [p-Dichlorobenzene]
N,N-Dimethyl formamide [DMF]
Ethyl benzene
Fluoranthene
Methanol [methyl alcohol]
Methyl tert-butyl ether [MTBE]
Pyridine
Styrene
Tetrachloroethylene [Perchloroethylene]
Toluene

(continued)

Table B-29. (continued)

Facilities having 11 chemicals with liver effects

Facility 104
Acenaphthene
Bis(2-ethylhexyl) phthalate [Dioctyl phthalate]
Chlorobenzene
Chloroform [Trichloromethane]
1,2-Dichloropropane [Propylene dichloride]
Ethyl benzene
Fluoranthene
Toluene
1,2,4-Trichlorobenzene
1,1,2-Trichloroethane [Vinyl trichloride]
Vinyl chloride [chloroethylene]

Facility 148
Chlordane, alpha & gamma isomers
2,4-D [2,4-Dichlorophenoxyacetic acid]
1,4-Dichlorobenzene [p-Dichlorobenzene]
2,4-Dinitrotoluene
Endrin
Heptachlor
Heptachlor epoxide, alpha, beta, and gamma isomers
Lindane [gamma-Hexachlorocyclohexane] [gamma-BHC]
Silvex [2,4,5-Trichlorophenoxypropionic acid]
Toxaphene [Chlorinated camphene]
2,4,5-Trichlorophenol

Facilities having 10 chemicals with liver effects

Facility 046
Acetone [2-Propanone]
Bis(2-chloroethyl) ether [sym-Dichloroethyl ether]
Bis(2-chloroisopropyl) ether [2,2'-Dichloroisopropyl ether]
Bis(2-ethylhexyl) phthalate [Dioctyl phthalate]
1,2-Dichloropropane [Propylene dichloride]
2,6-Dinitrotoluene
Ethyl benzene
Methanol [methyl alcohol]
Styrene
Toluene

Facility 103
Acetone [2-Propanone]
Chloroform [Trichloromethane]
Methanol [methyl alcohol]
Methyl isobutyl ketone [Hexone] [4-Methyl-2-pentanone] [MIBK]
Methylene chloride [Dichloromethane]
Pentachlorophenol [PCP]
Polychlorinated biphenyls [Aroclors]
2,3,7,8-TCDD [2,3,7,8-Tetrachlorodibenzo-p-dioxin]
2,3,4,6-Tetrachlorophenol
Thallium

Facilities having 8 chemicals with liver effects

Facility 021
Acetone [2-Propanone]
Allyl alcohol
n-Dioctyl phthalate

(continued)

Table B-29. (continued)

Ethyl benzene
Methanol [methyl alcohol]
Pyridine
Styrene
Toluene

Facility 085
Bis(2-ethylhexyl) phthalate [Dioctyl phthalate]
Bromodichloromethane [Dichlorobromomethane]
Bromoform [Tribromomethane]
Carbon tetrachloride
Chlorodibromomethane [Dibromochloromethane]
Chloroform [Trichloromethane]
n-Dioctyl phthalate
Methylene chloride [Dichloromethane]

Facilities having 7 chemicals with liver effects

Facility 023
Acetone [2-Propanone]
Allyl alcohol
Chloroform [Trichloromethane]
N,N-Dimethyl formamide [DMF]
Methanol [methyl alcohol]
Methyl tert-butyl ether [MTBE]
Pyridine

Facility 126
Acenaphthene
Acetone [2-Propanone]
Bromodichloromethane [Dichlorobromomethane]
Chloroform [Trichloromethane]
Fluoranthene
Methylene chloride [Dichloromethane]
Polychlorinated biphenyls [Aroclors]

Facilities having 6 chemicals with liver effects

Facility 105
Acenaphthene
Acetone [2-Propanone]
Ethyl benzene
Methanol [methyl alcohol]
Styrene
Toluene

Facility 118
Chloroform [Trichloromethane]
Methanol [methyl alcohol]
Methyl isobutyl ketone [Hexone] [4-Methyl-2-pentanone] [MIBK]
2,3,7,8-TCDD [2,3,7,8-Tetrachlorodibenzo-p-dioxin]
Thallium
2,4,5-Trichlorophenol

(continued)

Table B-29. (continued)

Facility 157
Bromodichloromethane [Dichlorobromomethane]
Chlorodibromomethane [Dibromochloromethane]
Chloroform [Trichloromethane]
Ethyl benzene
Methylene chloride [Dichloromethane]
Toluene

Facility 160
Acetone [2-Propanone]
Bromodichloromethane [Dichlorobromomethane]
Chloroform [Trichloromethane]
Ethyl benzene
Methylene chloride [Dichloromethane]
Toluene

Facilities having 5 chemicals with liver effects

Facility 002
Acetone [2-Propanone]
Bromodichloromethane [Dichlorobromomethane]
Chlorodibromomethane [Dibromochloromethane]
Chloroform [Trichloromethane]
Methyl tert-butyl ether [MTBE]

Facility 151
Acetone [2-Propanone]
beta-Hexachlorocyclohexane [beta-BHC]
Chloroform [Trichloromethane]
Heptachlor epoxide, alpha, beta, and gamma isomers
alpha-Hexachlorocyclohexane [alpha-BHC]

Facilities having 4 chemicals with liver effects

Facility 012
Acetone [2-Propanone]
Bromodichloromethane [Dichlorobromomethane]
Bromoform [Tribromomethane]
Chloroform [Trichloromethane]

Facility 038
Acetone [2-Propanone]
Chloroform [Trichloromethane]
Methanol [methyl alcohol]
2,3,7,8-TCDD [2,3,7,8-Tetrachlorodibenzo-p-dioxin]

Facility 048
Bromodichloromethane [Dichlorobromomethane]
Bromoform [Tribromomethane]
Chlorodibromomethane [Dibromochloromethane]
Chloroform [Trichloromethane]

Facility 081
Bromoform [Tribromomethane]
Chloroform [Trichloromethane]
1,1-Dichloroethylene [Vinylidene chloride]
Methylene chloride [Dichloromethane]

Facility 091
Acenaphthene

(continued)

Table B-29. (continued)

Ethyl benzene
Methyl tert-butyl ether [MTBE]
Toluene

Facility 156
Acetone [2-Propanone]
Methanol [methyl alcohol]
Methyl isobutyl ketone [Hexone] [4-Methyl-2-pentanone] [MIBK]
2,3,7,8-TCDD [2,3,7,8-Tetrachlorodibenzo-p-dioxin]

Facility 159
Ethyl benzene
Fluoranthene
Thallium
Toluene

Facility 174
Ethyl benzene
Fluoranthene
Methylene chloride [Dichloromethane]
Toluene

Facility 183
Ethyl benzene
Methanol [methyl alcohol]
Styrene
Toluene

Facilities having 3 chemicals with liver effects

Facility 022
Chloroform [Trichloromethane]
Furfural
Methanol [methyl alcohol]

Facility 035
Acenaphthene
Ethyl benzene
Toluene

Facility 077
Acetone [2-Propanone]
Methanol [methyl alcohol]
Toluene

Facility 084
Acetone [2-Propanone]
Fluoranthene
Methanol [methyl alcohol]

Facility 128
Bis(2-ethylhexyl) phthalate [Dioctyl phthalate]
Ethyl benzene
Toluene

Facility 167
Acetone [2-Propanone]
Toluene
1,2,4-Trichlorobenzene

(continued)

Table B-29. (continued)

Facility 172
Bis(2-ethylhexyl) phthalate [Dioctyl phthalate]
n-Dioctyl phthalate
Ethylene thiourea

Facility 173
Chloroform [Trichloromethane]
Methanol [methyl alcohol]
Toluene

Facility 180
Acetone [2-Propanone]
Chloroform [Trichloromethane]
Toluene

Facility 185
Chloroform [Trichloromethane]
Methanol [methyl alcohol]
Methylene chloride [Dichloromethane]

Facilities having 2 chemicals with liver effects

Facility 006
Chloroform [Trichloromethane]
Methanol [methyl alcohol]

Facility 013
Ethyl benzene
Toluene

Facility 018
Ethyl benzene
Toluene

Facility 039
Allyl alcohol
Methanol [methyl alcohol]

Facility 041
Methanol [methyl alcohol]
Styrene

Facility 053
Acetone [2-Propanone]
Methanol [methyl alcohol]

Facility 088
Chloroform [Trichloromethane]
Methanol [methyl alcohol]

Facility 098
Chloroform [Trichloromethane]
Methanol [methyl alcohol]

Facility 107
Chloroform [Trichloromethane]
Methylene chloride [Dichloromethane]

Facility 115
Chloroform [Trichloromethane]

(continued)

Table B-29. (continued)

Methylene chloride [Dichloromethane]

Facility 134
Chloroform [Trichloromethane]
Hexachlorobenzene

Facility 137
Acetone [2-Propanone]
Methanol [methyl alcohol]

Facility 158
Methanol [methyl alcohol]
Toluene

Facility 191
Bis(2-ethylhexyl) phthalate [Dioctyl phthalate]
Methanol [methyl alcohol]

Facility 193
Ethyl benzene
Toluene

Lung

Facilities having 4 chemicals with lung effects

Facility 080
Arsenic
Beryllium
Cadmium
Chromium VI [Hexavalent Chromium]

Facility 135
Arsenic
Beryllium
Cadmium
Chromium VI [Hexavalent Chromium]

Facilities having 3 chemicals with lung effects

Facility 012
Arsenic
Beryllium
Cadmium

Facility 014
Arsenic
Cadmium
Chromium VI [Hexavalent Chromium]

Facility 029
Beryllium
Cadmium
Chromium VI [Hexavalent Chromium]

Facility 036
Arsenic

(continued)

Table B-29. (continued)

Beryllium
Cadmium

Facility 068
Arsenic
Beryllium
Cadmium

Facility 103
Arsenic
Beryllium
Cadmium

Facility 118
Arsenic
Beryllium
Cadmium

Facility 160
Arsenic
Beryllium
Cadmium

Facilities having 2 chemicals with lung effects

Facility 004
Arsenic
Cadmium

Facility 007
Arsenic
Cadmium

Facility 037
Arsenic
Cadmium

Facility 040
Arsenic
Cadmium

Facility 044
Arsenic
Cadmium

Facility 046
Bis(2-chloroisopropyl) ether [2,2'-Dichloroisopropyl ether]
Chromium VI [Hexavalent Chromium]

Facility 050
Beryllium
Cadmium

Facility 067
Arsenic
Cadmium

Facility 085
Arsenic
Chromium VI [Hexavalent Chromium]

(continued)

Table B-29. (continued)

Facility 086
Cadmium
Chromium VI [Hexavalent Chromium]

Facility 126
Arsenic
Cadmium

Facility 157
Arsenic
Cadmium

Facility 159
Arsenic
Cadmium

Facility 174
Arsenic
Beryllium

Facility 176
Arsenic
Cadmium

Facility 182
Arsenic
Cadmium

Neurological

Facilities having 11 chemicals with neurological effects

Facility 068
Carbon disulfide
m-Cresol [3-Methyl phenol]
o-Cresol [2-Methyl phenol]
p-Cresol [4-Methyl phenol]
Cyanide
2,4-Dimethylphenol
Mercury
Methanol [methyl alcohol]
Styrene
Toluene
Xylenes, mixed isomers [Xylenes]

Facilities having 8 chemicals with neurological effects

Facility 118
Carbon disulfide
Cresols
Cyanide
Manganese
Mercury
Methanol [methyl alcohol]
Methyl isobutyl ketone [Hexone] [4-Methyl-2-pentanone] [MIBK]
Xylenes, mixed isomers [Xylenes]

(continued)

Table B-29. (continued)

Facilities having 7 chemicals with neurological effects

Facility 021
n-Butyl alcohol [n-Butanol]
o-Cresol [2-Methyl phenol]
p-Cresol [4-Methyl phenol]
Methanol [methyl alcohol]
Styrene
Toluene
Xylenes, mixed isomers [Xylenes]

Facility 041
Carbon disulfide
Cresols
n-Hexane
Manganese
Methanol [methyl alcohol]
Styrene
Xylenes, mixed isomers [Xylenes]

Facility 157
Cyanide
Manganese
Mercury
Toluene
m-Xylene
o-Xylene
p-Xylene

Facilities having 6 chemicals with neurological effects

Facility 046
2,6-Dinitrotoluene
Manganese
Mercury
Methanol [methyl alcohol]
Styrene
Toluene

Facility 091
o-Cresol [2-Methyl phenol]
p-Cresol [4-Methyl phenol]
2,4-Dimethylphenol
Mercury
Toluene
Xylenes, mixed isomers [Xylenes]

Facility 156
Carbon disulfide
Cresols
n-Hexane
Manganese
Methanol [methyl alcohol]
Methyl isobutyl ketone [Hexone] [4-Methyl-2-pentanone] [MIBK]

Facility 179
n-Butyl alcohol [n-Butanol]
Cyanide
Mercury
m-Xylene

(continued)

Table B-29. (continued)

o-Xylene
p-Xylene

Facilities having 5 chemicals with neurological effects

Facility 103
Carbon disulfide
Cresols
Manganese
Methanol [methyl alcohol]
Methyl isobutyl ketone [Hexone] [4-Methyl-2-pentanone] [MIBK]

Facility 130
m-Cresol [3-Methyl phenol]
o-Cresol [2-Methyl phenol]
p-Cresol [4-Methyl phenol]
Cresols
Mercury

Facility 148
m-Cresol [3-Methyl phenol]
o-Cresol [2-Methyl phenol]
p-Cresol [4-Methyl phenol]
2,4-Dinitrotoluene
Endrin

Facilities having 4 chemicals with neurological effects

Facility 018
Manganese
Toluene
o-Xylene
Xylenes, mixed isomers [Xylenes]

Facility 105
n-Butyl alcohol [n-Butanol]
Methanol [methyl alcohol]
Styrene
Toluene

Facility 137
n-Butyl alcohol [n-Butanol]
Cyanide
Isobutyl alcohol [Isobutanol]
Methanol [methyl alcohol]

Facility 159
Cyanide
Mercury
Toluene
Xylenes, mixed isomers [Xylenes]

Facility 173
Cresols
Manganese
Methanol [methyl alcohol]
Toluene

Facility 174
Manganese

(continued)

Table B-29. (continued)

Mercury
Toluene
Xylenes, mixed isomers [Xylenes]

Facility 180
Carbon disulfide
Manganese
Mercury
Toluene

Facility 183
Methanol [methyl alcohol]
Styrene
Toluene
Xylenes, mixed isomers [Xylenes]

Facilities having 3 chemicals with neurological effects

Facility 022
2,4-Dimethylphenol
Manganese
Methanol [methyl alcohol]

Facility 036
Cyanide
Manganese
Mercury

Facility 037
Mercury
Toluene
Xylenes, mixed isomers [Xylenes]

Facility 043
p-Cresol [4-Methyl phenol]
Manganese
Toluene

Facility 077
Manganese
Methanol [methyl alcohol]
Toluene

Facility 088
Manganese
Mercury
Methanol [methyl alcohol]

Facility 126
Cyanide
Manganese
Mercury

Facility 127
Cresols
Manganese
Methanol [methyl alcohol]

Facility 128
Mercury

(continued)

Table B-29. (continued)

Toluene
Xylenes, mixed isomers [Xylenes]

Facility 158
n-Butyl alcohol [n-Butanol]
Methanol [methyl alcohol]
Toluene

Facilities having 2 chemicals with neurological effects

Facility 005
Manganese
Mercury

Facility 006
Mercury
Methanol [methyl alcohol]

Facility 013
Toluene
Xylenes, mixed isomers [Xylenes]

Facility 023
Cyanide
Methanol [methyl alcohol]

Facility 032
Cyanide
Manganese

Facility 035
Toluene
Xylenes, mixed isomers [Xylenes]

Facility 038
Manganese
Methanol [methyl alcohol]

Facility 039
Allyl chloride
Methanol [methyl alcohol]

Facility 053
Manganese
Methanol [methyl alcohol]

Facility 080
Manganese
Mercury

Facility 084
Manganese
Methanol [methyl alcohol]

Facility 089
Cyanide
Manganese

(continued)

Table B-29. (continued)

Facility 090
Cyanide
Manganese

Facility 104
Cyanide
Toluene

Facility 119
Cyanide
Manganese

Facility 123
Manganese
Mercury

Facility 135
Cyanide
Manganese

Facility 151
Carbon disulfide
Cresols

Facility 160
Mercury
Toluene

Facility 164
Manganese
Mercury

Facility 185
Cyanide
Methanol [methyl alcohol]

Facility 187
Manganese
Mercury

Facility 189
Toluene
Xylenes, mixed isomers [Xylenes]

Facility 191
Cyanide
Methanol [methyl alcohol]

Facility 193
Toluene
Xylenes, mixed isomers [Xylenes]

(continued)

Table B-29. (continued)

Organ weight

Facilities having 2 chemicals with organ weight effects

Facility 068
Diethyl phthalate [DEP]
Nickel

Facility 158
Diethyl phthalate [DEP]
Nickel

Reproductive

Facilities having 2 chemicals with reproductive effects

Facility 012
Acrylonitrile
Barium

Facility 021
Acrylic acid [propenoic acid]
Barium

Facility 041
Barium
n-Hexane

Facility 046
Acrylonitrile
Barium

Facility 068
Barium
Ethylene dibromide [1,2-Dibromoethane]

Facility 103
Barium
2-Chlorophenol [o-Chlorophenol]

Facility 151
Barium
Methoxychlor

Facility 156
Barium
n-Hexane

Facility 160
Barium
2-Chlorophenol [o-Chlorophenol]

(continued)

Table B-29. (continued)

Respiratory

Facilities having 5 chemicals with respiratory effects

Facility 021
Acetaldehyde [Ethanal]
Acrylic acid [propenoic acid]
p-Cresol [4-Methyl phenol]
Naphthalene
Toluene

Facility 068
Beryllium
p-Cresol [4-Methyl phenol]
Naphthalene
Selenium
Toluene

Facility 091
Beryllium
p-Cresol [4-Methyl phenol]
Naphthalene
Selenium
Toluene

Facility 103
Acetaldehyde [Ethanal]
Beryllium
Naphthalene
Selenium
2,3,7,8-TCDD [2,3,7,8-Tetrachlorodibenzo-p-dioxin]

Facilities having 4 chemicals with respiratory effects

Facility 012
Acrolein [2-propenal]
Acrylonitrile
Beryllium
Selenium

Facility 046
Acrylonitrile
1,2-Dichloropropane [Propylene dichloride]
Naphthalene
Toluene

Facility 105
Acrylic acid [propenoic acid]
Naphthalene
Toluene
Vinyl acetate

Facility 118
Acetaldehyde [Ethanal]
Beryllium
Selenium
2,3,7,8-TCDD [2,3,7,8-Tetrachlorodibenzo-p-dioxin]

(continued)

Table B-29. (continued)

Facilities having 3 chemicals with respiratory effects

Facility 023
Acetaldehyde [Ethanal]
Selenium
Triethylamine

Facility 037
Naphthalene
Selenium
Toluene

Facility 104
1,2-Dichloropropane [Propylene dichloride]
Naphthalene
Toluene

Facility 156
Acetaldehyde [Ethanal]
n-Hexane
2,3,7,8-TCDD [2,3,7,8-Tetrachlorodibenzo-p-dioxin]

Facility 173
Acetaldehyde [Ethanal]
Naphthalene
Toluene

Facility 174
Beryllium
Selenium
Toluene

Facilities having 2 chemicals with respiratory effects

Facility 013
Chloroprene [2-Chloro-1,3-butadiene]
Toluene

Facility 022
Acetaldehyde [Ethanal]
Furfural

Facility 035
Naphthalene
Toluene

Facility 038
Acetaldehyde [Ethanal]
2,3,7,8-TCDD [2,3,7,8-Tetrachlorodibenzo-p-dioxin]

Facility 041
Acetaldehyde [Ethanal]
n-Hexane

Facility 043
p-Cresol [4-Methyl phenol]
Toluene

Facility 085
Bromomethane [Methyl bromide]

(continued)

Table B-29. (continued)

Selenium

Facility 088
Acetaldehyde [Ethanal]
Selenium

Facility 130
p-Cresol [4-Methyl phenol]
Selenium

Facility 134
Acrylic acid [propenoic acid]
Propylene oxide [1,2-Epoxypropane]

Facility 135
Beryllium
Selenium

Facility 137
Acrylic acid [propenoic acid]
Methyl methacrylate

Facility 159
Selenium
Toluene

Facility 160
Beryllium
Toluene

Facility 185
Acrolein [2-propenal]
Epichlorohydrin [1-Chloro-2,3-epoxypropane]

Facility 191
Epichlorohydrin [1-Chloro-2,3-epoxypropane]
Vinyl acetate

Facility 193
Naphthalene
Toluene

Skin

Facilities having 2 chemicals with skin effects

Facility 004
Arsenic
Silver

Facility 012
Arsenic
Silver

Facility 014
Arsenic
Silver

(continued)

Table B-29. (continued)

Facility 037
Arsenic
Silver

Facility 068
Arsenic
Silver

Facility 103
Arsenic
Silver

Facility 118
Arsenic
Silver

Facility 157
Arsenic
Silver

Facility 159
Arsenic
Silver

Facility 160
Arsenic
Silver

Vascular

Facilities having 2 chemicals with vascular effects

Facility 134
1,2-Dichloroethane [Ethylene dichloride]
Propylene oxide [1,2-Epoxypropane]

Table B-30. Facility-Level Co-occurance of Chemicals in Wastewater by Human Health Effect (Survey Database)

Target Health Effect [a]	Estimated Number of Facilities with Co-occurrences [b] in Wastewater [c]				
	Number of Chemicals Co-occurring Within/Across Impoundments [d]				All Facilities with 2 or More Co-occurrences
	2-3	4-6	7-10	11-20	
Cancer	621 (254)	328 (105)	390* (263)	30* (33)	1,369 (328)
Adrenal	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Bladder	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Body weight	984 (414)	193 (83)	13* (22)	0 (0)	1,191 (405)
Brain	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Cardiovascular	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Death	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Developmental	635 (220)	11* (21)	0 (0)	0 (0)	646 (220)
Eyes	13* (22)	0 (0)	0 (0)	0 (0)	13* (22)
Forestomach	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Gastrointestinal	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
General	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Hematological	1,246 (289)	76* (53)	11* (20)	0 (0)	1,334 (291)
Kidney	1,099 (379)	799 (220)	111* (67)	11* (20)	2,020 (412)
Leukemia	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Liver	972 (390)	339 (107)	212* (171)	221* (200)	1,743 (417)
Lung	766 (260)	64* (49)	0 (0)	0 (0)	830 (263)
Mammary	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Nasal cavity	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Neurological	873 (329)	696 (285)	73* (55)	10* (19)	1,653 (414)
Organ weight	13* (22)	0 (0)	0 (0)	0 (0)	13* (22)
Reproductive	123* (68)	0 (0)	0 (0)	0 (0)	123* (68)
Respiratory	832 (364)	131* (69)	0 (0)	0 (0)	962 (369)
Respiratory tract	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Skin	238 (96)	0 (0)	0 (0)	0 (0)	238 (96)
Spleen	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Stomach	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Thyroid	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Vascular	6* (15)	0 (0)	0 (0)	0 (0)	6* (15)

[a] For noncarcinogenic chemicals, target organ on which health benchmark (e.g., RfD) is based. Cancer or leukemia for carcinogenic chemicals. See Appendix C for discussion of health benchmarks.

[b] A facility-level co-occurrence is defined as when two or more chemicals with a common target health effect occur within or across impoundments at a single facility.

[c] Estimate for population of facilities with surface impoundments having constituents or pH of concern. Value in parentheses is standard error. Asterisk (*) indicates estimates that may not be reliable because of a large relative standard error (see Appendix A.5 for a discussion of standard error estimates).

[d] Lists of the co-occurring chemicals at each facility in the sample are provided in Appendix B.

Table B-31. Facility-Level Co-occurance of Chemicals in Sludge by Human Health Effect (Survey Database)

Target Health Effect [a]	Estimated Number of Facilities with Co-occurrences [b] in Sludge [c]				
	Number of Chemicals Co-occurring Within/Across Impoundments [d]				All Facilities with 2 or More Co-occurrences
	2-3	4-6	7-10	11-20	
Cancer	595 (220)	107* (64)	126* (69)	155* (136)	983 (245)
Adrenal	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Bladder	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Body weight	539 (186)	93* (60)	11* (20)	0 (0)	642 (180)
Brain	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Cardiovascular	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Death	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Developmental	314 (145)	10* (20)	0 (0)	0 (0)	324 (145)
Eyes	11* (21)	0 (0)	0 (0)	0 (0)	11* (21)
Forestomach	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Gastrointestinal	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
General	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Hematological	553 (170)	230* (140)	20* (28)	0 (0)	803 (198)
Kidney	737 (217)	424 (181)	71* (53)	10* (20)	1,242 (248)
Leukemia	54* (54)	0 (0)	0 (0)	0 (0)	54* (54)
Liver	475 (187)	72* (53)	82* (56)	147* (137)	776 (193)
Lung	1,064 (246)	51* (44)	0 (0)	0 (0)	1,116 (248)
Mammary	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Nasal cavity	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Neurological	530 (163)	210* (138)	189* (138)	10* (20)	939 (200)
Organ weight	11* (21)	0 (0)	0 (0)	0 (0)	11* (21)
Reproductive	221* (140)	0 (0)	0 (0)	0 (0)	221* (140)
Respiratory	444 (150)	234* (139)	0 (0)	0 (0)	678 (181)
Respiratory tract	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Skin	324 (109)	0 (0)	0 (0)	0 (0)	324 (109)
Spleen	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Stomach	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Thyroid	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Vascular	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Cancer	595 (220)	107* (64)	126* (69)	155* (136)	0 (0)
Adrenal	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Bladder	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

(continued)

Table B-31. (continued)

Target Health Effect [a]	Estimated Number of Facilities with Co-occurrences [b] in Sludge [c]				
	Number of Chemicals Co-occurring Within/Across Impoundments [d]				All Facilities with 2 or More Co-occurrences
	2-3	4-6	7-10	11-20	
Body weight	539 (186)	93* (60)	11* (20)	0 (0)	0 (0)
Brain	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Cardiovascular	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Death	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Developmental	314 (145)	10* (20)	0 (0)	0 (0)	0 (0)
Eyes	11* (21)	0 (0)	0 (0)	0 (0)	0 (0)
Forestomach	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Gastrointestinal	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
General	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Hematological	553 (170)	230* (140)	20* (28)	0 (0)	0 (0)
Kidney	737 (217)	424 (181)	71* (53)	10* (20)	0 (0)
Leukemia	54* (54)	0 (0)	0 (0)	0 (0)	0 (0)
Liver	475 (187)	72* (53)	82* (56)	147* (137)	0 (0)
Lung	1,064 (246)	51* (44)	0 (0)	0 (0)	0 (0)
Mammary	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Nasal cavity	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Neurological	530 (163)	210* (138)	189* (138)	10* (20)	0 (0)
Organ weight	11* (21)	0 (0)	0 (0)	0 (0)	0 (0)
Reproductive	221* (140)	0 (0)	0 (0)	0 (0)	0 (0)
Respiratory	444 (150)	234* (139)	0 (0)	0 (0)	0 (0)
Respiratory tract	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Skin	324 (109)	0 (0)	0 (0)	0 (0)	0 (0)
Spleen	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Stomach	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Thyroid	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Vascular	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

[a] For noncarcinogenic chemicals, target organ on which health benchmark (e.g., RfD) is based. Cancer or leukemia for carcinogenic chemicals. See Appendix C for discussion of health benchmarks.
[b] A facility-level co-occurrence is defined as when two or more chemicals with a common target health effect occur within or across impoundments at a single facility.
[c] Estimate for population of facilities with surface impoundments having constituents or pH of concern. Value in parentheses is standard error. Asterisk (*) indicates estimates that may not be reliable because of a large relative standard error (see Appendix A.5 for a discussion of standard error estimates).
[d] Lists of the co-occurring chemicals at each facility in the sample are provided in Appendix B.

Table B-32. Impoundment-Level Co-occurance of Chemicals in Wastewater by Human Health Effect (Survey Database)

Target Health Effect [a]	Estimated Number of Impoundments with Co-occurrences [b] in Wastewater [c]				
	Number of Chemicals Co-occurring Within/Across Impoundments				All Impoundments with 2 or More Co-occurrences
	2-3	4-6	7-10	11-20	
Cancer	1,230 (237)	670 (129)	536* (273)	25* (26)	2,461 (478)
Adrenal	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Bladder	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Body weight	2,061 (302)	573 (120)	11* (17)	0 (0)	2,646 (324)
Brain	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Cardiovascular	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Death	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Developmental	1,577 (363)	9* (15)	0 (0)	0 (0)	1,586 (363)
Eyes	9* (15)	0 (0)	0 (0)	0 (0)	9* (15)
Forestomach	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Gastrointestinal	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
General	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Hematological	3,326 (658)	121 (56)	9* (15)	0 (0)	3,456 (662)
Kidney	2,749 (333)	2,043 (348)	72* (47)	9* (15)	4,873 (531)
Leukemia	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Liver	2,942 (282)	574 (120)	384* (206)	205* (180)	4,105 (427)
Lung	1,636 (325)	169 (67)	0 (0)	0 (0)	1,805 (329)
Mammary	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Nasal cavity	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Neurological	3,616 (258)	737 (302)	452 (107)	9* (15)	4,814 (411)
Organ weight	9* (15)	0 (0)	0 (0)	0 (0)	9* (15)
Reproductive	183 (69)	0 (0)	0 (0)	0 (0)	183 (69)
Respiratory	2,003 (272)	231 (78)	0 (0)	0 (0)	2,235 (285)
Respiratory tract	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Skin	485 (111)	0 (0)	0 (0)	0 (0)	485 (111)
Spleen	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Stomach	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Thyroid	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Vascular	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Cancer	1,230 (237)	670 (129)	536* (273)	25* (26)	0 (0)
Adrenal	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Bladder	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

(continued)

Table B-32. (continued)

Target Health Effect [a]	Estimated Number of Facilities with Co-occurrences [b] in Sludge [c]				
	Number of Chemicals Co-occurring Within/Across Impoundments [d]				All Facilities with 2 or More Co-occurrences
	2-3	4-6	7-10	11-20	
Body weight	2,061 (302)	573 (120)	11* (17)	0 (0)	0 (0)
Brain	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Cardiovascular	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Death	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Developmental	1,577 (363)	9* (15)	0 (0)	0 (0)	0 (0)
Eyes	9* (15)	0 (0)	0 (0)	0 (0)	0 (0)
Forestomach	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Gastrointestinal	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
General	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Hematological	3,326 (658)	121 (56)	9* (15)	0 (0)	0 (0)
Kidney	2,749 (333)	2,043 (348)	72* (47)	9* (15)	0 (0)
Leukemia	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Liver	2,942 (282)	574 (120)	384* (206)	205* (180)	0 (0)
Lung	1,636 (325)	169 (67)	0 (0)	0 (0)	0 (0)
Mammary	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Nasal cavity	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Neurological	3,616 (258)	737 (302)	452 (107)	9* (15)	0 (0)
Organ weight	9* (15)	0 (0)	0 (0)	0 (0)	0 (0)
Reproductive	183 (69)	0 (0)	0 (0)	0 (0)	0 (0)
Respiratory	2,003 (272)	231 (78)	0 (0)	0 (0)	0 (0)
Respiratory tract	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Skin	485 (111)	0 (0)	0 (0)	0 (0)	0 (0)
Spleen	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Stomach	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Thyroid	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Vascular	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

[a] For noncarcinogenic chemicals, target organ on which health benchmark (e.g., RfD) is based. Cancer or leukemia for carcinogenic chemicals. See Appendix C for discussion of health benchmarks.
[b] An impoundment-level co-occurrence is defined as when two or more chemicals with a common target health effect occur within or across a single impoundment.
[c] Estimate for population of impoundments having constituents or pH of concern. Value in parentheses is standard error. Asterisk (*) indicates estimates that may not be reliable because of a large relative standard error (see Appendix A.5 for a discussion of standard error estimates).

Table B-33. Impoundment-Level Co-occurance of Chemicals in Sludge by Human Health Effect (Survey Data)

Target Health Effect [a]	Estimated Number of Impoundments with Co-occurrences [b] in Sludge [c]				
	Number of Chemicals Co-occurring Within/Across Impoundments				All Impoundments with 2 or More Co-occurrences
	2-3	4-6	7-10	11-20	
Cancer	843 (250)	247 (83)	130 (60)	304* (168)	1,526 (348)
Adrenal	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Bladder	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Body weight	978 (356)	123 (59)	45* (36)	0 (0)	1,146 (390)
Brain	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Cardiovascular	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Death	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Developmental	571 (213)	45* (36)	0 (0)	0 (0)	616 (213)
Eyes	45* (36)	0 (0)	0 (0)	0 (0)	45* (36)
Forestomach	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Gastrointestinal	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
General	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Hematological	1,254 (178)	420 (204)	45* (36)	0 (0)	1,718 (273)
Kidney	1,966 (397)	1,033 (215)	81* (48)	45* (36)	3,125 (550)
Leukemia	46* (46)	0 (0)	0 (0)	0 (0)	46* (46)
Liver	1,054 (226)	124 (59)	106* (54)	296* (168)	1,580 (324)
Lung	1,969 (450)	139 (62)	0 (0)	0 (0)	2,108 (451)
Mammary	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Nasal cavity	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Neurological	1,546 (258)	380 (172)	297* (201)	45* (36)	2,268 (388)
Organ weight	45* (36)	0 (0)	0 (0)	0 (0)	45* (36)
Reproductive	378* (202)	0 (0)	0 (0)	0 (0)	378* (202)
Respiratory	666 (155)	381* (202)	0 (0)	0 (0)	1,047 (261)
Respiratory tract	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Skin	678 (134)	0 (0)	0 (0)	0 (0)	678 (134)
Spleen	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Stomach	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Thyroid	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Vascular	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

[a] For noncarcinogenic chemicals, target organ on which health benchmark (e.g., RfD) is based. Cancer or leukemia for carcinogenic chemicals. See Appendix C for discussion of health benchmarks.

[b] An impoundment-level co-occurrence is defined as when two or more chemicals with a common target health effect occur within or across a single impoundment.

[c] Estimate for population of impoundments having constituents or pH of concern. Value in parentheses is standard error. Asterisk (*) indicates estimates that may not be reliable because of a large relative standard error (see Appendix A.5 for a discussion of standard error estimates).

Table B-34. Facility-Level Co-occurance of Chemicals in Wastewater by Human Health Effect (Risk Input Database)

Target Health Effect [a]	Estimated Number of Facilities with Co-occurrences [b] in Wastewater [c]					
	Number of Chemicals Co-occurring Within/Across Impoundments [d]					All Facilities with 2 or More Co-occurrences
	2-3	4-6	7-10	11-20	>20	
Cancer	631 (253)	326 (103)	432* (261)	241* (172)	77* (51)	1,706 (322)
Adrenal	230* (174)	56* (46)	0 (0)	0 (0)	0 (0)	286* (175)
Bladder	34* (36)	46* (42)	0 (0)	0 (0)	0 (0)	80* (55)
Body weight	836 (376)	397 (187)	93* (58)	16* (24)	0 (0)	1,342 (403)
Brain	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Cardiovascular	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Death	6* (15)	0 (0)	0 (0)	0 (0)	0 (0)	6* (15)
Developmental	718 (223)	109* (63)	0 (0)	0 (0)	0 (0)	827 (223)
Eyes	18* (27)	0 (0)	0 (0)	0 (0)	0 (0)	18* (27)
Forestomach	63* (49)	12* (21)	0 (0)	0 (0)	0 (0)	74* (53)
Gastrointestinal	28* (33)	30* (34)	0 (0)	0 (0)	0 (0)	57* (47)
General	12* (21)	0 (0)	0 (0)	0 (0)	0 (0)	12* (21)
Hematological	1,278 (291)	268* (176)	65* (49)	60* (47)	0 (0)	1,671 (270)
Kidney	1,557 (480)	556 (202)	331 (160)	38* (36)	46* (40)	2,528 (470)
Leukemia	114* (65)	0 (0)	0 (0)	0 (0)	0 (0)	114* (65)
Liver	916 (367)	379 (111)	348* (213)	282* (201)	68* (49)	1,993 (415)
Lung	1,270 (369)	101* (60)	45* (41)	0 (0)	0 (0)	1,416 (370)
Mammary	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Nasal cavity	12* (21)	0 (0)	0 (0)	0 (0)	0 (0)	12* (21)
Neurological	842 (330)	569 (262)	264* (177)	94* (57)	5* (13)	1,774 (414)
Organ weight	274* (177)	0 (0)	0 (0)	0 (0)	0 (0)	274* (177)
Reproductive	185 (82)	37* (37)	0 (0)	0 (0)	0 (0)	222 (90)
Respiratory	1,009 (377)	200 (83)	10* (19)	61* (47)	0 (0)	1,280 (383)
Respiratory tract	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Skin	680 (261)	0 (0)	0 (0)	0 (0)	0 (0)	680 (261)
Spleen	30* (34)	0 (0)	0 (0)	0 (0)	0 (0)	30* (34)
Stomach	23* (30)	0 (0)	0 (0)	0 (0)	0 (0)	23* (30)
Thyroid	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Vascular	85* (57)	0 (0)	0 (0)	0 (0)	0 (0)	85* (57)

[a] For noncarcinogenic chemicals, target organ on which health benchmark (e.g., RfD) is based. Cancer or leukemia for carcinogenic chemicals. See Appendix C for discussion of health benchmarks.
[b] A facility-level co-occurrence is defined as when two or more chemicals with a common target health effect occur within or across impoundments at a single facility.
[c] Estimate for population of facilities with surface impoundments having constituents or pH of concern. Value in parentheses is standard error. Asterisk (*) indicates estimates that may not be reliable because of a large relative standard error (see Appendix A.5 for a discussion of standard error estimates).
[d] Lists of the co-occurring chemicals at each facility in the sample are provided in Appendix B.

Table B-35. Facility-Level Co-occurance of Chemicals in Sludge by Human Health Effect (Risk Input Database)

Target Health Effect [a]	Estimated Number of Facilities with Co-occurrences [b] in Sludge [c]					
	Number of Chemicals Co-occurring Within/Across Impoundments [d]					All Facilities with 2 or More Co-occurrences
	2-3	4-6	7-10	11-20	>20	
Cancer	552 (203)	237 (85)	92* (54)	246* (129)	191* (125)	1,318 (238)
Adrenal	41* (37)	165* (126)	0 (0)	0 (0)	0 (0)	207* (127)
Bladder	12* (20)	161* (126)	0 (0)	0 (0)	0 (0)	173* (126)
Body weight	371 (138)	154 (69)	112* (59)	136* (124)	0 (0)	773 (172)
Brain	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Cardiovascular	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Death	129* (125)	0 (0)	0 (0)	0 (0)	0 (0)	129* (125)
Developmental	416 (141)	205* (128)	0 (0)	0 (0)	0 (0)	621 (169)
Eyes	13* (20)	0 (0)	0 (0)	0 (0)	0 (0)	13* (20)
Forestomach	161* (126)	8* (16)	0 (0)	0 (0)	0 (0)	169* (126)
Gastrointestinal	144* (125)	21* (26)	0 (0)	0 (0)	0 (0)	165* (126)
General	8* (16)	0 (0)	0 (0)	0 (0)	0 (0)	8* (16)
Hematological	560 (156)	250* (130)	49* (40)	173* (126)	0 (0)	1,033 (191)
Kidney	894 (290)	329 (140)	274 (130)	40* (36)	162* (124)	1,700 (328)
Leukemia	259 (129)	0 (0)	0 (0)	0 (0)	0 (0)	259 (129)
Liver	403 (144)	256 (88)	44* (38)	239* (128)	176* (125)	1,118 (192)
Lung	1,049 (223)	253* (133)	36* (34)	0 (0)	0 (0)	1,338 (228)
Mammary	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Nasal cavity	8* (16)	0 (0)	0 (0)	0 (0)	0 (0)	8* (16)
Neurological	326 (98)	266 (130)	245* (132)	198* (127)	4* (11)	1,039 (187)
Organ weight	207* (128)	0 (0)	0 (0)	0 (0)	0 (0)	207* (128)
Reproductive	386 (159)	30* (31)	0 (0)	0 (0)	0 (0)	416 (159)
Respiratory	431 (140)	341 (138)	8* (16)	164* (125)	0 (0)	944 (183)
Respiratory tract	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Skin	558 (126)	0 (0)	0 (0)	0 (0)	0 (0)	558 (126)
Spleen	21* (26)	0 (0)	0 (0)	0 (0)	0 (0)	21* (26)
Stomach	8* (16)	0 (0)	0 (0)	0 (0)	0 (0)	8* (16)
Thyroid	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Vascular	190* (126)	0 (0)	0 (0)	0 (0)	0 (0)	190* (126)

[a] For noncarcinogenic chemicals, target organ on which health benchmark (e.g., RfD) is based. Cancer or leukemia for carcinogenic chemicals. See Appendix C for discussion of health benchmarks.
[b] A facility-level co-occurrence is defined as when two or more chemicals with a common target health effect occur within or across impoundments at a single facility.
[c] Estimate for population of facilities with surface impoundments having constituents or pH of concern. Value in parentheses is standard error. Asterisk (*) indicates estimates that may not be reliable because of a large relative standard error (see Appendix A.5 for a discussion of standard error estimates).
[d] Lists of the co-occurring chemicals at each facility in the sample are provided in Appendix B.

Table B-36. Impoundment-Level Co-occurance of Chemicals in Wastewater by Human Health Effect (Risk Input Database)

Target Health Effect [a]	Estimated Number of Impoundments with Co-occurrences [b] in Wastewater [c]					
	Number of Chemicals Co-occurring Within/Across Impoundments					All Impoundments with 2 or More Co-occurrences
	2-3	4-6	7-10	11-20	>20	
Cancer	1,004 (223)	959 (153)	709 (278)	326 (160)	175 (67)	3,172 (577)
Adrenal	243* (155)	114 (55)	0 (0)	0 (0)	0 (0)	358 (158)
Bladder	72* (44)	102* (52)	0 (0)	0 (0)	0 (0)	175 (67)
Body weight	2,144 (280)	811 (168)	157 (64)	50* (36)	0 (0)	3,161 (361)
Brain	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Cardiovascular	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Death	4* (11)	0 (0)	0 (0)	0 (0)	0 (0)	4* (11)
Developmental	1,763 (375)	181 (69)	0 (0)	0 (0)	0 (0)	1,944 (391)
Eyes	52* (37)	0 (0)	0 (0)	0 (0)	0 (0)	52* (37)
Forestomach	116 (55)	42* (33)	0 (0)	0 (0)	0 (0)	158 (64)
Gastrointestinal	86* (47)	46* (35)	0 (0)	0 (0)	0 (0)	132 (59)
General	42* (33)	0 (0)	0 (0)	0 (0)	0 (0)	42* (33)
Hematological	3,293 (656)	429 (172)	101* (52)	131 (59)	0 (0)	3,954 (771)
Kidney	3,418 (568)	1,887 (264)	496 (173)	122 (57)	114 (55)	6,038 (824)
Leukemia	189 (70)	0 (0)	0 (0)	0 (0)	0 (0)	189 (70)
Liver	2,798 (307)	924 (150)	486* (327)	389 (188)	148 (62)	4,744 (492)
Lung	2,403 (537)	359 (96)	105 (53)	0 (0)	0 (0)	2,868 (555)
Mammary	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Nasal cavity	42* (33)	0 (0)	0 (0)	0 (0)	0 (0)	42* (33)
Neurological	3,578 (257)	747 (257)	665 (156)	191 (71)	4* (11)	5,186 (444)
Organ weight	359 (160)	0 (0)	0 (0)	0 (0)	0 (0)	359 (160)
Reproductive	257 (82)	102* (52)	0 (0)	0 (0)	0 (0)	360 (96)
Respiratory	2,116 (367)	793 (140)	17* (21)	131 (59)	0 (0)	3,057 (408)
Respiratory tract	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Skin	1,415 (258)	0 (0)	0 (0)	0 (0)	0 (0)	1,415 (258)
Spleen	55* (38)	0 (0)	0 (0)	0 (0)	0 (0)	55* (38)
Stomach	50* (36)	0 (0)	0 (0)	0 (0)	0 (0)	50* (36)
Thyroid	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Vascular	149 (62)	0 (0)	0 (0)	0 (0)	0 (0)	149 (62)

[a] For noncarcinogenic chemicals, target organ on which health benchmark (e.g., RfD) is based. Cancer or leukemia for carcinogenic chemicals. See Appendix C for discussion of health benchmarks.

[b] An impoundment-level co-occurrence is defined as when two or more chemicals with a common target health effect occur within or across a single impoundment.

[c] Estimate for population of impoundments having constituents or pH of concern. Value in parentheses is standard error. Asterisk (*) indicates estimates that may not be reliable because of a large relative standard error (see Appendix A.5 for a discussion of standard error estimates).

Table B-37. Impoundment-Level Co-occurance of Chemicals in Sludge by Human Health Effect (Risk Input Database)

Target Health Effect [a]	Estimated Number of Impoundments with Co-occurrences [b] in Sludge [c]					
	Number of Chemicals Co-occurring Within/Across Impoundments					All Impoundments with 2 or More Co-occurrences
	2-3	4-6	7-10	11-20	>20	
Cancer	930 (247)	816 (135)	267 (79)	568 (278)	280 (126)	2,861 (493)
Adrenal	229* (124)	214* (122)	0 (0)	0 (0)	0 (0)	443 (166)
Bladder	53* (36)	207* (122)	0 (0)	0 (0)	0 (0)	260 (124)
Body weight	885 (211)	605 (144)	184 (66)	165* (121)	0 (0)	1,838 (413)
Brain	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Cardiovascular	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Death	124* (121)	0 (0)	0 (0)	0 (0)	0 (0)	124* (121)
Developmental	1,372 (302)	306 (127)	0 (0)	0 (0)	0 (0)	1,677 (382)
Eyes	47* (33)	0 (0)	0 (0)	0 (0)	0 (0)	47* (33)
Forestomach	208* (123)	37* (30)	0 (0)	0 (0)	0 (0)	246* (124)
Gastrointestinal	189* (122)	41* (31)	0 (0)	0 (0)	0 (0)	230* (123)
General	37* (30)	0 (0)	0 (0)	0 (0)	0 (0)	37* (30)
Hematological	1,664 (229)	667 (284)	94* (47)	230* (123)	0 (0)	2,654 (565)
Kidney	2,134 (358)	1,103 (224)	702 (289)	125 (55)	214* (122)	4,278 (620)
Leukemia	349 (166)	0 (0)	0 (0)	0 (0)	0 (0)	349 (166)
Liver	1,421 (252)	661 (123)	168* (122)	487 (197)	241* (123)	2,978 (425)
Lung	2,087 (448)	453 (138)	87* (46)	0 (0)	0 (0)	2,627 (541)
Mammary	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Nasal cavity	37* (30)	0 (0)	0 (0)	0 (0)	0 (0)	37* (30)
Neurological	1,630 (243)	389 (104)	771 (280)	287 (127)	4* (9)	3,081 (536)
Organ weight	429 (165)	0 (0)	0 (0)	0 (0)	0 (0)	429 (165)
Reproductive	575* (296)	92* (47)	0 (0)	0 (0)	0 (0)	667 (298)
Respiratory	888 (185)	900 (221)	15* (19)	222* (123)	0 (0)	2,024 (421)
Respiratory tract	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Skin	1,265 (185)	0 (0)	0 (0)	0 (0)	0 (0)	1,265 (185)
Spleen	49* (34)	0 (0)	0 (0)	0 (0)	0 (0)	49* (34)
Stomach	37* (30)	0 (0)	0 (0)	0 (0)	0 (0)	37* (30)
Thyroid	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Vascular	277 (124)	0 (0)	0 (0)	0 (0)	0 (0)	277 (124)

[a] For noncarcinogenic chemicals, target organ on which health benchmark (e.g., RfD) is based. Cancer or leukemia for carcinogenic chemicals. See Appendix C for discussion of health benchmarks.

[b] An impoundment-level co-occurrence is defined as when two or more chemicals with a common target health effect occur within or across a single impoundment.

[c] Estimate for population of impoundments having constituents or pH of concern. Value in parentheses is standard error. Asterisk (*) indicates estimates that may not be reliable because of a large relative standard error (see Appendix A.5 for a discussion of standard error estimates).

Table B-38. 50th and 90th Percentile Wastewater Concentrations in Impoundment for Selected Chemicals

Chemical	Screening Factor [a]		TC Limit [b] (mg/L)	Wastewater Concentrations in Impoundment (mg/L)			
				Survey Data		Risk Input Data	
	Carcinogen (mg/L)	Noncarcinogen (mg/L)		50th Percentile	90th Percentile	50th Percentile	90th Percentile
Arsenic (7440-38-2)	6.6E-04	6.9E-03	5.0	9.0E-03	2.1E-02	9.0E-03	1.0E+00
Barium (7440-39-3)	NA	1.6E+00	100.0	1.3E-01	8.8E-01	3.0E-01	8.4E+00
Benzene (71-43-2)	1.8E-02	NA	0.5	1.1E-02	1.6E-02	5.3E-03	1.0E-01
Cadmium (7440-43-9)	NA	1.2E-02	1.0	3.0E-03	8.4E-03	3.1E-03	1.5E-01
Chloroform (67-66-3)	1.6E-01	2.3E-01	6.0	4.0E-03	2.8E+00	5.0E-03	2.8E+00
Chromium (7440-47-3)	NA	6.9E-02	5.0	8.0E-03	4.8E-02	1.6E-02	4.6E-01
Cresol (1319-77-3)	NA	1.2E+00	200.0	1.2E-02	3.1E-02	1.0E-02	1.1E-01
Lead (7439-92-1)	NA	NA	5.0	9.0E-03	4.0E-02	2.0E-02	4.0E-01
Mercury (7439-97-6)	NA	6.9E-03	0.2	6.0E-05	3.8E-03	2.0E-04	6.0E-03
Methyl Ethyl Ketone (78-93-3)	NA	1.4E+01	200.0	3.2E-01	1.4E+00	1.4E+00	2.1E+00
Selenium (7782-49-2)	NA	1.2E-01	1.0	5.5E-03	6.0E-02	1.0E-02	7.5E-01

[a] Human health based screening level (HBL) for drinking water (see Appendix C, Attachment 3).
[b] Source: RCRA §261.24, Table 1 – Maximum Concentration of Contaminants for the Toxicity Characteristic.

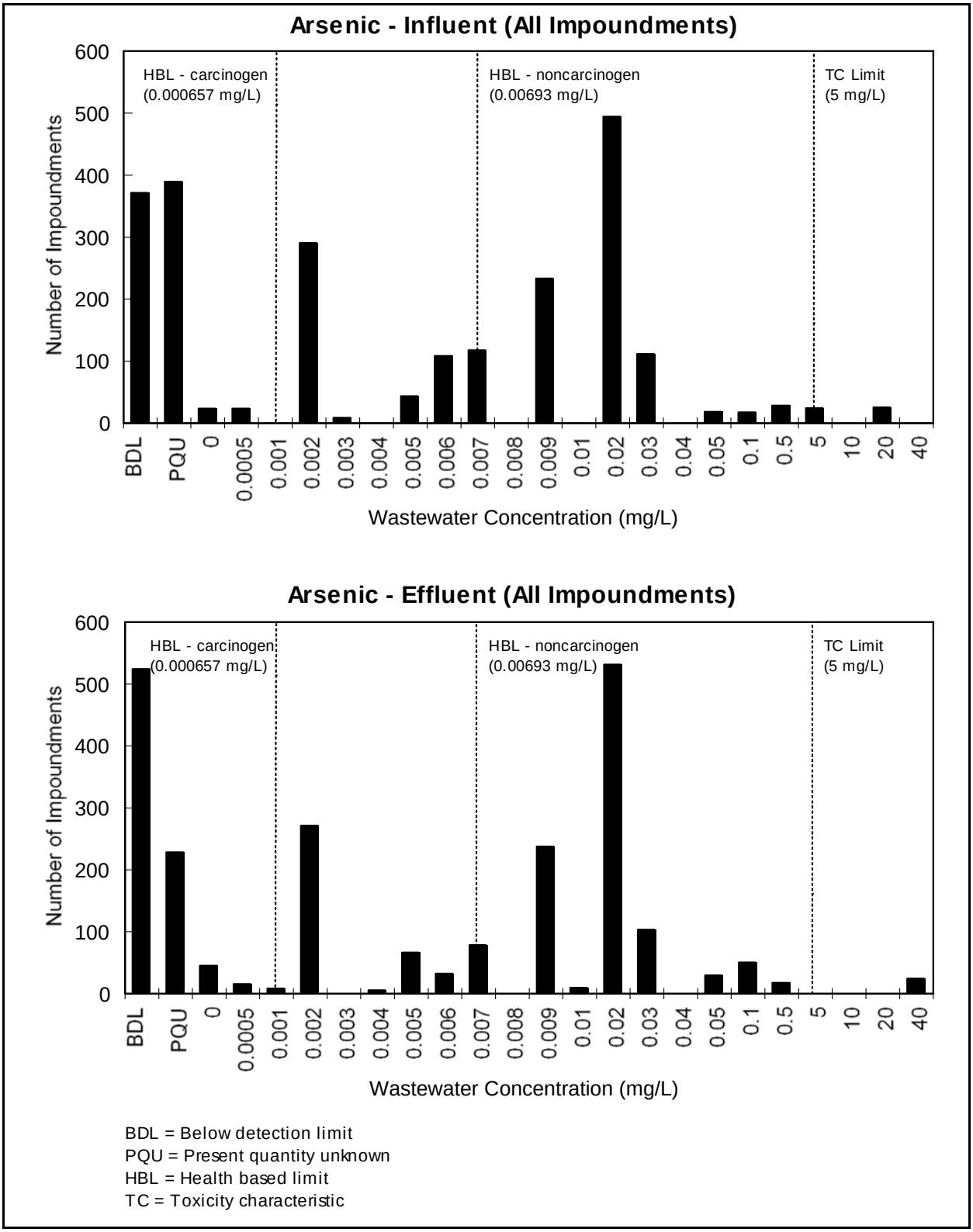


Figure B-1. Arsenic influent and effluent wastewater concentrations.

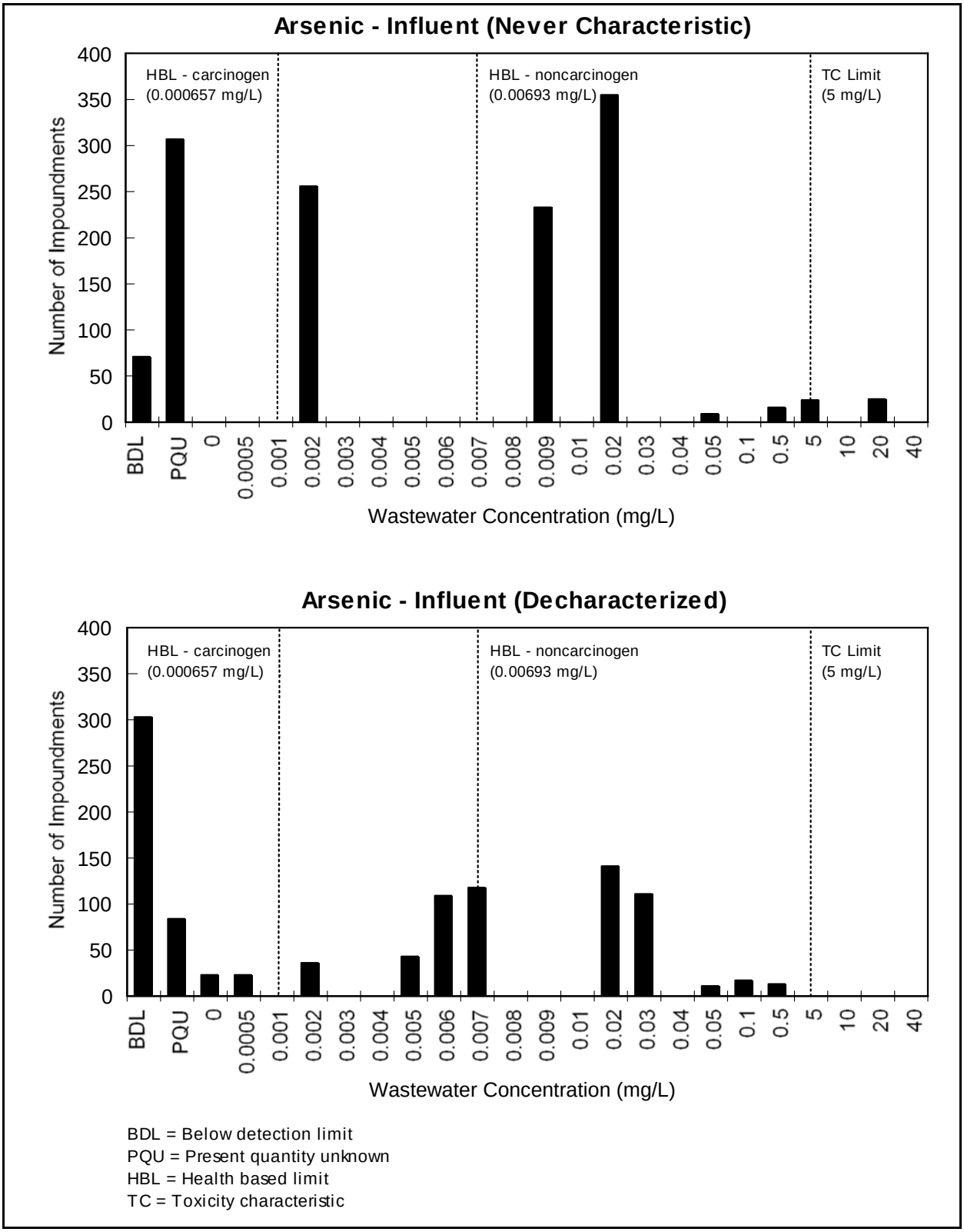


Figure B-2. Arsenic influent wastewater concentrations by decharacterization status.

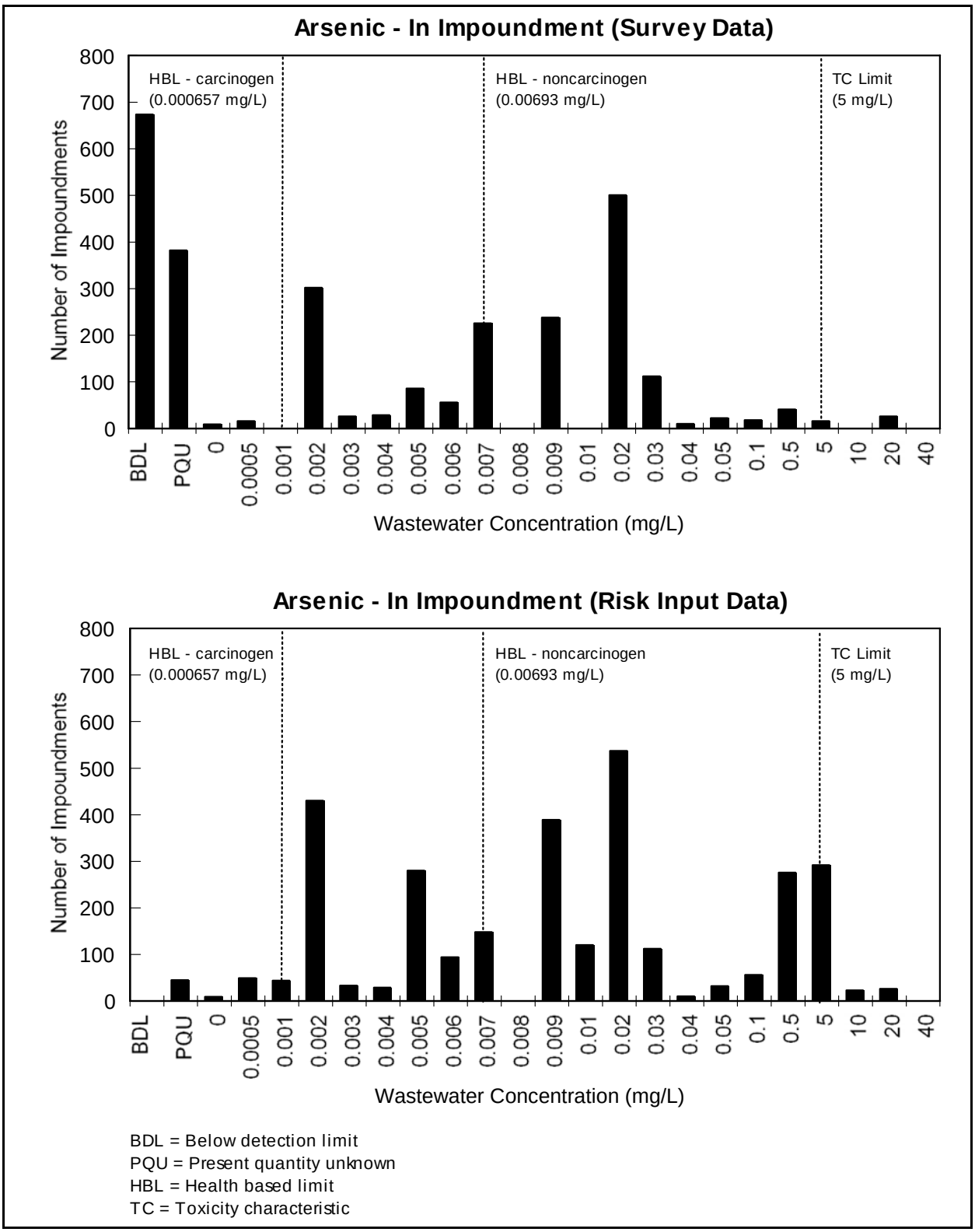


Figure B-3. Arsenic wastewater concentrations in impoundment (survey data vs. risk input data).

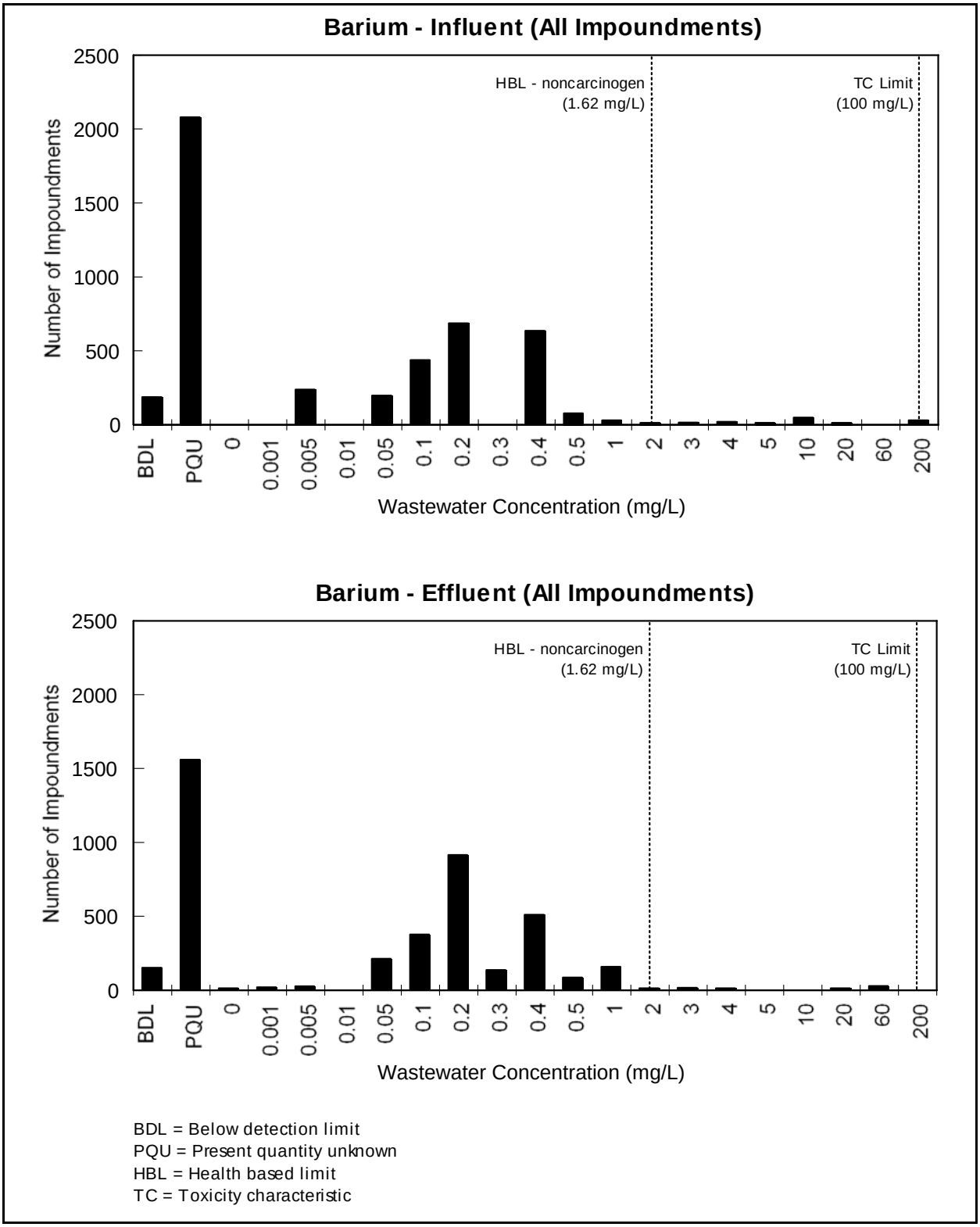


Figure B-4. Barium influent and effluent wastewater concentrations.

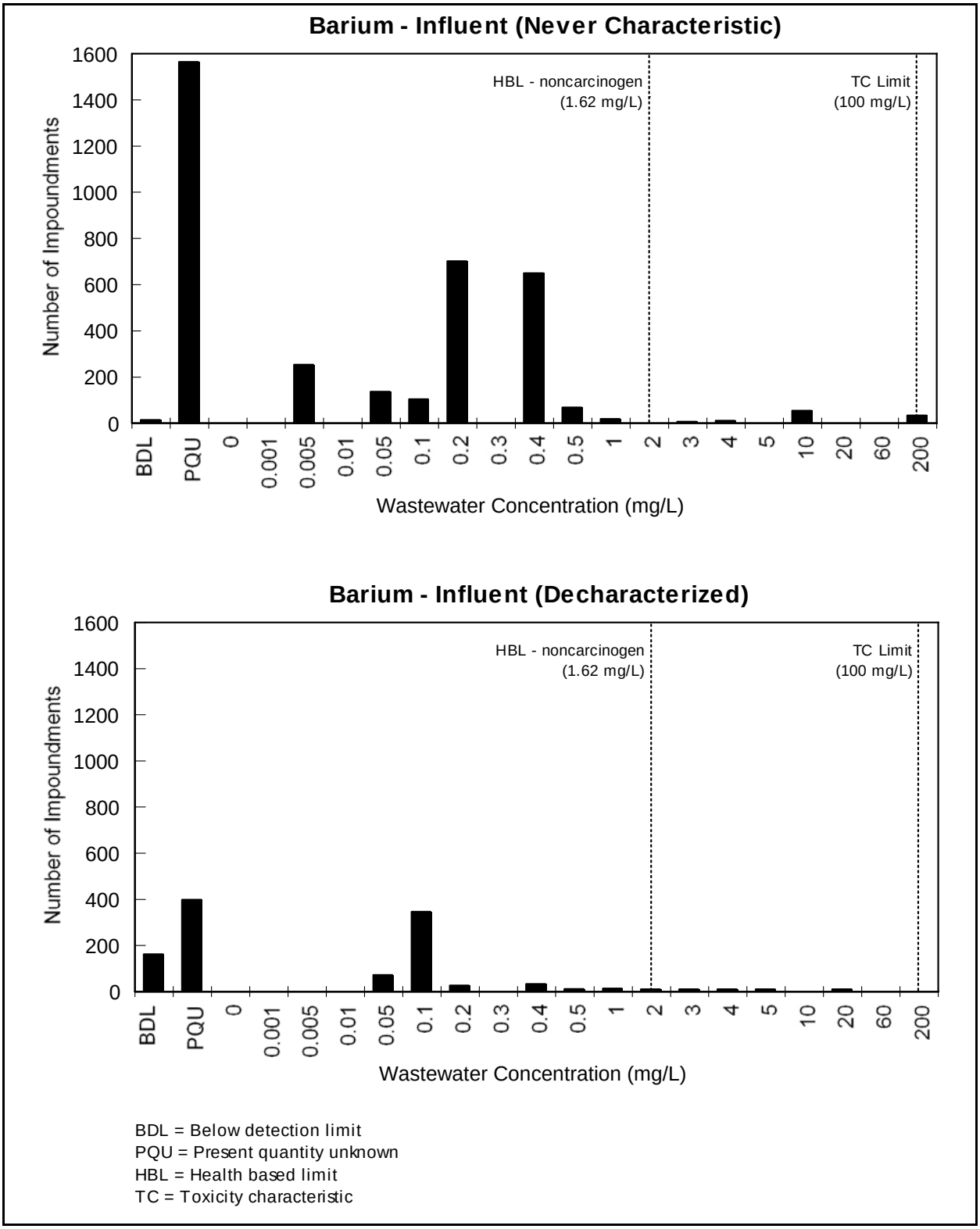


Figure B-5. Barium influent wastewater concentrations by decharacterization status.

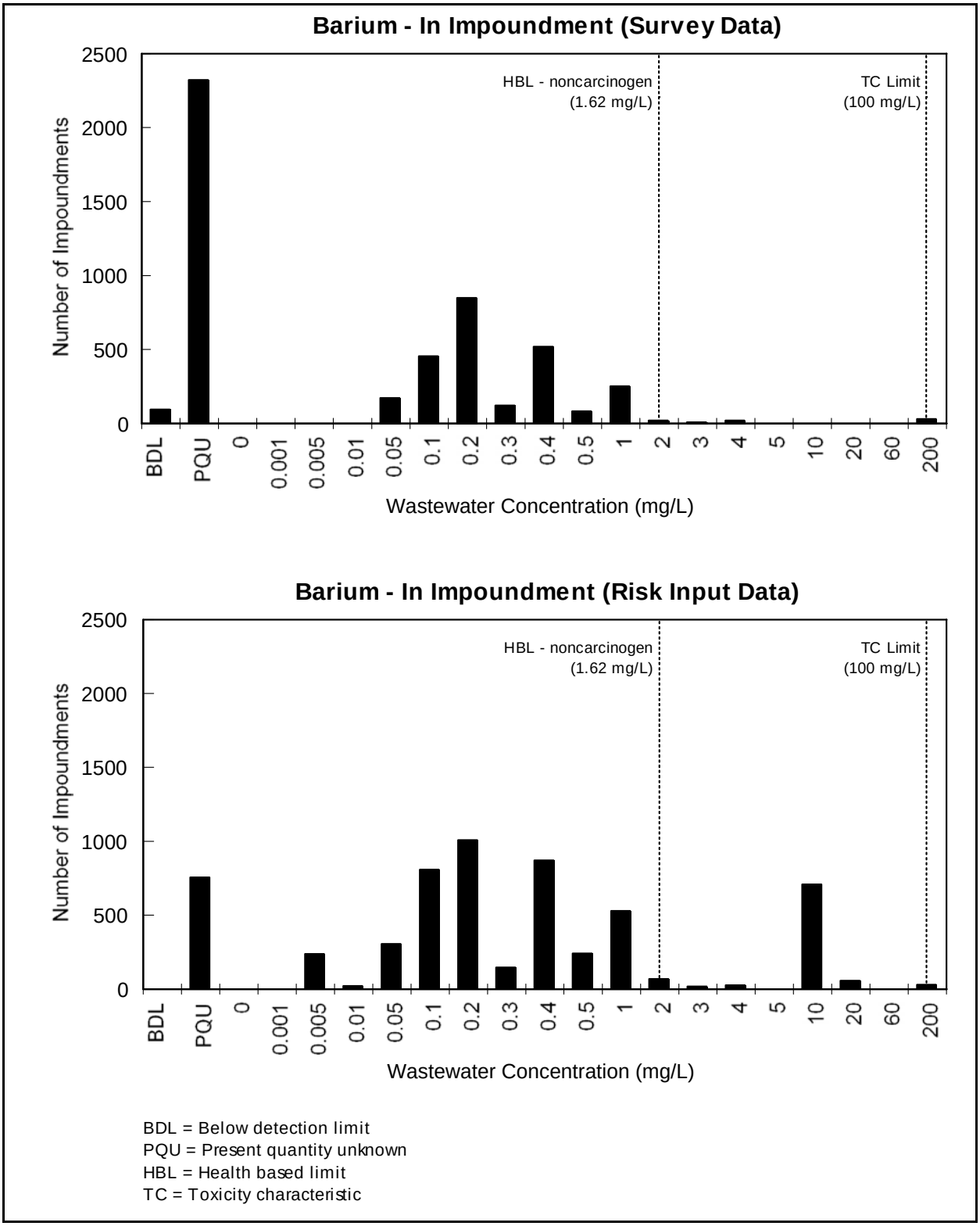


Figure B-6. Barium wastewater concentrations in impoundment (survey data vs. risk input data)

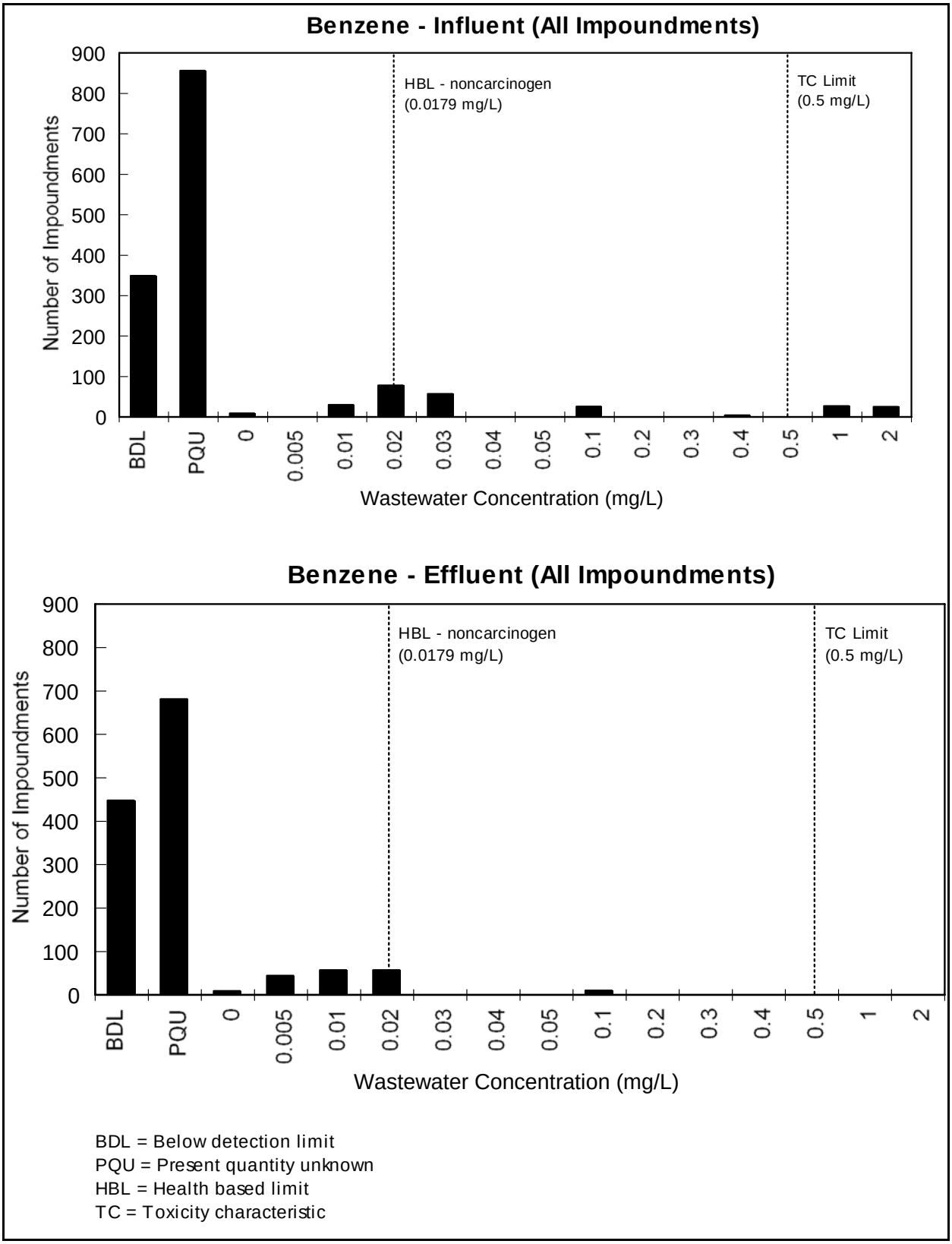


Figure B-7. Benzene influent and effluent wastewater concentrations.

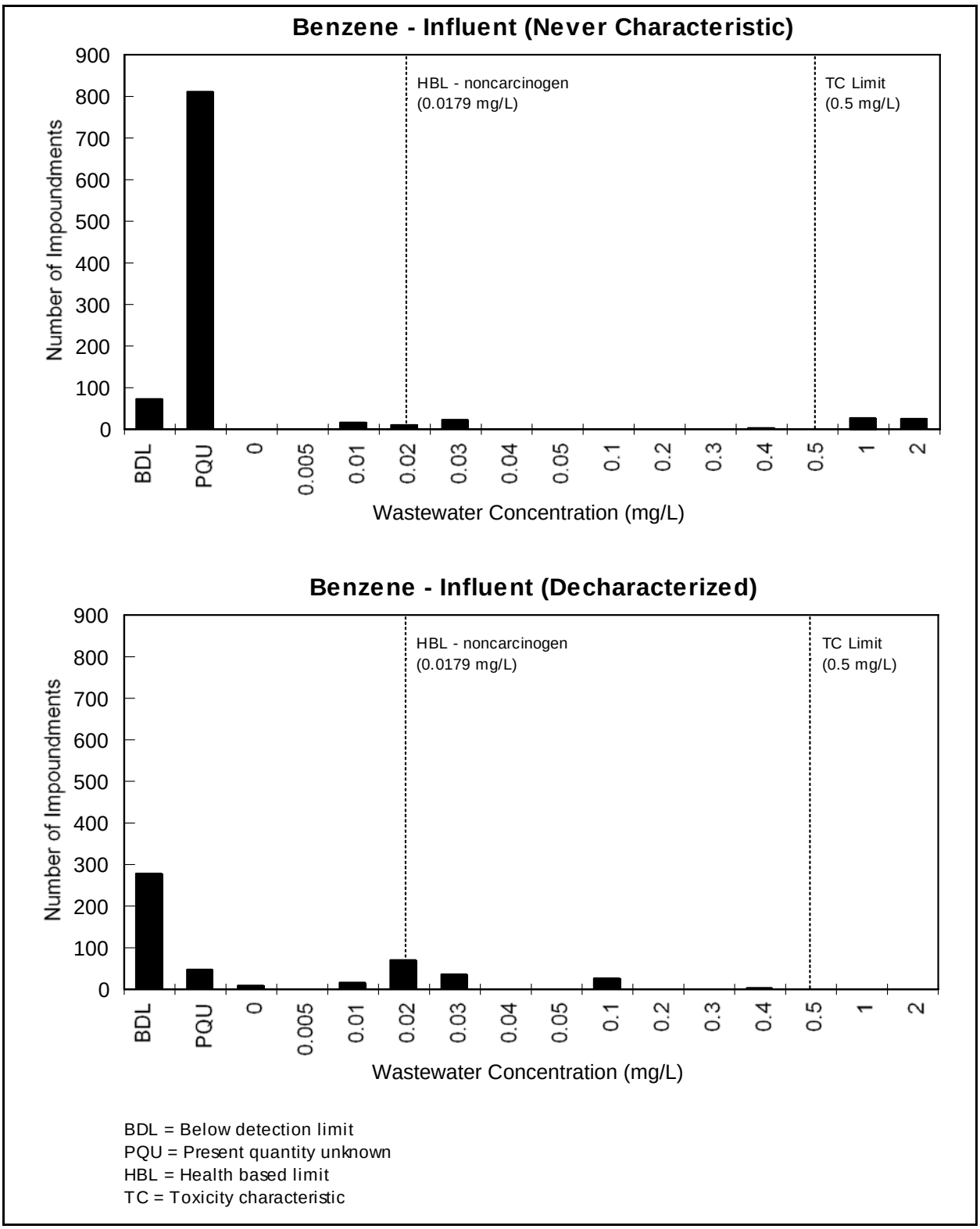


Figure B-8. Benzene influent wastewater concentrations by decharacterization status.

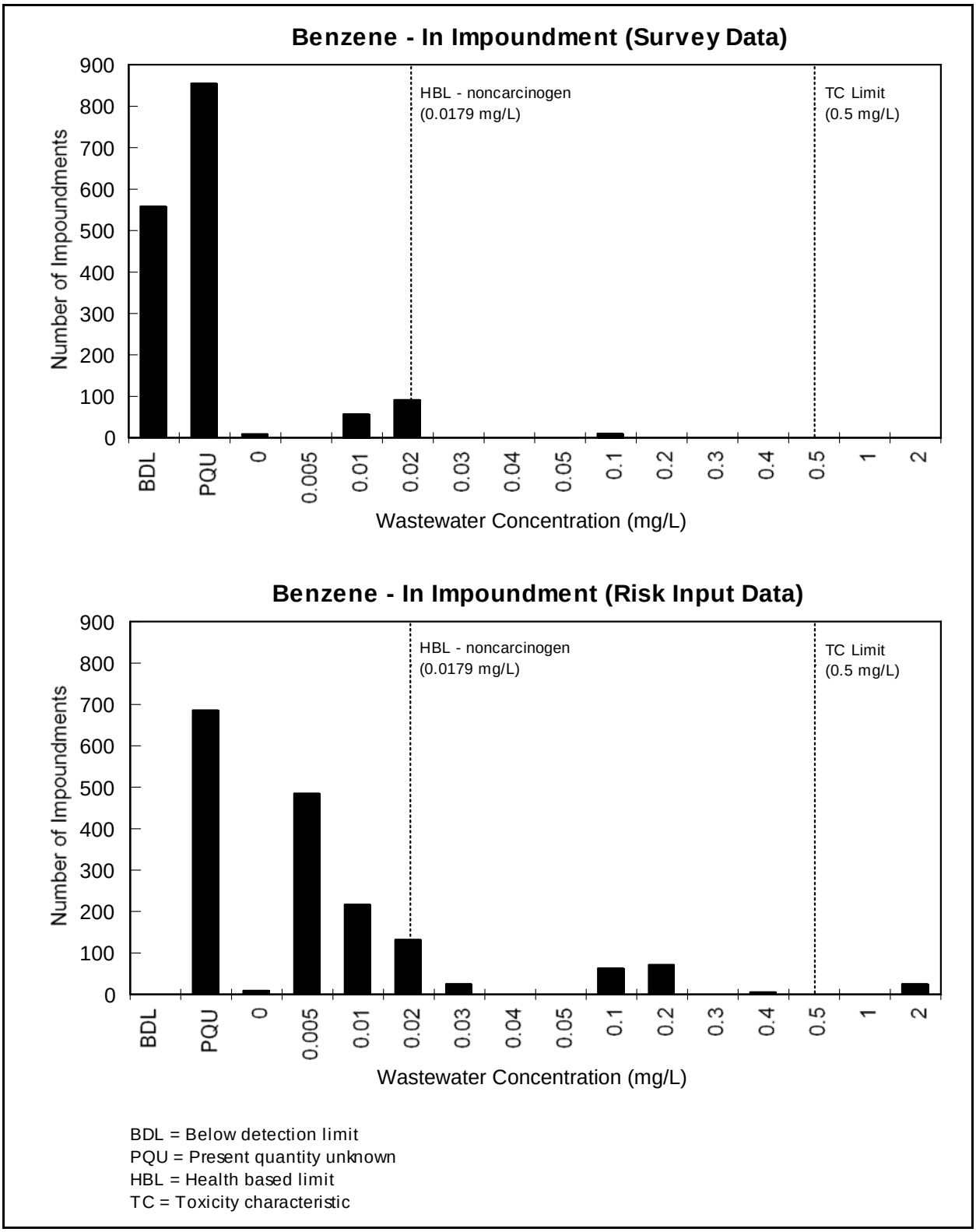


Figure B-9. Benzene wastewater concentrations in impoundment (survey data vs. risk input data).

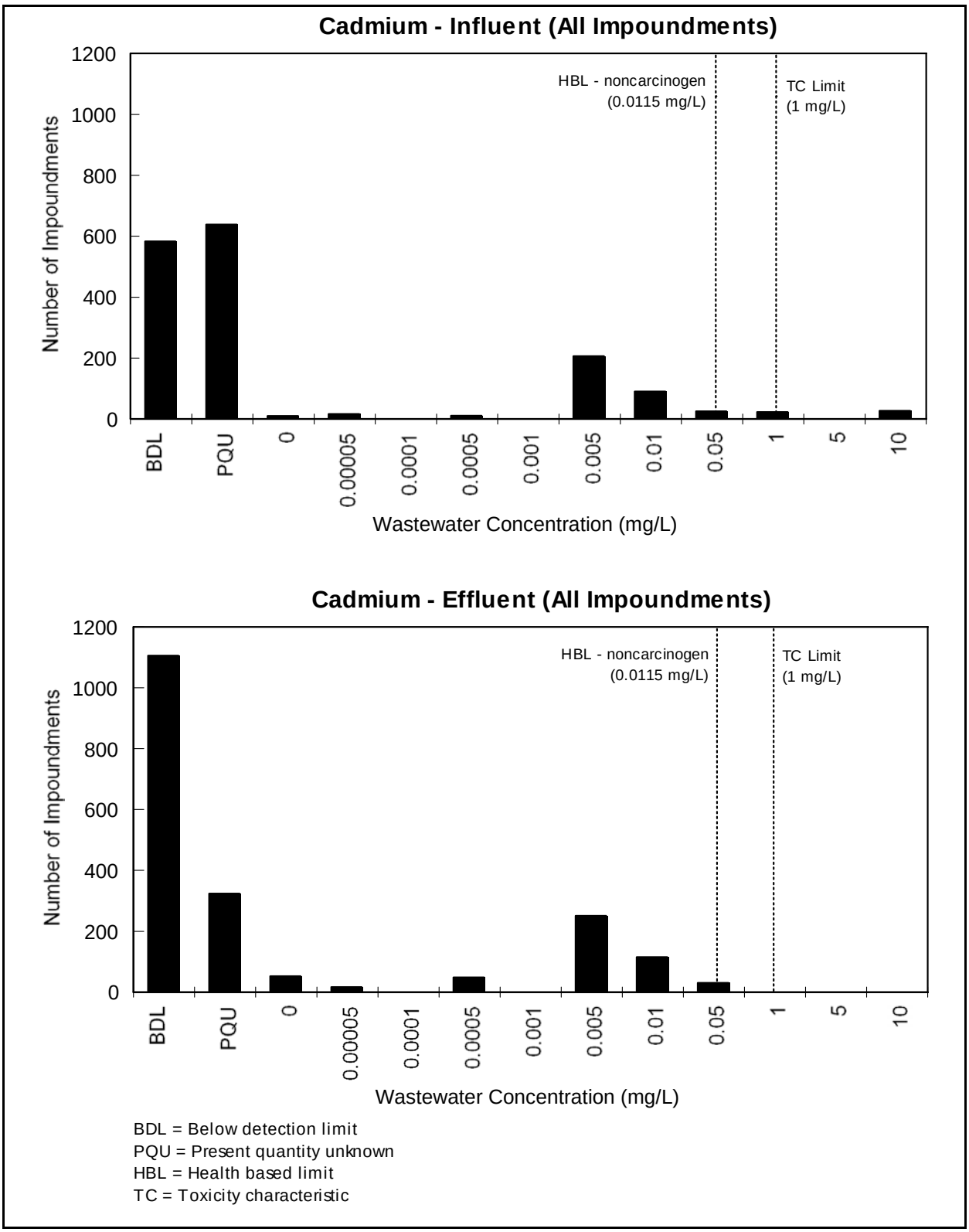


Figure B-10. Cadmium influent and effluent wastewater concentrations.

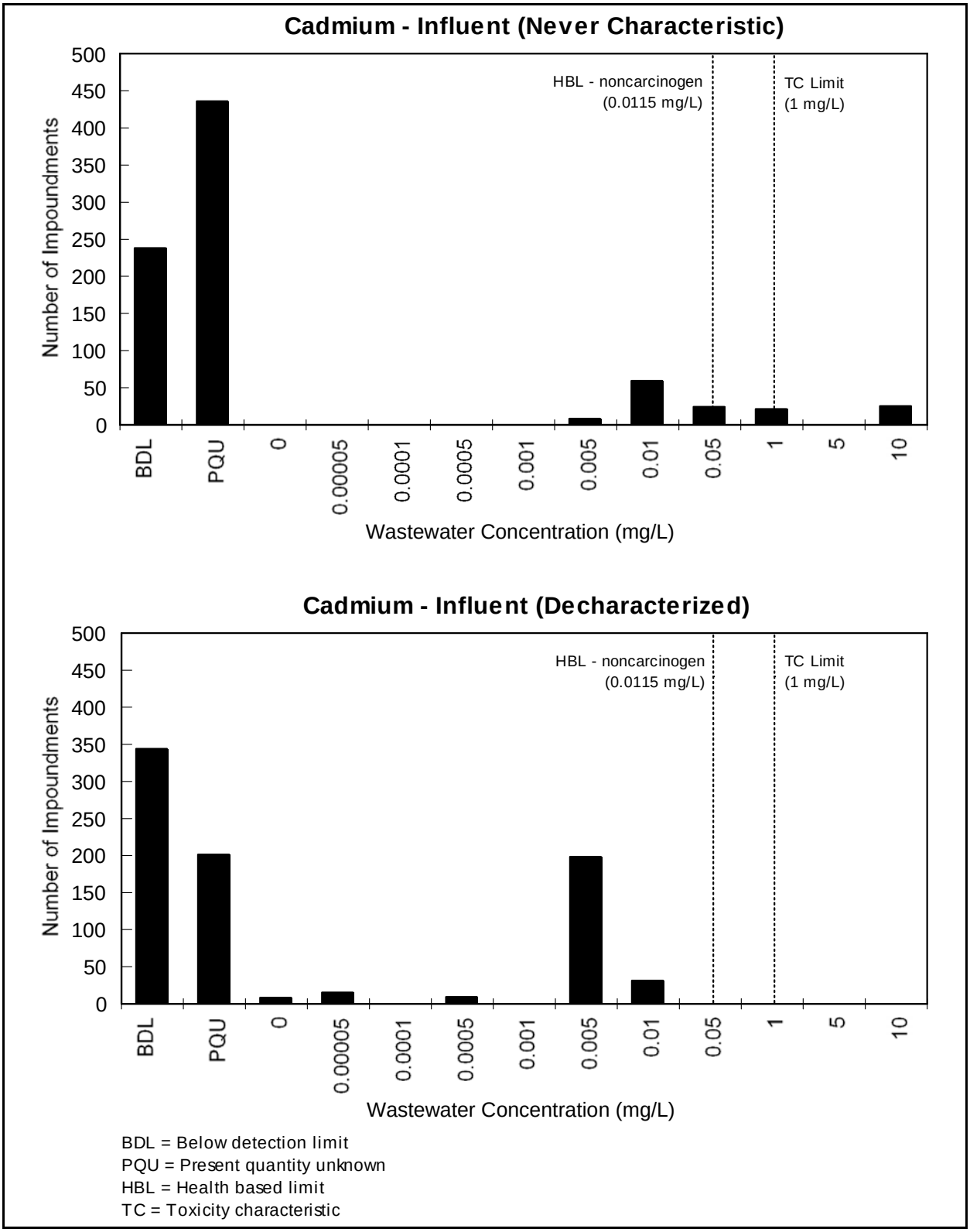


Figure B-11. Cadmium influent wastewater concentrations by decharacterization status.

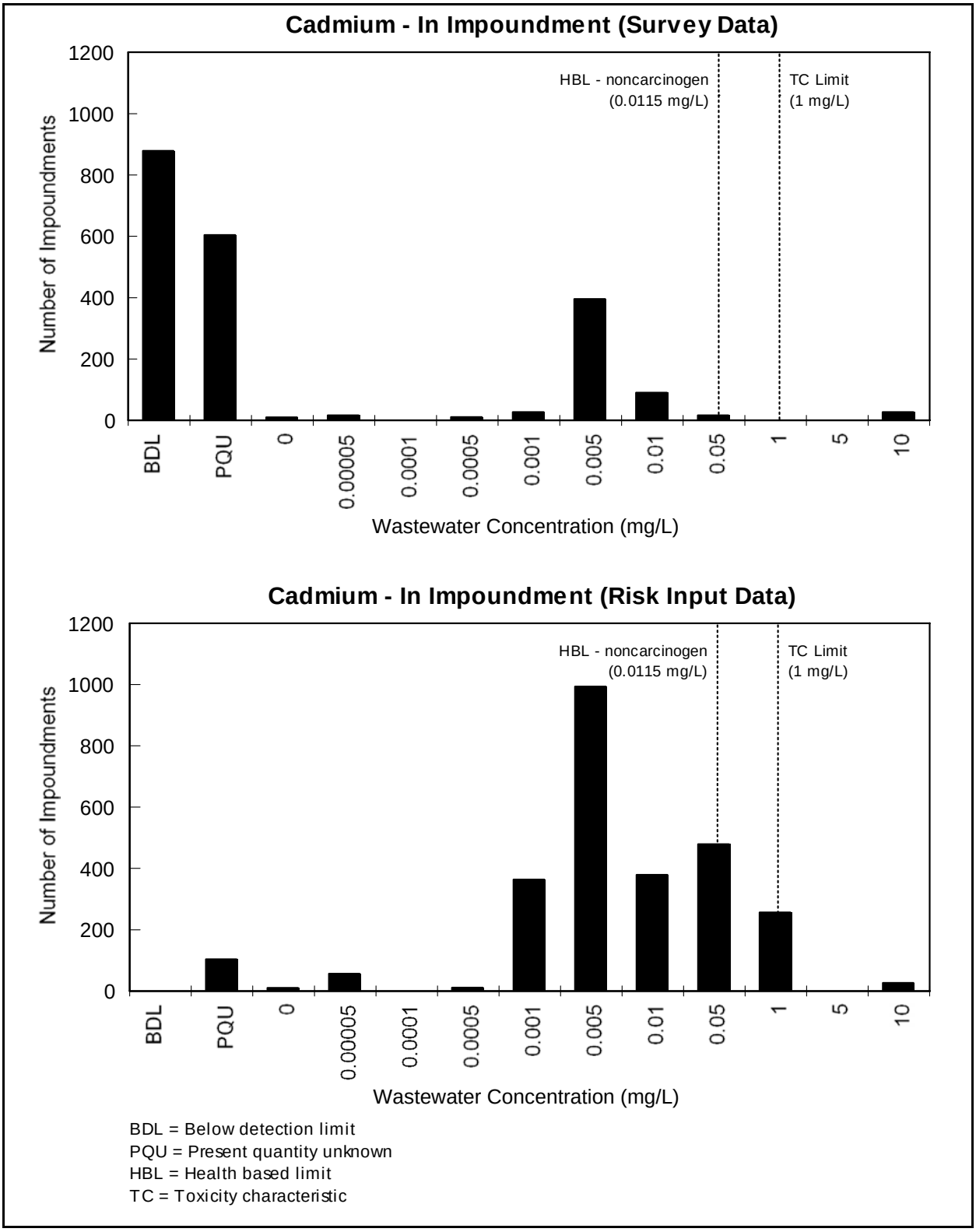


Figure B-12.Cadium wastewater concentrations in impoundment (survey data vs. risk input data).

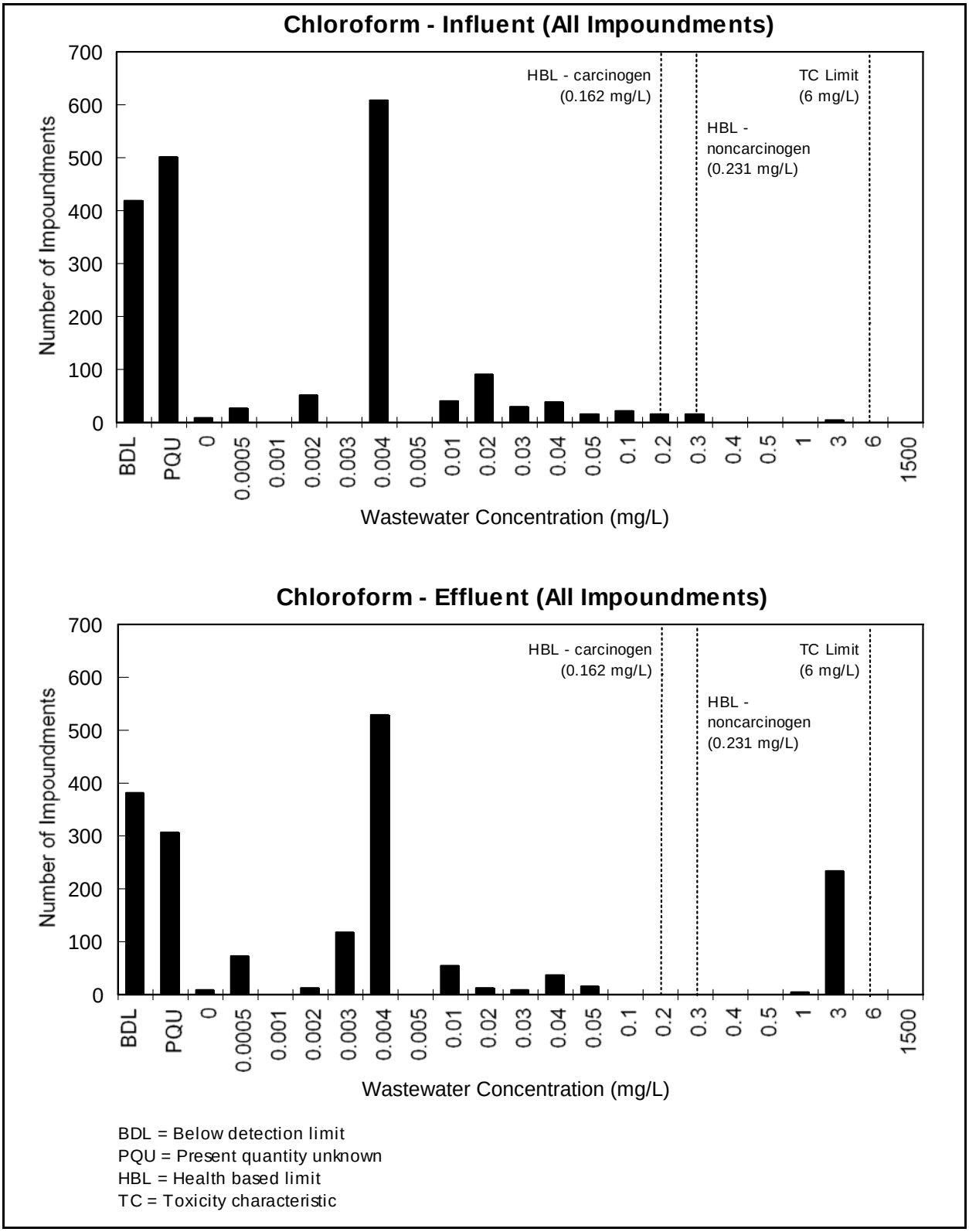


Figure B-13. Chloroform influent and effluent wastewater concentrations.

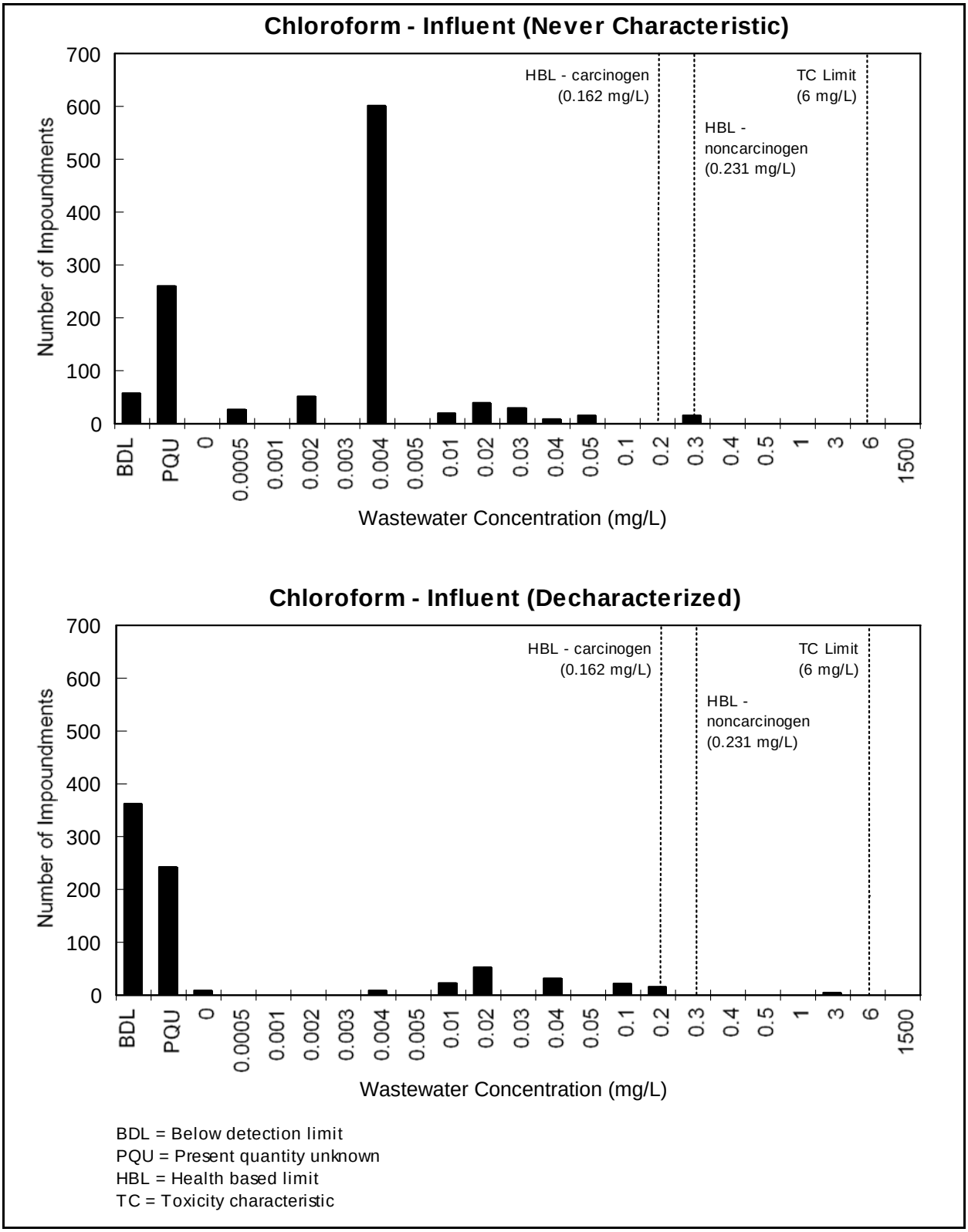


Figure B-14. Chloroform influent wastewater concentrations by decharacterization status.

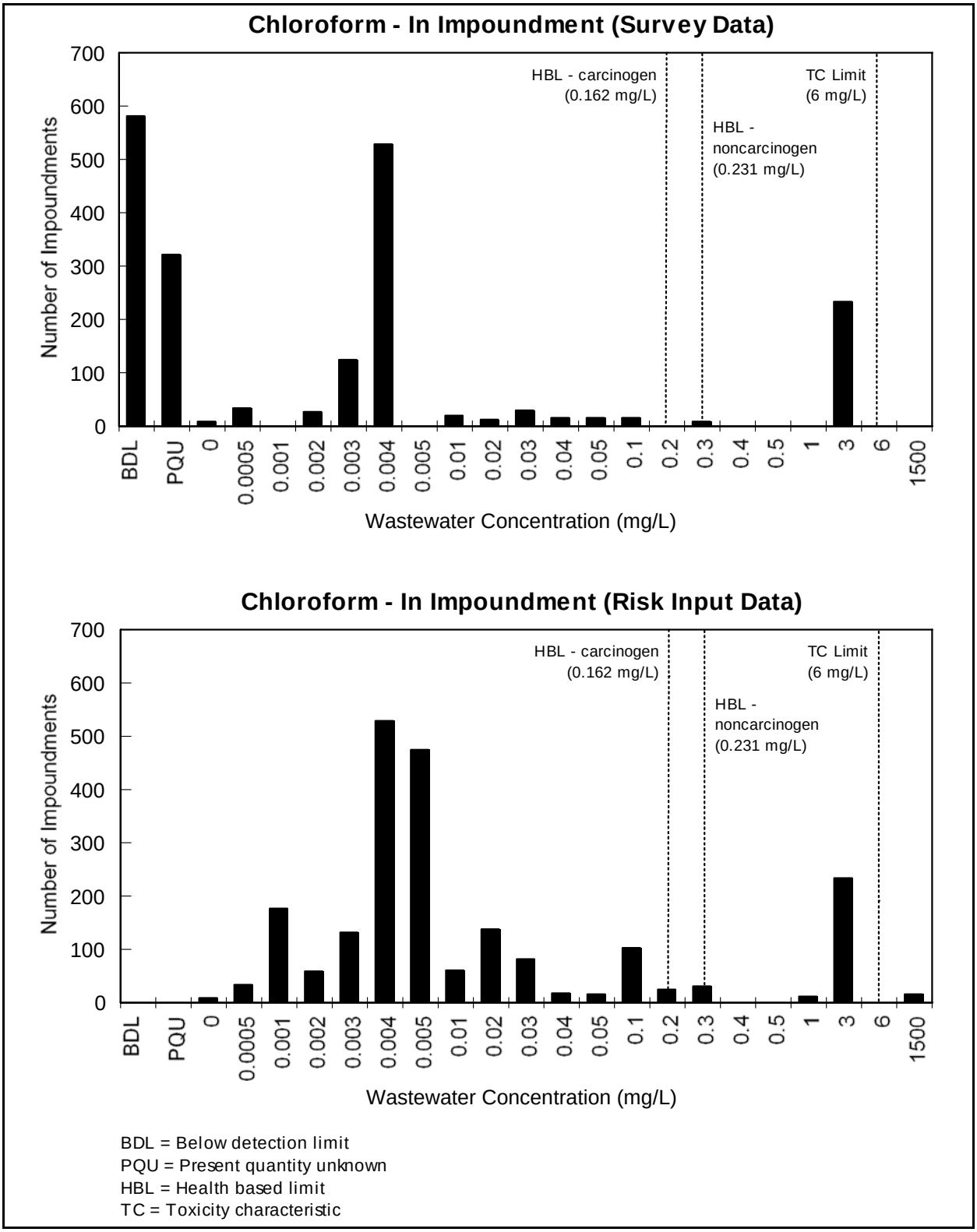


Figure B-15. Chloroform wastewater concentrations in impoundment (survey data vs. risk input data).

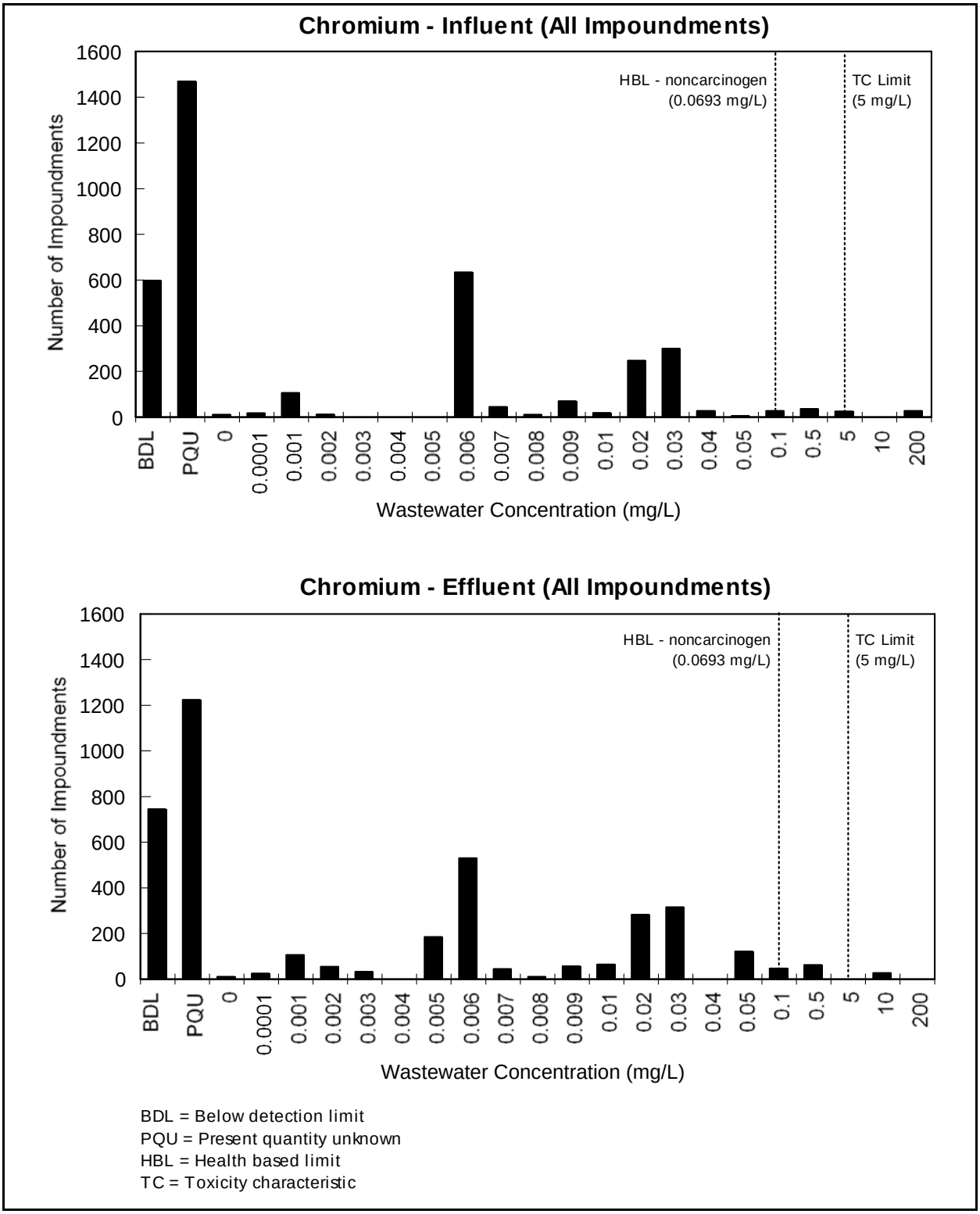


Figure B-16. Chromium influent and effluent wastewater concentrations.

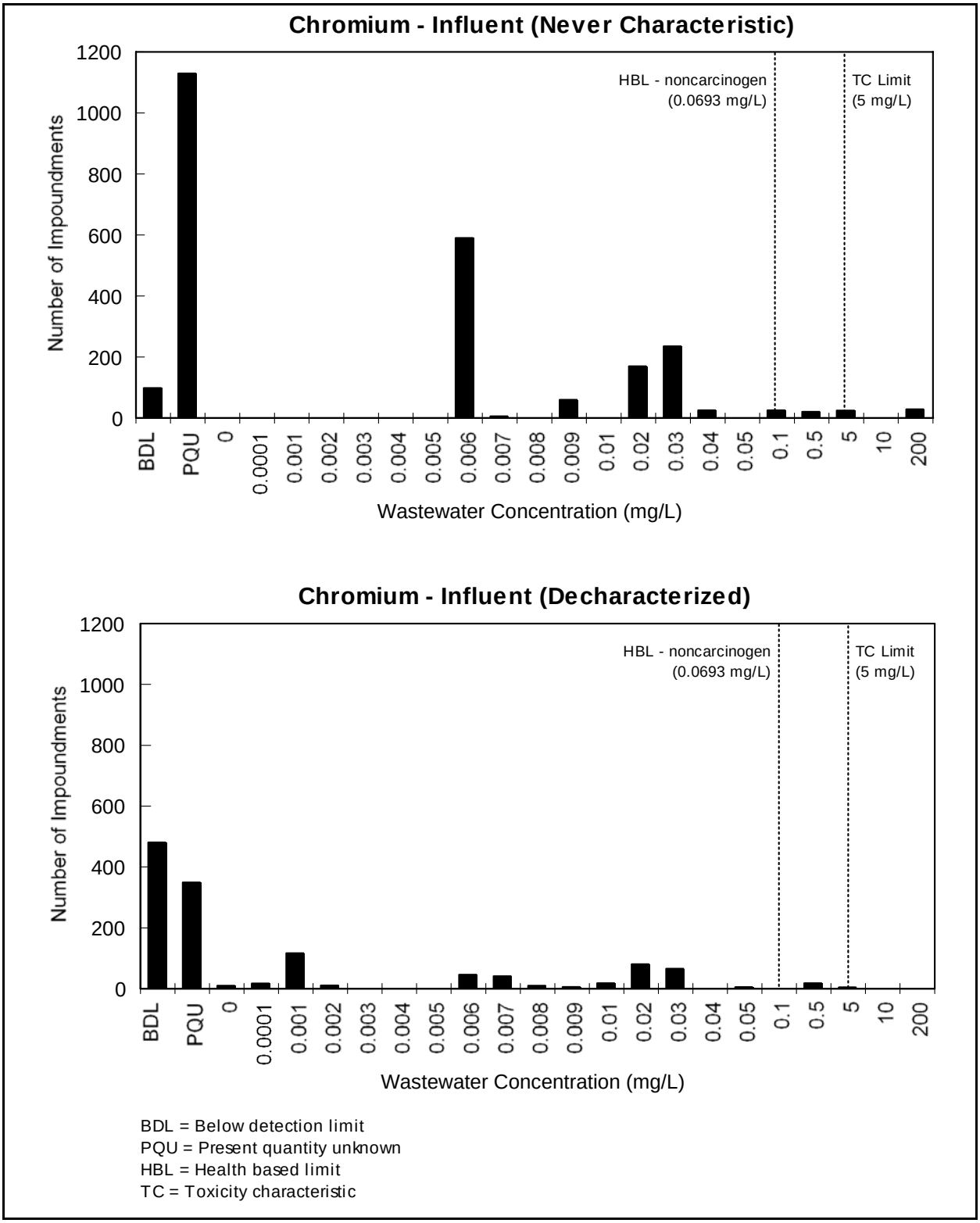


Figure B-17. Chromium influent wastewater concentrations by decharacterization status.

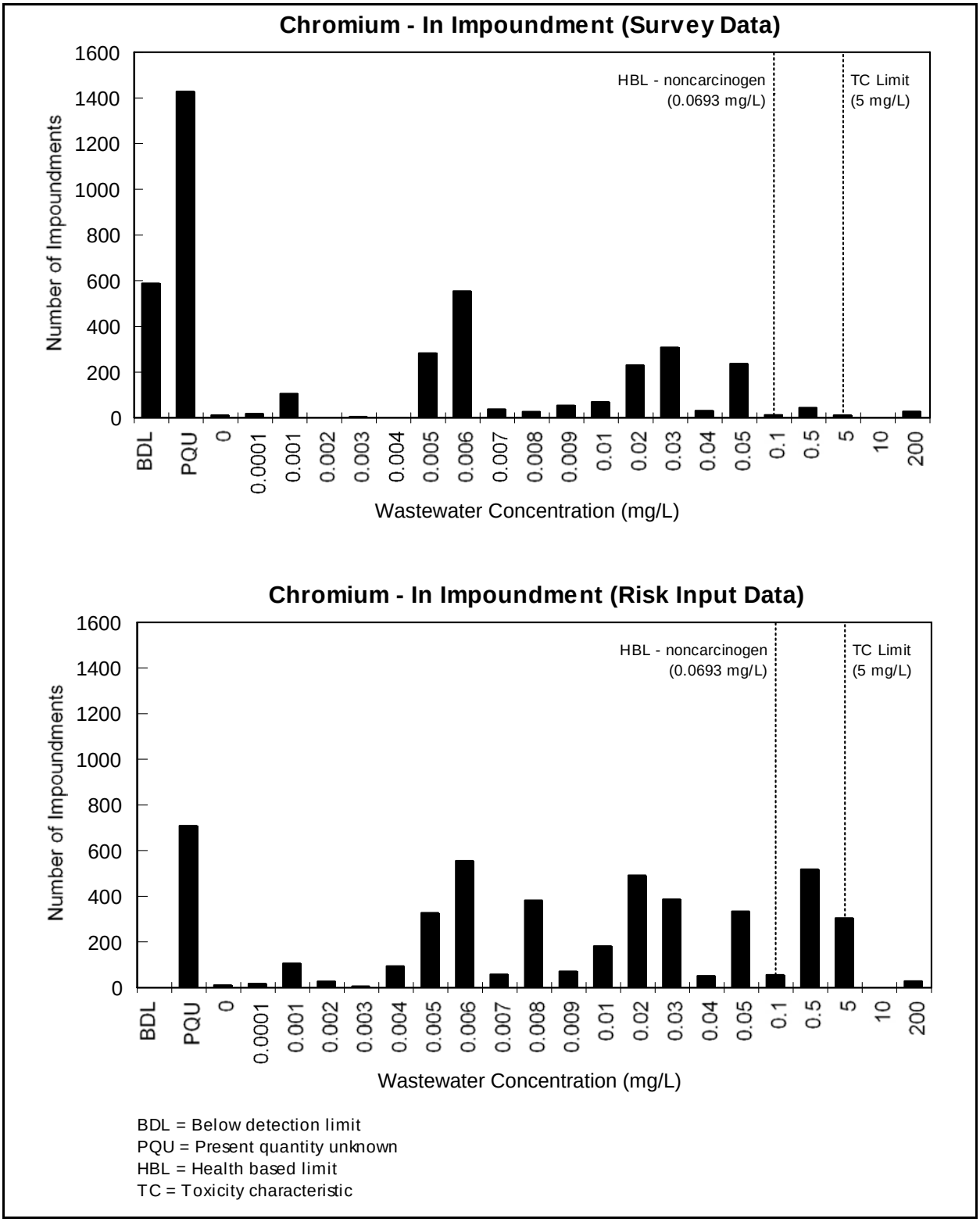


Figure B-18. Chromium wastewater concentrations in impoundment (survey data vs. risk input data).

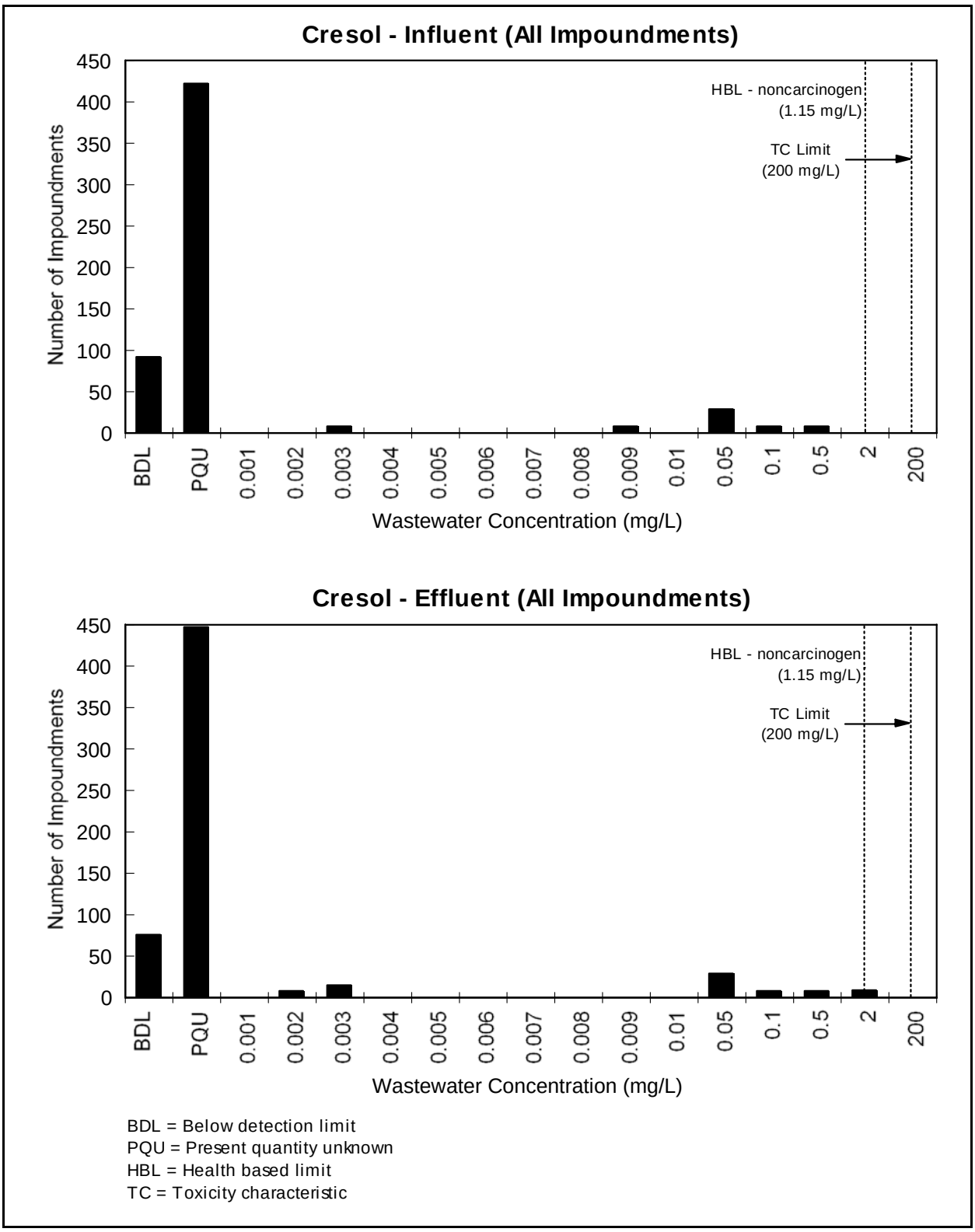


Figure B-19. Cresol influent and effluent wastewater concentrations.

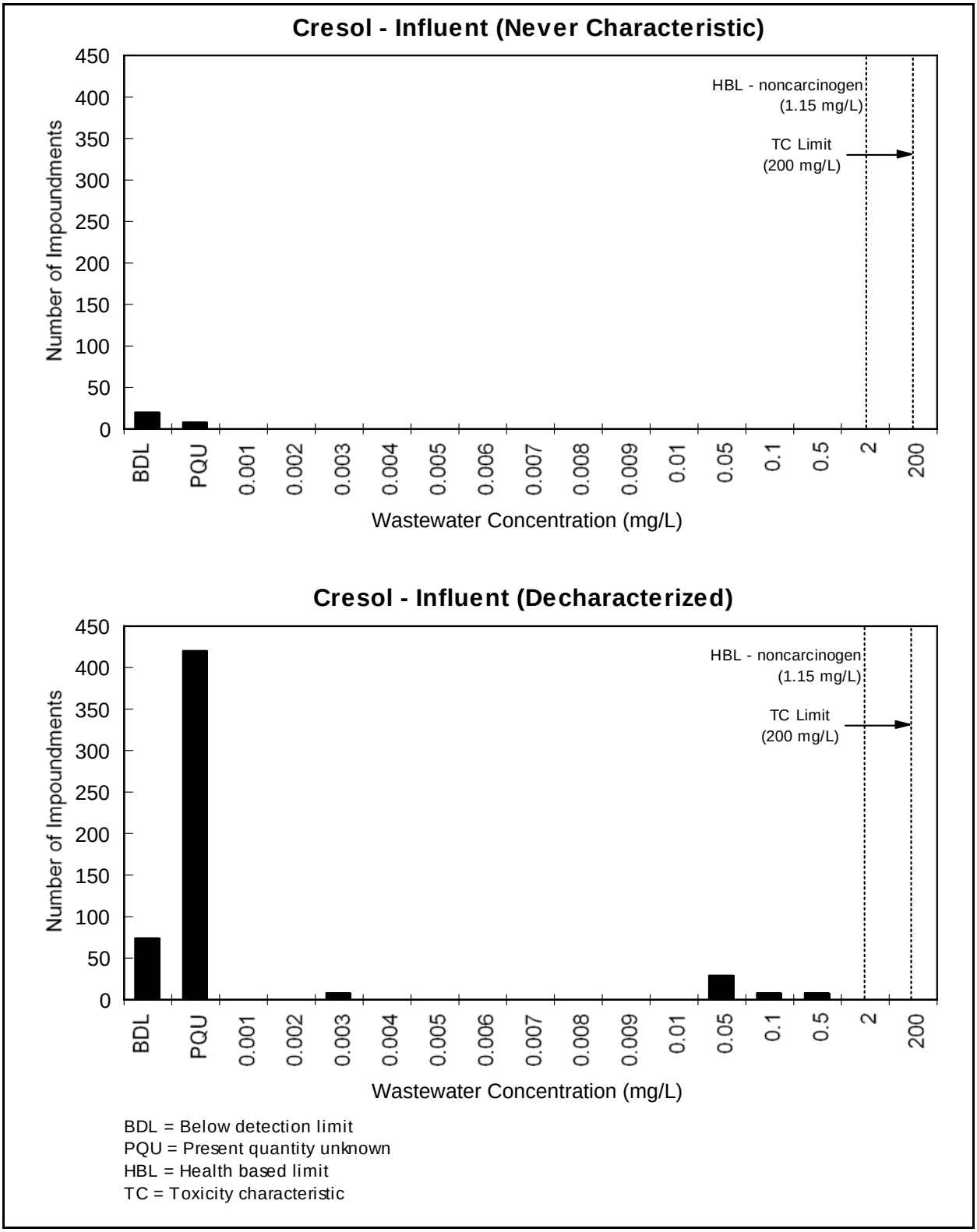


Figure B-20. Cresol influent wastewater concentrations by decharacterization status.

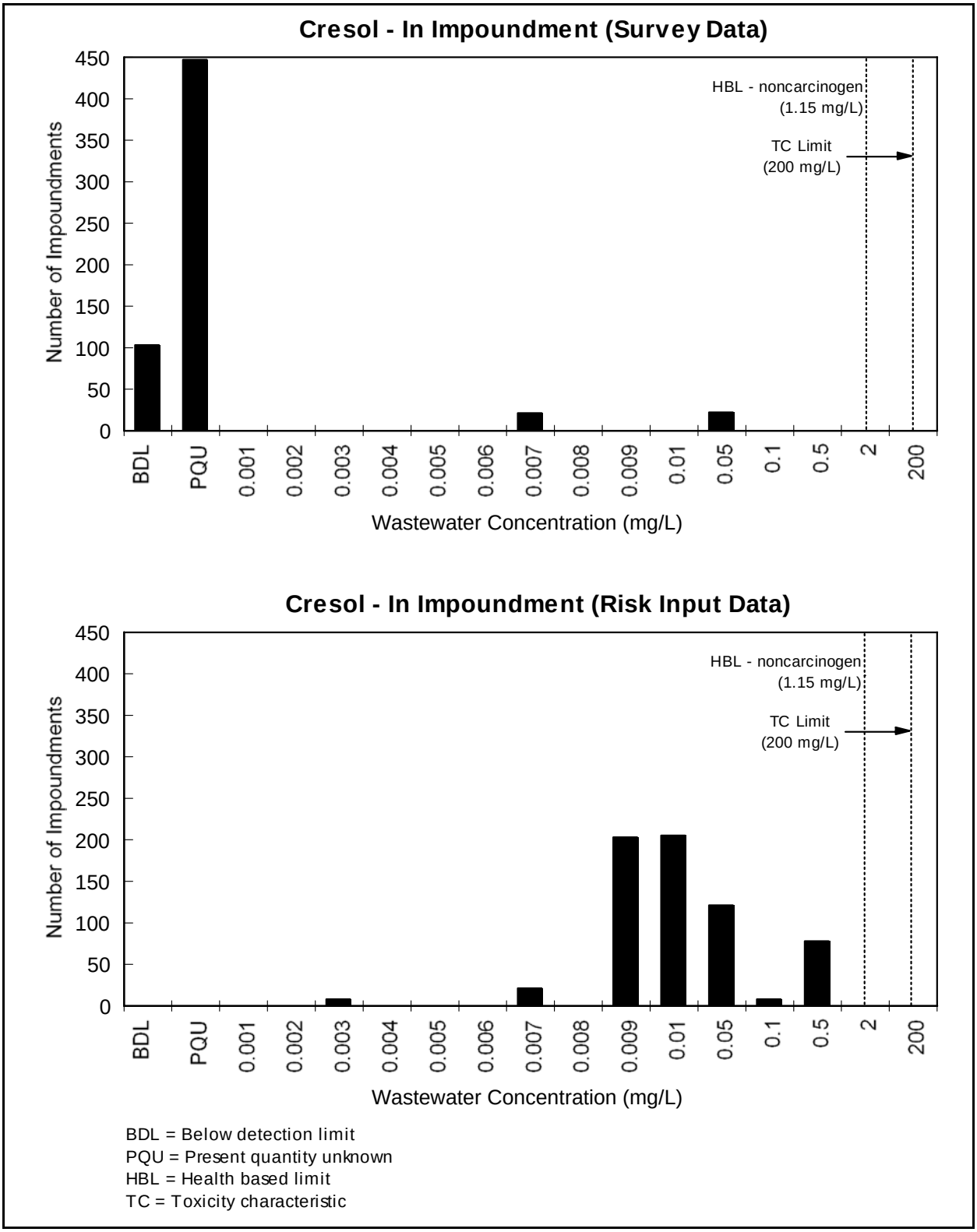


Figure B-21. Cresol wastewater concentrations in impoundment (survey data vs. risk input data).

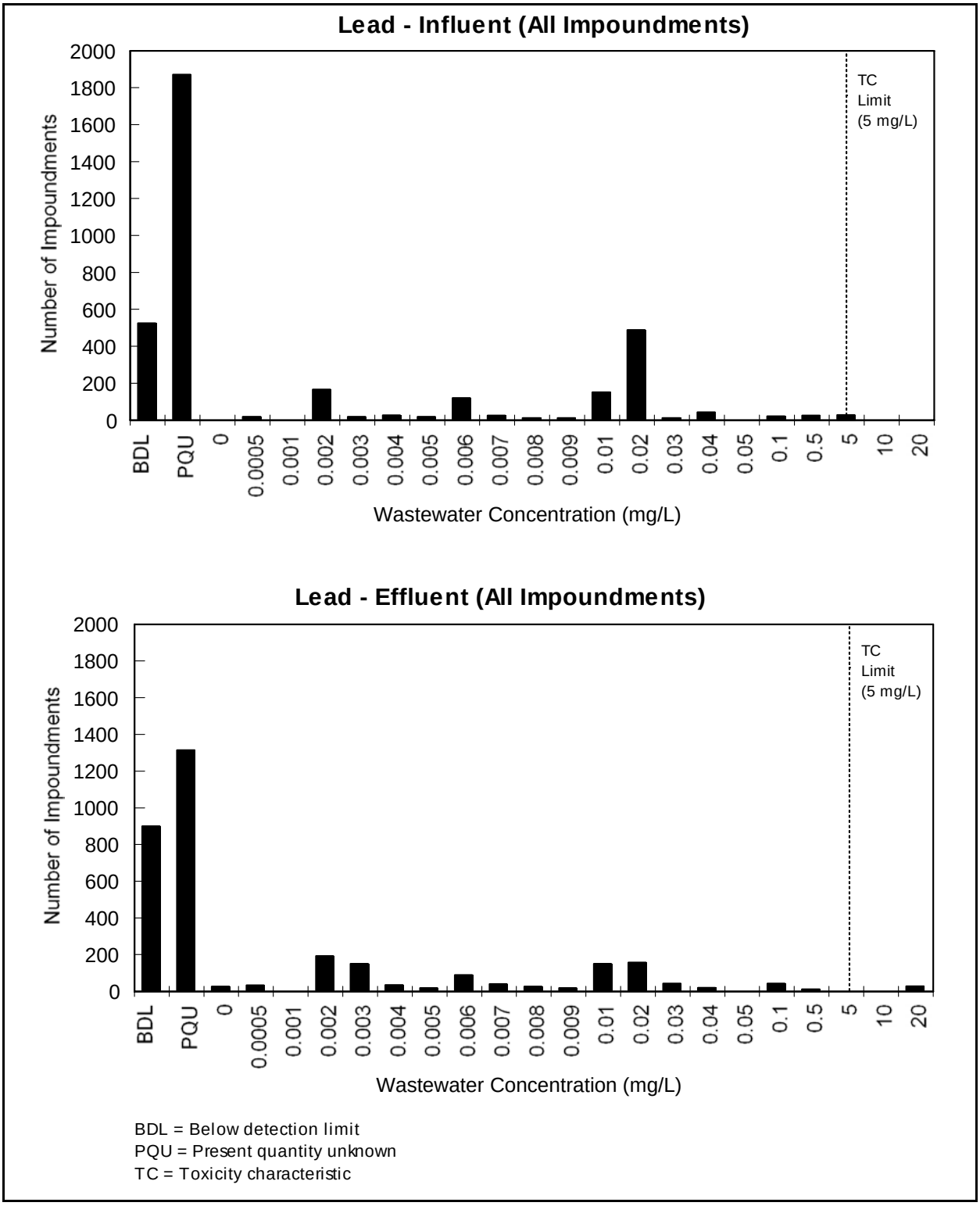


Figure B-22. Lead influent and effluent wastewater concentrations.

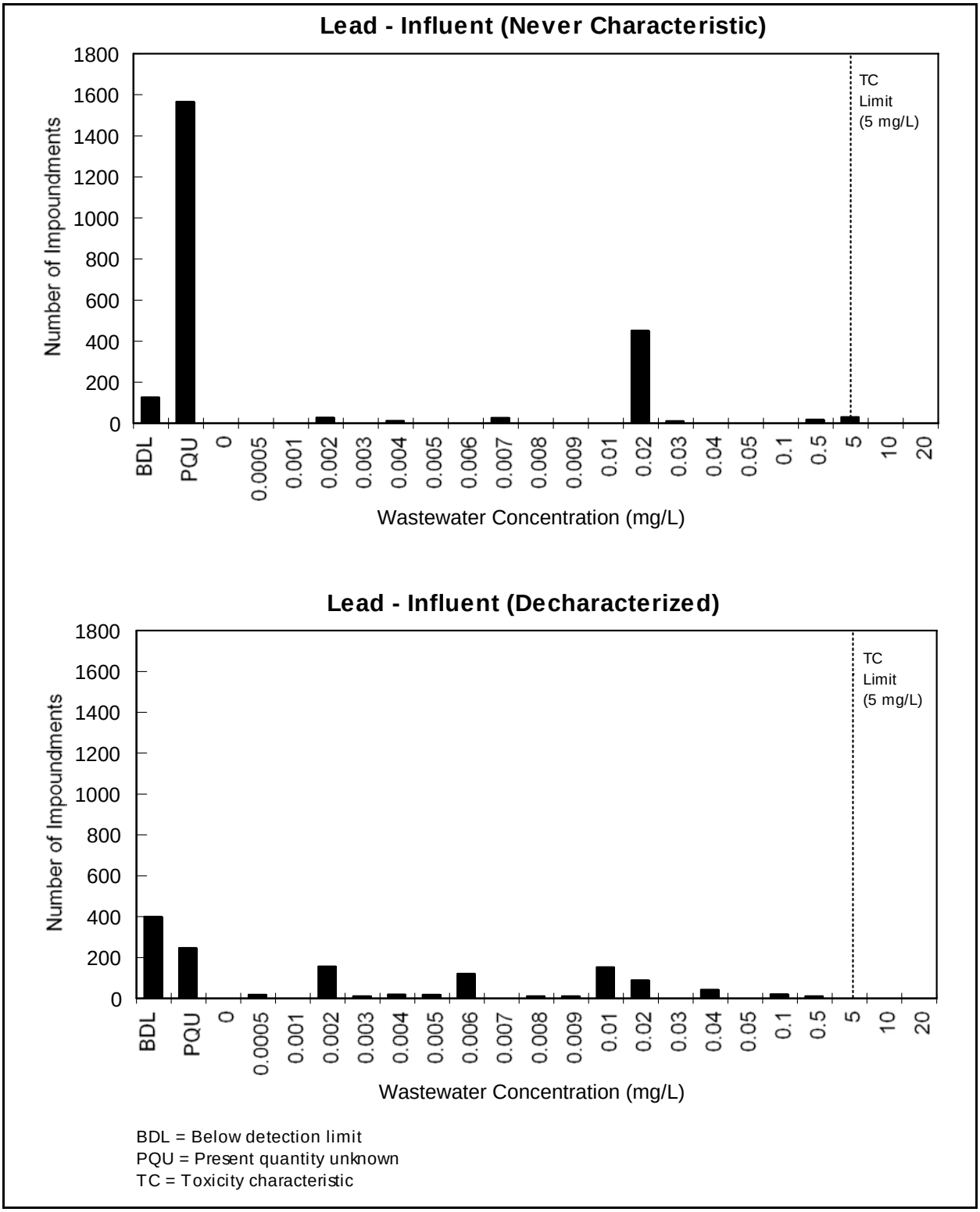


Figure B-23. Lead influent wastewater concentrations by decharacterization status.

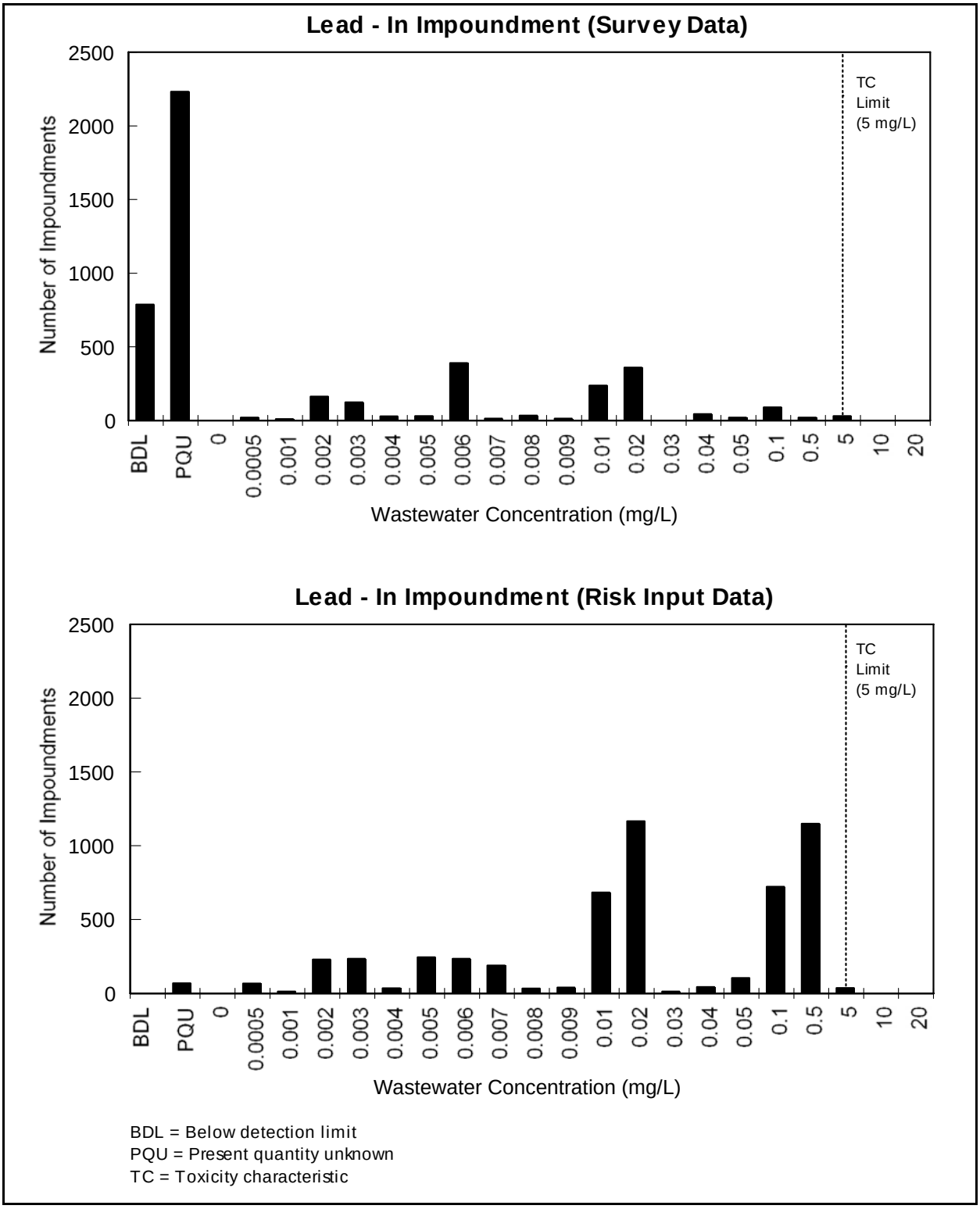


Figure B-24. Lead wastewater concentrations in impoundment (survey data vs. risk input data).

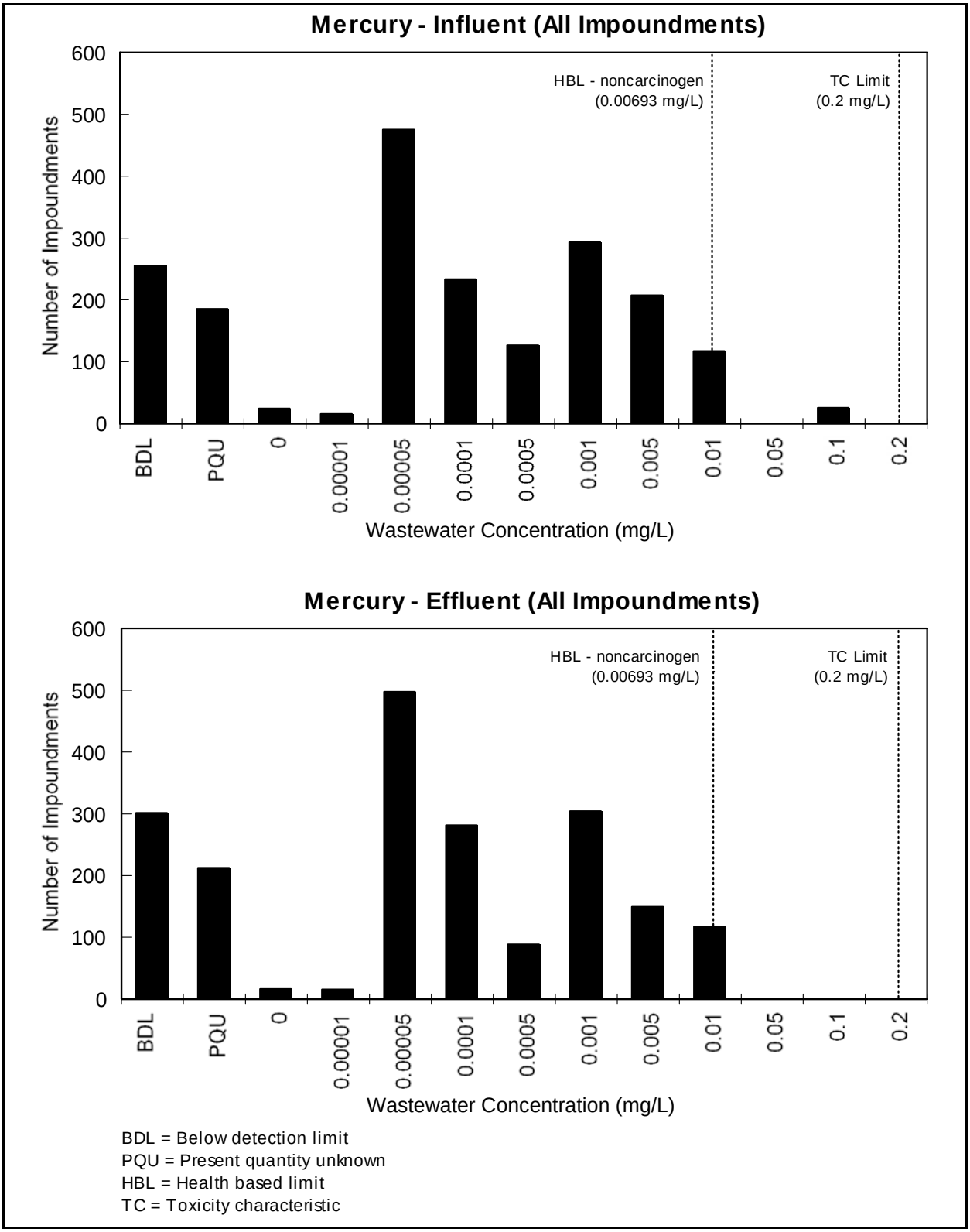


Figure B-25. Mercury influent and effluent wastewater concentrations.

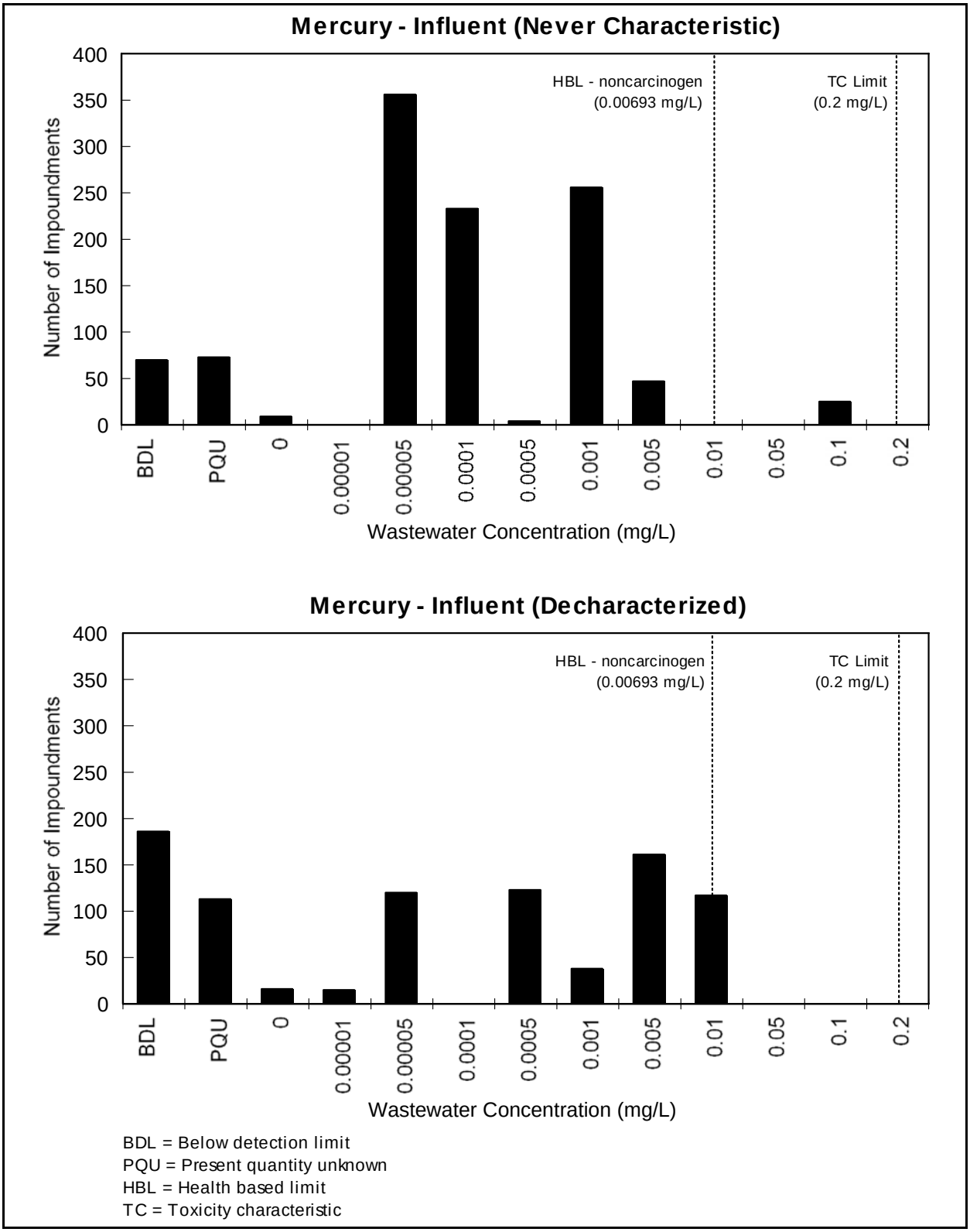


Figure B-26. Mercury influent wastewater concentrations by decharacterization status.

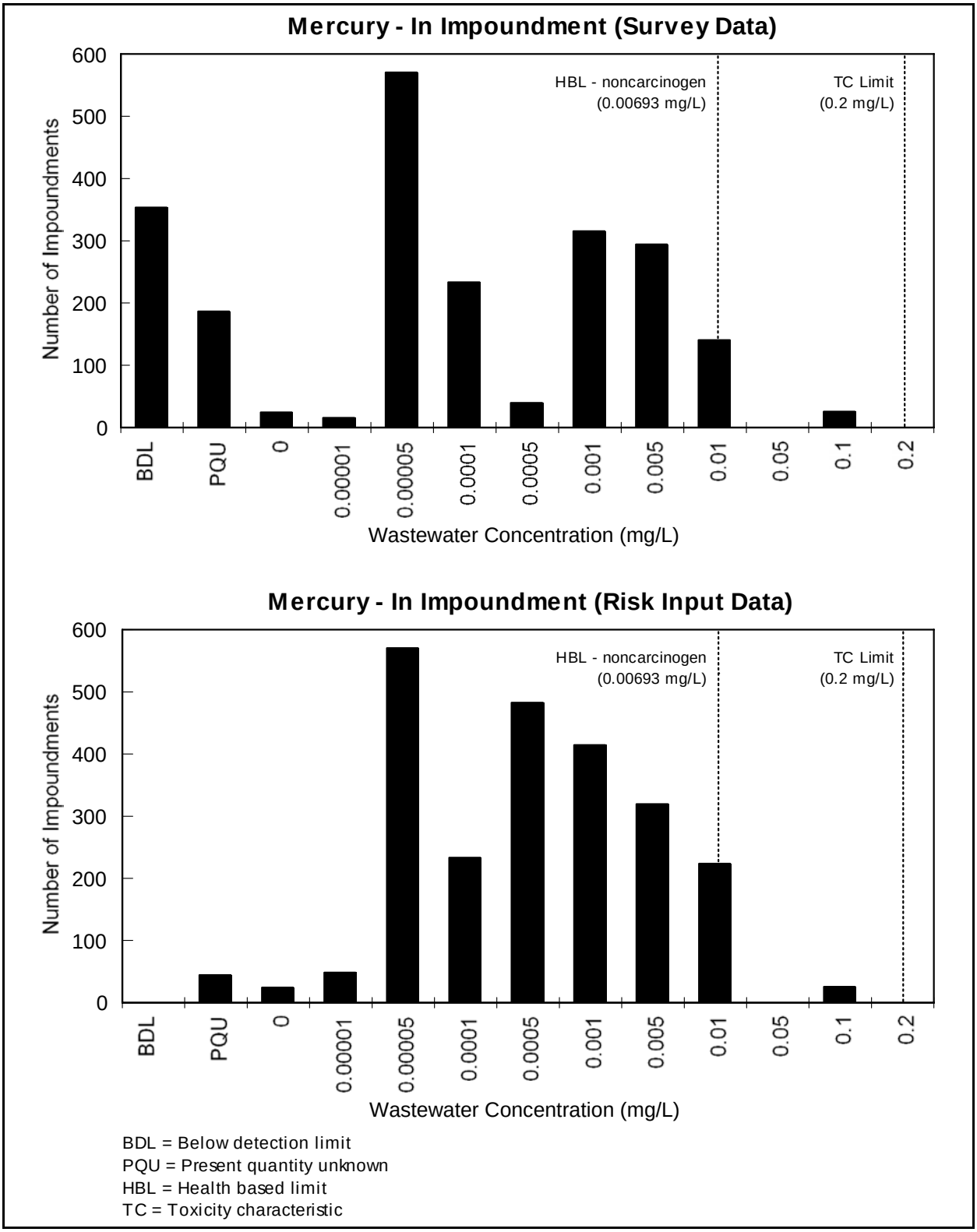


Figure B-27. Mercury wastewater concentrations in impoundment (survey data vs. risk input data).

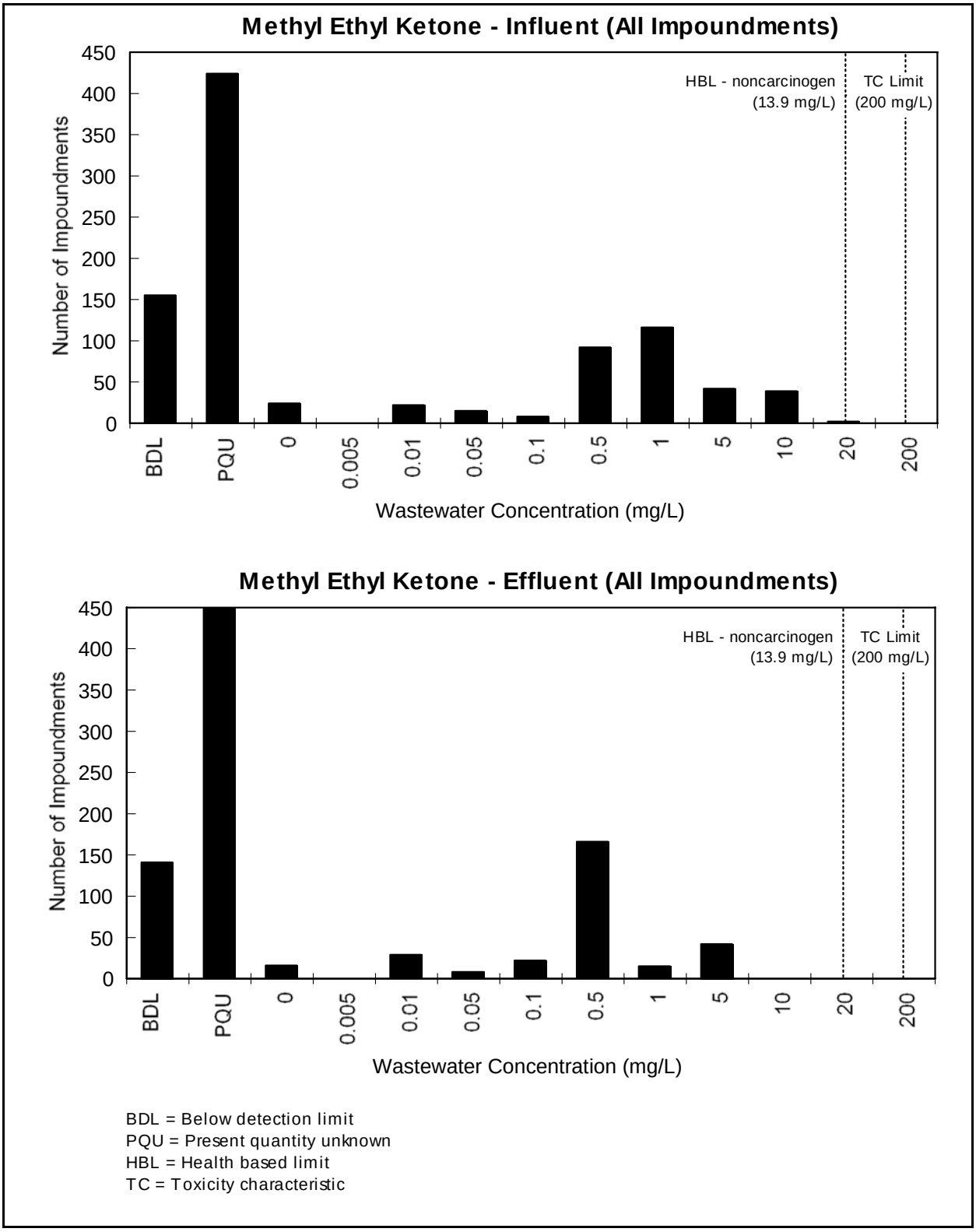


Figure B-28. Methyl ethyl ketone (MEK) influent and effluent wastewater concentrations.

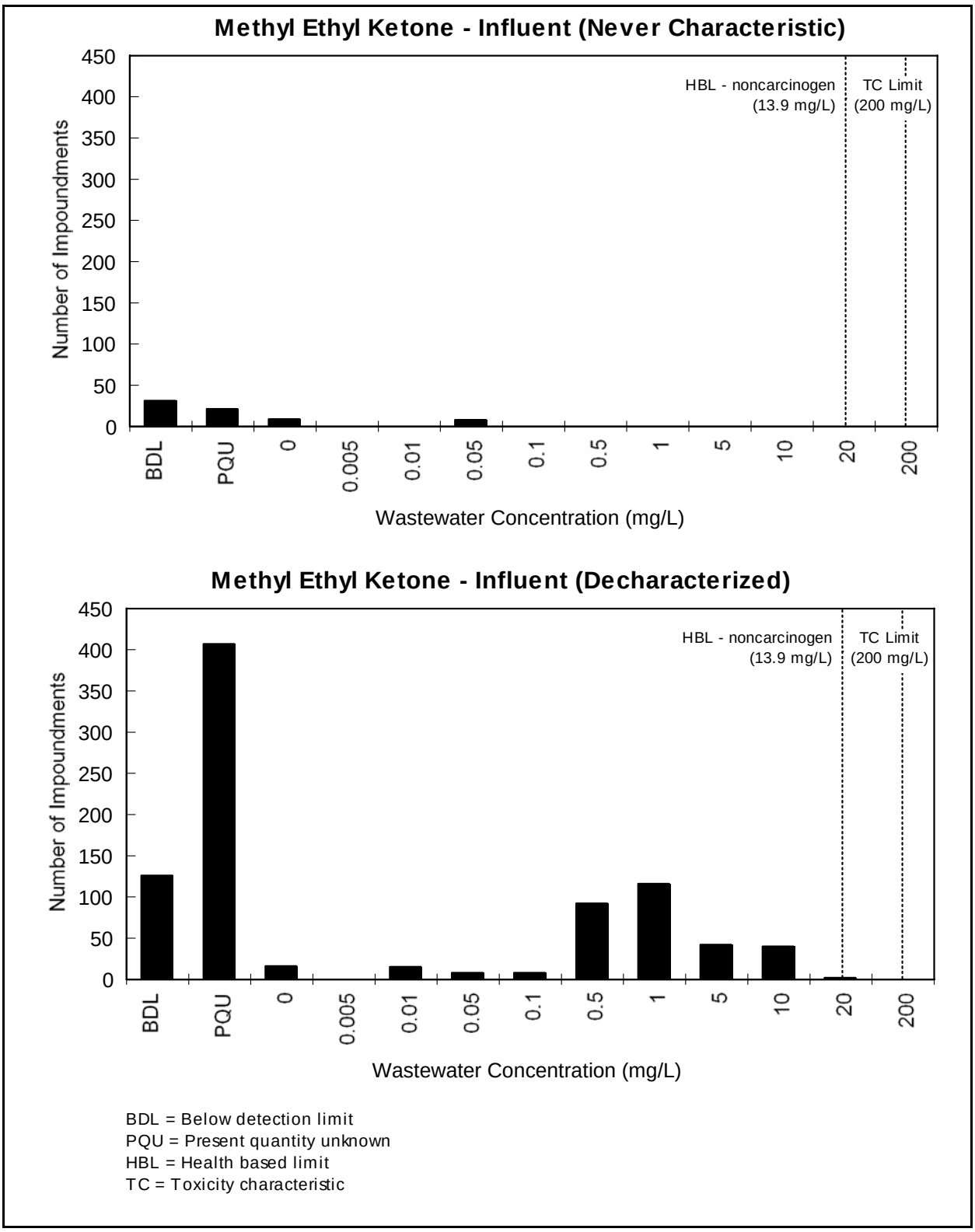


Figure B-29. Methyl ethyl ketone (MEK) influent wastewater concentrations by decharacterization status.

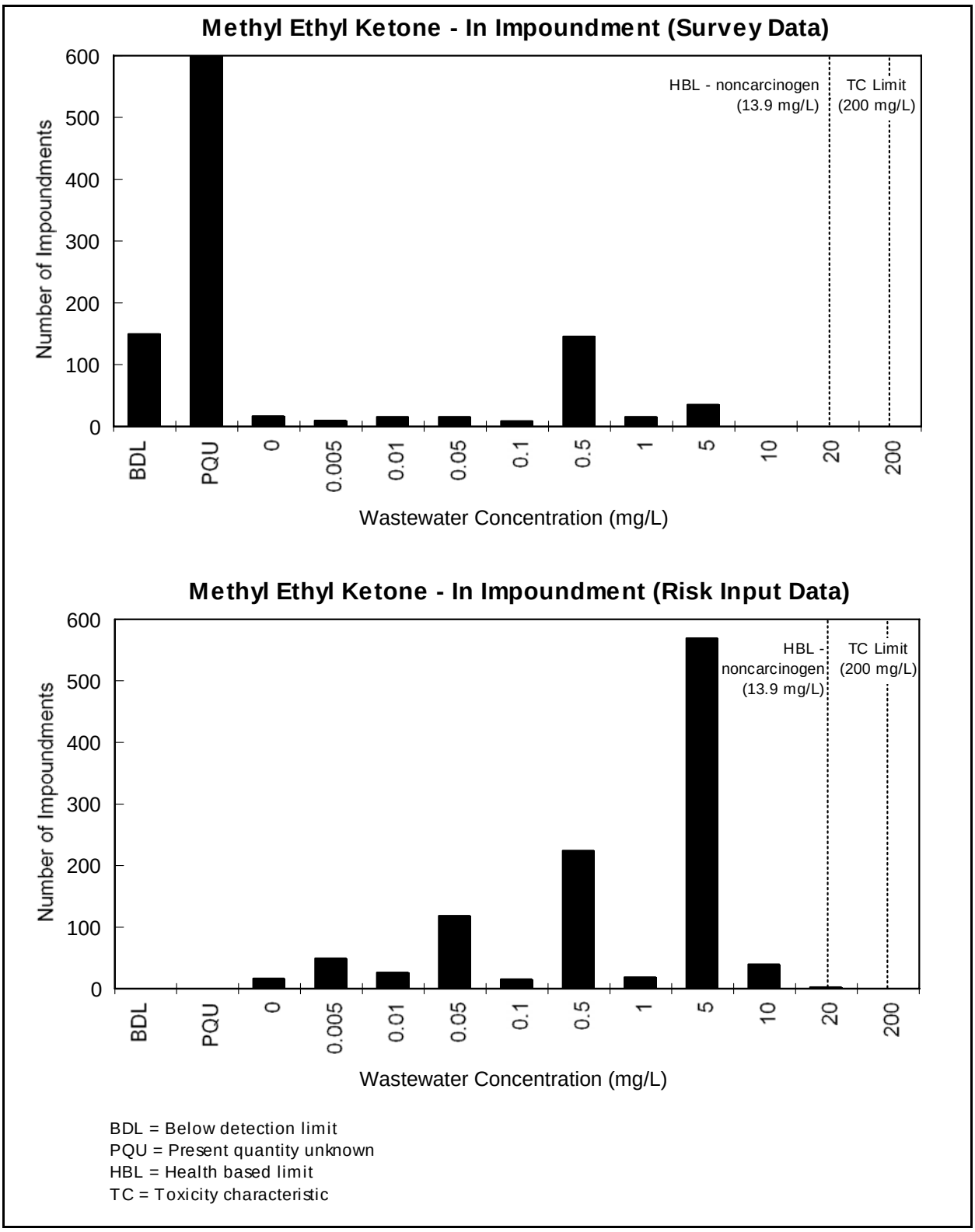


Figure B-30. Methyl ethyl ketone (MEK) wastewater concentrations in impoundment (survey data vs. risk input data).

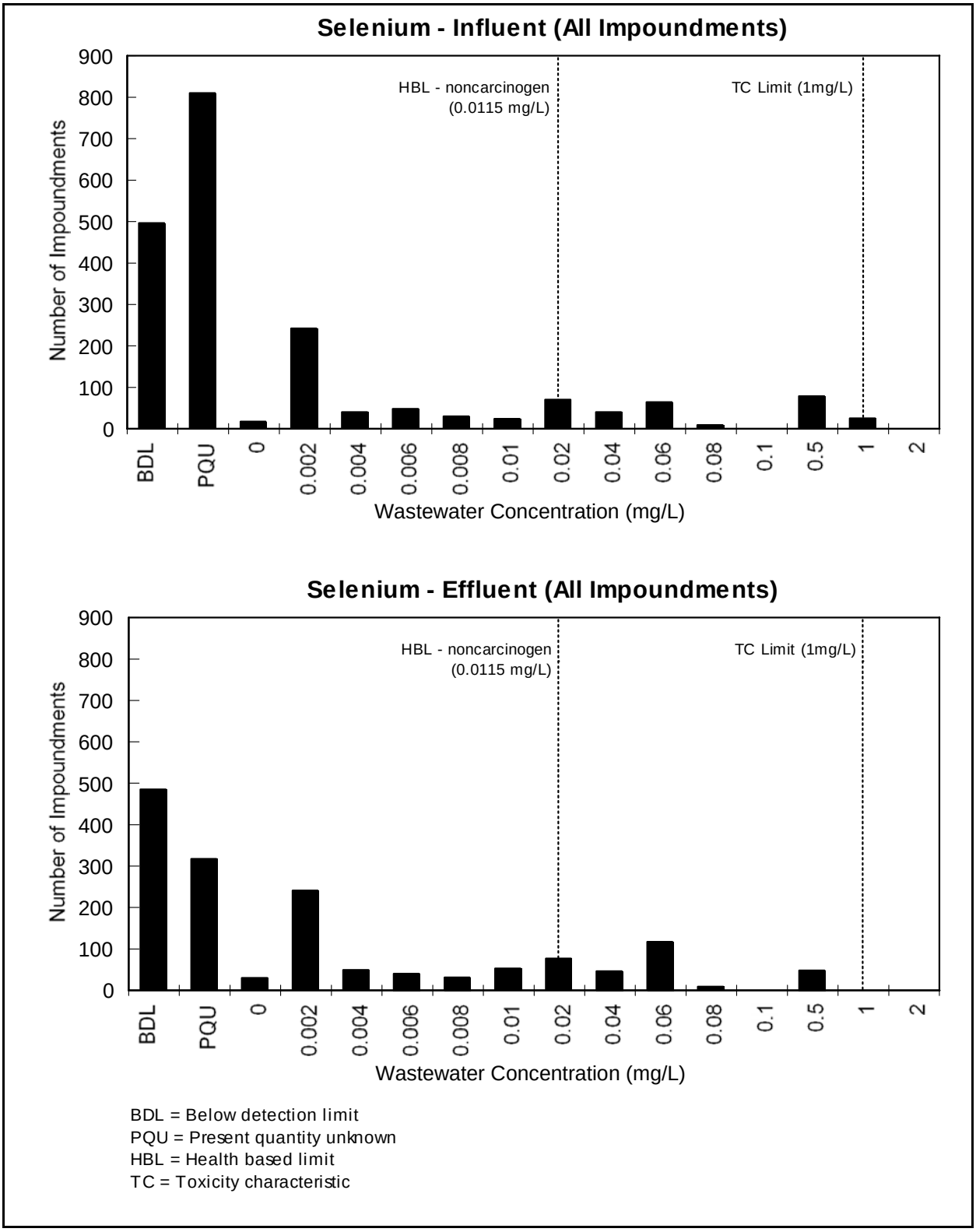


Figure B-31. Selenium influent and effluent wastewater concentrations.

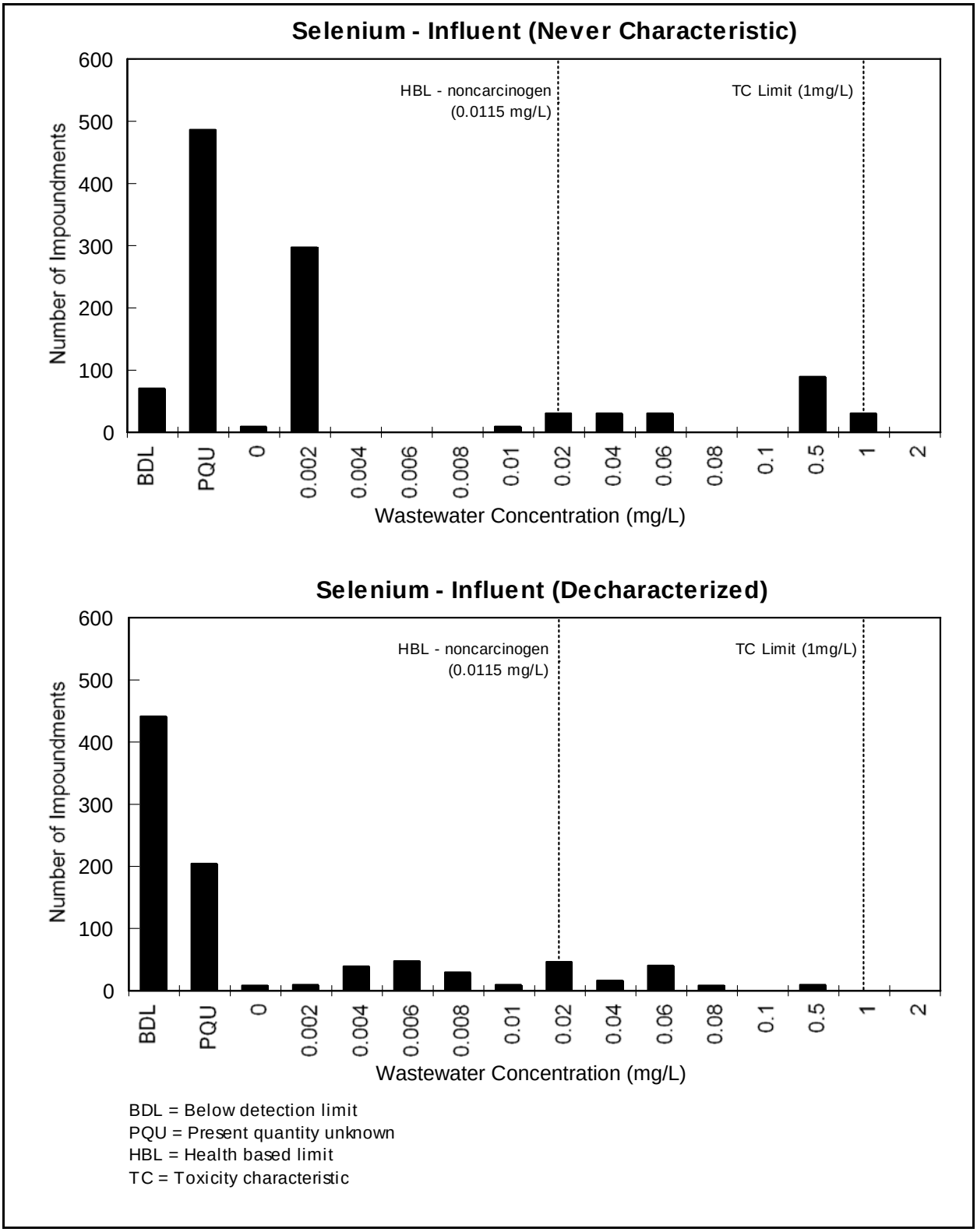


Figure B-32. Selenium influent wastewater concentrations by decharacterization status.

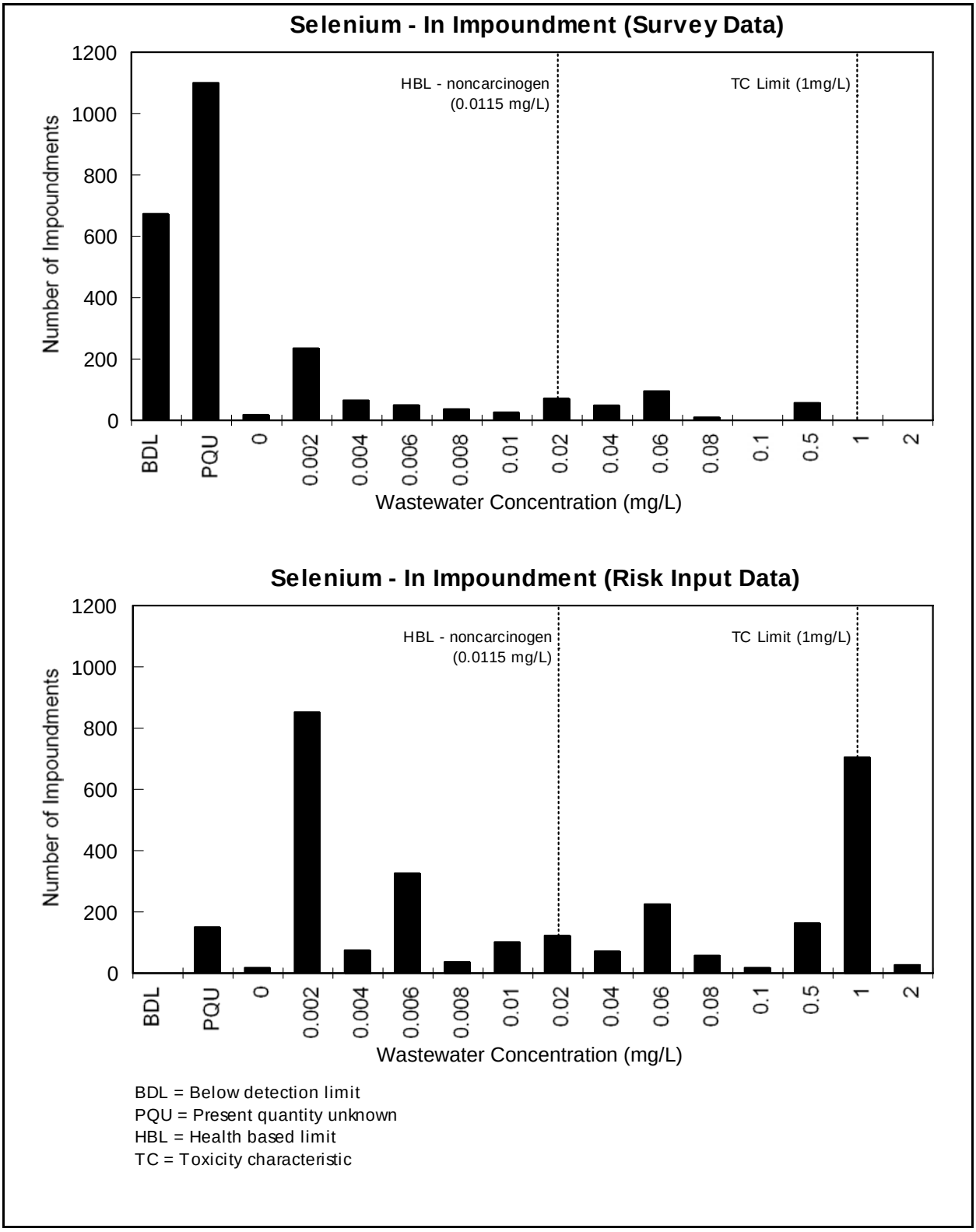


Figure B-33. Selenium wastewater concentrations in impoundment (survey data versus risk input data).

Appendix C

Risk Assessment Methodology and Results

Contents

Appendix **Page**

Contents (continued)

Attachments

Due to the volume and format of the information in the attachments, they are reproduced in electronic form and are available from EPA's RCRA Information Center.

Appendix C

Risk Assessment Methodology and Results

C.1 Appendix Overview and Discussion of Results

The purpose of this appendix is to present the tiered risk assessment methodology developed by EPA to characterize the risks associated with chemical constituents managed in surface impoundments considered in this study. This appendix builds on Chapter 3 of the study report, and provides an in-depth description of the methodology, assumptions, models, data sources, results, and uncertainties involved in this assessment. As appropriate, this appendix includes elements of the approach and terminology proposed in the *Surface Impoundment Study Technical Plan for the Human Health and Ecological Risk Assessment* (U.S. EPA, 2000c), referred to hereafter as the *Technical Plan*.

Appendix C is organized in six major sections. Section C.1 provides an overview of the methodology and a crosswalk between the tiered risk assessment conducted for the Surface Impoundment Study (SIS) and the two-phased risk assessment approach described in the Technical Plan. This section begins by summarizing the key results from this analysis and presents a discussion of key uncertainties that are relevant to any of the pathways for which quantitative risk results were predicted. In addition to an overall presentation of methods and results, Appendix C.1 presents a methods summary, key results, and a discussion of uncertainty for each of the three stages of this assessment: preliminary screen, release assessment, and risk modeling. This first section is organized as follows:

The other major sections of Appendix C include

The major sections provide a detailed description of the methodology, including assumptions, input parameters, and data sources, for each pathway. The discussion of key results and uncertainties for each of these pathways is discussed in Section C.1.1.

C.1.1 Overview

EPA proposed the *Technical Plan* for this assessment in February 2000. That *Technical Plan* was peer-reviewed and largely implemented in the SIS. However, based on an evaluation of the peer review comments, and in consideration of the initial sets of risk results from the screening stages of the analysis, EPA modified the methodology presented in the *Technical Plan.* As the assessment strategy evolved, EPA introduced these modifications to address the peer review comments and to reflect an increasing understanding of the technical risk assessment issues. This section provides a crosswalk with the technical plan that will allow the reader to identify features that were implemented largely as presented in the *Technical Plan* and provides a full description of the methods not covered by the technical plan but added to the assessment to better accomplish the goal of characterizing impoundment risks at a national level.

There are two principal differences between the *Technical Plan* and the tiered risk assessment methodology used to produce the national risk estimates presented in Chapter 3. First, EPA determined that the level of resolution offered by the release assessment (referred to as Phase IB in the *Technical Plan*) was insufficient to winnow down the number of facilities, impoundments, and constituents to be evaluated using a multimedia risk model to a reasonable number (referred to as Phase II in the *Technical Plan*). EPA decided that uncertainty in the results from the release assessment could be greatly reduced by conducting additional modeling using currently available peer-reviewed modeling tools, such as EPA's Composite Model for Leachate Migration with Transformation Products (EPACMTP). Site-specific data on receptor locations, surface water flow, and other site characteristics were used as input to the risk models to predict pathway-specific risks. Second, EPA determined that the 3MRA model (multimedia, multipathway, multireceptor risk assessment model) selected for Phase II was not sufficiently developed to provide reliable risk estimates within the timeframe for this study. The 3MRA model represents the state-of-the-science in multimedia modeling at EPA; however, EPA is currently evaluating peer review comments on the beta version of that model, and the subsequent version that addresses those comments would be a much more appropriate tool for this national assessment. The Phase II multimedia modeling plan was integrated with the prioritization scheme to identify facilities indirect pathway modeling as described in the *Technical Plan* (referred to as Phase IC). This integration produced a risk modeling approach that made full use of available site data to rank facilities for additional modeling and used peer-reviewed models to evaluate facilities that exceeded risk criteria during the release assessment for direct exposure to groundwater and air and indirect exposure through the groundwater to surface water pathway. For the assessment of other indirect exposure pathways, EPA developed a series of criteria based on a variety of data sources (including the survey responses) and created a numeric ranking of facilities according to their potential for completion of indirect exposure pathways such as the farm food chain. This integrated approach, referred to in this section as the Phase IC/II approach for a convenient reference to the *Technical Plan*, is described in substantial detail in Sections C.2 through C.5 of this appendix. Table C.1-1 provides a crosswalk between

Table C.1-1. Risk Assessment Methodology—Crosswalk with *Technical Plan*

Analysis Stage	SIS Approach	*Technical Plan* as Proposed	Modifications to *Technical Plan*
Preliminary Screen	• Based on health and ecological screening factors • Cumulative risks summed across pathways for each facility • Direct exposure to air • Direct exposure to groundwater • Includes human health and ecological risk • Indirect exposure through groundwater to surface water pathway • Facilities and impoundments that exceed risk criteria progress to **release assessment** • Constituents lacking adequate data to estimate an air concentration progress to **release assessment** for air	• Referred to as **Phase IA** • Based on health and ecological screening factors • Cumulative risks summed across pathways for each facility • Direct exposure to air • Direct exposure to groundwater • Direct exposure to sludge • Includes human health and ecological risk • Facilities and impoundments that exceed risk criteria progress to **Phase IB** for human health • Subset of facilities and impoundments that exceed risk criteria progress to **Phase II** for ecological risk	• Added methods to evaluate groundwater to surface water pathway by comparing leachate concentrations to ambient water quality criteria • Ecological risks were not evaluated beyond the preliminary screen • Direct exposure to sludge was considered but, due to the high uncertainty in modeling a postclosure scenario, the sludge exposure pathway was not modeled and only looked at in the indirect exposure pathway screening • Virtually all volatile and semivolatile constituents progressed to the **release assessment** for air due to a lack of suitable data to derive an air concentration
Release Assessment	• Based on human health screening factors • Cumulative risks summed within pathway for each facility • Screening-level modeling using IWEM for groundwater • Screening-level modeling using IWAIR for air • Dilution attenuation factors used to estimate groundwater concentration delivered to surface water • Facilities, impoundments, and constituents that exceed criteria progress to **risk modeling**	• Referred to as **Phase IB** • Based on human health screening factors • Cumulative risks summed within pathway for each facility • Screening-level modeling using groundwater screening model • Screening-level modeling using air screening model • Facilities, impoundments, and constituents that exceed criteria progress to **Phase II** for human health	• Added methods to compare estimate of groundwater concentration to ambient water quality criteria

continued

Table C.1-1 (Continued)

Analysis Stage	SIS Approach	*Technical Plan* as Proposed	Modifications to *Technical Plan*
Risk Modeling	• Cumulative risks summed within pathway and across impoundments for each facility • Ranking methodology developed to identify priority sites for groundwater modeling • Monte Carlo simulation using EPACMTP, and exposure/risk model used for groundwater pathway • Modeling for air pathway conducted using IWAIR at actual receptor distances • Ranking methodology developed to identify priority sites for surface water modeling • Modeling (screening) for surface water pathway using EPACMTP for infiltration rate and simplistic surface water dilution algorithm • Facilities that manage bioaccumulative chemicals identified for indirect exposure evaluation • Methodology developed to rank facilities according to their potential for complete indirect exposure pathways	• Referred to as **Phase II** • Cumulative risks summed within pathway and across impoundments for each facility • Prioritization of facilities that manage bioaccumulative chemicals referred to as **Phase IC** • Identified 3MRA model (multimedia, multipathway, multireceptor risk assessment model) to increase resolution of direct pathway modeling and to predict indirect pathway risks	• Referred to as **Phase IC/II** in the Section C.1.1 • Referred to as **risk modeling** in Chapter 3 • **Phase II** in the *Technical Plan* replaced by - direct exposure pathway risk modeling - indirect exposure pathway risk modeling for surface water - ranking scheme for indirect exposure pathway potential • **Phase IC** in the *Technical Plan* replaced by - ranking methodologies to identify additional sites for risk modeling for both direct and indirect exposure pathways

the *Technical Plan* proposed by EPA and the tiered risk assessment approach described in Chapter 3.

C.1.1.1 Methods Summary. As shown in Table C.1.1, EPA designed an analytical framework that progressed from precautionary screening stages to more realistic, site-based modeling using peer-reviewed simulation models. EPA used several different measures of chronic risk and hazard in the risk assessment. Cancer risks were expressed as individual lifetime excess probability of cancer; a threshold of 1 in 100,000 was used as the criteria for determining whether a constituent posed a risk of concern. The hazard associated with exposure to noncancer constituents was measured using a hazard quotient (HQ). The HQ is the ratio of the estimated exposure concentration to an EPA reference dose (RfD) for ingestion or reference concentration (RfC) for inhalation. RfDs and RfCs are threshold measures of hazard that are set at a level that EPA has estimated will not result in adverse effects in humans. The human health threats associated with surface water contamination were evaluated using ratios of estimated surface water concentrations to ambient water quality criteria for human health (HH-AWQC). The screening stages referred to in the technical plan as Phase IA and Phase IB, were based on clear science decision rules related to threshold concentrations of potential concern and low likelihood of exposures. These decision rules allowed EPA to screen out those constituents, impoundments, and facilities presenting negligible potential risks and to focus the risk modeling efforts on those facilities that may present higher potential risks. EPA used risk criteria of 10^{-5} for carcinogenic risk and HI = 1 for noncarcinogenic risk throughout the analysis. In this report, these stages are referred to as "preliminary screening" and "release assessment," respectively, to provide the reader with more descriptive terms for the risk assessment steps.

The **human health risk screening** of direct pathways consisted of a staged analysis described as a preliminary screen and release assessment. These stages can be summarized as follows:

- The preliminary screen (Phase IA) compared reported constituent concentrations in surface impoundments to concentrations protective of human health (called human health screening factors) for the air pathway and the groundwater pathway. This stage is described in detail in Section C.1.2 of this appendix.

- The release assessment (Phase IB) estimated human health risk levels based on exposure concentrations predicted using screening-level models for the air pathway, the groundwater pathway, and the groundwater to surface water pathway. The Phase IB risk screening was only performed for constituents not eliminated from further evaluation based on Phase IA. This stage is described in detail in Section C.1.3 of this appendix.

The **human health risk screening** of the groundwater to surface water pathway also consisted of a staged analysis described as a preliminary screen and release assessment. Because this pathway analysis was not discussed in the *Technical Plan*, it is described in Section C.4 of this appendix.

- The preliminary screen (Phase IA) compared reported constituent concentrations in surface impoundments to ambient water quality criteria developed for the protection of human health from ingestion of contaminated aquatic organisms and drinking water.

- The release assessment (Phase IB) estimated human health risk levels based on exposure concentrations predicted using screening-level models for the air pathway, the groundwater pathway, and the groundwater to surface water pathway. The Phase IB risk screening was only performed for constituents not eliminated from further evaluation based on Phase IA.

In addition to screening direct exposure pathways and the groundwater to surface water pathway, the **human health risk screening** also involved an assessment of the potential for other indirect exposure pathways to be completed at facilities that manage bioaccumulative chemical constituents. This screening assessment was qualitative and integrated information on site physiography, potential receptors, and impoundment characteristics into a numeric framework to rank facilities according to their potential for concern for indirect exposure. This methodology is based on Phase IC in the *Technical Plan*. It includes chemical-specific evaluations for bioaccumulative potential and a ranking scheme that takes full advantage of several data sources, including the survey responses, geographic information system (GIS) tools, and results from the Phase IB screening analysis. This methodology also borrows from Phase II of the *Technical Plan* in that it seeks to quantify the potential for indirect exposures at the facility level using an array of explicit criteria. Section C.5 of this appendix provides a complete discussion of the methods developed for this study to evaluate indirect pathways.

The **ecological risk screening** consisted of a single stage that parallels the human health Phase IA screening of direct pathways for noncancer chemicals:

- The preliminary screen (Phase I) compared reported constituent concentrations to concentrations protective of ecological receptors in freshwater aquatic, wetland, and terrestrial habitats, (called ecological screening factors). Exposure pathways included direct ingestion of contaminated plants, prey, and media, as well as direct contact with a contaminated medium for certain types of receptors such as soil biota. This assessment is presented in detail in Section C.6 of this appendix.

Based on the results of the release assessment, the **human health risk modeling** of direct pathways and surface water was conducted using peer-reviewed models, such as EPACMTP to develop site-based risk estimates for the air, groundwater, and groundwater to surface water pathways.[1] For the groundwater and groundwater to surface water pathways, EPA determined that the screening risk results were not sufficient justification to perform risk modeling. In many instances, the site characteristics did not support the completion of the exposure pathway. To identify those sites appropriate for risk modeling, EPA developed a series of criteria to rank

[1] The surface water modeling is considered a screening-level model and, although the methodology has been peer-reviewed, the approach does not involve modeling tools developed to the same level of sophistication as those used for the air and groundwater pathways.

facilities based on site attributes relevant to completion of a given pathway. For example, EPA reviewed technical reports on groundwater hydrology submitted by the survey respondents as input to a numeric ranking scheme. For each site, the available information on the stratigraphy (the composition of subsurface layers) and the location of receptor wells was assigned a numeric score for ranking purposes. Once this ranking was completed, EPA evaluated the potential for adverse impacts on water quality from the groundwater to surface water pathway for all of the highest ranked facilities.

- For the air pathway, EPA used Industrial Waste Air Model (IWAIR) to model risk at the actual location of the nearest receptor, identified using topographic maps and aerial photos. This methodology is described in detail in Section C.2 of this appendix.

- For the groundwater pathway, EPA conducted a Monte Carlo simulation of the fate and transport and exposure to predict the distribution of cancer risks and noncancer hazard, as appropriate, for chemicals of potential concern managed at each facility. This methodology is described in detail in Section C.3 of this appendix.

- For the groundwater to surface water pathway, EPA performed screening risk modeling using a simplified fate and transport construct to predict the surface water concentrations and compared those levels with the ambient water quality criteria. This methodology is described in detail in Section C.4 of this appendix.

C.1.1.2 Key Results of the Analysis. Table C.1-2 illustrates the progression of facilities in the sample population from the risk screening stages through the risk modeling stage.[2] Note that the results in this table are not weighted and that we do not distinguish between concentrations based on reported values and those based on surrogate protocols or detection limits (DLs). This table is intended to show that the analytical framework designed by EPA provided an effective tool for reducing the number of facilities/impoundments/constituent combinations requiring risk modeling. Notice that, at each stage, fewer facilities and impoundments enter the subsequent stage. For example, of the 71 facilities that exceed the risk criteria, only 10 facilities entered into the risk modeling stage; of these 10 facilities, only 7 facilities show risk exceedances, indicating that the conceptual approach of eliminating facilities from consideration because of very low potential risks is sound. Indeed, the peer review comments on the technical plan were, without exception, supportive of this framework. The results generated at each stage were updated so that the risk modeling results could be integrated with the screening results and ultimately weighted up to present a national risk characterization.

The overall results for the analysis are presented in Tables C.1-3 through C.1-6. Tables C.1-3 and C.1-4 present results at the facility level, and Tables C.1-5 and C.1-6 present results at the impoundment level. This set of tables presents the national risk characterization produced by weighting up the sample population results presented in Table C.1-2. The weighting methodology is described in detail in Appendix A. The tables contain information on the number

[2] This table presents results only for the direct pathways, air, and groundwarter.

Table C.1-2. Summary of Screening Process and Risk Analysis Results for Direct Pathways

Category	Number of Facilities in Sample	Number of Impoundments in Sample	Number of Chemicals in Sample	Number of Impoundment/ Chemical Combos in Sample
In SIS long survey				
Eligible	195	661	215	
With in-scope impoundments	157	531	215	9767
In-scope impoundments with chemical data	133	471	204	9462
Entered direct exposure pathway screening[a]				
Any pathway	133	442	193	8117
Inhalation	85	304	193	3125
Groundwater ingestion	133	436	193	7976
Exceeded risk criterion after direct exposure pathway screening[a]				
Any pathway	116	395	147	4097
Inhalation	85	290	90	2754
Groundwater ingestion	106	350	129	2123
Consider for site-based modeling (exceeded risk criterion after screening-level modeling)				
Any pathway	75	225	92	795
Inhalation	33	75	42	180
Groundwater ingestion-modeled	10	37	36	191
Groundwater ingestion-evaluated but not modeled	61	177	72	484
Exceeded risk criterion after site-based modeling				
Any pathway	15	36	25	74
Inhalation	11	17	11	23
Groundwater ingestion	7	204	15	53

[a] For inhalation, survey data on air concentration needed to perform direct exposure pathway screening were unavailable for most of the facilities. These facilities, impoundments, and chemicals are included here under the following categories: direct exposure pathway screening, exceeded risk criterion after direct exposure pathway screening, and entered screening-level modeling.

Table C.1-3. Facility-Level Overview of Human Health Results by Decharacterization Status

Facility Status	Below Risk Criteria		Environmental Release All Values		Exceeds Risk Criteria [a] All Values		Total	
Never Characteristic [b]	2,031 (46%)		1,410 (32%)		196* (4%)		3,638 (82%)	
	56%	91%	39%	74%	5%*	65%*	100%	82%
Decharacterized [c]	212 (5%)		499 (11%)		107* (2%)		818 (18%)	
	26%	9%	61%	26%	13%	35%*	100%	18%
All facilities	2,244 (50%)		1,909 (43%)		304* (7%)		4,457 (100%)	
	50%	100%	43%	100%	7%	100%	100%	100%

Table key: Number of facilities (% of all facilities).
Row %, Column %.

[a] Results are for groundwater, air, and groundwater to surface water pathways.

[b] Number of facilities (percentages are of the total number of facilities, approximately 4,500).

* This estimate may not be reliable because of a large relative standard error. See Appendix A.5 for details.

Table C.1-4. Facility-Level Overview of Human Health Results by Decharacterization Status—Reported Values and Surrogate/DL Values[a]

Facility Status	Below Risk Criteria		Environmental Release[b] Reported Values		Environmental Release[b] Surrogate/ DL Values		Exceeds Risk Criteria[b] Reported Values		Exceeds Risk Criteria[b] Surrogate/ DL Values		Total	
Never Characteristic	2,031 (46%)		598 (13%)		812 (18%)		196* (4%)		0 (0%)		3,638 (82%)	
	56%	91%	16%	64%*	22%	83%	5%*	83%*	0%	0%	100%	82%
Decharacterized	212 (5%)		330 (7%)		169 (4%)		41* (0.9%)		66* (1%)		818 (18%)	
	26%	9%	40%*	36%*	21%	17%	5%*	17%*	8%*	100%	100%	18%
All facilities	2,244 (50%)		928 (21%)		981 (22%)		237* (5%)		66* (1%)		4,457 (100%)	
	50%	100%	21%	100%	22%	100%	5%	100%	1%	100%	100%	100%

Table key: Number of facilities (% of all facilities).
Row %, Column %.

DL = Detection limit.

[a] Results are for groundwater, air, and groundwater to surface water pathways.

[b] Number of facilities (percentages are of the total number of facilities, approximately 4,500).

* This estimate may not be reliable because of a large relative standard error. See Appendix A.5 for details.

Table C.1-5. Impoundment-Level Overview of Human Health Results by Decharacterization Status[a]

Impoundment Status	Below Risk Criteria		Environmental Release[b] All Values		Exceeds Risk Criteria[b] All Values		Total	
Never Characteristic	5,329 (45%)		3,813 (32%)		202* (2%)		9,344 (79%)	
	57%	88%	41%	70%	2%	51%*	100%	79%
Decharacterized	697 (6%)		1,630 (14%)		193 (2%)		2,520 (21%)	
	28%	12%	65%	30%	8%	49%*	100%	21%
All Impoundments	6,025 (51%)		5,442 (46%)		396 (3%)		11,863 (100%)	
	51%	100%	46%	100%	3%	100%	100%	100%

Table key: Number of facilities (% of all facilities).
Row %, Column %.

[a] Results are for groundwater, air, and groundwater to surface water pathways.

[b] Number of facilities (percentages are of the total number of facilities, approximately 4,500).

* This estimate may not be reliable because of a large relative standard error. See Appendix A.5 for details.

Table C.1-6. Impoundment-Level Overview of Human Health Results by Decharacterization Status—Findings Shown for Reported Values and Surrogate/DL Values[a]

Impoundment Status	Below Risk Criteria		Environmental Release[b] Reported Values		Environmental Release[b] Surrogate/ DL Values		Exceeds Risk Criteria[b] Reported Values		Exceeds Risk Criteria[b] Surrogate/ DL Values		Total	
Never Characteristic	5,329 (45%)		1,703 (14%)		2,110 (18%)		187* (2%)		16* (0.1%)		9,344 (79%)	
	57%	88%	18%	60%*	23%	80%	2%	78%*	0.2%	10%*	100%	79%
Decharacterized	697 (6%)		1,117 (9%)		513 (4%)		54* (0.5%)		140 (1%)		2,520 (21%)	
	28%	12%	44%	40%*	20%	20%	2%	22%*	6%	90%*	100%	21%
All Impoundments	6,025 (51%)		2,820 (24%)		2,623 (22%)		240* (2%)		155 (1%)		11,863 (100%)	
	51%	100%	24%	100%	22%	100%	2%	100%	1%	100%	100%	100%

Table key: Number of facilities (% of all facilities).
Row %, Column %.
DL = Detection limit.

[a] Results are for groundwater, air, and groundwater to surface water pathways.

[b] Number of facilities (percentages are of the total number of facilities, approximately 4,500).

* This estimate may not be reliable because of a large relative standard error. See Appendix A.5 for details.

of facilities in each category (shown as numerical values), the percent of the total weighted population (shown in parentheses), and the percent within each category for both rows and columns. Consequently, the tables may be used to provide insight on total numbers of facilities and impoundments, percentages of the national picture, and percentages within categories of interest such as characterization status.[3] Attachment C-4 to Appendix C presents the complete array of tables, along with standard errors, for characterization status and regulatory classification (direct versus zero dischargers) developed for this analysis.

Table C.1-3 presents the overall results across the three pathways for which risks were quantified—air, groundwater, and groundwater to surface water— with facilities classified according to waste characterization categories. Table C.1-4 presents this same information according to whether the source concentration data were based on reported values or surrogate/DL values. Facilities with even one impoundment that manages formerly characteristic waste were classified under the "decharacterized" category; a facility was grouped under "never characteristic" only if none of the impoundments receive formerly characteristic waste. Notice that the results that are reported as "below risk criteria" are identical between Tables C.1-3 and C.1-4. This is because the "below risk" category was effectively removed from consideration, or screened out, in the analysis, and the focus was on characterizing those results indicating risk criteria exceedances or environmental releases. This same information is presented at the impoundment level in Tables C.1-5 and C.1-6. For the entire series of tables, it is important to realize that the categories of "reported values" and "surrogate/DLs" are mutually exclusive. That is, an impoundment or facility with one or more reported values that falls into the "exceeds risk criteria" or "environmental release" categories contributes only to the results under the reported values column. Also, an impoundment or facility that "exceeds risk criteria" if even one constituent and impoundment is reported only in that category. As discussed throughout this report, EPA regards the reported values as of sufficient quality to support risk findings.

The key findings from this series of tables can be summarized as follows:

- EPA estimates that 7 percent of all facilities may exceed risk criteria for one or more direct pathways and/or the groundwater to surface water pathway. The majority of results for those facilities are based on reported values; therefore, the risk exceedance estimates are largely based on reported data, not surrogate protocols or detection limits.

- Less than half the facilities (43 percent) were classified in the environmental release category. This percentage is based on the facilities that exceeded criteria after the screening-level modeling *and* did not show exceedances in the risk modeling stage either because (1) the facility was determined to be a low priority for risk modeling or (2) the results from the risk modeling were below levels of concern.

[3] The total percentages shown in the first table of each set will sometimes be slightly higher than the percentages shown in the detailed table with both reported and surrogate/DL concentrations. This is due to the convention adopted for these tables to limit entries to two significant figures. Hence, 19 percent may be shown in the table as 20% and, therefore, the totals do not appear to match exactly.

- The percentage of facilities that may exceed risk criteria is higher than the percentage of impoundments that may exceed risk criteria. Many facilities have multiple impoundments, and this finding suggests that, where risk exceedances occur, they generally include only a subset of the impoundments at the facility. Thus, facilities predicted to exceed risk criteria have proportionally fewer impoundments that exceed risk criteria than the entire group of facilities evaluated in this study. That is, the risk estimates at the impoundment level are below the risk estimates at the facility level.

C.1.1.3 Discussion of Key Uncertainties. This section describes the key uncertainties that EPA identified in the risk characterization of surface impoundments that are relevant to the entire study, regardless of the exposure pathway considered. The discussion is presented in order of importance, beginning with the uncertainties associated with a tiered risk assessment approach, and ending with the background concentrations. Additional pathway-specific discussions of uncertainty are included in Sections C.1.5 through C.1.9.

Uncertainties Associated with the Approach. A tiered risk assessment offers some distinct advantages with respect to the resources required to develop risk estimates across a large population of facilities, impoundments, and chemical constituents. In addition, the a tiered approach allows for the use of all information, both quantitative and qualitative, in characterizing risks. That is, the tiered framework is not constrained by an inflexible list of data requirements. For instance, only 15 of the 69 facilities that were classified under "environmental releases" in the release assessment stage of the analysis progressed to screening risk modeling. Because many of those facilities and impoundments did not exceed the risk criteria (i.e., ambient water quality criteria), EPA concluded that the ranking scheme developed to identify high-priority facilities was successful. Similarly, EPA conducted risk modeling for only 10 of the 71 facilities that exceeded the risk criteria during the screening-level modeling using Industrial Waste Evaluation Model (IWEM). If all 10 facilities that were evaluated during the risk modeling had shown risk exceedances, then EPA might have concluded that the numeric ranking criteria were not protective enough and that additional facilities needed to be modeled. If none of the facilities had shown risk exceedances, then EPA might have concluded that the early screening stages were excessively protective and that the final modeling was, in some cases, unnecessary. However, the final modeling showed that some facilities pose potential risks while others do not, and EPA concludes from this that the first two stages of analysis performed well in that they did not introduce a systematic bias to the risk estimates. EPA also concludes that the third stage served as a useful discriminator of facilities that should be considered to have risks of potential concern.

This logic notwithstanding, there are inherent uncertainties in a tiered approach that introduce uncertainty into the risk estimates. Specifically, it is not possible to determine with absolute certainty that the predicted risks for facilities that were *not* assessed in the risk modeling would not exceed risk criteria if they were modeled. Consequently, there is uncertainty with respect to our ability to identify all potential risk exceedances. However, given the relatively low level of risk exceedances for reported values (approximately 5 percent), and the apparent effectiveness of the ranking schemes developed for the groundwater and groundwater to surface

water pathways, respectively, it appears that the uncertainty in missing false positives (i.e., facilities that may exceed risk criteria but were not modeled) is low.[4]

Source Concentration Data. One of the most sensitive parameters in risk modeling is the source concentration term. Frequently, this term is associated with a high level of uncertainty because (1) the data on concentration may not be sufficient to characterize the variability due to changing waste streams, impoundment conditions, and other characteristics; and (2) the analytical methods may be insufficient to quantify the concentration term, so there is a lack of knowledge as to what the actual concentration might be or which chemicals are actually managed in given impoundment. The former has serious cost implications for industry because the reporting requirements to capture the entire picture of concentration variability would be prohibitive. The latter also has cost implications in that analytical packages with lower detection limits tend to be more costly. However, this may be a serious source of uncertainty because it is not known whether a chemical concentration reported as "below the detection limit" is slightly below the limit, 3 orders of magnitude below the limit, or simply an artifact of the sampling/analysis package chosen by a particular facility. To investigate the uncertainty in the source concentration data extracted from the survey responses, EPA conducted field sampling and analysis of a subset of facilities that received the survey. EPA evaluated the potential risks for direct exposure pathways using the sampling data, and compared those results to the results based on survey responses; these responses included reported detection limits or default detection limits if none were reported. Appendix E describes the field sampling and analysis program, including the methodology for sampling and a comparison of results to the survey data. The following discussion summarizes that approach and discusses the implications of the findings.

An Example of Sampling Data Indicating the Presence of Chemical Constituents

A facility reported no in-scope chemicals in their survey response, so were classified as not having an in-scope impoundment. No risk modeling was performed on this facility based on survey data.

The sampling program detected concentrations of 10 chemicals at this facility: 9 metals and 1 inorganic. None of these constituents are volatile, so air modeling was not conducted. However, groundwater modeling was conducted using sampling data. All but one metal (arsenic) screened out in the direct exposure pathway screening, and arsenic screened out at the screening-level modeling (assuming no liner, since actual liner data were not provided in the survey response).

Therefore, based on the sampling data, this facility would be classified as below risk criteria.

Risk Screening Approach. Risk modeling for the direct pathways (air and groundwater) was conducted on the sampling data, using the same methodology described in Section C.1.1.1.

[4] It was not necessary to develop a ranking scheme to identify facilities for risk modeling of the air pathway. Because of the limited number of facilities that exceeded risk criteria in the air release assessment, and because of the computational speed of IWAIR, EPA decided to model all facilities indicating the potential for environmental releases.

At each stage, some impoundment-chemical combinations dropped out, and the remainder progressed to the next stage. For groundwater, EPA conducted a preliminary screen (Phase IA) and release assessment (Phase IB) and compared the results for each facility to those obtained with the survey data at the conclusion of screening-level modeling. Site-based risk modeling was not conducted for groundwater for the sampling data. For air, the sampling data did not include the appropriate data for conducting a preliminary screen (this step requires air emissions or air concentration data, which were not obtained in the sampling program). Therefore, we conducted screening-level modeling and site-based risk modeling (as needed) for air. Because the sampling data represent a small subset of the facilities surveyed (12 of 195), national weights were not applied to these results.

Risk Results Using Sampling Data. None of the sampling data risk results exceeded the risk criteria; most of the risk results fell below the risk criteria, although a few qualify under the environmental release category. Table C.1-7 shows the impoundments with environmental releases for either air or groundwater based on the sampling data in contrast to the survey-based results for these impoundments. In all cases, the sampling-based risk result is the same or below the survey-based result.

Table C.1-7. Impoundment-level Results Comparison for Environmental Releases Based on Sampling Data

		Groundwater		Air	
Facility	**Impoundment**	**Survey-based Result for Impoundment**	**Sample-based Result for Impoundment**	**Survey-based Result for Impoundment**	**Sample-based Result for Impoundment**
6	2	Environmental release	Environmental release	Environmental release	Environmental release
68	2	Environmental release	Environmental release	Below risk criteria	Below risk criteria
135	1	Environmental release	Environmental release	Below risk criteria	Below risk criteria
173	4	Environmental release	Below risk criteria	Environmental release	Environmental release

Additional chemical-specific details for the groundwater pathway results that indicated potential environmental releases for the sampling data are presented in Table C.1-8. This table compares the risk results and underlying concentrations based on the survey data with the corresponding results and data from the sampling data. Of these seven impoundment-chemical combinations, five had been modeled based on survey data (although four of those five were modeled based on surrogate data rather than reported data). The sampling concentrations are generally higher than the survey concentrations. Three of the five impoundment-chemical combinations resulted in environmental release using the survey data; two resulted in risks below the risk criterion using survey data. Although all three of the facilities showing environmental

releases using sampling data also had environmental releases using survey data, none of the three was chosen for further evaluation because these facilities were ranked relatively low in the numeric ranking for groundwater risk modeling (see Attachment C-8 for ranking results). As discussed in Section C.3, these factors include environmental setting, hydrogeologic conditions, and direction and distance to receptor wells. In this example, the sampling data results support our results using survey data. As a result, we are confident that the sampling results are not of sufficient concern to merit additional groundwater modeling.

Table C.1-8. Environmental Releases for Groundwater Based on Sampling Data

Facility	Impoundment	Chemical	Survey-based Result	Survey Medium[a]	Survey Concentration (mg/L)	Sampling Medium	Sample Concentration (mg/L)
6	2	Fluoride[b]	Below risk criteria	Leachate	0.26	WW in impoundment	3.5
6	2	Chloroform[b]	Below risk criteria	Leachate	0.053	WW in impoundment	0.71
68	2	Arsenic	Environmental release	Leachate	0.17	WW in impoundment	0.023
135	1	Fluoride[b]	Environmental release	Leachate	3.75	WW in impoundment	11.6
135	1	Benzo(a)pyrene	Not modeled	NA	NA	WW influent	0.046
135	1	Benz(a,h)anthracene	Not modeled	NA	NA	WW influent	0.09
135	1	Arsenic[b]	Environmental release	Leachate	0.0014	WW in impoundment	0.052

NA = Not available.
WW = Wastewater.
[a] All impoundment-chemical concentrations also had wastewater within the impoundment concentrations, which were equal to the leachate concentrations.
[b] Survey result based on surrogate concentration data.

Additional, chemical-specific details for the air pathway results that indicated potential environmental releases for the sampling data are presented in Table C.1-9. This table compares the risk results and underlying concentrations based on the survey data with the corresponding results and data from the sampling data. Risk modeling was not performed for either of these impoundment-chemical combinations for the air pathway using survey data. Nevertheless, EPA conducted site-based modeling on both these impoundment-chemical combinations using actual receptor distances (roughly 1,000 meters in both cases) and obtained risks below the risk criterion, leaving them in the environmental release category.

Table C-1-9. Environmental Releases for Air Based on Sampling Data

Facility	Impoundment	Chemical	Survey-based Result	Survey Medium	Survey Concentration (mg/L)	Sampling Medium	Sample Concentration (mg/L)
6	2	Chloroform	Not modeled	NA	NA	WW influent	0.81
173	4	Chloroform	Not modeled	NA	NA	WW influent	0.071

The risk results comparison between the survey and sampling data suggest that the concentration data reported in the surveys may not constitute a serious source of uncertainty in this assessment. Although there are some differences in the concentrations reported in the sampling program, and some chemicals detected in the sampling program were not reported in the survey,[5] the sampling data do not change the impoundment-level results for any impoundment. Interestingly, the majority of survey-based results for impoundment-chemical combinations showing environmental releases were based on surrogate/DL protocols used to infer chemical concentrations (see Appendix A for a complete discussion of these protocols). Although EPA considers risk results based on surrogate/DL concentration values to be more uncertain, this comparative exercise with the sampling-based risk modeling suggests that the decisions regarding the use of surrogate data worked as intended.

Data Limitations. Virtually every input parameter required for risk modeling is associated with some data limitations and uncertainty. Health and ecological benchmarks, human health and ecological exposure factors and behavior patterns, and environmental characteristics of each site rely on data sources of differing quality and are incomplete to some degree. For example, human health benchmarks for inhalation were not available for all constituents evaluated in this study. The absence of air risk results for these constituents does not imply that there are no significant inhalation risks associated with those constituents or the facilities and impoundments in which they are managed. The absence of air risks for chemicals lacking inhalation benchmarks is a source of uncertainty that cannot be quantified given the current state-of-the science and available data. The implications of missing benchmarks along with other sources of uncertainty are discussed below.

Human Health and Ecological Benchmarks. Sources of uncertainty in toxicological benchmarks include one or more of the following: extrapolation from laboratory animal data to humans or ecological receptors, variability of response within the population of interest, extrapolation of responses at high experimental doses under controlled conditions to low doses under highly variable environmental conditions, and adequacy of the database (number of studies available, toxic endpoints evaluated, exposure routes evaluated, sample sizes, length of study, etc.). Toxicological benchmarks are designed to be protective (i.e., to potentially overestimate

[5] As reported in Appendix A, EPA expected to find chemical constituents not reported in the survey responses in some impoundments because the analytical methods used by EPA included lower detection limits for some chemicals.

risk) because of the uncertainties and challenges associated with condensing toxicity data into a single quantitative expression.

Cancer Slope Factors. Cancer slope factors (CSFs) were derived as the 95 percent upper confidence limit of the slope of the dose-response curve using a linear, no-threshold dose-response model. The cancer slope factor is, therefore, an upper-bound estimate of the cancer risk per unit dose and, for this reason, may overstate the magnitude of the risk. In addition, the use of CSFs in projecting excess individual cancer risk introduces uncertainty stemming from a number of factors, including

- Limited understanding of cancer biology
- Variability in the response of animal models
- Differential response in animal models versus humans
- Difference between animal dosing protocols and human exposure patterns.

A key step in CSF development is high- to low-dose extrapolation. Depending on the model used to fit the data, extrapolations to the low dose range can vary by several orders of magnitude, reflecting the potential uncertainty associated with the cancer slope factor.

Reference Doses and Reference Concentrations. Uncertainty in the toxicological and epidemiological data from which reference doses and reference concentrations are derived is accounted for by applying uncertainty factors. An RfD (or RfC) is "an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime" (U.S. EPA, 2000b). RfDs and RfCs are based on the no observed adverse effect level (NOAEL) or lowest observed adverse effects level (LOAEL) for the most sensitive effect in the most sensitive or most relevant species. A series of standard uncertainty factors are applied to the NOAEL or LOAEL to derive the RfD or RfC. The following uncertainty factors account for areas of scientific uncertainty:

- Intraspecies variation: accounts for variation in sensitivity among humans (including sensitive individuals such as children, the elderly, or asthmatics)

- Interspecies variation: accounts for extrapolating from animals to humans

- LOAEL to NOAEL extrapolation

- Subchronic to chronic: accounts for extrapolating from a subchronic NOAEL or LOAEL to a chronic NOAEL or LOAEL

- Incomplete database; accounts for the lack of data for critical endpoints (e.g., reproductive and developmental).

Uncertainty factors of 1, 3, or 10 are used. The default value is 10; however, an uncertainty factor of 3 may be used, for example, if appropriate pharmacokinetic data (or models) are available. In addition, a modifying factor may be applied to account for additional

uncertainties in accordance with professional judgment. The default value for the modifying factor is 1. All uncertainty factors (UFs) and the modifying factor (MF) are multiplied together to derive the total uncertainty factor (e.g., U.S. EPA, 1994e). Therefore, the RfD (or RfC) is derived using the following formula:

$$RfD = NOAEL/(UF \times MF).$$

The effect of applying uncertainty and modifying factors is to lower the estimate of the reference dose and increase the hazard quotient for a given exposure.

Exposure Factors. The uncertainty in selection of health and ecological exposure factors changes depending on which stage of the risk analysis is considered. For the preliminary screen (Phase IA) and release assessment (Phase IB), screening factors[6] were derived using protective, default values for exposure as discussed in the *Technical Plan*. The default exposure factors for human health are presented in Table C.1-10; because of the number of ecological receptors, the ecological exposure factors are presented in Attachment C-21. For the risk modeling of the air pathway, the default exposure factors for IWAIR are virtually identical to those shown in Table C.1-10 and, as a result, the choice of exposure factors for the inhalation pathway will also tend to overpredict risk. As described in the *Technical Plan*, the IWAIR model is not currently set up to run Monte Carlo simulations, and these protective exposure factors were used. These exposure factors are, by design, protective of human health and wildlife and, therefore, tend to overpredict risk.

Table C.1-10. Exposure Parameter Values Used to Calculate Human Health Risk Screening Factors

Receptor	Inhalation Rate (m^3/d)	Ingestion Rate of Water (L/d)	Ingestion Rate of Soil (mg/d)	Exposure Frequency (d/yr)	Exposure Duration (yr)	Body Weight (kg)
Child < 1	4.5	0.3	ID	350	1	9.1
Child 1-5	7.55	0.7	200	350	5	15.5
Child 6-11	11.75	0.79	50	350	6	30.8
Child 12-18	14	0.96	50	350	7	58.4
Adult Resident	13.3	1.38	50	350	11	71.4

ID = Insufficient data.

In contrast, the risk modeling of the groundwater pathway involved the use of distributions generated by fitting the data summaries in the *Exposure Factors Handbook* (EFH) (U.S. EPA, 1997c, 1997d, 1997e), in most cases by fitting distributions to selected percentiles. It is assumed that little information is lost by fitting to percentiles versus fitting to raw data. Three

[6] See Attachment C-3 for a complete list of human health screening factors, and Attachment C-23 for a complete list of ecological risk screening factors.

standard two-parameter probability statistical distributions (gamma, lognormal, and Weibull) were used in the groundwater pathway simulation. Other statistical distributions are possible (e.g., U.S. EPA, 2000d), but the technique used in this analysis offered considerable improvement over using a lognormal model in all cases.

Although they offer significant improvement in objectivity over visual estimation, goodness-of-fit tests used to determine which statistical distribution to use for a particular parameter are themselves subject to some uncertainty. One area of concern is uncertainty about how the survey statistics in the EFH (U.S. EPA, 1997c, 1997d, 1997e) were calculated. All of the statistics that have been used to assess goodness-of-fit assume a random sample, which may or may not be a valid assumption for EFH data. Specifically, many of the EFH data sources are surveys that, in many cases, do not involve purely random samples. Rather, they use clustering and stratification, primarily for economic reasons. The effect of this uncertainty on the risk modeling results is unknown.

Natural Background Exposures. In certain cases, EPA performs a risk assessment on wastes that contain contaminants that also are present in the environment as a result of both natural processes and anthropogenic activities. Under these circumstances, receptors potentially receive a "background" exposure that may be greater than the exposure resulting from release of contaminants from the waste. For national analyses like this assessment, the inclusion of background concentrations as part of the analysis is not feasible due to the variability of background concentrations nationwide and the lack of data on national background concentrations for each constituent. Although the margin of exposure and risk predicted during the tiered risk assessment may be used to represent the risk attributable to chemicals managed in surface impoundments, the methodology does not allow us to calculate risks or hazards that reflect both impoundment releases and other environmental sources. For instance, the margin of exposure attributable to a particular facility may be below levels of concern; however, in addition to other background exposures, the *total* risk to residents attributed to the facility and other sources of chemical exposure may be above levels of concern. The variability in background exposures is not reflected in this analysis and is considered a source of uncertainty that is not quantifiable in this analytical framework.

C.1.2 Phase IA: Preliminary Screen - Human Health

As described in the *Technical Plan*, the human health risk screening calculation was performed for each constituent in each surface impoundment for each of the in-scope sample facilities. For this phase, the screening risk estimates were constituent-specific cancer risks or hazard indices (HIs) summed across exposure pathways. Cumulative risks were then calculated for each impoundment and each facility and for each constituent (summed over all impoundments at the facility). The cumulative risk estimates were used to build initial risk distributions for the surface impoundments within the scope of the study. Risk distributions were generated by characterization status and regulatory status and divided into cancer risks and noncancer hazard. These risk estimates were used to exclude constituents, impoundments, and facilities from further analysis.

C.1.2.1 Methods Summary. The groundwater ingestion pathway was evaluated whenever wastewater concentrations or leachate concentrations were available. The air inhalation pathway was evaluated if the constituent was a volatile organic chemical (VOC) or a semivolatile organic chemical (SVOC), and airborne chemical concentration or emissions data were provided in the survey. The soil ingestion pathway was considered; however, EPA believed that uncertainties in characterizing the exposure scenario for postclosure were sufficiently high to render the screening risk results of little value. Environmental releases of sludge particles could occur through erosion/runoff or windblown emissions only assuming that: (1) the impoundment was not capped at closure, (2) the impoundment was completely filled with sludge to grade; and (3) no vegetation was allowed to grow on the sludge. This pathway was evaluated, instead, under the indirect exposure pathway assessment described in Section C.5. Once the air and water concentrations were determined from the survey results, the risks were calculated by dividing the concentration by the appropriate health screening factor, and then multiplying by the appropriate risk criterion. If the screening factor was based on a regulatory standard such as a maximum contaminant level (MCL), then the ratio of concentration to the screening factor was calculated. Finally, the constituent risk and HI were calculated by summing the risks and hazard quotients for all pathways for that particular constituent. If the screening for the constituent has used a regulatory standard, then the maximum ratio of all pathways for that constituent was selected.

Concentration data from the facility survey questionnaire provided the direct exposure concentrations for the Phase IA risk estimates. A special condition existed for calculating air inhalation risks from survey data: if the survey questionnaire did not provide an air concentration or emission rate for a VOC or SVOC constituent, the constituent automatically progressed to Phase IB.

Cumulative Risk Calculation. The calculated screening risks for each constituent for a specific impoundment and facility were combined to generate three cumulative risk estimates: impoundment risk, constituent risk, and facility risk. The cumulative risks were used in the risk screening and risk distributions, as described below.

The impoundment risk (i.e., risk for a particular impoundment for a particular facility) was determined as follows:

- For carcinogenic risks, sum risks from all carcinogenic constituents.
- For noncarcinogenic risks, sum the HIs for all constituents potentially affecting the same target organ, then select the maximum HI from the target organ HIs.

The constituent risk (i.e., risk for a particular constituent for a particular facility) was determined as follows:

- For carcinogenic risks, select the maximum risk for the constituent across all impoundments for the particular facility.
- For noncarcinogenic risks, select the maximum HI for the constituent across all impoundments for the particular facility.

Facility risks were calculated as follows:

- For carcinogenic risks, sum the constituent risks.
- For noncarcinogenic risks, sum the HIs from all constituents potentially affecting the same target organ, then select the maximum HI from the target organ HIs.

Note that this approach takes into account that an individual receptor's exposure factors will only be counted once for the entire facility (e.g., 1.4 L ingested per day or 13 m^3 inhaled per day).

Risk Distribution Development. Cumulative frequency histograms of the risks/HIs were developed from the impoundment, constituent, and facility cumulative risks. A risk cumulative histogram was defined by a set of six class intervals or "bins." The carcinogenic risk ranges defining those bins are: 0 to 10^{-8}, 10^{-8} to 10^{-7}, 10^{-7} to 10^{-6}, 10^{-6} to 10^{-5}, 10^{-5} to 10^{-4}, and 10^{-4}. An HI cumulative histogram was defined by six bins: 0 to 0.01, 0.01 to 0.1, 0.1 to 1.0, 1.0 to 10, 10 to 100, and greater than 100. For the nationally weighted risk results, all of the risk results below the risk criteria were aggregated into a single bin; however, the risk data were not aggregated in this manner prior to the application of national weights.

Risk Screening. The Phase IA risk screening used the three cumulative risk distributions to identify

- Constituents, impoundments, and facilities that have risks below a decision criterion and, therefore, are considered to have negligible risks and are not assessed further.
- Constituents, impoundments, and facilities that have risks above a decision criterion and that will be assessed in Phase IB.

The screening procedure first screened facilities by comparing the facility cumulative risk to the risk decision criteria. If the facility had a risk above the screening criteria, then the impoundment cumulative risk for each impoundment for that facility was compared to the screening criteria. If the impoundment had a risk above the screening criteria, then the constituent cumulative risk for that facility was compared to the screening criteria. If the constituent had a risk above the screening criteria, then the constituent passed to Phase IB for further screening. The constituent was further evaluated **only** for those impoundments at the facility that had risks above the screening criteria. The risk screening was performed for both cancer and noncancer risks.

EXAMPLE. Calculating the cumulative risks and risk screening for a facility.

The example facility has the risk estimates shown in Table C.1-11. The first table presents the risk estimates for each chemical in each of the four impoundments.

The second part of the table shows the cumulative facility, impoundment, and constituent risks. The impoundment risk is the sum of the chemical risks for the impoundment; the impoundment HI is the maximum HI of the two target organ HIs. For instance, for Impoundment A, the carcinogenic risk of 3.7×10^{-4} is the sum of Chemicals 1 and 4. The HI of 0.5 is the HI for Target Organ B.

The constituent risks and HIs are the maximum of risks and HI for all four impoundments. For instance, Chemical 1 is detected in Impoundments A, B, and D. Impoundment A has the maximum risk of 3.7×10^{-4} (from Impoundment A).

The facility risk of 3.7×10^{-4} is the summation of all carcinogenic constituent risks (Chemicals 1, 4, and 6). The facility HI of 11.05 is the summation of constituent HIs for target organ A. Specifically, this is Chemical 2 from Impoundment A and Chemical 5 from Impoundment B.

The third part of the table shows the risk screening results for the facility. One impoundment and three chemicals are screened from further assessment at this facility. Three chemicals at three impoundments move on for further assessment in Phase IB.

C.1.3 Phase IB: Release Assessment - Human Health

As described in the *Technical Plan*, the human health risk screening was performed for each constituent in each surface impoundment for each of the in-scope sample facilities that exceeded the risk criteria in Phase IA. As with Phase IA, the screening risk estimates were constituent-specific cancer risks or HIs summed across exposure pathways. Cumulative risks were then calculated for each impoundment and each facility and for each constituent and used to update the Phase IA risk results. Risk distributions were generated by characterization status and regulatory status and divided into cancer risks and noncancer hazard. These risk estimates were used to exclude constituents, impoundments, and facilities from further analysis.

C.1.3.1 Methods Summary. EPA used screening models to supplement the initial screening performed under Phase IA. Use of screening models provided additional characterization of exposure by evaluating the fate and transport of constituents from their release from the surface impoundment through the environmental media to the point of exposure.

Table C.1-11. Example Screening Risks for a Facility

			HI	
Impoundment	**Chemical**	**Risk**	**Target Organ A**	**Target Organ B**
Impoundment A	Chemical 1	3.7E-04		
	Chemical 2		0.05	
	Chemical 3			0.3
	Chemical 4	1e-08		
Impoundment B	Chemical 1	2.0E-05		
	Chemical 3			0.007
	Chemical 4	8.0E-08		
	Chemical 5		11.00	
Impoundment C	Chemical 2		0.0004	
	Chemical 3			0.8
	Chemical 5		0.003	
Impoundment D	Chemical 1	5.0E-12		
	Chemical 6	3e-08		
Cumulative risk		Risk	HI	
Impoundment risk				
	Impoundment A	3.7E-04	0.3	
	Impoundment B	2.0E-05	11.00	
	Impoundment C	-	0.8	
	Impoundment D	3.0E-08	-	
Constituent risk				
	Chemical 1	0		
	Chemical 2		0.05	
	Chemical 3		0.8	
	Chemical 4	8e-08		
	Chemical 5		11	
	Chemical 6	3e-08		
Facility risk		0	11.05	

Risk Screening Results:		
Tier 1	**Facility**	Risk and HI > decision criteria[a]
Tier 2	**Impoundment A**	Risk and HI > decision criteria[a]
	Impoundment B	Risk and HI > decision criteria[a]
	Impoundment C	HI > decision criteria[a]
	Impoundment D	Risk < decision criteria[a]
Tier 3	**Chemical 1**	Risk > decision criteria[a]
	Chemical 2	HI < decision criteria[a]
	Chemical 3	HI > decision criteria[a]
	Chemical 4	Risk < decision criteria[a]
	Chemical 5	HI > decision criteria[a]
	Chemical 6	Risk < decision criteria[a]
Conclusion	Impoundment A: Chemicals 1 and 3 to be assessed in next phase	
	Impoundment B: Chemicals 1 and 5 to be assessed in next phase	
	Impoundment C: Chemical 3 to be assessed in next phase	
	Impoundment D: No further assessment of chemicals 1 and 6; no further assessment at this facility	

[a] Decision criteria: 10^{-5} for cancer risk; 0.1 for noncancer risk.

The Phase IB screening addressed only the major routes of exposure that were expected to contribute significantly to potential risks (i.e., ingestion of drinking water and inhalation of air). However, because constituents from specific units may be screened from further analysis, the Phase IB modeling approach used several precautionary assumptions, such as assessing risks for close-in receptors.

The EPA screening models IWAIR and IWEM, developed for use under the Industrial D guidance, were used to calculate screening risk estimates. These risk estimates replaced the corresponding Phase IA screening risk estimates and, therefore, decreased the uncertainty of the overall screening risk distributions developed in Phase I.

Phase IB Human Health Screening Models. IWAIR and IWEM assess the risks from potential exposure of air and groundwater, respectively, from constituents released from surface impoundments. The screening models, as described below, use different approaches. However, both models provided screening analyses that are useful in characterizing exposure, and both models incorporated additional site-specific data. Despite the difference in modeling approaches, the results from each of the Phase IB models constitute a defensible basis to provide screening-level estimates of risk.

IWAIR. The IWAIR model (U.S. EPA, 1998b) was used to calculate risks due to inhalation of airborne volatile and semivolatile constituents released from surface impoundments. IWAIR incorporates the CHEMDAT8 volatile emission model to calculate the constituent release (i.e., emission rate) from an impoundment, uses dispersion factors developed from Industrial Source Complex Short Term (ISCST3) modeling simulations to calculate an air concentration, uses exposure and risk calculations following EPA guidance (*Risk Assessment Guidance for Superfund,* U.S. EPA, 1989b), and uses a chemical and toxicological database to calculate carcinogenic and noncarcinogenic chronic inhalation risks. CHEMDAT8 has undergone extensive review by both EPA and industry representatives and is publicly available. ISCST3 is another regulatory standard model that has undergone substantial review and use by industry. Dispersion factors for multiple source area sizes, receptor distances, and meteorological conditions are provided.

IWAIR uses the same exposure factors as Phase IA from the *Exposure Factors Handbook* (U.S. EPA, 1997d). An age-weighted resident was considered for carcinogenic chemicals. An adult resident was considered for noncarcinogenic chemicals. Phase IA toxicological benchmarks were used (in place of IWAIR toxicological benchmarks) to calculate screening risks with IWAIR. For SIS constituents that were not included in the IWAIR chemical database, the physicochemical properties from CHEMDAT8 and Phase IA toxicity benchmarks were added to IWAIR to calculate the constituent risks and HIs.

The IWAIR model is computationally fast and easy to use and requires input data on impoundment characteristics and meteorological conditions. The data required were obtained from the survey to the extent possible; these data include constituent waste concentration, impoundment depth, area, annual wastewater flow rate, and whether or not aeration occurs. Default or additional site-specific data were used for aeration

parameters and wastewater parameters important for biodegradation. The data protocols established to populate the data files for IWAIR are described in detail in Attachment C-5 of this appendix.

IWEM. The IWEM Tier 1 (U.S. EPA, 1999c) model was used to calculate the risks due to exposure to groundwater containing constituents released from surface impoundments. IWEM Tier 1 is based on a health-protective Monte Carlo probabilistic analysis that accounts for the nationwide variability of groundwater modeling parameters. The Monte Carlo approach used in EPACMTP and IWEM has been applied in various EPA regulatory efforts, including the proposed 1995 Hazardous Waste Identification Rule (HWIR) and hazardous waste listing evaluations. As such, the Monte Carlo procedure and its applicability to national analyses has been reviewed extensively within EPA and by the Science Advisory Board and has been subject to public review and comment (U.S. EPA, 1999a). The Monte Carlo procedure randomly drew input parameter values from representative statistical distributions for each parameter. A set of input parameter values was developed and the model was run to compute the groundwater monitoring well concentration and the dilution attenuation factor (DAF) at 150 m from the source along the centerline of the plume. This process was repeated thousands of times until a distribution of thousands of output values (DAFs) was produced. The DAF values were ranked from high to low, and the 90^{th} percentile DAF was determined. The 90^{th} percentile DAF represents the amount of dilution and attenuation that would occur in at least 90 percent of the cases modeled. In other words, the DAF is protective in at least 90 percent of the modeled cases. The selection of 90^{th} percentile DAF is based on

- The need to choose a level of protection that is protective and consistent with other EPA analyses, including the proposed HWIR of 1995 (U.S. EPA, 1995b) and hazardous waste listing evaluations (e.g., the Petroleum Refinery Waste Listing Determination, U.S. EPA, 1997g)

- The desire to have a large degree of confidence that the results are adequately protective of human health and the environment given the degree of uncertainty inherent in the data and the analyses.

Leachate concentration threshold values and DAFs are included for three impoundment liner scenarios in IWEM: no liner, single liner, and a composite liner. The no liner scenario represents an impoundment that is relying upon location-specific conditions such as low-permeability native soils beneath the unit or low annual precipitation rates to mitigate the release of contaminants to the groundwater. The single liner scenario represents a 3-foot-thick clay liner with a low hydraulic conductivity (10^{-7} cm/s) beneath the impoundment. The composite liner scenario consists of a 3-foot-thick clay liner beneath a well-installed and operated 40-mil-thick high-density polyethylene (HDPE) flexible membrane liner.

For each chemical, the DAF from the appropriate liner scenario was multiplied by the carcinogenic or noncarcinogenic risk screening factor from Phase IA to adjust the leachate concentration values in the IWEM Tier I table to reflect the same exposure

factors that were used in the Phase IA analysis. For example, the age-adjusted ingestion rates used in the Phase IA drinking water screening are different from the standard ingestion rate used to construct the IWEM Tier I table (i.e., adult-only rates). In effect, the Tier I table was normalized to the same exposure factors used throughout the Phase IA preliminary risk screening.

A number of SIS constituents are not included in the IWEM Tier 1 table. For these constituents, a leachate concentration threshold value using a DAF from a surrogate chemical was calculated (see Section C.3 for DAFs). The leachate concentration threshold value was calculated by using the IWEM procedure for estimating DAFs of chemicals for which EPACMTP was not simulated, as follows: the DAF was determined by interpolating between the DAFs of chemicals whose hydrolysis rate and retardation factor are in the same range as the hydrolysis rate and retardation factor of the new chemical.

Human Health Risk Calculation. Because IWAIR must represent wind conditions across the continental United States, IWAIR contains wind dispersion data based on 29 meteorological stations.[7] Because the wind pattern may not be representative of the actual site conditions, a close-in receptor at 25 m was assumed for the Phase IB screen. If a constituent was not currently in IWAIR, its physicochemical and toxicological data were added to the IWAIR chemical database.

The Phase IB groundwater risk calculation considered the type of lining at each impoundment in determining the appropriate groundwater screening factor, called the leachate concentration threshold value (LCTV) in IWEM. The risk calculation mirrors the Phase IA calculation: calculate the ratio of the leachate concentration to the LCTV and multiply by the risk criteria.

Cumulative Risk Calculation. The calculated screening risks for each constituent for a specific impoundment and facility were combined to generate three cumulative risk estimates: impoundment risk, constituent risk, and facility risk , as described in Section C.1.2.1. It is important to note that the cumulative risks are a combination of the Phase IA and Phase IB calculated risks for each constituent, because the Phase IB risk estimate is considered a refinement of the initial Phase IA risk estimate.

Risk Distribution Development. The risk distribution approach was identical to that defined in Phase IA. Because the Phase IB cumulative risks are a combination of the results from Phase IA and IB, the risk distributions also represent the combined analysis of Phase IA and IB. That is, overall results were updated using the Phase IB results.

Risk Screening. The risk screening approach is also identical to that defined in Phase IA.

[7] Dispersion data for 12 additional meteorological stations were added to IWAIR for this study.

C.1.4 Results of Screening Assessment—Phase IA and IB

The combined Phase IA and IB screening risks for each constituent, impoundment, and facility provided the initial screening-level risk distribution profiles for the sample population. The refinement of the screening-level risk distribution from Phase IA to Phase IB is shown in Figures C.1-1 and C.1-2 for cancer risks associated with the groundwater pathway, for decharacterized and never characteristic impoundments, respectively. These figures present the actual risk results derived for the Phase 1A and 1B analyses of the groundwater pathway on the sample population. Notice that these results are not aggregated according to the three bins described in Chapter 3—below risk criteria, environmental release, and potential concern—because these results are unweighted. The figures illustrate the progression of impoundment-chemical combinations through the screening process. Risk results calculated in Phase IA are shown as lightly shaded in the figures and are always below the risk criterion because any combinations that were above the risk criteria in Phase IA progressed to the Phase IB release assessment. The results of Phase IB darkly shaded in the figures indicate that, while a number of impoundments fell below the risk criteria, a significant number would be considered for risk modeling of the groundwater pathway and, ultimately, would either be shown as "environmental release" or "may exceed risk criteria." The impoundments that are shown to be above the risk criteria in these histograms became the subset that was considered for the groundwater pathway risk modeling described in detail in Section C.3. However, only those impoundments (and facilities) that were at the top of the numeric ranking scheme progressed to the risk modeling stage of the analysis.

C.1.5 PhaseIC/II: Risk Modeling— Air Pathway

C.1.5.1 Methods Summary and Key Results. In the risk modeling of the air pathway, EPA evaluated the risk to a person inhaling air contaminated with the chemicals released from surface impoundments. These chemicals reach the air by volatilizing from the surface impoundment. They may then be transported some distance from the impoundment before a person inhales them. The farther the person is from the impoundment, the lower the concentration of the chemical in the air and the lower the risk. Each of the screening steps described above is similar in that the risk criteria were established at 1E-5 for risk or 1 for hazard, and the release assessment and risk modeling used IWAIR. This model uses emissions data from the survey or, if no data are available, estimates emissions from concentration and other site-specific data from the SIS survey. IWAIR then estimates the concentration in air at some distance from the impoundment. The farther from the impoundment, the lower the air concentration. In the risk modeling stage, the default receptor distance of 25 meters was replaced with a site-specific distance identified in the survey responses or gleaned from GIS sources and a review of aerial photographs. Because the actual distance to the nearest receptor was typically higher than the default IWAIR distance of 25 meters, the risk estimates in this stage generally were lower than those predicted in the release assessment. Table C.1-12 presents the results for the air pathway with facilities classified according to waste characterization categories. Table C.1-13 presents this same information according to whether the source concentration data were based on reported values or surrogate/DL values. The complete risk results, standard errors, and additional descriptors on regulatory status (direct vs. zero dischargers) and impoundment type (e.g., aerated vs. nonaerated) are presented in Attachment C-7 to this appendix.

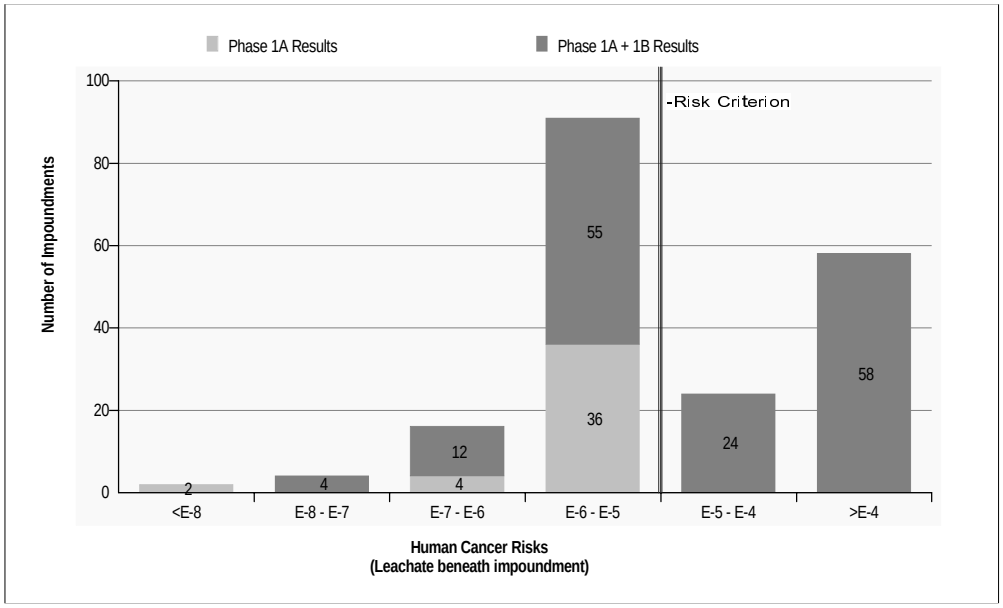


Figure C.1-1. Unweighted cancer risk results for sample population of impoundments for the groundwater pathway—decharacterized.

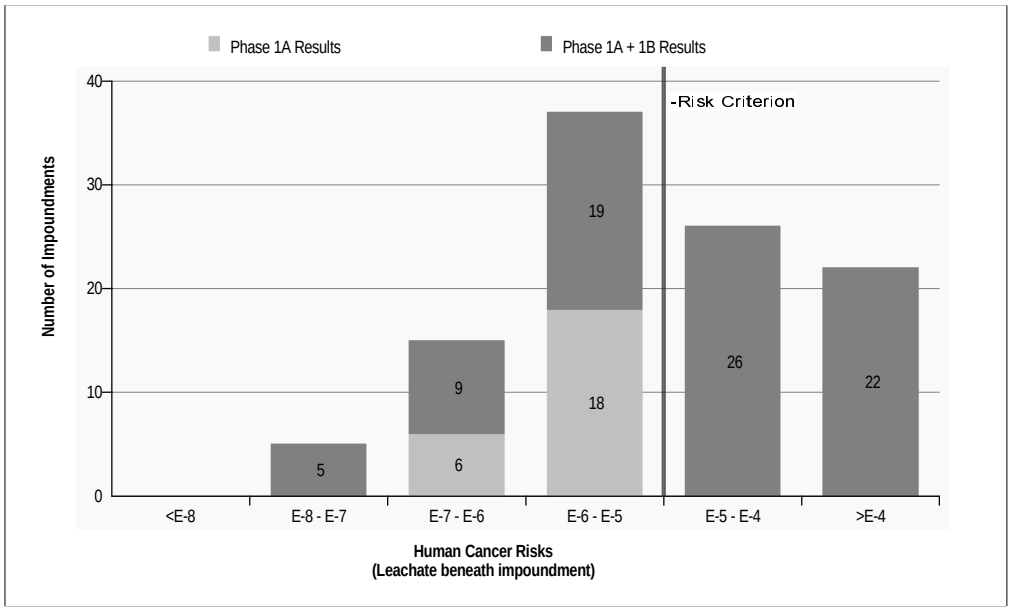


Figure C.1-2. Unweighted cancer risk results for sample population of impoundments for the groundwater pathway—never characteristic.

The results of the air pathway analysis indicate that, for facilities that may exceed the risk criteria, the weighted risk estimates may be associated with a significant standard error. Indeed, Table C.1-13 indicates that the national risk estimates may not be reliable for the facilities that may exceed the risk criteria based on reported concentration data. Although the standard errors associated with these results are large, the data suggest a trend that facilities that manage never characteristic wastes are associated with potentially higher risk levels than facilities that manage decharacterized waste.

Table C.1-12. Facility-Level Overview of Human Health Risk Results for Air Pathway by Decharacterization Status

Facility Status	Below Risk Criteria		Environmental Release[a] All Values		Exceeds Risk Criteria[a] All Values		Total	
Never Characteristic	3,344 (75%)		136 (3%)		158* (4%*)		3,638 (82%)	
	92%	86%	4%	41%*	4%*	68%*	100%	82%
Decharacterized	547 (12%)		198 (4%)		73* (2%)		818 (18%)	
	67%	14%	24%	59%*	9%	32%*	100%	18%
All Facilities	3,892 (87%)		334 (8%)		231* (5%)		4,457 (100%)	
	87%	100%	8%	100%	5%	100%	100%	100%

Table key: Number of facilities (% of all facilities).
Row %, Column %.
[a] Number of facilities (percentages are of the total number of facilities, approximately 4,500).
* This estimate may not be reliable because of a large relative standard error. See Appendix A.5 for details.

Table C.1-13. Facility-Level Overview of Human Health Risk Results for the Air Pathway by Decharacterization Status - Reported Values and Surrogate/DL Values

Facility Status	Below Risk Criteria		Environmental Release Reported Values		Environmental Release Surrogate/ DL Values		Exceeds Risk Criteria[a] Reported Values		Exceeds Risk Criteria[a] Surrogate/ DL Values		Total	
Never Characteristic[b]	3,344 (75%)		105* (2%)		31* (0.7%)		158* (4%*)		0 (0%)		3,638 (82%)	
	92%	86%	3%	62%*	0.9%	19%*	4%*	92%*	0%	0%	100%	82%
Decharacterized[c]	547 (12%)		64* (1%)		134 (3%)		13* (0.3%*)		60* (1%)		818 (18%)	
	67%	14%	8%*	38%*	16%	81%*	2%*	8%*	7%*	100%	100%	18%
All Facilities	3,892 (87%)		169 (4%)		165 (4%)		171* (4%*)		60* (1%)		4,457 (100%)	
	87%	100%	4%	100%	4%	100%	4%*	100%*	1%	100%	100%	100%

Table key: Number of facilities (% of all facilities).
Row %, Column %.
DL = Detection limit.
[a] Number of facilities (percentages are of the total number of facilities, approximately 4,500).
* This estimate may not be reliable because of a large relative standard error. See Appendix A.5 for details.

C.1.5.2 Discussion of Uncertainty. In its assessment of the air pathway, EPA relied on modeling tools that have been peer-reviewed and used in previous analyses, as much site-specific data as possible from the surveys, and standard EPA sources for important data such as exposure factors and health benchmarks. All of these factors contribute to a relatively robust analysis that met the study objectives of protective screening at earlier stages of the many impoundments and constituents and more robust modeling at the final stages of analysis. However, there are several key uncertainties that should be considered in interpreting the results of the air analysis. These are grouped under parameter uncertainties, modeling uncertainties, and results uncertainties. This section identifies these sources of uncertainty and qualitatively describes how each may influence the results.

Parameter Uncertainties. The key parameters required for the air pathway modeling included impoundment characteristics, receptor location, and exposure parameters.

- *Impoundment Characteristics*. To the extent possible, impoundment characteristics needed for the modeling were taken from the survey responses. However, some parameter values such as oxygen transfer rate, were not available from the survey responses for some or all impoundments. In these cases, assumptions or estimates were made, and these introduce uncertainty into the results. These assumptions and defaults could result in either under- or overprediction of risk, depending on the actual impoundment characteristics; however, they were generally chosen to be somewhat conservative (i.e., to overpredict risk), in keeping with the screening nature of this assessment.

- *Receptor Location*. The predicted risks were derived using actual receptor locations at each site. To the extent that some of these locations were based on old maps, there is some uncertainty introduced in the risk estimates, which could be either over- or underestimated, depending on whether the actual nearest receptor is nearer or farther from the site than the receptor location used. However, the conclusions regarding whether or not the risk may exceed the risk criteria are more robust, because in cases where this conclusion was sensitive to receptor location, the location was verified using recent aerial photos. Therefore, the uncertainties in the final results based on receptor location are small. It is important to note, however, that the air risks represent the nearest receptor to a given impoundment and do not necessarily reflect the "typical" risks to other receptors living within a 2-km radius of the facility; those "typical" risks are likely to be lower than the predicted risks for the closest receptor.

- *Exposure Parameters*. IWAIR uses standard EPA exposure factors, such as inhalation rate, body weight, and exposure duration. These parameters are based on the assumption of a receptor who ages from childhood to adulthood during the course of exposure. There is uncertainty in the risk results to the extent that actual receptors do not match these "typical" factors or this age profile. Exposure factors have been chosen to be somewhat conservative; therefore, this uncertainty will typically result in an overestimate of risk.

Modeling Uncertainties. The modeling for the air pathway simplifies the fate and transport of chemicals from an impoundment through air to a receptor. Many of these simplifications could result in either over- or underprediction of risk.

- *Volatile Emissions.* Emissions were modeled using CHEMDAT8. The level of peer review to which this model has been subjected supports confidence in the modeling construct to provide a solid basis for predicting inhalation risks. To the extent that this model is uncertain, it is unknown whether it would over- or underpredict emissions.

- *Hydrolysis*. The version of CHEMDAT8 incorporated in IWAIR cannot model hydrolysis. Hydrolysis rates are also not readily available for many chemicals. To the extent that constituents modeled with IWAIR do hydrolyze, IWAIR will overpredict emissions and therefore risks. For some constituents that hydrolyze quickly, this could be significant. For others, it will be less significant or insignificant, depending on the rate at which the constituent actually hydrolyzes in a particular impoundment.

- *Biodegradation Losses*. IWAIR does model biodegradation losses in the impoundment, using conservative (i.e., lowest available) biodegradation rate constants. The lower the level of biodegradation, the more constituent is available to volatilize, and the greater the emissions and risks. However, biodegradation is heavily influenced by such site-specific factors as temperature, pH, and other constituents present. Therefore, the emissions estimates are uncertain to the extent that actual biodegradation at a particular impoundment differs from the rate assumed. This uncertainty could result in either over- or underprediction of emissions and risks.

- *Dispersion Factors.* Dispersion factors were generated using the Industrial Source Complex model (ISC). ISC has been thoroughly peer-reviewed, which provides confidence in the modeling construct to provide a solid basis for predicting inhalation risks. To the extent that this model is uncertain, it is unknown whether it would over- or underpredict emissions.

- *Receptor Location Relative to Plume*. The receptor is assumed to be located at the centerline of the plume of constituent as it disperses around the site. Air concentrations are highest at the centerline of the plume, and decrease with distance from the centerline. Depending on the site-specific meteorology, particularly prevailing wind directions, the nearest receptor may not be located in the centerline of the plume. This uncertainty tends to overpredict air concentration at the nearest receptor, and thus risk.

- *Coverage of Meteorological Data in IWAIR*. IWAIR uses dispersion factors for a pre-determined set of 29 meteorological stations. Peer review of IWAIR suggested that additional meteorological stations would reduce uncertainty in the air concentration estimates; therefore, dispersion factors for 12 additional meteorological stations were generated and added to IWAIR for this study. There remains some uncertainty in the risk estimates to the extent that the 41 available meteorological stations do not fully

represent all possible locations where there are impoundments. However, this uncertainty, with the addition of new meteorological stations for IWAIR, is believed to be small. The direction of this uncertainty is not known—depending on the impoundment location, the air concentration (and thus risk) could be over- or underpredicted.

- *Interpolation of Dispersion Factors in IWAIR Based on Impoundment Area.* IWAIR uses dispersion factors generated for a fixed set of 14 impoundment areas. For impoundment areas that fall between the impoundment areas in IWAIR, there is some uncertainty based on this interpolation. The interpolation will result in the underprediction of air concentration, and therefore risk. This underprediction is expected to be modest; it will be greatest for small areas that fall close to half way between 2 of the 14 modeled areas. It will be less for areas that fall near 1 of the 14 modeled areas, and less for large areas regardless of closeness to one of the modeled areas (because the dispersion factor curve flattens out at large areas and is less sensitive to area).

- *Interpolation of Risk by Distance.* The IWAIR model can only be run at 7 preset distances. Therefore, risk results were interpolated to the actual distance of the nearest receptor. This interpolation is likely to slightly overpredict risk.

Results Uncertainties. As with any risk assessment, there is uncertainty in the risk results associated with simplifying assumptions and data limitations such as chemical-physical properties and health benchmarks. Several key uncertainties to consider in interpreting the risk results are presented below.

- *Standard Error*. The large standard error for the national estimate of potential risk exceedances for facilities with reported chemical concentrations indicates that there is considerable uncertainty in this estimate. Given the available data, it is not possible to quantify the magnitude or direction of this uncertainty with respect to protectiveness. Indeed, only two facilities in the sample population had potential exceedances for reported concentrations. The impact of our assumption that the receptor is located along the centerline of the air plume suggests that the risk estimates may be overprotective.

- *Multiple Constituent Exposures*. The risk of each constituent is considered separately in this analysis, and this may overlook additive or possible synergistic effects. This is a potential underestimation of adverse effects.

- *Chemical-Physical Properties*. IWAIR did not include all of the constituents of interest in this study that had inhalation benchmarks. Therefore, 25 additional constituents were added to IWAIR. However, adequate chemical-physical properties to run IWAIR were not available for 12 of these constituents. To the extent that these constituents may pose risks, this results in an underestimate of risk.

- *Health Benchmarks*. Many constituents in the scope of this study do not have health benchmarks for inhalation. This limited the number of constituents and facilities for which it was possible to assess inhalation risks. The absence of an inhalation health benchmark is generally taken as an indication that the constituent is not of great concern by the inhalation pathway; however, there is some uncertainty in this assumption. If health benchmarks were available for inhalation, a few more constituents might be found to pose risks; therefore, this uncertainty tends to result in an underestimate of risk.

C.1.6 Phase IC/II: Risk Modeling— Groundwater Pathway

C.1.6.1 Methods Summary and Key Results. In the risk modeling of the groundwater pathway, EPA evaluated the risk to a person drinking contaminated groundwater from the well located nearest to an impoundment that exceeded the risk criteria during the release assessment. Chemicals may reach a receptor well by leaching through the bottom of the impoundment into groundwater and migrating downgradient to residences that rely on drinking water wells. The potential for direct exposure to constituents via the groundwater pathway was assessed in three phases, each designed to be more protective than the previous phase. The first phase, direct exposure pathway screening, compared estimated leachate concentrations to screening factors for drinking water ingestion. The second phase, screening-level modeling, calculated risks and hazard quotients using EPA's IWEM. The third phase, site-based risk modeling, identified facility and impoundment combinations that have the greatest potential to impact receptor wells, and performed a Monte Carlo simulation to derive a site-specific distribution of risk for the nearest receptor well at each facility that was determined to be high priority for modeling.

The facilities were chosen for risk modeling using three basic decision rules:

- EPA evaluated the 71 facilities that exceeded risk criteria based on the IWEM Tier 1 screening analysis to determine if the potential exists for direct exposure to contamination via the groundwater pathway.

- EPA assumed the potential for exposure by determining if drinking water wells were present in the downgradient direction of groundwater flow.

- If receptor wells were not present, or if the receptor wells were determined not to be downgradient of the surface impoundment, EPA presumed the pathway to be incomplete and excluded the site from further evaluation.

For those facilities that were not excluded, two sets of criteria were developed and used to identify which facilities required site-based modeling. The first set of criteria focused on environmental setting characteristics (e.g., distance to receptor well), and the second set of criteria relied on professional judgment (e.g., conductivity of aquifer material). Each set of criteria and the method in which they were applied are described in Attachment C-8. Application of the two sets of ranking criteria resulted in the selection of 10 facilities that were considered the highest priority for site-based groundwater modeling. Site-based modeling involved assessing the fate and transport of chemical constituents present in surface impoundments by performing a

Monte Carlo simulation using EPACMTP and feeding the groundwater concentrations into a Monte Carlo exposure/risk simulation that varied human health exposure factors.

Table C.1-14 presents the results for the groundwater pathway with facilities classified according to waste characterization categories. Table C.1-15 presents this same information according to whether the source concentration data were based on reported values or surrogate/DL values. The complete risk results, standard errors, and additional descriptors on regulatory status (direct vs. zero dischargers) and impoundment characteristics (e.g., liner vs. no liner) are presented in Attachment C-12.

Table C.1-14. Facility-Level Overview of Human Health Risk Results for Groundwater Pathway by Decharacterization Status

Facility Status	Below Risk Criteria		Environmental Release[a] All Values		Exceeds Risk Criteria[a] All Values		Total	
Never Characteristic	2,574 (58%)		1,055 (24%)		9* (0.2%*)		3,638 (82%)	
	71%	88%	29%	71%	0.3%*	18%*	100%	82%
Decharacterized	345 (8%)		432 (10%)		41* (0.9%)		818 (18%)	
	42%*	12%	53%	29%	5%*	82%*	100%	18%
All Facilities	2,919 (65%)		1,488 (33%)		50* (1%)		4,457 (100%)	
	65%	100%	33%	100%	1%	100%	100%	100%

Table key: Number of facilities (% of all facilities).
Row %, Column %.

[a] Number of facilities (percentages are of the total number of facilities, approximately 4,500).

* This estimate may not be reliable because of a large relative standard error. See Appendix A.5 for details.

The results of the groundwater pathway analysis indicate that less than one percent of the facilities nationally that manage chemical constituents with reported values may exceed risk criteria for groundwater ingestion. Both tables suggest that facilities that manage decharacterized waste may potentially pose two to five times the risk of facilities that manage only waste that has never been characteristic.

C.1.6.2 Discussion of Uncertainty. In its assessment of the groundwater pathway, EPA relied on modeling tools that have been peer-reviewed and used in previous analyses, as much site-specific data as possible from the surveys, and standard EPA sources for important data such as exposure factors and health benchmarks. All of these factors contributed to a relatively robust analysis that met the study objectives of the Surface Impoundment Study. This section identifies the primary sources of uncertainty and qualitatively describes how each may influence the results of the risk assessment.

Table C.1-15. Facility-Level Overview of Human Health Risk Results for Groundwater Pathway by Decharacterization Status—Reported Values and Surrogate/DL Values

Facility Status	Below Risk Criteria		Environmental Release [a] Reported Values		Environmental Release [a] Surrogate/ DL Values		Exceeds Risk Criteria[a] Reported Values		Exceeds Risk Criteria[a] Surrogate/ DL Values		Total	
Never Characteristic	2,574 (58%)		341* (8%)		714 (16%)		9* (0.2%*)		0 (0%)		3,638 (82%)	
	71%	88%	9%	53%*	20%	84%*	0.3%*	33%*	0%	0%	100%	82%
Decharacterized	345 (8%)		300 (7%)		132* (3%)		18* (0.4%)		23* (0.5%)		818 (18%)	
	42%*	12%	37%	47%*	16%	16%*	2%*	67%*	3%*	100%	100%	18%
All Facilities	2,919 (65%)		641 (14%)		846 (19%)		27* (0.6%)		23* (0.5%)		4,457 (100%)	
	65%	100%	14%	100%	19%	100%	0.6%	100%	0.5%	100%	100%	100%

Table key: Number of facilities (% of all facilities).
Row %, Column %.
DL = Detection limit.
[a] Number of facilities (percentages are of the total number of facilities, approximately 4,500).
* This estimate may not be reliable because of a large relative standard error. See Appendix A.5 for details.

Parameter Uncertainties. The sources of parameter uncertainty include measurement errors, sampling errors, variability, and use of generic or surrogate data. Parameter uncertainty was incorporated in the Surface Impoundment Study by (1) executing a Monte Carlo analysis to capture the natural variability present in nature, and (2) using a regional site-based modeling approach that relied on data compiled at actual waste sites around the country. The critical parameters required for the screening of groundwater pathway included the distribution coefficients (K_d) and model parameter inputs.

- *Distribution Coefficients*. Empirical data were used to characterize partitioning of chemical contaminants between the aqueous phase and soil and aquifer materials. The K_d values used in the Surface Impoundment Study are based on values compiled from the literature. The values for all constituents are assumed to range over at least 3 orders of magnitude. For values with five or fewer literature values available for establishing a distribution of K_d values, a lognormal distribution was assumed centered on the mean value of the available log K_ds and extending for 1.5 log units on each side of the log mean. This uncertainty could result in either an underestimation or an overestimation of risk.

- *Model Input Parameters*. Application of the EPACMTP model requires input values for the source-specific, chemical-specific, unsaturated zone-specific, and saturated zone-specific model parameters. For this analysis, facility-specific values for impoundment location and waste, soil, and aquifer characteristics were used to the extent possible. Where facility-specific data were not available, regional databases were used to obtain the parameter values for soil and aquifer conditions. The use of facility-specific data reduces, but does not eliminate,

uncertainty. Use of regional databases may result in a greater spread of risks in Monte Carlo analyses.

- *Toxicological Endpoint for Fluoride*. The chemical that exceeds the risk criterion most often in the groundwater pathway assessment is fluoride. This is one of the two chemicals for which risk modeling indicates exceedances that are based on reported chemical concentrations. However, the endpoint of interest is currently dental fluorosis, an endpoint that is not considered to be an adverse effect by EPA. Although safe levels for fluoride of skeletal fluorosis are within a factor of 2 of the RfD for fluoride, there is considerable uncertainty in this value because there has been no formal workgroup process to derive a health benchmark.

Model Uncertainties. Model uncertainty is associated with all models used in all phases of a risk assessment because models and their mathematical expressions are simplifications of reality that are used to approximate real-world conditions, processes, and their relationships. Models used in the Surface Impoundment Study were selected based on science, policy, and professional judgment. These models were selected because they provide the information needed for this analysis and because they are generally considered to be state-of-the-science. Even though the models used in the risk analyses are used widely and have been accepted for numerous applications, they each retain significant sources of uncertainty. Evaluated as a whole, the sources of model uncertainty in this analysis could result in either an overestimation or underestimation of risk. Specific areas of modeling uncertainty in this analysis are as follows:

- *Channel Flow*. In modeling the fate and transport of chemicals in groundwater, complex hydrogeology such as karst or highly fractured aquifers was not assessed. Some fraction of the groundwater settings in this analysis are located in hydrogeologic environments where fracturing is likely. In general, fractured flow in groundwater can channel the contaminant plume, thus allowing it to move faster and in a more concentrated state than in a nonfractured flow environment. As a result, the modeling may under- or overestimate the concentrations in the groundwater.

- *Model Simplifications*. EPACMTP does not model colloidal transport nor does it model possible geochemical interactions among different contaminants in the leachate and the subsurface environment. The EPACMTP modeling incorporates the following assumptions: (1) transverse dispersion is negligible in the unsaturated zone, potentially resulting in an overestimation of risks; (2) receptors use the uppermost aquifer rather than a deeper aquifer as a domestic source of drinking water, which overestimates risks where the uppermost aquifer is not used;[8] and (3) hydrogeologic conditions that influence contaminant fate and

[8] Note that, for some facilities, EPA used technical materials supplied by the survey respondents to confirm that the uppermost aquifer was not used as a drinking water source. This information was entered in the numeric ranking scheme and used to identify facilities that were not considered to be a high priority with respect to potential groundwater risks.

transport are uniform spatially (i.e., no heterogeneity or fractured flow) as well as uniform temporally (i.e., over the 10,000-year time frame modeled). The use of these simplifications may result in a greater estimated spread of concentrations in the groundwater.

- *Groundwater Mounding*. Groundwater flow in the saturated zone is based on the assumption that the contribution of recharge from the unsaturated zone is small relative to the regional flow in the aquifer and the saturated aquifer thickness is large relative the rise due to infiltration. This assumption allows for the saturated zone to be modeled as having a uniform thickness (i.e., in the absence of mounding). The use of this simplification may result in a greater estimates spread of concentrations in the groundwater.

- *Recharge Rate*. The recharge rates used in this analysis were developed based on analyses that rely on regionalized climatic data and generalized soils types. These are not site-specific data but are intended to represent the range of conditions expected in the area. Although the model accounts for uncertainty using a probabilistic simulation, the recharge rates are not site-specific and may over- or underpredict the contaminant flux to groundwater.

- *Timeframe of Exposure*. There is uncertainty in predicting the movement of contaminants over long periods of time. The risk to receptors for the groundwater pathway was evaluated over a time period of 10,000 years. Depending on the constituent properties and rate as which it moves in groundwater, the time to peak concentration may be relatively long, on the order of hundreds or thousands of years. There are significant uncertainties concerning how exposure and environmental assumptions will change over time, and the modeling methodology does not change these assumptions over this 10,000-year period. As a result, groundwater concentrations may be under- or overestimated.

Results Uncertainties. It is important to consider several key uncertainties in interpreting the significance of the groundwater pathway results. The greatest uncertainty is focused around assumptions made in defining the geometric configuration of the modeled system, specifically, with regard to the groundwater flow direction and well construction. In addition, the risk results for reported values are based entirely on two chemical constituents: fluoride and acetone. As discussed above, the fluoride hazard is based on an effect that is not considered adverse by EPA, and the recommended safe value by EPA is approximately two times the health benchmark. Given the fact that fluoride is the risk driver for the entire groundwater pathway assessment and that the 90^{th} percentile hazard quotient for acetone is 13 (50^{th} percentile hazard quotient is 0.02), the groundwater hazard estimates may tend to be overprotective of actual adverse effects. Other uncertainties are discussed below.

- *Groundwater Flow Direction*. The direction of groundwater flow was not provided in the survey responses. Because the exact direction of the groundwater flow was unknown, the actual receptor well locations in the general the direction of the groundwater flow, as well as the physiography of the site were used to

define the angle "THETA." For each surface impoundment, THETA sets the bounds for the true direction of groundwater flow and, therefore, captures the uncertainty in centerline for groundwater flow and contaminant movement relative to the nearest receptor well to the impoundment. The error margin for THETA was based on professional judgment and was set to 5 degrees for all facilities evaluated in the risk modeling. The impact of this geometrical inexactitude is considered to be much smaller than the impact of several other uncertainties in the groundwater pathway analysis.

- *Well Construction*. The aquifer from which receptor wells drew water was not consistently reported in survey results. In the absence of technical information from the survey respondents indicating a site-specific well depth, it was assumed that the receptor wells considered in this analysis drew water from the uppermost unconfined saturated zone. This is a protective assumption and would tend to overestimate risk.

- *Volatilization*. The evaluation of the groundwater pathway was focused only on the ingestion of contaminated groundwater. EPA did not address volatilization of chemical constituents in groundwater that may result in inhalation exposures during showering. Because the inhalation pathway associated with shower exposure was not modeled, the groundwater pathway risk results may underestimate the total risk from leaching to groundwater. This contributes to the uncertainty in the risk estimates in the direction of underprotectiveness.

C.1.7 Phase IC/II: Risk Modeling—Groundwater to Surface Water Pathway Screening

C.1.7.1 Methods Summary and Key Results. In the risk modeling of the groundwater to surface water pathway, EPA evaluated the potential for degradation of surface water quality with respect to human usage. The basic approach to evaluating the potential for risks by this pathway was first to identify high-priority sites through a screening process (that considered groundwater concentrations, proximity to surface waterbodies, and the magnitude of potential dilution). For high-priority sites, modeling was conducted to generate flux rates from the surface impoundments, estimate groundwater concentrations that might contaminate the surface waterbody, and model the ensuing dilution. This analysis was conducted on all facilities that reported the presence of in-scope constituents. The basic steps in the assessment of this pathway were to

- Identify sites near (within 1 km) one or more fishable waterbodies

- Eliminate facilities from consideration based on a comparison of leachate concentrations to the ambient water quality criteria for the ingestion of surface water and aquatic organisms (HH-AWQC)

- For those that were not eliminated, estimate groundwater concentrations (from DAFs) and compare these to the HH-AWQC. The DAFs used were intended to

provide estimates of groundwater concentrations toward the high end of the possible distribution

- Using site-specific data (such as surface impoundment area) and reviewing topographical maps, identify sites with a high potential to impact surface water. Typically, this was based on a low probability of dilution by the surface waterbody based on flow data for the closest waterbody

- Conduct screening-level risk modeling using site-generated infiltration rates and flow rates for receiving waterbodies to estimate of chemical concentrations in surface water, and compare the resulting values to the HH-AWQC.

Table C.1-16 presents the results for the groundwater pathway with facilities classified according to waste characterization categories. Table C.1-17 presents this same information according to whether the source concentration data were based on reported values or surrogate/DL values. The complete risk results, standard errors, and additional descriptors on regulatory status (direct vs. zero dischargers) and impoundment characteristics (e.g., liner vs. no liner) are presented in Attachment C-15.

Table C.1-16. Facility-Level Overview of Human Health Risk Results for Groundwater to Surface Water Pathway by Decharacterization Status

Facility Status	Below Risk Criteria		Environmental Release[a] All Values		Exceed Risk Criteria[a] All Values		Total	
Never Characteristic	2,203 (49%)		1,397 (31%)		38* (0.9%)		3,638 (82%)	
	61%	88%	38%	75%	1%	52%*	100%	82%
Decharacterized	310 (7%)		472 (11%)		36* (0.8%)		818 (18%)	
	38%	12%	58%	25%	4%*	48%*	100%	18%
All Facilities	2,513 (56%)		1,869 (42%)		75* (2%)		4,457 (100%)	
	56%	100%	42%	100%	2%	100%	100%	100%

Table key: Number of facilities (% of all facilities).
Row %, Column %.

[a] Number of facilities (percentages are of the total number of facilities, approximately 4,500).

* This estimate may not be reliable because of a large relative standard error. See Appendix A.5 for details.

* This estimate may not be reliable because of a large relative standard error. See Appendix A.5 for details.

The results of the groundwater to surface water pathway analysis indicate that approximately 1 percent of the facilities nationally that manage chemical constituents with reported values may exceed risk criteria for adverse surface water impacts. The results are similar for risk exceedances predicted using surrogate/DL-based chemical concentrations. The overall trend using both types of concentration data does not indicate that decharacterized facilities are associated with higher potential risks than facilities that manage only never characteristic waste.

Table C.1-17. Facility-Level Overview of Human Health Risk Results for the Surface Water Pathway by Decharacterization Status - Reported Values and Surrogate/DL Values

Facility Status	Below Risk Criteria		Environmental Release[a]				Exceed Risk Criteria[a]				Total	
			Reported Values		Surrogate/ DL Values		Reported Values		Surrogate/ DL Values			
Never Characteristic	2,203 (49%)		479 (11%)		918 (21%)		29* (0.7%)		9* (0.2%*)		3,638 (82%)	
	61%	88%	13%	61%*	25%	85%	0.8%	67%*	0.3%*	30%*	100%	82%
Decharacterized	310 (7%)		311 (7%)		161 (4%)		14* (0.3%)		22* (0.5%)		818 (18%)	
	38%	12%	38%	39%*	20%	15%	2%*	33%*	3%*	70%*	100%	18%
All Facilities	2,513 (56%)		790 (18%)		1,079 (24%)		44* (1.0%)		31* (0.7%)		4,457 (100%)	
	56%	100%	18%	100%	24%	100%	1.0%	100%	0.7%	100%	100%	100%

Table key: Number of facilities (% of all facilities).
Row %, Column %.
DL = Detection limit.
[a] Number of facilities (percentages are of the total number of facilities, approximately 4,500).
* This estimate may not be reliable because of a large relative standard error. See Appendix A.5 for details.

C.1.7.2 *Discussion of Uncertainty*. There are several key uncertainties that should be considered in interpreting the results of the surface water quality screening assessment. These are grouped under parameter uncertainties, modeling uncertainties, and results uncertainties. This section identifies these sources of uncertainty and qualitatively describes how each may influence the results.

Parameter Uncertainties. The critical parameters required for the screening modeling of surface waterbodies included flow rates and DAFs.

- *Flow Rates*. Flow rates were a potentially significant source of uncertainty; the low flow rate (7Q10) was often greater than the average flow rate, suggesting that the data sources were highly variable. In addition, many flow rate estimates are based on end-of-stream locations, which could be a substantial distance from the point at which the groundwater could reasonably be expected to intersect with the surface waterbody. Consequently, the river dilution factor calculated from the flow rate may be highly uncertain.

- *Dilution Attenuation Factors*. For surface waterbodies within 150 meters, a default DAF of 1.0 was chosen. This value tends to overestimate the contaminant flux in groundwater that reaches the surface waterbody. The DAFs in IWEM were used for waterbodies beyond 150 meters and, as with the default DAF, these were developed for a protective groundwater screening tool. The resulting groundwater concentrations will generally lead to an overprediction of the contaminant concentration in the surface waterbody.

Modeling Uncertainties. The screening modeling for the groundwater to surface water pathway simplifies the fate and transport of chemicals from groundwater to surface water and is based on several protective assumptions. These simplifications generally rely on protective assumptions and, as a result, the modeling approach tends to overpredict the potential effects on water quality.

- *Groundwater Flow Direction*. For the surface water screening, groundwater flow direction was inferred from the topography, and a plausible groundwater flow direction was established perpendicular to the receiving waterbody—either a flowing waterbody or a quiescent system such as a small pond. In addition, the plume was assumed to completely intersect with the waterbody so that the groundwater would exert the maximum impact on the surface waterbody. The combination of these assumptions creates a bias toward higher surface water concentrations.

- *Designation of Fishable Waterbody*. The closest fishable waterbody was identified for each impoundment based on both survey responses and simple decision rules (e.g., a reach order of 3 or above is presumed to be fishable). However, there may be substantial uncertainty in this selection because, in many instances, survey responses were not useful in identifying the closest fishable waterbody.

- *Infiltration Rates*. The infiltration rates used in this analysis were developed using the HELP model using regionalized climatic data and generalized soils data. These are not site-specific data but are intended to represent the range of conditions expected in the area. Although the model accounts for uncertainty using a probabilistic simulation, the infiltration rates are not site-specific and may over- or underpredict the contaminant flux to groundwater.

Results Uncertainties. It is important to consider several key uncertainties in interpreting the significance of the surface water pathway results. The modeling approach is based on the assumption of instantaneous and thorough dilution throughout the surface waterbody, which would create a constant exposure profile for human usage throughout the entire receiving waterbody. In reality, contaminant release into the surface waterbody through this pathway would likely be associated with a concentration gradient that would vary the exposure pattern throughout the length of the waterbody. In many instances, only a small portion of the receiving waters may actually maintain chemical concentrations above the HH-AWQC. For the highest area of contamination (perhaps a "favorite" fishing spot), the dilution may mask a potentially adverse impact on surface water quality. It should be noted that the HH-AWQC used in this analysis are based on the consumption of aquatic organisms *and* surface water. In reality, the percentage of the population that consumes untreated surface water on a regular basis is very small. Therefore, the selection of the HH-AWQC for the ingestion of both aquatic organisms and surface will tend to produce an overestimate of the potential risks to surface water quality (relative to the actual usage of receiving waterbodies). The results of this analysis suggest that, despite the proximity of receiving waterbodies to surface impoundments, the risks from adverse effects to surface water quality are generally low nationwide.

A second potentially important source of uncertainty in the national risk estimates is based on the fact that HH-AWQC exceedances greater than a factor of 10 were observed for only one facility, and the only constituent with reported concentrations was arsenic. This finding in no way mitigates that risk potential at that particular facility. However, given the generally protective design of the screening risk modeling for this pathway, it is conceivable that this is the only facility (182) for which surface water impacts are of potential significance. Two other key uncertainties are worth considering when interpreting these results:

- *Data Gaps*. The screening criteria (HH-AWQC) selected for this analysis were identified in EPA's compilation of national recommended water quality criteria developed pursuant to section 304(a) of the Clean Water Act. An HH-AWQC was not available for all of the constituents that failed the preliminary screen and, therefore, the results may not capture impacts from all chemicals that may be released through this pathway.

- *Additive/Synergistic Effects*. The screening modeling does not address the possibility that other contaminant sources may be releasing the similar chemical constituents into the same waterbody. For waterbodies that are already receiving significant contaminant loads of the similar chemicals (or synergistic chemicals), the chemical release from an impoundment may be a significant contributor to water quality degradation.

C.1.8 Phase IC/II: Indirect Exposure Pathway Assessment

C.1.8.1 Methods Summary and Key Results. To characterize the potential for indirect exposures at facilities that manage bioaccumulative chemicals at in-scope surface impoundments, EPA conducted an indirect exposure pathway (IEP) screening analysis that used a combination of facility-specific and environmental setting criteria to assign each facility to one of three categories regarding the potential for indirect exposure pathway risk:

- **Potential concern** - The potential exists for indirect exposure pathway risk.

- **Lower concern** - There is a lower potential for indirect exposure pathway risk.

- Least concern - The analysis suggests that these facilities have the least potential for indirect exposure pathway risk.

In order for a facility to be placed in the category with the highest level of concern (i.e., the potential concern category), the IEP screening analysis had to suggest that the potential exists for indirect exposure pathway risk under current site conditions. Consequently, overall rankings for the facilities were assigned based on a current status scenario, which was designed to represent current conditions at the facilities. A future closure scenario was also included in the analysis to provide perspective on the number of facilities that had the potential to pose risk through an indirect exposure pathway after impoundment closure. This future closure scenario analysis was based on precautionary assumptions concerning postclosure actions and,

consequently, the results of the analysis were used only to qualify the results of the current status scenario (i.e., future closure results were not used in assigning overall rankings to the facilities).

The IEP analysis considered a set of exposure pathways, each linked to a specific release scenario and receptor population. For example, the analysis considered volatilization of chemicals from impoundments with subsequent transport to offsite residential home gardens (this represented a specific exposure pathway that was evaluated for the resident receptor population). Each of these exposure pathways was evaluated using a specific set of facility-specific and environmental setting criteria, which in turn, were used in a ranking algorithm to generate the overall ranking for that exposure pathway regarding the potential for indirect exposure pathway risk. Once all exposure pathways were evaluated for a given facility, those rankings were reviewed and an **overall ranking** was given to that facility for the IEP screening analysis. As noted above, these overall rankings were based only on the current status scenario.

Table C.1-18 presents the results for the indirect exposure pathway assessment with facilities classified according to waste characterization categories. Because the results of this assessment do not include quantified risk estimates that are chemical- and impoundment-specific, these results are not presented according to facilities with reported values or surrogate/DL values. The complete risk results, standard errors, and additional descriptors such as regulatory status are presented in Attachment C-18.

Table C.1-18. Facility-Level Overview of Human Health Risk Results for Indirect Exposure Pathway Assessment by Decharacterization Status

Facility Status	Least Concern[a]		Lower Concern[a]		Potential Concern[a]		Total	
Never characteristic	1,369 (31%)		2,153 (48%)		116* (3%)		3,638 (82%)	
	38%*	88%	59%*	82%	3%	41%*	100%	82%
Decharacterized	183 (4%)		466 (10%)		169 (4%)		818 (18%)	
	22%	12%	57%	18%	21%	59%*	100%	18%
All facilities	1,552 (35%)		2,620 (59%)		285 (6%)		4,457 (100%)	
	35%	100%	59%	100%	6%	100%	100%	100%

Table key: Number of facilities (% of all facilities).
Row %, Column %.

[a] Number of facilities (percentages are of the total number of facilities, approximately 4,500).

* This estimate may not be reliable because of a large relative standard error. See Appendix A.5 for details.

The results of the IEP screening analysis indicate that approximately 6 percent of the facilities nationally that manage bioaccumulative chemical constituents may present potential concern via indirect exposures. The overall results do not indicate that decharacterized facilities are associated with higher potential risks than facilities that manage only never characteristic waste.

C.1.8.2 Discussion of Uncertainty. The qualitative character of the indirect exposure pathway analysis leads to several major areas of uncertainty that affect interpretation of the results. These are grouped under parameter uncertainties, modeling uncertainties, and results uncertainties.

Parameter Uncertainties. Key parameters required for this analysis fall into one of two broad categories: facility performance parameters and environmental setting parameters. Various sources of uncertainty can impact each of these parameters. Those parameter uncertainties that are believed to have the greatest potential impact on the indirect exposure pathway screening assessment are discussed below.

- *Distance to nearest receptor*: The distance between specific impoundments and the nearest receptor (i.e., residential areas, farms, or fishable waterbodies) was estimated using a combination of aerial photos and topographic maps. Although these measurements were made using the most up to-date photos and maps available, some of the photos and maps were somewhat dated. This introduces uncertainty in the distance to nearest receptor measurements since land use change could result in a receptor either being added to or removed from a given study area (note, this is less of an issue in identifying fishable waterbodies).

- *Assessment of potential for erosion/runoff*: Topographic maps used to assess slope and the potential for sheet versus channel flow may not be current, in which case significant changes in land use (which would not show up on older maps) could introduce error into the characterization of this parameter.

Modeling Uncertainties. The indirect exposure pathway screening assessment is a facility-level evaluation intended to rank facilities according to their potential for complete indirect exposure pathways. This analysis uses a ranking algorithm together with facility-specific and environmental setting criteria to generate overall ranking scores for individual exposure pathways. The criteria used in this analysis were selected as surrogates for key factors related to human health risk (e.g., impoundment surface area was used as a surrogate for level of chemical emissions, distance to receptor was used as a surrogate for level of dispersion following source release). The use of these surrogate parameters as criteria in the ranking algorithms for individual exposure pathways, while appropriate given the screening-nature of the analysis, does introduce modeling uncertainty into the analysis. In addition, there are uncertainties associated with the ranking algorithms used in the anlaysis.

- *Use of ranking algorithms*: The ranking algorithm used in this analysis assumes an additive relationship between the criteria that are considered. However, in relation to actual risk, these criteria may have multiplicative or even nonlinear relationships to each other, in which case the overall importance of individual criteria could be misrepresented in the ranking algorithm.

- *Use of surface area as a surrogate parameter*. Total aggregated impoundment surface area for a given facility was used as a surrogate for the level of constituent emissions from that facility. However, a wide range of factors can influence the

degree of source emissions from an impoundment including chemical composition of the wastewater/sludge and other environmental setting/impoundment characteristics. Consequently, use of surface area as a surrogate for emissions levels does introduce uncertainty into the analysis.

- *Use of distance to receptor as a surrogate parameter*: The shortest distance from any of the impoundments at a facility to the nearest offsite receptor (i.e., resident, farmer, or fisher) was used as a surrogate for the degree of chemical dispersion that would occur following release. However, a wide range of factors in addition to distance to receptor can impact dispersion including meteorology, topography, and the specific characteristics of the source release.

Results Uncertainties. The indirect exposure pathway screening analysis is designed to identify which facilities have the potential to pose an indirect exposure pathway risk to surrounding populations. Given this scope, the analytical framework for the indirect exposure pathway screening analysis uses a combination of surrogate criteria and simple additive ranking algorithms in place of a formal site-specific risk assessment framework to generate ranking results. While this semiquantitative approach does support ranking of facilities with regard to the potential for indirect exposure pathway risk, care should be taken not to overextend conclusions drawn from the analysis. A similar issue applies to results produced for the current status scenario versus future closure scenario.

- *Drawing conclusions from the analysis*: Because the IEP screening analysis uses surrogate criteria combined with simple additive algorithms to rank facilities, there is significant uncertainty associated with the overall analysis that should be considered in interpreting results. While, this degree of uncertainty is considered acceptable for a first-pass assessment as to whether individual facilities have the potential for indirect exposure pathway risk, it precludes drawing any conclusions regarding the potential *level* of risk that these facilities could pose.

- *Current status scenario vs. future closure scenario results*: There is significantly greater uncertainty associated with results generated for the future closure scenario than for the current status scenario. This discrepancy results from the fact that the current status scenario is based on best available data regarding the current status of modeled facilities, while the future closure scenario is not intended as a "best guess" of future closure conditions at sites, but rather as a protective analysis of the potential for indirect exposure pathway risk should impoundments close without sufficient postclosure actions being taken to limit constituent mobility. Reflecting this discrepancy in uncertainty, overall rankings for the indirect exposure pathway screening analysis are based only on results for current status scenario—results from the future closure scenario are not considered in assigning these rankings. However, the results of the future closure scenario could be used to qualify the results of the current status scenario since they provide perspective on how many facilities could pose an indirect exposure pathway risk should impoundment closure occur without remediation.

C.1.9 Phase I: Preliminary Screen—Ecological Risk

C.1.9.1 Methods Summary and Key Results. The ecological risk screening is somewhat different from the human health screening in that a single comparison of screening factors and constituent concentrations was conducted. The screening ecological risk assessment focused on a subset of 43 constituents for which toxicological and exposure factor data were readily available. The habitats and receptors considered in this study are consistent with the national assessment strategy developed to support HWIR, proposed in November 1999. Because the HWIR risk assessment framework was intended to support national studies of waste management practices, the SIS has adopted this framework as the basis for selecting receptors and habitats. Depending on the ecological receptor of concern, the analysis estimated risks from either the ingestion of contaminated plants, prey, and media or from direct contact with a contaminated medium such as sediment or soil. The ecological risk estimates were compared to risk criteria to characterize the potential for adverse ecological effects at facilities of interest.

As with the preliminary screening of noncancer hazard for human health, the ecological screening analysis calculates risks to individual ecological receptors (e.g., red fox, aquatic biota) based on the ratio between risk screening factors and the concentrations of constituents in surface impoundments reported in the survey questionnaire. Consequently, ecological risk screening factors are given in units of concentration (e.g., mg/kg or mg/L). The use of screening factors is considered to be precautionary because the factors are

- Derived using established EPA protocols for use in evaluating ecological risk (e.g., sediment quality criteria)
- Based on highly protective assumptions regarding the toxicological potency of a constituent (e.g., no adverse effects levels and low adverse effects levels)
- Calculated assuming that all media and food items originate from a contaminated source.

In addition, the application of the screening factors assumes that ecological receptors are exposed directly to chemical concentrations in the sludge and wastewater found in the surface impoundment. For mammals, birds, and selected herpetofauna, these screening factors reflect ingestion of contaminated media, plants, and prey. For other receptor groups, such as soil fauna, these screening factors reflect both the direct contact and ingestion routes of exposure.

Table C.1-19 presents the results for the indirect exposure pathway assessment with facilities classified according to waste characterization categories. The categories for risk, although similar to those used in the IEP screening analysis, have a specific meaning in the context of the ecological risk assessment. The metric chosen to distinguish potential concern from lower concern was the number of receptors for which chemical concentrations exceeded ecological screening factors. The precautionary nature of the screening assessment resulted in a high percentage of "failures," that is, facilities and impoundments for which the predicted hazard quotient was greater than 1. Therefore, EPA used the median number of receptor of exceedances (38) across all facilities evaluated to discriminate between potential concern and lower concern.

Consequently, the national percentages shown in Table C.1-19 for potential concern reflect the potential for screening ecological risks to exceed the target criterion of 1 for more than 38 ecological receptors across various taxa. However, because the results of this assessment are considered screening-level, they are not presented according to facilities with reported values or surrogate/DL values. Table C.1-19 suggests that the majority of facilities have some potential for adverse ecological effects, and somewhat less than one third of the facilities have a relatively high level of potential concern based on the number of receptors for which risk exceedances were predicted. There is an apparent trend with regard to decharacterization status in that almost four times the number of facilities listed as of potential concern manage never characteristic waste.

Table C.1-20 provides insight into the ecological risks at facilities located near sensitive habitats such as wetlands and/or managed areas (e.g., national wildlife refuges). This table indicates that less than 10 percent of the facilities classified of potential concern are located within 1 km of a wetland or 3 km of a managed area. This figure trebles (roughly 30 percent) if the facilities classified as of lower concern are considered. Naturally, the "least concern" category refers to facilities for which ecological risks were not predicted at levels of potential concern. The complete risk results, standard errors, and additional descriptors such as regulatory status are presented in Attachment C-23.

Table C.1-19. Facility-Level Overview of Human Health Risk Results for Indirect Exposure Pathway Assessment by Decharacterization Status

Facility Status	Least Concern[a]		Lower Concern[a]		Potential Concern[a]		Total	
Never Characteristic	594* (13%)		2,007 (45%)		1,037 (23%)		3,638 (82%)	
	16%*	75%*	55%*	85%	28%	79%	100%	82%
Decharacterized	194 (4%)		352 (8%)		273 (6%)		818 (18%)	
	24%	25%*	43%*	15%	33%	21%	100%	18%
All Facilities	788 (18%)		2,359 (53%)		1,310 (29%)		4,457 (100%)	
	18%	100%	53%	100%	29%	100%	100%	100%

Table key: Number of facilities (% of all facilities).
Row %, Column %.

[a] Number of facilities (percentages are of the total number of facilities, approximately 4,500).

* This estimate may not be reliable because of a large relative standard error. See Appendix A.5 for details.

C.1.9.2 Discussion of Uncertainty. The screening nature of the analysis leads to several major areas of uncertainty that affect interpretation of the results. These are grouped under parameter uncertainties, modeling uncertainties, and results uncertainties.

Table C.1-20. Facility-Level Results for Ecological Risk by Proximity to Wetlands and Managed Areas

Facility Status	Least Concern[a]		Lower Concern[a]		Potential Concern[a]		Total	
Wetland Within 1 km	105* (2%)		460* (10%*)		263 (6%)		828 (19%)	
	13%*	17%*	56%*	19%*	32%*	19%	100%	19%
Managed Area Within 3 km	58* (1%)		326* (7%)		92 (2%)		476 (11%)	
	12%*	8%*	69%*	14%	19%*	7%	100%	11%
Wetland Within 1 km and Managed Area Within 3 km	9* (0.2%*)		5* (0.1%*)		40* (0.9%)		54* (1%)	
	17%*	1%*	9%*	0.2%*	75%*	3%	100%	1%

Table key: Number of facilities (% of all facilities).
Row %, Column %.

[a] Number of facilities (percentages are of the total number of facilities, approximately 4,500).

* This estimate may not be reliable because of a large relative standard error. See Appendix A.5 for details.

Parameter Uncertainties. The key parameters required for the ecological risk screening include the list of ecological receptors assigned to each facility, dietary assumptions, and ecological screening factors. As appropriate for screening-level analyses, the selection of parameter values tends to support a protective assessment.

- *Ecological Receptor Assignments*. Ecological receptors were assigned at each facility as a function of the land use patterns and presence of wetlands and/or fishable waterbodies. This adds to the protective nature of the screening assessment because not all facilities are located in areas of sufficient ecological quality to sustain those receptors.

- *Assumptions on Dietary Exposure*. Screening-level assessments typically assume exclusive intake of contaminated prey in the diets of primary and secondary consumers (i.e., 100 percent of the diet originates from the contaminated area), providing a very conservative estimate of potential risks.

- *Conservatism of Screening Factors*. Because the screening factors were generally based on benchmarks for very low levels of effect for sensitive endpoints, these factors tend to be very protective of wildlife species and natural communties.

Modeling Uncertainties. The screening ecological risk assessment did not involve fate and transport modeling of chemical movement and uptake into plants and prey items. Consequently, this direct exposure approach is protective in the sense that it implies actual usage of the impoundment as habitat.

- *Spatial Scale of Exposure*. The screening level of resolution does not provide insight into the scope/size of ecological impacts. The size of the contaminated

area is a critical determinant of the risk results because larger areas dilute chemical concentrations. Restricting the area to the impoundment tends to bias the results toward an overestimate of risk.

- *Temporal Scale of Exposure*. The timing is assumed to include the entire life stage of the wildlife species evaluated or, in the case of community-type receptors (e.g., soil biota), a period that is relevant to the structure and function of the community. The chronic, low-level exposure that this implies may be underprotective of some species during sensitive lifestages or of short-lived species.

- *Constant Chemical Concentration*. The chemical concentration was assumed to be constant for the screening analysis when, in reality, the chemical concentrations in plants, prey, and media will vary over time and space. A constant chemical concentration will tend to overpredict the potential risks to wildlife.

- *Chemical Behavior*. For screening purposes, all forms of a constituent are assumed to be equally bioavailable and toxic. This assumption may either overestimate or underestimate the actual exposures, depending on the environmental characteristics. For example, the form of arsenic (i.e., elemental, ionic, and methylated) has been shown to influence toxicity profoundly.

- *Single Chemical Exposures*. The risk of each constituent is considered separately in this analysis, and this may overlook possible synergistic effects. This is one example of a potential underestimation of adverse effects.

Results Uncertainties. As with any screening ecological risk assessment, there is considerable uncertainty in the risk results associated with simplifying assumptions and data limitations such as ecological benchmarks. Moreover, the screening analysis does not address the potential significance of predicted ecological impacts. Although the ecological risk results indicate that the potential for adverse ecological effects exists at these facilities, it is not possible to quantify that potential within the broader context of ecological health and sustainability. Several key uncertainties to consider in interpreting the risk results are presented below.

- *Concentration Data Source*. A portion of the risk findings are based on surrogate data and detection limits, rather than on reported concentrations, and this contributes to the overall uncertainty in the results.

- *Data Gaps*. Protective ecological screening factors were developed for constituents when sufficient data were available which, for this analysis, included 41 chemicals. The absence of benchmarks may lead to the underestimation of risks associated with stressors for those chemicals that could not be evaluated.

- *No Additional Stressors*. The only stressor assumed in the screening analysis is the introduction of chemicals into the environment. In the field, wildlife may be

exposed to a variety of stressors (e.g., habitat alteration); therefore, the risk results may underestimate the potential for adverse effects.

- *Threatened/Endangered Species*. Only common species were evaluated in this analysis. The sensitivity of endangered species that are already under substantial stress is not accounted for explicitly. Although the selection of screening approach and parameters is inherently protective, it is possible that the results do not capture the risks to sensitive species and habitats.

C.2 Direct Exposure Pathway–Air

The air pathway considers the risk to a person (or receptor) inhaling air contaminated with the chemicals present in surface impoundments. These chemicals reach the air by volatilizing from the surface impoundment. They may then be transported some distance from the impoundment before a person inhales them. The farther the person is from the impoundment, the lower the concentration of the chemical in the air and the lower the risk.

C.2.1 Methods

C.2.1.1 Overview. The air pathway was assessed using several screening steps, each less conservative than the previous. The first two steps, direct exposure pathway screening and screening level modeling, are summarized in Section C.1.1; additional details are provided in the *Technical Plan* (where they are referred to as Phase IA and IB, respectively). The third step, Site-based Modeling, was not covered by the *Technical Plan* but is discussed here.

Although each of the screening steps is similar, for each successive step, the person inhaling the air was placed farther from the impoundment and more site-specific data from the SIS survey were used.

In the direct exposure pathway screening, data from the SIS survey on air concentration of chemicals of concern in the air over the impoundment were used. A receptor was assumed to inhale that concentration from childhood through adulthood. The air concentration data needed for this step were not available from the survey for many impoundments and chemicals. If data were not available or the risk calculated by this step for an impoundment and chemical exceeded the risk criteria, which were 1E-5 for risk or 1 for HQ, they passed on to the next step.

In the screening level modeling, an air risk model called IWAIR (Industrial Waste Air Model) was used. This model uses emissions data from the survey or, if no data are available, estimates emissions from concentration and other site-specific data from the SIS survey. IWAIR then estimates the concentration in air at some distance from the impoundment. The farther from the impoundment, the lower the air concentration. In this step, a distance of 25 m was used. The person inhaling the chemicals was assumed to do so for 30 years, starting in childhood. Site-specific data from the survey were used for the model inputs that most affect the results, including the size of the impoundment, where it is located, and whether it is aerated.

In the site-based modeling, IWAIR was used again, with the same site-specific data as before, but with the receptor placed at the actual distance to the nearest residence for each impoundment (taken from the survey). This was typically more than the 25 m used in the previous step, so the risk was typically lower than in the screening level modeling step.

Because the data on distance to nearest residence were sometimes incomplete or based on old maps, census data and aerial photos that were acquired from the United States Geological Survey (USGS) were used as a check on the distance to the nearest residence. The distance to the nearest populated census block was used to identify sites that might change from being below risk criteria to exceeding risk criteria if there were residences nearer than the survey data

suggested. For those sites, aerial photos were examined. In most cases, the aerial photos confirmed the nearest residence location reported in the survey. When they did not, the receptor distance was updated based on the aerial photo, and the risk was recalculated.

C.2.1.2 IWAIR. IWAIR is an interactive computer program with three main components: an emissions model, a dispersion model to estimate fate and transport of constituents through the atmosphere and determine ambient air concentrations at specified receptor locations, and a risk model to calculate the risk to exposed individuals. IWAIR can model four types of waste management unit, but only the surface impoundment component was used for this study. IWAIR requires only a limited amount of site-specific information, including facility location, impoundment characteristics, waste characteristics, and receptor information. IWAIR was modified for this study to bypass the interactive user interface and read data compiled from the surface impoundment survey directly from a database.

A brief description of each component and other modifications made to IWAIR for this study follows. The *IWAIR Technical Background Document* (U.S. EPA, 1998b) contains a more detailed explanation of the IWAIR model.

Emissions Model. The emission model uses waste characterization, impoundment, and facility information to estimate emissions for 95 constituents identified in Table C.2-1. The emission model incorporated into IWAIR is EPA's CHEMDAT8 model. This model has undergone extensive review by both EPA and industry representatives and is publicly available from EPA's web page. For this study, data on 13 additional chemicals, identified in Table C.2-2, were added to IWAIR. These chemicals represent the chemicals reported in the survey that were not already in IWAIR and that have inhalation health benchmarks and sufficient chemical-physical properties data to be modeled using IWAIR.

Table C.2-1. Constituents Included in IWAIR

CAS No.	Chemical Name
75070	Acetaldehyde
67641	Acetone
75058	Acetonitrile
107028	Acrolein
79061	Acrylamide
79107	Acrylic acid
107131	Acrylonitrile
107051	Allyl chloride
62533	Aniline
71432	Benzene
92875	Benzidine
50328	Benzo(a)pyrene
75274	Bromodichloromethane
106990	Butadiene, 1,3-
75150	Carbon disulfide

(continued)

Table C.2-1. (continued)

CAS No.	Chemical Name
56235	Carbon tetrachloride
108907	Chlorobenzene
124481	Chlorodibromomethane
67663	Chloroform
95578	Chlorophenol, 2-
126998	Chloroprene
10061015	cis-1,3-Dichloropropylene
1319773	Cresols (total)
98828	Cumene
108930	Cyclohexanol
96128	Dibromo-3-chloropropane, 1,2-
75718	Dichlorodifluoromethane
107062	Dichloroethane, 1,2-
75354	Dichloroethylene, 1,1-
78875	Dichloropropane, 1,2 -
57976	Dimethylbenz[a,h]anthracene, 7, 12-
95658	Dimethylphenol, 3,4-
121142	Dinitrotoluene, 2,4-
123911	Dioxane, 1,4-
122667	Diphenylhydrazine, 1,2-
106898	Epichlorohydrin
106887	Epoxybutane, 1,2-
111159	Ethoxyethanol acetate, 2-
110805	Ethoxyethanol, 2-
100414	Ethylbenzene
106934	Ethylene dibromide
107211	Ethylene glycol
75218	Ethylene oxide
50000	Formaldehyde
98011	Furfural
87683	Hexachloro-1,3-butadiene
118741	Hexachlorobenzene
77474	Hexachlorocyclopentadiene
67721	Hexachloroethane
78591	Isophorone
7439976	Mercury
67561	Methanol
110496	Methoxyethanol acetate, 2-
109864	Methoxyethanol, 2-
74839	Methyl bromide
74873	Methyl chloride
78933	Methyl ethyl ketone
108101	Methyl isobutyl ketone
80626	Methyl methacrylate
1634044	Methyl tert-butyl ether
56495	Methylcholanthrene, 3-

(continued)

Table C.2-1. (continued)

CAS No.	Chemical Name
75092	Methylene chloride
68122	N,N-Dimethyl formamide
91203	Naphthalene
110543	n-Hexane
98953	Nitrobenzene
79469	Nitropropane, 2-
55185	N-Nitrosodiethylamine
924163	N-Nitrosodi-n-butylamine
930552	N-Nitrosopyrrolidine
95501	o-Dichlorobenzene
95534	o-Toluidine
106467	p-Dichlorobenzene
108952	Phenol
85449	Phthalic anhydride
75569	Propylene oxide
110861	Pyridine
100425	Styrene
1746016	TCDD, 2,3,7,8 -
630206	Tetrachloroethane, 1,1,1,2-
79345	Tetrachloroethane, 1,1,2,2-
127184	Tetrachloroethylene
108883	Toluene
10061026	trans-1,3-Dichloropropylene
75252	Tribromomethane
76131	Trichloro-1,2,2-trifluoroethane, 1,1,2-
120821	Trichlorobenzene, 1,2,4-
71556	Trichloroethane, 1,1,1-
79005	Trichloroethane, 1,1,2-
79016	Trichloroethylene
75694	Trichlorofluoromethane
121448	Triethylamine
108054	Vinyl acetate
75014	Vinyl chloride
1330207	Xylenes

Table C.2-2. Constituents Added to IWAIR for Surface Impoundment Study

CAS No.	Chemical Name
542881	Bis(chloromethyl)ether
75343	Dichloroethane, 1,1-
76448	Heptachlor
319846	Hexachlorocyclohexane, alpha-
319857	Hexachlorocyclohexane, beta-
55684941	Hexachlorodibenzofurans [HxCDFs]
34465468	Hexachlorodibenzo-p-dioxins [HxCDDs]
30402154	Pentachlorodibenzofurans [PeCDFs]
1336363	Polychlorinated biphenyls
55722275	Tetrachlorodibenzofurans [TCDFs]
41903575	Tetrachlorodibenzo-p-dioxins [TCDDs]
8001352	Toxaphene
88062	Trichlorophenol, 2,4,6-

Dispersion Model. IWAIR's second modeling component estimates dispersion of volatilized contaminants and determines air concentrations at specified receptor locations, using default dispersion factors developed with EPA's Industrial Source Complex, Short-Term Model, version 3. ISCST3 was run to calculate dispersion for a standardized unit emission rate (1 $\mu g/m^2$-s) to obtain a unitized air concentration (UAC), also called a dispersion factor, which is measured in μ/m^3 per $\mu g/m^2$-s. The total air concentration estimates are then developed by multiplying the constituent-specific emission rates derived from CHEMDAT8 with a site-specific dispersion factor. Running ISCST3 to develop a new dispersion factor for each location and impoundment is very time consuming and requires extensive meteorological data and technical expertise. Therefore, IWAIR incorporates default dispersion factors developed by ISCST3 for many separate scenarios designed to cover a broad range of unit characteristics, including

- 29 meteorological stations, chosen to represent the nine general climate regions of the continental United States
- 14 surface area sizes for surface impoundments
- 7 receptor distances from the unit (0, 25, 50, 75, 150, 500, 1000 meters)
- 16 directions in relation to the edge of the unit.

The default dispersion factors were derived by modeling each of these scenarios, then choosing as the default the maximum dispersion factor for each impoundment/surface area/meteorological station/receptor distance combination.

Peer review comments on IWAIR received before this study was completed suggested that the 29 meteorological stations were not sufficient to be fully representative of the United States. Therefore, 12 additional meteorological stations were selected to be added to IWAIR for

this study. These additional meteorological stations were selected to better represent the locations of surface impoundments, based on data from the surface impoundment survey. The appropriate dispersion factors for these new meteorological stations were developed and added to the IWAIR dispersion factor database. Table C.2-3 lists the original 29 meteorological stations included in IWAIR and the 12 new stations added to IWAIR for this study.

Table C.2-3. Meteorological Stations Included in and Added to IWAIR for Surface Impoundment Study

Original Met Stations		Added for SIS	
Met Station ID	**City**	**Met Station ID**	**City**
23050	Albuquerque, NM	3812	Asheville, NC
13874	Atlanta, GA	12842	Tampa, FL
24011	Bismarck, ND	12916	New Orleans, LA
24131	Boise, ID	13737	Norfolk, VA
24089	Casper, WY	13865	Meridian, MS
13880	Charleston, SC	13957	Shreveport, LA
94846	Chicago, IL	14742	Burlington, VT
14820	Cleveland, OH	14840	Muskegon, MI
23062	Denver, CO	24033	Billings, MT
93193	Fresno, CA	13897	Nashville, TN
14751	Harrisburg, PA	13968	Tulsa, OK
14740	Hartford, CT	14778	Williamsport, PA
12960	Houston, TX		
3860	Huntington, WV		
23169	Las Vegas, NV		
14939	Lincoln, NE		
13963	Little Rock, AR		
23174	Los Angeles, CA		
12839	Miami, FL		
14922	Minneapolis, MN		
13739	Philadelphia, PA		
23183	Phoenix, AZ		
14764	Portland, ME		
13722	Raleigh-Durham, NC		
24232	Salem, OR		

(continued)

Table C.2-3. (continued)

Original Met Stations		Added for SIS	
Met Station ID	**City**	**Met Station ID**	**City**
24127	Salt Lake City, UT		
23234	San Francisco, CA		
24233	Seattle, WA		
24128	Winnemucca, NV		

Based on the size and location of a unit, IWAIR selects an appropriate dispersion factor from the default dispersion factors in the model. If the impoundment surface area that falls between two of the sizes that have already been modeled, a linear interpolation method then estimates dispersion in relation to the two closest unit sizes.

Risk Model. The third component of IWAIR combines the constituent's air concentration with receptor exposure factors and toxicity benchmarks to calculate the risk from concentrations managed in the impoundment. The model applies default values for exposure factors, including inhalation rate, body weight, exposure duration, and exposure frequency. These default values are based on data presented in EPA's *Exposure Factors Handbook* (U.S. EPA, 1997c, d, e) and represent average exposure conditions. IWAIR maintains standard health benchmarks (cancer slope factors for carcinogens and reference concentrations for noncarcinogens) for 95 constituents. These health benchmarks are from the Integrated Risk Information System (IRIS) (U.S. EPA, 2000f) and the Health Effects Assessment Summary Tables (HEAST) (U.S. EPA, 1997h). As noted earlier, data on 13 additional chemicals reported in the surface impoundment survey were added to IWAIR.

C.2.1.3 Additional Methodology Details for Site-Based Modeling. The basic approach used for the site-based modeling step was to identify the location of the nearest receptor, interpolate the risk or HQ at that receptor, and evaluate that risk or HQ with respect to the risk criteria, which were 1E-5 for risk or 1 for HQ.

Calculating Risk at Nearest Receptor. IWAIR can only be run at seven preset distances: 0, 25, 50, 75, 150, 500, and 1,000 m. IWAIR had already been run at 25 m for the screening-level modeling. To conduct the site-based modeling, an interpolation approach was taken: IWAIR was run at all six remaining distances for the impoundment/chemical combinations that had risks in the screening level modeling that exceeded the risk criteria. EPA then interpolated the risk at the nearest receptor using standard interpolation techniques. Due to the overall shape of the risk-distance curve, which is not strictly linear but approaches zero risk asymptotically as distance increases, EPA did a log-log interpolation, as shown in Equation C-1.

$$\log(R) = \frac{(\log R2 - \log R1)}{(\log D2 - \log D1)} \times (\log D - \log D1) + \log R1 \qquad \text{(C-1)}$$

where

R_2 = upper-bound risk or HQ modeled by IWAIR
R_1 = lower-bound risk or HQ modeled by IWAIR
D_2 = upper-bound distance modeled by IWAIR (m)
D_1 = lower-bound distance modeled by IWAIR (m)
D = nearest receptor distance (m)
R = interpolated risk or HQ at nearest receptor distance.

The lower and upper bound distances are the distances at which IWAIR can be run that bracket the actual distance to the nearest receptor. For example, if the nearest receptor were at 100 m, the lower bound distance would be 75 m and the upper bound distance would be 150 m. The lower and upper bound risk or HQ is the modeled risk or HQ at the lower or upper bound distance. When the actual receptor distance is beyond the data modeled, the last two points modeled can be used to extrapolate using this same equation; for example, for a receptor distance of 1,200 m, the data for 500 m and 1,000 m can be used to extrapolate.

The interpolated risks were then compared to the risk or HQ criterion. If the risk exceeded the risk or HQ criterion (1E-5 for risk or 1 for HQ), the combination was retained for further analysis. If the risk or HQ was below the criterion, the combination was dropped from further analysis.

Identifying the Nearest Receptor. Based on the survey data, we identified the nearest residence for the impoundments for which the risk calculated in the screening-level modeling exceeded the risk criteria. The survey respondents were sent topographic maps of the area surrounding their facility. These maps show residences present at the time the map was last updated. Some maps had been updated recently and others had not been updated for many years. Survey respondents were asked to mark any additional residences on the map, verify the map as provided, or provide their own map with residences shown. Some respondents did not annotate the provided map or verify the map as provided. These maps were considered unverified. The returned maps were digitized, and a computer program was used to calculate the distance to the nearest marked residence.

Because some of the returned maps were old and unverified, EPA also considered two alternative methods of locating residences as checks.

One alternative method of locating residences is to assume that the nearest edge of the nearest populated census block edge is a reasonable minimum distance to the nearest residence. However, there may not be residences in that part of the census block, so this approach introduces a high degree of uncertainty. This distance can be determined by computer based on publicly available census data.

A more accurate method of locating the nearest residence is by examination of aerial photos of the area surrounding each facility. EPA acquired aerial photos from USGS for most sites in the survey at the time the survey was conducted. However, examination of aerial photos is very time consuming, so it could not realistically be done for all sites.

To make the most efficient use of resources, EPA used map date, verification status, and census block distance to identify facilities with the most uncertainty in residence location and most likely to change from having a risk below the risk criterion to having a risk that exceeds the risk criterion if there were residences closer than indicated by the survey. EPA examined aerial photos only for those facilities. Specifically, EPA performed the following steps:

- EPA calculated risk based on digitized (survey) residence location. If this risk exceeded the criterion, then that result was taken as final. Because the risk already exceeds the risk criterion, there is little to be gained by locating the nearest residence more precisely even if there is a closer residence.

- If the risk at the nearest digitized receptor was below the risk criterion, EPA considered whether the map was verified and the map date. If the map was verified, or if the map date was more recent than the most recent census data (1990), EPA considered the nearest digitized residence to be reliable, and the result stood.

- If the map was unverified and older than 1990, EPA calculated the risk based on the nearest edge of the nearest populated census block. This is a realistic worst case for residence distance; therefore, if the risk was below the risk criterion even at this distance, then the result based on the digitized receptor stood.

- If the risk at the census block edge exceeded the risk criterion, EPA examined the aerial photo to identify the actual nearest residence. If this was different than the digitized residence location, EPA updated that location and recalculated the risk at the new location. The risk at the updated location was then the final result, whether it exceeded or fell below the risk criterion.

Figure C.2-1 shows this same logic in a flow diagram.

In all cases, the final risk was that calculated at the digitized residence location or the location determined by examination of the aerial photo, if that was different. In most cases, the aerial photos confirmed the digitized residence location. In the few cases that they did not, the nearest residence was still considerably farther away than the nearest edge of the nearest populated census block. Therefore, risk at the edge of the census block was never used as the final risk.

Figures C.2-2 and C.2-3 show the digitized maps and aerial photos of two of the sites examined. The aerial photo of the site in Figure C.2-3 clearly shows residences closer to some of the impoundments than those shown on the digitized map from the survey.

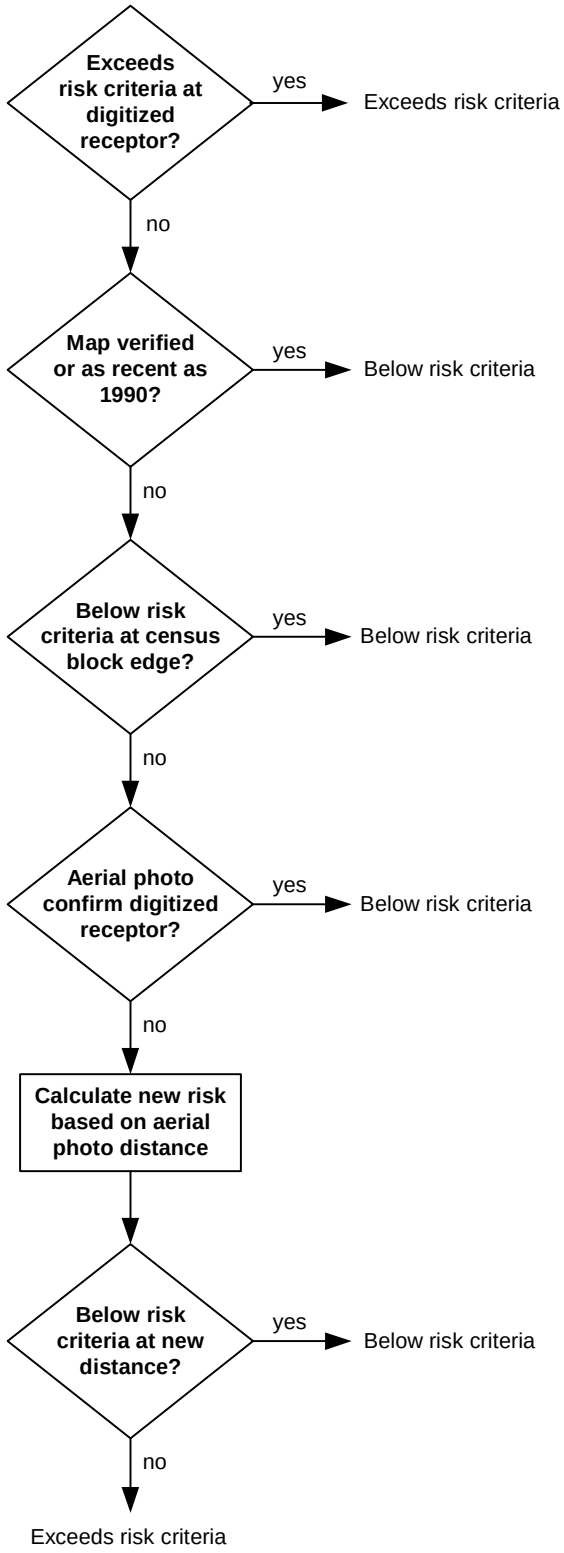


Figure C.2-1. Decision tree for performing air risk screening.

Figure C.2-2. Examples of nearest receptor: Example 1.

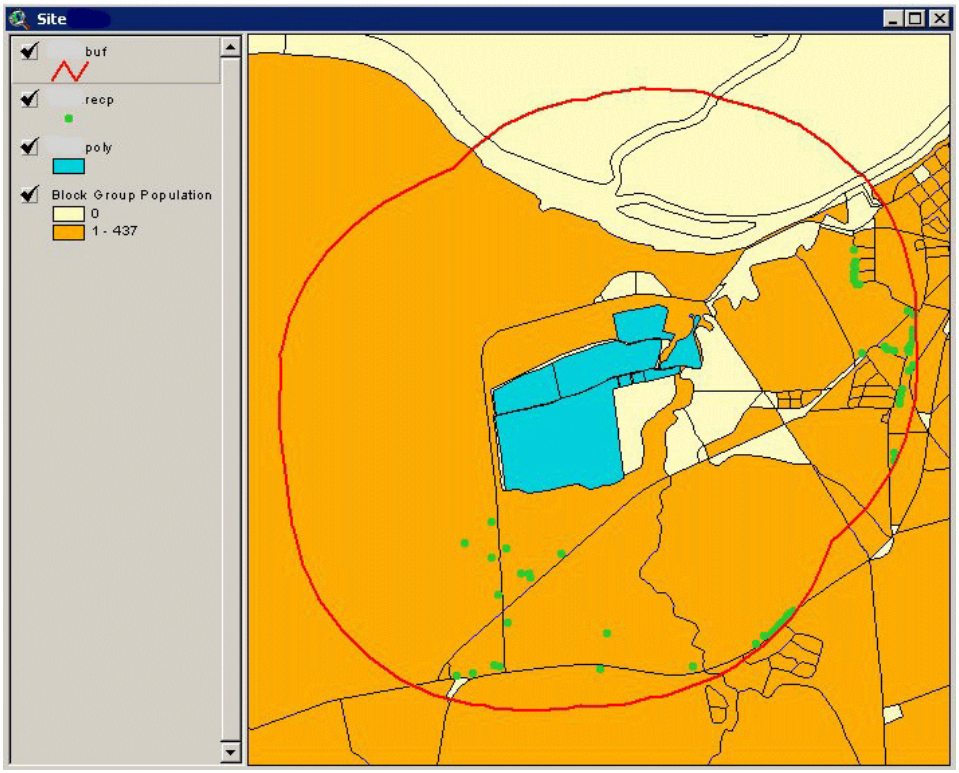


Figure C.2.3. Examples of nearest receptor: Example 2.

C.2.2 Results from Air Pathway Analysis

C.2.2.1 Direct Exposure Pathway Screening Results. A total of 39 constituents present in 84 surface impoundments at 19 facilities were considered in the initial screening step. When constituent air concentrations reported in the surface impoundments (or estimated from reported emissions rates) were compared to human health screening factors based on toxicity benchmarks for inhalation, 17 constituents in 28 surface impoundments at 11 facilities exceeded the risk criteria for the direct exposure pathway screening. The constituent counts reflect only those chemicals for which at least one human health benchmark was available. Many of the facilities and impoundments did not have the emissions or air concentration data needed for the direct exposure pathway screening for air; those impoundments were passed on for consideration in the screening-level modeling step.

C.2.2.2 Screening-Level Modeling Results. For those constituents, impoundments, and facilities that exceeded the risk criteria for the direct exposure pathway screening, plus those for which the direct exposure pathway screening could not be performed due to lack of data, a more realistic assessment of air risk was calculated using IWAIR. In this case, 90 constituents in 290 surface impoundments at 85 facilities were modeled. Forty-two constituents in 75 impoundments at 33 facilities exceeded the risk criteria at this step and were retained for site-based modeling.

C.2.2.3 Site-Based Modeling. Site-based modeling was conducted for the constituents, impoundments, and facilities that exceeded the risk criteria for screening-level modeling. After the site-based modeling, 12 constituents in 17 impoundments at 12 facilities exceeded the risk criteria. A summary of exceedances is presented in Table C.2-4. Attachment C-6 presents the full set of site-based air modeling results for the sample population. Attachment C-7 presents the national estimates for the air pathway results.

Table C.2-4. Summary of Hazard and Risk Exceedances for the Air Pathway

Facility	SI	Summary of HQ Exceedance	Summary of Risk Exceedance
Risk Exceedances Based on Reported Concentrations			
85	1		**Chlorodibromomethane** - 1e-05
151	1		**alpha-Hexachlorocyclohexane** -2.62e-05
Risk Exceedances Based on Surogate/DL Chemical Concentrations			
23	1	Chloroform - 2.2	
23	1	Acetonitrile -57.2	
23	4	Chloroform -1.82	
23	4	Acetonitrile - 47.7	
45	2	Acrolein -7.96	
			(continued)

Table C.2-4. (continued)

Facility	SI	Summary of Risk Exceedance	
45	4	Acrolein - 4.52	
45	5	Acrolein - 3.63	
46	3	Acrolein[b] -2.64	
46	3		Bis(chloromethyl) ether [b] - 4.84e-04
46	3		N-Nitrosodiethylamine [b] - 4.64e-05
46	3		N-Nitrosodi-n-butylamine [b]- 1.55e-05
46	4		Bis(chloromethyl) ether [b]- 1.05e-04
46	5		Bis(chloromethyl) ether [b]- 2.44e-04
77	1		Bis(chloromethyl) ether - 3.61e-01
84	4		Bis(chloromethyl) ether - 1.62e-04
84	5	Acrolein - 8.73	
84	5		Bis(chloromethyl) ether - 8.73e-03
84	5	Hexachlorocyclopentadiene - 1.5	
103	3		Tetrachlorodibenzofurans - 3.22e-05
175	3	Acrolein[b] - 11.5	
184	2		Toxaphene - 4.00e-03
Risk Exceedances Based on Summed Risks for the Facility			
156			Facility level sum - 1.5e-05
156	5		**Acetaldehyde** [a] - 6.00e-06
156	7		Tetrachlorodibenzodioxins - 9.00e-06

[a] This constituent and the other bolded ones are based on reported values.

[b] Industry representatives, subsequent to completion of the survey, have indicated that this constituent is not expected to be present at the facility. These constituents were reported to EPA in response to the Survey of Surface Impoundments in November 1999 as less than a specified limit of detection. When this constituent was evaluated in the risk analysis at the reported detection limit, the concentrations were high enough to predict the indicated risk/hazard of concern. EPA included the results in this table because of the methodology used throughout the study to evaluate less than detection limit data.

C.3 Direct Exposure Pathway—Groundwater

People may be exposed to constituents originating in surface impoundments if the constituents leach through the bottom of the impoundment into groundwater and migrate to downgradient receptor wells. The potential for direct exposure to constituents via the groundwater pathway was assessed in three phases, each less conservative than the previous phase. The first phase, direct exposure pathway screening, compared estimated leachate concentrations to screening factors for drinking water ingestion. The second phase, screening-level modeling, calculated risks and hazard quotients using EPA's Industrial Waste Evaluation Model. The third phase, site-based modeling, identified facility and impoundment combinations that have the greatest potential to impact receptor wells and provided quantitative risk estimates for the nearest receptor well at each site of interest.

Site-based modeling was accomplished in three basic steps:

- EPA evaluated the 71 facilities that exceeded risk criteria based on the IWEM Tier 1 screening analysis to determine if the potential exists for direct exposure to contamination via the groundwater pathway.

- EPA assumed the potential for exposure by determining if drinking water wells were present in the downgradient direction of groundwater flow.

- If receptor wells were not present, or if the receptor wells were determined not to be downgradient of the surface impoundment, EPA presumed the pathway to be incomplete and excluded the site from further evaluation.

For those facilities that were not excluded, two sets of criteria were developed and used to prioritize which facilities required site-based modeling. The first set of criteria focused on environmental setting characteristics (e.g., distance to receptor well) and the second set of criteria relied on professional judgment (e.g., conductivity of aquifer material). Each set of criteria and the method in which they were applied are detailed in Attachment C-8. Application of the two sets of screening criteria produced 10 facilities that were considered the highest priority for site-based groundwater modeling. The 10 facilities are identified in Attachment C-8 and summaries of pertinent site and risk characteristics are presented in Attachment C-9.

Characterization and data selection for the 10 modeled facilities are presented in Attachment C-10. Risk results and modeling for the groundwater pathway are presented in Attachments C-11 and C-12, respectively.

Site-based modeling was conducted following identification of the highest priority facilities. Modeling involved assessing the fate and transport of chemical constituents present in surface impoundments using Monte Carlo simulations executed using EPACMTP. Site-specific, regional, and national data, as appropriate, were used in model simulations.

These groundwater concentrations were then coupled with Monte Carlo-generated exposure parameters to generate individual cancer risk and noncancer hazard quotients for the 10 highest priority facilities. The results of this analysis are presented in Attachment C-12.

C.3.1 Numeric Ranking System for Facilities, Impoundments, and Constituents

The direct exposure pathway screening analysis compared constituent concentrations reported in surface impoundments to human health screening factors protective of residential exposure. Specifically, the risks posed to an individual receptor based on concentrations of constituents in surface impoundments were compared to human health risk screening factors based on toxicity benchmarks for direct ingestion of drinking water. These screening risks are highly protective of human health because the underlying assumption is that the resident drinks impoundment water. Those constituents, impoundments, and facilities that posed negligible risk (i.e., cancer risk less than 1E-5 or HQ less than 1.0) were below risk criteria for the analysis. This human health risk screening calculation was performed for each constituent in each surface impoundment for each of the 133 facilities. Of the 133 facilities, 106 facilities exceeded risk criteria.

For those constituents, impoundments, and facilities that exceeded risk criteria, a more refined assessment of groundwater risk was performed by evaluating fate and transport processes in the environment using EPA's IWEM Tier 1 screening model (U.S. EPA, 1999b, c). This phase of the screening process also used protective assumptions, such as assessing risks for receptor wells located 150 meters from the surface impoundment.

The IWEM Tier 1 screening model consists of tabulated leachate concentration threshold values for specific chemicals based on a dilution attenuation factor and the toxicity reference levels for 191 constituents. The toxicity reference level is based on toxicological benchmarks or the maximum contaminant level. The DAFs were generated by modeling the migration of waste constituents from an impoundment through the underlying soil to a monitoring point in the aquifer using EPACMTP in a national Monte Carlo probabilistic analysis. The DAFs are multiplied by the toxicity benchmark to provide the leachate concentration threshold value for each constituent.

To maintain consistency with the initial phase of risk screening, only the DAFs from IWEM were used. DAFs and leachate concentration threshold values were evaluated for three impoundment liner scenarios: no liner, single liner, and a composite liner. The no liner scenario represented an impoundment relying on location-specific conditions such as low-permeability native soils beneath the unit or low annual precipitation rates to mitigate the release of contaminants to the groundwater. The single liner scenario represented a 3-foot-thick clay liner with low hydraulic conductivity (10^{-7} cm/s) beneath the impoundment, and the composite liner scenario consisted of a 3-foot-thick clay liner beneath a 40-mil-thick high-density polyethylene (HDPE) flexible membrane liner. The DAFs for each constituent for each of the three liner scenarios are presented in Table C.3-1.

Table C.3-1. Constituent Dilution Attenuation Factors for Liner Scenarios

Constituent	CAS_NO	Scenario[a]	DAF
1,1,2,2-Tetrachloroethane	79345	1	3.9
1,1,2,2-Tetrachloroethane	79345	2	34000
1,1,2,2-Tetrachloroethane	79345	3	34000
1,1-Dichloroethylene [Vinylidene chloride]	75354	1	1.8
1,1-Dichloroethylene [Vinylidene chloride]	75354	2	7
1,1-Dichloroethylene [Vinylidene chloride]	75354	3	730000
1,2,3-Trichloropropane	96184	3	1.00E+06
1,2,3-Trichloropropane	96184	1	1.2
1,2,3-Trichloropropane	96184	2	10
1,2,4,5-Tetrachlorobenzene	95943	2	170
1,2,4,5-Tetrachlorobenzene	95943	3	170
1,2,4,5-Tetrachlorobenzene	95943	1	5.2
1,2-Dibromo-3-chloropropane	96128	1	1.8
1,2-Dibromo-3-chloropropane	96128	3	110000000
1,2-Dibromo-3-chloropropane	96128	2	13
1,2-Dichloroethane [Ethylene dichloride]	107062	3	1.00E+06
1,2-Dichloroethane [Ethylene dichloride]	107062	1	1.8
1,2-Dichloroethane [Ethylene dichloride]	107062	2	8.4
1,2-Dichloropropane [Propylene dichloride]	78875	1	1.9
1,2-Dichloropropane [Propylene dichloride]	78875	2	19
1,2-Dichloropropane [Propylene dichloride]	78875	3	19
1,2-Diphenylhydrazine	122667	1	1.8
1,2-Diphenylhydrazine	122667	3	130000
1,2-Diphenylhydrazine	122667	2	6.6
1,3-Dinitrobenzene [m-Dinitrobenzene]	99650	1	1.1

(continued)

Table C.3-1. (continued)

Constituent	CAS_NO	Scenario[a]	DAF
1,3-Dinitrobenzene [m-Dinitrobenzene]	99650	3	310000
1,3-Dinitrobenzene [m-dinitrobenzene]	99650	2	5
1,4-Dichlorobenzene [p-dichlorobenzene]	106467	3	11000000
1,4-Dichlorobenzene [p-dichlorobenzene]	106467	2	15
1,4-Dichlorobenzene [p-dichlorobenzene]	106467	1	2
1,4-Dioxane [1,4-diethyleneoxide]	123911	1	1.8
1,4-Dioxane [1,4-diethyleneoxide]	123911	3	130000
1,4-Dioxane [1,4-diethyleneoxide]	123911	2	6.6
2,3,7,8-TCDD [2,3,7,8-tetrachlorodibenzo-p-dioxin]	1746016	1	300
2,3,7,8-TCDD [2,3,7,8-tetrachlorodibenzo-p-dioxin]	1746016	2	7900000000
2,3,7,8-TCDD [2,3,7,8-tetrachlorodibenzo-p-dioxin]	1746016	3	7900000000
2,4,6-Trichlorophenol	88062	1	1.8
2,4,6-Trichlorophenol	88062	3	1900000
2,4,6-Trichlorophenol	88062	2	7.9
2,4-Dichlorophenol	120832	1	1.2
2,4-Dichlorophenol	120832	3	3100000
2,4-Dichlorophenol	120832	2	7.2
2,4-Dinitrophenol	51285	1	1.1
2,4-Dinitrophenol	51285	3	130000
2,4-Dinitrophenol	51285	2	4.8
2,4-Dinitrotoluene	121142	1	1.1
2,4-Dinitrotoluene	121142	2	5.2
2,4-Dinitrotoluene	121142	3	600000
2,6-Dinitrotoluene	606202	1	1.1
2,6-Dinitrotoluene	606202	3	380000

(continued)

Table C.3-1. (continued)

Constituent	CAS_NO	Scenario[a]	DAF
2,6-Dinitrotoluene	606202	2	5
2-Chlorophenol [o-chlorophenol]	95578	1	1.1
2-Chlorophenol [o-chlorophenol]	95578	2	5.4
2-Chlorophenol [o-chlorophenol]	95578	3	790000
3,3'-Dichlorobenzidine	91941	1	2.1
3,3'-Dichlorobenzidine	91941	3	21000000
3,3'-Dichlorobenzidine	91941	2	22
4,4'-Methylene bis(2-chloroaniline)	101144	3	1.00E+06
4,4'-Methylene bis(2-chloroaniline)	101144	1	1.8
4,4'-Methylene bis(2-chloroaniline)	101144	2	8
Acetone [2-Propanone]	67641	1	1.1
Acetone [2-Propanone]	67641	3	130000
Acetone [2-Propanone]	67641	2	4.8
Acrylic acid [propenoic acid]	79107	1	1.1
Acrylic acid [propenoic acid]	79107	3	130000
Acrylic acid [propenoic acid]	79107	2	4.8
Acrylonitrile	107131	1	1.8
Acrylonitrile	107131	3	190000
Acrylonitrile	107131	2	6.6
Aldrin	309002	1	360
Aldrin	309002	2	9800000000
Aldrin	309002	3	9800000000
Allyl alcohol	107186	1	1.1
Allyl alcohol	107186	3	130000
Allyl alcohol	107186	2	4.8

(continued)

Table C.3-1. (continued)

Constituent	CAS_NO	Scenario[a]	DAF
alpha-Hexachlorocyclohexane [α-BHC]	319846	2	230000000
alpha-Hexachlorocyclohexane [α-BHC]	319846	3	230000000
alpha-Hexachlorocyclohexane [α-BHC]	319846	1	59
Aniline	62533	2	6.6
Antimony	7440360	2	1360
Antimony	7440360	3	1360
Antimony	7440360	1	45
Arsenic	7440382	1	33
Arsenic	7440382	2	969
Arsenic	7440382	3	969
Barium	7440393	1	2.6585
Barium	7440393	3	232269.81
Barium	7440393	2	47.4
Benzene	71432	1	1.8
Benzene	71432	2	7.1
Benzene	71432	3	770000
Benzidine	92875	1	1.8
Benzidine	92875	3	320000
Benzidine	92875	2	6.7
Benzo(a)pyrene	50328	1	150
Benzo(a)pyrene	50328	2	3300000000
Benzo(a)pyrene	50328	3	3300000000
Benzo(b)fluoranthene	205992	1	150
Benzo(b)fluoranthene	205992	2	2100000000
Benzo(b)fluoranthene	205992	3	2100000000

(continued)

Table C.3-1. (continued)

Constituent	CAS_NO	Scenario[a]	DAF
Benzo[a]anthracene	56553	2	230000000
Benzo[a]anthracene	56553	3	230000000
Benzo[a]anthracene	56553	1	50
Benzyl chloride	100447	2	1.00E+06
Benzyl chloride	100447	1	1.00E+06
Benzyl chloride	100447	3	1.00E+06
Beryllium	7440417	3	1.00E+06
Beryllium	7440417	1	4.6
Beryllium	7440417	2	70
beta-Hexachlorocyclohexane [β-BHC]	319857	1	2.2
beta-Hexachlorocyclohexane [β-BHC]	319857	2	26
beta-Hexachlorocyclohexane [β-BHC]	319857	3	27000000
Bis(2-chloroethyl) ether [sym-dichloroethyl ether]	111444	1	2.3
Bis(2-chloroethyl) ether [sym-dichloroethyl ether]	111444	2	40
Bis(2-chloroethyl) ether [sym-dichloroethyl ether]	111444	3	40
Bis(2-chloroisopropyl) ether [2,2'-dichloroisopropyl ether]	39638329	1	1.8
Bis(2-chloroisopropyl) ether [2,2'-dichloroisopropyl ether]	39638329	3	2600000
Bis(2-chloroisopropyl) ether [2,2'-dichloroisopropyl ether]	39638329	2	8.4
Bis(chloromethyl) ether [sym-dichloromethyl ether]	542881	2	1.00E+06
Bis(chloromethyl) ether [sym-dichloromethyl ether]	542881	1	1.00E+06
Bis(chloromethyl) ether [sym-dichloromethyl ether]	542881	3	1.00E+06
Bromodichloromethane [dichlorobromomethane]	75274	1	1.8
Bromodichloromethane [dichlorobromomethane]	75274	3	1400000
Bromodichloromethane [dichlorobromomethane]	75274	2	8.1
Cadmium	7440439	3	1.00E+06

(continued)

Table C.3-1. (continued)

Constituent	CAS_NO	Scenario[a]	DAF
Cadmium	7440439	1	15.4
Cadmium	7440439	2	325.6
Carbon tetrachloride	56235	1	1.9
Carbon tetrachloride	56235	2	36
Carbon tetrachloride	56235	3	36
Chlordane, α & γ isomers	57749	2	130000
Chlordane, α & γ isomers	57749	3	130000
Chlordane, α & γ isomers	57749	1	176
Chlorobenzilate	510156	2	16000
Chlorobenzilate	510156	3	16000
Chlorobenzilate	510156	1	4.1
Chloroform [trichloromethane]	67663	1	1.8
Chloroform [trichloromethane]	67663	2	6.9
Chloroform [trichloromethane]	67663	3	930000
Chloromethane [methyl chloride]	74873	1	1.8
Chloromethane [methyl chloride]	74873	3	200000
Chloromethane [methyl chloride]	74873	2	6.6
Chromium	7440473	1	23
Chromium	7440473	2	645
Chromium	7440473	3	645
Chromium VI [hexavalent chromium]	18540299	3	1.00E+06
Chromium VI [hexavalent chromium]	18540299	1	23
Chromium VI [hexavalent chromium]	18540299	2	645
cis-1,3-Dichloropropylene	10061015	2	21000
cis-1,3-Dichloropropylene	10061015	1	21000

(continued)

Table C.3-1. (continued)

Constituent	CAS_NO	Scenario[a]	DAF
cis-1,3-Dichloropropylene	10061015	3	21000
Copper	7440508	2	164
Copper	7440508	3	313372.81
Copper	7440508	1	7.139
Cyanide	57125	2	1.00E+06
Cyanide	57125	3	1.00E+06
Cyanide	57125	1	28
Diallate	2303164	1	13
Diallate	2303164	2	830000
Diallate	2303164	3	830000
Dibenz[a,h]anthracene	53703	1	1059
Dibenz[a,h]anthracene	53703	2	2.9e+015
Dibenz[a,h]anthracene	53703	3	2.9e+015
Dieldrin	60571	2	2992
Dieldrin	60571	1	2992
Dieldrin	60571	3	2992
Ethyl acetate	141786	1	1.4
Ethyl acetate	141786	2	21
Ethyl acetate	141786	3	21
Ethylene dibromide [1,2-dibromoethane]	106934	2	1200
Ethylene dibromide [1,2-dibromoethane]	106934	3	1200
Ethylene dibromide [1,2-dibromoethane]	106934	1	3.1
Ethylene glycol	107211	1	1.1
Ethylene glycol	107211	3	130000
Ethylene glycol	107211	2	4.8

(continued)

Table C.3-1. (continued)

Constituent	CAS_NO	Scenario[a]	DAF
Ethylene oxide	75218	2	1.00E+06
Ethylene oxide	75218	3	1.00E+06
Ethylene oxide	75218	1	28
Fluoride	16984488	1	1.1
Fluoride	16984488	3	130000
Fluoride	16984488	2	4.8
Formaldehyde	50000	1	1.1
Formaldehyde	50000	3	130000
Formaldehyde	50000	2	4.8
Furfural	98011	1	1.1
Furfural	98011	3	130000
Furfural	98011	2	4.8
Heptachlor	76448	2	1.00E+06
Heptachlor	76448	1	1.00E+06
Heptachlor	76448	3	1.00E+06
Heptachlor epoxide, α, β, and γ isomers	1024573	2	557
Heptachlor epoxide, α, β, and γ isomers	1024573	1	557
Heptachlor epoxide, α, β, and γ isomers	1024573	3	557
Hexachloro-1,3-butadiene [hexachlorobutadiene]	87683	2	250
Hexachloro-1,3-butadiene [hexachlorobutadiene]	87683	3	250
Hexachloro-1,3-butadiene [hexachlorobutadiene]	87683	1	7.9
Hexachlorobenzene	118741	2	520000000
Hexachlorobenzene	118741	3	520000000
Hexachlorobenzene	118741	1	59
Hexachloroethane	67721	1	2.5

(continued)

Table C.3-1. (continued)

Constituent	CAS_NO	Scenario[a]	DAF
Hexachloroethane	67721	2	37
Hexachloroethane	67721	3	41000000
Hexachlorophene	70304	1	23
Hexachlorophene	70304	2	860
Hexachlorophene	70304	3	860
Indeno(1,2,3-cd) pyrene	193395	2	12000000000
Indeno(1,2,3-cd) pyrene	193395	3	12000000000
Indeno(1,2,3-cd) pyrene	193395	1	440
Kepone	143500	2	120
Kepone	143500	3	1e+030
Kepone	143500	1	4.7
Lead	7439921	3	1.00E+06
Lead	7439921	2	46290.666667
Lead	7439921	1	490.66666667
Manganese	7439965	3	1.00E+06
Manganese	7439965	1	11
Manganese	7439965	2	283.9
Mercury	7439976	1	15
Mercury	7439976	2	545
Mercury	7439976	3	545
Methanol [methyl alcohol]	67561	1	1.1
Methanol [methyl alcohol]	67561	3	130000
Methanol [methyl alcohol]	67561	2	4.8
Methyl ethyl ketone [2-butanone][MEK]	78933	1	1.1
Methyl ethyl ketone [2-butanone][MEK]	78933	3	130000

(continued)

Table C.3-1. (continued)

Constituent	CAS_NO	Scenario[a]	DAF
Methyl ethyl ketone [2-butanone][MEK]	78933	2	4.8
Methylene chloride [dichloromethane]	75092	1	1.8
Methylene chloride [dichloromethane]	75092	3	350000
Methylene chloride [dichloromethane]	75092	2	6.8
Molybdenum	7439987	3	1.00E+06
Molybdenum	7439987	1	23
Molybdenum	7439987	2	645
Naphthalene	91203	1	1.4
Naphthalene	91203	3	13000000
Naphthalene	91203	2	15
n-Butyl alcohol [n-butanol]	71363	1	1.1
n-Butyl alcohol [n-butanol]	71363	3	170000
n-Butyl alcohol [n-butanol]	71363	2	4.9
Nickel	7440020	3	1.00E+06
Nickel	7440020	1	11
Nickel	7440020	2	283.9
Nitrobenzene	98953	1	1.1
Nitrobenzene	98953	3	460000
Nitrobenzene	98953	2	5.1
N-Nitrosodiethylamine	55185	1	1.8
N-Nitrosodiethylamine	55185	3	130000
N-Nitrosodiethylamine	55185	2	6.6
N-Nitrosodimethylamine	62759	1	1.8
N-Nitrosodimethylamine	62759	3	170000
N-Nitrosodimethylamine	62759	2	6.6

(continued)

Table C.3-1. (continued)

Constituent	CAS_NO	Scenario[a]	DAF
N-Nitrosodi-n-butylamine	924163	1	1.8
N-Nitrosodi-n-butylamine	924163	3	1400000
N-Nitrosodi-n-butylamine	924163	2	7.5
N-Nitrosodi-n-propylamine [di-n-propylnitrosamine]	621647	1	1.8
N-Nitrosodi-n-propylamine [di-n-propylnitrosamine]	621647	3	240000
N-Nitrosodi-n-propylamine [di-n-propylnitrosamine]	621647	2	6.7
N-Nitroso-N-methylethylamine	10595956	1	1.8
N-Nitroso-N-methylethylamine	10595956	3	240000
N-Nitroso-N-methylethylamine	10595956	2	6.7
N-Nitrosopyrrolidine	930552	1	1.8
N-Nitrosopyrrolidine	930552	3	130000
N-Nitrosopyrrolidine	930552	2	6.6
o-Cresol [2-methyl phenol]	95487	1	1.1
o-Cresol [2-methyl phenol]	95487	2	5.3
o-Cresol [2-methyl phenol]	95487	3	680000
p-Cresol [4-methyl phenol]	106445	1	1.1
p-Cresol [4-methyl phenol]	106445	2	5.3
p-Cresol [4-methyl phenol]	106445	3	680000
Pentachlorobenzene	608935	2	280000000
Pentachlorobenzene	608935	3	280000000
Pentachlorobenzene	608935	1	56
Pentachlorophenol [PCP]	87865	3	12000000
Pentachlorophenol [PCP]	87865	2	15
Pentachlorophenol [PCP]	87865	1	2
Polychlorinated biphenyls [aroclors]	1336363	2	10000000000

(continued)

Table C.3-1. (continued)

Constituent	CAS_NO	Scenario[a]	DAF
Polychlorinated biphenyls [aroclors]	1336363	3	10000000000
Polychlorinated biphenyls [aroclors]	1336363	1	370
Pyridine	110861	1	1.1
Pyridine	110861	3	170000
Pyridine	110861	2	4.9
Selenium	7782492	2	166
Selenium	7782492	3	166
Selenium	7782492	1	6.7
Silver	7440224	3	388554.45
Silver	7440224	1	4.05
Silver	7440224	2	52.9
Tetrachlorodibenzofurans [TCDFs]	55722275	2	1.00E+06
Tetrachlorodibenzofurans [TCDFs]	55722275	3	1.00E+06
Tetrachlorodibenzofurans [TCDFs]	55722275	1	1059
Tetrachloroethylene [perchloroethylene]	127184	1	1.2
Tetrachloroethylene [perchloroethylene]	127184	3	1700000
Tetrachloroethylene [perchloroethylene]	127184	2	6.1
Thallium	7440280	2	2380
Thallium	7440280	3	2380
Thallium	7440280	1	73
Toluene	108883	1	1.2
Toluene	108883	3	2800000
Toluene	108883	2	6.9
Toxaphene [chlorinated camphene]	8001352	1	12
Toxaphene [chlorinated camphene]	8001352	2	640000

(continued)

Table C.3-1. (continued)

Constituent	CAS_NO	Scenario[a]	DAF
Toxaphene [chlorinated camphene]	8001352	3	640000
trans-1,3-Dichloropropylene	10061026	2	21000
trans-1,3-Dichloropropylene	10061026	1	21000
trans-1,3-Dichloropropylene	10061026	3	21000
Trichloroethylene [TCE]	79016	1	1.8
Trichloroethylene [TCE]	79016	3	1400000
Trichloroethylene [TCE]	79016	2	7.5
Vanadium	7440622	3	1000022.3
Vanadium	7440622	1	11.933333333
Vanadium	7440622	2	397.56666667
Vinyl chloride [chloroethylene]	75014	1	1.1
Vinyl chloride [chloroethylene]	75014	3	240000
Vinyl chloride [chloroethylene]	75014	2	4.9
Zinc	7440666	3	100000
Zinc	7440666	2	118.971
Zinc	7440666	1	6.328

[a] Liner scenario key:
1 = No liner.
2 = Single liner.
3= Composite liner.

For each constituent, the DAF from each liner scenario was multiplied by the carcinogenic or noncarcinogenic risk screening factor from the initial phase of risk screening to develop a new SI-modified IWEM Tier 1 table containing the leachate concentration threshold values. This approach ensured that receptors were evaluated with the same exposure factors (e.g., groundwater ingestion rate) used in the initial phase of risk screening.

There were a number of SIS constituents that were not included in the IWEM Tier 1 table. For those constituents, a leachate concentration threshold value was calculated using a DAF from a surrogate chemical. The leachate concentration threshold value was calculated by

using the IWEM procedure for estimating DAFs of chemicals for which EPACMTP was not simulated, as follows: the DAF was determined by interpolating between the DAFs of chemicals whose hydrolysis rate and retardation factor are in the same range as the hydrolysis rate and retardation factor of the new chemical.

Leachate concentration threshold values were exceeded for chemicals at 71 facilities in the IWEM Tier 1 screening model. Each of the 71 facilities was then evaluated to determine if the potential exists for direct exposure to contamination via the groundwater pathway.

Specifically, the topographic maps supplied by the facilities as part of their survey responses were evaluated to determine (1) whether drinking water wells were located within 2 km of any impoundment, (2) if the groundwater flow direction could be determined based on review of the topographic maps, and, if so, (3) if receptor wells were present in the downgradient direction.

The map review considered the location of the surface impoundments relative to surface waterbodies in the area. Surface waterbodies included bays, estuaries, rivers, lakes, streams, creeks, canals, harbors, and wetlands. The purpose of evaluating the relative location of impoundments to surface waterbodies was to determine the likely direction of groundwater flow. If the surface impoundment was situated proximate to the surface waterbody, it was assumed that leachate originating from the surface impoundment discharged in the direction of the nearby surface waterbody.

Survey respondents were also asked to identify the type and location of wells within a 2-km radius of the facility. Each of the topographic maps was reviewed to determine the location of receptor wells relative to the groundwater flow direction. To ensure that the assessment was conservative, all wells that might potentially be used for drinking water purposes, as identified by the facilities in their survey responses, were included in the assessment. The wells selected for consideration included the following categories:

- Private drinking water wells (residential)
- Public drinking water wells
- Industrial drinking water wells
- Business/commercial wells
- Church wells
- Drinking water services
- Wells designated as “don’t know”
- Wells designated as “other”
- Wells for which no designation was provided.

If no drinking water wells were present, or the groundwater flow was determined not to be in the downgradient direction of any receptor well, the potential for exposure via the groundwater pathway was presumed to be nonexistent and the site was excluded from further assessment. The facilities that were excluded from further assessment are presented in Attachment C-8. A numeric ranking of either 1 or 2 was assigned to the facilities for which

groundwater exposures could not definitively be ruled out. Table C.3-2 presents the ranking system used.

Table C.3-2. Ranking System for Groundwater Receptors

Score	Criteria
2	Groundwater direction can be determined **and** there are receptor wells located downgradient of the failed surface impoundments
1	Groundwater direction cannot be determined with certainty **but** the presence of potential receptor wells cannot be definitively ruled out
Exclude	Groundwater direction can be determined **and** there are no potential receptor wells located downgradient of the failed surface impoundments

Thirty-three of the 71 facilities were excluded from further assessment based on evidence that the groundwater pathway would not result in exposure. The remaining 38 facilities were evaluated using two sets of criteria developed to assign a numeric score that could be used to rank the facilities at greatest risk for groundwater exposures.

Two sets of criteria were developed for the groundwater analysis. The first set of criteria focused on easily quantifiable environmental setting characteristics such as distance to the nearest receptor well. The second set was based on professional judgment and involved detailed review of survey data and, in many cases, geotechnical reports submitted by the respondents. Each of the criteria was assigned a numeric score to rank facilities for additional site-based fate and transport modeling. The criteria and scoring methodology are discussed below.

C.3.1.1 Criteria Based on Environmental Setting Characteristics. Four criteria were selected to prioritize facilities and impoundments having potential for direct exposure to contaminants via the groundwater pathway. Each of the four criteria was selected to permit quantification of parameters that support the probability that the groundwater pathway may result in exposure. Hence, the criteria focus on the source of potential groundwater contamination (i.e., the chemicals present in the surface impoundment and their risk factors) and the point of exposure (i.e., the presence of wells used for drinking water consumption). Criteria were assigned a numeric score ranging from 1 to 3, with 3 having the highest potential for exposure. The four criteria were applied to the 38 facilities that exceeded the IWEM Tier 1 screening criteria. The four environmental setting criteria are

- Distance to the nearest receptor well
- Maximum cancer risk or HQ as determined using IWEM Tier 1
- Number of chemicals
- Surface area.

Distance to Nearest Receptor Well. The distance to the nearest receptor is an important indicator of the likelihood that exposure will occur as a result of consumption of contaminated drinking water. Receptor wells that are close to sources of contamination have a greater potential of being impacted than those located at great distances from the source of contamination. Hence, facilities that were characterized by receptor wells located at distances of less than 500 meters were given a higher ranking for modeling than facilities with receptor wells located at distances greater than 1,000 meters.

As noted above, survey respondents were asked to identify the type and location of wells within a 2-km radius of the facility. Distances from the surface impoundments to each of the wells identified as having the potential to be used for drinking water purposes were measured using the topographic maps. The minimum distance measured from the surface impoundment to a drinking water well was recorded and assigned a numeric scoring in accordance with Table C.3-3.

Although each of the facilities was asked to provide well information, not all respondents were able to supply this information. In the absence of survey data, the distance to the nearest populated census block within a census block group with residential wells was calculated. The minimum distance to the nearest populated census block was used in assessing well distances for facilities that did not supply well data. Table C.3-4 presents the distance value that was assigned and the associated scores.

Table C.3-3. Distance to Nearest Drinking Water Well (As Marked on Topographic Map)

Score	Criteria
3	0 < Distance ≤ 150 m
2	150 < Distance ≤ 500 m
1	500 < Distance ≤ 2,000 m

Table C.3-4. Distance to Populated Census Block

Score	Criteria	Assigned distance (m)
3	0 m < Residential well < 150 m	75
2	150 m < Residential well < 500 m	150
1	500 m < Residential well < 2000 m	500

Each facility received a single score based on well distance. Data supplied by the facility was the preferred source of data. Census data were only used as a default in the absence of facility-supplied well data. Scoring is presented in Attachment C-8.

Maximum Cancer Risk or HQ. Cancer risks and HQs were estimated during the IWEM screening analysis. The maximum cancer risk and the maximum HQ for each surface impoundment were compared and the risk or HQ that resulted in the highest overall score in accordance with Table C.3-5 was used in prioritization.

Table C.3-5. Maximum Cancer Risk or HQ

Score	Cancer Risk	Hazard Quotient
3	Cancer risk >10E-4	HQ >100
2	10E-6 ≤ Cancer risk ≤ 10E-4	10 < HQ ≤ 100
1	Cancer risk < 10E-6	1 ≥ HQ ≤ 10

Number of Chemicals. The total number of chemicals present at a facility was also scored. The larger the number of chemicals, the higher the score. Table C.3-6 presents the scores.

Table C.3-6. Total Number of Chemicals

Score	Criteria
3	Chemicals > 15
2	5 ≤ Chemicals ≤ 15
1	Chemicals < 5

Surface Area. The last criterion used was the surface area of the largest surface impoundment containing chemicals that exceeded the IWEM screening criteria. The scores were applied as presented in Table C.3-7.

Table C.3-7. Surface Area of Largest Surface Impoundment that Exceeded Risk Criteria

Score	Criteria (m^2)
3	Area > 75,000
2	10,000 < area ≤ 75,000
1	Area ≤ 10,000

Overall scores for the environmental setting criteria were calculated by summing each of the individual scores. A maximum of 14 points was possible.

C.3.1.2 Criteria Based on Professional Judgment. A second set of criteria were applied to refine the evaluation further. The second set of criteria were based on professional judgment and depended on detailed review of the survey responses and any supplemental geotechnical reports submitted with the surveys. These criteria were important because they added yet another dimension to assessing whether groundwater exposures were viable. These criteria depended on geometric considerations such as whether receptor wells are drawing water from a contaminated aquifer as opposed to drawing water from an aquifer situated hundreds of feet below the contaminated zone. The presence of low-conductivity layers that impede the downward migration of contaminants was also considered. These criteria were scored similarly to the environmental setting criteria in that scores ranged from 1 to 3, with 3 having the greatest potential for viable groundwater exposures.

Presence of Aquifers That Support Drinking Water Use. An aquifer is best defined as a saturated permeable layer that yields significant or economic quantities of groundwater. Ninety-six percent of the world's available fresh water reserve is groundwater and the U.S. Geologic Survey reports that groundwater supplies 51 percent of our nation's population with drinking water (U.S. EPA, 1998c). This water reaches the population through private water wells or through municipal systems that use groundwater as a source. The focus of this assessment is on private wells that supply drinking water.

Survey respondents were asked to provide information on whether the aquifers beneath the facility were suitable for drinking water purposes. If the aquifers were not suitable for use as a source of drinking water, the potential for exposure via the groundwater pathway was limited. A score of 1 to 3 was awarded to each facility based on the survey results (Table C.3-8).

Table C.3-8. Aquifers Support Domestic Supply

Score	Criteria
3	Facility indicates that aquifers are used for domestic supply
2	Facility does not know if aquifers are used for domestic supply
1	Facility indicates that aquifers are not used for domestic supply

Twelve facilities indicated that the aquifers beneath the site were used to supply drinking water (Attachment C-8). Two facilities indicated that the groundwater beneath their sites was not suitable for drinking water; however, a score of "3" was assigned to both of these sites. One of the facilities received a score of "3" because the existence of groundwater contamination confirmed the possibility of exposure via the groundwater pathway. The presence of an onsite potable well at the second facility showed that the groundwater was used for drinking water

purposes and, hence, could support drinking water purposes. Therefore, 14 facilities or 38 percent of the facilities were characterized by aquifers that support drinking water use.

Presence of Wells Screened in Aquifer. If the aquifer beneath the site was suitable to supply drinking water, the next step was to assess whether wells were drawing water from the aquifer for human consumption. Table C.3-9 illustrates the scoring system used.

Table C.3-9. Domestic Wells Screened in Aquifer

Score	Criteria
3	Facility indicates that wells draw water from an at-risk drinking water aquifer
2	Facility does not know if there are wells screened in the drinking water aquifer
1	Facility indicates that there are no wells screened in the drinking water aquifer at risk

Survey respondents were asked to indicate which subsurface saturated zone (or aquifer) supplied water to wells shown on the topographic map. This information was cross-referenced against aquifer information supplied in the survey and a judgment was made as to whether receptor wells draw drinking water from the aquifers of interest. Eleven facilities (or 38 percent) indicated that wells were screened in the drinking water aquifers (Attachment C-8).

Presence of a Continuous Confining Layer. Aquifers are defined as layers that yield significant quantities of water. Layers that do not produce or yield significant quantities of water are defined as aquitards. The most common aquitards are clays, chalk, shales, and dense crystalline rock. Definitions of aquifers and aquitards are imprecise because the terms are relative. For example, in an interlayered sand-silt sequence, the silts may be considered aquitards, whereas in a silt-clay system, the same silts may be described as aquifers. For purposes of this assessment, thick continuous layers (in excess of 20 feet) of clay or chalk were defined as aquitards.

Aquitards are characterized by low conductivity (10^{-4} m/d to 10^{-7} m/d). The low conductivity retards the downward migration of contamination. If an aquitard is present, contamination is unlikely to reach the underlying aquifer, and the groundwater pathway is considered incomplete. A score of either 1 or 2 was assigned (Table C.3-10).

Table C.3-10. Presence of a Low Conductivity Confining Layer

Score	Criteria
2	Thin, discontinuous, or absent confining layer
1	Well-defined confining layer > 20 feet thick

A score of 1 indicates that the potential for vertical migration of contaminants is negligible and the facility is excluded from further scoring. Eight facilities (22 percent) were characterized by the presence of a thick, continuous confining layer that made the groundwater pathway not viable (Attachment C-8).

Aquifer Conductivity. Aquifers are commonly characterized by hydraulic conductivities that range from 10^6 m/d to 10 m/d. The higher hydraulic conductivities are associated with well-sorted sands and gravels. If an aquifer is characterized by higher hydraulic conductivity, contaminants have the potential to migrate at a faster rate and impact receptor wells. Scoring was based on survey responses (Table C.3-11).

Eleven facilities were characterized by aquifer stratigraphy that was conducive to rapid migration of contaminants (Attachment C-8).

Table C.3-11. Aquifer Conductivity

Score	Criteria
3	Highly conductive stratigraphy (sand, sand and gravel)
2	Variable conductivity (silty sands)
1	Low conductive stratigraphy (clay, chalk)

Having scored each of the professional judgment criteria, both the environmental setting scores and the professional judgment scores were summed into a total score. The facilities that received the highest scores were prioritized for additional characterization using groundwater modeling. The methods and results for groundwater modeling are presented in Attachments C-11 and C-12.

C.3.2 Modeling Groundwater Exposure Concentrations

Groundwater fate and transport modeling was conducted for constituents that did not pass the screening analyses described in Section C.3.1. The modeling was conducted for wastewaters managed in onsite surface impoundments and was directed toward estimating groundwater concentrations in residential drinking water wells downgradient from the surface impoundment. Surface impoundment characteristics and constituent concentrations were obtained from data provided by operators in the Survey of Surface Impoundments.

The analysis used EPACMTP, a state-of-the-science vadose zone and groundwater fate and transport model designed specifically for regulatory applications. The model can be applied in either a probabilistic (Monte Carlo) or a deterministic mode. The version of EPACMTP used resulted from modifications made specifically for the Inorganics Listing Determination (U.S. EPA, 2000b) with two additional modifications. These modifications removed constraints on the depth of the receptor well location and the angle of the receptor well off plume centerline that were implemented specifically for the Inorganics Listing Determination. Additional details are

provided in Section C.3.2.2. Monte Carlo model runs were conducted in this analysis. Site-specific modeling data were used when available and supplemented by regional and national data sources. Distributions were used to characterize potential site variability and uncertainty in model input parameters.

Section C.3.2.1 presents a brief technical summary of the simulation model chosen for this analysis, the EPACMTP. The general modeling methodology and assumptions for this analysis are described in Section C.3.2.2, in addition to code modifications made specifically for this analysis. Data sources and assumptions for the modeling of conservative and non-conservative organic constituents are described in Section C.3.2.3. Data sources for site-specific characteristics and subsurface modeling parameters are described in Section C.3.2.4. Section C.3.2.5 presents the facility-specific modeling approach adopted for this analysis. The results of the Monte Carlo simulations are presented in Attachment C-11 of this Appendix.

C.3.2.1 EPACMTP Background. Only releases to groundwater were considered in this portion of the risk assessment. The EPACMTP groundwater model was used to estimate the fate and transport of constituents through the subsurface environment, as described here.

Description of EPACMTP. The groundwater pathway modeling conducted for this Monte Carlo analysis was performed to determine the residential groundwater well exposure concentrations resulting from the release of waste constituents from surface impoundments. Liquid that percolates through the surface impoundment generates leachate, which can infiltrate from the bottom of the impoundment into the subsurface. For surface impoundments, the liquid is the wastewater managed in the impoundments. The waste constituents dissolved in the leachate are then transported via aqueous phase migration through the vadose zone (unsaturated zone that lies below the bottom of the surface impoundment and above the water table) to the underlying aquifer (or saturated zone) and then downgradient to a groundwater receptor well. The exposure concentration is evaluated at the intake point of a hypothetical groundwater drinking water well located at a specified distance from the downgradient edge of the surface impoundment. This well is referred to hereafter as the "receptor well." This conceptual model of the groundwater fate and transport of contaminant releases from the surface impoundment is illustrated in Figure C.3-1.

The conceptual procedure described here is quantitatively evaluated with a groundwater model developed by EPA, EPACMTP (U.S. EPA, 1996d,e, 1997b). EPACMTP is a tool that has been widely peer reviewed and is used by EPA to assess wastes managed in land disposal units (landfills, surface impoundments, wastepiles, or land application units). EPACMTP simulates flow and transport of contaminants in the unsaturated zone and aquifer beneath a waste disposal unit to predict the maximum concentration arriving at a specified receptor well location. For use in risk assessments, the receptor well concentration can be reported as the peak concentration or as the highest average concentration over an appropriate exposure time interval.

Fate and transport processes accounted for in the model are advection, hydrodynamic dispersion, linear and nonlinear sorption at equilibrium, and chemical hydrolysis. The composite

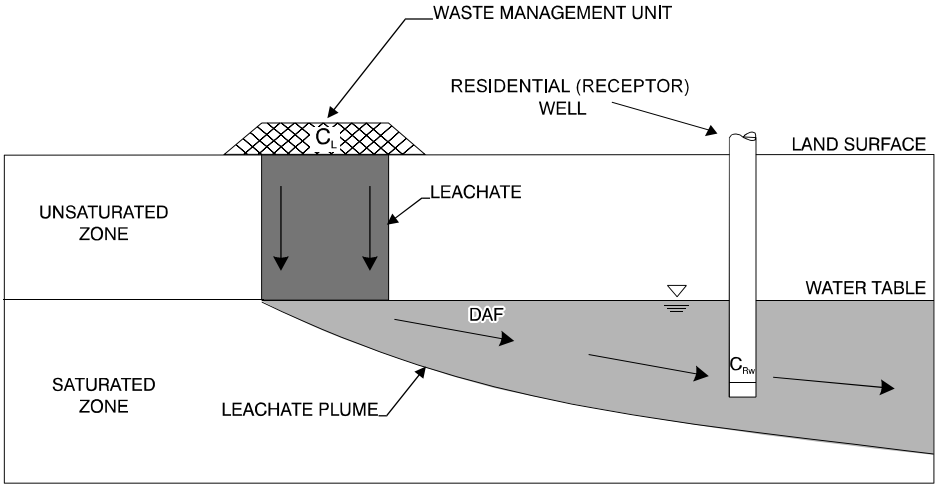


Figure C.3-1. Schematic diagram of groundwater modeling scenario.

model consists of two coupled modules: a one-dimensional (1-D) module that simulates infiltration and dissolved contaminant transport through the unsaturated zone and a saturated zone flow and transport module that can be run in either a fully 3-D or quasi-3-D mode. Quasi-3-D mode simplifies the fully 3-D flow and transport solutions to one of two 2-D conditions. For conditions where the saturated zone is thin and the contaminant mass flux into the saturated zone is large, fully mixed conditions are assumed and an areal (x-y) planar approximation is implemented. For conditions in which flow in the horizontal transverse (y) direction is of minor significance, such as when infiltration through the surface impoundment area is relatively low compared to the groundwater flow rate, a vertical 2-D cross-sectional solution is employed where a numerical solution is achieved in the x-z plane and an analytical solution is used to expand this in the transverse (y) direction. EPACMTP uses an automatic criterion for determining which of these quasi-3-D scenarios to apply based on the combination of aquifer parameters. The principal benefit of this quasi-3-D approach is that it provides substantial savings in computational effort, making large-scale Monte Carlo simulations feasible. It is for this reason that the quasi-3-D approach was used for all of the Monte Carlo runs in this analysis.

It is assumed that the soil and aquifer are uniform porous media and that flow and transport are described by the flow equation and the advection-dispersion equation, respectively. The flow equation is based on Darcy's law, which states that the flow per unit area of groundwater through porous media is the product of hydraulic conductivity and hydraulic gradient. The advection-dispersion equation describes solute transport by flowing groundwater (advection) and hydrodynamic dispersion resulting from mechanical mixing and molecular diffusion.

Flow and Transport Equations Used in EPACMTP. The groundwater flow simulation is based on the following simplifying assumptions:

- The aquifer is homogeneous.
- Groundwater flow is steady-state.
- Flow is isothermal and governed by Darcy's law.
- The fluid is slightly compressible and homogeneous.
- The principal directions of the hydraulic conductivity tensor are aligned with the Cartesian coordinate system.

According to Freeze and Cherry (1979), the governing equation for steady-state flow in three dimensions may be written:

$$k_r K_x \frac{\partial^2 H}{\partial x^2} + k_r K_y \frac{\partial^2 H}{\partial y^2} + k_r K_z \frac{\partial^2 H}{\partial z^2} = 0 \qquad \text{(C.3-1)}$$

where

H = hydraulic head (m)

k_r = relative permeability (dimensionless)

K_x, K_y, and K_z = hydraulic conductivities (m/yr) in the longitudinal (x), horizontal transverse (y), and vertical (z) directions, respectively.

Further details about these parameters may be found in Freeze and Cherry (1979). Equation (C.3-1) is solved subject to the boundary conditions given in U.S. EPA (1996e).

Flow in the vadose zone is modeled as steady-state, one-dimensional, and vertically downward from underneath the source surface impoundment toward the water table. The lower boundary of the vadose zone is the water table. The flow in the vadose zone is predominantly gravity-driven; therefore, the vertical flow component accounts for most of the fluid flux between the source and the water table. The flow rate is determined by the long-term average infiltration rate through the surface impoundment.

For the saturated zone, relative permeability k_r is equal to unity. Flow in the saturated zone is based on the assumption that the contribution of recharge from the unsaturated zone is small relative to the regional flow in the aquifer and the saturated aquifer thickness is large relative to the rise due to infiltration from the surface impoundment and recharge outside the surface impoundment so that the saturated zone can be modeled as having a uniform thickness.

The governing equation for transport in three dimensions is given by (Bear, 1979):

$$\frac{\partial}{\partial x_i}\left(D_{ij}\frac{\partial C_l}{\partial x_j}\right) - V_i\frac{\partial C_l}{\partial x_i} = \theta R_l\frac{\partial C_l}{\partial t} + \theta\, Q_l\lambda_l C_l + \sum_{m=1}^{M}\xi_{lm}Q_m\lambda_m C_m \qquad \text{(C.3-2)}$$

where

x_1, x_2, and x_3	=	x, y, and z Cartesian coordinates, respectively
t	=	time
C_l	=	concentration of the l-th component species in the n_c member decay chain, λ_l
R_l	=	first-order decay coefficient and retardation coefficient, both for species l
Q_l and Q_m	=	correction factors to account for sorbed phase decay of species l and parent m, respectively
θ	=	water content

and Einstein summation conventions are used to simplify the notation. For computation of the longitudinal, horizontal transverse, and vertical dispersion coefficients (D_{xx}, D_{yy}, and D_{zz}), the conventional dispersion tensor for isotropic porous media is modified to allow the use of different horizontal transverse and vertical dispersivities (U.S. EPA 1996e). The dispersion coefficients are given by:

$$\begin{aligned}
D_{xx} &= \alpha_L\frac{V_x^2}{|V|} + \alpha_T\frac{V_y^2}{|V|} + \alpha_V\frac{V_z^2}{|V|} + \theta D^*\\
D_{yy} &= \alpha_L\frac{V_y^2}{|V|} + \alpha_T\frac{V_x^2}{|V|} + \alpha_V\frac{V_z^2}{|V|} + \theta D^*\\
D_{zz} &= \alpha_L\frac{V_z^2}{|V|} + \alpha_V\frac{V_y^2}{|V|} + \alpha_V\frac{V_x^2}{|V|} + \theta D^*\\
D_{xy} &= D_{yx} = (\alpha_L - \alpha_T)\frac{V_xV_y}{|V|}\\
D_{xz} &= D_{zx} = (\alpha_L - \alpha_V)\frac{V_xV_z}{|V|}\\
D_{yz} &= D_{zy} = (\alpha_L - \alpha_V)\frac{V_yV_z}{|V|}
\end{aligned} \qquad \text{(C.3-3)}$$

where α_L, α_T, and α_V are the longitudinal, horizontal transverse, and vertical dispersivity (m), respectively, and D^* is the effective molecular diffusion coefficient (m^2/yr).

The water content, θ, and Darcy velocity V_i, are defined as follows:

$$\theta = \varphi S_w \tag{C.3-4}$$

$$\begin{aligned} V_x &= - k_r K_x \frac{\partial H}{\partial x} \\ V_y &= k_r K_y \frac{\partial H}{\partial y} \\ V_z &= k_r K_z \frac{\partial H}{\partial z} \end{aligned} \tag{C.3-5}$$

where

φ = effective porosity
S_W = degree of water saturation.

In the saturated zone, $S_W = 1$. Equation (C.3-2) is solved separately for the vadose and saturated zones. Details of boundary conditions and solution methods are given in U.S. EPA (1996e).

The retardation factor for each of the member species is given by

$$R = 1 + \frac{\rho_b \, ds}{\theta \, dC} \tag{C.3-6}$$

where

ρ_b = bulk density (g/m^3)
s = adsorbed concentration (g/g)

and

$$S = k_1 C^{\eta} , \tag{C.3-7}$$

where

k_1 = Freundlich coefficient
η = Freundlich exponent.

The subscript *l* has been dropped for convenience. Assuming the adsorption isotherm follows the equilibrium Freundlich equation, the retardation coefficient can be written as

$$R = 1 + \frac{\rho_b}{\theta} k_1 \eta C^{\eta-1} \quad . \qquad \text{(C.3-8)}$$

The coefficient Q is given by

$$Q = 1 + \frac{\rho_b}{\theta} k_1 \eta C^{\eta-1}. \qquad \text{(C.3-9)}$$

Note that, in general, the retardation factor is a nonlinear function of concentration. The Freundlich isotherm becomes linear when the exponent $\eta = 1$. The Freundlich coefficient, k_1 in this case, is the same as the familiar solid-liquid phase partition coefficient, K_d. When sorption is linear, the coefficients R and Q also become identical. For all the inorganic chemicals reported herein, $\eta = 1$, $\lambda_l = 0$, and $n_c = 1$.

EPACMTP does not account for heterogeneity, preferential pathways such as fractures and macropores, or colloidal transport, which may affect migration of strongly sorbing constituents such as metals. However, sites located in karstic terrain may be accommodated by using the associated solution limestone hydrogeologic environment provided in the HydroGeologic DataBase (Newell et al., 1990, U.S. EPA, 1997b) used by EPACMTP. The database is described in more detail in Section C.3.2.2.

EPACMTP simulates steady-state flow in both the unsaturated zone and the saturated zone; contaminant transport can be either steady-state or transient. The steady-state modeling option is used for continuous source modeling scenarios; the transient modeling option is used for finite source modeling scenarios. The output from EPACMTP is a prediction of the contaminant concentration arriving at a downgradient groundwater receptor well. This can be either a steady-state concentration value, corresponding to a continuous source scenario, or a time-dependent concentration, corresponding to a finite source scenario. In the latter case, the model can calculate the peak concentration arriving at the well or a time-averaged concentration corresponding to a specified exposure duration (e.g., a 9-year average residence time). For this analysis, either the peak or the average concentrations were calculated to determine the risks associated with noncarcinogenic or carcinogenic constituents, respectively. For all modeled constituents, the groundwater averaging time and exposure duration are assumed to follow a prespecified probability distribution instead of being input as constant values. For each given realization, however, the groundwater averaging time and exposure duration are identical.

For the probabilistic analysis, 10,000 realizations[1] were conducted for each modeling scenario, with the inputs specified as constant values, derived values, or statistical or empirical distribution of values. Each realization comprises a complete and distinct set of model input parameters and the flow and transport solution derived from those inputs. The input parameters for each realization are chosen by EPACMTP from the user-specified values or distributions based on a sequence of randomly generated numbers.

Source Terms and Release Mechanisms. The release of contaminants into the subsurface constitutes the source term for the groundwater fate and transport model. Because the modeled subsurface fate and transport processes are the same for each waste management scenario, the conceptual differences between different waste management scenarios are reflected solely in how the model source term is characterized. The contaminant source term for the EPACMTP fate and transport model is defined in terms of four primary parameters: (1) area of the waste unit, (2) leachate flux rate emanating from the waste unit (infiltration rate), (3) constituent-specific leachate concentration, and (4) duration of the constituent leaching. Leachate flux rate and leaching duration are determined as a function of both the design and operational characteristics of the waste management unit and the waste stream characteristics (waste quantities and waste constituent concentrations).

C.3.2.2 Modeling Methodology. The general modeling methodology and assumption for this analysis are described in this section, in addition to code modifications made specifically for this analysis, the Monte Carlo modeling approach, and a summary of modeling data sources.

Modeling Infiltration and Recharge Rates. EPACMTP requires inputs for both infiltration and recharge rates. Infiltration is defined as water percolating through the surface impoundment to the underlying soil, while recharge is water percolating through the soil to the aquifer outside of the surface impoundment. For recharge, EPACMTP uses estimates from the

[1] The Monte-Carlo groundwater pathway analysis was performed with 10,000 realizations based on the results of a previous bootstrap analysis to maintain consistency with previous analyses, such as the Petroleum Refining and Lead Based Paint Analyses. Bootstrap analysis is a technique of replicated resampling (usually by a computer) of an original data set for estimating standard errors, biases, confidence intervals, or other measures of statistical accuracy. It can automatically produce accuracy estimates in almost any situation without requiring subjective statistical assumptions about the original distribution.

In this case, the bootstrap analysis upon which this decision was based was documented in *EPACMTP Sensitivity Analyses* (U.S. EPA, 1996d). This report presents a bootstrap analysis conducted in response to public comments regarding the number of realizations used for the 1995 proposed Hazardous Waste Identification Rule. In using a Monte Carlo modeling approach, a higher number of realizations usually leads to a more convergent and more accurate result. However, it is not generally possible to determine beforehand how many realizations are needed to achieve a specified degree of convergence since the value can be highly dependent on parameter distributions. Therefore, EPA conducted a bootstrap analysis for the EPACMTP model to evaluate how convergence improves with increasing numbers of realizations. The analysis was based on a continuous source, landfill disposal scenario in which the 90th percentile DAF was 10. The bootstrap analysis results suggested that, with 10,000 realizations, the expected value of the 90th percentile DAF was 10 with a 95 percent confidence interval of 10 ± 0.7. The 95 percent confidence interval was near asymptotic. Because the parameter distributions used in the analyses for HWIR and this analysis are similar, the HWIR-related bootstrap analysis results were considered applicable.

HELP model, a hydrologic model for conducting water balance analysis of landfills, cover systems, and soil systems (U.S. EPA, 1994a, b). In the context of EPACMTP, HELP has been run for three soil textures (sandy loam, silt loam, silty clay loam) and 97 climatic centers across the country to represent nationwide variability in soil properties, cover characteristics, and climatic data (e.g., precipitation and evapotranspiration) that affect recharge and infiltration rates. For this risk assessment, recharge rates were selected from this set of data to represent site conditions of each facility.

Infiltration rates for this analysis were calculated using the semi-analytical solution defined below. Impoundment-specific data were used where available. In cases where the base of the impoundment is at or below the water table, the leachate flux to the aquifer was calculated outside of EPACMTP (using the method described in Bear, 1979), and this flux was directly applied to the saturated zone; that is, the vadose zone was not modeled.

A semi-analytical solution technique used in EPACMTP allows a very efficient and accurate solution of the vertical steady-state flow resulting from a surface impoundment unit. The surface impoundment scenario consists of a surface impoundment unit overlying a liner overlying the soil in the vadose zone. Ideally, an accurate method of determining the infiltration rate through the liner is to solve the variably saturated flow equation in a composite domain consisting of the liner and the vadose zone. However, this method requires a fine discretization to describe a relatively sharp pressure profile above the interface between the liner and the underlying soil. A simpler but conservative approach was, therefore, adopted by EPA. Infiltration rate through the liner is obtained by solving the non-linear variably saturated flow equation for the one-dimensional vertical flow domain encompassing the liner and the vadose zone soil (U.S. EPA, 1996e). For computational efficiency, the liner is assumed to be saturated at all times, and the gradient across the liner is uniform and may be approximated using the ponding depth (i.e., the height of wastwaters above the liner) and the thickness of the liner. The method tends to overestimate infiltration rate when the ponding depth is relatively small. When the ponding depth is relatively large, the infiltration rates estimated using the current method in EPACMTP approach the respective rates determined by the variably saturated flow equation.

An independent computational model has recently been developed to assist in estimating infiltration from surface impoundment units by solving the variably saturated flow equation in the whole flow domain (U.S. EPA, 1999e). This module allows the sediments at the bottom of the unit to settle and be consolidated by the overlying hydrostatic and loose sediment loads. In this case, the hydraulic function of the consolidated sediment layer is equivalent to that of a liner. In the module, the flow domain encompasses the compacted sediment and the native material in the vadose zone.

In the simulations described here, the EPACMTP *effective liner* layer consists of two components: a layer of in-unit compacted sediment derived from sludge solids in the waste water, underlain by a liner reported by the owner of the surface impoundment unit. The effective hydraulic conductivity of the effective liner layer is determined using the harmonic mean of the hydraulic conductivity of the liner (reported by the owner/ operator) and the consolidated sediment hydraulic conductivity using the constitutive relationship between the hydrostatic loads

above the consolidated sediment and hydraulic conductivity of the consolidated sediment (U.S. EPA, 1999e). When no liner information is reported, only the in-unit sediments contribute to the determination of the liner conductivity. The thickness of the compacted sediment is assumed to be one-half the total thickness of the sediment. If the total thickness of the sediment is not reported, a default value of 15 cm is used for the compacted sediment thickness. If the liner conductivity is not available, a value of 1.0×10^{-7} cm/s is assumed. The compacted sediment conductivity is given by the constitutive relationship between hydraulic conductivity and water-and-loose-sediment load as given in the HWIR99 background document for the surface impoundment source module (U.S. EPA, 1999e).

Infiltration rates for the composite-liner scenario, consisting of a clay liner with a flexible membrane liner (FML) on top of the clay layer, were computed using a liner leakage equation developed by Bonaparte et al. (1989) to estimate leakage through pinholes in a geomembrane for good contact conditions:

$$Q_L = 0.21 \cdot a^{0.1} \cdot h_W^{0.9} \cdot k_S^{0.74} \qquad \text{(C.3-10)}$$

where

Q_L = rate of leakage through a circular hole in the geomembrane component of the composite liner (m^3/s)

a = geomembrane hole area (m^2)

h_W = head of liquid on top of the geomembrane (m)

k_S = hydraulic conductivity of the low-permeability soil component of the composite liner (m/s)**.**

A geomembrane hole was assumed to have an area of 3×10^{-6} m^2 and a hole density of 1 hole per acre of membrane. These assumptions are consistent with those in IWEM (U.S. EPA 1999b, c).

Location and Time of Exposure. The selected receptors for the groundwater pathway were hypothetical adult and child residents who obtained drinking water from a groundwater well. The exposure point was determined as the nearest drinking water well likely to be exposed to constituent releases migrating through the groundwater from a surface impoundment at a facility. The nearest drinking water well was identified by an examination of each facility's topographic map and selecting wells in the probable direction of groundwater flow. Based on survey responses, these are well locations in potential use by residents.

The location of the receptor well is confined for each surface impoundment to a circular arc defined by an angle "THETA." The angle THETA is defined as the angle of the well off the plume centerline (based on the best estimate of the local groundwater flow direction) plus a small

amount as an additional margin of safety. For a fixed groundwater flow direction, THETA may be viewed as uncertainty associated with the well location. Conversely, for a fixed receptor well location, THETA implies uncertainty with respect to the groundwater flow direction. Since site maps were furnished with defined well locations, THETA is considered to be a measure of the uncertainty in the groundwater flow direction.

A potential problem arises in the event that multiple surface impoundments are present at a given facility. For consistency in calculating risks, it is imperative that all impoundments at a given facility have the same degree of uncertainty associated with the inferred average groundwater flow direction. This can be done by using a common angle THETA for all units at a given facility. Thus, THETA, the average uncertainty with respect to the groundwater flow direction at a given site, is defined as the sum of two angles:

- The average of the impoundment-specific values for THETA at that facility
- A small angle to account for an error margin.

The error margin is subjective and has been set to 5 degrees for all facilities for this analysis based on professional judgment. In the Monte Carlo EPACMTP modeling conducted for this project, THETA is enforced by assigning a minimum and a maximum value whose difference is THETA. Geometrically, the corresponding well locations for respective surface impoundments are located near one another; however, these locations are not quite identical. Effects due to this geometrical inexactitude are considered insignificant when compared with those due to other uncertainties in the modeling scenario.

A distribution of 10,000 exposure durations was selected from a Weibull distribution corresponding to all nonfarming residents and applied to all Monte Carlo simulations. The selection of the shape and scaling parameter for the Weibull distribution are described in Table C.3-15.

Description of Required Code Modifications. For the Surface Impoundment Study, only two modifications were made to EPACMTP to facilitate the groundwater analysis. EPACMTP Version 1.2.2 was created specifically for the Inorganics Listing Determination (U.S. EPA, 2000b) and subsequently tested (U.S. EPA, 2000e). In addition to the main input data file, an extra input file may be specified in EPACMTP version 1.2.2, also referred to as the source data file. The source data file contains values of parameters whose distribution types are set to "88" in the main input data file. The source data file permits output from source models or previous simulations of EPACMTP to be used as input to EPACMTP and provides the means to correlate parameters, such as leachate concentration, infiltration rate, and soil and aquifer type, to facility location. Version 1.2.2 limited the depth of the receptor location to vary uniformly throughout the aquifer thickness or throughout the upper 10 m of the aquifer thickness, whichever is less. That is, the well depth is never allowed to exceed 10 m below the water table. For this study, the 10-m depth restriction was removed.

In addition, logic was added to version 1.2.2 to override the existing receptor well location algorithm to permit the user to specify a constant value for the angle between the well

location and the plume centerline. This constraint was relaxed to allow the user to specify a range for the angle. The resulting EPACMTP version is version 1.2.3.

Monte Carlo Analysis. Application of the EPACMTP model requires input values for the source-specific, chemical-specific, unsaturated zone-specific, and saturated zone-specific model parameters. Each of these input parameters can be represented by a probability distribution reflecting the range of variation that may be encountered at the modeled waste site(s). The fate and transport simulation modules in EPACMTP are linked to a Monte Carlo module to allow quantitative estimation of the uncertainty in the downgradient receptor well concentration due to uncertainty and variability in the model input parameters.

Following is a brief description of the general Monte Carlo methodology used in EPACMTP. Additional information about Monte Carlo modeling using EPACMTP can be found in EPACMTP documents (U.S. EPA, 1996c, 1996e, 1997b).

The Monte Carlo option in EPACMTP is based on the module incorporated in EPA's Composite Model for Landfills (EPACML) (U.S. EPA, 1990). This module has been enhanced in three ways: (1) to account more directly for dependencies between various model parameters by using data from actual waste sites across the United States (2) to include a site-based methodology to directly associate the appropriate regional climatic and hydrogeologic conditions to the location of a waste site, and (3) to account for statistical correlations between two or more model parameters (e.g., hydraulic conductivity and gradient) when missing parameter values are generated.

The EPACMTP input parameters considered in the groundwater Monte Carlo modeling are presented in Table C.3-12. For modeling the surface impoundment, the depth of the sludge layer and the ponding depth were set to a constant value based on facility information; the hydraulic conductivity of the sediment layer at the base of impoundment and the underlying unsaturated zone were derived as described in the surface impoundment module documentation (U.S. EPA, 1999a).

Modified Regional Site-Based Methodology. The regional site-based approach offers several advantages over a strictly nationwide methodology. This methodology relies on data compiled at actual waste sites around the country, which can be linked to databases of climatic and hydrogeologic parameters through the use of climate and hydrogeologic indices. Thus, the regional site-based approach attempts to approximate the ideal situation where a complete set of the required site-specific values is available for each Monte Carlo realization without requiring the extensive sampling that would be required to actually gather these data.

Table C.3-12. EPACMTP Input Parameters for Monte Carlo Modeling

Impoundment Scenario/Parameter	Input Data Source
Surface impoundment scenario	
WMU area (m^2)	Site-specific data from SI Survey
Leachate concentration	Site-specific data from SI Survey
Regional recharge rate (m/yr)	Location-specific from national distribution based on proximity of facility to climate station (U.S. EPA, 1997b)
Infiltration rate (m/yr)	Derived using EPACMTP model or Darcy's law if liner is below water table
Pulse duration (yr)	Site-specific data from SI Survey or 50 years if impoundment is still operational and has operational life less than 50 years
Depth of wastewater (m)	Site-specific data from SI Survey or schematic drawings, if available
Liner thickness (m)	Site-specific data from SI Survey or schematic drawings, if available
Liner conductivity (m/yr)	Site-specific data from SI Survey or schematic drawings, if available, else assumed to be 1.0e-7 cm/s [3.15e-02 m/yr]
Chemical-specific parameters	
Organics	
Hydrolysis rate (yr^{-1})	Constituent-specific (Kollig et al., 1993)
K_{OC} (L/kg)	Constituent-specific (Kollig et al., 1993)
Inorganics	
K_d (L/kg)	Empirical or statistical distribution of values from the scientific literature (U.S. EPA, 2000b)
Both organics and inorganics	
Exposure duration (yr)	Weibull-based distribution; same for all Monte Carlo simulations
Unsaturated zone parameters	
Sat. hydraulic cond (cm/h)	Distribution based on soil type (Carsel and Parrish, 1988)
Hydraulic parameter, α (cm^{-1})	Distribution based on soil type (Carsel and Parrish, 1988)
Hydraulic parameter, β	Distribution based on soil type (Carsel and Parrish, 1988)
Residual water content	Distribution based on soil type (Carsel and Parrish, 1988)
Saturated water content	Distribution based on soil type (Carsel and Parrish, 1988)
Depth to groundwater (m)	Site-specific data from SI Survey or schematic drawings, if available, else distribution on HG region [a] (Newell et al., 1990)
Organic matter content (%)	Distribution based on soil type (Carsel et al., 1988)
Bulk density (g/cm^3)	Distribution based on soil type (Carsel et al., 1988)

(continued)

Table C.3-12 (continued)

Impoundment Scenario/Parameter	Input Data Source
Saturated zone parameters	
Particle diameter (cm)	National distribution (U.S. EPA, 1997b)
Saturated thickness (m)	Site-specific data from SI Survey or schematic drawings, if available, else distribution based on HG region [a] (Newell et al., 1989)
Hydraulic conductivity (m/yr)	Site-specific data from SI survey if available, else distribution based on HG region [a] (Newell et al., 1989)
Hydraulic gradient (m/m)	Site-specific data from SI survey if available, else distribution based on HG region [a] (Newell et al., 1989)
Longitudinal dispersivity (α_L)	Derived from distance to well (Gelhar et al., 1992; U.S.EPA, 1997b)
Transverse dispersivity (α_T)	Derived from distance to well (Gelhar et al., 1992; U.S.EPA, 1997b)
Vertical dispersivity (α_V)	Derived from distance to well (Gelhar et al., 1992; U.S.EPA, 1997b)
Groundwater temperature (°C)	Location-specific
Groundwater pH	Value based on soil type
Fraction organic carbon	National distribution (U.S. EPA, 1997a)
Receptor well location	
Radial well distance (m)	Site-specific data from topographic maps
Angle off plume centerline (°)	Site-specific data from topographic maps
X-well distance (m)	Derived from radial distance to well and angle off the plume centerline
Y-well location (m)	Derived from radial distance to well and angle off the plume centerline
Z-well depth (m)	Uniformly distributed throughout saturated thickness

[a] HG is the HydroGeologic database for modeling (Newell et al., 1990; U.S. EPA, 1997b).

The specific methodology for data gathering employed for this risk assessment can be summarized as follows:

- For sites where adequate site-specific data on soil and aquifer parameters were not available: (1) the site's geographic location was correlated with available GIS data and aquifer maps to classify the underlying aquifer as 1 of 13 types and to classify the soil as 1 of 3 types; (2) the site's geographic location was used to place the site within 1 of 97 climatic regions in the continental United States; and (3) the hydrogeologic and climatic indices were then used to define the site-specific distributions of hydrogeologic and climatic parameter values, respectively.

- For sites where adequate site-specific data on soil and aquifer parameters were available: (1) site-specific data were used to define the percentage of the three soil types present at the site and their associated pH, and values (or distribution of values) for aquifer parameters; and (2) the site's geographic location was used to place the site within 1 of 97 climatic regions in the continental United States, and

this climatic index and the soil type(s) present at the site were then used to define the site-specific recharge rate.

Once the percentages of soil types were defined for a facility, an ensemble of 10,000 soil type identifiers (1, 2, or 3) was randomly generated respecting the distribution of soil type percentages. These identifiers were used in the Monte Carlo simulation for all impoundments at a facility to choose from the appropriate distribution of values appropriate for that soil type (Carsel et al., 1988). These distributions are specified within the EPACMTP code, as described in U.S. EPA (1997b).

Data sources for the modified regional site-based methodology that were used to conduct this analysis include: (1) the infiltration and recharge analysis performed for 97 U.S. climatic centers using the HELP model (U.S. EPA, 1997b); (2) the USGS inventory of the groundwater resources of each state (USGS, 1985); and (3) the HydroGeologic DataBase for Modeling (HGDB) (Newell et al., 1990; U.S. EPA, 1997b), developed from a survey of hydrogeologic parameters for actual hazardous waste sites in the United States.

For this analysis, facility-specific values for impoundment location and waste, soil, and aquifer characteristics were used to the extent possible. Where site-specific data were not available, the following parameters were available from the HGDB database (Newell et al., 1990; U.S. EPA, 1997b):

- Depth to groundwater (m)
- Aquifer thickness (m)
- Hydraulic conductivity (m/yr)
- Hydraulic gradient (m/m).

Given a hydrogeologic environment, 10,000 values for the above four parameters were selected as correlated parameters according to the methodology described in U.S. EPA (1997b). If reliable site-specific values for any of the four were available, that value was used instead of the generated values. In most cases, sufficient information existed to establish values for the depth to groundwater and the thickness of the saturated region. Information about the remaining hydrogeologic parameters, hydraulic gradient and hydraulic conductivity of the aquifer, were generally not available, therefore, these parameters were generated using the hydrogeologic environment classification. It was assumed that the loss in correlation by supplanting correlated parameters with site-specific parameters was more than equaled by the uncertainty in other parameters (i.e., groundwater flow direction).

For surface impoundments, the infiltration rate was calculated using EPACMTP; the ambient recharge rate was set equal to the HELP model recharge rate for the nearest climate center.

For facilities without adequate site-specific data, the USGS inventory of state groundwater resource maps (USGS, 1985) and available GIS data were used to identify the predominant hydrogeologic environment (or aquifer type) underlying each impoundment to be

modeled. Once the aquifer type was determined, the HGDB was then used to specify the probability distribution for each of the groundwater parameters. The HGDB provides data on depth to groundwater, aquifer thickness, hydraulic gradient, hydraulic conductivity, and hydrogeologic classification for approximately 400 hazardous waste sites nationwide. These site-specific data were then regrouped according to hydrogeologic classification, and 13 aquifer types were classified (12 specific environments and one category called "other"). Each aquifer type consists of a distribution of values for each of the four aquifer parameters.

For this analysis, each site to be modeled was located on the appropriate state groundwater map from USGS (1985), and available GIS data were compiled and evaluated. Then the primary aquifer type for that location was classified according to the 13 aquifer types. The aquifer types and the parameter values for each are provided in the *EPACMTP User's Guide* (U.S. EPA, 1997b).

C.3.2.3 Chemical Data. Chemical properties used in the analysis include hydrolysis rate constants and the organic carbon partition coefficient K_{OC} for the organic constituents and soil-water partition coefficients for metals. These were collected from measured literature values as available and are described in U.S. EPA (2000b, c).

Many of the chemical constituents present at facilities included in this phase of the analysis can be characterized as *conservative* in that they do not sorb (K_{oc}=0) nor hydrolyze (lambda = 0) in partially or fully saturated environments. Conservative chemicals behave *linearly* with respect to advective and dispersive contaminant transport: an increase or decrease in the source concentration results in a proportional increase or decrease in observed concentrations in the groundwater. This behavior permits the use of a single *surrogate* chemical to represent all conservative chemicals.

All conservative chemical constituent modeling at a unique facility/impoundment combination was represented by a surrogate constituent in a single Monte Carlo simulation. The resulting normalized peak and average concentrations for the surrogate were then scaled by the leachate concentration of the constituents escaping the impoundment to produce constituent-specific results. For organics, a conservative constituent is defined as one with K_{OC} value equal to or less than that of benzene (K_{OC} = 63.1 L/kg; since the values in the nationwide distribution of fraction organic carbon are generally small, the resulting average unsaturated zone retardation coefficient for benzene is 1.17) and with an average hydrolysis rate in the unsaturated zone equal to or less than 1.0E-4 1/yr (this criterion was used to define nondegraders in modeling conducted for the 1995 HWIR proposed rule). Fluoride was also considered to behave as a conservative constituent since it is an anion in solution under environmental conditions.

To test the above assumptions, a chemical-specific modeling run was conducted for each of two of the organic constituents assumed to be conservative to verify our assumption that they behave conservatively during subsurface transport: benzene (in the impoundment at Facility 174) and chloroform (in impoundment 1 at Facility 23). Benzene was chosen because it has the highest K_{OC} of the organic constituents assumed to be conservative. Chloroform was chosen

because it has the highest hydrolysis rate of the organic constituents assumed to be conservative. No toxic daughter products were simulated in this analysis.

Test results are presented in Table C.3-13 as percent differences for select percentiles of the dilution-attenuation factor between simulations using constituent-specific constants (K_{OC} and hydrolysis rates) and conservative surrogate assumptions (Note: the 10th percentile DAF

Table C.3-13. Percent Difference for Selected Percentile DAFs for Benzene and Chloroform

	Benzene	Chloroform
Select Percentiles for DAF	**% Difference for Average DAF[a]**	**% Difference for Average DAF[a]**
50	5.4%	1.6%
25	7.4%	2.4%
20	6.9%	5.8%
15	7.8%	5.2%
10	8.6%	6.1%
5	5.9%	5.8%
2.5	7.2%	7.5%
1	4.9%	1.9%

[a] Percent difference is calculated as (Conservative Constituent Average DAF - Surrogate Average DAF)/Conservative Constituent Average DAF.

corresponds to the 90th percentile concentrations, peak and average). The maximum difference in the lower half of the distribution is 8.6 percent and represents the worst case scenario under this assumption.

The metals-modeling methodology in EPACMTP incorporates two options to specify the K_d for a given metal: distributions of values or sorption isotherms. For this analysis, the K_d for metals was defined based on a comprehensive review of literature K_d values performed for the Inorganics Listing Determination (U.S. EPA, 2000b). Based on this review, K_d was defined as an empirical distribution when sufficient data are available or a log uniform distribution of values when fewer data are available from the scientific literature. The second option is the automated use of adsorption isotherms, which are expressions of the equilibrium relationship between the aqueous concentration and the sorbed concentration of a metal (or other constituent) at constant temperature. This second option was not used for this analysis because of current modeling limitations for generating metal sorption isotherms.

C.3.2.4 *Sources for Site and Hydrogeologic Parameter Values*. Data collected from the surveys and any supporting information, such as reports and diagrams, were examined to extract the maximum amount of reliable site-specific data for use in this analysis. The data included information on impoundment areas, volumetric flows of wastewater and sludge into impoundments, liner information, constituents present in wastewaters and their concentration, operation life, and maps that identify real and potential receptor wells and surface waterbodies. Survey data were also cross-referenced with other data sources to supplement the data collection effort. These sources include STATSGO (U.S. EPA, 1998d), HGDB (Newell et al., 1990), and meteorological databases.

C.3.2.5 *Facility-Specific Modeling Approach*. The groundwater modeling approach adopted for this analysis attempted to incorporate the maximum amount of facility-specific data available from the following primary sources: survey responses, topographic maps, and schematic drawings. Technical reports, when provided by respondents, were also used in extracting parameter values. Table C.3-12 identifies the sources for specific input modeling parameters.

The following general procedure was applied to all facilities modeled in this analysis:

- Groundwater Flow Direction - Assess topological details on provided maps to determine the most probable flow direction; decision may be supplemented by technical reports, when available.

- Receptor Location Selection - Using topological maps and the assumed flow direction, identify the downgradient receptor well screened in the surficial aquifer nearest to the impoundment most likely to be impacted by a migrating contaminant plume. If multiple impoundments are present at the facility, select the receptor location that is most likely to be impacted by the most impoundments; if no receptor wells are identified, use identified residences.

- Radial Receptor Well Distance and Angle Off Plume Centerline- Determine the radial distance as shortest distance from each impoundment to the selected receptor location. Measure the angle defined by the radius and the groundwater flow direction; these angles will be used to calculate the angle range used in the simulation to account for uncertainty in flow direction. The method for angle range calculation is

  - Determine average angle, THETA and for each impoundment at the facility
  - Min Angle = maximum (0^o , THETA - Angle)
  - Max Angle = maximum (THETA, Angle) + 5^o

- Extract Impoundment-Specific Data - Collect the following parameters from the survey: impoundment area, operational life, liner thickness and conductivity, depth of wastewater and sludge in the impoundments, depth to groundwater,

saturated thickness, aquifer hydraulic conductivity, and regional groundwater gradient, if available. If multiple sources exist for parameter values, the most conservative value is used (e.g., survey indicates wastewater depth is 1m and schematic prescribes a 2-m depth, the value from the schematic is used).

- Calculate Effective Liner Parameters - Combine sludge and liner information to determine the effective liner conductivity and thickness. If bottom of impoundment is below the water table, calculate an infiltration rate using the gradient across the liner and compacted sludge (Darcy's law [Bear, 1979]).

- Chemical Parameters - Group constituents present in wastewater into conservative and nonconservative populations using the guidelines described in Section C.3.2.2. Select chemical constituent parameters/distributions needed for simulating sorption and decay processes. Extract the leachate concentration of each constituent from survey data.

- Compilation of Data - Combine and supplement the above parameters with region-based and location-based parameters/parameter distributions as described in Section C.3.2.2 with exposure duration distribution to create input files and source data files.

The results of the data extraction process are presented in Attachment C-10 of this Appendix.

C.3.3 Methods - Exposure/Risk Calculations

The purpose of exposure and risk assessment is to estimate a contaminant dose to each receptor by combining modeled groundwater concentrations with relevant intake rates for the individuals being modeled. The dose, coupled with the relevant human health benchmarks, allows an estimation of human health risk and/or hazard. This assessment focused on chronic cancer risk and noncancer hazard resulting from tap water ingestion. Consequently, for this analysis, exposure assessment involved combining modeled residential well concentrations with adult and child tap water ingestion rates and exposure durations to generate both average daily dose estimates for noncarcinogens and lifetime averaged daily dose estimates for carcinogens.

For all impoundments evaluated in this analysis, groundwater was assumed to be contaminated from contaminants leaching from the impoundment, through the vadose zone, into the underlying aquifer, and migrating to the offsite residential well location. It was further assumed that the groundwater well was used as the sole source of tap water for the adults and children living in that residence.

Both child and adult residents were modeled in this analysis. For noncancer risk, a child in the 1- to 6-year-old age range was modeled. Note: The use of the 1- to 6-year-old child cohort in this analysis excluded exposures in the first year of life. For carcinogenic risk, an adult resident between the ages of 20 and 64 was modeled.

C.3.3.1 Exposure Parameter Variability Distributions Used in Probabilistic Analysis. The probabilistic analysis requires exposure parameter variability distributions for exposure duration and tap water ingestion rates. Although water ingestion rates were required for both the adult and child, exposure duration is required only in cancer risk calculations; therefore, exposure duration variability data were needed only for the adult. See Section C.3.2 for a discussion of exposure duration.

Tap Water Intake Rates. Tap water ingestion rate data standardized for body weight (i.e., with units of mL/kg-d) were used in this analysis. Because intake data that were standardized for body weight were used, body weight was not a variable in the analysis.

The statistical parameters used to derive the distributions for tap water ingestion rates are presented in Table C.3-15. A critical issue in using continuous variability distributions in probabilistic risk analysis is the truncation of these distributions to avoid inclusion of exposure parameter estimates that are unreasonable (truncation is typically not an issue with discrete distributions since the upper-bound values in these distributions are generally defined as the highest percentile value for which data are available from the underlying study). In selecting the truncation strategy to develop continuous distributions, care must be taken to avoid the inclusion of unrealistic values, while still allowing for consideration of individuals who could experience intake rates beyond the 99th percentile (i.e., high-end exposure). A number of different strategies have been used in previous analyses to truncate exposure parameter variability distributions, including (1) setting the upper bound between 2 and 3 standard deviations, and (2) setting the upper bound at twice the 99th percentile. For this analysis, exposure parameter variability distributions for tap water ingestion rates were truncated at 3 standard deviations. This approach produced upper-bound tap water ingestion rates that fell between the 99th percentile and twice the 99th percentile, which represents a reasonable approximation of high-end behavior without including unreasonably high intake rates, yet allows the possibility of exposures above the 99th percentile. The truncation values for each of the tap water ingestion rate variability distributions are also included in Table C.3-15. Tables C.3-16 and C.3-17 present the intake rate data from the lognormal distributions developed for this risk assessment and compare them with the empirical data presented in Tables 3-7 and 3-30 in the EFH.

Average Daily Dose for Children (Noncancer Endpoints). The average daily dose (ADD) estimates for the child resident receptor were generated by combining a daily intake rate that reflected variability in tap water ingestion rates with a residential well concentration. This produced a distribution of 10,000 ADD estimates. The ADD distribution was used, in turn, to generate a distribution of 10,000 noncancer HQs for each surface impoundment constituent combination for the child resident receptor.

The daily intake rate for the child resident was generated using a two-step procedure for determining tap water ingestion rate variability for the 1- to 6-yr-old cohort. The procedure involved: (1) random selection of either the 1- to 3- or 4- to 6-yr-old cohort for the child being modeled and (2) random sampling of a tap water ingestion rate from the tap water ingestion rate distribution for that age. This approach generated a daily intake rate for the child resident that

Table C.3-15. Variability Distributions for Exposure Parameters Used in Probabilistic Risk Analysis

Receptor Population/ Cohort Age Group	Percentile Values and Statistical Parameters Used to Define Discrete and Continuous Variability Distributions	References/Comments
Tap water ingestion rates (mL/kg-d)		
1- to 3-yr-old cohort	lognormal distribution: mean: 46.8 STD: 28.1 truncation value (3 standard deviations): 211.35	 1997 EFH Table 3-7 1997 EFH Table 3-7 derived
4- to 6-yr-old cohort	lognormal distribution: mean: 37.9 STD: 21.8 truncation value (3 standard deviations): 164.26	 1997 EFH Table 3-7 1997 EFH Table 3-7 derived

Table C.3-16. Comparison of Lognormal Distribution with Empirical Data for Percentiles of Tap Water Intake Rates for Adults

	Lognormal Distribution (based on Table 3-7)	Empirical Data Total Tap Water Intake (Table 3-7)	Recommended Drinking Water Intake Rates (Table 3-30)
Percentile	**mL/kg-d**	**mL/kg-d**	**mL/kg-d**
1%	5.40	2.2	
5%	7.50	5.9	
10%	9.10	8	
25%	12.50	12.4	
50%	17.50	18.2	19
75%	24.50	25.3	
90%	33.60	33.7	34
95%	40.40	40.0	
99%	57.50	54.8	

Table C.3-17. Comparison of Percentiles of Tap Water Intake Rates Between Lognormal Distribution and Empirical Data for Empirical Data for Child Age Groups (mL/kg-d)

	Lognormal Distribution[a]	Empirical Data for Total Tap Water Intake[a]	Lognormal Distribution[a]	Lognormal Distribution[a]
Percentiles	**1-to 3-yr-old**		**4-to 6-yr-old**	
1%	11.1	2.7	9.6	3.4
5%	15.8	11.8	13.7	10.3
10%	19.6	17.8	16.5	14.9
25%	27.4	27.2	22.9	21.9
50%	39.6	41.4	32.7	33.3
75%	75.7	60.4	47.1	48.7
90%	81.1	82.1	65.6	69.3
95%	99.4	101.6	78.6	81.1
99%	144.1	140.6	112.7	103.4

[a] Based on Table 3-7 of *Exposure Factors Handbook* (U.S.EPA, 1997c).

reflected the age-specific differences in tap water ingestion rates that occurs within the 1- to 6-yr-old cohort.

Cohort aging was not considered in characterizing noncancer risk for the child resident because emphasis was placed on capturing the highest chronic exposure level within this age group, which was expected to occur in children in the youngest cohort due to their higher intake rate to body weight ratio. The exposure parameter variability distributions for tap water ingestion for both the 1- to 3- and 4- to 6-year-old cohorts were normalized for body weight (intakes are expressed as L/kg-d), which eliminated the need to account for the correlation between body weight and tap water ingestion rate.

Once the daily intake rate data set was generated, it was combined with the residential well concentration data set to generate a discrete distribution of ADD estimates. The following equation was used to generate each ADD estimate for the child resident receptor:

$$ADD_{child} = IR \times C_{drinking\ water} \times \frac{1\ L}{1000\ mL} \qquad \text{(C.3-11)}$$

Parameter	Definition (units)
ADD_{child}	Modeled average daily dose for the child resident receptor (mg/kg-d)
IR	Tap water ingestion rate sampled from the 1- to 6-yr-old cohort variability distribution for tap water ingestion normalized for body weight (mL/kg-d)
$C_{drinking\ water}$	Peak modeled annual drinking water well constituent concentration (mg/L)

The generalized distribution of the child ADD without the residential well concentration component is the same as the child intake distribution converted to liters per kilogram per day. The ADD distribution percentiles are presented in Table C.3-18. The ADD is then divided by the non-cancer RfD to develop the hazard quotient (HQ).

Table C.3-18. Percentiles for Child ADD (L/kg-d)

	Lognormal Distribution[a]	Total Tap Water Intake[b]			Recommended Drinking Water Intake Rates[c]
Percentiles	1- to 6-yr-old	1- to 3-yr-old	4- to 6-yr-old	1- to 6-yr-old (average of 1- to 3-yr-old and 4- to 6-yr-old)	1- to 10-yr-old
1%	0.0101	0.0027	0.0034	0.0031	
5%	0.0144	0.0118	0.0103	0.0111	
10%	0.0178	0.0178	0.0149	0.0164	
25%	0.0249	0.0272	0.0219	0.0246	
50%	0.0359	0.0414	0.0333	0.0374	0.031
75%	0.0525	0.0604	0.0487	0.0546	
90%	0.0731	0.0821	0.0693	0.0757	0.064
95%	0.0893	0.1016	0.0811	0.0914	0.0794
99%	0.1296	0.1406	0.1034	0.122	

[a] Based on Table 3-11 of *Exposure Factors Handbook* (U.S. EPA, 1997c)
[b] Based on Table 3-7 of *Exposure Factors Handbook* (U.S. EPA, 1997c)
[c] Based on Table 3-30 of *Exposure Factors Handbook* (U.S. EPA, 1997c)

Lifetime Average Daily Dose (LADD) for Adult (Cancer Endpoints). The LADD for the adult resident were estimated by combining 10,000 Monte Carlo-generated lifetime averaged daily intake rates for the adult resident with 10,000 Monte Carlo-generated drinking water well

concentrations for a given surface impoundment/constituent. The groundwater averaging time used to estimate the residential well concentration was matched with the exposure duration for each iteration of the risk estimate. For the adult resident, an exposure duration and a single tap water ingestion rate were sampled. An averaging time of 70 years was also used in this calculation. The equation used to generate each LADD estimate for the adult resident is

$$LADD_{adult} = \frac{C_{drinking\ water} \times IR_{adult\ cohort} \times ED_{adult\ cohort} \times EF \times \frac{1\ L}{1{,}000\ mL}}{AT \times 365} \qquad \text{(C.3-12)}$$

Parameter	Definition (units)
$LADD_{adult}$	Modeled lifetime average daily dose for the adult resident receptor (mg/kg-d)
$C_{drinking\ water}$	Modeled drinking water well constituent concentration derived using an averaging time that corresponds to the exposure duration sampled for this LADD estimate (mg/L)
IR_{adult}	Tap water ingestion rate sampled from the adult variability distribution for tap water ingestion normalized for body weight (mL/kg-d)
ED_{adult}	Exposure duration value sampled for this modeled adult resident (yr)
EF	Exposure frequency (d/yr)
AT	Average lifetime used to generate a lifetime average intake rate (d).

Note: LADD estimates are generated using an exposure frequency of 350 d/yr and an average lifetime of 25,500 days (i.e., 365 d × 70 yr).

The generalized distribution of the adult LADD without the residential well concentration component is presented in Table C.3-19. The LADD is multiplied by the oral CSF to calculate the cancer risk.

C.3.4 Results from Groundwater Pathway Analysis

C.3.4.1 Direct Exposure Pathway Screening Results. A total of 186 constituents present in 435 surface impoundments at 127 facilities were considered in the preliminary screen. When constituent concentrations reported in the surface impoundments were compared to human health screening factors based on toxicity benchmarks for direct ingestion of drinking water, 109 constituents in 320 surface impoundments at 101 facilities exceeded the human health benchmark. The constituent counts reflect only those chemicals for which at least one human health benchmark was available. Complete results from the direct exposure pathway screening analysis are presented in this appendix.

C.3.4.2 Screening-Level Modeling Results. For those constituents, impoundments, and facilities that did not screen out in the preliminary screen, a more realistic assessment of groundwater risk was calculated using IWEM; in this case, 76 constituents in 214 surface impoundments at 71 facilities exceeded the criteria.

Table C.3-19. Percentiles of Generalized Adult LADD

Percentile	Adult LADD (L/kg-d)
1%	0.000573
5%	0.00089
10%	0.00116
25%	0.00187
50%	0.00335
75%	0.00587
90%	0.00953
95%	0.0125
99%	0.0201

C.3.4.3 Site-Based Modeling. Site-based modeling was conducted for 10 facilities and a total of 39 surface impoundments. There were a total of 30 HQ exceedances and 48 risk exceedances for all facilities, impoundments, and constituents for all risk/hazard estimation (i.e., for all central tendancy and high-end estimations. There were six 50^{th} percentile HQ exceedances and fifteen 50^{th} percentile risk exceedances. Also, there were four incidences where a chemical had an exceedance for both HQ and risk. Therefore, there were a total of 53 different facility/impoundment/chemical combinations that showed an exceedance of either HQ or risk out of a possible 202 facility/impoundment/chemical combinations.

Seven of the 10 facilities had at least one exceedance and 24 of the 39 impoundments had at least one exceedance. A summary of exceedances is presented in Table C.3-20. Each modeled facility/impoundment combination is presented in Table C.3-20. If an exceedance was observed, the chemical that exceeded the threshold is noted, followed by the HQ or cancer risk that was observed for that chemical. The central tendency value for that particular exceedance is then noted in parentheses. Attachment C-11, Tables C-11 through C-125, presents the full set of site-based modeling results.

Table C.3-20. Summary of Hazard and Risk Exceedances for the Groundwater Pathway

Facility	SI	Summary of HQ Exceedance	Summary of Risk Exceedance
Risk exceedances based on reported concentrations			
23	1	**Acetone** - 13 (0.02)	None
78	2	**Fluoride** - 1.2 (0.01)	None
182	1	**Fluoride** - 27 (1.5)	None
182	2	**Fluoride** - 59 (12)	None
182	3	**Fluoride** - 6.1 (0.4)	None
182	4	**Fluoride** - 38 (8.1)	None
182	6	**Fluoride** - 10 (3.1)	None
182	8	**Fluoride** - 3.1 (0.3)	None
Risk exceedances based on surrogate/DL concentrations			
23	1	Chloroform - 50 (0.09) Methylene chloride - 8.2 (0.01) Pyridine - 1.7 (0.003) Toluene - 1.8 (0.004)	Chloroform - 1.5E-4 (2.1E-7) Methylene chloride - 1.8E-4 (2.6E-7))
23	2	Methanol - 1.7 (0.004) Allyl alcohol - 26 (0.06)	None
23	3	Methanol - 1.3 (0.002) Allyl alcohol - 20 (0.03)	None
23	4	Chloroform - 23 (0.004) Methylene chloride - 4 (0.0006) Acetone - 6 (0.0009)	Chloroform - 7.0E-5 (9.3E-9) Methylene chloride - 8.3E-5 (1.1E-8)
175	3	Thallium - 4.5 (0.03)	N-Nitrosodimethylamine - 2.6E-4 (1.3E-5) Benzidine [a] - 1.2E-2 (5.7E-4) N-Nitrosodi-n-propylamine [a] - 3.5E-5 (1.7E-6) Acrylonitrile - 2.5E-5 (1.3E-6)
12	2	Fluoride - 1.3 (0.1)	None
173	1	Methanol - 1.7 (0.03)	None
45	2	None	Acrylonitrile - 1.4E-5 (3.1E-6) N-Nitrosodi-n-propylamine - 4.4E-5 (9.6E-6) N-Nitrosodimethylamine - 3.2E-4 (7.0E-5) Vinyl Chloride - 1.1E-5 (2.3E-6) Benzidine - 7.3E-3 (1.6E-3)

(continued)

Table C.3-20. (continued)

Facility	SI	Summary of HQ Exceedance	Summary of Risk Exceedance
45	4	None	Acrylonitrile - 1.5E-5 (3.2E-6) N-Nitrosodi-n-propylamine - 4.5E-5 (1.0E-5) N-Nitrosodimethylamine - 3.3E-4 (7.3E-5) Vinyl Chloride - 1.1E-5 (2.4E-6) Benzidine - 7.5-3 (1.6E-3)
45	6	None	N-Nitrosodi-n-propylamine - 7.1E-5 (1.2E-5) Benzidine - 1.6E-3 (2.8E-4)
45	7	None	N-Nitrosodi-n-propylamine - 1.4E-5 (2.3E-6) N-Nitrosodimethylamine - 1.0E-4 (1.7E-5) Benzidine - 2.3E-3 (3.7E-4)
45	8	None	N-Nitrosodi-n-propylamine - 1.5E-5 (2.3E-6) N-Nitrosodimethylamine - 1.1E-4 (1.7E-5) Benzidine - 2.4E-3 (3.9E-4)
45	9	None	N-Nitrosodimethylamine - 2.7E-5 (3.1E-6) Benzidine - 6.2E-4 (6.8E-5)
45	10	None	N-Nitrosodimethylamine - 1.9E-5 (1.7E-6) Benzidine - 4.2E-4 (3.8E-5)
45	11	None	N-Nitrosodimethylamine - 1.6E-5 (1.4E-6) Benzidine - 3.7E-4 (3.2E-5)
78	2		Arsenic - 1.6E-5 (8.1E-9)
182	7	Fluoride - 37 (1.2)	None
182	9	Fluoride - 35 (3.7)	None

[a] Industry representatives, subsequent to completion of the survey, have indicated that this constituent is not expected to be present at the facility. These constituents were reported to EPA in response to the Survey of Surface Impoundments in November 1999 as less than a specified limit of detection. When this constituent was evaluated in the risk analysis at the reported detection limit, the concentrations were high enough to predict the indicated risk/hazard of concern. EPA included the results in this table because of the methodology used throughout the study to evaluate less than detection limit data.

C.4 Indirect Exposure Pathway Analysis—Groundwater to Surface Water

By design, surface impoundments are often located near receiving waterbodies. As described in Section 2.0, impoundments designed for final treatment are intended to produce effluent that meets regulatory standards (e.g., the National Pollutant Discharge Elimination System, or NPDES and, therefore, the effluent can discharge directly into the waterbody. However, many impoundments are designed as part of a treatment train and are not intended to produce effluent of sufficient quality to meet regulatory standards. Although these impoundments do not discharge directly to surface water, chemicals may be released through the bottom of the impoundment, travel through the subsurface, and impact nearby waterbodies. The intersection of groundwater flow with surface water is often referred to as groundwater discharge to surface water. This is potentially a significant exposure pathway because 75 percent of RCRA and Superfund sites are located within a half mile of a surface waterbody, and almost half of all Superfund sites have impacted surface water (U.S. EPA, 2000a, *Proceedings of the Ground-Water/Surface-Water Interactions Workshop*). Of the 133 facilities considered in the Surface Impoundment Study, approximately 84 percent (112) have one or more fishable waterbodies located within 1 km of an impoundment.

For chemicals that are moderately mobile, contaminant fate and transport in the subsurface may result in a contaminant flux to the surface waterbody as the groundwater discharges into a pond or stream. Depending on the resulting surface water concentrations, the water quality may be adversely affected. For chemicals that are also bioaccumulative, chemical concentrations in fish may approach or exceed levels of concern for the segment of the population that fishes. For convenience, we refer to the release, transport, and accumulation of chemicals in fish and other aquatic organisms as the groundwater to surface water pathway, or gw-sw pathway.

C.4.1 Numeric Ranking of Facilities

EPA did a numeric ranking of facilities according to their potential to discharge to surface waterbodies at significant levels. This ranking was the basis for selecting facilities to model. The ranking was accomplished as follows.

The area surrounding each of the facilities was evaluated to determine if fishable waterbodies were present within a 1-km radius of the impoundments. Fishable waterbodies were defined as streams of reach order 3 and above, as well as bays, estuaries, lakes, canals, harbors, and wetlands. The name of the closest fishable waterbody was recorded and the distance from it to the impoundment was measured on the topographic map. Fishable waterbodies within a 1-km radius were identified for 112 facilities and 353 surface impoundments.

Wastewater (or leachate, when available) concentrations of the constituents present in the 353 surface impoundments were then compared to water quality benchmarks. The benchmark for this screen was the human health (HH) level associated with the ambient water quality criteria, or HH-AWQC. Table C.4-1 lists the HH-AWQC levels for the constituents of concern.

Most are based on aquatic organism and surface water ingestion. For facilities near estuarine or other unpotable surface waterbodies, the HH-AWQC was based on aquatic organism ingestion only.

The leachate concentration of at least one constituent exceeded the HH-AWQC in 240 surface impoundments across 79 facilities. The magnitude of the exceedances ranged from approximately 1 to 1,538,000. Exceedances were documented for 66 chemicals.

Having compared wastewater concentrations to the HH-AWQC, the next step of the surface water analysis was to compare constituent concentrations estimated to be in groundwater to the HH-AWQC. The constituent concentration in groundwater was calculated by dividing the constituent concentration in wastewater by the dilution attenuation factors generated as part of the groundwater screening analysis. If the surface waterbody was located within 150 meters of the surface impoundment, the DAF was set equal to 1 for consistency with the IWEM screening analysis. Hence, for impoundments located within 150 meters of a surface waterbody, the calculated groundwater concentration equaled the wastewater concentration. For 204 surface impoundments distributed among 70 facilities, calculated groundwater concentrations exceeded the AWQC-HH. Sixty-three constituents exceeded the benchmark.

A set of criteria was developed for use in prioritizing the 70 facilities having the greatest potential to impact surface water quality adversely. The criteria consisted of five easily quantifiable factors:

- Area of the surface impoundment
- Dilution factor
- Number of constituents that exceeded the water quality criteria
- Magnitude of the exceedance
- Distance to the nearest fishable waterbody.

Each of the criteria was assigned a numeric score, and these were used to rank facilities for site-based fate and transport modeling. Distance from surface impoundment to the nearest fishable waterbody, the area of the surface impoundment, and dilution factor are important determinants in assessing potential impacts to surface water quality and, as a consequence, these three criteria were each weighted by a factor of 2. The criteria and scoring methodology are detailed below. The resulting scores are presented in Attachment C-13.

C.4.1.1 Area of Surface Impoundment. The area of the largest surface impoundment that contained chemicals exceeding the HH-AWQC was determined and ranked in accordance with Table C.4-2.

Table C.4-1. Ambient Water Quality Criteria for Human Health (HH-AWQC)

Constituent	CAS No.	HH-AWQC (µg/L)
Antimony	7440360	1.40E+01
Arsenic	7440382	1.80E-02[a]
Copper	7440508	1.30E+03
Mercury	7439976	5.00E-02
Nickel	7440020	6.10E+02
Selenium	7782492	1.70E+02
Thallium	7440280	1.70E+00[b]
Zinc	7440666	9.10E+03
Cyanide	57125	7.00E+02
2,3,7,8-TCDD	1746016	1.30E-08
Acrolein	107028	3.20E+02
Acrylonitrile	107131	5.90E-02
Benzene	71432	1.20E+00
Bromoform	75252	4.30E+00
Carbon tetrachloride	56235	2.50E-01
Chlorobenzene	108907	6.80E+02
Chlorodibromomethane	124481	4.10E-01
Chloroform	67663	5.70E+00
Dichlorobromomethane	75274	5.60E-01
1,2-Dichloroethane	107062	3.80E-01
1,1-Dichloroethylene	75354	5.70E-02
1,2-Dichloropropane	78875	5.20E-01
1,3-Dichloropropene	542756	1.00E+01
Ethylbenzene	100414	3.10E+03
Methyl bromide	74839	4.80E+01

(continued)

Table C.4-1. (continued)

Constituent	CAS No.	HH-AWQC (µg/L)
Methylene chloride	75092	4.70E+00
1,1,2,2-Tetrachloroethane	79345	1.70E-01
Tetrachloroethylene	127184	8.00E-01
Toluene	108883	6.80E+03
1,2-trans-Dichloroethylene	156605	7.00E+02
1,1,2-Trichloroethane	79005	6.00E-01
Trichloroethylene	79016	2.70E+00
Vinyl chloride	75014	2.00E+00
2-Chlorophenol	95578	1.20E+02
2,4-Dichlorophenol	120832	9.30E+01
2,4-Dimethylphenol	105679	5.40E+02
2-Methyl-4,6-dinitrophenol	534521	1.34E+01
2,4-Dinitrophenol	51285	7.00E+01
Pentachlorophenol	87865	2.80E-01
Phenol	108952	2.10E+04
2,4,6-Trichlorophenol	88062	2.10E+00
Acenaphthene	83329	1.20E+03
Anthracene	120127	9.60E+03
Benzidine	92875	1.20E-04
Benzo(a)anthracene	56553	4.40E-03
Benzo(a)pyrene	50328	4.40E-03
Benzo(b)fluoranthene	205992	4.40E-03
Benzo(k)fluoranthene	207089	4.40E-03
Bis2-chloroethyl ether	111444	3.10E-02
Bis2-Chloroisopropyl ether	39638329	1.40E+03
Bis2-ethylhexyl phthalate	117817	1.80E+00

(continued)

Table C.4-1. (continued)

Constituent	CAS No.	HH-AWQC (µg/L)
Butylbenzl phthalate	85687	3.00E+03
2-Chloronaphthalene	91587	1.70E+03
Chrysene	218019	4.40E-03
Dibenzo(a, h)anthracene	53703	4.40E-03
1,2-Dichlorobenzene	95501	2.70E+03
1,3-Dichlorobenzene	541731	4.00E+02
1,4-Dichlorobenzene	106467	4.00E+02
3,3-Dichlorobenzidine	91941	4.00E-02
Diethyl pthalate	84662	2.30E+04
Dimethyl phthalate	131113	3.13E+05
Di-n-butyl phthalate	84742	2.70E+03
2,4-Dinitrotoluene	121142	1.10E-01
1,2-Diphenylhydrazine	122667	4.00E-02
Fluoranthene	206440	3.00E+02
Fluorene	86737	1.30E+03
Hexachlorobenzene	118741	7.50E-04
Hexachlorobutadiene	87683	4.40E-01
Hexachlorocyclopentadiene	77474	2.40E+02
Hexachloroethane	67721	1.90E+00
Ideno 1,2,3-cd pyrene	193395	4.40E-03
Isophorone	78591	3.60E+01
Nitrobenzene	98953	1.70E+01
n-Nitrosodimethylamine	62759	6.90E-04
n-Nitrosodi-n-propylamine	621647	5.00E-03
n-Nitrosodiphenylamine	86306	5.00E+00
Pyrene	129000	9.60E+02

(continued)

Table C.4-1. (continued)

Constituent	CAS No.	HH-AWQC (µg/L)
1,2,4-Trichlorobenzene	120821	2.60E+02
Aldrin	309002	1.30E-04
α-BHC	319846	3.90E-03
β-BHC	319857	1.40E-02
δ-BHC	58899	1.90E-02
Chlordane	57749	2.10E-03
4,4-DDT	50293	5.90E-04
4,4-DDE	72559	5.90E-04
4,4-DDD	72548	8.30E-04
Dieldrin	60571	1.40E-04
α-Endosulfan	959988	1.10E+02
β-Endosulfan	33213659	1.10E+02
Endosulfan sulfate	1031078	1.10E+02
Endrin	72208	7.60E-01
Endrin aldehyde	7421934	7.60E-01
Heptachlor	76448	2.10E-04
Heptachlor epoxide	1024573	1.00E-04
Toxaphene	8001352	7.30E-04
PCBs	1336363	1.70E-04

[a] For one facility near unpotable water, a value of 1.4E-7 was used, which reflects only aquatic organism ingestion.

[b] For one facility near unpotable water, a value of 6.3E-6 was used, which reflects only aquatic organism ingestion.

Table C.4-2. Scoring Criteria for Surface Area

Score	Criteria
3	Area > 100,000 m^2
2	10,000 ≤ Area ≤ 100,000 m^2
1	0 < Area < 10,000 m^2

C.4.1.2 Dilution Factor. The fishable waterbodies identified as nearest each surface impoundment were evaluated to determine whether they were quiescent or nonquiescent. It was assumed that groundwater discharging into a nonquiescent (i.e., flowing) waterbody would be diluted to a greater degree than groundwater discharging into a quiescent waterbody. Flow in nonquiescent waterbodies was compiled from three sources:

- U.S. EPA Office of Water, 1996 (U.S. EPA, 1996a), *Database for "Better Assessment Science Integrating Point and Nonpoint Sources*." EPA-823-R-96-001.

- Web pages: http://waterdata.usgs.gov/nwis-w/us/

- van der Leeden et al., 1990, *The Water Encyclopedia* - Second Edition, Table 3-6 Flowing Water Resources of the United States, Lewis Publishers, Inc., pp. 176.

Data from the EPA database were used when available. Streams not listed in the Basins database or that had a station located far from the site were researched using the USGS and associated state geological survey web pages. When data were not available on web sites, the table from van der Leeden et al. was used. No data were collected for ocean or bay areas.

The surface areas for lakes, ponds, and river inlets were measured on USGS 1:24,000 topographic maps using a planimeter. For waterbodies smaller than 5,760 m^2 (limit of planimeter for scale), the area was estimated by measuring the length and width and calculating the square area. Some inlet areas may be considered quiescent.

If the surface waterbody was nonquiescent, the score was assigned in accordance with Table C.4-3. If, however, the surface waterbody was quiescent, the score was assigned in accordance with Table C.4-4.

C.4.1.3 Number of Constituents That Potentially Exceeded Water Quality Criteria. The total number of chemicals potentially exceeding the HH-AWQC present at a facility was also scored. The larger the number of chemicals, the higher the score. Table C.4-5 presents the scores.

Table C.4-3. Median Annual Flow Rate (mfr) of Flowing Waterbody (e.g., River, Creek)

Score	Criteria
3	mfr < 1,250 ft^3/s
2	1,250 ≤ mfr ≤ 5,000 ft^3/s
1	mfr > 5,000 ft^3/s

Table C.4-4. Surface Area of Quiescent Waterbody (e.g., Lake, Pond)

Score	Criteria
3	Area < 10,000 m^2
2	10,000 ≤ Area ≤ 150,000 m^2
1	Area > 150,000 m^2

Table C-4-5. Number of Chemical Constituents Potentially Exceeding a Groundwater / HH-AWQC Ratio of 1

Score	Criteria
3	Chemicals > 21
2	2 < Chemicals ≤ 21
1	Chemicals ≤ 1

C.4.1.4 Magnitude of Exceedance. The magnitude of the exceedance was defined as the maximum ratio of the calculated groundwater concentration to the HH-AWQC at each impoundment. If the ratio exceeded 1, it was scored in accordance with Table C.4-6.

C.4.1.5 Distance to Nearest Fishable Waterbody. The distance to the nearest fishable waterbody was also scored. The method of scoring is reflected in Table C.4-7.

As noted above, the distance from surface impoundment to the nearest fishable waterbody, the area of the surface impoundment, and the dilution factor were each weighted by a factor of 2 and the five individual scores were summed. The final scores were ranked in descending order and every surface impoundment that was characterized by a total score equal to

Table C.4-6. Maximum Groundwater Concentration / HH-AWQC Ratio

Score	Criteria
3	Ratio $\geq$ 100
2	10 $\leq$ Ratio < 100
1	1 $\leq$ Ratio < 10

Table C.4-7. Distance to Nearest Surface Waterbody (as Marked on Topographic Map)

Score	Criteria
3	0 < Distance $\leq$ 333 m
2	333 < Distance $\leq$ 667 m
1	Distance > 667 m

or exceeding 20 was identified for site-based modeling. If a facility had multiple surface impoundments and only one surface impoundment was characterized by a score equal to or exceeding 20, all surface impoundments at the facility were modeled, regardless of their individual scores. In summary, 15 facilities and 69 surface impoundments were modeled.

C.4.2 Surface Water Screening Modeling

The surface water screening analysis was conducted to quantify the potential for degradation of surface water quality with respect to human usage. The pathway begins with infiltration of the constituent into soils beneath the surface impoundment and is completed with the subsequent transport in aquifers and discharge into the surface waterbodies.

Section C.4.2.1 describes the simplifying assumptions made to perform this analysis; Section C.4.2.2 states the basis for screening results; and Section C.4.2 presents the screening procedure, required input parameters, and their values. The results of the groundwater to surface water pathway screening are presented in Attachment C-14 of this Appendix.

C.4.2.1 Assumptions. To simplify the surface water screening methodology and to ensure conservative results, it was assumed that:

- The liquid in the surface impoundment leaks through the base of the unit and the underlying vadose zone to the aquifer

- Constituent concentrations are assumed to be decreased during subsurface transport by a factor equal to the groundwater DAF defined in the IWEM Tier 1 tables (see Table C.3-1) corresponding to the constituent and liner scenario.[1]

- All of the seepage from the aquifer discharges into the river immediately and is fully and instantaneously mixed with the river water

- The river is initially uncontaminated. The result of this screening calculation is an estimate of the final concentration of the constituent of concern in the river after the leachate from the surface impoundment has mixed with the water in the river.

C.4.2.2 Water Quality Screen. The surface water screening methodology compared constituent concentrations to the ambient water quality criteria for the ingestion of surface water and aquatic organisms (HH-AWQC). Attachment C-14 tabulates the results of the comparision. Specifically, constituent concentrations in wastewater, groundwater, and river water were compared to the HH-AWQC in the preliminary screening, the release assessment, and the risk modeling, respectively. If the constituent concentration exceeded the HH-AWQC, the constituent was said to have failed the screen. If the constituent concentration did not exceed the HH-AWQC, the constituent was said to have passed the screen. A pass/fail result is provided in Attachment C-14 for each facility-impoundment-constituent combination.

C.4.2.3 Screening Procedure. The first step of the analysis was to determine the infiltration rate from the surface impoundment. For surface impoundments, infiltration rates were calculated using EPACMTP. For impoundments where the water table was at or above the bottom of the impoundment, the infiltration rate was calculated according to the methodology presented in Bear (1979). Soil parameter values, liner characteristics, and liquid depth of the impoundment were chosen in a manner consistent with the methodology used for the groundwater modeling, as described in Section C.3.2.4 (see Table C.4-8).

After the appropriate infiltration rate I was obtained, an areal leakage rate Q_i from beneath the waste management unit was calculated as follows:

$$Q_i = A\ I \qquad \text{(C.4-1)}$$

where

A = area of the waste management unit (m^2)
I = infiltration rate (m/yr).

[1] A DAF of 1.0 was assigned if the waterbody was closer to the impoundent than the IWEM default distance of 150 meters.

Table C.4-8. Parameters for Infiltration Rate Calculation Used in Screening

Facility	Impoundment ID	Predominant Soil Type	Unsaturated Zone Thickness[a] (m)	Water Table Elevation[b] (m)	Ponding Depth of Surface Impoundment (m)	Effective Thickness of Liner (m)	Effective Hydraulic Conductivity of Liner (m/yr)
22	1	Silty clay loam	14.17	-	4.09	0.15	4.02E-02
	3	Silty clay loam[c]	14.17[c]	-	4.42	0.15	4.01E-02
38	1	Silty clay loam	0.00	0.00	3.64	0.92	4.41E-02
	2	Silty clay loam	4.27	-	1.28	0.99	5.34E-02
45	1	Silty loam	0.00	0.61	2.25	0.15	4.07E-02
	2	Silty loam	0.00	2.18	4.42	0.15	4.01E-02
	3	Silty loam	0.00	5.22	5.57	0.15	4.00E-02
	4	Silty loam	0.00	1.26	2.21	0.15	4.07E-02
	5	Silty loam	0.00	4.46	5.03	0.15	4.00E-02
	6	Silty loam	1.33	-	6.07	0.15	3.99E-02
	7	Silty loam	1.34	-	4.77	0.15	4.01E-02
	8	Silty loam	0.00	0.25	2.60	0.15	4.05E-02
	9	Silty loam	0.00	1.25	4.53	0.15	4.01E-02
	10	Silty loam	0.00	2.47	4.53	0.15	4.01E-02
	11	Silty loam	0.00	2.77	4.53	0.15	4.01E-02
50	1	Silty loam	63.25	-	1.52	0.15	4.13E-02
61	3	Silty clay loam	0.61	-	1.91	0.08	4.03E-02
	4	Silty clay loam	1.22	-	2.22	0.08	4.01E-02
	5	Silty clay loam	0.76	-	1.30	0.08	4.05E-02
	6	Silty clay loam	0.00	0.61	2.03	0.68	4.56E-02
	7	Silty clay loam	0.61	-	1.07	2.28	2.89E-03
78	1	Sandy clay loam	0.91	4.57	3.0	2.1	5.21E-02
	2	Sandy clay loam	1.37	3.048	3.2	2.6	5.41E-02
	3	Sandy clay loam	1.52	-	4.9	3.1	5.08E-02
84	4	Silty loam	0.00		0.30	0.15	4.21E-02
	5	Silty loam	0.00	1.83	2.90	0.15	4.17E-02

(continued)

Table C-4-8. (continued)

Facility	Impoundment ID	Predominant Soil Type	Unsaturated Zone Thickness[a] (m)	Water Table Elevation[b] (m)	Ponding Depth of Surface Impoundment (m)	Effective Thickness of Liner (m)	Effective Hydraulic Conductivity of Liner (m/yr)
103	1	Silty loam	2.00[d]	-	5.49	0.15	4.00E-02
	2	Silty loam	1.22	-	2.90	0.15	4.04E-02
	3	Sandy clay loam	2.74	-	1.21	0.15	4.18E-02
	4	Silty loam	2.00[d]	-	2.90	0.15	4.04E-02
	5	Silty loam	2.00[d]	-	2.90	0.15	4.04E-02
	6	Silty loam	NA[e]	-	NA[e]	NA[e]	NA[e]
105	1	Silty clay loam	1.52	-	1.96	0.15	4.09E-02
127	1	Sandy clay loam	0.00	0.00	0.28	0.15	4.92E-02
	2	Sandy clay loam	0.00	0.00	2.78	0.66	4.38E-02
	5	Sandy clay loam	0.00	0.00	2.58	0.15	4.06E-02
151	1	Sandy clay loam	0.00	0.19	4.41	0.15	4.01E-02
	2	Sandy clay loam	0.00	NA[f]	2.15	1.53	5.23E-02
	3	Sandy clay loam	0.00	NA[f]	2.64	0.15	4.05E-02
	4	Sandy clay loam	1.52	-	2.59	0.15	4.05E-02
	6	Sandy clay loam	2.44	-	2.59	0.15	4.05E-02
	8	Sandy clay loam	2.90	-	9.55	1.91	4.31E-02
	18	Sandy clay loam	2.90	-	9.55	1.91	4.31E-02
156	6	Silty clay loam	0.00	1.49	2.29	0.15	4.07E-02
	7	Silty clay loam	0.00	1.37	1.84	0.15	4.10E-02
	8	Silty clay loam	0.00	1.68	2.29	0.15	4.07E-02
	9	Silty clay loam	0.00	1.66	4.88	1.22	4.41E-02
159	1	Silty clay loam	0.30	-	0.76	0.46	5.04E-02
	2	Silty clay loam	0.00	0.914	0.51	0.26	4.88E-02
	3	Silty clay loam	0.00	0.914	6.33	0.40	4.06E-02
	4	Silty clay loam	2.65	-	0.74	0.09	4.17E-02
	5	Silty clay loam[g]	0.31	-	0.16	0.15	5.63E-02

(continued)

Table C-4-8. (continued)

Facility	Impoundment ID	Predominant Soil Type	Unsaturated Zone Thickness[a] (m)	Water Table Elevation[b] (m)	Ponding Depth of Surface Impoundment (m)	Effective Thickness of Liner (m)	Effective Hydraulic Conductivity of Liner (m/yr)
173	4	Silty clay loam	3.66	-	4.53	0.45	3.39E-02
	5	Silty clay loam	3.66	-	3.41	0.45	3.40E-02
	6	Silty clay loam	3.66	-	2.14	0.45	3.41E-02
	7	Silty clay loam	7.65	-	0.60	0.45	3.48E-02
	8	Silty clay loam	5.97	-	0.93	0.76	3.32E-02
182	1	Sandy clay loam	6.10	-	1.14	0.15	4.19E-02
	2	Sandy clay loam	6.10	-	0.76	0.15	4.31E-02
	3	Sandy clay loam	6.10	-	0.76	0.15	4.31E-02
	4	Sandy clay loam	6.10	-	0.76	0.15	4.31E-02
	5	Sandy clay loam	6.10	-	0.76	0.15	4.31E-02
	6	Sandy clay loam	6.10	-	0.76	0.15	4.31E-02
	7	Sandy clay loam	6.10	-	0.76	0.15	4.31E-02
	8	Sandy clay loam	6.10	-	0.76	0.15	4.31E-02
	9	Sandy clay loam	6.10	-	0.76	0.15	4.31E-02
	10	Sandy clay loam	6.10	-	0.76	0.15	4.31E-02
184	2	Sandy clay loam	0.00	0.00	4.57	4.57	5.74E-02

a Value used in EPACMTP to calculate infiltration rate when bottom of impoundment is above the water table.
b Used to calculate the infiltration rate when the bottom of impoundment is at or below the water table; measured from bottom of impoundment.
c Data not available, used data from impoundment 1.
d Data not available, used the average of impoundments 2 and 3.
e Subsurface data not available; rate assumed to be average the rate of impoundments 1-5.
f Elevation of wastewater in the surface impoundment is below the water table.
g Data not available, assumed same soil type as impoundments 1-4.

The next step was to calculate a river dilution factor (RD) to account for the mixing of the seepage volume with the river water. RD is defined as

$$RD = \frac{Q_{River}}{Q_i} \qquad \text{(C.4-2)}$$

where

Q_{river} = river flow rate (m^3/yr).

The river flow rate, Q_{river}, was represented by the lowest 7-day average flow in a 10-year period (7Q10) when available. If the 7Q10 was not available, the mean flow rate was used.

The leachate migrating through the subsurface was assumed to be diluted by a factor equal to the groundwater DAF defined in the IWEM Tier 1 Tables (see Table C.3-1) corresponding to the constituent and liner scenario. Therefore, the concentration in the groundwater is given as:

$$C_{gw} = \frac{C_{leachate}}{DAF} \qquad \text{(C.4-3)}$$

where

C_{gw} = concentration in groundwater (mg/L),
$C_{leachate}$ = leachate concentration (mg/L), and
DAF = dilution attenuation factor.

The chemical concentration in groundwater reaches the river and is assumed to be instantaneously and fully mixed with clean river water. The resulting final river concentration is related to the appropriate analytical concentration in the leachate through the following equation:

$$C_{river} = \frac{C_{gw}}{RD} \qquad \text{(C.4-4)}$$

where

C_{river} = final river concentration (mg/L).

The final river concentration was then compared with the HH-AWQC concentration for the human usage. Specifically, if C_{river} was less than the appropriate HH-AWQC for a given constituent, then that constituent passed the surface water screening; however, if C_{river} equaled or exceeded the benchmark, then that constituent failed the screening. The modeling inputs for the surface water screening analysis are presented in Table C.4-9. Table C.4-10 identifies the exceedances at each of the nine facilities.

Table C.4-9 Input Parameters for Screening Calculations by Facility and Impoundment

Facility ID	Impound-ment ID	Surface Impoundment Area (m^2)	Liner Scenario	Distance to Surface Water Body (m)	Infiltration Rate[c] (m/yr)	Leachate Flux from Surface Impoundment (m^3/s)	River Flow Rate (m^3/s)	River Flow Rate Type	River Dilution Factor
22	1	7689	NA[a]	65	1.140	2.780E-04	2.251e-01	7Q10	8.099e+02
	3	148924	NA[a]	65	1.220	5.761E-03	2.266E-01	7Q10	3.933E+01
38	1	174015	No liner	200	0.219[d]	9.667E-04	2.286E+02	7Q10	1.892E+05
	2	129500	NA[a]	50	0.137	5.626E-04	2.286E+02	7Q10	4.063E+05
45	1	1012	No liner	270	0.486[d]	1.428E-05	3.115E-01	7Q10	1.997E+04
	2	169968	No liner	500	0.639[d]	3.228E-03	4.248E-01	Mean	1.233E+02
	3	6475	No liner	360	0.133[d]	1.916E-05	3.115E-01	7Q10	1.141E+04
	4	202343	NA[a]	140	0.299[d]	1.655E-03	4.248E-01	Mean	2.214E+02
	5	202343	NA[a]	25	0.192[d]	9.759E-04	3.115E-01	7Q10	2.529E+02
	6	24281	No liner	820	1.740	1.340E-03	4.248E-01	Mean	3.171E+02
	7	23067	No liner	845	1.410	1.031E-03	4.248E-01	Mean	4.119E+02
	8	48562	No liner	910	0.676[d]	9.781E-04	4.248E-01	Mean	4.081E+02
	9	8094	No liner	895	0.917[d]	2.250E-04	4.248E-01	Mean	1.805E+03
	10	8094	No liner	975	0.591[d]	1.413E-04	4.248E-01	Mean	2.801E+03
	11	8094	No liner	950	0.511[d]	1.207E-04	4.248E-01	Mean	3.239E+03
50	1	129904	No liner	280	0.632	2.603E-03	NA[B]	NA[b]	1.000E+00
68	3	708201	NA[a]	35	1.000	2.246E-02	1.558E+00	Mean	6.938E+01
	4	283280	NA[a]	35	1.220	1.096E-02	1.558E+00	7Q10	1.422E+02
	5	424920	NA[a]	35	0.744	1.002E-02	1.558E+00	7Q10	1.554E+02
	6	36422	NA[a]	20	0.141[d]	1.104E-04	1.558E+00	7Q10	9.567E+03
	7	26305	Single liner	215	0.005	4.146E-06	1.558E+00	7Q10	3.736E+05
78	1	26709	No liner	315	0.015[d]	2.685E-05	4.248e-01	Mean	3.344e+04
	2	30351	No liner	330	0.057[d]	1.424E-04	4.248E-01	Mean	7.744E+03
	3	62726	NA[a]	150	0.004[f]	7.340E-06	4.248E-01	Mean	5.339E+04
84	4	2023	NA[a]	65	0.327[d]	5.518E-06	5.914E+00	7Q10	2.819E+05
	5	469436	NA[a]	115	0.339[d]	5.051E-03	5.183E-02	7Q10	1.027E+01
103	1	6611	No liner	720	1.590	3.333E-04	4.248E-01	Mean	1.274E+03
	2	79318	No liner	565	0.948	2.384E-03	7.607E+00	7Q10	3.190E+03
	3	481576	No liner	670	0.488	7.452E-03	7.607E+00	7Q10	1.021E+03
	4	19223	NA[a]	40	0.956	5.827E-04	4.248E-01	Mean	7.290E+02
	5	19223	NA[a]	40	0.956	5.827E-04	4.248E-01	Mean	7.290E+02
	6	180490	NA[a]	95	0.988[g]	5.652E-03	1.487E+02	Mean	2.630E+04
105	1	109265	No liner	710	0.580	2.010E-03	9.884E+00	7Q10	4.918E+03
127	1	279233	No liner	905	0.141[d]	8.136E-04	6.587E+01	Mean	5.276E+04
	2	12141	No liner	950	0.229[d]	7.109E-05	2.719E+00	Mean	3.084E+04
	5	4856232	NA[a]	125	0.738[d]	1.074E-01	6.587E+01	Mean	5.796E+02
151	1	7469	No liner	395	1.169[d]	2.673E-04	6.522E+01	7Q10	2.356E+05
	2	20234	No liner	255	NA[e]	NA[e]	6.522E+01	7Q10	NA[E]
	3	214484	NA[a]	40	NA[e]	NA[e]	6.522E+01	7Q10	NA[E]
	4	348030	NA[a]	115	0.827	9.127E-03	6.522E+01	7Q10	7.146E+03

(continued)

Table C.4-9 (Continued)

Facility ID	Impound-ment ID	Surface Impoundment Area (m^2)	Liner Scenario	Distance to Surface Water Body (m)	Infiltration Rate[c] (m/yr)	Leachate Flux from Surface Impoundment (m^3/s)	River Flow Rate (m^3/s)	River Flow Rate Type	River Dilution Factor
151 (cont.)	6	24281	No liner	495	0.829	6.383E-04	6.522e+01	7Q10	1.022e+05
	8	48562	No liner	985	0.269	4.142E-04	6.522E+01	7Q10	1.574E+05
	18	48562	No liner	970	0.269	4.142E-04	6.522E+01	7Q10	1.574E+05
156	6	76890	NA[a]	20	0.257[d]	5.265E-04	2.832E+01	Mean	4.520E+04
	7	157828	No liner	215	0.169[d]	6.399E-04	2.832E+01	Mean	3.348E+04
	8	971	NA[a]	120	0.207[d]	5.122E-06	2.832E+01	Mean	4.443E+06
	9	267093	No liner	245	0.160[d]	9.850E-04	2.832E+01	Mean	2.090E+04
159	1	7525	No liner	460	0.150	3.579E-05	9.048E-01	Mean	2.528E+04
	2	52583	No liner	460	0.012[d]	3.652E-05	9.048E-01	Mean	4.522E+04
	3	18395	No liner	370	0.006[d]	3.476E-06	9.048E-01	Mean	2.585E+05
	4	436923	NA[a]	60	0.407	5.639E-03	9.048E-01	Mean	1.605E+02
	5	295421	NA[a]	30	0.167	1.564E-03	9.629E+00	Mean	6.155E+03
173	4	101172	No liner	795	0.376	1.206E-03	2.048E+02	7Q10	1.698E+05
	5	230671	No liner	270	0.295	2.158E-03	2.048E+02	7Q10	9.491E+04
	6	465389	NA[a]	105	0.206	3.040E-03	2.048E+02	7Q10	6.737E+04
	7	669	No liner	810	0.107	2.270E-06	2.048E+02	7Q10	9.023E+07
	8	3855	No liner	575	0.092	1.119E-05	2.048E+02	7Q10	1.821E+07
182	1	101172	No liner	700	0.469	1.505E-03	0.000E+00	NA[b]	1.000E+00
	2	215698	No liner	200	0.380	2.599E-03	0.000E+00	NA[b]	1.000E+00
	3	61917	NA[a]	20	0.380	7.461E-04	0.000E+00	NA[b]	1.000E+00
	4	531757	NA[a]	20	0.380	6.408E-03	0.000E+00	NA[b]	1.000E+00
	5	57061	NA[a]	40	0.380	6.876E-04	0.000E+00	NA[b]	1.000E+00
	6	135165	NA[a]	0	0.380	1.629E-03	0.000E+00	NA[b]	1.000E+00
	7	236337	No liner	300	0.380	2.848E-03	0.000E+00	NA[b]	1.000E+00
	8	28779	NA[a]	0	0.380	3.468E-04	0.000E+00	NA[b]	1.000E+00
	9	81034	NA[a]	0	0.380	9.764E-04	0.000E+00	NA[b]	1.000E+00
	10	7701	No liner	700	0.380	9.279E-05	0.000E+00	NA[b]	1.000E+00
184	2	230671	NA[a]	65	0.115[d]	1.612E-03	0.000E+00	7Q10	0.000E+00

[a] Liner scenario is not required since the impoundment is less than or equal to 150 meters; DAF assumed to be 1.0.
[b] The waterbody is a pond, therefore the River Flow Rate is essentially zero and the River Dilution Factor is assumed to be 1.
[c] Infiltration rates for this analysis were calculated using the semi-analytical solution in EPACMTP and impoundment-specific data unless otherwise noted.
[d] The base of the impoundment is at or below the water table, so the infiltration rate was calculated using the method described in Bear (1979).
[e] Infiltration rate, Leachate flux, and River Dilution Factor are not applicable because the elevation of the wastewater in the surface impoundment is at or below the water table.
[f] The infiltration rate was generated using the formula for composite liner leakage rate of Bonaparte et al. (1989).
[g] The infiltration rate was generated by averaging the infiltration from impoundments 1,2,3,4 and 5 because of the lack of subsurface data.

Table C.4-10. Summary of Water Quality Exceedances for Groundwater to Surface Water Pathway

Facility	SI	Constituent of Concern	C_{leach} [a] (mg/L)	C_{GW} [b] (mg/L)	C_{river} [c] (mg/L)	HH-AWQC [d] (mg/L)	C_{river}/HH-AWQC [e]
Risk Exceedances Based on Reported Chemical Concentrations							
50	1	Thallium	2.40e+00	3.29E-03	3.29E-03	1.70E-03	1.93E+00
68	3	Arsenic	1.20E-02	1.20E-02	1.73E-04	1.80E-05	9.61E+00
182	1	Arsenic	2.67E-01	8.09E-03	8.09E-03	1.80E-05	4.49E+02
182	2	Arsenic	2.53E-01	7.68E-03	7.68E-03	1.80E-05	4.26E+02
182	3	Arsenic	4.94E-02	4.94E-02	4.94E-02	1.80E-05	2.74E+03
182	4	Arsenic	1.55E-01	1.55E-01	1.55E-01	1.80E-05	8.63E+03
182	5	Arsenic	1.95E-01	1.95E-01	1.95E-01	1.80E-05	1.08E+04
182	8	Arsenic	3.70E-03	3.70E-03	3.70E-03	1.80E-05	2.06E+02
182	6	Arsenic	1.72E-02	1.72E-02	1.72E-02	1.80E-05	9.56E+02
Risk Exceedances Based on Surrogate/DL Chemical Concentrations							
22	1	Benzidine	3.50e+00	3.50E-02	4.32E-05	1.20E-07	3.60E+02
22	1	Benzo(a)anthracene	1.00E-02	1.00E-02	1.23E-05	4.40E-06	2.81E+00
22	1	Benzo(a)pyrene	1.00E-02	1.00E-02	1.23E-05	4.40E-06	2.81E+00
22	1	Benzo(b)fluoranthene	1.00E-02	1.00E-02	1.23E-05	4.40E-06	2.81E+00
22	1	Chrysene	5.00E-03	5.00E-03	6.17E-06	4.40E-06	1.40E+00
22	1	Dibenzo(a,h)anthracene	1.00E-02	1.00E-02	1.23E-05	4.40E-06	2.81E+00
22	1	Hexachlorobenzene	1.00E-02	1.00E-02	1.23E-05	7.50E-07	1.65E+01
22	1	Ideno 1,2,3-cd Pyrene	1.00E-02	1.00E-02	1.23E-05	4.40E-06	2.81E+00
22	1	N-Nitrosodimethylamine	5.00E-03	5.00E-03	6.17E-06	6.90E-07	8.95E+00
22	1	N-Nitrosodi-n-propylamine	1.00E-02	1.00E-02	1.23E-05	5.00E-06	2.47E+00
22	1	PCBs	1.75E-03	1.75E-03	2.16E-06	1.70E-07	1.27E+01
22	1	Toxaphene	1.00E-03	1.00E-03	1.23E-06	7.30E-07	1.69E+00
45	2	1,2-Diphenylhydrazine	1.00E-02	5.56E-03	4.50E-05	4.00E-05	1.13E+00
45	2	3,3'Dichlorobenzidine	2.00E-02	9.52E-03	7.72E-05	4.00E-05	1.93E+00
45	2	Acrylonitrile	4.33E-02	2.41E-02	1.95E-04	5.90E-05	3.31E+00
45	2	Benzidine	5.00E-02	2.78E-02	2.25E-04	1.20E-07	1.88E+03
45	2	Bis2-chloroethyl ether	1.00E-02	4.35E-03	3.53E-05	3.10E-05	1.14E+00
45	2	Hexachlorobenzene	1.00e+00	1.69E-04	1.37E-06	7.50E-07	1.83E+00

(continued)

Table C.4-10. (continued)

Facility	SI	Constituent of Concern	C_{leach} [a] (mg/L)	C_{GW} [b] (mg/L)	C_{river} [c] (mg/L)	HH-AWQC [d] (mg/L)	C_{river}/HH-AWQC [e]
45	2	n-Nitrosodimethylamine	1.00E-02	5.56E-03	4.50E-05	6.90E-07	6.53E+01
45	2	n-Nitrosodi-n-propylamine	1.00E-02	5.56E-03	4.50E-05	5.00E-06	9.01E+00
45	2	PCBs	1.65E-02	4.46E-05	3.62E-07	1.70E-07	2.13E+00
45	2	Toxaphene	8.80E-03	7.33E-04	5.95E-06	7.30E-07	8.15E+00
45	3	Benzidine	5.00E-02	2.78E-02	2.44E-06	1.20E-07	2.03E+01
45	4	1,2-Diphenylhydrazine	1.00E-02	1.00E-02	4.51E-05	4.00E-05	1.13E+00
45	4	3,3'Dichlorobenzidine	2.00E-02	2.00E-02	9.02E-05	4.00E-05	2.26E+00
45	4	4,4-DDD	3.67E-04	3.67E-04	1.65E-06	8.30E-07	1.99E+00
45	4	4,4-DDE	3.67E-04	3.67E-04	1.65E-06	5.90E-07	2.80E+00
45	4	4,4-DDT	3.67E-04	3.67E-04	1.65E-06	5.90E-07	2.80E+00
45	4	Acrylonitrile	4.33E-02	4.33E-02	1.96E-04	5.90E-05	3.31E+00
45	4	Aldrin	1.83E-04	1.83E-04	8.27E-07	1.30E-07	6.36E+00
45	4	Arsenic	1.00E-02	1.00E-02	4.51E-05	1.80E-05	2.51E+00
45	4	Benzidine	5.00E-02	5.00E-02	2.26E-04	1.20E-07	1.88E+03
45	4	Benzo(a)anthracene	1.00E-02	1.00E-02	4.51E-05	4.40E-06	1.03E+01
45	4	Benzo(a)pyrene	1.00E-02	1.00E-02	4.51E-05	4.40E-06	1.03E+01
45	4	Benzo(b)fluoranthene	1.00E-02	1.00E-02	4.51E-05	4.40E-06	1.03E+01
45	4	Bis2-chloroethyl ether	1.00E-02	1.00E-02	4.51E-05	3.10E-05	1.46E+00
45	4	Chlordane	7.33E-04	7.33E-04	3.31E-06	2.10E-06	1.58E+00
45	4	Chrysene	1.00E-02	1.00E-02	4.51E-05	4.40E-06	1.03E+01
45	4	Dibenzo(a,h)anthracene	1.00E-02	1.00E-02	4.51E-05	4.40E-06	1.03E+01
45	4	Dieldrin	7.33E-05	7.33E-05	3.31E-07	1.40E-07	2.36E+00
45	4	Heptachlor	1.83E-04	1.83E-04	8.27E-07	2.10E-07	3.94E+00
45	4	Heptachlor Epoxide	2.93E-03	2.93E-03	1.32E-05	1.00E-07	1.32E+02
45	4	Hexachlorobenzene	1.00E-02	1.00E-02	4.51E-05	7.50E-07	6.02E+01
45	4	Ideno 1,2,3-cd Pyrene	1.00E-02	1.00E-02	4.51E-05	4.40E-06	1.03E+01
45	4	n-Nitrosodimethylamine	1.00E-02	1.00E-02	4.51E-05	6.90E-07	6.54E+01
45	4	n-Nitrosodi-n-propylamine	1.00E-02	1.00E-02	4.51E-05	5.00E-06	9.02E+00
45	4	PCBs	1.65E-02	1.65E-02	7.45E-05	1.70E-07	4.38E+02
45	4	Toxaphene	8.80E-03	8.80E-03	3.97E-05	7.30E-07	5.44E+01

(continued)

Table C.4-10. (continued)

Facility	SI	Constituent of Concern	C_{leach} [a] (mg/L)	C_{GW} [b] (mg/L)	C_{river} [c] (mg/L)	HH-AWQC [d] (mg/L)	C_{river}/HH-AWQC [e]
45	5	3,3'Dichlorobenzidine	2.00e+00	2.00E-02	7.92E-05	4.00E-05	1.98E+00
45	5	4,4-DDD	3.67E-04	3.67E-04	1.45E-06	8.30E-07	1.75E+00
45	5	4,4-DDE	3.67E-04	3.67E-04	1.45E-06	5.90E-07	2.46E+00
45	5	4,4-DDT	3.67E-04	3.67E-04	1.45E-06	5.90E-07	2.46E+00
45	5	Acrylonitrile	4.33E-02	4.33E-02	1.72E-04	5.90E-05	2.91E+00
45	5	Aldrin	1.83E-04	1.83E-04	7.26E-07	1.30E-07	5.58E+00
45	5	Arsenic	1.00E-02	1.00E-02	3.96E-05	1.80E-05	2.20E+00
45	5	Benzidine	5.00E-02	5.00E-02	1.98E-04	1.20E-07	1.65E+03
45	5	Benzo(a)anthracene	1.00E-02	1.00E-02	3.96E-05	4.40E-06	9.00E+00
45	5	Benzo(a)pyrene	1.00E-02	1.00E-02	3.96E-05	4.40E-06	9.00E+00
45	5	Benzo(b)fluoranthene	1.00E-02	1.00E-02	3.96E-05	4.40E-06	9.00E+00
45	5	Bis2-chloroethyl ether	1.00E-02	1.00E-02	3.96E-05	3.10E-05	1.28E+00
45	5	Chlordane	7.33E-04	7.33E-04	2.90E-06	2.10E-06	1.38E+00
45	5	Chrysene	1.00E-02	1.00E-02	3.96E-05	4.40E-06	9.00E+00
45	5	Dibenzo(a,h)anthracene	1.00E-02	1.00E-02	3.96E-05	4.40E-06	9.00E+00
45	5	Dieldrin	7.33E-05	7.33E-05	2.90E-07	1.40E-07	2.07E+00
45	5	Heptachlor	1.83E-04	1.83E-04	7.26E-07	2.10E-07	3.46E+00
45	5	Heptachlor Epoxide	2.93E-03	2.93E-03	1.16E-05	1.00E-07	1.16E+02
45	5	Hexachlorobenzene	1.00E-02	1.00E-02	3.96E-05	7.50E-07	5.28E+01
45	5	Ideno 1,2,3-cd Pyrene	1.00E-02	1.00E-02	3.96E-05	4.40E-06	9.00E+00
45	5	n-Nitrosodimethylamine	1.00E-02	1.00E-02	3.96E-05	6.90E-07	5.74E+01
45	5	n-Nitrosodi-n-propylamine	1.00E-02	1.00E-02	3.96E-05	5.00E-06	7.92E+00
45	5	PCBs	1.65E-02	1.65E-02	6.53E-05	1.70E-07	3.84E+02
45	5	Toxaphene	8.80E-03	8.80E-03	3.48E-05	7.30E-07	4.77E+01
45	6	Acrylonitrile	4.33E-02	2.41E-02	7.59E-05	5.90E-05	1.29E+00
45	6	Benzidine	5.00E-02	2.78E-02	8.76E-05	1.20E-07	7.30E+02
45	6	n-Nitrosodimethylamine	1.00E-02	5.56E-03	1.75E-05	6.90E-07	2.54E+01
45	6	n-Nitrosodi-n-propylamine	1.00E-02	5.56E-03	1.75E-05	5.00E-06	3.50E+00
45	6	Toxaphene	8.80E-03	7.33E-04	2.31E-06	7.30E-07	3.17E+00
45	7	Benzidine	5.00E-02	2.78E-02	6.74E-05	1.20E-07	5.62E+02

(continued)

Table C.4-10. (continued)

Facility	SI	Constituent of Concern	C_{leach} [a] (mg/L)	C_{GW} [b] (mg/L)	C_{river} [c] (mg/L)	HH-AWQC [d] (mg/L)	C_{river}/HH-AWQC [e]
45	7	n-Nitrosodimethylamine	1.00E-02	5.56E-03	1.35E-05	6.90E-07	1.96E+01
45	7	n-Nitrosodi-n-propylamine	1.00e+00	5.56E-03	1.35E-05	5.00E-06	2.70E+00
45	7	Toxaphene	8.80E-03	7.33E-04	1.78E-06	7.30E-07	2.44E+00
45	8	Benzidine	5.00E-02	2.78E-02	6.81E-05	1.20E-07	5.67E+02
45	8	n-Nitrosodimethylamine	1.00E-02	5.56E-03	1.36E-05	6.90E-07	1.97E+01
45	8	n-Nitrosodi-n-propylamine	1.00E-02	5.56E-03	1.36E-05	5.00E-06	2.72E+00
45	8	Toxaphene	8.80E-03	7.33E-04	1.80E-06	7.30E-07	2.46E+00
45	9	Benzidine	5.00E-02	2.78E-02	1.54E-05	1.20E-07	1.28E+02
45	9	n-Nitrosodimethylamine	1.00E-02	5.56E-03	3.08E-06	6.90E-07	4.46E+00
45	10	Benzidine	5.00E-02	2.78E-02	9.91E-06	1.20E-07	8.26E+01
45	10	n-Nitrosodimethylamine	1.00E-02	5.56E-03	1.98E-06	6.90E-07	2.87E+00
45	11	Benzidine	5.00E-02	2.78E-02	8.57E-06	1.20E-07	7.14E+01
45	11	n-Nitrosodimethylamine	1.00E-02	5.56E-03	1.71E-06	6.90E-07	2.48E+00
50	1	Arsenic	5.00E-01	1.52E-02	1.52E-02	1.80E-05	8.42E+02
68	3	Benzo(a)anthracene	1.00E-02	1.00E-02	1.44E-04	4.40E-06	3.28E+01
68	3	Benzo(a)pyrene	1.00E-02	1.00E-02	1.44E-04	4.40E-06	3.28E+01
68	3	Benzo(b)fluoranthene	1.00E-02	1.00E-02	1.44E-04	4.40E-06	3.28E+01
68	3	Chrysene	1.00E-02	1.00E-02	1.44E-04	4.40E-06	3.28E+01
68	3	Dibenzo(a,h)anthracene	1.00E-02	1.00E-02	1.44E-04	4.40E-06	3.28E+01
68	3	Ideno 1,2,3-cd Pyrene	1.00E-02	1.00E-02	1.44E-04	4.40E-06	3.28E+01
78	2	Arsenic	1.00E+01	3.03E-01	3.93E-05	1.80E-05	2.18E+00
84	5	1,1,2,2-Tetrachloroethane	5.00E-03	5.00E-03	4.87E-04	1.70E-04	2.86E+00
84	5	1,1-Dichloroethylene	5.00E-03	5.00E-03	4.87E-04	5.70E-05	8.54E+00
84	5	1,2-Dichloroethane	5.00E-03	5.00E-03	4.87E-04	3.80E-04	1.28E+00
84	5	1,2-Diphenylhydrazine	1.00E-02	1.00E-02	9.73E-04	4.00E-05	2.43E+01
84	5	2,4-Dinitrotoluene	1.00E-02	1.00E-02	9.73E-04	1.10E-04	8.85E+00
84	5	3,3'-Dichlorobenzidine	1.00E-02	1.00E-02	9.73E-04	4.00E-05	2.43E+01
84	5	4,4-DDD	1.00E-05	1.00E-05	9.73E-07	8.30E-07	1.17E+00
84	5	4,4-DDE	1.00E-05	1.00E-05	9.73E-07	5.90E-07	1.65E+00
84	5	4,4-DDT	1.00E-05	1.00E-05	9.73E-07	5.90E-07	1.65E+00

(continued)

Table C.4-10. (continued)

Facility	SI	Constituent of Concern	C_{leach} [a] (mg/L)	C_{GW} [b] (mg/L)	C_{river} [c] (mg/L)	HH-AWQC [d] (mg/L)	C_{river}/HH-AWQC [e]
84	5	Acrylonitrile	1.00E-02	1.00E-02	9.73E-04	5.90E-05	1.65E+01
84	5	Aldrin	5.00E-05	5.00E-05	4.87E-06	1.30E-07	3.74E+01
84	5	Arsenic	3.00e+00	3.00E-03	2.92E-04	1.80E-05	1.62E+01
84	5	Benzidine	1.00E-02	1.00E-02	9.73E-04	1.20E-07	8.11E+03
84	5	Benzo(a)anthracene	5.00E-05	5.00E-05	4.87E-06	4.40E-06	1.11E+00
84	5	Benzo(a)pyrene	5.00E-05	5.00E-05	4.87E-06	4.40E-06	1.11E+00
84	5	Benzo(b)fluoranthene	5.00E-05	5.00E-05	4.87E-06	4.40E-06	1.11E+00
84	5	Bis(2-chloroethyl) ether	1.00E-02	1.00E-02	9.73E-04	3.10E-05	3.14E+01
84	5	Carbon Tetrachloride	5.00E-03	5.00E-03	4.87E-04	2.50E-04	1.95E+00
84	5	Chlordane	5.00E-05	5.00E-05	4.87E-06	2.10E-06	2.32E+00
84	5	Chlorodibromomethane	5.00E-03	5.00E-03	4.87E-04	4.10E-04	1.19E+00
84	5	Chrysene	5.00E-05	5.00E-05	4.87E-06	4.40E-06	1.11E+00
84	5	Dibenzo(a,h)anthracene	5.00E-05	5.00E-05	4.87E-06	4.40E-06	1.11E+00
84	5	Dieldrin	2.00E-04	2.00E-04	1.95E-05	1.40E-07	1.39E+02
84	5	Heptachlor	5.00E-05	5.00E-05	4.87E-06	2.10E-07	2.32E+01
84	5	Heptachlor Epoxide	5.00E-05	5.00E-05	4.87E-06	1.00E-07	4.87E+01
84	5	Hexachlorobenzene	5.00E-05	5.00E-05	4.87E-06	7.50E-07	6.49E+00
84	5	Hexachlorobutadiene	1.00E-02	1.00E-02	9.73E-04	4.40E-04	2.21E+00
84	5	Ideno 1,2,3-cd Pyrene	5.00E-05	5.00E-05	4.87E-06	4.40E-06	1.11E+00
84	5	N-Nitrosodimethylamine	1.00E-02	1.00E-02	9.73E-04	6.90E-07	1.41E+03
84	5	N-Nitrosodi-n-propylamine	1.00E-02	1.00E-02	9.73E-04	5.00E-06	1.95E+02
84	5	Pentachlorophenol	1.00E-02	1.00E-02	9.73E-04	2.80E-04	3.48E+00
84	5	Toxaphene	5.00E-03	5.00E-03	4.87E-04	7.30E-07	6.67E+02
159	4	Antimony	6.00E-02	6.00E-02	3.74E-04	1.40E-04	2.67E+00
159	4	Arsenic	3.00E-01	3.00E-01	1.87E-03	1.40E-04 [F]	1.34E+01
159	4	Thallium	2.00E+00	2.00E+00	1.25E-02	6.30E-03 [F]	1.98E+00
182	7	Arsenic	2.67E-01	8.09E-03	8.09E-03	1.80E-05	4.49E+02
182	9	Arsenic	2.53E-01	2.53E-01	2.53E-01	1.80E-05	1.41E+04
182	10	Arsenic	2.67E-01	8.09E-03	8.09E-03	1.80E-05	4.49E+02
184	2	Benzidine	5.00E-02	5.00E-02	3.82E-05	1.20E-07	3.19E+02

(continued)

Table C.4-10. (continued)

Facility	SI	Constituent of Concern	C_{leach} [a] (mg/L)	C_{GW} [b] (mg/L)	C_{river} [c] (mg/L)	HH-AWQC [d] (mg/L)	C_{river}/HH-AWQC [e]
184	2	Benzo(a)anthracene	1.00E-02	1.00E-02	7.65E-06	4.40E-06	1.74E+00
184	2	Benzo(a)pyrene	1.00E-02	1.00E-02	7.65E-06	4.40E-06	1.74E+00
184	2	Benzo(b)fluoranthene	1.00e+00	1.00E-02	7.65E-06	4.40E-06	1.74E+00
184	2	Chrysene	1.00E-02	1.00E-02	7.65E-06	4.40E-06	1.74E+00
184	2	Dibenzo(a,h)anthracene	1.00E-02	1.00E-02	7.65E-06	4.40E-06	1.74E+00
184	2	Hexachlorobenzene	1.00E-02	1.00E-02	7.65E-06	7.50E-07	1.02E+01
184	2	Ideno 1,2,3-cd Pyrene	1.00E-02	1.00E-02	7.65E-06	4.40E-06	1.74E+00
184	2	n-Nitrosodimethylamine	1.00E-02	1.00E-02	7.65E-06	6.90E-07	1.11E+01
184	2	n-Nitrosodi-n-propylamine	1.00E-02	1.00E-02	7.65E-06	5.00E-06	1.53E+00
184	2	PCBs	3.50E-02	3.50E-02	2.68E-05	1.70E-07	1.57E+02
184	2	Toxaphene	2.00E-03	2.00E-03	1.53E-06	7.30E-07	2.10E+00

[a] C_{leach} The estimated concentration in the leachate as it leaves the unit boundary.

[b] C_{GW} The estimated concentration in the groundwater as it enters the surface water; if this value exceeds a HH-AWQC then the facility is considered to have the potential for an environmental release.

[c] C_{river} The estimated concentration in the surface water after complete mixing.

[d] HH-AWQC Ambient Water Quality Criteria for human health.

[e] C_{river}/HH-AWQC The ratio of the surface water concentration to the ambient water quality criteria for human health; if this ratio exceeds one then the facility is considered to have a potential risk exceedance.

[f] The HH-AWQC selected is based on aquatic organism ingestion only because the impoundment is located next to an estuarine waterbody.

C.5 Indirect Exposure Pathway Analysis: Methodology and Results

C.5.1 Overview

The indirect exposure pathway (IEP) screening analysis was designed to evaluate the potential for indirect exposure pathway risk as a result of potential chemical release from surface impoundments. Only those facilities with impoundments that currently handle bioaccumulative constituents (i.e., SVOCs, dioxin-like compounds, mercury, and several additional metals), were included in this analysis.

Key Attributes of Indirect Exposure Pathway Screening Analysis

- Evaluated potential for indirect exposure pathway risk to offsite populations including residents, farmers, and fishers.
- Assigned facilities to one of three categories regarding potential for indirect exposure pathway risk: *potential concern, lower concern,* or *least concern*.
- Used numerical ranking algorithms combined with facility-specific and environmental setting criteria to assign rankings.
- Considered both current status and future closure scenarios. Future status scenario results were used only to qualify overall rankings, which were based on current status scenario results.

The IEP screening analysis used a combination of facility-specific and environmental setting criteria to assign each facility to one of three categories regarding the potential for indirect exposure pathway risk:

- **Potential concern:** The potential exists for indirect exposure pathway risk.
- **Lower concern**: There is a lower potential for indirect exposure pathway risk.
- Least concern: The analysis suggests that these facilities have the least potential for indirect exposure pathway risk.

In order for a facility to be placed in the category with the highest level of concern (i.e., the potential concern category), the IEP screening analysis had to suggest that the potential exists for indirect exposure pathway risk under current site conditions. Consequently, overall rankings for the facilities were assigned based on a current status scenario, which was designed to represent current conditions at the facilities. A future closure scenario was also included in the analysis to provide perspective on the number of facilities that could pose an indirect exposure pathway risk after impoundment closure. This future closure scenario analysis was based on precautionary assumptions regarding postclosure actions; consequently, the results of the analysis were used only to qualify the results of the current status scenario (i.e., future closure results were not used in assigning overall rankings to the facilities).

Although a number of the facility-specific and environmental setting criteria used in the numerical ranking of facilities were assessed at the impoundment level, the IEP screening analysis was implemented primarily at the facility level with overall rankings regarding indirect exposure pathway risk being assigned to facilities and not impoundments. In addition, although the types of chemical classes handled at facilities were considered part of the analysis (e.g., in determining which release scenarios were applicable), the analysis was not conducted at the level of individual chemicals and did not use chemical-specific concentration data. This level of analytical resolution was considered appropriate for the IEP screening analysis, which was

intended as a first-pass assessment of the potential for indirect exposure pathway risk at these facilities and not as a site-specific quantitative assessment of risk.

The IEP analysis considered a set of exposure pathways, each linked to a specific release scenario and receptor population. For example, the analysis considered volatilization of chemicals from impoundments with subsequent transport to offsite residential home gardens (this represented a specific exposure pathway that was evaluated for the resident receptor population). Each of these exposure pathways was evaluated using a specific set of facility-specific and environmental setting criteria, which in turn were used in a ranking algorithm to generate the overall ranking for that exposure pathway regarding the potential for indirect exposure pathway risk. Once all exposure pathways were evaluated for a given facility, those rankings were reviewed and an **overall ranking** was given to that facility for the IEP screening analysis. As noted above, these overall rankings were based only on the current status scenario.

The procedure used to complete the IEP screening analysis is presented below and illustrated in Figure C.5-1 (more detailed discussion of individual elements of the analytical framework is presented in the next section):

- *Step 1: Obtained facility-specific and environmental setting information used to establish criteria for the IEP screening analysis*. Reviewed SI survey data to obtain key facility-specific performance information (e.g., current impoundment status, postclosure actions taken for closed impoundments, impoundment size). Used U.S. Census data, aerial photos, topographic maps and other resources to characterize key environmental setting attributes (e.g., distance to receptor, potential for erosion/runoff, potential level of dilution for downgradient waterbodies)

- *Step 2: Converted information obtained in Step 1 into individual criteria scores used in the ranking algorithms for different exposure pathways*: Converted facility-specific and environmental setting information into specific criteria scores ranging from 1 to 3 (with 1 having a lower impact on potential exposure and risk, 2 having a moderate impact, and 3 having a higher impact). The parameter ranges that were used in defining the three categories for each criterion reflected the underlying characteristics of that parameter.

- *Step 3: Used exposure-pathway-specific ranking algorithms together with criteria from Step 2 to generate numerical rankings for each exposure pathway*: Separate ranking algorithms were developed for each exposure pathway reflecting the specific mix of criteria that should be considered in evaluating the potential for indirect exposure pathway risk for that pathway. These ranking algorithms were combined with applicable criteria to generate numerical rankings for each exposure pathway. Note that the numerical rankings were generated for both the current status scenario exposure pathways and the future closure scenario exposure pathways. This produced two sets of overall pathway-specific rankings for a given facility–one set for the current status scenario and

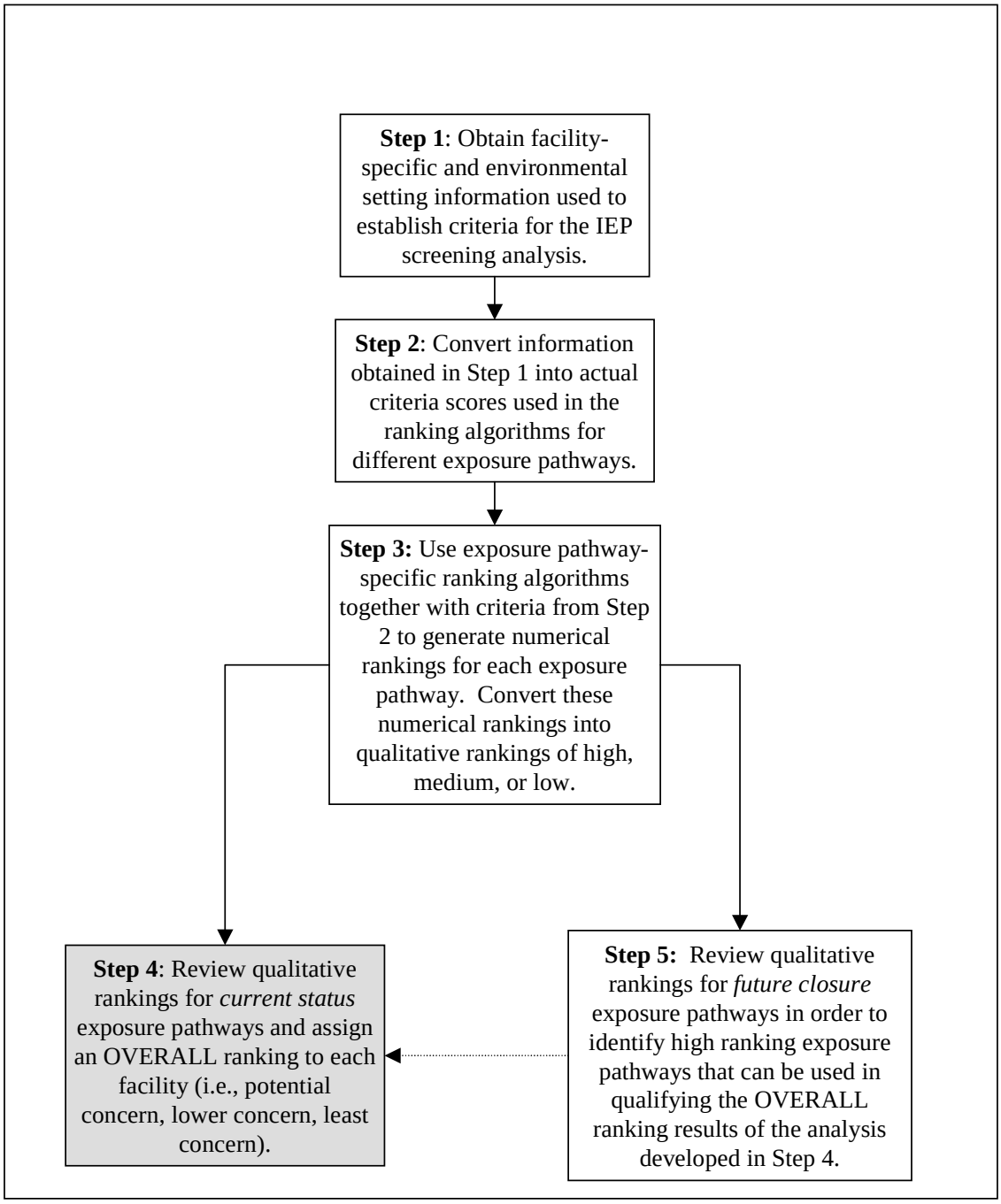


Figure C.5-1. Procedure used to assign overall rankings to facilities in indirect exposure pathway screening analysis.

one set for the future closure scenario. Ultimately, these exposure pathway-specific numerical rankings were converted into qualitative rankings of high, medium, or low for each exposure pathway, which were then used in assigning overall rankings to facilities.

- *Step 4: Reviewed qualitative rankings for current status exposure pathways and assigned an **overall** ranking to each facility*: Overall rankings for this analysis were assigned based on a review of the individual rankings assigned to each current status scenario exposure pathway. Specifically, to add confidence to conclusions that a facility has the potential for indirect exposure pathway risk (i.e., that that facility should be assigned a potential concern ranking), it was decided that a facility had to meet one of two criteria: (1) have at least two current scenario exposure pathways with a "high" ranking, or (2) have one current scenario pathway with a "high" rank and failure of the direct exposure pathway screen for air for at least one bioaccumulative constituent.

- *Step 5: Reviewed qualitative rankings for future closure exposure pathways in order to identify high-ranking exposure pathways that could be used in qualifying the **overall** ranking results of the analysis*: The results of pathway-specific rankings for the future closure scenario were reviewed for each facility to determine if any pathways have high rankings. This information was then used to qualify or augment overall rankings for those sites.

C.5.2 Technical Approach

This section provides an expanded discussion of the technical approach used in the IEP screening analysis, including a detailed explanation of how the semiquantitative ranking procedure was applied to each of the exposure pathways that were considered in the analysis.

C.5.2.1. Release Scenarios. To evaluate both the current status scenario and the future closure scenario, several different release scenarios were considered, including volatilization, particulate entrainment, erosion/runoff, and leaching to groundwater (with subsequent transport and release to surface water). Each of the release scenarios is associated with a specific set of indirect exposure pathways that can result when constituents are transported from the impoundments to different offsite receptor locations (i.e., residential areas with home gardens, farming areas with crop or grazing fields, or fishable waterbodies). Each of the release scenarios considered in the screening analysis is summarized below.

- **Volatilization:** Addressed release of volatile or semivolatile constituents from surface impoundments and subsequent transport to offsite receptors. This release scenario was considered only for constituents that have the potential to volatilize (i.e., SVOCs, dioxin-like compounds, and mercury–bioaccumulative metals other than mercury are not considered). Because the future closure scenario assumed that there was no residual wastewater in the impoundments after closure, volatilization was evaluated only for the current status scenario and was not considered for the future closure scenario.

- **Particulate entrainment.** Addressed the wind erosion and entrainment of particulates with subsequent dispersion and transport to offsite receptors. This release scenario was considered for all classes of constituents considered in the IEP screening analysis, since all have the potential to either exist in particulate form or be adsorbed to sludge particles. Particulate entrainment was considered only for those impoundments that are closed with the potential for exposed sludge which includes (1) facilities with currently closed impoundments that have been drained without being dredged or capped (this is a relatively small number) and (2) all facilities under the future closure scenario that assumed impoundments close without action being taken to reduce constituent mobility.

- **Erosion/runoff:** Addressed the potential for rainfall to create erosion and/or runoff from impoundments that impacts downgradient receptors including residential areas, farms, and waterbodies. This release scenario was considered for all classes of constituents, since it includes constituents that are either dissolved in rainwater (and carried offsite as runoff) or adsorbed to sludge particulates (and carried offsite as eroded material). The erosion/runoff release scenario was restricted to those facilities with impoundments that have closed without dredging or capping. These conditions would have to exist if rainfall in the vicinity of an impoundment results in either channel flow or sheet flow across the impoundment with subsequent runoff/erosion of sludge-bound constituents. Consequently, erosion/runoff was considered only for the current status scenario for those facilities with closed impoundments that have not been dredged or capped. The erosion/runoff scenario was considered for all facilities under the future closure scenario, since that scenario assumed that all impoundments close at grade without dredging or capping.

- **Groundwater to surface water recharge (gw-sw):** Addressed the potential for constituents in impoundments to leach into groundwater, move (with groundwater flow) offsite, and impact surfacewater through recharge. Once constituents have entered a surface waterbody through recharge, they then have the potential to bioaccumulate in fish, thereby presenting an indirect exposure pathway risk through fish ingestion. The gw-sw release scenario was evaluated for all bioaccumulative constituent groups. Because the future closure scenario assumes that all impoundments close without residual wastewater (i.e., only exposed sludge remains), this release scenario was considered only for the current status scenario.

Each of these four release scenarios was associated with specific indirect exposure pathways (e.g., volatilization of constituents can result in dispersion and transport of those constituents to adjacent farm fields where they can bioconcentrate in crops that are subsequently consumed by the farmer or the public). Table C.5-1 presents a matrix that shows which exposure pathways are associated with each release scenario and identifies whether each release scenario was considered for the current status scenario, the future closure scenario, or both.

Table C.5-1. Matrix Identifying which Facility Status Scenarios and Exposure Pathways are Considered for Each Release Scenario

Release Scenario	Facility Status Scenario		Exposure Pathway		
	Considered for Current Status Scenario	Considered for Future Closure Scenario	Home Garden Crop Consumption—Resident	Farm Commodity Consumption (Crops, Livestock, Dairy)—Commercial Farmer	Self-Caught Fish Consumption—Recreational/ Subsistence Fisher
Volatilization	Yes - considered for all volatile and semivolatile bioaccumulative chemicals at currently operational impoundments	No - only considered for currently operational impoundments	Yes - Constituents volatilize and travel to adjacent residential areas where they impact home gardens	Yes - Constituents volatilize and travel to adjacent farming areas where they impact farms (crops and grazing areas)	Yes - Constituents volatilize and travel to adjacent fishable waterbodies where they deposit directly (or from watersheds) and bioconcentrate in fish
Particulate entrainment	Yes - only for those impoundments that are currently closed without dredging or capping (relatively small number)	Yes - considered for all impoundments, since future closure scenario assumes SI closure with exposed sludge.	Yes - Constituents are entrained and carried to adjacent residential areas where they impact home gardens	Yes - Constituents are entrained and carried to adjacent farming areas where they impact farms (crops and grazing areas)	Yes - Constituents are entrained and carried to adjacent fishable waterbodies where they deposit directly (or from watersheds) and bioconcentrate in fish
Erosion/ runoff	Yes - only for those impoundments that are currently closed without dredging or capping (relatively small number)	Yes - considered for all impoundments, since future closure scenario assumes SI closure with exposed sludge.	Yes - Constituents are carried to downgradient residential areas as eroded material or in runoff where they impact home gardens	Yes - Constituents are carried to downgradient farm areas as eroded material or in runoff where they impact farms (crops and grazing areas)	Yes - Constituents are carried to downgradient waterbodies/ watersheds as eroded material or in runoff where they impact waterbodies and bioconcentrate in fish.

(continued)

Table C.5-1. (continued)

Release Scenario	Current Versus Future Scenarios		Exposure Pathway (Receptor Population)		
	Considered for Current Status Scenario	Considered for Future Closure Scenario	Home Garden Crop Consumption—Resident	Farm Commodity Consumption (Crops, Livestock, Dairy)—Commercial Farmer	Self-Caught Fish Consumption—Recreational/ Subsistence Fisher
Groundwater to surface water recharge	Yes - considered for all currently operating impoundments	No - considered only for currently operational SIS since release scenario requires presence of wastewater for leaching constituents to groundwater	No - only surface water recharge with possible fish bioconcentration considered[a]	No - only surface water recharge with possible fish bioconcentration considered	Yes - Constituents leach into groundwater and are discharged into surface water where they bioconcentrate in fish.

[a] Leaching of constituents into groundwater with subsequent transport to residential locations and possible health impacts through drinking water well usage is evaluated as part of the groundwater analysis (see Section C.3).

C.5.2.2 Criteria and Ranking Algorithms Used in Generating Rankings for Individual Exposure Pathways. Each exposure pathway was ranked for indirect exposure pathway risk using a specific mix of criteria and an additive unweighted ranking algorithm that allowed those criteria to be combined to generate an overall score for indirect exposure pathway risk. This score was then converted into a qualitative rank of high, medium, or low for each exposure pathway. The criteria were used as surrogates for key elements in the risk equation in order to support ranking of the facilities for indirect exposure pathway risk. For example, the following criteria were considered in evaluating the potential for indirect exposure pathway risk for the volatilization/home garden crop consumption exposure pathway: (1) aggregated surface area for all currently operating impoundments at the site under evaluation (represents a surrogate for source emissions strength for constituents from that site), and (2) distance between the facility and the nearest residential location (represents a surrogate for fate/transport and the resulting level of exposure for the receptor).

The criteria for a given exposure pathway were selected based on two factors: (1) what elements in the risk equation were most critical for assessing relative significance for a given exposure pathway, and (2) which elements could be characterized quantitatively or semiquantitatively given the combination of facility-specific and environmental setting data available for this screening analysis.

All of the criteria have assigned integer values ranging from 1 to 3, with 1 representing lower-risk facility-specific or environmental setting conditions, 2 representing intermediate conditions, and 3 representing higher risk conditions. One of two approaches was used in establishing the cutoff points for the criteria considered in the screening analyses:

- **Simple ranking of facility-specific and environmental values and separation into three equal-sized bins:** For those criteria where it was not possible to define the scores based on performance data (see next bullet), the raw criteria values across all facilities were simply ordered from lowest to highest and the 33rd percentile and 66th percentile values were identified as the cutoff points defining the boundary between the first, second, and third bins, respectively. This approach produced three equal-sized bins of values.

- **Performance-based cutoff points:** For several of the criteria, it was possible to use the results from previous regional- or national-scale risk assessments as a guide for defining cutoff points between the three scores (i.e., to support a performance-based approach). Specifically, for distance-to-receptor following volatilization and particulate entrainment, it was possible to review past modeling results for volatile air concentrations and dry deposition, respectively, to establish reasonable cutoff points for the distance to receptor criterion. In both cases, graphs of modeling results were reviewed to identify distances at which significant changes in vapor air concentration or particulate deposition occurred. These distance values were then used to establish the distance measures at which a receptor received a 1, 2, or 3. Ideally, the performance-based approach would have been used for more of the criteria; however, the complexity of the other

factors prohibits them from being evaluated using this approach without conducting sophisticated sensitivity analyses.

After the criteria for a specific exposure pathway were scored for a given facility (i.e., given values of 1 to 3 for each criterion), they were summed, without weighting, to generate an overall numerical score for that specific exposure pathway–the higher the aggregate score, the greater the level of concern for indirect exposure pathway impacts. The option of using weights to adjust the criteria to reflect differing degrees of significance in predicting indirect exposure pathway risk was considered as was the use of a different algorithm with a multiplicative or non-linear structure. However, for the IEP pathway screening analysis, it was decided that an unweighted summation approach would be used to derive the aggregated scores, since it would be difficult to develop defensible weights for individual criteria without further quantitative analysis or to develop a more complex algorithm.[1]

Table C.5-2 presents the specific criteria and the additive unweighted ranking algorithm used to generate numerical rankings for each exposure pathway. Table C.5-2 also presents the ranges for the numerical rankings that can be generated for each combination, as well as the ranges used in determining whether a given exposure pathway receives a high, medium, or low ranking for the potential for indirect exposure pathway risk. The specific approach and rationale used to establish cutoff points for assigning numerical scores of 1 to 3 for each of the criteria is presented in Table C.5-3. Figure C.5-2 presents a case study example for one of the facilities considered in the analysis that details the procedure followed in conducting the IEP screening analysis for a representative facility.

C.5.2.3 Use of Demographic Data to Augment Rankings. To provide additional information for assessing the potential for facilities to impact public health, the number of residents and farmers located within 1 km of the facility boundaries was estimated using 1990 U.S. Census block group-level data. Specifically, area-weighted apportionment was used to estimate the number of farmers and residents within the fraction of each block group that intersected the 1-km ring extending out from the facility boundaries. These demographic data were not included as a criterion in the ranking of individual facilities. Instead, they were used to augment the overall rankings assigned to each facility by flagging those facilities falling in each ranking category that also had a high ranking for either farmer or residential population totals. Cutoff points for a high ranking for both the residents and farmers were established by (1) ranking all of the facility population totals from lowest to highest, (2) identifying the 66th percentile facility within that ranking, and (3) using the population total for that facility as the cutoff point for a high ranking for population density (this analysis was completed separately for the residents and farmers, thereby generating two distinct cutoff points for population density).

[1] Because it can be argued that the criterion "distance to receptor" has greater predictive power in assessing indirect exposure pathway risk, the final aggregated rankings for the 107 facilities handling bioaccumulative constituents includes a category of results that flags those facilities with a high ranking for the potential for indirect exposure pathway risk and a 3 for "distance to receptor" for at least one exposure pathway (see Attachment C-17, Table C-17-2).

Table C.5-2. Criteria and Additive Unweighted Ranking Algorithms Used in Generating Aggregated Scores for Individual Release Scenario/Exposure Pathway Combinations

Exposure Pathway	Description of Exposure Pathway	Criteria[a]				Derivation of Aggregated Score for Exposure Pathways		
		SSI	DR	DF	PER	Additive Unweighted Ranking Algorithm	Range of Aggregated Score	Scores for Specific Qualitative Rankings
Volatilization/ home garden crop consumption	Constituents volatilize from impoundment and are transported to adjacent residential home gardens where they bioconcentrate in home garden crops	Yes	Yes	No	No	SSI + DR	36927	2-3: LOW 4: MED 5-6: HIGH
Volatilization/farm commodity consumption	Constituents volatilize from impoundment and are transported to adjacent farms where they bioconcentrate in crops and livestock	Yes	Yes	No	No	SSI + DR	36927	2-3: LOW 4: MED 5-6: HIGH
Volatilization/fish consumption	Constituents volatilize from impoundment and are transported to adjacent fishable waterbodies where they bioconcentrate in fish	Yes	Yes (receptor is waterbody)	Yes	No	SSI + DR + DF	36958	3-4: LOW 5-7: MED 8-9: HIGH
Particulate entrainment/home garden crop consumption	Constituents are entrained by wind erosion and transported to adjacent residential home gardens where they bioconcentrate in home garden crops	Yes	Yes	No	No	SSI + DR	36927	2-3: LOW 4: MED 5-6: HIGH
Particulate entrainment/farm commodity consumption	Constituents are entrained by wind erosion and transported to adjacent farms where they bioconcentrate in crops, and livestock	Yes	Yes	No	No	SSI + DR	36927	2-3: LOW 4: MED 5-6: HIGH
Particulate entrainment/fish consumption	Constituents are entrained by wind and transported to adjacent fishable waterbodies where they bioconcentrate in fish	Yes	Yes (receptor is waterbody)	Yes	No	SSI + DR + DF	36958	3-4: LOW 5-7: MED 8-9: HIGH

(continued)

Table C.5-2. (continued)

Release Scenario/ Exposure Pathway Combination	Description of Release Scenario/ Exposure Pathway Combination	Criteria[a]				Derivation of Aggregated Score for the RS/EP Combination		
		SSI	DR	DF	PER	Additive Unweighted Ranking Algorithm	Range of Aggregated Score	Scores for Specific Qualitative Rankings
Erosion-runoff/ home garden crop consumption	Erosion/runoff carries Constituents to downgradient offsite residential areas where they bioconcentrate in home garden crops	No - considered in establishing PER	Yes	No	Yes	DR + PER	36927	2-3: LOW 4: MED 5-6: HIGH
Erosion-runoff/ farm commodity consumption	Erosion/runoff carries Constituents to downgradient offsite farms where they bioconcentrate in crops and livestock	No - considered in establishing PER	Yes	No	Yes	DR + PER	36927	2-3: LOW 4: MED 5-6: HIGH
Erosion-runoff/ fish consumption	Erosion/runoff carries Constituents to downgradient offsite fishable waterbodies where they bioconcentrate in fish	No - considered in establishing PER	Yes (receptor is waterbody)	Yes	Yes	DR + DF + PER	36958	3-4: LOW 5-7: MED 8-9: HIGH
Groundwater to surface water recharge/fish consumption	Constituents leach from the impoundment to groundwater and are carried to adjacent waterbodies where they recharge into those waterbodies and bioconcentrate in fish	This release scenario/exposure pathway combination completed for bioaccumulative chemicals is a subset of the groundwater-surface water screening analysis completed for the full suite of SI chemicals. The methodology used in the screening analysis to rank BC sites for this combination is described in Section C.4						

DF = Dilution factor (for waterbodies).
DR = Distance to receptor.
PER = Potential for erosion/runoff.
SSI = Size of surface impoundment.

[a] All criteria have scores ranging from 1 to 3.

Table C.5-3. Overview of Methods Used to Establish Cutoff Points for Criteria Used in Generating Aggregated Scores for Individual Exposure Pathways

Criterion	Description	Approach Used to Establish Cutoff Points	Cutoff Points Established for Criterion
Surface area of impoundment	Surface area for impoundments aggregated across a facility represents a surrogate for the magnitude of potential source emissions of constituents from that facility.	*Ranking with three equal-sized bins:* Because of the range of factors that can influence the degree of source emissions (including impoundment surface area), a performance-based approach was not used. Instead, the aggregated surface area for all impoundments at each facility was calculated and these aggregated values were ranked from min to max and then the 33rd and 66th percentile surface area values were identified and used, respectively, as boundaries between the 1st and 2nd and 2nd and 3rd bins.[a]	1 = 0-4,214 m^2 2 = 4,214-59,937 m^2 3 = >59,937 m^2
Distance to receptor	The distance between the impoundment and nearest receptor (residential area, farm, or fishable waterbody) is a surrogate for the degree of exposure that an offsite receptor is likely to experience - as the distance between the receptor and the impoundment increases, the degree of exposure is likely to decrease (other things equal).	*Performance-based*: Although the relationship between receptor distance from the source and magnitude of indirect exposure pathway exposure is complex and is dependent on a wide range of factors in addition to receptor distance, past project work involving modeling of particulate and vapor dispersion that provide insights into how the degree of exposure may decrease as a receptor is located progressively farther from the source. Consequently, a performance-based approach was used to establish cutoff points for the distance to receptor criterion. Specifically, particulate deposition modeling results and vapor air concentration modeling results generated as part of evaluating risk for the application of sludge to agricultural fields were reviewed to identify reasonable distances from the sources where there were significant decreases in particulate deposition and vapor concentration, respectively.	Volatilization: 1 = >500 m 2 = 250-500 m 3 = <250 m Particulate entrainment: 1 = >300 m 2 = 150-300 m 3 = <150 m
Waterbody flow rate (flowing waterbodies) or surface area (stationary waterbodies)	Waterbody surface area (for stationary waterbodies) or flow rate (for flowing waterbodies) serves as a surrogate for the degree of dilution that is expected to occur once constituents are transported (by any of the 4 release scenarios considered in the IEP sensitivity analysis) to fishable waterbodies.	Because of the complexities associated with attempting to predict the degree of dilution (which depends on a range of waterbody characteristics), it was decided not to use a performance-based approach in establishing cutoff points for this criterion. Instead, waterbody surface areas (for stationary waterbodies) or flow rates (for flowing waterbodies) were ranked from lowest to highest and the 33rd and 66th percentile values were used to establish boundaries between the 1st and 2nd and 2nd and 3rd bins for this criterion (separate assessments were completed for the stationary and flowing waterbodies).	Stationary waterbodies 1 = >15,000 m^2 2 = 10,000-150,000 m^2 3 = < 10,000 m^2 Flowing waterbodies 1 = >5,000 ft^3/s 2 = 1,250-5,000 ft^3/s 3 = <5,000 ft^3/s

(continued)

Table C.5-3. (continued)

Criterion	Description	Approach Used to Establish Cutoff Points	Cutoff Points Established for Factor
Erosion/runoff potential	The potential for erosion/runoff was evaluated by reviewing USGS topographical maps and aerial photos; this criterion was not evaluated using a single surrogate factor as with other criteria in the IEP screening analysis	The potential for erosion/runoff was evaluated explicitly using a semiquantitative multi-factor approach that ranked each facility for the potential for significant erosion/runoff based on an analysis of USGS topographical maps and aerial photos. The following factors were considered in assessing erosion/runoff potential: ■ Slope: evaluated using criteria from EPA's Drastic model (1985) for evaluating potential for seepage to groundwater.[b] ■ Distance to downgradient receptors: evaluated using aerial photos. ■ Surface impoundment size: for impoundment selected for use in assessing erosion/runoff potential at a given facility (see below) The erosion/runoff score assigned to a given facility was based on the specific impoundment at each facility that (a) had a high potential for erosion/runoff, and (b) had the largest surface area. Once that impoundment was selected, it was assessed for the above factors and a numerical ranking of the potential for erosion/runoff was assigned (see categories in cell to right). Despite the use of quantitative site-specific data in conducting the erosion/runoff analysis for each facility, there was a certain amount of professional judgment associated with assigning the final erosion/runoff score to each facility. A number of judgment calls had to be made in assessing each facility for erosion/runoff potential, such as which impoundment had the greatest potential for erosion/runoff and therefore would be the focus of the analysis, how likely is it that erosion/runoff will reach a given downgradient receptor given the overall slope and specific topographical characteristics of the downslope area such as presence of gullies and physical barriers to flow.	None = slopes 0-2%; receptor >1 km or no receptors.[c] 1 = slopes 2%-6%; receptors 0.7-1 km; small SI. 2 = slopes 6%-12%; receptors 0.3-0.7 km; medium to small SI. 3 = close receptor <0.3 km; moderate to high slopes (>12%); size was given less importance for this category.

(continued)

Table C.5-3. (continued)

[a] The aggregated impoundment surface area values used in characterizing facilities for the "impoundment surface area" criterion were actually further differentiated based on several criteria. If a facility had a combination of currently operating and closed impoundments, then the aggregated impoundment surface area value for the current volatilization assessment would be based only on the aggregated value for currently operating impoundments (currently closed impoundments would be excluded). Similarly, only the aggregated closed impoundment surface areas would be considered in modeling the current particulate entrainment and current erosion/runoff scenarios (assuming those impoundments had not been dredged or capped). All impoundments were considered in generating the aggregated surface area estimate for use in the future particulate entrainment and future erosion/runoff scenarios.

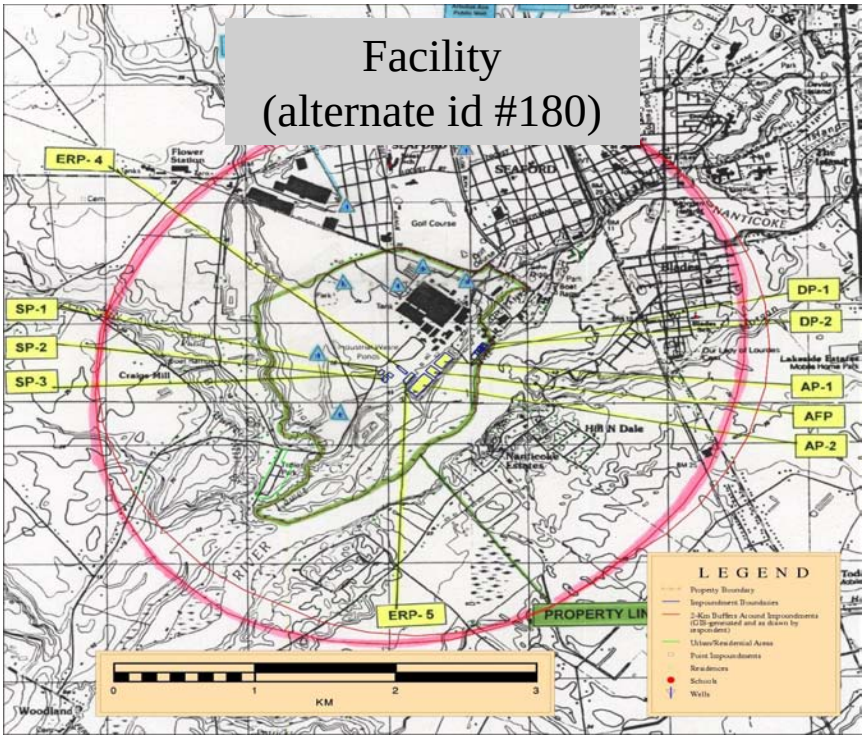
[b] Based on EPA's Drastic model, 0 to 2% slopes (i.e., 2 rise per 100 run is 2%) were identified as areas with minimal runoff, 2% to 6% slopes were assigned low runoff potential, 6% to 12% slopes were assigned medium runoff potential and anything greater was considered high. The slopes were measured from the topographical maps. Estimates of the slope were made using a general average of the topography both behind the SI and in the downgradient direction.

[c] Because the potential for erosion/runoff was evaluated explicitly, the assessment included a "none" category for those facilities for which erosion/runoff was judged to be highly unlikely or infeasible. Because other criteria considered in this screening analysis are based on surrogate factors that arguably have greater uncertainty than the erosion/runoff potential criterion, they do not include the "none" category. It is not possible to make a clear statement that the other surrogate factors have values sufficiently small (or large) to exclude consideration of a specific release scenario (e.g., the SI surface area cannot be so small as to completely rule out volatilization without considering other factors, while the presence of a railway embankment between an impoundment and a farm field could reduce the potential for erosion/runoff impacts to that farm to near zero).

USGS topographic map showing site boundary, impoundments and 2km site radius (red border).

• Used to assess runoff/erosion potential (e.g., slope of areas downgradient from impoundment, potential for sheet versus channel flow).

• Used along with aerial photograph to support identification of nearest fishable waterbody and downgradient waterbody.



Aerial photographs.

• Used to identify nearest receptors (farmers and residents) for volatilization and particulate entrainment and nearest downgradient receptors (farmers and residents) for erosion/runoff.

Figure C.5-2.Case study example of the IEP screening analysis procedure.

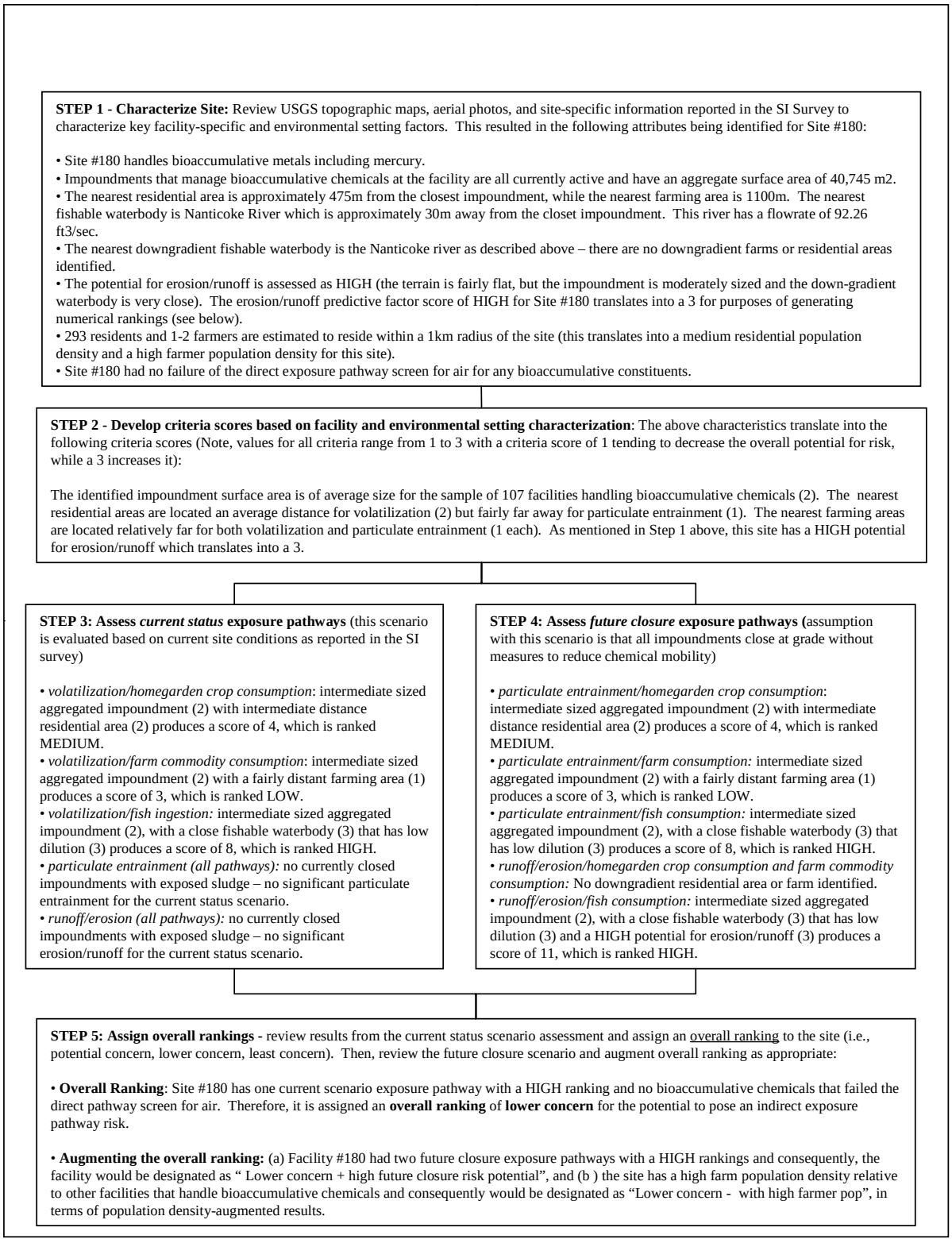


Figure C.5-2. (continued)

C.5.2.4 Results. This section presents the results of the indirect exposure pathway screening analysis completed for the SI study. Of the SI facility sample, 107 facilities reported managing bioaccumulative chemicals; consequently, the IEP screening analysis generated numerical rankings for this subset of facilities (all other facilities in the SI sample were assigned a default overall ranking of lowest criteria). The results presented in this section have not been weighted to reflect the entire SI universe (see Section 3.4 for presentation of weighted results). This section includes a variety of different results categories designed to present different perspectives of the IEP screening analysis including (all of the results presented in this section are aggregated across the 107 bioaccumulative constituent handling facilities):

- **Overall results**, which summarize the overall facility rankings across the set of 107 facilities that handle bioaccumulative chemicals.

- **Receptor population/exposure pathway perspective**, which presents aggregated results according to receptor population/exposure pathway

- **Release scenario perspective**, which presents aggregated results according to release scenario

- **Bioaccumulative chemical category perspective**, which presents aggregated results according to the bioaccumulative chemical category groups (i.e., SVOCs, mercury, dioxin-like compounds, metals).

The intent in providing these different categories of aggregated results is to allow consideration of a range of risk management questions in reviewing the results of the IEP screening analysis (e.g., "which receptor population appears to contribute the largest number of high ranked exposure pathway results in the analysis," or "how many facilities with at least one high ranking for the resident receptor also have a high residential population density within 1 km of the facility boundary?").

The remainder of this section is organized according to the four groupings of aggregated results listed above. In presenting these results, the significance of the different ranking categories is discussed as well as the sources of uncertainty that can impact each category.

C.5.2.5 Overall Results. This section presents the overall results for the 107 facilities that report managing bioaccumulative chemicals and, as such, represent the primary findings of the analysis. The overall rankings presented in this section are based on the current status scenario. The future status results were not considered in assigning overall rankings, but were used to augment the results as explained below. The overall rankings for the facilities were based on a review of the current status results for individual exposure pathways and the results of the screening-level modeling for air for the bioaccumulative chemicals at a given facility.

A facility could receive an overall ranking of potential concern if one of two criteria were met: (1) the facility had two or more current status exposure pathways with a high rank, or (2) the facility had one exposure pathway with a high rank and at least one bioaccumulative chemical that exceeded the direct exposure pathway screening analysis for air. This two-criteria approach

for identifying potential concern-ranked facilities, reflects the goal of having the IEP analysis identify the subset of facilities that have a strong probability of posing an indirect exposure pathway risk to nearby populations. Both of these criteria increase the potential that a facility will have completed indirect exposure pathways. With this approach, a facility with a single high-ranked exposure pathway (that does not exceed risk criteria for screening-level modeling for air) was assigned an overall rank of lower concern regarding the potential for indirect exposure pathway risk. Table C.5-4 presents the overall ranking results for the IEP screening analysis, which include the following categories (note, several categories of augmented results are included here):

- **Potential concern:** Identifies facilities that have either (1) two high-ranking current scenario exposure pathways, or (2) one high-ranking exposure pathway and at least one exceedance of the direct exposure pathway screen for air for a bioaccumulative chemical.

Table C.5-4. Overall Results for Indirect Exposure Pathway Screening Analysis (107 Unweighted BC Sites)

Category	Number of Sites
Overall Rankings	
Potential concern	**29**
Potential concern (high 2X)	27
Potential concern (one exceedance in air screening modeling)	12
Potential concern with nearby receptor	29
Potential concern + high future	7
Lower concern	**63**
Lower concern + high future	23
Least concern	**15**
Least concern + low future	3
Population density-augmented results	
Potential concern + high resident pop	9
Potential concern + high farmer pop	7
Lower concern + high resident pop	11
Lower concern + high farmer pop	4

- **Potential concern (high 2X):** Identifies the number of facilities that received a potential concern overall ranking because of having two or more current scenario exposure pathways with a high ranking.

- **Potential (one exceedance in air screen modeling):** Identifies the number of facilities that received a potential concern overall ranking because of having one current scenario exposure pathway with a high ranking and at least one bioaccumulative chemical that exceeded risk criteria for the screening level modeling for air.

- **Potential concern (with nearby receptor):** Identifies those sites that have a potential concern overall ranking that also have a "distance to receptor" criterion score of "3" for one of its high-ranking exposure pathways. A "3" distance to receptor criterion score designates that facility as having receptors very close/adjacent to impoundments. For example, a facility would fall into this category if it had a potential concern overall ranking and a high ranking for a volatilization/home garden exposure pathway where the resident location was less than 250 m from the facility and therefore received a score of "3" for distance to receptor. Inclusion of this category of results reflects the possibility that, all other things being equal, distance to receptor could have somewhat greater predictive power than the other criteria in characterizing the potential for indirect exposure pathway risk.

- **Potential concern + high future:** Identifies facilities assigned an overall ranking of potential concern (based on the current status scenario as described above) that also have at least one future closure scenario with a high rank.

- **Lower concern:** Identifies facilities that have either a single high-ranking current scenario exposure pathway, or at least one medium ranking current scenario exposure pathway and no high-ranking exposure pathway.

- **Lower concern + high future:** Identifies facilities assigned an overall ranking of lower concern that also have at least one future closure scenario exposure pathway with a high rank.

- **Least concern:** Identifies sites that have all current scenario exposure pathways assigned a low ranking.

- **Least concern + high future:** Identifies sites assigned an overall ranking of least concern that also have at least one future closure scenario exposure pathway with a high rank.

- **Potential concern + high resident pop**: Identifies those facilities that have a high ranking for resident-related exposure pathways and that also have a high residential population density (for the 1-km ring surrounding the facility boundary). For example, a facility that has a high ranking for volatilization of

constituents and transport to an adjacent residential area that also has a high ranking for residential population within the 1-km ring would have membership in this group. This category is included to allow more focused consideration of potential population-level impacts.

- **Potential concern + high farmer pop**: Parallels the "potential concern + high resident pop," except this category focuses on the farmer (i.e., farmer-related exposure pathways and farmer population density).

- **Lower concern + high resident pop; Lower concern + high farmer pop:** Mirror the last two categories described, except that these categories identify those facilities with medium-ranked exposure pathways that also have high rankings for the matching receptor population.

A number of conclusions can be drawn from the results presented in Table C.5-4, including (1) slightly less than one-third of the modeled facilities have a potential concern overall ranking for indirect exposure pathway risk, (2) nearly all of the sites with an overall ranking of potential concern (which is based on current status scenario results) also have at least one future closure pathway ranked as high, (3) all of the potential concern sites have receptor populations located very close to the facilities, and (4) roughly one-third of the potential concern facilities also have high population densities for residents and farmers. This subset of facilities could be given greater weight when considering the potential for population risk.

Sources of Uncertainty. A number of sources of uncertainty impact the overall ranking results presented in this section. Each of these sources of uncertainty is related to the broader issue of using criteria as surrogates for key elements in the risk equation. While the overall rankings given to the 107 bioaccumulative constituent handling facilities are considered to have sufficient confidence to support ranking of these facilities, there is the possibility that, when a potential concern facility is subjected to site-specific risk assessment, the risk estimates resulting from that assessment could show the facility to have insignificant risk. However, the goal of the IEP screening analysis is not to estimate potential risk levels for individual sites, but rather to identify the subset of facilities that would most likely have significant indirect exposures. Specific sources of uncertainty that impact the overall ranking results include the following:

- **Assessment of potential for erosion/runoff:** Topographic maps used to assess slope and the potential for sheet versus channel flow may not be current, in which case significant changes in land use (which would not show up on older maps) could introduce error into the characterization of this criterion.

- **Distance to nearest receptor**: The distance between specific impoundments and the nearest receptor (i.e., residential areas, farms, or fishable waterbodies) was estimated using a combination of aerial photos and topographic maps. Although these measurements were made using the most up-to-date photos and maps available, some of the photos and maps were somewhat dated. This introduces uncertainty in the distance to nearest receptor measurements because land use change could result in a receptor either being added to or removed from a given

study area (note, this is less of an issue in identifying fishable waterbodies). In addition, the possibility of having agricultural activity within facility boundaries was not considered, even though the aerial photos did show evidence of such activity. This activity could have been associated with bioremediation or some other non-agricultural commodity-related activity. If there is agricultural activity within facility boundaries, then some of the distance to nearest receptor measurements could be misrepresented.

- **Residential exposure scenarios and home gardening:** A critical assumption in assessing exposure pathways for the resident was that home gardening occurs within the residential areas located closest to the facility. To the extent that home gardening does not occur in these areas, then the exposure pathway would not be complete and any rankings for this receptor would be incorrect.

Receptor Population (Exposure Pathway) Perspective. This section presents aggregated results of the IEP screening analysis differentiated by receptor population (and, by implication, indirect exposure pathway).[2] The intent in presenting these results is to allow the reader to determine which receptor populations drive the overall rankings for the current status scenario for the 107 facilities that report handling bioaccumulative chemicals. As discussed below, each of the receptor populations has a different level of uncertainty associated with its inclusion in this screening analysis, which could impact the way rankings are interpreted.

Table C.5-5 shows the number of facilities that had achieved a given ranking for each of the three receptor populations (e.g., the number of facilities that had a high ranking for one of the exposure pathways that involved the resident).

Results presented in Table C.5-5 suggest that the resident and fisher receptor populations contribute the largest number of high-ranking exposure pathways in the screening analysis, although the farmer receptor population also makes a significant contribution. The fisher receptor population contributes the majority of the medium-ranking exposure pathways.

Table C.5-5. Receptor Population Perspective: Number of Facilities with Specific Ranking Level for Exposure Pathways Associated with Each Receptor Population

Receptor Population	High	Medium	Low
Resident	23	34	27
Farmer	14	25	20
Fisher	28	61	18

[2] Each of the receptor populations considered in this analysis is associated with a single, or distinct, set of indirect exposure pathways. These include fisher (self-caught fish consumption), resident (consumption of home garden-produced crops), and farmer (consumption of home-produced agriculture commodities such as crops, livestock, and dairy).

Sources of Uncertainty. Sources of uncertainty associated with this category of results include many of the same sources described in the last section for the overall ranking results. For example, the residential ranking results are impacted by (1) uncertainty associated with identifying the nearest residential areas using aerial photos that may be dated in some cases (i.e., land use change could have involved changes in the location of houses), and (2) uncertainty associated with the presence of home gardens in specific residential areas. Farmer rankings are impacted by the exclusion of areas within facility boundaries that could potentially be agricultural land use. Fisher rankings are impacted by uncertainty associated with assessing the potential for erosion/runoff and, consequently, assessing the magnitude of chemical loading to either nearest or downgradient fishable waterbodies.

Release Scenario Perspective. This section presents aggregated results of the IEP screening analysis differentiated by release scenario (i.e., volatilization, particulate entrainment, erosion/runoff, leaching to groundwater with subsequent transport, and surface water impact). This set of aggregated results is intended to provide perspective on how the rankings of exposure pathways relate to the different release scenarios considered in the analysis and, as such, can be used to answer a range of questions related to release scenarios and exposure pathway rankings (e.g., which release scenario dominates high exposure pathway rankings under the current status scenario).

Table C.5-6 presents the aggregated results differentiated by release scenario. Note that Table C.5-6 includes only particulate entrainment and erosion/runoff release scenarios for the future closure scenario since it is assumed for the future closure scenario that volatilization and groundwater impacts are minimal given the absence of wastewater recharge to the impoundment following closure.

Table C.5-6. Release Scenario Perspective: Number of Facilities with Specific Exposure Pathway Rankings for Each Release Scenario

Release scenario	Exposure Pathway Rankings		
	High	**Med**	**Low**
Current status			
Volatilization	40	31	1
Particulate entrainment (current)	5	20	2
Erosion/runoff (current)	5	13	3
Groundwater to surface water	15	49	43
Future closure			
Particulate entrainment (future)	42	43	10
Erosion/runoff (future)	39	56	12

Results presented in Table C.5-6 suggest that, for the current status scenario, volatilization is the dominant release scenario producing high rankings for indirect exposure pathways. However, high rankings under the future closure scenario are nearly evenly distributed between the two release scenarios considered for the future closure scenario (i.e., erosion/runoff and particulate entrainment).

Sources of Uncertainty. There is considerable uncertainty associated with using a screening approach based on predictive (surrogate) factors to represent complex fate/transport processes such as volatilization, dispersion, and runoff/erosion. However, the overall level of confidence associated with the approach used to represent these fate/transport processes in screening the facilities for indirect exposure pathway risk is considered sufficient to support the ranking and descriptive goal of the IEP screening analysis.

Bioaccumulative Chemical Group Perspective. This section presents overall rankings for the 107 bioaccumulative constituent handling facilities differentiated by constituent class (i.e., metals (excluding Hg), Hg, SVOCs, and dioxin-like compounds). This set of aggregated results is intended to provide perspective on how the rankings of facilities relate to the different bioaccumulative chemical classes considered in the analysis. Consequently, these results can be used to answer a range of questions related to bioaccumulative chemical classes and ranking scores (e.g., which chemical class is associated with potential concern-ranked sites).

Table C.5-7 presents the number of facilities with a specific overall rank that are reported to handle a particular bioaccumulative chemical class. In interpreting these results, it is important to note that the different chemical classes are not necessarily mutually exclusive (i.e., the set of eight facilities identified as having a "potential" overall ranking under the metals category for the current status scenario do not necessarily handle bioaccumulative metals exclusively; facilities in that category could also handle other constituents). However, the table does allow the reader to assess which chemical classes are consistently associated with potential concern, lower concern, or least concern ranks across all 107 facilities.

Table C.5-7. Bioaccumulative Chemical Group Perspective: Number of Facilities with Specific Overall Ranking for Each Chemical Class

	Overall IEP Screening Analysis Ranking		
Chemical Class	**Potential concern**	**Lower concern**	**Least concern**
Metals (excluding Hg)	25	56	15
Mercury	22	42	0
SVOCs	12	22	0
Dioxin-like compounds	17	10	0

SVOCs = Semivolatile organic compounds.

Results presented in Table C.5-7 suggest that the potential concern category is dominated by facilities that handle metals including mercury, although a significant number of potential concern facilities also handle SVOCs and dioxin-like compounds.

The different chemical classes cannot be differentiated in any meaningful way with regard to uncertainty in the screening analysis; consequently, the issue of uncertainty is not addressed specifically from the chemical class perspective.

C.6 Ecological Screening Assessment

Industrial wastes managed in surface impoundments not only can impact the health of people living near them, they can also have adverse effects on nonhuman organisms and natural systems. For example, wildlife can come into contact with contaminants by swimming or living in contaminated waters or by drinking or catching prey, such as fish, from contaminated waters. Plants that grow in soils containing constituents of concern (CoCs) can take them into their leaves and stems through root uptake, which can have detrimental effects on the plants as well as on the animals that eat them. Microorganisms and small invertebrates that live in close contact with the soil (e.g., worms) can accumulate CoCs through contact with contaminated soil. Therefore, it is important to evaluate risks posed to ecological receptors as well as those posed to humans. Protection of human health does not necessarily protect ecological receptors. Some chemicals are more toxic to nonhumans; wildlife species generally have higher metabolic rates than humans and, therefore, eat, drink, and breathe proportionately more contaminants than humans; and nonhuman organisms live in closer association with their immediate environment and often cannot avoid contamination or replace destroyed food sources as humans can (Suter, 1993).

The ecological risk screening is somewhat different from the human health screening in that a single comparison of screening factors and constituent concentrations was conducted. The scope of this phase of the assessment includes a subset of 43 constituents for which toxicological and exposure factor data were readily available. The assessment addresses 57 vertebrate species as well as 5 community-level receptors. Depending on the ecological receptor of concern, the analysis estimates risks from either the ingestion of contaminated plants, prey, and media or from direct contact with a contaminated medium such as sediment or soil. The ecological risk estimates were compared to risk criteria to prioritize the list of constituents, impoundments, and facilities that warrant further evaluation of the likelihood of adverse ecological effects.

C.6.1 Overview and Goals

The primary goal of the ecological screening assessment was to establish a priority list of constituents, impoundments, and facilities based on the potential for adverse ecological effects. The screening approach considers the potential for adverse effects to a suite of ecological receptors, including mammals and birds and aquatic, benthic, and soil fauna that are found in terrestrial, freshwater, and wetland habitats. Facilities with impoundments that exceed the ecological risk criterion for one or more chemicals are carried forward for further analysis. The habitats and receptors considered in this study are consistent with the national assessment strategy developed to support the Hazardous Waste Identification Rule proposed in November 1999. Because the HWIR risk assessment framework was intended to support national studies of waste management practices, the SI Study has adopted this framework as the basis for selecting receptors and habitats.

C.6.2 Management Goals and Assessment Endpoints

Assessment endpoints, defined as "explicit expressions of the actual environmental value that is to be protected" (U.S. EPA, 1998a), serve as a critical link between the ecological risk assessment and the management goals. For the SI Study, the management goals may be summarized as follows: "prioritize impoundments and facilities based on the potential for adverse ecological effects and describe the national distribution of ecological risks associated with the management of wastes in surface impoundments." Two key elements are required to define an assessment endpoint: (1) a valued ecological entity (e.g., a species, a community) and (2) an attribute of that entity that is important to protect (e.g., reproductive fitness).

For the SI Study, ecological exposures are assumed to occur at facilities that may be located anywhere within the contiguous United States. Consequently, a suite of assessment endpoints was chosen based on

- Significance for ecosystem functions
- Ability to represent a variety of habitat types
- Position along a continuum of trophic levels
- Susceptibility to chemical stressors managed in surface impoundments.

In Table C.6-1, the assessment endpoints (i.e., values to be protected) selected for the SI Study analysis are defined in terms of (1) the significance of an ecological entity, (2) the ecological receptor representing that entity, (3) the characteristic about the entity that is important to protect, and (4) the measures of effect used to predict risk. The intent of including multiple receptors is that, by protecting producers (i.e., plants) and consumers (i.e., predators) at different trophic levels, as well as certain structural components (e.g., benthic community), a degree of protection from chemical stressors may be inferred to the ecosystem as a whole. Consequently, the selection of the assessment endpoints for each receptor taxon is critical to the development of ecological screening factors.

Risk for sensitive receptors such as threatened and endangered species or managed lands (e.g., national wildlife refuges, state and national parks, and national forests) were not estimated for a screening level assessment. However, the SI Study included a qualitative assessment of the presence of sensitive ecosystems in proximity to SI facilities. Facilities with managed lands within 3 kilometers or with wetlands within 1 kilometer were identified, and this information was used in identifying facilities of potential concern.

C.6.3 Summary of Approach

As with the screening approach for human health, the ecological screening analysis calculates risks to individual ecological receptors (e.g., red fox, aquatic biota) based on the ratio between ecological risk screening factors and the concentrations of constituents in surface

Table C.6-1. Assessment Endpoints and Measures of Effects

Examples of Ecological Significance	Assessment Endpoint	Representative Receptors	Characteristic(s)	Measure of Effect
■ Multiple trophic levels represented ■ Represent species with large foraging ranges ■ Represent species with longer life spans ■ Variety of dietary exposures represented	Viable mammalian wildlife populations	Deer mouse, meadow vole, red fox, e.g.	Reproductive and developmental success	Chronic or subchronic NOAEL(s) for developmental and reproductive effects
	Viable avian wildlife populations	Red-tailed hawk, northern bobwhite, e.g.	Reproductive and developmental success	Chronic or subchronic NOAEL(s) for developmental and reproductive effects
■ Species represent unique habitat niches ■ Many species are particularly sensitive to exposure	Protection of amphibian and reptile populations ("herps") against acute effects	Frog, newt, snake, turtle, e.g.	Lethality and percent deformity	Acute LC_{50}s for developmental effects resulting from early life stage exposures
■ Represents base food web in terrestrial systems ■ Habitat vital to decomposers and soil aerators ■ Crucial to nutrient cycling	Sustainable soil community structure and function	Nematodes, soils mites, springtails, annelids, arthropods, e.g.	Growth, survival, and reproductive success	95% of species below no effects concentration at 50th percentile confidence interval
■ Primary producers ■ Act as food base for herbivores ■ Constitute essential habitat for virtually all receptor groups (e.g., nests)	Maintain terrestrial primary producers (plant community)	Soy beans, alfalfa, rye grass, e.g.	Growth, yield, germination	10th percentile from LOEC data distribution
■ Important food source for animals that live in waterbody margins ■ Diverse aquatic life important to maintain biotic integrity	Sustainable aquatic community structure and function	Fish (salmonids), aquatic invertebrates (daphnids), e.g.	Growth, survival, reproductive success	National Ambient Water Quality Criteria for aquatic life (95% species protection)
■ Provide habitat for reproductive lifestages (e.g., eggs, larval forms) ■ Act to process nutrients and decompose organic matter	Sustainable benthic community structure and function	Protozoa, flat worms, ostracods, e.g.	Growth, survival, reproductive success	10th percentile from LOEC data distribution
■ Primary producers ■ Base food source in the aquatic system	Maintain primary aquatic producers (algal and plant community)	Algae and vascular aquatic plants, e.g.	Growth, mortality, biomass, root length	EC_{20} for algae; lowest LOEC for aquatic plants

impoundments reported in the survey questionnaire. Consequently, ecological risk screening factors are given in units of concentration (e.g., mg/kg or mg/L). The use of screening factors is considered to be protective because the factors are

- Derived using established EPA protocols for use in evaluating ecological risk (e.g., sediment quality criteria)
- Based on highly protective assumptions regarding the toxicological potency of a constituent (e.g., no adverse effects levels and low adverse effects levels)
- Calculated assuming that all media and food items originate from a contaminated source.

In addition, the application of the screening factors assumes that ecological receptors are exposed directly to chemical concentrations in the sludge and wastewater found in the surface impoundment. For mammals, birds, and selected herpetofauna, these screening factors reflect ingestion of contaminated media, plants, and prey. For other receptor groups, such as soil fauna, these screening factors reflect both the direct contact and ingestion routes of exposure.

C.6.3.1 Selection of Representative Species/Receptor Groups. The 62 ecological receptors used for the HWIR assessment were selected for use in the screening analysis. The HWIR receptors were developed to support the assessment of ecological risks in 14 different terrestrial, waterbody margin, and wetland habitats. They are representative of the entire continental United States, and they reflect potential exposure for a variety of trophic levels, feeding strategies, and taxa (see Attachment C-19 to this appendix). Furthermore, the HWIR databases for these receptors contain complete exposure factor data as well as a compilation of selected ecotoxicological data that are relevant to the surface impoundment study endpoints. Thus, this group of receptors constitutes a readily available data set that is appropriate for use in the assessment.

In the screening analysis for the SI Study, it was assumed that each facility site supports terrestrial receptors. Receptors found in waterbody margin habitats (i.e., stream corridor and lake or pond margin) were assumed to occur at sites where there are fishable waterbodies. Fishable waterbodies were defined as lakes and ponds designated in Reach File Version 3.0 Alpha Release (RF3-Alpha) (U.S. EPA, 1994c) and streams of order 3 or higher. Receptors found in wetlands were assumed to occur at sites where wetlands are designated by the National Wetland Inventory (NWI) data (U.S. FWS, 1998), where available, or by EPA's Geographic Information Retrieval and Analysis System (GIRAS) (U.S. EPA, 1994d) where NWI coverage was not available. The HWIR ecological receptor databases include information on the geographic distribution of each receptor species. These data were used to match species distribution with facility location so that risk for each receptor species was estimated only at those facilities located within its geographic range.

C.6.3.2 Identification of Relevant Exposure Pathways. Ecological exposure pathways for the screening analysis were identified based on (1) both active and postclosure scenarios for surface impoundments, and (2) likely routes of exposure for receptors assigned to simple food

webs. Chemical constituents may volatilize from active surface impoundments and deposit onto adjacent soils, plants, or surface waters. In addition, constituents may leach into groundwater and contaminate nearby surface waters and sediments. Following closure, a surface impoundment may be integrated with local habitats (assuming the contaminant concentration does not prevent vegetative growth) and serve as a long-term source of exposure to certain types of constituents (e.g., metals). As shown in Figures C.6-1 and C.6-2, receptors may be exposed to contaminated media and/or prey and plants in both terrestrial and aquatic systems. Consequently, the exposure pathways that were assessed are

- Direct contact with contaminated sludge/soil (e.g., plants, soil fauna)
- Ingestion of contaminated sludge/soil (e.g., mammals, birds)
- Ingestion of plants/prey from contaminated sludge/soil (e.g., mammals, birds)
- Direct contact with contaminated surface water (e.g., fish, amphibians)
- Direct contact with contaminated sludge (e.g., benthos)
- Ingestion of aquatic plants/prey from contaminated surface water (e.g., birds)
- Ingestion of contaminated surface water (e.g., mammals).

Exposure routes that were not addressed in the ecological screening assessment include

- Dermal absorption from contaminated surface water or sludge (e.g., mammals)
- Inhalation of volatile constituents in air.

Dermal absorption of constituents is considered to be an insignificant exposure pathway for potentially exposed wildlife receptors and was not assessed for two reasons:

- Dense undercoat or down effectively prevents chemicals from reaching the skin of wildlife species and significantly reduces the total surface area of exposed skin (Peterle, 1991; U.S. ACE, 1996).

- Results of exposure studies indicate that exposures due to dermal absorption are insignificant compared to ingestion for terrestrial receptors (Peterle, 1991).

Inhalation of volatile compounds was not assessed for wildlife receptors for two reasons:

- Concentrations of volatile chemicals released from soil to aboveground air are drastically reduced, even near the soil surface (U.S. ACE, 1996).

- Significant concentrations of VOCs would be required to induce noncarcinogenic effects in wildlife based on inhalation toxicity data for laboratory rats and mice (U.S. ACE, 1996).

C.6.4 Development of Ecological Screening Factors

The screening analysis addresses constituents that were identified as occurring in surveyed surface impoundments and that were included in the HWIR analysis. Constituents included in the HWIR analysis are supported by available ecotoxicological data and by exposure

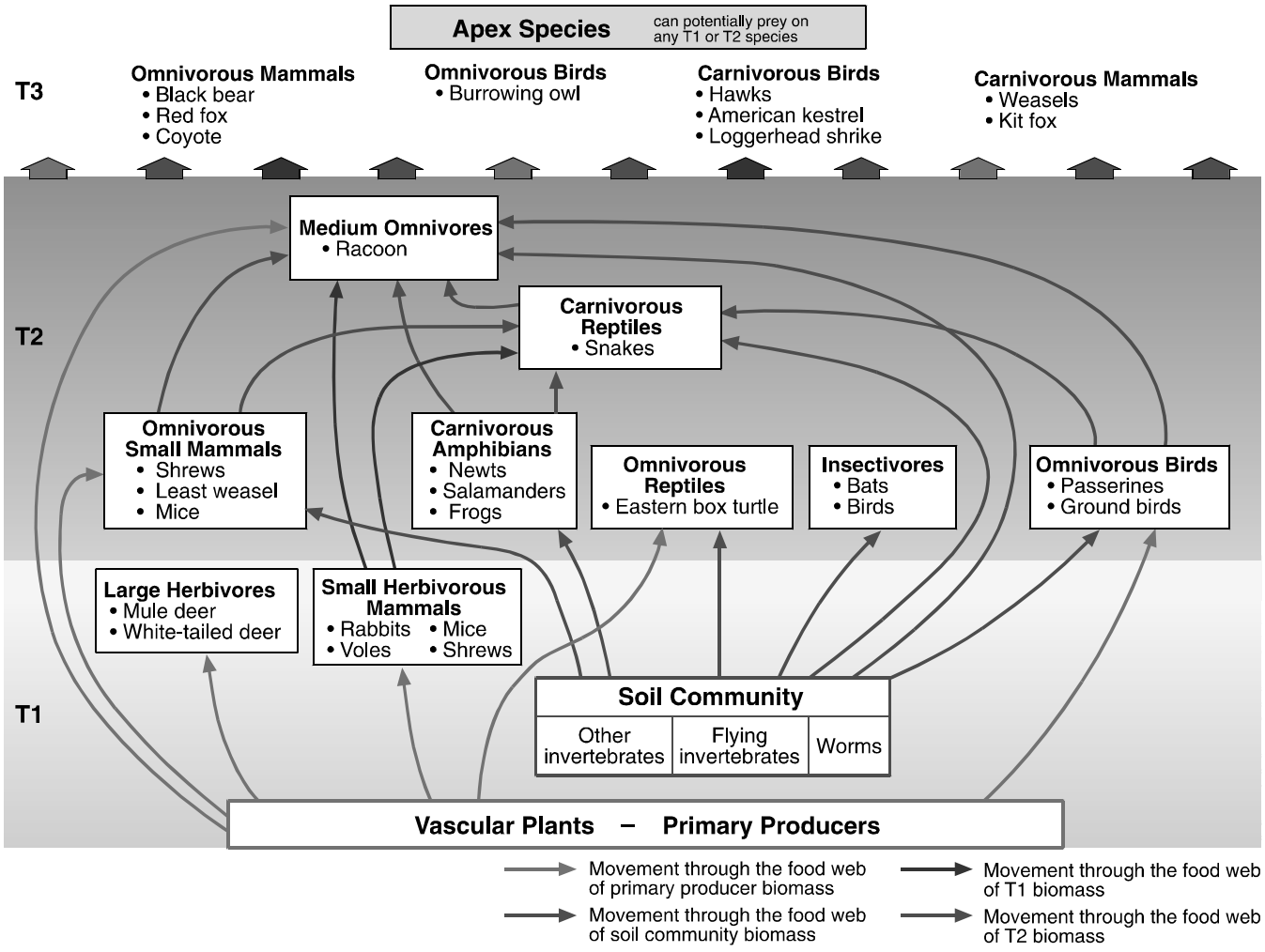


Figure C.6-1. Terrestrial web, including example receptors.

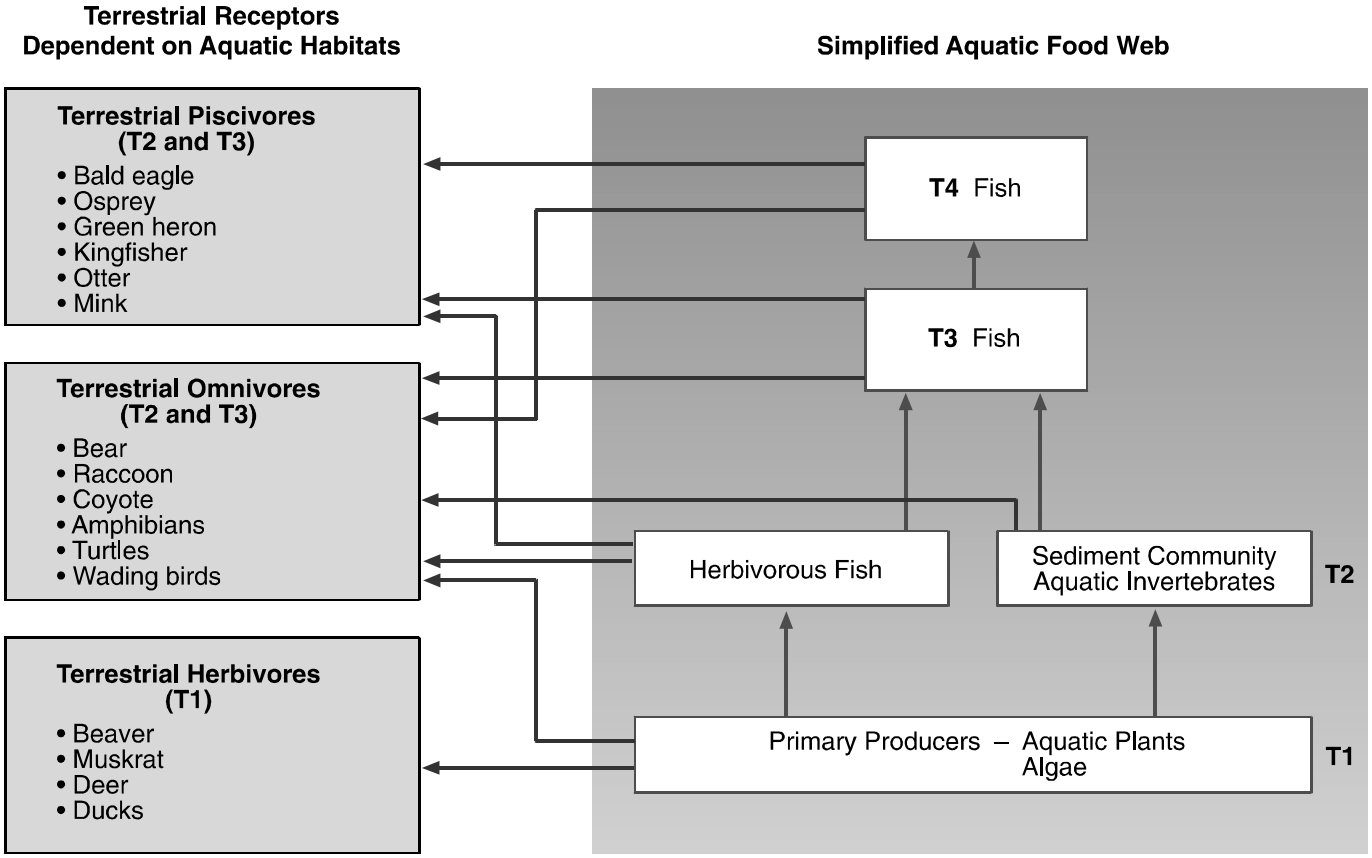


Figure C.6-2 Interface between terrestrial and aquatic food webs, including example receptors.

factor data for the relevant receptors and, therefore, could be assessed without further literature review or extensive data collection and processing. The screening factors for these constituents were taken directly from the HWIR analysis, where appropriate, and calculated using the HWIR ecological databases in other cases. The following discussion describes the methods and data sources used in the development of screening factors, which are presented in Attachment C-23 to this appendix.

C.6.4.1 Selection of Appropriate Ecotoxicological Studies—Population Inference. As suggested in Table C.6-1, risks to three groups of receptors (mammals, birds, and amphibians) were estimated based on endpoints relevant to population sustainability. It is important to note that screening factors were not developed based on population-level studies. Rather, ecotoxicological data on selected physiological endpoints (e.g., developmental effects) were used to infer risks to wildlife populations.

Table C.6-2 presents some examples of key data sources used analysis to identify suitable ecotoxicological studies.

Table C.6-2. Selected Sources of Toxicity Data

Databases

- Hazardous Substances Data Bank (HSDB). National Library of Medicine, National Toxicology Information Program. Bethesda, MD.
- PHYTOTOX. Chemical Information System (CIS) Database.
- Registry of Toxic Effects of Chemical Substances (RTECS). National Institute for Occupational Safety and Health (NIOSH), Washington, DC.

Compilations

- Agency for Toxic Substances and Disease Registry (ATSDR). 1997. *Toxicological Profiles*. On CD-ROM. CRC press. U.S. Public Health Service. Atlanta, GA.
- Devillers, J. and J.M. Exbrayat. 1992. *Ecotoxicity of Chemicals to Amphibians*. Grodon and Breach Science Publishers. Philadelphia, PA.
- Eisler, R. 1985-1993. *Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review*. U.S. Fish and Wildlife Service Biological Reports.
- Hudson, R.H., R.K. Tucker, and M.A. Haegele. 1984. *Handbook of Toxicity of Pesticides to Wildlife*. U.S. Fish and Wildlife Service. Resour. Publ. 153. 90 pp.
- Sample, B.E., D.M. Opresko, and G.W. Suter II. 1996. *Toxicological Benchmarks for Wildlife: 1996 Revision*. Prepared for the U.S. Department of Energy.

For amphibians, the development of screening factors is severely limited by data availability. Several compendia presenting amphibian ecotoxicity data (e.g., U.S. EPA, 1996a; Power et al., 1989) as well as primary literature sources were reviewed, and it was determined that there was a general lack of chronic or subchronic ecotoxicological studies. Consequently, studies on acute exposures during sensitive amphibian life stages were selected for developing

screening factors. The potential sensitivity of this receptor group warrants their inclusion even though chronic study data are not yet available. All studies used to develop amphibian screening factors included the following information:

- Test organism
- Toxicological endpoint
- Exposure duration
- Life stage at which exposure occurred (e.g., embryo, tadpole).

Appropriate toxicity data for amphibians included reproductive effects, developmental effects, or lethality from studies conducted for an exposure duration of less than 8 days. Limiting the study duration to short exposures allowed use of a larger data set in deriving the screening factors.

For mammals and birds, only toxicity studies relevant to ingestion were reviewed (e.g., gavage); studies where the chemical was administered via injection or implantation were not reviewed. At a minimum, studies reported the following data elements to be considered for use in developing the ecological screening factors:

- Test organism
- Toxicological endpoint
- Dose-response information
- Exposure duration
- Exposure route
- Sample size.

Preferred Studies—Toxicity studies that reported reproductive impairment, developmental abnormalities, and mortality were preferred to studies on other physiological endpoints because these endpoints are highly relevant to the assessment endpoints selected for the SI Study (e.g., population sustainability). In addition, the use of reproductive and developmental toxicity data has been recommended in guidance across several federal agencies (U.S. EPA, 1998b; Department of the Air Force, 1997; U.S. ACE, 1996). Studies that report NOAELs as well as LOAELs were preferred. Several other important aspects of study selection are summarized below.

Duration of Exposure. Duration is critical in assessing the potential for adverse effects to wildlife. However, since definitive guidance is not available on subchronic versus chronic exposures, chronic exposures are defined as greater than 50 percent of the life span of mammalian wildlife representative species. Little information exists concerning the life span of birds used in toxicity studies, and a standard study duration has not been established for avian toxicity tests. Therefore, exposures greater than 10 weeks were considered chronic for birds; exposures less than 10 weeks were considered subchronic (Sample et al., 1996).

Timing of Exposure. The timing of exposure is critical in assessing the potential for adverse effects to wildlife. For example, early development is a particularly sensitive life stage due to the rapid growth and differentiation occurring within the embryo and juvenile. For many species, exposures of a few hours to a few days during gestation and early fetal development may

produce severe adverse effects (Sample et al., 1996). Therefore, in the absence of chronic studies on developmental or reproductive effects (e.g., multigenerational studies), studies that report exposures during reproductive and/or developmental stages were in some cases selected for use in developing ecological screening factors.

Endpoint of Interest. A review of toxicity data indicated that reproductive or developmental effects were frequently observed at lower doses than those causing mortality . Therefore, chronic mortality studies were used only when reproductive or developmental data were not available. Physiological (e.g., enzyme activity), systemic, and behavioral responses were less preferred because it is often difficult to relate these responses to quantifiable decreases in reproductive fitness or the persistence of wildlife populations. Tumorigenic and carcinogenic toxicity studies are not considered ecologically relevant and were not used to develop toxicity benchmarks because debilitating cancers in wildlife are exceedingly rare under field conditions.

C.6.4.2 Selection of Appropriate Ecotoxicological Studies—Community Inference. The community-based screening factors generally reflect direct exposures to a contaminated medium, which, in the screening analysis, is represented by actual impoundment concentrations in water and sludge. Risks were estimated for five community-level receptors: soil fauna, terrestrial plants, aquatic biota, algae and aquatic plants, and benthos. Risk was estimated based on endpoints relevant to sustainability of community structure and function. The screening factors for communities generally are not based on community-level studies in the sense that they do not reflect endpoints relevant to community dynamics (e.g., predator-prey interactions). Rather, they are based on the theory that protection of 95 percent of the species in the community will provide a sufficient level of protection for the community (see, for example, Stephan et al., 1985, for additional detail). As with the wildlife populations, ecotoxicological data on individual species were used to infer risks to the community.

Appropriate ecotoxicological studies to derive screening factors for these receptor groups were identified in a number of compendia; as a result, it was not necessary to conduct primary literature reviews to identify suitable studies. These compendia generally present threshold concentrations that may be used directly as screening factors with little or no modification. Table C.6-3 presents the primary data sources used to support the derivation of screening factors for the community receptors. The selection process for screening factors and the screening factor calculations are discussed in the following section.

C.6.4.3 Calculation of Ecological Screening Factors—Receptor Populations. Screening factors for receptor populations consist of media concentrations that are assumed to be protective. Each screening factor is species- and medium-specific. Calculation of the screening factors was based on the ecotoxicological data identified as described above in Section C.6.4 and on species-specific exposure factors from the HWIR analysis. These exposure factors include body weight, ingeston rates, and dietary composition; Attachment 21 presents the exposure factor values used in the assessment.

Table C.6-3. Examples of Primary Data Sources for Derivation of Screening Factors for Community Receptors

Source	Contents
Plant Community	
Efroymson, R.A., M.E. Will, G.W. Suter II, and A.C. Wooten. 1997a. *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision*.	This document provides effects data for terrestrial plants exposed in soil and solution mediums. Approximately 45 constituents have proposed soil criteria.
PHYTOTOX Database. Office of Research and Development, U.S. Environmental Protection Agency.	This database contains over 49,000 toxicity tests on terrestrial plants for more the 1,600 organic and inorganic chemicals and 900 species.
Freshwater Community / Algae and Aquatic Plants	
AQUIRE (AQUatic toxicity Information REtrieval) Database. 1997. Environmental Research Laboratory, Office of Research and Development, U.S. EPA, Duluth, MN	This database contains over 145,000 toxicity tests for more than 5,900 organic and inorganic chemicals and 2,900 aquatic species.
U.S. EPA. 1989a. *Ambient Water Quality Criteria.* Washington, DC.	These chemical-specific documents provide the ecotoxicity data and derivation methodologies used to develop the National Ambient Water Quality Criteria (NAWQC).
U.S. EPA. 1995. *Great Lakes Water Quality Initiative Criteria Documents for the Protection of Aquatic Life in Ambient Water. Office of Water*. (U.S. EPA, 1996a Update)	For a limited number of constituents, the GLWQI has proposed surface water criteria for aquatic biota using analogous methods as implemented in the derivation of the NAWQC.
Suter II, G.W., and C. Tsao. 1996. *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Aquatic Biota: 1996 Revision.*	This compendia reference provides acute and chronic water quality criteria for freshwater species including algae.
Soil Community	
Efroymson, R.A., M.E. Will, and G.W. Suter II. 1997b. *Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision*. Oak Ridge National Laboratory.	This document provides effects data for soil biota (i.e., microbial processes and earthworms). Approximately 35 constituents have proposed soil criteria, and some field studies are included.
CCME (Canadian Council of Ministers of the Environment), 1997. *Recommended Canadian Soil Quality Guidelines*.	The criteria developed by the CCME are concentrations above which effects are likely to be observed.
Sediment Community	
U.S. EPA. 1993a. *Technical Basis for Deriving Sediment Quality Criteria for Nonionic Organic Contaminants for the Protection of Benthic Organisms by Using Equilibrium Partitioning*.	This document supplies toxicological criteria for nonionic hydrophobic organic chemicals using FCVs (final chronic values) and SCVs (secondary chronic values) developed for surface water (Sediment Quality Criteria, SQC).

(continued)

Table C.6-3. (continued)

Source	Contents
Plant Community (continued)	
Long and Morgan. 1991. *The Potential for Biological Effects of Sediment-Sorbed Contaminants Tested in the National Status and Trends Program*. National Oceanic and Atmospheric Administration (NOAA) Technical Memorandum. Update: (Long et al., 1995)	Field-measured sediment concentrations are correlated with impacts to sediment biota in estuarine environments. Measures of abundance, mortality, and species composition are the primary toxicity endpoints.
Jones, D.S., G.W. Sutter III, and R.N. Hall. 1997. *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Sediment-Associated Biota: 1997 Revision.* Oak Ridge National Laboratory.	This document proposes sediment criteria for both organic and inorganic constituents using both field and estimation methodologies.
MacDonald, D.D. 1994. *Approach to the Assessment of Sediment Quality in Florida Coastal Waters*. Florida Department of Environmental Protection (FDEP), Tallahassee.	This approach applies statistical derivation methods to determine sediment criteria using NOAA data. The resulting criteria are more conservative than NOAA values.

The calculation of ecological screening factors for receptor populations is based on the implicit assumption that each receptor species forages only within the contaminated area, regardless of the size of its home range. For smaller animals, this assumption has little impact on the estimates of exposure. However, for larger animals with more extensive foraging areas, this assumption may overestimate exposure if the animal's foraging patterns tend to be evenly spread over the home range. Thus, it is important to recognize both the explicit **and** implicit sources of protection in this methodology.

For amphibian populations, a screening factor for water (SF_{water})was derived as the geometric mean of acute studies meeting the data requirements discussed above (i.e., relevant endpoint, acute exposure, high effect level). However, it is important to point out that this screening factor should be construed as only "protective" of gross effects to amphibian populations (e.g., lethality to 50 percent of the population), and careful consideration should be given in interpreting the screening results for amphibians. The remainder of this section outlines the basic technical approach used to convert avian or mammalian benchmarks (in daily doses) to soil and water screening factors (in units of concentration).

Once the appropriate ecotoxicological study was identified for mammals and/or birds,[1] the screening factors were calculated for each medium of interest using a three-step process:

1. Scale benchmark from test species to receptor species.
2. Identify uptake/accumulation factors.
3. Calculate protective concentration (i.e., screening factor).

[1] Reptiles are not discussed in this section because of the data deficiencies for this receptor group.

Step 1. Scale Benchmark from Study Species to Receptor Species

The benchmarks for the mammalian and avian receptors were extrapolated from the study species to the receptor species within the same taxa using a cross-species scaling equation (Sample et al., 1996). Benchmarks were based on the geometric mean of NOAEL and LOAEL values. For population-inference benchmarks for mammals, the extrapolation is performed using Equation C.6-1.

$$GEOMN_{RS} = GEOMN_{SS} \cdot \left(\frac{bw_{SS}}{bw_{RS}} \right)^{1/4} \quad \text{(C.6-1)}$$

where

$GEOMN_{SS}$	=	GEOMN for the study species
bw_{RS}	=	body weight of the receptor species
bw_{SS}	=	body weight of the study species.

This is the default methodology EPA proposed for carcinogenicity assessments and reportable quantity documents for adjusting animal data to an equivalent human dose.

For avian species, research suggests that the cross-species scaling equation used for mammals is not appropriate (Mineau et al., 1996). Mineau et al. (1996) used a database that characterized acute toxicity of pesticides to avian receptors of various body weights. The results of the regression analysis revealed that applying mammalian scaling equations may not predict sufficiently protective doses for avian species. Mineau et al. (1996) suggested that a scaling factor of 1 provides a better dose estimate for birds, as shown in Equation C.6-2. This recommendation was adopted for developing screening factors for avian receptors.

$$GEOMN_{RS} = GEOMN_{SS} \cdot \left(\frac{bw_{SS}}{bw_{RS}} \right)^{1} \quad \text{(C.6-2)}$$

Attachment 20 to this appendix presents the scaled benchmarks for mammals and birds.

Step 2. Identify Uptake/Accumulation Factors

Movement of contaminants through the food web is an important exposure vector for mammals and birds. Consequently, estimates of chemical accumulation in the tissues of plants and prey items are required. For receptors likely to rely on aquatic systems for food (e.g., kingfisher), bioaccumulation factors and/or bioconcentration factors are required for aquatic biota such as fish, benthos, and aquatic plants. These data were identified in the open literature or estimated for organic constituents using regression equations such as that shown in Equation C.6-3 (Lyman et al., 1990):

$$\log BCF = 0.76 \ [\log (K_{ow})] - 0.23 \quad \text{(C.6-3)}$$

where

BCF = estimated bioconcentration factor for fish
K_{ow} = constituent-specific octanol-water partition coefficient.

For receptors found primarily in terrestrial systems, bioconcentration factors (BCFs) were required for terrestrial plants, soil invertebrates (e.g., earthworms), and vertebrates. These BCFs report the relationship between tissue concentrations and soil concentrations. As with aquatic accumulation factors, these values were identified in the open literature and EPA references or calculated based on the relationship between log K_{ow} and accumulation in lipid tissue (Sample et al., 1998a, 1998b). To ensure that the ecological screening assessment is protective, a default value of 1 was assigned to each uptake/accumulation factor that could not be derived through estimation methods or identified in the literature. Attachment 22 presents the biouptake factors used in the screening factor calculations.

Step 3. Calculate Protective Concentration for Receptor

Based on the $GEOMN_{RS}$, the screening factor for a receptor that relies on aquatic biota as the primary food source was calculated as a function of the receptor's body weight, the receptor's ingestion rate for food and water, and the bioaccumulation potential of the constituent, as shown in Equation C.6-4:

$$SF_{water} = \frac{GEOMN_{RS} \; x \; bw}{(I_{food} \sum BAF_j \; x \; F_j \; x \; AB_j) \; + \; (I_{water})} \qquad \text{(C.6-4)}$$

where

bw = body weight (kg)
I_{food} = total daily intake of aquatic biota (kg WW/d)
BAF_j = bioaccumulation factor for food item j (L/kg WW))
F_j = fraction of diet consisting of food item j (unitless)
AB_j = absorption of chemical in the gut from food item j (assumed = 1)
I_{water} = total daily soil intake (kg/d).

Equation C.6-4 can also be used to derive an "impoundment use only" screening factor for sites that do not have any fishable waterbodies identified in the survey data. For these cases, only I_{water} would be included in the denominator to reflect use of the impoundment as a drinking water source.

For terrestrial systems, Equation C.6-5 is simply modified to account for soil or sludge intake:

$$SF_{soil/sludge} = \frac{GEOMN_{RS} \; x \; bw}{(I_{food} \sum BCF_j \; x \; F_j \; x \; AB_j) \; + \; (I_{soil/sludge})} \qquad \text{(C.6-5)}$$

where

bw	=	body weight (kg)
I_{food}	=	total daily food intake of terrestrial biota (kg/d)
BCF_j	=	bioconcentration factor for food item j (assumed unitless)
F_j	=	fraction of diet consisting of food item j (unitless)
AB_j	=	absorption of chemical in the gut from food item j (assumed = 1)
$I_{soil/sludge}$	=	total daily soil intake (kg/d).

Information sources to develop the input values for body weight (bw), ingestion rates (I_{xx}), and dietary fractions (F_j) were taken from the extensive HWIR databases. The HWIR databases were developed using EPA's *Wildlife Exposure Factors Handbook* (U.S. EPA, 1993b) and augmented by substantial literature review and synthesis of a variety of information sources.

The dietary fractions (F_j) were derived from the HWIR dietary preference database and reflect the variability in receptor species' dietary composition. The dietary preference database consists of the minimum and maximum proportion of a species'diet that different diet items can constitute. Diet items are categorized as one of 17 types, including different types of vegetation (e.g., fruits, forage, grain, roots) and several categories of prey (e.g., small birds, small mammals, invertebrates, fish). For example, the Eastern box turtle's dietary proportion ranges are:

Diet Item	Dietary Proportion Range
Soil invertebrates	8 to 93
Fruits	7 to 92
Worms	15 to 27
Forage	0 to 24

The development of the dietary preference database is fully described in the HWIR documentation (U.S. EPA 1999d). Each receptor's diet was constructed using the midpoint of dietary proportions for each diet item, beginning with the item with highest midpoint value and proceeding through the diet items until a full diet (100 percent) was accumulated. Thus, the turtle's diet would consist of 50.5 percent soil invertebrates and 49.5 percent fruits based on the following dietary proportion midpoints:

Diet Item	Dietary Proportion Midpoint
Soil invertebrates	50.5
Fruits	49.5
Worms	21
Forage	12

The dietary composition used for each receptor species is presented in Attachment 21.

C.6.4.4 Calculation of Ecological Screening Factors—Receptor Communities. The calculation of ecological screening factors for receptor communities relied heavily on existing

data sources, many of which have produced peer-reviewed concentrations for soils and surface water presumed to be protective of ecological receptors. Examples include:

- **Aquatic Biota:** U.S. EPA's National Ambient Water Quality Criteria
- **Sediment-Associated Biota:** National Oceanic and Atmospheric Administration's (NOAA) Effects Range-Low (ER-Ls)
- **Soil Invertebrates:** Dutch National Institute of Public Health and Environmental Protection's (RIVM) Ecotoxicological Intervention Values (EIVs).

The methods used to develop each of the receptor community screening factors are briefly described here.

***Aquatic Community*.** For aquatic biota in freshwater systems, the final chronic value (FCV) developed for the National Ambient Water Quality Criteria were chosen as the screening factor. If an AWQC was not available, the continuous chronic criterion (CCC) developed for the Great Lakes Water Quality Initiative (GLWQI) was used (U.S. EPA, 1995a, 1996f). If neither of these criteria were available, a secondary chronic value (SCV) was calculated using the Tier II methods developed through the Great Lakes Initiative (Stephan et al., 1985; Suter and Tsao, 1996).

The SCV is calculated using methods analogous to those applied in calculating the FCV. However, the Tier II methods (1) require chronic data on only one of the eight family requirements, (2) use a secondary acute value (SAV) in place of the FAV, and (3) are derived based on a statistical analysis of AWQC data conducted by Host et al. Host et al. (1991) developed adjustment factors (AFs) depending on the number of taxonomic families that are represented in the database. The Tier II methodology was designed to generate SCVs that are below FCVs (for a complete data set) with a 95 percent confidence limit.

***Algae and Aquatic Plants*.** For algae and aquatic plants, toxicological data were available in the open literature and in data compilations such as the *Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision* (Suter and Tsao, 1996). Studies on freshwater vascular plants are seldom available; however, toxicity data are available from standard algal tests. In order of preference, the screening factors for algae and aquatic plants were based on either (1) a lowest observed effects concentration (LOEC) for vascular aquatic plants or (2) an effective concentration (EC_{xx}) for a species of freshwater algae, generally a species of green algae.

***Benthic Community*.** Two methods were applied to develop screening factors for the sediment community. The first and preferred method uses measured sediment concentrations that resulted in de minimis effects to the composition and abundance of the sediment community. The second derivation method uses the equilibrium partitioning relationship between sediments and surface waters to predict a protective concentration for the benthic community using the chronic FCV. A brief discussion of each method is provided below.

- **Screening Factors from Measured Data:** The premier sources of measured sediment toxicity data are NOAA and the Florida Department of Environmental Protection (FDEP). These data are used by NOAA to estimate the 10th percentile effects concentration effects range-low (ER-L) and a median effects concentration effects range-median (ER-M) for adverse effects in the sediment community. The FDEP sediment criteria are developed from the ER-L and ER-M values to approximate a threshold effects level (TEL) (estimated from ER-L data). The TELs are preferable to the ER-L primarily because they have been shown to be analogous to TELs observed in freshwater organisms (Smith et al., 1996).

- **Predicted Sediment CSCLs.** If neither a TEL nor an ER-L is available for nonionic, organic constituents, the screening factor will be calculated using the sediment quality criteria (SQC) method (U.S. EPA, 1993b). This method assumes that equilibrium-partitioning between the sediment and water column is a function of the organic carbon fraction (f_{oc}) in sediment and the organic carbon partition coefficient of the constituent. The screening factor is calculated as shown in Equation C.6-6, assuming that the f_{oc} is equivalent to 1 percent total organic carbon (Jones et al., 1997).

$$SF_{sediment} = f_{oc} \times K_{oc} \times FCV \qquad \text{(C.6-6)}$$

Terrestrial Plant Community. For the terrestrial plant community, screening factors for soil were derived according to the methodology presented in the *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision* (Efroymson et al., 1997a). The authors derive ecologically relevant benchmarks by rank-ordering the phytotoxicity data according to the LOECs. This analysis adopted the same approach and selected screening factors for constituents with 10 or fewer values at the lowest LOEC. For constituents with more than 10 LOEC values, the 10th percentile LOEC was selected. Because the toxicity endpoints reflect endpoints such as plant growth and yield reduction, the screening factors are presumed to be relevant to sustaining "healthy" plant communities.

Soil Community. The screening factors for soil fauna were estimated to protect species found in a typical soil community, including earthworms, insects, and other soil fauna. Eight taxa of soil fauna are represented to reflect the key structural (e.g., trophic elements) and functional (e.g., decomposers) components of the soil community. The methodology presumes that protecting 95 percent of the soil species will ensure long-term sustainability of a functioning soil community. The toxicity data on soil fauna were gleaned from several major compendia and supplemented with additional studies identified in the open literature. The mathematical construct shown in Equation C.6-7 was developed by Dutch scientists (i.e., the RIVM methodology) and was used to calculate screening factors at a 50th percentile level of confidence (Sloof, 1992). For the screening factors for soil biota ($SF_{soil5\%}$), the 50th percentile level of confidence was selected because the 95th percentile has been shown to be overly conservative (e.g., well below background levels).

$$SF_{soil_5\%} = [x_m - k_l\ s_m] \quad \text{(C.6-7)}$$

where

x_m = sample mean of log LOEC data
k_l = extrapolation constant for calculating one-sided leftmost confidence limit
s_m = sample standard deviation of log LOEC data.

When data were insufficient to calculate screening factors using this methodology, two other sources of screening factors were used. First, the ecotoxicological data presented on indicator species such as earthworms were used to select a protective soil concentration (Efroymson et al., 1997b). Second, the criteria developed by the Canadian Council of Ministers of the Environment (CCME, 1997) for the protection of soil organisms were adopted as screening factors.

C.6.5 Screening Procedures

In most respects, the ecological risk screening procedure mirrors the methods for the risks from noncancer constituents to human health. The salient features of the ecological risk screening are summarized below.

C.6.5.1 Risk Calculation. Ecological risks were estimated by selecting appropriate screening factors and constituent concentrations for each facility and impoundment and calculating HQs. The screening factors for the assessment were developed from the HWIR ecological databases, as described in the previous sections. It was assumed that all sites supported terrestrial receptors (e.g., terrestrial plants, birds, and mammals). However, surface impoundments are not intended to support aquatic plants, aquatic invertebrates, fish, or sediment-associated receptors; therefore, aquatic and sediment-associated biota were assessed only if a potentially affected waterbody was identified within 2 kilometers of the surface impoundment. Although not intended to support amphibians, birds, and mammals, surface impoundments are likely to be attractive to these receptors (especially if impoundments support vegetation); therefore, amphibians, birds, and mammals were assessed for all surface impoundments.

Risk was defined as the ratio between the impoundment concentration and the screening factor, or hazard quotient. To evaluate the receptor risks from exposure to a chemical constituent at a particular surface impoundment, Equation C.6-8 was used:

$$HQ^{\,i}_{constituent} = \frac{C_{imp_{water}}}{SF_{water}} \quad or \quad \frac{C_{imp_{sludge}}}{SF_{sludge}} \quad or \quad \frac{C_{imp_{soil}(sludge)}}{SF_{soil}} \quad \text{(C.6-8)}$$

where

C_{imp_water}	=	impoundment water concentration
C_{imp_sludge} and C_{imp_soil}(sludge)	=	impoundment sludge concentration
SF_{water}, SF_{sludge}, and SF_{soil}	=	corresponding ecological screening factors for each medium.
$HQ^{i}_{constituent}$	=	risk to receptor i associated with that impoundment and facility.

The HQ values for each receptor i may be summed across the entire facility in generating facility risks because (1) the screening factors for each receptor are based on the same study data (and endpoints) and (2) receptors may be exposed through both terrestrial and aquatic systems. Attachment C-23 shows the results of the ecological screening assessment.

C.6.5.2 Risk Screening Methods. Risk estimates generated by the ecological screening assessment were reported for receptors, constituents, surface impoundments, and facilities by the following categories of interest.

Facility

- Regulatory status

Surface Impoundment

- Waste type
- Treatment type

Constituent

- Constituent type

Ecological Attributes

- Receptor group
- Habitat type.

The facility risk is defined as the maximum surface impoundment risk to receptor i for a particular facility. Facility risk estimates are used to develop regulatory-type risk distributions. The surface impoundment risk is defined as the cumulative risk to receptor i from exposure to all constituents at a particular surface impoundment.

For the ecological screening assessment, the constituent risk is defined as risk to the most sensitive receptor across all impoundments at a facility. Constituent risk estimates are used to develop constituent-specific risk distributions.

Construct Risk Distributions. Separate risk distributions were constructed from risk estimates to evaluate categories of interest. Risk distributions consist of the following five risk intervals (risk bin):

- <0.1
- ≥0.1 and <1
- ≥1 and <10
- ≥10 and <100
- ≥100.

A unitary value (1), representing the constituent, surface impoundment, or facility, was added to the appropriate risk bin. Since sample facilities represent a number of facilities nationwide, unitary values were weighted by the facility sample weight before being added to the bin.

The facility- and surface impoundment-related risk distributions were constructed from risk estimates for all receptors considered at a particular surface impoundment or facility. These risk distributions are used to screen facilities, surface impoundments, and constituents. Risk distributions constructed from maximum risk estimates (i.e., risk estimate for the most sensitive receptor) were compared to risk distributions for all receptors to determine if the number of receptors affects the facility- and impoundment-level risk distributions. In addition, risk distributions for each trophic level were developed to evaluate potential impacts on food webs. These risk distributions for receptor groups and trophic levels provide useful metrics for the risk characterization.

Establish Risk Criterion. A risk criterion of 1 was used to screen ecological risk estimates. Risk estimates less than 1 (e.g., $HQ^i < 1$) indicate a negligible potential for adverse ecological impacts. Alternatively, risk estimates of 1 or greater indicate a potential for adverse ecological effects. Surface impoundments and facilities with risk estimates of 1 or greater may be assigned for further evaluation, depending on the results of the human health screening.

Conduct Risk Screening. The ecological risk screening process is very similar to the health risk decision process. However, there are distinct differences in the ecological risk screening procedure. Whereas the human health risk screening is intended to protect individuals, the ecological risk screening is intended to protect species populations and communities from adverse effects. In addition, the ecological risk screening does not include cancer effects; only the endpoints described under Section C.6.1 were considered.

Based on the results of the surface impoundment pilot study, it was anticipated that, for each facility, at least one constituent would exceed the ecological risk criterion for the terrestrial plant receptor group. Because impoundment sludge/soils are not intended to support terrestrial habitats and because the screening factors for terrestrial plants are based on a data set that does not reflect adaptation by plant communities, EPA determined that a simple exceedance of the plant screening factor does not provide an adequate basis to determine the potential for adverse ecological effects. Thus, if plants are the only receptors with an HQ of 1 or higher, the

constituent, impoundment, or facility proceeds to further analysis only if the HQ for plants exceeds 10 (indicating a greater potential for adverse effects than a simple exceedance).

C.6.6 Screening Results

Ecological risk was calculated in a manner similar to that used to estimate noncancer risks for humans. Chemical concentrations that are assumed to be protective of wildlife and plants were established based on toxicological data. These protective concentrations are referred to as screening factors. Individual screening factors were developed for each of 62 receptors for 35 chemicals. The screening factors and the reported chemical concentrations in surface impoundments were used to calculate hazard quotients for each chemical and each receptor at each impoundment at each facility. HQs were calculated by dividing the chemical concentration in the impoundment by the receptor's screening factor.

Results by Facility. A total of 108 facilities out of 133 exceeded the ecological risk criterion for at least one receptor. Table C.6-4 shows a summary of the screening results by facility. Forty-six facilities had exceedances at three or more impoundments, 24 facilities had exceedances at two impoundments, and 38 facilities had exceedances at only one impoundment.

Results by Chemical. A total of 34 chemicals exceeded the risk criterion for at least one receptor at one impoundment. Table C.6-5 shows how frequently each chemical had the highest HQ for a particular impoundment. These chemicals are referred to as the "risk drivers" for that impoundment.

Results by Receptor. The screening ecological assessment addressed 62 receptors, including several species of mammals, birds, and amphibians as well as several ecological communities (e.g., the soil community and the sediment community). (See Attachment C-19 for a list of receptor species.) Based on the screening results, 54 receptors exceeded the risk criterion at at least 1 impoundment. One receptor, the Great Basin pocket mouse inhabits a relatively limited geographic area in the northwestern United States; no SI facilities fell within its geographic range, and, therefore, no exceedances occurred for this receptor. Table C.6-6 shows the receptors that exceeded the risk criterion.

The receptors that exceeded the risk criterion include all of the community receptors assessed as well as representative mammals and birds at all level of the food chain. Furthermore, receptors that depend on aquatic systems for food (e.g., mink, river otter, kingfisher, great blue heron) as well as those that depend on terrestrial systems (e.g., terrestrial plants, coyote, white tailed deer, and cerulean warbler) exceeded the risk criterion. HQs greater than 1 also occurred for receptors in all three habitat types—terrestrial, wetland, and aquatic, indicating that potential ecological risks are not restricted to any single type of habitat.

Sensitive Ecosystems. The presence of managed areas was assessed for 133 sites; 21 sites had managed areas within 3 km. Considering only the 108 sites that exceeded the risk criterion (i.e., had at least one HQ greater than 1), 18 facilities are within 3 km of a managed area. Twenty seven of the 108 facilities are within 1 km of wetlands. Three facilities are both

within 3 km of a managed area and within 1 km of a wetland. Table C.6-7 summarizes the proximity to sensitive habitats for facilities with exceedances.

Table C.6-4. Summary of Risk Criterion Exceedances by Facility

Facility	Number of Impoundments		Number of Constituents	
	Lower Concern	Potential Concern	Lower Concern	Potential Concern
1		1	5	2
4		1	6	2
5		1	8	1
7		1	6	2
11		1	1	2
12	1	3	19	6
14	1	1	10	1
18		2	10	1
19		3		3
22	2	2	20	4
28	1	1	3	3
29	6	1	11	1
32		4	14	3
33		1	4	
35	1	2	5	1
36	4	9	6	8
38	1	1	4	1
41	4	10	7	5
44		1	6	1
45		11	11	14
46	2	3	19	8
50		1	13	
57		2	1	1
64		1	1	1
68		7	13	11
71	6	1	3	2
78	1	2	2	1
80		5	7	11
82	1	1	3	1

(continued)

Table C.6-4 (Continued)

Facility	Number of Impoundments		Number of Constituents	
	Lower Concern	Potential Concern	Lower Concern	Potential Concern
84		5	15	11
86	1	3	7	5
96		1	1	2
98		2	14	3
103		6	8	8
104		2	15	2
115	1	2	14	3
116		1	2	1
120		1	2	1
126	1	2	12	4
127	4	6	4	6
133	3	1		2
135		5	3	9
140	1	1	8	
144		1	2	1
156	1	8	2	3
157	1	2	8	1
160		1	16	1
164		3	10	9
172		2	1	2
173	5	3	5	2
176	1	1	5	1
180	8	2	6	6
182	7	3	1	2
2	4		6	2
6	7		3	5
8	2		2	
13	2		2	
21	2		6	

(continued)

Table C.6-4 (Continued)

Facility	Number of Impoundments		Number of Constituents	
	Lower Concern	Potential Concern	Lower Concern	Potential Concern
23	4		7	6
31	2		17	4
40	1		9	
43	1		21	
47	6		12	
48	1		4	
49	1		3	
51	5		1	1
52	1		7	
54	4		1	
55	1		3	
58	3		10	1
63	1		1	
65	2		4	
67	2		6	
70	2		4	2
74	1		1	
81	10		4	
85	2		8	
89	5		3	1
90	1		5	
91	9		11	6
97	1		7	
105	2		5	
107	1		4	
111	2		1	
112	1		2	
118	9		6	11
122	1		2	

(continued)

Table C.6-4 (Continued)

Facility	Number of Impoundments		Number of Constituents	
	Lower Concern	Potential Concern	Lower Concern	Potential Concern
132	1		2	
134	1		1	
137	1		4	
141	1		2	
145	1		3	
148	1		1	
149	1		4	
151	23		7	2
153	1		1	
155	3		11	
159	6		11	5
167	1		1	
170	2		6	1
175	3		17	4
177	2		1	
181	2		5	
183	1		2	
185	9		2	2
186	1		5	
187	15		5	5
193	3		1	

Table C.6-5. Frequency That Constituent Has the Maximum HQ Value Exceeding a Risk Criterion at an Impoundment

Constituent of Concern	Number of Impoundments where Constituent Is Max HQ
Toluene	8
Phenol	20
Bis(2-ethylhexyl) phthalate [dioctyl phthalate]	6
2,3,7,8-TCDD [2,3,7,8-Tetrachlorodibenzo-p-dioxin]	18
Chromium VI [hexavalent chromium]	1
Benzo(a)pyrene	9
Dibenz[a,h]anthracene	27
Chloroform [trichloromethane]	6
Benzene	3
Methoxychlor	1
Lead	107
Mercury	10
Nickel	18
Silver	3
Thallium	3
Arsenic	49
Barium	37
Beryllium	6
Cadmium	2
Vanadium	4
Zinc	35
Carbon disulfide	8
Selenium	5
Pentachlorophenol [PCP]	1

Table C.6-6. Receptors with HQ >1

Trophic Level	Species Common Name	Number of Exceedances
Communities	Aquatic Community	1306
Communities	Sediment Community	1481
Communities	Soil Community	732
Producers	Aquatic Plants	565
Producers	Terrestrial Plants	299
T1	Beaver	799
T1	Black-Tailed Jackrabbit	97
T1	Canada Goose	614
T1	Eastern Cottontail	489
T1	Meadow Vole	280
T1	Mule Deer	49
T1	Muskrat	694
T1	Pine Vole	340
T1	Prairie Vole	142
T1	White-tailed Deer	605
T2	American Kestrel	779
T2	American Robin	797
T2	American Woodcock	788
T2	Belted Kingfisher	869
T2	Bullfrog	366
T2	Burrowing Owl	229
T2	Cerulean Warbler	354
T2	Deer Mouse	280
T2	Eastern Newt	519
T2	Flatwoods Salamander	197
T2	Gopher Frog	192
T2	Great Blue Heron	791
T2	Green Frog	445
T2	Green Heron	872
T2	Herring Gull	934
T2	Least Weasel	71
T2	Lesser Scaup	742
T2	Little Brown Bat	554
T2	Loggerhead Shrike	721
T2	Long-Tailed Weasel	554

(continued)

Table C.6-1. (Continued)

Trophic Level	Species Common Name	Number of Exceedances
T2	Mallard Duck	975
T2	Marsh Wren	602
T2	Mink	992
T2	Northern Bobwhite	616
T2	Raccoon	1057
T2	River Otter	847
T2	Short-Tailed Shrew	399
T2	Short-Tailed Weasel	69
T2	Spotted Sandpiper	1104
T2	Tree Swallow	944
T2	Western Meadowlark	245
T3	Bald Eagle	896
T3	Black Bear	616
T3	Cooper's Hawk	578
T3	Coyote	717
T3	Kit Fox	51
T3	Osprey	536
T3	Red Fox	635
T3	Red-Tailed Hawk	614

Table C.6-7. Facilities That Have Exceedances and Are Near Sensitive Habitats

Facility	Wetlands Within 1 km	Managed Area Within 3 km	Wetland Within 1 km and Managed Area Within 3 km
1	No	No	No
2	No	No	No
4	Yes	No	No
5	No	Yes	No
6	No	No	No
7	No	No	No
8	Yes	No	No
11	No	No	No
12	No	No	No
13	No	No	No
14	No	No	No
18	No	No	No
19	No	No	No
21	Yes	No	No
22	No	No	No
23	No	No	No
28	No	No	No
29	No	No	No
31	Yes	No	No
32	No	No	No
33	No	No	No
35	No	No	No
36	No	Yes	No
38	Yes	No	No
40	No	Yes	No
41	No	No	No
43	No	No	No
44	Yes	No	No
45	Yes	No	No
46	Yes	No	No

(continued)

Table C.6-7. (Continued)

Facility	Wetlands Within 1 km	Managed Area Within 3 km	Wetland Within 1 km and Managed Area Within 3 km
47	No	Yes	No
48	No	Yes	No
49	Yes	No	No
50	No	No	No
51	Yes	Yes	Yes
52	No	No	No
54	No	No	No
55	No	No	No
57	No	No	No
58	No	No	No
63	No	No	No
64	No	No	No
65	No	Yes	No
67	No	No	No
68	No	No	No
70	No	No	No
71	No	No	No
74	No	Yes	No
78	No	No	No
80	No	No	No
81	Yes	No	No
82	No	No	No
84	Yes	No	No
85	No	Yes	No
86	No	No	No
89	No	No	No
90	No	No	No
91	No	No	No
96	No	No	No

(continued)

Table C.6-7. (Continued)

Facility	Wetlands Within 1 km	Managed Area Within 3 km	Wetland Within 1 km and Managed Area Within 3 km
97	No	Yes	No
98	No	Yes	No
103	Yes	No	No
104	Yes	No	No
105	Yes	No	No
107	Yes	No	No
111	No	No	No
112	No	No	No
115	No	No	No
116	No	No	No
118	Yes	No	No
120	No	No	No
122	No	No	No
126	Yes	Yes	Yes
127	No	No	No
132	No	No	No
133	No	No	No
134	Yes	No	No
135	No	Yes	No
137	No	Yes	No
140	No	No	No
141	No	Yes	No
144	No	No	No
145	No	No	No
148	No	No	No
149	Yes	No	No
151	Yes	No	No
153	No	No	No
155	Yes	No	No

(continued)

Table C.6-7. (Continued)

Facility	Wetlands Within 1 km	Managed Area Within 3 km	Wetland Within 1 km and Managed Area Within 3 km
156	Yes	No	No
157	No	No	No
159	No	Yes	No
160	Yes	No	No
164	No	No	No
167	No	No	No
170	No	No	No
172	No	No	No
173	No	No	No
175	No	No	No
176	Yes	Yes	Yes
177	No	No	No
180	No	No	No
181	No	No	No
182	Yes	No	No
183	No	Yes	No
185	No	No	No
186	No	No	No
187	No	No	No
193	Yes	No	no

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Appendix D

Regulatory/Program Coverage and Gaps Analysis

Section D-1

Summary of State Regulations and Programs Covering Nonhazardous Industrial Waste Surface Impoundments[1]

[1] The EPA's analysis of state waste regulations and programs in this appendix is based on publicly available information rather than a survey of state regulators. Therefore, the analysis may not have identified all state waste regulations and programs that address nonhazardous waste industrial surface impoundments. Readers should consult state regulatory agencies for more detailed and up-to-date information.

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Alabama

In Alabama, responsibility for regulating and permitting surface impoundments is consolidated in the state's water program under the Alabama Department of Environmental Management (ADEM). Surface impoundments for the management of nonhazardous waste are required to obtain a state NPDES permit and are subject to non-regulatory state guidelines as indicated in the chart below.

ADEM guidelines call for the permit applicant to submit a description of the proposed impoundment, signed by a Registered Engineer, that includes the following information:

- Proposed use of the impoundment, including a description of the liquids to be introduced into the impoundment
- Impoundment configuration and orientation
- Plot and plan drawings of the impoundment
- Proposed liner material and thickness
- Soil boring logs for the impoundment site or other information concerning the site geology.

Alabama Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	Yes (guidance only)	Not specified in state regulations.
Design Criteria (liner, leachate collection)	Yes (guidance only)	Not specified in state regulations.
Operating Criteria	Yes (guidance only)	Not specified in state regulations.
Monitoring	Yes (guidance only)	Not specified in state regulations.
Reporting and Recordkeeping	No	Not specified in state regulations.
Inspection and Enforcement	No	Not specified in state regulations.
Performance Standards and Corrective Action	Yes (guidance only)	Not specified in state regulations.
Closure/Postclosure Care	Yes (guidance only)	Not specified in state regulations.
Financial Assurance	No	Not specified in state regulations.

(continued)

Alabama Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the state's regulations or programs.

Sources:

Alabama Administrative Code (AAC).

Alabama Department of Environmental Management (ADEM) web page (http://www.adem.state.al.US).

ADEM. 2000. Closure Guidelines For Industrial Wastewater Impoundments. Water Division - Industrial Section. Revised 03/00.

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Alaska

Alaska does not have any regulations or programs applicable to nonhazardous waste surface impoundments – there are not even state NPDES regulations that apply since Alaska is not an NPDES-authorized state.

Alaska Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	No	Not specified in state regulations.
Design Criteria (liner, leachate collection)	No	Not specified in state regulations.
Operating Criteria	No	Not specified in state regulations.
Monitoring	No	Not specified in state regulations.
Reporting and Recordkeeping	No	Not specified in state regulations.
Inspection and Enforcement	No	Not specified in state regulations.
Performance Standards and Corrective Action	No	Not specified in state regulations.
Closure/Postclosure Care	No	Not specified in state regulations.
Financial Assurance	No	Not specified in state regulations.
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the states regulation or program.

Sources:
Alaska Statutes and Alaska Administrative Code.

Arkansas

Arkansas requires a state NPDES permit for discharges to surface water, but does not further regulate surface impoundments, except for a few design and operating requirements for surface impoundments for confined animal feeding operations (CAFOs) and oil drilling activities. The requirements for the latter are included in the table below.

Arkansas Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	No	Not specified in state regulations.
Design Criteria (liner, leachate collection)	Yes	Regarding oil drilling activities, surface disposal of salt water and other liquid waste sin earthen pits must be underlaid by tight soil such as heavy clay or hardpan, or lined with asphalt or other water-tight material and of sufficient size to assure adequate disposal of the volume of waste to be impoundment therein. Where the soil under an underground pit is porous and closely underlaid by gravel or sand stratum, impounding of salt water or other liquid wastes therein will not be allowed.
Operating Criteria	Yes	Regarding oil drilling activities, surface impoundments must have minimum freeboard of at least 12 inches.
Monitoring	No	Not specified in state regulations.
Reporting and Recordkeeping	No	Not specified in state regulations.
Inspection and Enforcement	Yes	State regulations give the authority to inspect, but do not specify the frequency.
Performance Standards and Corrective Action	No	Not specified in state regulations.
Closure/Postclosure Care	No	Not specified in state regulations.
Financial Assurance	No	Not specified in state regulations.

(continued)

Arkansas Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the states regulation or program.

Source:

Arkansas Water Division Regulations No. 1, No. 5, and No. 6.

Arizona

In Arizona, responsibility for regulating and permitting surface impoundments is consolidated in the state's water pollution control division of the Arizona Department of Environmental Quality (ADEQ). Surface impoundments discharging to waters of the United States must obtain an NPDES permit from USEPA.

ADEQ requires an aquifer protection permit for the construction of a surface impoundment. The maximum duration of the permit extends through the end of the postclosure period. All permit applications must contain two copies of a location map; two copies of a site plan; two copies of facility design drawings; a characterization of discharge; a demonstration of Best Available Demonstrated Control Technologies (BDACT); demonstration of compliance with standards; demonstration of technical capability; demonstration of financial capability; past environmental performance; and evidence that the facility complies with applicable municipal or county zoning ordinance and regulations.

Arizona Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	No	Not specified in state regulations.
Design Criteria (liner, leachate collection)	No	Not specified in state regulations, but may be applied on a permit-specific basis.
Operating Criteria	No	Not specified in state regulations, but may be applied on a permit-specific basis.
Monitoring	Case-by-case	**Groundwater:** The state agency may require a hydrologic study on a case-by-case basis. Monitoring requirements are determined on a permit-specific basis.
Reporting and Recordkeeping	Yes	State regulations require a facility to maintain records for monitoring (10 years) and notification of any violations of permit conditions. Other reporting and recordkeeping requirements are determined on a permit-specific basis.
Inspection and Enforcement	Yes	State regulations give the authority to inspect, but do not specify the frequency.

(continued)

Arizona Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Performance Standards and Corrective Action	Yes	The Aquifer Protection permit establishes the point of compliance on a site-specific basis, not farther than the property line or 750 feet from the waste boundary. The Permit also establishes alert levels for appropriate constituents. A notification is required if alert levels are exceeded or if there is a reasonable expectation that state groundwater standards may be exceeded. A contingency plan is required detailing site-specific conditions for response actions. This may include verification sampling, additional monitoring, assessment of impacts, and/or corrective action.
Closure/Postclosure Care	Yes	Closure and postclosure plans are required by the state regulations. The specific requirements, including postclosure duration, are determined on a permit-specific basis.
Financial Assurance	Yes	For closure and postclosure, a bond, insurance, or trust fund is required.
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the states regulation or program.

Sources:

Arizona Administrative Code (ACC) Title 18-9-1.

Arizona Department of Environmental Quality(ADEQ) web page (http://www.adeq.state.az.us/).

California

California has consolidated all of its environmental agencies under the California EPA (Cal EPA); however, each board remains autonomous under the Cal EPA as do the Regional Boards. The California Integrated Waste Management Board (CIWMB) is responsible for regulating solid waste and solid waste management facilities, except surface impoundments. The State Water Resources Control Board (SWRCB) regulates and governs the design, operation, and maintenance of surface impoundments in the California Water Regulations. Regional Water Quality Control Boards implement the NPDES and state waste management programs.

California is authorized to implement the federal Clean Water Act (CWA) NPDES program. Any owner/operator of a surface impoundment subject to NPDES requirements must submit a federal NPDES permit application, which is channeled to the Regional board and receives approval from the SWRCB and USEPA Region. California has also developed a general NPDES permit. California has waste discharge requirements (WDRs) that regulates discharges of waste to land.

California Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	Yes	New and existing surface impoundments must be a minimum distance of 5 feet above the highest anticipated elevation of underlying groundwater. All engineered structures constituting any portion of a surface impoundment must be capable of providing support and capable of withstanding hydraulic pressure gradients to prevent failure due to settlement, compression, or uplift and all effects of ground motion resulting from the maximum probable earthquake and provide adequate foundations or support for the waste management unit. New and existing Class II surface impoundments must comply with flooding, tidal wave, seismic design, and rapid geologic change (e.g., earthquake) requirements. New Class II units and expansions of existing Class II units must not be located within 200 feet of a Holocene fault. Materials used in containment structures must comply with specific permeability requirements.

(continued)

California Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Design Criteria (liner, leachate collection)	Yes	New surface impoundments must comply with stringent liner requirements. Existing surface impoundments must be lined and fitted with subsurface barriers as needed and feasible. Synthetic liners are not required for surface impoundments, but if used must be inspected weekly. New surface impoundments must comply with stringent leachate collection and removal system requirements. Existing surface impoundments must be fitted with leachate collection and removal systems as feasible.
Operating Criteria	Yes	Specific mandatory precipitation and drainage control requirements exist for surface impoundments. Surface impoundments must have sufficient freeboard to accommodate seasonal precipitation, but in no case less than two feet and designed and constructed to prevent overtopping as a result of wind conditions likely to accompany such precipitation, except where potential overflows would be to exterior surface impoundments. In addition, no discharges from surface impoundments are allowed except as authorized by waste discharge requirements. Slope requirements, especially in drier areas of the state, are incorporated on a site-specific basis through WDRs. The General Storm Water Permit Application requires development and implementation of Storm Water Pollution Prevention Plans. These plans must contain over ten specific elements, such as practices to reduce pollutants, elimination of non-storm water discharges, and spill prevention and response procedures.

(continued)

California Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Monitoring	Yes	**Groundwater:** At a minimum, monitoring must occur quarterly. Regional boards must also establish a water quality protection standard containing a list of constituents of concern, concentration limits, and points of compliance. Monitoring must consist of a sufficient number of wells, installed at appropriate locations and depths to yield groundwater samples that indicate leakage from a waste management unit; represent the backgroundwater quality; and represent the quality of groundwater passing the points of compliance. Detailed, statistical procedures are provided to determine whether to initiate corrective action. Owners/operators of new units must collect monitoring data before wastes are managed and must collect background soil-pore liquid data from beneath the unit before construction occurs. The General Industrial Storm Water Permit also contains a four-tier, highly detailed monitoring strategy. **Surface Water:** Extensive surface water monitoring requirements exist that contain essentially the same components as the groundwater monitoring program. **Waste Analysis Requirements:** Owners/operators must report the types, quantities, and concentrations of wastes proposed to be managed at each waste unit. They must also provide an analysis of projected waste decomposition processes for each unit. The following Information also is required on: (1) the physical characteristics of the waste management unit; (2) how the unit will affect surrounding ground and surface water; and (3) how these waters may affect the unit. Additional reporting requirements exist.
Reporting and Recordkeeping	Yes	State regulations specify requirements for reporting and recordkeeping.
Inspection and Enforcement	Yes	State regulations give the authority to inspect, but do not specify the frequency.

(continued)

California Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Performance Standards and Corrective Action	Yes	**Contingency Plan:** Dischargers must submit operation plans describing the waste management unit operation which shall include contingency plans for the failure or breakdown of waste handling facilities or containment systems, including notice of any such failure, or any detection of waste or leachate in monitoring facilities to the regional board, local governments, and water users downgradient of the surface impoundment (23 CCR Article 9 2596). **Emergency Planning:** Owners/operators must implement detection monitoring and evaluation monitoring programs and corrective action measures, as necessary, to comply with water quality protection standards and reporting requirements. **Corrective Action:** Regional boards will establish the water quality protection standards for corrective action. In conjunction with corrective action measures, owners/operators must establish and implement a water quality monitoring program to demonstrate the effectiveness of the corrective action program and must submit reports at least semiannually on the effectiveness of the program. If an owner/operator is involved in corrective action at the end of a waste management unit's compliance period, the compliance period must be extended so that the unit is in continuous compliance with its water quality protection standard for at least 3 consecutive years.
Closure/Postclosure Care	Yes	Mandatory Clean-Closure Attempt: Unless the discharger demonstrates, and the RWQCB finds, that it is infeasible to attempt clean-closure of the impoundment, then all residual wastes, including sludges, precipitates, settled solids, and liner materials contaminated by wastes, shall be completely removed from the impoundment and discharged to an approved Unit. Remaining containment features shall be inspected for contamination and, if not contaminated, can be dismantled. Any natural geologic materials beneath or adjacent to the closed impoundment that have been contaminated shall be removed for disposal at an appropriate Unit. For surface impoundments that are successfully clean-closed, as herein described, the RWQCB shall declare the Unit no longer subject to the SWRCB-promulgated requirements of this title. If, after reasonable attempts to remove such contaminated materials, the discharger demonstrates that removal of all remaining contamination is infeasible, the surface impoundment shall be closed as a landfill or land treatment unit.
Financial Assurance	Yes	State regulations specify requirements for financial assurance.

(continued)

California Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	Yes	State regulations specify requirements for air emissions from surface impoundments.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the states regulation or program.

Source:

California Code of Regulations (CCR).

Colorado

In Colorado, responsibility for regulating and permitting surface impoundments is consolidated in the Hazardous Materials and Waste Management Division of the Colorado Department of Public Health and the Environment (CDPHE).

Colorado's industrial waste regulations specify a set of standards and criteria for waste impoundments as indicated in the table below. Industrial wastes disposed of on the property of the generator are not required to obtain a permit (known as the "Certification of Designation") but must still abide by the regulations. In addition, impoundments that discharge to surface water or groundwater must obtain a State NPDES discharge permit.

Colorado Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	No	Not specified in state regulations.
Design Criteria (liner, leachate collection)	Yes	State solid waste regulations require that impoundments constructed after October 9, 1993 must have an engineering design report and, for certain groundwater classes, a liner and leachate collection system is required. Groundwater monitoring, however, may be required for impoundments permitted prior to this date if seepage and impairment of groundwater is probable. State regulations also specify that impoundments meet embankment design requirements. (Volume 6 CCR 1007-2 Part 1B-9)
Operating Criteria	Yes	State solid waste regulations specify that impoundments must meet standards for measurement of depth and have operational inspections. For impoundments constructed after October 9, 1993, an operations report and a minimum of 2 feet of freeboard is required. (Volume 6 CCR 1007-2 Part 1B-9)
Monitoring	Yes	The state NPDES regulations require groundwater monitoring. The solid waste regulations further specify that groundwater monitoring is required of indicator parameters of upgradient and downgradient wells on an annual or quarterly basis (depending on groundwater classification) for impoundments constructed after October 9, 1993. (Volume 6 CCR 1007-2 Part 1B-9)
Reporting and Recordkeeping	Yes	For impoundments constructed after October 9, 1993, the state NPDES regulations require monthly summary records be maintained until closure.
Inspection and Enforcement	Yes	State regulations give the authority to inspect, but do not specify the frequency.

(continued)

Colorado Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Performance Standards and Corrective Action	Yes	State NPDES regulations require a contingency plan for impoundments constructed after October 9, 1993 in certain groundwater classes dictating conditions for corrective action
Closure/Postclosure Care	Yes	State solid waste regulations require closure and postclosure plans. The Plans include a final cover sufficient to ensure compliance with state groundwater standards. Regulations specify that the postclosure period be a minimum of 30 years (duration subject to modification a case-by-case basis), and include maintenance and monitoring. An additional requirement for surface impoundments includes characterization of residual sediments for hazardous characteristics for impoundments constructed after October 9, 1993.
Financial Assurance	Yes	For closure, postclosure, and corrective action, state solid waste regulations require a trust fund, letter of credit, surety bond, insurance, financial test, corporate guarantee certificate of deposit, or combination. The financial assurance requirements are applicable to those impoundments operating after October 9, 1997 (if they dispose less than 20 tons per day) or April 9, 1997 (if they dispose greater than 20 tons per day).
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	Yes	State regulations require the operator of a facility employing evaporative treatment to calculate and record on a quarterly basis: the total volume of wastes and precipitation added to each impoundment; the total PAN evaporation during the quarter at the Weather Service or other station specified, multiplied by the appropriate "Lake Evaporation Coefficient," then multiplied by the average surface area of each impoundment during the quarter, to give the maximum possible volume of evaporate loss; and the total change in volume of wastes stored in each impoundment by two methods: (1) volume on first day of quarter subtracted from the volume on the last day of the quarter (from depth readings); and (2) maximum evaporative loss subtracted from the total added. Seepage shall be neglected in this calculation.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the states regulation or program.

Sources:

Colorado Code of Regulations (CCR) – 6 CCR 1007-2 Part 1; 5 CCR 1002-61.

Colorado Department of Public Health and the Environment (CDPHE) web page (http://www.cdphe.state.co.us).

Connecticut

Connecticut's Waste Engineering and Enforcement Division indicates that nonhazardous surface impoundments may be regulated under the State Remediation Standards, depending on the amount and type of constituents in the ground near the surface impoundments. In addition, surface impoundments may be regulated under the state's NPDES program if they discharge to surface waters. Connecticut is authorized to administer the federal NPDES program under its Surface Water Discharge Permit Program. Connecticut also has a Groundwater Discharge Permit Program that regulates discharges to groundwater from any source, including but not limited to large septic systems, agricultural waste management systems, and all waste landfills.

Connecticut Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	No	Not specified in state regulations.
Design Criteria (liner, leachate collection)	No	Not specified in state regulations.
Operating Criteria	Yes	The commissioner may require any applicant or permittee for a NPDES permit, as part of the detailed design of any treatment facilities and/or spill prevention and control systems required, to develop an operation and maintenance manual which shall fully describe the operation and maintenance of the systems, including but not limited to the following aspects: (1) A plan for operational monitoring and inspection (2) Instrument calibration frequency (3) Inventory of necessary chemicals, equipment and spare parts (4) A plan for preventive maintenance (5) Operating instructions (6) Housekeeping (7) Security measures.
Monitoring	Yes	State regulations specify that any permittee of the NPDES permit has requirements for monitoring of discharges.
Reporting and Recordkeeping	Yes	All monitoring reports shall be submitted to the director in accordance with the requirements and the terms and conditions of the NPDES permit.
Inspection and Enforcement	Yes	State regulations give the authority to inspect, but do not specify the frequency.
Performance Standards and Corrective Action	No	Not specified in state regulations.

(continued)

Connecticut Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Closure/Postclosure Care	No	Not specified in state regulations.
Financial Assurance	No	Not specified in state regulations.
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the states regulation or program.

Source:

Connecticut General Statutes (CGS)

Delaware

The Division of Water Resources of the Delaware Department of Natural Resources and Environmental Control has authority over surface impoundments in the state. Because Delaware regulates surface impoundments in conjunction with other programs, it does not classify surface impoundments or waste types; however, permits are required. Surface impoundments must be covered by a state operating permit (required for the construction and/or operation of facilities handling liquid waste), and a state NPDES permit for discharges into surface or groundwater. For facilities that discharge, the NPDES permit and state operating permit are consolidated into one permit.

Delaware Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	No	Not specified in state regulations.
Design Criteria (liner, leachate collection)	Yes (guidance only)	Not specified in state regulations, but included in the Recommended Standards for Sewage Treatment Works (Ten States Standards).
Operating Criteria	Yes (guidance only)	Not specified in state regulations, but included in the Recommended Standards for Sewage Treatment Works (Ten States Standards).
Monitoring	Case-by-case	The monitoring requirements specified by the Department in the State operating permit may include groundwater monitoring. [WPCR § 5.01(g)(8)]
Reporting and Recordkeeping	No	Not specified in state regulations.
Inspection and Enforcement	Yes	State regulations give the authority to inspect but do not specify the frequency.
Performance Standards and Corrective Action	No	Not specified in state regulations.
Closure/Postclosure Care	No	Not specified in state regulations.
Financial Assurance	No	Not specified in state regulations.

(continued)

Delaware Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	Yes	A permit is required for surface impoundments that emit more than 25 tons/year of volatile organic compounds (VOCs). Owners or operators of a regulated source must perform testing to demonstrate that the source is in compliance with State standards, and maintain records of the testing for a minimum of 5 years.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the states regulation or program.

Sources:

Delaware Code of Regulations Governing Water Pollution (WPCR).

Air Pollution (APCR) Regulation No. 24-50.

Florida

The Florida Department of Environmental Protection requires groundwater permits and state NPDES permits (for discharges to surface water only) for surface impoundments used to manage nonhazardous waste. Surface impoundments that manage leachate are regulated separately under the solid waste management facilities regulations. Otherwise, surface impoundments are excluded from the solid waste management facilities regulations.

Florida Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	No	Not specified in state regulations.
Design Criteria (liner, leachate collection)	No	Not specified in state regulations.
Operating Criteria	No	Not specified in state regulations.
Monitoring	Yes	State regulations require groundwater monitoring for certain classes of groundwater, with at least 1 upgradient, 1 intermediate, and 1 compliance well. The constituents are not specified in the regulations.
Reporting and Recordkeeping	Yes	State regulations require quarterly groundwater monitoring reports be maintained.
Inspection and Enforcement	Yes	State regulations give the authority to inspect, but do not specify the frequency.
Performance Standards and Corrective Action	Yes	State regulations require corrective action if groundwater exceeds state standards outside ZOD and include secondary standards for certain classes of groundwater.
Closure/Postclosure Care	Yes	Closure with waste in place is allowed by state regulations if the impoundment is dewatered, lined, and measures (such as leachate collection) are in place to ensure liner integrity. The regulations do not specify any other closure/postclosure provisions.
Financial Assurance	No	Not specified in state regulations.

(continued)

Florida Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the states regulation or program.

Sources:

Florida Administrative Code (FAC) Chapters 62-520; 62-522; 62-620; 62-701.

Florida Department of Environmental Protection (FDEP) web page (http://www.dep.state.fl.us/).

Georgia

The Environmental Protection Division (EPD) of the Georgia Department of Natural Resources has the responsibility for regulating surface impoundments in Georgia. EPD does not require permits for non-discharging ponds, however, a few slow infiltration ponds are permitted. Surface impoundments that discharge to groundwater must obtain a state land disposal system permit. Impoundments that discharge to surface water must obtain a state NPDES permit.

Georgia Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	No	Not specified in state regulations, but may be applied on a permit-specific basis.
Design Criteria (liner, leachate collection)	No	Not specified in state regulations, but may be applied on a permit-specific basis.
Operating Criteria	No	Not specified in state regulations, but may be applied on a permit-specific basis.
Monitoring	Case-by-case	Groundwater monitoring may be required under land disposal system permit, with details determined on a site specific basis.
Reporting and Recordkeeping	No	Not specified in state regulations, but may be applied on a permit-specific basis.
Inspection and Enforcement	Yes	State regulations give the authority to inspect, but do not specify the frequency.
Performance Standards and Corrective Action	Yes	The under land disposal permit requires that groundwater must be within state maximum contaminant levels (MCLs). Where groundwater exceeds state MCLs, corrective measures and a compliance schedules are determined on a site-specific basis.
Closure/Postclosure Care	No	Not specified in state regulations, but may be applied on a permit-specific basis.
Financial Assurance	No	Not specified in state regulations, but may be applied on a permit-specific basis.

(continued)

Georgia Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the states regulation or program.

Sources:

Official Code of Georgia Statutes (OCGA) 12-8-20.

Georgia Regulations – Control No. 391-3-4; 391-3-6-.11.

Georgia Department of Natural Resources (GDNR) web page (http://www.dnr.state.ga.us/dnr/environ).

Hawaii

Hawaii's environmental regulations, administered by the Environmental Management Division of the Department of Health, include few requirements applicable to nonhazardous waste surface impoundments beyond the requirements associated with a state NPDES permit for discharges to surface or groundwater. In addition to the NPDES regulations, there are separate regulations and guidance governing wastewater treatment works.

Hawaii Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	Yes	For wastewater treatment works, treatment units must be located 25 feet or more from the property line and more than 10 feet away from buildings and swimming pools. Private wastewater treatment works must also conform to the Recommended Standards for Wastewater Facilities (Ten State Standards).
Design Criteria (liner, leachate collection)	No	Not specified in state regulations.
Operating Criteria	No	Not specified in state regulations.
Monitoring	No	Not specified in state regulations.
Reporting and Recordkeeping	No	Not specified in state regulations.
Inspection and Enforcement	Yes	State regulations give the authority to inspect, but do not specify the frequency.
Performance Standards and Corrective Action	No	Not specified in state regulations.
Closure/Postclosure Care	No	Not specified in state regulations.
Financial Assurance	No	Not specified in state regulations.

(continued)

Hawaii Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the states regulation or program.

Source:

Hawaii Administrative Rules Chapter 55.

Idaho

In Idaho, the only regulations applicable to surface impoundments are design and operating requirements for ore processing by cyanidation or mine tailing impoundments – there are not even state NPDES regulations that apply since Idaho is not an NPDES-authorized state. Idaho relies on Recommended Standards for Sewage Treatment Works (Ten State Standards) in reviewing wastewater treatment plant plans.

Idaho Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	No	Not specified in state regulations.
Design Criteria (liner, leachate collection)	No	Not specified in state regulations.
Operating Criteria	No	Not specified in state regulations.
Monitoring	No	Not specified in state regulations.
Reporting and Recordkeeping	No	Not specified in state regulations.
Inspection and Enforcement	Yes	State regulations give the authority to inspect, but do not specify the frequency.
Performance Standards and Corrective Action	No	Not specified in state regulations.
Closure/Postclosure Care	No	Not specified in state regulations.
Financial Assurance	No	Not specified in state regulations.
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the states regulation or program.

Source:

Idaho Regulations – IDAPA Department of Environmental Quality Title 01 Chapter 02.

Illinois

Illinois requirements regarding nonhazardous surface impoundments are administered by the Illinois Environmental Protection Agency (IEPA) by the Bureau of Water.

The Illinois Environmental Protection Act exempts on-site treatment, storage, and disposal from permitting requirements. Owners/operators of surface impoundments, however, that receive special waste (i.e., from off-site) not listed in an NPDES permit must obtain an operating permit, unless the owner/operator gives notice of the operation to IEPA 30 days after operations begin, and every three years thereafter. In the three-year notice, the owner/operator must submit information on the types and amounts of waste stored, treated, or disposed each year; the remaining capacity of the facility; and the remaining expected life of the facility. A state NPDES permit is required for impoundments discharging into surface waters.

In addition, Illinois has specific design standards for new or modified livestock waste treatment lagoons after November 12, 1998 (35 IAC 503.204). Owners/operators of these lagoons must construct or modify the lagoon in accordance with "Design of Anaerobic Lagoons for Animal Waste Management" which is incorporated by reference in 35 IAC 506.104. Some of these requirements are included in the table below.

The IEPA Bureau of Air implements the requirements of the Clean Air Act, develops state rules governing air quality standards, evaluates and issues permits for construction and operation, and monitors Illinois' air quality.

Illinois Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	No	Not specified in state regulations, but may be applied on a permit-specific basis.
Design Criteria (liner, leachate collection)	No	Not specified in state regulations, but may be applied on a permit-specific basis.
Operating Criteria	Yes	Livestock waste treatment lagoons must include: • The use of a liner at least 2 feet thick. • Entrapment dikes and other appropriate control measures to prevent any spillage of contaminants from causing water pollution. • Freeboard of at least 2 feet above the fluid surface level of the lagoon. Extensive groundwater quality standards exist, and owners/operators cannot cause, threaten, or allow the release of any contaminant so as to violate a groundwater quality standard.

(continued)

Illinois Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Monitoring	No	Not specified in state regulations, but may be applied on a permit-specific basis.
Reporting and Recordkeeping	No	Not specified in state regulations, but may be applied on a permit-specific basis.
Inspection and Enforcement	Yes	The state regulations provide IEPA with the authority to require periodic reports, inspect facilities, and have access to records. The frequency of the inspections is not specified.
Performance Standards and Corrective Action	Yes	No person shall cause or allow the release of any contaminant to a resource groundwater such that: treatment is necessary to continue an existing use or to assure a potential use of such groundwater, or an existing or potential use of such groundwater is precluded.
Closure/Postclosure Care	No	Not specified in state regulations.
Financial Assurance	No	Not specified in state regulations
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the states regulation or program.

Sources:

Illinois Regulations: Title 35 Subtitle C Parts 305, 309; Title 35 Subtitle E Part 506.

Illinois Statutes: 415 ILCS 5/21(d).

Illinois Environmental Protection Agency (IEPA) web page (http://www.epa.state.il.us/water/index.html).

Indiana

In Indiana, nonhazardous waste surface impoundments are regulated through the Indiana Department of Environmental Management (IDEM) by the Office of Land Quality (OLQ) and the Office of Water Management (OWM). Nonhazardous waste surface impoundments are exempt from Indiana's Solid Waste Management requirements; however, closure of an impoundment is subject to approval by IDEM and usually occurs, at the discretion of IDEM, in the same manner as other solid waste management facilities (e.g., final cover and groundwater monitoring required).

The construction, installation, or modification of any facility used for wastewater treatment requires that a construction permit be obtained from the OWM Permits Branch. These permits are required for the construction of all water pollution treatment/control facilities including industrial wastewater facilities. All new facilities (i.e., within the last 20 years) must have a construction permit.

Off-site "earthen lagoons" that store industrial waste product are regulated by the Water Pollution Control Board under 327 IAC 6.1. IDEM's OWM implements and enforces the Federal Water Pollution Control Act (as amended), also referred to as the Clean Water Act. IDEM's OWM Wastewater Permitting Branch has responsibility for the permit program.

Under 329 IAC 10-8.1-4, decharacterized wastes can be classified as a "special waste" if the waste contains a toxicity characteristic contaminant listed in 40 CFR 261.24, Table 1, at a level equal to or greater than seventy-five percent (75%) of the regulatory level for that contaminant.

The IDEM Office of Air Management (OAM) implements the requirements of the Clean Air Act, develops state rules governing air quality standards, evaluates and issues permits for construction and operation, and monitors Indiana's air quality.

Indiana Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	Case-by-case	Design criteria and location standards are not specified in state regulations, but may be applied through construction permits on a site-specific basis. Location restriction are specified for earthen lagoons under 327 IAC 6.1-8-3 ("Site restrictions for off-site storage structures").

(continued)

Indiana Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Design Criteria (liner, leachate collection)	Case-by-case	Not specified in state regulations. May be applied through construction permits on a site-specific basis. Generally, IDEM and owners/operators follow the Recommended Standards for Wastewater Facilities and Sewage Works (Ten States Standards), 1990 edition, as guidance. Owners/operators of wastewater treatment ponds generally must comply with standards for liners, soil borings/freeboard limits, etc., to protect the waters of the state.
Operating Criteria	Yes	The industrial activity permit requirements contain a waste discharge/run-off control performance standard. Freeboard requirements are specified in 327 IAC 6.1 for earthen lagoons. Other operating criteria for earthen lagoon are specified at 327 IAC 6.1-8-7 ("Operational requirements for off-site storage structures").
Monitoring	Case-by-case	Not specified in state regulations. May be applied by the IDEM on a site-specific basis upon closure with waste in place.
Reporting and Recordkeeping	Yes	Reporting of discharge monitoring results must be maintained for 3 years.
Inspection and Enforcement	Yes	Owners/operators conducting practices that are likely to cause exceedances of applicable effluent limitations must notify the commissioner. IDEM must be allowed to enter the premises of a facility at any reasonable time to inspect, sample, or monitor. IDEM's Office of Enforcement has authority to issue civil, administrative, judicial, and criminal penalties.
Performance Standards and Corrective Action	No	Not specified in state regulations.
Closure/Postclosure Care	Yes	327 IAC 6.1-8-8, "Closure and abandonment of off-site storage structures" applies.
Financial Assurance	No	Not specified in state regulations.
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the state's regulation or program.

Sources:

Indiana Administrative Code (IAC)

Indiana Department of Environmental Management (IDEM) web page (http://www.state.in.us/idem/index.html).

Iowa

In Iowa, nonhazardous waste surface impoundments are regulated through the Environmental Protection Division (EPD) of the Iowa Department of Natural Resources (IDNR). The Wastewater Section of the EPD issues construction, operation (discharges to groundwater), and NPDES permits (discharges to surface water) for surface impoundments.

Iowa also has specific requirements in place for waste stabilization ponds under the state water rules. These requirements are included below.

Iowa Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	Yes	State permit-to-construct regulations require that all surface impoundments must be located 1000 feet from residences and commercial buildings, 400 feet or more from wells (depending on type) and lakes, and 25 feet from property lines.
Design Criteria (liner, leachate collection)	Yes	For waste stabilization ponds only, pond length can not exceed three times the width, capacity must be equivalent to 180 times the average daily design flow, bottom lined with impermeable natural or man-made material, and the depth must be uniform from 3 to 5 feet. For other types of impoundments, not specified in regulations but may be required as part of construction permit on a site-specific basis.
Operating Criteria	Yes	For waste stabilization ponds only, a minimum freeboard of 2 feet is required, as well as fencing and vegetation. For other types of impoundments, not specified in regulations but may be required as part of NPDES or operating permit on a site-specific basis.
Monitoring	No	Not specified in regulations but groundwater monitoring may be required on a site-specific basis.
Reporting and Recordkeeping	Yes	State regulations require monthly submission of records of operation.
Inspection and Enforcement	Yes	State regulations provide the authority to inspect, but do not specify the frequency.
Performance Standards and Corrective Action	Case-by-case	Determined on a permit-specific basis.
Closure/Postclosure Care	No	Not specified in state regulations.
Financial Assurance	No	Not specified in state regulations.

(continued)

Iowa Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the state's regulation or program.

Sources:

Iowa Administrative Code (IAC) Title IV, Chapters 63, 64 and 69.

Iowa Department of Natural Resources (IDNR) web page (http://www.state.ia.us/government/dnr).

Kansas

In Kansas, nonhazardous waste surface impoundments are regulated through the Bureau of Waste Management, Division of Environment, Kansas Department of Health and Environment.

Kansas requires a solid waste disposal permit if the owner/operator plans to close the surface impoundment with waste still in place; the expiration date of this permit is determined on a case-by-case basis. In addition, all impoundments that discharge to surface or groundwater must obtain a state NPDES permit, which is valid for up to 5 years.

Kansas Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	Yes	The solid was disposal permit regulations require that surface impoundments be located at least one-half mile from a navigable stream used for interstate commerce; one mile from a public surface water supply; and 25 feet from pipelines, underground utility lines, or an electric transmission line easement. There are also restrictions on 100-year floodplains and endangered species areas.
Design Criteria (liner, leachate collection)	Yes	The solid waste disposal permit regulations specify restrictions for limited access and requires all-weather access roads.
Operating Criteria	No	Not specified in state regulations.
Monitoring	Yes	Appropriate groundwater monitoring required, but specific details are not listed in the regulations (determined on a permit-specific basis).
Reporting and Recordkeeping	Yes	The solid waste disposal permit regulations require the facility to retain records of volume or tonnage of waste received, land area used, and other records as specified in the permit. A summary report of these records must be submitted to the Department.
Inspection and Enforcement	Yes	State regulations provide the authority to inspect, but do not specify the frequency.
Performance Standards and Corrective Action	No	Not specified in state regulations.
Closure/Postclosure Care	Yes	The solid waste permit regulations require a closure plan, including provisions for postclosure operation and maintenance. The plan may also include liners and leachate collection if deemed applicable by the state. There is a postclosure period of at least 30 years.

(continued)

Kansas Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Financial Assurance	Yes	The solid waste permit regulations require a trust fund, surety bond, irrevocable letter of credit, or insurance; or pass a financial test or obtain a financial guarantee from a related entity. The operator/owner of the impoundment must also have liability insurance coverage.
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the state's regulation or program.

Sources:

Kansas Statutes – KSA 65-33; 65-34.

Kansas Regulations – KAR 28-13; 28-16; 28-29-2 through 28-29-23.

Kansas Department of Health and Environment (KDHE) web page (http://www.kdhe.state.ks.us/waste/).

Kentucky

In Kentucky, nonhazardous waste surface impoundments with discharges to surface or groundwater must obtain a state NPDES (KPDES) permit. The regulations are largely silent on the requirements under these permits, leaving specific requirements to be determined by the permit writer on a case-by-case basis. Surface impoundments that have a KPDES permit are covered under a Permit-by-Rule for purposes of the solid waste regulations. The Permit-by-Rule contains no specific requirements beyond those of the KPDES regulations, except that groundwater monitoring may be required on a case-by-case basis and that the state has authority to require corrective action.

In addition to the KPDES and solid waste permit, surface impoundments constructed after August 24, 1994 are required to develop a Groundwater Protection Plan (GWPP). The GWPP must consider site hydrogeology and minimize discharges to soil. The actions required to meet the goals of the GWPP are determined by the facility operator, and minimization of discharges to soil may be accomplished through liners, secondary containment, leak detection, or other measures.

Kentucky Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	Yes	The regulations specify restrictions for floodplains, endangered species habitats, and wetlands.
Design Criteria (liner, leachate collection)	Yes	The required GWPP must consider hydrogeology and minimize discharges to soil. At the operator's option, this may be accomplished through liners, secondary containment, leak detection, or other measures. No other controls are specified by the NPDES or solid waste regulations, but may be required in the permits on a site-specific basis.
Operating Criteria	No	Not specified in state regulations.
Monitoring	Case-by-case	The solid waste regulations specify that groundwater monitoring may be required on a case-by-case basis.
Reporting and Recordkeeping	Yes	A GWPP must be submitted upon request, and records of compliance must be retained. The solid waste regulations require annual or quarterly reports covering facility activities, as determined in the permit.
Inspection and Enforcement	Yes	State regulations give the authority to inspect, but do not specify the frequency.

(continued)

Kentucky Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Performance Standards and Corrective Action	Yes	The solid waste regulations provide the authority to require that appropriate corrective action to be implemented if needed. The regulations also specify that surface impoundments may not cause exceedances of MCLs in groundwater, adversely impact endangered species, or violate applicable air pollution requirements.
Closure/Postclosure Care	No	Not specified in state regulations
Financial Assurance	Yes	The solid waste regulations state that financial assurance requirements apply to owners/operators of any solid waste disposal site or facility. Mechanisms can include performance bond, surety bond, letter of credit, escrow or trust fund. Not specified in state regulations.
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the state's regulation or program.

Sources:

Kentucky Administrative Regulations (KAR) Title 401, Chapters 5, 47, and 48.

Kentucky Department for Environmental Protection (KDEP) web page (http://www.nr.state.ky.us/nrepc/dep/dep2.htm/).

Louisiana

In Louisiana, nonhazardous waste surface impoundments are regulated by the Solid Waste Division, Office of Solid and Hazardous Waste, Department of Environmental Quality (Title 33, Part VII, Subpart 1, Chapter 7, Subchapter B of the Louisiana Code). Section 709–Standards Governing All Solid Waste Disposal Facilities (Type I and II)–establishes the basic management program for solid waste within the state. A Type I surface impoundment is used for the disposal of industrial solid wastes, and a Type II surface impoundment is used for the disposal of commercial or residential solid wastes. Discharges are subject to the Louisiana Pollutant Discharge Elimination System (LPDES) program at Title 33, Part IX.

All surface impoundments (dischargers and nondischargers) storing nonhazardous waste are required to obtain a state solid waste permit. In addition, all impoundments that discharge are required to obtain a state NPDES permit.

Louisiana Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	Yes	Location standards are specified in Louisiana Administrative Code (LAC) Sections 521, 709, and 713. These standards include (1) requirements for accessing (e.g., via water or land) surface impoundment facilities; (2) restrictions for siting such facilities near airports, critical environmental areas (e.g., wetlands, estuaries, wildlife hatchery areas; habitats of endangered species), faults, 100-year flood plains, and other requirements; and (3) requirement for compliance with local land use and zoning laws.
Design Criteria (liner, leachate collection)	Yes	State regulations specify requirements for liners, leachate detection, collection, and removal systems, run-on/run-off controls, standards for dikes and berms, and freeboard limits.
Operating Criteria	Yes	Facilities must have a barrier around the facility that prevents unauthorized ingress or egress, except by willful entry. During operating hours, each facility entry point must be continuously monitored, manned, or locked. During non-operating hours, each facility entry point must be locked. These standards also include requirements for buffer zones, fire protection and medical care, and other requirements. Surface impoundments must be inspected daily and after storms to detect evidence of deterioration of the dikes and levees, overtopping, malfunctions, or improper operation.

(continued)

Louisiana Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Monitoring	Yes	**Groundwater Monitoring:** A groundwater monitoring system must be installed at each facility. The system must contain a sufficient number of wells, installed at appropriate locations and depths, to yield groundwater samples from the uppermost aquifer. These standards include specific requirements for groundwater sampling, location of wells, well construction, post-construction, plugging and abandonment of monitoring wells. **Surface Water Monitoring**: Under the Louisiana Water Discharge Permit System, effluent standards and limitations are imposed upon discharges. The control and treatment limitations must be equivalent to secondary treatment, best practicable control technology currently available, best conventional technology for conventional pollutants, and/or best available control technology economically achievable for nonconventional or toxic pollutants. The permitting authority may, however, prescribe more stringent or seasonal limitations.
Reporting and Recordkeeping	Yes	Facilities must submit annual reports to the administrative authority indicating quantities and types of solid waste and an estimate of the remaining permitted capacity. Records must be maintained for the life of the facility and at least three years after closure.
Inspection and Enforcement	Yes	The Solid Waste Division will inspect each facility and each facility's records periodically to determine the facility's compliance with the terms of standard or temporary permits and these regulations.
Performance Standards and Corrective Action	Yes	Performance standards and corrective action requirements are specified by the state regulations.
Closure/Postclosure Care	Yes	Standards governing facility closure are contained in LAC 33:VII.713.E (Type I and II surface impoundments). The closure plan for all facilities must include the following: the date of final closure, the method to be used and steps necessary for closing the facility; and the estimated cost of closure of the facility, based on the cost of hiring a third party to close the facility at the point in the facility's operating life when the extent and manner of its operation would make closure the most expensive.
Financial Assurance	Yes	The state solid waste permit requires evidence of a financial assurance mechanism for closure and/or postclosure care and corrective action for known releases when needed.

(continued)

Louisiana Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	Yes	Facilities receiving waste with a potential to produce methane gas are subject to air monitoring requirements.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the states regulation or program.

Sources:

Louisiana Administrative Code (LAC).

Louisiana Department of Environmental Quality (LDEQ) web page (http://www.deq.state.la.us).

Maine

Maine does not have any regulatory standards or management guidelines specific to surface impoundments. However, if the facility discharges, Maine's Bureau of Land & Water Quality Control (L&W) may include, on a case-by-case basis, standards and guidelines for surface impoundments in the state's wastewater discharge permit and site approval process.

If a surface impoundment has a point source discharge to surface waters of the United States, the owner/operator must obtain a federal NPDES permit pursuant to Section 402 of the Clean Water Act (CWA). Also pursuant to Section 402 of the CWA, NPDES permits are required for storm water discharges associated with an industrial activity. (Note: Region 1 issues NPDES permits, as Maine is not authorized.)

Licenses are required for discharges to surface waters and groundwater. Discharges to groundwater may be direct or indirect (e.g., infiltration-percolation lagoon). Discharges are subject to effluent limitations that require application of "best practicable treatment" (38 MRSA Section 414-A). Permits are issued by L&W. (Note: Maine has no infiltration-percolation lagoons holding industrial nonharardous wastewater. Some exist to hold storm water, which require a federal NPDES Permit.)

L&W must approve all industrial developments that occupy a land or water area in excess of 20 acres. L&W will approve the development as long as it will not adversely effect the natural environment; cause unreasonable erosion of soil or inhibit the natural transfer of the soil; cause unreasonable erosion of soil or inhibit the natural transfer of the soil; discharge to a significant groundwater aquifer; cause or increase flooding, etc. State contacts report that no on-site industrial nonharardous waste surface has land site approval. This may be because the impoundment was constructed prior to 1970 (in which case the impoundment is "grandfathered"), does not meet the minimum size requirement, or is not a permitting priority.

Maine Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	No	Not specified in state regulations.
Design Criteria (liner, leachate collection)	Case-by-case	L&W usually includes an impervious clay liner requirement in the wastewater discharge permit.
Operating Criteria	No	Not specified in state regulations.

(continued)

Maine Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Monitoring	Case-by-case	**Groundwater Monitoring:** L&W may include groundwater monitoring as a requirement for site approval, however, only in limited circumstances. **Surface Water Monitoring:** Surface water monitoring is required if the facility has a federal NPDES permit.
Reporting and Recordkeeping	No	Not specified in state regulations.
Inspection and Enforcement	Yes	MDEP is authorized to conduct on-site inspections of wastewater discharge licenses (38 MRSA Section 414). MDEP also has administrative, civil, and criminal enforcement authority, including the authority to levy penalties.
Performance Standards and Corrective Action	No	Not specified in state regulations.
Closure/Postclosure Care	No	Not specified in state regulations.
Financial Assurance	No	Not specified in state regulations.
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the states regulation or program.

Sources:

Maine Revised Statutes Annotated (MRSA).

Maine Department of Environmental Protection (MDEP) web page (http://janus.state.me.us/dep/home.htm).

Maryland

In Maryland, nonhazardous waste surface impoundments are regulated by the Water Management Administration, Wastewater Discharge Program (WDP) of the Maryland Department of the Environment (MDE) and the Air and Radiation Management Administration (ARMA). The WDP has regulatory responsibility for the control of surface water discharges from industrial impoundments, including most other requirements for surface impoundments. ARMA is responsible for regulating air emissions from industrial surface impoundments. Maryland currently requires surface impoundments to have a permit to construct unless they are specifically exempt (exemptions listed in COMAR 26.11.02.10).

Maryland Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	Case-by-case	Not specified in state regulations. May be applied by the Department on a site-specific basis.
Design Criteria (liner, leachate collection)	Case-by-case	Not specified in state regulations. May be applied by the Department on a site-specific basis.
Operating Criteria	Yes	State regulations specify requirements for runon/runoff controls only. Additional requirements may be applied by the Department on a site-specific basis.
Monitoring	Case-by-case	**Groundwater/Leak Detection:** Not specified in state regulations. May be applied by the Department on a site-specific basis. **Surface Water Monitoring**: Not specified in state regulations. May be applied by the Department on a site-specific basis.
Reporting and Recordkeeping	No	Not specified in state regulations.
Inspection and Enforcement	Yes	State regulations give the authority to inspect, but do not specify the frequency.
Performance Standards and Corrective Action	No	Not specified in state regulations.
Closure/Postclosure Care	No	Not specified in state regulations.
Financial Assurance	No	Not specified in state regulations.

(continued)

Maryland Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	Yes	The Air and Regulations Management Administration regulations requires surface impoundments to have a permit to construct.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the states regulation, program, or guidance.

Sources:

Annotated Code of Maryland.

Code of Maryland Regulations (COMAR).

Maryland Department of the Environment (MDE) web page (http://www.mde.state.md.us).

Massachusetts

The Massachusetts Department of Environmental Protection does not regulate nonhazardous surface impoundments under solid waste regulations. Massachusetts is not authorized to administer the federal NPDES program.

Massachusetts Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	No	Not specified in state regulations.
Design Criteria (liner, leachate collection)	No	Not specified in state regulations.
Operating Criteria	No	Not specified in state regulations.
Monitoring	No	Not specified in state regulations.
Reporting and Recordkeeping	No	Not specified in state regulations.
Inspection and Enforcement	No	Not specified in state regulations.
Performance Standards and Corrective Action	No	Not specified in state regulations.
Closure/Postclosure Care	No	Not specified in state regulations.
Financial Assurance	No	Not specified in state regulations.
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the states regulation, program, or guidance.

Sources:

Code of Massachusetts Regulations (CMR).

Massachusetts Department of Environmental Protection web page (http://www.state.ma.us/dep).

Michigan

In Michigan, responsibility for regulating and permitting surface impoundments is consolidated in the state's water program of the Michigan Department of Environmental Quality (MDEQ) if wastewater is discharged to surface or groundwater. If an impoundment is being closed with waste in place, it is regulated under the Solid Waste Management Division.

An NPDES permit is required for impoundments that discharge to surface water and a State permit is required for discharges to groundwater. Both permits are valid for no more than five years, after which they must be renewed.

Michigan Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	Yes	State regulations require surface impoundments discharging to groundwater to be located 50 or more feet (depending on well type) from water supply wells. There must also be 4 feet of vertical isolation between the bottom of the pit and the uppermost groundwater level.
Design Criteria (liner, leachate collection)	Yes	A surface impoundment must have a composite liner, demonstrate that an impoundment is not leaking (at a rate likely to impact groundwater), or conduct monitoring verifying that the impoundment has not impacted groundwater and is not likely to do so.
Operating Criteria	Yes	Surface impoundments must meet certain operating criteria. This includes a minimum of 2 feet of freeboard, and earthen dikes must meet structural integrity and erosion control requirements.
Monitoring	Yes	Groundwater discharge permits require unlined impoundments to monitor for parameters and frequency which are specified in the permit on a case-by-case basis.
Reporting and Recordkeeping	Yes	The owner/operator of impoundments must report monitoring results at least annually.
Inspection and Enforcement	Yes	State regulations give the authority to inspect, but do not specify the frequency.
Performance Standards and Corrective Action	Yes	Notification is required and response action is determined by the state agency if groundwater exceeds state standards.

(continued)

Michigan Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Closure/Postclosure Care	Yes	Impoundments closing with waste in place are subject to Type III landfill closure requirements (i.e., final cover, 6 inches of topsoil, revegetation and erosion control, 30-year postclosure period, and biannual groundwater monitoring), and must remove all free liquids and demonstrate that waste has sufficient bearing capacity for final cover.
Financial Assurance	Yes	Impoundments closing with waste in place are subject to Type III landfill financial assurance requirements that mandate a bond, perpetual care trust, escrow account, or financial test for closure and postclosure care.
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the state's regulation or program.

Sources:

Michigan Administrative Code (MAC).

Michigan Department of Environmental Quality (MDEW) web page (http://www.deq.state.mi.us/).

Minnesota

In Minnesota, nonhazardous waste surface impoundments are regulated through the Water Quality Division of the Minnesota Pollution Control Agency (MPCA). A surface impoundment must be covered by the state NPDES permit for discharges to surface or groundwater.

Minnesota Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	No	Not specified in state regulations, but may be applied on a permit-specific basis.
Design Criteria (liner, leachate collection)	No	Not specified in state regulations, but may be applied on a permit-specific basis.
Operating Criteria	No	Not specified in state regulations, but may be applied on a permit-specific basis.
Monitoring	No	Groundwater monitoring not specified in state regulations, but may be applied on a permit-specific basis.
Reporting and Recordkeeping	No	No specified in state regulations.
Inspection and Enforcement	Yes	State regulations give the authority to inspect, but do not specify the frequency. Enforcement mechanisms are not specified in the regulations.
Performance Standards and Corrective Action	Yes	All surface impoundments must conform to applicable effluent limitations and water quality standards.
Closure/Postclosure Care	No	Not specified in state regulations.
Financial Assurance	No	Not specified in state regulations.

(continued)

Minnesota Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the state's regulation or program.

Sources:

Minnesota Statute – Chapter 115.

Minnesota Regulations – Chapters 7001 and 7050.

Minnesota Pollution Control Agency (MPCA) web page (http://www.state.in.us/idem/index.html).

Mississippi

In Mississippi, responsibility for regulating and permitting surface impoundments is consolidated in the state's Office of Pollution Control's Surface Water Division of the Mississippi Department of Environmental Quality (DEQ). Mississippi DEQ established guidelines for permitting of surface impoundments within the state.

Any person discharging wastes into waters of Mississippi must obtain an individual NPDES permit or be covered under a general NPDES permit. Any person operating a treatment works from which no discharge of wastes occurs must obtain a state operating permit. Permit writers have the flexibility to impose additional and/or more stringent conditions in the permits. The permit writers have internal guidance that they use. NPDES permits have a fixed term not to exceed five years. At the time of expiration, NPDES permits are reviewed. Permits are modified only if DEQ discovers new information about a facility or upon the request of permittee. State wastewater permits may be issued for a period up to the operating life of the facility.

Mississippi Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	Yes	The location of all surface impoundments within the state must be at least 150 feet from the nearest adjoining property line except where the adjoining property is zoned for commercial or industrial use, or where the adjoining property, dwelling, or commercial establishment is used for commercial or industrial use. The Permit Board will consider requests for exception.
Design Criteria (liner, leachate collection)	No	Not specified in state regulations.
Operating Criteria	No	Not specified in state regulations.
Monitoring	Yes	**Surface Water Monitoring:** Dischargers are subject to applicable federal effluent standards and limitations if the limitations are not in conflict with state laws. The Permit Board is authorized to specify more stringent effluent limitations to meet applicable water quality standards, treatment standards, or schedules of compliance established by state laws or regulations. The Permit Board specifies average and maximum daily quantitative limitations for the level of wastewater constituents in the discharge in terms of weight and, if appropriate, average or maximum concentration limits.
Reporting and Recordkeeping	Yes	A permittee required to monitor discharges must maintain records and results of the monitoring activities for a minimum of three years. The Permit Board must request the monitoring reports at least once a year.

(continued)

Mississippi Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Inspection and Enforcement	Yes	DEQ is authorized to conduct investigations relating to water quality and pollution causes, prevention, control, and abatement as it deems necessary. DEQ is also authorized to enforce the Mississippi Air and Water Pollution Control Law and all rules and regulations and orders promulgated thereunder.
Performance Standards and Corrective Action	No	Not specified in state regulations.
Closure/Postclosure Care	No	Not specified in state regulations.
Financial Assurance	No	Not specified in state regulations.
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the states regulation or program.

Sources:

Mississippi Statutes and Regulations.

Mississippi Department of Environmental Quality (MDEQ) web page (http://www.deq.state.ms.us).

Missouri

In Missouri, the Water Pollution Control Division of the Missouri Department of Natural Resources has the responsibility for regulating and permitting surface impoundments. The regulations for surface impoundments depend on whether there will be surface water or groundwater discharges, and whether the facility plans to close with waste in place. Surface impoundments that remove waste prior to closure are subject to the following permit programs:

- Wastewater construction permit
- State NPDES wastewater operation permit if discharging to surface water or groundwater
- No Discharge Permit if not discharging to surface water or groundwater.

Surface impoundments closing with waste in place are subject to the following permit programs:

- Wastewater construction permit
- State NPDES wastewater operation permit if discharging to surface water or groundwater
- Solid Waste Disposal Area construction and operation permits, but EXEMPT from this requirement if already covered by a state NPDES permit and comply with the solid waste regulation regarding filing of the survey plat with the county recorder upon closure. [10 CSR 80-2.030(2)(B)].

The multiple regulations concerning nonhazardous waste surface impoundments are largely silent on specific requirements and details, leaving them to the discretion of the permit writer.

Missouri Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	No	Not specified in state regulations, but may be required on a permit-specific basis.
Design Criteria (liner, leachate collection)	No	Not specified in state regulations, but may be required on a permit-specific basis.

(continued)

Missouri Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Operating Criteria	No	Not specified in state regulations, but may be required on a permit-specific basis.
Monitoring	Case-by-case	The regulations provide for groundwater monitoring to be required in an NPDES or No-Discharge permit on a case-by-case basis.
Reporting and Recordkeeping	No	Not specified in state regulations, but may be required on a permit-specific basis.
Inspection and Enforcement	Yes	The state regulations provide the authority to inspect but do not specify the frequency.
Performance Standards and Corrective Action	No	Not specified in state regulations, but may be required on a permit-specific basis.
Closure/Postclosure Care	Yes	All impoundments must be closed in accordance with a closure plan, details of plan not specified in regulations. If waste is to be left in place and NPDES permit coverage is obtained, solid waste regulations require the filing of the survey plat with the county recorder upon closure.
Financial Assurance	No	Not specified in state regulations, but may be required on a permit-specific basis.
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the state's regulations or programs.

Sources:

Missouri Statutes: RSMo 16-260; 40-644.

Missouri Regulations: 10 CSR 20-6; 20-8; 80-2; 80-11.

Montana

In Montana, responsibility for regulating and permitting surface impoundments is consolidated in the state's water quality Section of the Montana Department of Environmental Quality (DEQ). Additional state water program requirements are detailed below.

Montana regulations do not include design and operating criteria for surface impoundments. The Montana DEQ, Water Quality Bureau (WQB) reviews the applicable information submitted in the Montana Pollutant Discharge Elimination System (MPDES) and Montana Groundwater Pollution Control System (MGWPCS) permit applications and includes criteria in the conditions of the permit on a case-by-case basis.

The state has full authority to administer the federal NPDES permit program and to issue general permits. Owners and/or operators must obtain a two part MPDES permit that establishes effluent limitations, and monitoring and reporting requirements for discharges into surface waters of Montana. MPDES permit application requirements parallel the federal program. WQB issues MPDES permits.

An owner and/or operator of any source that may discharge pollutants into state groundwaters must obtain a MGWPCS permit. All applications for a MGWPCS permit must include general information on the site, processes, existing groundwater quality, etc. The state may require submission of more detailed information, such as specific design criteria; description of liner; proposed emergency procedures; and specifically for industrial waste, a description of the waste volumes and concentrations. WQB issues MGWPCS permits. Holders of MGWPCS permits must assure compliance with the groundwater quality standards and non-degradation policy.

Montana Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	No	Not specified in state regulations.
Design Criteria (liner, leachate collection)	Case-by-case	WQB may include design criteria (e.g., liners) in MGWPCS on a case-by-case basis.
Operating Criteria	Case-by-case	WQB may include operating criteria in MGWPCS on a case-by-case basis.

(continued)

Montana Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Monitoring	Yes	**Surface Water Monitoring:** MPDES regulations adopt the monitoring and reporting requirements at 40 CFR 122.44. **Groundwater Monitoring:** All MGWPCS permits must include self-monitoring requirements for each discharge. Permits must discuss monitoring well configuration, pollutants to be monitored, frequency of monitoring, sampling methods, and recording and reporting procedures.
Reporting and Recordkeeping	No	Not specified in state regulations.
Inspection and Enforcement	No	Not specified in state regulations.
Performance Standards and Corrective Action	Case-by-case	WQB may include remediation requirements (e.g., emergency procedures) in MGWPCS on a case-by-case basis.
Closure/Postclosure Care	No	Not specified in state regulations.
Financial Assurance	No	Not specified in state regulations.
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the states regulation, program, or guidance.

Sources:

Montana Administrative Code (MAC).

Montana Department of Environmental Quality (MDEQ) web page (http://www.deq.state.mt.us).

Nebraska

In Nebraska, responsibility for regulating and permitting surface impoundments is consolidated in the state's water quality division of the Nebraska Department of Environmental Quality (NDEQ). NDEQ established guidelines for permitting of surface impoundments within the state.

Nebraska is authorized to issue NPDES permits in the state. In addition, the state is also authorized to implement and enforce the pretreatment program pursuant to 40 CFR 403.10(e).

Nebraska Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	Yes	A lagoon shall not be installed or operated on a property less than 3 acres in size. The floor of the lagoon shall be located at least 2 feet above the highest expected groundwater level and at least 2 feet above fractured bedrock. The regulations specify the maximum permissible distances to surface water, types of wells, and property lines.
Design Criteria (liner, leachate collection)	Yes	The soil material of the impoundment floor shall be designed so that it shall not seep more than 1/8th inch per day. If soil borings and tests indicate that the existing soils are not conducive to compaction, then soda ash, bentonite, or a synthetic liner shall be used. The floor of the impoundment shall be level with a difference of plus or minus 3 inches is permitted. The regulations specify the maximum slope permissible.
Operating Criteria	Yes	A minimum of one foot of freeboard is required. The crest elevation of the impoundment should be greater than the elevation of a 100-year flood elevation. The impoundment shall be located and constructed so it will not receive surface runoff water. The lagoon shall be fenced with a 4-foot high woven wire, welded wire, or 7 strand barbed wire with the first strand starting 3 inches from the ground and the following strands spaced evenly. The fence shall be equipped with a standard main gate that is kept locked. The fence shall be placed on the outside edge of the top of the dike or 4 feet outside the toe of the dike. Signs shall be located on each gate with a warning of "NO TRESPASSING - WASTEWATER LAGOON."
Monitoring	Yes	**Groundwater Quality:** The Department may require, as a permit condition, groundwater monitoring for any onsite wastewater treatment system if there is a potential for groundwater pollution.
Reporting and Recordkeeping	No	Not specified in state regulations.
Inspection and Enforcement	Yes	NDEQ has administrative enforcement authority and the authority to levy a penalty.

(continued)

Nebraska Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Performance Standards and Corrective Action	No	Not specified in state regulations.
Closure/Postclosure Care	No	Not specified in state regulations.
Financial Assurance	No	Not specified in state regulations.
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the states regulation, program, or guidance.

Source:

Nebraska Administrative Code (NAC).

Nebraska Department of Environmental Quality (NDEQ) web page (http://www.deq.state.ne.us).

Nevada

Nevada regulates surface impoundments as part of its water program. A Surface Water Discharge Permit is required before any discharge to surface waters or to an area where surface waters may be affected. Permits are valid for five years.

Nevada Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	No	Not specified in state regulations.
Design Criteria (liner, leachate collection)	Yes	All ponds that are intended to contain process fluids must have a primary synthetic liner and a secondary liner. Ponds that are primarily designed to contain excess quantities of process fluids that result from storm events for limited periods may be constructed with a single liner if approved by the department. Ponds containing nonprocess fluids may be required to be lined depending on their potential to degrade waters of the state. A tailings impoundment must utilize a system of containment equivalent to 12 inches of recompacted native, imported, or amended soils which have an in place recompacted coefficient of permeability of no more than 1 x 10-6 cm/sec; or competent bedrock or other geologic formations underlying the site that has been demonstrated to provide a degree of containment equivalent 1 x 10^{-6} cm/sec. No operator who conducts oil or gas development and production may use unlined collecting pits for storage and evaporation of brines from the oil field. Between the liners there must be a material which has the ability to rapidly transport any fluids entering it to a collection point which is accessible and has a system for recovering those fluids. When the material between the liners is unable to collect, transport and remove all liquids at a rate that will prevent hydraulic head transference from the primary liner to the secondary liner, the pond must be shut down.
Operating Criteria	No	Not specified in state regulations.
Monitoring	Yes	Surface water monitoring is required for surface impoundments that are permitted under the NPDES program.
Reporting and Recordkeeping	No	Not specified in state regulations.
Inspection and Enforcement	Yes	State regulations give the authority to inspect, but do not specify the frequency.
Performance Standards and Corrective Action	No	Not specified in state regulations.

(continued)

Nevada Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Closure/Postclosure Care	No	Not specified in state regulations.
Financial Assurance	No	Not specified in state regulations.
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the states regulation, program, or guidance.

Sources:

Nevada Administrative Code (NAC).

Nevada Department of Environmental Protection (NDEP) web page (http://www.state.nv.us/ndep).

New Hampshire

The responsibility for regulating surface impoundments is found in New Hampshire's Division of Water program of the New Hampshire Department of Environmental Services. New Hampshire is not delegated NPDES authority. EPA is responsible for implementing the NPDES permit process in accordance with Section 402 of the CWA. The state works closely with EPA to establish appropriate discharge limits. Prior to issuance of the NPDES permit, the state must certify that the permit meets state water quality laws and regulations. Permits are generally issued for five years.

New Hampshire Department of Environmental Services (DES) established regulations regarding surface impoundments within the state. Key elements of the regulations are highlighted below.

New Hampshire Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	No	Not specified in state regulations.
Design Criteria (liner, leachate collection)	Yes	Plastic membrane liners must be installed in all new lagoons. Lagoon bottoms must form a stable structure impervious to seepage of lagoon liquid. The lagoon bottom must be smooth and level at all points. Finished elevations must vary not more than 3 inches from the average elevation of the bottom. Lagoons must be designed such that surface water shall not flow or drain into the lagoons. Lagoon dikes, embankments, and bottoms shall form a stable structure impervious to seepage of lagoon liquid. The minimum top width of a dike or embankment must be 8 feet to permit access by maintenance vehicles. The embankments must have inner faces not steeper than a 3:1 (horizontal to vertical) slope nor shallower than a 4:1 slope, and outer faces not steeper than a 3:1 slope.
Operating Criteria	Yes	Lagoon dikes must be designed to provide a minimum of three feet of freeboard above normal lagoon water surface elevation. The maximum and minimum normal operating depths shall be 5 feet and 3 feet, respectively. Seeding and erosion control shall have all outside slopes seeded and inside slopes shall have rip rap of suitable size and weight installed to at least one foot below normal lagoon level. To prevent erosion due to discharge at the termination of distribution piping, the piping must rest on a concrete apron 4 feet square, as a minimum.
Monitoring	No	Not specified in state regulations.
Reporting and Recordkeeping	No	Not specified in state regulations.

(continued)

New Hampshire Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Inspection and Enforcement	Yes	State regulations give the authority to inspect, but do not specify the frequency. Formal enforcement actions may be taken. These may include Letters of Deficiency (LOD), Administrative Orders (AO), Administrative Fines, Consent Agreements, or Consent Decrees. In cases where court orders such Consent Agreements or Consent Decrees are to be issued, a referral is made to the New Hampshire Department of Justice. Depending on the availability of resources, and the specifics of a case, enforcement actions may be turned over to the EPA or performed in conjunction with EPA
Performance Standards and Corrective Action	No	Not specified in state regulations.
Closure/Postclosure Care	No	Not specified in state regulations.
Financial Assurance	No	Not specified in state regulations.
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the states regulation, program, or guidance.

Sources:

New Hampshire Administrative Rules.

New Hampshire Department of Environmental Services (DES) web page (http://www.des.state.nh.us).

New Jersey

In New Jersey, responsibility for regulating and permitting surface impoundments is consolidated in the state's water quality Section of the New Jersey Department of Environmental Protection (NJDEP). NJDEP established guidelines for permitting of surface impoundments within the state. State Regulations require a New Jersey Pollutant Discharge Elimination System (NJPDES) permit for any discharge of any pollutant. NJDEP has full authority to administer the Federal NPDES permit program and to issue general permits.

New Jersey Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	Yes	NJDEP requires applicants to submit scale plan; topographic, geologic, soil, and water table maps; a plot plan showing the impoundment area; and a soils evaluation report. NJDEP usually requires some type of siting or location standards. In general NJDEP will not allow applicants to site impoundments in a 100-year floodplain, unless the applicant proves that the impoundment will not create a danger to health or the environment.
Design Criteria (liner, leachate collection)	Yes	All surface impoundments must have a liner either of natural or man-made material. The liners must be impervious, which is defined as having a permeability of 10-7 cm/sec. Leachate collection and removal systems are not usually required for nonharardous waste surface impoundments. However, if NJDEP finds the waste constituents to be a potential danger to human health and the environment, a leachate collection system (e.g. underdrains) may be required.
Operating Criteria	Yes	A minimum of 2 feet of freeboard is required. NJDEP incorporates standards into the permit on a case-by-case basis for soil erosion and sedimentation control. At a minimum, vegetation must be placed on earthen dikes to prevent erosion. NJDEP incorporates standards into the permit on a case-by-case basis. At a minimum, dikes must be maintained to prevent failure.
Monitoring	Yes	NPDES permittees must comply with extensive sampling, analysis, and water monitoring requirements, and must submit monthly monitoring reports. **Groundwater and Surface Water**: Surface impoundment applications must include designs for groundwater and surface water monitoring, including the proposed location and sampling procedures. Nonharardous waste facilities must conduct groundwater quality monitoring according to the requirements for hazardous waste facilities, including number and type of wells, sampling and analysis procedures, sampling parameters, etc.

(continued)

New Jersey Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Reporting and Recordkeeping	Yes	Applicants must submit information on waste volume, degree of treatment, and raw and treated effluent analyses of several parameters. NJDEP incorporates standards into the permit on a case-by-case basis.
Inspection and Enforcement	Yes	Permits include monthly operator inspection requirements of the liner and dikes.
Performance Standards and Corrective Action	Yes	If leakage occurs, the amount of corrective measures to be taken is contingent on the potential danger of the waste to human health and the environment. If a low-impact leak occurs, corrective measures may include placement of wells to monitor impact on groundwater. A high-impact leak may require removal of the wastewater from the impoundment, removal and replacement of liner, and soil sampling. Permits include plans for accidents and emergencies. In the event of an accident or an emergency, the owner/operator must be able to stop the flow of wastewater into the impoundment, empty the impoundment, and take other measures necessary to correct the problem. Owner/operators must notify NJDEP in the event of dike failure, overflow, or substantial drop in level of wastewater in pond.
Closure/Postclosure Care	Yes	The state NJPDES permit specifies regulations for impoundments which discharge to surface or groundwater.
Financial Assurance	No	Not specified in state regulations.
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the states regulation, program, or guidance.

Sources:

NJDEP Regulations.

New Jersey Department of Environmental Protection (NJDEP) web page (http://www.state.nj.us/dep/).

New Mexico

In New Mexico, nonhazardous waste surface impoundments are regulated through the New Mexico Environment Department (NMED). Surface impoundments that discharge to groundwater must have a groundwater discharge plan approved by the NMED (maximum duration of 5 years). Additional requirements may be imposed on surface water dischargers by the EPA region under the NPDES program.

New Mexico Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	No	Not specified in state regulations.
Design Criteria (liner, leachate collection)	Yes	State regulations require that the design of a surface impoundment must include the site and method for flow measurement and sampling.
Operating Criteria	No	Not specified in state regulations.
Monitoring	Case-by-case	The state agency may require monitoring as part of groundwater discharge plan on a site-specific basis.
Reporting and Recordkeeping	Case-by-case	The state agency may require submission of monitoring results, retention of records for 5 years, and other reporting and recordkeeping as part of groundwater discharge plan on a site-specific basis.
Inspection and Enforcement	Yes	State regulations give the authority to inspect, but do not specify the frequency.
Performance Standards and Corrective Action	Case-by-case	The state agency may require a site-specific contingency plan as part of a groundwater discharge plan. The facility may be required to modify the discharge plan (or prepare an abatement plan if the discharge plan has expired or been terminated) if groundwater exceeds state standards at the current or foreseeable withdrawal points; or surface water exceeds state standards.
Closure/Postclosure Care	Case-by-case	The state agency may require a closure plan sufficient to prevent exceedances of state standards as part of a groundwater discharge plan. The closure plan may include provisions for postclosure monitoring and maintenance.
Financial Assurance	Case-by-case	The closure plan may include requirements for financial assurance. The allowable mechanisms are not specified in the state regulations.

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New Mexico Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the state's regulation or program.

Sources:

New Mexico Administrative Code (NMAC) Chapter 6, Part 2, Subparts III & IV.

New Mexico Environment Department (NMED) web page (http://www.nmenv.state.nm.us).

New York

New York requirements regarding nondischarge, nonhazardous surface impoundments are found in the state's RCRA program under the New York State Department of Environmental Conservation (NYDEC). Surface impoundments that discharge to waters of the state are permitted under the water program.

For other surface impoundments, New York requires permits. Under the solid waste regulations, surface impoundments are regulated as land application units and also are subject to requirements for liquid storage. Permits for surface impoundments must include a description of the liquid to be stored; the estimated volume of liquid generated and a proposed recordkeeping system to record actual quantities stored; a schedule of liquid removal; a description of the final treatment and disposal of the liquid stored; a description of the liquid storage facility design; and a closure plan.

RCRA permit: Solid waste permits are valid for up to 10 years, except that permits issued pursuant to the Clean Water Act for sewage sludge must not be issued for a period exceeding five years.

NYPDES permit: New York is authorized to implement the federal CWA NPDES program. Any owner/operator of a surface impoundment subject to NPDES requirements (i.e., discharging directly to waters of the state) must submit an NPDES permit application. NYDEC also establishes and ensures compliance with effluent limitations or other more stringent limitations to ensure compliance with water quality standards.

The requirements below do not apply to a facility that exclusively treats wastewater that is regulated under the Clean Water Act.

New York Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	Yes	Solid waste management facilities must not be constructed or operated in a manner that causes or contributes to the taking of any endangered or threatened species or to the destruction or adverse modification of their critical habitat. Siting is prohibited in agricultural land, floodplains (unless provisions have been made to prevent the encroachment of flood waters), or within the boundary of a regulated wetland. Any surface impoundment must be constructed a minimum of 5 feet above the seasonally high groundwater table, and a minimum of 5 feet of vertical separation must be maintained between the base of the constructed liner and bedrock. Surface impoundments must be constructed above the 100-year flood elevation.

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New York Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Design Criteria (liner, leachate collection)	Yes	Surface impoundments must be constructed with a liner system to minimize percolation. Surface impoundments must be constructed with a liner system consisting of a minimum of two liners and a leak-detection system. The top liner must be a geosynthetic liner with a minimum thickness equal to 60 mils. Ballast material, such as rounded gravel or sand, that will not cause damage to the geosynthetic liner must be placed on top of the liner to preserve liner integrity. The lower composite liner must consist of a minimum of 2 feet of compacted soil with a maximum coefficient of permeability of 1 x 10-7 centimeters per second overlain by a geosynthetic liner at least 60 mils thick. The bottom of the impoundment liner system must be a minimum of 5 feet above both the seasonal high groundwater table and top of bedrock.
Operating Criteria	Yes	All solid waste management facilities must be constructed, operated and closed in a manner that minimizes the generation of leachate that must be disposed of and prevent the migration of leachate into surface and groundwaters. Leachate must not be allowed to drain or discharge into surface water except pursuant to a State Pollutant Discharge Elimination System permit and must not cause or contribute to contravention of groundwater quality standards established by the state. A leak detection and removal system must be installed between the two synthetic liners. Surface impoundments must have a minimum 2 feet of freeboard. Proper site grading must be maintained to prevent depressions, desiccation cracks or soil erosion and minimize ponding. Facilities are required to have a waste control plan as part of their permit.
Monitoring	Yes	**Surface and groundwater quality monitoring:** Solid waste must not be deposited in, and must be prevented from, entering surface waters or groundwaters. Groundwater monitoring is required. A minimum of three groundwater monitoring wells, one upgradient and two downgradient of the surface impoundment, must be installed and sampled. Quarterly sampling of the wells at the surface impoundment must be conducted on the following parameters: chloride, nitrate, sulfate, specific conductivity, total hardness, alkalinity, and total organic carbon or chemical oxygen demand. Samples and measurements taken for the purpose of monitoring must be representative of the monitored activity and must be conducted in a manner approved by the department, including the use of a laboratory and data-reporting format acceptable to the department.
Reporting and Recordkeeping	No	Not specified in state regulations.

(continued)

New York Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Inspection and Enforcement	Yes	NYDEC is authorized to implement the RCRA solid waste requirements by the state legislature. New York has the authority to implement the federal CWA requirements.
Performance Standards and Corrective Action	Yes	Every application for a permit must include a contingency plan. For surface impoundments, the contingency plan must address the steps that will be taken in the event of contamination detected in the downgradient wells or leak detection system. Contingency plans approved by the department for emergency situations must be implemented in accordance with the terms of the plan.
Closure/Postclosure Care	Yes	Regulations specify specific requirements for non-discharging impoundments.
Financial Assurance	Yes	Financial assurance is required for non-discharging impoundments.
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the states regulation or program.

Sources:

New York Codes, Rules and Regulations (NYCRR).

New York State Department of Environmental Conservation (NYS DEC) web page (http://www.dec.state.ny.us).

North Carolina

In North Carolina, responsibility for regulating and permitting nonharardous surface impoundments is consolidated in the Water Quality Section of the North Carolina Department of Environment and Natural Resources (DENR). An impoundment must be covered by either a state NPDES permit if it discharges to surface water or a state permit if it does not. The regulations outlined in the table below apply to discharging and non-discharging facilities unless otherwise indicated.

North Carolina Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	Yes	State regulations require that a surface impoundment must be at least 4 feet above the seasonal water table; 50 feet from property lines rivers, and streams; and 500 feet from dwellings and wells. Restrictions also apply for locations near 100-year floodplains, endangered species habitats, and historical sites and parks.
Design Criteria (liner, leachate collection)	Yes	State regulations require that if waste is less than 4 feet above bedrock there must be a liner of 10^{-7} hydraulic conductivity or demonstration that the design will meet groundwater standards.
Operating Criteria	Yes	State regulations identify minimum freeboard requirements.
Monitoring	Yes	State regulations require that nondischargers monitor groundwater quality, but details determined on case-by-case basis.
Reporting and Recordkeeping	No	Not specified in state regulations.
Inspection and Enforcement	Yes	State regulations give the authority to inspect with the frequency not specified.
Performance Standards and Corrective Action	Yes	Corrective action is required if groundwater exceeds state standards at compliance boundary (250 feet from waste boundary). Assessment and possible preventative measures are required if groundwater exceeds state standards at review boundary (midway to compliance boundary).
Closure/Postclosure Care	No	Not specified in state regulations, but may be applied on a permit-specific basis.
Financial Assurance	No	The authority to require financial assurance exists, but no specific mechanisms are identified/required in the state regulations.

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North Carolina Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the state's regulations or programs.

Sources:

North Carolina Administrative Code (NCAC) Title 15A, Chapter 2, Subchapters 2L & 2H; Title 15A Chapter 13, Subchapter 13B.

North Carolina Department of Environment and Natural Resources (DENR) web page (http://h2o.enr.state.nc.us/admin/rules/).

North Dakota

In North Dakota, nonhazardous waste surface impoundments are regulated through the Department of Health's Division of Waste Management. Impoundments must be covered by a solid waste management permit (duration not specified in the regulations), and an NPDES permit if discharging to surface water (duration of up to 5 years). If an impoundment has both permits because it is a surface water discharger, the design and operating criteria specified in the solid waste management permit regulations are not applicable.

North Dakota Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	Yes	State regulations require surface impoundments to be located 1,000 feet downgradient from drinking water wells, 200 feet from surface water or wetlands, 200 feet from surface water or wetlands, and 1,000 feet from parks. The regulations specify prohibitions for disposal within an aquifer, wellhead protection areas, 100-year flood plains, unstable areas, critical habitats, principal glacial drift aquifers, and pipelines and transmission lines.
Design Criteria (liner, leachate collection)	Yes	**Non-discharging impoundments:** Impoundments that do not discharge to surface water must have a liner that is 4 feet thick with a permeability of less than 10^{-7} or equivalent (applicable to units permitted after December 1, 1992) and meet dike construction criteria. **Surface water discharging impoundments:** Not specified in state regulations. May be required as part of permit on a site-specific basis.
Operating Criteria	Yes	**Non-discharging impoundments:** Impoundments that do not discharge to surface water must have a minimum of 2 feet of freeboard, monthly operational inspections, and a contingency plan. **Surface water discharging impoundments:** Not specified in state regulations. May be required as part of permit on a site-specific basis.
Monitoring	Yes	State regulations require a measurement of quantity of waste disposed if >20 tons per day. Semiannual groundwater monitoring of at least 1 upgradient and 2 downgradient wells is required (constituents determined on case-by-case basis). Monitoring of compliance boundary is required within property line no more than 500 feet from the unit.
Reporting and Recordkeeping	Yes	Semiannual groundwater monitoring results; operating records; annual audits of financial assurance mechanisms; and annual reporting of waste quantity and noncompliances.
Inspection and Enforcement	Yes	State regulations give the authority to inspect, but do not specify the frequency.

(continued)

North Dakota Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Performance Standards and Corrective Action	Yes	Remedial measures are required if groundwater exceeds state standards or other permit limits at compliance boundary.
Closure/Postclosure Care	Yes	State regulations require a closure plan. Closure in place is allowed if liquids are removed, impoundment is lined with low-permeability material (applicable to units permitted after December 1, 1992), a final cover is installed with vegetation and a permeability less than the liner, run-on and erosion controls are installed, and postclosure monitoring is conducted.
Financial Assurance	Yes	A reserve account, trust fund, surety bond, irrevocable letter of credit, financial test insurance policy, or corporate guarantee is required for closure, postclosure, and corrective action (for facilities closed after April 9, 1994).
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the state's regulations or program.

Sources:

North Dakota Century Code (NDCC) Chapters 23–29 & 33–20.

North Dakota Department of Health (NDHD) web page (http://www.health.state.nd.us/ndhd/environ/wm/index.htm).

Ohio

The Permits Section in the Division of Water Pollution Control of the Ohio Environmental Protection Agency (OEPA) oversees the regulations and permits regarding nonharardous waste surface impoundments. The regulatory program related to surface impoundments has two components: the permit to install (valid for life of the facility) and the NPDES permit for discharges to surface water or groundwater (valid for up to 5 years).

Ohio Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	No	Not specified in state regulations, but may be required as part of a permit on a site-specific basis.
Design Criteria (liner, leachate collection)	No	Not specified in state regulations, but may be required as part of a permit on a site-specific basis.
Operating Criteria	No	Not specified in state regulations, but may be required as part of a permit on a site-specific basis.
Monitoring	No	Not specified in state regulations, but may be required as part of a permit on a site-specific basis.
Reporting and Recordkeeping	Yes	State regulations require monthly and annual reports with information as specified in the permit. If applicable, reports of monitoring are required at least annually.
Inspection and Enforcement	Yes	State regulations give the authority to inspect, but do not specify the frequency.
Performance Standards and Corrective Action	Yes	State regulations require compliance with applicable effluent limitations, water quality standards, and standards which prohibit significant degradation of waters of the state. Specific enforcement mechanisms, however, are not specified in the regulations.
Closure/Postclosure Care	No	Not specified in state regulations, but may be required as part of a permit on a site-specific basis.
Financial Assurance	No	Not specified in state regulations, but may be required as part of a permit on a site-specific basis.

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Ohio Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the state's regulations or programs.

Sources:

Ohio Regulations: Ohio Administrative Code (OAC) 3745-31; 3745-33.

Ohio Environmental Protection Agency (OEPA) web page (http://www.epa.state.oh.us).

Oklahoma

In Oklahoma, nonhazardous waste surface impoundments are regulated through the Oklahoma Department of Environmental Quality (ODEQ) under its water program. A State Operation Permit is required for all impoundments (valid for up to 5 years), while a state NPDES permit is required for discharges to surface water or groundwater (valid for up to 5 years).

The state regulations establish five classes of surface impoundments with little difference in the regulatory requirements for each class. The determination of impoundment class is at the discretion of the permit writer. In general, Classes I and II contain wastes with high concentrations of harmful pollutants with (I) high or (II) low mobility in groundwater; Class III contains wastes with other pollutants that may, if discharged, pollute the environment or waters of the state; Class IV contains sanitary wastewater; and Class V contains industrial wastewater not otherwise classified. The regulations outlined in the table below apply to all classes of impoundments unless otherwise indicated.

Oklahoma Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	Yes	The state regulations specify the following location/siting standards: • Not in floodways or floodplains • 50 feet from private wells • 300 feet from public water supplies • 10 feet from property lines • Crest of dikes must be at least 1 foot above 100-year flood elevation • Bottom of impoundment must be15 feet above groundwater table
Design Criteria (liner, leachate collection)	Yes	The state regulations specify the following design standards: • Run-on/run-off controls • Erosion controls • Dike slopes no steeper than 1:3 • Liner system (native soil, compacted clay with 12 inches of soil, flexible membrane liner with protective soil cover, or composite liner) depending on class of impoundment
Operating Criteria	Yes	The state regulations specify a minimum of 3 feet of freeboard. In addition, a written Maintenance and Operation Plan is required for Classes I and II only.
Monitoring	Case-by-case	Groundwater monitoring may be required when there is a potential for groundwater contamination. If required, there must be 1 upgradient and 2 downgradient wells, and a detailed monitoring plan must be submitted.
Reporting and Recordkeeping	Yes	The state regulations require submission of Self-Monitoring Report forms and reports of spills or releases.

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Oklahoma Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Inspection and Enforcement	Yes	State regulations give the authority to inspect, but do not specify the frequency.
Performance Standards and Corrective Action	Yes	The state regulations require conformance to applicable water quality standards.
Closure/Postclosure Care	Yes	The state regulations require the submission of a preclosure sampling and analysis plan, and a closure plan. In addition, caps must be installed in conformance with liner requirements. The state agency may require submission of a postclosure maintenance plan on a case-by-case basis. A postclosure duration is not specified in the state regulations.
Financial Assurance	Yes	The state regulations stipulate that the owner/operator of the impoundment must demonstrate financial capability for operation, maintenance, replacement, and closure. The types of mechanisms and duration are not specified in the state regulations.
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the state's regulations or programs.

Sources:

Oklahoma Agency Rules (OAR) 252-605 & 252-616.

Oklahoma Department of Environmental Quality (ODEQ) web page (http://www.deq.state.ok.us).

Oregon

In Oregon, the responsibility for regulating and permitting nonharardous surface impoundments is divided between the Water Quality Program and the Recycling and Solid Waste Program of the Oregon Department of Environmental Quality. The RCRA program requirements provide a general basis for surface impoundment regulations. Additional facility-specific requirements may be added to permits.

All sources that discharge wastewater to surface waters of the state must obtain a NPDES permit. Sources that discharge wastes into a sewerage system do not have to obtain a permit. General requirements require effluent and discharge limitations, recordkeeping, monitoring and reporting, and operation and maintenance responsibilities.

Along with a NPDES permit, facilities containing land irrigation systems, evaporation lagoons, industrial seepage pits, and on-site sewage disposal systems designed for wastewater flows greater than 2,500 gallons per day that have no direct discharge to surface waters are required to obtain a water pollution control facility permit.

Some facilities are required to obtain a storm water permit dependent on the facility's industrial activity.

A facility is required to obtain a solid waste permit prior to operation if it plans to store, receive, or landfill any garbage, demolition waste, industrial waste, or sludge. Typical requirements of these permits generally include the use of "best management practices" to prevent contamination of the surrounding environment.

Oregon Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	Yes	Location of disposal sites shall be determined by giving special consideration to the topography and geology of the surrounding area as well as other characteristics as they may affect the protection of ground and surface waters and air pollution. All industrial solid waste impoundments shall be located a minimum of 100 feet horizontal distance from the normal highwater mark of any public waters. All sludge lagoons shall be located a minimum of 1/4 mile from the nearest residence. Barriers shall be constructed to prevent public access to the facility.

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Oregon Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Design Criteria (liner, leachate collection)	Yes	All surface impoundments must include a readily washable landfill-type liner with a leachate removal system. The liner must demonstrate both physical and chemical compatibility with the waste being stored. Liners must be impervious to damage suck as cracks and leaks. A concrete slab is not considered an acceptable liner. The impoundment shall also have a tight lid or cover. All impoundments are required to have a leachate removal system incorporated with a liner unless the facility contains a vadose monitoring system. Some facilities may be required to incorporate such physical features as dikes and berms into the design criteria for the impoundment.
Operating Criteria	Yes	Each facility is to ensure that surface runoff and leachate seeps are controlled as to minimize discharge of pollutants to public waters. A minimum of 3 feet of dike freeboard shall be maintained above the maximum water level within a sludge lagoon. It is required that all facilities dispose of nonharardous sludge.
Monitoring	Yes	**Groundwater:** The department and/or solid waste permits may require a groundwater monitoring system dependent on the type of waste contained in the impoundments and the facility's cover, run-on controls and irrigation system. **Surface Water:** NPDES requirements include surface water monitoring, analysis, and recordkeeping and reporting.
Reporting and Recordkeeping	Yes	The state solid waste storage permit specifies reporting and recordkeeping requirements.
Inspection and Enforcement	Yes	All nonharardous waste producing facilities are required to grant inspection authority to the appropriate implementing agency. The terms of these inspections are permit specific for each facility. The Environmental Quality Commission has the authority to take the necessary appropriate actions to ensure the enforcement of its rules or orders, as well as, levy both criminal and civil penalties against a facility.
Performance Standards and Corrective Action	Yes	The state solid waste storage permit specifies that corrective action is required if necessary.
Closure/Postclosure Care	Yes	The state solid waste storage permit specifies that closure/postclosure care is required.
Financial Assurance	Yes	The state solid waste storage permit specifies that financial care is required.

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Oregon Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the states regulation, program, or guidance.

Sources:

Oregon Administrative Rules (OAR).

Oregon Department of Environmental Quality web page (http://www.deq.state.or.us).

Pennsylvania

Pennsylvania Department of Environmental Resource (PADEP) regulates surface impoundments based on their type and establishes design and operating requirements based on the nature of the waste being managed.

In Pennsylvania, responsibility for regulating and permitting nonharardous surface impoundments is delegated between the state's Division of Water Quality, responsible for the NPDES program for discharging impoundments, and the Division of Municipal and Residual Waste, responsible for managing disposal and processing impoundments under the residual waste program.

Operators of disposal surface impoundments must obtain a Residual Waste Disposal Permit, and a Water Quality Management Permit Part I (i.e., NPDES permit) if the impoundment will discharge to waters of the state. A "disposal" impoundment is one that stores waste for more than 1 year without regularly removing the waste. Disposal impoundments are classified into two types, the only difference in requirements being the type of liner system:

- Type 1: Wastes with TCLP ≥50 times Federal MCLs
- Type 2: Wastes with TCLP <50 times Federal MCLs.

Operators of captive processing surface impoundments must abide by the residual waste Permit-by-Rule regulations, and must obtain a Water Quality Management Permit Part I (i.e., NPDES permit) if the impoundment will discharge to waters of the state.

The residual waste regulations for the Permit-by-Rule and Residual Waste Disposal Permit address all the criteria listed in the table below. The table includes the regulatory requirements under the Residual Waste Disposal Permit–some requirements are less stringent under the Permit-by-Rule regulations.

Pennsylvania Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	Yes	The residual permit regulations specify restrictions for 100-year floodplains, wetlands, sinkhole-prone limestone and carbonate formations, perennial streams, property lines, and nearby water sources.
Design Criteria (liner, leachate collection)	Yes	The residual permit regulations specify requirements for liners, leachate detection and collection, structural integrity, and run-on/run-off controls.

(continued)

Pennsylvania Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Operating Criteria	Yes	The residual permit regulations specify minimum freeboard requirements, separation of liquids from solid waste, and solidification of waste times.
Monitoring	Yes	The residual permit regulations require a monitoring plan and upgradient and downgradient groundwater monitoring within 200 feet of disposal area. Regulations require that indicators shall be monitored quarterly, and metals and VOCs shall be samples annually.
Reporting and Recordkeeping	Yes	The residual permit regulations require annual waste quantity and disposition reports; quarterly groundwater results; and daily, quarterly and annual operational reports. These records must be maintained for the entire length of the bond held for that facility.
Inspection and Enforcement	Yes	The residual permit regulations allow PADER to conduct up to 12 inspections per year. However, there is no established minimum number of inspections per year for any given facility.
Performance Standards and Corrective Action	Yes	The residual permit regulations require abatement if: groundwater exceeds permit-specific trigger levels, groundwater exceeds state standards, groundwater exceeds background where background is greater than state standards, or degradation of groundwater at property boundaries.
Closure/Postclosure Care	Yes	The residual permit regulations require an approved closure plan that includes plans for caps, leachate management, and revegetation. There is no postclosure period specified by the regulations.
Financial Assurance	Yes	The residual permit regulations stipulate that a surety bond, collateral bond, letter of credit, certificate of deposit, or combination thereof must be maintained for a duration of 10 years after final closure along with public liability insurance.
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	Yes	The state regulations require all owners/operators of surface impoundments to implement fugitive air contaminant control measures. If the waste managed at the facility generates gas, the operator must monitor quarterly off-site gas migration and gas accumulation on and off the site.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the state's regulations or programs.

Sources:

Pennsylvania Code (PAC) Chapters 92, 287, 289.

Pennsylvania Department of Environmental Protection (PADEP) web page (http://www.dep.state.pa.us/business_industry/default.htm).

Rhode Island

Rhode Island requires a state NPDES permit for discharges to surface and groundwater, administered by the Division of Water Resources in the Department of Environmental Management, but does not further regulate nonhazardous waste surface impoundments. If an impoundment has a liner and doesn't not leach or overflow, an NPDES permit is not necessary, but the liner is not required.

Rhode Island Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	No	Not specified in state regulations.
Design Criteria (liner, leachate collection)	No	Not specified in state regulations.
Operating Criteria	No	Not specified in state regulations.
Monitoring	No	Not specified in state regulations.
Reporting and Recordkeeping	No	Not specified in state regulations.
Inspection and Enforcement	Yes	State regulations give the authority to inspect, but do not specify the frequency.
Performance Standards and Corrective Action	No	Not specified in state regulations.
Closure/Postclosure Care	No	Not specified in state regulations.
Financial Assurance	No	Not specified in state regulations.
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the states regulation or program.

Source:

Rhode Island Administrative Rules 12-190 et seq.

South Carolina

The Bureau of Water Pollution Control under the South Carolina Department of Environmental Control administers the programs concerning nonhazardous waste surface impoundments. Surface impoundments must be covered either by a state NPDES permit (if discharge to surface or groundwater), or a nondischarge permit. In addition, construction and operation permits need to be obtained if an impoundment exceeds wastestream limitations.

South Carolina Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	No	Not specified in state regulations.
Design Criteria (liner, leachate collection)	No	Not specified in state regulations. Under non-discharge permit, determined on a case-by-case basis.
Operating Criteria	No	Not specified in state regulations. Under non-discharge permit, determined on a case-by-case basis.
Monitoring	Yes	Non-discharge permits require groundwater monitoring
Reporting and Recordkeeping	No	Not specified in state regulations.
Inspection and Enforcement	No	Not specified in state regulations.
Performance Standards and Corrective Action	Yes	Non-discharge permits require the facility's groundwater monitoring system to meet state groundwater standards.
Closure/Postclosure Care	Yes	State regulations specify closure guidelines and require monitoring on case-by-case basis as necessary to prevent water quality violations or nuisance conditions.
Financial Assurance	No	Not specified in state regulations.
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the states regulation or program.

Source:

South Carolina Regulations Title 61-9 and 61-82.

South Dakota

South Dakota's Department of Environment and Natural Resources administers the programs regulating nonhazardous waste surface impoundments. Such impoundments are subject to water, solid waste, and air regulations. Required permits include a solid waste facility permit, a state NPDES permit for discharges to surface or groundwater, and a state groundwater discharge permit for discharges to groundwater. In addition, the Department has published non-regulatory design criteria for wastewater stabilization and pollution control ponds, and aerated ponds.

South Dakota Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	Yes	Solid waste permit regulations specify that impoundments can not be located in a 100-year floodplain, wetlands, or unstable areas. They also cannot be located within 1,000 feet of dwelling, school, hospital, interstate, highway, or public park. If surface waters can be polluted, not within 1,000 feet of surface waters.
Design Criteria (liner, leachate collection)	Case-by-case	Solid waste permit regulations state that a liner and leachate collection system may be required.
Operating Criteria	Yes	Solid waste permit regulations specify operating criteria for impoundments as appropriate.
Monitoring	Yes	Groundwater monitoring required under solid waste and groundwater discharge permit regulations, and may be required by a state NPDES permit.
Reporting and Recordkeeping	Case-by-case	Solid waste permit regulations and groundwater discharge permit regulations state that the reporting and recordkeeping requirements are those as specified in the permits by the permit writer.
Inspection and Enforcement	Yes	State regulations give the authority to inspect, but do not specify the frequency.
Performance Standards and Corrective Action	Yes	Solid waste permit regulations and groundwater discharge permit regulations require meeting groundwater quality standards. The groundwater discharge permit also requires a contingency plan for bringing the facility into compliance with such standards.
Closure/Postclosure Care	Yes	Solid waste permit regulations require closure and postclosure plans, and specify some criteria to be addressed in the plans.
Financial Assurance	Yes	Solid waste permit regulations require financial assurance mechanisms for closure/postclosure care, such as trust fund, surety bond, letter of credit, insurance, or cash.

(continued)

South Dakota Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the states regulation or program.

Source:

South Dakota Regulations Title 74, Articles 74-27, 74-52, and 74-54.

Tennessee

The responsibility for regulating and permitting surface impoundments is held by the Tennessee Department of Health and Environment. Under this Department, the Division of Water Quality and the Division of Solid Waste Management enforce the regulations and oversee closure of surface impoundments, respectively.

Three sets of regulations apply to nonhazardous waste surface impoundments.

- State NPDES permit is required for dischargers to surface or groundwater (valid for up to 5 years).
- State Operation Permit is required for nondischargers (valid for up to 5 years).
- If closing with waste in place, solid waste regulations for Class VI Disposal Facilities apply (to facilities in operation on or after March 19, 1990), but a Solid Waste Processing and Disposal Permit is not required.

Tennessee Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	No	Not specified in state regulations, but may be applied on a permit-specific basis.
Design Criteria (liner, leachate collection)	No	Not specified in state regulations, but may be applied on a permit-specific basis.
Operating Criteria	No	Not specified in state regulations, but may be applied on a permit-specific basis.
Monitoring	Case-by-case	Monitoring requirements are determined on a case-by-case basis and specified in applicable permits.
Reporting and Recordkeeping	No	Not specified in state regulations.
Inspection and Enforcement	Yes	State regulations give the authority to inspect, but do not specify the frequency.
Performance Standards and Corrective Action	Yes	The operator must comply with applicable effluent standards, limitations, and water quality standards. Specific enforcement mechanisms are not specified in the regulations.

(continued)

Tennessee Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Closure/Postclosure Care	Yes	If closing with waste in place, closure/postclosure plans are required, but specific details of the plans are not specified in the state regulations.
Financial Assurance	Yes	If closing with waste in place, state regulations require a trust fund, surety bond, personal bond, letter of credit, insurance, financial test, and corporate guarantee for closure and postclosure care of an impoundment.
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the state's regulations or programs.

Sources:

Tennessee Code Annotated (TCA) 1200-1-7 & 1200-4-10.

Tennessee Department of Environment and Conservation (TDEC) web page (http://www.state.tn.us/environment).

Texas

The Waste Permits Division and the Water Permits & Resource Management Division, under the Office of Permitting, Remediation & Registration of the Texas Natural Resource Conservation Commission (TNRCC), are responsible for permitting nonharardous waste surface impoundments.

Both solid waste and water quality regulations apply to surface impoundments. Facilities that discharge into or adjacent to surface water or groundwater must obtain a State Water Quality Permit. A solid waste management permit is not required, but facilities must notify the TNRCC with information including waste composition, facility design, and geology. The specific regulations and guidelines for surface impoundments are largely determined on a case-by-case basis and are found in each individual facility's permit.

Texas Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	No	Not specified in state regulations, but may be required as part of a Water Quality Permit on a site-specific basis.
Design Criteria (liner, leachate collection)	No	Not specified in state regulations, but may be required as part of a Water Quality Permit on a site-specific basis.
Operating Criteria	No	Not specified in state regulations, but may be required as part of a Water Quality Permit on a site-specific basis.
Monitoring	Yes	Waste characterization and surface-water discharge monitoring are required by state regulations. Groundwater monitoring may be required as part of Water Quality Permit on a site-specific basis.
Reporting and Recordkeeping	Yes	State regulations require the maintenance of records of quantity of waste generated, disposition of waste, and waste characteristics.
Inspection and Enforcement	Yes	State regulations authorize the state to audit records and to inspect dischargers (frequency not specified in the regulations).
Performance Standards and Corrective Action	Yes	The regulations stipulate that waste disposal may not cause a nuisance or endanger public health and welfare. They also state that dischargers must comply with state water quality standards. In addition, groundwater degradation is not allowed, although specific enforcement mechanisms are not specified in regulations beyond the authority to issue emergency orders.

(continued)

Texas Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Closure/Postclosure Care	Yes	The state regulations state that the decision to close a surface impoundment is at the operator's discretion and that prior notification of TNRCC is required. Closure must be in a manner that is compliant with the risk-based standards of the Texas Risk Reduction Program: • Minimize or eliminate postclosure escape of waste, contaminants, leachate, or run-off. • Minimize or eliminate the need for further maintenance and control • Specific closure controls and activities are not specified in regulations
Financial Assurance	No	Not specified in state regulations, but may be required as part of a Water Quality Permit on a site-specific basis.
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the state's regulations or programs.

Sources:

Texas Administrative Code (TAC).

Texas Natural Resource Conservation Commission (TNRCC) web page (http://www.tnrcc.state.tx.us).

Utah

In Utah, the Utah Department of Environmental Quality's Division of Water Quality is responsible for regulating and permitting nonhazardous surface impoundments. Utah regulations require owners/operators obtain a construction permit prior to building storage or treatment surface impoundments (valid for one year). In addition, dischargers to surface water or groundwater must obtain a state NPDES permit (valid for up to five years), and dischargers or potential dischargers to groundwater must also obtain a state groundwater permit (valid for up to five years).

Utah Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	No	Not specified in state regulations, but may be required in a permit on a site-specific basis.
Design Criteria (liner, leachate collection)	No	Not specified in state regulations, but may be required in a permit on a site-specific basis.
Operating Criteria	No	Not specified in state regulations, but may be required in a permit on a site-specific basis.
Monitoring	Yes	State regulations require groundwater monitoring; however, monitoring details are determined on a site-specific basis and are included in the groundwater permit.
Reporting and Recordkeeping	No	Not specified in state regulations.
Inspection and Enforcement	Yes	State regulations give the authority to inspect, but do not specify the frequency.
Performance Standards and Corrective Action	Yes	State regulations require a contamination investigation and corrective action plan if monitoring indicates violation or possible violation of water quality standards.
Closure/Postclosure Care	No	Not specified in state regulations, but may be required in a permit on a site-specific basis.
Financial Assurance	No	Not specified in state regulations, but may be required in a permit on a site-specific basis.

(continued)

Utah Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the state's regulations or programs.

Sources:

Utah Administrative Rules (UAR) 317-1; 317-6; 317-8.

Utah Department of Environmental Quality (UDEQ) web page (http://www.deq.state.ut.us).

Vermont

Vermont's Department of Environmental Conservation under the Agency of Natural Resources is responsible for overseeing the regulations regarding nonhazardous waste surface impoundments. Vermont requires discharge (to surface water) and indirect discharge (to groundwater) permits for all impoundments with discharges. Storage surface impoundments are also subject to solid waste regulations. However, "wastewater treatment lagoons and digesters" are exempt from the solid waste regulations if they are covered by a discharge and/or indirect discharge permit. In addition, there are dam safety regulations that apply to industrial lagoons greater than 50,000 cubic feet.

Vermont Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	Yes	The state solid waste regulations specify siting requirements with minimum isolation and separation distances from drinking water sources and property lines.
Design Criteria (liner, leachate collection)	Yes	The state solid waste regulations include design standards such as 5 months minimum storage capacity, standards for synthetic or clay liners, and freeboard requirements
Operating Criteria	Yes	The owner and operator shall take all steps necessary to prevent and/or control spills, nuisance dust, vectors, wind blown debris, and odors. The owner and operator shall take all practicable steps to prevent the inclusion of hazardous wastes, as defined and regulated by Vermont's Hazardous Waste Management Regulations, into the waste stream being managed by the facility.
Monitoring	Yes	Groundwater monitoring required by indirect discharge permit and may be required under solid waste regulations.
Reporting and Recordkeeping	No	Not specified in state regulations.
Inspection and Enforcement	Yes	State regulations give the authority to inspect, but do not specify the frequency.
Performance Standards and Corrective Action	No	Not specified in state regulations.

(continued)

Vermont Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Closure/Postclosure Care	Yes	The closure plan must identify steps necessary to completely close the facility at any point during its intended life. The closure plan must include, at least a description of the steps necessary to close the facility; a listing of labor, materials, and testing necessary to close the facility; an estimate of the expected year of closure; a schedule for final closure including, at a minimum, the total time required to close the facility and the time required for the various steps or phases in the closure process; a cost estimate for facility closure that satisfies the requirements of Section 6-1004; a description of the methods for compliance with the closure requirements; and any remedial action necessary prior to closure, if required by the Secretary pursuant to Section 6-311.
Financial Assurance	No	Not specified in state regulations.
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the states regulation or program.

Sources:

Vermont Administrative Code Chapters 6 and 13.

Vermont Agency of Natural Resources web page (http://www.anr.state.vt.us/dec/dec.htm).

Virginia

The Water Division of the Virginia Department of Environmental Quality administers the permit program pertaining to nonhazardous waste surface impoundments. Lagoons and surface impoundments are regulated under state water control law and by agencies other than the Department. Impoundments must be covered either by a state NPDES permit if it discharges directly to surface waters, or a Virginia Pollution Abatement (VPA) permit if it does not.

Virginia Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	Case-by-case	Determined on a site-specific basis in VPA permit.
Design Criteria (liner, leachate collection)	Case-by-case	Determined on a site-specific basis in VPA permit.
Operating Criteria	Case-by-case	Determined on a site-specific basis in VPA permit.
Monitoring	Yes	Groundwater monitoring is required under the VPA permit.
Reporting and Recordkeeping	No	Not specified in state regulations.
Inspection and Enforcement	Yes	State regulations give the authority to inspect, but do not specify the frequency.
Performance Standards and Corrective Action	No	Not specified in state regulations.
Closure/Postclosure Care	Yes	Applies only if closure with waste left in place.
Financial Assurance	Yes	Applies only if closure with waste left in place.
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the states regulation or program.

Sources:

Virginia Administrative Code – Title 9 VAC 25.

Virginia Department of Environmental Quality web page (http://www.deq.state.va.us/).

Washington

The responsibility for regulating and permitting surface impoundments in the state of Washington is administered by the Washington Department of Ecology (DE). The department that actually regulates surface impoundments is dependent on the type of waste handled and whether the impoundment discharges to a water of the state. The Solid and Hazardous Waste Program (SHWP) and Jurisdictional Health Department regulate impoundments handling dangerous and nonharardous wastes that do not discharge to a water of the state. All impoundments handling nonharardous waste that discharge to waters of the state are regulated by the Water Quality Program (WQP). State RCRA requirements are located in the Water Pollution Control Act and the Solid Waste Management Act and are described in detail below.

Impoundments managing dangerous wastes are required to have a dangerous waste permit, which are issued by the SHWP.

Solid Waste Facility Permit: Impoundments that handle nondangerous waste, but do not discharge into waters of the state are required to obtain a Solid Waste Facility Permit. Permits are not required if the impoundment obtains a state waste discharge permit. Permits are issued by the jurisdictional health departments.

State Waste Discharge Permit: Surface impoundments that discharge to groundwater, or have the potential to discharge to groundwater and/or impair groundwater quality, must obtain a state waste discharge permit. Permits are issued by WQP.

State NPDES Permit: Surface impoundments that have a point source discharge to surface water must obtain a state NPDES permit. Permits are issued by WQP.

Construction Permits: Surface impoundments handling more than 10 acre-feet of water must obtain dam safety approval and a construction permit from WPR. Construction permits ensure that the impoundment will remain intact throughout its life and will not threaten human health or the environment. Criteria include requirements for dikes and berms and freeboard limits.

The states regulatory and management guidelines for surface impoundments depend on the type of waste managed in the impoundment and whether the impoundment discharges to waters of the state.

Washington Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	Yes	**Surface Impoundments Discharging Non-Dangerous Waste to Waters of the State:** Not specified in state regulations. **Surface Impoundments Managing Dangerous and Non-Dangerous Waste, But Not Discharging to Waters of the State:** Impoundments managing dangerous waste must not be located within a 500-year floodplain or in areas having a mean annual precipitation greater than 100 inches and must comply with restrictions concerning proximity to faults, public water sources, wetlands, critical habitats, and depth to groundwater.
Design Criteria (liner, leachate collection)	Yes	**Surface Impoundments Discharging Non-Dangerous Waste to Waters of the State:** Permit conditions for waste discharges may include requirements for liners to protect the beneficial uses of groundwater by specifying. **Surface Impoundments Managing Dangerous and Non-Dangerous Waste, But Not Discharging to Waters of the State:** Surface impoundments must have an in place or imported soil liner of at least 2 feet of 1 x 10 -7 cm/sec permeability or an equivalent combination of any thickness greater than 2 feet and a greater permeability to protect the underlying aquifers or a 30 mil reinforced artificial liner. DE may exempt the operator from the liner requirement if an alternate design will prevent migration of pollutants into ground and surface waters. Surface impoundments must have either a groundwater monitoring system that is consistent with permit regulations, or a leachate detection, collection and treatment system, for facilities having a capacity of more than two million gallons unless the jurisdictional health department and the DE require either for smaller surface impoundments. Impoundments managing dangerous wastes must have dikes with slopes as to maintain the structural integrity under conditions of a leaking liner and must be capable of withstanding erosion from wave action.

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Washington Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Operating Criteria	Yes	**Surface Impoundments Discharging Non-Dangerous Waste to Waters of the State:** Permit conditions for waste discharge permits and NPDES permits may require prevention and control of pollutant discharges from plant site run-off. NPDES and state waste discharge permits contain conditions to prevent and control pollutant discharges from sludge disposal. **Surface Impoundments Managing Dangerous and Non-Dangerous Waste, But Not Discharging to Waters of the State:** Impoundments managing dangerous waste must have the freeboard equal to or greater than 18n inches to avoid overtopping from wave action, overfilling, or precipitation. In addition, impoundments should be designed and operated to prevent overtopping and designed so that any flow of waste into the impoundment can be shut off should overtopping or linear failure occur. Impoundments managing dangerous waste must have earthen dikes with a protective cover to minimize wind and water erosion. Dangerous wastes must not be stored in an impoundment for more than 5 years after the waste is first placed in the impoundment. Operators of impoundments managing dangerous waste must perform weekly inspections. In addition, operators must inspect the facility after each storm event to detect any deterioration to dikes and containment devices, malfunction of overtopping

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Washington Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Monitoring	Yes	**Surface Impoundments Discharging Non-Dangerous Waste to Waters of the State:** **Groundwater:** Waste discharge permits must contain any monitoring requirements specified by the DE, including any applicable requirements under the federal CWA. **Surface Water**: NPDES permits are subject to monitoring requirements as determined by DE. The monitoring requirements include: flow, pollutants subject to reduction or elimination under the permit, pollutants that may have adverse impact on human health and the environment, and pollutants specified by the DE. **Waste Analysis:** DE requires NPDES permitees to monitor intake water, influent to treatment facilities, internal waste streams, and/or receiving waters when determined necessary. **Surface Impoundments Managing Dangerous and Non-Dangerous Waste, But Not Discharging to Waters of the State:** **Groundwater:** Operators of impoundments managing dangerous waste and having a capacity of more than two million gallons must implement a groundwater monitoring program to detect releases to the groundwater. The jurisdictional health departments may require a groundwater monitoring program for facilities with less than two million gallons capacity. **Waste Analysis Requirements:** Operators of impoundments managing dangerous wastes must perform a chemical, physical and/or biological analysis of each dangerous waste that is stored, treated or disposed. The analysis may consist of existing data or data obtained via testing.
Reporting and Recordkeeping	No	Not specified in state regulations.
Inspection and Enforcement	Yes	**Inspections:** DE is authorized to inspect facilities having a state waste discharge and NPDES permits. Jurisdiction health departments to inspect solid waste facility permittees. **Enforcement/Penalties:** DE has administrative, civil, and criminal enforcement authority, including the authority to levy penalties. Penalties for violations to waste discharge and NPDES permits are $10,000 per day of violation.

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Washington Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Performance Standards and Corrective Action	Yes	**Surface Impoundments Discharging Non-Dangerous Waste to Waters of the State:** Not specified in state regulations. **Surface Impoundments Managing Dangerous and Non-Dangerous Waste, But Not Discharging to Waters of the State:** Operators of impoundments managing dangerous waste must maintain a contingency plan at the facility in case of facility failure.
Closure/Postclosure Care	Yes	Impoundments managing dangerous waste, but not discharging to waters of the state and impoundments Managing nondangerous waste, but not discharging to waters of the state have specific regulations requiring closure/postclosure care.
Financial Assurance	Yes	Impoundments managing dangerous waste, but not discharging to waters of the state have specific requirements for financial assurance.
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the states regulation or program.

Sources:

Washington Administrative Code (WAC).

Washington Department of Ecology (DEC) web page (http://www.ecy.wa.gov).

West Virginia

The Office of Water Resources of the West Virginia Department of Environmental Protection is responsible for permitting and enforcement of nonhazardous waste surface impoundments.

All nonhazardous waste surface impoundments at industrial facilities are subject to the applicable solid waste regulations for Class F (i.e., industrial) Solid Waste Facilities and a solid waste facility permit must be obtained. These regulations are not applicable to surface impoundments in existence on or before May 1, 1990 which are operating under a state NPDES permit, except that all such impoundments are required to have an adequate groundwater monitoring system in place.

The Groundwater Protection Rule also applies and is addressed in the regulatory provisions for the solid waste permit.

Finally, a state NPDES permit is required for discharges to surface water and groundwater.

West Virginia Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	Yes	State regulations specify that surface impoundments must be located at least 5 feet above the groundwater table and must maintain a distance of 4 feet between liner and bedrock. The facilities also must comply with restrictions for natural wetlands and endangered species.
Design Criteria (liner, leachate collection)	Yes	The state regulations require a composite liner (18-inch compacted clay, 60 mil HDPE) and a leachate detection and collection system.
Operating Criteria	Yes	Freeboard requirements are specified in the regulations (minimum of 2 feet).
Monitoring	Yes	**Groundwater/Leachate:** Regulations specify that a minimum of three groundwater monitoring wells are required, one up-gradient and two down -gradient of any surface impoundment. Baseline and background monitoring must be completed along with semiannual monitoring for conventional parameters and metals. Daily monitoring of flow rate and volume, and semiannual testing for conventional parameters and metals for leachate must also be completed.
Reporting and Recordkeeping	No	Not specified in state regulations.

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West Virginia Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Inspection and Enforcement	Yes	The DEP is authorized to inspect any facility, but the frequency is not specified in the regulations.
Performance Standards and Corrective Action	Yes	Expansion of monitoring if statistically significant increase in one or more groundwater parameters. Corrective action assessment required if: • evidence of groundwater contamination • significant increase in a Phase II monitoring parameter • groundwater exceeds state standards
Closure/Postclosure Care	Yes	Closure and postclosure plans are required by the regulations. The plans must include final cover (details not specified by the regulations) and revegetation. Additional requirements determined on a case-by-case basis.
Financial Assurance	No	The regulations do not require financial assistance for non-commercial facilities.
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the state's regulations or programs.

Sources:

West Virginia Solid Waste Regulations (WVSWR) Titles 33-1; 47-10; 47-58.

West Virginia Department of Environmental Protection (WVDEP) web page (http://www.dep.state.wv.us/offices.html).

Wisconsin

Responsibility for surface impoundments resides with the Wisconsin Department of Natural Resources Division of Water if the surface impoundment discharges to waters of the state and has a Wisconsin Pollutant Discharge Elimination System (WPDES) permit. If the surface impoundment does not have a WPDES permit and is designed for the disposal of solid waste, it is subject to solid waste regulations. The solid waste regulations require a permit, a closure plan, and, on a case-by-case basis, proof of financial responsibility for closure of the impoundment.

Wisconsin Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	Yes	**For WPDES permitted impoundments:** The regulations stipulate that the impoundment may not be located 1,000 feet from a well serving a community public water supply system, 250 feet from other potable water supplies, or 500 feet from an inhabited dwelling, in a floodway, or in a wetland. In addition, a separation of 5 feet is required between the bottom of the impoundment and either bedrock or groundwater table, whichever is higher.
Design Criteria (liner, leachate collection)	Yes	**For WPDES permitted impoundments:** Natural soil materials, soil-bentonite mixtures, or synthetic liners may be used. The bottom must be compacted to a depth of 6 inches, and an additional inorganic layer to protect the liner may be required. The permeability of a soil or soil-bentonite liner may not exceed 10^{-7}. Specific requirements for oil, soil-bentonite, and synthetic liners are provided in the regulations. Synthetic liners must be at least 30 mils thick. Water losses from impoundment may not exceed 500 gallons per acre per day.
Operating Criteria	No	Not specified in state regulations, but may be applied on a permit-specific basis.
Monitoring	Case-by-case	Groundwater monitoring may be required on a case-by-case basis under either a WPDES or solid waste permit.
Reporting and Recordkeeping	No	Not specified in state regulations.
Inspection and Enforcement	Yes	State regulations give the authority to inspect, but do not specify the frequency.

(continued)

Wisconsin Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Performance Standards and Corrective Action	Yes	For solid waste permitted impoundments: The regulations stipulate that facilities may not cause a detrimental effect on any surface or groundwater or exceedances of water quality standards, significant adverse impact on wetlands or critical habitat areas, or emissions of any hazardous air contaminant exceeding the limitations for those substances.
Closure/Postclosure Care	Yes	For solid waste permitted impoundments: The regulations require a closure plan. Postclosure groundwater monitoring may be required on a site-specific basis.
Financial Assurance	Case-by-case	For solid waste permitted impoundments: The regulations state that financial assurance may be required on a site-specific basis.
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the state's regulations or programs.

Sources:

Wisconsin Administrative Code (WAC) Chapters 213 and 502.

Wisconsin Department of Natural Resources (WDNR) web page (http://www.dnr.state.wi.us/).

Wyoming

In Wyoming, responsibility for regulating and permitting surface impoundments is consolidated in the Wyoming Department of Environmental Quality's Water Quality Division. Industrial nonhazardous waste surface impoundments must be covered by a Permit to Construct, Install, Modify or Operate, and a state NPDES discharge permit (if discharging to surface water). The applicable regulations for the Permit to Construct are found under the nonbiological treatment ponds section. The summary table contains these standards.

Wyoming State Requirements for Nonhazardous Waste Surface Impoundments

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Location or Siting Standards	Yes	The Permit to Construct regulations state that impoundments can not be located within high-water mark of perennial water bodies, and not where surface water and groundwater are able to enter it.
Design Criteria (liner, leachate collection)	Yes	The Permit to Construct regulations: • provide guidelines for inlet and outlet structures, and dike protection • specify water depth on a case-by-case basis • require a permanent flow measuring device • require a composite liner if wastewater characteristics or site conditions will not ensure the protection of the groundwater
Operating Criteria	Yes	The Permit to Construct regulations require a minimum of 3 feet of freeboard (or 2 feet for impoundments less than 2 acres)
Monitoring	No	Groundwater monitoring not specified in state regulations.
Reporting and Recordkeeping	No	Not specified in state regulations.
Inspection and Enforcement	Yes	State regulations give the authority to inspect, but do not specify the frequency. Specific enforcement mechanisms are also not specified in the regulations.
Performance Standards and Corrective Action	Yes	All surface impoundments must conform to applicable ground and surface water quality standards.
Closure/Postclosure Care	No	Not specified in state regulations.
Financial Assurance	No	Not specified in state regulations.

(continued)

Wyoming Requirements for Nonhazardous Waste Surface Impoundments (continued)

Criteria	Program or Regulation Addresses Criteria?	Description of Regulation or Program
Air Emission Controls, Operating Requirements, and Recordkeeping Requirements	No	Not specified in state regulations.

Yes: Regulation or program addresses criteria.
No: There is no specific state regulation or program that addresses the criteria.
Case-by-case: The criteria can be addressed by the state via a permit condition or as allowed under the flexibility built in to the state's regulations or programs.

Sources:

Wyoming Regulations: Department of Environmental Quality, Water Quality, Chapters 2, 3 and 11.

Wyoming Statutes: 35-11-101 et seq.

Wyoming Department of Environmental Quality (WDEQ) web page (http://deq.state.wy.us/wqd/w&ww.htm).

Section D-2

Table for Comparison of TC Levels to Wastewater Concentrations in Surface Impoundments Predicted to Cause Environmental Releases

CAS Number	Constituent	TC Regulatory Level (mg/L)	Range of Wastewater Concentrations (mg/L) (number of facility-unit risk estimates in the range)		
			No Predicted Environmental Releases as Indicated by Screening Level Inhalation Risks < Risk Criteria	**Predicted Environmental Releases as Indicated by Screening Level Inhalation Risks = 10E-5 to 10E-4 or HI = 1 to 10**	**Predicted Environmental Releases as Indicated by Screening Level Inhalation Risks > 10-4 or HI > 10**
7440-38-2	Arsenic	5	NA	NA	NA
7440-39-3	Barium	100	NA	NA	NA
71-43-2	Benzene	0.5	0 - 1.1 (79)	**0.005 - 0.125** (4)	No data
7440-43-9	Cadmium	1	NA	NA	NA
56-23-5	Carbon tetrachloride	0.5	0 - 0.125(34)	**0.005 - 0.01166**(2)	No data
57-74-9	Chlordane, alpha & gamma isomers	0.03	NA	NA	NA
108-90-7	Chlorobenzene	100	0 - 0.125(44)	No data	No data
67-66-3	Chloroform[a]	6	0 - 0.99819(96)	**0.0037 - 0.99819**(15)	No data
7440-47-3	Chromium	5	NA	NA	NA
95-48-7	o-Cresol [2-Methyl phenol]	200	NA	NA	NA
108-39-4	m-Cresol [3-Methyl phenol]	200	NA	NA	NA
106-44-5	p-Cresol [4-Methyl phenol]	200	NA	NA	NA
1319-77-3	Cresols (total)	200	0.0022 - 0.03(47)	No data	No data
94-75-7	2,4-D [2,4-Dichlorophenoxyacetic acid]	10	NA	NA	NA
106-46-7	1,4-Dichlorobenzene	7.5	0.001 - 0.1(43)	No data	No data
107-06-2	1,2-Dichloroethane [ethylene dichloride]	0.5	0.00087 - 0.125(48)	**0.01166**(1)	No data
75-35-4	1,1-Dichloroethylene [vinylidene chloride]	0.7	0 - 0.125(39)	**0.005 - 0.125**(7)	No data
121-14-2	2,4-Dinitrotoluene	0.13	0 - 0.1(33)	No data	No data
72-20-8	Endrin	0.02	NA	NA	NA
76-44-8	Heptachlor	0.008	NA	NA	NA
118-74-1	Hexachlorobenzene	0.13	0 - 0.1(21)	**.01 - 0.1**(9)	No data
87-68-3	Hexachloro-1,3-butadiene [hexachlorobutadiene]	0.5	0.0075 - 0.1(26)	**0.01**(4)	No data
67-72-1	Hexachloroethane	3	0 - 0.1(30)	No data	No data
7439-92-1	Lead	5	NA	NA	NA

(continued)

Table (continued)

CAS Number	Constituent	TC Regulatory Level (mg/L)	Range of Wastewater Concentrations (mg/L) (number of facility-unit risk estimates in the range)		
			No Predicted Environmental Releases as Indicated by Screening Level Inhalation Risks < Risk Criteria	**Predicited Environmental Releases as Indicated by Screening Level Inhalation Risks = 10E-5 to 10E-4 or HI = 1 to 10**	**Predicted Environmental Releases as Indicated by Screening Level Inhalation Risks > 10-4 or HI > 10**
58-89-9	Lindane	0.4	NA	NA	NA
7439-97-6	Mercury	0.2	0 - 0.01(106)	No data	**0.00055 - 0.07**(2)
72-43-5	Methoxychlor	10	NA	NA	NA
78-93-3	Methyl ethyl ketone [2-butanone] [MEK]	200	0 - 18.28(96)	No data	No data
98-95-3	Nitrobenzene	2	0 - 0.1(34)	No data	No data
87-86-5	Pentachlorophenol [PCP]	100	NA	NA	NA
110-86-1	Pyridine	5	0.01 - 0.1(24)	**5**(2)	No data
7782-49-2	Selenium	1	NA	NA	NA
7440-22-4	Silver	5	NA	NA	NA
127-18-4	Tetrachloroethylene [perchloroethylene]	0.7	0 - 0.125(49)	No data	No data
8001-35-2	Toxaphene [chlorinated camphene][a]	0.5	NA	NA	NA
79-01-6	Trichloroethylene [TCE]	0.5	0.001 - 0.125(43)	No data	No data
95-95-4	2,4,5-Trichlorophenol	400	NA	NA	NA
88-06-2	2,4,6-Trichlorophenol	2	NA	NA	NA
93-72-1	Silvex [2,4,5-Trichlorophenoxypropionic acid]	1	NA	NA	NA
75-01-4	Vinyl chloride [chloroethylene]	0.2	0.00053 - 0.125(36)	**0.02333**(1)	No data

NA = Not applicable because the constituent was not evaluated for air risks.
No Data = no concentration data were reported in response to the long survey that, when modeled, indicated risks in the specified range.
Note: **Bold** entries indicate concentration ranges less than TC regulatory levels **and** causing envionrmetal air release. Values in ( ) indicate the number of concentration values in the range used to estimate risk for each facility, unit, and chemical combination.
[a] Indicates the constituent also exceeded the risk criteria for the air pathway in the risk assessment in which actual (rather than default) distances to receptors were used.

Section D-3

Table of In-Scope Industry Sectors and Potentially Applicable NSPS VOC Standards

SIC Industry Code	SIC Title	NSPS	Regulatory Citation
2011*, 2022*, 2035*, 2063*, 2092*	Food and Kindred Products	No VOC NSPS standard	N/A
2211, 2251	Testile mill products	No VOC NSPS standard	N/A
2435, 2436	Hardwood, softwood veneer and plywood	No VOC NSPS standard	N/A
2611*, 2621*, 2631*, 2653*, 2679*	Paper and allied producrs (e.g., pulp and paper mills, etc.)	No VOC NSPS standard	N/A
2819*	Industrial inorganic chemicals, not elsewhere classified	No VOC NSPS standard	N/A
2821*	Plastics materials and resins	VOC Emissions from Polymer Manufacturing Industry	40 CFR 60 Subpart DDD
2824*	Organic fibers, noncellulosic	Synthetic Fiber Production Facilities	40 CFR 60 Subpart H.H.
2833*	Medicinals and botanicals	No VOC NSPS standard	N/A
2834*	Pharmaceutical preparations	No VOC NSPS standard	N/A
2843*	Surface active agents	No VOC NSPS standard	N/A
2865*	Cyclic crudes and intermediates, and organic dyes and pigments	No VOC NSPS standard	N/A

(continued)

Table (Continued)

SIC Industry Code	SIC Title	NSPS	Regulatory Citation
2869*	Industrial organic chemicals, not elsewhere classified	Equipment Leaks of VOC Synthetic Organic Chemical Manufacturing Industry (SOCMI)	40 CFR 60 Subpart VV
		VOC Emissions from the SOCMI Air Oxidation Unit Processes	40 CFR 60 Subpart III
		VOC Emissions from the SOCMI Air Distillation Operations	40 CFR 60 Subpart NNN
		VOC Emissions from the SOCMI Reactor Processes	40 CFR 60 Subpart RRR
		(Proposed) VOC Emissions from the SOCMI Wastewater	40 CFR 60 Subpart YYY
2873*	Nitrogenous fertilizers	No VOC NSPS standard	N/A
2874*	Phosphatic fertilizers	No VOC NSPS standard	N/A
2899*	Chemical preparations, not elsewhere classified	No VOC NSPS standard	N/A
2911*	Petroleum refining	VOC Emissions from Petroleum Refinery Wastewater Systems	40 CFR 60 Subpart QQQ
2952*	Asphalt felts and coatings	No VOC NSPS standard	N/A
3011	Tires and inner tubes	Rubber Tire Manufacturing Industry	40 CFR 60 Subpart BBB
3052	Rubber & plastics hose and belting	No VOC NSPS standard	N/A
3069	Fabricated rubber products, not elsewhere classified	Pressure Sensitive Tape and Label Surface Coating	40 CFR 60 Subpart RR
3081	Unsupported plastics film & sheet	Polymeric Coating of Supporting Substrates Facilities	40 CFR 60 Subpart VVV
3087	Custom compound purchased resins	No VOC NSPS standard	N/A
3089	Plastics products, not elsewhere classified	Polymeric Coating of Supporting Substrates Facilities	40 CFR 60 Subpart VVV
3229*	Pressed and blown glass, not elsewhere classified	No VOC NSPS standard	N/A
3273*	Ready-mixed concrete	No VOC NSPS standard	N/A
3312*	Blast furnaces and steel mills	Metal Coil Surface Coating	40 CFR 60 Subpart TT
3313*	Electro metallurgical products	Metal Coil Surface Coating	40 CFR 60 Subpart TT

(continued)

Table (Continued)

SIC Industry Code	SIC Title	NSPS	Regulatory Citation
3316*	Cold finishing of steel shapes	Metal Coil Surface Coating	40 CFR 60 Subpart TT
3317*	Steel pipe and tubes	Metal Coil Surface Coating	40 CFR 60 Subpart TT
3321*	Gray and ductile iron foundries	No VOC NSPS standard	N/A
3324*	Steel investment foundries	No VOC NSPS standard	N/A
3334*	Primary aluminum	Metal Coil Surface Coating	40 CFR 60 Subpart TT
3339*	Primary nonferrous metals, not elsewhere classified	No VOC NSPS standard	N/A
3341*	Secondary nonferrous, metals	Metal Coil Surface Coating	40 CFR 60 Subpart TT
3351*	Copper rolling and drawing	No VOC NSPS standard	N/A
3353*	Aluminum sheet, plate, and foil	Metal Coil Surface Coating	40 CFR 60 Subpart TT
3357*	Nonferrous wiredrawing & insulating	No VOC NSPS standard	N/A
3398*	Metal heat treating	No VOC NSPS standard	N/A
3399*	Primary metal products, not elsewhere classified	No VOC NSPS standard	N/A
3462	Iron and steel forgings	No VOC NSPS standard	N/A
3499	Fabricating metal products, not elsewhere classified	Metal Coil Surface Coating	40 CFR 60 Subpart TT
		Surface Coating of Metal Furniture	40 CFR 60 Subpart EE
3624, 3674	Electronic and other electric equipment	No VOC NSPS standard	N/A
3731, 3761	Transprotation equipment	No VOC NSPS standard	N/A
4952, 4953	Electric, gas, and sanitary services	No VOC NSPS standard	N/A
5171*	Petroleum bulk stations and terminals	Bulk Gasoline Terminal	40 CFR 60 Subpart XX
9711	National security	No VOC NSPS standard	N/A

* Denotes SIC code is associated with one of the seven two-digit SIC Code that manage 98 percent of the wastewater capacity at impoundments within the scope of this study.

SURFACE IMPOUNDMENT STUDY

TECHNICAL PLAN FOR HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT

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DISCLAIMER

The work presented in this document has been funded by the U.S. Environmental Protection Agency. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the Agency.

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1.0 Executive Summary

1.1 Background

1.1.1 Legislative Mandate for the Surface Impoundment Study and Consent Decree

The 1996 Land Disposal Program Flexibility Act (LDPFA) amended section 3004(g) of the Resource Conservation and Recovery Act (RCRA) to exempt decharacterized wastes from provisions of the RCRA land disposal restrictions. Decharacterized nonhazardous wastes are RCRA hazardous wastes whose hazardous characteristics of ignitability, corrosivity, reactivity, or toxicity have been removed through dilution or other treatment prior to being managed in land-based waste management units. The LDPFA exemption allows decharacterized wastes to be either (1) placed in surface impoundments that are part of wastewater treatment systems whose ultimate discharge is regulated under the Clean Water Act (CWA), or (2) disposed of in Class 1 nonhazardous injection wells regulated under the Safe Drinking Water Act (SDWA). Congress also mandated in the 1996 LDPFA that a 5-year study be conducted to evaluate any human health or environmental risks posed by the exempted wastes that are managed in these ways and to evaluate the extent to which existing state regulations address any such risks.

The Office of Solid Waste (OSW) in the U.S. Environmental Protection Agency (EPA, or the Agency) is conducting this study to assess those exempted wastes placed in surface impoundments and regulated under the Clean Water Act. (EPA's Office of Water is separately preparing a study to evaluate any risks through disposal of the exempted wastes in Class 1 nonhazardous injection wells.) In addition, the Surface Impoundment (SI) Study scope was expanded from decharacterized wastewater only to include all nonhazardous industrial wastewaters managed in surface impoundments whether or not they were once characteristic hazardous wastes to satisfy a requirement of Civ. No. 89-0598, *Environmental Defense Fund vs. Browner*. The expanded scope thus covers two regulatory status categories based on RCRA: impoundments with decharacterized wastes and impoundments with other nonhazardous industrial wastes that have never exhibited any of the characteristics of corrosivity, ignitability, reactivity, or toxicity.

1.1.2 Major Objectives of the Surface Impoundment Study

After reviewing the legislative history of the LDPFA, in 1997 OSW defined the principal study question as "Determine, with an acceptable degree of certainty, what risks to human health and the environment are posed by industrial wastewaters managed in surface impoundments." Together with a randomized two-stage sample design and a separate field sampling effort intended to "ground-truth" the data on existence of specific chemicals and their quantities, this technical plan provides the analytic approach for answering the principal study question.

To answer the study question, EPA will (1) develop descriptive statistics of nonhazardous wastes managed in surface impoundments, the geographic distribution of these surface impoundments, and their proximity to human populations and sensitive ecosystems; and (2) develop a screening-level risk profile (for human and ecological receptors) that presents risk ranges associated with different constituents, unit types, and facility types. These two steps will satisfy the legislative and consent decree requirements to conduct a study of human and ecological risks associated with surface impoundments. In addition, the Agency may conduct a more detailed risk analysis based on multimedia modeling for constituents, units, and pathways of potential concern either during the time frame of this study or subsequent to this study.

1.1.3 Study Design and Components

The Surface Impoundment Study is designed to be based to the extent possible on data collected from a representative sample of the study population. This section briefly describes the definition of facilities, impoundments, and constituents within the scope of the study; the selection of a representative sampling of facilities to survey and assess; other data sources that will be used in addition to the survey results; and the analytic procedure for assessing these data and drawing conclusions about potential risks presented by industrial wastewaters managed in surface impoundments.

1.1.3.1 Definition of "In-scope" Facilities and "In-scope" Surface Impoundments. A facility is within the scope of this study if it meets the following criteria:

- It is a direct discharger (i.e., has a National Pollutant Discharge Elimination System [NPDES] permit), a zero discharger (generally, designed to infiltrate or evaporate wastewater), or an indirect discharger (discharges wastewater to a publicly owned treatment works).

- It conducts activities within the manufacturing sector (Standard Industrial Classification [SIC] codes 20-39), selected transportation subsectors (SIC codes 4212 - Local Trucking Without Storage, and 4581 - Airports, Flying Fields, and Airport Terminal Services), the waste management service sector (SIC codes 4953 - Refuse Systems and 4952 - Sewerage Systems, but excluding publicly owned treatment works), or selected wholesale trade subsectors (SIC codes 5085 - Industrial Supplies, 5093 - Scrap and Waste Materials, and 5171 - petroleum bulk terminals).

- It has one or more "in-scope" surface impoundments. A surface impoundment is within the scope of the study if it has been used to manage certain nonhazardous wastes since June 1990.

1.1.3.2 Definition of "In-scope" Wastes (Based on Type of Constituents and pH). Nonhazardous wastes are within the scope of the study if they either contain at least one of 256 constituents of potential concern or have a typical pH that falls just outside the range of hazardous wastes. The pH criterion is included because one of the common "hazardous characteristics" that is removed when wastewaters are treated is the corrosivity characteristic,

defined as the condition when a representative sample of a waste has a pH below 2 or above 12.5. EPA is interested in knowing the extent to which wastewaters in surface impoundments are managed in the pH range just outside the hazardous characteristic range. EPA developed the list of 256 constituents to include constituents that are of interest from a policy standpoint and constituents required to be studied based on the *EDF vs Browner* consent decree. Appendix A lists the constituents within the scope of this study.

1.1.4 Selection of Representative Sample for Data Collection

In February 1999, EPA conducted a "screener" survey of over 2,000 facilities to identify facilities and surface impoundments that are potentially within the scope of the survey. Selecting from among the facilities that reported having in-scope impoundments and wastes, EPA developed a representative sample of 215 facilities to participate in a more detailed survey. EPA developed this representative sample of facilities for the study by selecting a stratified random sample of the direct and zero dischargers and a purposive sample of the indirect dischargers (since there were relatively few indirect dischargers that reportedly used surface impoundments).

The 215 selected facilities received a second detailed survey in November 1999, the Survey of Surface Impoundments, with responses due in February and March 2000. This survey requests detailed data on impoundment design, operation, and closure; the constituents that are present in impoundments and emissions; and data on the subsurface hydrogeology and activities of nearby humans. Both the long survey and the list of facilities that received it (excluding facilities whose information is being handled as confidential business information) can be viewed at http://www.epa.gov/epaoswer/hazwaste/ldr/icr/ldr-impd.htm.

Figure 1-1 shows the estimated distribution of study-eligible facilities used to select the sample population of 215 facilities completing the detailed survey.

1.1.5 Current Knowledge of Study Population

Based on the responses to the 1999 screener survey, EPA estimates that the number of nonhazardous waste surface impoundments in the United States that meet the criteria for inclusion in the Surface Impoundment Study is 19,000 impoundments, located at 8,500 facilities. Major industries represented include the food processing, paper, chemical, petroleum, and stone/clay/glass/concrete industries. An estimated 1,000 facilities, predominantly in the paper, chemical, and petroleum refining sectors, have at least one impoundment with decharacterized wastewaters.

Figure 1-2 shows the universe of surface impoundment facilities having in-scope impoundments by industry category.

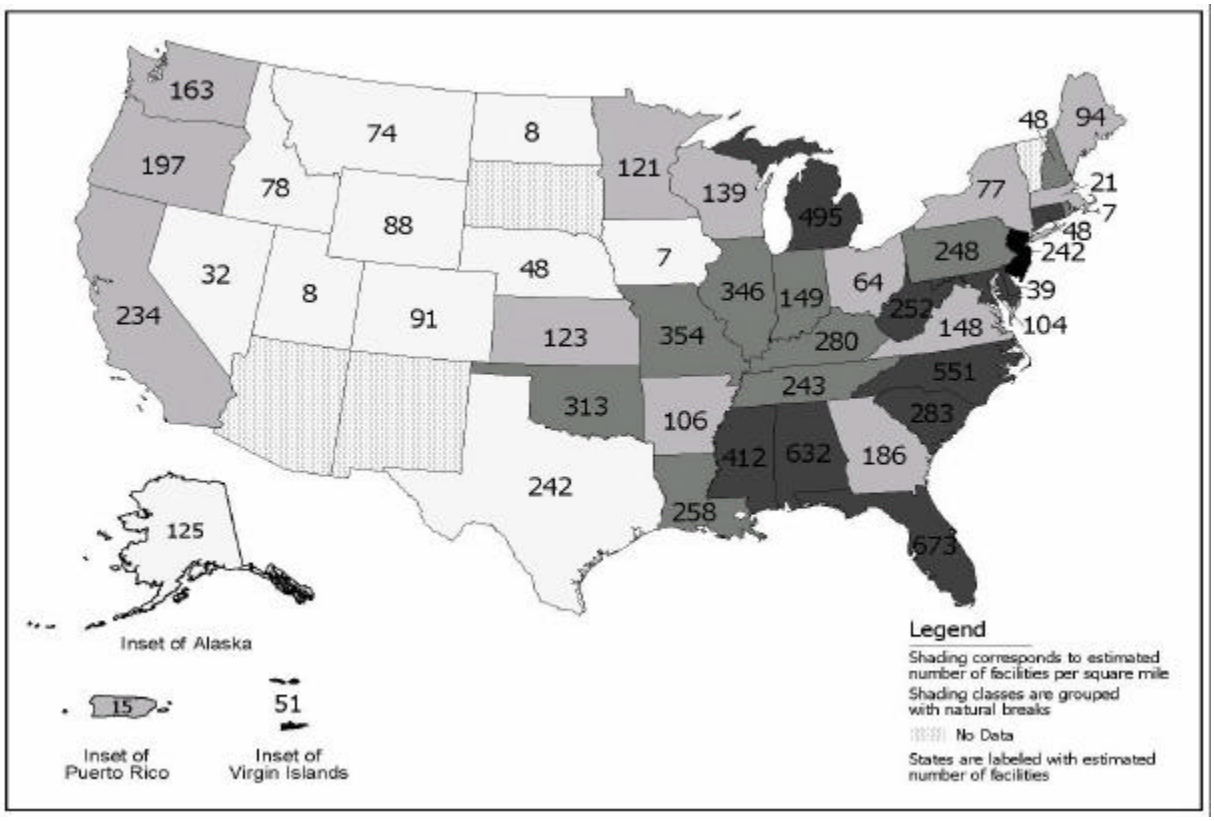
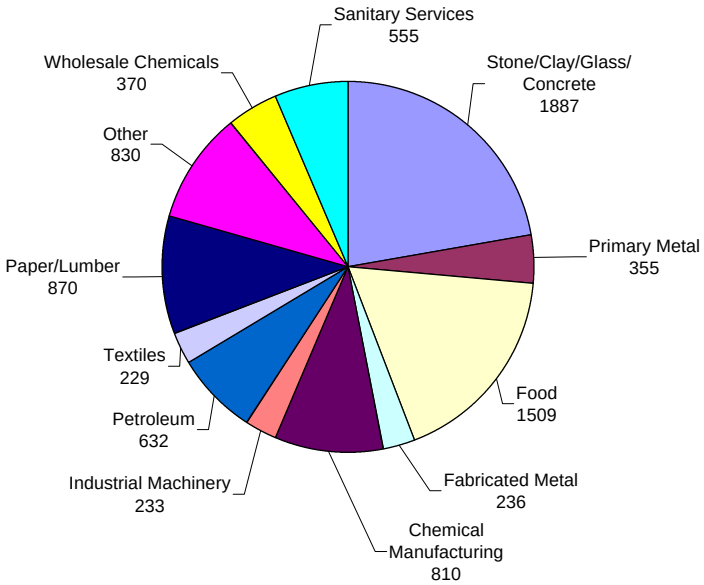


Figure 1-1. Estimated distribution of study-eligible facilities with surface impoundments



Note: Values shown are national estimates of the number of "study-eligible" facilities (facilities using surface impoundments that meet criteria for being in the study).

Figure 1-2. Universe of surface impoundment facilities with in-scope impoundments by industry category.

1.1.6 Additional Data Sources for Study

In addition to the survey results, EPA will also use data from EPA Region and state files (for those facilities that are permitted under RCRA and under EPA authorities); publicly available data sources including census tract data to help evaluate the potential for population exposures; and geographic information system (GIS) data to assist in describing Regional and site-specific geological and ecological conditions. EPA will also collect and analyze wastewater and sludge samples at 15 to 20 facilities selected from among the 215 facilities being surveyed. This is a relatively major sampling effort that will provide important information to supplement that submitted under the survey and will also serve as a quality assurance step. In addition, EPA will include six facilities that were the subject of a 1997-1998 pilot study. Thus, in all, there are 221 facilities under review in this study.

1.1.7 Science Advisory Board Comments

The Agency has submitted the overall design and methodology for the Surface Impoundment Study to EPA's Science Advisory Board (SAB). SAB commented that they found "considerable technical merit in the proposed study structure . . ." (U.S. EPA, 1998c). The SAB also commented that it would be extremely resource-intensive to undertake comprehensive site characterization for multiple units and constituents, and that therefore EPA should use a screening approach to prioritize its efforts.

1.1.8 Purposes of Technical Plan

The major purposes of this technical plan are to provide the analytic blueprint for assessing potential risks associated with the surface impoundment universe (using the data from the surveys and other sources) and to obtain peer review comment on the approaches and methodologies described.

1.2 Summary of Technical Plan for the Analysis

EPA will conduct the technical risk analysis in two stages, with the basic objective of screening all the reported surface impoundment units and constituents during Phase I and conducting more detailed multimedia modeling on some units and constituents in Phase II. Phase I will be the screening and prioritization stage, during which the large number of surface impoundments and constituents anticipated to be reported under the survey will be examined, screened, and prioritized using clear and straightforward science decision rules. During Phase I, EPA will screen out from further analysis those constituents or units that pose negligible risks and will prioritize for additional analysis the remaining units and constituents. Those units and constituents that merit additional analysis of potential risks will proceed to Phase II. In addition, some ambiguous cases will proceed to Phase II to ensure that the Agency is not overlooking areas of potential risk. During Phase II, EPA will use the multimedia model developed for the Hazardous Waste Identification Rule (HWIR), updated for the Surface Impoundment Study, to conduct fate and transport modeling and assess potential risks associated with these units and constituents. (Development of this model is near completion and the model is currently undergoing independent verification to support its use in this and other analyses.) The risk

results for the Phase II stage of the analysis will be used to revise the appropriate portions of the overall risk profile generated during Phase I.

EPA anticipates that the screening-level risk profile of the universe of surface impoundments generated during Phase I and the risk analyses conducted on higher priority units, constituents, and pathways during Phase II will be completed by March 2001 and will be included in the final study that satisfies the statutory and consent decree requirements described above. The Phase I risk profile, because it is a screening-level assessment and based on protective assumptions, will not be a precise representation of risks. As work progresses on Phase II multimedia analyses, the new risk estimates that are based on more realistic exposure assumptions will replace the corresponding Phase I risk estimates, and EPA anticipates that the overall risk profile will generally decrease. (One exception will be for constituents with a high potential to bioaccumulate or persist, for which the Phase II multimedia modeling may show potential risks not identified during Phase I.) The Agency also anticipates that the relative risks will remain approximately the same in the two phases (e.g., comparing different industry categories, constituents, or unit types.) This two-stage analysis is designed to optimize EPA's ability to identify areas of potential concern within a limited period of time.

1.2.1 Phase I. Screening and Prioritization of Constituents, Units, and Pathways of Potential Concern

1.2.1.1 Background. Given the large number of constituents (256 chemicals), in-scope impoundments (anticipated to be approximately 600 surface impoundments at 221 reporting facilities), EPA must conduct a screening in order to prioritize those units, constituents, and pathways of most concern. This point was reinforced by the comments of EPA's Science Advisory Board that it would be extremely resource-intensive to undertake comprehensive site characterization for multiple units and constituents and that EPA would need to prioritize areas for review. In addition, the Agency anticipates that a significant number of units may contain very low levels of constituents and not require lengthy and costly fate and transport modeling. Therefore, two major purposes of Phase I of the analysis are to screen the reported constituents, units, and pathways to identify those of negligible concern that will not require fate and transport modeling and to prioritize those that proceed for further analysis.

At appropriate points throughout the screening and prioritization process, EPA will verify the presence of expected constituents by comparing with constituents that are identified in NPDES and RCRA permits (where applicable), and by cross checking within particular industry categories. If a constituent has not been reported that one might reasonably have expected would be reported, one of several actions could occur: the facility might be considered a candidate for sampling conducted by EPA; the facility might receive followup queries concerning the nature of the waste; and/or EPA might infer the presence of the constituent for modeling purposes.

EPA considers that a sound screening process is a fundamental and integral part of the analysis and is proposing to base the screening on clear science decisions rules related to threshold concentrations of potential concern.

1.2.1.2 Development and Use of Science Decision Rules. EPA proposes to sequentially apply a series of decision rules in determining whether to retain a reported constituent at a reported surface impoundment for further analysis in Phase II.

1.2.1.3 Phase IA: Initial Screening

Basic Approach: Use of Screening Factors. The first step will be for EPA to compare the reported concentration data (in surface impoundment water, sludge, and emissions) collected from the facility survey with threshold concentrations that are protective of human health (residential exposures) and protective of selected representative ecological receptors. The threshold concentrations, or "screening factors," will be developed to provide a suitable margin of protection that, in most cases, will encompass the potential for indirect exposures and background exposures, as discussed below. Surface impoundment units reporting concentrations below the screening factors will be screened out from any further analysis for that particular constituent or pathway. However, the screening level risk that is calculated will be included in the overall risk profile for the surface impoundment universe.

Appendix A provides a table of the health-based benchmarks selected to use in this study for the constituents within the scope of this study; and Section 2.2 the methodology used to calculate screening factors from these benchmarks. This methodology includes the use, at this stage, of highly protective exposure factors, such as direct ingestion of surface impoundment wastewaters and direct inhalation of emissions.

Section 2.3 describes the screening process for ecological risks in detail, including the selection of existing benchmarks for species representative of major taxonomic groupings and protective exposure assumptions. In selecting benchmarks, the preferred toxicological responses will be those related to reproductive fitness and the stability of populations. In addition, EPA will highlight for special evaluation any facilities that are proximate to sensitive habitats such as managed wildlife preserves.

At this stage, EPA's objective is to ensure a suitable margin of protection to human health and the environment in the screening decisions because of the final nature of the screening action in removing a particular constituent, unit, or pathway from any further analysis, with the consequence that there will be no further consideration of the contributions to indirect and cumulative exposures. EPA considers that, for many constituents, screening based on direct ingestion of the surface impoundment influent and direct inhalation of the emissions is, by its nature, very protective. That is, if fate and transport modeling were to be conducted, the potential risks would invariably be lower. EPA may also provide an additional margin of protection to recognize the potential for indirect exposures and for exposures to background levels (i.e., sources other than those within the scope of the survey). In addition, special consideration will be given to constituents with relatively high potential to bioaccumulate or persist in the environment (see discussion below).

Special-Case Constituents. There are a number of constituents with a relatively high potential to be persistent or bioaccumulative that require special consideration. These constituents may represent human health or ecological risks, yet not be identified as constituents

with potential risks through the Phase I screening process. To ensure that these types of constituents are identified, each constituent will be ranked on the basis of persistence (P), bioaccumulation (B), and toxicity (T) to human and ecological receptors, using the procedures and criteria developed for the Revised Waste Management Prioritization Tool (WMPT) (U.S. EPA, 1998e). "Special-case" constituents will be those identified as having high-ranking PBT scores and will be reported along with the relative-risk distributions developed under Phase I. These special-case constituents will proceed to the Phase II multimedia risk analysis.

Risk Criteria. The risk criteria—the levels above which the risk to an individual are considered significant—are as follows:

- For carcinogens: excess cancer risk = 10^{-5}
- For noncarcinogens: hazard index (HI) =1.

These criteria apply to a specific constituent-unit-pathway combination as well as to summations of risks for a constituent, an impoundment, or a facility. Summations of HIs will be considered only if to the same target organ. By separating risks according to target organ, the resulting HI can be summed across the ingestion and inhalation exposure pathways for each of the potentially affected target organs.

Margin of Protection. For purposes of its initial screening, EPA will apply an additional margin of protection of 10^{-1}. This is intended to allow reasonable certainty that constituents and units screened out from further consideration present a negligible risk. Among the considerations leading to the use of a margin of protection are that EPA is not assessing multimedia risks through indirect pathways in Phase I or background levels of exposures that are not within the scope of this study. Note, however, that special-case constituents with high potential to bioaccumulate or persist in the environment will automatically proceed to Phase II analysis.

Representing Risk Ranges and Cumulative Risks. The calculated screening risks for each constituent for a specific impoundment and facility will be combined to generate three cumulative risk estimates: constituent risk, impoundment risk, and facility risk. The risk estimates generated during Phase I for specific constituents, impoundments, and facilities will be accumulated into risk ranges or "bins" to portray potential risk distributions for the surface impoundment universe and various subsets (such as zero dischargers, particular industries, or particular constituents). The human health risk bins currently under consideration include:

- **Excess Cancer Risk (6 bins):** $< 10^{-8}$, $\geq 10^{-8}$ and $< 10^{-7}$, $\geq 10^{-7}$ and $< 10^{-6}$, $\geq 10^{-6}$ and $< 10^{-5}$, $\geq 10^{-5}$ and $< 10^{-4}$, $\geq 10^{-4}$.

- **Noncancer HI (6 bins, by target organ):** < 0.01, ≥ 0.01 and < 0.1, ≥ 0.1 and < 1, ≥ 1 and < 10, ≥ 10 and < 100, ≥ 100).

- **Ecological HQ (5 bins):** < 0.1, ≥ 0.1 and < 1, ≥ 1 and < 10, ≥ 10 and < 100, ≥ 100).

Section 2.2.1 describes the process of aggregating risks for purposes of presenting an initial risk profile after completion of Phase I.

The execution of the screening process (as a practical matter) occurs in a tiered approach, beginning at the facility level and proceeding down through individual units and constituents. The net effect is that constituent, unit, and pathway combinations that are of negligible concern do not proceed to Phase II. For a unit to reach Phase II analysis, it must manage wastes with at least one constituent exceeding the decision criteria; for a facility to reach Phase II analysis, it must manage wastes with at least one constituent exceeding the decision criteria.

The constituents and units of negligible concern will be included in the lowest risk bins at this stage and that risk description will carry forward for them. Even though they will not be analyzed further based on more realistic exposure assumptions, the risks associated with them are already projected to be negligible.

This "binning" approach is taken to serve the dual objectives of (1) screening out particular constituent/unit/pathway combinations of negligible concern from further analysis; and (2) developing an initial overall relative risk ranking of the surface impoundment universe.

Figure 1-3 provides a sample representation of risk ranges based on Phase IA screening results.

Phase IB Human Health Screening Models. EPA expects to use screening-level fate and transport models IWAIR and IWEM[1] (developed for use under the Industrial D guidance) to supplement the initial screening performed under Phase IA. In general these screening models will be appropriate where the major routes of exposure are expected to be direct ingestion of drinking water or direct inhalation (i.e. indirect pathways are not expected to contribute significantly). Also, IWAIR will be used in cases where volatile constituents are known to be present, but there are no air concentration data provided in the surveys. At this stage, EPA will use a limited amount of data from the surveys for the most sensitive parameters, including constituent concentrations, unit size, and close-in receptors. Because some constituents and units may be screened from further analysis, EPA is proposing to use some protective modeling approaches, such as assessing risks for close-in receptors. This stage of screening-level fate and transport modeling is expected to improve the precision of the risk estimates and likely will yield lower risk results than use of the screening factors in Phase IA. The relative-risk profile developed under Phase IA will be revised and updated based on the results of the Phase IB modeling.

[1] The Agency is reviewing the IWAIR and IWEM models to ensure they are updated based on major comments received during a recent peer review, such as the need to correctly incorporate biodegradation rates in IWAIR. This process is expected to be completed in time to use these models in the Surface Impoundment Study. Alternative models that may be used include SCREEN 3 or CHEMDAT 8 for inhalation pathway and EPACMTP for ingestion of drinking water.

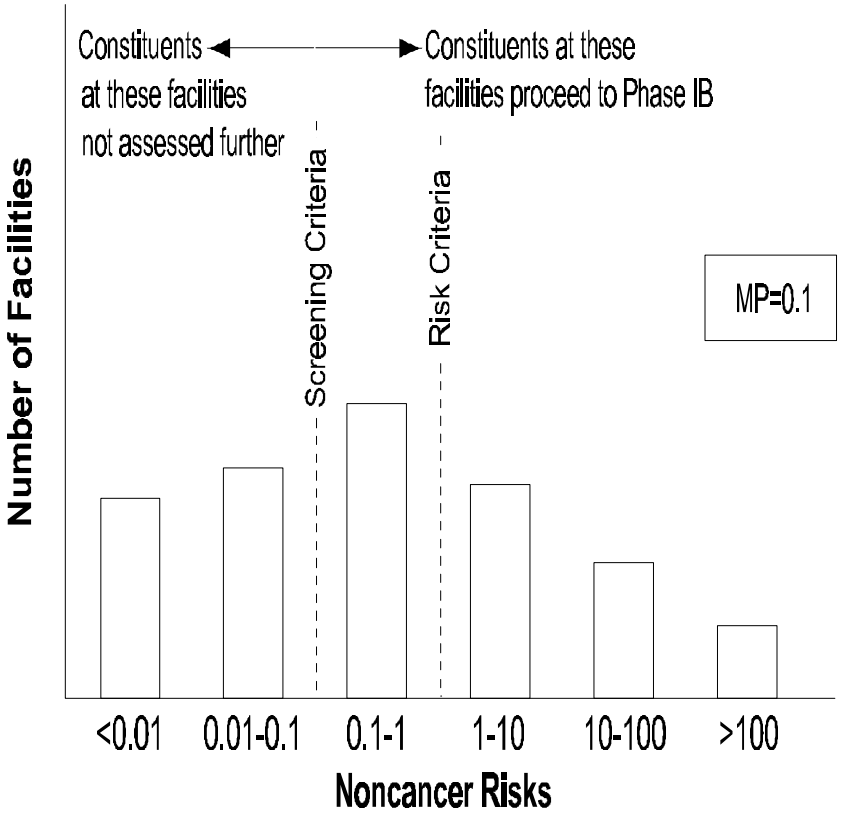


Figure 1-3. Sample representation of risk ranges based on Phase IA screening results.

Phase IC Prioritization. If the number of constituents, units, and facilities that could move into Phase II is large (e.g., more than 25 percent of the study sample), then EPA will prioritize them for further analysis based on the relative risk rankings that were developed during Phases IA and IB. Alternatively, if the number of constituents, units, and facilities that move to Phase II is small and the resulting Phase II effort is within allocated resources, then the prioritization scheme will not be necessary.

Prioritization will occur by assigning overall scores of 1 (highest priority), 2, or 3 based on the degree to which a constituent/unit or facility exceeds the risk criteria for human and ecological risks. For example, an HI of 100 would receive a higher score (1) than an HI of 10 (score = 2). The ranking will also integrate the human health and ecological scores into one score, placing greater emphasis on human health considerations but also addressing high-priority ecological concerns. A qualitative review of Phase I relative risk distributions may also lead the Agency to focus on particular industries, unit types, or constituents of concern. The result of Phase IC will be to identify high-priority constituents, units, and facilities for comprehensive multimedia risk modeling during Phase II.

Anticipated Outcome of Phase I. The outcome of Phase I will be development of an initial risk profile, which represents a relative ranking of potential risks associated with different constituents, unit types, or facilities within the surface impoundment universe. Because this will

be a screening-level risk profile based on protective exposure assumptions, subsequent analysis will develop greater precision for these initial risk estimates. Another outcome of Phase I will be the identification of a subset of surface impoundment units, constituents, and pathways that will proceed for further risk analysis during Phase II.

Units and constituents screened out during Phase I will be presented as having negligible risks in the overall risk profile in the final Surface Impoundment Study. The units and constituents to be studied further, as well as those screened out from further analysis, will be profiled according to significant patterns (if any) such as industry type, unit characteristic, and constituent type.

1.2.2 Phase II Modeling Approaches for Constituents and Units of Potential Concern

1.2.2.1 Background. There will be some units and constituents identified during Phase I that meet the criteria for proceeding to the Phase II analysis and merit further analysis to characterize with greater precision any potential risks to health and the environment. The magnitude of the Phase II effort is unknown at this time, and, depending on the number of units and constituents that require further analysis, EPA intends to undertake one of two approaches. If, as anticipated, a fairly limited number of units and constituents proceed to Phase II, EPA will conduct multimedia fate and transport modeling of potential human and ecological risks using the HWIR multimedia model, as modified for the Surface Impoundment Study and using, to the extent possible, the site-specific hydrogeologic data, watershed parameters, and receptor data provided in the surveys and available through other data sources such as GIS files. This is a fairly intensive modeling approach that will be possible only for a relatively limited number of cases. Alternatively, in the event that a large number of sites meet the criteria for proceeding to Phase II, EPA will develop a range of appropriate hydrogeologic and watershed "scenarios" (approximately 20 to 30 representative scenarios) to simplify the process of data file development and modeling for a large number of sites. This will greatly streamline the use of the HWIR model while maintaining the advantages of this powerful tool to describe multimedia fate and transport. The Agency is also considering extending the "representative scenario" approach to include representative ranges of populations exposed.

Phase II results will be used to revise the risk profile for the surface impoundment universe based on more realistic exposure assumptions and multimedia fate and transport modeling.

1.2.2.2 Choice of Models to Use during Phase II. EPA's preferred approach for the multimedia modeling during Phase II will be to use its multimedia, multipathway, multireceptor risk analysis (3MRA) model being developed to support the HWIR rulemaking and other analytic efforts. An alternative approach considered was to use the MMSOILS model, as currently updated. Major considerations leading to the recommendation that 3MRA be used were the ability to use many of the same data files for default parameters that had been developed to support the HWIR effort; the automatic integration of the various modules for different media thereby minimizing the quality assurance/quality control (QA/QC) necessary for manual integration of modules; and (3) the feasibility of using the system both in screening-level multimedia analyses and comprehensive multimedia analyses. The MMSOILS model met many

of these criteria; however, the integration of the modules for various media is not fully automated and the manual integration is expected to be too time-consuming to consider for this analysis.

1.2.2.3 Alternative Approaches for Data File Development. At this point it is not possible to foresee the number of constituents and units that will require modeling during Phase II after completion of the screening and prioritization that occurs during Phase I. Depending on the number, the Agency proposes to manage the effort in one of two ways that differ primarily in the level of site-specific data required to be developed and entered for each unit.

- **Screening-level multimedia analysis for a large number of units and constituents:** EPA will use the information reported in the surveys to choose the closest matching from among a series of representative scenarios of hydrogeologic and watershed conditions. The representative scenarios will be defined using the HWIR database, and EPA will ensure that the scenarios span the appropriate range of conditions reported in the Surface Impoundment Survey. EPA will review data reported in the surveys to select the best representative scenario, including number and proximity of waterbodies, hydrogeologic information, soil types, and receptor types and ranges. In the modeling, EPA will directly use a significant amount of site-specific data from the surveys, such as the location of actual close-in receptors and direction of groundwater flow, information on constituent concentrations, and information of sensitive ecological habitats.

- **Comprehensive multimedia analysis for a small number of units and constituents:** EPA will develop input parameters for the 3MRA model using as much site-specific data as possible from the surveys, Regional and state files, and publicly available databases. A comprehensive data file will be developed for each site, which will be modeled to account, with the greatest possible precision, for any potential risks associated with that site.

Under either alternative, EPA will use the 3MRA model in a deterministic mode for as many iterations as possible within the allocated time and resources. The basic approach will be to model at least one "high-end" and central tendency analysis for each pathway, based on the closest real receptors ("high-end") and central tendency receptors as reported in the surveys or identified from other data sources.

1.2.2.4 Risk Profile Generated. EPA anticipates that the risk estimates generated during Phase II will provide a comprehensive National profile of potential risks posed by the universe of surface impoundments for several reasons:

- The sample of 215 facilities is a statistically representative sample of the universe

- The potential risks modeled for major pathways at each surface impoundment are based on real concentration and exposure data reported by facilities and Regions

- The high-end and central tendency scenarios–based on these real receptors–provide a realistic span of potential risks.

This risk profile generated during Phase II will also serve to identify any unit types, constituents, or facilities (industries) that may require additional followup analysis.

1.2.3 Anticipated Outcome of Analysis

The Agency will prepare a study by March 2001 that characterizes the potential risks associated with the surface impoundment universe for 256 constituents.[2] This will include a discussion of any constituents, unit types, or facility categories for which additional analysis is recommended subsequent to the study. The study will provide a profile of the surface impoundment universe by unit type, industry type, and constituent; provide a descriptive profile of the subset of the universe that is of negligible concern and requires no further risk analysis; and provide a relative-risk profile for the entire universe of surface impoundments for these 256 constituents. The study is expected to also include risk analyses based on multimedia modeling for a limited number of high-priority constituents, units, and facilities.

1.3 Peer Review Process and Comments Solicited

EPA is providing this technical plan to several peer reviewers with expertise in human and ecological risk analyses, fate and transport modeling, and screening and statistical procedures for identifying potential risks from managing industrial wastewaters in surface impoundments. The Agency is seeking comments on the technical merits of the overall approach and is specifically soliciting comments in the following areas:

- **Derivation of human health screening factors:** EPA is seeking comment on whether the methodology for calculating screening factors is a suitable methodology and whether there are other data sources that are readily available that would provide credible benchmarks for the limited number of cases for which we do not have benchmarks.

- **Derivation of ecological screening factors:** EPA is seeking comment on whether the list of representative species is suitable for achieving a screening level assessment that will highlight possible ecological risks associated with surface impoundments and whether there are any serious gaps in the consideration of potential ecological risks that can be addressed by readily available data and benchmarks not identified here.

- **Level of protectiveness:** EPA has designed the screening process to ensure that constituents and units proceeding to subsequent stages of the analysis merit

[2] There are a few constituents in the list of 256 in-scope constituents that currently lack human health benchmarks. EPA is attempting to identify suitable benchmarks to allow their inclusion in this screening analysis. If benchmarks are not available, then EPA will include these constituents in the overall description of the survey results but not conduct any risk analyses on them.

further analysis and that those that do not proceed to subsequent stages have negligible risks (or alternatively, have very well-characterized risks and do not require further analysis). The intent is that the early stages of the analysis will include protective assumptions and that there will be a negligible possibility of overlooking potential risks. The Agency is seeking comment on whether the proposed screening approach achieves these objectives.

- **Approach for dealing with lack of information on chemical composition of wastewater in the impoundments or emissions:** The technical plan proposes a number of approaches for dealing with situations where facilities do not report concentration or emissions data for constituents that are present in impoundments. These include approaches for the use of data from other impoundments at the same facility, the use of data from other facilities in the same industrial category, the use of sampling data acquired by EPA from facilities in the same industrial category and modeling or backcalculating to infer concentrations. EPA is soliciting comment on these various approaches for estimating concentration data that are not reported.

- **Approach for representing cumulative risks:** EPA has designed an approach for representing cumulative risks for each constituent, unit, and facility reported under this survey. (An assessment of background risks, i.e., due to sources other than in-scope surface impoundments, is beyond the scope of this survey and analysis.) The Agency is seeking comment on the methodology for accumulating and representing risks within the scope of this survey.

- **Modeling approaches:** EPA is seeking comment on the overall approach and methodology for conducting screening-level modeling during Phase I and multimedia modeling during Phase II. For example, at this point EPA is uncertain how many units and constituents will merit multimedia modeling. As time and resources allow, EPA will undertake comprehensive multimedia modeling for each site. Alternatively, if a large number of sites merit modeling, EPA may use predefined representative scenarios for hydrogeologic conditions and watersheds (while still using as much site-based data as possible.) EPA seeks comments on these alternatives as well as the other modeling strategies outlined in this Technical Plan.

1.4 Organization of the Technical Plan

The remainder of this Technical Plan is organized as follows:

- Section 2 describes the Phase IA and IB human health and Phase I ecological risk screening process, and the Phase IC method of prioritizing results of Phase I.

- Section 3 describes the Phase II multimedia, multipathway modeling approach to estimate risks to human and ecological receptors.

- References are included in Section 4.

Supporting documentation is included in the following appendixes:

- Appendix A, Comprehensive List of Toxicity Benchmarks for Human Health Risk Assessment
- Appendix B, Statistical Analysis Weights and Variance Estimation for the Surface Impoundment Study Screening Survey
- Appendix C, Examples of Toxicity Benchmarks for Ecological Risk Assessment
- Appendix D, 3MRA Simulation Modules: Assumptions, Limitations, Inputs, and Outputs

2.0 Phase I Screening Assessment

2.1 Introduction

Experience to date suggests that comprehensive risk analysis, based on multimedia fate and transport modeling, is both time consuming and costly and should be used where screening analyses point to the need for sophisticated modeling. The Agency expects that a number of responses to the detailed questionnaires sent to 215 facilities will describe very low levels of some constituents in some impoundments. Two major purposes of this stage of the analysis are to screen (i.e., reduce the number of) constituents, impoundments, and facilities that require fate and transport modeling and to prioritize those remaining for subsequent analysis. The screening and prioritization will be based on clear science decision rules related to threshold concentrations of potential concern and low likelihood of exposures. These decision rules will allow EPA to screen out those constituents, impoundments, and facilities presenting negligible potential risks and to focus on analyzing those that may present higher potential risks.

EPA proposes to apply a series of decision rules sequentially in determining the constituents, impoundments, and facilities that will be evaluated further in Phase II, as shown in Figure 2-1. Both human health and ecological risk decision rules will be applied.

Human health risk screening consists of two phases:

- Phase IA compares reported constituent concentrations in surface impoundments to concentrations protective of human health.

- Phase IB estimates human health risk levels based on modeled exposure concentrations. Phase IB risk screening will be done for all constituents not eliminated from further evaluation based on Phase IA.

Ecological risk screening consists of one phase that parallels the human health Phase IA screening:

- Phase I compares reported constituent concentrations to concentrations protective of ecological receptors.

Risk screening identifies those constituents, impoundments, and facilities that have risks that are greater than the identified risk criteria and therefore require further analysis. Risk screening may still result in a large number of constituents, impoundments, and facilities for Phase II analysis. Therefore, Phase IC decision rules will be applied:

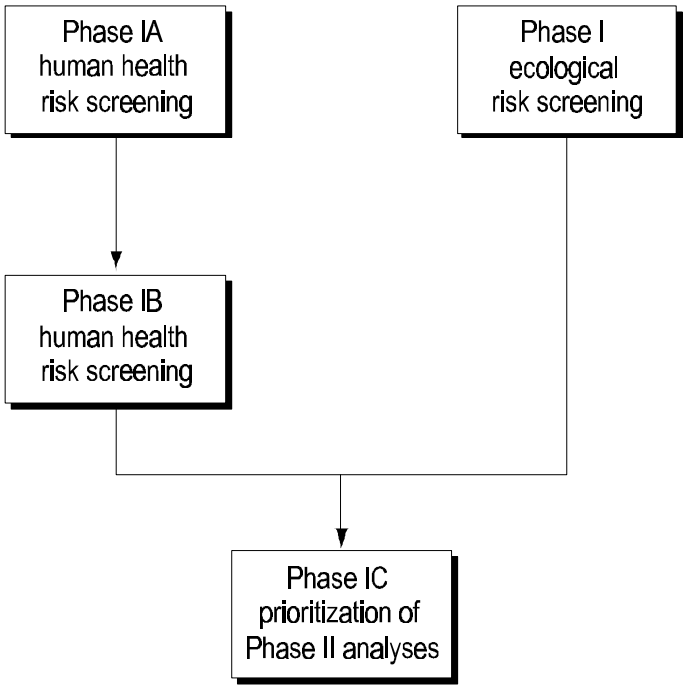


Figure 2-1. Overview of Phase I decision rules.

- Phase IC ranks the human health and ecological screening risks to prioritize constituent impoundments and facilities for Phase II analysis.

Key features of the human health risk screening approach are as follows:

- There are two stages in human health risk screening.

- The first stage will compare the arithmetic mean of reported concentration data (water, sediment, and air) collected from the facility survey to backcalculated health screening factors protective of residential exposure.

- The second stage will include more realistic evaluations of air and groundwater risks by evaluating fate and transport processes in the environment. The EPA screening models Industrial Waste Air Model (IWAIR) and Industrial Waste Evaluation Model (IWEM) (U.S. EPA, 1998a, b; 1999a, b) will be used to calculate risks.

The ecological risk screening approach can be characterized by the following key features:

- The screening will compare the arithmetic mean of reported concentration data (water and sediment) collected from the facility survey to screening factors.

- Screening factors will be existing threshold concentrations for adverse ecological effects such as the Ambient Water Quality Criteria for the protection of aquatic life.

- Screening factors for a limited set of representative species and representative habitats will be established using peer-reviewed data from HWIR (i.e., wildlife exposure factors, biological uptake factors, toxicity benchmarks) supplemented by toxicity data gathered for constituents not evaluated in HWIR (U.S. EPA, 1999n).

2.2 Phase I Human Health Risk Screening

The Phase I human health risk screening consists of a series of two decision rules, Phase IA and IB, applied to evaluate whether a constituent, impoundment, or facility can be excluded from further evaluation or must continue to Phase II. The Phase IA decision rule will calculate risk estimates for groundwater ingestion, soil ingestion, and air inhalation based on reported impoundment concentrations. The Phase IB decision rule will calculate risk estimates for groundwater ingestion and air inhalation based on air and groundwater screening model exposure concentration estimates. The risk estimates will be compared to risk criteria to determine if the constituent, impoundment, or facility can be excluded from further evaluation. Phase IB will be invoked for two conditions: (1) constituents that volatilize but for which there are no air concentration data provided in the responses to the survey questionnaire, and (2) constituents that were not excluded based on the Phase IA risk screening.

2.2.1 Phase IA Human Health Initial Risk Screening

The Phase IA risk screening is described in four sections:

- Design goals and overview
- Development of screening factors
- Procedure for risk screening
- Results of risk screening.

2.2.1.1 <u>Phase IA Human Health Design Goals and Overview</u>. The goal of the Phase IA initial screening assessment is to identify constituents, impoundments, and facilities that have negligible risks and do not need further assessment in the SI Study. The Phase IA approach will calculate screening risks to an individual receptor based on concentrations of constituents in and emissions from surface impoundments reported in the survey questionnaire and risk screening factors. The human health risk screening factors will be based on toxicity benchmarks for direct ingestion of drinking water, direct air inhalation, and direct soil ingestion (for the in-place closure scenario). These screening risks will be protective because they are based on the highly protective assumptions that a resident will drink the impoundment water, inhale the air at the impoundment, and eat the sludge. To account for indirect exposures and cumulative exposures from multiple constituents or impoundments, the Agency may choose

to use a margin of protection (MP) in determining whether a constituent, impoundment, or facility should be excluded from further evaluation. If risks are less than the selected risk criteria times the MP, then they will be considered negligible risks and no longer considered in subsequent phases.

The screening risks for each constituent, impoundment, and facility will also be accumulated to provide initial risk distributions. Risk distributions will provide the basis for prioritizing for Phase II (see Section 2.4). These risk distributions, while protective, will also provide the initial risk profiles that describe the national scale surface impoundment population. That is, although we expect the risk estimates to decrease as more site-specific data collection and multimedia exposure modeling are performed in subsequent phases, the overall distribution should be similar. For instance, if a certain industry has Phase I screening risks that are high relative to other industries, then the relative risk level will likely remain in Phase II. One major exception may be constituents that tend to persist and bioaccumulate. The relative risks for these constituents may be very different in Phase II because indirect (rather than direct) exposure pathways are driving the risks. These risk distributions will be refined with each subsequent phase.

2.2.1.2 <u>Development of Phase IA Human Health Screening Factors</u>. The Phase IA screening risk will be calculated as the ratio of the reported concentrations to the screening factors multiplied by the risk criteria, as follows:

$$Screening\ Risk = \frac{Reported\ Concentration}{Risk\ Screening\ Factor}\ x\ Risk\ Criteria\ .$$

It should be noted that the screening risk calculation is mathematically equivalent to a standard forward calculation of risk, whereby the exposure concentration is converted to a dose and multiplied by the cancer slope factor (if carcinogenic) or divided by the reference dose (if noncarcinogenic). The risk calculation process is also equivalent to the standard approach for evaluating airborne chemical exposures wherein exposure concentrations are divided by the reference concentration (if noncarcinogenic). The above calculation is easier to use for this SI Study screening phase. Also, development of the risk screening factor as a threshold concentration provides a simple comparison method that EPA, regulated parties, and the public can use to examine the survey data and screening results.

To develop a human health risk screening factor for each constituent, EPA will

- Identify human receptors
- Identify exposure pathways
- Define toxicity benchmarks
- Identify the risk criteria
- Calculate screening factors.

Human Receptor Types. The human health-based risk screening factors will be based on residential exposure. The exposure factors used to characterize the residents will be based on the receptor, toxicological endpoint, and exposure pathways evaluated as follows:

- For carcinogenic risks, a time-weighted child/adult resident
- For noncarcinogenic risks, a child resident for the soil and groundwater ingestion pathways and an adult resident for the air inhalation pathway.

A time-weighted resident is considered for carcinogenic risks because of concerns that a child with a small body weight typically has higher levels of exposure for the same levels of intake as an adult. Inclusion of multiple age groups more accurately reflects potential residential exposures and is supported by data provided in EPA guidance for different age groups (*Exposure Factors Handbook*, U.S. EPA, 1997a). A child resident is considered for noncarcinogenic risks for the soil and groundwater ingestion pathways to ensure a protective level of exposure, since a child with a small body weight typically has higher levels of exposure for the same levels of intake as an adult. An adult resident is considered for noncarcinogenic risks for the air inhalation pathway only because development of the toxicological benchmark for the inhalation pathway, the reference concentration (RfC), is based on the assumption that an exposed individual would be comparable to an adult resident (i.e., have a default inhalation rate of 20 m^3 per day and a body weight of 70 kg). EPA considers the RfC protective of child and adult receptors. Although this approach to evaluating inhalation risks may result in some level of uncertainty in the risk estimates, EPA considers this acceptable for screening purposes.

Human Exposure Pathways. Risk screening factors will be developed for the following exposure pathways:

- Ingestion of impoundment water (as a protective estimate of groundwater ingestion)
- Ingestion of sludge/soil (as a protective estimate of postclosure in place)
- Inhalation of volatile emissions from an impoundment (as a protective estimate of inhalation).

Inhalation of particulate emissions from sludge (postclosure in place) will not be considered because this pathway typically represents negligible risks.

Figure 2-2 presents the Phase I risk conceptual model and potential exposure pathways for human receptors.

Toxicity Benchmarks. Human health risk screening factors will be based on toxicity benchmarks (i.e., cancer slope factors, reference doses, and reference concentrations) in the Integrated Risk Information System (IRIS) and Health Effects Assessment Summary Tables (HEAST) (U.S. EPA, 1999c; U.S. EPA, 1997c). If benchmarks are not available in IRIS or HEAST, then other EPA or alternative (e.g., ATSDR) health benchmarks will be considered. If

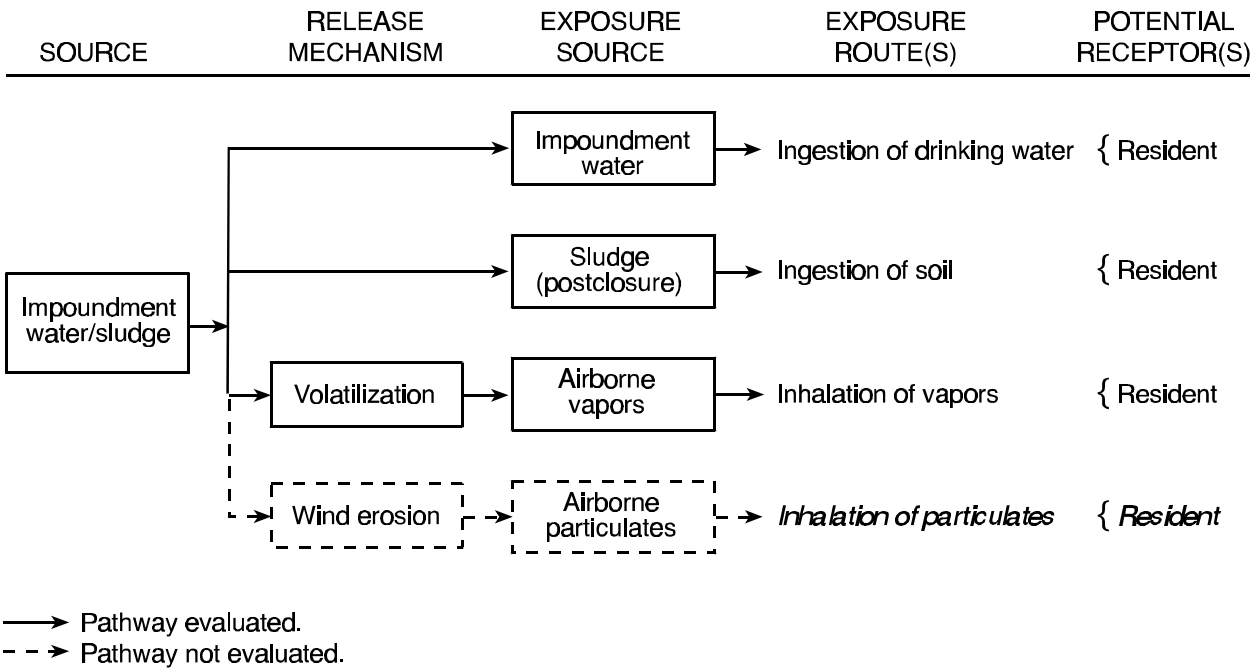


Figure 2-2. Phase I human health risk conceptual model and potential exposure pathways.

no health benchmarks are available, a regulatory standard (e.g., maximum contaminant level [MCL]) may be used to develop the risk screening factor. If benchmarks or regulatory standards are not available, then the Agency proposes using the provisional approach developed for HWIR to develop interim human health benchmarks for screening purposes. This process may also incorporate use of risk-based criteria, such as the preliminary remediation goal for residential exposure to lead in soil, to ensure that all toxicants of concern are addressed.

Risk Criteria. The risk criteria, the levels above which the risk to an individual are considered significant, are as follows:

- For carcinogens, excess cancer risk = 10^{-5}
- For noncarcinogens, hazard index (HI) = 1.

These criteria apply to a specific constituent-impoundment-pathway combination as well as to summations of risks for a constituent, an impoundment, and a facility. Summations of HIs will be considered only if to the same target organ. By separating risks according to target organ, the resulting HIs can be summed across the ingestion and inhalation exposure pathways for each of the potentially affected target organs.

Calculation of Human Health Screening Factors. The carcinogenic and noncarcinogenic risk screening factors will be developed using the equations shown in Table 2-1. The equations for the three pathways are based on EPA guidance (U.S. EPA, 1989).

Table 2-1. Equations for Development of Human Health Screening Factors

Carcinogenic	Noncarcinogenic
Inhalation	***Inhalation***
$$CRSF_{air} = \frac{RC_c \cdot AT \cdot 365}{SF \cdot EF \cdot \left(\sum_{i=1}^{5} \frac{INR_i \cdot ED_i}{BW_i} \right)}$$	$$NCRSF_{air} = RC_n \cdot RfC$$
where	where
$CRSF_{air}$ = carcinogenic risk screening factor for air (mg/m^3) RC_c = risk criteria for carcinogens AT = averaging time (yr) = 70 SF = slope factor (kg-d/mg) EF = exposure frequency (d/yr) i = index on age group (e.g., <1 yr, 1-5 yr, 6-11 yr, 12-18 yr, adult) INR_i = inhalation rate of air for age group i (m^3/d) BW_i = body weight for age group i (kg) ED_i = exposure duration for age group i (yr)	$NCRSF_{air}$ = noncarcinogenic risk screening factor for air (mg/m^3) RC_n = risk criteria for noncarcinogens RfC = reference concentration (mg/m^3)
Ingestion of Water	***Ingestion of Water***
$$CRSF_{water} = \frac{RC_c \cdot AT \cdot 365}{SF \cdot EF \cdot \left(\sum_{i=1}^{5} \frac{IRW_i \cdot ED_i}{BW_i} \right)}$$	$$NCRSF_{water} = \frac{RC_n \cdot BW_c \cdot RfD \cdot 365}{EF \cdot IRW_c}$$
where	where
$CRSF_{water}$ = carcinogenic risk screening factor for water (mg/L) RC_c = risk criteria for carcinogens AT = averaging time (yr) = 70 EF = exposure frequency (d/yr) SF = slope factor (kg-d/mg) i = index on age group (e.g., <1 yr, 1-5 yr, 6-11 yr, 12-18 yr, adult) IRW_i = ingestion rate of water for age group i (L/d) BW_i = body weight for age group i (kg) ED_i = exposure duration for age group i (yr)	$NCRSF_{water}$ = noncarcinogenic risk screening factor for water (mg/L) RC_n = risk criteria for noncarcinogens RfD = reference dose (mg/kg-d) BW_c = body weight for child (kg) EF = exposure frequency (d/yr) IRW_c = ingestion rate of water for child, ages 1-5 yrs (L/d)

(continued)

Table 2-1. (continued)

Carcinogenic	Noncarcinogenic
Ingestion of Soil	***Ingestion of Soil***
$$CRSF_{soil} = \frac{RC_c \cdot AT \cdot 365}{SF \cdot EF \cdot 10^{-6} \cdot \left(\sum_{i=1}^{5} \frac{IRS_i \cdot ED_i}{BW_i} \right)}$$	$$NCRSF_{soil} = \frac{RC \cdot RfD \cdot BW_c \cdot 365}{EF \cdot IRS_c \cdot 10^{-5}}$$
where	where
$CRSF_{soil}$ = carcinogenic risk screening factor for soil (mg/kg) RC_c = risk criteria for carcinogens AT = averaging time (yr) = 70 EF = exposure frequency (d/yr) SF = slope factor (kg-d/mg) i = index on age group (e.g., <1 yr, 1-5 yr, 6-11 yr, 12-18 yr, adult) IRS_i = ingestion rate of soil for age group i (mg/d) BW_i = body weight for age group i (kg) ED_i = exposure duration for age group i (yr)	$NCRSF_{soil}$ = noncarcinogenic risk screening factor for soil (mg/kg) RC_n = risk criteria for noncarcinogens RfD = reference dose (mg/kg-d) BW_c = body weight for child (kg) EF = exposure frequency (d/yr) IRS_c = ingestion rate of soil for child, ages 1-5 yr (mg/d)

The values of the exposure parameters used in the equations are provided in Table 2-2. All data are from the *Exposure Factors Handbook* (U.S. EPA, 1997b). The means for inhalation rate, water intake rate, and body weight are consistent with the data means identified or calculated in HWIR's Human Exposure Factors (U.S. EPA, 1999q). All human exposure factors were developed for the following subpopulations:

- Adult resident
- Children ages 12 to 19 years
- Children ages 6 to 11 years
- Children ages 1 to 5 years
- Children ages <1 year (infants).

For noncarcinogenic risks for the soil and groundwater ingestion pathways, the age group that produces the lowest screening factor (i.e., has the highest ratio of ingestion rate to body weight) will be used. For the soil ingestion pathway and the groundwater ingestion pathway, this is the 1- to 5-yr-old age group.

The age ranges for children are consistent with the age groups for which most data are provided in the *Exposure Factors Handbook*. With the exception of exposure duration and soil

Table 2-2. Exposure Parameter Values

Receptor	Inhalation Rate (m^3/d)	Ingestion Rate of Water (L/d)	Ingestion Rate of Soil (mg/d)	Exposure Frequency (d/yr)	Exposure Duration (yr)	Body Weight (kg)
Child < 1	4.5	0.30	ND	350	1	9.1
Child 1-5	7.55	0.70	200	350	5	15.5
Child 6-11	11.75	0.79	50	350	6	30.8
Child 12-18	14.0	0.96	50	350	7	58.4
Adult Resident	13.3	1.38	50	350	11	71.4

ingestion rates for children, exposure factors were selected to represent typical or central tendency values, not high-end values.

An overall exposure duration of 30 years was selected as a high-end value for residents. This was then allocated to the various age ranges desired, based on the number of years in each age bracket. The exposure frequency is the number of days per year that a receptor is exposed. A value of 350 days per year was selected for all residents, based on an exposure of 7 days per week, with the receptor being elsewhere on vacation for 2 weeks per year (U.S. EPA, 1997b).

Based on data provided in the *Exposure Factors Handbook* (Layton, 1993), the inhalation rates for each age group were first averaged for males and females for each age group if they were not presented as combined male and female. The combined male/female mean inhalation rates for each child age group were then averaged to get the desired age groups (e.g., combined values for ages 1 to 2 and 3 to 5 were averaged to get value for ages 1 to 5). For adults (19 to 65+ years), the recommended mean values for males and females (15.2 and 11.3 m^3/d, respectively) were averaged.

For soil ingestion rates, the *Exposure Factors Handbook* only distinguishes between children under 6 and all other ages, so the ingestion rates were assigned accordingly. EPA recommends 100 mg/d as the best estimate of mean soil ingestion for children under the age of 6; however, EPA also notes that this value may underestimate soil intake rates because children were studied for short periods of time and the prevalence of pica behavior is not known. Therefore, EPA recommends 200 mg/d as a conservative mean for soil intake in children under 6 years of age. No soil ingestion data are available for infants (children <1 year old).

Based on data provided in the *Exposure Factors Handbook* (Ershow and Cantor, 1989), the mean drinking water intake rates were calculated from weighted (by sample size) averages of means for each age group.

For body weights, the *Exposure Factors Handbook* contained mean body weights for 1-year age intervals for male and female children; these values were averaged (weighted by

sample size) across the ranges used here. For mean adult body weight, the weighted average (based on sample size) of the values presented in the *Exposure Factors Handbook* for males and females ages 18 to 74 were used.

If a carcinogenic or noncarcinogenic risk screening factor cannot be developed for a chemical based on an EPA or alternative health benchmark, a risk screening factor that is equivalent to the regulatory standard (e.g., maximum contaminant level or MCL) may be used. If a regulatory standard is unavailable, then an interim toxicity benchmark will be developed and used. The Agency considers that, for a screening level analysis, it is appropriate to use draft provisional benchmarks for constituents lacking established health benchmarks.

Cumulative Effects. The cumulative effects for air, groundwater, and soil exposure to the same resident will be evaluated, although the exposures may occur at different times. This is a protective assumption to ensure that risks are not underestimated.

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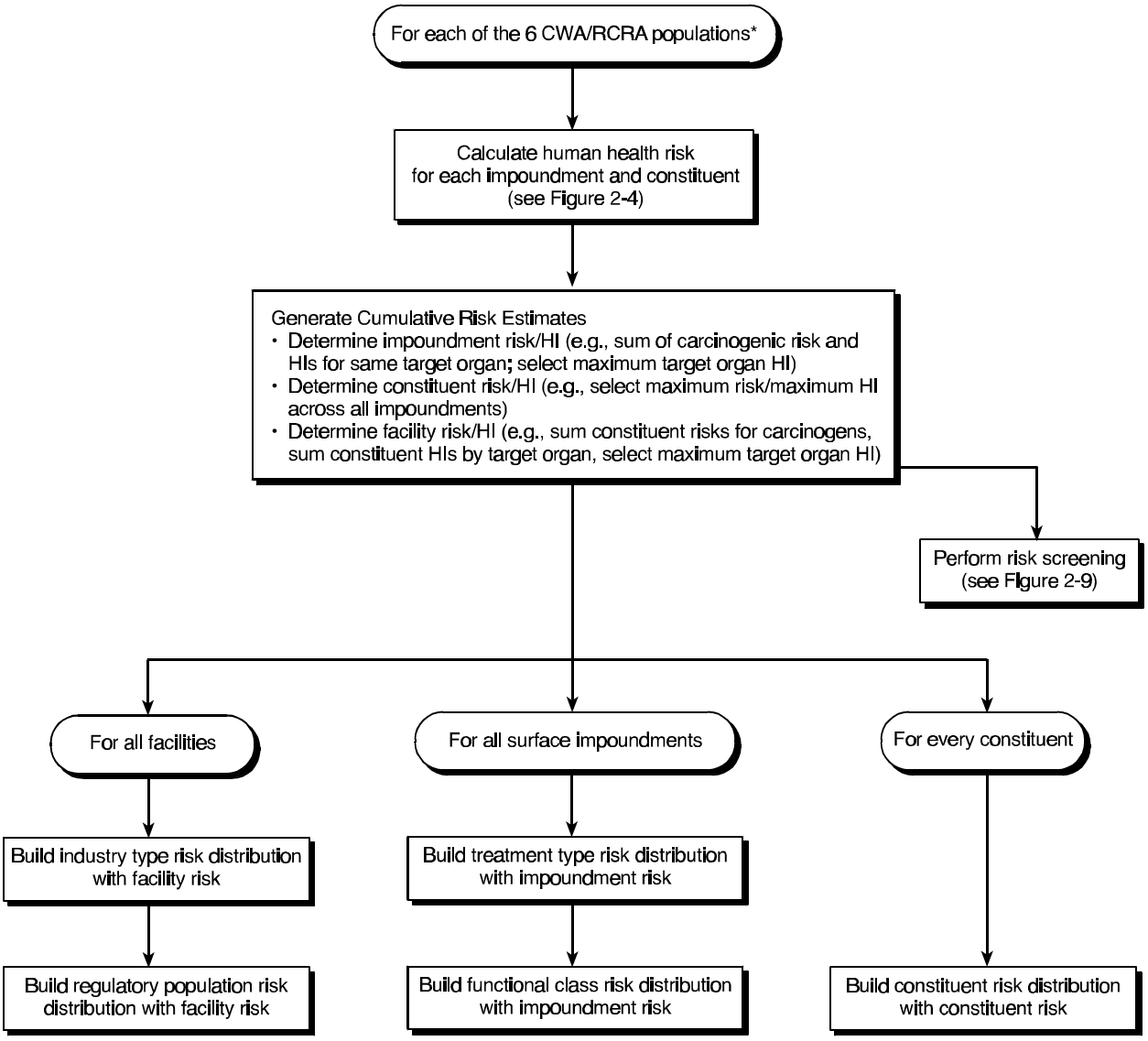
2.2.1.3 <u>Procedure for Phase IA Human Health Risk Screening</u>. The overall human health screening process is shown in Figure 2-3. The human health risk screening calculation will be performed for each constituent in each surface impoundment for each of the 221 sample facilities. At this point, the screening risk estimates will be constituent-specific risks or HIs that have been summed across exposure pathways. Cumulative risks will then be calculated for each impoundment and each facility and for each constituent (summed over all impoundments at the facility) . The cumulative risk estimates will be used to build initial risk distributions for the surface impoundments within the scope of the study. The units within the study scope are defined in Section 1. These fall within six categories ("populations") depending upon their regulatory status under the Clean Water Act and RCRA. Risk distributions will be generated for impoundment functional type, impoundment treatment type, industry type, and constituent. The risk distributions will be used to exclude constituents, impoundment types, or facilities from further analysis. Further, the risk distributions will provide the basis for prioritizing evaluations conducted in Phase II (see Phase IC discussion in Section 2.4).

The four main elements to the Phase IA human health screening process are

- Human health risk calculation
- Cumulative risk calculation
- Risk distribution development
- Risk screening.

Human Health Risk Calculation. The risk calculation process is shown in Figure 2-4. The groundwater ingestion pathway will always be evaluated; surface impoundment wastewater concentrations will be used in Phase IA as conservative estimates of potential groundwater exposure levels. The air inhalation pathway will be evaluated for a constituent in Phase IA if the constituent is a volatile organic chemical (VOC) and airborne chemical concentration or emissions data are provided by the survey. The soil ingestion pathway will be evaluated for a constituent if sludge accumulates in the impoundment. Once the air, water, and sludge



Notes:
*Direct discharger - decharacterized
Direct discharger - nondecharacterized
Indirect discharger - decharacterized
Indirect discharger - nondecharacterized
Zero discharger - decharacterized
Zero discharger - nondecharacterized

Figure 2-3. Flow diagram for Phase IA human health risk screening.

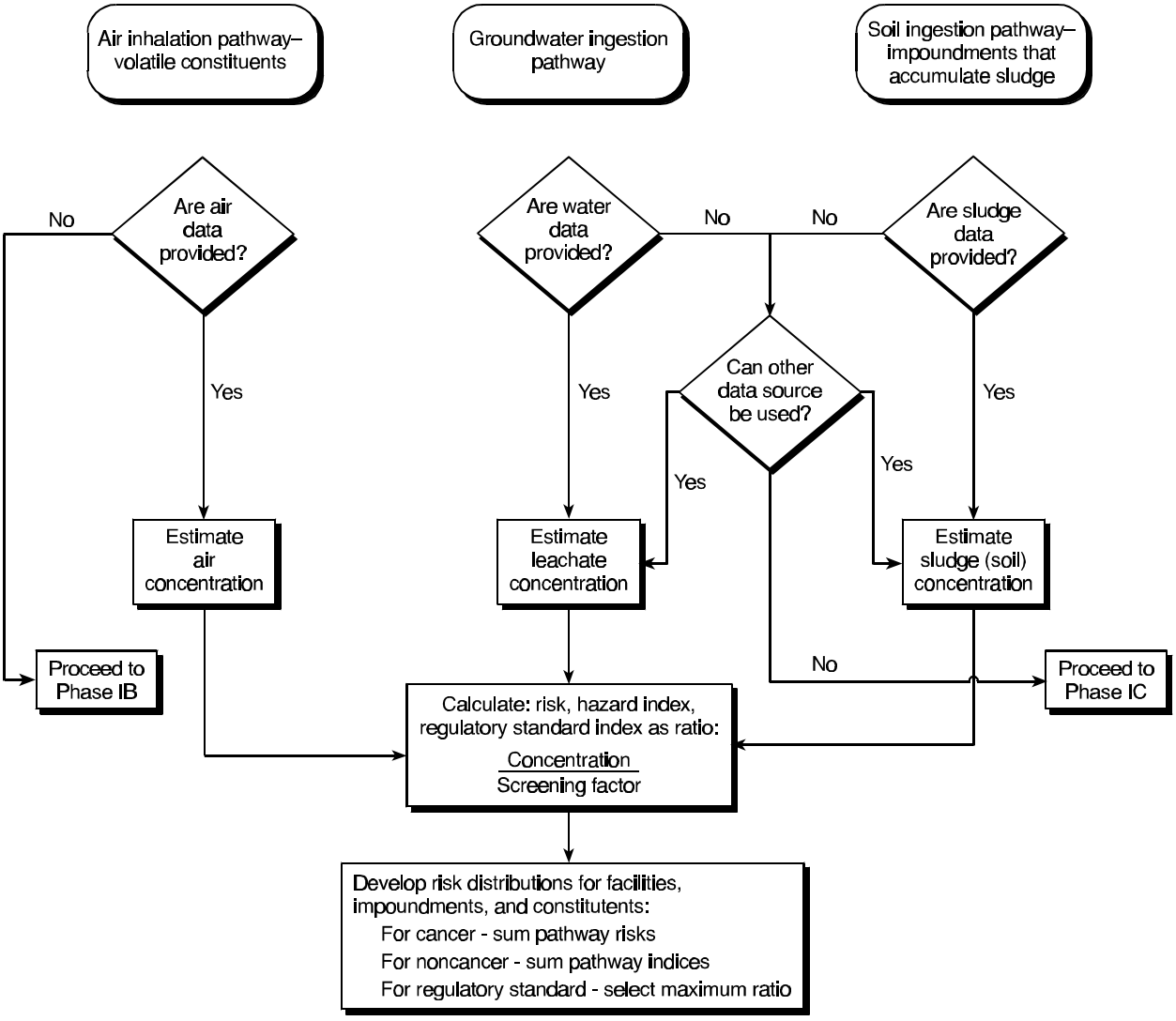


Figure 2-4. Decision tree for calculating Phase IA human health risk estimates.

concentrations are determined from the survey results, the risks will be calculated by dividing the concentration by the appropriate screening factor and then multiplying by the risk criteria. If the screening factor is based on a regulatory standard, then the ratio of concentration to the screening factor will be calculated. Finally, the constituent risk and HI will be calculated by summing the risks and hazard quotients (HQs) for all pathways for that particular constituent. If the screening for the constituent has used a regulatory standard, then the maximum ratio of all pathways for that constituent will be selected.

Concentration data from the facility survey questionnaire will provide exposure concentrations for the Phase IA risk estimates. Figures 2-5 through 2-8 describe how the air, water, and sludge concentrations will be used or calculated from the facility survey data. The decision trees outline the order of preference for using concentration data. The specific survey questions that will provide the data are noted in the decision trees. A special condition exists for calculating air inhalation risks from survey data. If the survey questionnaire does not provide an air concentration or emission rate for a VOC constituent but does provide water concentrations, then the air emissions and concentration will be estimated using screening models and will be performed in Phase IB (see Section 2.2.2).

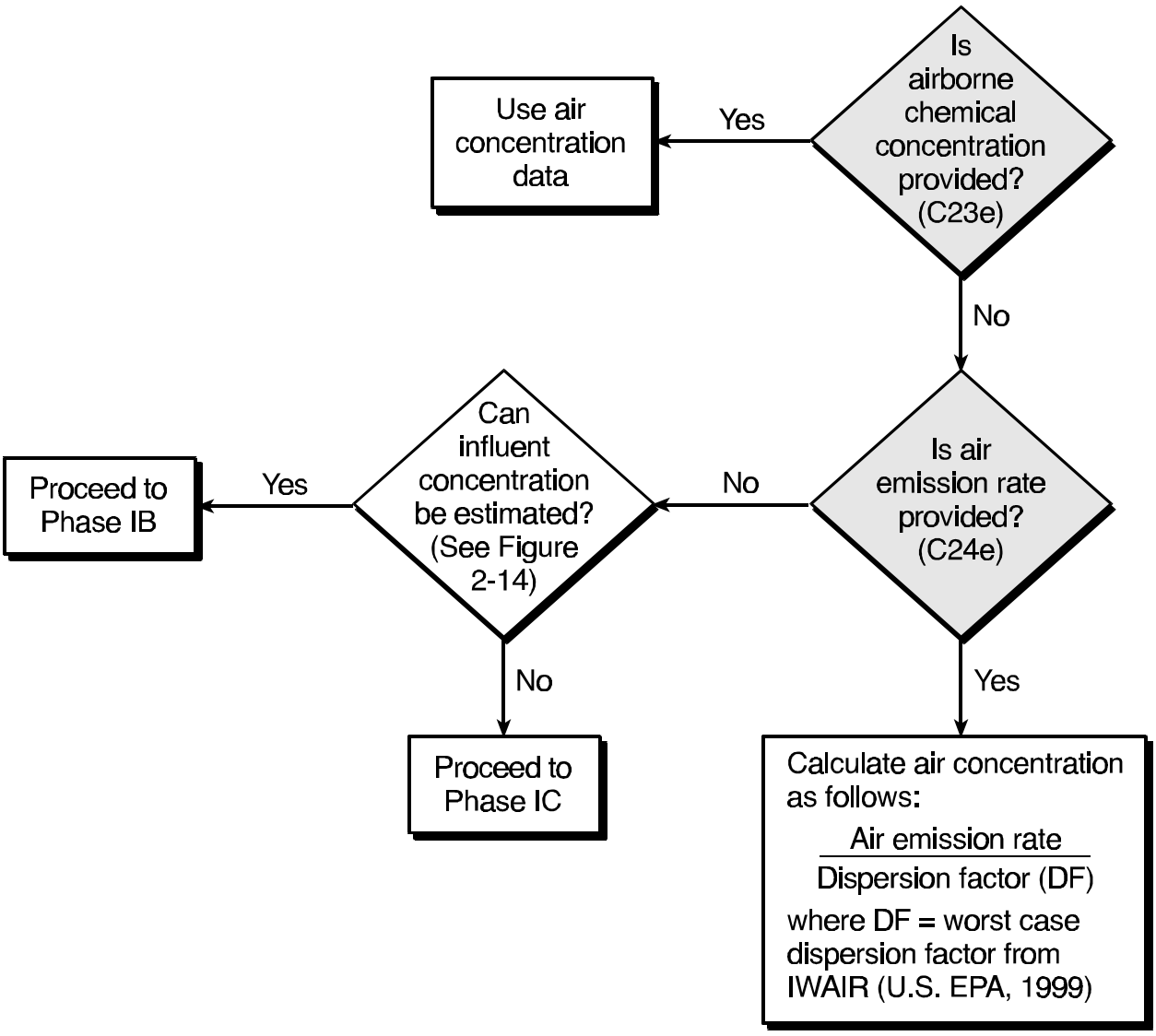
In cases when the air, wastewater, or sludge concentration is not provided in the survey questionnaire, a concentration will be estimated. An air concentration will be estimated from the survey-reported emission rate using the worst case dispersion factor from IWAIR (see Section 2.2.2 and Figure 2-5). A sludge concentration will be estimated from the leachate concentration assuming equilibrium partitioning to sludge (see Figure 2-8). If the survey questionnaire does not provide water concentration data for a particular impoundment, data from other impoundments will be used to estimate the water concentration (see Figure 2-7).

Average concentrations of constituents in impoundments have been requested as part of the survey questionnaire. The average concentration is considered to be a reasonable level of exposure to use in evaluating long-term chronic exposures because an individual is unlikely to be exposed to the maximum concentration of a constituent for 30 years. Thus, average concentrations are likely to represent long-term exposures. This approach is considered protective for this screening health risk analysis because risks are based on highly protective exposure assumptions, such as assuming that an individual would directly consume water from the surface impoundments.

Cumulative Risk Calculation. The calculated screening risks for each constituent for a specific impoundment and facility will be combined to generate three cumulative risk estimates: impoundment risk, constituent risk, and facility risk. The cumulative risks will be used in the risk screening and risk distributions, as follows.

HQ - Hazard quotient is the ratio of estimated exposure (dose or concentration) and the appropriate toxicity value (reference dose or reference concentration) for a single exposure pathway and chemical.

HI - Hazard index is the summation of HQs across pathways and across chemicals affecting the same target organ.



Key:
Shaded boxes indicate information needed from survey questionnaire.
Survey question number appears in parentheses.

Figure 2-5. Decision tree for determining Phase IA air concentrations.

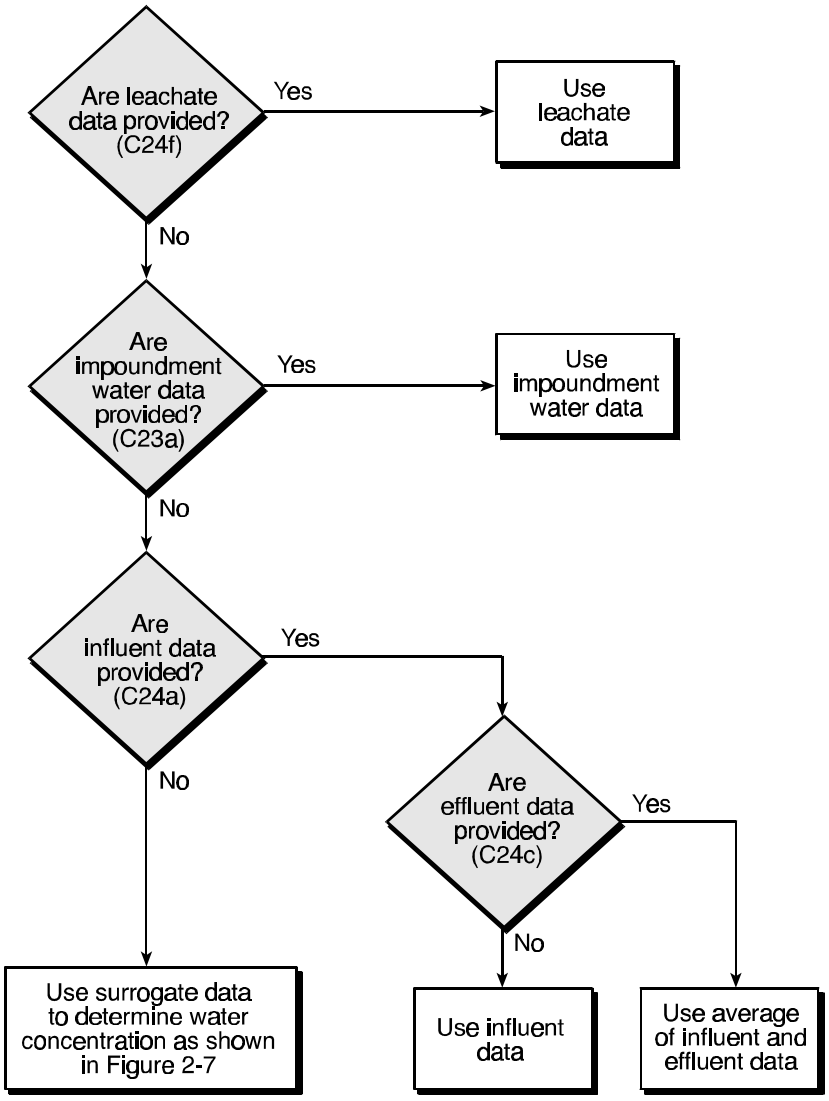


Figure 2-6. Decision tree for determining Phase IA water concentration.

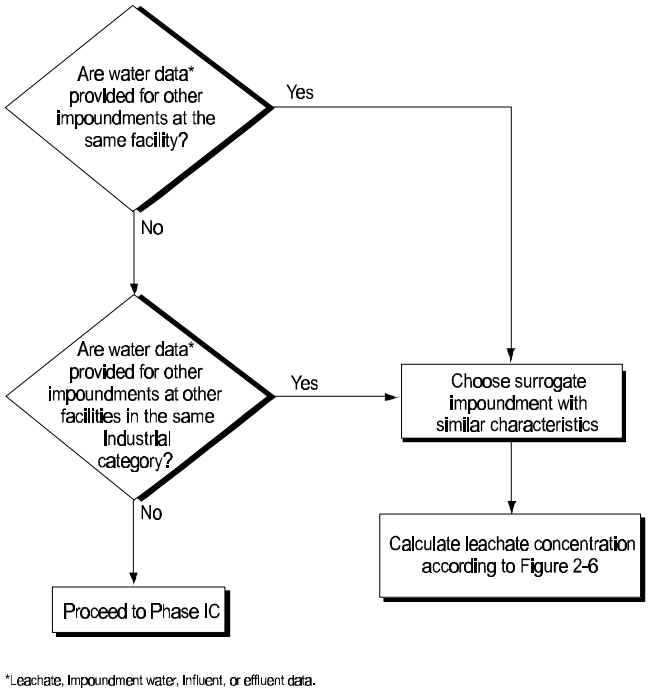


Figure 2-7. Steps to calculate impoundment water concentration if no survey data available.

The impoundment risk (i.e., risk for a particular impoundment for a particular facility)

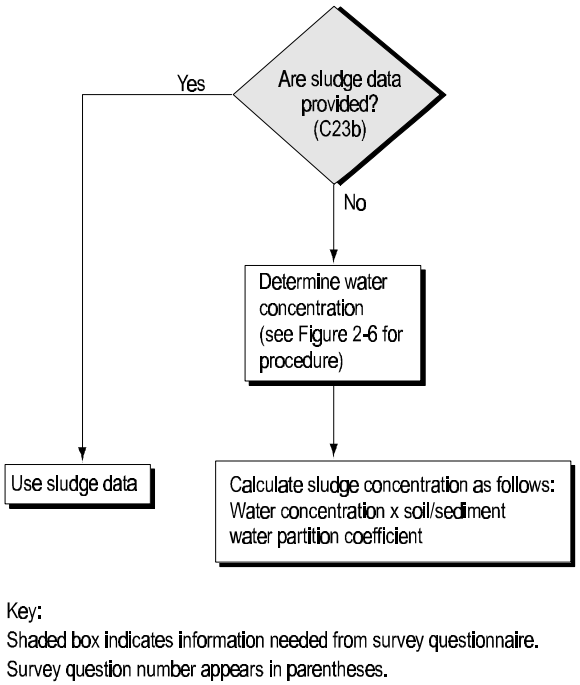


Figure 2-8. Decision tree for determining sludge concentration.

will be determined as follows:

- For carcinogenic risks, sum risks from all carcinogenic constituents.
- For noncarcinogenic risks, sum the HIs for all constituents potentially affecting the same target organ; then select the maximum HI from the target organ HIs.
- To represent constituents with risks based on regulatory standards, select the maximum ratio.

The constituent risk (i.e., risk for a particular constituent for a particular facility) will be determined as follows:

- For carcinogenic risks, select the maximum risk for the constituent across all impoundments for the particular facility.
- For noncarcinogenic risks, select the maximum HI for the constituent across all impoundments for the particular facility.
- To represent constituents with risks based on regulatory standards, select the maximum ratio across all impoundments for the particular facility.

Facility risks will be calculated as follows:

- For carcinogenic risks, sum the constituent risks.
- For noncarcinogenic risks, sum the HIs from all constituents potentially affecting the same target organ; then select the maximum HI from the target organ HIs.
- To represent chemicals with risks based on regulatory standards, select the maximum ratio from all constituents.

Note that this approach takes into account that an individual receptor's exposure factors will only be counted once for the entire facility (e.g., 1.4 L ingested per day or 11 m^3 inhaled per day).

Risk Distribution Development. Cumulative frequency histograms of the risks/HIs will be developed from the impoundment, constituent, and facility cumulative risks. A risk cumulative histogram will be defined by a set of six class intervals or "bins." The carcinogenic risk ranges defining those bins are: 0 to 10^{-8}, 10^{-8} to 10^{-7}, 10^{-7} to 10^{-6}, 10^{-6} to 10^{-5}, 10^{-5} to 10^{-4}, and 10^{-4}. An HI cumulative histogram will be defined by six bins: 0 to 0.01, 0.01 to 0.1, 0.1 to 1.0, 1.0 to 10, 10 to 100, and greater than 100.

Impoundment risks will be used to develop the impoundment type risk and treatment type risk distributions. For a given impoundment, the impoundment risk will be compared to the risk bins and the appropriate bin identified. A unitary value (1), representing the impoundment, will then be placed in the appropriate bin in the risk distribution. If the impoundment is in a statistically sampled population, the unitary value will be multiplied by the facility sample weight (see Appendix B for a discussion of the facility sample weights before being added to the bin.

Constituent risks will be used to develop the chemical-specific risk distribution. Facility risks will be used to develop the industry-type-specific risk distributions and the regulatory population-specific risk distributions. The development of these risk distributions follows the procedure described above for the impoundment risk distribution.

EXAMPLE: Adding an impoundment risk to a treatment type risk distribution.

An impoundment for a particular facility (ID 6123) is a biological treatment unit and has a cumulative impoundment cancer risk of 2×10^{-5} and a cumulative impoundment HI of 0.06. The facility is in the CWA direct discharger population. The risks will be added to the biological treatment type risk distributions. There will be two risk distributions, one for cancer risk and one for HI. For the cancer risk distribution, the cancer risk falls in the 10^{-5} to 10^{-4} risk bin. Because the CWA direct discharger population is a statistically sampled population, the unitary value is multiplied by the sample weight for that facility (weight = 38.7). This value is added to the risk bin. For the noncancer risk distribution, the HI falls in the 0.01 to 0.1 bin. The value of 38.7 is added to the 0.01 to 0.1 bin.

Risk Screening. The Phase IA risk screening will use the three cumulative risk distributions to identify

- Constituents, impoundments, and facilities that have risks below a decision criterion and therefore are considered to have negligible risks and are not assessed in any further phases.

- Constituents, impoundments, and facilities that have risks above a decision criterion and that will be assessed in Phase IB.

The risk screening procedure is outlined in the decision tree shown in Figure 2-9. A three-tiered approach is taken because each descending tier provides less information on the overall facility risk characterization but more detail on what constituents or impoundments can be excluded from further evaluation. The facility risk accounts for cumulative effects of multiple impoundments and constituents. Therefore, it is used as the first tier. However, the first tier indicates only if a facility must be assessed further or not; it does not indicate whether specific impoundments or constituents can be excluded. The second tier screens using the cumulative impoundment risk. This tier, however, can only address cumulative effects for multiple constituents at a single impoundment; it does not indicate whether specific constituents can be excluded. However, this second tier provides the subcategory of impoundments for a facility that

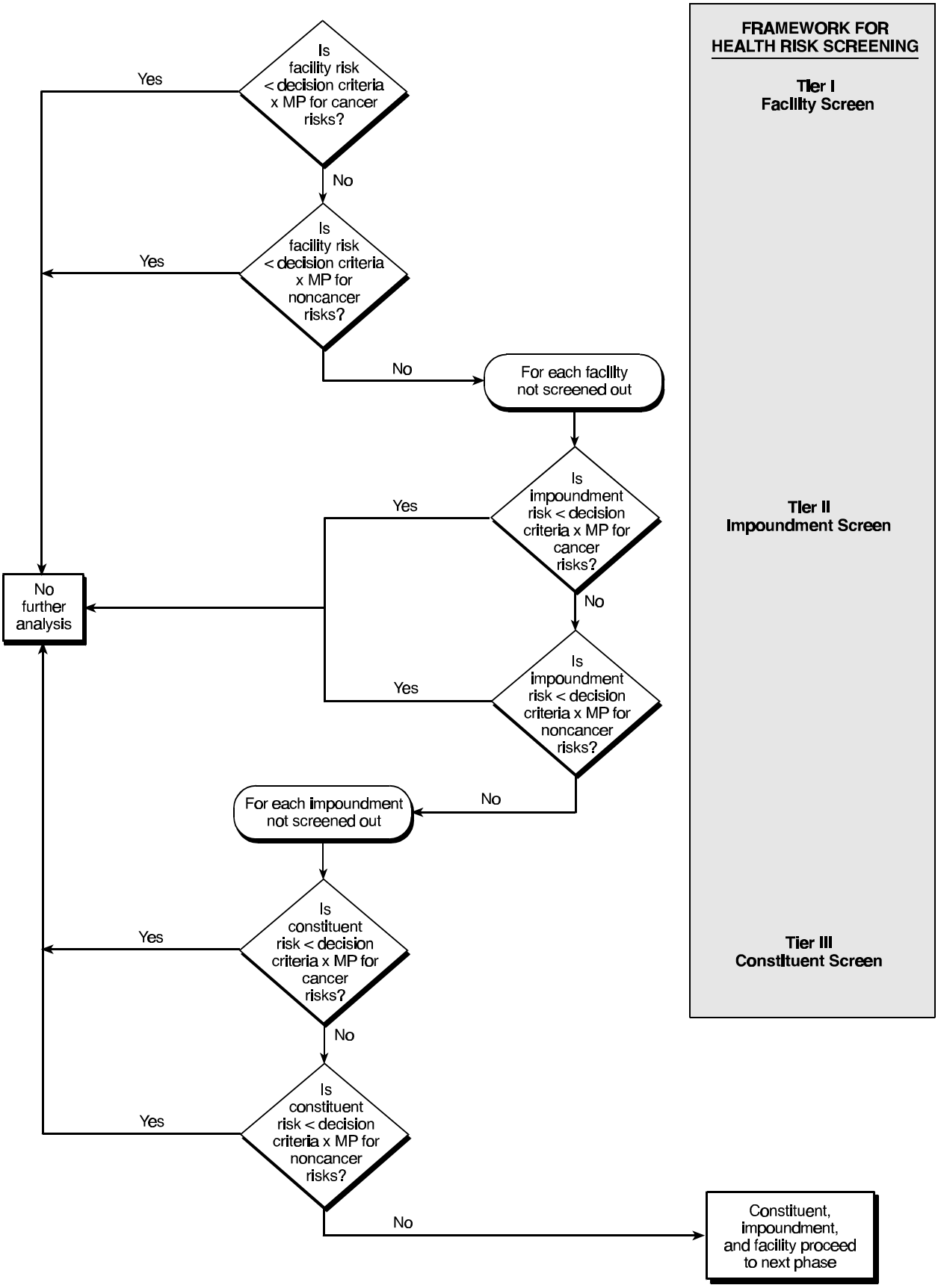


Figure 2-9. Decision tree for performing Phase I human health risk screening.

must proceed to Phase IB. The third tier identifies the constituents for the Tier 2 impoundments that must proceed to Phase IB.

The screening procedure first screens facilities by comparing the facility cumulative risk to the risk decision criteria, which may be adjusted by a margin of protection of 0.1 (risk decision criteria × MP = "screening criteria"). If the facility has a risk above the screening criteria, then the impoundment cumulative risk for each impoundment for that facility is compared to the screening criteria. If the impoundment has a risk above the screening criteria, then the constituent cumulative risk for that facility is compared to the screening criteria. If the constituent has a risk above the screening criteria, then the constituent passes to Phase IB for further screening. The constituent will be further evaluated **only** for those impoundments at the facility that have risks above the screening criteria. The risk screening will be performed for both cancer and noncancer risks.

EXAMPLE. Calculating the cumulative risks and risk screening for a facility.

The example facility has the risk estimates shown in Table 2-3. The first table presents the risk estimates for each chemical in each of the four impoundments.

The second table shows the cumulative facility, impoundment, and constituent risks. The impoundment risk is the sum of the chemical risks for the impoundment; the impoundment HI is the maximum HI of the two target organ HIs. For instance, for Impoundment A, the carcinogenic risk of 3.7×10^{-4} is the sum of Chemicals 1 and 4. The HI of 0.5 is the HI for Target Organ B.

The constituent risks and HIs are the maximum of risks and HI for all four impoundments. For instance, Chemical 1 is detected in Impoundments A, B, and D. Impoundment A has the maximum risk of 3.7×10^{-4} (from Impoundment A).

The facility risk of 3.7×10^{-4} is the summation of all carcinogenic constituent risks (Chemicals 1, 4, and 6). The facility HI of 11.05 is the summation of constituent HIs for target organ A. Specifically, this is Chemical 2 from Impoundment A and Chemical 5 from Impoundment B.

The third table shows the risk screening results for the facility. One impoundment and three chemicals are screened from further assessment at this facility. Three chemicals at three impoundments move on for further assessment in Phase IB.

This example illustrates that the decision criteria incorporate a margin of protection in determining which units and constituents proceed to Phase IB and II; however, the calculated risks with no MP are added to the risk distribution (see further discussion below).

Table 2-3. Example Screening Risks for a Facility

			HI	
Impoundment	**Chemical**	**Risk**	**Target Organ A**	**Target Organ B**
Impoundment A	Chemical 1	3.7E-04		
	Chemical 2		0.05	
	Chemical 3			0.3
	Chemical 4	1.1E-08		
Impoundment B	Chemical 1	2.0E-05		
	Chemical 3			0.007
	Chemical 4	8.0E-08		
	Chemical 5		11.00	
Impoundment C	Chemical 2		0.0004	
	Chemical 3			0.8
	Chemical 5		0.003	
Impoundment D	Chemical 1	5.0E-12		
	Chemical 6	3.0E-08		
Cumulative Risk		Risk	HI	
Impoundment Risk				
	Impoundment A	3.7E-04	0.3	
	Impoundment B	2.0E-05	11.00	
	Impoundment C	-	0.80	
	Impoundment D	3.0E-08	-	
Constituent Risk				
	Chemical 1	3.7E-04		
	Chemical 2		0.05	
	Chemical 3		0.8	
	Chemical 4	8.0E-08		
	Chemical 5		11	
	Chemical 6	3.0E-08		
Facility Risk		3.7E-04	11.05	

Risk Screening Results:		
Tier 1	**Facility**	risk and HI > decision criteria*
Tier 2	**Impoundment A**	risk and HI > decision criteria*
	Impoundment B	risk and HI > decision criteria*
	Impoundment C	HI > decision criteria*
	Impoundment D	risk < decision criteria*
Tier 3	**Chemical 1**	risk > decision criteria*
	Chemical 2	HI < decision criteria*
	Chemical 3	HI > decision criteria*
	Chemical 4	risk < decision criteria*
	Chemical 5	HI > decision criteria*
	Chemical 6	risk < decision criteria*
Conclusion:	Impoundment A: Chemicals 1 and 3 to be assessed in next phase	
	Impoundment B: Chemicals 1 and 5 to be assessed in next phase	
	Impoundment C: Chemical 3 to be assessed in next phase	
	Impoundment D: No further assessment of chemicals 1 and 6; no further assessment at this facility	

*Decision criteria: 10^{-5} for cancer risk; 0.1 for noncancer risk.

Decision Criteria. As described above, the Agency will use risk criteria of 10^{-5} for carcinogenic risk and HI = 1 for noncarcinogenic risk throughout the analysis. The decision to remove a particular constituent, unit, or facility from any further analysis is final (i.e., no further analysis is warranted). Therefore, EPA may apply a margin of protection of 0.1 in Phase I to determine whether Phase IB and II modeling is necessary. EPA may consider applying alternative MPs depending on the screening results presented in the risk distributions.

EPA considers that, for many constituents, screening based on direct ingestion of the surface impoundment influent and direct inhalation of the emissions is by its nature very protective; that is, if fate and transport modeling were to be conducted, the potential risks would invariably be lower. The intent of a margin of protection is to address potential concerns for indirect exposures. In addition, special consideration will be given to constituents known to bioaccumulate in setting priorities during Phase IC.

2.2.1.4 Results of Phase IA Human Health Risk Screening. The risk characterization resulting from the Phase IA analyses will consist of two primary outputs:

- Phase IA risk distributions
- Screening of constituents, impoundments, and facilities.

Risk Distributions. The Phase IA screening risks for each constituent, impoundment, and facility will provide initial risk distribution profiles that describe the national scale surface impoundment population. The risk distributions will be provided for the categories that are of concern to the SI Study:

- Six regulatory status categories of interest
- Three functional classes (storage, treatment, and disposal)
- Types of treatment (e.g., biological, settling)
- Types of industry (by SIC code)
- Types of constituents.

By providing risk distributions for these categories, EPA can determine what types of industries or impoundments have the highest potential risks and merit additional analysis.

The distribution of the sample population of facilities is shown in Tables 2-4 and 2-5 by regulatory category and industry type. The direct discharger and zero discharger types are statistically sampled populations and have the largest number of facilities. The indirect discharger population is smaller and consists of preselected and purposively selected facilities. Risk distributions will be provided for the CWA discharger type and RCRA nonhazardous waste type.

The facility distribution by industry type (see Table 2-4) shows that certain industries were given higher priority in the SI Study; these industries (e.g., SIC group 26, 28, 29, 32, and 33) are sampled at a higher rate. Development of risk distributions by industrial type may be grouped by high- or low-priority industry groups, and, because the CWA discharger types are

Table 2-4. Facility Distribution by Regulatory Category

Type of CWA Facility	Type of RCRA Nonhazardous Waste	Number of Facilities
Direct discharger	Decharacterized	79
	Nondecharacterized [a]	82
Zero discharger	Decharacterized	6
	Nondecharacterized [a]	34
Indirect discharger	Decharacterized	2
	Nondecharacterized [a]	12
	TOTAL	**215**

[a]Could include some missing responses.

three distinct populations, risk distributions by industry type will be developed separately for each CWA discharger type.

EXAMPLE: An example distribution by industry type is provided in Figure 2-10. Risk distributions are shown for three different industry types for cancer risks. The figure indicates that industry type B has the highest percentage of its facilities with cancer risks less than the screening decision criteria of 10^{-6}. In contrast, industry type C has a large percentage of its facilities with risks greater than the risk decision criteria.

The distributions of the sample population of facilities by functional class, treatment type, and constituent will be defined by the survey questionnaire responses.

These risk distributions will be refined with each subsequent phase (see Phase IB Risk Characterization Outputs for approach). The risk distributions will also provide the basis for the prioritization for evaluations to be conducted in Phase II (see Section 2.4).

Risk Screening. The Phase IA risk screening approach identifies

- Constituents, impoundments, and facilities that have risks below the screening criteria and therefore are considered to have negligible risks and are not assessed in any further phases.

- Constituents for specific impoundments and facilities that have risks above the screening criteria and will proceed to Phase IB risk screening.

Table 2-5. Facility Distribution by Industry Type

SIC Major Group	SIC Code	Description	Number of Industry Facilities
20	-	Food and Kindred Products	19
22	-	Textile Mill Products	5
24	-	Lumber and Wood Products, Except Furniture	7
26	-	Paper and Allied Products	31
28	-	Chemicals and Allied Products	38
29	-	Petroleum Refining and Related Industries	25
30	-	Rubber and Miscellaneous Plastics Products	9
32	-	Stone, Clay, Glass, and Concrete Products	20
33	-	Primary Metal Industries	24
34	-	Fabricated Metal Products, Except Machinery and Transportation Equipment	5
35	-	Industrial and Commercial Machinery and Computer Equipment	3
36	-	Electronic and Other Electrical Equipment and Components, Except Computer Equipment	5
37	-	Transportation Equipment	5
49	4952 (Except POTWs)	Sewerage Systems	1
	4953	Refuse Systems	3
50	5085	Industrial Supplies	1
51	5171	Petroleum Bulk Stations and Terminals	7
97	-	National Security and International Affairs	2
		TOTAL	**210**[a]

[a]Total does not include five CBI facilities

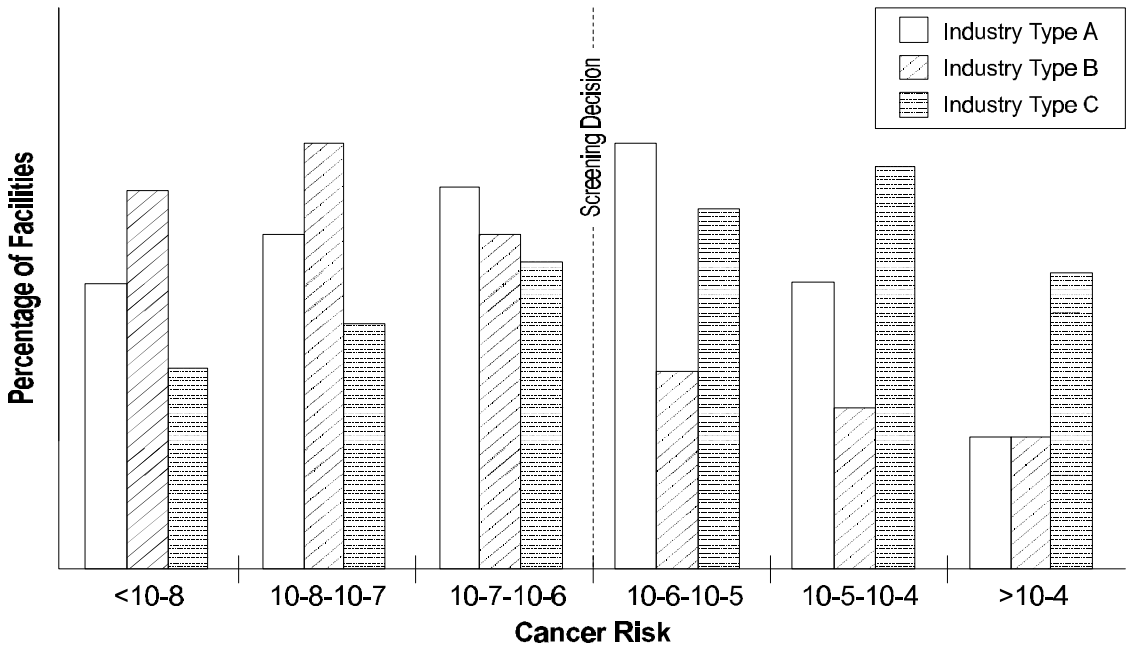


Figure 2-10. Example risk distributions for three industry types.

The results of the risk screening are best presented using the risk distributions based on the constituent, impoundment, and facility risks. These are unweighted distributions because the purpose is to present the number of facilities that must be assessed further. (In comparison, the risk distributions in Figure 2-10 show percentage of facilities because we want to characterize the national population.)

EXAMPLE. An example of the screening results is shown in Figure 2-11. The facility risk distribution for noncancer risks clearly delineates the facilities that will be assessed further in Phase IB and those that are considered to have negligible risks and will not be further evaluated. The screening criteria separate the two categories. The impoundment risk distribution is also divided into two categories based on the screening criteria. The impoundments proceeding to Phase IB are only associated with the facilities that must be assessed further. Some of the impoundments for a facility that must go to Phase IB are not further analyzed; these impoundments fall to the left of the criteria. The third distribution is on a constituent basis and shows the constituents that will be assessed in Phase IB. This constituent distribution applies to the subset of impoundments and facilities that have proceeded to Phase IB. Note that a margin of protection will be considered at each screening decision.

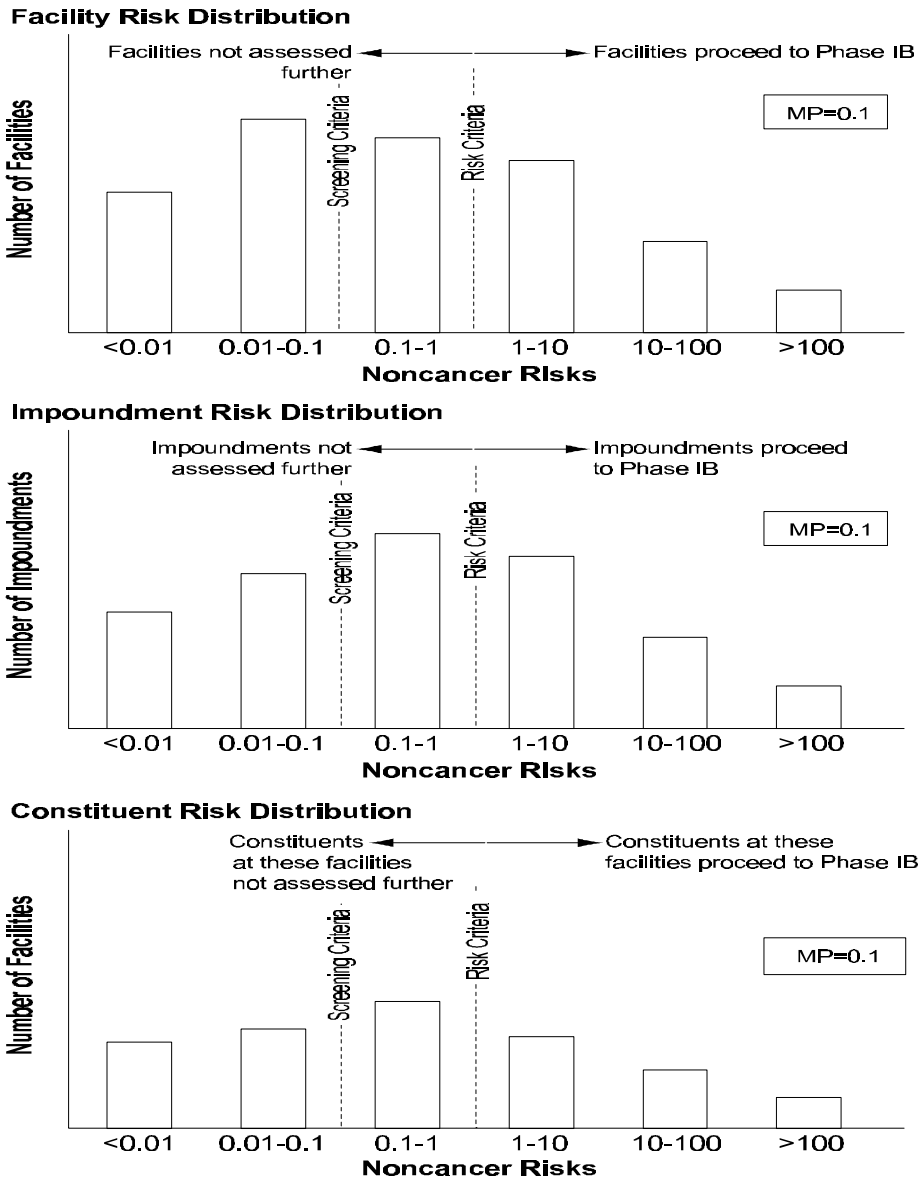


Figure 2-11. Example risk screening results.

2.2.2 Phase IB Human Health Screening

The Phase IB risk screening is described in four sections:

- Design goals and overview
- Screening models
- Procedure for risk screening
- Results of risk screening.

2.2.2.1 Phase IB Human Health Screening Design Goals and Overview. EPA will use screening models to supplement the initial screening performed under Phase IA. Use of screening models provides additional characterization of exposure by evaluating the fate and transport of constituents from their release from the surface impoundment through the environmental media to the point of exposure. Therefore, the Phase IB screening will provide a more realistic tier in the phased approach.

The use of screening models will be necessary when there is uncertainty about eliminating a constituent from further evaluation. Two main categories of uncertainty will be addressed: (1) constituents that volatilize, but for which there are no air concentration data provided in the survey questionnaire, and (2) constituents that were not eliminated for the Phase IA screening. Phase IB modeling will be performed on all constituents identified by the Phase IA screening.

The Phase IB screening will address only the major routes of exposure that are expected to contribute significantly to potential risks (i.e., ingestion of drinking water and inhalation of air). This phase will use a limited amount of site-specific data from the survey questionnaire. However, because constituents from specific units may be screened from further analysis, the Phase IB modeling approach will use protective assumptions, such as assessing risks for close-in receptors.

EPA screening models IWAIR and IWEM, developed for use under the Industrial D guidance, will be used to calculate screening risk estimates. These risk estimates will replace or supplement the corresponding Phase IA screening risk estimates and therefore will refine and improve the overall Phase IA risk distributions.

2.2.2.2 Phase IB Human Health Screening Models. IWAIR and IWEM assess the risks from potential exposure of air and groundwater, respectively, due to constituents released from surface impoundments. The screening models, as described below, follow different approaches. However, both models will provide screening analyses that are useful in characterizing exposure and incorporate more site-specific data. Despite the difference in modeling approaches, the results from each of the Phase IB models constitute a defensible basis to provide screening-level estimaters of risk. Use of IWAIR and IWEM for Phase IB assumes that any software model errors that were identified by the previous peer review will have been addressed.

IWAIR. The IWAIR model will be used to calculate risks due to inhalation of airborne volatile constituents released from surface impoundments. IWAIR incorporates the CHEMDAT8 volatile emission model to calculate the constituent release (i.e., emission rate) from an impoundment, uses dispersion factors developed from Industrial Source Complex Short Term (ISCST3) modeling simulations to calculate an air concentration, uses exposure and risk calculations following EPA guidance (*Risk Assessment Guidance for Superfund*, U.S. EPA, 1989), and uses a chemical and toxicological database for 95 chemicals to calculate carcinogenic and noncarcinogenic chronic inhalation risks. CHEMDAT8 has undergone extensive review by both EPA and industry representatives and is publicly available. ISCST3 is another regulatory

standard model that has undergone substantial review and use by industry. The dispersion factor approach for risk screening purposes is recommended by EPA guidance (*Soil Screening Guidance*, U.S. EPA, 1996d, e). Dispersion factors for multiple source area sizes, receptor distances, and meteorological conditions are provided.

IWAIR uses the same exposure factors as Phase IA from the *Exposure Factors Handbook* (U.S. EPA, 1997b). An age-weighted resident is considered for carcinogenic chemicals. This approach is also generally consistent with the establishment of risk-based criteria such as ambient water quality criteria. An adult resident is considered for noncarcinogenic chemicals. Phase IA toxicological benchmarks will be used (in place of IWAIR toxicological benchmarks) to calculate screening risks with IWAIR. For SI Study constituents that are not included in the IWAIR chemical database, the physicochemical properties from CHEMDAT8 and Phase IA toxicity benchmarks will be added to IWAIR. IWAIR will then be used to calculate the constituent risks and HIs.

The IWAIR model is computationally fast and easy to use and requires minimal input data. The site-specific data required will be obtained from the survey and include: constituent waste concentration, impoundment depth, area, annual wastewater flow rate, and whether or not aeration occurs. Default or additional site-specific data can be provided for aeration parameters and wastewater parameters important for biodegradation. These are attributes required by the Phase IB screening because a large number of constituents and units may be assessed in Phase IB.

The IWAIR model is currently in the public comment period. Peer review comments have been favorable to the approach and the computer program. Use of the IWAIR model in the SI Study Phase IB calculations is outlined in Section 2.2.2.3.

IWEM. The IWEM Tier 1 model will be used to calculate the risks due to exposure to groundwater containing constituents released from surface impoundments. IWEM Tier 1 is a table containing leachate concentration threshold values for a specific chemical based on a dilution attenuation factor (DAF) and the toxicity reference levels for 190 constituents. The toxicity reference level is based on the toxicological benchmark or the MCL. The DAFs were generated by modeling the migration of waste constituents from an impoundment through the underlying soil to a monitoring point in the aquifer using the EPA Composite Module for Leachate Migration with Transformation Products (EPACMTP) in a national Monte Carlo probabilistic analysis. The DAFs are multiplied by the toxicity benchmark to provide the leachate concentration threshold value for each chemical.

Leachate concentration threshold values and DAFs are provided for three impoundment liner scenarios: no liner, single liner, and a composite liner. The no liner scenario represents an impoundment that is relying upon location-specific conditions such as low-permeability native soils beneath the unit or low annual precipitation rates to mitigate the release of contaminants to the groundwater. The single liner scenario represents a 3-foot-thick clay liner with a low hydraulic conductivity (10^{-7} cm/s) beneath the impoundment. The composite liner scenario consists of a 3-foot-thick clay liner beneath a 40-mil-thick high-density polyethylene (HDPE) flexible membrane liner.

IWEM Tier 1 is based on a health-protective Monte Carlo probabilistic analysis that accounts for the nationwide variability of groundwater modeling parameters. The Monte Carlo procedure randomly drew input parameter values from representative statistical distributions for each parameter. A set of input parameter values was developed and the model was run to compute the groundwater monitoring well concentration and the DAF. This process was repeated thousands of times until a distribution of thousands of output values (DAFs) was produced. The DAF values were ranked from high to low, and the 90th percentile DAF was determined. The 90th percentile DAF represents the amount of dilution and attenuation that would occur in at least 90 percent of the cases modeled. In other words, the DAF is protective in at least 90 percent of the modeled cases. The selection of 90th percentile DAF is based on

- The need to choose a level of protection that is protective and consistent with other EPA analyses, including the proposed Hazardous Waste Identification Rule (HWIR) of 1995 (U.S. EPA, 1995b) and hazardous waste listing evaluations (e.g., the Petroleum Refinery Waste Listing Determination, U.S. EPA, 1997d)

- The desire to have a large degree of confidence that the results are adequately protective of human health and the environment given the degree of uncertainty inherent in the data and the analyses.

The Monte Carlo approach used in EPACMTP has been applied in various EPA regulatory efforts, including the proposed 1995 HWIR and hazardous waste listing evaluations, such as those mentioned previously. As such, the Monte Carlo procedure and its applicability to national analyses has been extensively reviewed within EPA and by the Science Advisory Board and has been subject to public review and comment (U.S. EPA, 1999aa). The model is currently in the public comment period.

To maintain consistency with Phase IA in the risk calculation, only the DAFs from IWEM will be used. For each chemical, the DAF from each liner scenario will be multiplied by the carcinogenic or noncarcinogenic risk screening factor from Phase IA to develop a new SI Study-modified IWEM Tier 1 table containing the leachate concentration threshold values. This approach ensures that receptors are evaluated with the same exposure factors (e.g., amount ingested and inhaled) used in Phase IA.

There are a number of SI Study constituents that are not included in the IWEM Tier 1 table. For these constituents, a leachate concentration threshold value using a DAF from a surrogate chemical will be calculated. The leachate concentration threshold value will be calculated by using the IWEM procedure for estimating DAFs of chemicals for which EPACMTP was not simulated, as follows: the DAF will be determined by interpolating between the DAFs of chemicals whose hydrolysis rate and retardation factor are in the same range as the hydrolysis rate and retardation factor of the new chemical.

Use of the SI Study-modified IWEM Tier 1 table in the SI Study Phase IB calculations is outlined in Section 2.2.2.3.

2.2.2.3 Procedure for Phase IB Risk Screening. The overall human health screening process is shown in Figure 2-12. The overall process is the same as Phase IA:

- Risks will be calculated for each constituent, impoundment, facility, and regulatory population.
- Cumulative risks will be calculated.
- Risk distributions will be developed.
- Risk screening will be performed.

The analyses, however, will be performed only for a subset of constituents, impoundments, and facilities defined by the Phase IA screening results. Each element is outlined in more detail below. The primary difference between Phase IA and IB is the procedures used for calculating risks.

Human Health Risk Calculation. Phase IB risk estimates will be for the air inhalation and groundwater ingestion pathways only (see Figure 2-12). Phase IB does not include the soil ingestion pathway. Risks for the air exposure pathway will be estimated using IWAIR if the Phase IA risk estimate is greater than the screening criteria or if the constituent is a VOC, but air concentration or emission data were not provided in the survey response. Risks for the groundwater exposure pathway will be estimated using IWEM if the Phase IA risk estimate is greater than the screening criteria.

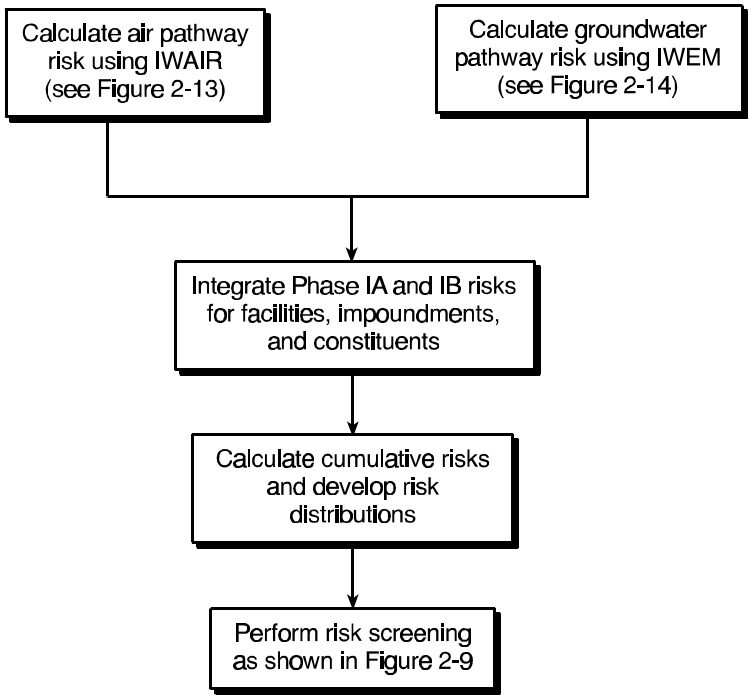


Figure 2-12. Decision tree for Phase IB human health risk screening.

The decision tree for calculating the Phase IB air exposure risks using IWAIR is presented in Figure 2-13. The types of site-specific data that will be used are outlined; the survey question that will provide the data is noted in the figure. The decision tree for defining the influent waste concentration from survey data is shown in Figure 2-14. IWAIR default data will likely be used for the aeration and waste characteristics data. Because IWAIR must represent wind conditions across the continental United States, IWAIR contains wind dispersion data based on 29 meteorological stations. Because the wind pattern may not be representative of the actual site conditions, a close-in receptor at 25 m will be assumed for the Phase IB screen. If a constituent is not currently in IWAIR, its physicochemical and toxicological data will be added to the IWAIR chemical database.

The decision tree for calculating the Phase IB groundwater exposure risks using the modified IWEM Tier 1 table is presented in Figure 2-15. The Phase IB groundwater risk calculation will consider the type of lining at each impoundment in determining the appropriate groundwater screening factor, called the leachate concentration threshold value (LCTV) in IWEM. The site-specific liner questions are outlined in Figure 2-15. The calculation of the leachate concentration is shown in Figure 2-6. The risk calculation mirrors the Phase IA calculation: calculate the ratio of the leachate concentration to the LCTV and multiply by the risk criteria.

Cumulative Risk Calculation. The calculated screening risks for each constituent for a specific impoundment and facility will be combined to generate three cumulative risk estimates: impoundment risk, constituent risk, and facility risk. The calculation of the cumulative risks is defined in Figure 2-3 and Section 2.2.1.3. It is important to note that the cumulative risks are a combination of the Phase IA and Phase IB calculated risks for each constituent, because the Phase IB risk estimate is considered a refinement of the initial Phase IA risk estimate.

Risk Distribution Development. The risk distribution approach is identical to that defined in Phase IA (see Section 2.2.1.3 for the development approach). Because the Phase IB cumulative risks are a combination of Phases IA and IB results, the risk distributions also represent the combined analysis of Phase IA and IB.

Risk Screening. The risk screening approach is also identical to that defined in Phase IA (see Section 2.2.1.3 for the development approach).

2.2.2.4 Results of Phase IB Risk Screening. The risk characterization resulting from the Phase IB analyses will consist of two primary outputs:

- Combined Phase IA and IB risk distributions
- Combined Phase IA and IB screening of constituents, impoundments, and facilities.

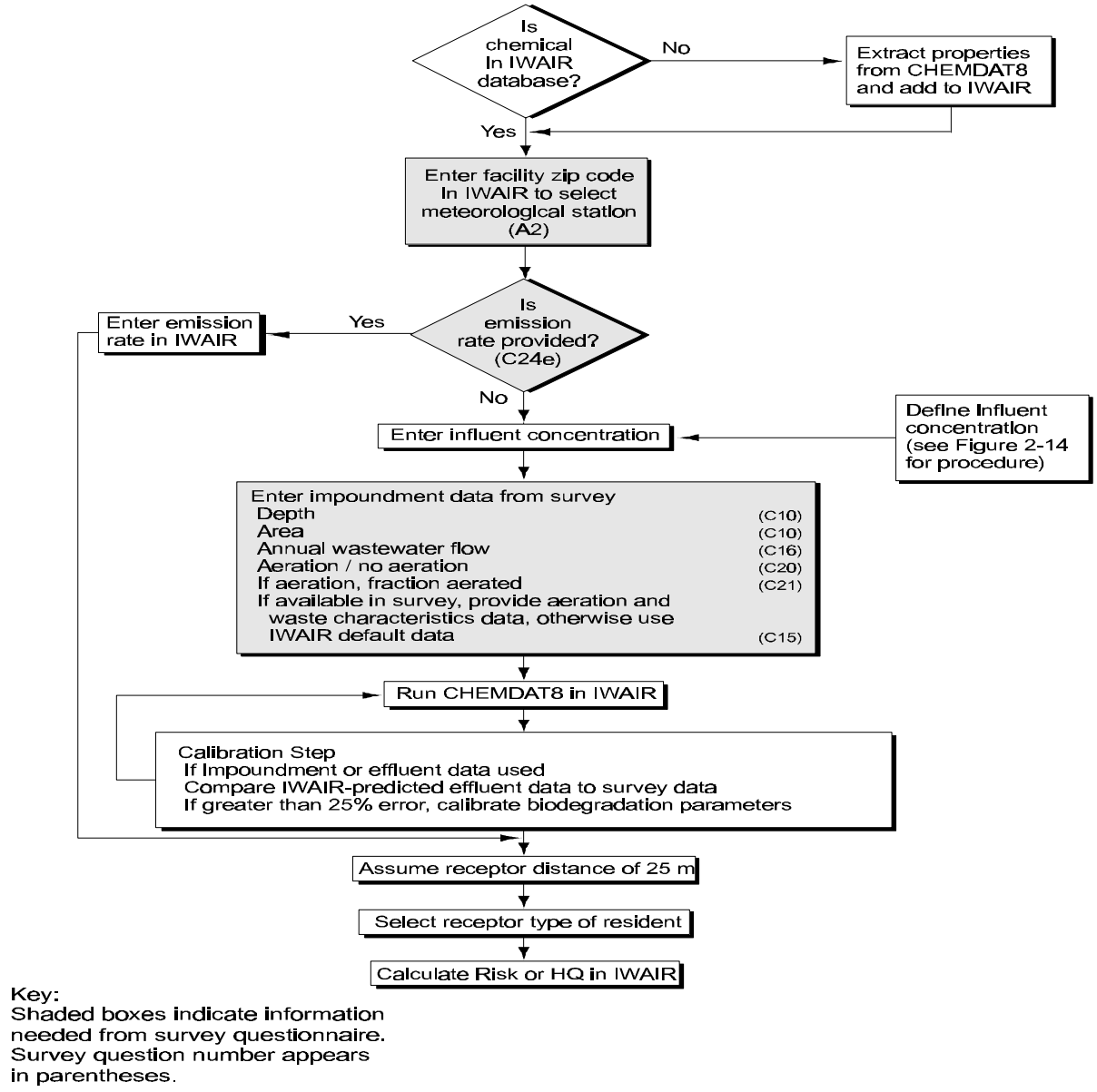


Figure 2-13. Decision tree for Phase IB air screening using IWAIR.

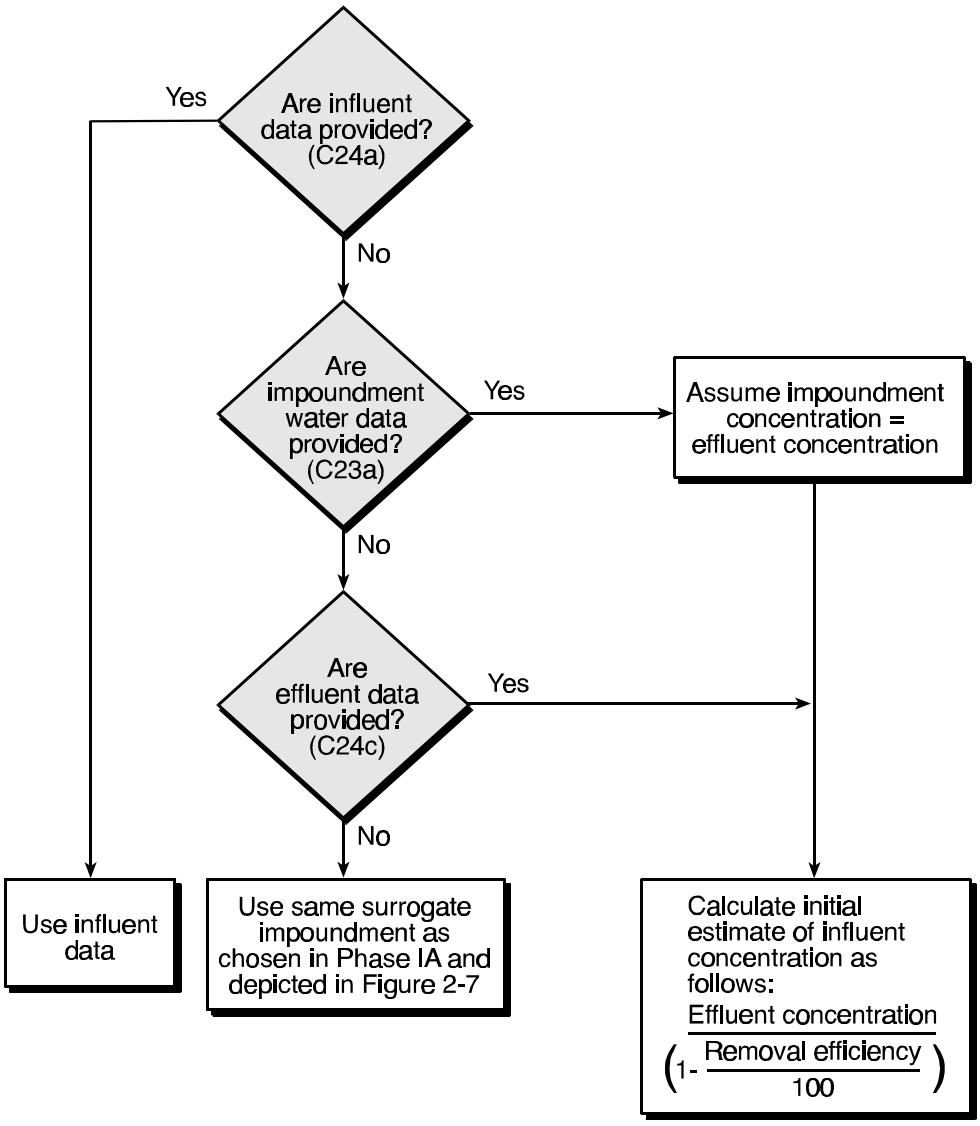
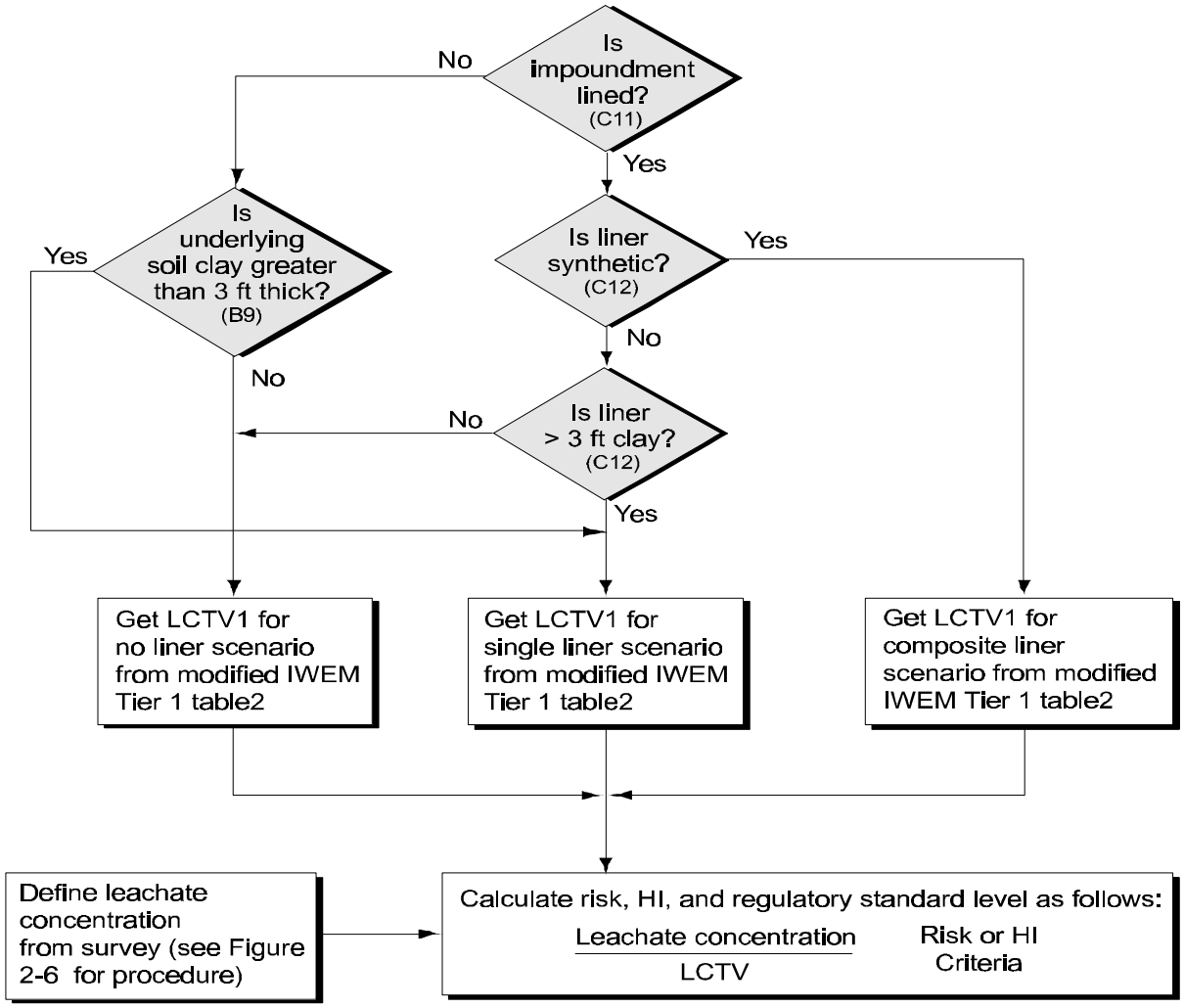


Figure 2-14. Decision tree for calculating influent waste concentration for IWAIR.



Key:

1Leachate concentration threshold value.

2IWEM lookup table modified to include HWIR toxicity data and all SI study chemicals.

Shaded boxes Indicate Information needed from survey questionnaire.

Survey question number appears in parentheses.

Figure 2-15. Decision tree for Phase IB groundwater screening using IWEM.

Risk Distributions. The combined Phase IA and IB screening risks for each constituent, impoundment, and facility will provide initial screening-level risk distribution profiles for the national scale surface impoundment population. The risk distributions will be provided for the categories that are of concern to the SIS, as outlined in Section 2.2.1.4.

The refinement of the screening-level risk distribution from Phase IA to Phase IB is shown in Figure 2-16. The example risk distribution shown previously for Phase IA (see Figure 2-10) is now updated to include the Phase IB risk screening results. The new figure shows the modified risk distributions for the three industry types. It is expected that the Phase IB analyses, by including the attenuating factor of exposure modeling, will result in more accurate and generally lower risk estimates. Therefore, percentages below the screening criteria are expected to increase. The shaded portions of the percentages of facilities in each risk bin are the added Phase IB percentages. Above the screening criteria, the percentages are expected to decrease. For the most part, the facilities with risks above the screening criteria are from Phase IB analyses. Only risks from sludge ingestion, which is a Phase IA analysis only, would contribute to the facilities with risks above the screening criteria.

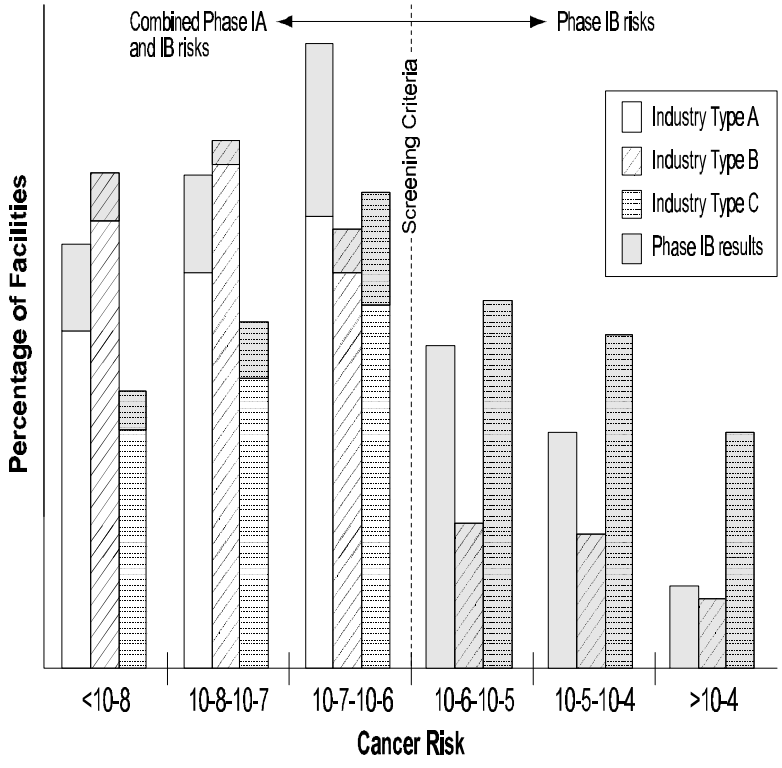


Figure 2-16. Example combined Phase IA and IB risk distributions for three industry types.

Risk Screening. The combined Phase IA and IB risk screening approach identifies

- Constituents, impoundments, and facilities that have risks below the screening criteria and therefore are considered to have negligible risks and are not assessed in any further phases

- Constituents for specific impoundments and facilities that have risks above the screening criteria and should proceed to Phase II analysis, depending on the factors described in the Phase IC initial prioritization.

In addition to the risk screening, constituents that are considered special cases will automatically proceed to Phase II. The definition and categorization of special cases is discussed in the next section.

2.2.3 Special Cases

Certain constituents may present human health or ecological risks yet not be identified as constituents with high risks in the screening process described above. These constituents are likely to be persistent or bioaccumulative. To ensure that these types of constituents are identified, each constituent will be ranked according to a special set of criteria. EPA developed the Revised Waste Minimization Prioritization Tool (U.S. EPA, 1998e), which scores constituents on the basis of their persistence (P) in the environment, bioaccumulation (B) potential, and toxicity (T) to humans and ecological receptors. Because the SI Study is concerned with the same issues, the procedures used in the WMPT will be used to score constituents (see Figure 2-17). The persistence (P) scoring is based on a steady-state, nonequilibrium multimedia partitioning model to estimate constituent half-life. The potential for bioaccumulation (B) is scored using either measured or estimated bioaccumulation factors (BAFs) or bioconcentration factors (BCFs). Human and ecological toxicity (T) of the constituents is also scored. For human health, the highest score for either the carcinogenic or noncarcinogenic health effects is selected. For ecological effects, the highest toxic effect to aquatic organisms is identified. Depending on the data available to assess constituent characteristics, P, B, and T scores are qualified to indicate which data from the established hierarchy (i.e., high, medium, or low data preferences) have been used in the scoring process. These factors are consolidated into an overall score for human health effects from each constituent by summing the P and B scores and summing this score with the highest T score for either noncarcinogenic or carcinogenic chemicals. A similar process is used to develop scores for ecologically important constituents, with aquatic toxicity data used to develop T scores for the ecologically important constituents. The final score is the higher of either the human or ecological scores.

The SIS will use the PBT scores developed by the WMPT after reviewing the toxicity data to determine whether the data used in both studies are consistent. If necessary, new scores will be developed for constituents with new toxicity data or for constituents not evaluated previously. Furthermore, since EPA intends to continue revising the WMPT in response to the public and EPA comments, changes in the WMPT procedures will also be addressed, if necessary. Thus, special case constituents will be identified as those with the highest PBT

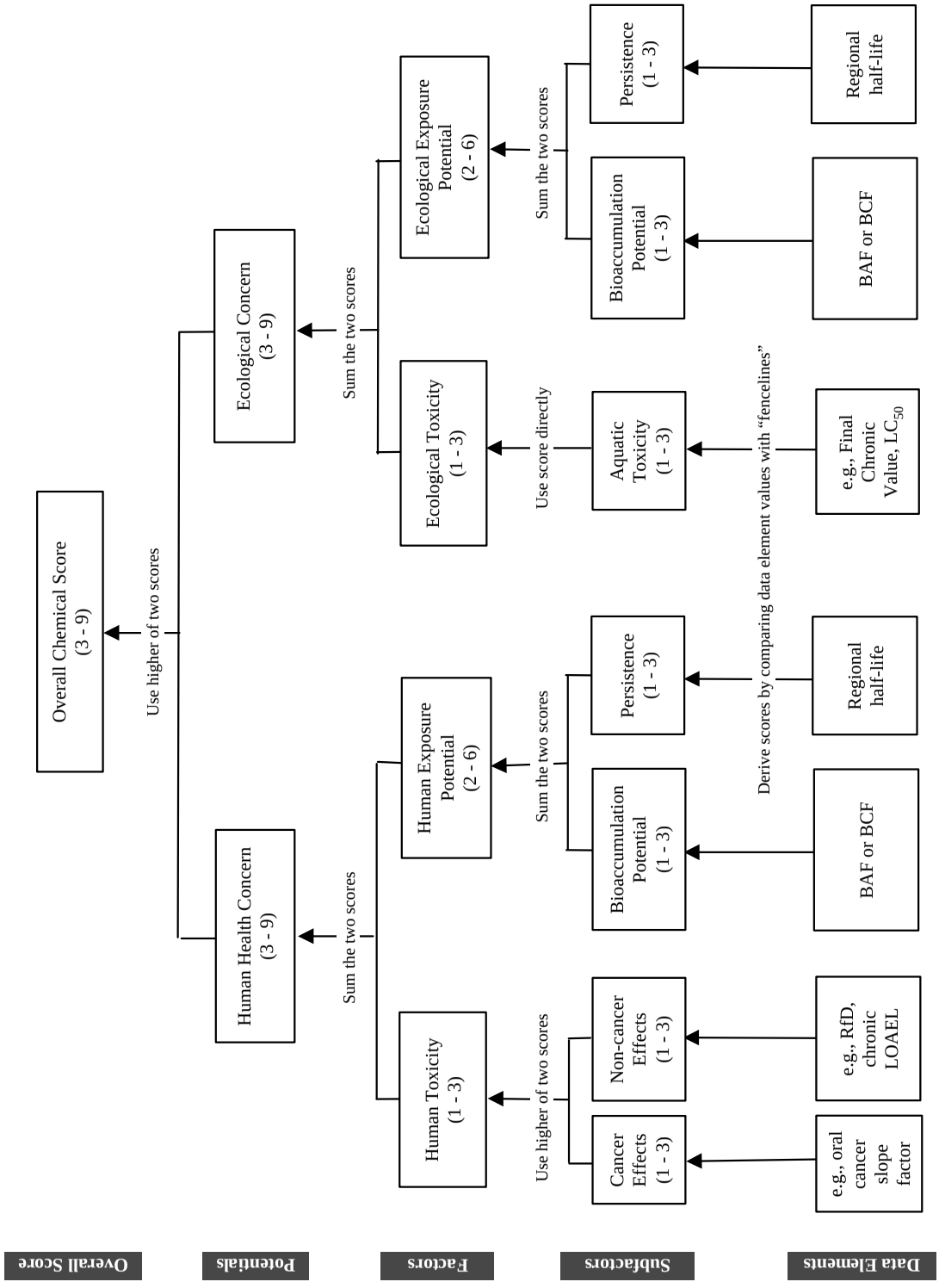


Figure 2-17. Overview of the revised WMPT scoring algorithm (U.S. EPA, 1998e).

ranking. The list of special case constituents will be reported with the risk distributions reported for the Phase I screening process.

2.3 Phase I: Ecological Screening Assessment

The Phase I ecological risk screening is somewhat different from the Phase I human health screening in that a single comparison between screening factors and constituent concentrations is conducted to determine whether a constituent, impoundment, or facility should be included for further evaluation in Phase II. Depending on the ecological receptor of concern, the Phase I analysis will either estimate risks from the ingestion of contaminated plants, prey, and media, or it will estimate risks associated primarily with direct contact with a contaminated medium such as sediment or soil. The ecological risk estimates will be compared to risk criteria to prioritize the list of constituents, impoundments, and facilities that may warrant further evaluation to determine the likelihood of adverse ecological effects. It is important to note that the ecological priority list will be used **in conjunction** with the Phase I human health screening results to delineate the universe for the Phase II analysis. The Phase I results from the ecological screening will be used to inform the selection of constituents, impoundments, and facilities that are most likely to pose significant risks to both human **and** ecological receptors.

2.3.1 Phase I Ecological Risk Screening

The Phase I ecological risk screening is described in five sections:

- Design goals and overview
- Management goals and assessment endpoints
- Development of screening factors
- Procedure for risk screening
- Results of risk screening/prioritization.

2.3.1.1 <u>Design Goals and Overview</u>. As suggested above, the primary goal of the Phase I ecological screening assessment is to establish a priority list of constituents, impoundments, and facilities based on the potential for adverse ecological effects. The secondary goal of this phase is to use the screening-level results to generate ecological risk profiles for the universe of surface impoundments included in the SI Study. These risk profiles provide a "snapshot" of the potential for environmental effects and will be used to identify constituents, impoundments, and facilities that have negligible ecological risks. The Phase I approach considers the potential for adverse effects to a suite of ecological receptors that may be attributed to terrestrial, freshwater, and wetland habitats including, for example, mammals, birds, and soil and benthic fauna. The habitats and receptors considered in this study are consistent with the national assessment strategy developed to support the Hazardous Waste Identification Rule (HWIR) proposed in November 1999. Because the HWIR risk assessment framework was intended to support national studies of waste management practices, the SI Study has adopted this framework as the basis for selecting receptors and habitats.

As with the Phase I screening approach for human health, the ecological screening analysis calculates risks to individual ecological receptors (e.g., red fox, aquatic biota) based on the ratio between ecological risk screening factors and the reported concentrations of constituents

in surface impoundments reported in the survey questionnaire. Consequently, ecological risk screening factors are given in units of concentration (e.g., mg/kg or mg/L). The ecological risk screening factors will include both standard ecological benchmarks such as the Ambient Water Quality Criteria (AWQC) as well as benchmarks developed for other EPA analyses such as HWIR. The use of screening factors is considered to be protective because the factors are:

- # Derived using established EPA protocols for use in evaluating ecological risk (e.g., sediment quality criteria)
- # Based on highly protective assumptions regarding the toxicological potency of a constituent (e.g., no adverse effects levels)
- # Calculated assuming that all media and food items originate from a contaminated source.

In addition, the application of the screening factors assumes that ecological receptors are exposed directly to chemical concentrations in the sludge and wastewater found in the surface impoundment. For mammals, birds, and selected herpetofauna, these screening factors reflect ingestion of contaminated media, plants, and prey. For other receptor groups such as soil fauna, these screening factors are intended to reflect both the direct contact and ingestion routes of exposure. The results of the screening assessment for these representative species will be used to infer potential risks to taxonomically and ecologically similar receptors.

2.3.1.2 Management Goals and Assessment Endpoints. Perhaps the most important step in developing the assessment strategy (often referred to as the problem formulation phase) is the selection of assessment endpoints. The selection of assessment endpoints, defined as "explicit expressions of the actual environmental value that is to be protected" (U.S. EPA, 1998f) serves as a critical link between the ecological risk assessment (ERA) and the management goals. For the SI Study, the management goals may be summarized as follows: "prioritize the constituents, impoundments, and facilities based on the potential for adverse ecological effects, and describe the national distribution of ecological risks associated with the management of wastes in surface impoundments." Candidates for assessment endpoints often include threatened/endangered species, commercially or recreationally important species, functional attributes that support food sources or flood control, or aesthetic values, such as the existence of charismatic species like eagles (U.S. EPA, 1998f). However, it should be emphasized that two key elements are required to define an assessment endpoint: (1) a valued ecological entity (e.g., a species, a community) and (2) an attribute of that entity is important to protect (e.g., reproductive fitness).

Given the similarity in the management goals for HWIR, the assessment endpoints for the SI Study were chosen to be consistent with those selected for the proposed Hazardous Waste Identification Rule. As with the HWIR risk analysis, ecological exposures are presumed to occur at facilities that may be located anywhere within the contiguous United States. Consequently, a suite of assessment endpoints was chosen based on: (1) their significance to the ecosystem, (2) their ability to represent a variety of habitat types, (3) their position along a continuum of trophic levels, and (4) their susceptibility to chemical stressors managed in surface impoundments meeting certain regulatory criteria. In Table 2-6, the assessment endpoints (i.e., values to be protected) selected for the SI Study analysis are defined in terms of: (1) the

significance of an ecological entity, (2) the ecological receptor representing that entity, (3) the characteristic about the entity that is important to protect, and (4) the measures of effect used to predict risk. The intent of including multiple receptors is that, by protecting producers (i.e., plants) and consumers (i.e., predators) at different trophic levels, as well as certain structural components (e.g., benthic community), a degree of protection from chemical stressors may be inferred to the ecosystem as a whole. Consequently, the selection of the assessment endpoints for each receptor taxon is critical to the development of ecological screening factors.

In addition to using screening factors to infer risks to representative species populations and communities, it is also important to consider the potential effects on managed lands (e.g., National Wildlife Refuges), critical habitats (e.g., wetlands), and threatened and endangered species. Although metrics to evaluate the impacts on the ecological "health" of these entities are not available for use in screening analyses, the presence of valued habitats and species may require alternative risk modeling approaches to determine the likelihood of adverse effects. These assessment endpoints will not be evaluated in Phase I; however, the intrinsic value of managed lands and critical habitats will be considered in Phase IC and Phase II.

2.3.1.3 Development of Ecological Screening Factors. The development of ecological screening factors will involve four basic steps:

Select representative species and receptor groups.

Identify relevant exposure pathways.

Select appropriate ecotoxicological studies:

- studies used in population-inference
- studies used in community-inference.

Calculate ecological screening factors

- screening factors for receptor populations
- screening factors for receptor communities.

Examples of ecological screening factors and the studies selected to support their development are presented in Appendix C. Because these data will be used in both the Phase I and Phase II analysis, Appendix C uses the generic term of "toxicity benchmarks" to refer to screening factors as well as ecotoxicological study data. The following discussion describes the methods and data sources used in the development of screening factors shown in Appendix C.

Selection of Representative Species/Receptor Groups. The HWIR ecological risk assessment approach included a series of representative habitats for terrestrial (five), freshwater margins (three), and wetlands (three permanently flooded). These habitats were selected to capture the variability in ecological systems throughout the United States and to provide a

Table 2-6. Assessment Endpoints and Measures of Effects

Examples of Ecological Significance	Assessment Endpoint	Representative Receptors	Characteristic(s)	Measure of Effect
# Multiple trophic levels represented # Represent species with large foraging ranges # Represent species with longer life spans # Variety of dietary exposures represented	Viable mammalian wildlife populations	Deer mouse, meadow vole, red fox, e.g.	Reproductive and developmental success	Chronic or subchronic NOAEL(s) for developmental and reproductive effects
	Viable avian wildlife populations	Red-tailed hawk, northern bobwhite, e.g.	Reproductive and developmental success	Chronic or subchronic NOAEL(s) for developmental and reproductive effects
# Species represent unique habitat niches # Many species are particularly sensitive to exposure	Protection of amphibian and reptile populations ("herps") against acute effects	Frog, newt, snake, turtle, e.g.	Lethality and percent deformity	Acute LC_{50}s for developmental effects resulting from early life stage exposures
# Represents base food web in terrestrial systems # Habitat vital to decomposers and soil aerators # Crucial to nutrient cycling	Sustainable soil community structure and function	Nematodes, soils mites, springtails, annelids, arthropods, e.g.	Growth, survival, and reproductive success	95% of species below no effects concentration at 50th percentile confidence interval
# Primary producers # Act as food base for herbivores # Constitute essential habitat for virtually all receptor groups (e.g., nests)	Maintain terrestrial primary producers (plant community)	Soy beans, alfalfa, rye grass, e.g.	Growth, yield, germination	10th percentile from LOEC data distribution
# Important food source for animals that live in waterbody margins # Diverse aquatic life important to maintain biotic integrity	Sustainable aquatic community structure and function	Fish (salmonids), aquatic invertebrates (daphnids), e.g.	Growth, survival, reproductive success	National Ambient Water Quality Criteria for aquatic life (95% species protection)
# Provide habitat for reproductive lifestages (e.g., eggs, larval forms) # Act to process nutrients and decompose organic matter	Sustainable benthic community structure and function	Protozoa, flat worms, ostracods, e.g.	Growth, survival, reproductive success	10th percentile from LOEC data distribution
# Primary producers # Base food source in the aquatic system	Maintain primary aquatic producers (algal and plant community)	Algae and vascular aquatic plants, e.g.	Growth, mortality, biomass, root length	EC_{20} for algae; lowest LOEC for aquatic plants

meaningful "ecological context" for receptor selection. A detailed description of the criteria used to identify representative habitats is provided in the HWIR documentation, *Ecological Receptors and Habitats* (U.S. EPA, 1999n); however, it is important to recognize that the intent of a representative habitat scheme was to develop a site-based framework to perform spatially explicit risk analyses. In the Phase I screening analysis for the SI Study, the representative habitats will simply be used to support the inclusion of representative species and receptor groups.

Because one of the major goals of the Phase I assessment is to prioritize facilities, impoundments, and constituents for further analysis, a strategy was developed to: (1) organize receptors into feeding guilds of taxonomically similar organisms (e.g., herbivorous birds, carnivorous mammals), and (2) select a species to represent each guild. Habitat-receptor correlations, food webs, and available exposure factors will be used to identify "screening-indicator" species that could be expected to receive the highest exposure to constituents, thus ensuring a protective screening assessment. Common species generally will be preferred as indicator species because they are found in a variety of habitats and may be used to represent different guilds. Table 2-7 presents the crosswalk of some of the likely indicator species for various guilds and the representative habitats with which they are associated.

Identification of Relevant Exposure Pathways. Ecological exposure pathways for the Phase I screening analysis will be identified based on: (1) both active and postclosure scenarios for surface impoundments, and (2) likely routes of exposure for receptors assigned to simple food webs. Chemical constituents may volatilize from active surface impoundments and deposit onto adjacent soils, plants, or surface waters. In addition, constituents may leach into ground water and contaminate nearby surface waters and sediments. Following closure, a surface impoundment may be integrated with local habitats (assuming the contaminant concentration does not prevent vegetative growth) and serve as a long-term source of exposure to certain types of constituents (e.g., metals). As shown in Figure 2-18, receptors may be exposed to contaminated media and/or prey and plants in both terrestrial and aquatic systems. Consequently, the exposure pathways that will be represented in Phase I are:

- Direct contact with contaminated sludge/soil (e.g., plants, soil fauna)
- Ingestion of contaminated sludge/soil (e.g., mammals, birds)
- Ingestion of plants/prey on contaminated sludge/soil (e.g., mammals, birds)
- Direct contact with contaminated surface water (e.g., fish, amphibians)
- Direct contact with contaminated sludge (e.g., benthos)
- Ingestion of aquatic plants/prey in contaminated surface water (e.g., birds)
- Ingestion of contaminated surface water (e.g., mammals)

Exposure routes that will be not addressed in the Phase I ecological screening assessment include

- Dermal absorption from contaminated surface water or sludge (e.g., mammals)
- Inhalation of volatile constituents in air.

Table 2-7. Representative Habitats, Receptor Groups, and Representative Species

Representative Species	Representative Habitats									
	Aquatic Habitats			Wetland Habitats			Terrestrial Habitats			
	Impoundment/Ponds	Streams/Rivers	Lakes	Permanently Flooded Grasslands	Permanently Flooded Shrubs/Scrub	Permanently Flooded Woodlands	Grasslands	Shrubs/Scrub	Forests	Crops/Pastures
Plants										
Algae and emergent aquatic plants	!	!	!	!	!	!				
Terrestrial plants							!	!	!	!
Invertebrates										
Aquatic invertebrates	!	!	!							
Sediment-associated biota	!	!	!	!	!	!				
Soil invertebrates				!	!	!	!	!	!	!
Fish	!	!	!	!	!	!				
Amphibians										
Bullfrog	!	!	!	!	!	!				!
Gopher frog							!	!	!	
Reptiles[a]	!	!	!	!	!	!	!	!	!	!
Birds										
Herbivorous Birds[b]										
Song sparrow	!	!	!				!	!	!	!
Mallard	!	!	!	!	!	!				
Insectivorous Birds[c]										
American robin							!	!	!	!
Tree swallow				!						
American woodcock	!	!	!		!	!				
Carnivorous Birds[d]										
American kestrel	!	!	!	!	!	!			!	
Red-tailed hawk							!	!		!
Mammals										
Herbivorous Mammals										
Meadow vole	!	!	!	!	!		!	!		!
Pine vole									!	
Mule deer				!	!	!				
White-tailed deer	!	!	!				!	!	!	!
Insectivorous Mammals										
Short-tailed shrew							!			!
Deer mouse	!	!	!		!	!		!	!	
Carnivorous Mammals										
Raccoon	!	!	!	!	!	!				
Coyote	!	!	!				!	!	!	!

[a] Reptiles will not be assessed in Phase I due to the lack of applicable toxicity data.
[b] Birds and mammals whose diet is predominantly plants (i.e., vegetative, flowers, fruits, and/or seeds)
[c] Birds and mammals whose diet is predominantly invertebrates (e.g., insects, soil invertebrates, sediment-associated invertebrates).
[d] Birds and mammals whose diet is predominantly birds or mammals.

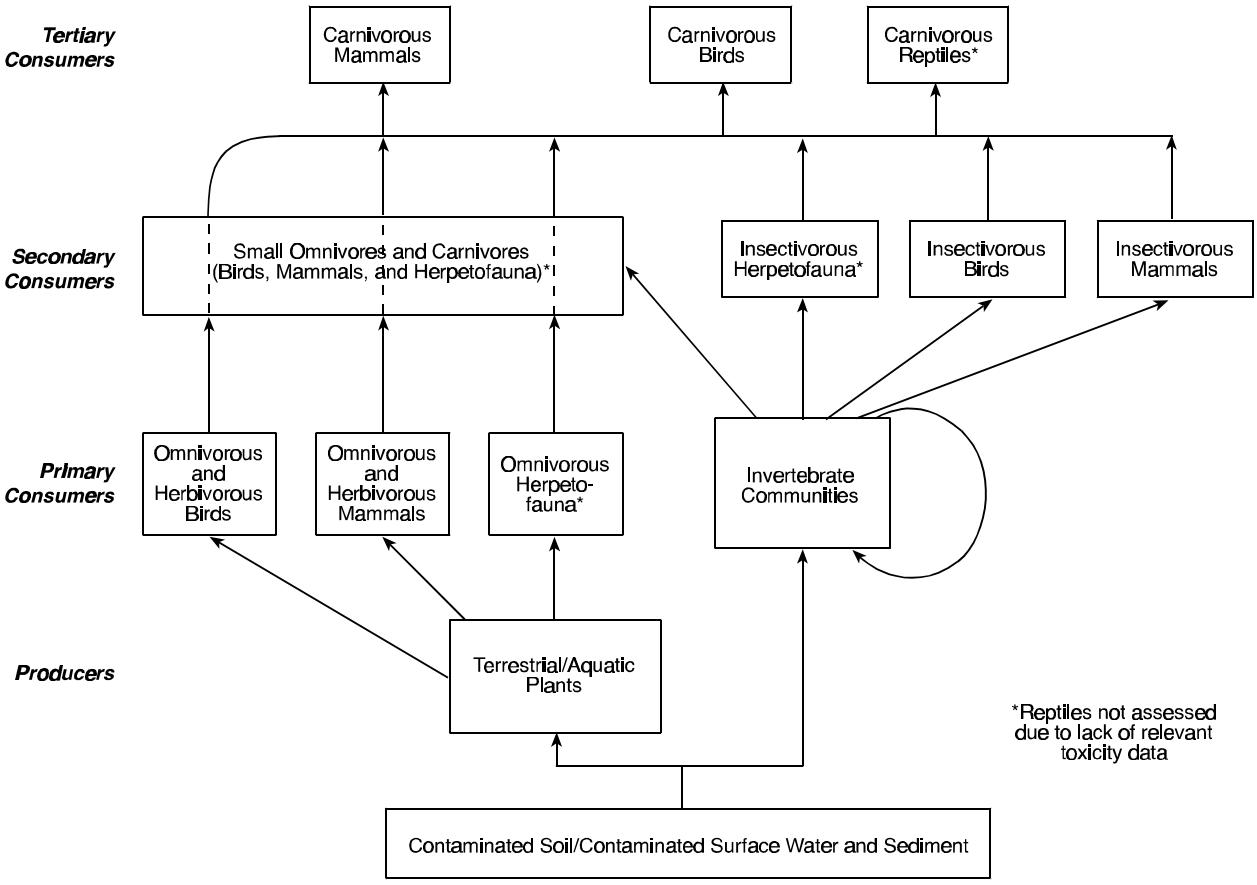


Figure 2-18. General food web model for aquatic and terrestrial systems.

Dermal absorption of constituents is considered to be an insignificant exposure pathway for potentially exposed wildlife receptors and will not be assessed because

- Dense undercoats or down effectively prevents chemicals from reaching the skin of wildlife species and significantly reduces the total surface area of exposed skin (Peterle, 1991; U.S. ACE, 1996)

- Results of exposure studies indicate that exposures due to dermal absorption are insignificant compared to ingestion for terrestrial receptors (Peterle, 1991).

Inhalation of volatile compounds will not be assessed for wildlife receptors because

- Concentrations of volatile chemicals released from soil to aboveground air are drastically reduced, even near the soil surface (U.S. ACE, 1996)

- Significant concentrations of VOCs would be required to induce noncarcinogenic effects in wildlife based on inhalation toxicity data for laboratory rats and mice (U.S. ACE, 1996).

Selection of Appropriate Ecotoxicological Studies—Population Inference. As suggested in Table 2-6, risks to four groups of receptors (mammals, birds, amphibians, and reptiles) will be estimated based on endpoints relevant to population sustainability. It is important to note that screening factors will not be developed based on population-level studies. Rather, we will use ecotoxicological data on selected physiological endpoints (e.g., developmental effects) to infer risks to wildlife populations.

For amphibians, the development of screening factors is severely limited by data availability. After a review of several compendia presenting amphibian ecotoxicity data (e.g., U.S. EPA, 1996g; Power et al., 1989) as well as primary literature sources, it was determined that there was a general lack of chronic or subchronic ecotoxicological studies. Consequently, studies on acute exposures during sensitive amphibian life stages will be selected to develop screening factors. The potential sensitivity of this receptor group warrants their inclusion even though chronic study data are not yet available. Amphibian studies considered appropriate for development of Phase I screening factors must include the following information:

- Test organism
- Toxicological endpoint
- Exposure duration
- Life stage at which exposure occurred (e.g., embryo, tadpole).

Appropriate toxicity data for amphibians will include reproductive effects, developmental effects, or lethality from studies conducted for an exposure duration of less than 8 days. Limiting the study duration to short exposures will allow use of a larger data set in deriving the screening factors.

For mammals, birds, and reptiles, only toxicity studies relevant to ingestion will be reviewed (e.g., gavage); studies where the chemical was administered via injection or implantation will not be reviewed. At a minimum, studies must report the following to be considered for use in developing the ecological screening factors:

- Test organism
- Toxicological endpoint
- Dose-response information
- Exposure duration
- Exposure route
- Sample size

Preferred Studies. Toxicity studies that reported reproductive impairment, developmental abnormalities, and mortality will be preferred to studies on other physiological endpoints because these endpoints are highly relevant to the assessment endpoints selected for the SI Study (e.g., population sustainability). In addition, the use of reproductive and developmental toxicity data has been recommended in guidance across several federal agencies (U.S. EPA, 1998f; Department of the Air Force, 1997; U.S. ACE, 1996). Studies that report no observed adverse effects levels (NOAELs) will be preferred to those that include only effects levels and low observed adverse effects levels (LOAELs). Several other important aspects of study selection are summarized below.

Duration of exposure - Duration is critical in assessing the potential for adverse effects to wildlife. However, since definitive guidance is not available on subchronic versus chronic exposures, we will define chronic exposures as greater than 50 percent of the life span of mammalian wildlife representative species. Little information exists concerning the life span of birds used in toxicity studies, and a standard study duration has not been established for avian toxicity tests. Therefore, exposures greater than 10 weeks will be considered chronic for birds; exposures less than 10 weeks will be considered subchronic (Sample et al., 1996).

Timing of exposure - The timing of exposure is critical in assessing the potential for adverse effects to wildlife. For example, early development is a particularly sensitive life stage due to the rapid growth and differentiation occurring within the embryo and juvenile. For many species, exposures of a few hours to a few days during gestation and early fetal development may produce severe adverse effects (Sample et al., 1996). Therefore, in the absence of chronic studies on developmental or reproductive effects (e.g., multigenerational studies), studies that report exposures during reproductive and/or developmental stages may be selected for use in developing ecological screening factors.

Endpoint of interest - Our review of toxicity data indicated that reproductive or developmental effects were frequently observed at doses that were lower than those causing mortality . Therefore, chronic mortality studies will only be used when reproductive or developmental data are not available. Physiological (e.g., enzyme activity), systemic, and behavioral responses will be less preferred because it is often difficult to relate these responses to quantifiable decreases in reproductive fitness or the persistence of wildlife populations. Tumorigenic and carcinogenic toxicity studies will not be considered ecologically relevant and

will not be used to develop toxicity benchmarks because debilitating cancers in wildlife are exceedingly rare under field conditions.

Data gaps - From previous analyses such as HWIR, it is apparent that there will be a number of data gaps in the ecotoxicological database on mammals, birds, and reptiles. In fact, chronic studies on reptiles are generally unavailable. Similarly, there is a paucity of relevant studies on birds that meet the selection criteria described above. Two alternatives will be considered in developing screening factors:

1. **Use of Surrogate Chemicals.** For some classes of constituents, toxicity data exist for only a few, well-studied constituents (e.g., polycyclic aromatic hydrocarbons). Research on qualitative (QSARs) suggests that chemicals with similar molecular or physicochemical properties have similar biological reactivity and toxicity (Donkin, 1994; Nirmalakhandan and Speece, 1988). Therefore, these chemicals may be used as surrogates for other detected members of the chemical class.

2. **Use of Uncertainty Factors.** In screening ecological risk assessments, it is often standard practice to adopt uncertainty factors to derive benchmarks intended to represent chronic exposures. We will use these factors to ensure that critical receptors are not eliminated from the Phase I screening.

Selection of Appropriate Ecotoxicological Studies—Community Inference. The community-based screening factors generally reflect direct exposures to a contaminated medium, which, in the Phase I screening analysis, is represented by actual impoundment concentrations in water and sludge. As shown in Table 2-6, risks to five groups will be estimated based on endpoints relevant to sustainability of community structure and function: soil fauna, terrestrial plants, aquatic biota, algae and aquatic plants, and benthos. It should be noted that the screening factors for communities generally are not based on community-level studies in the sense that they do not reflect endpoints relevant to community dynamics (e.g., predator-prey interactions). Rather, they are based on the theory that protection of 95 percent of the species in the community will provide a sufficient level of protection for the community (see, for example, Stephan et al., 1985, for additional detail). As with the wildlife populations, ecotoxicological data on individual species will be used to infer risks to the community.

Appropriate ecotoxicological studies to derive screening factors for these receptor groups are available in a number of compendia and, as a result, it is often not necessary to conduct primary literature reviews to identify suitable studies. These compendia frequently present threshold concentrations for effects that may be used directly as screening factors with little or no modification. Table 2-8 presents the primary data sources that will be used to support the derivation of screening factors for the community receptors. The selection process for screening factors among different sources and the screening factor calculations are discussed in the following section.

Calculation of Ecological Screening Factors—Receptor Populations. The calculation of ecological screening factors for receptor populations is based on the implicit assumption that

Table 2-8. Examples of Primary Data Sources for Derivation of Screening Factors for Community Receptors

Source	Contents
Plant Community	
Efroymson, R.A., M.E. Will, G.W. Suter II, and A.C. Wooten. 1997a. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision.	This document provides effects data for terrestrial plants exposed in soil and solution mediums. Approximately 45 constituents have proposed soil criteria.
PHYTOTOX Database. Office of Research and Development. Environmental Protection Agency.	This database contains over 49,000 toxicity tests on terrestrial plants for more the 1,600 organic and inorganic chemicals and 900 species.
Freshwater Community / Algae and Aquatic Plants	
AQUIRE (AQUatic toxicity Information REtrieval) Database. 1997. Environmental Research Laboratory, Office of Research and Development, U.S. EPA, Duluth, MN	This database contains over 145,000 toxicity tests for more than 5,900 organic and inorganic chemicals and 2,900 aquatic species.
U.S. EPA. *Ambient Water Quality Criteria*. U.S. EPA, Washington, DC.	These chemical-specific documents provide the ecotoxicity data and derivation methodologies used to develop the National Ambient Water Quality Criteria (NAWQC).
U.S. EPA. 1995a. Great Lakes Water Quality initiative Criteria Documents for the Protection of Aquatic Life in Ambient Water. Office of Water. (U.S. EPA, 1996a Update)	For a limited number of constituents, the GLWQI has proposed surface water criteria for aquatic biota using analogous methods as implemented in the derivation of the NAWQC.
Suter II, G.W. and C. Tsao. 1996. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Aquatic Biota: 1996 Revision	This compendia reference provides acute and chronic water quality criteria for freshwater species including algae.
Soil Community	
Efroymson, R.A., M.E. Will, and G.W. Suter II. 1997b. Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision. Oak Ridge National Laboratory.	This document provides effects data for soil biota (i.e., microbial processes and earthworms). Approximately 35 constituents have proposed soil criteria, and some field studies are included.
CCME (Canadian Council of Ministers of the Environment), 1997. Recommended Canadian Soil Quality Guidelines.	The criteria developed by the CCME are concentrations above which effects are likely to be observed.
Sediment Community	
U.S. EPA. 1993. *Technical Basis for Deriving Sediment Quality Criteria for Nonionic Organic Contaminants for the Protection of Benthic Organisms by Using Equilibrium Partitioning*.	This document supplies toxicological criteria for nonionic hydrophobic organic chemicals using FCVs (final chronic values) and SCVs (secondary chronic values) developed for surface water (Sediment Quality Criteria, SQC).
Long and Morgan. 1991. *The Potential for Biological Effects of Sediment-Sorbed Contaminants Tested in the National Status and Trends Program*. National Oceanic and Atmospheric Administration (NOAA) Technical Memorandum. Update: (Long et al., 1995)	Field measured sediment concentrations are correlated with impacts to sediment biota in estuarine environments. Measures of abundance, mortality, and species composition are the primary toxicity endpoints.
Jones, D.S., G.W. Sutter III, and R.N. Hall. 1997. *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Sediment-Associated Biota: 1997 Revision.* Oak Ridge National Laboratory.	This document proposes sediment criteria for both organic and inorganic constituents using both field and estimation methodologies.
MacDonald, D.D. 1994. Approach to the Assessment of Sediment Quality in Florida Coastal Waters. Florida Department of Environmental Protection (FDEP), Tallahassee.	This approach applies statistical derivation methods to determine sediment criteria using NOAA data. The resulting criteria are more conservative than NOAA values.

each receptor species forages only within the contaminated area, regardless of the size of its home range. For smaller animals, this assumption has little impact on the estimates of exposure. However, for larger animals with more extensive foraging areas, this assumption may overestimate exposure if the animal's foraging patterns tend to be evenly spread over the home range. Thus, it is important to recognize both the explicit *and* implicit sources of protection in this methodology.

For amphibian populations, a screening factor for water (SF_{water}) will be derived as the geometric mean of acute studies meeting the data requirements discussed above (i.e., relevant endpoint, acute exposure, high effect level). However, it is important to point out that this screening factor should be construed as only "protective" of gross effects to amphibian populations (e.g., lethality to 50 percent of the population). As a result, careful consideration will be given in interpreting the results of the screening results during the risk characterization. The remainder of this section outlines the basic technical approach used to convert avian or mammalian benchmarks (in daily doses) to soil and water screening factors (in units of concentration) that will be compared with surface impoundment sludge and water concentrations, respectively.

Once the appropriate ecotoxicological study is identified for mammals and/or birds,[1] the screening factors will be calculated for each medium of interest using a four-step process:

1. Adjust study benchmark using uncertainty factor.
2. Scale benchmark from test species to receptor species.
3. Identify uptake/accumulation factors.
4. Calculate protective concentration (i.e., screening factor).

STEP 1: Adjust Study Benchmark Using Uncertainty Factor

For benchmarks that are based on acute studies, uncertainty factors may be used to extrapolate from acute exposures to chronic exposures. Based on the review of a toxicity database of over 4,000 records, we propose using the following:

Extrapolation	Uncertainty Factor
Acute LD_{50} to chronic NOAEL	100
Acute LOAEL to chronic NOAEL	50

These uncertainty factors are consistent with DTSC (1996) guidance and an independent review of toxicity data by other authors (Calabrese and Baldwin, 1993; Sample et al., 1996). To convert the acute benchmark to a chronic benchmark, Equation 2-1 will be used:

$$\text{Chronic Benchmark}_{\text{Study Species}} = \text{Acute Benchmark}_{\text{Study Species}} / \text{Uncertainty Factor} \qquad (2\text{-}1)$$

The intent of this conversion is to provide a benchmark for the study species that represents a no observed adverse effects level. Consequently, we refer to this value as the $NOAEL_{SS}$ to indicate the effects level and the fact that it applies to the study species.

[1] Reptiles are not discussed in this section because of the data deficiencies for this receptor group.

STEP 2: Scale Benchmark from Study Species to Receptor Species

The benchmark chosen to represent the mammalian or avian taxa will be extrapolated from the study species to the receptor species ($NOAEL_{RS}$) within the same taxa using a cross-species scaling equation (Sample et al., 1996). For population-inference benchmarks for mammals, the extrapolation is performed using Equation 2-2.

$$NOAEL_{RS} = NOAEL_{SS} \cdot \left(\frac{bw_{SS}}{bw_{RS}} \right)^{1/4} \quad (2\text{-}2)$$

where $NOAEL_{SS}$ is the NOAEL for the study species, bw_{RS} is the body weight of the receptor species, and bw_{SS} is the body weight of the study species. This is the default methodology EPA proposed for carcinogenicity assessments and reportable quantity documents for adjusting animal data to an equivalent human dose.

For avian species, new research suggests that the cross-species scaling equation used for mammals is not appropriate (Mineau et al., 1996). Mineau et al. (1996) used a database that characterized acute toxicity of pesticides to avian receptors of various body weights. The results of the regression analysis revealed that applying mammalian scaling equations may not predict sufficiently protective doses for avian species. Mineau et al. (1996) suggested that a scaling factor of 1 provides a better dose estimate for birds, as shown in Equation 2-3. This recommendation will be adopted for avian receptors in this assessment.

$$NOAEL_{RS} = NOAEL_{SS} \cdot \left(\frac{bw_{SS}}{bw_{RS}} \right)^{1} \quad (2\text{-}3)$$

STEP 3: Identify Uptake/Accumulation Factors

As suggested in Figure 2-18, movement of contaminants through the food web is an important exposure vector for mammals and birds. Consequently, estimates of chemical accumulation in the tissues of plants and prey items are required. For receptors likely to rely on aquatic systems for food (e.g., kingfisher), bioaccumulation factors and/or bioconcentration factors are required for aquatic biota such as fish, benthos, and aquatic plants. These data may be identified in the open literature or they may be estimated for organic constituents using regression equations such as that shown in Equation 2-4 (Lyman et al., 1990):

$$\log BCF = 0.76 \, [\log (K_{ow})] - 0.23 \quad (2\text{-}4)$$

where BCF is the estimated bioconcentration factor for fish and the K_{ow} is the constituent-specific octanol-water partition coefficient.

For receptors found primarily in terrestrial systems, bioconcentration factors are required for terrestrial plants, soil invertebrates (e.g., earthworms), and vertebrates that report the relationship between tissue concentrations and soil concentrations. As with aquatic

accumulation factors, these data may be identified in the literature or estimated using recently developed methods for earthworms and small mammals (Sample et al., 1998a, 1998b).

In short, these values are typically identified in the open literature and EPA references or calculated based on the relationship between log K_{ow} and accumulation in lipid tissue. The primary source of data is the methodology developed for HWIR and described more fully in Section 3 of this technical plan. To ensure that the Phase I ecological screening assessment is protective, a default value of 1 will be assigned to each uptake/accumulation factor that cannot be derived through estimation methods or identified in the literature.

STEP 4: Calculate Protective Concentration for Receptor

Based on the $NOAEL_{RS}$, the screening factor for a receptor that relies on aquatic biota as the primary food source will be calculated as a function of the receptor's body weight, the receptor's ingestion rate for food and water, and the bioaccumulation potential of the constituent. As shown in Equation 2-5:

$$SF_{water} = \frac{NOAEL_{RS} \times bw}{(I_{food} \sum BAF_j \times F_j \times AB_j) + (I_{water})} \quad (2\text{-}5)$$

where

bw	=	body weight (kg)
I_{food}	=	total daily intake of aquatic biota (kg WW/d)
I_{water}	=	total daily soil intake (kg/d)
BAF_j	=	bioaccumulation factor for food item j (L/kg WW))
F_j	=	fraction of diet consisting of food item j (unitless)
AB_j	=	absorption of chemical in the gut from food item j (assumed = 1).

Equation 2-5 can also be used to derive an "impoundment use only" screening factor for sites that do not have any fishable waterbodies identified in the survey data. For these cases, only I_{water} would be included in the denominator to reflect use of the impoundment as a drinking water source.

For terrestrial systems, Equation 2-6 is simply modified to account for soil or sludge intake:

$$SF_{soil/sludge} = \frac{NOAEL_{RS} \times bw}{(I_{food} \sum BCF_j \times F_j \times AB_j) + (I_{soil/sludge})} \quad (2\text{-}6)$$

where

bw	=	body weight (kg)
I_{food}	=	total daily food intake of terrestrial biota (kg/d)
BCF_j	=	bioconcentration factor for food item j (assumed unitless)
F_j	=	fraction of diet consisting of food item j (unitless)
AB_j	=	absorption of chemical in the gut from food item j (assumed = 1)
$I_{soil/sludge}$	=	total daily soil intake (kg/d).

Information sources to develop the input values for body weight (bw), ingestion rates (I_{xx}), and dietary fractions (F_j) will generally be taken from the extensive HWIR databases. The HWIR databases were developed using EPA's *Wildlife Exposure Factors Handbook* (U.S. EPA, 1993c) and augmented by substantial literature review and synthesis of a variety of information sources. However, it may be necessary to expand the data collection efforts beyond the current HWIR universe of constituents; in particular, the identification of suitable ecotoxicological studies to support the development of receptor species benchmarks ($NOAEL_{RS}$) will require significant effort. In addition to the review of primary literature, Table 2-9 presents some examples of key data sources that may be used to identify suitable ecotoxicological studies.

Calculation of Ecological Screening Factors—Receptor Communities. The calculation of ecological screening factors for receptor communities relies heavily on existing data sources, many of which have produced peer-reviewed concentrations for soils and surface water presumed to be protective of ecological receptors. Example include

- **Aquatic Biota**: U.S. EPA's National Ambient Water Quality Criteria
- **Sediment-Associated Biota**: National Oceanic and Atmospheric Administration's (NOAA) Effects Range-Low (ER-Ls)
- **Soil Invertebrates**: Dutch National Institute of Public Health and Environmental Protection's (RIVM) Ecotoxicological Intervention Values (EIVs)

To the extent possible, we will rely on existing data sources as well as the ecotoxicity databases developed under HWIR and other studies conducted by EPA. For constituents lacking readily available sources, we will use the following approach to calculate ecological screening factors.

Aquatic community—For aquatic biota in freshwater systems, the final chronic value (FCV) developed for the National Ambient Water Quality Criteria (AWQC) will be chosen as the screening factor. If an AWQC is not available, the continuous chronic criterion (CCC) developed for the Great Lakes Water Quality Initiative (GLWQI) will be used as the screening factor (U.S. EPA, 1995a, 1996a). If neither of these criteria are available, we will calculate a secondary chronic value (SCV) using the Tier II methods developed through the Great Lakes Initiative (Stephan et al., 1985; Suter and Tsao, 1996; RTI, 1995a, 1995b).

The SCV is calculated using methods analogous to those applied in calculating the FCV. However, the Tier II methods: (1) require chronic data on only one of the eight family requirements, (2) use a secondary acute value (SAV) in place of the FAV, and (3) are derived based on a statistical analysis of AWQC data conducted by Host et al. (1991). Host et al. (1991) developed adjustment factors (AFs) depending on the number of taxonomic families that are represented in the database. The Tier II methodology was designed to generate SCVs that are below FCVs (for a complete data set) with a 95 percent confidence limit.

Table 2-9. Selected Sources of Toxicity Data

Databases

- Hazardous Substances Data Bank (HSDB). National Library of Medicine, National Toxicology Information Program. Bethesda, MD.
- PHYTOTOX. Chemical Information System (CIS) Database.
- Registry of Toxic Effects of Chemical Substances (RTECS). National Institute for Occupational Safety and Health (NIOSH), Washington, D.C.

Compilations

- Agency for Toxic Substances and Disease Registry (ATSDR). 1997. *Toxicological Profiles*. On CD-ROM. CRC press. U.S. Public Health Service. Atlanta, GA.
- Devillers, J. and J.M. Exbrayat. 1992. *Ecotoxicity of Chemicals to Amphibians*. Grodon and Breach Science Publishers. Philadelphia, PA.
- Eisler, R. 1985-1993. *Hazards to fish, wildlife, and invertebrates: A synoptic review*. U.S. Fish Wildlife Service Biological Reports
- Hudson, R.H., R.K. Tucker, and M.A. Haegele. 1984. *Handbook of toxicity of pesticides to wildlife*. U.S. Fish and Wildlife Serv. Resour. Publ. 153. 90 pp.
- Sample, B.E., D.M. Opresko, and G.W. Suter II. 1996. Toxicological benchmarks for wildlife: 1996 Revision. Prepared for the U.S. Department of Energy.

Algae and aquatic plants—For algae and aquatic plants, toxicological data are available in the open literature and in data compilations such as the *Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision* (Suter and Tsao, 1996). Studies on freshwater vascular plants are seldom available; however, toxicity data are available from standard algal tests. In order of preference, the screening factors for algae and aquatic plants will be based on either (1) a lowest observed effects concentration (LOEC) for vascular aquatic plants or (2) an effective concentration (EC_{xx}) for a species of freshwater algae, generally a species of green algae.

Benthic community—Two methods will be applied to develop screening factors for the sediment community. The first and preferred method will use measured sediment concentrations that resulted in *de minimis* effects to the composition and abundance of the sediment community. The second derivation method uses the equilibrium partitioning relationship between sediments and surface waters to predict a protective concentration for the benthic community using the chronic FCV. A brief discussion of each method is provided below.

- **Screening Factors from Measured Data:** The premier sources of measured sediment toxicity data are the National Oceanic and Atmospheric Administration (NOAA) and the Florida Department of Environmental Protection (FDEP). These data are used by NOAA to estimate the 10th percentile effects concentration effects range-low (ER-L) and a median effects concentration effects range-median (ER-M) for adverse effects in the sediment community. The FDEP sediment

criteria are developed from the ER-L and ER-M values to approximate a threshold effects level (TEL) (estimated from ER-L data). The TELs are preferable to the ER-L primarily because they have been shown to be analogous to TELs observed in freshwater organisms (Smith et al., 1996).

Predicted Sediment CSCLs. If neither a TEL nor an ER-L is available for nonionic, organic constituents, the screening factor will be calculated using the sediment quality criteria (SQC) method (U.S. EPA, 1993b). This method assumes equilibrium-partitioning between the sediment and water column is a function of the organic carbon fraction (f_{oc}) in sediment and the organic carbon partition coefficient of the constituent. The screening factor is calculated as shown in Equation 2-7, assuming that the f_{oc} is equivalent to 1 percent total organic carbon (Jones et al., 1997).

Terrestrial plant community—For the terrestrial plant community, screening factors for soil will generally be derived according to the methodology presented in the *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision* (Efroymson et al., 1997a). The authors derive ecologically relevant benchmarks by rank ordering the phytotoxicity data according to the lowest observed effects concentrations (LOECs). We are proposing to adopt that same approach and select screening factors for constituents with 10 or fewer values at the lowest LOEC. For constituents with more than 10 LOEC values, the 10th percentile LOEC will be selected. Because the toxicity endpoints reflect endpoints such as plant growth and yield reduction, the screening factors are presumed to be

$$SF_{sediment} = f_{oc} \; x \; K_{oc} \; x \; FCV \qquad (2\text{-}7)$$

relevant to sustaining "healthy" plant communities.

Soil community—For the soil community, screening factors will be calculated using the methodology developed under HWIR. In brief, the screening factors for soil fauna are estimated to protect species found in a typical soil community, including earthworms, insects, and other soil fauna. Eight taxa of soil fauna are represented to reflect the key structural (e.g., trophic elements) and functional (e.g., decomposers) components of the soil community. The methodology presumes that protecting 95 percent of the soil species will ensure long-term sustainability of a functioning soil community. The toxicity data on soil fauna will be gleaned from several major compendia and supplemented with additional studies identified in the open literature. The mathematical construct shown in Equation 2-8 was developed by Dutch scientists (i.e., the RIVM methodology) and will be used to calculate screening factors at a 50th percentile level of confidence (Sloof, 1992). For the screening factors for soil biota ($SF_{soil5\%}$), the 50th percentile level of confidence will be selected because the 95th percentile has been shown to be overly conservative (e.g., well below background levels).

$$SF_{soil_5\%} = [x_m - k_l \; s_m] \qquad (2\text{-}8)$$

where

x_m = sample mean of the log LOEC data
k_l = extrapolation constant for calculating the one-sided leftmost confidence limit
s_m = sample standard deviation of the log LOEC data.

When data are insufficient to calculate screening factors using this methodology, two other sources of screening factors will be used. First, the ecotoxicological data presented on indicator species such as earthworms will be used to select a protective soil concentration (Efroymson et al., 1997b). Second, the criteria developed by the Canadian Council of Ministers of the Environment (CCME, 1997) for the protection of soil organisms will be adopted as screening factors.

2.3.1.4 Procedure for Phase I Ecological Risk Screening. In most respects, the ecological risk screening procedure mirrors the framework presented in Figure 2-9 for the risks from noncancer constituents to human health. Therefore, this discussion is intentionally brief to avoid duplicating the technical plan described in Section 2.2. The salient features of the Phase I ecological risk screening are summarized below.

Select Appropriate Screening Factors. The underlying strategy for the Phase I assessment is to identify screening factors that are appropriate for a given facility. Screening factors for terrestrial receptors (e.g., plants, raccoons) will be used routinely at each site since these "common" receptors were selected to be broadly applicable across the contiguous United States. However, surface impoundments are not intended to support aquatic plants, aquatic invertebrates, fish, or sediment-associated biota; therefore, aquatic and sediment-associated biota will be assessed only if a potentially affected waterbody is identified near the surface impoundment. Although not intended to support amphibians, birds, and mammals, surface impoundments are likely to be attractive to these receptors (especially if impoundments support vegetation); therefore amphibians, birds, and mammals will be assessed for all surface impoundments. Consequently, not all screening factors will be applied to each facility.

Select Appropriate Surface Impoundment Concentrations. Whenever possible, reported mean concentrations for impoundment water and sludge will be used in the Phase I ecological screening assessment. If impoundment water concentrations are not reported, available data will be used in the same order of preference as shown in Figure 2-6 to estimate impoundment water concentrations.

If sludge concentrations are not reported for the surface impoundment, available data will be used in the following order of preference as shown in Figure 2-8 to estimate impoundment sludge concentrations.

Calculate Risks. To evaluate the receptor risks (defined as the ratio between the impoundment concentration and the screening factor, or hazard quotient) from exposure to a chemical constituent at a particular surface impoundment, Equation 2-9 will be used:

$$HQ^{\,i}_{\,constituent} = \frac{C_{imp_{water}}}{SF_{water}} \quad or \quad \frac{C_{imp_{sludge}}}{SF_{sludge}} \quad or \quad \frac{C_{imp_{soil}(sludge)}}{SF_{soil}} \qquad (2\text{-}9)$$

where C_{imp_water}, and C_{imp_sludge}, and C_{imp_soil}(sludge) are the impoundment water concentration and the impoundment sludge concentration, respectively; and SF_{water}, SF_{sludge}, and SF_{soil} are the ecological screening factors applicable to that site. The $HQ^{i}_{constituent}$ is the risk to receptor i associated with that impoundment and facility. The HQ values for each receptor i may be summed across the entire facility in generating facility risks because (1) the screening factors for each receptor are based on the same study data (and endpoints) and (2) receptors may be exposed through both terrestrial and aquatic systems.

2.3.1.5 <u>Results of Phase I Risk Screening/Prioritization</u>. Risk estimates generated by the Phase I ecological screening assessment must be suitable to characterize, screen, and prioritize constituents, surface impoundments, and facilities by the following categories of interest (see also Section 2.4, Phase IC Initial Prioritization):

Facility

Regulatory status
Industry type

Surface Impoundment

Treatment type
Functional class

Constituent

Constituent type

The facility risk is defined as the maximum surface impoundment risk ro receptor i for a particular facility. Facility risk estimates are used to develop industry type and regulatory type risk distributions.

The surface impoundment risk is defined as the cumulative risk to receptor i from exposure to all constituents at a particular surface impoundment. Surface impoundment risk estimates will be used to develop treatment type- and functional class type-specific distributions.

For the Phase I ecological screening assessment, the constituent risk is defined as risk to the most sensitive receptor across all impoundments at a facility. Constituent risk estimates will be used to develop constituent-specific risk distributions.

Construct Risk Distributions. Separate risk distributions will be constructed from risk estimates to evaluate categories of interest. Proposed Phase I risk distributions will consist of the following five risk intervals (risk bin):

- # < 0.1
- # ≥ 0.1 and < 1
- # ≥ 1 and < 10
- # ≥ 10 and < 100
- # ≥100.

A unitary value (1), representing the constituent, surface impoundment, or facility, will be added to the appropriate risk bin. Since sample facilities represent a number of facilities nationwide, unitary values may be weighted by the facility sample weight before being added to the bin. The Agency may modify risk intervals to provide a more suitable distribution of risks to evaluate categories of interest.

The facility- and surface impoundment-related risk distributions will be constructed from risk estimates for all receptors considered at a particular surface impoundment or facility. These risk distributions will be used to screen facilities, surface impoundments, and constituents. Risk distributions constructed from maximum risk estimates (i.e., risk estimate for the most sensitive receptor) will be compared to risk distributions for all receptors to determine if the number of receptors affects the facility- and impoundment-level risk distributions. In addition, risk distributions for each trophic level will be developed to evaluate potential impacts on food webs. These risk distributions for receptor groups and trophic levels will provide useful metrics for the Phase I risk characterization.

Establish Risk Criteria. A risk criterion of 1 is proposed to screen ecological risk estimates. Risk estimates less than 1 (e.g., $HQ^i < 1$) indicate a negligible potential for adverse ecological impacts. Alternatively, risk estimates of 1 or greater indicate a potential for adverse ecological effects. Surface impoundments and facilities with risk estimates of one or greater may be assigned for further evaluation in Phase II, depending on the results of the Phase I human health screening.

Conduct Risk Screening. The ecological risk screening process is outlined in the decision tree shown in Figure 2-19. As expected, the decision tree is very similar to the health risk decision tree illustrated in Figure 2-9. However, there are three distinct differences in the ecological risk screening procedure. First, the decision tree does not include a margin of protection (MP) for ecological receptors. Whereas, the human health risk screening is

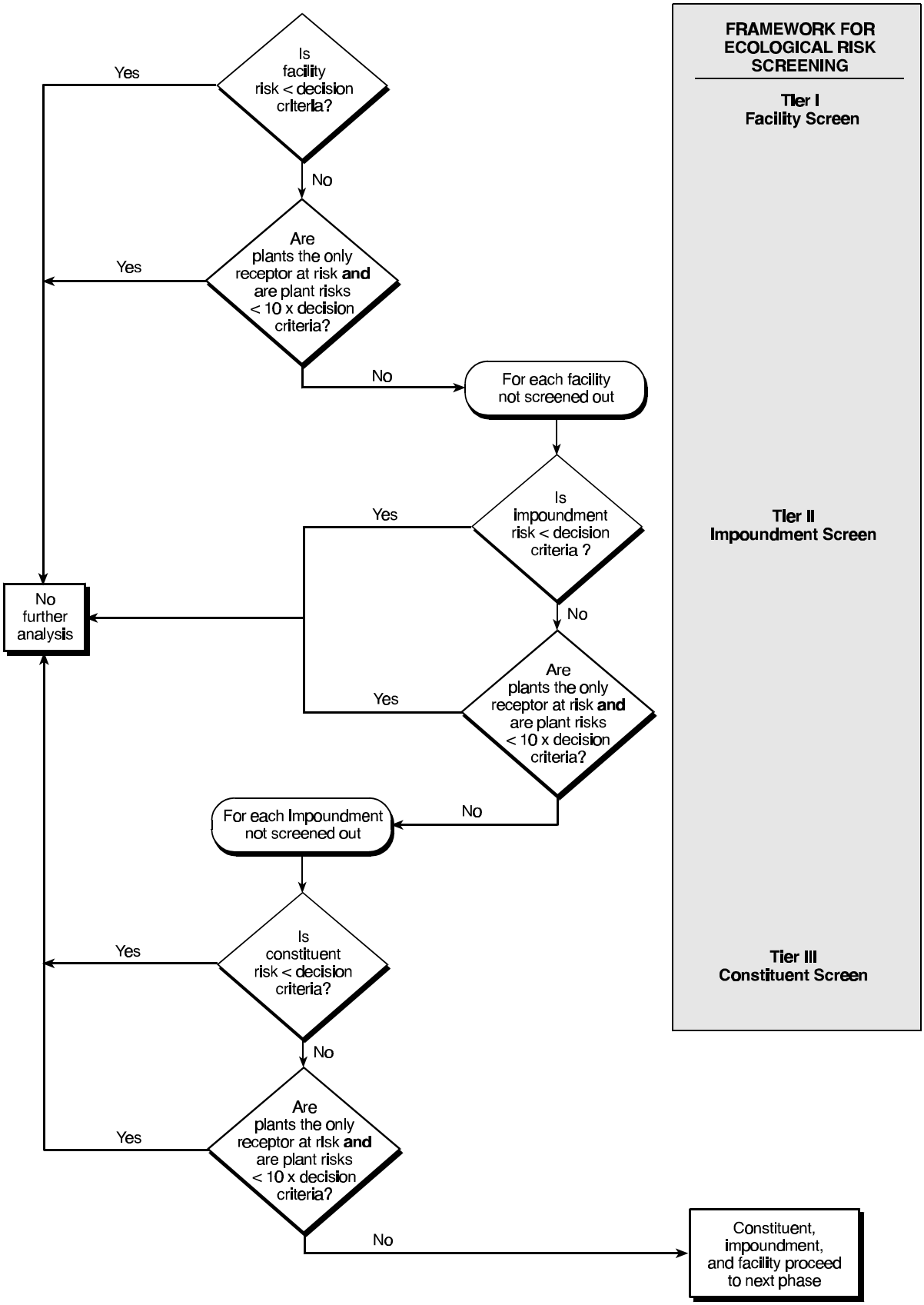


Figure 2-19. Decision tree for performing Phase I ecological risk screening.

intended to protect individuals, the ecological risk screening is intended to protect species populations and communities from adverse effects. Although the Agency considered adding an MP to the risk screening for sites co-located with sensitive habitats (e.g., wildlife refuges), these "special cases" will be considered prior to the conduct of the ecological risk screen, as shown in Figure 2-20. The Agency may consider the use of an MP for ecological risk in special cases in which facilities identify threatened and endangered species located within a 2 km radius of the impoundments. Second, the ecological risk screening does not include cancer effects; only the endpoints described under Section 2.3.1.3 on the development of screening factors will be considered. Third, the figure includes an additional decision point that pertains to the receptor group for which risk is indicated. The results of the surface impoundment pilot study suggested that, for each facility, at least one constituent will fail the ecological risk screening for the terrestrial plant receptor group. Because impoundment sludge/soils are not intended to support terrestrial habitats, and because the screening factors for terrestrial plants are based on a data set that does not reflect adaptation by plant communities, EPA determined that a simple exceedance of the plant screening factor does not provide an adequate basis to determine the potential for adverse ecological effects. Thus, constituents, surface impoundments, or facilities will only proceed to the Phase IC analysis if: (1) the hazard quotient for plants exceeds 10 (indicating a greater potential for adverse effects than a simple exceedance) and (2) the hazard quotient for at least one other receptor group (e.g., amphibians, birds, or mammals) exceeds the risk criterion of 1.

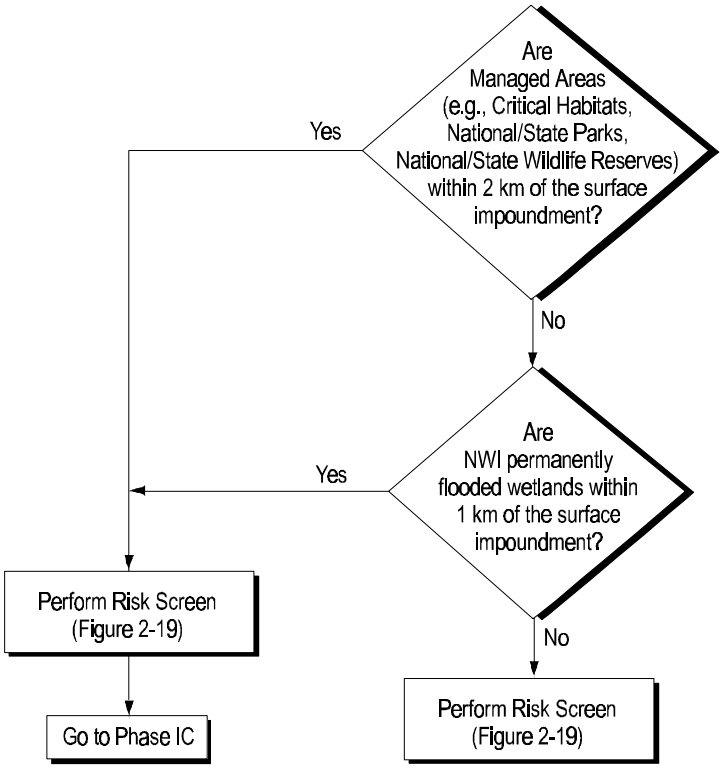


Figure 2-20. Decision diagram for evaluating special cases.

The risk characterization for ecological receptors will be used to determine the priority of facilities, impoundments, and constituents within the context of the human health risk screening results (see discussion on Phase IC). That is, the results of the Phase I ecological risk screening will be used in support of the prioritization, not as an independent screen to identify facilities, impoundments, and constituents for Phase II. The ecological risk characterization will:

- Characterize facility-level risks to address cumulative effects of multiple surface impoundments and constituents
- Characterize impoundment-level risks to address the cumulative effects of multiple constituents at a single surface impoundment.
- Characterize constituent-level risks to address the effects of a single constituent.

The risk estimates (i.e., hazard quotients) will be the primary tool used to prioritize constituents, surface impoundments, and facilities according to the potential for adverse ecological effects. The output from the risk screening will be presented in cumulative frequency histograms similar to those shown in Figure 2-21 to provide EPA with several descriptions of ecological risk that are relevant to ecological receptors as well as the impoundments and facilities. In addition, the presence of protected or potentially sensitive habitats will be considered when prioritizing constituents, surface impoundments, and facilities for further evaluation in Phase IC. These "special cases" will include managed areas and permanently flooded wetlands as designated by the National Wildlife Inventory (NWI). As shown in the decision tree in Figure 2-20, the presence of either managed areas or designated wetlands will be sufficient to assign a high priority risk score to the facility and impoundments found at that site. Notice that the figure allows for the performance of a risk screen for high priority sites as well as those sites that are not co-located with managed areas or designated wetlands. This will support development of risk distributions for this subset of sites and provide a more complete risk distribution for the national data set. A brief description of the criteria for managed areas and designated wetlands is included below.

Managed Areas. Managed areas are specifically protected by law to ensure that plants and wildlife are preserved. Thus, managed areas may need to be evaluated in further detail than that provided in the Phase I ecological screening assessment. A high priority score will be assigned to those facilities and impoundments that are within 2 kilometer of the following areas, irrespective of the risk estimates:

- National or state parks
- National or state wildlife reserves
- Critical Habitats (designated by the U.S. Fish and Wildlife Service)
- Wild and Scenic Rivers (designated by the U.S. Department of the Interior)

GIS coverages from the Managed Areas Database provide the data needed to quickly identify surface impoundments within 2 kilometers of a managed area. A distance of 2 kilometer is proposed because, even for a screening level assessment, the presumption of wildlife use and exposure to a surface impoundment becomes increasingly tenuous as the distance from the

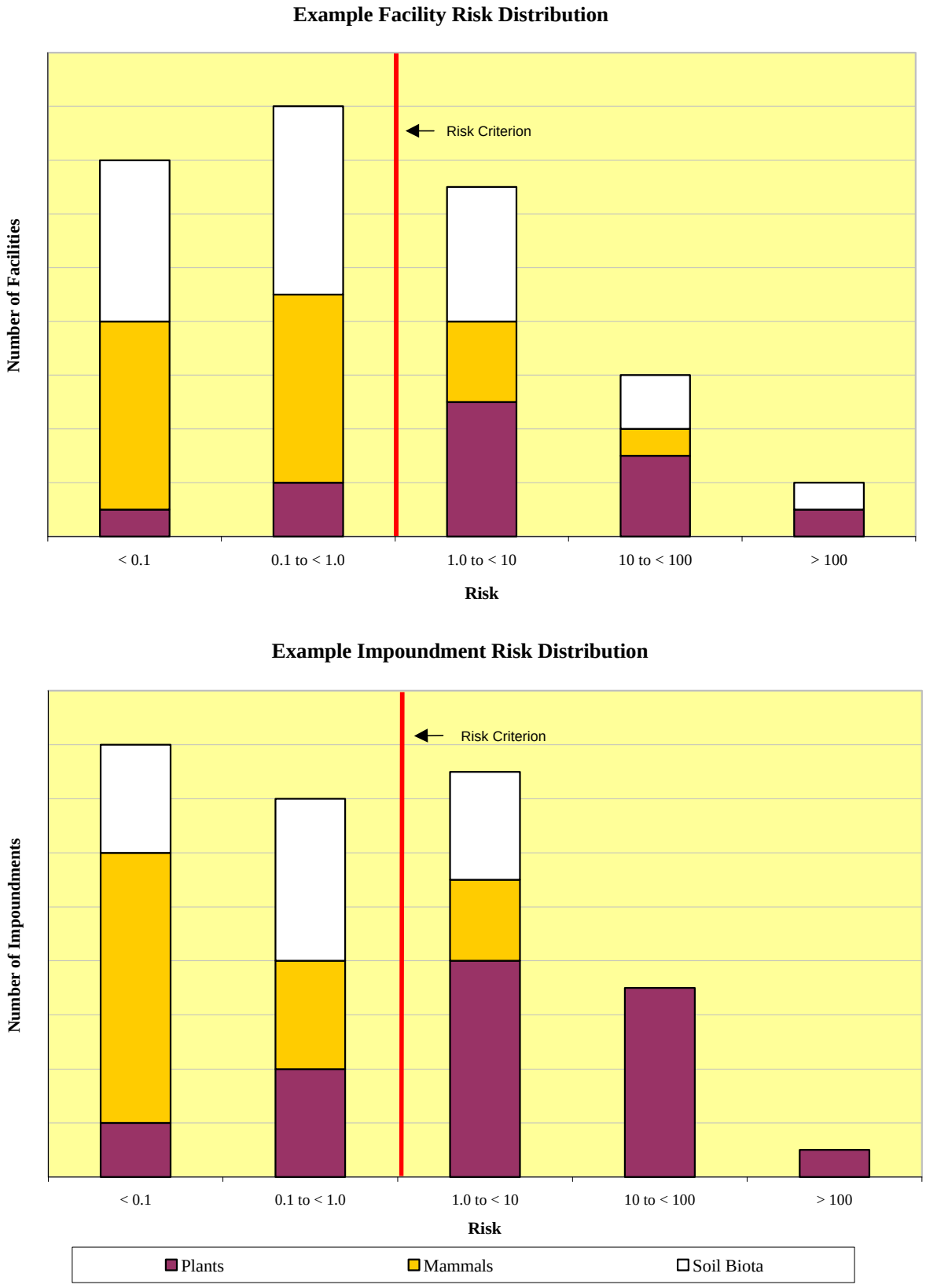


Figure 2-21. Example Phase I ecological screening assessment output.

impoundment increases. In short, it is not possible to determine whether foraging patterns of receptors living in managed areas might include the impoundments at a given facility.

Designated Wetlands. If surface impoundments are located within 1 kilometer of wetlands designated as permanently flooded by the NWI then these surface impoundments and facilities will receive a high priority score for Phase IC. The NWI GIS coverages will provide the data needed to quickly identify surface impoundments within 1 kilometer of a designated wetland. A distance of 1 kilometer is proposed because wetlands near the impoundment are more likely to be influenced through surface water recharge or drainage systems and, as a result, they may be significantly affected by the impoundment.

2.4 Phase IC Initial Prioritization

The Phase IA and IB human health and Phase I ecological risk screening will identify the constituents, impoundments, and facilities that should proceed to Phase II. The screening process, as described in the Phase IA and IB human health and Phase I ecological risk screening (Sections 2.2 and 2.3), defines constituents, impoundments, and facilities that will be considered for proceeding to Phase II analysis as those that have risks greater than the risk decision criteria (risk $\geq 10^{-5}$ and HI ≥ 1). Phase IC provides a method of analyzing the Phase I risk distributions for this subset of constituents, impoundments, and facilities to aid in defining the scope of Phase II given the limited resources of the SI Study. A prioritization scheme is proposed because of concern that the number of constituents, units, and facilities that could move into Phase II will be large (e.g., greater than 25 percent of the study sample) and may exceed the resources allocated for Phase II. If the number of constituents, units, and facilities that could move to Phase II is small and the resulting Phase II effort is within its allocated resources, the prioritization scheme will not be necessary.

2.4.1 Design Goals and Overview

The goal of Phase IC is to prioritize the Phase II analysis of these constituents, impoundments, and facilities. The Phase IC prioritization scheme is based on the risk distributions generated by the Phase I screening analyses. The prioritization scheme consists of five key features:

- Scoring system for facility risks and constituent risks
- Options for combining facility and constituent scores depending on resource limitations
- Separate scores for human health and ecological risks
- Ranking system combining human health and ecological scores
- Prioritization based on a qualitative review of risk distributions for the categories that are of concern to the SI Study (e.g., industry type, treatment type).

Priority will be given to those facilities and constituents with the highest screening risks. Constituents that were not screened in Phase IA and IB because they were considered special cases (e.g., constituents that bioaccumulate) are also given highest priority in the Phase II prioritization scheme.

2.4.2 Approach

The Phase IC prioritization scheme consists of four steps:

- Score facility risks and constituent risks
- Rank facility and constituent scores
- Rank combined human health and ecological scores
- Prioritize based on a qualitative review of risk distributions for the categories that are of concern to the SI Study (e.g., industry type, treatment type).

2.4.2.1 Facility and Constituent Risks Scoring System. The Phase IC prioritization system is based on the Phase IA and IB risk distribution by facility and constituent. The facility risk is the cumulative risk from all constituents and impoundments. For human health, a separate facility risk is provided for both carcinogenic and noncarcinogenic risks for the individual resident. For ecological risk, a single facility risk based on the maximally impacted receptor type is provided. The constituent risk for a facility is the cumulative risk for all impoundments at a facility. For human health, the cumulative risk is a summation of carcinogenic or noncarcinogenic risks by toxic endpoint for the individual resident. For ecological risk, the cumulative risk is the maximum risk from any impoundment for the maximally impacted receptor type. Facility and constituent risk are defined in Sections 2.2 and 2.3.

The risk distributions are risk histograms. For Phase II, only risk bins above the risk decision criteria are of concern. The risk decision criteria are 10^{-5} for excess individual human cancer risk and 1 for human noncancer risk and ecological risk. Each risk bin in the risk histogram that exceeds the risk decision criteria will be given an integer score. A score of 1 is given to the largest numeric risk bin and so forth. The scoring system for both facility risks and constituent risks is shown in Table 2-11.

For example, if a constituent for a facility has a human noncancer hazard index in the $\geq$100 risk bin, then it has a score of 1. If the constituent has a hazard index in the $\geq$10 and <100 risk bin, then it has a score of 2. Finally, if the constituent has a hazard index in the $\geq$1 and <10 risk bin, then it has a score of 3.

If the constituent is considered a human health special case (i.e., a constituent that bioaccumulates), then it receives a score of 1. If the constituent does not receive an ecological score because the risk screening can not be performed due to a lack of suitable toxicity data, then the ecological score is 3.

Table 2-11. Phase IC Prioritization Scoring System

Score	Human Health Individual Excess Cancer Risk Bin	Human Health Noncancer Hazard Index	Ecological Hazard Index
1	$\geq 10^{-4}$	≥ 100	≥ 100
2	$\geq 10^{-5}$ and $< 10^{-4}$	≥ 10 and < 100	≥ 10 and < 100
3	$\geq 10^{-6}$ and $< 10^{-5}$	≥ 1 and < 10	≥ 1 and < 10; NA

NA = Not available.

Human health and ecological risk screening will be scored separately. For human health risk screening, the maximum of the cancer and noncancer risks provides the constituent's score. For ecological risk, the maximum of all receptor types provides the constituent's score.

2.4.2.2 Ranking System for Facility and Constituent Scores. There are currently two options under consideration to rank facilities and constituents:

- **Option 1:** The facility scoring alone will provide the ranking system. The constituent score is not used. This option automatically addresses the issue of cumulative effects of multiple chemicals and multiple impoundments. This approach also recognizes that the resource efforts to set up the modeling evaluation for a facility will be the most resource intensive. Therefore, including all constituents (of all three ranks) will add minimal level of effort to the modeling setup effort.

- **Option 2:** The facility and constituent scores will be combined to provide a single rank. In this option, the constituents that score the highest are given highest priority (see Table 2-12). This option recognizes that some constituents (and impoundments) may constitute more of the facility risk than others. Therefore, the constituent score will be used to prioritize the rank.

2.4.2.3 Ranking System Combining Human Health and Ecological Scores. The Phase 1C ranking will combine the human health and ecological risk scores. The ranking of the nine possible combinations is shown in Table 2-13. This ranking process assumes that the human health score will be the primary ranking factor and the ecological score will be the secondary ranking factor. The ranking system is used only to establish order and priority to our Phase II modeling, not to characterize risks. We expect that high potential risks to ecological receptors will also be captured under this approach; multimedia modeling includes ecological receptors; and prioritization based upon a qualitative review (i.e., special cases) will address high ecological risk scenarios. If resources are limited, then the number of ranks assessed in Phase II could be reduced (e.g., evaluate only Ranks 1 through 5).

Table 2-12. Option 2 Ranking System

Rank	Facility Score	Constituent Score
1a	1	1
1b	2	1
1c	3	1
2a	1	2
2b	2	2
2c	3	2
3a	1	3
3b	2	3
3c	3	3

Table 2-13. Phase IC Ranking System

Rank	Human Health Score	Ecological Score
1	1	1
2		2
3	1	3
4	2	1
5	2	2
6	2	3
7	3	1
8	3	2
9	3	3

2.4.2.4 Prioritization Based on Qualitative Review of Risk Distributions for SI Study Categories. Consideration will also be given to a qualitative review of the Phase IA and IB risk screening distributions for the SI Study categories. The risk distributions may provide interesting conclusions on which EPA may want to focus or reduce attention.

- Example 1: If 95 percent of the risk distribution for a certain industry or treatment type is below the risk decision criteria, then all facilities in the industry or treatment type could be reprioritized with the lowest prioritization **or the industry or treatment type could be omitted entirely** from Phase II. If the same is true for any constituent's risk distribution, then the constituent could be demoted in rank or omitted from Phase II.

- Example 2: If comparison of industry-type risk distributions indicates that a particular industry type (e.g., chemicals and allied products) has a risk distribution that is skewed toward high risks, then facilities that are in that industry type will be given highest priority.

2.4.3 Risk Characterization Outputs

The outcome of Phase IC will be the identification of a subset of surface impoundments, constituents, pathways, and facilities that will be given high priority for further risk characterization during Phase II. The surface impoundments will be profiled according to significant patterns (if any), such as industry type, unit characteristic, and constituent type, using the risk distributions developed during Phase I.

3.0 Phase II Risk Assessment

Phase I of the surface impoundment risk assessment will likely identify a number of units and constituents that need further risk analysis. EPA has designed Phase II to provide that analysis by characterizing risk for constituents, units, and facilities of concern from Phase 1 using state-of-the-science risk assessment models. Phase II will expand the Phase I risk profile of the SI universe based on a true multimedia and multiple exposure pathway model and will take full advantage of site-based data available from the SI Survey results. These data will be supplemented, as necessary and practicable, by site-based, regional, and national data collected using methodologies developed for the Hazardous Waste Identification Rule.

Because of run-time constraints, EPA is considering developing central tendency and high-end risk results during Phase II, with a Monte Carlo analysis conducted as a possible third phase. Thus, EPA still considers Phase II to be a screening analysis. However, the risk estimates generated during Phase II will provide a comprehensive national profile of potential risks posed by the universe of surface impoundments for several reasons:

- It is based on a sample of facilities selected to statistically represent the SI universe.
- It covers the significant exposure pathways and receptors likely to be present at an SI site.
- The potential risks modeled for the major pathways at each site will be based, to the extent possible, on real concentration and exposure data reported by facilities and regions in the survey.
- Because the high-end and central tendency scenarios will be based on real receptors, they will provide a realistic span of potential risks.

The risk profile generated during Phase II will also serve to identify a smaller subset of units and constituents to be characterized, if necessary, using a full Monte Carlo analysis in future analysis.

To develop Phase II risk estimates, EPA has selected the state-of-the-art, multimedia, multiple exposure pathway, multiple receptor risk assessment (3MRA) model it developed for HWIR. This section of the technical plan

- Provides an overview of the Phase II technical framework that summarizes how the risks will be modeled and how the 3MRA modeling system will be implemented (Section 3.1)

- Describes the conceptual model and technical approach for the risk assessment, including sources, exposure pathways, receptors, spatial and temporal scale, and risk benchmarks and metrics (Section 3.2)

- Reviews the modeling system proposed to be used for the Phase II assessment, including summaries of the functionality, inputs, and outputs for each 3MRA component module (Section 3.3)

- Describes modifications to the HWIR 3MRA modeling system and data collection methodologies that may be necessary for SI Study application, including data collection requirements (Section 3.4).

Phase II is based heavily on the HWIR 3MRA model and data collection methodologies; as a result, this writeup depends upon the HWIR 3MRA background documents that are cited throughout. To fully understand the 3MRA model and its many components, the reader is encouraged to review these documents, which may be found at: http://www.epa.gov/epaoswer/hazwaste/id/hwirwste/risk.htm.

3.1 Overview

Phase II of the Surface Impoundment Study risk assessment will include a multimedia, multiple exposure pathway, multiple receptor risk assessment of the management of industrial wastes in surface impoundments. The simulation model EPA selected for this phase is the 3MRA model, which was developed by EPA to support the proposed Hazardous Waste Identification Rule. The 3MRA model provides the core functionality required for the Surface Impoundment Study, including:

- **Spatial scale** - 2-km radius or less

- **Temporal scale** - future risk, extended as needed to capture peak exposure concentrations in media of concern; hourly, daily, monthly, or annual time steps used in specific models as appropriate for source type or exposure pathway

- **Receptors** - human and ecological

- **Exposure pathways** - direct and indirect, including air, surface water, groundwater, soil, and both terrestrial and aquatic food chains

- **Model components** - designed to characterize risk by estimating contaminant release, multimedia fate and transport, exposure, and dose response.

Figure 3-1 shows the Phase II analysis in relation to Phase I.

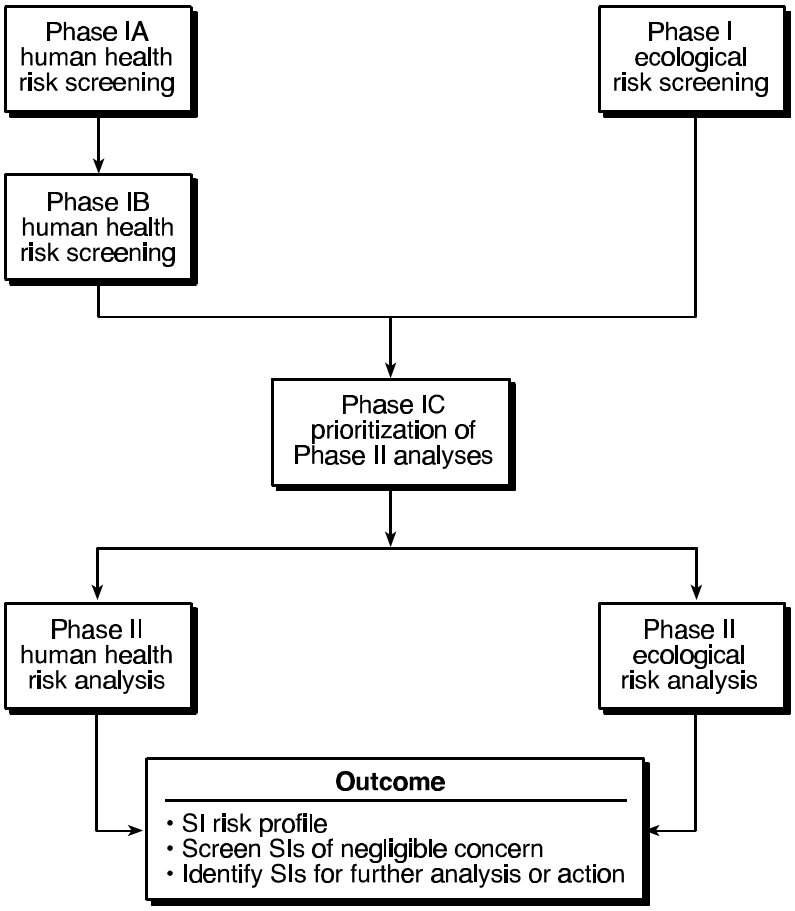


Figure 3-1. Overview of the SI study risk analysis.

3.1.1 Key Features

Key features of human health and ecological risk assessment approach for the SI study include the following.

- **#** Receptor types and exposure pathways are the same as for HWIR (Section 3.2.3).

- **#** Models are the same as for HWIR, except that the SI source module will need specific modifications in use and possibly function to address multiple impoundment, postclosure, and possibly other scenarios (such as catastrophic failures). In addition, the exit level processor (ELP) and 3MRA system will need modification to compile and save risk results in a manner consistent with the study goals (see Sections 3.4.1 and 3.4.2).

- **#** Data collection will begin with the SI survey that will characterize the facilities, units, waste streams, and constituents to be modeled, including receptor locations. HWIR data and data collection methodologies will be applied as needed to supplement these site-specific data with site-based, regional, and national data.

- # Modifications to data collection methodologies will be necessary for human receptor placement to update 1990 U.S. Census and land use data with SI Survey, map, and aerial photo data available for each SI site. In addition, modification to HWIR waterbody and watershed delineation methods is recommended to take advantage of newly available hydrography and elevation data sets (see Section 3.4.3).

- # Risk metrics will be similar to HWIR (i.e., risk distributions based on risk cumulative frequency distributions [cdfs]), modified as necessary to satisfy SI Study objectives. Concern will be defined by excess cancer risk or HQ above EPA-set action levels (see Sections 3.2.3 and 3.2.4).

- # Phase II results will update Phase I risk bins for sites not screened out in Phase I. This will require comparability between phases to be considered during design.

- # Two alternative data collection approaches have been developed: representative and site-specific:

    - The representative method uses a limited number of site layouts to represent conditions at a larger number of sites.

    - The site-specific approach develops site layouts for all surface impoundment sites of potential concern.

- # Alternatives also exist in terms of necessary modifications to the 3MRA modules and modeling system.

Table 3-1 summarizes options currently envisioned for the alternative approaches to Phase II. The 3MRA will be used for both alternatives; differences in implementation for the second alternative can include changes to the source models and system to better represent SI study objectives and an increase in site-specific resolution for data collection efforts (i.e., all sites represented).

The representative data collection alternative will be needed only if there are a large number of sites to evaluate in Phase II and resources (time or budget) limit the number of site layouts and model revisions that can be developed. Note that because the representative scenarios will be carefully chosen to span the range of conditions reported under the SI Survey, and because the modeling takes advantage of a powerful multimedia model, the results will be more realistic than in Phase I. Still, if undecided between two possible representative scenarios for a given site, EPA intends to choose the one with the more protective assumptions, i.e., the less protective environmental settings.

3.1.2 Decision Methodology

Phase II will follow a similar decision process as Phase I, with facilities routed through Phase II as follows:

Table 3-1. Alternative Stages for Phase II SI Risk Analysis

Activity	Representative Alternative	Site-Specific Alternative
Data Collection	Use representative site layout data, population profiles for a subset of SI Study sites to reflect surface impoundment settings Use existing HWIR regional data for SI Study sites Use SI Survey data as available and practicable.	Collect data and define site layouts for all SI sites Process additional meteorological station data as necessary to cover SI sites. Use SI Survey data as available
Model Revisions	Use 3MRA models "as is" except adjustments to exit level processor to fit SI Study goals/objectives. Model multiple units separately or as mega-units. Model postclosure as land application unit separately for each site.	*(Optional)* Revise SI model and 3MRA system to better fit SI Study goals and objectives. Model revisions could include # Model multiple SIs # Model catastrophic failures # Model postclosure in one run

- # Loop over multiple impoundments, multiple chemicals.
- # Compare risk against screening criteria.
- # Assign facilities, impoundments, and chemicals to risk bins for identifying and prioritizing possible followup activities.

Figure 3-2 pictures the Phase II decision process.

3.1.3 Anticipated Outcome

After the completion of Phase II, the Agency will prepare a report by March 2001 that characterizes the potential risks associated with the SI universe for 256 constituents. This report will include

- # Identification of any constituents, unit types, or facility categories for which additional comprehensive analysis may be needed.
- # A profile of risks for the SI universe by unit type, industry type, and constituent.
- # A descriptive profile of the subset of the universe that is of negligible concern and requires no further risk analysis.

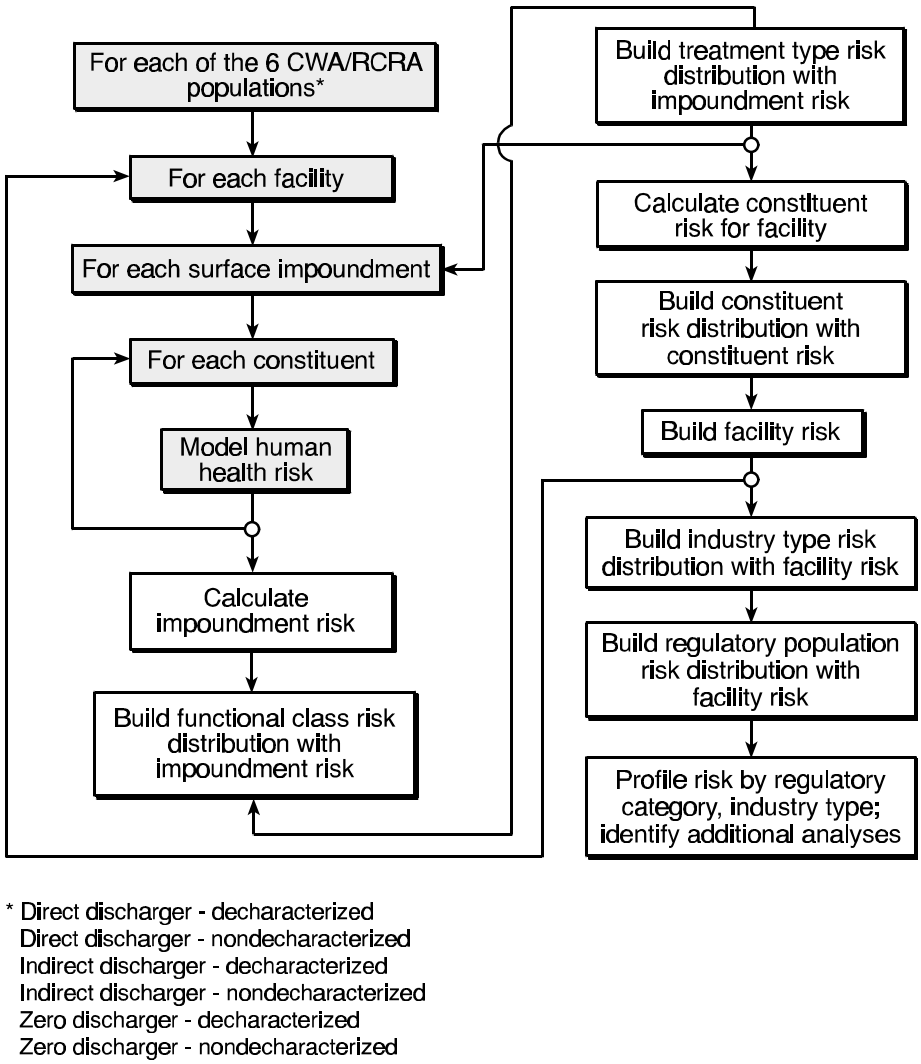


Figure 3-2. Phase II decision process.

Recommendation for additional analysis for the remaining facilities that show significant risks.

The Phase II analysis is designed to provide the risk information necessary to formulate these profiles and risks.

3.2 Conceptual Model and Approach

The approach to conducting the SI Study risk assessment begins with the conceptual model of a surface impoundment site. Figure 3-3 diagrams this conceptual model for human exposure, beginning with the multimedia release of chemicals from a surface impoundment, both during its active life and following closure. Once released, the chemicals travel through environmental media that define the exposure pathways for the analysis: air, vadose zone and groundwater, watershed, and surface water. In addition, plants and animals take up the chemicals

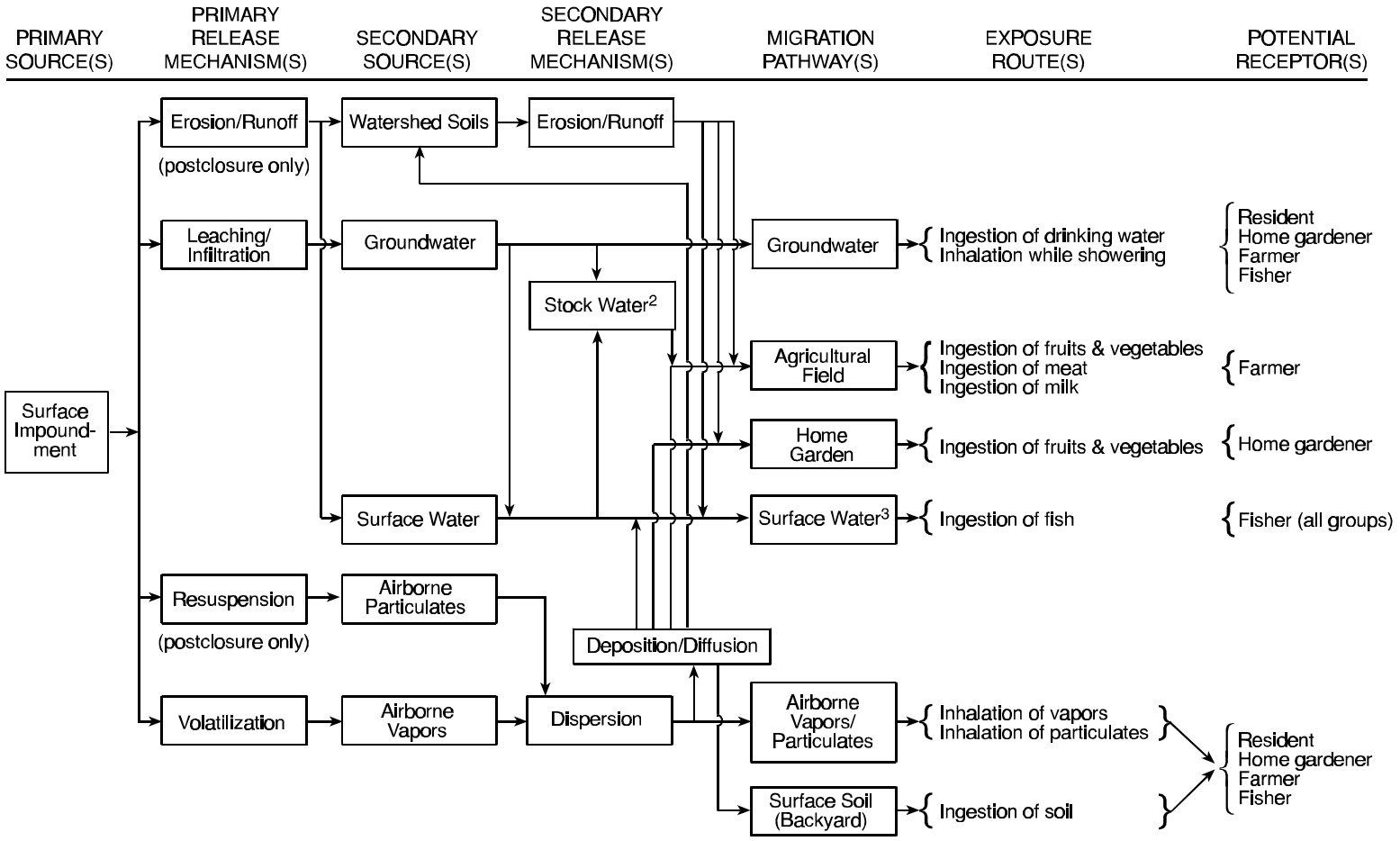


Figure 3-3. Conceptual exposure model for human receptors.

either directly from the different fate and transport media or by bioaccumulation of chemicals in terrestrial and aquatic food webs. Eventually, human and ecological receptors are exposed to chemicals in the environment as a result of inhalation or ingestion of contaminated media and/or biota.

Human receptor types considered in the SI Study include residents, gardeners, farmers, and fishers, each divided into five age cohorts. The conceptual model diagram (Figure 3-3) shows the exposure pathways for each type of receptor. For example, the exposure pathways that will be evaluated for an adult resident include ingestion of soil and groundwater and inhalation of airborne vapors and particulates. Contaminated foodstuffs are considered only for resident gardeners and farmers.

The ecological risk assessment provides descriptions of risk to representative wildlife species in representative habitats. The ecological receptor types include plants, invertebrates, amphibians, reptiles, birds, and mammals. The conceptual exposure model demonstrating the environmental exposure pathways for each type of ecological receptor is shown in Figure 3-4. For example, the exposure pathways that will be evaluated for a mammal include ingestion of soil, water, and terrestrial food items.

Figure 3-5 itemizes the dimensions of the 3MRA as it will be implemented to address the SI Study conceptual model. These dimensions include 11 major categories:

- Chemicals addressed
- Source type (i.e., surface impoundment)
- Source term characteristics
- Source release mechanisms
- Transport media
- Fate processes
- Intermedia contaminant fluxes
- Food chain/food web components
- Receptors and habitats
- Exposure pathways
- Human and ecological risk measures.

These categories characterize the Phase II analysis that will provide a state-of-the-art representation of risks. A more detailed overview of the 3MRA model, including each component module and its conceptual basis, is provided in Section 3.3 and the HWIR background documents referenced therein.

3.2.1 Spatial Scale and Layout

Phase II of the SI Study will adopt the same spatial scale and site layout framework as used for the HWIR 3MRA. The area of interest (AOI) for the analysis is defined by a 2-km radius from the corner of a square surface impoundment (Figure 3-6). This distance was determined to encompass the area of greatest risk for the air and groundwater pathways. In addition, concentric

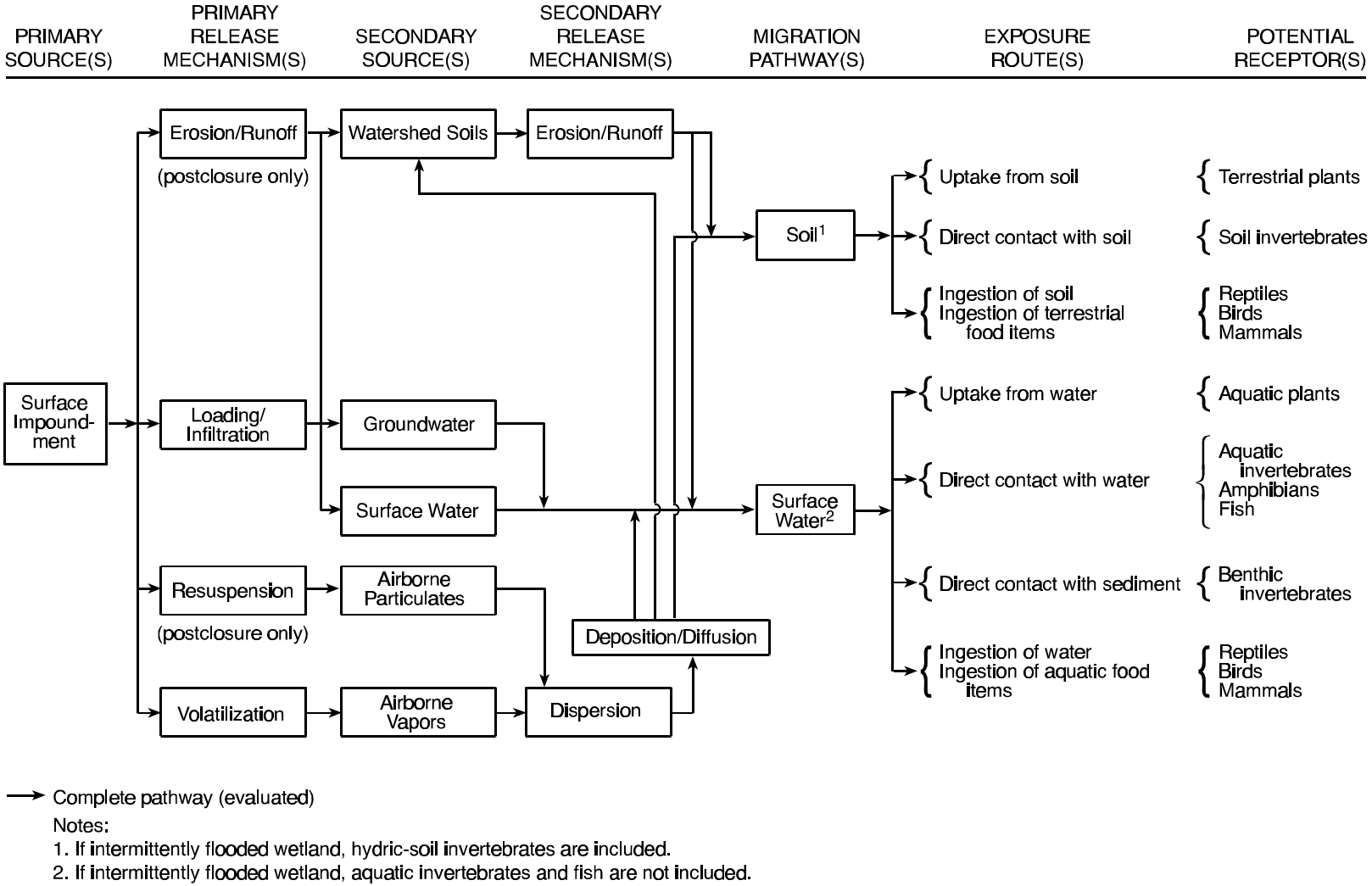


Figure 3-4. Conceptual exposure model for ecological receptors.

Chemicals
- Organic chemicals (227)
- Metals (17)
- Nonmetallic inorganic chemicals (8)

Source Type
- Surface impoundment (operating and postclosure)

Source Term Characteristics
- Mass balance
- Multiphase partitioning
- First-order degradation
- Source depletion

Source Release Mechanisms
- Volatilization
- Leaching
- Runoff (postclosure, surface failure)
- Erosion (postclosure, surface failure)
- Particle resuspension (postclosure)

Transport Media
- Atmosphere
- Watershed
- Vadose zone/Groundwater
- Surface water

Fate Processes
- Chemical/biological transformation (and associated products)
- Linear partitioning (water/air, water/soil, air/plant, water/biota)
- Nonlinear partitioning (metals in vadose zone)
- Chemical reactions/speciation (mercury in surface waters)

Intermedia Contaminant Fluxes

Source	→	Air (volatilization, resuspension)
Source	→	Vadose zone (leaching)
Source	→	Local watershed soil (erosion, runoff)
Air	→	Watershed/farm habitat soil (wet/dry deposition, vapor diffusion)
Air	→	Surface water (wet/dry deposition, vapor diffusion)
Watershed soil	→	Surface water (erosion, runoff)
Surface water	→	Sediment (sedimentation)
Vadose zone	→	Groundwater (infiltration)
Watershed soil	→	Air (volatilization)
Groundwater	→	Surface water

Food Chain/Food Web Fluxes

Air	→	Vegetation (particulate deposition; vapor diffusion)
Farm/habitat/garden soil	→	Vegetation (root uptake, translocation)
Vegetation, soil, surface water, groundwater	→	Animals (uptake)
Surface water	→	Aquatic organisms (uptake)

Receptors and Habitats

Ecological Habitats:
- Terrestrial
- Freshwater aquatic

Human Receptors*:
- Resident
- Home gardener
- Dairy farmer
- Beef farmer
- Fisher**

Ecological Receptors:
- Plants
- Invertebrates
- Amphibians
- Reptiles
- Birds
- Mammals

*For each human receptor type, consider 5 age cohorts

**All receptor types can be fishers.

Exposure Pathways

Human
- Ingestion (plant, meat, milk, fish, water, soil, breast milk)
- Inhalation (gases, particulates)

Ecological
- Ingestion (plant, animal, water, soil)
- Direct contact (surface water, sediment, soil)

Human And Ecological Risk Measures
- Cancer (risk probability)
- Noncancer (hazard quotient)
- Human: population
- Ecological: population

Figure 3-5. Dimensions of the 3MRA conceptual model for surface impoundments.

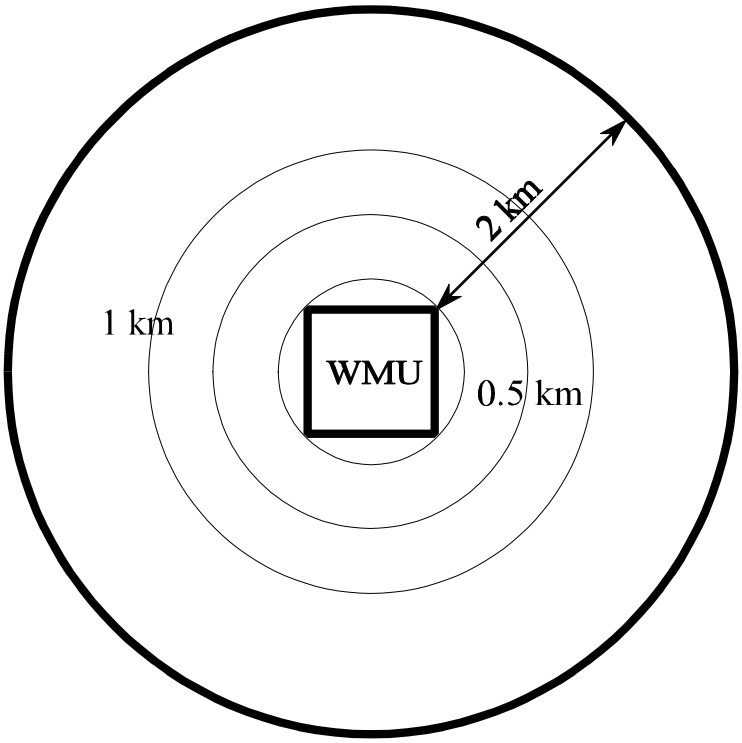


Figure 3-6. Area of interest (AOI) and risk rings for SI Study 3MRA.

risk rings are defined within the 2-km radius (Figure 3-6) to provide additional spatial resolution for the risk results:

- Humans risks are totaled within the 0 to 0.5 km, 0.5 to 1 km, and 1 to 2 km distances from the edge of the SI.

- Ecological risks are totaled with the 0 to 1 km, 1 to 2 km, and 0 to 2 km distances from the edge of the surface impoundment.

Human and ecological risk results will be tracked and maintained for each of these risk rings within the AOI to provide information on the distribution of risk with distance from the SI.

Another important determinant of the spatial scale of the analysis is the size of watershed subbasins delineated across the 2-km AOI. For the 3MRA model, watershed subbasins define the areas over which deposition rates and soil concentrations are averaged and assumed to be uniform. Although watershed size is determined mainly by the topography and hydrography at the site, the size of the subbasins subdividing these watersheds is defined during watershed delineation. Currently, these are defined in 3MRA so that there are generally about 10 to 12 watershed subbasins within the AOI at a site, with an average subbasin area of about 1 million

square meters within the AOI (Figure 3-7).[1] This provides adequate spatial resolution to map soil concentration gradients across the site while keeping the total number of watersheds at a given site to a reasonable number from a run-time perspective. This decision could be revisited when watersheds are delineated at the SI sites.

The spatial resolution is also limited by the resolution of the underlying data (topographic, waterbodies, land use, soils) used in the site-based data collection process. Because many of these data sources (i.e., topographic, land use, soils) have a scale of 1:250,000, that scale was used to define a minimum resolution for the coordinate system used to pass spatial data from the geographic information system (GIS) data sources to the 3MRA model. Figure 3-8 shows how the site grid system, based on 100 m × 100 m grid cells, defined the data resolution used to pass watersheds, waterbodies, farms, and ecological habitats.

In HWIR, human receptor locations at a site are defined by the centroids of 1990 U.S. Census blocks or by the ring/block centroid where the blocks cross a risk ring. Figure 3-9 illustrates human receptor locations at a typical HWIR site. Note that the density of receptor points will vary with population density because census blocks are sized by the population they contain. Because some site-specific receptor location data will be available from the SI Survey results, there may be a need to modify receptor point placement for SI sites. There also may be onsite receptors placed within the SI after closure, a scenario not addressed in HWIR. These issues are discussed in Section 3.4 along with other modifications to the HWIR data collection methodologies.

Ecological habitats are defined in the 3MRA primarily by land use and waterbody coverages (see U.S. EPA, 1999n, for description of the habitat delineation methodology). Four receptor home range bins are placed within each habitat in an overlapping fashion, with receptors assigned to the appropriately sized home range bin. Figure 3-10 illustrates a typical habitat and home ranges. This approach will likely be used "as is" to place ecological receptors around the SI Study sites.

3.2.2 Temporal Scale, Frame, and Integration

The SI Study considers in-scope impoundments to be those in active operation on or after June 1, 1990. Selection of this date ensures that the study will be limited to wastes managed according to practices that have become more commonplace in recent years. Therefore, the study will evaluate the release of in-scope constituents starting from June 1, 1990, through the remainder of its active lifetime and, if appropriate, for the postclosure lifetime of the impoundment.

3.2.2.1 <u>Model Temporal Scale</u>. The 3MRA model operates on an annual average time scale, with individual module results being reported as a time series of annual average concentrations or fluxes. Individual modules may operate on different time scales, depending on

[1] Note that some watershed subbasins extend outside of the AOI in Figure 3-7 to capture the entire drainage area for each watershed draining into the AOI. This is necessary to calculate accurate runoff and solids loads for the 3MRA surface water module.

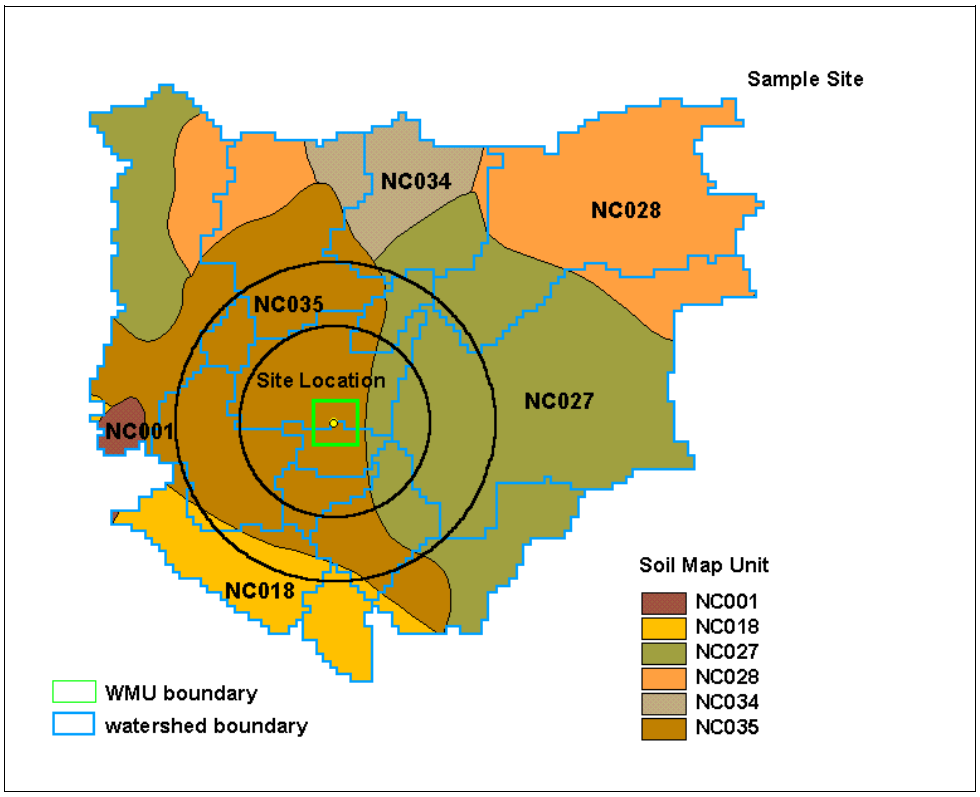


Figure 3-7. Typical watershed layout for HWIR 3MRA.

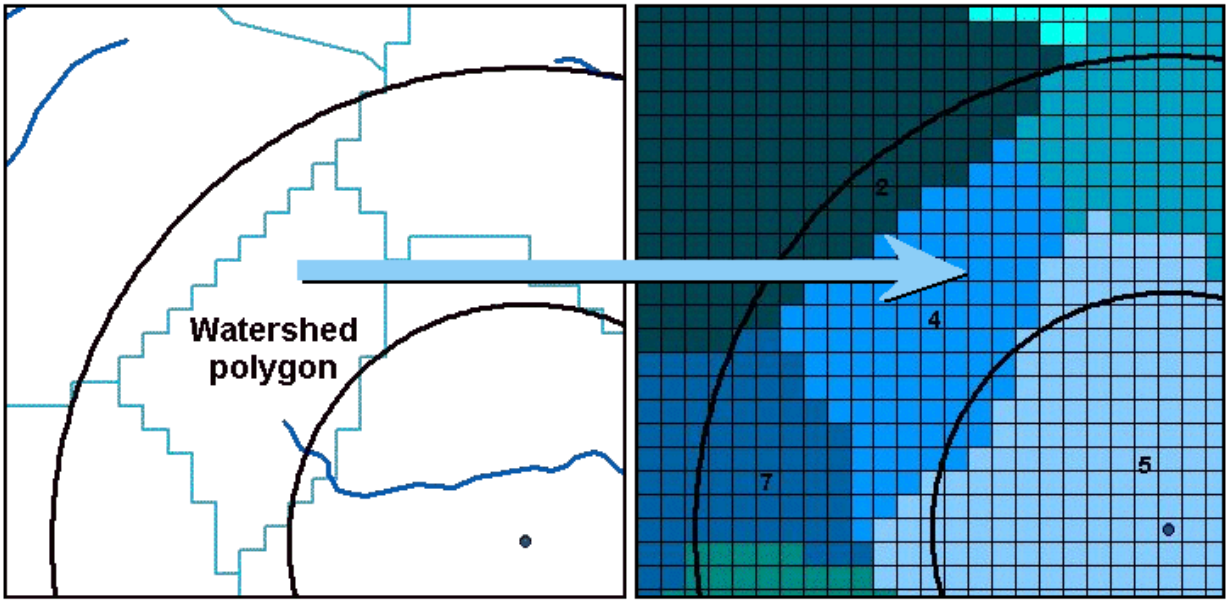


Figure 3-8. Transfer of watershed polygons to 100- by 100-m template grid.

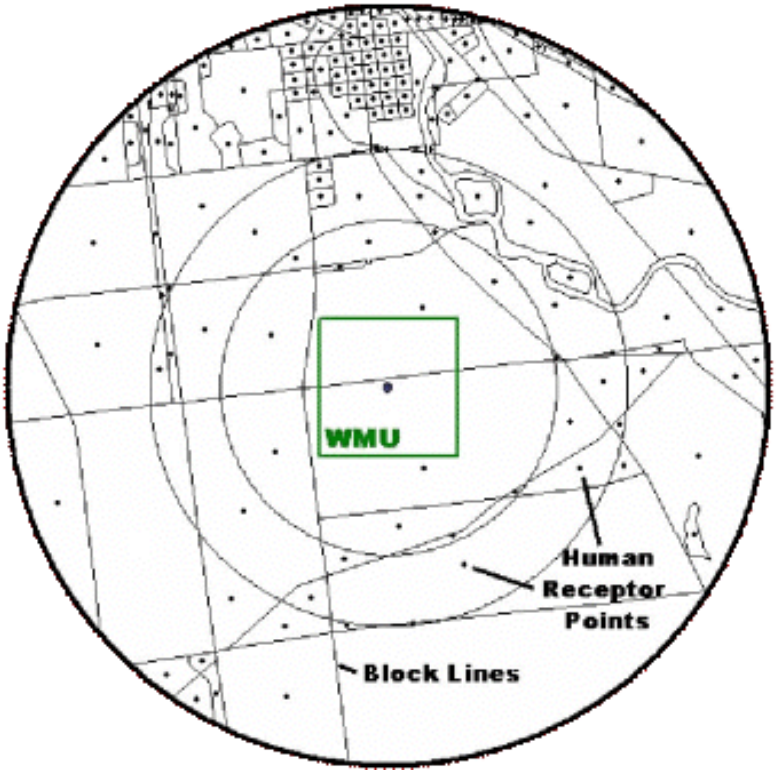


Figure 3-9. Example human receptor placement for HWIR 3MRA.

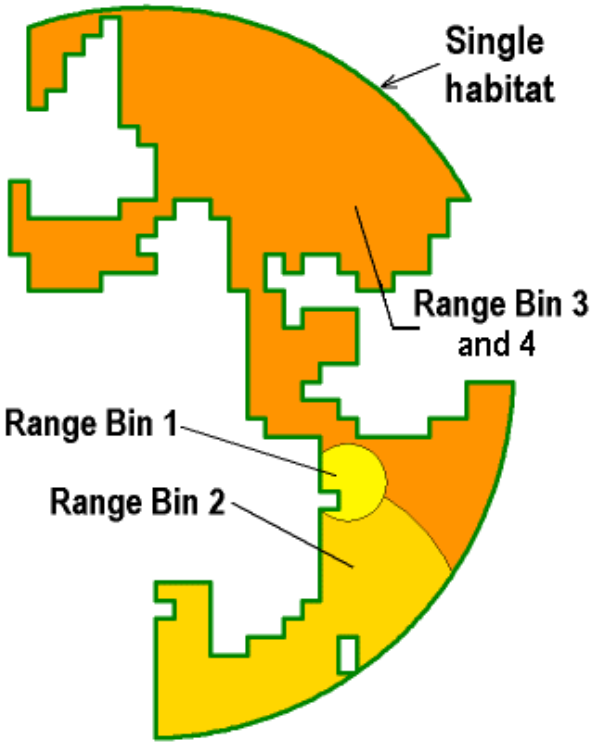


Figure 3-10. Example ecological habitat and home range bins.

Table 3-2. Meteorological Data Time Scales, by 3MRA Model Module

3MRA Module	Hourly	Twice Daily	Daily	Monthly	Annual	Long-term
Surface impoundment				!		
Land application unit			!	!	!	!
Air	!	!				!
Watershed			!	!		!
Surface water						!

what is appropriate for modeling objectives. This is reflected by which type of meteorological data each module reads, shown in Table 3-2. Reasons for departures from annual average conditions include the need for shorter time scales to accurately estimate release or fate and transport in media sensitive to fluctuations in meteorological data. For example, the surface impoundment module needs monthly data to capture temperature extremes that can impact volatilization. The land application unit (LAU)[2] and watershed modules require daily precipitation data to accurately estimate precipitation-driven runoff and erosion events.

3.2.2.2 Study Time Frame. The study time frame for exposure and risk depends on the migration times of the constituents in the receiving media. For most media (i.e., air, surface water, soil), the exposure and risk occur in the same time frame as the release from the impoundment. For media such as groundwater, where the media and chemical properties attenuate the migration process, the exposure and risk time frame can be tens to thousands of years after the release. The study time frame, therefore, varies for each chemical and environmental medium considered for each specific facility and impoundment. A maximum time limit for considering exposure and risk is defined as 5,000 years. This should capture the significant impacts of most chemicals included in the analysis.

3.2.2.3 Temporal Integration. A given receptor will be considered subject to exposure from various but not necessarily all pathways simultaneously. The aggregate risk to any individual receptor is defined as the sum of the risks from each pathway over a given time period. Given that the exposure in the different media can occur over significantly different times, aggregation of risk is performed for exposures that occur at the same time. For instance, exposures and risks due to contaminated air occurring in the first 10-year time frame is not aggregated with exposures and risks due to contaminated groundwater occurring in the hundredth year time frame. Figure 3-11 illustrates how risks of different time periods will be overlaid and aggregated across exposure pathways for a given receptor and constituent. Note that risks will be aggregated across different exposure routes (i.e., ingestion, inhalation) only after considering current EPA practices for route-to-route extrapolation. In general, combining pathways and routes involves the following considerations:

[2] The LAU module is being used to model a postclosure surface impoundment; see Section 3.3.1.

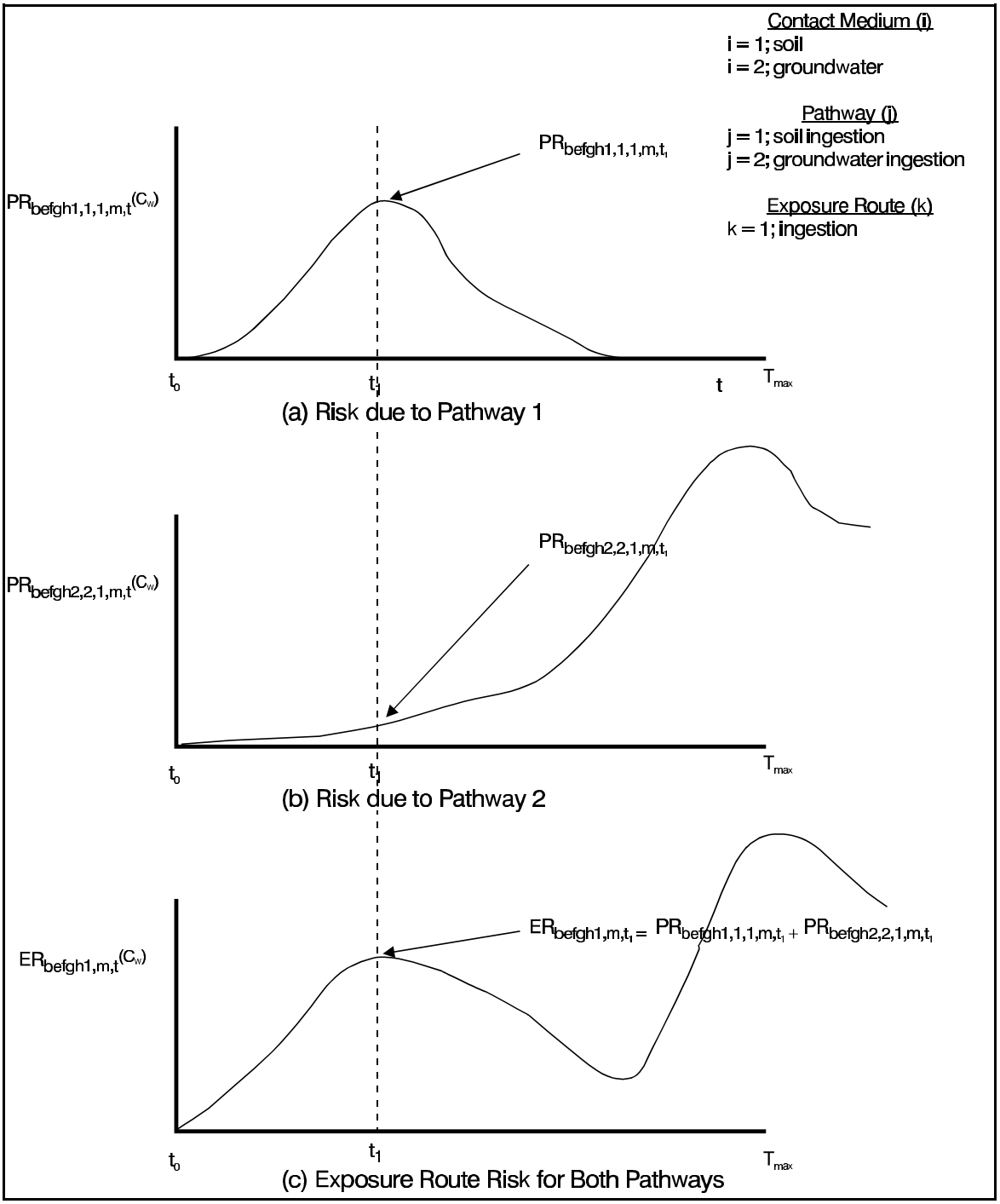


Figure 3-11. Illustration of concurrent time aggregation of risks.

Source: U.S. EPA (1999aa).

- # Pathway-specific benchmarks
- # All ingestion pathways combined
- # All inhalation pathways combined
- # Results flagged in database if oral and inhalation routes could be combined
- # Cancer risk and hazard quotients not combined.

Once risk estimates are integrated temporally, the 3MRA human risk module determines and outputs that critical year, T_{crit}, during which the maximum cumulative risk and/or hazard quotient occurs across the population for each receptor/cohort combination and for each exposure pathway and pathway aggregation. This process involves adding receptors across all risk bins for each year of the analysis to calculate total risk/hazard for each period. The year with maximum total risk/hazard is T_{crit}. Types of outputs at T_{crit} include population-weighted risk or hazard quotient.

T_{crit} is determined by the following steps:

1. Calculate total risk/hazard for each period

2. Find period with maximum total risk/hazard

   - # by nine exposure pathways
     - by route (ingestion or inhalation) or
     - by combined routes
   - # by distance (3 risk rings)
   - # by four receptor types
   - # by five age cohorts.

T_{crit} is determined in a similar fashion in the ecological risk module for receptor types, groups, and distances. An example of a simple T_{crit} determination is shown in Figure 3-12.

3.2.3 Human Health

Example of 2-year analysis with T_{crit} = year 2

	Bin 1 $<10^{-8}$	Bin 2 10^{-8} - $<10^{-7}$	Bin 3 10^{-7} - $<10^{6}$	Bin 4 10^{6} - $<10^{-5}$	Bin 5 10^{-5} - $<10^{-4}$	Bin 6 10^{-4} - 1	Total	
Year 1	10	10	10	10	10	10	5.5E-3	
Year 2	0	0	0	20	20	20	1.1E-2	(T_{crit})

Figure 3-12. Finding T_{crit} (year with maximum risk).

The human health risk assessment (HRA) will evaluate the potential for adverse human health effects that may occur as a result of chemical releases at the surface impoundments investigated as part of the study. The results of the HRA will be used to assess the potential risks associated with the impounded wastes. The HRA for the SI Study is designed to be consistent with EPA guidance (U.S. EPA, 1989, 1991a, 1992c, 1997d, in press) and consists of the following components:

- Identification of chemicals of potential concern
- Identification of potential human receptors
- Assessment of exposure
- Assessment of chemical toxicity
- Characterization of risk
- Analysis of sources of uncertainty in the predicted risk estimates.

3.2.3.1 Chemicals of Potential Concern. Chemicals of potential concern (COPCs) are those identified in the environment that may cause adverse health effects in exposed individuals. The general types of COPCs identified within the scope of the SI Study are listed in Figure 3-5 and include:

- 227 organic chemicals
- 17 metals
- 8 nonmetallic inorganic chemicals
- 4 other.

EPA will select the final list of COPCs based on the results of the SI Survey (i.e., chemicals detected in the SI wastes) as well as policy and regulatory concerns (e.g., the three specific target chemicals beryllium, 1,1,2-trichloroethane, 1,1,2,2-tetrachloroethane). In addition, the Phase II analysis will address only those chemicals that were not screened out in the Phase I analysis.

3.2.3.2 Human Receptor Types. EPA is concerned with the potential risk to the exposed population within a 2-km radius of the surface impoundments at a facility. Census and land use data will be used in conjunction with the SI Survey results to identify receptor types and populations that are potentially exposed in the AOI for each SI site. Receptor types and age cohorts to be evaluated using 3MRA are shown in Table 3-3.

EPA risk assessments are expected to address or provide descriptions of individual risk to important subgroups of the population such as highly exposed or highly susceptible groups or individuals, if known. EPA plans to evaluate the risk burden carried by different subgroups of the exposed population, with particular concern over the potentially disproportionate risks to children and subsistence populations (e.g., Native Americans who rely on indigenous fish species as a major portion of their diets) in the study area. EPA believes that these concerns will exhibit themselves on a site-specific basis and plans to address such risk in separate, site-specific analyses.

Table 3-3. Matrix of Human Receptor Types and Age Cohorts[a]

Receptor Type	Age Cohort				
	Infant[b]	**Child (1-5)**	**Child (6-11)**	**Child (12-19)**	**Adult**
Resident[c]	✓	✓	✓	✓	✓
Home gardener[c]	✓	✓	✓	✓	✓
Beef farmer	✓	✓	✓	✓	✓
Dairy farmer	✓	✓	✓	✓	✓
Fishers[d]	✓	✓	✓	✓	✓

[a] There is no overlap between receptor types or age cohorts (unique sets).

[b] Infant is less than 1 year old and is evaluated only for dioxin-like compounds in breast milk.

[c] May include onsite future resident for time periods after closure of an impoundment.

[d] Fishers defined for all four receptor types: resident, home gardener, beef farmer, dairy farmer, and across noninfant age cohorts.

3.2.3.3 <u>Human Exposure Pathways</u>. The human exposure assessment will estimate the type, timing, and magnitude of exposures that receptors may experience due to contact with the chemicals of potential concern (these exposures are calculated using the human exposure module, which is described in Section 3.3.9). Exposures will be evaluated for potentially complete exposure pathways. An exposure pathway describes the course that a chemical takes from a source to an exposed individual. An exposure pathway is complete when there is a route by which a human receptor takes up a chemical that was released from the source of concern (in this case, a surface impoundment).

Exposure routes include uptake mechanisms such as ingestion, dermal contact, and inhalation. When modeling human exposure, the exposure routes that will be considered are

- Direct ingestion of soil
- Direct ingestion of contaminated groundwater (private groundwater wells only)
- Inhalation of contaminated shower air (private groundwater wells only)
- Inhalation of volatile emissions from impoundment
- Inhalation of particulate emissions from sludge (postclosure in place)

- Indirect exposure through ingestion of produce (gardeners, farmers) and meat and dairy (farmers only) contaminated from air deposition or sludge erosion/runoff to soil and subsequent plant uptake and consumption

- Indirect exposure (all recreational fishers) through ingestion of T3 and T4 fish contaminated through the aquatic food web from air deposition onto or sludge erosion/runoff into surface waterbodies surrounding each SI.

These routes define the exposure media to be modeled in the risk analysis (i.e., groundwater, soil, air, vegetables, meat, dairy products, and fish). OSW considered the inclusion of dermal routes of exposure but decided that health benchmarks for dermal toxicity derived from oral toxicity studies are not sufficiently developed at this time for use in analyses that could support regulatory decisions and, therefore, has decided not to include dermal exposure routes.

The exposure pathways and routes that will be evaluated for each receptor type at each site are shown in Table 3-4. These pathways were previously pictured in the conceptual model diagram (Figure 3-3) for human receptors. Residents are exposed to some level of contaminant in the air (inhalation) and the soil (incidental ingestion) and are assumed to be exposed to potentially contaminated groundwater (inhalation and ingestion) if the house is not on a public water supply. Home gardeners are residents who also grow some portion of their fruits and vegetables. Farmers have the same exposure pathways as home gardeners with the additional exposure to either contaminated beef or contaminated dairy products (depending on the type of farms present at a site). Recreational fishers are any of the above receptors with the added pathway of eating contaminated fish from local streams or lakes. Thus, some fraction of residents, home gardeners, and farmers also are fishers.

As shown in Figure 3-3, a receptor may be exposed simultaneously via multiple pathways, each involving different combinations of contact media and exposure routes. The human exposure model component will aggregate exposures across exposure pathways and routes, when appropriate (e.g., daily doses of beef contaminated by uptake from forage, silage, grain, soil, and drinking water), and provide estimates of total exposure for the eight routes listed above. Because human health benchmarks are pathway-specific, pathways and routes are combined in the analysis as follows in the 3MRA model:

- All ingestion pathways are combined.
- All inhalation pathways are combined
- Flag placed in database if oral and inhalation routes could be combined.
- Cancer risk and hazard quotients are not combined.

The evaluation of human exposure must include evaluation of spatial variability and temporal variability in exposure across a site and also variability and uncertainty in exposure factors for each receptor type. The exposure for each of these receptor types is estimated at each receptor location across the study area to capture spatial variability in exposure and for every year over the modeling time frame to capture temporal variability at each location. In addition, each receptor type has distributions for all exposure factors for each of the age groups. In HWIR, these age cohort-specific distributions were derived from percentile data for contact rates, body

Table 3-4. Human Exposure Pathways by Receptor Type

	Receptors (as output by Human Risk Module)			
	Resident	**Resident Gardener**	**Fisher**	**Farmer**
	Receptors (as output by Human Exposure Module)			
Pathway	**Resident**	**Resident Gardener**	**Resident Fisher**	**Resident Gardener Fisher**	**Beef Farmer Fisher**	**Dairy Farmer Fisher**	**Beef Farmer**	**Dairy Farmer**
Air inhalation	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Shower air inhalation	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Soil ingestion	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Water ingestion	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Crop ingestion	No	Yes	No	Yes	Yes	Yes	Yes	Yes
Beef ingestion	No	No	No	No	Yes	No	Yes	No
Milk ingestion	No	No	No	No	No	Yes	No	Yes
Fish ingestion	No	No	Yes	Yes	Yes	Yes	No	No

weight, etc. in the *Exposure Factors Handbook* (U.S. EPA, 1997b), as described in U.S. EPA (1999v). Exceptions include fixed values assumed for exposure duration (9 years for carcinogens, 1 year for noncarcinogens), and medium or food-specific estimates of fraction contaminated.

Lead exposures and risk evaluations will differ from those used with other exposure pathways. This set of evaluations will be developed as a separate model because EPA (FR 56[110]:26460-26564) evaluates lead exposures in terms of potential blood lead (Pb) concentrations (μg/dL-blood) rather than as intake or absorbed doses (i.e., μg/kg-d). The reasons for using this different protocol are discussed in Section 3.2.3.4.

3.2.3.4 <u>Human Health Effect Benchmarks</u>. The health effect benchmarks that will be used in the human health risk assessment are chemical- and exposure pathway-specific and include

Cancer Risk

- **#** Oral cancer slope factor
- **#** Inhalation cancer slope factor

Noncancer (Toxic) Effects

- Oral reference dose (RfD)
- Inhalation reference concentration (RfC).

The Agency has a comprehensive human health benchmark database to support risk assessment projects, which will be used to populate the SI Study database and is based on the following sources, listed in order of preference:

- Integrated Risk Information System (IRIS)
- Health Effects Assessment Summary Tables (HEAST)
- EPA-approved toxicity equivalency factors (TEFs)
- Superfund Technical Support Center Provisional Benchmarks
- Various EPA criteria documents.

When benchmarks are not available from the above sources, alternative sources include the following:

- Agency for Toxic Substances and Disease Control (ATSDR) minimal risk levels (MRLs)

- California Environmental Protection Agency (CalEPA)

- Interim benchmarks developed from primary scientific literature.

Each of these sources is briefly reviewed below.

IRIS is EPA's electronic database containing information on human health effects (U.S. EPA, 1999s). Each chemical file contains descriptive and quantitative information on potential health effects. Health benchmarks for chronic noncarcinogenic health effects include RfDs and RfCs. Cancer classification and oral and inhalation CSFs are included for carcinogenic effects. IRIS is the official repository of Agency-wide consensus of human health risk information.

HEAST is a listing of provisional noncarcinogenic and carcinogenic health toxicity values (RfDs, RfCs, and CSFs) derived by EPA (U.S. EPA, 1997c). Although the health toxicity values in HEAST have undergone review, they have not been updated in several years and do not represent Agency-wide consensus information.

Cancer slope factors for some dioxin-like compounds and polychlorinated aliphatic hydrocarbons (PAHs) were calculated by using the TEF approach. For the TEF approach, the toxicity of a group of chemically related constituents that typically occur in the environment as mixtures is based on estimates of the toxic potency of each constituent as compared with a reference compound within the group. TEF estimates are based on a knowledge of the mechanism of action, available experimental data, and other structure-activity information. TEFs have been established for a number of polychlorinated dibenzodioxins, polychlorinated dibenzofurans, and polychlorinated biphenyl (PCB) congeners thought to have dioxin-like

toxicity (Ahlborg et al., 1994; U.S. EPA, 1998d). TEFs for several PAHs also have been established (U.S. EPA, 1993b).

The Superfund Technical Support Center (U.S. EPA, National Center for Environmental Assessment or NCEA) derives provisional RfCs, RfDs, and CSFs for certain chemicals. These provisional health benchmarks can be found in Risk Assessment Issue Papers. These provisional values have not undergone EPA's formal review process for finalizing benchmarks, and do not represent Agency-wide consensus information.

EPA has also derived health benchmark values in other risk assessment documents such as Health Assessment Documents (HADs), Health Effect Assessments (HEAs), Health and Environmental Effects Profiles (HEEPs), Health and Environmental Effects Documents (HEEDs), Drinking Water Criteria Documents, and Ambient Water Quality Criteria Documents. Evaluations of potential carcinogenicity of chemicals in support of reportable quantity adjustments were published by EPA's Carcinogen Assessment Group (CAG) and may include cancer potency factor estimates. Health toxicity values identified in these EPA documents are usually dated and are not recognized as Agency-wide consensus information or verified benchmarks, however.

The ATSDR minimal risk levels are substance-specific health guidance levels for noncarcinogenic endpoints. An MRL is an estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse noncancer health effects over a specified duration of exposure. MRLs are derived for acute, intermediate, and chronic exposure durations for oral and inhalation routes of exposure. Inhalation and oral MRLs are similar to EPA's RfCs and RfDs, respectively; however, MRLs are intended to serve as screening levels.

CalEPA has developed cancer potency factors for chemicals regulated under California's Hot Spots Air Toxics Program (CalEPA, 1999a). The cancer potency factors are analogous to EPA's oral and inhalation CSFs. CalEPA has also developed chronic inhalation reference exposure levels (RELs), analogous to EPA's RfC, for 120 substances (CalEPA, 1999b). CalEPA used EPA's 1994 inhalation dosimetry methodology in the derivation of inhalation RELs. The cancer potency factors and inhalation RELs have undergone internal peer review by various California agencies and have been the subject of public comment.

Appendix B provides a comprehensive list of EPA and non-EPA benchmarks available for the 256 SI study constituents. At least one benchmark was available from EPA sources for all but the following 25 constituents:

- # Ammonium perchlorate
- # Ammonium vanadate
- # Chloral hydrate
- # Chlordecone
- # Chloromethyl methyl ether
- # Copper
- # Cresol mixtures
- # Cyanide (total)
- # Cyclohexanol
- # tris(2,3-Dibromo propyl)phosphate
- # cis-1,3-Dichloropropylene
- # trans-1,3-Dichloropropylene
- # 7,12-Dimethyl benz[a]anthracene
- # Dimethylphthalate
- # Ethyl methanesulfonate
- # Fluoride

- # Lead and compounds
- # 3-Methyl cholanthrene
- # N-Nitrosopiperidine
- # Perchlorate
- # Safrole
- # Styrene-7,8-oxide
- # Sulfide
- # Thallium
- # p-Xylene

Possible benchmark options for several of these constituents are discussed in the remainder of this section.

Alternatives for addressing constituents without EPA benchmarks include omitting them from the quantitative risk assessment, using provisional benchmarks from other sources (e.g., ATSDR, CalEPA), or estimating benchmarks (for screening purposes) if suitable toxicological data are available.

EPA considers that, for a screening-level analysis, it is appropriate to identify or develop and use draft provisional benchmarks where necessary. For 9 of the chemicals listed above, IRIS benchmarks for similar chemicals could be used as their benchmarks. The rationale for these chemicals is as follows:

- # Chloral hydrate could be based on chloral. The IRIS RfD for chloral (2E-03 mg/kg-d) was based on a study that used chloral hydrate.

- # Chloromethyl methyl ether could be based on bischloromethylether. The IRIS file for chloromethyl methyl ether states that the risk is not likely to be greater than for bischloromethylether (a contaminant of chloromethyl methyl ether). The CSF for bischloromethylether is 220 $(mg/kg\text{-}d)^{-1}$ and the URF is 6.2E-02 $(\mu g/m^3)^{-1}$.

- # cis-1,3-Dichloropropylene and trans-1,3-dichloropropylene could be based on 1,3-dichloropropene. The studies cited in the IRIS file for 1,3-dichloropropene used a technical-grade chemical that contained about a 50/50 mixture of the cis- and trans-isomers. The RfD is 3E-04 mg/kg-d and the RfC is 2E-02 mg/m^3.

- # Cresol mixtures could be based on m-cresol. Cresol mixtures contain all three cresol isomers; therefore, it is appropriate to use the lowest RfD (5E-02 mg/kg-d for m-cresol) from the cresol isomers to represent the mixture.

- # Total cyanide could be based on amenable cyanide. The IRIS RfD is 0.02 mg/kg-d.

- # Fluoride could be based on fluorine. The RfD for fluorine (6E-02 mg/kg-d) is based on soluble fluoride.

- # Thallium could be based on thallium chloride. There are several thallium salts that have RfDs in IRIS. The lowest value among the thallium salts is routinely used to represent thallium in risk assessments.

- **#** p-Xylene could be based on total xylenes. An RfD of 2 mg/kg-d is listed for total xylenes, m-xylene, and o-xylene in IRIS. Total xylenes contains a mixture of all three isomers; therefore, the RfD likely is appropriate for p-xylene.

Copper and lead present special cases. Although HEAST lists an RfD of 1.3 mg/L for copper, HEAST notes that there is a drinking water standard and that data are inadequate to calculate an RfD. Nevertheless, the drinking water standard is sometimes used to calculate an RfD of 0.037 mg/kg-d (assuming a 70-kg body weight and ingestion of 2 L of water per day). This RfD has previously been used.

Even though lead toxicity has been investigated for decades, the data do not fit into the typical RfD methodology. EPA has determined that lead exposure can result in various health effects, depending on the level of exposure. Also, potential health effects differ, depending on whether exposure occurs to an adult or a child and, at blood-lead levels of 10 to 15 μg/dL or possibly lower, effects may include inhibited activity of enzymes involved in red blood cell metabolism, interference with heme synthesis, interference with vitamin D hormone synthesis, altered brain wave activity, deficits in IQ and other mental indices, early childhood growth reductions, and increases in blood pressure (FR 56[110]:26460-26564). Some of these effects may not have a threshold. The EPA RfD workgroup concluded that it was inappropriate to develop an RfD for lead. Consequently, a biokinetic uptake model was developed to predict blood lead levels in young children exposed to lead. A soil screening guidance level of 400 mg/kg (U.S. EPA, 1996d) was developed based on the lead model. EPA is considering use of a screening value (for sludge) of 400 mg/kg in the surface impoundment study and 10 to 15 mg/L for water.

EPA is in the process of developing a revised RfD for perchlorate. A peer review workshop was held in February 1999 to review the toxicological data used as the basis for the revised RfD (0.0009 mg/kg-d). This value is still undergoing review; however, if it were to be finalized in the near future it could be used in the risk assessment. A provisional RfC of 2.0E-3 mg/m^3 was derived for cyclohexanol in the listing rule for solvents (63 FR 64371) and could be used in the SI study. The Agency will use a screening value (for sludges) of 400 mg/kg in the surface impoundment study.

In summary, EPA benchmarks exist for 240 SI constituents. Of the 24 without benchmarks, suitable draft benchmarks may be readily identified for about one-third and subsequent literature searches may identify suitable studies to develop benchmarks for several others. These special cases will be clearly identified in presenting analytic findings based on draft benchmarks. For the few remaining chemicals for which benchmarks cannot be developed, a quantitative risk assessment will not be possible; however, information concerning the frequency of detection and concentrations should be considered carefully in a qualitative assessment.

3.2.3.5 <u>Human Health Risk Measures</u>. Risk characterization integrates the exposure and toxicity assessments to produce quantitative estimates of potential health risks associated with the chemicals of potential concern. Risks will be determined for individual chemical parameters as well as for additive effects (across pathways) and cumulative effects for multiple

chemicals. The following are key features of the calculation of cancer and noncancer risk in the SI Study:

- # Excess cancer risk criterion = 10^{-5}
- # HQ criterion = 1
- # Cancer risks can be cumulative across chemicals
- # HQs can be summed across chemicals if effects are to same target organs.

Because of fundamental differences in the calculation of critical toxicity values, the estimates of potential excess carcinogenic risks and noncarcinogenic health effects are calculated separately.

Risk probabilities determined for each carcinogen generally will be considered to be additive over all exposure pathways so that an overall risk of cancer will be estimated for each group of potentially exposed receptors. Cancer risks will not be summed if inhalation or ingestion of a chemical results in health effects at the point of exposure or has other immediate effects.

Consistent with previous EPA practice in the assessment of human cancer risks from constituents, if an individual's probability of developing cancer due to an exposure to the constituent in question is estimated to be in the range of 1 in 100,000 (1×10^{-5}), with a confidence level consistent with the levels that can be achieved with the existing state of chemical constituent risk assessment methodologies, then that exposure would be of concern.

In a manner similar to carcinogens, HQ values will be summed for chemical exposures causing the same health effect (i.e., affecting the same target organ) to develop hazard indices (HIs). HQs and HIs are not risk probabilities but are accepted by EPA as quantitative levels of risks for noncarcinogens. Consistent with previous EPA practice in the assessment of human noncancer health effects from constituents, if the ratio of the individual's exposure and the applicable toxicity value is greater than 1, again with a confidence level consistent with the levels that can be achieved with the existing state of chemical constituent risk assessment methodologies, then that exposure would be of concern.

Lead Risk Evaluations. A separate model will be developed for risks from potential exposures to lead. Blood-lead levels for potentially exposed receptors will be compared with a selected action level. EPA typically considers that action may be warranted if the 95th percentile of blood-lead levels exceeds 10 μg/dL (i.e., action may be considered if there is a 5 percent chance that a sensitive receptor exposed to lead would have a blood-lead level greater than 10 μg/dL). To be health protective, predicted blood-lead levels exceeding this criterion would be noted for receptors at each facility.

To accommodate this method in the SI Study requires integrating potential lead exposures calculated by the 3MRA model with the EPA model used to estimate blood-lead levels corresponding to different levels of exposure and then comparing the predicted blood-lead levels with a selected action level. A suggested approach to implement this method would be to use the 3MRA model to estimate multimedia lead exposure point concentrations and evaluate risks to children using EPA's Integrated Exposure and Uptake Biokinetic (IEUBK) Model (U.S. EPA,

1994a). The IEUBK Model combines estimates of environmental exposures with pharmocokinetic modeling to predict blood-lead levels in children. Blood lead levels could also be estimated using an EPA method for estimating adult blood lead levels.

Infant Risks. Risk to infants will be estimated only for exposures to dioxin and dioxin-like compounds via the breast milk pathway. This exposure will be calculated on the basis of the total exposure to the adult (maternal) exposures of each receptor type. The risk will be characterized as a margin of error (MOE) using a measure of background exposures for comparison purposes.

Risk Estimates. Carcinogenic risk estimates and noncarcinogenic HI values will be estimated for each receptor type in each exposure area and, as appropriate, for each exposure route in the vicinity of a facility. In the case of carcinogens (or noncarcinogens where inhalation and ingestion act on the same organ), the individual exposure route risks can be aggregated to estimate the aggregate risks. Each set of risk analyses will provide a determination of the contribution of each exposure pathway and the other dimensions for the SI Study risk analysis.

Individual vs. Population-Weighted Risk Estimates. EPA risk assessments are expected to address or provide descriptions of individual risk and population risk. The estimates of the potential distribution of human health risk will be communicated, or described, in terms of the number of individuals who (currently) have or (in the future) can reasonably be expected to incur risks from the constituents from the impoundments in either the central tendency range or the high end of the estimated risk distribution. The risk summary processor will include the proportion of the population whose exposures are modeled who can reasonably be expected to incur risks above the levels described previously for cancer and noncancer effects, the proportion of people within the modeled exposed population with risks estimated to be above those levels, and pathways, receptors, and age cohorts exceeding identified risk levels.

Population-weighted risk estimates will be produced by multiplying the population estimates for each exposure area to the individual risk estimate and summing the adjusted risk estimates for all exposure areas. Normalized population risk estimates will be provided for each receptor type to provide the distribution of risk across all receptors in the study area. The population-weighted risk estimate is shown as

$$PRr = \sum_{Ne} (Rr,e \times Nr) \; / \; \sum_{Ne} Nr \qquad (3\text{-}1)$$

where

PRr = Population-weighted risk estimate for receptor type r
Rr,e = Risk estimate for receptor type r in exposure area e
Nr = Number of receptors of receptor type r in exposure area e
Ne = Number of exposure areas in the study area.

3.2.3.6 <u>Uncertainty Analysis</u>. Potential sources of uncertainty and variability will be identified and evaluated using a semiquantitative uncertainty analysis. The uncertainty analysis

will provide an evaluation of the variability in the estimated risks and allow the identification of sources of uncertainty that are potentially reducible.

3.2.4 Ecological Health

The ecological risk assessment (ERA) for the SI Study will evaluate the potential for adverse ecological impacts that may occur as result of chemical releases at surface impoundments. The results of this ERA may provide information to assist in evaluating the need for future regulation of surface impoundments. The ERA for the SI Study is consistent with EPA guidance (U.S. EPA, 1998) and, as such, will be structured around the following main sections:

- Problem formulation
- Analysis phase
- Risk characterization.

3.2.4.1 Problem Formulation. The problem formulation establishes the scope of the ERA by (1) ensuring that ecological receptors (e.g., plants, wildlife) likely to be exposed are evaluated and (2) evaluating exposure scenarios relevant to different habitats. The problem formulation for the SI Study will describe the following elements, which are detailed in this section:

- Representative ecological receptors
- Chemicals of potential concern
- Potential and relevant exposure pathways
- Assessment and measurement endpoints.

Representative Ecological Receptors. In general, ecological receptors are species of plants and wildlife that may be exposed and adversely impacted by chemicals released from surface impoundments. The ecological receptors that will be evaluated in this ERA include the following:

- Terrestrial wildlife using habitats at or near surface impoundments can be exposed by either drinking directly from the surface impoundment and/or consuming plants, soil, or prey items that bioaccumulate chemicals present in the impoundment.

- Aquatic plants and other biota may be exposed to chemicals that are transported from surface impoundments to nearby aquatic habitats.

- Vascular plants and other terrestrial biota may be exposed to chemicals that are transported from the surface impoundment to nearby terrestrial habitats (e.g., surficial soils).

Because all potentially affected species cannot be individually assessed, ecological receptors will be identified by organizing potentially affected plants and wildlife into guilds of taxonomically and functionally related organisms (e.g., herbivorous birds, insectivorous birds,

carnivorous mammals). Receptors will be selected to represent each guild based on taxonomic relatedness, function in the ecosystem, and availability of wildlife exposure factors and toxicity data. For example, the American robin may be selected to represent insectivorous birds at an impoundment because (1) it is a bird, (2) it eats insects and worms, (3) it is one of many thrushes observed at or near the impoundment, and (4) wildlife exposure factors have been established (U.S. EPA, 1993d).

For the SI Study, a 2-km radius around the impoundment is considered a conservative estimate of the habitat area in which receptors may be affected by the surface impoundment. Habitats within the 2-km radius of the site will be characterized and assigned based on site-specific and regional data. Risks to aquatic biota (i.e., fish and aquatic invertebrates) living in surface impoundments will not be evaluated in the SI Study since impoundments are expected to provide poor habitat for these organisms, and impoundments are not intended to support freshwater aquatic biota. Habitats that will be considered in the SI Study include

Terrestrial Habitats

- Grasslands
- Shrub/scrub
- Forest
- Crop fields and pastures
- Residential

Freshwater Habitats

- Rivers/streams
- Ponds
- Lakes

Wetland Habitats

- Permanently or intermittently flooded grassland
- Permanently or intermittently flooded shrub/scrub
- Permanently or intermittently flooded forest.

These habitats are intended to represent habitats across the United States that may be found at or near surface impoundments and that support wildlife receptors. Although estuarine and marine ecosystems may potentially be impacted, evaluating these systems would require substantial effort in data collection on estuarine receptors (e.g., ecotoxicity data) as well as in adapting the multimedia modeling construct to simulate the complex environmental behavior of chemicals in the brackish and marine waters of estuarine systems. Currently, there is no system developed to support this type of assessment; as such, these habitats will not be included in the analyses.

Once site-specific habitats are identified, representative ecological receptors will be assigned to appropriate habitats based on documented foraging and feeding behavior and habitat

usage. Representative ecological receptors for the following groups of taxa will be used to populate habitats:

Terrestrial Habitats

- Terrestrial plants
- Soil invertebrates
- Reptiles
- Herbivorous birds, soil invertebrate-consuming birds, and carnivorous birds
- Herbivorous mammals, soil invertebrate-consuming mammals, and carnivorous mammals

Freshwater Habitats

- Aquatic plants
- Aquatic invertebrates
- Benthic invertebrates
- Fish
- Amphibians
- Herbivorous birds, benthic invertebrate-consuming birds, piscivorous birds, and carnivorous birds (including migratory birds and waterfowl)
- Herbivorous mammals, benthic invertebrate-consuming mammals, and carnivorous mammals

Wetland Habitats

- Wetland plants
- Hydric soil-associated invertebrates
- Aquatic invertebrates (permanently flooded wetlands only)
- Fish (permanently flooded wetlands only)
- Amphibians

- Reptiles
- Herbivorous birds, invertebrate-consuming birds, and carnivorous birds (including migratory birds and waterfowl)
- Herbivorous mammals, piscivorous mammals, and carnivorous mammals.

Chemicals of Potential Concern. Chemicals of potential concern are detected chemicals in exposure media (e.g., soil, surface water, prey tissue) that may adversely impact ecological receptors. Specific COPCs within the study scope are discussed in Section 3.2.3.1.

Ecological Exposure Pathways. The complete exposure pathways to be evaluated in this analysis must conform to the following elements:

- A source and mechanism of COPC release
- A transport medium
- A point or area where ecological receptors may be exposed to COPCs
- An exposure route through which COPC uptake occurs.

Figure 3-4 graphically presents the risk conceptual model and potentially complete exposure pathways for ecological receptors. Table 3-5 lists the media and exposure routes that will be evaluated in the analysis.

Direct contact to COPCs by terrestrial wildlife will not be evaluated because (1) dense undercoats or down effectively prevents chemicals from reaching the skin of wildlife species and significantly reduces the total surface area of exposed skin (Peterle, 1991; U.S. ACE, 1996) and (2) results of exposure studies indicate that exposures due to dermal absorption are insignificant compared to ingestion for terrestrial wildlife (Peterle, 1991). Similarly, inhalation of volatile organic chemicals (VOCs) will not be evaluated because (1) concentrations of volatile chemicals released from soil to aboveground air are drastically reduced, even near the soil surface (U.S. ACE, 1996) and (2) VOC concentrations in soils would have to be great to induce noncarcinogenic effects in wildlife based on inhalation toxicity data for laboratory rats and mice (U.S. ACE, 1996). In addition, availability of inhalation benchmarks for ecological receptors is limited.

Assessment and Measurement Endpoints. Assessment endpoints describe attributes of ecological receptors that are considered environmentally important and that reflect environmental values to be protected. Assessment endpoints are selected to reflect regulatory and policy goals as well as the environmental conditions addressed by the risk assessment. In selecting assessment endpoints, it is crucial to establish the relationship between the assessment endpoints (i.e., the ecological values to be protected) and the measures of effect (e.g., the ecotoxicity data used to support benchmarks). The measures of effect generally reflect toxicity to individual organisms while the assessment endpoints represent ecological values that go beyond the individual receptor.

Table 3-5. Ecological Exposure Routes Evaluated by Receptor Type

Receptor	Root Uptake		Direct Contact			Ingestion		
	Surface Water	Soil	Surface Water	Sediment	Soil	Surface Water	Soil	Food
Plants								
Aquatic plants	x							
Terrestrial plants		x						
Invertebrates								
Aquatic invertebrates			x					
Sediment-associated invertebrates				x				
Soil invertebrates					x			
Wildlife								
Fish			x					
Amphibians			x					
Reptiles						x	x	x
Birds						x	x	x
Mammals						x	x	x

Assessment endpoints are defined based on the identification of potentially exposed ecological receptors and potentially complete exposure pathways. Development of assessment endpoints is based on the assumption that protection of a population or community can be inferred from protection of developmental and reproductive functions in individuals. Toxicity endpoints that can reasonably be assumed to influence the potential of a population to sustain itself (e.g., developmental and reproductive effects) are used to infer a level of protection to populations. This inference, however, has yet to be validated from field or microcosm studies on exposed populations. This is currently a limitation in the state-of-the-science and limits our ability to interpret ecological risk results.

3.2.4.2 Analysis. The analysis phase for the SI Study will estimate COPC exposures and establish toxicity benchmarks for ecological receptors.

Exposure Assessment. Estimates of exposure (doses or medium concentrations) for each representative receptor will be calculated according to EPA guidance (U.S. EPA, 1993d).

Exposure Point Concentrations. Concentrations in accessible media (including food items) are needed to estimate exposures to representative species. Because the risk assessment is intended to be an evaluation of receptors at large (rather than of the maximally exposed receptor), estimates of the mean exposure point concentrations in accessible environmental media will be predicted using the 3MRA fate and transport models described in Section 3.3.

For receptors that receive significant exposures through their food, simple food webs will be constructed to show the major trophic levels and pathways through which chemicals are transferred up the food chain. Estimates of COPC concentrations in terrestrial and aquatic food items will be calculated using COPC concentrations in environmental media and biological uptake factors such as bioaccumulation factors, bioconcentration factors, and biotransfer factors. Estimates of exposure will include evaluations of spatial and temporal variability in exposure point concentrations.

Wildlife Exposure Factors. Species-specific wildlife exposure factors will be established for each representative receptor. These factors include body weight; food, soil, and water ingestion rates; dietary preferences; and foraging range. For receptors with foraging areas smaller than the habitat, the foraging area will be randomly located within the habitat boundaries. For receptors with foraging areas larger than the habitat, the estimated dose is weighted as the ratio of the habitat area to the foraging area (habitat area/foraging area). This weighting is used to adjust the dose for the fraction of the receptor's diet taken from the habitat that is potentially affected by the surface impoundment.

The exposure assessment will include an algorithm to construct a unique, randomly selected diet for each receptor species at each site where it occurs, thus reflecting the variability in receptor species' dietary composition. The algorithm requires dietary preference data consisting of a list of potential diet items for each species and the maximum and minimum proportion of the species' diet that each item can constitute. The prey preference algorithm ranks diet items by maximum potential dietary fraction, and then constructs the diet from these ranges, starting with the most preferred food item (largest maximum) and randomly selecting dietary fractions from within the given ranges. The dietary composition is habitat-specific because the same species (e.g., raccoon) may be assigned to aquatic and terrestrial habitats, resulting in different dietary preferences.

Because the risk assessment is intended to be an evaluation of receptors at large (rather than of the maximally exposed receptor), estimates of the mean wildlife exposure factors will be used in the SI Study. Ingestion rates are a function of body weight and, thus, will also reflect central tendency values.

Effects Assessment. Ecological benchmarks based on the toxicological effects of chemicals on representative ecological receptors will be used to evaluate whether estimated exposures are likely to result in adverse ecological effects. Population-level effects will be inferred from benchmarks developed from toxicity studies examining reproductive, developmental, or mortality endpoints. Community-level effects will be inferred from toxicity benchmarks established to protect a specified percentage of the community (e.g., ambient water quality criteria).

Benchmark Development. The specific methods used to calculate the protective level (i.e., benchmarks and chemical stressor concentration limits [CSCLs]) are taken from the HWIR methodology and vary with the receptor taxa.[3] For the HWIR analysis, protective CSCLs were derived (in ppm) for specific communities and populations in direct contact with contaminated media (i.e., terrestrial plants, soil biota, sediment biota, fish/aquatic invertebrates, and herpetofauna). Protective benchmark doses (mg/kg-d) were developed for mammals and birds based on exposure through the food web by ingestion of contaminated prey items.

Ecological Benchmarks for Representative Receptors (ChemEBRec). Ecological benchmarks (EBs), derived in units of dose (mg/kg-d), were developed for representative taxa of mammals and birds. The EBs were appropriate for upper-trophic-level consumers because the primary exposure route occurs through ingestion of contaminated prey items. The approach adopted for HWIR uses a hierarchy for the selection of ecotoxicity data and extrapolates from a test species to the species of interest (in this case, wildlife).

Benchmark studies for mammals and birds were selected using a few key guidelines. These guidelines represent the minimum requirements for a study to be of sufficient rigor for benchmark derivation.

- *Measurement Endpoints*—Studies containing measurement endpoints reported as either a no-observed-adverse-effect level (NOAEL) or a lowest-observed-adverse-effect level (LOAEL) in units of daily dose were preferred. From these results, the geometric mean between the NOAEL and the LOAEL (i.e., maximum acceptable toxicant concentration [MATC]) was calculated. The MATC was the preferred benchmark for representative mammalian and avian species.

- *Toxicity Endpoints*—Because population viability in mammals and birds was selected as the assessment endpoint, the benchmarks were developed from toxicity endpoints of reproductive or developmental success or, if unavailable, other effects that could conceivably impair population dynamics.

- *Methods*—No specific test methodologies were required in studies used for benchmark derivation. Standard laboratory practices (e.g., control dose groups), however, were required. Field data may not be appropriate to develop a daily dose exposure.

- *Receptor Requirements*—Ecotoxicity data for wildlife species were preferred (e.g., mallards or mink); however, because of the paucity of studies exposing wildlife species, rats and mice were typically the surrogate species exposed in benchmark studies.

[3] For this analysis, CSCLs refer to constituent concentrations (e.g., mg/kg soil) in environmental media that are presumed to cause de minimis effects on ecological receptors. Benchmarks, in mg/kg-d, provide protective ingestion doses that are estimated to cause de minimis effects to mammalian and avian receptors.

- *Durations*—Studies were selected that reflected chronic or subchronic exposure durations extending over a large percentage of the test species' lifetime, over multiple generations, or over a particularly sensitive life stage of a species.

- *Exposure Routes*—Studies indicating oral exposure (e.g., dietary, gavage) were preferred to studies using other exposure routes (e.g., intraperitoneal injection). Mammals and birds in the field are typically more highly exposed through ingestion of contaminated prey than through inhalation or direct contact, although there are exceptions (e.g., burrowing animals).

- *Dosing Scheme*—Dose-response curves characterized by at least three data points were selected over studies exposing animals to one dose level. This helped identify both a NOAEL and a LOAEL for MATC calculations.

Mammalian and avian benchmarks represent population-inference benchmarks. By developing benchmarks from NOAELs and LOAELs in mammals and birds, benchmarks were estimated to provide protection from ingested doses that may inhibit the reproductive capacities of these populations. The ability of the population to sustain itself (within normal biological variation) was inferred from individual effects such as fecundity. This inference, however, has yet to be validated from field or microcosm studies on exposed populations. Without validation, it is likely that some benchmarks are overprotective and others are underprotective of wildlife populations. Although this method does not confirm protection of populations, by protecting individuals from adverse effects to reproductive and developmental endpoints, some level of protection is provided to populations.

Once the benchmark study was identified, a scaled benchmark was calculated for representative receptors of mammals. This method used an allometric scaling equation based on body weight to extrapolate test species doses to estimate wildlife species doses. For mammals, a scaling factor of 3/4 was used (Equation 3-2). This is the default methodology EPA proposes for carcinogenicity assessments and reportable quantity documents for adjusting animal data to an equivalent human dose (U.S. EPA, 1992b). For birds, recent research suggests that the cross-species scaling equation used for mammals is not appropriate for avian species (Mineau et al., 1996). Using a database that characterized acute toxicity of pesticides to avian receptors of various body weights, Mineau et al. (1996) concluded that applying mammalian scaling equations may not sufficiently predict protective doses for avian species. Benchmarks scaled for small-bodied avian species using the mammalian equation generated scaled doses that were not protective enough for small birds. Mineau et al. (1996) suggested that a scaling factor of 1 provided a better dose estimate for birds. Therefore, a scaling factor of 1 was applied for avian receptors (Equation 3-3).

$$EB_w = MATC_t \, x \left(\frac{bw_t}{bw_w} \right)^{1/4} \qquad (3\text{-}1)$$

$$EB_w = MATC_t x \left(\frac{bw_t}{bw_w} \right)^0 \quad (3\text{-}2)$$

where

EB_w	=	scaled ecological benchmark for species w (mg/kg-d)
$MATC_t$	=	maximum acceptable toxicant concentration (mg/kg-d)
bw_t	=	body weight of the surrogate test species (kg)
bw_w	=	body weight of the representative wildlife species (kg).

Total Surface Water CSCLs. The CSCLs developed for surface water based on total concentrations of the constituent covered the following receptor taxa: freshwater community (i.e., fish and aquatic invertebrates), algae/aquatic plants, and herpetofauna.[4] The methods used to derive CSCLs are reviewed here for each receptor taxon. The CSCL developed for the freshwater community was derived to reflect both total and dissolved water concentrations.

Freshwater community – The freshwater community CSCL was developed to protect species of fish and aquatic invertebrates. The CSCL does not extend to protect species of mammals and birds that may forage in freshwater ecosystems. The methods adopted to develop freshwater community CSCLs are consistent with those supported across EPA offices. The CSCLs were derived using methodologies founded through the development of the National Ambient Water Quality Criteria (NAWQC). These methods require the compilation of appropriate acute and chronic ecotoxicity data reporting effects to survival, growth, and reproduction in aquatic biota for specific members of the freshwater community. The NAWQC method uses a list of ecotoxicity data requirements for eight taxonomic families that represent typical freshwater species (see text box). Whether a final chronic value (FCV) or a secondary chronic value (SCV) is calculated depends on how well the eight taxonomic families are represented by the data.

Data Requirements for FCV Calculation

- The family *Salmonidae* in the class Osteichthyes
- One other family (preferably a commercially or recreationally important warmwater species) in the class Osteichthyes (e.g., bluegill, channel catfish)
- A third family in the phylum Chordata (e.g., fish, amphibian)
- A planktonic crustacean (e.g., a cladoceran, copepod)
- A benthic crustacean (e.g., ostracod, isopod, amphipod)
- An insect (e.g., mayfly, dragonfly, damselfly, stonefly, midge)
- A family in a phylum other than Arthropoda or Chordata (e.g., Rotifera, Annelida, Mollusca)
- A family in any order of insect or any phylum not already presented.

[4] Herpetofauna includes species of amphibians and reptiles. Insufficient ecotoxicity data were identified to derive CSCLs for reptiles. Therefore, continued discussions only review amphibians.

For populations of the freshwater community (e.g., fish, aquatic invertebrates), the FCV developed for the NAWQC or the criterion continuous concentration (CCC) developed for the Great Lakes Water Quality Initiative (GLWQI) was the preferred CSCL to use for this analysis (U.S. EPA, 1995a, 1996f). If neither a CCC nor an FCV was available, an SCV was calculated using Tier II methods developed through the GLWQI (Stephan et al., 1985; Suter and Tsao, 1996).

Algae and aquatic plants – For algae and aquatic plants, toxicological benchmarks were identified in the open literature or from data compiled in *Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision* (Suter and Tsao, 1996). For most contaminants, studies were not available for aquatic vascular plants, but lowest-effects concentrations were identified for algae. The criteria for algae and aquatic plants were based on a lowest-observed-effect concentration (LOEC) for vascular aquatic plants or an effective concentration (EC_{xx}) for a species of freshwater algae, frequently a species of green algae (e.g., *Selenastrum capricornutum*). Because of the lack of data in this receptor group and the differences between vascular aquatic plants and algae sensitivity, usually the lowest value of those identified was used. In instances where only a median effective concentration (EC_{50}) was identified to characterize effects to algae growth and survival, a safety factor of 5 was applied to generate an estimated low effects concentration.

Amphibians – Amphibians appear to be highly sensitive to a number of toxicants (e.g., trace metals) during the developmental stages of their life cycle. Amphibians are essential parts of a number of food webs (particularly wetlands) and are likely to provide a fairly sensitive indicator for chemical stressors relevant to higher levels of biological organization. Though amphibians are a significant ecological receptor, ecotoxicity data characterizing the chronic dose-response relationship for chemicals of concern are limited. After a review of several compendia presenting amphibian ecotoxicity data (e.g., Devillers and Exbrayat, 1992; Power et al., 1989; U.S. EPA, 1996g) as well as primary literature sources, no suitable subchronic or chronic studies were identified that reported effects to reproductive or developmental endpoints in amphibian species. Therefore, a CSCL based on chronic endpoints and exposure durations was not derived. Instead, the CSCL was developed from a geometric mean of acute (i.e., LC_{50}, lethal water concentration resulting in 50 percent mortality) amphibian ecotoxicity data. A few general guidelines were followed in selecting analogous acute studies for developing the CSCL:

- Test duration was usually less than 15 d.
- Toxicity endpoints included mortality (LC_{50})
- Exposure occurred during early life stages (i.e., embryo, larvae, and tadpole).

Because the criteria are based on acute data (i.e., lethality), the severity of the potential adverse effects that this criterion indicates is significant. Incorporating the amphibian data into the NAWQC within the data requirement categories is currently under consideration. Because amphibian species are more likely to breed in standing waters such as wetlands, ponds, or temporary puddles, the appropriateness of combining protection of amphibian receptors with the freshwater community CSCL is unclear.

Dissolved Surface Water CSCLs. Conversion factors were available for several of the metal constituents to convert total metal concentrations in the water column to total dissolved concentrations (U.S. EPA, 1999y). Although the total concentrations supplied by the NAWQC and GLWQI are still deemed scientifically defensible by EPA, the Agency recommends the use of dissolved metal concentrations when they are available (Prothro, 1993).

Methods are currently available to develop dissolved CSCLs only for metals in the freshwater community. Dissolved CSCLs were derived from total water CSCLs using a conversion factor. The conversion factors applicable to chronic criteria in freshwater are presented in Table 3-6. The conversion factors were developed by EPA using a series of filtration experiments that measured the difference between filtered and unfiltered concentrations of metals in surface waters. Dissolved CSCLs were derived by multiplying the total CSCL by the conversion factor (Equation 3-4).

$$Metal\ CSCL_{dissolved} = (Metal\ CSCL_{total})\ x\ (Conversion\ Factor) \qquad (3\text{-}4)$$

where

Metal CSCL $_{total}$ = either an FCV or an SCV in freshwater
Conversion Factor = the fraction of dissolved metal.

Sediment CSCL. Two methods were applied in developing the CSCL for the benthic community (e.g., worms, amphipods). The first and preferred method used measured sediment concentrations that resulted in minimal effects to the composition and abundance of the sediment community. The sediment criteria were derived from the upper limit of the range of sediment contaminant concentrations that are derived from no-effects data, species diversity, and abundance endpoints. Measurements to derive the CSCLs were taken at the national scale and reflected a variety of sediment types and benthic community species. The second CSCL derivation method used the equilibrium partitioning (EqP) relationship between sediments and surface waters to predict a protective concentration for the benthic community. This method was used only for nonionic organic constituents. For the benthic community, the approach used to establish CSCLs was based on a complete assessment of several sources proposing protective sediment CSCLs. A discussion of each method (i.e., measured and estimated CSCLs) is provided.

Measured sediment CSCLs – The premier sources of measured sediment CSCLs are the National Oceanic and Atmospheric Administration (NOAA) and the Florida Department of Environmental Protection (FDEP) sediment documents. NOAA annually collects and analyzes sediment samples from sites located in coastal marine and estuarine environments throughout the United States as part of the National Status and Trends (NS&T) Program. Data collected by NOAA include measured sediment concentrations and the corresponding measures of toxicity in resident species such as amphipods, arthropods, and bivalves on a variety of community-based endpoints (e.g., abundance, mortality, species composition, and species richness). These data are used by NOAA to estimate the 10th percentile effects concentration (ER-L) and a median effects concentration (ER-M) for adverse

Table 3-6. Conversion Factors for Dissolved Metal[a]

Constituent	Conversion Factor
Arsenic	1.00
Cadmium[b]	1.1017-[(ln hardness)(0.04184)]
Chromium III[b]	0.860
Chromium VI	0.960
Lead[b]	1.4620-[(ln hardness)(0.14571)]
Mercury	0.850
Zinc[b]	0.986

[a]Conversion factor for chronic CSCLs in freshwater.
[b]Dependent on the water hardness (assumed to be 100 mg $CaCO_3$/L for this analysis).

effects in the sediment community. These values are not NOAA standards; rather, they are used to rank sites based on the potential for adverse ecological effects. In contrast, the FDEP sediment criteria were developed from the ER-L and ER-M data to approximate a probable effects level (PEL, estimated from ER-M data) and a threshold effects level (TEL, estimated from ER-L data). PELs and TELs correspond to the statistically derived upper limit of contaminated sediment concentrations that demonstrate probable effects and no effects to the benthic community, respectively. Generally, FDEP values are more conservative than NOAA values. Even though these criteria were developed for a marine community, researchers have demonstrated that marine TELs have good correlation with no-effects levels found for freshwater systems (Smith et al., 1996). In order of preference, TELs were adopted as CSCLs if available; if not, ER-L values were used. The FDEP criteria were chosen above the NOAA criteria for the following reasons:

- The same database was used for both the NOAA criteria and the FDEP criteria development.
- In most cases, the FDEP criteria were more conservative than the NOAA criteria because a larger portion of the low-effects data was used in benchmark development.
- The marine TELs developed by the FDEP were found to be analogous to TELs observed in freshwater organisms (Smith et al., 1996).

Estimated sediment CSCLs. When measured effects data were not available for organic constituents using the TEL or ER-L approach, the value was derived using the EqP approach to estimate the sediment CSCL (U.S. EPA, 1993c). The surface water FCV or SCV was used to generate a sediment CSCL using the partitioning relationships among surface water, pore water,

and organic carbon in sediment. This method assumes that the equilibrium partitioning between the sediment and the water column is a function of the organic carbon. Equations 3-5 and 3-6 were used to calculate the sediment CSCL depending on whether an FCV or an SCV was available. In calculating sediment CSCL for nonionic chemicals, the fraction organic carbon (f_{oc}) was assumed to be 1 percent total organic carbon and K_{oc}s (organic carbon partitioning coefficients) were adopted as reported in Jones et al. (1997). However, because sediment CSCLs were derived for organic constituents based on site-specific f_{oc}, some of the CSCLs were recalculated within the HWIR modeling framework on a site-specific basis.

$$Sediment\ CSCL = f_{oc} \times K_{oc} \times FCV \tag{3-5}$$

$$Sediment\ CSCL = f_{oc} \times K_{oc} \times SCV \tag{3-6}$$

Soil CSCLs. Soil CSCLs were derived for the terrestrial plant community and the soil community. Each of the specific methods, including the rationale and the derivation methods, is outlined in the following sections.

Terrestrial plants – For the terrestrial plant community, toxicological benchmarks were identified from a summary document prepared at the Oak Ridge National Laboratory (ORNL): *Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Terrestrial Plants: 1997 Revision* (Efroymson et al., 1997). The measurement endpoints were generally limited to growth and yield parameters for the following reasons:

- They are the most common class of responses reported in phytotoxicity studies and, therefore, allow for criterion calculations for a large number of constituents.
- They are ecologically significant responses, both in terms of plant populations and, by extension, the ability of producers to support higher trophic levels.

As presented in Efroymson et al. (1997), criteria for phytotoxicity were selected by rank-ordering the LOEC values and then approximating the 10th percentile. If there were 10 or fewer values for a chemical, the lowest LOEC was used. If there were more than 10 values, the 10th percentile LOEC was used.

Soil community – Two methods were used in deriving soil community CSCLs: a community-based CSCL and an earthworm/microbial CSCL.

- **Community-Based CSCL**—The first, and preferred, method was based on a community-level approach similar to that applied in deriving the NAWQC. This method developed a CSCL based on NOECs to reproductive and development endpoints in a number of key functional taxa in the soil community. The CSCL was designed to protect the structure and function of the soil community and its critical role in the overall nutrient processing that occurs in the terrestrial food web.

Two key uncertainties were noted in the development of community-based CSCLs. First, the ecotoxicity data used in the method are based on NOECs. The CSCLs developed using the earthworm/microbial method for the soil community were based on low-effects levels. Because these CSCLs are based on no-effects soil concentrations, some added conservatism was generated in the soil community CSCLs for lead and cadmium. Second, the species taxa groups designed to represent key compartments in the soil community did not include microbes. This introduces some uncertainty in the soil CSCL because microflora make up approximately 80 to 90 percent of the biomass in soil and microflora are responsible for the majority of the biological activity in soil (e.g., N mineralization).

Earthworm and Microbial CSCLs—The second method used to derive soil CSCLs required the identification of LOECs for earthworms and microbial endpoints. However, because a single species alone cannot predict the potential toxicological impacts to the soil community, the community-based method was preferred over using an earthworm or microbial CSCL.

Earthworms have been recognized to play important roles in promoting soil fertility, releasing nutrients, and providing aeration and aggregation of soil, as well as being an important food source for higher trophic level organisms. In addition, their constant contact with soil media and permeable epidermis makes them more susceptible to contaminant exposures. Likewise, microbial communities play a key functional role in soil fertility, decomposition processes, and nutrient cycling, providing nutrients in available forms to plants. Microbial CSCLs were only used when they indicated a significantly higher sensitivity to a particular constituent than the corresponding earthworm toxicity data.

The earthworm and microbial CSCLs were developed using the ER-L approach, which was also applied to develop terrestrial plant CSCLs. When more than 10 studies were identified reporting LOECs, then the 10th percentile of the values was derived as the CSCL. When less than 10 values were identified, however, the lowest LOEC was selected as the CSCL.

3.2.4.3 Risk Characterization. Risk characterization integrates the results of the analysis phase to evaluate the likelihood of adverse ecological impacts associated with exposures to COPCs (U.S. EPA, 1992b). The potential for adverse ecological impacts will be characterized using hazard quotients HQs. HQ is the ratio of the estimated exposure dose to the toxicity benchmark for ecological receptors:

An HQ less than 1 (HQ < 1) indicates a negligible potential for adverse ecological impacts due to exposure to a particular COPC; whereas, an HQ of 1 or greater (HQ $\geq$ 1) indicates a potential for adverse ecological impacts due to exposure to a particular COPC.

Risk results will be considered in the context of two additional site-specific

$$Hazard\ Quotient = \frac{Estimated\ Exposure\ Dose}{Toxicity\ Benchmark}. \qquad (3\text{-}7)$$

characteristics:

- # Presence or proximity of managed areas (e.g., state or national parks, wildlife refuges, or wild and scenic rivers
- # Presence or proximity of federally listed threatened or endangered (T&E) species.

Locations of managed areas will be determined using the Managed Area Database. At sites where significant managed areas are potentially impacted, ecological risks may be considered greater than equivalent risks at other sites. Presence of T&E species can be determined from U.S. Fish and Wildlife Service (U.S. FWS) data or from State Natural Heritage Program data. In either case, precise locations of T&E populations are not likely to be available. Therefore, the significance of relevant T&E documentation will be weighed on a case-by-case basis.

Uncertainty Analysis. Where wildlife exposure factors, biological uptake factors, and/or toxicity benchmarks are not available, HQs will not be evaluated. Representative ecological receptors and chemicals that cannot be assessed using HQs will be identified. A methodology for a qualitative analysis of uncertainty was developed for the HWIR analysis and will be applied to the surface impoundments ecological risk assessment.

For ecological risks, the constituent-specific concentrations in wastes generated in the HWIR assessment that are determined to pose de minimis risk (i.e., the exemption criteria) were based on two types of risk metrics: (1) the ecological hazard quotient, that is, the ratio between exposure concentrations or dose and appropriate ecological benchmarks,[5] and (2) the probability of protection for ecological receptors. However, the ecological benchmarks include a variety of receptors (e.g., soil fauna, mammals, plants), and, because the quality and quantity of relevant data vary widely across receptors, the ecological exemption criteria represent different levels of knowledge regarding the exposure and toxicity of chemical stressors. The variability in supporting data suggests that the level of confidence in the exemption criteria is dependent on the quantity and quality of available data. In short, the ecological exemption criteria do not reflect a standard data set; rather, they reflect a continuum of data on toxicity and exposure (e.g., bioaccumulation factors) of varying levels of quality. To provide an effective tool to characterize where on the continuum a given exemption criterion falls, a framework was developed to assign confidence indicators based on the sufficiency of the data set supporting an exemption criterion. Sufficiency, in this framework, is determined according to how well an exemption criterion (1) captures risks to all relevant receptor groups in a habitat, (2) is supported by ecotoxicity data of high quality, and (3) represents all significant routes of exposure to ecological receptors. Consequently, the confidence indicators reflect all three of these "attributes" of an ecological exemption criterion.

[5] The term "ecological benchmarks" is used here in a broad sense to refer to two descriptors that were used to identify protective levels: ecotoxicological benchmarks and chemical stressor concentration limits. Briefly, this distinction was made to clearly represent the differences in the level of biological organization. Ecotoxicological benchmarks are threshold doses intended to protect wildlife populations from significant adverse effects from the ingestion of contaminated media and prey and are expressed in units of mg/kg-d. In contrast, chemical stressor concentration limits are medium-specific concentrations (e.g., sediment) intended to protect assemblages of species in contact with a contaminated medium.

The development of confidence indicators must address the completeness of the data set with regard to receptors of concern (in each type of habitat), as well as the confidence in data on toxicity and on uptake and accumulation. Consequently, the confidence indicator consists of three parts: (1) the habitat confidence indicator, (2) the benchmark confidence indicator, and (3) the exposure confidence indicator. A brief discussion is provided here of each of these three parts; a more extensive treatment of the confidence indicators and methods used in their development is provided in *Data Requirements and Confidence Indicators for Ecological Benchmarks Supporting Exemption Criteria for the Hazardous Waste Identification Rule (HWIR99)* (U.S.EPA, 1999z).

Habitat Confidence Indicator. The confidence indicator for habitats is a qualitative statement used to convey the relationship between chemical properties and data availability on receptor groups in terrestrial and aquatic habitats, respectively. For example, to achieve a high level of confidence in assessing a persistent, bioaccumulative constituent, we would require ecotoxicological data on all receptor groups assigned to a habitat. In contrast, we may achieve a high level of confidence in assessing a readily biodegradable constituent that does not bioaccumulate with data on fewer receptor groups because: (1) the spatial impact of the constituent will be extremely limited by rapid breakdown (assuming nontoxic daughter products) and (2) food web exposures are unlikely to be significant. Three habitat confidence indicators were used to establish the data requirements for all combinations of persistence and bioaccumulation potential: "A" indicates high confidence, "B" indicates moderate confidence, and "C" indicates low confidence in the data set. Hence, a habitat confidence indicator of "B" means that, given the persistence and bioaccumulation rating for the constituent, there is moderate confidence in the ability of the data set to assess all appropriate receptors. To afford the maximum flexibility in this indicator, terrestrial and aquatic habitat indicators are reported separately for each constituent.

Benchmark Confidence Indicator. The secondary confidence indicator reflects specific criteria for ecotoxicological data used to develop ecological benchmarks (EBs) and chemical stressor concentration limits (CSCLs). For each EB and CSCL, a data quality confidence indicator was established: a "1" indicates high confidence in the study data, a "2" indicates moderate confidence in the study data, and a "3" indicates low confidence in the study data. For those receptors for which data are available, an average confidence indicator is calculated and assigned to the exemption criterion for the terrestrial and aquatic habitats, as appropriate. This is a critical distinction in interpreting the benchmark confidence indicator. The indicator only refers to the confidence in those data that were actually used to support the development of EBs and CSCLs; it does not address the quantity of receptors for which data are available. For instance, a confidence indicator of "C1" for an aquatic habitat means that, although we have low confidence in the data set to represent a sufficient number of receptors in freshwater systems, we have high confidence in the benchmarks (or CSCLs) that were developed.

Exposure Confidence Indicator. The tertiary confidence indicator reflects the quality of the data and models that are available to predict exposures through the food chain. In addition, this indicator also acknowledges the importance of these pathways given the bioaccumulation potential and persistence of a constituent. For instance, lack of empirical data on bioaccumulation for a constituent rated as having low potential for bioaccumulation should not necessarily result in a lower indicator of confidence. If exposure via the food web is determined

to be insignificant, the data requirements on uptake and accumulation in plants and prey may be lower. Thus, the exposure confidence indicator addresses our ability to evaluate the exposure pathways of concern that are likely to be of concern and acknowledges that, for certain constituents, exposure pathways through the food chain may not be completed. A confidence indicator of "exp-1" indicates that we have high confidence in our ability to evaluate relevant exposure pathways. However, this indicator may be applied to bioaccumulative as well as nonbioaccumulative constituents. For example, an overall confidence indicator of "B2exp-1" could describe two different situations: (1) moderate confidence in sufficiency of the data set across receptors as well as in the toxicity data, and high confidence in the bioaccumulation data for use in terrestrial systems, or (2) moderate confidence in sufficiency of the data set across receptors as well as in the toxicity data and low potential for exposure via the food web. In either case, our confidence is high that we are able to evaluate relevant exposure pathways of concern. In contrast, an "exp-3" indicator would suggest that the data/models are insufficient to evaluate potential exposure pathways of concern and that our confidence in the exposure profile is low.

3.2.5 Risk Metrics

Risk metrics for Phase II will be shaped by current capabilities of the 3MRA system, output needs for the SI study, and EPA decisions to modify the 3MRA system. These metrics represent the outputs of the risk analysis. The 3MRA system currently contains the exit level processor to store, process, and display risk metrics. The ELP contains three components:

- The ELP-I reads the human health and ecological risk/hazard results from the human risk and ecological risk modules and stores these results in a series of Risk Summary Output Files (RSOFs).

- The Risk Visualization Processor graphically displays the RSOFs.

- The ELP-II provides chemical-specific waste stream concentrations that meet a prespecified level of protectiveness.

Additional detail on each of these components can be found in U.S. EPA (1999v, 1999w), including example outputs.

Because the objective of the SI study is to characterize risk from impoundments in the SI universe rather than calculate protective waste concentrations, the ELP-II will not be required in its current form. EPA will decide on whether to modify the 3MRA RVP and ELP-II to meet SI Study objectives or develop a different system to process and analyze the 3MRA RSOFs depending on resources and system capabilities.

3.2.5.1 Risk Bins. The Phase II analysis will use the same risk bins as those used in Phase I. This will allow the Phase II results to be used to update risk bins used in Phase I. The human health risk bins currently under consideration include:

- **Excess Cancer Risk (6 bins):** $< 10^{-8}$, $\geq 10^{-8}$ and $< 10^{-7}$, $\geq 10^{-7}$ and $< 10^{-6}$, $\geq 10^{-6}$ and $< 10^{-5}$, $\geq 10^{-5}$ and $< 10^{-4}$, $\geq 10^{-4}$.

- **Noncancer HI (6 bins, by target organ):** < 0.01, ≥ 0.01and < 0.1, ≥ 0.1 and < 1, ≥ 1 and < 10, ≥ 10 and < 100, ≥ 100).

- **Ecological HQ (5 bins):** < 0.1, ≥ 0.1 and < 1, ≥ 1 and < 10, ≥ 10 and < 100, ≥100).

The current HWIR risk bins are not quite compatible with the bins above - additional resolution is available in the 10^{-7} to 10^{-5} cancer risk range and there are only four human HQ bins. HWIR risk bins are as follows:

- **Excess Cancer Risk (7 bins):** < 10^{-8}, ≥10^{-8} and < 5×10^{-7}, ≥ 5×10^{-7} and < 10^{-6}, ≥ 10^{-6} and < 5×10^{-5},≥ 5×10^{-5} and < 1×10^{-5}, ≥ 10^{-5} and < 10^{-4}, ≥10^{-4}.

- **Noncancer HQ (4 bins, by target organ):** <0.1, ≥0.1 and <1, ≥1 and <10, ≥ 10)

- **Ecological HQ (5 bins):** < 0.1, > 0.1 and < 1, > 1 and < 10, > 10 and < 100, > 100).

However, the number of bins and the bin ranges are specific inputs to the HWIR 3MRA model and can be easily adjusted to meet SI Study objectives.

3.2.5.2 <u>Reporting and Maintenance of Results</u>. As with Phase I, all Phase II risk cumulative probability functions (cdfs) will be reported and maintained according to the SI Study risk attributes:

- Five regulatory status categories
- Three functional classes (storage, treatment, and disposal)
- Ttreatment types (e.g., biological, settling)
- Iindustry types
- Contaminants.

These represent five dimensions by which risk outputs will need to be organized and compiled and will require modifications to the 3MRA system as described below. Additional categories can be included and maintained as necessary (prior to the analysis) to support regulatory decision-making.

Human Health Risk Summary Output. For human risk, the HWIR 3MRA ELP1 stores and maintains, by chemical and WMU type, the number of "site and iteration" pairs that protects at least some percentile of the human population (currently 0%, 5%, 25%, 50%, 75%, 85%, 90%, 95%, 98%, and 99%) for each "risk bin/waste concentration" pair by distance, pathway, receptor, cohort,[6] and critical-year (T_{crit}) method. The ELP2 takes these results and determines the Protective Summary Output File (PSOF) that specifies which waste concentrations will provide risks below the target risk level for the selected 95 percent receptors for the exposure at 80

[6] Note that the 3MRA ELP1 rolls the 5 age cohorts into 4 age cohorts by combining the age 1-6 and 7-12 child age ranges.

percent of the sites. The SI Study does not need this functionality, and, furthermore, needs to segment the SI universe into the five categories or dimensions listed above. For these reasons, a new exit level processor may be needed to produce the human risk summary outputs needed for the SI study.

The population risks estimated across facilities will be summarized for each CWA population. The aggregation will include the facility weighting for the statistically sampled CWA populations (direct and zero dischargers). For each CWA population, multiple ways of viewing the risk summaries may be needed to answer the study objectives. Most of the ways to view the risk summaries, called dimensions, are provided by the existing HWIR model (see above). These include: by exposure pathway, by receptor type, and by chemical. The five additional dimensions needed to address the SI Study study objectives (by regulatory status category, industry, treatment type, and chemical) represent a new functionality that will be needed in the 3MRA ELP. In addition, there may be the need to adjust the 3MRA RVP to graphically display risk summaries for ease of interpretation of SI risk results.

Ecological Risk Summary Output. For ecological risks, the current 3MRA ELP1 produces RSOFs with ecological hazard quotient bins that store, by chemical and WMU type, the number of "site and iteration" pairs that protects at least some percentile of the population for each critical-year method and "hazard-bin/C_w" pair by distance and habitat group, distance and habitat type, distance and receptor group, distance and trophic level, receptor group and habitat group, or trophic level and habitat group. As with the ELP1 human risk RSOFs, these outputs should be adequate for SI Study purposes, but a new ELP2 and possibly RVS will be needed to accommodate the five additional dimensions needed to address the SI Study study objectives.

3.3 Overview of Simulation Modules

The SI Study will use the 3MRA model for the Phase II risk assessment. To address multiple exposure simultaneously, the 3MRA model includes 17 functional modules. Figure 3-13 shows the 14 component modules of the 3MRA model that will be applied to the SI Study risk assessment.[7] These modules are briefly described in this section, with assumptions and limitations, detailed input and output requirements, and functionality provided for each module in Appendix A.

[7] Three 3MRA source modules are not needed for the SI Study risk assessment: landfill, wastepile, and aerated tank.

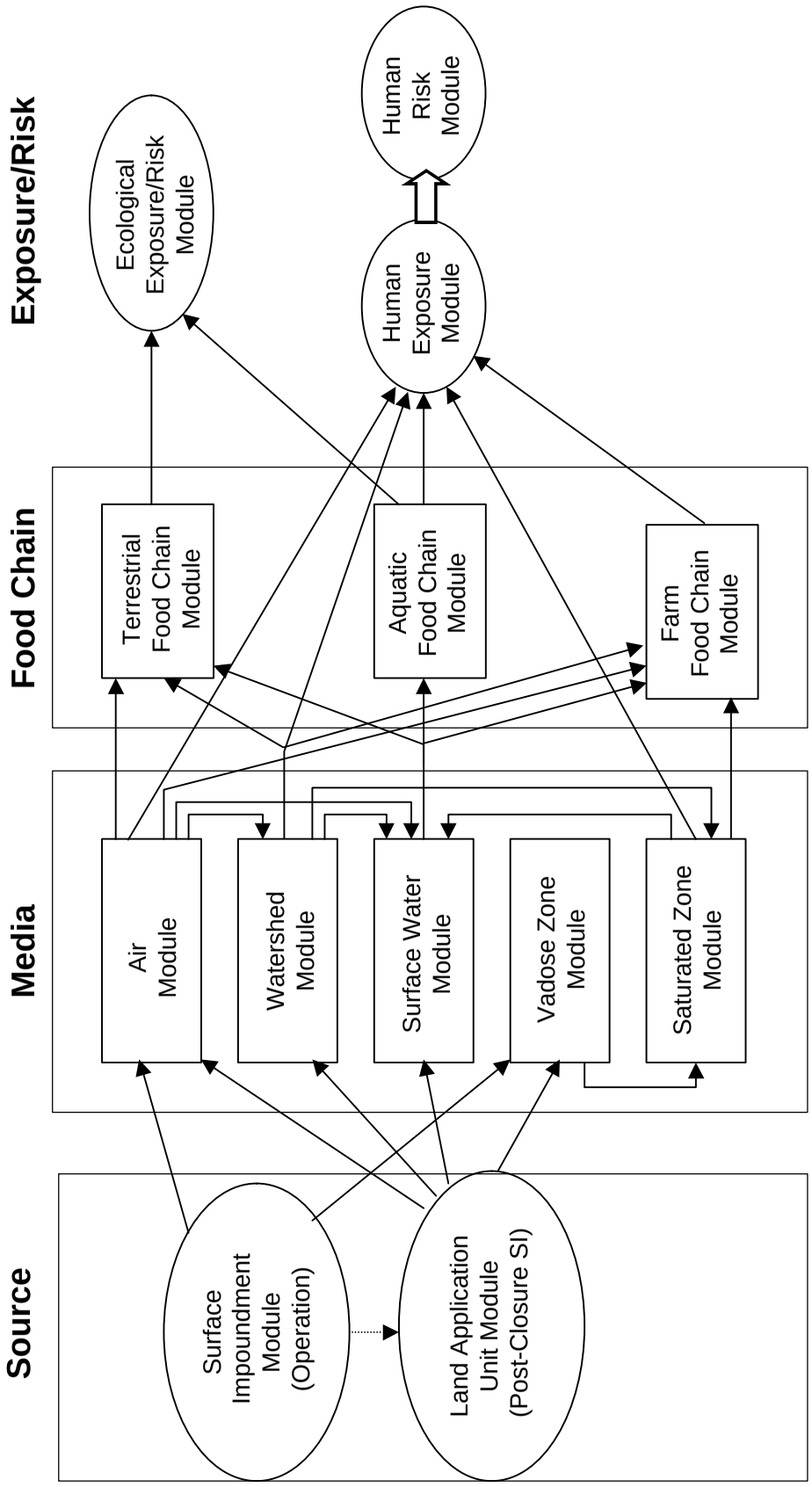


Figure 3-13. Diagram of 3MRA Model as applied to surface impoundments.

3.3.1 Source Modules

The source module employed for the SI Study risk analysis must model multimedia releases both before and after closure of the impoundment. The SI module currently in the 3MRA model only models releases up to closure. For the SI Study risk assessment, sludge from SI operation will be assumed to be left in place after closure where it is subject to volatilization, wind and water erosion, and leaching. Currently, the best option to model these processes is the 3MRA land application unit module, which includes all needed release mechanisms and can be adapted to the SI postclosure scenario simply by adjusting input variables.

The remainder of this section provides an overview of the 3MRA SI and LAU modules to be used in the SI Study risk analysis. This information was extracted and adapted from the HWIR 3MRA background documents for source modules (U.S. EPA, 1999a, 1999b), which contain additional detail, including all assumptions, governing equations, boundary conditions, solution techniques, and supporting references.

3.3.1.1 <u>Overview - SI Operating Module</u>. The SI module divides an operating SI into two primary compartments: a "liquid" compartment and a "sediment" compartment. Mass balances are performed on these primary compartments at time intervals small enough that the hydraulic retention time in the liquid compartment is not significantly impacted by the solids settling and accumulation. Figure 3-14 provides a general schematic of a module construct for an SI.

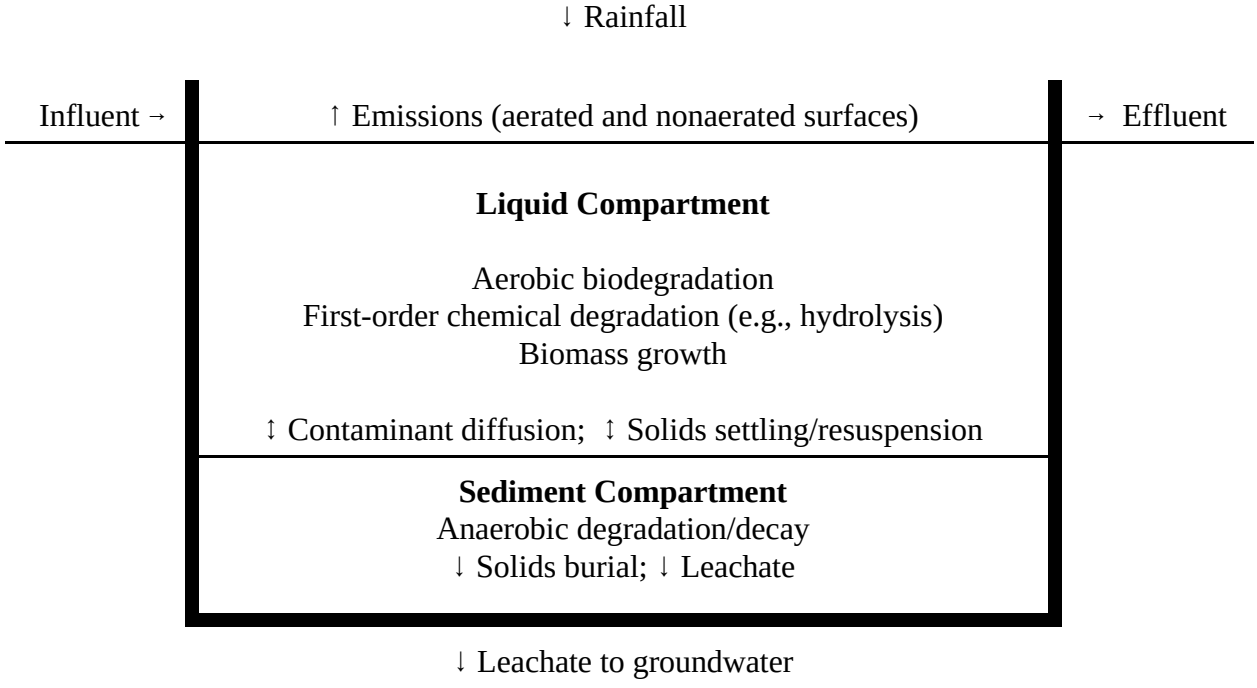


Figure 3-14. Schematic of general surface impoundment module construct.

In the liquid compartment, there is flow both in and out of the waste management unit. There is also a leachate flow to the sediment compartment and out the bottom of the surface impoundment. The leachate flow rate is estimated from liquid depth and from the hydraulic conductivities and thicknesses of the sediment compartment, the clogged native soil layer, and the underlying soil layer.

Within the liquid compartment, there is contaminant loss through volatilization, hydrolysis, biodegradation (presumably aerobic), and particle burial (net sedimentation). The sediment compartment has contaminant losses due to (anaerobic) biodegradation and hydrolysis. Some contaminant mixing between the liquid and sediment compartments occurs due to contaminant diffusion and due to particle sedimentation and resuspension.

Solids generation occurs in the liquid compartment due to biological growth; solids destruction occurs in the sediment compartment due to sludge digestion. Using a well-mixed assumption, the suspended solids concentration within the WMU is assumed to be constant throughout the WMU. However, some stratification of sediment is expected across the length and depth of the WMU so that the effective total suspended solids (TSS) concentration within the tank is assumed to be a function of the WMU's TSS removal efficiency rather than equal to the effluent TSS concentration. The liquid (dissolved) phase contaminant concentration within the tank, however, is assumed to be equal to the effluent dissolved phase concentration (i.e., liquid is well mixed). Consequently, the term "mostly well mixed" describes the liquid compartment.

The procedure used to determine the leaching rate follows the method outlined in *EPA Composite Module for Leachate Migration with Transformation Products (EPACMTP) Background Document* (U.S. EPA, 1996a). There are two important differences: (1) the liquid depth is known and (2) there is a sediment layer between the liquid and the liner.

3.3.1.2 LAU (SI Postclosure) Module. At the end of its operating life, an SI may be closed with sludges removed or in place. After that, remaining contaminants in the sludge and/or subsoil solid matrices are subject to release and migration through leaching, volatilization, erosion, and transport by wind and water. Although the current 3MRA SI module currently cannot model these processes from a solid matrix, the LAU module does, and can be adapted to model the SI post-closure period by modifying the model inputs.

The watershed including an LAU (or postclosure SI) is termed here the “local” watershed and is illustrated in Figure 3-15. A local watershed is defined as that drainage area that just contains the LAU (or a portion thereof — there can be multiple local watersheds where a LAU crosses a drainage divide) in the lateral (perpendicular to runoff flow) direction. The local watershed extends downslope to the point that runoff flows and eroded soil loads would enter a waterbody. Areas downslope of the LAU within the local watershed are subject to chemical contamination from the LAU through overland runoff and soil erosion.

Figure 3-16 illustrates how the local watershed is conceptualized within the LAU module, that is, as a two-dimensional, two-medium system. The dimensions are longitudinal, i.e., downslope or in the direction of runoff flow, and vertical, i.e., through the soil column. The media are the soil column

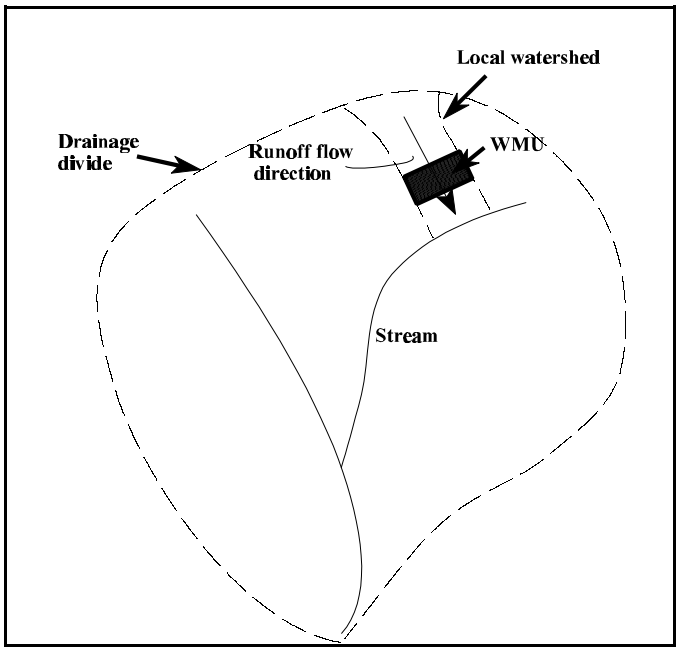


Figure 3-15. Local watershed containing WMU.

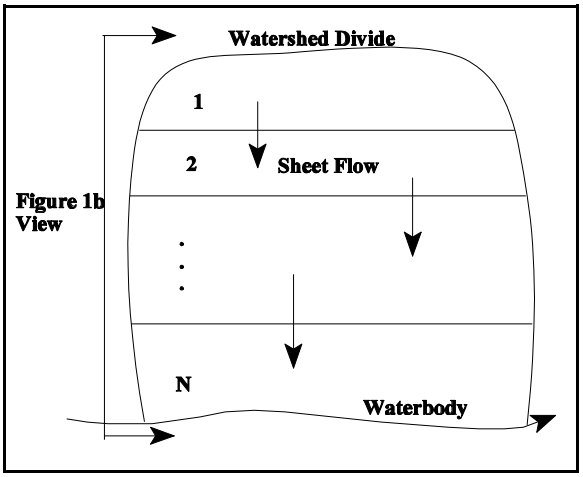


Figure 3-16a. Local watershed.

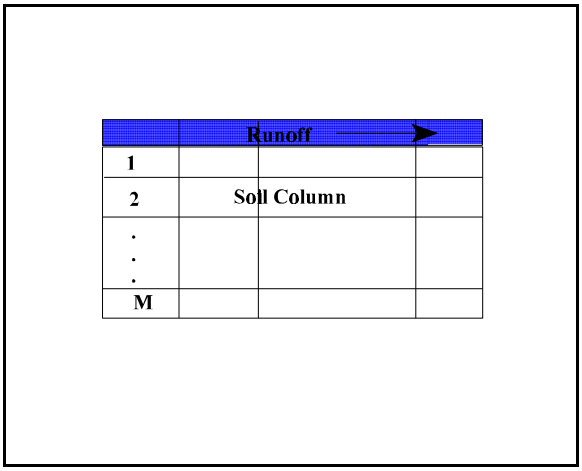


Figure 3-16b. Cross-section view.

and, during runoff events, the overlying runoff water column. The local watershed is assumed to be made up of, in the longitudinal direction, an arbitrary number of land subareas that may have differing surface or subsurface characteristics, e.g., land uses, soil properties, and chemical concentrations. For example, subarea 2 might be a WMU, subarea 1 would then represent an upslope area, and subareas 3 through N would be downslope buffer areas extending to the waterbody.

3.3.2 Air Module

The purpose of the atmospheric modeling for the 3MRA is to estimate, at various receptor points in the area of interest, the annual average air concentration of dispersed constituents (particles and vapors) and the annual deposition rates for vapors and particles. The area of interest is defined by a 2-km radius measured from the edge of the largest area source (WMU) at the site. Additional detail on the air module can be found in U.S. EPA (1999c and 1999d).

The atmospheric module simulates the transport and diffusion of chemical constituents, which are in the form of volatilized gases or fugitive dust emitted from area sources. The simulated air concentrations are used to estimate bio-uptake from plants and human exposures due to direct inhalation. The predicted deposition rates are used to determine chemical loadings to watershed soils, farm crop areas, and surface waters.

The atmospheric concentration and deposition of constituents can be determined in several ways. However, the selected procedure has to be computationally efficient to satisfy the HWIR requirements of numerous simulations within a Monte Carlo framework. Because the modeling is site-based, the steady-state Gaussian plume modeling approach was considered to be appropriate and, the ISCST3 model was selected. The model provides estimates of contaminant concentration, dry deposition (particles only), and wet deposition (particles and gases) for user-specified averaging periods (i.e., annually).

ISCST3 is used as legacy code in the 3MRA framework. That is, the model is left intact and the necessary interfacing to the framework is handled using pre- and postprocessors. Together, the EPA air quality model (ISCST3) and the pre- and postprocessing code that integrates ISCST3 into the 3MRA environment are referred to as the Air Module. The pre- and postprocessing code also provides additional functionality to support other 3MRA framework requirements.

3.3.3 Watershed Module

Chemical mass can be released from a surface impoundment in the form of volatile emissions from an operating impoundment or volatile and particulate emissions from a closed unit (modeled by the source module, Section 3.3.1). These emissions can then be transported and deposited onto the soils of nearby land areas as wet or dry deposition (modeled by the air module, Section 3.3.2). Once deposited, a chemical is then subject to fate and transport processes within the watershed on which it is deposited and it is available either for direct exposure to human or ecological receptors or indirect exposure through a food chain. It is the purpose of the watershed module to model these fate and transport processes. Additional detail, including all governing equations, can be found in U.S. EPA (1999f).

Fate and transport processes simulated by the watershed module are volatilization, leaching, runoff, erosion, and biological and/or chemical degradation. Transport of chemical by runoff and erosion is into adjacent waterbodies. Because the surface transport processes are hydrologically related, the land areas surrounding the surface impoundment are disaggregated

into watershed subbasins. A watershed subbasin can vary in size from a portion of a hillside, similar to the local watershed construct of the land application unit module (see Section 3.3.1.2), to much larger areas encompassing regional stream or river networks. In all cases, a watershed is modeled as a single, homogeneous area with respect to soil characteristics, runoff and erosion characteristics, and chemical concentrations in soil. No spatial disaggregation below the watershed level is made; that is, no spatial chemical concentration gradients are simulated within a given watershed.

3.3.4 Groundwater (Vadose and Aquifer) Modules

The HWIR 3MRA vadose and aquifer modules are a modified version of EPACMTP (U.S. EPA, 1996a,b,c). This code simulates the fate and transport of contaminants released from land-based waste management units through the underlying unsaturated or vadose zone (soil) and saturated zone (surficial aquifer). EPACMTP replaced EPACML (U.S. EPA, 1993a) as the best available tool to predict potential exposure at a downstream receptor well. EPACMTP offers improvements to EPACML by considering: (1) the formation and transport of transformation products; (2) the impact of groundwater mounding on groundwater velocity; (3) finite source as well as continuous source scenarios; and (4) metal transport.

The composite vadose/aquifer model consists of a one-dimensional module that simulates infiltration and dissolved constituent transport through the vadose zone, which is coupled with a three-dimensional saturated zone module. The saturated zone module consists of a three-dimensional groundwater flow submodule and three-dimensional transport submodules. The saturated zone groundwater flow submodule accounts for the effects of leakage from the land disposal unit and regional recharge on the magnitude and direction of groundwater flow. The saturated zone transport submodule accounts for three-dimensional advection and dispersion and linear or nonlinear equilibrium sorption.

Interrelationships between the vadose and saturated zone modules and other modules (through water and chemical mass fluxes) under the 3MRA framework are shown in Figure 3-17. As shown in the figure, the vadose zone module receives infiltration and solute mass fluxes from the source module. The migration of contaminants in the vadose zone is terminated at the water table where the contaminant fluxes, in the form of concentrations, are transferred to the saturated zone module. The SZM also receives areal recharge from the watershed module. The SZM provides time-dependent, annual average contaminant concentrations at receptor wells and annual average contaminant fluxes at an intercepting stream located somewhere in the modeled domain.

Detailed descriptions of both modules, including their purpose and scope of application, mathematical formulations, and use in HWIR99, are provided in U.S. EPA (1999g). Additional information relating to the EPACMTP and its verification is provided in the background documents for EPACMTP (U.S. EPA, 1996a,b,c, 1997a).

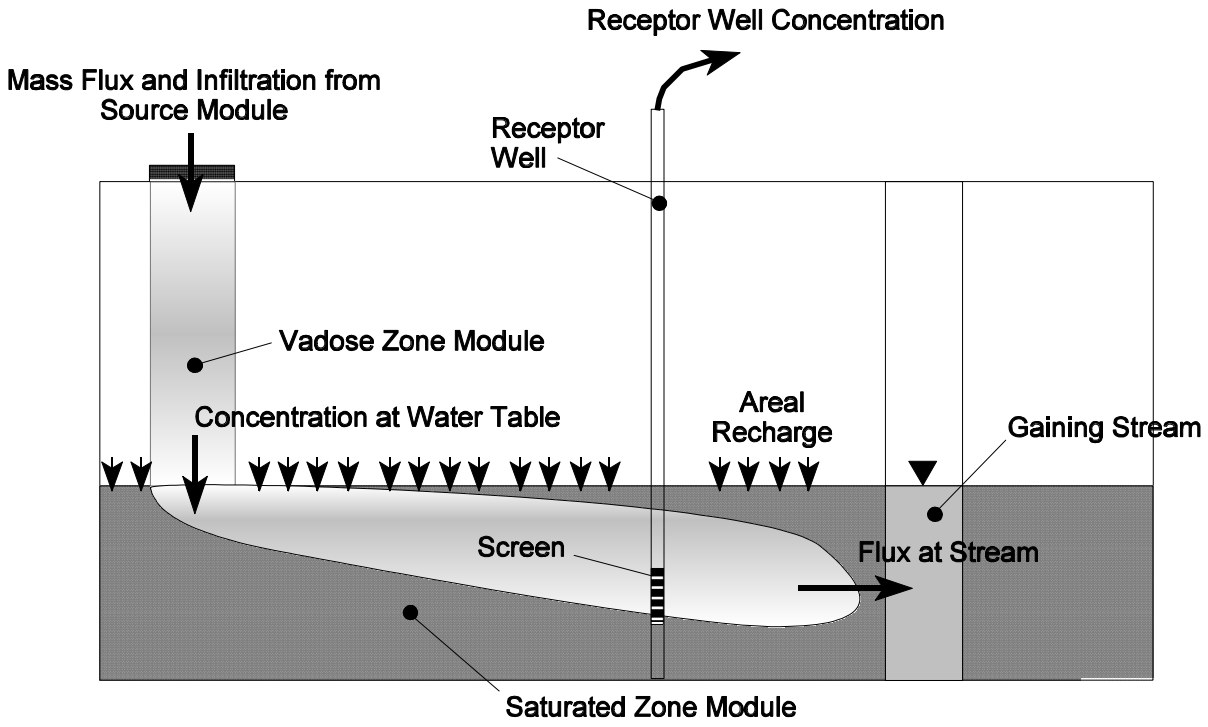


Figure 3-17. Conceptual model of vadose zone and saturated zone.

3.3.5 Surface Water Module

The 3MRA surface water module models streams, lakes, ponds, and wetlands. Chemical mass released from a WMU can enter a nearby surface waterbody network in runoff and erosion directly from the WMU, from atmospheric deposition to the water surface, in runoff and erosion from adjoining watershed subbasins, and by interception of contaminated groundwater. The chemical is then subject to transport and transformation processes occurring within the waterbody network, resulting in variable chemical concentrations in the water column and in the underlying sediments. These chemical concentrations are the basis for direct exposure to human and ecological receptors and indirect exposure through uptake in the aquatic food web.

The 3MRA surface water module consists of the core model EXAMS II (Burns, 1997; Burns et al., 1982) and the interface module ExamsIO. More detailed documentation can be found in U.S. EPA (1999u), from which the following material was extracted.

The surface water module estimates annual average total and dissolved chemical concentrations in the water column and in the underlying sediments at various receptor points within the affected waterbody. Transport/transfer processes modeled include advection, vertical diffusion, volatilization, deposition to the sediment bed, resuspension to the water column, and burial to deep sediments. Transformation processes modeled include hydrolysis and biodegradation as pseudo-first-order reactions influenced by temperature and pH. Outputs from

the surface water module include water column and sediment concentrations that are used by the aquatic food web module and the ecological exposure module.

In the HWIR 3MRA, stream reaches of orders 3 to 5 are evaluated, as defined by the Strahler ordering system (Strahler, 1957). Order three reaches are assumed to support fish populations. Reaches of order greater than 5 are assumed to carry sufficient annual average dilution flow that concentrations of chemicals of interest can be reasonably assumed to be at background levels (U.S. EPA, 1999u).

3.3.6 Farm Food Chain Module

The farm food chain (FFC) module calculates the concentration of a chemical in homegrown produce (fruits and vegetables), farm crops for cattle (forage, grain, and silage), beef, and milk. The concentrations in homegrown produce, beef, and milk are inputs to the human exposure module and are used to calculate the applied dose to human receptors who consume them. The modeling construct for the FFC module is based on recent and ongoing research conducted by EPA's Office of Research and Development (ORD) and presented in *Methodology for Assessing Health Risks Associated with Multiple Exposure Pathways to Combustor Emissions* (U.S. EPA, in press). Additional detail about the background and implementation of the model is available in U.S. EPA (1999i).

The FFC module is designed to predict the accumulation of a contaminant in the edible parts of a plant from uptake of contaminants in soil and through transpiration and direct deposition of the contaminant in air. Concentrations are predicted for three main categories of food crops presumed to be eaten by humans: exposed fruits and vegetables (i.e., those without protective coverings, such as lettuce), protected vegetables (e.g., those with protective covering, such as corn), and root vegetables (e.g., potatoes). In addition, the module estimates the contaminant concentration from the biotransfer of contaminants in feed (i.e., forage, grain, and silage), soil, and drinking water to beef and dairy cattle through ingestion.

The FFC module contains two separate programs; one predicts the concentration of contaminants in produce grown by home gardeners and the other predicts the concentration of contaminant in food crops, beef, and milk produced on farms. The module was designed with this functionality because not all study areas contain farms, and the methodology developed for farms is different than that developed for the home gardener. The program for home gardeners uses point estimates of air and soil concentrations at the residential receptor location assigned to each census block. In contrast, the program used for farms calculates an area-weighted average soil concentration for the farm and uses an interpolation subroutine to estimate the average air concentration across the area of the farm. Thus, the predicted concentrations in farm food crops reflect the spatial average for the farm. Similarly, the feed concentrations for the cattle are derived using spatial averages. In predicting concentrations in beef and milk, the contribution from contaminated drinking water sources, such as farm ponds or wells on the farm, is also considered. However, irrigation of crops and home gardens is not modeled.

Because the behavior of each chemical constituent is, to a large degree, determined by chemical properties, the module includes a series of chemical-specific switches that turn on the appropriate subroutines, depending on whether the chemical is an organic (O), metal (M), special

(S), or dioxin-like (D). For most organic chemicals, the industrial exposure module calculates chemical-specific values for the biotransfer factors used in the various equations, including air-to-plant biotransfer factor, root concentration factor, and soil-to-plant biotransfer factor. Metals, dioxin-like chemicals, and special chemicals generally use literature values for these various biotransfer factors, when available. For dioxin-like compounds and special chemicals, the biotransfer factors are calculated in the same way as for organics if literature values are not available.

3.3.7 Terrestrial Food Web Module

The terrestrial food web module (TerFW) calculates chemical concentrations in soil, terrestrial plants, and various prey items consumed by ecological receptors, including earthworms, other soil invertebrates, and vertebrates. These concentrations are used as input to the ecological exposure (EcoEx) module to determine the applied dose to each receptor of interest (e.g., deer, kestrel). The module is designed to calculate spatially averaged soil concentrations in the top layer of soil (i.e., surficial soil) as well as deeper soil horizons (i.e., depth-averaged over approximately 5 cm). The spatial averages are defined by the home ranges and habitats that are delineated within the area of interest at each site. Once the average soil concentrations are calculated, these values are multiplied by empirical bioconcentration factors (for animals) and biotransfer factors (for plants) to predict the tissue concentrations for items in the terrestrial food web. Supporting detail about the background and implementation of the model is available in U.S. EPA (1999j).

The conceptual approach used in developing the TerFW module was designed to predict a range of concentrations in plants and prey items to which a given receptor may be exposed. The predator and various prey are represented in the site layout by allowing the respective home ranges to overlap. For plants and soil fauna, the TerFW estimates concentrations based on the spatially averaged soil and air concentrations across each home range. Receptors that ingest plants and soil invertebrates as part of the diet are presumed to forage only within that part of the home range that is contained within the AOI at a given site. Consequently, home range defines the spatial scale for concentrations in soil, plants, and prey (both mobile and relatively immobile) to which a given receptor is exposed.[8]

As with the Farm Food Chain module, the TerFW modeling construct is based on recent and ongoing research conducted by EPA ORD and presented in *Methodology for Assessing Health Risks Associated with Multiple Exposure Pathways to Combustor Emissions* (U.S. EPA, in press). The model subroutine distinguishes among different types of chemicals, using empirically derived algorithms for some chemicals and bio-uptake data from field or greenhouse studies for other chemicals. The TerFW module accounts for uptake via root-to-plant translocation, air-to-plant transfer for volatile and semivolatile chemicals, and particle-bound deposition to edible plant surfaces. Specific differences exist between the FFC module and the TerFW module in predicting plant concentrations.

[8] Exposures are prorated depending upon the relationship of the home range to the habitat contained within the area of interest. For details, see U.S. EPA, 1999l.

To estimate the concentrations in other categories of terrestrial prey items (e.g., earthworms, small birds), the TerFW relies on soil-to-organism bioconcentration factors identified from empirical studies and/or generated using regression methods developed by the Oak Ridge National Laboratory (see, for example, Sample et al., 1998). A thorough discussion of these data is provided in the data collection documentation for the FFC and TerFW modules.

3.3.8 Aquatic Food Web Module

The aquatic food web (AqFW) module calculates chemical concentrations in aquatic organisms that are consumed by human and ecological receptors (e.g., fish filet, aquatic macrophytes). These concentrations are used as input to the human and ecological exposure modules to determine the applied dose to receptors of interest. The module is designed to predict concentrations in aquatic organisms for cold water and warm water aquatic habitats. Supporting detail about the background and implementation of the model is available in U.S. EPA (1999k).

The underlying framework for the AqFW module is the development of representative freshwater habitats for warmwater and coldwater systems. Four basic types of freshwater systems were included for the two temperature categories: streams/rivers, permanently flooded wetlands, ponds, and lakes. Simple food webs were constructed for each of the eight freshwater habitats (four cold water and four warm water) that specify: (1) the predator-prey interactions, (2) the physical and biological characteristics of the species that are assigned to each habitat (e.g., size, lipid content), and (3) the dietary preferences for fish in trophic levels 3 (TL3) and 4 (TL4). Prey preferences are based on optimal foraging theory (Gerking, 1994). For each freshwater habitat, the feeding guilds for various types and sizes of fish (e.g., medium benthivore) were used to construct a simple food web and to map dietary preferences for organisms in each habitat (U.S. EPA, 1999o). The habitat types are less important for some constituents (e.g., metals) for which empirical data are used to relate the water concentration to tissue concentration. However, the food web structure and species assignments are critical in determining concentrations of hydrophobic constituents in aquatic organisms.

The AqFW methodology introduces several new approaches to modeling representative aquatic systems. First, the AqFW module uses a probabilistic algorithm that cycles through the database on prey preferences to select dietary fractions for TL3 and TL4 fish for predicting tissue concentrations. Second, the AqFW module implements a flexible matrix that allows for the simultaneous solution of all compartments (e.g., benthos, zooplankton, fish) in the system. This functionality allows the module to perform calculations efficiently and provides the flexibility for adding additional compartments and/or interactions to the food web structure.

3.3.9 Human Exposure Module

The human exposure module calculates the applied dose (milligram of constituent per killogram of body weight) to human receptors from media and food concentrations calculated by other modules in the 3MRA methodology. These calculations are performed for each receptor, cohort, exposure pathway, and year at each exposure area.[9]

[9] See Section 3.3.10 for the list of receptors and cohorts and applicable exposure pathways.

The human exposure module calculates exposures for two basic receptor types: residential receptors (residents and home gardeners) and farmers. Residential receptors may also be recreational fishers in addition to being a resident or home gardener. Farmers may be beef farmers or dairy farmers, and either type of farmer may also be a recreational fisher. The subcategories within residential receptors and farmers differ in the particular exposures they incur. For example, a resident (only) differs from a home gardener in that home gardeners are exposed to contaminated fruits and vegetables, but residents are not. Within each of the two basic receptor types, the human exposure module calculates exposures for five age cohorts: infants (ages 0-1 year), children ages 1-5 years, children ages 6-11 years, children ages 12-19 years, and adults (ages 20 years and up). Additional detail about the background and implementation of the model is available in U.S. EPA (1999q).

For HWIR, the human exposure module uses distributions for most exposure factors (e.g., contact rates, body weight) that are derived from data in the *Exposure Factors Handbook* (U.S. EPA, 1997b). Exceptions include exposure duration (9 years for carcinogens, 1 year for noncarcinogens) and "fraction contaminated," specified as point estimates for each medium/feed item.

3.3.10 Human Risk Module

The essence of the 3MRA for human health is an evaluation of total risks to receptors incurred as a result of simultaneous exposure from different pathways. To calculate risks from multiple pathway exposures, the 3MRA human risk module considers two basic human receptor types: residential receptors (residents and home gardeners) and farmers. Residential receptors may also be recreational fishers in addition to being a resident or home gardener. Farmers may be beef farmers or dairy farmers, and either type of farmer may also be a recreational fisher. These receptor categories were developed considering the exposure pathways of concern, and the category names suggest the associated exposure pathway(s). For example, a resident is exposed only to the baseline exposure pathways, i.e., inhalation via ambient air and shower along with soil and groundwater ingestion, with the home gardener being exposed through these exposure pathways plus ingestion of homegrown produce. Additional detail about the background and implementation of the model is available in U.S. EPA (1999r).

In total there are eight categories of human receptors: resident, home gardener, resident fisher, home gardener fisher, beef farmer fisher, dairy farmer fisher, beef farmer, and dairy farmer. The human exposure module models each of these eight categories and provides outputs for each. The human risk module uses these outputs to calculate risks and/or HQs for each category. However, to maintain output storage at reasonable levels, it aggregates results into four[10] composite receptor categories (resident, resident gardener, fisher, and farmer) to develop the cumulative population[11] frequency histograms and critical years. These three basic human risk module functions (calculating risk/HQ, building cumulative frequency histograms, and

[10] The 3MRA Exit Level Processor (ELP) preserves this receptor resolution, but also aggregates these four receptors into a fifth, "all receptors" category.

[11] Site-specific receptor populations identified as part of HWIR data collection activities are specified by receptor category, exposure area (farm or census block), and distance ring (U.S. EPA, 1999t).

determining critical year) are performed for each radial distance in a series of nested loops, as illustrated in Figures 3-18a through 3-18c.[12]

For example, the composite "fisher" receptor population consists of subpopulations from the resident fisher, resident gardener fisher, beef farmer fisher, and dairy farmer fisher receptor categories. Similarly, beef farmers and dairy farmers are aggregated into a single, composite "farmer." A complete mapping of the eight receptor categories as output by the Human exposure module to their composited receptor categories as output by the human risk module is presented in Table 3-7. Table 3-7 also shows the applicable exposure pathways for the receptor categories. In this section, the term "receptor" is used to mean either one of the eight most disaggregated receptor categories, or one of the four composited receptor categories, as appropriate to the context. In addition, a cohort is defined as a receptor subpopulation based on age. Five cohort classes are considered in the human risk module[13]: Child 1 (0 to 1 year old), Child 2 (1 to 5 years old), Child 3 (6 to 11 years old), Child 4 (12 to 19 years old), and adult (greater than 19 years old).

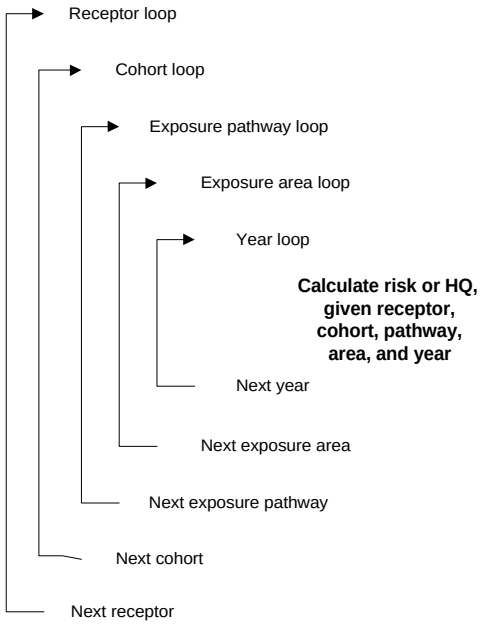


Figure 3-18a. Looping structure to calculate risk or HQ.

[12] These illustrations are intended only to facilitate overall understanding of the module; the implementing computer code is significantly different to optimize performance.

[13] For purposes of storage efficiency, the ELP combines the Child 2 and 3 cohort classes as output by the human risk module into a single composite cohort class (ages 1 to 11). Child 4 is also combined with the adult cohort class by the ELP.

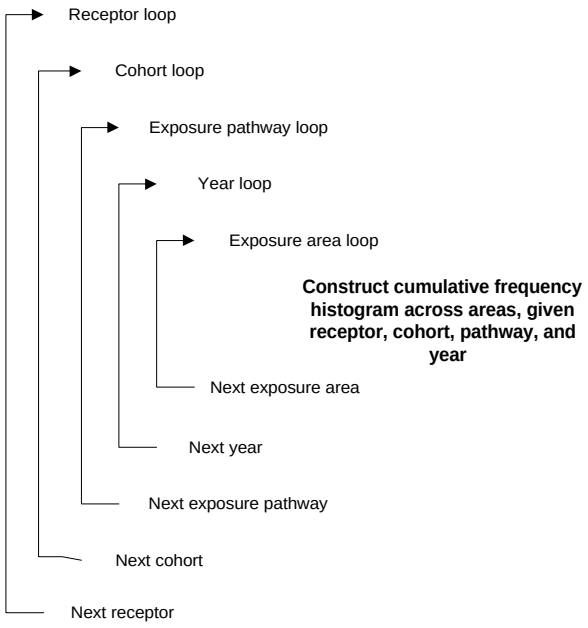


Figure 3-18b. Looping structure to build cumulative frequency histograms.

Table 3-7. Applicable Receptor/Pathway Combinations

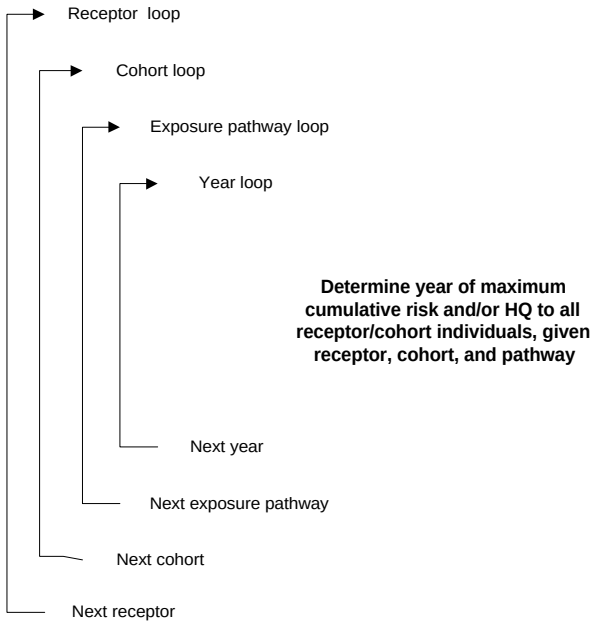


Figure 3-18c. Looping structure to determine critical year.

	Receptors (as output by Human Risk Module)							
	Resident	Resident Gardener	Fisher				Farmer	
	Receptors (as output by Human Exposure Module)							
Pathway	Resident	Resident Gardener	Resident Fisher	Resident Gardener Fisher	Beef Farmer Fisher	Dairy Farmer Fisher	Beef Farmer	Dairy Farmer
1. Air inhalation	yes	yes	yes	yes	yes	yes	yes	yes
2. Soil ingestion	yes	yes	yes	yes	yes	yes	yes	yes
3. Water ingestion	yes	yes	yes	yes	yes	yes	yes	yes
4. Crop ingestion	no	yes	no	yes	yes	yes	yes	yes
5. Beef ingestion	no	no	no	no	yes	no	yes	no
6. Milk ingestion	no	no	no	no	no	yes	no	yes
7. Fish ingestion	no	no	yes	yes	yes	yes	no	no
8. Shower inhalation[a]	yes	yes	yes	yes	yes	yes	yes	yes
9. Infant breast milk[b]	yes	yes	yes	yes	yes	yes	yes	yes

[a] Shower inhalation applies only to child 4 and adult cohorts. All other pathways shown apply to all noninfant cohorts.
[b] Applies only to child 1 (infant) cohorts.

The nine individual exposure pathways considered by the human risk module are shown in Table 3-7. All exposure pathways do not apply to all receptors; those that are applicable are indicated by "yes" in the table. With respect to applicability among receptor cohorts, if a pathway applies to a receptor, then it applies to all cohorts of that receptor, with two exceptions: (1) shower inhalation applies only to child 4 and adult cohorts (younger children are assumed to bathe as opposed to shower), and (2) the infant breast milk pathway applies only to breastfeeding infants.[14, 15]

Because the essence of a multipathway risk assessment is the evaluation of total risks incurred as a result of simultaneous exposure from different pathways, the human risk module considers four different pathway aggregations as shown in Table 3-8. The inhalation route aggregates over the two inhalation pathways. The ingestion route aggregates over all ingestion

[14] For HWIR99, the infant breast milk pathway is evaluated only for a single chemical, the dioxin species 2,3,7,8 -TCDD TEQ [CAS No. 1746-01-6]. (That is, the logical flag *ChemBreastMilkExp* will be set to "true" only for this chemical in the chemical properties input file, cp.ssf.)

[15] For the infant breast milk pathway, the margin of exposure [MOE] (mg/kg-d) is analogous to HQ for infant breast milk exposure. Hereinafter, HQ will be understood to mean "MOE" for the Child 1 cohort and breast milk pathway.

Table 3-8. Pathway Aggregations

Pathway	Inhalation Route	Ingestion Route	Groundwater	Multipathway
1. Air inhalation	✓			✓
2. Soil ingestion		✓		✓
3. Water ingestion		✓	✓	✓
4. Crop ingestion		✓		✓
5. Beef ingestion		✓		✓
6. Milk ingestion		✓		✓
7. Fish ingestion		✓		✓
8. Shower inhalation	✓		✓	✓

pathways. The groundwater aggregation includes the two groundwater-based pathways (drinking water ingestion and shower inhalation). Finally, the multipathway aggregation includes all combinable[16] pathways. (The infant breast milk pathway is a separate pathway that is not relevant to the route aggregations and is not included in the table.)

The radial distance rings are set at 500 meters, 1,500 meters, and 2,000 meters from a circle circumscribing the (square) WMU (Figure 3-19). Thus, the first set of risk and/or HQ results is applicable only to those receptors residing within 500 meters of the WMU boundary. The second set applies to **all** receptors within 1,000 meters, including those previously considered within 500 meters. The third set applies to all receptors within 2,000 meters, which includes all receptors within the overall Area of Interest.

3.3.11 Ecological Exposure Module

The ecological exposure (EcoEx) module, initially developed in support of the HWIR 3MRA, calculates the applied dose (in mg/kg-d) to ecological receptors that are exposed to contaminants via ingestion of contaminated plants, prey, and media (i.e., soil, sediment, and surface water). These dose estimates are then used as inputs to the ecological risk module. The EcoEx module calculates exposures for each receptor placed within a terrestrial or freshwater aquatic habitat (as defined in the site layout). Thus, exposure is a function of: (1) the habitat to which the receptor is assigned; (2) the spatial boundaries of the species home range, (3) the food items (plants and prey) that are available in a particular home range, (4) the dietary preferences for food items that are available, and (5) the media concentrations in the receptor's home range.

[16] The feasibility of pathway additivity is chemical-specific and is specified by the logical variables *ChemC_add* and *ChemNC_add* in the chemical properties input file.

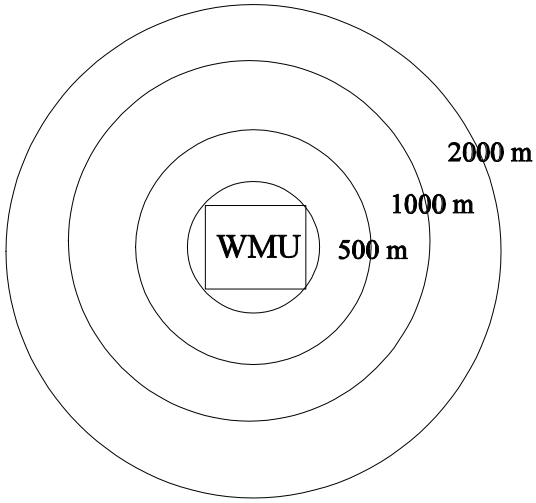


Figure 3-19. WMU with three radial distance rings.

In essence, the module estimates an applied dose for birds, mammals, and selected herpetofauna that reflects the spatial and temporal characteristics of the exposure (i.e., exposure is tracked through time and space). Additional detail about the background and implementation of the model is available in U.S. EPA (1999l).

The conceptual approach in developing the ecological exposure assessment for HWIR was to reflect the major sources of variability in ecological exposures. In particular, the approach considers variability through: (1) the development of representative habitats; (2) selection of receptors based on ecological region; (3) the recognition of opportunistic feeding and foraging behavior using probabilistic methods; (4) the creation of a dietary scheme specific to region, habitat, and receptor; and (5) the application of appropriate graphical tools to capture spatial variability in exposure. The underlying framework for the EcoEx module is based on a representative habitat scheme to increase the resolution of general terrestrial and freshwater systems. The spatial characteristics of the site-based database were determined using a geographic information system (GIS) delineation tool to define habitat boundaries and linkages, home ranges, wetland areas, and surface waterbodies. A cross-referencing database was developed to automate the selection of receptors and assign them to habitats based on habitat characteristics and ecological region. A complete description of the habitats, home ranges, receptors, and delineation scheme implemented in the GIS format is found in U.S. EPA (1999n).

Depending on the type of habitat and chemical-specific uptake and accumulation, animals may be exposed through the ingestion of plants (both aquatic and terrestrial), soil invertebrates, aquatic invertebrates, fish, terrestrial vertebrates, media, or any combination that is reflected by the dietary preferences of the particular species. For example, an omnivorous vertebrate that inhabits a freshwater stream corridor habitat may ingest fish, small terrestrial vertebrates found in the stream corridor, terrestrial and aquatic plants, surface water, and soil. The dietary preferences are independent of the chemical type and, therefore, contaminant concentrations in some food items may be near zero for chemicals that do not bioaccumulate. The dietary preferences for

each receptor are supported by an extensive exposure factors database containing information on, for example, dietary habits and natural history for over 50 representative species of interest. The module includes an innovative approach to characterizing the diet: a probabilistic algorithm that cycles through the database on minimum and maximum prey preferences to simulate dietary variability.

3.3.12 Ecological Risk Module

The ecological risk (EcoRisk) module calculates HQs[17] for a suite of ecological receptors assigned to habitats delineated for study sites. These receptors fall into eight receptor groups: mammals, birds, herpetofauna, terrestrial plants, soil community, aquatic plants and algae, aquatic community, and benthic community. The spatial resolution of the EcoRisk module is, to a large degree, determined by both the home ranges and habitats delineated at each site. Additional detail about the background and implementation of the ecological risk module is available in U.S. EPA (1999m).

Home range areas are defined in terms of species-specific foraging area size as well as the habitat and predator-prey interactions, that is, the home ranges are constrained by habitat boundaries[18] and represent predator-prey interactions. Spatially averaged concentrations in media, plants, and prey items are calculated for each home range and used to estimate the applied dose to receptors in the ecological exposure (EcoEx) module. In addition, soil concentrations for each home range are compared to threshold concentrations for adverse effects in plants and soil biota.

The habitat area is important in assessing risks to several receptor groups (e.g., benthic community); exposures and associated risks are considered across the entire habitat rather than for one or more home ranges. For example, contaminant concentrations to which the aquatic community is exposed are represented by a habitat-wide average that may include multiple stream reaches. The temporal resolution is based on annual average applied doses (for comparison with EBs) and media concentrations (for comparison with CSCLs).

The HQs for all receptors assigned to the study site are calculated and placed into one of five risk bins developed to assist decision-makers in creating appropriate risk metrics. The HQ risk bins are used in developing cumulative distribution functions of risk and are defined as: (1) below 0.1, (2) between 0.1 and 1, (3) between 1 and 10, (4) between 10 and 100, and (5) above 100. Each of the HQs calculated by the EcoRisk module has a series of attributes associated with it that allows ecological risks to be interpreted in a number of ways. For instance, distance from the source (i.e., 1 km, 1 to 2 km, or across the entire site) is important in understanding the spatial character of potential ecological risks.

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[17] Hazard quotients are defined as: (1) the ratio between applied dose received from the ingestion of contaminated media and food items and an ecological benchmark (EB in units of dose), and (2) the ratio between the concentration in the medium of interest (soil, sediment, or surface water) and a chemical stressor concentration limit (CSCL in units of concentration).

[18] If the home range area is larger than the area of the habitat, the home range is presumed to extend beyond the 2-km radius that defines the area of interest; that is, habitats are exclusive. If the home range is smaller than the habitat, the entire home range is presumed to fall within the habitat boundaries within the area of interest.

Other attributes considered relevant to ecological risks and regulatory decision-making include the following:

- # Habitat type (e.g., grassland, pond, permanently flooded forest)
- # Habitat group (i.e., terrestrial, aquatic, and wetland)
- # Rreceptor group (e.g., mammals, amphibians, soil community)
- # Ttrophic level (i.e., producers, TL1, TL2, TL3 top predators).

The maximum HQ across the site is also reported along with its ecological risk attributes. This metric was added for use in "pass/fail" analyses that may be needed to prioritize sites for additional analyses.

In calculating receptor-specific HQs, the EcoRisk module does all of the necessary accounting to develop distributions based on the specific receptor and habitat groupings of interest. The EcoRisk module reads in information about the chemical concentrations that each receptor is exposed to, calculates hazard quotients based on the EB or CSCL and the chemical exposure information, and provides summaries of ecological risk information for the simulation to determine when critical years with maximum HQs are experienced. For any given year, the set of HQ data is stored as a series of distributions along with their attributes. As indicated above, the cumulative frequency distributions are composed of a series of bins for different ranges of HQ values. The bins are populated based on the number of receptors with HQ values in the range defined for the given bin.

Each site is constructed as a set of habitats, each located within one or more distance rings at the site, and a set of receptors inhabiting ranges within each of those habitats. Habitats have a variety of characteristics, including a unique index identifier, a habitat type and group, a number of reaches, a number of ranges containing receptors, and the receptors associated with each range. Reaches, habitats, and ranges also have chemical concentrations associated with them. Each receptor has an index, type, name, group, trophic level. To a large degree, the habitats reflect differences in vegetative communities based on various land use and land cover data layers. Home ranges are assigned to each habitat based on the median size of receptor species' foraging and feeding ranges. Ecological receptors were grouped into four different home range sizes: 1,000,000,000, 10,000,000, 1,000,000, and 100,000 square meters. These home ranges were approximated for size (by an expanding a circular polygon) and randomly placed within each habitat polygon so that they overlap to reflect predator-prey relationships.

Outputs are generated for three areas of the site relative to the distance from the edge of the waste management unit. These distances are termed EcoRings and depict the following: (1) habitats that fall within 1 km of the WMU, (2) habitats that fall between 1 and 2 km from the WMU, and (3) habitats within 2 km of the WMU (i.e., across the entire site). It is important to note that the HQ results for habitats that intersect both EcoRings are attributed to the risk results for both of those distances. In other words, the habitat risks are not apportioned by distance, they are reported as though they are positioned entirely within each distance ring. Because the fundamental unit of this analysis is the representative habitat (not distance to the waste management unit), it was considered inappropriate to truncate risks by distance.

3.4 3MRA Modifications and Data Collection Requirements

As described previously, the 3MRA Model has the basic functionality and features necessary to characterize risks for the purposes of the SI Study. However, because the specific needs of the SI Study are somewhat different than those for HWIR, there will be some necessary modifications to the 3MRA component models and modeling system. In addition, data availability is better for the SI Study, both in terms of site-specific data from the SI Survey and better, more complete data from other sources. Using these improved data sources in the 3MRA model for the SI Study will require some modifications to the HWIR data collection methodologies.

This section summarizes the model and data collection modifications that may be necessary to implement the 3MRA model for the SI Study. It is intended to outline the major topic areas and alternatives for planning purposes. Although this represents the major areas to be addressed, other changes may be necessary as the analysis evolves. As the Phase I screening analysis progresses, EPA will continue to investigate and expand on these modifications, addressing those necessary before Phase II modeling begins.

3.4.1 Model Modifications

The basic functionality of the 3MRA model will be maintained for the SI Study. Modifications of the HWIR modeling construct for the SI Study that can be handled with simple changes in model inputs (e.g., risk bins, risk distance rings) are not addressed here. More substantive revisions to the current model construct are needed to address the following limitations.

- The current 3MRA system cannot model multiple units at a site.
- The current surface impoundment model cannot model a postclosure scenario or catastrophic failures.
- The Exit Level Processor 2 (ELP2), which produces exit level waste concentrations from the ELP1 risk database, does not meet SI Study objectives.

Current objectives require that the SI Study Phase II risk results be organized in terms of the SI Study risk attributes that are beyond the dimensions currently addressed by 3MRA.

3.4.1.1 Multiple Surface Impoundments. Multiple surface impoundments cannot be modeled simultaneously by the 3MRA Model, and modifying the current system to allow this would require an extensive, system-wide redesign that is well beyond the scope of this effort. To address risks from multiple units will require running the model separately for each unit and combining risk results after modeling during postprocessing. This will require cognizance of this need during data collection and site layout definition (i.e., an identical site layout for all units at a site), as well as consideration of this need during the development of postprocessing techniques for Phase II SI Study risk results.

3.4.1.2 SI Postclosure Scenario. As discussed in Section 3.3.1, the postclosure scenario for the SI Study will be handled by using the LAU module to model a closed SI with sludge left

in place. The LAU module has the functionality necessary to model a closed SI with just changes in module inputs. Currently envisioned alternatives for using the LAU module in this context include

- Combining the SI and LAU modules into a single source module
- Modification of the 3MRA Site Definition Processor to run the LAU module after the SI module to model the SI post closure period and to combine results of the two modules into a single source module output file
- Separate 3MRA model runs for operating and postclosure periods.

The latter option could be problematic because SI module outputs (i.e., sludge concentrations) will be needed as inputs for the LAU module.

3.4.1.3 SI Catastrophic Failure. The SI Survey is collecting data on occurrences of catastrophic failures within the SI universe. EPA will evaluate these results in deciding whether to analyze the risks that could result from such events.

3.4.1.4 ELP - Postprocessing Options. The postprocessing functionality of the ELP2 is not needed for the SI Study and this module will not be used during Phase II modeling. The ELP1 does provide and access a database of the results needed for the SI Study objectives, but additional data processing will be required to summarize results by the SI Study risk attributes:

- Multiple impoundments at a site
- Five regulatory status categories
- Three functional classes (storage, treatment, and disposal)
- Treatment types (e.g., biological, settling)
- Industry types
- Contaminants.

These represent additional dimensions to those currently provided by the 3MRA ELP1. Risk outputs will need to be organized and compiled by these dimensions; this will require either modifications to the 3MRA system or separate postprocessing of the Access database (ouput by the ELP1) containing the Protective Summary Output Files (PSOFs). EPA will decide on the best option, considering the need for automation (i.e., system modifications) in light of the number of SI facilities modeled and data analyses necessary to meet decision-making needs.

3.4.2 Data Collection Requirements

In general, data collection methods developed and documented for the HWIR implementation of 3MRA will be adequate for the SI Study. National and regional data collected for HWIR will likely be suitable for SI Study purposes, although it may be necessary to employ automated HWIR methodologies to collect data to characterize regions with SI sites not covered for the HWIR sites. The main effort necessary for the SI Study will be the collection of site-based

data to characterize the SI Study sites. Specific issues associated with this effort are discussed in the following section.

3.4.2.1 Utilization of SI Survey Data. The SI Survey provides a rich source of data for the Phase II analyses, providing accurate facility locations, SI dimensions and operating characteristics, waste properties and constituents, soil and hydrogeologic information, and receptor locations. Incorporation of these data will require some modification to current 3MRA data collection methods, but will result in a more robust and accurate dataset. EPA is currently designing the survey data coding and database to be compatible with 3MRA data needs. Most of the following points relate to the use of these data.

3.4.2.2 Modificationof the Area of Interest (AOI). Because multiple SIs are present at many facilities, and because the SI Study design requires risks to be combined for such multiple units, a single AOI will be needed so that receptors and other aspects of the site layout will be identical for all units at the site. This, and knowledge of the exact shape of each SI will require an irregular AOI, as shown in the example in Figure 3-20. This is not a problem from the system standpoint, but does represent a change from the circular 3MRA AOI.

3.4.2.3 Receptor Locations. Ecological receptors and habitats will be delineated as they were for the HWIR analysis. Human receptor data are being collected in the survey as residence locations on topographic maps. Initial evaluation of the survey results suggests that these data are variable in extent, quality, and time frame from respondent to respondent. It is possible that the 3MRA automated data collection methodologies for U.S. Census data will be needed to supplement the survey receptor data. The combined dataset will provide improved resolution and accuracy of receptor locations over the use of the Census data alone, especially in sparsely populated areas where residences are far apart. In more populated areas, the Census data will be valuable in providing additional information on the number of households in dense residential areas. The combination of these data at an SI site with varying residential densities is shown in Figure 3-20.

3.4.2.4 Watershed and Waterbody Delineation. Limited resolution and data quality problems of the topographic and hydrographic base data posed a challenge during watershed and waterbody delineation for the HWIR 3MRA. Fortunately, higher-resolution, better-quality data are now available as the National Elevation Dataset (NED) and the National Hydrography Dataset (NHD), as well as in the topographic maps available for every SI facility. These data, combined with the now finalized 3MRA site layout system, should greatly improve the efficiency of waterbody and watershed delineations for the SI Study sites addressed in the Phase II analysis.

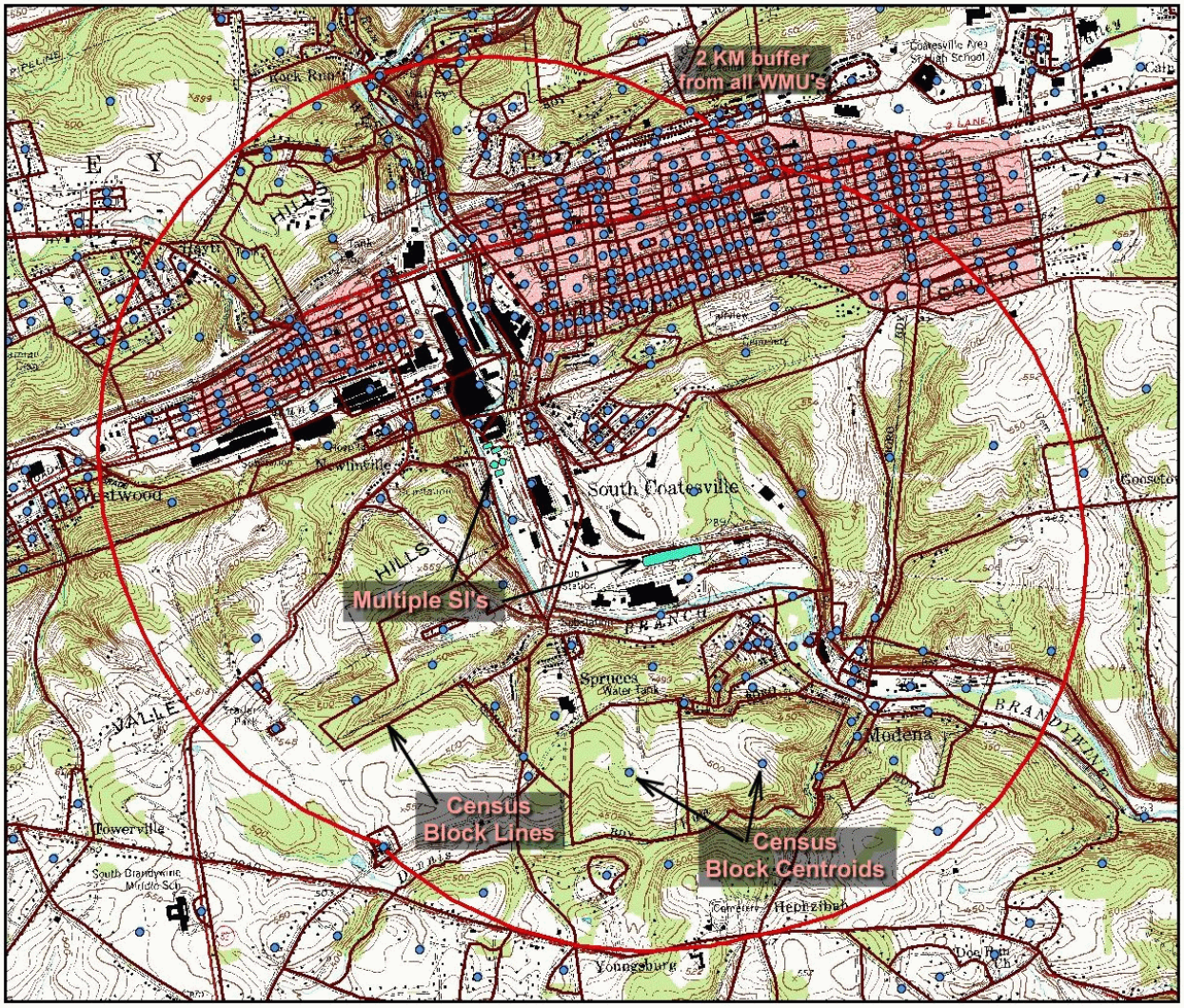

Figure 3-20. Area of interest for multiple SI site illustrating overlay of topographic and U.S. census data.

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Appendix A

Comprehensive List of Toxicity Benchmarks for Human Health Risk Assessment

Table A-1. Comprehensive List of Toxicity Benchmarks

Constituent Name	CAS No.	Benchmarks Selected for Use in Deriving Phase 1A Screening Levels					
		Oral (RfD)	RfC (mg/m^3)	Oral CSF (food) (per mg/kg/d)	Oral CSF (H2O) (per mg/kg/d)	Inh URF (per ug/m^3)	Inh CSF (per mg/kg/d)
Acenaphthene	83329	6.0E-02					
Acetaldehyde	75-07-0		9.0E-03			2.2E-6	
Acetone	67641	1.0E-01					
Acetonitrile	75-05-8		6.0E-02				
Acetophenone	98-86-2	1.0E-01					
Acrolein	107-02-8	2.0E-02	2.0E-05				
Acrylamide	79-06-1	2.0E-04		4.5E+0	4.5E+0	1.3E-3	4.5E+0
Acrylic acid	79-10-7	5.0E-01	1.0E-03				
Acrylonitrile	107-13-1	1.0E-03	2.0E-03	5.4E-1	5.4E-1	6.8E-5	2.4E-1
Aldicarb	116-06-3	1.0E-03					
Aldrin	309-00-2	3.0E-05		1.7E+1	1.7E+1	4.9E-3	1.7E+1
Allyl alcohol	107-18-6	5.0E-03					
Allyl chloride (3-chloropropene)	107-05-1		1.0E-03				
Ammonium vanadate	7803-55-6						
Amonium perchlorate	7790-98-9						
Aniline	62-53-3		1.0E-03	5.7E-3	5.7E-3		
Anthracene	120-12-7	3.0E-01					
Antimony	7440-36-0	4.0E-04					
Antimony trioxide	1309-64-4	4.0E-04	2.0E-04				
Aramite	140-57-8	5.0E-02		2.5E-2	2.5E-2	7.1E-6	2.5E-2
Arsenic, inorganic	7440-38-2	3.0E-04		1.5E+0	1.5E+0	4.3E-3	
Barium	7440-39-3	7.0E-02	5.0E-04				
Benz(a)anthracene	56-55-3			7.3E-01	7.3E-01		
Benzene	71-43-2			2.9E-2[a]	2.9E-2[a]	8.3E-6[a]	2.9E-2[a]
Benzidine	92-87-5	3.0E-03		2.3E+2	2.3E+2	6.7E-2	2.3E+2
Benzo(a)pyrene	50-32-8			7.3E+0	7.3E+0		
Benzo(b)fluoranthene	205-99-2			7.3E-01	7.3E-01		
Benzyl alcohol	100-51-6	3.0E-01					
Benzyl chloride	100-44-7			1.7E-1	1.7E-1		
Beryllium	7440-41-7	2.0E-03	2.0E-05			2.4E-3	8.4E+0
Bis(2-chloroethyl)ether	111-44-4			1.1E+0	1.1E+0	3.3E-4	1.1E+0
Bis(2-chloroisopropyl)ether	39638-32-9	4.0E-02		7.0E-2	7.0E-2	1.0E-5	3.5E-2
Bis(2-ethylhexyl)phthalate (DEHP; also di-)	117-81-7	2.0E-02		1.4E-2	1.4E-2		
Bis(chloromethyl)ether	542-88-1			2.2E+2	2.2E+2	6.2E-2	2.2E+2
Bromoform	75-25-2	2.0E-02		7.9E-3	7.9E-3	1.1E-6	3.9E-3
Bromomethane (methyl bromide)	74-83-9	1.4E-03	5.0E-03				
Butadiene, 1,3-	106-99-0					2.8E-4	1.8E+0
Butanol, n- (n-butyl alcohol)	71-36-3	1.0E-01					

(continued)

Table A-1. (continued)

Constituent Name	CAS No.	Benchmarks Selected for Use in Deriving Phase 1A Screening Levels					
		Oral (RfD)	RfC (mg/m^3)	Oral CSF (food) (per mg/kg/d)	Oral CSF (H_2O) (per mg/kg/d)	Inh URF (per ug/m^3)	Inh CSF (per mg/kg/d)
Butyl benzyl phthalate	85-68-7	2.0E-01					
Cadmium	7440-43-9	5.0E-04				1.8E-3	
Carbon disulfide	75-15-0	1.0E-01	7.0E-01				
Carbon tetrachloride (tetrachloromethane)	56-23-5	7.0E-04		1.3E-1	1.3E-1	1.5E-5	5.3E-2
Chloral	75-87-6	2.0E-03					
Chloral hydrate [trichloroacetaldehyde hydrate]	302-17-0						
Chlordane	57-74-9	5.0E-04	7.0E-04	3.5E-1	3.5E-1	1.0E-4	1.3E+0
Chlordecone	143-50-0						
Chlorine cyanide (cyanogen chloride)	506-77-4	5.0E-02					
Chloro-1,3-butadiene, 2- (chloroprene)	126-99-8	2.0E-02	7.0E-03				
Chloroaniline, 4- (p-)	106-47-8	4.0E-03					
Chlorobenzene	108-90-7	2.0E-02	2.0E-02				
Chlorobenzilate	510-15-6	2.0E-02		2.7E-1	2.7E-1	7.8E-5	2.7E-1
Chlorodibromomethane (dibromochloromethane)	124-48-1	2.0E-02		8.4E-2	8.4E-2		
Chloroform (trichloromethane)	67-66-3	1.0E-02		6.1E-3	6.1E-3	2.3E-5	8.1E-2
Chloromethane (methyl chloride)	74-87-3			1.3E-2	1.3E-2	1.8E-6	6.3E-3
Chloromethyl methyl ether	107-30-2						
Chloronaphthalene, beta-	91-58-7	8.0E-02					
Chlorophenol, 2-	95-57-8	5.0E-03					
Chromium (III), insoluble salts	16065-83-1	1.5E+00					
Chromium (VI)	18540-29-9	3.0E-03				1.2E-2	4.1E+1
Chromium (VI) - chromic acid mists & dissolved Cr aerosols	18540-29-9		8.0E-06				
Chromium (VI) - Cr particulates	18540-29-9		1.0E-04				
Chrysene	218-01-9			7.3E-03	7.3E-03		
cis-1,3-Dichloropropylene	10061-01-5						
Cobalt (and cmpds)	7440-48-4	6.0E-02					
Copper	7440-50-8						
Cresol mixtures	1319-77-3						
Cresol, m- (3-methylphenol)	108-39-4	5.0E-02					
Cresol, o- (2-Methylphenol)	95-48-7	5.0E-02					
Cresol, p- (4-methylphenol)	106-44-5	5.0E-03					
Cumene	98-82-8	1.0E-01	4.0E-01				
Cyanide (amenable)	57-12-5	2.0E-02					
Cyanogen bromide	506-68-3	9.0E-02					

(continued)

Table A-1. (continued)

Constituent Name	CAS No.	Benchmarks Selected for Use in Deriving Phase 1A Screening Levels					
		Oral (RfD)	RfC (mg/m^3)	Oral CSF (food) (per mg/kg/d)	Oral CSF (H_2O) (per mg/kg/d)	Inh URF (per ug/m^3)	Inh CSF (per mg/kg/d)
Cyclohexanol	108-93-0						
Cyclohexanone	108-94-1	5.0E+00					
DDD (p,p'-dichlorodiphenyldichloroethane)	72-54-8			2.4E-1	2.4E-1		
DDE (p,p'-dichlorodiphenyldichloroethylene)	72-55-9			3.4E-1	3.4E-1		
DDT (p,p'-dichlorodiphenyltrichloroethane)	50-29-3	5.0E-04		3.4E-1	3.4E-1	9.7E-5	3.4E-1
Diallate	2303-16-4			6.1E-2	6.1E-2		
Dibenzo(a,h)anthracene	53-70-3			7.3E+00	7.3E+00		
Dibromo-3-chloropropane, 1,2- (DBCP)	96-12-8		2.0E-04	1.4E+0	1.4E+0	6.9E-7	2.4E-03
Dibromoethane, 1,2- (ethylene dibromide)	106-93-4		2.0E-04	8.5E+1	8.5E+1	2.2E-4	7.6E-1
Dichlorobenzene, 1,2- (o-)	95-50-1	9.0E-02	2.0E-01				
Dichlorobenzene, 1,4-	106-46-7		8.0E-01	2.4E-2	2.4E-2		
Dichlorobenzidine, 3,3'-	91-94-1			4.5E-1	4.5E-1		
Dichlorobromomethane (bromodichloromethane)	75-27-4	2.0E-02		6.2E-2	6.2E-2		
Dichlorodifluoromethane [CFC-12]	75-71-8	2.0E-01	2.0E-01				
Dichloroethane, 1,1-	75-34-3	1.0E-01	5.0E-01				
Dichloroethane, 1,2- (ethylene dichloride)	107-06-2			9.1E-2	9.1E-2	2.6E-5	
Dichloroethylene, 1,1-	75-35-4	9.0E-03		6.0E-1	6.0E-1	5.0E-5	2.0E-1
Dichloroethylene, 1,2- (cis)	156-59-2	1.0E-02					
Dichloroethylene, 1,2- (trans)	156-60-5	2.0E-02					
Dichlorophenol, 2,4-	120-83-2	3.0E-03					
Dichlorophenoxyacetic acid, 2,4- (2,4-D)	94-75-7	1.0E-02					
Dichloropropane, 1,2-	78-87-5		4.0E-03	6.8E-2	6.8E-2		
Dieldrin	60-57-1	5.0E-05		1.6E+1	1.6E+1	4.6E-3	1.6E+1
Diethyl phthalate	84-66-2	8.0E-01					
Diethylstilbestrol	56-53-1			4.7E+3	4.7E+3		
Dimethoate	60-51-5	2.0E-04					
Dimethoxybenzidine, 3,3'-	119-90-4			1.4E-2	1.4E-2		
Dimethylbenz[a]anthracene, 7,12-	57-97-6						
Dimethylbenzidine, 3,3'-	119-93-7			9.2E+0	9.2E+0		
Dimethylformamide, N,N-	68-12-2	1.0E-01	3.0E-02				
Dimethylphenol, 2,4-	105-67-9	2.0E-02					
Dimethylphenol, 3,4-	95-65-8	1.0E-03					
Dimethylphthalate	131-11-3						
Di-n-butyl phthalate	84-74-2	1.0E-01					

(continued)

Table A-1. (continued)

Constituent Name	CAS No.	Benchmarks Selected for Use in Deriving Phase 1A Screening Levels					
		Oral (RfD)	RfC (mg/m^3)	Oral CSF (food) (per mg/kg/d)	Oral CSF (H_2O) (per mg/kg/d)	Inh URF (per ug/m^3)	Inh CSF (per mg/kg/d)
Dinitrobenzene, 1,3- (m-)	99-65-0	1.0E-04					
Dinitrophenol, 2,4-	51-28-5	2.0E-03					
Dinitrotoluene, 2,4-	121-14-2	2.0E-03					
Dinitrotoluene, 2,6-	606-20-2	1.0E-03					
Di-N-octyl phthalate	117-84-0	2.0E-02					
Dinoseb	88-85-7	1.0E-03					
Dioxane, 1,4-	123-91-1			1.1E-2	1.1E-2		
Diphenylamine, N,N-	122-39-4	2.5E-02					
Diphenylhydrazine, 1,2-	122-66-7			8.0E-1	8.0E-1	2.2E-4	8.0E-1
Direct Black 38	1937-37-7			8.6E+0	8.6E+0		
Direct Blue 6	2602-46-2			8.1E+0	8.1E+0		
Direct Brown 95	16071-86-6			9.3E+0	9.3E+0		
Disulfoton	298-04-4	4.0E-05					
Endosulfan	115-29-7	6.0E-03					
Endothall	145-73-3	2.0E-02					
Endrin	72-20-8	3.0E-04					
Epichlorohydrin	106-89-8	2.0E-03	1.0E-03	9.9E-3	9.9E-3	1.2E-6	4.2E-3
Epoxybutane, 1,2-	106-88-7		2.0E-02				
Ethoxyethanol acetate, 2-	111-15-9	3.0E-01					
Ethoxyethanol, 2- (ethylene glycol monoethyl ether)	110-80-5	4.0E-01	2.0E-01				
Ethyl acetate	141-78-6	9.0E-01					
Ethyl chloride (chloroethane)	75-00-3		1.0E+01				
Ethyl ether	60-29-7	2.0E-01					
Ethyl methacrylate	97-63-2	9.0E-02					
Ethyl methanesulfonate	62-50-0						
Ethylbenzene	100-41-4	1.0E-01	1.0E+00				
Ethylene glycol	107-21-1	2.0E+00					
Ethylene oxide	75-21-8			1.0E+0	1.0E+0	1.0E-4	3.5E-1
Ethylene thiourea	96-45-7	8.0E-05		1.1E-1	1.1E-1		
Fluoranthene	206-44-0	4.0E-02					
Fluorene	86-73-7	4.0E-02					
Fluoride	16984-48-8						
Formaldehyde	50-00-0	2.0E-01				1.3E-5	4.5E-2
Formic acid	64-18-6	2.0E+00					
Furan	110-00-9	1.0E-03					
Furfural	98-01-1	3.0E-03	5.0E-02				
Glycidaldehyde	765-34-4	4.0E-04	1.0E-03				
Heptachlor	76-44-8	5.0E-04		4.5E+0	4.5E+0	1.3E-3	4.5E+0
Heptachlor epoxide	1024-57-3	1.3E-05		9.1E+0	9.1E+0	2.6E-3	9.1E+0
Hexachlorobenzene	118-74-1	8.0E-04		1.6E+0	1.6E+0	4.6E-4	1.6E+0

(continued)

Table A-1. (continued)

Constituent Name	CAS No.	Benchmarks Selected for Use in Deriving Phase 1A Screening Levels					
		Oral (RfD)	RfC (mg/m^3)	Oral CSF (food) (per mg/kg/d)	Oral CSF (H_2O) (per mg/kg/d)	Inh URF (per ug/m^3)	Inh CSF (per mg/kg/d)
Hexachlorobutadiene	87-68-3	2.0E-04		7.8E-2	7.8E-2	2.2E-5	7.8E-2
Hexachlorocyclohexane, alpha-	319-84-6			6.3E+0	6.3E+0	1.8E-3	6.3E+0
Hexachlorocyclohexane, beta-	319-85-7			1.8E+0	1.8E+0	5.3E-4	1.8E+0
Hexachlorocyclohexane, gamma- (lindane)	58-89-9	3.0E-04		1.3E+0	1.3E+0		
Hexachlorocyclopentadiene	77-47-4	7.0E-03	7.0E-05				
Hexachloroethane	67-72-1	1.0E-03		1.4E-2	1.4E-2	4.0E-6	1.4E-2
Hexachlorophene	70-30-4	3.0E-04					
Hexane, n-	110-54-3	6.0E-02	2.0E-01				
Hydrazine	302-01-2			3.0E+0	3.0E+0	4.9E-3	1.7E+1
Ideno[1,2,3-cd]pyrene	193-39-5			7.3E-01	7.3E-01		
Isobutyl alcohol	78-83-1	3.0E-01					
Isophorone	78-59-1	2.0E-01		9.5E-4	9.5E-4		
Lead and cmpds (inorganic)	7439-92-1						
Maleic anhydride	108-31-6	1.0E-01					
Maleic hydrazide	123-33-1	5.0E-01					
Manganese	7439-96-5	1.4E-01	5.0E-05				
Mercuric chloride	7487-94-7	3.0E-04					
Mercury (elemental)	7439-97-6		3.0E-04				
Methacrylonitrile	126-98-7	1.0E-04	7.0E-04				
Methanol	67-56-1	5.0E-01					
Methomyl	16752-77-5	2.5E-02					
Methoxychlor	72-43-5	5.0E-03					
Methoxyethanol acetate, 2-	110-49-6	2.0E-03					
Methoxyethanol, 2- (ethylene glycol methyl ether)	109-86-4	1.0E-03	2.0E-02				
Methyl ethyl ketone	78-93-3	6.0E-01	1.0E+00				
Methyl isobutyl ketone	108-10-1	8.0E-02	8.0E-02				
Methyl mercury	22967-92-6	1.0E-04					
Methyl methacrylate	80-62-6	1.4E+00	7.0E-01				
Methyl parathion	298-00-0	2.5E-04					
Methyl tert-butyl ether	1634-04-4		3.0E+00				
Methylaniline, 2- (o-toluidine)	95-53-4			2.4E-1	2.4E-1		
Methylcholanthrene, 3-	56-49-5						
Methylene bromide	74-95-3	1.0E-02					
Methylene chloride (dichloromethane)	75-09-2	6.0E-02	3.0E+00	7.5E-3	7.5E-3	4.7E-7	
Methylene-bis(2-chloroaniline), 4,4'- (MBOCA)	101-14-4	7.0E-04		1.3E-1	1.3E-1	3.7E-5	1.3E-1
Molybdenum	7439-98-7	5.0E-03					
Naphthalene	91-20-3	2.0E-02	3.0E-03				
Nickel subsulfide	12035-72-2					4.8E-4	1.7E+0

(continued)

Table A-1. (continued)

Constituent Name	CAS No.	Benchmarks Selected for Use in Deriving Phase 1A Screening Levels					
		Oral (RfD)	RfC (mg/m^3)	Oral CSF (food) (per mg/kg/d)	Oral CSF (H_2O) (per mg/kg/d)	Inh URF (per ug/m^3)	Inh CSF (per mg/kg/d)
Nickel, soluble salts	7440-02-0	2.0E-02					
Nitrobenzene	98-95-3	5.0E-04	2.0E-03				
Nitropropane, 2-	79-46-9		2.0E-02			2.7E-3	9.4E+0
N-Nitrosodiethylamine	55-18-5			1.5E+2	1.5E+2	4.3E-2	1.5E+2
N-Nitrosodimethylamine (N-methyl-N-nitroso-methanamine)	62-75-9			5.1E+1	5.1E+1	1.4E-2	5.1E+1
N-Nitroso-di-n-butylamine	924-16-3			5.4E+0	5.4E+0	1.6E-3	5.4E+0
N-Nitrosodi-n-propylamine	621-64-7			7.0E+0	7.0E+0		
N-Nitrosodiphenylamine	86-30-6			4.9E-3	4.9E-3		
N-Nitroso-N-methylethylamine	10595-95-6			2.2E+1	2.2E+1		
N-Nitrosopiperidine	100-75-4						
N-Nitrosopyrrolidine	930-55-2			2.1E+0	2.1E+0	6.1E-4	2.1E+0
Octamethylpyrophosphoamide	152-16-9	2.0E-03					
Parathion	56-38-2	6.0E-03					
Pentachlorobenzene	608-93-5	8.0E-04					
Pentachlorodibenzofuran, 1,2,3,7,8-	57117-41-6			7.5E+3	7.5E+3	1.7E+0	7.5E+3
Pentachlorodibenzofuran, 2,3,4,7,8-	57117-31-4			7.5E+4	7.5E+4	1.7E+1	7.5E+4
Pentachlorodibenzo-p-dioxin, 1,2,3,7,8-	40321-76-4			1.5E+5	1.5E+5	3.3E+1	1.5E+5
Pentachloronitrobenzene	82-68-8	3.0E-03		2.6E-1	2.6E-1		
Pentachlorophenol	87-86-5	3.0E-02		1.2E-1	1.2E-1		
Perchlorate	14797-73-0						
Phenol	108-95-2	6.0E-01					
Phenylenediamine , m-	108-45-2	6.0E-03					
Phorate	298-02-2	2.0E-04					
Phthalic anhydride	85-44-9	2.0E+00	1.2E-01				
Polychlorinated biphenyls	1336-36-3			2	0.4	0.0001	see note
Pronamide	23950-58-5	7.5E-02					
Propylene oxide	75-56-9		3.0E-02	2.4E-1	2.4E-1	3.7E-6	1.3E-2
Pyrene	129-00-0	3.0E-02					
Pyridine	110-86-1	1.0E-03					
Safrole	94-59-7						
Selenium	7782-49-2	5.0E-03					
Silver	7440-22-4	5.0E-03					
Strychnine and salts	57-24-9	3.0E-04					
Styrene	100-42-5	2.0E-01	1.0E+00				
Styrene-7,8-oxide	96-09-3						
Sulfide	18496-25-8						
TCDD, 2,3,7,8-	1746-01-6			1.5E+5	1.5E+5	3.3E+1	1.5E+5
Tetrachlorobenzene, 1,2,4,5-	95-94-3	3.0E-04					

(continued)

Table A-1. (continued)

Constituent Name	CAS No.	Benchmarks Selected for Use in Deriving Phase 1A Screening Levels					
		Oral (RfD)	RfC (mg/m^3)	Oral CSF (food) (per mg/kg/d)	Oral CSF (H_2O) (per mg/kg/d)	Inh URF (per ug/m^3)	Inh CSF (per mg/kg/d)
Tetrachlorodibenzodioxins	41903-57-5			0	0	0	0
Tetrachlorodibenzofurans	55722-27-5			0	0	0	0
Tetrachloroethane, 1,1,1,2-	630-20-6	3.0E-02		2.6E-2	2.6E-2	7.4E-6	2.6E-2
Tetrachloroethane, 1,1,2,2-	79-34-5			2.0E-1	2.0E-1	5.8E-5	2.0E-1
Tetrachloroethylene (perchloroethylene)	127-18-4	1.0E-02		5.2E-2	5.2E-2	5.8E-7	2.0E-3
Tetrachlorophenol, 2,3,4,6-	58-90-2	3.0E-02					
Tetraethyldithiopyrophosphate	3689-24-5	5.0E-04					
Thallium	7440-28-0						
Thallium (I) acetate	563-68-8	9.0E-05					
Thallium (I) carbonate	6533-73-9	8.0E-05					
Thallium (I) chloride	7791-12-0	8.0E-05					
Thallium (I) nitrate	10102-45-1	9.0E-05					
Thallium (I) sulfate	7446-18-6	8.0E-05					
Thiram	137-26-8	5.0E-03					
Toluene	108-88-3	2.0E-01	4.0E-01				
Toluene-2,4-diamine (2,4-diaminotoluene)	95-80-7			3.2E+0	3.2E+0		
Toluidine, p-	106-49-0			1.9E-1	1.9E-1		
Toxaphene	8001-35-2			1.1E+0	1.1E+0	3.2E-4	1.1E+0
trans-1,3-Dichloropropylene	10061-02-6						
Trichloro-1,2,2-trifluoroethane, 1,1,2- (Freon 113)	76-13-1	3.0E+01	3.0E+01				
Trichlorobenzene, 1,2,4-	120-82-1	1.0E-02	2.0E-01				
Trichloroethane, 1,1,1- (methyl chloroform)	71-55-6		1.0E+00				
Trichloroethane, 1,1,2- (vinyl trichloride)	79-00-5	4.0E-03		5.7E-2	5.7E-2	1.6E-5	5.7E-2
Trichloroethylene	79-01-6			1.1E-02	1.1E-02	1.7E-06	6.0E-03
Trichlorofluoromethane (CFC-11)	75-69-4	3.0E-01	7.0E-01				
Trichlorophenol, 2,4,5-	95-95-4	1.0E-01					
Trichlorophenol, 2,4,6-	88-06-2			1.1E-2	1.1E-2	3.1E-6	1.0E-2
Trichlorophenoxy) propionic acid, 2 (2,4,5-	93-72-1	8.0E-03					
Trichlorophenoxyacetic acid, 2,4,5-	93-76-5	1.0E-02					
Trichloropropane, 1,2,3-	96-18-4	6.0E-03		7.0E+0	7.0E+0		
Triethylamine	121-44-8		7.0E-03				
Trinitrobenzene, 1,3,5- (sym-)	99-35-4	3.0E-02					
tris(2,3-Dibromopropyl)phosphate	126-72-7						
Vanadium	7440-62-2	7.0E-03					
Vinyl acetate	108-05-4	1.0E+00	2.0E-01				
Vinyl chloride	75-01-4			1.9E+0	1.9E+0	8.4E-5	3.0E-1

(continued)

Table A-1. (continued)

Constituent Name	CAS No.	Benchmarks Selected for Use in Deriving Phase 1A Screening Levels					
		Oral (RfD)	RfC (mg/m^3)	Oral CSF (food) (per mg/kg/d)	Oral CSF (H_2O) (per mg/kg/d)	Inh URF (per ug/m^3)	Inh CSF (per mg/kg/d)
Warfarin	81-81-2	3.0E-04					
Xylene, m-	108-38-3	2.0E+00					
Xylene, o-	95-47-6	2.0E+00					
Xylene, p-	106-42-3						
Xylenes (total)	1330-20-7	2.0E+00					
Zinc	7440-66-6	3.0E-01					

(continued)

Table A-1. (continued)

Constituent Name	CAS No.	EPA Benchmarks											
		RfD (mg/kg/d)	RfD Source	RfC (mg/m3)	RfC source	Oral CSF (mkd)-1	Oral CSF Source	Drinking H2O URF (per ug/L)	Oral URF Source	Inhal Unit Risk (ug/m3)-1	Inhal URF Source	HEAST inhal CSF (mkd)-1	Super-fund values
Acenaphthene	83329	6.0E-02	IRIS										
Acetaldehyde	75-07-0			9.0E-03	IRIS					2.2E-6	IRIS		
Acetone	67641	1.0E-01	IRIS										
Acetonitrile	75-05-8			6.0E-02	IRIS								
Acetophenone	98-86-2	1.0E-01	IRIS										
Acrolein	107-02-8	2.0E-02	HEAST	2.0E-05	IRIS								
Acrylamide	79-06-1	2.0E-04	IRIS			4.5E+0	IRIS	1.3E-04	IRIS	1.3E-3	IRIS	4.5E+0	
Acrylic acid	79-10-7	5.0E-01	IRIS	1.0E-03	IRIS								
Acrylonitrile	107-13-1	1.0E-03	HEAST	2.0E-03	IRIS	5.4E-1	IRIS	1.5E-05	IRIS	6.8E-5	IRIS	2.4E-1	
Aldicarb	116-06-3	1.0E-03	IRIS										
Aldrin	309-00-2	3.0E-05	IRIS			1.7E+1	IRIS	4.9E-04	IRIS	4.9E-3	IRIS	1.7E+1	
Allyl alcohol	107-18-6	5.0E-03	IRIS										
Allyl chloride (3-chloropropene)	107-05-1			1.0E-03	IRIS								
Ammonium vanadate	7803-55-6												
Amonium perchlorate	7790-98-9												
Aniline	62-53-3			1.0E-03	IRIS	5.7E-3	IRIS	1.6E-07	IRIS				
Anthracene	120-12-7	3.0E-01	IRIS										
Antimony	7440-36-0	4.0E-04	IRIS										
Antimony trioxide	1309-64-4	4.0E-04	HEAST	2.0E-04	IRIS								
Aramite	140-57-8	5.0E-02	HEAST			2.5E-2	IRIS	7.1E-07	IRIS	7.1E-6	IRIS	2.5E-2	
Arsenic, inorganic	7440-38-2	3.0E-04	IRIS			1.5E+0	IRIS	5.0E-05	IRIS	4.3E-3	IRIS		
Barium	7440-39-3	7.0E-02	IRIS	5.0E-04	HEAST2								
Benz(a)anthracene	56-55-3					7.3E-01	TEF	2.1E-05	TEF				
Benzene	71-43-2					2.9E-2[a]	IRIS	8.3E-07[a]	IRIS	8.3E-6[a]	IRIS	2.9E-2	6E-2 mg/m3 (subchronic RfC)

(continued)

Table A-1. (continued)

Constituent Name	CAS No.	EPA Benchmarks											
		RfD (mg/kg/d)	RfD Source	RfC (mg/m3)	RfC source	Oral CSF (mkd)-1	Oral CSF Source	Drinking H2O URF (per ug/L)	Oral URF Source	Inhal Unit Risk (ug/m3)-1	Inhal URF Source	HEAST inhal CSF (mkd)-1	Super-fund values
Benzidine	92-87-5	3.0E-03	IRIS			2.3E+2	IRIS	6.7E-03	IRIS	6.7E-2	IRIS	2.3E+2	
Benzo(a)pyrene	50-32-8					7.3E+0	IRIS	2.1E-04	IRIS				
Benzo(b)fluoranthene	205-99-2					7.3E-01	TEF	2.1E-05	TEF				
Benzyl alcohol	100-51-6	3.0E-01	HEAST										
Benzyl chloride	100-44-7					1.7E-1	IRIS	4.9E-06	IRIS				
Beryllium	7440-41-7	2.0E-03	IRIS	2.0E-05	IRIS					2.4E-3	IRIS	8.4E+0	
Bis(2-chloroethyl)ether	111-44-4					1.1E+0	IRIS	3.3E-05	IRIS	3.3E-4	IRIS	1.1E+0	
Bis(2-chloroisopropyl)ether	39638-32-9	4.0E-02	IRIS			7.0E-2	HEAST	2.0E-06	HEAST	1.0E-5	HEAST	3.5E-2	
Bis(2-ethylhexyl)phthalate (DEHP; also di-)	117-81-7	2.0E-02	IRIS			1.4E-2	IRIS	4.0E-07	IRIS				subchronic RfC= 1E-2 mg/m3
Bis(chloromethyl)ether	542-88-1					2.2E+2	IRIS	6.2E-03	IRIS	6.2E-2	IRIS	2.2E+2	
Bromoform	75-25-2	2.0E-02	IRIS			7.9E-3	IRIS	2.3E-07	IRIS	1.1E-6	IRIS	3.9E-3	
Bromomethane (methyl bromide)	74-83-9	1.4E-03	IRIS	5.0E-03	IRIS								
Butadiene, 1,3-	106-99-0									2.8E-4	IRIS	1.8E+0	
Butanol, n- (n-butyl alcohol)	71-36-3	1.0E-01	IRIS										
Butyl benzyl phthalate	85-68-7	2.0E-01	IRIS										
Cadmium	7440-43-9	5.0E-04	IRIS							1.8E-3	IRIS		
Carbon disulfide	75-15-0	1.0E-01	IRIS	7.0E-01	IRIS								
Carbon tetrachloride (tetrachloromethane)	56-23-5	7.0E-04	IRIS			1.3E-1	IRIS	3.7E-06	IRIS	1.5E-5	IRIS	5.3E-2	subchronic RfC=2E-2 mg/m3
Chloral	75-87-6	2.0E-03	IRIS										
Chloral hydrate [trichloroacetaldehyde hydrate]	302-17-0												
Chlordane	57-74-9	5.0E-04	IRIS	7.0E-04	IRIS	3.5E-1	IRIS	1.0E-05	IRIS	1.0E-4	IRIS	1.3E+0	
Chlordecone	143-50-0												
Chlorine cyanide (cyanogen chloride)	506-77-4	5.0E-02	IRIS										

(continued)

Table A-1. (continued)

Constituent Name	CAS No.	EPA Benchmarks											
		RfD (mg/kg/d)	RfD Source	RfC (mg/m3)	RfC source	Oral CSF (mkd)-1	Oral CSF Source	Drinking H2O URF (per ug/L)	Oral URF Source	Inhal Unit Risk (ug/m3)-1	Inhal URF Source	HEAST inhal CSF (mkd)-1	Super-fund values
Chloro-1,3-butadiene, 2- (chloroprene)	126-99-8	2.0E-02	HEAST2	7.0E-03	HEAST								
Chloroaniline, 4- (p-)	106-47-8	4.0E-03	IRIS										
Chlorobenzene	108-90-7	2.0E-02	IRIS	2.0E-02	HEAST2								subchronic RfC= 2E-1 mg/m3
Chlorobenzilate	510-15-6	2.0E-02	IRIS			2.7E-1	HEAST	7.8E-06	HEAST	7.8E-5	HEAST	2.7E-1	
Chlorodibromomethane (dibromochloromethane)	124-48-1	2.0E-02	IRIS			8.4E-2	IRIS	2.4E-06	IRIS				
Chloroform (trichloromethane)	67-66-3	1.0E-02	IRIS			6.1E-3	IRIS	1.7E-07	IRIS	2.3E-5	IRIS	8.1E-2	RfC not current
Chloromethane (methyl chloride)	74-87-3					1.3E-2	HEAST	3.7E-07	HEAST	1.8E-6	HEAST	6.3E-3	RfC=0.3 mg/m3
Chloromethyl methyl ether	107-30-2												
Chloronaphthalene, beta-	91-58-7	8.0E-02	IRIS										
Chlorophenol, 2-	95-57-8	5.0E-03	IRIS										
Chromium (III), insoluble salts	16065-83-1	1.5E+00	IRIS										
Chromium (VI)	18540-29-9	3.0E-03	IRIS	8E-6 or 1E-4	IRIS					1.2E-2	IRIS	4.1E+1	subchronic RfC= 4E-6 mg/m3
Chromium (VI) - chromic acid mists & dissolved Cr aerosols	18540-29-9			8.0E-06	IRIS								
Chromium (VI) - Cr particulates	18540-29-9			1.0E-04	IRIS								
Chrysene	218-01-9					7.3E-03	TEF	2.1E-07	TEF				
cis-1,3-Dichloropropylene	10061-01-5												
Cobalt (and cmpds)	7440-48-4												0.06 mkd (chronic RfD)
Copper	7440-50-8	*MCL only	HEAST										
Cresol mixtures	1319-77-3												
Cresol, m- (3-methylphenol)	108-39-4	5.0E-02	IRIS										
Cresol, o- (2-Methylphenol)	95-48-7	5.0E-02	IRIS										

(continued)

Table A-1. (continued)

Constituent Name	CAS No.	EPA Benchmarks											
		RfD (mg/kg/d)	RfD Source	RfC (mg/m3)	RfC source	Oral CSF (mkd)-1	Oral CSF Source	Drinking H2O URF (per ug/L)	Oral URF Source	Inhal Unit Risk (ug/m3)-1	Inhal URF Source	HEAST inhal CSF (mkd)-1	Super-fund values
Cresol, p- (4-methylphenol)	106-44-5	5.0E-03	HEAST										
Cumene	98-82-8	1.0E-01	IRIS	4.0E-01	IRIS								
Cyanide (amenable)	57-12-5	2.0E-02	IRIS										
Cyanogen bromide	506-68-3	9.0E-02	IRIS										
Cyclohexanol	108-93-0												
Cyclohexanone	108-94-1	5.0E+00	IRIS										
DDD (p,p'-dichlorodiphenyldichloroethane)	72-54-8					2.4E-1	IRIS	6.9E-06	IRIS				
DDE (p,p'-dichlorodiphenyldichloroethylene)	72-55-9					3.4E-1	IRIS	9.7E-06	IRIS				
DDT (p,p'-dichlorodiphenyltrichloroethane)	50-29-3	5.0E-04	IRIS			3.4E-1	IRIS	9.7E-06	IRIS	9.7E-5	IRIS	3.4E-1	
Diallate	2303-16-4					6.1E-2	HEAST	1.7E-06	HEAST				
Dibenzo(a,h)anthracene	53-70-3					7.3E+0	TEF	2.1E-04	TEF				
Dibromo-3-chloropropane, 1,2- (DBCP)	96-12-8			2.0E-04	IRIS	1.4E+0	HEAST	4.0E-05	HEAST	6.9E-7	HEAST	2.4E-03	
Dibromoethane, 1,2- (ethylene dibromide)	106-93-4			2.0E-04	HEAST	8.5E+1	IRIS	2.5E-03	IRIS	2.2E-4	IRIS	7.6E-1	
Dichlorobenzene, 1,2- (o-)	95-50-1	9.0E-02	IRIS	2.0E-01	HEAST2								
Dichlorobenzene, 1,4-	106-46-7			8.0E-01	IRIS	2.4E-2	HEAST	6.8E-07	HEAST				
Dichlorobenzidine, 3,3'-	91-94-1					4.5E-1	IRIS	1.3E-05	IRIS				
Dichlorobromomethane (bromodichloromethane)	75-27-4	2.0E-02	IRIS			6.2E-2	IRIS	1.8E-06	IRIS				
Dichlorodifluoromethane [CFC-12]	75-71-8	2.0E-01	IRIS	2.0E-01	HEAST2								
Dichloroethane, 1,1-	75-34-3	1.0E-01	HEAST	5.0E-01	HEAST2								
Dichloroethane, 1,2- (ethylene dichloride)	107-06-2					9.1E-2	IRIS	2.6E-06	IRIS	2.6E-5	IRIS		
Dichloroethylene, 1,1-	75-35-4	9.0E-03	IRIS			6.0E-1	IRIS	1.7E-05	IRIS	5.0E-5	IRIS	2.0E-1	
Dichloroethylene, 1,2- (cis)	156-59-2	1.0E-02	HEAST										
Dichloroethylene, 1,2- (trans)	156-60-5	2.0E-02	IRIS										

(continued)

Table A-1. (continued)

Constituent Name	CAS No.	EPA Benchmarks											
		RfD (mg/kg/d)	RfD Source	RfC (mg/m3)	RfC source	Oral CSF (mkd)-1	Oral CSF Source	Drinking H2O URF (per ug/L)	Oral URF Source	Inhal Unit Risk (ug/m3)-1	Inhal URF Source	HEAST inhal CSF (mkd)-1	Super-fund values
Dichlorophenol, 2,4-	120-83-2	3.0E-03	IRIS										
Dichlorophenoxyacetic acid, 2,4-(2,4-D)	94-75-7	1.0E-02	IRIS										
Dichloropropane, 1,2-	78-87-5			4.0E-03	IRIS	6.8E-2	HEAST	1.9E-06	HEAST				
Dieldrin	60-57-1	5.0E-05	IRIS			1.6E+1	IRIS	4.6E-04	IRIS	4.6E-3	IRIS	1.6E+1	
Diethyl phthalate	84-66-2	8.0E-01	IRIS										
Diethylstilbestrol	56-53-1					4.7E+3	HEAST	1.3E-01	HEAST				
Dimethoate	60-51-5	2.0E-04	IRIS										
Dimethoxybenzidine, 3,3'-	119-90-4					1.4E-2	HEAST	4.0E-07	HEAST				
Dimethylbenz[a]anthracene, 7,12-	57-97-6												
Dimethylbenzidine, 3,3'-	119-93-7					9.2E+0	HEAST	2.6E-04	HEAST				
Dimethylformamide, N,N-	68-12-2	1.0E-01	HEAST	3.0E-02	IRIS								
Dimethylphenol, 2,4-	105-67-9	2.0E-02	IRIS										
Dimethylphenol, 3,4-	95-65-8	1.0E-03	IRIS										
Dimethylphthalate	131-11-3												
Di-n-butyl phthalate	84-74-2	1.0E-01	IRIS										
Dinitrobenzene, 1,3- (m-)	99-65-0	1.0E-04	IRIS										
Dinitrophenol, 2,4-	51-28-5	2.0E-03	IRIS										
Dinitrotoluene, 2,4-	121-14-2	2.0E-03	IRIS										
Dinitrotoluene, 2,6-	606-20-2	1.0E-03	HEAST										
Di-N-octyl phthalate	117-84-0	2.0E-02	HEAST										
Dinoseb	88-85-7	1.0E-03	IRIS										
Dioxane, 1,4-	123-91-1					1.1E-2	IRIS	3.1E-07	IRIS				
Diphenylamine, N,N-	122-39-4	2.5E-02	IRIS										
Diphenylhydrazine, 1,2-	122-66-7					8.0E-1	IRIS	2.2E-05	IRIS	2.2E-4	IRIS	8.0E-1	
Direct Black 38	1937-37-7					8.6E+0	HEAST	2.4E-04	HEAST				
Direct Blue 6	2602-46-2					8.1E+0	HEAST	2.3E-04	HEAST				
Direct Brown 95	16071-86-6					9.3E+0	HEAST	2.6E-04	HEAST				

(continued)

Table A-1. (continued)

Constituent Name	CAS No.	EPA Benchmarks											
		RfD (mg/kg/d)	RfD Source	RfC (mg/m3)	RfC source	Oral CSF (mkd)-1	Oral CSF Source	Drinking H2O URF (per ug/L)	Oral URF Source	Inhal Unit Risk (ug/m3)-1	Inhal URF Source	HEAST inhal CSF (mkd)-1	Super-fund values
Disulfoton	298-04-4	4.0E-05	IRIS										
Endosulfan	115-29-7	6.0E-03	IRIS										
Endothall	145-73-3	2.0E-02	IRIS										
Endrin	72-20-8	3.0E-04	IRIS										
Epichlorohydrin	106-89-8	2.0E-03	HEAST	1.0E-03	IRIS	9.9E-3	IRIS	2.8E-07	IRIS	1.2E-6	IRIS	4.2E-3	
Epoxybutane, 1,2-	106-88-7			2.0E-02	IRIS								
Ethoxyethanol acetate, 2-	111-15-9	3.0E-01	HEAST2										
Ethoxyethanol, 2- (ethylene glycol monoethyl ether)	110-80-5	4.0E-01	HEAST	2.0E-01	IRIS								
Ethyl acetate	141-78-6	9.0E-01	IRIS										
Ethyl chloride (chloroethane)	75-00-3			1.0E+01	IRIS								
Ethyl ether	60-29-7	2.0E-01	IRIS										
Ethyl methacrylate	97-63-2	9.0E-02	HEAST										
Ethyl methanesulfonate	62-50-0												
Ethylbenzene	100-41-4	1.0E-01	IRIS	1.0E+00	IRIS								
Ethylene glycol	107-21-1	2.0E+00	IRIS										
Ethylene oxide	75-21-8					1.0E+0	HEAST	2.9E-05	HEAST	1.0E-4	HEAST	3.5E-1	
Ethylene thiourea	96-45-7	8.0E-05	IRIS			1.1E-1	HEAST	3.4E-06	HEAST				
Fluoranthene	206-44-0	4.0E-02	IRIS										
Fluorene	86-73-7	4.0E-02	IRIS										
Fluoride	16984-48-8												
Formaldehyde	50-00-0	2.0E-01	IRIS							1.3E-5	IRIS	4.5E-2	
Formic acid	64-18-6	2.0E+00	HEAST										
Furan	110-00-9	1.0E-03	IRIS										
Furfural	98-01-1	3.0E-03	IRIS	5.0E-02	HEAST2								
Glycidaldehyde	765-34-4	4.0E-04	IRIS	1.0E-03	HEAST								
Heptachlor	76-44-8	5.0E-04	IRIS			4.5E+0	IRIS	1.3E-04	IRIS	1.3E-3	IRIS	4.5E+0	
Heptachlor epoxide	1024-57-3	1.3E-05	IRIS			9.1E+0	IRIS	2.6E-04	IRIS	2.6E-3	IRIS	9.1E+0	

(continued)

Table A-1. (continued)

Constituent Name	CAS No.	EPA Benchmarks											
		RfD (mg/kg/d)	RfD Source	RfC (mg/m3)	RfC source	Oral CSF (mkd)-1	Oral CSF Source	Drinking H2O URF (per ug/L)	Oral URF Source	Inhal Unit Risk (ug/m3)-1	Inhal URF Source	HEAST inhal CSF (mkd)-1	Super-fund values
Hexachlorobenzene	118-74-1	8.0E-04	IRIS			1.6E+0	IRIS	4.6E-05	IRIS	4.6E-4	IRIS	1.6E+0	
Hexachlorobutadiene	87-68-3	2.0E-04	HEAST			7.8E-2	IRIS	2.2E-06	IRIS	2.2E-5	IRIS	7.8E-2	
Hexachlorocyclohexane, alpha-	319-84-6					6.3E+0	IRIS	1.8E-04	IRIS	1.8E-3	IRIS	6.3E+0	
Hexachlorocyclohexane, beta-	319-85-7					1.8E+0	IRIS	5.3E-05	IRIS	5.3E-4	IRIS	1.8E+0	
Hexachlorocyclohexane, gamma- (lindane)	58-89-9	3.0E-04	IRIS			1.3E+0	HEAST	3.7E-05	HEAST				
Hexachlorocyclopentadiene	77-47-4	7.0E-03	IRIS	7.0E-05	HEAST								
Hexachloroethane	67-72-1	1.0E-03	IRIS			1.4E-2	IRIS	4.0E-07	IRIS	4.0E-6	IRIS	1.4E-2	
Hexachlorophene	70-30-4	3.0E-04	IRIS										
Hexane, n-	110-54-3	6.0E-02	HEAST	2.0E-01	IRIS								
Hydrazine	302-01-2					3.0E+0	IRIS	8.5E-05	IRIS	4.9E-3	IRIS	1.7E+1	
Ideno[1,2,3-cd]pyrene	193-39-5					7.3E-1	TEF	2.1E-05	TEF				
Isobutyl alcohol	78-83-1	3.0E-01	IRIS										
Isophorone	78-59-1	2.0E-01	IRIS			9.5E-4	IRIS	2.7E-08	IRIS				
Lead and cmpds (inorganic)	7439-92-1												
Maleic anhydride	108-31-6	1.0E-01	IRIS										
Maleic hydrazide	123-33-1	5.0E-01	IRIS										
Manganese	7439-96-5	1.4E-01	IRIS	5.0E-05	IRIS								
Mercuric chloride	7487-94-7	3.0E-04	HEAST										
Mercury (elemental)	7439-97-6			3.0E-04	IRIS								
Methacrylonitrile	126-98-7	1.0E-04	IRIS	7.0E-04	HEAST2								
Methanol	67-56-1	5.0E-01	IRIS										
Methomyl	16752-77-5	2.5E-02	IRIS										
Methoxychlor	72-43-5	5.0E-03	IRIS										
Methoxyethanol acetate, 2-	110-49-6	2.0E-03	HEAST2										
Methoxyethanol, 2- (ethylene glycol methyl ether)	109-86-4	1.0E-03	HEAST2	2.0E-02	IRIS								
Methyl ethyl ketone	78-93-3	6.0E-01	IRIS	1.0E+00	IRIS								
Methyl isobutyl ketone	108-10-1	8.0E-02	HEAST	8.0E-02	HEAST2								

(continued)

Table A-1. (continued)

Constituent Name	CAS No.	EPA Benchmarks											
		RfD (mg/kg/d)	RfD Source	RfC (mg/m3)	RfC source	Oral CSF (mkd)-1	Oral CSF Source	Drinking H2O URF (per ug/L)	Oral URF Source	Inhal Unit Risk (ug/m3)-1	Inhal URF Source	HEAST inhal CSF (mkd)-1	Super-fund values
Methyl mercury	22967-92-6	1.0E-04	IRIS										
Methyl methacrylate	80-62-6	1.4E+00	IRIS	7.0E-01	IRIS								
Methyl parathion	298-00-0	2.5E-04	IRIS										
Methyl tert-butyl ether	1634-04-4			3.0E+00	IRIS								
Methylaniline, 2- (o-toluidine)	95-53-4					2.4E-1	HEAST	6.9E-06	HEAST				
Methylcholanthrene, 3-	56-49-5												
Methylene bromide	74-95-3	1.0E-02	HEAST2										
Methylene chloride (dichloromethane)	75-09-2	6.0E-02	IRIS	3.0E+00	HEAST	7.5E-3	IRIS	2.1E-07	IRIS	4.7E-7	IRIS		
Methylene-bis(2-chloroaniline), 4,4'- (MBOCA)	101-14-4	7.0E-04	HEAST			1.3E-1	HEAST	3.7E-06	HEAST	3.7E-5	HEAST	1.3E-1	
Molybdenum	7439-98-7	5.0E-03	IRIS										
Naphthalene	91-20-3	2.0E-02	IRIS	3.0E-03	IRIS								RfD= 4E-2 mg/kg/d
Nickel subsulfide	12035-72-2									4.8E-4	IRIS	1.7E+0	
Nickel, soluble salts	7440-02-0	2.0E-02	IRIS										
Nitrobenzene	98-95-3	5.0E-04	IRIS	2.0E-03	HEAST2								
Nitropropane, 2-	79-46-9			2.0E-02	IRIS					2.7E-3	HEAST	9.4E+0	
N-Nitrosodiethylamine	55-18-5					1.5E+2	IRIS	4.3E-03	IRIS	4.3E-2	IRIS	1.5E+2	
N-Nitrosodimethylamine (N-methyl-N-nitroso-methanamine)	62-75-9					5.1E+1	IRIS	1.4E-03	IRIS	1.4E-2	IRIS	5.1E+1	
N-Nitroso-di-n-butylamine	924-16-3					5.4E+0	IRIS	1.6E-04	IRIS	1.6E-3	IRIS	5.4E+0	
N-Nitrosodi-n-propylamine	621-64-7					7.0E+0	IRIS	2.0E-04	IRIS				
N-Nitrosodiphenylamine	86-30-6					4.9E-3	IRIS	1.4E-07	IRIS				
N-Nitroso-N-methylethylamine	10595-95-6					2.2E+1	IRIS	6.3E-04	IRIS				
N-Nitrosopiperidine	100-75-4												
N-Nitrosopyrrolidine	930-55-2					2.1E+0	IRIS	6.1E-05	IRIS	6.1E-4	IRIS	2.1E+0	
Octamethylpyrophosphoamide	152-16-9	2.0E-03	HEAST										
Parathion	56-38-2	6.0E-03	HEAST										

(continued)

Table A-1. (continued)

Constituent Name	CAS No.	EPA Benchmarks											
		RfD (mg/kg/d)	RfD Source	RfC (mg/m3)	RfC source	Oral CSF (mkd)-1	Oral CSF Source	Drinking H2O URF (per ug/L)	Oral URF Source	Inhal Unit Risk (ug/m3)-1	Inhal URF Source	HEAST inhal CSF (mkd)-1	Super-fund values
Pentachlorobenzene	608-93-5	8.0E-04	IRIS										
Pentachlorodibenzofuran, 1,2,3,7,8-	57117-41-6					7.5E+3	TEF	2.3E-01	TEF	1.7E+0	TEF	7.5E+3	
Pentachlorodibenzofuran, 2,3,4,7,8-	57117-31-4					7.5E+4	TEF	2.3E+00	TEF	1.7E+1	TEF	7.5E+4	
Pentachlorodibenzo-p-dioxin, 1,2,3,7,8-	40321-76-4					1.5E+5	TEF	4.5E+00	TEF	3.3E+1	TEF	1.5E+5	
Pentachloronitrobenzene	82-68-8	3.0E-03	IRIS			2.6E-1	HEAST	7.4E-06	HEAST				
Pentachlorophenol	87-86-5	3.0E-02	IRIS			1.2E-1	IRIS	3.0E-06	IRIS				
Perchlorate	14797-73-0												
Phenol	108-95-2	6.0E-01	IRIS										
Phenylenediamine , m-	108-45-2	6.0E-03	IRIS										
Phorate	298-02-2	2.0E-04	HEAST										
Phthalic anhydride	85-44-9	2.0E+00	IRIS	1.2E-01	HEAST								
Polychlorinated biphenyls	1336-36-3					2.0 (food), 0.4 (H2O)	IRIS			0.0001 (evap congenr)	IRIS	2.0 (dust, aerosol), 0.4 (evap c)	
Pronamide	23950-58-5	7.5E-02	IRIS										
Propylene oxide	75-56-9			3.0E-02	IRIS	2.4E-1	IRIS	6.8E-06	IRIS	3.7E-6	IRIS	1.3E-2	
Pyrene	129-00-0	3.0E-02	IRIS										
Pyridine	110-86-1	1.0E-03	IRIS										
Safrole	94-59-7												
Selenium	7782-49-2	5.0E-03	IRIS										
Silver	7440-22-4	5.0E-03	IRIS										
Strychnine and salts	57-24-9	3.0E-04	IRIS										
Styrene	100-42-5	2.0E-01	IRIS	1.0E+00	IRIS								
Styrene-7,8-oxide	96-09-3												
Sulfide	18496-25-8												
TCDD, 2,3,7,8-	1746-01-6					1.5E+5	HEAST	4.5E+00	HEAST	3.3E+1	HEAST	1.5E+5	

(continued)

Table A-1. (continued)

Constituent Name	CAS No.	EPA Benchmarks											
		RfD (mg/kg/d)	RfD Source	RfC (mg/m3)	RfC source	Oral CSF (mkd)-1	Oral CSF Source	Drinking H2O URF (per ug/L)	Oral URF Source	Inhal Unit Risk (ug/m3)-1	Inhal URF Source	HEAST inhal CSF (mkd)-1	Super-fund values
Tetrachlorobenzene, 1,2,4,5-	95-94-3	3.0E-04	IRIS										
Tetrachlorodibenzodioxins	41903-57-5					0.0E+0	TEF	0.0E+00	TEF	0.0E+0	TEF	0.0E+0	
Tetrachlorodibenzofurans	55722-27-5					0.0E+0	TEF	0.0E+00	TEF	0.0E+0	TEF	0.0E+0	
Tetrachloroethane, 1,1,1,2-	630-20-6	3.0E-02	IRIS			2.6E-2	IRIS	7.4E-07	IRIS	7.4E-6	IRIS	2.6E-2	
Tetrachloroethane, 1,1,2,2-	79-34-5					2.0E-1	IRIS	5.8E-06	IRIS	5.8E-5	IRIS	2.0E-1	
Tetrachloroethylene (perchloroethylene)	127-18-4	1.0E-02	IRIS			5.2E-02	HAD	1.5E-06	HAD	5.8E-07	HAD		
Tetrachlorophenol, 2,3,4,6-	58-90-2	3.0E-02	IRIS										
Tetraethyldithiopyrophosphate	3689-24-5	5.0E-04	IRIS										
Thallium	7440-28-0												
Thallium (I) acetate	563-68-8	9.0E-05	IRIS										
Thallium (I) carbonate	6533-73-9	8.0E-05	IRIS										
Thallium (I) chloride	7791-12-0	8.0E-05	IRIS										
Thallium (I) nitrate	10102-45-1	9.0E-05	IRIS										
Thallium (I) sulfate	7446-18-6	8.0E-05	IRIS										
Thiram	137-26-8	5.0E-03	IRIS										
Toluene	108-88-3	2.0E-01	IRIS	4.0E-01	IRIS								
Toluene-2,4-diamine (2,4-diaminotoluene)	95-80-7					3.2E+0	HEAST	9.1E-05	HEAST				
Toluidine, p-	106-49-0					1.9E-1	HEAST	5.4E-06	HEAST				
Toxaphene	8001-35-2					1.1E+0	IRIS	3.2E-05	IRIS	3.2E-4	IRIS	1.1E+0	
trans-1,3-Dichloropropylene	10061-02-6												
Trichloro-1,2,2-trifluoroethane, 1,1,2- (Freon 113)	76-13-1	3.0E+01	IRIS	3.0E+01	HEAST								
Trichlorobenzene, 1,2,4-	120-82-1	1.0E-02	IRIS	2.0E-01	HEAST								
Trichloroethane, 1,1,1- (methyl chloroform)	71-55-6												RfC= 1.0 mg/m3
Trichloroethane, 1,1,2- (vinyl trichloride)	79-00-5	4.0E-03	IRIS			5.7E-2	IRIS	1.6E-06	IRIS	1.6E-5	IRIS	5.7E-2	

(continued)

Table A-1. (continued)

Constituent Name	CAS No.	EPA Benchmarks											
		RfD (mg/kg/d)	RfD Source	RfC (mg/m3)	RfC source	Oral CSF (mkd)-1	Oral CSF Source	Drinking H2O URF (per ug/L)	Oral URF Source	Inhal Unit Risk (ug/m3)-1	Inhal URF Source	HEAST inhal CSF (mkd)-1	Super-fund values
Trichloroethylene	79-01-6												oral URF=3.2 E-7; oral CSF=1.1 E-2; inh URF=1.7 E-6; inh CSF=6E-3
Trichlorofluoromethane (CFC-11)	75-69-4	3.0E-01	IRIS	7.0E-01	HEAST2								
Trichlorophenol, 2,4,5-	95-95-4	1.0E-01	IRIS										
Trichlorophenol, 2,4,6-	88-06-2					1.1E-2	IRIS	3.1E-07	IRIS	3.1E-6	IRIS	1.0E-2	
Trichlorophenoxy) propionic acid, 2 (2,4,5-	93-72-1	8.0E-03	IRIS										
Trichlorophenoxyacetic acid, 2,4,5-	93-76-5	1.0E-02	IRIS										
Trichloropropane, 1,2,3-	96-18-4	6.0E-03	IRIS			7.0E+0	HEAST	2.0E-04	HEAST				
Triethylamine	121-44-8			7.0E-03	IRIS								
Trinitrobenzene, 1,3,5- (sym-)	99-35-4	3.0E-02	IRIS										
tris(2,3-Dibromopropyl)phosphate	126-72-7												
Vanadium	7440-62-2	7.0E-03	HEAST										
Vinyl acetate	108-05-4	1.0E+00	HEAST	2.0E-01	IRIS								
Vinyl chloride	75-01-4					1.9E+0	HEAST	5.4E-05	HEAST	8.4E-5	HEAST	3.0E-1	
Warfarin	81-81-2	3.0E-04	IRIS										
Xylene, m-	108-38-3	2.0E+00	HEAST										
Xylene, o-	95-47-6	2.0E+00	HEAST										
Xylene, p-	106-42-3												
Xylenes (total)	1330-20-7	2.0E+00	IRIS										
Zinc	7440-66-6	3.0E-01	IRIS										

(continued)

Table A-1. (continued)

Constituent Name	CAS No.	Additional Benchmarks (non-IRIS, non-HEAST, non-Superfund)								
		Other EPA values	Source(s)	ATSDR oral MRL - chronic (mg/kg/d)	ATSDR inhal MRL - chronic (ppm)	CalEPA97 chronic inhal REL (mg/m3)	CalEPA99 chronic inhal REL (mg/m3)	CalEPA99 inhal unit risk (ug/m3)-1	CalEPA99 inhal CSF (mkd)-1	CalEPA99 Oral CSF (mkd)-1
Acenaphthene	83329									
Acetaldehyde	75-07-0					9.0E-03	not updated	2.7E-06		1.0E-02
Acetone	67641				13					
Acetonitrile	75-05-8									
Acetophenone	98-86-2									
Acrolein	107-02-8			0.0005		2.0E-05	2.0E-05			
Acrylamide	79-06-1					7.0E-04	not updated	1.3E-03		4.5E+00
Acrylic acid	79-10-7					1.0E-03	not updated			
Acrylonitrile	107-13-1			0.04		2.0E-03	2.0E-03	2.9E-04		1.0E+00
Aldicarb	116-06-3									
Aldrin	309-00-2			0.00003						
Allyl alcohol	107-18-6									
Allyl chloride (3-chloropropene)	107-05-1					1.0E-03	not updated	6.0E-06		2.1E-02
Ammonium vanadate	7803-55-6									
Amonium perchlorate	7790-98-9									
Aniline	62-53-3					1.0E-03	not updated	1.6E-06		5.7E-03
Anthracene	120-12-7									
Antimony	7440-36-0									
Antimony trioxide	1309-64-4					2.0E-04	not updated			
Aramite	140-57-8									
Arsenic, inorganic	7440-38-2			0.0003		3.0E-05	3.0E-05	3.3E-03	1.2E+01	1.5E+00

(continued)

Table A-1. (continued)

Constituent Name	CAS No.	Additional Benchmarks (non-IRIS, non-HEAST, non-Superfund)								
		Other EPA values	Source(s)	ATSDR oral MRL - chronic (mg/kg/d)	ATSDR inhal MRL - chronic (ppm)	CalEPA97 chronic inhal REL (mg/m3)	CalEPA99 chronic inhal REL (mg/m3)	CalEPA99 inhal unit risk (ug/m3)-1	CalEPA99 inhal CSF (mkd)-1	CalEPA99 Oral CSF (mkd)-1
Barium	7440-39-3									
Benz(a)anthracene	56-55-3							1.1E-04	3.9E-01	1.2E+00
Benzene	71-43-2					6.0E-02	6.0E-02	2.9E-05		1.0E-01
Benzidine	92-87-5					1.0E-02	not updated	1.4E-01		5.0E+02
Benzo(a)pyrene	50-32-8							1.1E-03	3.9E+00	1.2E+01
Benzo(b)fluoranthene	205-99-2							1.1E-04	3.9E-01	1.2E+00
Benzyl alcohol	100-51-6									
Benzyl chloride	100-44-7							4.9E-05		1.7E-01
Beryllium	7440-41-7					1.0E-06	1.0E-06	2.4E-03		8.4E+00
Bis(2-chloroethyl)ether	111-44-4							7.1E-04		2.5E+00
Bis(2-chloroisopropyl)ether	39638-32-9									
Bis(2-ethylhexyl)phthalate (DEHP; also di-)	117-81-7					1.0E-02	1.0E-02	2.4E-06		8.4E-03
Bis(chloromethyl)ether	542-88-1							1.3E-02		4.6E+02
Bromoform	75-25-2			0.2						
Bromomethane (methyl bromide)	74-83-9				0.005	5.0E-03	5.0E-03			
Butadiene, 1,3-	106-99-0					8.0E-03	8.0E-03	1.7E-04		3.4E+00
Butanol, n- (n-butyl alcohol)	71-36-3									
Butyl benzyl phthalate	85-68-7									
Cadmium	7440-43-9			0.0002		1.0E-05	2.0E-05	4.2E-03		1.5E+01
Carbon disulfide	75-15-0				0.3	7.0E-01	7.0E-01			
Carbon tetrachloride (tetrachloromethane)	56-23-5					4.0E-02	4.0E-02	4.2E-05		1.5E-01
Chloral	75-87-6									

(continued)

Table A-1. (continued)

Constituent Name	CAS No.	Additional Benchmarks (non-IRIS, non-HEAST, non-Superfund)								
		Other EPA values	Source(s)	ATSDR oral MRL - chronic (mg/kg/d)	ATSDR inhal MRL - chronic (ppm)	CalEPA97 chronic inhal REL (mg/m3)	CalEPA99 chronic inhal REL (mg/m3)	CalEPA99 inhal unit risk (ug/m3)-1	CalEPA99 inhal CSF (mkd)-1	CalEPA99 Oral CSF (mkd)-1
Chloral hydrate [trichloroacetaldehyde hydrate]	302-17-0									
Chlordane	57-74-9			0.0006	0.00002 mg/m3					
Chlordecone	143-50-0			0.0005						
Chlorine cyanide (cyanogen chloride)	506-77-4									
Chloro-1,3-butadiene, 2- (chloroprene)	126-99-8									
Chloroaniline, 4- (p-)	106-47-8									
Chlorobenzene	108-90-7					1.0E+00	1.0E+00			
Chlorobenzilate	510-15-6									
Chlorodibromomethane (dibromochloromethane)	124-48-1	Inh CSF = 8.4E-2 per mkd; URF=2.4E-5 per μµg/m^3	Air Char. Study0.03							
Chloroform (trichloromethane)	67-66-3			0.01	0.02	3.0E-01	3.0E-01	5.3E-06		1.9E-02
Chloromethane (methyl chloride)	74-87-3				0.05					
Chloromethyl methyl ether	107-30-2									
Chloronaphthalene, beta-	91-58-7									
Chlorophenol, 2-	95-57-8	RfC=0.0014 mg/m^3	Air Char. Study							
Chromium (III), insoluble salts	16065-83-1									
Chromium (VI)	18540-29-9					8.0E-07	8.0E-07	1.5E-01	5.1E+02	4.2E-01
Chromium (VI) - chromic acid mists & dissolved Cr aerosols	18540-29-9				1E-4 mg/3					
Chromium (VI) - Cr particulates	18540-29-9									
Chrysene	218-01-9							1.1E-05	3.9E-02	1.2E-01
cis-1,3-Dichloropropylene	10061-01-5									

(continued)

Table A-1. (continued)

Constituent Name	CAS No.	Additional Benchmarks (non-IRIS, non-HEAST, non-Superfund)								
		Other EPA values	Source(s)	ATSDR oral MRL - chronic (mg/kg/d)	ATSDR inhal MRL - chronic (ppm)	CalEPA97 chronic inhal REL (mg/m3)	CalEPA99 chronic inhal REL (mg/m3)	CalEPA99 inhal unit risk (ug/m3)-1	CalEPA99 inhal CSF (mkd)-1	CalEPA99 Oral CSF (mkd)-1
Cobalt (and cmpds)	7440-48-4	RfC=1E-5 mg/m^3	Air Char. Study5.0E-06not updated							
Copper	7440-50-8					2.0E-05	not updated			
Cresol mixtures	1319-77-3	RfC=4E-4mg/m^3	Air Char. Study4.0E-031.8E-01							
Cresol, m- (3-methylphenol)	108-39-4									
Cresol, o- (2-Methylphenol)	95-48-7									
Cresol, p- (4-methylphenol)	106-44-5									
Cumene	98-82-8									
Cyanide (amenable)	57-12-5									
Cyanogen bromide	506-68-3									
Cyclohexanol	108-93-0	prov RfD=1.7E-5 mkd; prov RfC=6.0E-5 or 2.0E-5 mg/m^3	61FR 42317-354; 63FR 64371-402							
Cyclohexanone	108-94-1									
DDD (p,p'-dichlorodiphenyldichloroethane)	72-54-8									
DDE (p,p'-dichlorodiphenyldichloroethylene)	72-55-9									
DDT (p,p'-dichlorodiphenyltrichloroethane)	50-29-3									
Diallate	2303-16-4									
Dibenzo(a,h)anthracene	53-70-3							1.2E-03		4.1E+00
Dibromo-3-chloropropane, 1,2- (DBCP)	96-12-8							2.0E-03		7.0E+00
Dibromoethane, 1,2- (ethylene dibromide)	106-93-4					8.0E-04	8.0E-04	7.1E-05		2.5E-01

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Table A-1. (continued)

Constituent Name	CAS No.	Additional Benchmarks (non-IRIS, non-HEAST, non-Superfund)								
		Other EPA values	Source(s)	ATSDR oral MRL - chronic (mg/kg/d)	ATSDR inhal MRL - chronic (ppm)	CalEPA97 chronic inhal REL (mg/m3)	CalEPA99 chronic inhal REL (mg/m3)	CalEPA99 inhal unit risk (ug/m3)-1	CalEPA99 inhal CSF (mkd)-1	CalEPA99 Oral CSF (mkd)-1
Dichlorobenzene, 1,2- (o-)	95-50-1									
Dichlorobenzene, 1,4-	106-46-7				0.1	8.0E-01	8.0E-01	1.1E-05		4.0E-02
Dichlorobenzidine, 3,3'-	91-94-1							3.4E-04		1.2E+00
Dichlorobromomethane (bromodichloromethane)	75-27-4	inh CSF=6.2E-2 per mkd; URF=1.8E-5 per μµg/m^3	Air Char. Study	0.02						
Dichlorodifluoromethane [CFC-12]	75-71-8					1.0E+00	not updated			
Dichloroethane, 1,1-	75-34-3							1.6E-06		5.7E-03
Dichloroethane, 1,2- (ethylene dichloride)	107-06-2					4.0E-01	4.0E-01	2.2E-05		7.0E-02
Dichloroethylene, 1,1-	75-35-4			0.009		2.0E-02	2.0E-02			
Dichloroethylene, 1,2- (cis)	156-59-2									
Dichloroethylene, 1,2- (trans)	156-60-5									
Dichlorophenol, 2,4-	120-83-2									
Dichlorophenoxyacetic acid, 2,4- (2,4-D)	94-75-7									
Dichloropropane, 1,2-	78-87-5			0.09						
Dieldrin	60-57-1			0.00005						
Diethyl phthalate	84-66-2									
Diethylstilbestrol	56-53-1									
Dimethoate	60-51-5									
Dimethoxybenzidine, 3,3'-	119-90-4									
Dimethylbenz[a]anthracene, 7,12-	57-97-6	inh CSF=84 per mkd; URF=2.4E-2 per μµg/m^3	Air Char. Study					7.1E-02		2.5E+02

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Table A-1. (continued)

Constituent Name	CAS No.	Additional Benchmarks (non-IRIS, non-HEAST, non-Superfund)								
		Other EPA values	Source(s)	ATSDR oral MRL - chronic (mg/kg/d)	ATSDR inhal MRL - chronic (ppm)	CalEPA97 chronic inhal REL (mg/m3)	CalEPA99 chronic inhal REL (mg/m3)	CalEPA99 inhal unit risk (ug/m3)-1	CalEPA99 inhal CSF (mkd)-1	CalEPA99 Oral CSF (mkd)-1
Dimethylbenzidine, 3,3'-	119-93-7									
Dimethylformamide, N,N-	68-12-2					3.0E-02	3.0E-02			
Dimethylphenol, 2,4-	105-67-9									
Dimethylphenol, 3,4-	95-65-8									
Dimethylphthalate	131-11-3									
Di-n-butyl phthalate	84-74-2									
Dinitrobenzene, 1,3- (m-)	99-65-0									
Dinitrophenol, 2,4-	51-28-5									
Dinitrotoluene, 2,4-	121-14-2	inh CSF=6.8E-1 per mkd; URF=1.9E-4 per μg/m^3	Air Char. Study	0.002		7.0E-03	not updated	8.9E-05		3.1E-01
Dinitrotoluene, 2,6-	606-20-2									
Di-N-octyl phthalate	117-84-0									
Dinoseb	88-85-7									
Dioxane, 1,4-	123-91-1	RfC=0.8 mg/m^3	Air Char. Study	3.0E+00	3.0E+00			7.7E-06		2.7E-02
Diphenylamine, N,N-	122-39-4									
Diphenylhydrazine, 1,2-	122-66-7									
Direct Black 38	1937-37-7									
Direct Blue 6	2602-46-2									
Direct Brown 95	16071-86-6									
Disulfoton	298-04-4			0.00006						
Endosulfan	115-29-7			0.002						
Endothall	145-73-3									
Endrin	72-20-8			0.0003						

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Table A-1. (continued)

Constituent Name	CAS No.	Additional Benchmarks (non-IRIS, non-HEAST, non-Superfund)								
		Other EPA values	Source(s)	ATSDR oral MRL - chronic (mg/kg/d)	ATSDR inhal MRL - chronic (ppm)	CalEPA97 chronic inhal REL (mg/m3)	CalEPA99 chronic inhal REL (mg/m3)	CalEPA99 inhal unit risk (ug/m3)-1	CalEPA99 inhal CSF (mkd)-1	CalEPA99 Oral CSF (mkd)-1
Epichlorohydrin	106-89-8					1.0E-03	1.0E-03	2.3E-05		8.0E-02
Epoxybutane, 1,2-	106-88-7					2.0E-02	2.0E-02			
Ethoxyethanol acetate, 2-	111-15-9	RfC=0.3 mg/m^3	Air Char. Study3.0E-013.0E-01							
Ethoxyethanol, 2- (ethylene glycol monoethyl ether)	110-80-5					2.0E-01	2.0E-01			
Ethyl acetate	141-78-6									
Ethyl chloride (chloroethane)	75-00-3					1.0E+01	1.0E+01			
Ethyl ether	60-29-7									
Ethyl methacrylate	97-63-2									
Ethyl methanesulfonate	62-50-0									
Ethylbenzene	100-41-4					1.0E+00	1.0E+00			
Ethylene glycol	107-21-1	RfC=0.6 mg/m^3	Air Char. Study2			4.0E-01	4.0E-01			
Ethylene oxide	75-21-8					5.0E-03	3.0E-02	8.8E-05		3.1E-01
Ethylene thiourea	96-45-7					3.0E-03	not updated	1.3E-05		4.5E-02
Fluoranthene	206-44-0									
Fluorene	86-73-7									
Fluoride	16984-48-8									
Formaldehyde	50-00-0			0.2	0.008	2.0E-03	3.0E-03	6.0E-06		2.1E-02
Formic acid	64-18-6									
Furan	110-00-9									
Furfural	98-01-1									
Glycidaldehyde	765-34-4									
Heptachlor	76-44-8									
Heptachlor epoxide	1024-57-3									

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Table A-1. (continued)

Constituent Name	CAS No.	Additional Benchmarks (non-IRIS, non-HEAST, non-Superfund)								
		Other EPA values	Source(s)	ATSDR oral MRL - chronic (mg/kg/d)	ATSDR inhal MRL - chronic (ppm)	CalEPA97 chronic inhal REL (mg/m3)	CalEPA99 chronic inhal REL (mg/m3)	CalEPA99 inhal unit risk (ug/m3)-1	CalEPA99 inhal CSF (mkd)-1	CalEPA99 Oral CSF (mkd)-1
Hexachlorobenzene	118-74-1			0.00002		3.0E-03	not updated	5.1E-04		1.8E+00
Hexachlorobutadiene	87-68-3					9.0E-02	not updated			
Hexachlorocyclohexane, alpha-	319-84-6			0.008		2.0E-02	not updated			
Hexachlorocyclohexane, beta-	319-85-7					2.0E-03	not updated			
Hexachlorocyclohexane, gamma-(lindane)	58-89-9					3.0E-04	not updated	3.1E-04		1.1E+00
Hexachlorocyclopentadiene	77-47-4				0.0002	7.0E-04	not updated			
Hexachloroethane	67-72-1					8.0E-02	not updated			
Hexachlorophene	70-30-4									
Hexane, n-	110-54-3				0.6	2.0E-01	2.0E-01			
Hydrazine	302-01-2					2.0E-04	2.0E-04	4.9E-03	1.7E+01	3.0E+00
Ideno[1,2,3-cd]pyrene	193-39-5							1.1E-04	3.9E-01	1.2E+00
Isobutyl alcohol	78-83-1									
Isophorone	78-59-1	RfC=0.012 or 0.0037 mg/m^3	63FR 64371 and 61FR 423170.2			2.0E+00	2.0E+00			
Lead and cmpds (inorganic)	7439-92-1							1.2E-05	4.2E-02	8.5E-03
Maleic anhydride	108-31-6					2.0E-04	1.0E-03			
Maleic hydrazide	123-33-1									
Manganese	7439-96-5				0.00004 mg/m3	5.0E-05	5.0E-05			
Mercuric chloride	7487-94-7									
Mercury (elemental)	7439-97-6				0.0002 mg/m3	3.0E-04	3.0E-04			

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Table A-1. (continued)

Constituent Name	CAS No.	Additional Benchmarks (non-IRIS, non-HEAST, non-Superfund)								
		Other EPA values	Source(s)	ATSDR oral MRL - chronic (mg/kg/d)	ATSDR inhal MRL - chronic (ppm)	CalEPA97 chronic inhal REL (mg/m3)	CalEPA99 chronic inhal REL (mg/m3)	CalEPA99 inhal unit risk (ug/m3)-1	CalEPA99 inhal CSF (mkd)-1	CalEPA99 Oral CSF (mkd)-1
Methacrylonitrile	126-98-7									
Methanol	67-56-1	RfC=13 mg/m^3	Air Char. Study1.0E+011.0E+01							
Methomyl	16752-77-5									
Methoxychlor	72-43-5									
Methoxyethanol acetate, 2-	110-49-6	prov RfD=0.0057 mkd; prov RfC=0.03 mg/m^3	61FR 42317 and Air Char. Study9.0E-029.0E-02							
Methoxyethanol, 2- (ethylene glycol methyl ether)	109-86-4	prov RfD=0.0057 mkd	61FR 42317 2.0E-022.0E-02							
Methyl ethyl ketone	78-93-3					1.0E+00	1.0E+01			
Methyl isobutyl ketone	108-10-1									
Methyl mercury	22967-92-6			0.5 ug/kg/d						
Methyl methacrylate	80-62-6					1.0E-01	not updated			
Methyl parathion	298-00-0			0.0003						
Methyl tert-butyl ether	1634-04-4				0.7	3.0E+00	3.0E+00			
Methylaniline, 2- (o-toluidine)	95-53-4	inh CSF=2.4E-1 per mkd; URF=6.9E-5 per μµg/m^3	Air Char. Study							
Methylcholanthrene, 3-	56-49-5	inh CSF=7.4 per mkd; URF=2.1E-3 per μµg/m^3	Air Char. Study					6.3E-03		2.2E+01
Methylene bromide	74-95-3									
Methylene chloride (dichloromethane)	75-09-2			0.2	0.3	3.0E-01	4.0E-01	1.0E-06	3.5E-03	

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Table A-1. (continued)

Constituent Name	CAS No.	Additional Benchmarks (non-IRIS, non-HEAST, non-Superfund)								
		Other EPA values	Source(s)	ATSDR oral MRL - chronic (mg/kg/d)	ATSDR inhal MRL - chronic (ppm)	CalEPA97 chronic inhal REL (mg/m3)	CalEPA99 chronic inhal REL (mg/m3)	CalEPA99 inhal unit risk (ug/m3)-1	CalEPA99 inhal CSF (mkd)-1	CalEPA99 Oral CSF (mkd)-1
Methylene-bis(2-chloroaniline), 4,4'- (MBOCA)	101-14-4			0.003				4.3E-04		1.5E+00
Molybdenum	7439-98-7									
Naphthalene	91-20-3				0.002	9.0E-03	9.0E-03			
Nickel subsulfide	12035-72-2									
Nickel, soluble salts	7440-02-0				0.0002 mg/m3	5.0E-05	5.0E-05	2.6E-04		9.1E-01
Nitrobenzene	98-95-3					3.0E-02	not updated			
Nitropropane, 2-	79-46-9					2.0E-02	not updated			
N-Nitrosodiethylamine	55-18-5							1.0E-02		3.6E+01
N-Nitrosodimethylamine (N-methyl-N-nitroso-methanamine)	62-75-9							4.6E-03		1.6E+01
N-Nitroso-di-n-butylamine	924-16-3							3.1E-03		1.1E+01
N-Nitrosodi-n-propylamine	621-64-7							2.0E-03		7.0E+00
N-Nitrosodiphenylamine	86-30-6							2.6E-06		9.0E-03
N-Nitroso-N-methylethylamine	10595-95-6							6.3E-03		3.7E+00
N-Nitrosopiperidine	100-75-4							2.7E-03		9.4E+00
N-Nitrosopyrrolidine	930-55-2							6.0E-04		2.1E+00
Octamethylpyrophosphoamide	152-16-9									
Parathion	56-38-2									
Pentachlorobenzene	608-93-5									
Pentachlorodibenzofuran, 1,2,3,7,8-	57117-41-6							1.9E+00		6.5E+03
Pentachlorodibenzofuran, 2,3,4,7,8-	57117-31-4							1.9E+01		6.5E+04

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Table A-1. (continued)

Constituent Name	CAS No.	Additional Benchmarks (non-IRIS, non-HEAST, non-Superfund)								
		Other EPA values	Source(s)	ATSDR oral MRL - chronic (mg/kg/d)	ATSDR inhal MRL - chronic (ppm)	CalEPA97 chronic inhal REL (mg/m3)	CalEPA99 chronic inhal REL (mg/m3)	CalEPA99 inhal unit risk (ug/m3)-1	CalEPA99 inhal CSF (mkd)-1	CalEPA99 Oral CSF (mkd)-1
Pentachlorodibenzo-p-dioxin, 1,2,3,7,8-	40321-76-4							1.9E+01		6.5E+04
Pentachloronitrobenzene	82-68-8									
Pentachlorophenol	87-86-5			0.001		1.0E-01	not updated	5.1E-06		1.8E-02
Perchlorate	14797-73-0									
Phenol	108-95-2	prov RfC=0.02 or 0.006 mg/m^3	61FR 42317 and 63FR 24596			6.0E-01	6.0E-01			
Phenylenediamine , m-	108-45-2									
Phorate	298-02-2									
Phthalic anhydride	85-44-9					1.0E-02	1.0E-02			
Polychlorinated biphenyls	1336-36-3							5.7E-4 (high) (low)	2.0E-5	2.0E+0 (high) 7.0E-2 (low)
Pronamide	23950-58-5									
Propylene oxide	75-56-9					3.0E+00	3.0E-02	3.7E-06	1.3E-02	2.4E-01
Pyrene	129-00-0									
Pyridine	110-86-1									
Safrole	94-59-7									
Selenium	7782-49-2			0.005		8.0E-05	2.0E-02			
Silver	7440-22-4					2.0E-02	not updated			
Strychnine and salts	57-24-9									
Styrene	100-42-5				0.06	1.0E+00	1.0E+00			

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Table A-1. (continued)

Constituent Name	CAS No.	Additional Benchmarks (non-IRIS, non-HEAST, non-Superfund)								
		Other EPA values	Source(s)	ATSDR oral MRL - chronic (mg/kg/d)	ATSDR inhal MRL - chronic (ppm)	CalEPA97 chronic inhal REL (mg/m3)	CalEPA99 chronic inhal REL (mg/m3)	CalEPA99 inhal unit risk (ug/m3)-1	CalEPA99 inhal CSF (mkd)-1	CalEPA99 Oral CSF (mkd)-1
Styrene-7,8-oxide	96-09-3					6.0E-03	not updated			
Sulfide	18496-25-8									
TCDD, 2,3,7,8-	1746-01-6			0.000001 ug/kg/d				3.8E+01		1.3E+05
Tetrachlorobenzene, 1,2,4,5-	95-94-3									
Tetrachlorodibenzodioxins	41903-57-5									
Tetrachlorodibenzofurans	55722-27-5									
Tetrachloroethane, 1,1,1,2-	630-20-6									
Tetrachloroethane, 1,1,2,2-	79-34-5			0.04				5.8E-05		2.0E-01
Tetrachloroethylene (perchloroethylene)	127-18-4	oral URF=1.5E-6; oral CSF =5.2E-2; inh URF=5.8E-7; inh CSF=2E-3	1985 HAD & 1987 addend		0.04	4.0E-02	not updated	5.9E-06	2.1E-02	5.1E-02
Tetrachlorophenol, 2,3,4,6-	58-90-2					9.0E-02	not updated			
Tetraethyldithiopyrophosphate	3689-24-5									
Thallium	7440-28-0									
Thallium (I) acetate	563-68-8									
Thallium (I) carbonate	6533-73-9									
Thallium (I) chloride	7791-12-0									
Thallium (I) nitrate	10102-45-1									
Thallium (I) sulfate	7446-18-6									
Thiram	137-26-8									
Toluene	108-88-3				0.4	4.0E-01	4.0E-01			
Toluene-2,4-diamine (2,4-diaminotoluene)	95-80-7							1.1E-03		4.0E+00
Toluidine, p-	106-49-0									

(continued)

Table A-1. (continued)

Constituent Name	CAS No.	Additional Benchmarks (non-IRIS, non-HEAST, non-Superfund)								
		Other EPA values	Source(s)	ATSDR oral MRL - chronic (mg/kg/d)	ATSDR inhal MRL - chronic (ppm)	CalEPA97 chronic inhal REL (mg/m3)	CalEPA99 chronic inhal REL (mg/m3)	CalEPA99 inhal unit risk (ug/m3)-1	CalEPA99 inhal CSF (mkd)-1	CalEPA99 Oral CSF (mkd)-1
Toxaphene	8001-35-2									
trans-1,3-Dichloropropylene	10061-02-6									
Trichloro-1,2,2-trifluoroethane, 1,1,2- (Freon 113)	76-13-1					9.0E+01	not updated			
Trichlorobenzene, 1,2,4-	120-82-1									
Trichloroethane, 1,1,1- (methyl chloroform)	71-55-6					1.0E+00	1.0E+00			
Trichloroethane, 1,1,2- (vinyl trichloride)	79-00-5					4.0E-01	not updated	1.6E-05		5.7E-02
Trichloroethylene	79-01-6					6.0E-01	6.0E-01	2.0E-06	1.0E-02	1.5E-02
Trichlorofluoromethane (CFC-11)	75-69-4					2.0E+01	not updated			
Trichlorophenol, 2,4,5-	95-95-4									
Trichlorophenol, 2,4,6-	88-06-2							2.0E-05		7.0E-02
Trichlorophenoxy) propionic acid, 2 (2,4,5-	93-72-1									
Trichlorophenoxyacetic acid, 2,4,5-	93-76-5									
Trichloropropane, 1,2,3-	96-18-4									
Triethylamine	121-44-8					7.0E-03	7.0E-03			
Trinitrobenzene, 1,3,5- (sym-)	99-35-4									
tris(2,3-Dibromopropyl)phosphate	126-72-7									
Vanadium	7440-62-2	RfC=7E-5 mg/m^3	Air Char. Study							
Vinyl acetate	108-05-4					2.0E-01	2.0E-01			

(continued)

Table A-1. (continued)

Constituent Name	CAS No.	Additional Benchmarks (non-IRIS, non-HEAST, non-Superfund)								
		Other EPA values	Source(s)	ATSDR oral MRL - chronic (mg/kg/d)	ATSDR inhal MRL - chronic (ppm)	CalEPA97 chronic inhal REL (mg/m3)	CalEPA99 chronic inhal REL (mg/m3)	CalEPA99 inhal unit risk (ug/m3)-1	CalEPA99 inhal CSF (mkd)-1	CalEPA99 Oral CSF (mkd)-1
Vinyl chloride	75-01-4			0.00002		5.0E-03	not updated	7.8E-05		2.7E-01
Warfarin	81-81-2									
Xylene, m-	108-38-3									
Xylene, o-	95-47-6									
Xylene, p-	106-42-3									
Xylenes (total)	1330-20-7				0.1	2.0E-01	7.0E-01			
Zinc	7440-66-6			0.3		9.0E-04	not updated			

References

References for TEFs:
EPA98= http://www.epa.gov/nceawww1/dchem.htm
EPA93=Provisional guidance for quantitative risk assessment of PAHs, EPA/600/R-93-089

[a] Benzene oral CSF (food, water) = 0.015 to 0.055 per mg/kg/day; inhalation URF = 2.2×10^{-6} to 7.8×10^{-6} per $\mu g/m^3$; inhalation CSF = 7.7×10^{-3} to 2.7×10^{-2} per mg/kg/day (revised on IRIS 1/00).

Appendix B

Statistical Analysis Weights and Variance Estimation for the Surface Impoundment Study Screening Survey

Appendix B

Statistical Analysis Weights and Variance Estimation for the Surface Impoundment Study Screening Survey

The statistical analysis weights for the observational units in any probability-based sample survey are the initial sampling weights adjusted to reduce the potential for bias due to survey nonresponse. The initial sampling weight for each unit is the reciprocal of the probability that the unit was selected into the sample. If each unit could have more than one linkage to the sampling frame (or list) from which the sample was selected, the initial sampling weights must be adjusted to compensate for this multiplicity. Finally, a model-based estimate of the probability of responding is usually used to reduce the potential for bias due to nonresponse. In the sections that follow, we discuss each of these steps for computing the statistical analysis weights for the Surface Impoundment Study screening survey. In the last section, we discuss estimation of sampling variances using the screening survey data.

B.1 Initial Sampling Weights

Because of major differences in the sources and availability of sampling frame data, three primary sampling strata were defined for selection of facilities for the screening survey based on the facility's regulatory status under the Clean Water Act:

1. **Direct discharge (Section 402) impoundments:** These impoundments treat waste in systems that ultimately discharge directly into surface waters. This subpopulation is regulated under CWA Section 402, which requires National Pollution Discharge Elimination System (NPDES) permits for all facilities that discharge to "waters of the United States."

2. **"Zero discharge" impoundments:** These impoundments are not designed to discharge waste into the environment except through infiltration into soil or evaporation. Facilities that use infiltration or evaporation ponds for waste treatment or disposal may be regulated under a variety of state laws addressing both waste handling and groundwater protection. Specific regulations regarding these impoundments vary by State.

3. **Indirect discharge (Section 307) impoundments:** These impoundments treat or hold waste prior to discharging to a publicly owned treatment works (POTW). Facilities that discharge significant waste flows to POTWs must comply with federal and local standards for pretreatment of waste in order to prevent adverse impacts on the public treatment plants. Local POTWs are the principal permitting authorities for CWA Section 307 facilities.

For direct discharge facilities, RTI constructed an essentially complete sampling frame of 43,050 facilities from the NPDES permits in the EPA's Permit Compliance System (PCS) database. We partitioned the sampling frame into three primary sampling strata, defined as follows:

1. Facilities in high-priority SICs (26, 2819, 2824, 2834, 2869, 2897, 2911, 30, 33, or 36).

2. All other facilities with in-scope SICs.

3. The six pilot study facilities.

Stratum 1, the high-priority SICs, were expected to contain a higher proportion of facilities that use surface impoundments to manage decharacterized waste waters. Hence, this stratum was sampled at a higher rate than Stratum 2, the remainder of the in-scope SICs, to ensure that the Phase 1 screening survey would include an adequate number of facilities using surface impoundments to manage decharacterized waste waters. Each of these strata was then partitioned into substrata based on SIC codes, and the substrata were all sampled at the same rate within each primary sampling stratum. Hence, a stratified simple random sample of 2,000 facilities was selected from 15 sampling strata, and the six pilot study facilities were retained with certainty.

For zero discharge facilities, IEc constructed a sampling frame of 5,807 facilities from available state data and two federal databases: EPA's Toxics Release Inventory (TRI) and the AIRS Facility Subsystem (AFS). We stratified the sampling frame according to the general categories of completeness for the different state and federal data sources, and according to high and low priority SIC codes. Table B-1 summarizes the sampling strata for the zero discharge facilities. A stratified random sample of 250 facilities was selected using the same sampling rate for all strata except for the Oklahoma database of private sewage treatment facilities. We expected this group of facilities to be mostly out-of-scope, and, if in-scope, to be relatively homogeneous. Hence, we sampled them at one-half the rate used for the other strata.

Because local POTWs are the principal permitting authorities for indirect discharge facilities, IEc used anecdotal information collected from EPA, state and local personnel, and database information from EPA Region 7 to construct a purposive sampling frame of 35 facilities. All 35 facilities were included in the screening sample.

Table B-1. Zero Discharge Sample Frame Stratification

Database Strata	Facilities in TRI/AFS	High Priority SIC Code Facilities	Low Priority SIC Code Facilities	Facilities with No SIC Code	Facilities in SIC Code 4952
Complete Databases: CA, KY, MI, NV, NH, NM, NC, OK(1), OK(2),[a] PA, TN, VT, WI	228	61	306	1155	886 facilities in OK(2)[a]
General Databases: FL, KS, MD, MN, MI, NJ, NY, OR, VA, WA	128	127	543	1592	95
Partial Databases: AR, HI, ME, MA, MT, RI, TX, UT	116	121		117	138
No State Information: AL, AK, AZ, CO, CT, DE, GA, ID, IL, IN, IO, LA, MO, NE, ND, OH, SC, SD, WY, WV, PR	194	N/A	N/A	N/A	N/A

Notes:

[a] The Oklahoma (2) database includes an unusually extensive listing of private sewage treatment facilities. We expect most of these facilities to be out of scope, and we therefore sampled only this database at a rate lower then the rest of the frame in order to avoid spending considerable project resources examining these facilities.

Subsequent to selection of this sample for the screening survey, EPA and IEc determined that some of the sample facilities were ineligible for Phase 2 of the study, and those facilities were removed from the sample before mailing the screening questionnaires. Hence, we have computed the initial sampling weight for each of the 2,019 facilities that were mailed the screening questionnaire. The sampling weight for each of the 35 indirect discharge facilities is undefined (missing) because these facilities were purposively selected. If the six pilot study facilities are included in any statistical analyses their analysis weight will unity (1.00) because they were included in the sample with certainty. For each of the other 1,984 facilities mailed a screener, the initial sampling weight was computed as

$$w_1(j) = N_1(j) / n_1(j),$$

where

$N_1(j)$ = Total number of facilities in stratum j, and
$n_1(j)$ = Number of facilities selected into the sample from stratum j.

The frame count, $N_1(j)$, sample size, $n_1(j)$, and initial sampling weight, $w_1(j)$, are shown for each stratum in B-Table 2.[1]

B.2 Multiplicity Adjustments

The PCS data used to construct the sampling frame for the direct discharger sample were outfall- or pipe-level records. We first collapsed the pipe-level records to the permit level by permit number (NPID). We then combined permits to the facility level, but there was no unique facility ID to guide this process. Hence, we conservatively merged permits to the facility level only when it was quite clear that there were multiple permits for the same facility. We merged up to three different permits into a single facility-level record. Any facilities that had multiple permits that did not get merged into a single facility-level record on the sampling frame had multiple chances to be selected into the sample.

Therefore, in the screening questionnaire we listed all permits that had been used to define the facility on the sampling frame, and we asked each facility to list any additional permits that had been active for the facility at any time since June 1, 1990. Partway through data collection, we discovered that some facilities did not understand that these additional permits should include stormwater permits. Hence, we set up a computer-assisted telephone interviewing (CATI) application to call the screener respondents and probe for any additional permits that had not been listed in their questionnaire responses. We used both the responses to the original question, Question 7, as well as the responses to the supplemental CATI question to make the weight adjustments for frame multiplicity.

We first cleaned the responses to the questions regarding the additional permits. NPDES permit numbers are all 9-digit ID numbers for which the first two digits are a U.S. State or Territory abbreviation. Of course, the permit numbers reported in the survey did not all conform to this format. The data cleaning consisted of removing extraneous characters (e.g., blank, dash, #, NPDES, etc.) as needed to produce ID numbers in the proper format for matching against the NPDES permit numbers on the sampling frame. Leading zeros and/or state abbreviations were inserted into other reported numbers when those edits produced ID numbers in the NPDES format. In addition, when two permits numbers had been keyed as a single response in the survey, those permit numbers were moved into separate variables, which resulted in one additional Question 7 response variable that was not in the raw survey responses. Permit numbers that clearly were not in the format of an NPDES permit number received only minimal editing.

[1] The sample of 250 facilities was selected as an initial sample of 150 facilities plus 10 independent supplemental samples of 10 facilities each, resulting in some unintended variation in the stratum sampling rates for the combined sample.

Table B-2. Initial Sampling Weights

Type of Facility	Sampling Stratum	Frame Count	Sample Size	Initial Weight
Direct Dischargers (DISCHARG=1)	126	927	142	6.528
	128	1019	156	6.532
	129	440	67	6.567
	130	1478	226	6.540
	133	1752	268	6.537
	136	919	141	6.518
	2A	5169	141	36.660
	2B	3442	95	36.232
	2C	3000	82	36.585
	2D	3212	88	36.500
	2E	2680	73	36.712
	2F	3642	100	36.420
	2G	2688	74	36.324
	2H	9276	254	36.520
	2I	3400	93	36.559
	3	6	6	1.000
Zero Dischargers (DISCHARG=2)	1	228	13	17.539
	2	128	6	21.333
	3	116	4	29.000
	4	194	6	32.333
	5	61	5	12.200
	6	127	6	21.167
	7	121	6	20.167
	8	301	13	23.154
	9	543	25	21.720
	10	1155	55	21.000
	11	1592	74	21.514
	12	117	4	29.250
	13	891	22	40.500

After having completed the cleaning of the permit numbers for all screeners, we determined if any facilities reported any of the preloaded permit numbers as additional permits. For this task, we can confined our attention to the completed screeners for direct discharge facilities (DISCHARG=1), including the screeners completed by former owners. For each sampled direct discharge facility, we first compared the permit numbers reported in the screeners as additional permit numbers against the up to three NPDES permit numbers that defined the facility on the sampling frame. If the facility incorrectly reported any of these permit numbers as *additional* permit numbers, they were deleted from the cleaned variables identifying the additional permit numbers reported in the survey.

The next step was to determine the sample multiplicity for each of the 1,603 direct discharge facilities for which the current or most recent owner was a respondent (P1RESP=1). The multiplicity, *m(j)*, of the *j*-th sample facility is the number of facilities on the full sampling frame of 43,050 facilities that were linked to the sample facility. We merged the additional permits numbers (not preloaded) that were reported by each facility against the facility-level sampling frame permit numbers to determine the number of *additional* facilities on the sampling frame that were linked to the sample facility. The facility's multiplicity, *m(j)*, is then this count plus one (i.e., the number of additional facilities plus the one originally selected). For most direct discharge facilities, the multiplicity is one (1.00) because there were no additional facilities on the sampling frame that were linked to the sample facility.

The nonresponse adjustments require that the frame multiplicity be known for every sample facility, not just the responding facilities. Therefore, for each direct discharger sampling stratum, we computed the average multiplicity among the facilities with known multiplicity (the respondents) and imputed the multiplicity for each nonresponding facility within each sampling stratum to be the average multiplicity for the stratum. After having computed or imputed the multiplicity, *m(j)*, for each direct discharge sample facility, we computed the multiplicity-adjustment to the sampling weight for the *j*-th facility as follows:

$w_2(j) = 1 / m(j)$ for direct discharge facilities
$w_2(j) = 1$ for zero discharge facilities.

Lessler and Kalsbeek (1992, Section 5.2.2) show how this using this multiplicity adjustment produces survey estimates that are design-unbiased.

B.3 Nonresponse Adjustments

Weight adjustments to reduce the potential bias due to survey nonresponse are based on models for the probability of responding, using data that are available for both the respondents and the nonrespondents. Since the sampling stratum was the only thing we knew about the nonresponding facilities, we used sample-based ratio adjustments based on the sampling strata (Kalton and Maligalig, 1991). The nonresponse adjustments were defined only for the direct and zero discharge facilities because the indirect discharger sample was not a probability-based sample.

The weight adjustment for nonresponse is simply the reciprocal of the weighted response rate. Therefore, strata for which the number of respondents is small (e.g., less than 20) must be collapsed with other strata to form weighting classes. Moreover, combining strata to form weighting classes reduces the variance inflation that results from variability in the analysis weights. Hence, in order to determine weighting classes for the screening survey, we reviewed the following statistics for each sampling stratum:

- # number of sample facilities, n_s
- # number of facilities with known eligibility status, n_k
- # response rate for eligibility determination, $r_k = (n_k / n_s) * 100$
- # number of eligible facilities, n_e
- # number of responding facilities, n_r
- # unweighted response rate, $r_u = (n_r / n_e) * 100$.

After reviewing the pattern of survey responses and eligibility by sampling strata, we decided that each of the 15 sampling strata for the direct discharger sample contained sufficient numbers of respondents to be a separate weighting class. These are the first 15 weighting classes. However, because of the smaller sample size for the zero discharger sample, we combined strata to form weighting classes as follows:

- # Weighting class 16 consists of zero discharger strata 1 through 4: the facilities from the TRI or AFS portion of the sampling frame;

- # Weighting class 17 consists of zero discharger strata 5, 6, and 9: the facilities with high-priority SICs; and

- # Weighting class 18 consists of the remainder of the zero discharger facilities.

Having defined the weighting classes for nonresponse adjustment, we implemented the weight adjustments for nonresponse in two stages. We first made an adjustment for inability to determine whether or not a facility was eligible for the Phase 1 screening interview (i.e., was in operation at any time since June 1, 1990). The second stage of nonresponse adjustment was an adjustment for nonresponse among the facilities known to be eligible for the screening survey.

The weight adjustment factor for inability to determine eligibility for the screening interview was computed for the *c*-th weighting class follows:

$$w_3(c) = \frac{\sum_{j \in c} w_1(j)\, w_2(j)}{\sum_{j \in c} w_1(j)\, w_2(j)\, I_k(j)} \quad ,$$

where $I_k(j)$ is an indicator that the eligibility status or the *j*-th facility is known, i.e.,

$I_k(j) = 1$ if the eligibility status of the *j*-th facility is known (P1ELIG=1 or 2)
$I_r(j) = 0$ otherwise.

This adjustment is equivalent to assuming that the proportion of sample facilities that are eligible for the screening survey (i.e., in operation at any time since June 1, 1990) is the same among those with known and unknown eligibility status.

Similarly, the weight adjustment factor for survey nonresponse was defined for the *c*-th weighting class as follows:

where I_r and I_e are indicators of response and eligibility status, respectively, i.e.,

$I_r(j) = 1$	if the *j*-th facility was a screener respondent (P1RESP=1)
$I_r(j) = 0$	otherwise, and
$I_e(j) = 1$	if the *j*-th facility was eligible for Phase 1 (P1ELIG=1)
$I_e(j) = 0$	otherwise.

The final statistical analysis weight was then be defined for the *j*-th facility in the *c*-th weighting class as the product of the various weight components, as follows:

$$w_5(j) = w_1(j)\, w_2(j)\, w_3(c)\, w_4(c)\, I_r(j) .$$

One property of this analysis weight is that the sum of this weight for the respondents in each weighting class is identical to the sum of the multiplicity-adjusted weights of all eligible sample facilities in that weighting class, exactly as if all the facilities had responded.

After computing these analysis weights, we performed several weight checks to verify that each weight component had been computed correctly.

B.4 Variance Estimation

Since sample facilities were selected using a stratified simple random sampling design, standard textbook formulae for stratified random sampling designs can be used to compute sampling variances, except that the observations must be weighted by the statistical analysis weights to account for survey nonresponse. However, the number of responding facilities is as small as two in some of the sampling strata used for the zero discharger sample because of the small sample sizes and high rates of ineligibility for zero dischargers. Therefore, we recommend that the collapsed sampling strata used for the weighting classes (P1WTCLAS) be used as the analysis strata when computing sampling variances.

If one wishes to compute sample means and proportions, those estimates are ratio estimates. Ratio estimators are nonlinear statistics, which require special-purpose software. One option is to use RTI's SUDAAN® software package. If one uses SUDAAN to analyze the data, we recommend that the following design options be used to compute sampling variances.

```
DESIGN=STRWR
NEST=P1WTCLAS.
```

These options specify that the design is a stratified random sampling design in which units were selected with replacement and that the variable P1WTCLAS defines the analysis strata. The with-replacement option is recommended because the survey results will be used to make inferences regarding the super-population of all survey-eligible facilities, whether or not they were included on the sampling frame constructed for this study and because the zero discharger frame is known to be incomplete.

References

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Appendix C

Examples of Toxicity Benchmarks for Ecological Risk Assessment

Table C-1. Selected Sources of Toxicity Data.

DATABASES

- Hazardous Substances Data Bank (HSDB). National Library of Medicine, National Toxicology Information Program. Bethesda, MD.
- Integrated Risk Information System (IRIS). U.S. EPA, Office of Health and Environmental Assessment, Environmental Criteria and Assessment Office.
- PHYTOTOX. Chemical Information System (CIS) Database.
- Registry of Toxic Effects of Chemical Substances (RTECS). National Institute for Occupational Safety and Health (NIOSH), Washington, D.C.

COMPILATIONS

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- U.S. Environmental Protection Agency (U.S. EPA). 1986. Quality Criteria for Water 1986. EPA 440/5-86-001. Office of Water Regulations and Standards, Criteria and Standards Division, U.S. Environmental Protection Agency. Washington, DC.
- U.S. Environmental Protection Agency (U.S. EPA). 1995. Great Lake Water Quality Criteria Documents for the Protection of Wildlife. EPA 820/b-85/008. Office of Water. Washington, D.C.
- U.S. Navy (U.S. Navy). 1997. Development of toxicity reference values as part of a regional approach for conducting ecological risk assessments at naval facilities in California. Draft Technical Memorandum. Prepared for the U.S. Navy
- Venugopal, B. and T.D. Luckey. 1978. *Metal Toxicity in Mammals. 2* . Plenum Press. New York, NY.
- Will, M.E. and G.W. Suter II. 1995. Toxicological benchmarks for screening potential contaminants of concern for effects on terrestrial plants: 1995 revision. Prepared for the U.S. Department of Energy.

PRIMARY LITERATURE

- Over 400 citations

Table C-2
Toxicity Benchmarks for Mammals

Chemical	Test Species	Age	Observed Effect	Effect Level	Exposure Duration	Food Conc. (mg/kg)	Water Conc. (mg/L)	% Chem.	Ingest. Rate (g/d)	Drink Rate (mL/d)	Conv. Factor	Body Weight (kg)	Toxicity Benchmark (mg/kg-d)	Reference	Uncertainty Factor: Subchronic-to-Chronic	Uncertainty Factor: Endpoint-to-NOAEL
Inorganics																
Antimony	Mouse	Not given	• No adverse effect on survivorship, and no histopathological changes and only minor reductions in growth at 540 days and median life	NOAEL	Lifetime		5	1		5	0.001	0.025	1.0	Schroeder *et al.* 1968	—	—
Arsenic	Mouse	Weanling	• No adverse effects on maternal survival, mean litter size, number of runts, and number of still • births	NOAEL	3 generations		5	1		5	0.001	0.025	1.0	Schroeder & Mitchener 1971	—	—
Barium	Rat	Weanling	• No adverse effect on growth or food and water consumption	NOAEL	16 months		100	1		22	0.001	0.435	5.1	Perry *et al*. 1983	—	—
Beryllium	Rat	Weanling	• No adverse effect on survival, growth, median life span, and longevity	NOAEL	Lifetime		5	1		25	0.001	0.25	0.5	Schroeder & Mitchener 1975	—	—
Cadmium	Rat	Adult	• No adverse effects on number of copulating females, number of pregnant females, total implants, live fetuses, average fetal weight, and	NOAEL	12 weeks							0.25	1.0	Sutou *et al*. 1980b	—	—
Chromium III	Rat	Adult and offspring	• No adverse effects on reproduction and longevity	NOAEL	2 years	50,000		0.68	15		0.001	0.25	2,000	Ivankovic & Preussmann 197	—	—
Chromium VI	Rat	Adult	• No adverse effect on growth and no adverse systemic pathologies	NOAEL	1 year		25	1		25	0.001	0.25	2.5	MacKenzie *et al*. 1985	—	—
Cobalt	Rat	Newborn	• Decreased growth in rat pups	LOAEL	30 days							0.25	12	Domingo *et al.* 1985	—	10
Copper	Mink	Kit	• No adverse effects on kit mortality, length of gestation, and kit weight	NOAEL	1 year	85.5		1	137		0.001	1	12	Aulerich *et al*. 1982	—	—
Lead, organo-	Rat	Adult	• Increased young deaths and number of runts; by the second generation (F_2), there were insufficient numbers to continue the investigation	Effects Level	3 generations							0.25	1.0	Azar *et al*. 1973 Schoreder & Mitchener 1971	—	—
Manganese	Rat	14-day-old pups to adult	• No effect on growth, percent pregnant, litter size, ovulations, fetal resorptions, pre-implantation deaths, or fetal weight	NOAEL	> 100 days	1100		1	15		0.001	0.25	88	Laskey *et al.* 1982	—	—
Mercury	Mink	Adult	• No adverse effects on fertility, kit weight, and kit survivorship	NOAEL	6 months	10		0.739	137		0.001	1	1.0	Aulerich *et al.* 1974	—	—
Mercury, Organo-	Rat	Adult	• No adverse effects on prenatal development	NOAEL	3 generations	0.5		0.7989	15		0.001	0.25	0.024	Verschuuren *et al.* 1976	—	—
Molybdenum	Mouse	Adult	• Reduced reproductive success and increased incidence of runts	LOAEL	3 generations	0.45	10	1	3	5	0.001	0.025	2.1	Schroeder & Mitchener 1971	—	10
Nickel	Rat	Adult	• No adverse effects on fertility, gestation, offspring viability, and lactation indices	NOAEL	3 generations	250		1	15		0.001	0.25	15	Ambrose *et al*. 1976	—	—
Selenium	Rat	Adult	• No adverse effects on fertility, number of young, juvenile growth, and juvenile survival	NOAEL	2 generations		1.5	1		25	0.001	0.25	0.15	Rosenfeld & Beath 1954	—	—
Silver	Rat	Adult	• "Excellent clinical condition" was reported and no adverse effect on behavior and fluid consumption	NOAEL	12 weeks		648	1		25	0.001	0.25	65	Walker 1971	—	—
Thallium	Rat	Adult	• No adverse effects on male reproductive tract morphology or function	NOAEL	60 days							0.365	0.74	Formigli et al. 1986	—	—
Vanadium	Rat	Adult	• No adverse effects on fertility, number of litters, number of dead offspring/litter, and average body	NOAEL	60 days (gestation)			0.4178				0.26	2.1	Domingo *et al.* 1986	—	—
Zinc	Rat	Adult	• No adverse effect on fetal development	NOAEL	16 days (gestation)	2,000		1	15		0.001	0.25	120	Schlicker & Cox 1968	—	—
Volatile Organic Compounds																
BTEX																
Benzene	Mouse	Adult	• Increased maternal mortality and embryonic resorption	EL	10 days (gestation)		0.26361				1,000	0.025	264	Nawrot & Staples 1979	—	10
Toluene	Rat	Adult	• Increased maternal mortality and embryonic resorption	EL	10 days (gestation)		0.2598				1,000	0.25	260	Nawrot & Staples 1979	—	10
Ethylbenzene	• No toxicity benchmark is proposed •															
Xylene	Rat	Adult	• No adverse histopathological changes in reproductive organs	NOAEL	10 days (gestation)							0.25	500	NTP 1986	—	—
Trichloroethene-Related VOCs																
Dichloroethene, 1,2-	Rat	Adult	• No adverse histopathological changes in reproductive organs	NOAEL	90 days							0.25	206	McCauley *et al*. 1990	10	—
Dichloroethane, 1,2-	Mouse	Adult	• No adverse effects on fertility, number of live fetuses, litter survival and growth, malformations, pathology, or adult mortality	NOAEL	2 generations (24 to 25 weeks each)		290	1		6	1,000	0.035	50	Lane *et al.* 1982	—	—

Table C-2
Toxicity Benchmarks for Mammals

Chemical	Test Species	Age	Observed Effect	Effect Level	Exposure Duration	Food Conc. (mg/kg)	Water Conc. (mg/L)	% Chem.	Ingest. Rate (g/d)	Drink Rate (mL/d)	Conv. Factor	Body Weight (kg)	Toxicity Benchmark (mg/kg-d)	Reference	Uncertainty Factor: Subchronic-to-Chronic	Uncertainty Factor: Endpoint-to-NOAEL
Tetrachloroethene	Rat	Adult	• Increased mortality, however, no adverse effects on testes and ovaries	LOAEL	78 weeks							0.25	385	NCI 1977	—	10
Trichloroethane	Mouse	Adult	• No effects on fertility, incidence of implants or resorptions, number of live fetuses, frequency of live litters, litter size, postnatal growth, postnatal survival, or incidence of congenital malformations	NOAEL	2 generations (24 to 25 weeks each)		5,830	0.97		6	1,000	0.035	1,000	Lane *et al.* 1982	—	—
Trichloroethene	Rat	Adult	• No adverse maternal toxicity, fetal mortality, and teratogenic effects	NOAEL	35 days (gestation)							0.25	100	Manson *et al*. 1984	—	—
Chlorobenzene-Related VOCs																
Chlorobenzene	Mouse	Adult	• No decrease in survival.	NOAEL	103 weeks							0.025	120	Kluwe *et al.* 1985	—	—
Dichlorobenzene	Rat	Fetus	• Decrease in maternal weight and an increase in the incidence of an extra rib in the fetuses of pregnant rats	LOAEL	10 days							0.25	500	Giavini et al. 1986	—	10
Other VOCs																
Acetone	Rat	Adult	• No adverse effect on sperm motility, incidence of abnormal sperm, and testicular histopathology	NOAEL	13 weeks							0.25	1,700	Dietz et al. 1991	10	—
Dichloropropane, 1,2-	• No toxicity benchmark is proposed •															
Polycyclic Aromatic Hydrocarbons and Semivolatile Organic Compounds																
Benzo[a]pyrene	Mouse	Adult	• Reduced F1 fertility, fewer and smaller F2 litters, and decreased weight of 42-day-old pups	LOAEL	10 days (gestation)							0.025	10	MacKenzie and Angevine 1981	—	10
Naphthalene	Rat	Adult	• No adverse effects on body weight and water consumption	NOAEL	10 days (gestation)							0.25	50	Navarro et al. 1991	—	—
Methylphenol, 2-	Mink	Adult	• No adverse effect on reproduction	NOAEL	6 months	1,600		1	120		1,000	1	200	Homshaw *et al.* 1986	—	—
Pentachlorophenol	Rat	Adult	• No adverse effects on number of pups born alive or development	NOAEL	4 months	3		1	15		0.001	0.25	0.18	Schwetz *et al.* 1978	—	—
Chlorinated Pesticides																
Aldrin / Dieldrin	Rat	Adult	• No adverse effects on number of pregnancies, number of pups per litter, offspring mortality, and weight of young at weanling	NOAEL	3 generations							0.25	0.10	Treon and Cleveland 1954, 1955	—	—
BHC	Rat	Adult	• No adverse effects on survival, fertility, litter size, birth weights, and pup and weanling body weights	NOAEL	4 generations	40		1	15		0.001	0.25	2.4	Grant et al. 1977	—	—
Chlordane	Rat	Adult	• No adverse effects viability and abundance of	NOAEL	6 generations	25		1	3		0.001	0.025	3.0	Keplinger et al. 1968	—	—
DDT / DDD / DDE	Rat	Adult	• No adverse effects on number of young produced	NOAEL	2 years	10		1	28		0.001	0.35	0.80	Fitzhugh 1948	—	—
Endosulfan	Rat	Adult	• No adverse effect on development	NOAEL	84 days							0.25	0.20	Hoeschst 1984	—	—
Heptaclor	Mink	Adult	• No adverse effect on percentage of successful litters, percent of kits born alive, kit birth weight, kit survival, body weight of the parental generation, and central nervous system effects	NOAEL	181 days							1.0	1.0	Crum et al. 1993	—	—
Polychlorinated Biphenyls																
Total PCBs	Mink	Adult	• No adverse effects on maternal mortality, number of offspring, or offspring survival	NOAEL	4.5 months	1		1	140		0.001	1.0	0.14	Aulerich & Ringer 1977	—	—
Dioxins and Furans																
2,3,7,8-TCDD	Rat	Adult/ Fetus	• Decreased gestational survival index; decreased fetal weight	LOAEL	3 generations							0.25	0.000001	Murray *et al.* 1979	—	10

Definitions:

BHC	-	Benzene hexachloride.
% Chem.	-	Percent of chemical.
g/d	-	Grams per day.
kg	-	Kilogram.
mg/kg	-	Milligrams per kilogram.
mg/kg-d	-	Milligrams per kilogram per day.
mg/L	-	Milligrams per liter.
mL/d	-	Milliliters per day.
NOAEL	-	No observed adverse effect level.
LOAEL	-	Low observed adverse effect level.
PAHs	-	Polycyclic aromatic hydrocarbons.

Table C-2
Toxicity Benchmarks for Mammals

Chemical	Test Species	Age	Observed Effect	Effect Level	Exposure Duration	Food Conc. (mg/kg)	Water Conc. (mg/L)	% Chem.	Ingest. Rate (g/d)	Drink Rate (mL/d)	Conv. Factor	Body Weight (kg)	Toxicity Benchmark (mg/kg-d)	Reference	Uncertainty Factor: Subchronic-to-Chronic	Uncertainty Factor: Endpoint-to-NOAEL
PCBs	-	Polychlorinated biphenyls.														
RTV	-	Reference toxicity value.														
TCDD	-	Tetrachlorodibenzo-*p*-dioxin.														
VOCs	-	Volatile organic chemicals.														

Table C-3
Toxicity Benchmarks for Birds

Chemical	Test Species	Age	Observed Effect	Effect Level	Duration	Food Conc. (mg/kg)	Water Conc. (mg/L)	% Chem.	Ingest. Rate (g/d)	Drink Rate (ml/d)	Conv. Factor	Body Weight (kg)	Toxicity Benchmark (mg/kg-d)	Reference	Uncertainty Factor: Subchronic-to-Chronic	Uncertainty Factor: Endpoint-to-NOAEL
Inorganics																
Antimony	• No toxicity benchmark is proposed •															
Arsenic	Mallard	1 year	• No effect on egg weight, duckling production, duckling body weight, duckling growth, or number of days between pairing and 1st egg.	NOAEL	4 weeks prior to pairing through multiple hatchings							1	5.5	Stanley, Jr. *et al*. 1994	—	—
Barium	Chicken	1-day-old	• Well tolerated by the chicks	NOAEL	4 weeks	1,000		1	13		0.001	0.121	100	Johnson *et al*. 1960		
Beryllium	• No toxicity benchmark is proposed •															
Cadmium	Chicken	Adult	• No adverse effects on egg production	NOAEL	8 months	12		1	140		0.001	0.8	2.1	Leach *et al*. 1979	—	—
Chromium III	American black duck		• No adverse systemic pathologies and no adverse effect on growth	NOAEL	10 months	10		1	125		0.001	1.25	1.0	Haseltine *et al*. 1985	—	—
Chromium VI	• No toxicity benchmark is proposed •															
Cobalt	• No toxicity benchmark is proposed •															
Copper	Chicks	1 day	• No adverse effects on growth	NOAEL	10 weeks	403		1	44		0.001	0.534	33	Mehring *et al*. 1960	10	—
Lead, metallic	American	Adult	• No adverse effects on survival and	NOAEL	6 months	50		1	10		0.001	0.13	3.8	Patee 1984	—	—
Lead, organo-	Japanese quail	Adult	• No adverse effect on growth and hatching success, and minor reductions in number of	NOAEL	12 weeks	1		1	17		0.001	0.15	0.11	Edens *et al*. 1976	—	—
Manganese	Japanese quail	1 day	• No adverse effect on growth	NOAEL	75 days							0.072	980	Laskey & Edens 1985	—	—
Mercury	Japanese quail	Adult	• Reduced fertility and hatchability	NOAEL	1 year	4.0		1	17		0.001	0.15	0.45	Hill and Schaffner 1976	—	10
Mercury, Organo-	Mallard	Adult and 9-day-old	• Fewer eggs and ducklings	LOAEL	3 generations	0.5		1	128		0.001	1	0.06	Heinz 1979	—	10
Molybdenum	Chicken	7 months	• Fewer eggs were laid and embryo viability was reduced	LOAEL	21 days	500		1	140		0.001	0.8	88	Lepore & Miller 1965	—	10
Nickel	Mallard	1-day-old	• No adverse effects on survivorship and growth	NOAEL	90 days	176		1	78.2		0.001	0.782	18	Cain & Pafford 1981	—	—
Selenium	Mallard	Adult	• No adverse effects on growth, adult survival, duckling survival, and deformed embryos	NOAEL	78 days	5		1	100		0.001	1	0.5	Heinz et al. 1987	—	—
Silver	• No toxicity benchmark is proposed •															
Thallium	• No toxicity benchmark is proposed •															
Vanadium	Mallard	Adult	• No adverse effects on mortality, body weight, or blood chemistry	NOAEL	12 days	110		1	121		0.001	1.17	11	White & Dieter 1978	10	—
Zinc	Chicken	Adult	• No adverse effects on fertility, egg hatchability, and body weight of 3-week old	NOAEL	44 weeks	228		1	123		0.001	1.935	14	Stahl *et al*. 1990	—	—
Volatile Organic Compounds																
BTEX																
Benzene	• No toxicity benchmark is proposed •															
Toluene	• No toxicity benchmark is proposed •															
Ethylbenzene	• No toxicity benchmark is proposed •															
Xylene	• No toxicity benchmark is proposed •															
Trichloroethene-Related VOCs																
Dichloroethene, 1,2-	• No toxicity benchmark is proposed •															
Dichloroethane, 1,2-	Chicken	Chick to adult	• Reduced egg weight.	LAOEL	2 years	250		1	100		0.001	1.6	16	Alumot *et al*. 1976b	—	10
Tetrachloroethene	• No toxicity benchmark is proposed •															
Trichloroethane	• No toxicity benchmark is proposed •															
Trichloroethene	• No toxicity benchmark is proposed •															
Chlorobenzene-Related VOCs																
Chlorobenzene	• No toxicity benchmark is proposed •															
Dichlorobenzene	• No toxicity benchmark is proposed •															

Table C-3
Toxicity Benchmarks for Birds

Chemical	Test Species	Age	Observed Effect	Effect Level	Duration	Food Conc. (mg/kg)	Water Conc. (mg/L)	% Chem.	Ingest. Rate (g/d)	Drink Rate (ml/d)	Conv. Factor	Body Weight (kg)	Toxicity Benchmark (mg/kg-d)	Reference	Uncertainty Factor: Subchronic-to-Chronic	Uncertainty Factor: Endpoint-to-NOAEL
Other VOCs																
Acetone	Japanese quail	Adult	• No mortality	NOAEL	5 days	40000		1	17		0.001	0.15	4,500	Hill *et al.* 1975	10	—
Dichloropropane, 1,2-	• No toxicity benchmark is proposed •															
Polycyclic Aromatic Hydrocarbons and Semivolatile Organic Compounds																
Benzo[a]pyrene	• No toxicity benchmark is proposed •															
Naphthalene	• No toxicity benchmark is proposed •															
Methylphenol, 4-	• No toxicity benchmark is proposed •															
Pentachlorophenol	Japanese quail	14 days	• Mortality	NOAEL	5 days	3,100		1	14		0.001	0.1	440	Hill & Camardese 1986	10	—
Chlorinated Pesticides																
Aldrin / Dieldrin	Mallard	Adult	• Some mortality	LOAEL	30 days							1.0	5.0	Hudson *et al.* 1984	10	10
BHC	Mallard	Adult	• No adverse effects on food intake, water consumption, body weight, egg laying frequency, egg size and weight, eggshell thinning, and eggshell porosity	NOAEL	8 weeks							1.0	5.7	Chakravarty & Lahiri 1986	—	—
Chlordane	Red-winged blackbird	Adult	• No mortality	NOAEL	84 days	10			14		0.001	0.064	2.2	Stickel *et al.* 1983	10	—
DDT / DDD / DDE	Pelican	Adult	• Adverse effects on reproductive success	LOAEL	6 years	0.15		1	660		0.001	3.5	0.028	Anderson *et al.* 1975	—	3
Endosulfan	Gray partridge	Adult	• No reproductive effect	NOAEL	4 weeks	125		1	32		0.001	0.4	10	Abiola 1992	—	—
Heptachlor	Bobwhite quail	Adult	• Mortality	LD_{50}	5 days							0.15	11	Hill *et al.* 1975	—	100
Polychlorinated Biphenyls																
Total PCBs	Screech owl	Adult	• No adverse effects on fertility and	NOAEL	2 generations	3			25		0.001	0.2	0.42	McLane & Hughes 1980	—	—
Dioxins and Furans																
2,3,7,8-TCDD	Chicken	3-day-old	• No mortality or chick edema	Subchronic	21 days							0.203	0.0001	Schwetz *et al.* 1973	10	—
2,3,7,8-TCDF	Chicken	1-day-old	• No mortality or chick edema	Subchronic	21 days							0.178	0.001	McKinney *et al.* 1976	10	10

Definitions:

BHC	-	Benzene hexachloride.
% Chem.	-	Percent of chemical.
g/d	-	Grams per day.
kg	-	Kilogram.
LD50	-	Lethal dose (50%).
mg/kg	-	Milligrams per kilogram.
mg/kg-d	-	Milligrams per kilogram per day.
mg/L	-	Milligrams per liter.
mL/d	-	Milliliters per day.
NOAEL	-	No observed adverse effect level.
LOAEL	-	Low observed adverse effect level.
PAHs	-	Polycyclic aromatic hydrocarbons.
PCBs	-	Polychlorinated biphenyls.
RTV	-	Reference toxicity value.
TCDD	-	Tetrachlorodibenzo-*p*-dioxin.
TCDF	-	Tetrachlorodibenzofuran.
VOCs	-	Volatile organic chemicals.

Table C-4
Toxicity Benchmarks for Amphibians

Chemical	Test Species	Age	Observed Effect	Effect Level	Duration	Toxicity Benchmark (ug/L)	Reference	Duration-to-Chronic	Endpoint-to-NOAEL	Amphibian RTVs (ug/L)
Inorganics										
Antimony					• No toxicity benchmark is proposed •					
Arsenic					• No toxicity benchmark is proposed •					
Barium					• No toxicity benchmark is proposed •					
Beryllium	Spotted	Larva	• Mortality	LC_{50}	96 hours	3,100	Slonim and Ray 1975	—	100	31
Cadmium	Clawed Toad	3-4 weeks	• No inhibition of larval development	NOAEL	100 days	9	Canton and Sloof 1982	—	—	9.0
Chromium					• No toxicity benchmark is proposed •					
Cobalt					• No toxicity benchmark is proposed •					
Copper	Clawed Toad	3-4 weeks	• Mortality	LC_{50}	48 hours	1,700	de Zwart and Sloof 1987	—	100	17
Lead	Argentine Toad	Embryo	• Arrested development	EC_{50}	48 hours	470	Perez-Coll *et al*. 1988	—	100	4.7
Manganese					• No toxicity benchmark is proposed •					
Mercury	Eastern narrow-mouthed toad	Embryo	• Arrested development	EC_{50}	96 hours post-hatching	1.3	Birge *et al*. 1983	—	100	0.013
Molybdenum					• No toxicity benchmark is proposed •					
Nickel					• No toxicity benchmark is proposed •					
Selenium	Clawed Toad	Embryo	• Arrested development	EC_{50}	7 days	1,500	Browne *et al*. 1979	—	100	15
Silver					• No toxicity benchmark is proposed •					
Thallium					• No toxicity benchmark is proposed •					
Vanadium					• No toxicity benchmark is proposed •					
Zinc	Clawed Toad	Embryo	• Arrested development	EC_{50}	96 hours	3,600	Dawson *et al*. 1988	—	100	36
Volatile Organic Compounds										
BTEX										
Benzene	Leopard frog	3-4 weeks	• Mortality	LC_{50}	48 hours	3,700	Sloof *et al*. 1983	—	100	37
Toluene	Leopard frog	Embryo	• Arrested development	LC_{50}	> 4 days	390		—	100	3.9
Ethylbenzene					• No toxicity benchmark is proposed •					
Xylene					• No toxicity benchmark is proposed •					
Trichloroethene-Related VOCs										
Dichloroethene, 1,2-					• No toxicity benchmark is proposed •					
Dichloroethane, 1,2-					• No toxicity benchmark is proposed •					
Tetrachloroethene					• No toxicity benchmark is proposed •					
Trichloroethane					• No toxicity benchmark is proposed •					
Trichloroethene	Clawed Toad	3-4 weeks	• Mortality	NOAEL	48 hours	29,000	Sloof *et al*. 1983	10	—	2,900
Chlorobenzene-Related VOCs										
Chlorobenzene	Northern leopard frog	Tadpole	• Mortality	LC_{50}	Fertilization to 4 days post-hatching	1,200	Birge and Cassidy 1983	—	100	12
Dichlorobenzene					• No toxicity benchmark is proposed •					
Other VOCs										
Acetone	Axolotl	Larva	• Mortality	LC_{50}	48 hours	20,000	Sloof & Baerselman 1980	10	10	200
Dichloropropane, 1,2-					• No toxicity benchmark is proposed •					
Polycyclic Aromatic Hydrocarbons and Semivolatile Organic Compounds										
Benzo[a]pyrene	Ribbed salamander	Larva	• Clastogenic effect	EC_{50}	8 days	10	Siboulet *et al*. 1984	—	10	1.0
Naphthalene	Clawed toad	Larva	• Absence of swimming	EC_{50}	6 hours	1,700	Edmisten *et al*. 1982	—	100	17
Methylphenol, 2-	Clawed toad	Tadpole	• Mortality	NOAEL	48 hours	24,000	Sloof *et al.* 1983	10	—	2,400
Pentachlorophenol	Bullfrog	Tadpole	• Mortality	LC_{50}	96 hours	210	Thurston *et al.* 1985	10	10	2.1
Chlorinated Pesticides										
Aldrin / Dieldrin	Fowler's toad	Tadpole	• Mortality	LC_{50}	96 hours	68	Mayer & Ellersieck 1986	—	100	0.68
BHC	Chorus frog	Tadpole	• Mortality	LC_{50}	96 hours	2,600	Mayer & Ellersieck 1986	—	100	26

Table C-4
Toxicity Benchmarks for Amphibians

Chemical	Test Species	Age	Observed Effect	Effect Level	Duration	Toxicity Benchmark (ug/L)	Reference	Duration-to-Chronic	Endpoint-to-NOAEL	Amphibian RTVs (ug/L)
Chlordane	Northern leopard frog	Adult	• Mortality	LC_{50}	96 hours	500	Kaplan and Overpeck 1964	—	100	5.0
DDT / DDD / DDE	Fowler's toad	7 weeks	• Mortality	LC_{50}	96 hours	30	Mayer & Ellersieck 1986	—	100	0.3
Endosulfan	• No toxicity benchmark is proposed •									
Heptachlor	• No toxicity benchmark is proposed •									
Polychlorinated Biphenyls										
Total PCBs	American toad	Embyros	• Mortality	LC_{50}	Fertilization to 4 days post-hatching	2.0	Birge & Cassidy 1983	—	100	0.02
Dioxins and Furans										
PCDDs and PCDFs	• No toxicity benchmark is proposed •									

Definitions:

BHC	-	Benzene hexachloride.
EC_{50}	-	Effect concentration (50%).
LC_{50}	-	Lethal concentration (50%).
mg/L	-	Micrograms per liter.
NOAEL	-	No observed adverse effect level.
PAHs	-	Polycyclic aromatic hydrocarbons.
PCBs	-	Polychlorinated biphenyls.
PCDDs	-	Polychlorinated dibenzo-*p* -dioxins.
PCDFs	-	Polychlorinated dibenzofurans.
RTV	-	Reference toxicity value.
VOCs	-	Volatile organic chemicals.

Table C-5
Toxicity Benchmarks for Soil Invertebrates

Chemical	Toxicity Benchmark (mg/kg_{soil})	Reference
Inorganics		
Antimony	• No toxicity benchmark is proposed •	
Arsenic	40	van den Berg *et al.* 1993
Barium	620	van den Berg *et al.* 1993
Beryllium	• No toxicity benchmark is proposed •	
Cadmium	12	van den Berg *et al.* 1993
Chromium	230	van den Berg *et al.* 1993
Cobalt	240	van den Berg *et al.* 1993
Copper	190	van den Berg *et al.* 1993
Lead	290	van den Berg *et al.* 1993
Manganese	• No toxicity benchmark is proposed •	
Mercury	10	van den Berg *et al.* 1993
Molybdenum	480	van den Berg *et al.* 1993
Nickel	210	van den Berg *et al.* 1993
Selenium	• No toxicity benchmark is proposed •	
Silver	• No toxicity benchmark is proposed •	
Thallium	• No toxicity benchmark is proposed •	
Vanadium	• No toxicity benchmark is proposed •	
Zinc	720	van den Berg *et al.* 1993
Volatile Organic Compounds		
BTEX		
Benzene	• No toxicity benchmark is proposed •	
Toluene	• No toxicity benchmark is proposed •	
Ethylbenzene	• No toxicity benchmark is proposed •	
Xylene	• No toxicity benchmark is proposed •	
Trichloroethene-Related VOCs		
Dichloroethene, 1,2-	• No toxicity benchmark is proposed •	
Dichloroethane, 1,2-	• No toxicity benchmark is proposed •	
Tetrachloroethene	• No toxicity benchmark is proposed •	
Trichloroethane	• No toxicity benchmark is proposed •	
Trichloroethene	• No toxicity benchmark is proposed •	
Chlorobenzene-Related VOCs		
Chlorobenzene	30	van den Berg *et al.* 1993
Dichlorobenzene	• No toxicity benchmark is proposed •	
Other VOCs		
Acetone	• No toxicity benchmark is proposed •	
Dichloropropane, 1,2-	• No toxicity benchmark is proposed •	
Polycyclic Aromatic Hydrocarbons and Semivolatile Organic Compounds		
Benzo[a]pyrene	• No toxicity benchmark is proposed •	
Naphthalene	• No toxicity benchmark is proposed •	
Methylphenol, 4-	• No toxicity benchmark is proposed •	
Pentachlorophenol	5	van den Berg *et al.* 1993

Table C-5
Toxicity Benchmarks for Soil Invertebrates

Chemical	Toxicity Benchmark (mg/kg_{soil})	Reference
Chlorinated Pesticides		
Aldrin / Dieldrin	• No toxicity benchmark is proposed •	
BHC	• No toxicity benchmark is proposed •	
Chlordane	• No toxicity benchmark is proposed •	
DDT / DDD / DDE	• No toxicity benchmark is proposed •	
Endosulfan	• No toxicity benchmark is proposed •	
Heptachlor	• No toxicity benchmark is proposed •	
Polychlorinated Biphenyls		
Total PCBs	• No toxicity benchmark is proposed •	
Dioxins and Furans		
2,3,7,8-TCDD	5	Reinecke and Nash 1984

Definitions:

BHC	-	Benzene hexachloride.
mg/kg_{soil}	-	Milligrams per kilogram soil.
PAHs	-	Polycyclic aromatic hydrocarbons.
PCBs	-	Polychlorinated biphenyls.
TCDD	-	Tetrachlorodibenzo-*p* -dioxin.
VOCs	-	Volatile organic chemicals.

Table C-6
Toxicity Benchmarks for Plants

Chemical	Observed Effect	Effect Level	Conc. in leaf (mg/kg_{leaf})	BCF (kg_{soil}/kg_{leaf})	Toxicity Benchmark (mg/kg_{soil})	Reference	Endpoint-to-NOAEL	Plant RTV (mg/kg_{soil})
Inorganics								
Antimony	Normal concentration in leaves	NOAEL	50	0.2	250	Kabata-Pendias & Pendias 1984	—	250
Arsenic	Normal concentration in leaves	NOAEL	1.7	0.04	43	Kabata-Pendias & Pendias 1984	—	43
Barium	Excessive concentration in leaves	LOAEL	500	0.15	3,300	Kabata-Pendias & Pendias 1984	10	330
Beryllium	Normal concentration in leaves	NOAEL	7.0	0.01	700	Kabata-Pendias & Pendias 1984	—	700
Cadmium	Normal concentration in leaves	NOAEL	0.2	0.36	0.56	Kabata-Pendias & Pendias 1984	—	0.56
Chromium	Normal concentration in leaves	NOAEL	0.5	0.0075	67	Kabata-Pendias & Pendias 1984	—	67
Cobalt	Normal concentration in leaves	NOAEL	1.0	0.02	50	Kabata-Pendias & Pendias 1984	—	50
Copper	Normal concentration in leaves	NOAEL	30	0.40	75	Kabata-Pendias & Pendias 1984	—	75
Lead	Normal concentration in leaves	NOAEL	10	0.045	220	Kabata-Pendias & Pendias 1984	—	220
Manganese	Normal concentration in leaves	NOAEL	300	0.25	1,200	Kabata-Pendias & Pendias 1984	—	1,200
Mercury	Excessive concentration in leaves	LOAEL	1.0	0.9	1.1	Kabata-Pendias & Pendias 1984	10	0.11
Molybdenum	Normal concentration in leaves	NOAEL	1.0	0.25	4.0	Kabata-Pendias & Pendias 1984	—	4.0
Nickel	Normal concentration in leaves	NOAEL	5.0	0.06	83	Kabata-Pendias & Pendias 1984	—	83
Selenium	Normal concentration in leaves	NOAEL	2.0	0.025	80	Kabata-Pendias & Pendias 1984	—	80
Silver	Normal concentration in leaves	NOAEL	0.5	0.4	1.3	Kabata-Pendias & Pendias 1984	—	1.3
Thallium	Excessive concentration in leaves	LOAEL	20	0.004	5,000	Kabata-Pendias & Pendias 1984	10	500
Vanadium	Normal concentration in leaves	NOAEL	1.5	0.0055	270	Kabata-Pendias & Pendias 1984	—	270
Zinc	Normal concentration in leaves	NOAEL	150	1.5	100	Kabata-Pendias & Pendias 1984	—	100
Volatile Organic Compounds								
BTEX								
Benzene	• No phytotoxicity benchmark is proposed •							
Toluene	Reduced seed germination	LOAEL			2,000	Will & Suter 1995	10	200
Ethylbenzene	• No phytotoxicity benchmark is proposed •							
Xylene	Reduced root length	LOAEL			100	Hulzebos et al. 1993	10	10
Trichloroethene-Related VOCs								
Dichloroethene, 1,2-	• No phytotoxicity benchmark is proposed •							
Dichloroethane, 1,2-	• No phytotoxicity benchmark is proposed •							
Tetrachloroethene	• No phytotoxicity benchmark is proposed •							
Trichloroethane	• No phytotoxicity benchmark is proposed •							
Trichloroethene	• No phytotoxicity benchmark is proposed •							
Chlorobenzene-Related VOCs								
Chlorobenzene	• No phytotoxicity benchmark is proposed •							
Dichlorobenzene	• No phytotoxicity benchmark is proposed •							
Other VOCs								
Acetone	• No phytotoxicity benchmark is proposed •							
Dichloropropane, 1,2-	• No phytotoxicity benchmark is proposed •							
Polycyclic Aromatic Hydrocarbons and Semivolatile Organic Compounds								
Benzo[a]pyrene	• No phytotoxicity benchmark is proposed •							
Naphthalene	Reduced lettuce seed germination and growth	EC_{50}			100	Hulzebos et al. 1993	100	1.0
Methylphenol, 4-	• No phytotoxicity benchmark is proposed •							
Pentachlorophenol	• No phytotoxicity benchmark is proposed •							
Chlorinated Pesticides								
Aldrin / Dieldrin	• No phytotoxicity benchmark is proposed •							
BHC	• No phytotoxicity benchmark is proposed •							
Chlordane	• No phytotoxicity benchmark is proposed •							
DDT / DDD / DDE	• No phytotoxicity benchmark is proposed •							
Endosulfan	• No phytotoxicity benchmark is proposed •							
Heptachlor	• No phytotoxicity benchmark is proposed •							

Table C-6
Toxicity Benchmarks for Plants

Chemical	Observed Effect	Effect Level	Conc. in leaf (mg/kg_{leaf})	BCF (kg_{soil}/kg_{leaf})	Toxicity Benchmark (mg/kg_{soil})	Reference	Endpoint-to-NOAEL	Plant RTV (mg/kg_{soil})
Polychlorinated Biphenyls								
Total PCBs	No effect on growth	NOAEL			40	Strek & Weber 1980	—	40
Dioxins and Furans								
PCDDs	• No phytotoxicity benchmark is proposed •							
PCDFs	• No phytotoxicity benchmark is proposed •							

Definitions:

BHC	-	Benzene hexachloride.
EC_{50}	-	Effect concentration (50%).
kg_{soil}/kg_{leaf}	-	Kilograms in soil per kilograms in leaf.
mg/kg_{leaf}	-	Milligrams per kilogram leaf.
mg/kg_{soil}	-	Milligrams per kilogram soil.
NOAEL	-	No observed adverse effect level.
LOAEL	-	Low observed adverse effect level.
PAHs	-	Polycyclic aromatic hydrocarbons.
PCBs	-	Polychlorinated biphenyls.
PCDDs	-	Polychlorinated dibenzo-*p*-dioxins.
PCDFs	-	Polychlorinated dibenzofurans.
VOCs	-	Volatile organic chemicals.

Table C-7
Toxicity Benchmarks for Freshwater Aquatic Biota

Chemical	Toxicity Benchmark (µg/L)	Reference
Inorganics		
Antimony	30	U.S. EPA 1986
Arsenic	150	U.S. EPA 1999
Barium	4.0	U.S. EPA 1993b
Beryllium	0.66	U.S. EPA 1993b
Cadmium	TBC	U.S. EPA 1999
Chromium III	TBC	U.S. EPA 1999
Chromium VI	11	U.S. EPA 1999
Cobalt	23	U.S. EPA 1993b
Copper	TBC	U.S. EPA 1999
Lead	TBC	U.S. EPA 1999
Manganese	120	U.S. EPA 1993b
Mercury	0.77	U.S. EPA 1999
Molybdenum	370	U.S. EPA 1993b
Nickel	TBC	U.S. EPA 1999
Selenium	5.0	U.S. EPA 1999
Silver	3.4[a]	U.S. EPA 1999
Thallium	12	U.S. EPA 1993b
Vanadium	20	U.S. EPA 1993b
Zinc	TBC	U.S. EPA 1999
Volatile Organic Compounds		
BTEX		
Benzene	130	U.S. EPA 1993b
Toluene	9.8	U.S. EPA 1993b
Ethylbenzene	7.3	U.S. EPA 1993b
Xylene	13	U.S. EPA 1993b
Trichloroethene-Related VOCs		
Dichloroethene, 1,2-	590	U.S. EPA 1993b
Dichloroethane, 1,2-	910	U.S. EPA 1993b
Tetrachloroethene	98	U.S. EPA 1993b
Trichloroethane	11	U.S. EPA 1993b
Trichloroethene	47	U.S. EPA 1993b
Chlorobenzene-Related VOCs		
Chlorobenzene	64	U.S. EPA 1993b
Dichlorobenzene	15	U.S. EPA 1993b
Other VOCs		
Acetone	1,500	U.S. EPA 1993b
Dichloropropane, 1,2-	5,700[b]	U.S. EPA 1986

Table C-7
Toxicity Benchmarks for Freshwater Aquatic Biota

Chemical	Toxicity Benchmark (µg/L)	Reference
Polycyclic Aromatic Hydrocarbons and Semivolatile Organic Compounds		
Benzo[a]pyrene	0.014	U.S. EPA 1993b
Naphthalene	12	U.S. EPA 1993b
Methylphenol, 2-	13	U.S. EPA 1986
Pentachlorophenol	• No toxicity benchmark is proposed •	
Chlorinated Pesticides		
Aldrin / Dieldrin	0.056	U.S. EPA 1999
BHC	0.95[a]	U.S. EPA 1986
Chlordane	0.0043	U.S. EPA 1999
DDT / DDD / DDE	0.1	U.S. EPA 1993b
Endosulfan	0.051	U.S. EPA 1993b
Heptachlor	0.0038	U.S. EPA 1993b
Polychlorinated Biphenyls		
Total PCBs	0.14	U.S. EPA 1993b
Dioxins and Furans		
PCDDs	• No toxicity benchmark is proposed •	
PCDFs	• No toxicity benchmark is proposed •	

Definitions:

BHC	Benzene hexachloride.
PAHs	Polycyclic aromatic hydrocarbons.
PCBs	Polychlorinated biphenyls.
PCDDs	Polychlorinated dibenzo-*p*-dioxins.
PCDFs	Polychlorinated dibenzofurans.
TBC	To be calculated. (The toxicity benchmark for this metal is expres and will be calculated based on the hardness of impoundment wat
µg/L	Micrograms per liter.
VOCs	Volatile organic chemicals.

Notes:

a = Criterion maximum concentration (U.S. EPA 1999)

b = lowest chronic value

Table C-8
Toxicity Benchmarks for Sediment Associated Biota

Chemical	Toxicity Benchmark (mg/kg_{sed})	Reference
Inorganics		
Antimony	2.0	Long *et al.* 1995
Arsenic	8.2	Long *et al.* 1995
Barium	• No toxicity benchmark is proposed •	
Beryllium	• No toxicity benchmark is proposed •	
Cadmium	1.2	Long *et al* . 1995
Chromium	81	Long *et al* . 1995
Cobalt	• No toxicity benchmark is proposed •	
Copper	34	Long *et al* . 1995
Lead	47	Long *et al* . 1995
Manganese	• No toxicity benchmark is proposed •	
Mercury	0.15	Long *et al.* 1995
Molybdenum	• No toxicity benchmark is proposed •	
Nickel	21	Long *et al.* 1995
Selenium	• No toxicity benchmark is proposed •	
Silver	1.0	Long *et al* . 1995
Thallium	• No toxicity benchmark is proposed •	
Vanadium	• No toxicity benchmark is proposed •	
Zinc	150	Long *et al.* 1995
Volatile Organic Compounds		
BTEX		
Benzene	• No toxicity benchmark is proposed •	
Toluene	• No toxicity benchmark is proposed •	
Ethylbenzene	• No toxicity benchmark is proposed •	
Xylene	• No toxicity benchmark is proposed •	
Trichloroethene-Related VOCs		
Dichloroethene, 1,2-	• No toxicity benchmark is proposed •	
Dichloroethane, 1,2-	• No toxicity benchmark is proposed •	
Tetrachloroethene	• No toxicity benchmark is proposed •	
Trichloroethane	• No toxicity benchmark is proposed •	
Trichloroethene	• No toxicity benchmark is proposed •	
Chlorobenzene-Related VOCs		
Chlorobenzene	• No toxicity benchmark is proposed •	
Dichlorobenzene	• No toxicity benchmark is proposed •	
Other VOCs		
Acetone	• No toxicity benchmark is proposed •	
Dichloropropane, 1,2-	• No toxicity benchmark is proposed •	
Polycyclic Aromatic Hydrocarbons and Semivolatile Organic Compounds		
Benzo[a]pyrene	0.43	Long *et al.* 1995
Naphthalene	0.16	Long *et al.* 1995
Methylphenol, 4-	• No toxicity benchmark is proposed •	
Pentachlorophenol	• No toxicity benchmark is proposed •	

Table C-8
Toxicity Benchmarks for Sediment Associated Biota

Chemical	Toxicity Benchmark (mg/kg_{sed})	Reference
Chlorinated Pesticides		
Aldrin / Dieldrin	• No toxicity benchmark is proposed •	
BHC	• No toxicity benchmark is proposed •	
Chlordane	• No toxicity benchmark is proposed •	
DDT / DDD / DDE	0.0016	Long *et al.* 1995
Endosulfan	• No toxicity benchmark is proposed •	
Heptachlor	• No toxicity benchmark is proposed •	
Polychlorinated Biphenyls		
Total PCBs	0.023	Long *et al.* 1995
Dioxins and Furans		
PCDDs	• No toxicity benchmark is proposed •	
PCDFs	• No toxicity benchmark is proposed •	

Definitions:

BHC	-	Benzene hexachloride.
mg/kg_{sed}	-	Milligrams per kilogram sediment.
PAHs	-	Polycyclic aromatic hydrocarbons.
PCBs	-	Polychlorinated biphenyls.
PCDDs	-	Polychlorinated dibenzo-*p*-dioxins.
PCDFs	-	Polychlorinated dibenzofurans.
VOCs	-	Volatile organic chemicals.

Appendix D

3MRA Simulation Modules

Assumptions, Limitations, Inputs, and Outputs

Appendix D

3MRA Simulation Modules

Assumptions, Limitations, Inputs, and Outputs

The SI Study will utilize the HWIR 3MRA Model for the Phase II risk assessment. To address multiple exposure simultaneously, the 3MRA Model includes 17 functional modules. Fourteen of these component modules will be applied to the SI Study risk assessment[1]. The assumptions and limitations and detailed input and output requirements are provided for each module in this Appendix.

D.1 System Input/Output Specifications

Within the 3MRA system, data are passed to and between modules using prespecified formats and file structures.There are three types of sequence- independent, comma-separated value (CSV) files used by the 3MRA module: site simulation files (*.SSF), global result files (*.GRF), and dictionary files (*.DIC). Sequence-independence means that a parameter can be read from anywhere in a file without having to query the file line by line. Sequence independence also implies that the ordering of parameters within the file is inconsequential.

Using this convention, established by PNNL (PNNL 1998) for HWIR99, a parameter may be read directly from a file with the assistance of functions in 3MRA (PNNL 1998). These ASCII, comma-delimited files are accessed by the module using a specially-provided dynamic link library provided in the HWIRIO.DLL. Each file has a corresponding data dictionary file in the /SSF/ subdirectory (i.e., sl.dic, cp.dic, and sw.dic).

Figure 3-11 shows how data is passed between modules in the 3MRA model; these data are transferred via *.GRF files. Dictionary files (DIC) define the parameters found in corresponding *.SSFs and *.GRFs. The "*" represents a module abbreviation. For example, VZ.DIC defines all parameters which may appear in VZ.SSF and VZ.GRF. A detailed discussion of each file type follows.

[1] Three 3MRA source modules are not needed for the SI Study risk assessment: landfill, waste pile, and aerated tank.

- # *.DIC files define what parameters are allowable as well as their specifications. These dictionary files list the variable names along with their dimensions, data type (i.e., character or “string”, real or “float,” or integer), minimum and maximum limits, units, and a brief description. For some arrays, the maximum number of entries are also given.

- # Site simulation files (*.SSF) contain parameters for input only (e.g., read-only files) used by specific modules. Their access is limited to one module except for the site layout SSF (SL.SSF), which includes site layout and other variables needed by several simulation modules, and the chemical properties SSF (CP.SSF) that contains all chemical-specific properties and benchmarks.

- # Global result files (*.GRF) are files generated by modules, which, in turn, may be used as input files for other modules (e.g., read and write files).

The file name (*.SSF or *.GRF) is provided for each of the inputs and outputs listed below by module.

D.2 Source Modules

The source module employed for the Surface Impoundment (SI) Study risk analysis must model multimedia releases both before and after closure of the impoundment. The SI module currently in the HWIR 3MRA Model only models releases up to closure. For the SI Study risk assessment, sludge from SI operation will be assumed to be left in place after closure, where it is subject to volatilization, wind and water erosion, and leaching. Currently, the best option to model these processes is the 3MRA land application unit (LAU) module, which includes all needed release mechanisms and can be adapted to the SI post-closure scenario simply by adjusting input variables.

The remainder of this section provides the assumptions and limitations of the 3MRA SI and LAU modules and details their input requirements and outputs. This information was extracted and adapted from the HWIR 3MRA background documents (U.S. EPA, 1999a, 1999b), which contain additional detail, including all assumptions, governing equations, boundary conditions, solution techniques, and supporting references.

D.2.1 Functionality - SI Operating Module

The SI operating module functionality may be summarized as follows:

- Models single unit (cannot model multiple impoundments at a site)
- Uses mass balance approach considering contaminant removal by volatilization, biodegradation, hydrolysis, leaching, and partitioning to solids
- Estimates volatilization rates for both aerated and quiescent surfaces
- Estimates infiltration rate and contaminant leachate flux rates
- Estimates suspended solids removal (settling) efficiency
- Estimates temperature effects on contaminant degradation and volatilization
- Cannot model catastrophic failures.

The SI module calculates volatile emissions flux from a simulated wastewater treatment tank. The unit has only volatile air emissions (no particulates) and is assumed to have a pervious bottom so that contaminant leaching to the subsurface can occur. There is no runoff and overland flow of contaminant. The module is a quasi-steady-state module, and the emissions occur only while the unit operates.

D.2.2 Assumptions and Limitations - SI Module

The general module construct used for the SI module includes losses due to volatilization from aerated and/or quiescent surfaces, biodegradation, hydrolysis, solids settling/accumulation,

and leaching. This general module construct can be useful for a wide variety of types of SIs. However, certain processes, such as chemical precipitation, however, may not be explicitly modeled with this module construct. However, with judicious selection of the input parameters, the general module construct can provide accurate fate estimates for most tank and SI waste applications. For example, if the precipitation rate for chemical precipitation is known, the input parameters used for "biomass" growth could be manipulated to simulate the solids generation rate caused by precipitation (rather than biomass growth).

The following assumptions are used in the development of the SI module solution:

- Two-compartment module: "mostly" well-mixed liquid compartment and a well-mixed sediment compartment, which includes a temporary accumulating solids compartment
- First-order kinetics for volatilization in liquid compartment
- First-order kinetics for hydrolysis in both liquid and sediment compartment
- First-order kinetics for biodegradation with respect to both contaminant concentration and biomass concentration in liquid compartment
- First-order kinetics for biodegradation in sediment compartment
- Darcy's law for calculating the infiltration rate
- First-order kinetics for solids settling
- First-order biomass growth rate with respect to total biological oxygen demand (BOD) loading
- First-order biomass decay rate within the accumulating sediment compartment
- No contaminant in precipitation/rainfall
- Linear contaminant partitioning among adsorbed solids, dissolved phases, and vapor phases
- Consideration of only one contaminant at a time (does not simulate fate and transport of reaction products or multiple chemicals).
- Limitation of the maximum infiltration rate to that which does not cause ground water "mounding" and to no more than 99 percent of the maximum influent rate.
- Limitation of the minimum effluent rate to no less than one percent of the influent rate..

Due to the simplicity of the biodegradation rate module employed and the use of Henry's law partitioning coefficients, the module is most applicable to dilute aqueous wastes. At higher contaminant concentrations, biodegradation of toxic constituents may be expected to exhibit zero-order or even inhibitory rate kinetics. For waste streams with high contaminant or high total organic concentrations, vapor phase contaminant partitioning may be better estimated using partial pressure (Raoult's law) rather than Henry's law. Also, because daughter products are not included in the module, any contaminant emissions or leachate generated as a reaction intermediate or end product from either biodegradation or hydrolysis are not included in the module output.

D.2.3 Functionality - LAU (SI Postclosure) Module

The source term module developed for LAUs estimates annual average surface soil constituent concentrations and constituent mass emission rates to air, surface water, and groundwater. The LAU source emission module includes a local watershed module to estimate constituent mass flux rates from runoff and erosion to a downslope waterbody, as well as surface soil constituent concentrations in buffer areas downslope of a land-based waste management unit (WMU). The LAU module also includes a Generic Soil Column Module (GSCM) that describes the dynamics of constituent mass fate and transport within nonwastewater WMUs and near-surface soils in watershed subareas.[2] The LAU module functionality may be summarized as follows:

- Performs constituent mass balance
- Can consider waste additions/removals to simulate active facilities
- Jointly estimates constituent mass losses due to a variety of first-order mechanisms, including:
  - Volatilization of gas-phase constituent mass from the surface to the air
  - Leaching of aqueous-phase constituent mass by advection or diffusion from the bottom of the WMU or vadose zone
  - Hydrolysis and biodegradation
  - Suspension of constituent mass adsorbed to surface particles due to wind action and vehicular activity
  - Suspension of constituent mass adsorbed to surface particles due to water erosion
  - Surface runoff of aqueous-phase constituent mass.

[2] The term "soil" is used loosely here to refer to a porous medium, whether it is sludge left in place after SI closure or near-surface soil in a watershed subarea downslope from the SI.

Governing equations for the LAU module are similar to those used by Jury et al. (1983, 1990) and Shan and Stevens (1995) modified to allow for the periodic addition of constituent mass and enhanced constituent mass loss rates in the surface soil (e.g., due to runoff, erosion, wind, and mechanical processes) (U.S. EPA, 1999b).

D.2.4 Assumptions and Limitations - LAU (SI Post-Closure) Module

The following assumptions were made in the development of the LAU module to be used to model the SI after closure:

- The contaminant partitions to three phases: adsorbed (solid), dissolved (liquid), and gaseous (as in Jury et al., 1983, 1990). The model is not applicable if nonaqueous phase liquid (NAPL) is present. Similarly, with metals, the presence of a precipitate is not allowed.

- The contaminant undergoes reversible, linear equilibrium partitioning between the adsorbed and dissolved phases (as in Jury et al., 1983, 1990). The sorptive capacity of the soil column solids is considered to be infinite with respect to the total mass of contaminant over the duration of the simulation (i.e., the soil column sorptive capacity does not become exhausted).
- Contaminant in the dissolved and gaseous phases is assumed to be in equilibrium and to follow Henry's law (as in Jury et al., 1983, 1990).

- The total water flux or infiltration rate (I, m/d) is constant in space and time (as in Jury et al., 1983, 1990) and greater than or equal to zero. It is specified as an annual average.

- Although some inputs are annual average, others (e.g., wind velocities) are long-term annual averages. Accordingly, the outputs are not strictly applicable to individual years (i.e., the module is designed to only support estimation of chronic, long-term average risk estimates).

- Material in the soil column (including waste) can be approximated as unconsolidated homogeneous porous media whose basic properties (density, organic carbon, water content, porosity) are average annual values, constant in space.

- Contaminant mass may be lost from the soil column due to one or more first-order loss processes.

- The total chemical flux is the sum of the vapor flux and the flux of the dissolved solute (as in Jury et al., 1983, 1990).

- The chemical is transported in one dimension (up or down) through the soil column (as in Jury et al., 1983, 1990).

- The vapor-phase and liquid-phase porosity and tortuosity factors obey the module of Millington and Quirk (1961) (as in Jury et al., 1983, 1990).

- The modeled spatial domain of the soil column remains constant in volume and fixed in space with respect to a vertical reference, e.g., the water table.

- The module allows consideration of only one contaminant at a time and does not simulate fate and transport of reaction products or multiple chemicals.

D.2.5 Inputs for the Source Modules

Table D-1 summarizes the input variables for the SI module and Table D-2 lists the values used by the LAU module. Both modules use data provided from the header file (hd.ssf), site layout file (sl.ssf), source module-specific file (i.e., si.ssf, la.sf), and the daily (LAU), monthly (SI), annual (LA), and long-term annual average (LAU) meteorological data files. All SSF files are expected to be in an SSF subdirectory; the meteorological data are expected to be in a MetData subdirectory. For the SI, because the operating temperature in the unit may vary as a function of the ambient temperature and hydraulic residence time, the module also uses chemical property information calculated as a function of the unit temperature. Much of these data are provided through calls to the chemical property dll functions (which use data files stored in a chemical properties subdirectory). Some temperature correction routines are embedded within the SI module program. The LAU receives chemical data corrected to the long-term annual average temperature at the site.

D.2.6 Outputs from the Source Modules

Table D-3 lists the outputs from the SI module. The primary outputs of the SI module include:

- *Outputs to Air Module* - the annual average volatilization rate, which provides input for calculations of air transport of contaminant using the air module.

- *Outputs to the Vadose Zone Module* - the average annual infiltration rate and the average annual leachate contaminant flux rate, which are inputs used by the vadose zone module to calculate contaminant flux to groundwater.

The volatilation rate is calculated for a number of years specified either as the total number of years of the simulation or the number of years the unit is operated. Infiltration to the vadose zone is assumed to be driven by the hydrostatic pressure head produced by the wastewater in the unit and when the unit ceases operation it is assumed that no additional contaminant leaches from the source. Annual liquid infiltration rates and contaminant leachate flux rates are both calculated at the base of the unit.

The SI module generates a results file (sr.grf) in the grf subdirectory containing all module outputs used as inputs for other modules. The program may also generate warning messages (e.g., if the calculated unit temperature is below freezing, a warning is generated).

Table D-4 lists the outputs from the LAU module. Time series outputs to the various other HWIR99 modules include:

- *Outputs to Air Module.* All annual time series outputs to the Air Module are reported up to and including the last year that there is nonzero volatile or particulate emission flux. After this all emissions will be zero and are not reported. Thus, the annual time series outputs to the Air Module are all the same length.

- *Outputs to the Vadose Zone Module*. The annual time series of leachate flux for each local watershed is reported up to and including the last year that there is a nonzero flux in any local watershed. This results in the same time series length for all local watersheds. After this, all leachate flux values for all local watersheds will be zero and are not reported. Annual infiltration rate is reported from year one to the last year that meteorological data are available for the simulation.

- *Outputs to the Surface Water Module*. The annual time series of contaminant loading to the waterbody are reported up to and including the last year that there is nonzero loading from any local watershed. This results in the same reported time series length for all local watersheds. Solids loads and runoff from all local watershed(s) are reported up to the last year that meteorological data are available.

- *Outputs to Exposure Modules (Human and Ecological)*. The annual time series of depth-weighted average soil contaminant concentrations in the LAU and in the buffer area downslope from the LAU is reported to the the last year of nonzero concentrations in each local watershed and subarea. Thus, the length of the reported time series for soil concentrations in each local watershed and subarea may differ. The same is true for surface soil contaminant concentrations.

The LAU module generates a results file (sr.grf) in the grf subdirectory containing all module outputs used as inputs for other modules. The program may also generate warning messages (e.g., if constituent solubility is exceeded in the WMU a warning is generated).

Table D-1. Summary of Inputs for Surface Impoundment Source Module

File	Variable Name	Units	Data Type	Variable Name in Module Code	Description
HD.SSF	CPDirectory		String	m_pathname, pathname	Path for location of chemical properties files
	MetData		String	MetPath	Path for location of meteorological files
SL.SSF	SrcArea	m^2	Real	m_A_wmu, A_wmu, A_tot	Area of the waste management unit
	SiteLatitude	degrees	Real	m_Lat	Latitude of the site
	SiteLongitude	degrees	Real	m_Long	Longitude of the site
	MetSta		String	m_MetSta, MetSta	ID number for meteorological station associated with site
	NyrMax	years	Integer	m_NyrMax	Maximum module simulation time
	SrcPh	pH units	Real	m_pH, pH	Waste pH
	SrcTemp	degrees Celsius	Real	m_T_waste, T_waste	Temperature of the waste
	SrcType		String	m_WMUType, WMUType	Type of waste management unit (AT or SI)
	SrcNumLWS		Integer	m_SrcNumLWS, SrcNumLWS	Number of local watersheds (SI only)
	SrcLWSNumSubArea		Integer	m_SrcLWSNumSubArea[ ]	Number of subareas in the local watershed (SI only)
	SrcLWSSubAreaIndex	unitless	Integer	m_SrcLWSSubAreaIndex[ ]	Local watershed subarea containing WMU (SI only)
	SrcLWSSubAreaArea	m^2	Real	m_SrcLWSSubAreaArea[ ]	Area of a subarea in the local watershed (SI only)
	TermFrac	fraction	Real	m_TermFrac	Peak output fraction for simulation termination
	SrcDepth	m	Real	m_SrcDepth	Depth of source (0 for AT)
	NumVad		Integer	m_NumVad, NumVad	Number of vadose zones (SI only)

(continued)

Table D-1. (continued)

File	Variable Name	Units	Data Type	Variable Name in Module Code	Description
	N_stot[a]	unitless	Integer	m_N_stot, N_stot	Number of subsurface soil layers (currently hardwired to 1) (SI only)[a]
	VadSATK	cm/h	Real	m_hydc_s[ ], hydc_s[ ]	Saturated hydraulic conductivity in the subsurface soil layer (SI only)
	VadThick[a]	m	Real	m_d_s[ ][ ], d_s[ ]	Thickness of the subsurface soil layer (SI only)[a]
	VadALPHA	1/cm	Real	m_alpha_s[ ], alpha_s[ ]	Alpha soil parameter for subsurface soil (SI only)
	VadBETA	unitless	Real	m_beta_s[ ], beta_s[ ]	Beta soil parameter for subsurface soil (SI only)
SI.SSF	VadSATK	cm/h	Real	m_hydc_liner, hydc_liner	Hydraulic conductivity of the liner (SI only)
	d_liner	m	Real	m_d_liner, d_liner	Thickness of SI liner (currently hardwired to 0.5 m) (SI only)
	VadALPHA	1/cm	Real	m_alpha_liner, alpha_liner	Alpha soil parameter for SI liner (SI only)
	VadBETA	unitless	Real	m_beta_liner, beta_liner	Beta soil parameter for SI liner (SI only)
	hydc_sed	m/s	Real	m_hydc_sed, hydc_sed	Hydraulic conductivity of the sediment that accumulates in the unit (SI only)
	bio_yield	g/g	Real	m_bio_yield, bio_yield	Biomass yield in g dry wt biomass/g CBOD
	CBOD	g/cm^3	Real	m_CBOD, CBOD	Carbonaceous biochemical oxygen demand for the chemical
	C_in	mg/L	Real	m_C_in, C_in	Concentration of chemical in hazardous waste
	EconLife	year	Integer	m_EconLife, EconLife	Economic life of the unit

(continued)

Table D-1. (continued)

File	Variable Name	Units	Data Type	Variable Name in Module Code	Description
	NumEcon		Integer	m_NumEcon, NumEcon	Number of economic lifetimes that the unit operates
	d_imp	cm	Real	m_d_imp, d_imp	Diameter of the impeller used to aerate the unit
	dmeanTSS	cm	Real	m_m, m	Mean particle of an influent particle
	d_setpt	fraction	Real	m_d_setpt, d_setpt	Fraction full of sediment at which unit is dredged
	d_wmu	m	Real	m_d_wmu, d_wmu, d_tot	Depth of the waste management Unit
	F_aer	fraction	Real	m_F_aer, F_aer	Fraction of the unit surface area that is aerated
	focW	mass fraction	Real	m_foc, foc	Fraction of organic carbon in the waste
	fwmu	mass fraction	Real	m_fwmu, fwmu	Fraction of waste that is hazardous
	J	lb O_2/h-hp	Real	m_J, J	O_2 transfer rating of aerator
	kba1	unitless	Real	m_kba1, kba1	Ratio of biologically active solids to the total solids concentration
	k_dec	1/s	Real	m_k_dec, k_dec	Anaerobic digestion/decay constant of the organic sediment
	u_l	g/cm-s	Real	m_mu_H2O, mu_H2O	Viscosity of water
	MWt_H2O	g/mol	Real	m_MWt_H2O, MWt_H2O	Molecular weight of water
	n_imp	unitless	Integer	m_n_imp, n_imp	Number of impellers/aerators
	O2Eff	unitless	Real	m_O2eff, O2eff	O_2 transfer correction factor
	Powr	hp	Real	m_Powr, Powr	Total power to aerators/impellers

(continued)

Table D-1. (continued)

File	Variable Name	Units	Data Type	Variable Name in Module Code	Description
	Q_wmu	m^3/s	Real	m_Q_wmu, Q_wmu, Q_in	Total influent flow rate into the unit
	rho_l	g/cm^3	Real	m_rho_H2O, rho_H2O	Density of water
	rho_part	g/cm^3	Real	m_rho_part, rho_part	Density of particles in the influent waste
	TSS_in	g/cm^3	Real	m_TSS_in, TSS_in	Total suspended solids concentration in the influent
	w_imp	rad/s	Real	m_w_imp , w_imp	Rotational speed of impellers
CP.SSF	NumChem		Integer	m_NumChem,	Number of chemical species
	ChemType		String	m_ChemType, ChemType	Type of chemical
	ChemADiff	cm^2/s	Real	m_Da, Da	Diffusivity of chemical in air
	ChemWDiff	cm^2/s	Real	m_Dw, Dw	Diffusivity of chemical in water
	ChemHLC	(atm m^3) / mol	Real	m_HLC, HLC	Henry's law constant for the chemical
	ChemKoc	mL/g	Real	m_Koc, Koc	Soil-water partitioning coefficient for the chemical
	ChemAnaBioRate	1/day	Real	m_kbiou, kbs	Biodegradation / decay rate of contaminant in sediment compartment
	ChemAerBioRate[b]	1/day	Real	m_kbioa, kbm	Complex first-order biodegradation rate constant for the chemical[b]
	ChemHydRate	1/day	Real	m_k_hyd, k_hyd	Hydrolysis rate for the chemical
	ChemSol	mg/L	Real	m_Sol, Sol	Chemical solubility
	ChemCASID		String	m_CAS, CAS	Chemical CAS ID number
	ChemName		String	m_ChemName, ChemName	Chemical name

(continued)

Table D-1. (continued)

File	Variable Name	Units	Data Type	Variable Name in Module Code	Description
	ChemKd	L/kg	Real	m_Kds, Kds	Solid/water partition coefficient
Met data file	---	°C	Real	m_AvgTemp[ ][ ]	Average monthly temperature
	---	m/s	Real	m_um[y][z]	Monthly average windspeed
	---	m/d	Real	m_AvgPpt[ ][ ]	Average monthly precipitation
	---	m/d	Real	m_E[ ][ ]	Average monthly evaporation
	---		Integer	NyrMet	Number of years of meteorological data

[a] The module currently assumes there is one native soil layer and that the thickness of the underlying soil layer is assumed to be a minimum of 1 meter thick. If the regional vadose zone thickness is less than $1+d_{wmu}$, then the impoundment is assumed to be built up (via an earthen berm) so that there is 1 meter of soil between the bottom of the SI and the ground water.

[b] Note: If normalized biodegradation rate constants are unavailable, normalized biodegradation rates constants are estimated from first-order biodegradation rate constants developed for soil systems by assuming the effective biomass in the soil system is 2.0×10^{-6} Mg/m^3. This value was developed by RTI as an interim estimate until a more rigorously developed value for this parameter is available from EPA.

Table D-2. Summary of Inputs for Land Application Unit (LAU) Source Module

File	Variable Name	Units	Data Type	Description
HD.SSF	CPDirectory		String	Path for location of chemical properties files
	MetData		String	Path for location of meteorological files
SL.SSF	SrcArea	m^2	Real	Area of LAU
	SiteLatitude	degrees	Real	Latitude of the site
	MetSta		String	ID number for meteorological station associated with site
	NyrMax	years	Integer	Maximum module simulation time
	SrcNumLWS		Integer	Number of local watersheds
	SrcLWSNumSubArea		Integer	Number of subareas in the local watershed
	SrcLWSSubAreaIndex	unitless	Integer	Local watershed subarea containing LAU
	SrcLWSSubAreaArea	m^2	Real	Area of a subarea in the local watershed
	TermFrac	fraction	Real	Peak output fraction for simulation termination
	SrcDepth	m	Real	Depth of source (tilling depth)
LA.SSF	asdm	mm	Float	Mode of the aggregate size distribution (LAU surface)
	bcm	unitless	Float	Boundary condition multiplier (lower boundary)
	BDw	g/cm3	Float	Waste density (wet waste)
	C	unitless	Float	USLE cover factor (all local watershed subareas except LAU)
	CN	unitless	Float	SCS curve number (by local watershed subarea)
	CNwmu	unitless	Float	SCS curve number (LAU)
	ConVs	m/d	Float	Settling velocity (suspended solids)
	CTPwaste	ug/g	Float	Waste constituent concentration (LAU)
	CutOffYr	year	Integer	Operating life
	Cwmu	unitless	Float	USLE cover factor (LAU)
	deltDiv	unitless	Integer	Time step divider (for debugging)
	DRZ	cm	Float	Root zone depth (by local watershed subarea)
	effdust	unitless	Float	Dust suppression control efficiency
	fcult	unitless	Float	Number of cultivations per application

(continued)

Table D-2. (continued)

File	Variable Name	Units	Data Type	Description
	fd	1/mo	Float	Frequency of surface disturbance per month, active LAU
	focS	mass fraction	Float	Surface soil fraction organic carbon (by local watershed subarea)
	focW	mass fraction	Float	Fraction organic carbon (waste solids)
	fwmu	mass fraction	Float	Fraction hazardous waste applied to LAU
	Infild	m/d	Float	Input infiltration rate (for debugging)
	K	kg/m2	Float	USLE soil erodibility factor (by local watershed subarea)
	Ksat	cm/h	Float	Soil saturated hydraulic conductivity (by local watershed subarea)
	Kwmu	kg/m2	Float	USLE soil erodibility factor (LAU)
	Lc	unitless	Float	Roughness ratio (LAU)
	mt	m	Float	Distance vehicle travels on LAU surface
LA.SSF	Nappl	1/year	Integer	Waste applications per year
	nv	1/d	Float	Vehicles/day (mean annual)
	nw	unitless	Float	Wheels per vehicle (mean)
	P	unitless	Float	USLE soil erosion control factor (all local watershed subareas except LAU)
	Pwmu	unitless	Float	USLE soil erosion control factor (LAU)
	Rappl	Mg/m2-year	Float	wet waste application rate
	RunID		string	Run identification label (optional)
	SMb	unitless	Float	soil moisture coefficient b (by local watershed subarea)
	SMFC	volume %	Float	soil moisture field capacity (by layer and local watershed subarea)
	SMWP	volume %	Float	soil moisture wilting point (by layer and local watershed subarea)
	solid	mass percent	Float	percent solids (waste)

(continued)

Table D-2. (continued)

File	Variable Name	Units	Data Type	Description
	Ss	mass percent	Float	surface soil silt content
	Sw	mass percent	Float	waste solids silt content (as applied)
	Theta	degrees	Float	slope (by local watershed)
	thetawZ1d	volume fraction	Float	input volumetric water content in till zone (for debugging)
	thetawZ2d	volume fraction	Float	input volumetric water content in subsoil zone (for debugging)
	veg	fraction	Float	post-closure fraction vegetative cover
	vs	km/h	Float	vehicle speed (mean)
	vw	Mg	Float	vehicle weight (mean)
	WCS	volume fraction	Float	soil saturated water content or total porosity (by local watershed subarea)
	X	m	Float	flow length (by local watershed)
	zava	m	Float	averaging depth upper (depth averaged soil concentration)
	zavb	m	Float	averaging depth lower (depth averaged soil concentration)
	zruf	cm	Float	post-closure roughness height(LAU)
	zZ1sa	m	Float	modeled soil column depth (local watershed subareas other than LAU)
	zZ1WMU	m	Float	tilling depth (LAU)
	zZ2WMU	m	Float	subsoil layer thickness
CP.SSF	ChemCASID		String	CAS number of chemical
	ChemName		String	Chemical name
	ChemType		String	Type of chemical
	ChemTemp	degrees C	Real	Temperature for chemical properties
	ChemFracNeutral	Fraction	Real	Fraction of chemical in the neutral form
	ChemADiff	cm^2/s	Real	Diffusivity of chemical in air

(continued)

Table D-2. (continued)

File	Variable Name	Units	Data Type	Description
	ChemWDiff	cm^2/s	Real	Diffusivity of chemical in water
	ChemHLC	(atm m^3) / mol	Real	Henry's law constant for the chemical
	ChemKoc	mL/g	Real	Soil organic carbon - water partitioning coefficient (organic compounds)
	ChemAnaBioRate	1/day	Real	Biodegradation / decay rate of contaminant in sediment compartment
	ChemAerBioRate[b]	1/day	Real	Complex first-order biodegradation rate constant for the chemical[b]
	ChemHydRate	1/day	Real	Hydrolysis rate for the chemical
	ChemSol	mg/L	Real	Chemical solubility
	ChemKd	L/kg	Real	Solid/water partition coefficient (inorganic compounds; by media)
Met file	temp	degrees C	Real	Average daily air temperature
	jday		Integer	Julian day
	dailyR	1/t	Real	Daily USLE rainfall erosivity factor
	dailyppt	cm/d	Real	Total daily precipitation
	AvgTemp	degrees C	Real	Monthly mean temperature
	maxtemp	degrees C	Real	Maximum daily average temperature for month
	mintemp	degrees C	Real	Minimum daily average temperature for month
	PE		Real	Thornthwaite Precipitation Evaporation Index
	fw1	%	Real	Percent time wind speed is greater than 5.4 m/s
	up	m/s	Real	Long term mean annual windspeed
	Uplus	m/s	Real	Annual average fastest mile of wind
	p_days	d/yr	Real	Days per year with precipitation > 0.01 in
	pp	d/yr	Real	Mean number of days per year with ≥0.01 in precipitation
	Ed	m/d	Real	Average daily evaporation
	tsc	degrees C	Real	Long term average soil column temperature

(continued)

Table D-2. (continued)

File	Variable Name	Units	Data Type	Description
	---		Integer	Number of years of meteorological data

[a] The module currently assumes there is one native soil layer and that the thickness of the underlying soil layer is assumed to be a minimum of 1 meter thick. If the regional vadose zone thickness is less than $1+d_{wmu}$, then the impoundment is assumed to be built up (via an earthen berm) so that there is 1 meter of soil between the bottom of the SI and the ground water.

[b] Note: If normalized biodegradation rate constants are unavailable, normalized biodegradation rates constants are estimated from first-order biodegradation rate constants developed for soil systems by assuming the effective biomass in the soil system is 2.0×10^{-6} Mg/m^3. This value was developed by RTI as an interim estimate until a more rigorously developed value for this parameter is available from EPA.

Table D-3. Output Summary (SR.GRF) for Surface Impoundment Source Module

File	Code	Units	Data Type	Variable Name in Module Code	Description
SR.GRF	VENY		Integer	VENumOut	number of years in VE outputs
	VEYR	year	Integer	VEOutYear[ ]	Year associated with VE output
	VE	$g/m^2/d$	Real	E_wmu_t[ ]	Volatile emission rate
	LeachFluxNY		Integer	LeachFluxNumOut[ ]	Number of years in leach flux outputs (SI only)
	LeachFluxYR	year	Integer	LeachFluxOutYear[ ][ ]	Year associated with leach flux output (SI only)
	LeachFlux	$g/m^2/d$	Real	L_wmu_t[ ]	Leachate contaminant flux (SI only)
	NyrMet	year	Integer	nyrs	Number of years in the available met record (set equal to number of year unit operates)
	AnnInfil	m/d	Real	Infil_t[ ]	Annual average leachate infiltration rate (SI only)
	SrcOvl		Logic	l_SrcOvl	Flag for overland flow presence
	SrcSoil		Logic	l_SrcSoil	Flag for soil presence
	SrcLeachSrc		Logic	l_SrcLeachSrc	Flag for leachate presence when leachate is not met-driven (unit is active)
	SrcLeachMet		Logic	l_SrcLeachMet	Flag for leachate presence when leachate is met-driven
	SrcVE		Logic	l_SrcVE	Flag for volatile emissions presence
	SrcCE		Logic	l_SrcCE	Flag for chemical sorbed to particulates emissions presence
	SrcH2O		Logic	l_SrcH2O	Flag for surface water presence

Table D-4. Output Summary (SR.GRF) for the LAU Source Module (Post-Closure SI)

	Variable Name[a]			
File	**Module**	**Code**	**Definition**	**Units**
SR.GRF	I	AnnInfil	Leachate infiltration rate (annual avg., WMU subarea(s) only)	m/d
	J_{vol}	VE	Volatile emission rate	$g/m^2/d$
		VEYR	Year associated with output	Year
		VENY	Number of years in outputs	Unitless
	CE30	CE	Constituent mass emission rate-PM30	$g/m^2/d$
		CEYR	Year associated with output	Year
		CENY	Number of years in outputs	Unitless
	E30	PE30	Eroded solids mass emission rate-PM30	$g/m^2/d$
		PE30YR	Year associated with output	Year
		PE30NY	Number of years in outputs	Unitless
	pmf	PMF	Particulate emission particle size distribution	Mass frac.
		PMFYR	Year associated with output	Year
		PMFNY	Number of years in outputs	Unitless
	Q	Runoff	Runoff flow to waterbody	m3/d
	J_{lch}	LeachFlux	Leachate contaminant flux	$g/m^2/d$
		LeachFluxYR	Year associated with output	Year
	LeachFluxNY	LeachFluxNY	Number of years in outputs	Unitless
		SWLoadChem	Chemical load to waterbody	g/d
		SWLoadChemYr	Year associated with output	year
		SWLoadChemNY	Number of years in outputs	Unitless
	CSL	SWLoadSolid	Total suspended solids load to waterbody	g/d
	C1	SWConcTot	Total chemical concentration in surface water runoff	mg/L
		SWConcTotYR	Year associated with output	Year
		SWConcTotNY	Number of years in outputs	Unitless
	C_T	CTss	Soil concentration in surface soil layer	µg/g
		CTssYR	Year associated with output	Year

(continued)

Table D-4. (continued)

Variable Name[a]				
File	**Module**	**Code**	**Definition**	**Units**
		CTssNY	Number of years in outputs	Unitless
	C_T	CTda	Depth-weighted average soil concentration (from zava to zavb)	µg/g
		CTdaYR	Year associated with output	Year
		CTdaNY	Number of years in outputs	Unitless
		SrcSoil	Flag for soil presence (true)	Logical
		SrcOvl	Flag for overland flow presence (true)	Logical
		SrcLeachMet	Flag for leachate presence when leachate is met-driven (true)	Logical
		SrcLeachSrc	Flag for leachate presence when leachate is not met-driven (false)	Logical
		SrcVE	Flag for volatile emissions presence (true)	Logical
		SrcCE	Flag for chemical sorbed to particulates emissions presence (true)	Logical
		SrcH2O	Flag for surface water presence for eco-exposure (false)	Logical
		NyrMet	Number of years in the available met record	Unitless

[a] Where the variable name is used in the code but not in the documentation, the first column is left blank.

D.3 Air Module

The HWIR 3MRA model air module is the Industrial Source Complex-Short Term (ISCST3) model, with pre- and postprocessors incorporated to adapt it to the 3MRA system,. The air module provides estimates of contaminant concentration, dry deposition (particles only), and wet deposition (particles and gases) for user-specified averaging periods (i.e., annually for HWIR99).

ISCST3 is used as legacy code in the 3MRA framework. That is, the model is left intact and system interfacing is handled using the pre- and postprocessors. The pre- and postprocessing code also provides additional functionality to support other 3MRA framework requirements. This section provides an overview of the assumptions, limitations, inputs, and outputs of the 3MRA air module as applied in HWIR; additional detail can be found in U.S. EPA (1999c and 1999d).

D.3.1 Functionality

ISCST3 is a steady-state Gaussian plume model. The model provides point estimates of ambient air concentration, dry deposition (particles only), and wet deposition (particles and gases) for user-specified averaging periods (e.g., annual). The regulatory version of the model has been modified to sample from a file of hourly meteorological data at regular intervals (SCIM function) and thus will only model a fraction of the hours for the period of record (e.g., 20 years). Sampling intervals of every 8 hours for wet deposition and every 8 days for dry deposition have been tested and are currently being used in HWIR. Sampling enables the model to execute more quickly while producing long-term annual averages comparable to those obtained from the full data set.

Because of computational time burden, the air model component is run outside of the FRAMES-HWIR system. The air concentrations and deposition rates are saved into a database that the FRAMES-HWIR system accesses. During 3MRA implementation, normalized emission rates (from the 3MRA source modules) are used as inputs along with the sampled meteorological data. Chemical-specific and temporal-specific concentrations and deposition rates are calculated in the ISCST3 postprocessor by multiplying the normalized concentration and deposition predictions by these chemical-specific annual emission rates.

For the outside 3MRA runs, ISCST3 predicts normalized concentrations and depositions at a set of grid points within the 2-km area of interest surrounding an impoundment, locations that are optimized by 3MRA to represent concentrations at human receptor points and deposition rates for watersheds, waterbodies, farms, and ecological habitats. Although a spline interpolation routine is available in the 3MRA postprocessor ISC3, this feature is not being used.

The major functionality provided by the pre- and postprocessing code is the following:

- **Decision to execute ISCST3.** If a given site/WMU combination has already been run by the Air Module in a set of model runs, the preexisting (saved) ISCST3 output file is used to calculate parameters for the Air Module output file, ar.grf. If not, ISCST3 is executed with pre- and postprocessing, which saves the ISC output files for future use in the grf\lfo directory and calculates parameters for the Air Module output file.

- **MASSFRAX calculation.** The preprocessor can calculate a source-specific, long-term average particulate mass fraction distribution (ISCST3 input variable, *MASSFRAX*) from the land-based source modules (landfill, wastepile, or land application unit) output time series *PMF* (the particle size distribution) and *PE30* (the mass flux of 30 µm or smaller particles). If the internal calculation of *MASSFRAX* is not exercised, then *MASSFRAX* is read as a fixed distribution (not WMU-specific) from the ar.ssf file.

- **Spline interpolation decision.** The preprocessor determines whether to execute ISCST3 to model **directly** ("ISCST3-model") to all site-specific output x-y coordinates requested by the 3MRA framework or, alternatively, to model to a prespecified (fixed) set of polar coordinates and then use a two-dimensional cubic spline method to interpolate from this polar set to the (larger) 3MRA-requested set of interest. The spline option was not used for HWIR99.

Other new features added to ISCST3 include a revised plume depletion scheme that replaces the computationally intensive Horst (1983) plume depletion algorithm with a faster, more robust plume depletion and settling algorithm developed by Venkatram (1988). This algorithm depletes material in a surface-based internal boundary layer that grows with distance from the source. In conjunction with this change, the deposition velocity algorithm was also modified by removing the inertial impaction term, which overestimates deposition velocity for some particle sizes. Also, a new output option was required to allow examination of concentration and deposition by particle size so that inhalation risks can be determined for pollutants with particle sizes $\leq$10 µm.

D.3.2 Assumptions and Limitations

- The ISCST3 modeling does not simulate chemical-specific fate processes such as photolysis and degradation.

- To conserve mass in the 3MRA framework, ISCST3 includes a source depletion algorithm that adjusts for the mass lost to deposition. However, module simulations showed that less than 1 percent of emitted mass is deposited within a 2-km radius with source depletion on. Therefore, to reduce computational burden, source depletion for deposition loss was not implemented in HWIR.

- One of the largest areas of uncertainty in the 3MRA air modeling is related to gas deposition. Although previous modeling exercises used a transfer coefficient to model the dry deposition of gases it is a challenge to preserve conservation of mass. Therefore, dry deposition of gases is not considered in HWIR

- Although chemical-specific scavenging coefficients should be used to calculate the wet deposition of gases, these values are not readily available. Instead, HWIR uses a single scavenging coefficient for all gases that approximates gases as very small particles. This approach may underpredict wet deposition for some gases and overpredict for others.

D.3.3 Inputs for the Air Module

Table D-5 summarizes the inputs passed by the 3MRA model system and read by the air module preprocessor. The input file for ISCST3-HWIR is generated by the Air Module preprocessor based on the module-specific input file, ar.ssf, the generic site layout file, sl.ssf, modeled inputs from the generic source output file, sr.grf, and certain "hard-wired" options set by certain variables in the ar.ssf file. The following options used by ISCST3-HWIR are identical for each model run:

- Calms processing routine is used

- Missing data processing routine is used

- SCIM is not used

- Plume depletion due to dry (particles only) and wet (vapors and particles) deposition is considered.

The use of rural or urban dispersion parameters is selected on a site-by-site basis. The type of model output depends on the facility, with concentration, dry deposition, and wet deposition being calculated for land application units, waste piles, and landfills. Only concentration and wet deposition were calculated for the surface impoundments and aerated tanks because the pollutants are only in the gaseous phase.

Source Parameters. Surface impoundments and land application units are modeled as ground-level area sources by ISCST3-HWIR. The air model receives inputs that are output by these source module(s) in the SR.GRF model file. These inputs include volatile constituent emission rates (*VE*) from both unit types and, from the LAU, particulate mass emission rates (*PE30*), and constituent mass emission rates for particulates (*CE*). Becaue a variable mass fraction distribution for particulates (MASSFRAXOption on) would make it necessary to rerun ISCST3 with each Monte Carlo sampling, a fixed MASSFRAX distribution for all sources was used to enable complete reuse of ISCST3 outputs from sample to sample. ISCST3 requires scavenging coefficients by particle size category for liquid precipitation one for frozen precipitation. Scavenging coefficients are assigned based on the size of the particles. Frozen and liquid precipitation were assumed to scavenge particles at the same rate.

Receptor Locations. Air modeling points (*AirLocX, AirLocY*) depend on the layout of the waterbodies, watersheds, human receptors, farms, and habitats around a site. For HWIR, ISCST3 model directly to all site-specific output x-y coordinates requested by the 3MRA framework.

Meteorological Inputs. Meteorological data are collected regionally by meteorological station, with a modeled site assigned to the nearest station with similar weather conditions and adequate weather data for the analysis. Hourly meteorological data are sent to the air module in separate ASCII files prepared by PCRAMMET and read directly by the model. These files were created for the meteorological surface stations and associated upper air stations necessary to cover meteorlogical condtions for the facilities being modeled. The hourly files are designated as #######h.dat, where ####### is the surface meteorological station number, and are formatted as follows.

Header Record
Sfc Station # Sfc Sta. Year Mixing Ht. Station # Mixing Ht. Sta. Year

Data Records (in each row, with each row corresponding to one hour)

Variable	*Description*	*Units*
001	Year	
002	Month	
003	Day	
004	Hour	
005	Random flow vector (wind dir)	(degrees)
006	Wind Speed	(m/s)
007	Ambient Temperature	(K)
008	Stability Category	
009	Rural Mixing Height	(m)
010	Urban Mixing Height	(m)
011	Friction Velocity at Application Site	(m/s)
012	Monin-Obukhov Length at app. Site	(m)
013	Roughness length at application site	(m)
014	Precipitation Code	
015	Precipitation Amount	(mm)

The length of the hourly meteorological files varies based on availability of data with a minimum file length of 10 years.

Most meteorological data were extracted from Solar and Meteorological Surface Observation Network (SAMSON; U.S. DOC and U.S. DOE, 1993) hourly data files and converted as necessary to daily time series, monthly time series, annual time series, and long-term averages for use with the various media modules. Because SAMSON precipitation data were inadequate, precipitation data were obtained from cooperative station daily summaries (NCDC et al., 1995), with SAMSON data used to help allocate these daily data to hourly time series. Mixing heights were obtained from upper air station data. Programs were used to fill in data where it was missing in SAMSON or NCDC datasets. Land use data also were required in

the vicinity of each meteorological station to derive air model inputs such as Bowen ratio, surface roughness height, minimum Monin-Obukhov length, noontime albedo, and the fraction of net radiation absorbed by the ground. Additional details on meteorological data collection and processing using PCRAMMET can be found in U.S. EPA (1999e).

D.3.4 Outputs from the Air Module

The air model output file (ar.grf) includes the following output variables, along with variables necessary to define the time series /receptor location arrays for each:

- PM10 concentrations
- Volatile concentrations (CVap)
- Vapor wet deposition (VapWDep)
- Particulate dry deposition (ParDDep)
- Particulate wet deposition (ParWDep).

Table D-6 summarizes the ouputs from the air module post processor.

Table D-5. Air Module Input Parameters

Input Parameter	Units	Description
Module-Specific Parameters (AR.SSF)		
NumAirSplineDist	unitless	Number of distances used to construct the polar mesh used to construct the spline
NumAirSplineAngle	unitless	Number of angles used to construct the polar mesh used to construct the spline
AirSplineDistance	m	Array of radial distances of polar mesh
AirSplineAngle	degrees	Array of angles used in polar mesh
SplineOption	unitless	Whether or not splining is an option. 0=no spline, 1=spline
StartYr		Required by ISCST3. Starting year of Met. file
ScimStr		Required by ISCST3. SCIM option
RuralStr		Required by ISCST3. Rural or Urban
DryDpStr		Required by ISCST3. Dry Depletion Option
WetDpStr		Required by ISCST3. Wet Depletion Option.
AirData		Required by ISCST3. Upper Air (Met.) Station number
SurfData		Required by ISCST3. Surface (Met.) Station number
AnemHght	m	Required by ISCST3. Anemometer height
SHight	m	Required by ISCST3. Source height
ArrayLen	unitless	Required by ISCST3. Length of array
MASSFRAXOption	unitless	Logical flag for whether to internally calculate *MASSFRAX* distribution (false) or read a fixed *MASSFRAX* (true) from AR.SSF.
MASSFRAX	fraction	Required by ISCST3. Fraction of particle size (1 dim. array for each particle-emitting source type, i.e. LAU, LF, and WP in that order)
PARTDIAM	μm	Required by ISCST3. Particle diameter (1 dim. array)
PARTSLIQ	h/s-mm	Required by ISCST3. Particle scavenging coefficient by liquid precipitation (1 dim. array)
PARTSICE	h/s-mm	Required by ISCST3. Particle scavenging coefficient by frozen precipitation (1 dim. array)
LiqScav	h/s-mm	Required by ISCST3. Gas scavenging coefficient by liquid precipitation (1 dim. array)
IceScav	h/s-mm	Required by ISCST3. Gas scavenging coefficient by frozen precipitation (1 dim. array)

(continued)

Table D-5. (continued)

Input Parameter	Units	Description
SCIMBYHR	unitless	Required by ISCST3. Sets model to skim through Metfile, picking certain hours according to array specifications
Site Layout Inputs (SL.SSF)		
AirLocX	m	Array for easting in site coordinate system (for each receptor location)
AirLocY	m	Array for northing in site coordinate system (for each receptor location)
MetSta		Met. Station identifier (<MetSta>L.dat (L: long-term), <MetSta>A.dat (A: annual time series), <MetSta>M.dat (M: monthly time series), <MetSta>D.dat (D: daily time series), <MetSta>H.dat (H: hourly time series))
NumAir		Number of air points
SettingID		Srctype (*One of LAU, LF, WP, AT, SI) + SiteID
SrcArea	m^2	Area of source
SrcLocX	m	Easting in site coordinate system (Source location). 0 at source centroid
SrcLocY	m	Northing in site coordinate system (Source location). 0 at source centroid
SrcType		One of {LAU, LF, WP, AT, SI}
Inputs from Source Module (SR.GRF)		
CE	float	$g/m^2/d$
PE30	float	$g/m^2/d$
PE30NY	integer	
PMF	float	
VE	float	$g/m^2/d$
VENY	integer	
SrcVE	logical	
SrcCE	logical	

Table D-6. AR.GRF Output Variables (Air Module Outputs)

Variable Name	Unit	Description
PM10	$\mu g/m^3$	2-dimensional array that provides information on total number of years of activity for PM10 at each receptor location and PM10 concentration in each year.
PM10YR	Year	Time series of years corresponding to this variable.
PM10NY	unitless	Number of years in the time series corresponding to this variable.
CVap	$\mu g/m^3$	2-dimensional array that provides information on total number of years of activity for volatiles at each receptor location and volatile concentration in each year.
CVapYR	Year	Time series of years corresponding to this variable.
CVapNY	unitless	Number of years in the time series corresponding to this variable.
VapWDep	$g/m^2/d$	2-dimensional array that provides information on total number of years of activity for vapor wet deposition at each receptor location and wet deposition flux for each year.
VapWDepYR	Year	Time series of years corresponding to this variable.
VapWDepNY	unitless	Number of years in the time series corresponding to this variable.
ParDDep	$g/m^2/d$	2-dimensional array that provides information on total number of years of activity for particulate dry deposition at each receptor location and dry deposition flux for each year.
ParDDepYR	Year	Time series of years corresponding to this variable.
ParDDepNY	unitless	Number of years in the time series corresponding to this variable.
ParWDep	$g/m^2/d$	2-dimensional array that provides information on total number of years of activity for particulate wet deposition at each receptor location and particulate wet deposition flux for each year.
ParWDepYR	Year	Time series of years corresponding to this variable.
ParWDepNY	unitless	Number of years in the time series corresponding to this variable.
SrcVE		Flag to tell if vapor
SrcCE		Flag to tell if particulate

D.4 Watershed Module

The watershed module models chemical fate and transport processes within a watershed subbasin, including erosion, runoff, leaching, volatilization, and degradation. It also estimates runoff and solids loads to surface waterbodies and recharge as an input for the aquifer module. This section summarizes the assumptions, limitations, inputs, and outputs. Additional detail, including all governing equations, can be found in U.S. EPA (1999f).

D.4.1 Functionality

The watershed module estimates soil chemical concentrations for each subbasin; streamflow and chemical and solids loading estimates for the surface water module (Section 3.3.5); and regional infiltration (recharge) estimates for the vadose zone module (Section 3.3.4). In summary, the watershed module addresses the following specific objectives:

- Simulate the time series of annual average chemical concentrations in surficial soil (top 1 cm) resulting from aerial deposition throughout the area of interest surrounding the WMU. (Note that, although chemical mass losses due to volatilization and leaching from the soil column are evaluated, these losses are simulated only for the purpose of estimating soil concentrations and waterbody loads; that is, these losses are not subsequently received as inputs by the Air or Vadose modules because they are secondary sources.)

- Simulate the time series of annual average chemical loadings in surface runoff and erosion that will enter individual waterbody reaches throughout the AOI.

- Simulate the time series of annual average runoff that will enter waterbodies throughout the AOI.

- Simulate the time series of annual average stream baseflow (dry weather streamflow) in waterbodies throughout the AOI. (Runoff plus baseflow represents total streamflow.)

- Simulate the time series of annual average eroded solids loads that will enter waterbodies throughout the AOI.

- Simulate the time series of annual average infiltration (recharge) rates for each watershed in the AOI.

Note that the watershed module simulates only **indirect** chemical loads to the waterbody; that is, the sole source of chemical to the watershed soils is aerial deposition. Chemical loads to the waterbody resulting from **direct** runoff and erosion from a closed surface impoundment are simulated by the LAU source module. Similarly, if a receptor is located in a buffer area between the closed impoundment and the downslope waterbody (i.e., in the local watershed), the **total** surficial soil concentration to which the receptor is exposed includes the aerial deposition-related

concentration simulated by the watershed module (for the subbasin containing the local watershed) **plus** the runoff/erosion-related concentration simulated by the LAU module.

D.4.2 Assumptions and Limitations

The watershed module's conceptual and mathematical models are very similar to those already described for the LAU module — the combined "local watershed/soil column". This algorithm is a dynamic, two-dimensional, fate and transport model that also includes hydrological functionality; assumptions and limitations associated with its application in either module are listed in Section D.2.1. However, the watershed module differs in that algorithm is applied to each watershed subbasin as a whole and subbasins are not disaggregated into "subareas" as are the local watersheds. Hence, the watershed module is a one-dimensional [vertical], lumped model that simulates each watershed individually. In the watershed module, although the depth of the soil column is a user-specified input, set at a default of 5 cm. Each soil column layer is 1 cm thick.

Another difference with the LAU module involves the size of the computational time step used to determine contaminant concentrations in runoff water. Because **indirect** soil concentrations resulting from aerial deposition are likely to be significantly less than soil concentrations resulting from **direct** runoff/erosion from a source, and aerial because deposition rates in 3MRA are known only on an average annual basis (not daily) the watershed module includes the following features.

- Soil erosion and runoff models are executed on a daily time step, with daily results rolled up to annual average soil erosion (CSL) and runoff volume (Q), which are used to estimate chemical losses in erosion and runoff as well as runoff flow and suspended solids loading to waterbodies.

- The computational time step used by the watershed/soil column algorithm is based on numerical considerations but does not exceed 1 year.

- Annual average runoff-related parameters and the annual average aerial deposition rates are used in applying the watershed/soil column algorithm at each computational time step.

In summary, annual average soil erosion and runoff are estimated on a daily time step, while the remainder of the model (contaminant mass fate and transport simulation) is executed on a computational time step that is typically much larger than one day and can vary each year of the simulation. All outputs are ultimately reported as annual averages, regardless of their individual computational time steps.

The watershed module uses the identical hydrology submodel used in the LAU model to estimate stormwater runoff and ground water infiltration. Streamflows are assumed to be made up of both stormwater runoff and baseflow. Baseflow is streamflow occurring during nonrunoff periods and is derived from ground water discharge to streams or interflow (shallow infiltration flowing parallel to the ground surface). Although baseflow can vary seasonally, or even near

continuously, as ground water levels and/or interflow varies, it was considered unnecessary (and computationally impractical) to attempt to estimate within-year variability in baseflows. Rather, a single estimate was derived based on 30Q2 low flow data, i.e., the minimum 30-day average flow occurring, on average, at least once every other year. A descriptions of how this flow statistic was derived can be found in U.S. EPA (1999f).

Like the LAU module, the watershed module also uses the (modified) Universal Soil Loss Equation (MUSLE), as described in U.S. EPA (1999a, 1999f), to predict soil erosion from watersheds considered in their entirety. In applying this model, watersheds are assumed to be homogeneous in terms of erosion characteristics, including sheet flow length and slope, as described in U.S. EPA (1999a, 1999f).

D.4.3 Inputs for the Watershed Module

Because of its similar design and construction, the watershed module inputs are similar to those previously shown in Table D-2 for the LAU module, except without the waste and WMU-related parameters. Table D-7 summarizes the watershed inputs. Note that like other modules, the watershed module receives inputs from the site layout and header files (sl.ssf, hd.ssf), as well as a module-specific input file (ws.ssf) containing inputs specific to the watershed module, and separate meteorological data files for daily and long term average meteorological data. In addition, the watershed module reads the ar.grf output file for dry and wet deposition rates.

D.4.4 Outputs from the Watershed Module

Table D-8 summarizes the outputs of the watershed module. These include, for each watershed subbasin, soil concentrations, infiltration rates, runoff to the downslope waterbodies, and chemical and solids loadings in this runoff. In addition the module provides stream baseflow estimates for each watershed subbasin. Note that time series reporting is subbasin-specific; that is, all outputs for a given subbasin are reported, including zeros, up to the year that the subbasin simulation is terminated.

Table D-7. Summary of Inputs for Watershed Module

File	Variable Name	Units	Data Type	Description
HD.SSF	CPDirectory		String	Path for location of chemical properties files
	MetData		String	Path for location of meteorological files
AR.GRF	SrcCE		Integer	Flag to tell if particulate
	VapWDep	$g/m^2/d$		Array of number of years of activity for vapor wet deposition and wet deposition flux for each year (by air point)
	VapWDepYR	Year		Time series of years for VapWDep
	VapWDepNY	unitless		Number of years in VapWDep time series
	ParDDep	$g/m^2/d$		Array of number of years of activity for particulate dry deposition by dry deposition flux for each year (by air point)
	ParDDepYR	Year		Time series of years for ParDDep
	ParDDepNY	unitless		Number of years in the ParDDep time series
	ParWDep	$g/m^2/d$		Array of total number of years of activity for particulate wet deposition by particulate wet deposition flux for each year (by air point)
	ParWDepYR	Year		Time series of years for ParWDep
	ParWDepNY	unitless		Number of years in the ParWDep time series
SL.SSF	SiteLatitude	degrees	Float	Latitude of the site
	MetSta		String	ID number for meteorological station associated with site
	NyrMax	years	Integer	Maximum module simulation time
	TermFrac	fraction	Float	Peak output fraction for simulation termination
	AirTemp	degrees C	Float	Long term annual air temperature for site
	NumAir		Integer	Number of air points at site
	WSSubAirFrac	fraction	Float	Fraction of watershed subbasin represented by air points
	WSSubAirIndex		Integer	Index of air points representing subbasin (by subbasin)
	WSSubNumAir		Integer	Number of air points that represent subbasin (by subbasin)
	NumWSSub		Integer	Number of watershed subbasins

(continued)

Table D-7. (continued)

File	Variable Name	Units	Data Type	Description
	WSSubArea	m2	Float	Area of subbasin (by watershed subbasin)
	WSSubNumSubArea		Integer	Number of subbasin subareas (= 1; by WS subbasin)
	WSTemp	degrees C	Float	Average watershed temperature (by site)
	focS	fraction	Float	soil fraction organic carbon (by WS subbasin)
WS.SSF	a_BF	m/day	Float	regression coefficient a for baseflow model
	b_BF	m/day	Float	regression coefficient b for baseflow model
	bcm	unitless	Float	Boundary condition multiplier (lower boundary)
	C	unitless	Float	USLE cover factor (by watershed subbasin)
	CN	unitless	Float	SCS curve number (by watershed subbasin)
	ConVs	m/d	Float	Settling velocity (suspended solids)
	deltDiv	unitless	Integer	Time step divider (for debugging only)
	DRZ	cm	Float	Root zone depth (by watershed subbasin)
	Infild	m/d	Float	Input infiltration rate (for debugging only)
	K	kg/m2	Float	USLE soil erodibility factor (by watershed subbasin)
	Ksat	cm/h	Float	Soil saturated hydraulic conductivity (by watershed subbasin)
	P	unitless	Float	USLE soil erosion control factor (by watershed subbasin)
	RunID		string	Run identification label (optional)
	SMb	unitless	Float	soil moisture coefficient b (by watershed subbasin)
	SMFC	volume %	Float	soil moisture field capacity (by layer and watershed subbasin)
	SMWP	volume %	Float	soil moisture wilting point (by layer and watershed subbasin)
	Theta	degrees	Float	slope (by local watershed)
	thetawZ1d	volume fraction	Float	input volumetric water content in till zone (for debugging)
	WCS	volume fraction	Float	soil saturated water content or total porosity (by watershed subbasin)
	X	m	Float	flow length (by watershed subbasin)

(continued)

Table D-7. (continued)

File	Variable Name	Units	Data Type	Description
	zava	m	Float	averaging depth upper (depth-averaged soil concentration)
	zavb	m	Float	averaging depth lower (depth-averaged soil concentration)
	zZ1sa	m	Float	modeled soil column depth (by watershed subbasin)
CP.SSF	ChemName		String	Name of chemical
	ChemCASID		String	Chemical CAS number
	ChemType		String	Type of chemical
	ChemTemp	degrees C	Real	Temperature for chemical properties
	ChemFracNeutral	fraction	Real	Fraction of chemical in neutral form
	ChemADiff	cm^2/s	Float	Diffusivity of chemical in air
	ChemWDiff	cm^2/s	Float	Diffusivity of chemical in water
	ChemHLC	(atm m^3) / mol	Float	Henry's law constant for the chemical
	ChemKoc	mL/g	Float	Soil organic carbon - water partitioning coefficient (organic compounds)
	ChemAnaBioRate	1/day	Float	Biodegradation / decay rate of contaminant in sediment compartment
	ChemAerBioRate[b]	1/day	Float	Complex first-order biodegradation rate constant for the chemical[b]
	ChemHydRate	1/day	Float	Hydrolysis rate for the chemical
	ChemSol	mg/L	Float	Chemical solubility
	ChemKd	L/kg	Float	Solid/water partition coefficient (inorganic compounds; by media)
Met file	temp	degrees C	Float	Average daily air temperature
	jday		Integer	Julian day
	dailyR	1/t	Float	Daily USLE rainfall erosivity factor (daily)
	dailyppt	cm/d	Float	Total daily precipitation
	AvgTemp	degrees C	Float	Mean monthly temperature
	maxtemp	degrees C	Float	Maximum daily average temperature for month
	mintemp	degrees C	Float	Minimum daily average temperature for month

(continued)

Table D-7. (continued)

File	Variable Name	Units	Data Type	Description
	PE		Float	Thornthwaite Precipitation Evaporation Index
	Ed	m/d	Float	Average daily evaporation
	tsc	degrees C	Float	Long term average soil column temperature
	---		Integer	Number of years of meteorological data

[a] The module currently assumes there is one native soil layer and that the thickness of the underlying soil layer is assumed to be a minimum of 1 meter thick. If the regional vadose zone thickness is less than $1+d_{wmu}$, then the impoundment is assumed to be built up (via an earthen berm) so that there is 1 meter of soil between the bottom of the SI and the ground water.

[b] Note: If normalized biodegradation rate constants are unavailable, normalized biodegradation rates constants are estimated from first-order biodegradation rate constants developed for soil systems by assuming the effective biomass in the soil system is 2.0×10^{-6} Mg/m^3. This value was developed by RTI as an interim estimate until a more rigorously developed value for this parameter is available from EPA.

Table D-8. Summary of Outputs (WS.GRF) for the Watershed Module

Output Variable	Description	Units
NyrMet	Number of years in the available meteorological record	Year
CTdaR	Depth-averaged soil concentration (from zava to zavb)	µg/g
CTdaRYR	Year associated with output	Year
CTdaRNY	Number of years in outputs	Unitless
CTssR	Surface soil concentration	µg/g
CTssRYR	Year associated with output	Year
CTssRNY	Number of years in outputs	Unitless
RunoffR	Annual average runoff flow to waterbody	m^3/d
BFann	Long-term annual average baseflow to waterbody	m^3/d
AnnInfil	Annual average recharge rate	m/d
SWLoadChemR	Chemical load (resulting from deposition only) to waterbody	g/d
SWLoadChemRYR	Year associated with output	year
SWLoadChemRNY	Number of years in outputs	Unitless
SWLoadSolidR	Total suspended solids in runoff	g/d

D.5 Vadose and Aquifer Modules

The HWIR 3MRA vadose and aquifer modules are a modified version of EPA's Composite Model for leachate migration with Transformation Products (EPACMTP) (US EPA, 1996a,b,c). This code simulates the fate and transport of contaminants released from land-based waste management units through the underlying unsaturated or vadose zone (soil) and saturated zone (surficial aquifer). EPACMTP replaced EPACML (US EPA, 1993) as the best available tool to predict potential exposure at a downstream receptor well. EPACMTP offers improvements to EPACML by considering: 1) the formation and transport of transformation products; 2) the impact of groundwater mounding on groundwater velocity; 3) finite source as well as continuous source scenarios; and 4) metal transport.

Detailed descriptions of both modules, including their purpose and scope of application, mathematical formulations, and use in HWIR99 may be found in U.S. EPA (1999g). Additional information relating to the EPACMTP and its verification is provided in the background documents for EPACMTP (US EPA, 1996a,b,c, 1997).

D.5.1 Functionality

EPACMTP comprises three major simulation components:

- A module that performs one-dimensional analytical and numerical solutions for water flow and contaminant transport in the vadose zone underlying a waste management unit.
- A numerical module that simulates steady-state groundwater flow subject to recharge from the vadose zone.
- A module comprising analytical and numerical solutions for contaminant transport in the saturated zone.

For 3MRA, portions of the EPACMTP code pertaining to the vadose zone make up the vadose zone module (VZM), and portions pertaining to the saturated zone make up the saturated zone module (SZM).

The VZM simulates infiltration and contaminant transport between the top of the vadose zone and the water table (see Figure 3-17). Flow in the vadose zone is modeled as steady-state, one-dimensional (vertical) flow from underneath the source (the WMU). Recharge occurs from the soil outside the WMU toward the water table. The lower boundary of the vadose zone is the water table. The flow in the vadose zone is predominantly gravity-driven, and therefore the vertical flow component accounts for most of the fluid flux between the source and the water table. The flow rate is determined by the long-term average infiltration rate through the waste management unit and recharge downgradient from the WMU.

Contaminant is transported in the vadose zone by advection and dispersion. The vadose zone is assumed to be initially contaminant-free, and it is assumed that contaminants migrate

vertically downward. The VZM can simulate both steady-state and transient transport, with single or multiple species chain decay reactions and linear or nonlinear sorption. The VZM consists of two submodules: one for flow calculations and one for transport.

The SZM simulates groundwater flow using either a three- or one-dimensional steady-state solution for predicting hydraulic head and Darcy velocities. The saturated groundwater system is assumed to be of constant thickness, subject to recharge along the top of the aquifer and a regional gradient defined by upstream and downstream head boundary conditions. The saturated zone transport module describes the advective-dispersive transport of dissolved contaminants in a three-dimensional, constant thickness aquifer. The initial contaminant concentration is set to zero. The concentration gradient along the downstream boundary is zero, and the lower aquifer boundary is taken to be impermeable. A zero concentration condition is used for the upstream aquifer boundary. Contaminants enter the saturated zone through a patch source on the upper aquifer boundary directly beneath the source. Recharge of contaminant-free infiltration water occurs along the upper aquifer boundary outside the patch source. Transport mechanisms considered are advection, dispersion, linear or nonlinear equilibrium adsorption, and first-order decay with daughter product formation. As in the unsaturated zone, the saturated zone transport module can simulate multispecies transport involving chain decay reactions. The saturated zone module performs a fully three-dimensional transport simulation.

The VZM and SZM, derived from the EPACMTP code, are, together, capable of simulating the fate and transport of dissolved contaminants from a point of release at the base of a waste disposal unit, through the unsaturated zone and underlying aquifer, to one or more receptor wells at arbitrary downstream locations in the groundwater system. The modules account for the major mechanisms affecting contaminant migration, including: transport by advection and hydrodynamic dispersion, retardation due to reversible linear or nonlinear equilibrium adsorption onto the soil and aquifer solid phase, and biochemical degradation processes. The latter may involve chain decay reactions if the contaminant(s) of concern form a decay chain.

D.5.2 Assumptions and Limitations

As is true of any model, EPACMTP and, its modules are based on a number of simplifying assumptions which make the code easier to use and ensure its computational efficiency. These assumptions, however, may cause application of the model to be inappropriate in certain situations. The inherent assumptions and limitations of the vadose zone module (VZM) and saturated zone module (SZM) are summarized below:

1) Soil and Aquifer Medium Properties. Soil and aquifer are uniform porous media, and flow and transport are governed by Darcy's law (Bear, 1972) and the advection-dispersion equation, respectively. The model does not account for the presence of preferential pathways such as fractures and macro-pores. Although the aquifer properties are assumed to be uniform, the model does allow for anisotropy in the hydraulic conductivity. Also, in the saturated zone module, effects due to the presence of fractures and heterogeneity are superimposed onto the base homogeneous model.

2) Flow in the Unsaturated Zone. Flow in the unsaturated zone is steady-state, one-dimensional vertical flow from underneath the source toward the lower boundary of the unsaturated zone, that is, toward the water table. The flow in the unsaturated zone is predominantly gravity-driven, and, therefore, the vertical flow component accounts for most of the fluid flux between the source and the water table. The flow rate is determined by the long-term average infiltration rate through the waste management unit. The long-term average infiltration rate is calculated from a series of annual average infiltration rates.

3) Flow in the Saturated Zone. The SZM is designed to simulate flow in an unconfined aquifer with constant saturated thickness. The concept employed is that of regional flow in the horizontal direction, with vertical disturbance due to recharge and infiltration from the overlying unsaturated zone and waste disposal facility. The lower boundary of the aquifer is assumed to be impermeable. Flow in the saturated zone is assumed to be steady-state.

   The SZM accounts for different recharge rates underneath and outside the source area. Groundwater mounding beneath the source is represented in the flow system by increased hydraulic head values at the top of the aquifer. This approach is reasonable as long as the height of the mound is small relative to the thickness of the saturated zone.

4) Transport in the Unsaturated Zone. Contaminant transport in the unsaturated zone is by advection and dispersion. The unsaturated zone is assumed to be initially contaminant-free and contaminants are assumed to migrate vertically downward from the disposal facility. The VZM simulates transient transport in the unsaturated zone, with single species or multiple species chain decay reactions, and linear or nonlinear sorption.

5) Transport in the Saturated Zone. Contaminant transport in the saturated zone is due to advection and dispersion. The aquifer is assumed to be initially contaminant-free and contaminants enter the aquifer only from the unsaturated zone immediately underneath the waste disposal facility, which is modeled as a rectangular horizontal plane source. The SZM simulates transient transport in a fully three-dimensional mode in order to obtain a scientifically rigorous analysis. The concentration at the water table must be specified as a function of time. The SZM is capable of simulating transient transport in a quasi-three dimensional mode when computational efficiency is desired (e.g., Monte Carlo simulations). The SZM can consider linear sorption and the transport of a single species or multiple species chain decay reactions.

6) Contaminant Phases. The VZM and SZM simulate constituent transport in the aqueous phase only, and disregard interphase mass transfer processes other than adsorption onto immobile solids. The modules do not account for volatilization in the unsaturated zone; this is a conservative approach for volatile chemicals in the aqueous phase. The modules also do not account for the presence of a NAPL (e.g.

oil) or transport in gas phase. When a mobile oil phase is present, significant migration may occur within it, so that the VZM and SZM may under predict the movement of hydrophobic chemicals.

7) Chemical Reactions. The groundwater pathway (VZM and SZM) modules take into account chemical reactions by adsorption and decay processes. The VZM allows sorption of organic compounds in the unsaturated zone to be represented by linear or nonlinear adsorption isotherms, while sorption in the saturated zone is always linear. It is assumed that the adsorption of contaminants onto the soil or aquifer solid phase occurs instantaneously and is entirely reversible.

The effect of geochemical interactions is especially important in the fate and transport analyses of metals. For the simulation of metals with non-linear adsorption, both modules utilize sorption isotherms generated by MINTEQA2 (Allison et al., 1991, a metal speciation model). MINTEQA2 generates concentration-dependent effective partition coefficients for various combinations of geochemical conditions. This procedure is described in the background document for the modeling of metals transport (EPA, 1996b).

The VZM and SZM also account for chemical and biological transformation processes. All transformation reactions are represented by first-order decay processes. An overall decay rate is determined within the modules, so that the modules cannot explicitly consider the separate effects of multiple degradation processes such as oxidation, hydrolysis and biodegradation. In order to increase their flexibility, both modules have the capability to determine the overall decay rate from chemical-specific hydrolysis constants and soil and aquifer temperature and pH values, and from biodegradation rates selected from a database. It is assumed that biodegradation is aerobic in the unsaturated zone and anaerobic in the saturated zone.

Both modules assume that the reaction stoichiometry is prescribed for scenarios involving chain decay reactions and applys to all transformation processes. The speciation factors are specified as constants by the user (see the EPACMTP Background Document, EPA, 1996a). In reality, these coefficients may change as functions of aquifer conditions (e.g., temperature and pH) and/or concentration levels of other chemical components.

D.5.3 Inputs for the Vadose and Saturated Zone Modules

A list of vadose zone-specific input parameters is provided in Table D-9, showing variables by file name. The VZM requires input about the site from the site layout SSF (sl.ssf), inputs specific to the vadose zone (e.g.,control parameters, soil characteristics, etc.) from the vadose zone module SSF (vz.ssf), chemical-specific data from the chemical properties SSF (cp.ssf), and outputs from the source module (i.e., chemical and water fluxes) from the source GRF (sr.grf).

A list of saturated zone-specific input parameters is provided in Table D-10. The SZM requires input about the site (sl.ssf), information specific to the aquifer (aq.ssf), and chemical-specific data from the chemical properties SSF (cp.ssf), as well as outputs from the source (sr.grf), watershed (ws.grf), and vadose zone (vz.grf) modules. Tables D-9 through D-12 specify source and destination files for all parameters in the VZM and SZM (SZM is also referred to as the aquifer module).

Table D-9. Vadose Zone Module Input Parameters

File	Code	Units	Data Type	Description
SL.SSF	AquFEOX	fraction	Float	Hydrous ferric oxide (HFO) adsorbent content
	AquLOM	mg/L	Float	Leachate organic matter
	NumVad		Integer	Number of vadose zones = number of local watersheds
	NyrMax	years	Integer	Maximum model simulation time
	SrcArea	m^2	Float	Area of source
	SrcLWSSubAreaArea	m2	Float	Area of local watershed subarea
	SrcLWSSubAreaIndex	unitless	Integer	Local watershed subarea containing WMU
	SrcNumLWS		Integer	Number of local watersheds
	TermFrac	fraction	Float	Termination peak fraction criteria
	VadALPHA	1/cm	Float	Soil retention paramter alpha
	VadBETA	unitless	Float	Soil retention paramter beta
	VadID		String	Setting ID for vadose zone
	VadPh	pH units	Float	Average vadose zone pH
	VadSATK	cm/hr	Float	Saturated hydraulic conductivity
	VadTemp	degrees C	Float	Average vadose zone temperature
	VadThick	m	Float	Vadose zone thickness
	VadWCR	L/L	Float	Residual water content
	VadWCS	L/L	Float	Saturated water content
VZ.SSF	DISPR	m	Float	Longitudinal dispersivity
	POM	g/g	Float	Percent organic matter
	RHOB	g/cm3	Float	Bulk density of soil
CP.SSF	ChemCASID		String	CASID
	ChemHydNumProd		Integer	Number of products
	ChemHydProdCASID		String	Product CASID
	ChemHydProdYield	moles/moles	Float	Product yield coefficient
	ChemHydRate	1/day	Float	Hydrolysis rate
	ChemKoc	mL/g	Float	Koc
	ChemMolWt	g/mole	Float	Molecular weight
	NumChem		Integer	Number of chemicals assc. W/parent
	ChemAerBioRate	1/day	Float	Aerobic biodegradation rate
SR.GRF	AnnInfil	m/d	Float	Leachate infiltration rate (annual avg. WMU only)
	LeachFlux	g/m2/d	float	Leachate contaminant flux
	LeachFluxNY		integer	Number of years in outputs
	LeachFluxYR	year	integer	Year associated with output
	NyrMet	year	Integer	Number of years in the available met record
	SrcLeachMet		Logical	Flag for leachate presence when leachate is met-driven
	SrcLeachSrc		Logical	Flag for leachate presence when leachate is not met-driven (active surface impoundments)
	TWT	yr	Float	Times for CWT

Table D-10. Aquifer Module Input Parameters

File	Code	Units	Data Type	Description
SL.SSF	AquDir	degrees	Float	Groundwater flow direction in degrees from North
	AquFEOX	fraction	Float	Hydrous ferric oxide (HFO) adsorbent content
	AquGrad		Float	Regional groundwater gradient
	AquId		String	Environmental setting ID for aquifer
	AquLOM	mg/L	Float	Leachate organic matter concentration
	AquPh	pH units	Float	Average aquifer pH
	AquSatk	m/yr	Float	Saturated hydraulic conductivity (aquifer)
	AquTemp	degrees C	Float	Average Aquifer Temperature
	AquThick	m	Float	Saturated zone thickness
	AquVadIndex		Integer	Index of vadose zone per aquifer
	AquWellFracZ	fraction	Float	Fractional depth of well in aquifer measured from watertable
	AquWellLocX	m	Float	Easting in UTM
	AquWellLocY	m	Float	Northing in UTM
	NumAqu		Integer	Number of aquifers
	NumAquWell		Integer	Number of drinking water wells
	NumWBN		Integer	Number of waterbody networks
	NumWSSub		Integer	Number of watershed sub basins
	NyrMax	years	Integer	Maximum model simulation time
	SrcArea	m^2	Float	Area of source
	SrcLocX	m	Float	Easting in site coordinate system (0)
	SrcLocY	m	Float	Northing in site coordinate system (0)
	TermFrac	fraction	Float	Termination peak fraction criteria
	VadID		String	Environmental setting ID for aquifer
	WBNNumRch		Integer	Number of reaches for this network
	WBNRchAquIndex		Integer	Index of aquifer that impacts this reach
	WBNRchLength	m	Float	Reach length
	WBNRchLocX	m	Float	Easting in UTM
	WBNRchLocY	m	Float	Northing in UTM
	WBNRchNumAqu		Integer	Number of aquifer that impact this reach
	WBNRchNumLoc	unitless	Integer	Number of x,y points associated with watershed
	WSSubArea	m^2	float	Area of watershed subbasin
AQ.SSF	AL	m	Float	Longitudinal dispersivity
	ALATRatio	m	Float	Horizontal transverse dispersivity
	ALAVRatio	m	Float	Vertical transverse dispersivity
	ANIST		Float	Anisotropy ratio

(continued)

Table D-10. (continued)

File	Code	Units	Data Type	Description
	AquAnaBioRandUnif		Integer	Uniformly distributed random number used to choose the anaerobic biodegradation regime: 0=methanogenic; 1= sulfate reducing
	AquDoFracture		Logical	Logical flag to turn fractures on or off
	AquDoHetero		Logical	Logical flag to turn heterogeneity on or off
	AquFractureID		Integer	Indicator for degree of fracturing of saturated porous media
	AquRandFractUnif		Float	Uniformly distributed random number-used when AquDoFracture==TRUE
	AquRandHeteroNorm		Float	Normally distributed random numbers with 0 mean and std of 1-used when AquDoHetero==TRUE
	AquRandHeteroUnif		Float	Uniformly distributed random number-used when AquDoHetero==TRUE
	BDENS	g/cm3	Float	Bulk density of soil
	FOC	fraction	Float	Fraction organic carbon
	POR		Float	Effective porosity
CP.SSF	ChemCASID		String	CASID
	ChemHydNumProd		Integer	Number of products
	ChemHydProdCASID		String	Product CASID
	ChemHydProdYield	moles/mole	Float	Product yield coefficient
	ChemHydRate	1/day	Float	Hydrolysis Rate
	ChemKoc	mL/g	Float	Koc
	ChemMetBioRate	1/day	Float	Anaerobic biodegradation under methanogenic red.
	ChemMolWt	g/mole	Float	Molecular weight
	ChemSO4BioRate	1/day	Float	Anaerobic biodegradation under SO4 reduction
	NumChem		Integer	Number of chemicals assc. w/parent
SR.GRF	SrcLeachMet		Logical	Flag for leachate presence when leachate is met-driven
	SrcLeachSrc		Logical	Flag for leachate presence when leachate is not met-driven (active surface impoundment)
WS.GRF	AnnInfil	m/d	Float	Annual average recharge rate (time series by watershed subbasin)
	NyrMet	year	Integer	Number of years in the available met record
VZ.GRF	CWT	mg/L	Float	Concentration at water table
	NTS	yr	Integer	Number of time-conc/flux pairs in TWT and CWT
	SINFIL	m/yr	Float	Long term average waterflux beneath source
	TSOURC	yr	Float	Duration of source boundary condition
	TWT	yr	Float	Times for CWT

Table D-11. Vadose Zone Module Outputs

File	Code	Units	Data Type	Description
VZ.GRF	CWT	mg/L	Float	Concentrations at water table
	NTS	yr	Integer	Number of time-conc/flux pairs in TWT and CWT
	SINFIL	m/yr	Float	Longterm average waterflux beneath source
	TSOURC	yr	Float	Duration of source boundary condition

Table D-12. Aquifer Module Outputs

File	Code	Units	Data Type	Description
AQ.SSF	AquRchMassFlux	g/yr	Float	Mass flux from aquifer to reach (time series by reach)
	AquRchMassFluxNY		Integer	Number of time - mass-flux-to-reach pairs
	AquRchMassFluxYR	year	Float	Time of mass flux from aquifer to reach
	AquRchWaterFlux	m3/day	Float	Total GW flux to reach
	AquWellConc	mg/L	Float	Observed well concentration
	AquWellConcFlag		Logical	Flag indicating well is within plume: T - yes, F - no (by well)
	AquWellConcNY		Integer	Number of time - observed well conc pairs
	AquWellConcYr	year	Integer	Time of observed well concentration

D.6 Surface Water Module

The HWIR 3MRA surface water module models streams, lakes, ponds, and wetlands and consists of the core model EXAMS II (Burns, 1997, Burns et al., 1982) and the interface module ExamsIO. This section describes the assumptions, limitations, inputs, and outputs of this module. Detailed documentation can be found in U.S. EPA (1999u), from which the following material was extracted.

D.6.1 Functionality

The 3MRA surface water module takes the loadings calculated by the source, atmospheric, watershed, and groundwater modules, along with data on meteorology, hydrology, environmental conditions, and chemical reactivity, and calculates the chemical concentrations throughout the waterbody network over time. The 3MRA surface water module contains the core model EXAMS II (Burns, 1997; Burns et al., 1982), which is a general surface water fate model for organic chemicals. This compartment model has been used routinely by both EPA and industry analysts for the analysis of expected pesticide concentrations in generically defined environments, such as farm ponds. It has also been used for site-specific analysis of pesticide concentrations in various waterbodies around the world. The interface module ExamsIO was developed specifically for this 3MRA project. It reads data from other 3MRA modules and databases and builds EXAMS input files describing the waterbody environment and chemical properties, along with the command file that specifies the chemical loading history and controls the EXAMS simulation. ExamsIO passes control to EXAMS, which conducts the simulation and produces intermediate results files. ExamsIO then processes the intermediate files and passes the output data back to the proper 3MRA database.

EXAMS II is an interactive modeling system that allows a user to specify and store the properties of chemicals and ecosystems, modify either via simple commands, and conduct rapid evaluations and sensitivity analyses of the probable aquatic fate of synthetic organic chemicals. EXAMS combines chemical loadings, transport, and transformation into a set of differential equations using the law of conservation of mass as an accounting principle. It accounts for all the chemical mass entering and leaving a system as the algebraic sum of external loadings, transport processes that export the compound from the system, and transformation processes within the system that convert the chemical to daughter products. The program produces output tables and simple graphics describing chemical exposure, fate, and persistence.

EXAMS represents each waterbody via a set of segments or distinct zones in the system. The program is based on a series of mass balances for the segments that give rise to a single differential equation for each segment. Working from the individual transport and transformation process equations, EXAMS compiles an overall equation for the net rate of change of chemical concentration in each segment. The resulting system of differential equations describes the mass balance for the entire system, which is then solved by the method of lines. EXAMS includes a descriptor language that simplifies the specification of system geometry and connectedness.

EXAMS includes process models of the physical, chemical, and biological phenomena governing the transport and fate of compounds. Each of the unit process equations used to

compute the kinetics of chemicals accounts for the interactions between the chemistry of a compound and the environmental forces that shape its behavior in aquatic systems. This "second-order" or "system-independent" approach lets one study the fundamental chemistry of compounds in the laboratory and then, based on independent studies of the levels of driving forces in aquatic systems, evaluate the probable behavior of the compound in systems that have never been exposed to it. Most of the process equations are based on standard theoretical constructs or accepted empirical relationships. The user can specify reaction pathways for the production of transformation products of concern, whose further fate and transport can then be simultaneously simulated by EXAMS.

EXAMS contains process modules for several chemical reactions. Equilibrium reactions are used for sorption and ionization. Kinetic reactions are used for volatilization, hydrolysis (acid, base, and neutral), biodegradation (water column and sediments), photolysis, oxidation, and reduction. EXAMS uses these modules as determined by the input chemical properties. EXAMS has been designed to accept standard water quality parameters and system characteristics that are commonly measured by limnologists throughout the world and chemical datasets conventionally measured or required by EPA regulatory procedures.

The contaminant fate algorithms in EXAMS include sorption to suspended solids, biotic solids, and sediment solids, but EXAMS does not simulate a solids balance. Solids concentrations are specified as input data. The effects of settling and resuspension on chemical fate are accounted for in a bulk sediment-water exchange term.

EXAMS can be run in three modes: steady-state, quasi-dynamic with steady environmental data, and quasi-dynamic with monthly environmental data. H-Exams implements mode 2, in which the model integrates the equations over specified time periods with given environmental and loading conditions. Pulse loadings are allowed by EXAMS in mode 2 simulations, but this capability is not implemented by H-Exams. The EXAMS simulation proceeds in yearly increments using yearly-average loadings and environmental conditions.

While EXAMS can be run interactively or as a batch program, H-Exams is implemented solely as a batch process. H-Exams does not consider transformations due to photolysis or oxidation. Transformation rate constants for hydrolysis, biodegradation, and reduction are calculated by the HWIR chemical processor and passed through the batch chemical database to EXAMS. Internal EXAMS algorithms for calculating rate constants are bypassed.

D.6.2 Assumptions and Limitations

EXAMS incorporates a few major assumptions. The model was designed to evaluate the consequences of longer-term, primarily time-averaged chemical loadings that ultimately result in trace-level contamination of aquatic systems. EXAMS generates a steady-state, average flow field (long-term or monthly) for the ecosystem. The program cannot then fully evaluate the transient, high concentrations that arise from chemical spills, although spills under average hydrological conditions can be studied. An assumption of trace-level chemical concentrations was used to design the process equations. The chemical is assumed not to radically change the environmental variables that drive its transformations. EXAMS uses linear sorption isotherms, and second-order

(rather than Michaelis-Menten-Monod) expressions for biotransformation kinetics, which is known to be valid for low concentrations of pollutants. Sorption is treated as a thermodynamic or constitutive property of each compartment in the system, that is, sorption-desorption kinetics are assumed to be rapid compared to other processes. While this assumption may be violated by extensively-sorbed chemicals, they tend to be captured by benthic sediments, where their release to the water column is controlled by benthic exchange processes.

In addition to the assumptions incorporated by EXAMS, the 3MRA implementation of Exams (H-Exams) employs several simplifications in order to meet requirements and constraints associated with the 3MRA system . The project design calls for repeated long simulations (200 to 10,000 years) executed quickly (seconds to minutes). This requirement limits the temporal resolution at which simulations can be conducted. Another important constraint is limited site-specific data. This constraint limits the accuracy with which a particular site can be described. The major model simplifications made in response to these project constraints include the use of average-yearly hydrological and loading inputs, the use of national distributions to specify some site-specific environmental conditions, and the use of a simple solids balance with no settling and burial. For sites that experience periodic drying, a small positive flow equivalent to 5 mm/year of direct precipitation onto the water body surface is maintained in order to keep the model functioning.

These simplifications lead to a degree of model error in the calculated concentrations. Using annual-average loadings and flows rather than daily loadings and flows will lead to calculated annual-average concentrations that are biased somewhat high, depending on the correlation between flow and loading at a particular site. This bias is somewhat mitigated for reactive and volatile chemicals where the loss rate is proportional to the concentration. The use of national distributions rather than site-specific environmental data could cause calculated concentrations to be low or high at a given location, with no known general bias. The simple solids balance will overestimate suspended solids concentrations slightly in streams and more significantly in ponds, wetlands, and lakes. Calculated total water column chemical concentrations will be high, while the dissolved chemical fraction will be low. The net result for dissolved water column chemical concentrations, which are used for fish exposure, is not expected to be biased significantly high or low.

The procedure for preventing drying of surface water reaches is more difficult to evaluate. This procedure conducts chemical loads downstream within a remnant aquatic reach rather than within runoff over a dry bed or subsurface flow within the bed. While the mass balance is maintained, the chemical and solids concentrations will tend to be elevated within the remnant reach. These elevated concentrations are probably realistic for years in which evaporation exceeds all hydrologic inflows.

D.6.3 Inputs for the Surface Water Module

Three site simulation files are generated for each execution of the surface water module – the site layout file sl.ssf, the chemical property file cpstream.ssf, and the surface water body file(s) sw*.ssf (where * stands for the water body number at a site). Table D-13 lists the input parameters contained in the various SSF and GRF files read by the surface water module. The

site layout SSF contains 35 variables used by the surface water module. The surface water SSF files contain 25 variables that are relevant only to the surface water module. The chemical SSF file contains 44 variables reead by the surface water module.

In addition the surface water model reads several global results files (GRFs) containing water, solids, contaminant loadings from other modules: 9 variables from the air module (ar.ssf), 7 variables from the source module (sr.grf), 7 variables from the watershed module (ws.grf), and 4 variables from the groundwater module (aq.grf).

The groundwater (aquifer) results file contains 9 variables, 4 of which are used by the surface water module.

D.6.4 Outputs from the Surface Water Module

The surface water model produces water and sediment chemical concentrations (dissolved and total) that are used by the aquatic foodweb, farm food chain, ecological exposure, and ecological risk modules, along with the number of values and output years. These variables are contained in the sw.grf and are listed in Table D-14.

Table D-13. Surface Water Module Inputs

File	Code	Units	Data Type	Description
sw.ssf	ahyd_d	m	FLOAT	hydraulic coefficient depth multiplier
sw.ssf	bhyd_d		FLOAT	hydraulic coefficient depth exponent
sw.ssf	ahyd_W	m	FLOAT	hydraulic coefficient width multiplier
sw.ssf	bhyd_W		FLOAT	hydraulic coefficient width exponent
sw.ssf	DepthSedRes	cm	float	underlying sediment layer depth
sw.ssf	DepthBenthos	cm	float	surficial sediment layer depth
sw.ssf	d_pond	m	float	depth of pond
sw.ssf	d_wtlnd	m	float	depth of wetland
sw.ssf	d_epil	m	FLOAT	depth of epilimnion
sw.ssf	d_hypol	m	FLOAT	depth of hypolimnion
sw.ssf	E_sw	cm2/sec	float	sediment-water column diffusion coefficient
sw.ssf	E_thermocline	cm2/sec	FLOAT	thermocline diffusion coefficient
sw.ssf	rhoDSedRes	g/mL	FLOAT	underlying sediment layer dry bulk density
sw.ssf	rhoDBenthos	g/mL	FLOAT	surficial sediment layer dry bulk density
sw.ssf	porSedRes	Lw/L	FLOAT	underlying sediment layer porosity
sw.ssf	porBenthos	Lw/L	FLOAT	surficial sediment layer porosity
sw.ssf	k_PlankCMin	yr^-1	FLOAT	Plankton carbon mineralization rate constant; not used in this HWIR application.
sw.ssf	k_SedG2	yr^-1	FLOAT	Sediment mineralization rate constant, G2 fraction; not used in this HWIR application.
sw.ssf	k_SedG3	yr^-1	FLOAT	Sediment mineralization rate constant, G3 fraction; not used in this HWIR application.
sw.ssf	v_bury	mm/yr	FLOAT	underlying sediment layer burial rate
sw.ssf	TrophicIndex		INTEGER	trophic index
sw.ssf	S_upstream	mg/L	FLOAT	[upstream suspended solids concentration]
sw.ssf	C_upstream	mg/L	FLOAT	upstream chemical concentration
sw.ssf	Q_upstream	m3/day	FLOAT	upstream flow
sl.ssf	WBNDOC	mg/L	Float	DOC of stream, lake, and wetland reaches in waterbody network
sl.ssf	WBNfocAbS	fraction	Float	fraction organic carbon of abiotic solids in water column
sl.ssf	WBNfocBioS	fraction	Float	fraction organic carbon of biotic solids in water column
sl.ssf	WBNfocSed	fraction	Float	fraction organic carbon in sediments of stream, lake, and wetland reaches
sl.ssf	WBNId		Integer	Environmental Setting Id for WBN
sl.ssf	WBNNumRch		Integer	Number of reaches for this network
sl.ssf	WBNpH	pH units	Float	pH of stream, lake, and wetland reaches in the waterbody network

(continued)

Table D-13. (continued)

File	Code	Units	Data Type	Description
sl.ssf	WBNRchAirFrac	fraction	Float	Fraction of this reach impacted by air point
sl.ssf	WBNRchAirIndex		Integer	Index of air point that impacts this reach
sl.ssf	WBNRchAquFrac	fraction	Float	Fraction of this reach impacted by the aquifer
sl.ssf	WBNRchAquIndex		Integer	Index of aquifer that impacts this reach
sl.ssf	WBNRchArea	m2	Float	reach surface area (nonstream reaches)
sl.ssf	WBNRchBodyType		String	Type of waterbody (Stream, Lake, Wetland)
sl.ssf	WBNRchHypoAreaFrac	fraction	Float	fraction of total surface area for hypolimnion
sl.ssf	WBNRchLength	m	Float	Reach Length
sl.ssf	WBNRchNumAir		Integer	Number of points that impact this reach
sl.ssf	WBNRchNumAqu		Integer	Number of aquifer that impact this reach
sl.ssf	WBNRchNumLoc	unitless	Integer	number of x,y points associated with watershed
sl.ssf	WBNRchNumRch		Integer	Number of reaches that impact this reach
sl.ssf	WBNRchNumWSSub		Integer	Number of watersheds that impacts this reach
sl.ssf	WBNRchOrder	unitless	Integer	stream order
sl.ssf	WBNRchRchFrac	fraction	Float	Fraction of this reach impacted by another reach
sl.ssf	WBNRchRchIndex		Integer	Index of reach that impacts this reach
sl.ssf	WBNRchSrcLWSFrac	fraction	Float	fraction of waterbody network reach impacted by the source local watershed
sl.ssf	WBNRchSrcLWSIndex		Integer	index of local watershed from source
sl.ssf	WBNRchType		String	Type of reach (Headwater, exiting, other)
sl.ssf	WBNRchWSSubFrac	fraction	Float	Fraction of this reach impacted by watershed
sl.ssf	WBNRchWSSubIndex		Integer	Index of watershed that impacts this reach
sl.ssf	WBNTemp	degrees Celsius	Float	median temperature of stream, lake, and wetland reaches in waterbody network
sl.ssf	WBNTOC	mg/L	Float	TOC of stream, lake, and wetland reaches in waterbody network
sl.ssf	WBNTSS	mg/L	Float	TSS of stream, lake, and wetland reaches in waterbody network
cp.ssf	ChemName		String	Chemical Name
cp.ssf	ChemActBioNumProd		Integer	Number of products
cp.ssf	ChemActBioProdCASID		String	Product CASID
cp.ssf	ChemActBioProdName		String	Product Name
cp.ssf	ChemActBioProdYield	moles/moles	Float	Product Yield Coefficient
cp.ssf	ChemActBioRate	1/day	Float	Activated Biodegradation
cp.ssf	ChemADiff	cm^2/s	Float	Air Diffusion Coefficient
cp.ssf	ChemAerBioNumProd		Integer	Number of products
cp.ssf	ChemAerBioProdCASID		String	Product CASID
cp.ssf	ChemAerBioProdName		String	Product Name

(continued)

Table D-13. (continued)

File	Code	Units	Data Type	Description
cp.ssf	ChemAerBioProdYield	moles/moles	Float	Product Yield Coefficient
cp.ssf	ChemAerBioRate	1/day	Float	Aerobic Biodegradation rate
cp.ssf	ChemAnaBioNumProd		Integer	Number of products
cp.ssf	ChemAnaBioProdCASID		String	Product CASID
cp.ssf	ChemAnaBioProdName		String	Product Name
cp.ssf	ChemAnaBioProdYield	moles/moles	Float	Product Yield Coefficient
cp.ssf	ChemAnaBioRate	1/day	Float	Anaerobic Biodegradation
cp.ssf	ChemAnaRedNumProd		Integer	Number of products
cp.ssf	ChemAnaRedProdCASID		String	Product CASID
cp.ssf	ChemAnaRedProdName		String	Product Name
cp.ssf	ChemAnaRedProdYield	moles/moles	Float	Product Yield Coefficient
cp.ssf	ChemAnaRedRate	1/day	Float	Anaerobic Reduction
cp.ssf	ChemDen	g/mL	Float	Density
cp.ssf	Chemfoc	fraction	Float	Fraction Organic Content of Medium
cp.ssf	ChemHLC	(atm m^3)/mol	Float	Henry's Law Constant
cp.ssf	ChemHydNumProd		Integer	Number of products
cp.ssf	ChemHydProdCASID		String	Product CASID
cp.ssf	ChemHydProdName		String	Product Name
cp.ssf	ChemHydProdYield	moles/moles	Float	Product Yield Coefficient
cp.ssf	ChemHydRate	1/day	Float	Catalyzed Hydrolysis
cp.ssf	ChemKd	L/kg	Float	Partition Coefficient for Med
cp.ssf	ChemKoc	mL/g	Float	Koc
cp.ssf	ChemKow		Float	Kow
cp.ssf	ChemMed		String	Solubility Media (Soil, Sediment,Surface Water, Waste)
cp.ssf	ChemMolWt	g/mole	Float	Molecular weight for the chemical
cp.ssf	ChemName		String	Name
cp.ssf	ChemPh	pH units	Float	[pH assumed for these properties]
cp.ssf	ChemSol	mg/L	Float	Solubility for each media
cp.ssf	ChemTemp	degrees Celsius	Float	Temperature assumed for these properties
cp.ssf	ChemType		string	Chemical Type (O, M, Hg, S, D)
cp.ssf	ChemVol	mL	Float	Volume
cp.ssf	ChemVp	torr	Float	Vapor Pressure
cp.ssf	ChemWDiff	cm^2/s	Float	Water Diffusion Coefficient
cp.ssf	NumChem		Integer	Number of chemicals described
sr.grf	Runoff	m3/d	float	runoff

(continued)

Table D-13. (continued)

File	Code	Units	Data Type	Description
sr.grf	SWLoadChem	g/d	float	chemical load to waterbody
sr.grf	SWLoadChemYR	year	integer	year associated with output
sr.grf	SWLoadChemNY		integer	number of years in outputs
sr.grf	SrcOvl		logical	flag for overland flow presence
sr.grf	SrcH2O		logical	flag for surface water presence
sr.grf	NyrMet	year	integer	number of years in the available met record
ar.grf	VapWDep	g/m2/d	FLOAT	vapor wet deposition flux
ar.grf	VapWDepYR	Year	Integer	year corresponding to vapor wet deposition flux value
ar.grf	VapWDepNY		Integer	number of annual vapor wet deposition flux values
ar.grf	ParDDep	g/m2/d	FLOAT	particle dry deposition flux
ar.grf	ParDDepYR	Year	Integer	year corresponding to particle dry deposition flux value
ar.grf	ParDDepNY		Integer	number of particle dry deposition flux values
ar.grf	ParWDep	g/m2/d	FLOAT	particle wet deposition flux
ar.grf	ParWDepYR	Year	Integer	year corresponding to particle dry deposition flux value
ar.grf	ParWDepNY		Integer	number of particle dry deposition flux values
ws.grf	NyrMet	year	integer	number of years in the available met record
ws.grf	RunoffR	m3/d	float	runoff flow to waterbody
ws.grf	BFann	m3/d	float	long-term avg baseflow to waterbody
ws.grf	SWLoadChemR	g/d	float	chemical load (deposition only) to waterbody
ws.grf	SWLoadChemRYR	year	integer	year associated with output
ws.grf	SWLoadChemRNY		integer	number of years in outputs
ws.grf	SWLoadSolidR	g/d	float	total suspended solids (runoff)
aq.grf	AquRchMassFlux	g/yr	Float	Mass Flux from Aquifer to Reach
aq.grf	AquRchMassFluxNY		Integer	Number of Time - Mass-Flux-to-Reach Pairs
aq.grf	AquRchMassFluxYR	year	Integer	Time of Mass Flux from Aquifer to Reach
aq.grf	AquRchWaterFlux	m3/day	Float	Total GW Flux to Reach

Table D-14. Surface Water Module Outputs (SW.GRF)

Code	Units	Data Type	Description
WBNConcBenthDiss	mg/L	Float	Dissolved chemical concentration in the surficial benthic layer
WBNConcBenthDissNY		Integer	Number of dissolved chemical concentration values in the surficial benthic layer
WBNConcBenthDissYr	year	Integer	Year corresponding to dissolved chemical concentration in benthic layer
WBNConcBenthTot	ug/g	Float	Total chemical concentration in the surficial benthic layer
WBNConcBenthTotNY		Integer	Number of total chemical concentration values in the surficial benthic layer
WBNConcBenthTotYr	year	Integer	Year corresponding to total chemical concentration in benthic layer
WBNConcWaterDiss	mg/L	Float	Dissolved chemical concentration in the water column
WBNConcWaterDissNY		Integer	Number of dissolved chemical concentration values in the water column
WBNConcWaterDissYr	year	Integer	Year corresponding to dissolved chemical concentration in the water column
WBNConcWaterTot	mg/L	Float	Total chemical concentration in the water column
WBNConcWaterTotNY		Integer	Number of total chemical concentration values in the water column
WBNConcWaterTotYr	year	Integer	Year corresponding to dissolved chemical concentration in the water column
WBNfocBenth	fraction	Float	Organic carbon content of benthic sediments
WBNfocBenthNY		Integer	Number of organic carbon content values
WBNfocBenthYr	year	Integer	Year corresponding to organic content values
WBNNumChem		Integer	Number of chemicals in output file
WBNTSSWater	mg/L	Float	Total suspended solids concentration in the water column
WBNTSSWaterNY		Integer	Number of suspended solids concentration values
WBNTSSWaterYr	year	Integer	Year corresponding to suspended solids values

D.7 Farm Food Chain Module

The farm food chain (FFC) module calculates the concentration of a chemical in homegrown produce (fruits and vegetables), farm crops for cattle (forage, grain, and silage), beef, and milk.. The module is designed to predict the accumulation of a contaminant in the edible parts of a plant from uptake of contaminants in soil and through transpiration and direct deposition of the contaminant in air. In addition, the module estimates the contaminant concentration from the biotransfer of contaminants in feed (i.e., forage, grain, and silage), soil, and drinking water to beef and dairy cattle through ingestion.

The modeling construct for the FFC module is based on recent and ongoing research conducted by the U.S. Environmental Protection Agency (EPA) Office of Research and Development (ORD) and presented in *Methodology for Assessing Health Risks Associated with Multiple Exposure Pathways to Combustor Emissions* (U.S. EPA, in press). Additional detail about the background and implementation of the model is available in U.S. EPA (1999i).

D.7.1 Functionality

The major computational functions performed by the Farm Food Chain Module are the following:

- *Concentrations of contaminants in homegrown produce.* The concentrations of contaminants in fruits and vegetables are calculated for home gardens and for farms.

- *Concentrations of contaminants in cattle feed.* The concentrations of contaminants in pasture grass (i.e., forage), silage, and grain are calculated for beef and dairy farms.

- *Concentrations of contaminants in locally grown beef and milk.* The concentrations of contaminants in beef and milk produced on local farms are calculated.

D.7.2 Assumptions and Limitations

The contaminant concentration calculations used in the Farm Food Chain Module reflect a number of assumptions and/or limitations:

- *Study area is bounded at 2 km.* It is assumed that all significant contaminant concentrations occur within 2 km of the source. Concentrations are not determined outside the 2-km study area.

- *Homogeneous concentrations in fruits and vegetables are assumed.* For unprotected fruits and vegetables, the exposure methodology makes no provision for the possible chemical concentration gradients within the produce that might result in different concentrations in edible portions.

- *Resuspension and redeposition on plants are not considered.* Plant concentrations are a function of the deposition of the contaminants that have been emitted from the waste management unit (WMU). Plant concentrations do not consider resuspension and redeposition. These processes can occur due to tillage, wind erosion, vehicular resuspension, and rainsplash, but will not be examined by this model.

- *Inhalation and dermal exposure are not considered in cattle.* Beef and dairy cattle calculations consider only contaminant pathways of food, soil, and water ingestion. Other pathways such as inhalation or dermal exposure are not considered in this module.

D.7.3 Inputs for the Farm Food Chain Module

The farm food chain module receives inputs from its module-specific input file (ff.ssf), the generic site layout file (Sl.ssf), the generic chemical properties file (cp.ssf), and modeled inputs from the following other modules: aquifer module (aq.grf), air module (ar.grf), surface water module (sw.grf), watershed module (ws.grf), and those source modules outputting (to a common grf file, sr.grf) a "true" for the soil-presence logical flag, srcsoil. These sources are the land application unit, landfill, wastepile, and surface impoundment. Input variables are listed and described in Table D-15.

D.7.4 Outputs from the Farm Food Chain Module

The farm food chain module outputs are written to the ff.grf file. The soil, plant, beef and milk outputs are 2-dimensional arrays indexed on time and space. Output variables are listed and described in Tables D-16.

Table D-15. Summary of Inputs for Farm Food Chain Module

File	Input Parameters	Units	Description
ff.ssf	*Fforage_<cattle type>*	Fraction	Fraction of forage grown in contaminated soil. (Note: "<cattle type>" is replaced with beef and milk.)
ff.ssf	*Fgrain_<cattle type>*	Fraction	Fraction of grain grown in contaminated soil. (Note: "<cattle type>" is replaced with beef and milk.)
ff.ssf	*Fsilage_<cattle type>*	Fraction	Fraction of silage grown in contaminated soil. (Note: "<cattle type>" is replaced with beef and milk.)
ff.ssf	*Fw_<plant type>*	Unitless	Fraction of wet deposition that adheres to the plant. (Note: "<plant type>" is replaced with exfruit, exveg, forage, and silage.)
ff.ssf	*MAF<plant type>*	Percent	Moisture adjustment factor to convert DW into WW. (Note: "<plant type>" is replaced with exfruit, exveg, leaf, profruit, proveg, and root.)
ff.ssf	*MAFleaf*	Percent	Moisture content in leaf.
ff.ssf	*Qp_forage_<cattle type>*	kg DW/d	Consumption rate of forage by cattle. (Note: "<cattle type>" is replaced with beef and milk.)
ff.ssf	*Qp_grain_<cattle type>*	kg DW/d	Consumption rate of grain by cattle. (Note: "<cattle type>" is replaced with beef and milk.)
ff.ssf	*Qp_silage_<cattle type>*	kg DW/d	Consumption rate of silage by cattle. (Note: "<cattle type>" is replaced with beef and milk.)
ff.ssf	*Qs_<cattle type>*	kg/d	Consumption rate of contaminated soil. (Note: "<cattle type>" is replaced with beef and milk.)
ff.ssf	*Qw_<cattle type>*	L/d	Consumption rate of water. (Note: "<cattle type>" is replaced with beef and milk.)
ff.ssf	*rho_leaf*	g/L	Density of the leaf.
ff.ssf	*Rp_<plant type>*	Unitless	Interception fraction. (Note: "<plant type>" is replaced with exfruit, exveg, forage, and silage.)
ff.ssf	*tp_<plant type>*	Year	Length of plant exposure to deposition. (Note: "<plant type>" is replaced with exfruit, exveg, forage, and silage.)
ff.ssf	*VapDdv*	cm/s	Vapor-phase dry deposition velocity.
ff.ssf	*VGag_<plant type>*	Unitless	Empirical correction factor. (Note: "<plant type>" is replaced with exfruit, exveg, forage, and silage.)
ff.ssf	*VGbg_root*	Unitless	Empirical correction factor for roots.
ff.ssf	*Yp_<plant type>*	kg DW/m^2	Yield or standing crop biomass. (Note: "<plant type>" is replaced with exfruit, exveg, forage, and silage.)
sl.ssf	*FarmAirFrac*	Fraction	Fraction of farm or crop area impacted by air points.

(continued)

Table D-15. (continued)

File	Input Parameters	Units	Description
sl.ssf	*FarmAirIndex*	NA	Index of points that impacts farm or crop area.
sl.ssf	*FarmAquIndex*	NA	Index of aquifer that impacts farm or crop area.
sl.ssf	*FarmAquWellFrac*	Fraction	Fraction farm uses aquifer well as animal DW source.
sl.ssf	*FarmAquWellIndex*	NA	Index of contributing subarea in local watershed indices associated with each farm.
sl.ssf	*FarmLWSIndex*	NA	Local watershed indices associated with each farm.
sl.ssf	*FarmLWSSubAreaFrac*	Fraction	Fraction of contribution of subarea in local watershed indices associated with each farm.
sl.ssf	*FarmNumAir*	Unitless	Number of air points that impact farm or crop area.
sl.ssf	*FarmNumAquWell*	Unitless	Number of wells in each aquifer impacting farm.
sl.ssf	*FarmNumLWS*	Unitless	Number of local watersheds impacting farm or crop area.
sl.ssf	*FarmNumWBNRch*	Unitless	Number of WBN reach that impact farm or crop area.
sl.ssf	*FarmNumWSSub*	Unitless	Number of watersheds that impact farm or crop area.
sl.ssf	*FarmWBNIndex*	NA	Index of WBN that impacts farm or crop area.
sl.ssf	*FarmWBNRchFrac*	Fraction	Fraction of farm or crop area impacted by WBN reach.
sl.ssf	*FarmWBNRchIndex*	NA	Index of WBN reach that impacts farm or crop area.
sl.ssf	*FarmWSSubFrac*	Fraction	Fraction of each watershed on farm.
sl.ssf	*FarmWSSubIndex*	NA	Index of watershed on farm.
sl.ssf	*focS*	Mass fraction	Fraction organic carbon (soil).
sl.ssf	*HumRcpAirIndex*	NA	Index of air points that impact receptor.
sl.ssf	*HumRcpLWSAreaIndex*	NA	Local watershed index for each human receptor.
sl.ssf	*HumRcpLWSSubAreaIndex*	NA	Local watershed subarea index for each human receptor.
sl.ssf	*HumRcpWSSubIndex*	NA	Index of watershed that impacts receptor.
sl.ssf	*NumFarm*	Unitless	Number of farm or crop areas.
cp.ssf	*ChemBa_<#>*	d/g	Biotransfer factor. (Note: "<plant type>" is replaced with beef and milk.)
cp.ssf	*ChemBa_water*	d/g	Biotransfer factor for dissolved contaminant in surface water.

(continued)

Table D-15. (continued)

File	Input Parameters	Units	Description
cp.ssf	*ChemBr_<plant type>*	(μg/g DW plant) / (μg/g soil)	Soil-to-plant bioconcentration factor. (Note: "<plant type>" is replaced with exfruit, exveg, forage, grain, profruit, proveg, root, and silage.)
cp.ssf	*ChemBs*	Fraction	Bioavailability fraction of contaminant in soil relative to vegetation.
cp.ssf	*ChemBv_ecf_plant*	Unitless	Empirical correction factor for Bv.
cp.ssf	*ChemBv_<plant type>*	(μg/g DW plant) / (μg/g air)	Mass-based air-to-plant biotransfer factor. (Note: "<plant type>" is replaced with exfruit, exveg, forage, and silage.)
cp.ssf	*ChemHLC*	(atm-m^3)/mol	Henry's law constant.
cp.ssf	*ChemKoc*	mL/g	Organic carbon partition coefficient
cp.ssf	*ChemKow*	Unitless	Octanol/water partition coefficient
cp.ssf	*ChemkpPar_<plant type>*	1/ yr	Plant surface loss of particle-bound constituent. (Note: "<plant type>" is replaced with exfruit, exveg, forage, and silage.)
cp.ssf	*ChemkpVap_<plant type>*	1/ yr	Degradation loss of vapor-phase constituents. (Note: "<plant type>" is replaced with exfruit, exveg, forage, and silage.)
cp.ssf	*ChemRCF*	(μg/g WW plant) / (μg/mL soil water)	Root concentration factor.
cp.ssf	*ChemType*	NA	Chemical type (O, M, Hg, S, or D)
aq.grf	*AquWellConc*	mg/L	Concentration of contaminant in the water of an aquifer well.
aq.grf	*AquWellConcNY*	Year	Number of years in the time series corresponding to this variable.
aq.grf	*AquWellConcYR*	Unitless	Time series of years corresponding to this variable.
ar.grf	*CVap*	μg/m^3	Concentration of chemical in air vapor.
ar.grf	*CVapNY*	Unitless	Number of years in the time series corresponding to this variable.
ar.grf	*CVapYR*	Year	Time series of years corresponding to this variable.
ar.grf	*ParDDep*	g/m2/d	Particle dry deposition rate.
ar.grf	*ParDDepNY*	Unitless	Number of years in the time series corresponding to this variable.
ar.grf	*ParDDepYR*	Year	Time series of years corresponding to this variable.

(continued)

Table D-15. (continued)

File	Input Parameters	Units	Description
ar.grf	*ParWDep*	$g/m^2/d$	Particle wet deposition rate.
ar.grf	*ParWDepNY*	Unitless	Number of years in the time series corresponding to this variable.
ar.grf	*ParWDepYR*	Year	Time series of years corresponding to this variable.
ar.grf	*VapWDep*	$g/m^2/d$	Vapor wet deposition rate.
ar.grf	*VapWDepNY*	Unitless	Number of years in the time series corresponding to this variable.
ar.grf	*VapWDepYR*	Year	Time series of years corresponding to this variable.
sr.grf	*CTda*	$\mu g/g$	Depth-averaged soil concentration across farm area.
sr.grf	*CTdaNY*	Year	Number of years in the time series corresponding to this variable.
sr.grf	*CTdaYR*	Unitless	Time series of years corresponding to this variable.
sr.grf	*CTss*	$\mu g/g$	Surficial soil concentration across farm area.
sr.grf	*CTssNY*	Year	Number of years in the time series corresponding to this variable.
sr .grf	*CTssYR*	Unitless	Time series of years corresponding to this variable.
sw.grf	*CTdaR*	$\mu g/g$	Depth-averaged soil concentration for the regional watershed area.
sw.grf	*CTdaRNY*	Year	Number of years in the time series corresponding to this variable.
sw.grf	*CTdaRYR*	Unitless	Time series of years corresponding to this variable.
sw.grf	*CTssR*	$\mu g/g$	Surface soil concentration for the regional watershed area.
swrf	*CTssRNY*	Year	Number of years in the time series corresponding to this variable.
sw.grf	*CTssRYR*	Unitless	Time series of years corresponding to this variable.

NA = Not applicable

Table D-16. Summary of Outputs Parameters for the Farm Food Chain Module

File	Code	Units	Description
ff.grf	*Abeef_farm*	mg/kg WW	Concentration of contaminant in beef.
ff.grf	*Abeef_farmNY*	Year	Number of years in the time series corresponding to this variable.
ff.grf	*Abeef_farmYR*	Unitless	Time series of years corresponding to this variable.
ff.grf	*Amilk_farm*	mg/kg WW	Concentration of contaminant in milk.
ff.grf	*Amilk_farmNY*	Year	Number of years in the time series corresponding to this variable.
ff.grf	*Amilk_farmYR*	Unitless	Time series of years corresponding to this variable.
ff.grf	*CTssAve_farm*	μg/g	Chemical concentration in surficial soil averaged over farm area.
ff.grf	*CTssAve_farmNY*	Year	Number of years in the time series corresponding to this variable.
ff.grf	*CTssAve_farmYR*	Unitless	Time series of years corresponding to this variable.
ff.grf	*P<plant type>_farmYR*	Unitless	Time series of years corresponding to this variable.
ff.grf	*P<plant type>_farm*	mg/kg WW	Concentration of contaminant for specific fruit and vegetable categories grown on a farm. (Note: "<plant type>" is replaced with exfruit, exveg, profruit, proveg, and root.)
ff.grf	*P<plant type>_farmNY*	Year	Number of years in the time series corresponding to this variable.
ff.grf	*P<plant type>_garden*	mg/kg WW	Concentration of contaminant for specific fruit and vegetable categories grown in a garden. (Note: "<plant type>" is replaced with exfruit, exveg, profruit, proveg, and root.)
ff.grf	*P<plant type>_gardenYR*	Unitless	Time series of years corresponding to this variable.
ff.grf	*P<plant type>_gardenNY*	Year	Number of years in the time series corresponding to this variable.

D.8 Terrestrial Food Web Module

The terrestrial food web module (TerFW) calculates chemical concentrations in soil, terrestrial plants, and various prey items consumed by ecological receptors, including earthworms, other soil invertebrates, and vertebrates. These concentrations are used as input to the ecological exposure (EcoEx) module to determine the applied dose to each receptor of interest (e.g., deer, kestrel). The module is designed to calculate spatially-averaged soil concentrations in the top layer of soil (i.e., surficial soil) as well as deeper soil horizons (i.e., depth-averaged over approximately 5 cm). The spatial averages are defined by the home ranges and habitats that are delineated within the area of interest (AOI) at each site. Once the average soil concentrations are calculated, these values are multiplied by empirical bioconcentration factors (for animals) and biotransfer factors (for plants) to predict the tissue concentrations for items in the terrestrial food web. Additional detail on the TerFW module can be found in U.S. EPA (1999j).

D.8.1 Functionality

The major computational functions performed by the Terrestrial Food Web module are the following:

- *Time series management*. The TerFW module determines the overall duration of the time period to be simulated (including concentration data from discontinuous time periods) and identifies the individual years within the overall duration that will be simulated.

- *Module loops over the time series, through habitats and home ranges.* The TerFW module has three basic loops: (1) over the time series, (2) over each habitat delineated at the site, and (3) over the four home range areas delineated within each habitat.

- *Calculation of time series soil and plant concentrations and minimum and maximum concentrations in terrestrial prey types (e.g., small mammals).* This is the fundamental structure of the TerFW module, namely, to develop soil and tissue concentrations for each year of the simulation that reflect the range of potential exposure concentrations. These concentrations are spatially explicit with regard to the home range for each ecological receptor.

The major steps performed by the Terrestrial Food Web module that are required to predict concentrations in soil (surficial and depth-averaged), plants, and other prey types can be summarized as follows:

- Select terrestrial habitat of interest (i.e., cropland, residential area, grassland, forest, shrub/scrub).

- Select home range within habitat (i.e., one of four home range areas).

- # Calculate average soil concentration within home range for surficial soil and depth-averaged soil.

- # Calculate concentration for all categories of terrestrial plants within home range.

- # Calculate tissue concentration in soil fauna within home range (i.e., earthworms and other soil invertebrates).

- # Calculate tissue concentrations in receptors assigned to home range (e.g., small mammals, omnivores).

- # Loop through all home ranges within habitat of interest and repeat calculations of soil and tissue concentrations.

- # Report minimum and maximum values for tissue concentrations in prey types other than terrestrial plants and soil fauna.

D.8.2 Assumptions and Limitations

The contaminant concentration calculations used in the Terrestrial Food Web module reflect a number of assumptions and limitations, which are listed below.

D.8.2.1 Assumptions

- # *Study area is bounded at 2 km.* EPA assumed that significant exposures to source-related contaminants do not occur for ecological receptors that are beyond 2 km of the source. Consequently, tissue concentrations in food items located outside of the study (measured from the edge of the source to a point 2 km away) are presumed to be zero.

- # *Uptake and accumulation of chemicals within categories of plants (e.g., exposed vegetables) is assumed to be similar.* The algorithms used to estimate biotransfer factors do not distinguish physiological differences across various kinds of plants. For example, the category "forage" includes forbs, grasses, fungi, shrubs, trees, and unclassified plants. Therefore, in estimating biotransfer factors for this category, it is implicitly assumed that the physiological differences in different plant species do not significantly affect chemical loadings in plant tissues. The use of empirical data on selected plant species (typically crops) also assumes similar mechanisms of uptake and accumulation.

- # *No less than 10 percent of the diet is attributed to the study area.* In many instances, the home range for a given receptor exceeds the size of the habitat. In general we assumed that the percent of the home range that "fits" into the habitat is a suitable surrogate with which to scale exposure and predict tissue concentration. However, the purpose of this analysis is to determine acceptable waste concentrations assuming that the study area (e.g., forests) would be used as habitat by wildlife. Therefore, we assumed that no less than 10 percent of the diet

originated from the study area, even if the fraction of the home range inside the habitat fell below 10 percent.

A reasonable averaging depth for soil concentrations is 5 cm. In view of the multiple purposes of this soil concentration (e.g., evaluate risks to soil fauna; predict tissue concentrations in prey using soil-based bioaccumulation factors), this was selected as a depth that was ecologically meaningful (with regard to organisms occupying different soil horizons) and consistent with the goals for the ecological risk analysis. However, this assumption carries with it some uncertainty in its application within the exposure and risk modules.

D.8.2.2 Limitations

Concentrations in terrestrial prey are based on soil-to-prey bioaccumulation factors (BAFs). The most significant limitation in predicting tissue concentrations in terrestrial prey is the paucity of mechanistic models and data sources with which to estimate food web dynamics. For instance, the tissue concentration in small birds is generally predicted using a BAF for soil rather than a biotransfer factor (or BAF) from earthworms and insects into birds. As a result, the TerFW can not rely on the matrix solution technique used by the Aquatic Food Web module to solve for concentrations in various prey items.

Some chemicals rely heavily on empirical uptake data. This limitation is similar to that noted for the Farm Food Chain module. In essence, the paucity of data on uptake and accumulation of constituents in terrestrial food items introduces significant uncertainty into this module.

Estimates of tissue concentrations reflect a single home range setting. The TerFW module calculates tissue concentrations in prey items for a single random placement of four home range sizes.[3] As a result, the four home ranges in the site layout may not reflect the spatial variability in soil contamination, particularly for large habitats (i.e., habitats that cover substantially greater areas than most of the home ranges).

Resuspension and redeposition on plants are not considered. Plant concentrations are a function of the deposition on plants of the contaminants that have been emitted from the waste management unit. Plant concentrations do not reflect resuspension and redeposition, which can occur due to tillage, wind erosion, vehicular resuspension, and rainsplash

[3] As described in U.S. EPA (1999n), each receptor is assigned to one of four discrete home range sizes, depending on the receptor-specific home range size. The four home ranges overlap in a manner that reflects the predator-prey relationships.

D.8.3 Inputs

The concentration inputs required by the TerFW module are provided by the Air module, the Regional Watershed (RW) module, and two source modules: the Wastepile and Land Application Unit. The Air (Ar) module provides air concentrations and deposition rates relevant to plant loadings. The RW module provides surficial and depth-averaged soil concentrations for watersheds within the AOI, and the source modules provide soil concentrations within the drainage sub-basin that includes the source. The average chemical concentration in soil calculated for a given home range may include contributions from regional watersheds as well as from a source-related drainage sub-basin (referred to as the local watershed). These inputs include:

Air Module

- vapor concentration for each home range and habitat within the AOI
- wet vapor deposition rate for each home range and habitat within the AOI
- dry particle deposition rate for each home range and habitat within the AOI
- wet particle deposition rate for each home range and habitat within the AOI

Regional Watershed

- surficial soil concentration for each watershed within the AOI
- depth-averaged soil concentration for each watershed within the AOI

Source Modules

- surficial soil concentration for the each local watershed within the AOI
- depth-averaged soil concentration for each local watershed within the AOI

The terrestrial food web module receives inputs from its module-specific input file (tf.ssf), the generic site layout file (sl.ssf), the generic chemical properties file (cp.ssf), and modeled inputs from the following other modules: air module (ar.grf), watershed module (ws.grf), and those source modules outputting to a common grf file (sr.grf) a “true” for the soil-presence logical flag, SrcSoil. These sources are the land application unit, landfill, wastepile, and surface impoundment. The soil, plant, invertebrate, and worm concentration outputs are three-dimensional arrays indexed on time, space, and receptor. The small birds, small herpetofauna, small mammals, herbiverts, and omniverts are two-dimensional arrays indexed on time and space. All input variables are listed and described in Table D-17.

D.8.4 Outputs from the Terrestrial Food Web Module

The terrestrial food web module outputs are written to the tf.grf file. All output variables are listed and described in Table D-18.

Table D-17. Summary of Inputs for the Terrestrial Food Web Module

File	Input Parameters	Units	Description
tf.ssf	*Bv_ecf_plant*	unitless	Empirical correction factor for Bv.
tf.ssf	*Fw_<plant type>*	unitless	Fraction of wet deposition that adheres to the plant. (Note: "<plant type>" is replaced with exfruit, exveg, forage, and silage.)
tf.ssf	*MAF<plant type>*	percent	Moisture adjustment factor to convert DW into WW. (Note: "<plant type>" is replaced with exfruit, exveg, leaf, profruit, proveg, and root.)
tf.ssf	*MAFleaf*	percent	Moisture content in leaf.
tf.ssf	*rho_leaf*	g/L	Density of the leaf.
tf.ssf	*Rp_<plant type>*	unitless	Interception fraction. (Note: "<plant type>" is replaced with exfruit, exveg, forage, and silage.)
tf.ssf	*tp_<plant type>*	year	Length of plant exposure to deposition. (Note: "<plant type>" is replaced with exfruit, exveg, forage, and silage.)
tf.ssf	*VapDdv*	cen/sec	Vapor phase dry deposition velocity.
tf.ssf	*VGag_<plant type>*	unitless	Empirical correction factor. (Note: "<plant type>" is replaced with exfruit, exveg, forage, and silage.)
tf.ssf	*VGbg_root*	unitless	Empirical correction factor for roots.
tf.ssf	*Yp_<plant type>*	kg DW/m^2	Yield or standing crop biomass. (Note: "<plant type>" is replaced with exfruit, exveg, forage, and silage.)
sl.ssf	*focS*	mass fraction	Fraction organic carbon (soil).
sl.ssf	*HabRangeAirIndex*	NA	Index of air points that impacts a home range.
sl.ssf	*HabRangeAirFrac*	fraction	Fraction of home range impacted by air points.
sl.ssf	*HabRangeNumWSSub*	unitless	Number of watersheds that impact a home range.
sl.ssf	*HabRangeLWSSubAFrac*	fraction	Fraction of contributing local watershed subarea.
sl.ssf	*HabRangeWSSubFrac*	fraction	Fraction of home range impacted by watershed.
cp.ssf	*ChemBAF<animal>*	unitless	Bioaccumulation factor for small birds, herbiverts, small herpetofauna, invertebrates, small mammals, omniverts, and worms.
cp.ssf	*ChemBr_<plant type>*	(μg/g DW plant) / (μg/g soil)	Soil-to-plant bioconcentration factor. (Note: "<plant type>" is replaced with exfruit, exveg, forage, grain, profruit, proveg, root, and silage.)
cp.ssf	*ChemBv_ecf_plant*	unitless	Empirical correction factor for Bv.
cp.ssf	*ChemBv_<plant type>*	(μg/g DW plant) / (μg/g air)	Mass-based air-to-plant biotransfer factor. (Note: "<plant type>" is replaced with exfruit, exveg, forage, and silage.)

(continued)

Table D-17. (continued)

File	Input Parameters	Units	Description
cp.ssf	*ChemHLC*	(atm-m^3) / mol	Henry's law constant.
cp.ssf	*ChemKoc*	mL/g	Organic carbon partition coefficient
cp.ssf	*ChemKow*	unitless	Octanol/water partition coefficient
cp.ssf	*ChemkpPar_<plant type>*	1/ year	Plant surface loss of particulate-bound constituent. (Note: "<plant type>" is replaced with exfruit, exveg, forage, and silage.)
cp.ssf	*ChemkpVap_<plant type>*	1/ year	Degradation loss of vapor phase constituents. (Note: "<plant type>" is replaced with exfruit, exveg, forage, and silage.)
cp.ssf	*ChemRCF*	(μg/g WW plant) / (μg/mL sl water)	Root concentration factor.
cp.ssf	*ChemType*	NA	Chemical type (O, M, Hg, S, or D)
ar.grf	*CVap*	μg/m3	Concentration of chemical in air vapor.
ar.grf	*CVapNY*	unitless	Number of years in the time series corresponding to this variable.
ar.grf	*CVapYR*	year	Time series of years corresponding to this variable.
ar.grf	*ParDDep*	g/m2/d	Particle dry deposition rate.
ar.grf	*ParDDepNY*	unitless	Number of years in the time series corresponding to this variable.
ar.grf	*ParDDepYR*	year	Time series of years corresponding to this variable.
ar.grf	*ParWDep*	g/m2/d	Particle wet deposition rate.
ar.grf	*ParWDepNY*	unitless	Number of years in the time series corresponding to this variable.
ar.grf	*ParWDepYR*	year	Time series of years corresponding to this variable.
ar.grf	*VapWDep*	g/m2/d	Vapor wet deposition rate.
ar.grf	*VapWDepNY*	unitless	Number of years in the time series corresponding to this variable.
ar.grf	*VapWDepYR*	year	Time series of years corresponding to this variable.
sr.grf	*CTda*	μg/g	Depth-averaged soil concentration across farm area.
sr.grf	*CTdaNY*	year	Number of years in the time series corresponding to this variable.
sr.grf	*CTdaYR*	unitless	Time series of years corresponding to this variable.

(continued)

Table D-17. (continued)

File	Input Parameters	Units	Description
sr.grf	*CTss*	μg/g	Surficial soil concentration across farm area.
sr.grf	*CTssNY*	year	Number of years in the time series corresponding to this variable.
sr.grf	*CTssYR*	unitless	Time series of years corresponding to this variable.
ws.grf	*CTdaR*	μg/g	Depth-averaged soil concentration for the regional watershed area.
ws.grf	*CTdaRNY*	year	Number of years in the time series corresponding to this variable.
ws.grf	*CTdaRYR*	unitless	Time series of years corresponding to this variable.
ws.grf	*CTssR*	μg/g	Surface soil concentration for the regional watershed area.
ws.grf	*CTssRNY*	year	Number of years in the time series corresponding to this variable.
ws.grf	*CTssRYR*	unitless	Time series of years corresponding to this variable.

NA = not applicable

Table D-18. Summary of Outputs from the Terrestrial Food Web Module

File	Output Parameters	Units	Description
tf.grf	*C<animals>_<max or min>NY*	unitless	Number of years in the time series corresponding to this variable.
tf.grf	*C<animals>_<max or min>*	mg/kg	Concentration of contaminant found in herbiverts and omniverts.
tf.grf	*C<animals>_<max or min>YR*	year	Time series of years corresponding to this variable.
tf.grf	*C<animals>_HabRange*	mg/kg	Concentration of contaminant found in invertebrates and worms.
tf.grf	*C<animals>_HabRangeNY*	unitless	Number of years in the time series corresponding to this variable.
tf.grf	*C<animals>_HabRangeYR*	year	Time series of years corresponding to this variable.
tf.grf	*C<animals>_sm_<max or min>*	mg/kg	Concentration of contaminant found in small birds, herpetofauna, and mammals.
tf.grf	*C<animals>_sm_<max or min>YR*	year	Time series of years corresponding to this variable.
tf.grf	*C<animals>_sm_<max or min>NY*	unitless	Number of years in the time series corresponding to this variable.
tf.grf	*CTdaAveHabRange*	μg/g	Average depth average soil concentration in each home range.
tf.grf	*CtdaAveHabRangeNY*	unitless	Number of years in the time series corresponding to this variable.
tf.grf	*CTdaAveHabRangeYR*	year	Time series of years corresponding to this variable.
tf.grf	*CTssAveHabRange*	μg/g	Average depth average soil concentration in each home range.
tf.grf	*CTssAveHabRangeNY*	unitless	Number of years in the time series corresponding to this variable.
tf.grf	*CTssAveHabRangeYR*	year	Time series of years corresponding to this variable.
tf.grf	*P<plant type>_HabRangeNY*	unitless	Number of years in the time series corresponding to this variable.
tf.grf	*P<plant type>_HabRangeYR*	year	Time series of years corresponding to this variable.
tf.grf	*P<plant type>_HabRange*	mg/kg	Concentration of contaminant found in exfruit, exveg, forage, grain, root, and silage.

D.9 Aquatic Food Web Module

The aquatic food web (AqFW) module calculates chemical concentrations in aquatic organisms that are consumed by human and ecological receptors (e.g., fish filet; aquatic macrophytes). These concentrations are used as input to the human and ecological exposure modules to determine the applied dose to receptors of interest. The module is designed to predict concentrations in aquatic organisms for cold water and warm water aquatic habitats. It uses both property-based calculations and empirical data to estimate uptake and accumulation. Addition detail on the model design and construction, including governing equations, may be found in U.S. EPA (1999o).

D.9.1 Functionality

The major computational functions performed by the Aquatic Food Web module can be summarized as follows:

- *Time series management*. The AqFW module determines the overall duration of the time period to be simulated (including concentration data from discontinuous time periods) and identifies the individual years within the overall duration that will be simulated.

- *Module loops over the time series, through aquatic habitats, and reaches.* The AqFW module has three basic loops: (1) over the time series, (2) over each aquatic habitat delineated at the site, and (3) over the "fishable" reaches within each aquatic habitat. The module considers all reach order 3 streams, ponds, lakes, and certain types of permanently flooded wetlands as fishable by human and ecological receptors.

- *Calculation of time series tissue concentrations for fish and other aquatic organisms.* The AqFW module predicts concentrations for each year of the simulation for aquatic organisms assigned to each habitat. These concentrations are defined spatially for each reach even though a stream habitat or wetland may contain multiple reaches.[4] Similarly, the module predicts concentrations in ponds and lakes as though the system is fully mixed and at steady state.

The major steps performed by the Aquatic Food Web module that are required to predict concentrations in aquatic organisms may be summarized as follows:

- Select fishable reach of interest (i.e., stream or wetland reach, pond, or lake).

- Determine temperature and set aquatic habitat type (e.g., cold water stream).

- Construct dietary matrix for fish in aquatic habitat.

[4] Reaches are defined in the site layout file and modeled by the Surface Water module as homogeneous segments (i.e., there is no concentration gradient throughout the reach).

Calculate whole-body tissue concentrations (for ecological receptors)

- Identify chemical type (e.g., hydrophobic organic, metal, mercury).
- If chemical type is not readily metabolizable (i.e., special), check K_{ow} value.
- If chemical is hydrophobic (log $K_{ow} \geq 4.0$ is true), run matrix solution to estimate whole-body tissue concentrations.
- If chemical is hydrophilic (log $K_{ow} < 4.0$ is true), run regression models to estimate whole-body tissue concentrations.
- If chemical is metal, readily metabolizable, or mercury, get empirical bioaccumulation data and calculate whole-body tissue concentrations.

Calculate filet concentrations (for human receptors).

D.9.2 Assumptions and Limitations

The methodology used in the aquatic food web module reflects a number of assumptions and/or limitations, which are listed below. It should be noted that, because the AqFW module relies on the surface water module (U.S. EPA, 1999p) to provide concentrations in surface water and sediment, the assumptions and limitations identified for the SW module are relevant to the AqFW module. For example, the SW module provides annualized average concentrations for stream reaches and other waterbodies. Consequently, the methods developed to estimate tissue concentrations in aquatic organisms were developed to be use the annual average surface water concentrations predicted with the SW model. The assumptions and limitations implicit in the SW module are not discussed in this section.

D.9.2.1 Assumptions

*Study area is bounded at 2 km.* EPA assumed that significant exposures to source-related contaminants do not occur for ecological receptors that are beyond 2 km of the source. Consequently, concentrations were not calculated in aquatic organisms in waterbodies outside of the study area, measured from the corner of the source to a point 2 km away.

*All waterbodies that define aquatic habitats are fishable.* The module assumes that all third order stream reaches (and above), ponds, lakes, and certain permanently flooded wetlands support a multi-compartment aquatic food web. The simple food webs developed for each of these aquatic habitats provide a useful framework for predicting tissue concentrations in aquatic organisms for a national assessment. Nevertheless, it is a certainty that not all of the waterbodies designated as fishable in this analysis will be of sufficient quality to sustain a multi-compartment food web.

- *Variability in aquatic systems is reasonably represented.* The underlying framework developed for the AqFW module (as applied in a national analysis) is the eight representative aquatic habitats. It is implicitly assumed that these eight habitats provide adequate resolution of the major types of freshwater systems within the constraints of available data and modeling tools.

- *Hydrophobic organics may be defined as organic chemicals with log $K_{ow} \geq 4.0$.* Although a strict definition for hydrophobic organics has not appeared in the literature, the AqFW module assumes that a reasonable cutoff is a log K_{ow} value of 4.0. Comparisons of predicted bioaccumulation factors (BAFs) derived with mechanistic models versus BAFs derived using regression equations suggests that, below log $K_{ow} = 4.0$, the difference in BAF estimates is below the level of resolution that these models are capable of.

- *The model construct is applicable to waterbodies other than coldwater lakes.* A number of journal articles (e.g., Morrison et al., 1997) and reference texts (e.g., Rand, 1995) were reviewed in evaluating appropriate mechanistic models to simulate the uptake and accumulation of hydrophobic organics in aquatic organisms. From that review, it was determined that the underlying theory for these models is remarkably similar and that there is no inherent advantage in selecting one model over another. Although the Gobas (1993) model was calibrated for coldwater lakes (i.e., Lake Ontario), it was determined that this model construct was appropriate for use on other aquatic systems under the general assumption of steady-state conditions.

D.9.2.2 Limitations

- *Steady-state conditions are generally assumed.* Because annual average concentrations are provided by the SW module, the AqFW module assumes steady-state conditions. As a result, the module can not be used to evaluate the impacts from storm events nor can it be used to distinguish the impacts on tissue concentrations from peak events and subsequent averaging from long-term, low-level exposures. For example, a storm event may contaminate a given reach for relatively short periods of time, probably well below the duration required for organisms to reach steady-state for most chemicals.

- *The module relies heavily on empirical data for many chemicals.* For chemicals that have not been shown to be readily metabolizable (e.g., other than PAHs, selected phthalates), mechanistic models are not used to predict tissue concentrations. Hence, the AqFW module estimates tissue concentrations by multiplying empirical factors (primarily bioconcentration factors, or BCFs) by water concentrations. As discussed in the data collection documentation on the AqFW parameters, these BCFs are measured under conditions that may not be relevant to all possible conditions (and species) included in the analysis.

- *The module does not allow for separate treatment of essential metals.* Bioconcentration of essential metals is not linear and modeling approaches are available to account for nonlinearity (see Bergman and Dorward-King, 1997). Bioconcentration of essential metals tends to be much greater at low concentrations than at higher concentrations since organisms actively seek to sequester necessary nutrients. Because many metals are regulated in biological systems, the apparent bioconcentration of metals at low concentrations may simply result in metal accumulation at "healthy" levels.

- *The module currently lacks the capability to use sediment concentrations directly in predicting tissue concentrations.* The AqFW module was developed, primarily, to utilize dissolved and total contaminant concentrations to predict tissue concentrations. Although sediment concentrations are used in predicting uptake and accumulation into benthic dwellers, the AqFW module lacks the necessary algorithms to use these data directly to predict concentrations in plants or fish. For certain constituents (e.g., dioxins), it may be useful to build this functionality into the module to provide greater flexibility in data use.

- *The module has not been validated in field studies.* Much of the modeling theory on which the AqFW module is based is widely accepted and has been used in numerous analyses. In particular, the methods used to predict concentrations of hydrophobic organics have been validated in coldwater lakes. However, the module has not been validated for other freshwater aquatic habitats, nor has it been validated *in toto* for application in a national-scale analysis.

D.9.3 Inputs

The only concentration inputs required by the AqFW module are provided by the surface water module (SW). These inputs include:

- average, reach-specific total concentration in sediment
- average, reach-specific total concentration in surface water
- average, reach-specific dissolved concentration in surface water

The aquatic food web module receives inputs from its module-specific input file, af.ssf, the generic site layout file (sl.ssf), the chemical properties file (cp.ssf), and modeled inputs from the surface water module (sw.grf). All AqFW module outputs are 3-dimensional arrays indexed on time, waterbody network, and reach. Input variables are listed and described in Table D-19.

D.9.4 Outputs from the Aquatic Food Web Module

The aquatic food web module outputs are written to the af.grf file. Output variables are listed and described in Table D-20.

Table D-19. Summary of Inputs for the Aquatic Food Web Module

File	Input Parameters	Units	Description
af.ssf	*a_fish*	unitless	Slope of BCF regression equation across all tissues in fish.
af.ssf	*a_mus*	unitless	Slope of BCF regression equation for muscle tissue in fish.
af.ssf	*b_fish*	unitless	Slope (2) of BCF regression equation across all tissues in fish.
af.ssf	*b_mus*	unitless	Slope (2) of BCF regression equation for muscle tissue in fish.
af.ssf	*BiotaTypeIndex*	unitless	Numerical index of each biota type.
af.ssf	*BwFish*	unitless	Fish body weight.
af.ssf	*c_fish*	unitless	Error term in BCF regression equation across all tissues in fish.
af.ssf	*c_mus*	unitless	Error term in BCF regression equation for muscle tissues in fish.
af.ssf	*FiletFrac*	unitless	Fraction of fish that is a filet based on lipid content.
af.ssf	*FishWaterFrac*	unitless	Water fraction across all tissues of fish.
af.ssf	*LipFrac*	unitless	Lipid fraction.
af.ssf	*LipFracMus*	unitless	Lipid fraction in fish muscle.
af.ssf	*MaxPreyPref*	unitless	Maximum dietary preference for item in the aquatic food web.
af.ssf	*MinPreyPref*	unitless	Minimum dietary preference for item in the aquatic food web.
af.ssf	*MusWaterFrac*	unitless	Water fraction in muscle of fish.
af.ssf	*NumBiotaTypes*	unitless	Number of biota types in the aquatic food web.
af.ssf	*rho_lip*	kg/L	Density of organic carbon.
af.ssf	*rho_oc*	kg/L	Density of lipids.
af.ssf	*T3EdibleFish*	unitless	Edible trophic level 3 fish for human consumption.
af.ssf	*T3NumEdibleFish*	unitless	Number of edible trophic level 3 fish in the aquatic food web.
af.ssf	*T3NumFish*	unitless	Number of trophic level 3 fish in the aquatic food web.
sl.ssf	*NumWBN*	unitless	Number of waterbody networks.
sl.ssf	*WBNFishableRchIndex*	unitless	Index of reaches that are fishable.
sl.ssf	*WBNNumFishableRch*	unitless	Number of fishable reaches.

(continued)

Table D-19. (continued)

File	Input Parameters	Units	Description
sl.ssf	*WBNRchArea*	m^2	Reach surface area.
sl.ssf	*WBNRchOrder*	unitless	Reach order of stream.
sl.ssf	*WBNRchBodyType*	unitless	Type of waterbody (e.g., pond, stream).
sl.ssf	*WBNTemp*	degrees Celsius	Median temperature of waterbody network.
sl.ssf	*WBNTempMax*	degrees Celsius	Maximum temperature of reaches in the waterbody network.
cp.ssf	*ChemT3musBAFm*	L/kg ww	Empirical bioaccumulation factor in filet of TL3 fish.
cp.ssf	*ChemT3fishBAFm*	L/kg ww	Empirical bioaccumulation factor in whole-body of TL3 fish.
cp.ssf	*ChemT4musBAFm*	L/kg ww	Empirical bioaccumulation factor in filet of TL4 fish.
cp.ssf	*ChemT4fishBAFm*	L/kg ww	Empirical bioaccumulation factor in whole-body of TL4 fish.
cp.ssf	*ChemaqmpBCFm*	L/kg ww	Empirical bioconcentration factor for aquatic macrophytes.
cp.ssf	*ChembenthffBAFm*	L/kg ww	Empirical bioaccumulation factor in benthic filter feeders.
cp.ssf	*ChemKm*	1/day	Metabolic rate constant for fish.
cp.ssf	*ChemKow*	unitless	Octanol/water partition coefficient.
cp.ssf	*ChemType*	NA	Chemical Type
sw.grf	*WBNConcBenthTot*	μg/g	Concentration of contaminant in benthic solids.
sw.grf	*WBNConcBenthTotNY*	unitless	Number of years in the time series corresponding to this variable.
sw.grf	*WBNConcBenthTotYR*	year	Time series of years corresponding to this variable.
sw.grf	*WBNConcWaterTot*	mg/L	Total contaminant concentration in surface water.
sw.grf	*WBNConcWaterTotNY*	unitless	Number of years in the time series corresponding to this variable.
sw.grf	*WBNConcWaterTotYR*	year	Time series of years corresponding to this variable.
sw.grf	*WBNConcWaterDiss*	mg/L	Freely dissolved contaminant concentration in surface water.
sw.grf	*WBNConcWaterDissNY*	unitless	Number of years in the time series corresponding to this variable.
sw.grf	*WBNConcWaterDissYR*	year	Time series of years corresponding to this variable.
sw.grf	*WBNfocBenth*	fraction	Benthivore fraction of organic carbon.

(continued)

Table D-19. (continued)

File	Input Parameters	Units	Description
sw.grf	*WBNfocBenthNY*	unitless	Number of years in the time series corresponding to this variable.
sw.grf	*WBNfocBenthYR*	year	Time series of years corresponding to this variable.

NA = not applicable

Table D-20. Summary of Outputs for the Aquatic Food Web Module

File	Code	Units	Description
af.grf	*Caqmp*	mg/kg ww	Concentration of contaminant in aquatic plants.
af.grf	*CaqmpNY*	unitless	Number of years in the time series corresponding to this variable.
af.grf	*CaqmpYR*	year	Time series of years corresponding to this variable.
af.grf	*Cbenthff*	mg/kg ww	Concentration of contaminant in benthic filter feeders.
af.grf	*CbenthffNY*	unitless	Number of years in the time series corresponding to this variable.
af.grf	*CbenthffYR*	year	Time series of years corresponding to this variable.
af.grf	*CT3Filet*	mg/kg ww	Concentration in filet of contaminant in TL3 fish.
af.grf	*CT3FiletNY*	unitless	Number of years in the time series corresponding to this variable.
af.grf	*CT3FiletYR*	year	Time series of years corresponding to this variable.
af.grf	*CT3Fish*	mg/kg ww	Whole-body concentration of contaminant in TL3 fish.
af.grf	*CT3FishNY*	unitless	Number of years in the time series corresponding to this variable.
af.grf	*CT3FishYR*	year	Time series of years corresponding to this variable.
af.grf	*CT4Filet*	mg/kg ww	Concentration in filet of contaminant in TL4 fish.
af.grf	*CT4FiletNY*	unitless	Number of years in the time series corresponding to this variable.
af.grf	*CT4FiletYR*	year	Time series of years corresponding to this variable.
af.grf	*CT4Fish*	mg/kg ww	Whole-body concentration of contaminant in TL4 fish.
af.grf	*CT4FishNY*	unitless	Number of years in the time series corresponding to this variable.
af.grf	*CT4FishYR*	year	Time series of years corresponding to this variable.

D.10 Human Exposure Module

The human exposure module calculates the applied dose (mg of constituent per kg of body weight), to human receptors from media and food concentrations calculated by other modules in the multimedia, multipathway and multiple receptor risk assessment (3MRA) methodology. These calculations are performed for each receptor, cohort, exposure pathway, and year at each exposure area.[5] The human exposure module calculates exposures for two basic receptor types: residential receptors (residents and home gardeners) and farmers. Residential receptors may also be recreational fishers in addition to being a resident or home gardener. Farmers may be beef farmers or dairy farmers, and either type of farmer may also be a recreational fisher. The subcategories within residential receptors and farmers differ in the particular exposures they incur. For example, a resident (only) differs from a home gardener in that home gardeners are exposed to contaminated fruits and vegetables, but residents are not. Within each of the two basic receptor types, the human exposure module calculates exposures for 5 age cohorts: infants (ages 0-1 year), children ages 1-5 years, children ages 6-11 years, children ages 12-19 years, and adults (ages 20 years and up). Additional detail about the background and implementation of the model is available in U.S. EPA (1999q).

D.10.1 Functionality

The major computational functions performed by the human exposure module are the following:

- *Time series management*. The human exposure module determines the overall duration of the time period to be simulated, which could possibly be discontinuous, and the individual years within this duration to be simulated.

- *Calculation of time series exposure concentrations and doses from time series media and food concentrations*. This is the fundamental purpose of the human exposure module and is performed by a set of equations specific to each exposure pathway and carcinogenic/noncarcinogenic chemical property.

Exposure to humans other than infants may occur through eight pathways: inhalation of ambient air, inhalation of shower air, ingestion of groundwater, ingestion of soil, ingestion of fruits and vegetables, ingestion of beef, ingestion of milk, and ingestion of fish. However, not all receptors are exposed via all of these pathways. Residents are exposed via inhalation of ambient air, inhalation of shower air, ingestion of groundwater, and ingestion of soil. Home gardeners have the same exposures as a resident, plus exposure via ingestion of fruits and vegetables. All farmers are exposed via inhalation of ambient air, inhalation of shower air, ingestion of groundwater, ingestion of soil, and ingestion of fruits and vegetables. In addition, beef farmers are exposed via ingestion of beef, and dairy farmers are exposed via ingestion of milk. Recreational fishers have the same exposures as one of the other receptor types plus fish ingestion. Not all age cohorts are exposed via all pathways; shower exposures are calculated only for adults and children ages 12 to 19 years.

[5] See Section 3.3.10 for the list of receptors and cohorts and applicable exposure pathways.

The media inputs for which the human exposure module calculates exposure concentrations and doses include ambient air concentration (both vapor and particulate), soil concentration, groundwater concentration, exposed vegetable concentration, protected vegetable concentration, exposed fruit concentration, protected fruit concentration, root vegetable concentration, beef concentration, milk concentration, and fish filet concentration for trophic level 3 and trophic level 4 fish. For vegetables and fruits, the terms "exposed" and "protected" refer to whether the edible portion of the plant is exposed to the atmosphere.

Infant exposure occurs via breast milk ingestion. The human exposure module tracks noninfant exposure by the eight pathways described above. For infant exposure via breast milk, the maternal exposure via all pathways must be summed. Therefore, infant exposures are calculated for eight maternal exposure configurations: resident, home gardener, beef farmer, dairy farmer, resident/recreational fisher, home gardener/recreational fisher, beef farmer/recreational fisher, and dairy farmer/recreational fisher. The mother is assumed to be an adult (as opposed to a teenager) for the purpose of calculating maternal dose in the infant breast milk pathway.

D.10.2 Assumptions and Limitations

The exposure characterization methodology used in the human exposure module reflects a number of assumptions and/or limitations, which are listed below.

- Study area is bounded at 2 km. EPA assumed that all significant exposure by human receptors occurs within 2 km of the source. Exposures are not evaluated for individuals residing outside of the 2-km study area, measured from the source periphery.

- *Human receptors are stationary.* EPA assumed in characterizing exposure that human receptors both reside and work at the receptor location identified for them during site characterization (i.e., the farm area for farmers or residential exposure area for nonfarmers). The point of exposure is, in general, the census block centroid for a resident and home gardener and the centroid of a farm for farmers. This assumption may overestimate or underestimate exposure, because it is possible that individuals may reside at the identified location within the study area but commute to work areas outside of the study area or could commute to more or less contaminated areas within the study area.

- *Incremental exposure is modeled*. The HWIR model generates incremental exposures in accordance with standard practice. No provision is made for considering background exposures for the purpose of generating cummulative or total risk, HQ, or MOE estimates for modeled receptors.

- *Homogeneous concentrations in fruits and vegetables are assumed*. The exposure methodology makes no provision for possible chemical concentration gradients within fruits or vegetables that might result in different concentrations in edible portions than when averaged throughout the food item.

- *Food preparation has no effect*. No diminution of chemical concentration in food items is assumed to occur through food preparation, e.g., washing of fruits and vegetables.

- Annual average concentrations/doses for exposure. No shorter term average or spikes evaluated. All outputs from this module are on an annual basis.

- Ingestion rates are age cohort specific. The ingestion and inhalation rates, as well as body weight, are based on the age cohort. For example, a 1 to 5-year-old child would ingest less water on a daily basis then a 6- to 10-year-old child.

D.10.3 Inputs for the Human Exposure Module

The human exposure module receives inputs from its module-specific input file, he.ssf, the generic site layout file (sl.ssf), the generic chemical properties file (cp.ssf), and the following modeled outputs from other 3MRA modules: ground water concentrations from the aquifer module (aq.grf); fish filet concentration for trophic level 3 and trophic level 4 fish from the aquatic food web module (af.grf); exposed vegetable concentration, protected vegetable concentration, exposed fruit concentration, protected fruit concentration, root vegetable concentration, beef concentration, and milk concentration from the farm food chain module (ff.grf)[6]; soil concentrations from the watershed module (ws.grf); ambient air concentration (both vapor and particulate) from the air module (ar.grf); and soil concentrations from those source modules outputting (to a common grf file, sr.grf) a "true" for the soil-presence logical flag, *SrcSoil*. (SrcSoil = true signifies that contaminated soil is present, which is an exposure pathway.) These sources are the land application unit, landfill, wastepile, and surface impoundment. All input variables for the human exposure module are listed and described in Table D-21.

D.10.4 Outputs from the Human Exposure Module

Human exposure module outputs are written to the he.grf file. All exposure outputs except infant breastmilk exposures are three-dimensional arrays indexed on time, space, and age cohort. The spatial component may be x-y coordinate representing receptor locations as the centroid of a census block or farm represented by a set of x,y coordinates. Infant breast milk exposures are two-dimensional arrays on time and space. They apply to only one age cohort, infants, so there is no third dimension. Output variables are listed and described in Table D-22.

[6] For vegetables and fruits, the terms "exposed" and "protected" refer to whether the edible portion of the plant is exposed to the atmosphere.

Table D-21. Summary of Input Parameters for the Human Exposure Module

File	Input Parameter	Units	Description
he.ssf	*Bri_<cr#>*	m^3/d	Cohort-specific inhalation rate for the four child resident cohorts (Note: "<cr#>" is replaced with the actual cohort designation in the variables used by the human exposure module)
he.ssf	*Bri_r*	m^3/d	Inhalation rate for the adult resident.
he.ssf	*BW<cr#>*	kg	Cohort-specific body weight for each of the four child cohorts (Note: this parameter is not differentiated for farmer versus non-farmer receptor)
he.ssf	*BW_r*	kg	Body weight for adult receptors
he.ssf	*CRb_cf_<#>*	gWW/kg/d	Beef consumption rate for the three farmer child cohorts 2-4 (Note: "<#>" is replaced with the actual cohort number in the variables used by the human exposure module)
he.ssf	*CRb_af*	gWW/kg/d	Beef consumption rate for the adult farmer
he.ssf	*CRbm_cf_1*	mL/d	Breast milk ingestion rate for the farmer infant
he.ssf	*CRfr_cf_<#>*	gWW/kg/d	Exposed fruit consumption rate for the three farmer child cohorts 2-4 (Note: "<#>" is replaced with the actual cohort number in the variables used by the human exposure module)
he.ssf	*CRfr_f*	gWW/kg/d	Exposed fruit consumption rate for the adult farmer
he.ssf	*CRfr_cg_<#>*	gWW/kg/d	Exposed fruit consumption rate for the three gardener child cohorts 2-4 (Note: "<#>" is replaced with the actual cohort number in the variables used by the human exposure module)
he.ssf	*CRfr_g*	gWW/kg/d	Exposed fruit consumption rate for the adult gardener
he.ssf	*CRfs_c_<#>*	gWW/kg/d	Home-caught fish consumption rate for the three child cohorts 2-4 (Note: "<#>" is replaced with the actual cohort number in the variables used by the human exposure module)
he.ssf	*CRfs_a*	gWW/kg/d	Home-caught fish consumption rate for the adult
he.ssf	*CRl_cf_-#-*	gWW/kg/d	Exposed vegetables consumption rate for the three farmer child cohorts 2-4 (Note: "<#>" is replaced with the actual cohort number in the variables used by the human exposure module)
he.ssf	*CRl_f*	gWW/kg/d	Exposed vegetables consumption rate for the adult farmer

(continued)

Table D-21. (continued)

File	Input Parameter	Units	Description
he.ssf	*CRl_cg_<#>*	gWW/kg/d	Exposed vegetables consumption rate for the three gardener child cohorts 2-4 (Note: "<#>" is replaced with the actual cohort number in the variables used by the human exposure module)
he.ssf	*CRl_g*	gWW/kg/d	Exposed vegetables consumption rate for the adult gardener
he.ssf	*CRpfr_cf_<#>*	gWW/kg/d	Protected fruit consumption rate for the three farmer child cohorts 2-4 (Note: "<#>" is replaced with the actual cohort number in the variables used by the human exposure module)
he.ssf	*CRpfr_f*	gWW/kg/d	Protected fruit consumption rate for the adult farmer
he.ssf	*CRpfr_cg_<#>*	gWW/kg/d	Protected fruit consumption rate for the three gardener child cohorts 2-4 (Note: "<#>" is replaced with the actual cohort number in the variables used by the human exposure module)
he.ssf	*CRpfr_g*	gWW/kg/d	Protected fruit consumption rate for the adult gardener
he.ssf	*CRpl_cf_<#>*	gWW/kg/d	Protected vegetables consumption rate for the three farmer child cohorts 2-4 (Note: "<#>" is replaced with the actual cohort number in the variables used by the human exposure module)
he.ssf	*CRpl_f*	gWW/kg/d	Protected vegetables consumption rate for the adult farmer
he.ssf	*CRpl_cg_<#>*	gWW/kg/d	Protected vegetables consumption rate for the three gardener child cohorts 2-4 (Note: "<#>" is replaced with the actual cohort number in the variables used by the human exposure module)
he.ssf	*CRpl_g*	gWW/kg/d	Root vegetables consumption rate for the adult gardener
he.ssf	*CRr_cf_<#>*	gWW/kg/d	Root vegetables consumption rate for the three farmer child cohorts 2-4 (Note: "<#>" is replaced with the actual cohort number in the variables used by the human exposure module)
he.ssf	*CRr_f*	gWW/kg/d	Root vegetables consumption rate for the adult farmer
he.ssf	*CRr_cg_<#>*	gWW/kg/d	Root vegetables consumption rate for the three gardener child cohorts 2-4 (Note: "<#>" is replaced with the actual cohort number in the variables used by the human exposure module)
he.ssf	*CRr_g*	gWW/kg/d	Root vegetables consumption rate for the adult gardener

(continued)

Table D-21. (continued)

File	Input Parameter	Units	Description
he.ssf	*CRw_cr_<#>*	gWW/kg/d	Drinking water consumption rate for the four child cohorts 1-4 (Note: "<#>" is replaced with the actual cohort number in the variables used by the human exposure module)
he.ssf	*CRw_r*	gWW/kg/d	Drinking water consumption rate for the adult receptor
he.ssf	*CRs_cr_<#>*	gWW/kg/d	Incidental soil ingestion rate for the three child cohorts 2-4 (Note: "<#>" is replaced with the actual cohort number in the variables used by the human exposure module)
he.ssf	*CRs_r*	gWW/kg/d	Incidental soil ingestion rate for the adult receptor
he.ssf	*CRm_cf_<#>*	gWW/kg/d	Milk consumption rate for the three child farmer cohorts 2-4 (Note: "<#>" is replaced with the actual cohort number in the variables used by the human exposure module)
he.ssf	*CRm_af*	gWW/kg/d	Milk consumption rate for the adult farmer receptor
he.ssf	*DD*	cm	Water droplet diameter
he.ssf	*EFr*	d/yr	Exposure frequency (adult resident)
he.ssf	*F<dietary item>_<receptor category>*	Unitless	Fraction of <dietary item> consumed (e.g., exposed fruit, exposed vegetables, beef, drinking water) that is contaminated (for the "f" farmer or "g" gardener). (Note: in the actual variable names, <dietary item> and <receptor category> are replaced with acronyms referring to appropriate terms - e.g., "m" for milk and "f" for farmer, respectively)
he.ssf	*fbp*	Unitless	Fraction of whole blood that is plasma
he.ssf	*ffm*	Unitless	Fraction of mother's weight that is fat
he.ssf	*fmbm*	Unitless	Fraction of fat in maternal breastmilk
he.ssf	*fpm*	Unitless	Fraction of mother's weight that is plasma
he.ssf	*Fs*	Unitless	Fraction of contaminated soil
he.ssf	*FT<#>fish*	Unitless	Fraction of fish consumed that is T# (i.e., T3 or T4)
he.ssf	*Hn*	cm	Shower nozzle height
he.ssf	*Rshower*	L/min	Shower rate
he.ssf	*t_sb*	min	Time in shower and bathroom
he.ssf	*t_shower*	min	Shower time
he.ssf	*Vbath*	m^3	Bathroom volume

(continued)

Table D-21. (continued)

File	Input Parameter	Units	Description
he.ssf	*Vn*	cm/s	Terminal velocity of shower droplet
he.ssf	*VRbh*	L/min	Bathroom to house ventilation rate
he.ssf	*Vrsb*	L/min	Shower to bathroom ventilation rate
he.ssf	*Vshower*	m^3	Shower volume
sl.ssf	*FarmAquIndex*	NA	Index of aquifer that impacts farm or crop area
sl.ssf	*FarmLWSIndex*	NA	Local watershed indices associated with each farm
sl.ssf	*FarmLWSSubAreaFrac*	Fraction	Fraction of contribution of subarea to farm
sl.ssf	*FarmLWSSubAreaIndex*	NA	Index of contributing subarea in local watershed indices associated with each farm
sl.ssf	*FarmNumLWSSubArea*	NA	Contributing subarea in local watershed indices associated with each farm
sl.ssf	*FarmNumWSSub*	Unitless	Number of watersheds that impact farm or crop area
sl.ssf	*FarmWBNIndex*	NA	Index of WBN that impacts farm or crop area
sl.ssf	*FarmWBNRchIndex*	NA	Index of WBN reach that impacts farm or crop area
sl.ssf	*FarmWSSubFrac*	Unitless	Fraction of each watershed on farm
sl.ssf	*FarmWSSubIndex*	NA	Index of watersheds that impact farm or crop area
sl.ssf	*focS*	Mass fraction	Fraction organic carbon (soil)
sl.ssf	*HumRcpAirIndex*	NA	Index of air points that impact receptor
sl.ssf	*HumRcpAquIndex*	Unitless	Index of aquifer that impacts receptor
sl.ssf	*HumRcpAquWellIndex*	Unitless	Index of well that impacts receptor for the given aquifer
sl.ssf	*HumRcpLWSIndex*	NA	Local watershed index for each human receptor
sl.ssf	*HumRcpLWSSubAreaInde*	NA	Local watershed subarea index for each human receptor
sl.ssf	*HumRcpPh*	pH units	Average shower water pH
sl.ssf	*HumRcpTemp*	° Celsius	Typical shower temperature
sl.ssf	*HumRcpWSSubIndex*	NA	Index of watershed that impacts receptor
sl.ssf	*NumFarm*	Unitless	Number of farm or crop areas
sl.ssf	*NumHumRcp*	Unitless	Number of human receptor points at a site
sl.ssf	*NumWBN*	Unitless	Number of waterbody networks
sl.ssf	*NyrMax*	Years	Maximum model simulation time

(continued)

Table D-21. (continued)

File	Input Parameter	Units	Description
sl.ssf	*TermFrac*	Fraction	Peak output fraction for simulation termination
sl.ssf	*WBNFishableRchIndex*	Unitless	Index of reaches that are fishable
sl.ssf	*WBNNumFishableRch*	Unitless	Number of fishable reaches
cp.ssf	*ChemBreast MilkExp*	Unitless	Causes breast milk exposure? (1=yes, 0=no)
cp.ssf	*ChemCSFfood*	$(mg/kg\text{-}d)^{-1}$	Cancer slope factor (food ingestion)
cp.ssf	*ChemCSFinhal*	$(mg/kg\text{-}d)^{-1}$	Cancer slope factor (inhalation)
cp.ssf	*ChemCSFwater*	$(mg/kg\text{-}d)^{-1}$	Cancer slope factor (drinking water ingestion)
cp.ssf	*ChemRfC*	mg/m^3	Reference concentration (inhalation)
cp.ssf	*ChemRfDfish*	mg/kg-d	Reference dose (fish ingestion)
cp.ssf	*ChemRfDfood*	mg/kg-d	Reference dose (food ingestion)
cp.ssf	*ChemRfDwater*	mg/kg-d	Reference dose (drinking water ingestion)
cp.ssf	*Chemfai*	Fraction	Fraction of ingested contaminant by the infant which is absorbed
cp.ssf	*ChemFam*	Fraction	Fraction of contaminant ingested by mother that is absorbed
cp.ssf	*ChemFbl*	Fraction	Fraction of contaminant in whole blood compartment
cp.ssf	*ChemFf*	Fraction	Fraction of contaminant stored in maternal fat
cp.ssf	*Chemkpm*	Unitless	Concentration proportionality constant between plasma and breast milk aqueous phase
cp.ssf	*ChemKrbc*	Unitless	Concentration proportionality constant between red blood cells and plasma
cp.ssf	*Chemt_halfb*	d	Biological half-life of chemical in lactating women
cp.ssf	*ChemADiff*	cm^2/s	Air diffusion coefficient
cp.ssf	*ChemHLC*	$(atm\ m^3)/mol$	Henry's law constant
cp.ssf	*ChemWDiff*	cm^2/s	Water diffusion coefficient
af.ssf	*CT3filet*	mg/kg WW	Chemical concentration in trophic level 3 fish filet
af.ssf	*CT4filet*	mg/kg WW	Chemical concentration in trophic level 4 fish filet
ff.ssf	*CTssAve_farm*	µg/g	Chemical concentration in surficial soil averaged over farm area

(continued)

Table D-21. (continued)

File	Input Parameter	Units	Description
ff.ssf	*CtssAve_farmYR*	Unitless	Time series of years corresponding to this variable
ff.ssf	*CTssAve_farmNY*	Unitless	Number of years in the time series corresponding to this variable
ff.ssf	*Abeef_farm*	mg/kg WW	Modeled beef concentration
ff.ssf	*Abeef_farmYR*	Unitless	Time series of years corresponding to this variable
ff.ssf	*Abeef_farmNY*	Unitless	Number of years in the time series corresponding to this variable
ff.ssf	*Amilk_farm*	mg/kg WW	Modeled milk concentration
ff.ssf	*Amilk_farmYR*	Unitless	Time series of years corresponding to this variable
ff.ssf	*Amilk_farmNY*	Unitless	Number of years in the time series corresponding to this variable
ff.ssf	*P<vegetable or fruit type>_farm*	mg/kg WW	Modeled concentration for specific fruit and vegetable categories (e.g., <vegetable or fruit type> would be replaced by: “exveg”, “proveg” or “root” for exposed vegetables, protected vegetables or root vegetables, respectively) raised on farms
ff.ssf	*P<vegetable or fruittype>_farmYR*	Unitless	Time series of years corresponding to this variable
ff.ssf	*P<vegetable or fruittype>_farmNY*	Unitless	Number of years in the time series corresponding to this variable
ff.ssf	*P<vegetable or fruittype>_garden*	mg/kg WW	Modeled concentration for specific fruit and vegetable categories (e.g., <vegetable or fruit type> would be replaced by: “exveg”, “proveg” or “root” for exposed vegetables, protected vegetables or root vegetables, respectively) raised in home gardens
ff.ssf	*P<vegetable or fruittype>_gardenYR*	Unitless	Time series of years corresponding to this variable
ff.ssf	*P<vegetable or fruittype>_gardenNY*	Unitless	Number of years in the time series corresponding to this variable
sr.ssf	*SrcSoil*	NA	Flag for soil presence
sr.ssf	*CTss*	µg/g	Soil concentration (annual average, all subareas)
sr.ssf	*CTssYR*	Unitless	Time series of years corresponding to this variable
sr.ssf	*CTssNY*	Unitless	Number of years in the time series corresponding to this variable

(continued)

Table D-21. (continued)

File	Input Parameter	Units	Description
ar.ssf	*PM10*	µg/m^3	Concentration of particles = 10 microns
ar.ssf	*PM10YR*	Unitless	Time series of years corresponding to this variable
ar.ssf	*PM10NY*	Unitless	Number of years in the time series corresponding to this variable
ar.ssf	*CVap*	µg/m^3	Concentration of chemical in air vapor
ar.ssf	*CVapYR*	Unitless	Time series of years corresponding to this variable
ar.ssf	*CVapNY*	Unitless	Number of years in the time series corresponding to this variable
ws.ssf	*CTssR*	µg/g	Surface soil concentrations for modeled watersheds
ws.ssf	*CTssYR*	Unitless	Time series of years corresponding to this variable
ws.ssf	*CTssNY*	Unitless	Number of years in the time series corresponding to this variable

NA = not applicable

Table D-22. Summary of Output Parameters for the Human Exposure Module

File	Input Parameter	Units	Description
he.grf	*IngBM<pathway>H*	mg/kg-d	Chemical- and pathway-specific average daily dose for the nonfarmer infant resulting from breast milk ingestion. (Note: "<pathway>" denotes the actual pathway name in the variables generated by the human exposure module.)
he.grf	*IngBM<pathway>HYR*	Unitless	Time series of years corresponding to this variable.
he.grf	*IngBM<pathway>HNY*	Unitless	Number of years in the time series corresponding to this variable
he.grf	*IngBM<pathway>F*	mg/kg-d	Chemical- and pathway-specific average daily dose for the farmer infant resulting from breast milk ingestion (Note: "<pathway>" denotes the actual pathway name in the variables generated by the human exposure module.)
he.grf	*IngBM<pathway>FYR*	Unitless	Time series of years corresponding to this variable
he.grf	*IngBM<pathway>FNY*	Unitless	Number of years in the time series corresponding to this variable
he.grf	*Cambient_Farm*	mg/m^3	Farm area-specific modeled ambient air concentration used in evaluating inhalation risk; separate estimates are generated for each modeled year
he.grf	*Cambient_FarmYR*	Unitless	Time series of years corresponding to this variable
he.grf	*Cambient_FarmNY*	Unitless	Number of years in the time series corresponding to this variable
he.grf	*Cambient_HumRcp*	mg/m^3	Residential location-specific modeled ambient air concentration used in evaluating inhalation risk; separate estimates are generated for each modeled year
he.grf	*Cambient_HumRcpYR*	Unitless	Time series of years corresponding to this variable
he.grf	*Cambient_HumRcpNY*	Unitless	Number of years in the time series corresponding to this variable
he.grf	*Csb_Farm*	mg/m^3	Farm area-specific modeled shower/bath air concentration used in evaluating inhalation risk; separate estimates are generated for each modeled year
he.grf	*Csb_FarmYR*	Unitless	Time series of years corresponding to this variable
he.grf	*Csb_FarmNY*	Unitless	Number of years in the time series corresponding to this variable
he.grf	*Csb_HumRcp*	mg/m^3	Residential location-specific modeled shower/bath air concentration used in evaluating inhalation risk; separate estimates are generated for each modeled year
he.grf	*Csb_HumRcpYR*	Unitless	Time series of years corresponding to this variable

(continued)

Table D-22. (continued)

File	Input Parameter	Units	Description
he.grf	*Csb_HumRcpNY*	Unitless	Number of years in the time series corresponding to this variable
he.grf	*Ing<pathway>_Farm*	mg/kg-d	Chemical- and pathway- specific average daily dose for the farmer resulting from ingestion of the dietary item identified as the "pathway" by the variable (Note: "<pathway>" denotes the actual pathway name in the variables generated by the human exposure module.)
he.grf	*Ing<pathway>_FarmYR*	Unitless	Time series of years corresponding to this variable
he.grf	*Ing<pathway>_FarmNY*	Unitless	Number of years in the time series corresponding to this variable
he.grf	*Ing<pathway>_HumRcp*	mg/kg-d	Chemical- and pathway- specific average daily dose for the non-farmer resulting from ingestion of the dietary item identified as the "pathway" by the variable (Note: "<pathway>" denotes the actual pathway name in the variables generated by the human exposure module.)
he.grf	*Ing<pathway>_HumRcp YR*	Unitless	Time series of years corresponding to this variable
he.grf	*Ing<pathway>_HumRcp NY*	Unitless	Number of years in the time series corresponding to this variable

D.11 Human Risk Module

The human risk module considers two basic human receptor types are considered: residential receptors (residents and home gardeners) and farmers. Residential receptors may also be recreational fishers in addition to being a resident or home gardener. Farmers may be beef farmers or dairy farmers, and either type of farmer may also be a recreational fisher. This results in eight categories of human receptors: resident, resident gardener, resident fisher, resident gardener fisher, beef farmer fisher, dairy farmer fisher, beef farmer, and dairy farmer.

The eight receptor categories were developed in consideration of exposure pathways; for example, a residential resident is a receptor that is exposed only to the baseline exposure pathways, i.e., inhalation via air and shower and ingestion via soil and water. A resident gardener is a resident exposed through these exposure pathways plus ingestion of homegrown produce.

The human exposure module's output has eight-receptor resolution; the human risk module calculates risks and/or HQs for each of these eight receptor categories but then aggregates these eight categories into four[7] composite receptor categories: resident, resident gardener, fisher, and farmer, for purposes of developing the cumulative population[8] frequency histograms and critical years. For example, the composite "fisher" receptor population consists of subpopulations from the resident fisher, resident gardener fisher, beef farmer fisher, and dairy farmer fisher receptor categories. Similarly, beef farmers and dairy farmers are aggregated into a single, composite "farmer." For every receptor type (four or eight), five age cohort classes are considered[9]: Child 1 (0 to 1 year old), Child 2 (1 to 5 years old), Child 3 (6 to 11 years old), Child 4 (12 to 19 years old), and Adult (greater than 19 years old). For the Child 1 (infant) cohort, only the breast milk pathway applies.[10] The margin of exposure [MOE] (mg/kg-d) for the infant breast milk pathway is analogous to HQ for infant breast milk exposure.

D.11.1 Functionality

The human risk module processes modeled outputs from the human exposure module (human receptor exposure estimates) and performs three major functions using these data:

[7] The 3MRA Exit Level Processor I (ELP I) preserves this receptor resolution, but also aggregates these four receptors into a fifth, "all receptors" category.

[8] Site-specific receptor populations were identified as part of the HWIR99 data collection activities and are specified by receptor category, exposure area (farm or census block), and distance ring. See US EPA (1999c) for discussion of the methodology.

[9] For purposes of storage efficiency, the ELP I combines the Child 2 and 3 cohort classes as output by the human risk module into a single composite cohort class (ages 1 to 11). Child 4 is also combined with the adult cohort class by the ELP I.

[10] For HWIR99, the infant breast milk pathway is evaluated only for a single chemical, the dioxin species 2,3,7,8 -TCDD TEQ [CAS No. 1746-01-6]. (That is, the logical flag *ChemBreastMilkExp* will be set to "true" only for this chemical in the chemical properties input file, cp.ssf.)

1. *It calculates risk and/or hazard quotient for each receptor, cohort, exposure pathway, exposure area, and year.* Whether risk, HQ, or both are calculated is determined as a function of the chemical under consideration. For carcinogenic chemicals, risks are calculated as average risks over a 9-year exposure duration. For noncarcinogens, HQs are calculated as a 1-year average.

2. *It constructs cumulative frequency histograms that quantify the distributions of receptor/cohort-specific populations among different levels of risk and/or HQ for each exposure pathway and aggregation of pathways[11] and year*. The populations consist of individual receptor/cohorts residing at the various exposure areas (residential areas and farms).

3. *It determines and outputs that critical year during which the maximum cumulative risk and/or HQ occurs across the population for each receptor/cohort combination and for each exposure pathway and pathway aggregation.*

These functions are performed three times, once for each of three radial distances outward from the centroid of the waste management unit. The purpose of distance-specific results is to assess the sensitivity of risk results to distance from the chemical source.

These functions are performed by the human risk module by a series of nested loops. Figures 3-17a through 3-17c illustrate the general looping structure used for a given radial distance. These illustrations are intended only to facilitate overall understanding of the module; the implementing computer code is significantly different to optimize performance.

D.11.2 Assumptions and Limitations

Calculations performed by the human risk module reflect a number of assumptions and/or limitations including:

- *Risks are calculated for a 2-km radius study area.* EPA assumed that all significant exposure and risk/HQ to human receptors occurs within 2 km of the source boundary based on the types of waste management unit sources currently in the 3MRA model.

- *Human receptors are stationary.* EPA assumed that human receptors both reside and work at the receptor location identified for them during site characterization. (Farmer receptors are on farms, and residential receptors are assumed to be at the centroid of census blocks within radial distance rings.) This assumption may overestimate or underestimate exposure, because it is possible that individuals

[11] Aggregation of risks occurring simultaneously over multiple pathways is the essence of multipathway risk assessment. For example, if a receptor is exposed to chemicals from both ingestion of contaminated groundwater and ingestion of contaminated fish, then it is appropriate to estimate the cumulative risk that is incurred across these pathways. In some instances, it is appropriate to aggregate risk across portals of entry (i.e., ingestion and inhalation).

may reside at the identified location within the study area but either commute to work outside of the study area or commute to more or less highly contaminated areas within the study area.

- *Incremental risk is considered.* No provision is made for considering background exposures and their risks for the purpose of generating total risk estimates.

- *Risk and HQ estimates are aggregated for certain receptors.* As mentioned, the four receptors considered—resident, residential gardener, farmer, and fisher—are fewer in number than the number of receptor categories output by the Human exposure module. Risks are aggregated for certain receptors to maintain output storage requirements at reasonable levels. Such aggregation results in some loss in risk resolution. For example, the risks specific to farmers who drink contaminated milk but do not ingest contaminated beef will not be available.

- *Lifetime and exposure duration for carcinogens.* For carcinogenic risk calculations, receptors are assumed to live 76.5 years. Of this lifetime, the exposure duration is assumed to be 9 years.

- *Carcinogenic risks are proportionately disaggregated from lifetime exposure to the assumed exposure duration.* Incurred risks are assumed to be lifetime risks that are reduced in direct proportion to the fraction of a lifetime actually exposed, i.e., 350 of 365 days per year (15 days away per year) for each year of exposure duration.

- *Synergistic or antagonistic effects among multiple chemicals and individual chemical speciation on risk estimates are not considered.* The human risk module is executed by the 3MRA system with a system-level chemical loop so that only one chemical is considered at any single execution. Chemicals are considered to be independent.

- *Cancer slope factors do not vary with cohort age.* Age-specific differences in exposure responses are not available and consequently are not considered.

- *Maximum HQ estimates are conservatively based on a single year of exposure.* Unlike carcinogenic risk estimates, which use a moving average over multiyear exposure periods (as discussed in the next section), HQ estimates treat each year independently, i.e., their time series reflects 1-year average values. Thus, a single high year of maximum exposure would not be "diluted" by a multiyear averaging period. This is a protective approach.

- *If any residents in a census block group ingest ground water,* all *residents in the component census blocks are assumed to ingest ground water*. The census data report the number of households within a census block group that are served by ground water wells. However, this information is available only at the census block group level, and it is not possible to determine from census data alone

whether individual census blocks within a block group with wells have wells or not. The human risk module loops over census blocks when considering residential exposure areas. Consequently, the actual fraction of residents on wells for any individual residential exposure area is uncertain. To resolve this lack of information, the protective assumption is made that, if any residents in the block group containing the residential exposure area (or census block) under consideration are on wells, then all residents in the exposure area are on wells. That is not to say, of course, that all well water is contaminated. Only those wells lying within the ground water plume from the source are potentially contaminated.

D.11.3 Inputs for the Human Risk Module

The human risk module receives inputs from its module-specific input file, hr.ssf, the generic site layout file (sl.ssf), the generic chemical properties file (cp.ssf), and modeled inputs from the human exposure module's output file, he.grf. Input variables are listed and described in Table D-23.

D.11.4 Outputs from the Human Risk Module

Human risk module outputs are written to hr.grf, and include all risk estimates necessary to determine risk by distance from the source, exposure pathway, exposure route, receptor type, and age cohort as well as total and maximum risk estimates. Output variables are listed and described in Table D-24.

Table D-23. Summary of Inputs for the Human Risk Module

File	Input Parameter	Units	Description
hr.ssf	*LifeTime*	years	Human lifetime used in carcinogenic risk calculation
hr.ssf	*ExDur_Car_Farm*	years	Exposure duration used for modeling carcinogenic risk for all farming receptor populations
hr.ssf	*ExDur_Car_Block*	years	Exposure duration used for modeling carcinogenic risk for all residential receptor populations
hr.ssf	*ExDur_NCar_Farm*	years	Exposure duration used for modeling noncarcinogenic HQ/MOE for all farming receptors.
hr.ssf	*ExDur_NCar_Block*	years	Exposure duration used for modeling noncarcinogenic HQ/MOE for all residential receptors.
hr.ssf	*RegPercentile*	percent	Regulatory criterion used in calculating total risk incurred by a given percentage of the population. *RegPercentile* is the percentage.
hr.ssf	*DoExposed*	unitless	Logical flag indicating whether the output CDFs comprise (1) only actually exposed receptors (true), or (2) all receptors (false).
sl.ssf	*BinRange_Min_C*	unitless	Carcinogenic risk values used to define the minimum value for each of the carcinogenic risk bins.
sl.ssf	*BinRange_Min_NC*	unitless	Noncarcinogenic HQ values used to define the minimum value for each of the noncarcinogenic HQ bins.
sl.ssf	*NumBinC*	unitless	Number of bins used in reporting cancer risk (i.e., number of bins used to define the cumulative risk distribution)
sl.ssf	*NumBinNC*	unitless	Number of bins used in reporting noncancer HQs (i.e., number of bins used to define the cumulative HQ distribution)
sl.ssf	*NumHumRcp*	unitless	Number of residential locations (i.e., number of human receptor points excluding farms)
sl.ssf	*NumFarm*	unitless	Number of beef and/or dairy farms
sl.ssf	*NumRing*	unitless	Number of concentric rings used to subdivide the site for purposes of estimating risk or HQ/MOE distributions conditional on distance from the source.
sl.ssf	*FarmPopulation*	unitless	Number of farmers associated with each of the farms/crop areas identified for a given site. These population estimates are farmer-, type-, and cohort-specific.
sl.ssf	*HumRcpPopulation*	unitless	Number of residents (nonfarmers) associated with each of the residential locations identified for a given site. These population estimates are receptor population- and cohort-specific.

(continued)

Table D-23. (continued)

File	Input Parameter	Units	Description
sl.ssf	*RingFarmFrac*	fraction	The fraction of a given farm that is located within a given ring. This variable is used to allocate farm population into different rings for purposes of ring-specific risk or HQ/MOE estimates when the farm occurs in multiple rings.
cp.ssf	*ChemC_Add*	unitless	Identifies whether carcinogenic risk for a given chemical can be added across routes.
cp.ssf	*ChemNC_Add*	unitless	Identifies whether noncarcinogenic HQ/MOEs for a given chemical can be added across routes.
cp.ssf	*ChemBreastMilkExp*	unitless	Identifies whether a given chemical should be assessed for breast milk exposure (i.e., does it bioconcentrate in breast milk)
cp.ssf	*ChemCSFinhal*	$(mg/kg\text{-}d)^{-1}$	Inhalation cancer slope factor
cp.ssf	*ChemCSFfood*	$(mg/kg\text{-}d)^{-1}$	Cancer slope factor used to evaluate dietary exposure and incidental soil ingestion (excluding drinking water)
cp.ssf	*ChemCSFwater*	$(mg/kg\text{-}d)^{-1}$	Cancer slope factor used to evaluate ingestion of drinking water
cp.ssf	*ChemRFC*	mg/m^3	Inhalation reference concentration
cp.ssf	*ChemRFDfood*	mg/kg-d	Reference dose used to evaluate dietary exposure and incidental soil ingestion (excluding drinking water and fish)
cp.ssf	*ChemRFDwater*	mg/kg-d	Reference dose used to evaluate ingestion of drinking water
cp.ssf	*ChemRFDfish*	mg/kg-d	Reference dose used to evaluate dietary exposure to fish
cp.ssf	*ChemBM*	mg/kg-d	Background-drived breast milk exposure value used in generating margin of exposure estimate for breast milk consumption in infants
he.grf	*IngBM<pathway>H*	mg/kg-d	Chemical- and pathway- specific average daily dose for the nonfarmer infant resulting from breast milk ingestion. (Note: "<pathway>" denotes the actual pathway name in the variables generated by the human exposure module.)
he.grf	*IngBM<pathway>HYR*	unitless	Time series of years corresponding to this variable.
he.grf	*IngBM<pathway>HNY*	unitless	Number of years in the time series corresponding to this variable.
he.grf	*IngBM<pathway>F*	mg/kg-d	Chemical- and pathway- specific average daily dose for the farmer infant resulting from breast milk ingestion. (Note: "<pathway>" denotes the actual pathway name in the variables generated by the human exposure module.)
he.grf	*IngBM<pathway>FYR*	unitless	Time series of years corresponding to this variable.

(continued)

Table D-23. (continued)

File	Input Parameter	Units	Description
he.grf	*IngBM<pathway>FNY*	unitless	Number of years in the time series corresponding to this variable.
he.grf	*Cambient_Farm*	mg/m^3	Farm-specific modeled ambient air concentration used in evaluating inhalation risk. Separate estimates are generated for each modeled year.
he.grf	*Cambient_FarmYR*	unitless	Time series of years corresponding to this variable.
he.grf	*Cambient_FarmNY*	unitless	Number of years in the time series corresponding to this variable.

NA = not applicable

Table D-24. Summary of Outputs from the Human Risk Module

File	Code	Units	Description
hr.grf	*Risk_1_Index; Risk_2_Index; Risk_3_Index*	unitless	Number of exposure pathway-specific (Risk_1_Index), exposure route-specific (Risk_2_Index), or total (Risk_3_Index) carcinogenic risk estimates generated for each receptor population/age cohort combination. Separate exposure pathway-, exposure route-, and total risk estimates are generated for each ring modeled. Risk results for each of these three categories are only reported for Tcrit (i.e., for the maximum risk year) and not for all modeled years.
hr.grf	*HQ_1_Index; HQ_2_Index; HQ_3_Index*	unitless	Number of exposure pathway-specific (HQ_1_Index), exposure route-specific (HQ_2_Index), or total (HQ_3_Index) non-carcinogenic HQ estimates generated for each receptor population/age cohort/chemical combination. Separate exposure pathway-, exposure route-, and total HQ estimates are generated for each ring modeled. HQ results for each of these three categories are only reported for Tcrit (i.e., for the maximum risk year) and not for all modeled years.
hr.grf	*Risk_1; Risk_2; Risk_3*	unitless	CDFs of population in risk bins for exposure pathway-specific (Risk_1), exposure route-specific (Risk_2), and total (Risk_3) carcinogenic risk. Separate CDFs are generated for each receptor/cohort/ring combination. These estimates are only reported for Tcrit.
hr.grf	*HQ_1; HQ_2; HQ_3*	unitless	CDFs of population in HQ bins for exposure pathway-specific (HQ_1), exposure route-specific (HQ_2) and total (HQ_3) non-carcinogenic HQ estimate. Separate CDFs are generated for each receptor population/cohort/ring combination. These estimates are only reported for Tcrit.
hr.grf	*Risk_1_TcrIndex; Risk_2_TcrIndex; Risk_3_TcrIndex*	years	Tcrit (critical year or maximum risk year) for carcinogenic risk. Separate Tcrits are identified for exposure pathways (Risk_1_TcrIndex), exposure routes (Risk_2_TcrIndex), and for total risk (Risk_3_TcrIndex).
hr.grf	*Risk_1_RingIndex; Risk_2_RingIndex; Risk_3_RingIndex*	unitless	The specific ring associated with each of the Tcrit values identified through the Risk_#_TcrIndex variables (i.e., Risk_1_RingIndex, Risk_2_RingIndex, and Risk_3_RingIndex).
hr.grf	*Risk_1_PathIndex; Risk_2_PathIndex; Risk_3_PathIndex*	unitless	The specific exposure pathway associated with each of the Tcrit values identified through the Risk_#_TcrIndex variables (i.e., Risk_1_RingIndex, Risk_2_RingIndex, and Risk_3_RingIndex).
hr.grf	*HQ_1_TcrIndex; HQ_2_TcrIndex; HQ_3_TcrIndex*	years	Tcrit (critical year or maximum HQ year) for noncarcinogenic HQ. Separate Tcrit values are identified for exposure pathways (HQ_1_TcrIndex), exposure routes (HQ_2_TcrIndex), and for total HQ (HQ_3_TcrIndex).
hr.grf	*HQ_1_RingIndex; HQ_2_RingIndex; HQ_3_RingIndex*	unitless	The specific ring associated with each of the Tcrit values identified through the HQ_#_TcrIndex variables (i.e., HQ_1_RingIndex, HQ_2_RingIndex, and HQ_3_RingIndex).
hr.grf	*HQ_1_PathIndex; HQ_2_PathIndex; HQ_3_PathIndex*	unitless	The specific exposure pathway associated with each of the Tcrit values identified through the HQ_#_TcrIndex variables (i.e., HQ_1_RingIndex, HQ_2_RingIndex, and HQ_3_RingIndex).

D.12 Ecological Exposure Module

The ecological exposure (EcoEx) module calculates the applied dose (in mg/kg-d) to ecological receptors that are exposed to contaminants via ingestion of contaminated plants, prey, and media (i.e., soil, sediment, and surface water). These dose estimates are then used as inputs to the ecological risk module. The EcoEx module calculates exposures for each receptor home range placed within a terrestrial or freshwater aquatic habitat (as defined in the site layout). Thus, exposure is a function of: (1) the home range (or portion, thereof) to which the receptor is assigned; (2) the spatial boundaries of the home range, (3) the food items (plants and prey) that are available in a particular home range, (4) the dietary preferences for food items that are available, and the media concentrations in the receptor's home range. In essence, the module estimates an applied dose for birds, mammals, and selected herpetofauna that reflects the spatial and temporal characteristics of the exposure (i.e., exposure is tracked through time and space). Supporting detail about the background and implementation of the model is available in U.S. EPA (1999l).

D.12.1 Functionality

The major computational functions performed by the ecological exposure module can be summarized as follows:

- *Time series management*. The EcoEx module determines the overall duration of the time period to be simulated (including concentration data from discontinuous time periods) and identifies the individual years within the overall duration that will be simulated.

- *Module loops over the time series, through habitats and receptors.* The EcoEx module has three basic loops: (1) over the time series, (2) over each habitat delineated at the site, and (3) over the mammalian, avian, and selected herpetofauna receptors assigned to each habitat.

- *Calculation of time series exposures from time series media and food concentrations.* This is the fundamental structure of the EcoEx module, namely, to develop exposure concentrations for each year of the simulation that include all relevant receptors, food items, and media. These exposure concentrations are spatially explicit with regard to the home range for each ecological receptor.

The major calculation steps performed by the ecological exposure module that are required to calculate an applied dose may be summarized as follows:

- Select receptor of interest.
- Get media concentrations from TerFW module, SW module, and SR module.
- Calculate average media concentrations to which receptor is exposed.
- Construct diet for receptor of interest (i.e., composition and preferences).
- Get plant and prey concentrations for dietary items from TerFW.
- Sum intake from media and food sources.

- # Calculate potential applied dose by adjusting for body weight.
- # Calculate applied dose by prorating dose by habitat / home range ratio.

D.12.2 Assumptions and Limitations

The exposure characterization methodology used in the ecological exposure module reflects a number of assumptions and/or limitations, which are listed below.

D.12.2.1 Assumptions.

- # *Study area is bounded at 2 km.* EPA assumed that significant exposures to source-related contaminants do not occur for ecological receptors that are beyond 2 km of the source. Consequently, exposures are not evaluated for receptors outside of the study area, measured from the edge of the source to a point 2 km away.

- # *All areas delineated as habitat support wildlife.* EPA assumed that habitats delineated at each site are capable of sustaining a variety of wildlife. Because the predator-prey interactions for each habitat are represented by a simple food web, we assumed each habitat to be of sufficient quality to support multiple trophic levels and at least one reproducing pair of upper trophic level predators. Hence, exposure estimates reflect essentially free access to any of the food items suggested in the database on ecological exposure factors.

- # *There are no other chemical stressors in the study area.* Because this is a site-based (rather than site-specific) assessment we assumed that ecological receptors were not subjected to other stressors within the study area. Background concentrations of constituents were not considered in developing exposure estimates, nor were other potential nonchemical stressors such as habitat fragmentation.

- # *No less than 10 percent of the diet is attributed to the study area.* In many instances, the home range for a given receptor exceeds the size of the habitat. In general we assumed that the percent of the home range that "fits" into the habitat is a suitable surrogate with which to scale exposures. However, the purpose of this analysis is to determine acceptable waste concentrations assuming that suitable portions of the study area (e.g., forests) would be used as habitat by wildlife. Therefore, we assumed that no less than 10 percent of the diet originated from the study area, even if the fraction of the home range inside the habitat fell below 10 percent.

- # *Spatial averaging of exposures is defined by habitat and home range.* For this site-based assessment of representative habitats, we assumed that a reasonable approach to define the spatial extent of exposure for each receptor was to place the home range within the habitat boundaries. If the home range was larger than the habitat (i.e., extends beyond AOI) the exposure was averaged across the

habitat and then prorated. However, alternative approaches were considered, including the calculation of exposure point concentrations based on a random walk across various habitats.

D.12.2.2 Limitations.

- *Plant categories were defined by analogy.* Vegetation categories relevant to wildlife were extrapolated from the plant categories defined for use in the Farm Food Chain (FFC) module. The cross reference for vegetative categories consumed by wildlife is presented in the Terrestrial Food Web module documentation.

- *Annual average concentrations define exposure.* The exposure profiles generated with the EcoEx module are based on the average annual concentrations in food items and media. Consequently, concentration spikes due to episodic events (e.g., rain storms) or elevated source releases following waste additions are not evaluated. In addition the annual average approach does not capture elevated exposures during critical life stages.

- *Exposures are predicted only for adult animals.* Because concentrations are annualized, the module predicts exposures only for adult animals; intrayear contaminant exposures to juveniles, often with very different dietary preferences, are not predicted.

- *Dietary preferences remain constant over the year.* The EcoEx module constructs the dietary preferences for each receptor based on dietary data covering one or more seasons. Some of the seasonal variability in the diet is captured indirectly by the hierarchical algorithm used to determine the dietary preferences. However, the algorithm is implemented on data across multiple seasons and, therefore, does not necessarily reflect seasonal differences.

- *Exposure estimates reflect a single home range setting.* The EcoEx module calculates the applied doses to receptors for a single random placement of four home range sizes.[12] As a result, the four home ranges in the site layout may not reflect the spatial variability in exposure patterns, particularly for large habitats (i.e., habitats that cover substantially greater areas than most of the home ranges).

D.12.3 Inputs for the Ecological Exposure Module

The concentration inputs required by the EcoEx module are provided by the terrestrial food web module (TerFW), the aquatic food web module (AqFW), the surface water module

[12] As described in U.S. EPA (1999n), each receptor is assigned to one of four discrete home range sizes, depending on the receptor-specific home range. The four home ranges are spatially linked in that the ranges overlap in a manner that reflects the dietary preferences of the predator species.

(SW), and the surface impoundment module (a common source output file). These inputs include:

Terrestrial Food Web (TF.GRF)

- # Spatially averaged surficial soil concentration by home range
- # Spatially averaged concentration in soil invertebrates by home range
- # Spatially averaged concentration in various plant types by home range
- # Minimum and maximum concentrations in various categories of vertebrates across the habitat (e.g., small mammals, small birds, omnivores)

Aquatic Food Web (AF.GRF)

- # Average, reach-specific concentration in aquatic (water column) invertebrates
- # Average, reach-specific concentration in benthic invertebrates
- # Average, reach-specific concentration in aquatic macrophytes
- # Average, reach-specific concentration in trophic level 3 (T3) fish
- # Average, reach-specific concentration in trophic level 4 (T4) fish

Surface Water (SW.GRF)

- # Average, reach-specific concentration in sediment
- # Average, reach-specific concentration in surface water

Surface Impoundment (SR.GRF)

- # Average concentration in surface impoundment water

The ecological exposure module receives inputs from its module-specific input file, ee.ssf, the generic site layout file (sl.ssf), and modeled inputs from the following other modules: terrestrial food web module (tf.grf), aquatic food web module (af.grf), surface water module (sw.grf), and those source modules outputting (to a common grf file, sr.grf) a "true" for the surface water logical flag, *SrcH2O*. In the HWIR application, these sources are the land application unit, landfill, wastepile, and surface impoundment; currently, only the surface impoundment reports true for this flag. Input variables are listed and described in Table D-25.

D.12.3 Outputs from the Ecological Exposure Module

The ecological exposure module outputs are written to the ee.grf file. All ecological exposure outputs are 3-dimensional arrays indexed on time, habitat, and receptor. Output variables are listed and described in Table D-26.

Table D-25. Summary of Input Parameters for the Ecological Exposure Module

File	Code	Units	Description
ee.ssf	*BodyWt_rec*	kg	Body weight of each receptor.
ee.ssf	*CR_food*	kg/d	Consumption rate of food items for each receptor.
ee.ssf	*CR_water*	L/d	Consumption rate of water for each receptor.
ee.ssf	*CRfrac_sed*	mass fraction	Consumption rate of sediment for each receptor.
ee.ssf	*CRfrac_soil*	mass fraction	Consumption rate of surficial soil for each receptor.
ee.ssf	*HabitatIndex*	unitless	Index of habitat types.
ee.ssf	*HabitatType*	NA	Description of habitat types.
ee.ssf	*MaxPreyPref_HabRange*	unitless	Maximum dietary preference for items found in a habitat range.
ee.ssf	*MinPreyPref_HabRange*	unitless	Minimum dietary preference for items found in a habitat range.
ee.ssf	*NumHabitat*	unitless	Number of habitat types represented.
ee.ssf	*NumPrey*	unitless	Number of potential prey items.
ee.ssf	*PreyIndex*	unitless	Numerical index of potential prey items.
ee.ssf	*PreyType*	NA	Description of each prey item.
sl.ssf	*HabArea*	m^2	Area of habitat.
sl.ssf	*HabIndex*	unitless	Index of habitat type.
sl.ssf	*HabNumRange*	unitless	Number of home ranges per habitat.
sl.ssf	*HabNumWBNRch*	unitless	Number of WBN reaches that impact each habitat range.
sl.ssf	*HabRangeAreaFrac*	fraction	Fraction of total home range area that falls within each habitat.
sl.ssf	*HabRangeFishWBNIndex*	unitless	Index of WBN containing fishable reaches that impact each habitat range.
sl.ssf	*HabRangeNumSISrc*	unitless	Number of surface impoundments that intersect each habitat range.
sl.ssf	*HabRangeNumWBNRch*	unitless	Number of WBN reaches found within each habitat range.
sl.ssf	*HabRangeNumWSSub*	unitless	Number of watersheds that impact each habitat range.
sl.ssf	*HabRangeRecIndex*	unitless	Receptor index associated with each habitat range.
sl.ssf	*HabRangeWBNIndex*	unitless	Index of WBN that impacts each habitat range.
sl.ssf	*HabRangeWBNRchIndex*	unitless	Index of WBN reaches that impact each habitat range.
sl.ssf	*HabRangeWSSubIndex*	unitless	Index of watershed that impacts each habitat range.
sl.ssf	*HabType*	NA	Type of representative habitat.

(continued)

Table D-25. (continued)

File	Code	Units	Description
sl.ssf	*HabWBNIndex*	unitless	Index of WBN that impacts each habitat.
sl.ssf	*HabWBNRchFrac*	unitless	Fraction of habitat range impacted by each reach.
sl.ssf	*HabWBNRchIndex*	unitless	Index of WBN reaches that impact each habitat.
sl.ssf	*HRangeFishWBNRchIndex*	unitless	Index of fishable reaches that impact each habitat range.
sl.ssf	*HRangeNumFishWBNRch*	unitless	Number of fishable reaches that cross each habitat range.
sl.ssf	*NumHab*	unitless	Number of habitats selected for site simulation.
sl.ssf	*NumReceptor*	unitless	Complete receptor list across all habitat types.
sl.ssf	*NumWBN*	unitless	Number of waterbody networks.
sl.ssf	*NumWSSub*	unitless	Number of watershed sub basins.
sl.ssf	*ReceptorIndex*	unitless	Indices assigned to each receptor.
sl.ssf	*ReceptorName*	NA	Name of receptor.
sl.ssf	*ReceptorType*	NA	Description of receptor.
sl.ssf	*WBNFishableRchIndex*	unitless	Index of reaches that are fishable.
sl.ssf	*WBNNumFishableRch*	unitless	Number of fishable reaches.
sl.ssf	*WBNNumRch*	unitless	Number of reaches for each waterbody network.
af.grf	*Caqmp*	mg/kg	Concentration of contaminant in aquatic plants.
af.grf	*CaqmpNY*	unitless	Number of years in the time series corresponding to this variable.
af.grf	*CaqmpYR*	year	Time series of years corresponding to this variable.
af.grf	*Cbenthff*	mg/kg	Concentration of contaminant in benthic organisms.
af.grf	*CbenthffNY*	unitless	Number of years in the time series corresponding to this variable.
af.grf	*CbenthffYR*	year	Time series of years corresponding to this variable.
af.grf	*CT3Fish*	mg/kg	Concentration of contaminants in trophic level 3 fish.
af.grf	*CT3FishNY*	unitless	Number of years in the time series corresponding to this variable.
af.grf	*CT3FishYR*	year	Time series of years corresponding to this variable.
af.grf	*CT4Fish*	mg/kg	Concentration of contaminants in trophic level 4 fish.
af.grf	*CT4FishNY*	unitless	Number of years in the time series corresponding to this variable.
af.grf	*CT4FishYR*	year	Time series of years corresponding to this variable.
sr.grf	*SrcH2O*	NA	Flag for surface water presence.
sr.grf	*SWConcTot*	mg/L	Contaminant concentration in surface water.

(continued)

Table D-25. (continued)

File	Code	Units	Description
sr.grf	*SWConcTotNY*	unitless	Number of years in the time series corresponding to this variable.
sr.grf	*SWConcTotYR*	year	Time series of years corresponding to this variable.
sw.grf	*WBNConcWaterTot*	mg/L	Dissolved concentration in surface water used as drinking water source by cattle.
sw.grf	*WBNConcWaterTotNY*	unitless	Number of years in the times series corresponding to this variable.
sw.grf	*WBNConcWaterTotYR*	year	Time series of years corresponding to this variable.
tf.grf	*C<animals>_<max or min>NY*	unitless	Number of years in the time series corresponding to this variable.
tf.grf	*C<animals>_<max or min>*	mg/kg	Concentration of contaminant found in herbiverts and omniverts.
tf.grf	*C<animals>_<max or min>YR*	year	Time series of years corresponding to this variable.
tf.grf	*C<animals>_HabRange*	mg/kg	Concentration of contaminant found in invertebrates and worms.
tf.grf	*C<animals>_HabRangeNY*	unitless	Number of years in the time series corresponding to this variable.
tf.grf	*C<animals>_HabRangeYR*	year	Time series of years corresponding to this variable.
tf.grf	*C<animals>_sm_<max or min>*	mg/kg	Concentration of contaminant found in small birds, herpetofauna, and mammals.
tf.grf	*C<animals>_sm_<max or min>YR*	year	Time series of years corresponding to this variable.
tf.grf	*C<animals>_sm_<max or min>NY*	unitless	Number of years in the time series corresponding to this variable.
tf.grf	*CTdaAveHabRange*	μg/g	Average depth average soil concentration in each habitat range.
tf.grf	*CTdaAveHabRangeNY*	unitless	Number of years in the time series corresponding to this variable.
tf.grf	*CTdaAveHabRangeYR*	year	Time series of years corresponding to this variable.
tf.grf	*CTssAveHabRange*	μg/g	Average depth average soil concentration in each habitat range.
tf.grf	*CTssAveHabRangeNY*	unitless	Number of years in the time series corresponding to this variable.
tf.grf	*CTssAveHabRangeYR*	year	Time series of years corresponding to this variable.
tf.grf	*P<plant type>_HabRangeNY*	unitless	Number of years in the time series corresponding to this variable.

(continued)

Table D-25. (continued)

File	Code	Units	Description
tf.grf	*P<plant type>_HabRangeYR*	year	Time series of years corresponding to this variable.
tf.grf	*P<plant type>_HabRange*	mg/kg	Concentration of contaminant found in exfruit, exveg, forage, grain, root, and silage.

NA = not applicable

Table D-26. Summary of Output Parameters for the Ecological Exposure Module

File	Code	Units	Description
ee.grf	*Dose_rec*	mg/kg-d	Dose of contaminant to receptor.
ee.grf	*Dose_recNY*	unitless	Number of years in the time series corresponding to this variable.
ee.grf	*Dose_recYR*	year	Time series of years corresponding to this variable.

D.13 Ecological Risk Module

The ecological risk (EcoRisk) module calculates hazard quotients[13] (HQs) for a suite of ecological receptors assigned to habitats delineated for study sites. These receptors fall into eight receptor groups: (1) mammals, (2) birds, (3) herpetofauna, (4) terrestrial plants, (5) soil community, (6) aquatic plants and algae, (7) aquatic community, and (8) benthic community. The spatial resolution of the EcoRisk module is, to a large degree, determined by both the home ranges and habitats delineated at each site.

The HQs for the for all receptors assigned to the study site are calculated and placed into one of five risk bins developed to assist decision-makers in creating appropriate risk metrics. The HQ risk bins are used in developing cumulative distribution functions of risk and are defined as: (1) below 0.1, (2) between 0.1 and 1, (3) between 1 and 10, (4) between 10 and 100, and (5) above 100. Each of the HQs calculated by the EcoRisk module has a series of attributes associated with it that allows ecological risks to be interpreted in a number of ways. For instance, distance from the source (i.e., 1 km, 1 km to 2 km, or across the entire site) is important in understanding the spatial character of potential ecological risks.

Outputs are generated for three areas of the site relative to the distance from the edge of the waste management unit. These distances are termed EcoRings and depict the following: (1) habitats that fall within 1 km of the WMU, (2) habitats that fall between 1 and 2 km from the WMU, and (3) habitats within 2 km of the WMU (i.e. across the entire site). It is important to note that the HQ results for habitats that intersect both EcoRings are attributed to the risk results for both of those distances. In other words, the habitat risks are not apportioned by distance, they are reported as though they are positioned entirely within each distance ring. Because the fundamental unit of this analysis is the representative habitat (not distance to the waste management unit), it was considered inappropriate to truncate risks by distance.

D.13.1 Functionality

The major computational functions performed by the ecological risk module may be summarized as follows:

- *Time series management*. The EcoRisk module determines the overall duration of the time period to be simulated (including concentration data from discontinuous time periods) and identifies the individual years within the overall duration that will be simulated.

- *Module loops over the time series, through habitats, and receptors.* The EcoRisk module has three basic loops: (1) over the time series, (2) over each habitat, and (3) over each receptor assigned to the habitat.

[13] Hazard quotients are defined as: (1) the ratio between applied dose received from the ingestion of contaminated media and food items and an ecological benchmark (EB in units of dose), and (2) the ratio between the concentration in the medium of interest (soil, sediment, or surface water) and a chemical stressor concentration limit (CSCL in units of concentration).

- *Calculation of time series hazard quotients for ecological receptors.* The EcoRisk module predicts HQs for each year of the simulation for receptors in each habitat. These HQs are defined in terms of a number of attributes to facilitate clarity in the risk characterization.

The major steps performed by the EcoRisk module that are required to predict ecological risks are summarized as follows:

- Select the ecological distance ring of interest (i.e., 0 to 1 km; 1 to 2 km, entire site).

- Read in all data required to calculate HQs for all receptors (e.g., EBs, CSCLs, site layout characteristics such as water hardness).

- Calculate HQs for all receptors within the area of interest for each year of the simulation.

- Calculate probability density functions for each year of the simulation (this is performed in much the same manner as with the Human Risk module).

- Identify and output the cumulative density functions for various receptor and habitat groups for the year in which the maximum total HQ was experienced.

- Identify and output information about the receptor experiencing the maximum HQ across all years of the simulation and the year in which the maximum occurred.

D.13.2 Assumptions and Limitations

The methodology used in the ecological risk module reflects a number of assumptions and/or limitations, which are listed below. Several key assumptions listed for the ecological exposure module (see Section D.12.1) are also relevant to the EcoRisk module. For example, the assumption that all areas delineated as habitat support wildlife also applies to the EcoRisk module in that HQs calculated within each habitat are presumed to reflect potential risks to ecological receptors. For convenience, these assumptions are included below as well as assumptions and limitations that are unique to the EcoRisk module.

D.13.2.1 Assumptions

- *Study area is bounded at 2 km.* We assumed that significant risks to source-related contaminants do not occur for ecological receptors that are beyond 2 km of the source. Consequently, HQs were not calculated for receptors outside of the study area, measured from the corner of the source to a point 2 km away.

- *All areas delineated as habitat support wildlife.* It is assumed that habitats delineated at each site are capable of sustaining a variety of wildlife. Since the predator-prey interactions for each habitat are represented by a simple food web,

each habitat is assumed to be of sufficient quality to support multiple trophic levels and, at least, one reproducing pair of upper trophic level predators. Hence, risk calculations assume that the receptors of interest are present in each habitat.

- *There is only one source for each chemical stressors in the study area.* Background concentrations of constituents were not considered in developing exposure estimates. Contributions to ecological exposures from other sources, or pre-existing conditions such as a fish advisory were not addressed.

- *The most appropriate endpoints for population sustainability are reproductive and developmental effects.* In calculating HQs for populations of mammals and birds, it is implicitly assumed that endpoints associated with the populations' ability to reproduce and grow are an appropriate surrogate for true population-level endpoints (e.g., adverse effects leading to a 10% reduction in the population size).

- *One and only one population of each wildlife species is carried by a given habitat.* For example, although there may be a number of receptors assigned to a habitat, multiple populations of shrews or robins are not evaluated. Each receptor population has the same spatial characteristics, as defined by the home range. Hence, there is one HQ calculated for each receptor in each habitat.

- *Maximum HQ estimates are based on a single year of exposure.* The ecological HQ estimates are based on annual averages: the smallest increment of time that for which the 3MRA system is designed. This time step represents much longer than lifetime exposures for some receptors, and substantially less than lifetime for other receptors.

D.13.2.2 Limitations

- *The HQs are not calculated at the population or community level; ecological risks must be inferred to higher levels of biological organization.* Ecosystems are enormously complex, and our understanding of even simple community dynamics is limited. Data on chemical stressors are seldom available above the level of an individual organism; that is, the study endpoints focus on individual organisms rather than processes crucial to assemblages of organisms. Even the CSCLs developed to evaluate risks to communities are derived by statistical inference on toxicity data for individual organisms. Therefore, the data are generally insufficient to allow us to truly evaluate effects at the population or community levels. This is currently a limitation in the state-of-the-science, particularly for national analyses.

- *It is not possible to verify that reproductive and developmental endpoints are, in all cases, sufficient to protect the assessment endpoints for wildlife populations.* The endpoints for certain wildlife populations (i.e., mammals, birds) were almost exclusively taken from reproductive and developmental studies. Although

reproductive and developmental endpoints have been recognized by EPA as relevant to population sustainability, they are not always the critical effect associated with a chemical stressor. The assumption that other effects that may occur at lower environmental concentrations are not significant with respect to the population sustainability limits confidence in predicting ecological risk. Studies regarding this question are inconclusive and, therefore, there is some uncertainty in using only reproductive and developmental studies to address the assessment endpoint of population sustainability.

- *The HQ estimates are generated based on one, and only one, home range area.* For the purposes of creating the site layout file, four home range areas are placed in each habitat. Once these areas are delineated and appropriate receptors are assigned, the spatial characteristics of the risk for each home range is established. Variability associated with exposures in different areas of the habitat is not reflected in this scheme. This limitation may result in significant differences for receptors with small home ranges, and can influence the risk estimates for predators with large home ranges (i.e., home range ≈ habitat) since tissue concentrations in prey items are constrained by the same spatial characteristics. As a result, the representativeness of the HQs with regard to the spatial character of the exposure is limited.

- *The effects of multiple stressors (chemical and non-chemical) are not considered in developing estimates of potential ecological risk.* This is a source of considerable uncertainty in the HQ estimates. The EcoRisk module is executed within the FRAMES system within a system-level chemical loop such that only a single chemical is evaluated per iteration of the model. As a result, risks are predicted assuming a single chemical exposure. Data availability on the antagonistic and synergistic effects associated with multiple stressors are extremely limited at this time (with the possible exception narcotic contaminants in aqueous systems) and prevented the development of a multi-stressor analytical approach for the HWIR universe of constituents. Data limitations notwithstanding, the inability to consider multiple stressors is a limitation in our ability to interpret the risk results generated by this module.

- *The HQ estimates for the aquatic and benthic communities, respectively, are resolved at the habitat, rather than reach level.* There is some uncertainty associated with calculating risks to aquatic life across an entire habitat (as defined within the study area). Species of fish such as brown trout tend to utilize certain segments of stream habitats and, therefore, HQs at the reach level may be more appropriate. Conversely, establishing artificial boundaries between stream reaches is contrary to the goals of the assessment strategy, namely, to evaluate ecological risks using the habitat as the fundamental unit.

- *The HQ estimates reflect different endpoints at varying levels of effect.* The HQ methodology - the ratio of an exposure to a benchmark - is applied uniformly across all ecological receptors. However, the data supporting the HQ calculation

vary in that they include endpoints from lethality to reproductive fitness and address and community-level effects by inference. To some degree, the HQ estimates for different receptor groups represent different risk metrics. The interpretation of these HQ estimates is, therefore, limited by our understanding of the potential ecological significance of the measures of effect as well as overall confidence in the data used to support the calculations.

D.13.3 Inputs for the Ecological Risk Module

The concentration and dose inputs required by the EcoRisk module are provided by the ecological exposure (EcoEx) module, the Terrestrial Food Web module (TerFW), and the Surface Water (SW) module. These inputs include:

Ecological Exposure (ee.grf)

- **#** applied dose to receptors by home range and habitat

Terrestrial Food Web (tf.grf)

- **#** spatially-averaged surficial soil concentration by home range

Surface Water (sw.grf)

- **#** average, reach-specific total concentration in sediment
- **#** average, reach-specific total concentration in surface water
- **#** average, reach-specific dissolved concentration in surface water

The ecological risk module receives inputs from its module-specific input file, er.ssf, the generic site layout file (sl.ssf), the chemical properties file (cp.ssf), and modeled inputs from the surface water module (sw.grf), terrestrial food web module (tf.grf), and the ecological exposure module (ee.grf). Input variables are listed and described in Table D-27.

D.13.4 Outputs

The ecological risk module outputs are written to the er.grf file. All ecological risk outputs are 3-dimensional arrays indexed on time, habitat, and receptor. Output variables are listed and described in Table D-28.

Table D-27. Summary of Inputs for the Ecological Risk Module

File	Code	Units	Description
er.ssf	EcoRegPercentile	unitless	Policy criterion for selecting critical year for maximum HQ
sl.ssf	NumEcoBin	unitless	Number of bins for cumulative distribution function
sl.ssf	EcoRingNumHab	unitless	Number of habitats in each ecoring
sl.ssf	EcoBinRange_Min	unitless	Minimum HQ for each ecobin
sl.ssf	NumEcoRing	unitless	Number of ecorings at the site
sl.ssf	EcoRingHabIndex	unitless	Habitat index for a habitat in a given ecoring
sl.ssf	HabNumRange	unitless	Number of ranges in a given habitat
sl.ssf	HabNumWBNRch	unitless	Number of reaches in a given habitat
sl.ssf	HabType	NA	String description of the habitat type for a given habitat
sl.ssf	ReceptorType	NA	String description of the receptor type for a given receptor
sl.ssf	ReceptorName	NA	Receptor name
sl.ssf	RecGroup	NA	String description of receptor group
sl.ssf	RecTrophicLevel	NA	String description of receptor trophic level
sl.ssf	HabRangeRecIndex	unitless	Index for a given receptor in a given habitat
sl.ssf	WBNWaterHardness	mg CaCO3 eq/L	Water hardness for a given waterbody network type
sl.ssf	HabWBNIndex	unitless	Waterbody network index for a given reach in a given habitat
sl.ssf	HabWBNRchIndex	unitless	Reach index for a given reach in a waterbody network in a given habitat
sl.ssf	WBNRchBodyType	NA	String description of reach body type for a given reach in a given waterbody network
cp.ssf	ChemCASID	NA	Chemical abstracts service registry number for the chemical
cp.ssf	ChemType	NA	Chemical type
cp.ssf	ChemKoc	mL/g	Organic carbon partition coefficient for the chemical
cp.ssf	ChemEBRec	mg/kg-day	Ecological benchmark for the chemical for a given receptor
cp.ssf	ChemCSCLWaterDissRec	mg/L	Chemical stressor concentration limit for the chemical dissolved in water for a given receptor
cp.ssf	ChemCSCLWaterTotRec	mg/L	Chemical stressor concentration limit for the total chemical in water for a given receptor

(continued)

Table D-27. (continued)

File	Code	Units	Description
cp.ssf	ChemCSCLSediment Rec	ug/g	Chemical stressor concentration limit for the chemical in sediment for a given receptor
cp.ssf	ChemCSCLSoilRec	ug/g	Chemical stressor concentration limit for the chemical in soil for a given receptor
sw.grf	WBNNumChem	NA	Number of chemical species for the chemical
sw.grf	WBNConcWaterDiss	mg/L	Dissolved concentration of chemical in a given WBN reach in a given year
sw.grf	WBNConcWaterTot	mg/L	Total concentration of a chemical in a given WBN reach in a given year
sw.grf	WBNConcBenthTot	ug/g	Total concentration of a chemical in the benthic column of a given WBN reach in a given year
sw.grf	WBNfocBenth	fraction	Fraction organic carbon in the benthic column of a given WBN reach in a given year
tf.grf	CTdaAveHabRange	ug/g	Depth-averaged total chemical concentration in soil, averaged over a given habitat and range in a given year
ee.grf	Dose_rec	mg/kg-day	The chemical dose experienced by a receptor in a given habitat and range in a given year

NA = not applicable

Table D-28. Summary of Outputs for the Ecological Risk Module

File	Code	Units	Description
er.grf	HQcdf_HabGroup	unitless	Cumulative percentile of receptor HQs, by habitat group for each ecoring for the
er.grf	HQcdf_HabType	unitless	Cumulative percentile of receptor HQs, by habitat type
er.grf	HQcdf_RecGroup	unitless	Cumulative percentile of receptor HQs, by receptor group
er.grf	HQcdf_RGHabGroup	unitless	Cumulative percentile of receptor HQs, by receptor group and habitat group (ecoring 3 only)
er.grf	HQcdf_TLHabGroup	unitless	Cumulative percentile of receptor HQs, by trophic level and habitat group (ecoring 3 only)
er.grf	HQcdf_TrophicLevel	unitless	Cumulative percentile of receptor HQs, by trophic level
er.grf	HQHabTypeTcrit	year	Time output at which maximum HQ occurs for each habitat type
er.grf	HQHabGroupTcrit	year	Time output at which maximum HQ occurs for each habitat group
er.grf	HQMax	unitless	Maximum HQ across the ecoring
er.grf	HQMaxHabGroup	unitless	Habitat group index for the maximum HQ in the ecoring
er.grf	HQMaxHabType	NA	Habitat type for the maximum HQ in the ecoring
er.grf	HQMaxRec	unitless	Receptor index for the maximum HQ in the ecoring
er.grf	HQMaxRecGroup	NA	Receptor group for the maximum HQ in the ecoring
er.grf	HQMaxTcrit	year	Year with maximum HQ across all eco receptors in the ecoring
er.grf	HQMaxTrophicLevel	unitless	Trophic level of receptor for the maximum HQ in the ecoring
er.grf	HQRecGroupTcrit	year	Time output at which maximum HQ occurs for each receptor group
er.grf	HQRGHabGroupTcrit	year	Time output at which maximum HQ occurs for each receptor group/habitat group combination
er.grf	HQTLHabGroupTcrit	year	Time output at which maximum HQ occurs for each trophic level/habitat group combination
er.grf	HQTrophicLevelTcrit	year	Time output at which maximum HQ occurs for each trophic level

NA = not applicable