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Summary of Ecological Risks, Assessment Methods, and Risk Management Decisions in Superfund and RCRA

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SUMMARY OF ECOLOGICAL RISKS, ASSESSMENT METHODS, AND RISK MANAGEMENT DECISIONS IN SUPERFUND AND RCRA

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OVERVIEW OF REPORT

This report summarizes a study conducted by the Office of Policy Analysis/Office of Policy, Planning, and Evaluation (OPA/OPPE) of the U.S. Environmental Protection Agency (EPA) concerning the nature and extent, assessment methods, and management issues relating to ecological damages and risks at Superfund sites and RCRA facilities.[1] More detailed reports, which should be consulted for a complete description of the study, have also been prepared by OPA. These reports are as follows:

- "The Nature and Extent of Ecological Risks at Superfund Sites and RCRA Facilities," EPA-230-03-89-043 (June 1989).
- "Ecological Risk Assessment Methods: A Review and Evaluation of Past Practices in the Superfund and RCRA Programs," EPA-230-03-89-044 (June 1989).
- "Ecological Risk Management in the Superfund and RCRA Programs," EPA-230-03-89-045 (June 1989).

This summary report is organized in two parts. Part I highlights the key OPA study findings with regard to the Superfund program and discusses their overall implications. Part II of this report describes the key findings and implications concerning the RCRA program. Readers should refer to the three more detailed reports listed above for additional information on the study methods and findings and for full reference lists (only key references are cited in this summary report).

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[1] In this report, the term ecological "threat" is used to refer collectively to both observed and predicted impacts. As used in this report, the term "damage" refers to observed impacts only, and the term "risk" generally refers to predicted impacts.

PART I: SUPERFUND

1. INTRODUCTION

In developing and implementing programs under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, or Superfund), EPA has focused primarily on analysis and mitigation of human health risks. In general, less emphasis has been placed on analysis and mitigation of ecological threats at Superfund sites.

This program emphasis has resulted partly because of the general absence of standardized EPA policy and guidance in the areas of ecological assessment methods and ecological risk management under Superfund. As an initial step in investigating issues related to ecological threats at Superfund sites, EPA's Office of Policy Analysis (OPA) has conducted a study of three broad topics: (1) the nature and extent of ecological threats at Superfund sites; (2) the ecological assessment methods that have been used in the Superfund program; and (3) the extent to which ecological concerns have been used as a basis for decision making (i.e., ecological risk management) at Superfund sites.

This part of the summary report is organized into five main sections. In Section 2, the study approach and key information sources upon which the analysis is based are briefly described. Sections 3, 4, and 5 summarize results from the studies of the nature and extent of ecological threats, ecological assessment methods, and ecological risk management issues in the Superfund program, respectively. Finally, Section 6 discusses the implications of these results, opportunities for program improvements, and needs for further study.

2. STUDY APPROACH

As mentioned in the introduction to this part, the study was conducted by analyzing three related topics: the nature and extent of ecological threats, ecological assessment methods, and ecological management issues at Superfund sites. These topics were analyzed based on information obtained from a telephone survey, personal interviews, and a review of Superfund site documentation and other relevant reports.

A telephone survey was conducted to ask people in government agencies questions related to ecological threats at Superfund sites. In particular, interviewees were asked to identify sites with known or suspected ecological threats, describe methods used to assess those threats, and describe how and to what extent ecological threat information has been used in selecting Superfund site remedies. More than 50 people were called, including representatives of EPA Headquarters and Regions, the Department of the Interior (DOI), the National Oceanic and Atmospheric Administration (NOAA), and state Superfund offices. In some cases, follow-up meetings were held with representatives from these organizations.

Several non-site-specific documents were reviewed for ecological threat information related to Superfund sites. Particular references that were reviewed include:

- a draft interim final version of the "Risk Assessment Guidance for Superfund -- Environmental Evaluation Manual," being prepared by EPA's Office of Solid Waste and Emergency Response (OSWER);
- draft "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA" prepared by the Office of Emergency and Remedial Response (OERR);
- OERR's draft "CERCLA Compliance With Other Laws Manual;"
- "Interim Final Guidance on Preparing Superfund Decision Documents: The Proposed Plan and Record of Decision" being prepared by OERR;
- a report by EPA's Office of Policy, Planning and Evaluation (OPPE) entitled "Unfinished Business: A Comparative Assessment of Environmental Problems;"
- a critique of the Superfund program entitled "Right Train, Wrong Track: Failed Leadership in the Superfund Program" by the Environmental Defense Fund and others; and
- a report entitled "Are We Cleaning Up? 10 Superfund Case Studies" prepared by the Office of Technology Assessment.

Based on the telephone survey and review of written documentation, approximately 250 Superfund sites were identified as potentially posing some level of ecological threat. Of these 250 sites, site-specific reports were reviewed in detail for ecological threat information for a sample of 52 sites. The 52-site sample was selected based primarily on the quantity and

apparent quality of relevant documentation available for each site.[2] The primary site-specific reports reviewed were remedial investigations (RIs), feasibility studies (FSs), records of decision (RODs), and ecological assessment reports, when available.

An unavoidable limitation in the approach is that almost all of the information obtained and reviewed for the study pertains to National Priorities List (NPL) sites. Very few removal and non-NPL sites were examined because limited documentation was available that describes ecological issues at these kinds of sites.

[2] Although all candidate sites were identified by at least one source as having known or suspected ecological threats, most of the 250 sites had insufficient documentation to allow in-depth review and thus were necessarily excluded from the smaller subsample.

3. NATURE AND EXTENT OF ECOLOGICAL RISKS

Detailed results of the study characterizing ecological risks at Superfund sites are presented in OPA's report entitled "The Nature and Extent of Ecological Risks at Superfund Sites and RCRA Facilities," EPA-230-03-89-043, dated June 1989. This section summarizes key findings from that report. Section 3.1 summarizes the nature of ecological threats at a sample of 52 NPL sites; the extent of threats across this sample is summarized in Section 3.2. Section 3.3 describes how the ecological threats appear to be associated with certain factors and, in Section 3.4, generalizations concerning the significance of these threats are discussed.

3.1 Nature of Threats at Superfund Sites

Exhibit I-1 shows the general types of ecosystems affected and environmental media contaminated at the 52 NPL sites examined. Based on the site documentation reviewed, almost 90 percent of the sites in this sample pose a threat to freshwater ecosystems. Threats to terrestrial ecosystems have been observed or projected less frequently (at slightly less than 50 percent of the sites). This may be more a function of the extent to which terrestrial effects were investigated at sites rather than a true indication of the frequency of these effects (terrestrial effects generally were analyzed less rigorously than aquatic effects in the reports reviewed).[3] Soil, ground water, surface water, and surface water sediments were all frequently observed to be contaminated at the sample sites.

Exhibit I-2 identifies the biota that were observed or projected to be contaminated at the sample sites, as well as the observed or projected effects caused by this contamination. As shown, the biota most frequently observed to be contaminated are fish, vegetation, and aquatic invertebrates; although few field monitoring data were reported, birds and mammals were projected to be contaminated at a large portion of the sites. For example, fish or aquatic invertebrates were observed to be contaminated at roughly 60 percent of the sites, while birds or mammals were projected to be contaminated at approximately 70 percent of the sites. A variety of toxic effects to aquatic fauna were observed at approximately 25 percent of the sites and projected at another 45 percent. In addition, fish kills were reported at almost 8 percent of the sites, bioaccumulation within the food chain was observed or projected at 54 percent of the sites, and decreased species diversity was observed or projected at 21 percent of the sites. When noted, adverse terrestrial effects usually took the form of damaged or killed vegetation, loss of habitat, contamination or loss of food sources, and projected toxic effects to birds and mammals.

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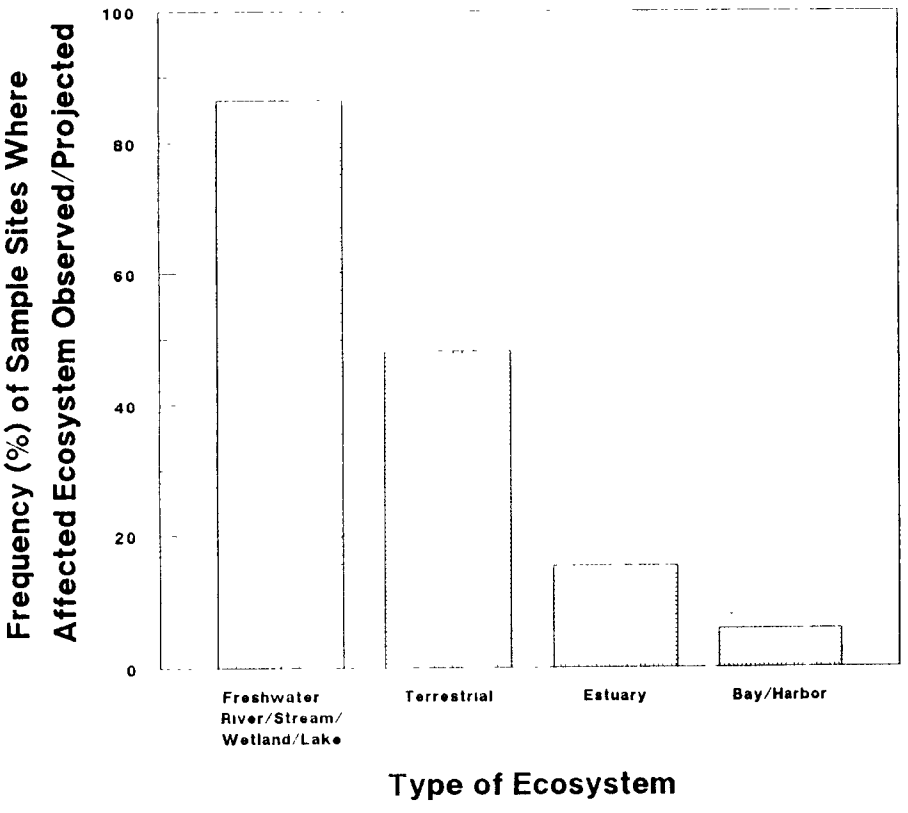
[3] In general, EPA has focused principally on the study of aquatic ecological damages and risks, leading to the development of expertise, criteria, and policy in that area. Because of this internal expertise, surface water problems may have received more consideration than possible terrestrial impacts.

EXHIBIT I-1

ECOSYSTEMS AND MEDIA OBSERVED OR PROJECTED TO BE AFFECTED/CONTAMINATED IN THE 52-SITE SAMPLE



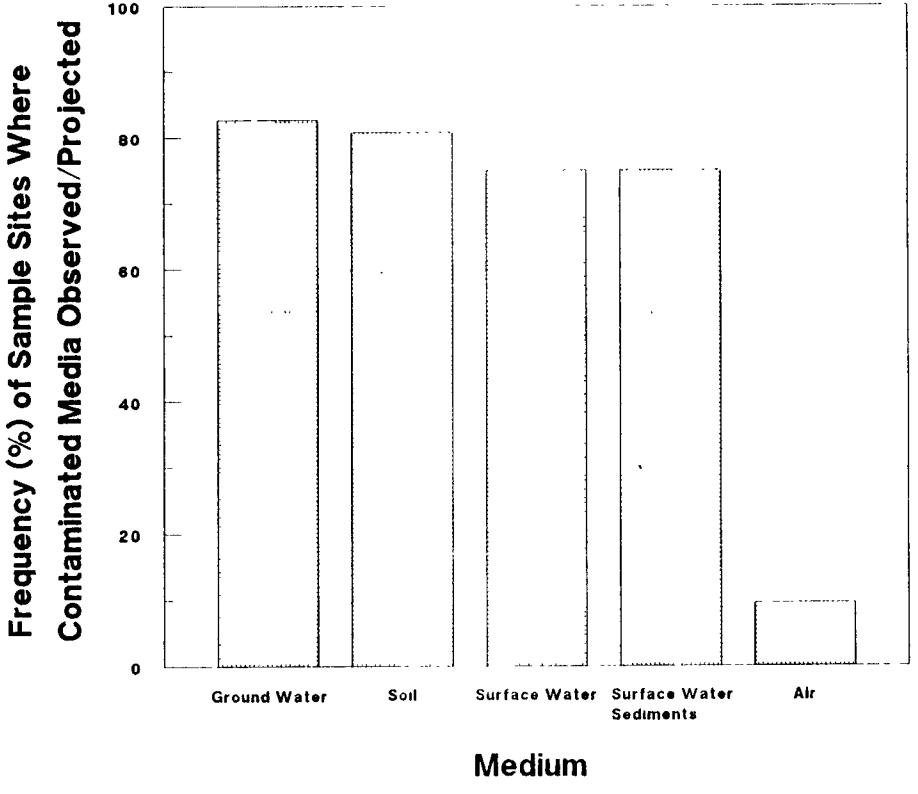
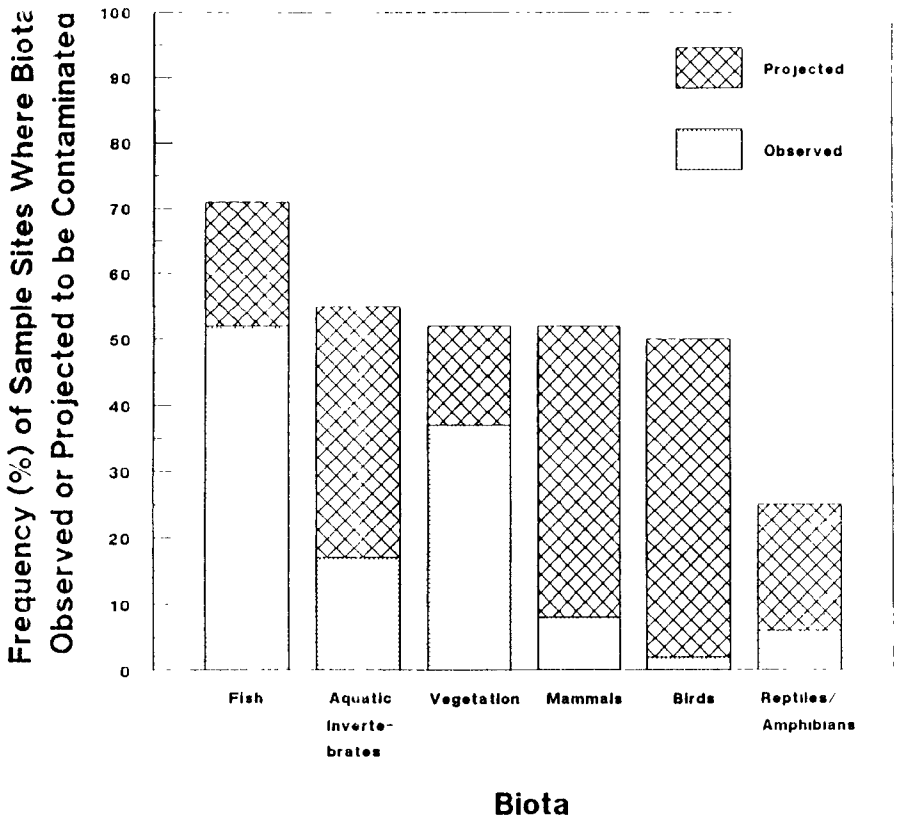
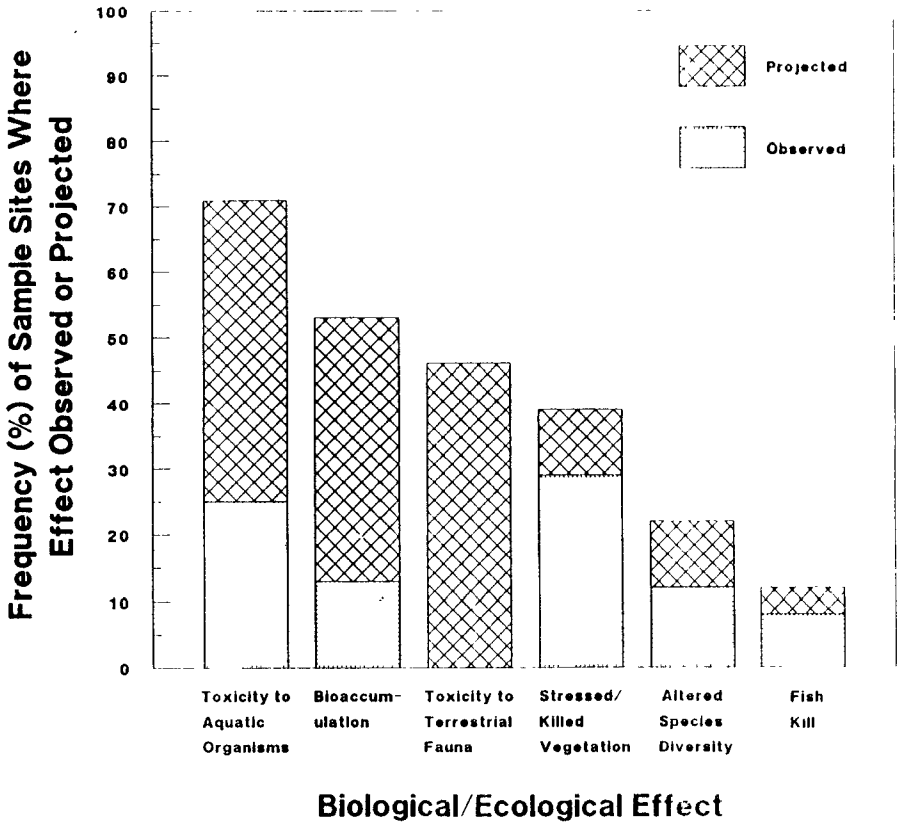


EXHIBIT I-2

NATURE OF BIOTA CONTAMINATION AND BIOLOGICAL/ECOLOGICAL EFFECTS IN THE 52-SITE SAMPLE





3.2 Extent of Threats at Superfund Sites

The reports reviewed for this study contained limited quantitative information on the extent of ecological threats, and most of the information that was available was limited to only a few sites. In particular, quantitative estimates of ecological risk (i.e., predicted impacts) were almost non-existent. Available information for the sample sites is summarized in Exhibit I-3. When available, information on both the areal extent and magnitude of contamination and effects is provided.

The extent of threats varies widely across the sample, both in terms of the area affected and magnitude of impact. Based on the site documentation reviewed, there are five sites (approximately 10 percent of the sample) that appear to present relatively severe ecological threats, characterized by high levels of environmental contamination spread over relatively large areas with large populations of organisms that are (or could be) exposed. There is an equal number that appears to present relatively minor threats, generally characterized by low levels of environmental contamination confined to small areas and relatively small numbers of potential ecological receptors. Therefore, based on the documentation reviewed, the majority (roughly 80 percent) of the sites can be categorized as relatively moderate in terms of ecological threats. It is important to clarify that many of the sites grouped into this "moderate" category have resulted in adverse effects and even death to some biota, or have caused environmental contamination that is likely to cause adverse effects to biota. However, the threats at the majority of these sites were categorized as moderate, for the purpose of relative ranking only, mainly because: (1) the area affected generally appears to be small to moderate in size and the biota affected generally appear to be limited to organisms close to the site; and/or (2) contaminant levels appear to be below acutely toxic levels in most areas and the potential for effects of chronic exposures at these sites is not well understood.

3.3 Analysis of Trends

Available data for the 52 sample sites suggest that a wide variety of waste types and constituents are contributing to ecological threats at Superfund sites. As shown in Exhibit I-4, the most frequently occurring waste type in the sample (present at roughly a third of the sites) is municipal/commercial/industrial waste commingled in a landfill, with the specific components and sources of these wastes often being unknown. The relative high frequency of this waste mixture illustrates the point that mixtures of several different chemicals, rather than just one or two, are probably contributing to ecological threats at most sites. Exhibit I-5 identifies the principal contaminants observed at the 52 sample sites. The most frequently encountered inorganics in the sample are lead, cadmium, arsenic, chromium, and zinc; the most frequently encountered organics are volatile organic compounds (e.g., benzene, toluene, trichloroethylene), PCBs, and polynuclear aromatic hydrocarbons (e.g., naphthalene, benzo(a)pyrene). Because of limitations in the available site information, it was not possible to determine the substances responsible for most of the ecological threats.

As shown in Exhibit I-6, the most common types of waste management practices resulting in releases at the 52 sites are landfills/dumps and surface impoundments, which together account for roughly 80 percent of the sample. Of the sites with a landfill and/or

EXHIBIT I-3

EXTENT OF ECOLOGICAL IMPACTS IN THE 52-SITE SAMPLE

Category of Impact	Number of Sites With Information on Extent a/	Cumulative Areal Extent at Sites With Information	Contaminants/Magnitude b/
Surface Water Contamination	9	▪ 209 stream miles; and ▪ 3,954 acres	▪ Concentrations of 8 metals, PCBs, and pentachlorophenol exceed AWQC 1.5 to 414,000 times.
Contamination of Surface Water Sediments	9	▪ 209 stream miles; and ▪ 3,937 acres	▪ Observed contaminants include 7 metals, PCBs, and asbestos. ▪ Concentrations frequently exceed background levels, ranging from 15 to 820 times. ▪ Amounts of 4 metals and PCBs in sediments range from 10 pounds to 229 metric tons per site.
Soil Contamination	15	2,240 acres	▪ Observed contaminants include 6 metals, asbestos, PCBs, phenols, nitroaromatics, and other organics. ▪ Concentrations frequently exceed background levels, ranging from 3 to 2,600 times. ▪ Volumes of contaminated soil range from 17,000 to 535,000 cubic yards per site.
Fish Kills	4	27 stream miles	▪ Severity of observed fish kills ranges from 100% to 10% for affected areas.

EXHIBIT I-3 (continued)

EXTENT OF ECOLOGICAL IMPACTS IN THE 52-SITE SAMPLE

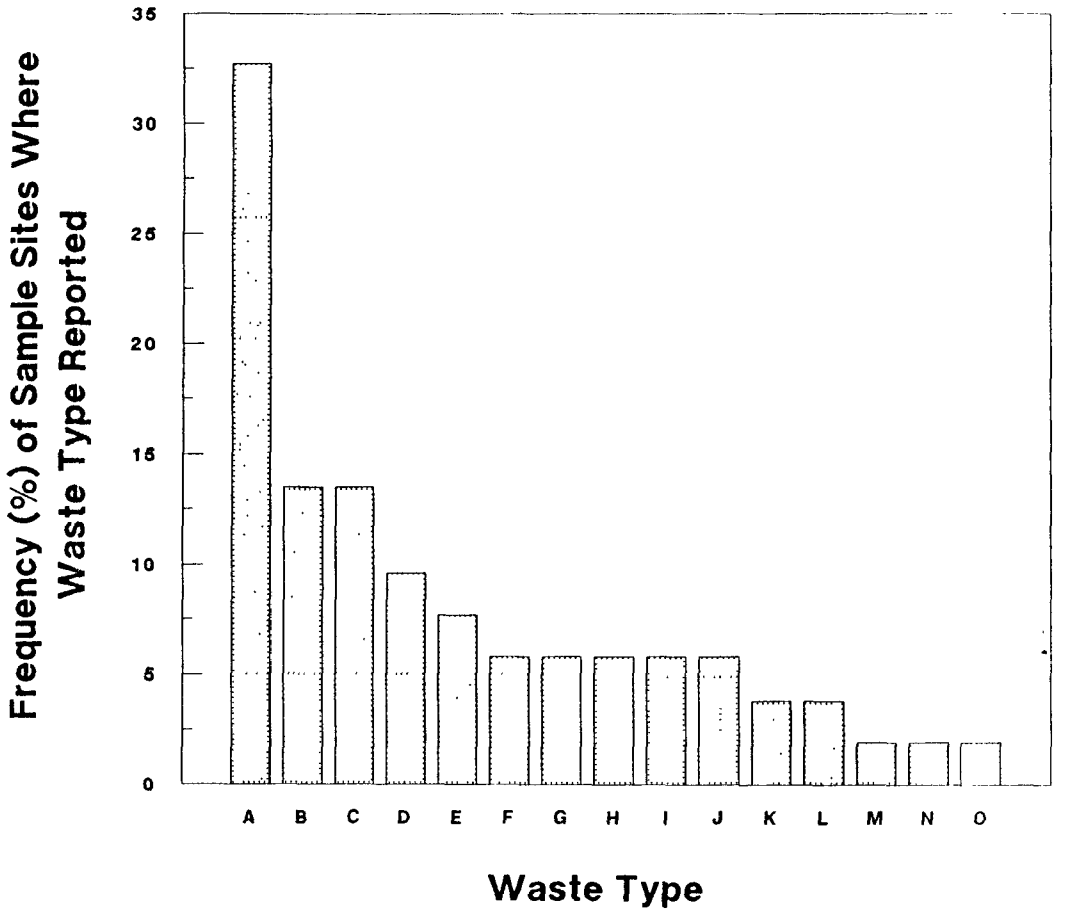
Category of Impact	Number of Sites With Information on Extent a/	Cumulative Areal Extent at Sites With Information	Contaminants/Magnitude b/
Defoliation	5	2,014 acres	▪ Observed contaminants include 3 metals and pentachlorophenol.
Contamination/Degradation of Wetlands/Marshes	5	324 acres	▪ Observed contaminants include 2 metals, oils, and PCBs. ▪ Concentrations in sediments frequently exceed background levels.

a/ Explicit information was provided on the areal extent or magnitude of contamination for 28 of the 52 sites in the sample; information from only those 28 sites is included in this exhibit.

b/ Indicates degree to which contaminant levels exceed criteria such as EPA's ambient water quality criteria (AWQC). Information on the exceedance of criteria is not provided for soil and sediment contamination because generally applicable criteria for these media do not exist.

EXHIBIT I-4

PRINCIPAL WASTE TYPES IN THE 52-SITE SAMPLE



A - Mixed municipal/commercial/ industrial wastes

B - Waste oil/oily sludge

C - Solvents/degreasers/paint thinners/metal finishing liquids

D - Mine/mill/smelter wastes

E - Battery casings and reconditioning wastes

F - Wood preserving/treating wastes

G - Waste transformer oil/ hydraulic fluids

H - Pesticide manufacturing wastes

I - Tire residues/waste tires

J - Unspecified hazardous wastes

K - Electrical equipment manufacturing wastes

L - Waste from unidentified sources

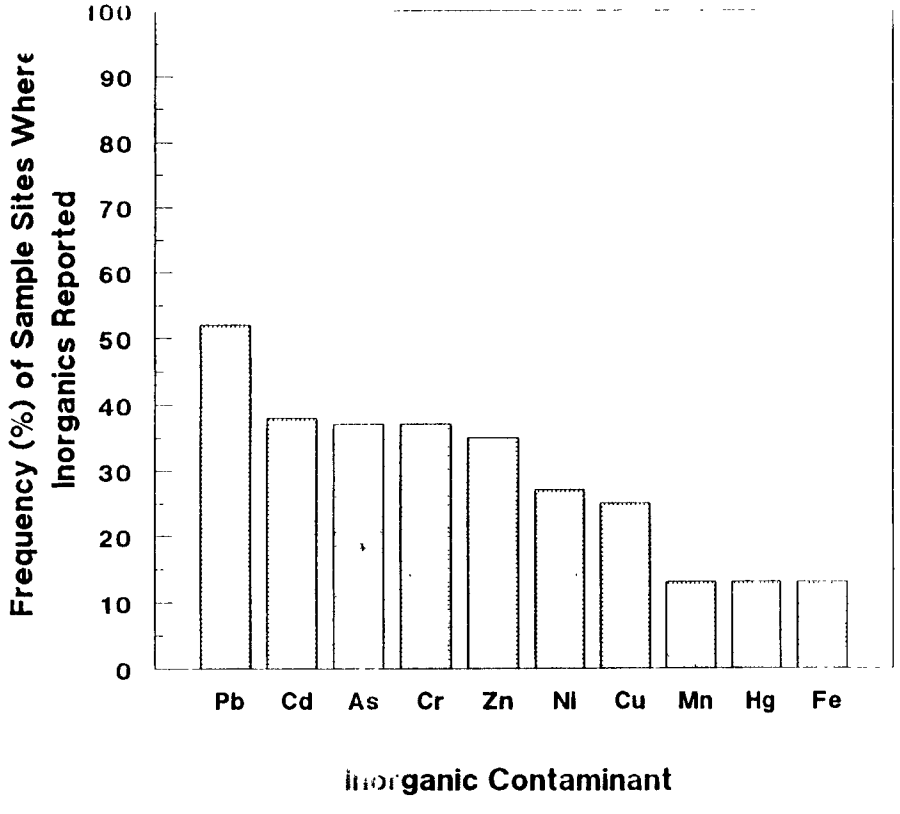
M - Fly ash

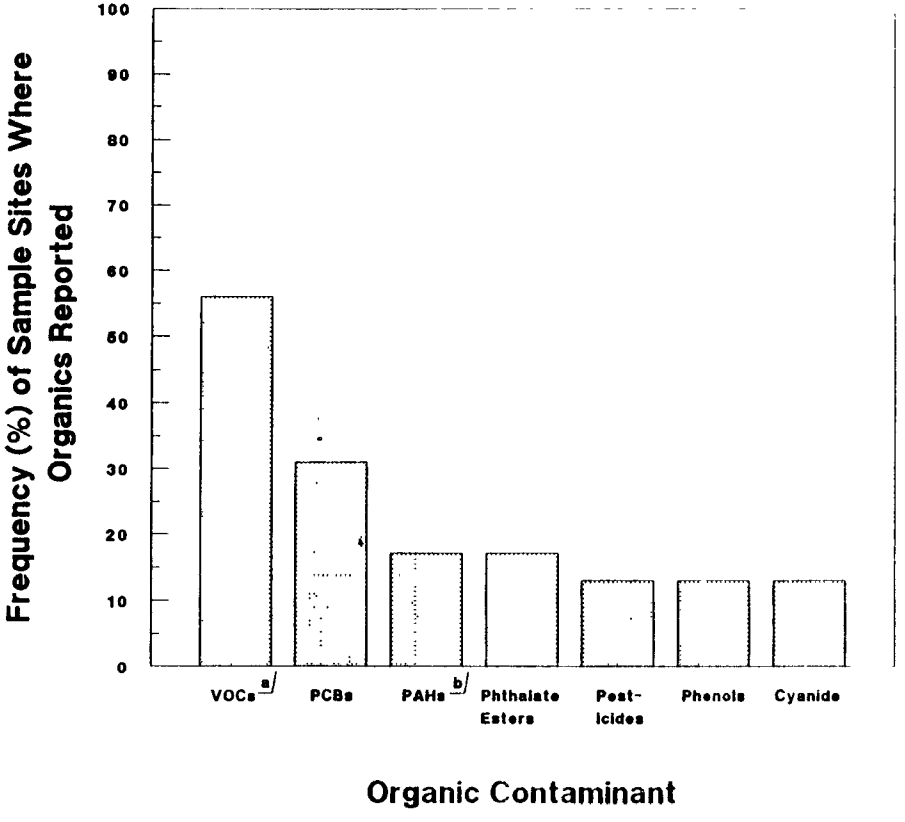
N - Explosive manufacturing wastes

O - Steel foundry wastes

EXHIBIT I-5

PRINCIPAL CONTAMINANTS IN THE 52-SITE SAMPLE



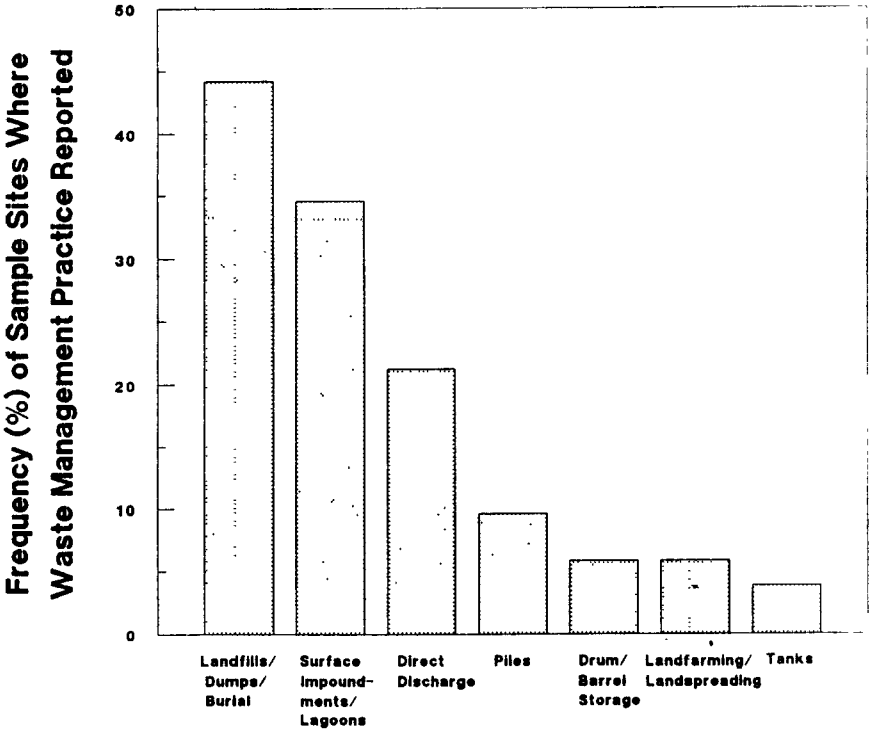


a/ Volatile organic compounds. This category includes a variety of both aromatic hydrocarbons (e.g., benzene, toluene) and aliphatic hydrocarbons (e.g., trichloroethylene and vinyl chloride).

b/ Polynuclear aromatic hydrocarbons (e.g., benzo(a)pyrene, naphthalene).

EXHIBIT I-6

FREQUENCY OF WASTE MANAGEMENT PRACTICES AND ENVIRONMENTAL SETTINGS IN THE 52-SITE SAMPLE



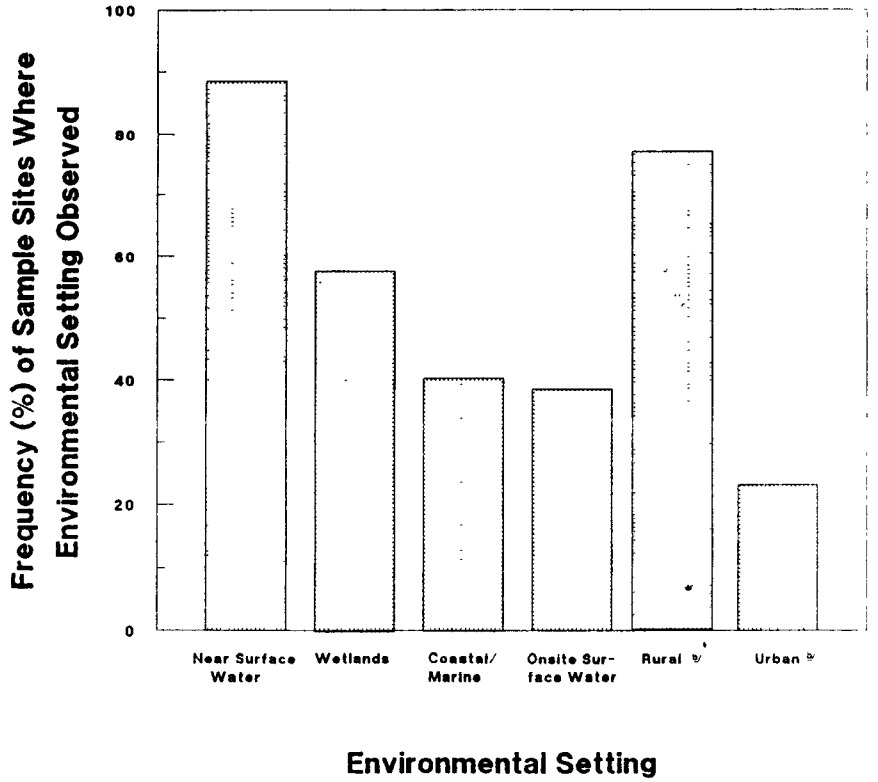


EXHIBIT I-6 (continued)

FREQUENCY OF WASTE MANAGEMENT PRACTICES AND ENVIRONMENTAL SETTINGS IN THE 52-SITE SAMPLE

FOOTNOTES

a/ While several of the sites employed more than one waste management practice, these are the practices that were principally implicated as the sources of hazardous substance releases.

b/ Site environments were classified as generally rural if surrounding land uses are described in reports as being predominantly agricultural, rural, residential, or light industrial in combination with one or more of the preceding land uses. Site environments were classified as generally urban if surrounding land uses were described as commercial and/or industrial.

surface impoundment, the most commonly observed waste migration pathway affecting ecological resources is seepage into ground water that in turn discharges to surface water (observed at almost 65 percent of these sites). However, at most sites multiple release and migration pathways from multiple sources were either observed or projected (e.g., runoff, erosion, direct discharges).

In terms of environmental setting characteristics, the factor that appears to have the greatest bearing on reported ecological threats is the proximity of the site to surface water (see Exhibit 6). Almost 90 percent of the sites in the sample are either adjacent to or near (generally within one or two miles) a surface water body, and roughly 60 percent are near a wetland, swamp, or marsh. In addition, almost 40 percent of the sites were noted to have surface water onsite, most commonly drainage ditches or small creeks that appear to act as conduits for waste constituent migration, as well as habitat for aquatic receptors.

3.4 Generalizations Concerning the Significance of Threats

It is difficult to draw firm conclusions about the overall extent and significance of ecological threats at Superfund sites because of: (1) major limitations in the available ecological data (even for the 52 sample sites selected in part because they had the most information); (2) a lack of ecological toxicity reference levels (i.e., "benchmarks") for many substances; (3) scientific uncertainties about the response of ecosystems to chemical contamination; and (4) a lack of Superfund policy on what constitutes a "significant" ecological threat. Nevertheless, generalizations can be made concerning the following four aspects that relate to the significance of ecological effects: the intensity of the effects, the duration of the effects, the extent to which unique or particularly valuable resources are threatened, and the overall context of the threats (i.e., whether they are local, regional, national, or global). Section 3.4.1 provides generalizations across the 52 sites studied in this project, and Section 3.4.2 discusses generalizations across all Superfund sites.

3.4.1 Generalizations Across Sample of 52 Sites

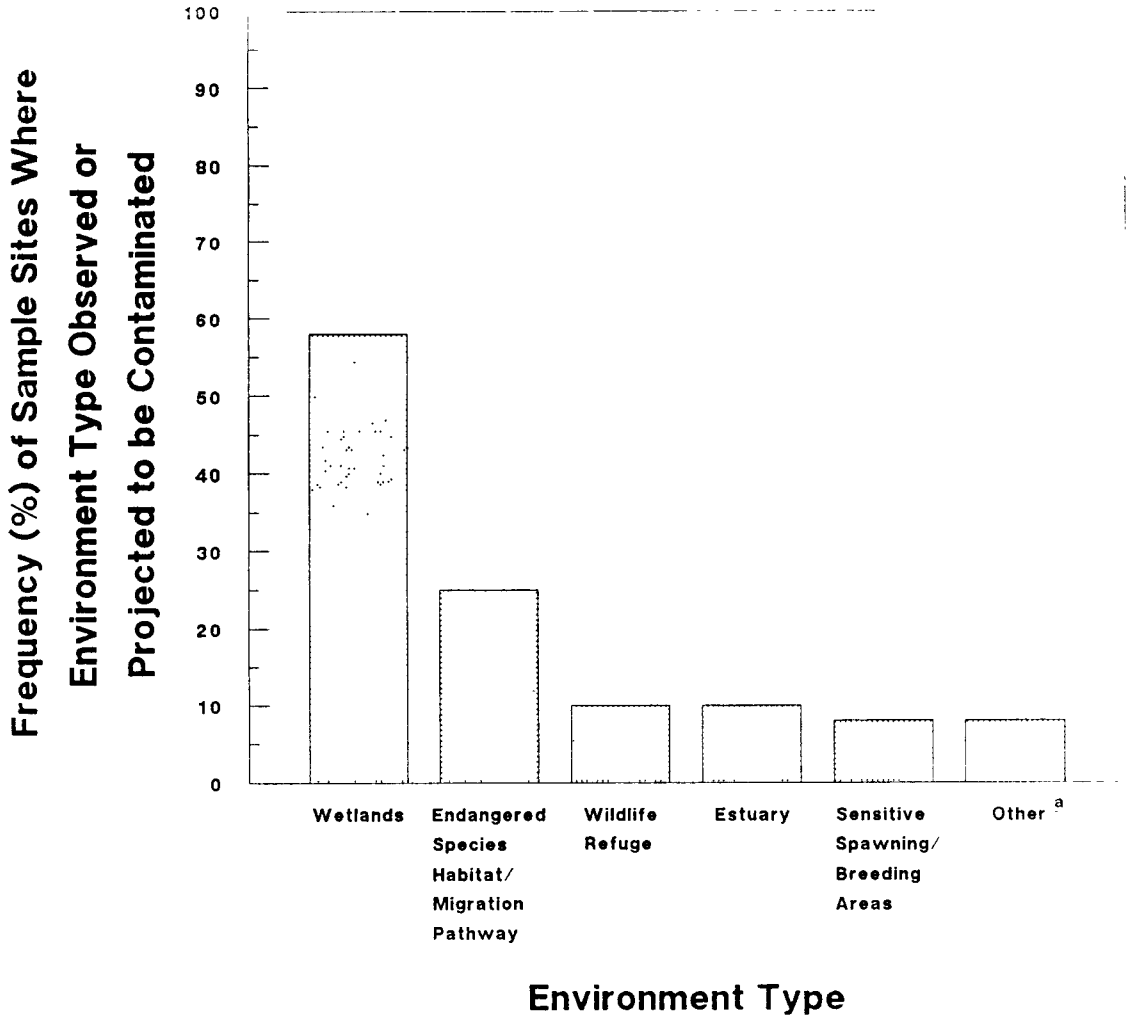
The adverse ecological effects at Superfund sites can be very intense, including death to aquatic and terrestrial organisms and complete devastation of habitat. Almost all of the sites in the sample have contaminants present that are acutely toxic to aquatic organisms when present in sufficient concentrations. In the sample studied, however, very intense (or acute) effects were observed or projected at only a small fraction of the sites or appeared to be limited to small areas. Most sites appear to present more of a long-term threat that to date has not resulted in adverse effects that are easy to detect.

Based solely on the types of contaminants observed, it appears that ecological exposures and adverse effects caused by contamination at the sample sites could persist for long periods of time if no response action were taken. Most of the sites are contaminated with chemicals that are persistent and bioaccumulative (e.g., PAHs, PCBs, lead, cadmium).

Ecological threats may be considered by some to be more significant if the resources at risk are particularly valuable (i.e., unique, vulnerable, commercially significant, or recreationally important). In that regard, Exhibit I-7 identifies certain "sensitive or special" environments that are or may be contaminated in the 52-site sample. Almost 60 percent of the sample sites appear to be threatening wetland/marsh/swamp systems, and 25 percent may be threatening endangered species or their habitats. In addition, roughly 10 percent of the sites are located in

EXHIBIT I-7

OBSERVED OR PROJECTED CONTAMINATION OF SENSITIVE/SPECIAL ENVIRONMENTS IN THE 52-SITE SAMPLE



a/ This category includes state parks, lakes adjacent to parks, and nature study areas.

or near wildlife refuges, and approximately 7 percent are possibly threatening aquatic habitat noted in the site reports to be sensitive spawning areas for fish. The commercial resources that appear to be at highest risk are fish and shellfish: approximately 17 percent of the sites noted observed or projected threats to fish or shellfish that appear commercially significant. Very few data are available on the recreational value of the resources potentially affected, except that roughly seven percent of the sites may have contaminated areas likely to be used for recreational purposes (e.g., state parks, lakes adjacent to parks, and nature study areas).

Virtually all of the sample sites individually pose ecological threats that are local in nature. Only one site conceivably could cause adverse effects on a regional level. However, the threats at individual sites must be considered along with the fact that there is a large number of Superfund sites in order to assess the aggregate national extent of ecological threat.

3.4.2 Generalizations Across All Superfund Sites

The sample of 52 sites studied in this analysis may not be representative of all Superfund sites, and it certainly was not a statistically based sample of the site universe.[4] The sample was drawn from a limited set of selectively identified sites, and probably is biased toward sites with more obvious ecological threats (i.e., when compared to the universe of all sites, the sample of 52 is likely to contain a larger fraction of sites with more obvious ecological threats because they were recognized and investigated). The sample may also be biased toward sites with more severe ecological threats, although that is less certain. Furthermore, the representativeness of the sample results is uncertain given the fact that comprehensive efforts to identify sites where ecological threats exist generally have not been made prior to this study. For these reasons, statistically valid extrapolations of the sample results to the general population of Superfund sites are not possible.

Simply for the purpose of illustration, however, the sample results can be generalized over the entire Superfund site universe if it is assumed that the 52 sample sites examined here are representative of sites having the potential for significant ecological threats. Using information collected for this study, a very rough, preliminary estimate of the number of NPL sites that have the potential for significant ecological impacts or risks would be between 220 and 420 sites (between approximately 18 percent and 35 percent of all sites either on or proposed for the NPL).[5] Furthermore, there is little reason to believe that non-NPL sites pose less of an ecological threat than NPL sites. Therefore, if it is assumed that the estimated percentage of NPL sites potentially posing significant ecological threats is valid for the 15,000 or so sites currently listed in CERCLIS as candidates for further investigation (i.e., roughly 16,000 of the 31,000 sites in CERCLIS will not undergo further investigation because they have been categorized as "no further response action planned"), the total number of Superfund sites with the potential for significant ecological threats would be between 2,700 and 5,300. The total number of sites currently exhibiting relatively severe ecological effects is probably much smaller.

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[4] At this time, a retrospective analysis of a statistically drawn sample would have limited value because of severe ecological data limitations for the sites.

[5] See OPA's report on the nature and extent of ecological risks at Superfund sites and RCRA facilities (EPA-230-03-89-043) for complete details on these illustrative numerical generalizations.

If it is assumed that the 52 sample sites examined here are representative of sites having the potential for significant ecological threats, the characterization of ecological threats at the sample sites would illustrate the nature of threats that may occur at all Superfund sites having the potential for significant ecological threats. In order to make quantitative projections about the extent of ecological threats across all Superfund sites, one would have to further assume that: (1) the subset of 28 sample sites for which data are available on the extent of threats is also representative; (2) available data on the extent of ecological threats are complete and accurate; and (3) the above estimates of the total number of sites with the potential for significant ecological threats are accurate. If these assumptions are valid and if the results for the 52 sites are extrapolated over the upper bound of 5,300 sites with the potential for significant threats, the total national extent of ecological impacts caused by Superfund sites would include surface water contamination in as many as 12,000 stream miles, up to 8,000 stream miles of contamination of surface water sediments, as many as 64,000 acres of soil contamination, fish kills in up to 1,700 stream miles, defoliation over 22,000 acres, and contamination of up to 22,000 acres of wetlands and marshes (see detailed report on the nature and extent of ecological risks at Superfund sites for more specifics on the derivation of these numbers).

To help put these estimates in perspective, Keup (1985)[6] estimates that there are approximately 3,250,000 total stream miles in the U.S. The rough estimates given above for surface water and surface water sediment contamination caused by Superfund sites are less than 0.5 percent of the nation's stream miles. According to EPA (1987),[7] it is suspected that severe contamination of sediments with toxicants released from all sources might exist in perhaps 1 percent of the nation's stream miles (not counting possible sediment contamination in the nation's lakes, estuaries, or marine areas). The estimate given above for fish kills caused by Superfund sites is less than 0.1 percent of the nation's stream miles. For comparison, EPA and the Fish and Wildlife Service (1984)[8] have estimated that fish kills caused by all sources have occurred in 15 percent of the nation's stream miles and that toxic substances from all sources have adversely affected fish in roughly 10 percent of the nation's stream miles (not counting fish kills or toxic substance contamination that may have occurred in estuaries, coastal waters, wetlands, or the Great Lakes). Moreover, the rough estimate given above for the number of acres of wetlands and marshes contaminated by Superfund sites represents less than 0.03 percent of the nation's total inventory of wetlands in the 1970's in the 48 conterminous United States.[9] Roughly 20 times more wetlands are lost each year as a result of all other stresses,[10] with agriculture and development alone resulting in an annual loss of roughly 10 times more

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[6] Keup, 1985, "Flowing Water Resources," Water Resources Bulletin, American Water Resources Association, Vol. 21, No. 2, April.

[7] EPA, 1987, "Unfinished Business: A Comparative Assessment of Environmental Problems -- Appendix III," Ecological Risk Work Group, February.

[8] EPA and Fish and Wildlife Service, 1984, "1982 National Fisheries Survey Volume I Technical Report: Initial Findings," FWS/OBS-84-06.

[9] Fish and Wildlife Service, 1983, "Status and Trends of Wetlands and Deepwater Habitats in the Conterminous United States, 1950's to 1970's," April.

[10] Ibid.

wetlands than predicted to be contaminated by Superfund sites.[11] Assuming these estimates are valid, therefore, the relative contribution of Superfund sites to the nation's ecological impacts appears moderate to small. This conclusion generally is supported by other EPA studies.[12]

Clearly, these numerical extrapolations are highly uncertain; they are provided only to illustrate the possible extent of the problem, and as a quantitative point of departure to be refined in future studies.

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[11] EPA, Office of Solid Waste, 1988, "Final Regulatory Impact Assessment/Background Information Document -- Wetlands."

[12] EPA, 1987, "Unfinished Business: A Comparative Assessment of Environmental Problems -- Appendix III," Ecological Risk Work Group, February.

4. ECOLOGICAL RISK ASSESSMENT METHODS

OPA's report reviewing ecological assessment methods in OSWER is titled "Ecological Risk Assessment Methods: A Review and Evaluation of Past Practices in the Superfund and RCRA Programs," EPA-230-03-89-044 (June 1989). That report focuses on major approaches that have been used for characterizing impacts and risks rather than on a detailed analysis of specific elements of these approaches. Each major methodological approach is evaluated in terms of the ecological assumptions inherent in the approach, the types of ecological impacts it can and cannot characterize, its main limitations, and its utility for risk management. In addition, assessment approaches are analyzed in terms of the relative level of effort required versus the type and quality of information yielded by that effort. This section summarizes key findings related to Superfund sites from the detailed methods review report.

In general, the methods used to characterize ecological impacts at Superfund sites can be divided into three broad categories: (1) screening-level methods for (a) determining the overall nature and extent of ecological impacts associated with a number of diverse problem areas, including Superfund sites, and (b) establishing remedial priorities at hazardous waste sites; (2) methods for characterizing actual ecological impacts (i.e., those that have been measured or observed) resulting from the release of chemicals at specific sites; and (3) methods for characterizing potential ecological impacts (i.e., those that have not been measured or observed, but are predicted) that might result from the release of chemicals at specific sites. Actual impacts have been distinguished from potential impacts because the methods and data used to characterize the two types of impacts differ markedly. Characterization of actual impacts requires some type of survey or sampling of the condition of ecological receptors at and near a site. Characterization of potential impacts is more predictive in nature and requires information on chemical hazard, exposure potential, and exposure-response relationships for the ecological receptors. These three categories of methods are described and evaluated briefly in the following subsections.

4.1 Screening-Level Analyses

Two types of screening-level analyses have included, or are being used at, Superfund sites: analyses for establishing policy and regulatory priorities, and the Hazard Ranking System (HRS). Each of these types of analyses is described and evaluated briefly in a following subsection.

4.1.1 Analyses for Establishing Policy and Regulatory Priorities

Description. The purpose of these screening-level analyses is to provide a broad overview of the nature and extent of ecological impacts associated with diverse problem areas, different types of facilities, or various waste management practices. The primary type of priority analysis that included Superfund sites is a comparative risk study.

Three EPA comparative risk studies that were reviewed[13] included a screening-level evaluation of ecological threats posed by Superfund sites. In these studies, the relative ecological impacts associated with diverse problem areas, including Superfund sites, were assessed and ranked. Information on exposure levels and/or potential, types and societal value of ecological receptors, hazards of constituents to receptors, and the areal extent and reversibility of potential impacts was combined using professional judgment to derive a semi-quantitative relative risk ranking for each problem area.

Evaluation. Comparative risk estimation can provide a nationwide overview of the ecological hazards and/or impacts associated with Superfund sites relative to other problem areas being analyzed. Comparative risk estimation cannot be used to establish remedial priorities within the Superfund program itself. Such priorities are established with the HRS (see section 4.1.2). The ranking procedure can be based on potential impacts, potential impacts and likelihood of exposure, and/or actual impacts resulting from known levels of exposure. Information on known impacts provides a better evaluation of the current extent of ecological problems, while information on potential impacts provides a better evaluation of the extent of possible future ecological problems (or uninvestigated current problems). Comparative risk estimation does not provide new information about ecological impacts or quantitative estimates of ecological risks.

4.1.2 Analyses for Establishing Superfund Remedial Priorities

Description. The Superfund program uses the HRS as a screening-level device for establishing remedial priorities at hazardous waste sites. The HRS score is used to determine whether a site is placed on the National Priorities List (NPL) and thus eligible for Superfund-financed remediation. The HRS is a scoring system that evaluates factors (e.g., toxicity of substances, number and type of potential receptors) that are indicators of the risks to human health or the environment associated with a given site.

Evaluation. An evaluation of the HRS was beyond the scope of this project. Both the current HRS and the proposed revisions to the HRS (53 FR 51962, December 23, 1988) consider ecological risks to a specified list of "sensitive environments," but in both models human health risks are weighted more heavily than ecological risks. Under the current HRS, a site cannot be listed on the NPL solely on the basis of ecological concerns, although such concerns can contribute to NPL listing. The final form of the revised HRS will not be available until early 1990. Although it will expand the consideration of ecological concerns, the extent to which this will affect NPL listing cannot be determined at present.

4.2 Approaches for Characterizing Actual Impacts

Description. At the 52 Superfund sites reviewed in this study, three main approaches were used to characterize actual ecological impacts: evaluation of biotic community structure, analysis of the morphological and/or physiological condition of individual organisms, and

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[13] EPA/OSWER, draft report, "Ecological Risk Characterization Methodology" (April 1988); EPA/OPPE, final report, "Unfinished Business: A Comparative Assessment of Environmental Problems" (February 1987); and ICF Incorporated, draft report, "Regional and State Comparative Risk Project: Approaches for Ranking Based on Ecological Risk/Impact" (December 1987).

comparison of measured contaminant concentrations to ecological benchmark levels[14] (see Exhibit I-8).

In the first approach, biotic community structure was compared in ecosystems exposed to site contaminants and in nearby reference ecosystems. Measures of community structure included species diversity or evenness indices, the presence of "indicator" species associated with stressed ecosystems, a qualitative description of the community, and stressed or absent vegetation. The techniques used most commonly to evaluate community structure were systematic, quantitative field sampling or qualitative surveys, although aerial photography was used at a few sites. Evaluations of this type focused on four major taxonomic groups or organisms: terrestrial plants, vertebrates (e.g., fish, mammals, birds), benthic macroinvertebrates, and shellfish.

A second approach used to characterize actual impacts was to compare the physiological and/or morphological condition of individual organisms inhabiting the exposed ecosystem to those in a reference area. The most common technique for making this comparison, used at nearly all sites, was to collect organisms directly from the exposed ecosystem and from the reference ecosystem and to examine the collected specimens. The most common endpoint used to evaluate the condition of these specimens was tissue residue levels of contaminants, although strictly speaking, elevated tissue residue levels do not indicate the presence of adverse biological effects unless coupled with independent evidence of such effects. At some sites, additional evaluation using histopathology or necropsy was conducted to measure the incidence of tumors, lesions, developmental abnormalities, and other morphological or physiological symptoms of stress. Evaluations focused generally on the taxonomic groups most likely to be exposed to site contaminants.

A third approach for characterizing actual impacts was to compare measured concentrations of contaminants in environmental media to ecological benchmark levels to determine whether contaminant concentrations had reached a level likely to result in adverse ecological effects. This approach was used most commonly for aquatic or wetland ecosystems, and usually no specific organisms or endpoints of concern were identified.

Evaluation. Exhibit I-9 provides a summary evaluation of the main approaches and techniques used to characterize actual ecological impacts at Superfund sites. A qualitative survey of biotic community structure can detect large, readily apparent impacts to exposed ecosystems, including the presence or absence of indicator species. It also can be used to determine the areal extent of such impacts. However, community-level impacts that are more difficult to observe and impacts to populations or individual organisms generally will not be detected with this approach. Severity of impacts is difficult to determine with this technique unless it is extreme.

A quantitative measure of biotic community structure can detect less noticeable alterations in community structure. Hence, sites at which community-level impacts are not readily apparent might be identified with this approach. This approach also can provide a numerical measure of the severity of impacts, although it is difficult to evaluate the ecological

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[14] Although comparing measured contaminant concentrations to ecological benchmarks is not a valid measure of actual ecological impacts, it was used as a surrogate measure of actual impacts at 17 of the Superfund sites reviewed.

EXHIBIT I-8

APPROACHES, TECHNIQUES, AND ENDPOINTS USED TO CHARACTERIZE ACTUAL IMPACTS AT SUPERFUND SITES

Approaches	Techniques	Endpoints
Evaluation of Biotic Community Structure	- Quantitative Sampling - Qualitative Surveys - Aerial Photography	- Diversity Indices - Indicator Species - Description of Community - Absent/Stressed Vegetation
Evaluation of Individual Morphology or Physiology	- Field Sampling - Histopathology, Necropsy - Records of Mortality - Detailed Field Studies	- Tissue Residue Levels - Disease/Abnormalities - Reproduction
Comparison of Contaminant Concentrations to Ecological Benchmarks a/	- Field Sampling	- Contaminated Media - Hazard Quotients

a/ Although this approach does not establish the existence of actual ecological impacts, it was used as a surrogate measure of actual impacts at 17 of the sites examined.

EXHIBIT I-9

SUMMARY EVALUATION OF APPROACHES AND TECHNIQUES USED TO CHARACTERIZE ACTUAL IMPACTS AT SUPERFUND SITES

Approach or Technique	Information Provided by This Approach or Technique	Information Not Provided by This Approach or Technique	Information Gained by Adding This Approach or Technique
Evaluation of Biotic Community Structure			
Qualitative Surveys	Identification of large, readily apparent impacts	Identification of subtle impacts	Identification of sites with major impacts to biotic communities
	Areal extent of impacts	Impacts to individuals or populations	
		Severity of impacts (unless extreme)	
Quantitative Measures	Quantification of small, subtle impacts	Impacts to individuals or populations	Identification of sites with minor impacts to biotic communities
	Severity of impacts		
	Areal extent of impacts		
Evaluation of Individual Morphology or Physiology			
Examination of Specimens	Direct evidence of injury to individual organisms	Impacts to populations, communities or the ecosystem	Identification of sites with major impacts to individual organisms
	Areal extent or magnitude of impacts		

EXHIBIT I-9 (continued)

SUMMARY EVALUATION OF APPROACHES AND TECHNIQUES USED TO CHARACTERIZE ACTUAL IMPACTS AT SUPERFUND SITES

Approach or Technique	Information Provided by This Approach or Technique	Information Not Provided by This Approach or Technique	Information Gained by Adding This Approach or Technique
Comparison of Measured Contaminant Concentrations to Ecological Benchmarks			
Field Sampling	Nature and areal extent of contamination/contamination above benchmarks	Direct evidence of actual impacts	Identification of exposure pathways

significance of a particular change in a community diversity or evenness index. Areal extent of impacts can be determined by field sampling or, in some situations, by use of aerial photography. The quality of information provided by quantitative measures of community structure depends considerably on the scope and intensity of the sampling effort. Moreover, the effectiveness of quantitative measures of community structure in characterizing actual impacts depends largely on how well the ecological significance of any observed change in community structure can be documented. For most quantitative metrics, there is no scientific consensus on what constitutes an ecologically significant change, and a change considered significant for one ecosystem might not be considered so for another.

Evaluation of the morphological or physiological condition of individual organisms provides direct evidence of whether or not actual impacts have occurred in the organisms of concern, and sufficient sampling can delineate the areal extent or magnitude (e.g., number of individuals or size of population affected) of such impacts. Impacts can be evaluated with a variety of techniques; the appropriate technique(s) for a given site will be determined to a large extent by the particular contaminants present at the site. Use of this approach can identify sites at which impacts to individual organisms have occurred even when community structure is not affected significantly (or the ecological significance of any observed change in community structure cannot be determined).

Evaluation of the morphological or physiological condition of individual organisms and evaluation of community structure represent two different and somewhat complementary approaches for characterizing actual impacts. Evaluation of community structure provides little information about individual organisms within that community. Similarly, evaluation of the morphological or physiological condition of individual organisms provides little information about communities within the ecosystem. If there is little reason to expect one type of effect more than the other at a given site, use of both approaches together will identify sites at which effects on one or the other level might be overlooked. Neither of the above approaches characterizes impacts to biotic populations. Relatively intensive field studies generally are required for most population-level measures (e.g., density, age structure, survivorship, reproductive rate). Historical records of fish kills were used as evidence of population-level impacts at four Superfund sites, but no field population studies were conducted at the sites reviewed.

Comparison of measured media contamination levels to ecological benchmarks is not a valid approach for characterizing actual impacts. Evidence of concentrations of contaminants above benchmark levels confirms the presence of an exposure pathway and the likely magnitude of exposure but does not establish the existence of actual ecological impacts. Such evidence might be considered a surrogate measure of actual impacts but is a more valid measure of potential ecological impacts (see Section 4.3). At the sites where it was used as a surrogate for actual impacts, this approach served mainly to document the nature and areal extent of contamination.

4.3 Approaches for Characterizing Potential Impacts

Description. Four main approaches were used at the 52 Superfund sites reviewed in this study to characterize potential ecological impacts: comparison of measured and/or projected environmental concentrations of contaminants to ecological benchmark levels (i.e., the quotient method), evaluation of potential impacts from estimates of exposure potential, evaluation of potential impacts from estimates of hazard potential based on toxicity tests, and

quantitative risk modeling (see Exhibit I-10). In the first approach, measured and/or projected concentrations of contaminants in environmental media or biota were compared to ecological benchmark levels derived from toxicity studies on laboratory organisms. This approach was applied most commonly to aquatic or wetland ecosystems. Ecological benchmarks used most frequently were EPA's ambient water quality criteria (AWQC) and state water quality standards. At some sites, additional benchmarks for contaminants in soil, sediments, or biota were derived from chronic lowest-observed-effect levels (LOELs), chronic no-observed-effect levels (NOELs), and acute LC_{50}s or dietary LD_{50}s.[15] At most sites, the specific ecological endpoints being assessed for potential impact were not identified in the documentation, although AWQC are based on population-level effects. At sites where endpoints were specified, population-level endpoints in vertebrates and invertebrates (e.g., excess mortality, depressed reproduction) were the endpoints selected most frequently.

A second approach used to characterize potential ecological impacts consisted of a quantitative or qualitative estimate of exposure potential, a qualitative description of the types of ecological receptors likely to be exposed, and a qualitative discussion of the types of impacts that might occur in those receptors. This approach was applied most commonly to terrestrial ecosystems and wetlands. In this approach, no ecological benchmark is used to determine an exposure level of concern. At most sites, no specific ecological endpoints were identified in the documentation. At sites where endpoints were specified, excess mortality and depressed reproduction in birds, mammals, and plants were the endpoints selected most frequently.

A third approach for characterizing potential ecological impacts was to evaluate hazard potential, as determined by toxicity tests (i.e., exposing organisms to contaminated media in situ or in a controlled laboratory setting). At the sample sites, toxicity tests were conducted using sediments, leachate, and/or surface water. Organisms used in the toxicity tests included fish, shellfish, daphnids, and bacteria. Endpoints used were either at the population level (e.g.,excess mortality, depressed reproduction) or at the individual level (e.g., tissue residue levels). At the sites reviewed, this approach was used exclusively for aquatic ecosystems or the aquatic components of wetlands, although it also is applicable to terrestrial ecosystems.

A final approach used to characterize potential impacts (used only at one sample site) was a mathematical model to evaluate the likelihood of a significant impact to the ecosystem (i.e., catastrophic failure of fish reproduction) using an assumed food web, exposure/intake assumptions, bioconcentration factors, and exposure/response information.

Evaluation. Exhibit I-11 provides a summary evaluation of the approaches used to characterize potential ecological impacts at Superfund sites. Comparison of measured and/or projected environmental concentrations of contaminants to ecological benchmarks provides dichotomous (yes/no) information on whether adverse ecological impacts are likely. This approach provides little information about the severity of effects if benchmark concentrations are exceeded, although higher ratios in general will be correlated with more severe impacts. This approach also provides little information on the effects resulting from exposure of biotic receptors to multiple contaminants. Numerous specific techniques can be followed within this general approach, and each provides different types of information. Evaluating measured contaminant concentrations in environmental media provides information about potential impacts resulting from exposures via direct contact with such media. Modeling contaminant

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[15] The concentration (LC_{50}) or dietary dose (LD_{50}) lethal to half the exposed organisms.

EXHIBIT I-10

APPROACHES, TECHNIQUES, AND ENDPOINTS USED TO CHARACTERIZE POTENTIAL IMPACTS AT SUPERFUND SITES

Approaches	Techniques	Endpoints
Comparison of Measured and/or Projected Contaminant Concentrations to Ecological Benchmarks	- Measured Concentrations - Projected Concentrations	- Mortality - Reproduction - Growth - Community Structure
Estimate of Exposure Potential (No Benchmarks)	- Measured Concentrations - Projected Concentrations - Qualitative Evaluation	- Mortality - Reproduction - Growth - Community Structure
Estimate of Hazard Potential (Media Toxicity Tests)	- Laboratory Toxicity Tests - In situ Toxicity Tests	- Mortality - Reproduction - Growth - Tissue Residue Levels
Quantitative Risk Modeling	- Fault-Tree Analysis a/	- Fish Reproductive Failure

a/ The specific model used was not described in detail in the available documents.

EXHIBIT I-11

SUMMARY EVALUATION OF APPROACHES USED TO CHARACTERIZE POTENTIAL IMPACTS AT SUPERFUND SITES

Approach	Information Provided by This Approach	Information Not Provided by This Approach	Information Gained by Adding This Approach
Comparison of Measured and/or Projected Contaminant Concentrations to Ecological Benchmarks	Yes/no information as to whether impacts are likely	Quantitative measure of severity of impacts if benchmarks are exceeded	Ecologically based cleanup criteria for single contaminants
	Impacts resulting from direct exposures to contaminated media and indirect exposures via food chains	Impacts to communities or the ecosystem (unless benchmarks specifically account for these)	
Estimate of Exposure Potential	Types of ecosystems and receptors potentially exposed to contaminants	Likelihood or severity of potential impacts	Identification of sites with potential ecological impacts
			Identification of potential exposure pathways
Estimate of Hazard Potential (Media Toxicity Tests)	Quantification of likelihood and severity of impacts to exposed populations of test organims	Impacts to communities or the ecosystem	Ecologically based cleanup criteria for mixtures of contaminants
	Identification of hazards to site-specific populations		Ecologically based cleanup criteria for contaminants in soils and sediments
	Areal extent of impacts (if media tested at sufficient number of locations)		

EXHIBIT I-11 (continued)

SUMMARY EVALUATION OF APPROACHES USED TO CHARACTERIZE POTENTIAL IMPACTS AT SUPERFUND SITES

Approach	Information Provided by This Approach	Information Not Provided by This Approach	Information Gained by Adding This Approach
Quantitative Risk Modeling	Likelihood of specific impacts to individual organisms, populations, communities, or the ecosystem Severity of impacts Areal extent of impacts	not known[a/]	Quantification of ecological risks for risk management decisions

[a/] The specific model used was not described in detail in the available documents.

concentrations at various trophic levels in a food chain provides information about impacts resulting from indirect exposures. Evaluations of this type could be limited to substances with widely accepted ecological criteria (e.g., AWQC), or they could include additional substances with site-specific benchmarks derived from other toxicity data. Also, evaluations of this type could consider each substance singly, or could incorporate hazard indices to evaluate potential effects from exposure to multiple chemicals. As more of the above techniques are incorporated into an evaluation, the likelihood of detecting potential ecological impacts at a site will increase.

A qualitative evaluation of exposure potential provides information on the types of ecosystems and organisms that might be exposed to site contaminants and the possible types of impacts that might result, but it does not provide any information on the likelihood, severity, or ecological significance of such impacts.

Toxicity tests of environmental media provide information on the likelihood and severity of particular adverse effects to populations of test organisms exposed to site contaminants. The results from toxicity tests also can be used to evaluate hazards to site-specific organisms if the test organisms are valid surrogates (e.g., they are particularly sensitive to site-specific contaminants). Toxicity tests are particularly useful for identifying hazardous conditions at sites with complex mixtures of chemicals and at sites where contaminants are present in media for which no widely accepted benchmarks exist (e.g., soils, sediments). In principle, toxicity tests can indicate the relative severity of potential impacts. For example, the dilution at which an aquatic sample is lethal to 50 percent of the test organisms is an inverse measure of relative severity. Such information can be used to identify levels of concern for toxicity test results, as has been done for the NPDES permitting program (see Section 5.3). At the Superfund sites reviewed, levels of concern for toxicity test results were not identified.

Use of toxicity tests is an approach that is complementary to comparison of environmental concentrations of contaminants to ecological benchmarks, because the two approaches identify different aspects of potential ecological impact. The former approach evaluates the bioavailability of and hazards associated with particular mixtures of substances at a site, while the latter approach evaluates the potential impacts associated with specific contaminants of concern. Hence, use of both approaches at a particular site will increase the likelihood of identifying potential ecological impacts. At present, comparison of environmental concentrations of contaminants to ecological benchmarks can aid directly in the selection of a mitigative remedy because most remedies are chemical-concentration specific (e.g., removal of all soil with concentrations of PCBs above 50 ppm). In principle, toxicty tests also can be used to select a mitigative remedy (e.g., removal of all soil toxic to more than 10 percent of the test organisms), but in practice a prohibitively large number of toxicity tests might be required (e.g., to define the three-dimensional boundaries of the area to be remediated).

Quantitative risk modeling provides a specific probabilistic prediction of the likelihood of a particular adverse effect in a given ecosystem. At present, there are few if any widely accepted ecosystem risk assessment models. It might be possible to develop generalized models for certain contamination scenarios so that only minor adaptations of the model to site-specific conditions would be required. In most cases, however, it probably would be necessary to develop models on a site-specific basis, an expensive and time-consuming effort. However, quantitative risk modeling probably is the only way to quantitatively evaluate risks to a specific element of an ecosystem (e.g., a commercial fishery) that is of concern at a particular site. Numerous widely accepted release, transport, and fate models are available at present and could be applied to a variety of terrestrial and aquatic systems to quantify exposure, chemical

persistence, and other key risk assessment elements. These models, if incorporated into a tiered and integrated modeling/data collection and analysis process, could provide more accurate risk estimates in a resource-efficient manner. Exposure models were used at some of the sites reviewed, primarily to estimate chemical concentrations in specific media and biota.

5. SUPERFUND ECOLOGICAL RISK MANAGEMENT ISSUES

This section summarizes OPA's report entitled "Ecological Risk Management in the Superfund and RCRA Programs," EPA-230-03-89-045 (June 1989). Section 5.1 identifies when and describes how ecological risks are considered in the Superfund program, focusing primarily on the remedial response part of the program. In Section 5.2, ecological risk management in the context of the Regional biological technical assistance groups is briefly described. Finally, Section 5.3 discusses several issues and problems that might impede effective ecological risk management under Superfund.

5.1 When and How Ecological Risks Are Considered

Ecological risk management occurs principally at two points in the Superfund remedial response process. The first is the determination of whether to place sites on the National Priorities List (NPL), and the second is in the development and selection of remedies for individual sites during the remedial investigation/feasibility study (RI/FS).

In most cases, the decision to place a site on the NPL is based on its Hazard Ranking System (HRS) score. The inclusion of ecological factors in the current HRS is limited; ecological hazard is scored simply in terms of the distance from a site to the nearest "sensitive environment." Under the current HRS scoring algorithm, NPL listing is impossible for sites where ecological risks are the sole concern. Obviously, sites that score just below the NPL listing threshold based on human health concerns can be pushed past the threshold based on ecological concerns, but ecological risk is not the driving factor. Because Superfund remedial action is less likely to occur at a site if it is not listed on the NPL, this is a crucial decision point in the Superfund program, and one in which ecological risk is not an important consideration. The proposed revisions to the HRS (53 Fed. Reg. 51962, December 23, 1988) would expand the consideration of ecological concerns, but at this time it is uncertain to what extent the revisions will affect site placement on the NPL.

The selection of a remedial action for a Superfund site is the most important ecological risk management event for sites that have been placed on the NPL. To determine the extent to which ecological concerns influenced remedy selection in the past, 20 records of decision (RODs; Superfund program documents that explain the remedy selection decision for specific sites) for sites exhibiting potential ecological problems were reviewed. Based on information in the RODs, ecological concerns did not significantly affect remedy selection at almost half of these sites. However, Agency representatives familiar with ongoing activities at Superfund sites indicate that ecological threats are being considered in remedy selection more frequently now than in the past. Based on the review of RODs and conversations with Superfund program officials, ecological risk information is being incorporated into remedial site decision making in several different ways, including those listed below.

- Ecological toxicity testing and field surveys have been used in conjunction with chemical testing (e.g., sampling and analysis of sediments) as a basis for determining the need for remedial action, or for identifying the portions of a site that require cleanup. For example, at the Vineland Chemical site in New Jersey, a benthic survey was used to determine which areas of a contaminated stream showed evidence of ecological impacts and therefore required remediation. Toxicity testing on sediment samples was

used to correlate effects in the benthic population with laboratory-controlled studies on benthic invertebrates. A similar approach is being used as a basis for delineating the portion of the site requiring remediation at Clear Creek, Colorado.

- Performance goals, or target cleanup levels, for remedial actions have been set at concentrations intended to be protective of ecological receptors. For example, at the Marathon Battery site in New York, a site-specific remediation level of cadmium in marsh sediments was selected to protect against the threat to the environment. At the Outboard Marine site in Illinois, the selected remedial action involves the cleanup of sediments to a level designed to ensure that water column concentrations of PCBs would not exceed the chronic AWQC.

- Effluent standards for ground-water treatment system effluents have been set at ecologically protective levels. For example, at the Geiger site in South Carolina, ground-water cleanup levels were driven by ecological considerations, and effluent limits for a ground-water treatment system are to be based in part on bioassays.

- Ecological considerations have led to the elimination of remedial alternatives judged to have unacceptable ecological impacts. For example, at the Mowbray site in Alabama, onsite encapsulation of contaminated soils was rejected as a remedial action because it would limit the ability of the site to be revegetated. Similarly, stabilization/solidification of contaminated soils was rejected because it would result in "permanent loss of wetland resources in areas where soils are solidified."

At some sites, a remedial action has been selected even though site managers know that it will not comply with ecologically based applicable or relevant and appropriate requirements (ARARs). This has been justified in some cases based on the fund balancing provision of the National Contingency Plan (NCP) (40 CFR 300.68(i)(1)). This provision allows EPA to choose a remedy that does not meet ARARs when the need for ARARs compliance is outweighed by the need for action at other sites, given the total amount of Superfund resources. For example, the selected remedy at the Iron Mountain Mine in Redding, California, is capping the mine to reduce infiltration of clean water, diverting runon, and assessing the feasibility of using concrete to reduce acid drainage. This remedy will not reduce metals in adjacent surface water to levels below the AWQC, nor will it necessarily protect the winter run of an endangered species of salmon. A more expensive remedial alternative (removal of waste rock, tailings piles, and sediments) that could have met ARARs was rejected as too costly ($1.4 billion) under the fund balancing provision of the NCP.

Ecological concerns have also entered the remedy selection process in a number of other ways, such as the imposition of requirements to continue environmental monitoring after a remedial action to assure ecological protection, the selection of remedial actions to protect recreational uses of natural resources, and decisions to defer remedial actions until more detailed ecological data are available. Additional site-specific examples of how ecological

concerns are being considered at Superfund sites are provided in OPA's detailed report on ecological risk management.

5.2 Biological Technical Assistance Groups

In some EPA Regions, biological technical assistance groups have been formed to assist Superfund remedial project managers in making sure that site response actions fully consider ecological concerns. EPA Region 3 has had such a group for approximately four years, a group has been operating for longer than a year in Region 2, and groups have been formed in Regions 1, 4, and 10. Regions 5, 6, and 9 are well along in developing biological technical assistance groups, and Region 8 is beginning to address how a group will be utilized if it were organized. These groups have been supported through the Emergency Response Division and the Hazardous Site Evaluation Division for over two years.

The biological technical assistance groups serve four main functions: (1) provide a forum for communication; (2) identify ecological concerns; (3) determine data needs; and (4) make recommendations. To help ensure effective communication, the groups consist of officials not only from EPA, but also from other agencies that are natural resource trustees under Superfund (e.g., the Department of the Interior, the National Oceanic and Atmospheric Administration, states). The types of ecological concerns identified by the group include any natural resources that may be affected by the site, the contaminants of ecological concern, and the pathways by which contaminants may migrate to ecological receptors. The data needs identified by the groups usually pertain to the extent and character of contamination in specific areas, media, and pathways. Group recommendations to site managers consist primarily of instructions to use particular ecological endpoints and assessment methods to satisfy data needs. These recommendations often are phrased in terms of suggested monitoring activities, sampling plans, and other analytical techniques. Recommendations also can identify ARARs, as well as some of the beneficial and detrimental aspects of possible remedial alternatives.

The growing use of biological technical assistance groups in EPA Regional offices has improved the consideration of ecological problems at NPL sites and should bring even more improvement in the future. However, such groups do not exist in all Regions and, in the Regions where biological technical assistance groups do exist, the useful guidance provided from these groups still suffers from limits on available resources, personnel, and standards.

5.3 Ecological Risk Management Issues and Impediments

Important ecological risk management issues and impediments identified in this study are briefly described below.

Limitations in Policy and Guidance. The most frequently cited cause for the lack of effective ecological risk management is the absence of clear policy and guidance that articulate the extent to which ecological data should be collected and used in the remedy selection process. The absence of policy and guidance in many cases is due to a lack of appropriate scientific knowledge and data, and additional fundamental research addressing these data gaps clearly is needed. Although the difficulty of developing such policy and guidance in the face of existing scientific uncertainties is widely recognized, some policy decisions could be reached given current knowledge and data. For example, one of the most fundamental risk management issues is the selection of appropriate biotic receptors and ecological effects to evaluate. There is a virtually infinite number of combinations of receptors and effects that can be considered at

a site. However, there currently is no policy or guidance for Superfund managers on which receptors and endpoints should be assigned priority in terms of evaluating and minimizing effects (e.g., Should impacts directly related to human health concerns or involving species with economic value be given priority?). Given current ecological knowledge, it should be possible to identify a set of receptors, endpoints, and levels of concern to be assigned priority at Superfund sites. In addition, limited policy and guidance exists on how to interpret ecological survey and toxicity test results.[16] Therefore, even when extensive ecological assessments are conducted, site managers have virtually no basis for judging the acceptability of ecological damages and risks, or determining "how clean is clean." OSWER's "Risk Assessment Guidance for Superfund -- Environmental Evaluation Manual" (Draft Interim Final, March 1989) should supply useful guidance in these areas by providing an overview of topics to be considered, as well as an excellent primer on ecology and ecological impacts. A recent memorandum (dated December 29, 1988) from the Directors of OERR and the Office of Waste Programs Enforcement to Regional Division Directors also provides a useful statement of policy concerning the need to evaluate ecological issues in Superfund remedial actions and removals. However, neither the recently published manual nor the policy statement provides complete answers to the kinds of questions outlined above.

A Lack of Ecological Threat Criteria. Within the Superfund program, the only widely used criteria for identifying and evaluating contaminant levels in the environment that are of ecological concern are the AWQC. Unfortunately, chronic AWQC (which are often more relevant to Superfund sites than acute criteria) or EPA-identified chronic LOELs (identified by EPA when data are insufficient to support a chronic AWQC) are available for fewer than 40 percent of the substances found most frequently in high concentrations at Superfund sites. Human health protection criteria are available for a larger number of substances; however, these criteria often are not protective for ecological receptors. For example, approximately 50 percent of the drinking water maximum contaminant levels (MCLs) are higher than ecological reference concentrations. Cleanup levels based on MCLs for these contaminants may not be protective of aquatic life. In addition to this lack of criteria for evaluating threats to aquatic organisms, even fewer criteria or toxicity data exist for evaluating potential impacts to terrestrial organisms, and there are no widely accepted criteria for evaluating the significance of soil contamination. Criteria for evaluating surface water sediment contamination also are very sparse: EPA recently has developed a method for determining ecologically based sediment criteria for organic compounds (and has developed interim criteria for 12 organic compounds), but is just starting to develop a method for determining sediment criteria for heavy metals.

A Lack of Site-Specific Ecological Data. Partly because of the lack of policy and criteria noted above, it appears that site managers often have insufficient ecological data for their sites on which to make a sound decision. Information obtained from the review of assessment methods (see Section 4) and from telephone interviewees indicates that ecological assessments are often qualitative rather than quantitative, limited in scope, and not uniform from site to site.

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[16] Guidance for denoting levels of concern for toxicity tests has been developed for the NPDES permitting process. (See two EPA Office of Water reports; one entitled "Technical Support Document for Water Quality-Based Toxics Control," September 1985, EPA-440/4-85-032; the other titled "Permit Writer's Guide to Water Quality-Based Permitting for Toxic Pollutants," July 1987, EPA-440/4-87-005.)

A Lack of Resources. Because of the lack of funds and personnel committed to ecological assessments, Superfund site managers are forced to set priorities for addressing ecological concerns, both within and among sites. Priority-setting requires resolution of a host of tradeoff issues. For example, when should ecological concerns be incorporated into cleanup decisions, and what is the appropriate balance between the use of resources for protecting human health versus the environment? In the process of ranking sites or selecting remedial actions for specific sites, which ecological impacts should be given priority? What is the appropriate decision process for choosing between the need for immediate cleanup at a site and the need for thorough and time-consuming evaluation of ecological threats posed by a site?

6. SUPERFUND PROGRAM IMPLICATIONS AND OPPORTUNITIES

Section 6.1 summarizes and discusses implications of the findings presented in Sections 3, 4, and 5. In Section 6.2, opportunities for further study and program improvements are identified and briefly discussed.

6.1 Implications

Based on the information summarized in Section 3, one cannot conclude that ecological threats at Superfund sites are negligible. Of the 52 sample sites examined in this study, virtually all are contaminated with persistent and bioaccumulative chemicals that may present long-term threats if not cleaned up; slightly more than half appear to be threatening unique, vulnerable, commercially important, or recreationally important resources; and roughly 10 percent appear to present locally severe ecological threats. Moreover, at most sites the extent and significance of terrestrial effects, ecosystem-level effects, and effects of chronic exposures are not well characterized. Considering the sites reviewed in this study, and the large number of all Superfund sites estimated to have the potential for significant ecological threats, Superfund sites collectively may present an important ecological problem that the Office of Solid Waste and Emergency Response has responsibility and authority to control.

The ecological assessment methods identified in this review varied considerably among sites in approach, level of effort, and how data were utilized, presented, and evaluated. This variability appeared to result primarily from a lack of policy and guidance rather than a lack of ecological expertise among Superfund professionals. In particular, there is limited or no guidance for: selecting the appropriate contaminants, receptors, and ecological endpoints of concern; choosing background values and/or reference sampling locations; selecting an appropriate approach and level of effort for a given site; and interpreting survey and toxicity test results. In addition, criteria for identifying and evaluating site contamination often are lacking, and there is no general guidance on how to use available toxicity data in lieu of such criteria. Without clear policy and guidance in key areas, evaluations of ecological threats will continue to be inconsistent, may overlook significant ecological impacts or risks, and may not provide information useful for the purpose of risk management decisions.

Given the limited ecological policy, guidance, and criteria available at the present time, it appears that Superfund site managers are forced to make ecological risk management decisions in the face of considerable uncertainty. At a minimum, this situation creates the potential for decisions to be inconsistent among sites, a problem that may increase in significance in the future due to the increased emphasis being placed on conducting ecological assessments and the limitations in current Agency or program guidance on how to interpret the findings from such investigations. The lack of sufficient policy and guidance also may result in inadequate ecological management decisions, in the sense that opportunities for ecological protection or enhancement may be lost or that ecologically detrimental remedies may be selected. However, the most widespread effect of the lack of sufficient policy and guidance appears to be a general absence of systematic, detailed consideration of ecological threats in decisionmaking. In the current absence of clear policy and guidance, and in the remaining Regions where biological technical assistance groups do not exist to provide support, decisions to remedy environmental problems at a site sometimes have been criticized as reflecting the manager's personal values and beliefs rather than EPA policy.

6.2 Opportunities for Further Study and Program Improvements

If EPA determines that more systematic inclusion of information on ecological threats is warranted for Superfund risk management decisions, moderate investment of resources in developing policy and guidance, modifying and standardizing current approaches, and further development of promising assessment methods will improve the consistency, accuracy, and comprehensiveness of ecological assessments and ecological risk management at Superfund sites. The paragraphs that follow identify and briefly describe a few opportunities for further study and program improvements.

Develop Clear Directions for Including Ecological Risk Considerations in Superfund Site-Specific Decision Making. OSWER's Risk Assessment Guidance for Superfund -- Environmental Evaluation Manual will help emphasize the role of ecological assessment in the Superfund program. Similarly, a recent memorandum (dated December 29, 1988) from the Directors of OERR and the Office of Waste Programs Enforcement to Regional Division Directors provides a general policy statement on the need for effective environmental evaluation in all Superfund remedial actions and removals. Neither the Environmental Evaluation Manual nor the December 29 memorandum, however, provide clear guidance for site managers on how to interpret and use results from ecological assessments. The proposed revision to the National Contingency Plan provides fairly explicit guidance on remediation goals to address human health risks, including ranges of "acceptable" risk, but it is vague in defining protectiveness in terms of ecological threats (except for the directive to meet applicable or relevant and appropriate requirements). Thus, specific guidance is needed for determining "how clean is clean," and for determining when an ecological threat is "significant" and thus worthy of a Superfund response. Although it may be difficult to define significant effects in quantitative terms (e.g., number of acres contaminated, magnitude of exceedance of AWQC, number of organisms potentially affected), qualitative criteria or factors to consider when judging significance should be developed at a minimum. For example, the Council on Environmental Quality's regulations for implementing the National Environmental Policy Act define "significantly" in qualitative terms by discussing factors related to the context and intensity of an effect (see 40 CFR §1508.27). Guidance in this area should clarify whether determinations of the significance of ecological threats should be made on a program-wide or site-specific basis, or both. Such guidance would be useful in implementing essentially all Superfund programs and activities.

Assist in the Development of Ecological Protection Criteria and Advisories. There currently are few ecological toxicity benchmarks to use in evaluating site contamination. For example, EPA chronic AWQC are available for fewer than 20 percent of the substances found most frequently in high concentrations at Superfund sites, making the characterization and management of risks to aquatic organisms at these sites extremely difficult. In view of the need for AWQC, but also in view of reduced budget allocations for the development of these criteria, EPA's Office of Water Regulations and Standards (OWRS) initiated an Ambient Water Quality Advisory (AWQA) program in 1986. The purpose of this program is to develop AWQAs that are analogous to the chronic AWQC, but which are based on more limited toxicity data and thus may be established more quickly. OSWER could assist OWRS in the identification of substances that are of particular ecological concern at Superfund sites by providing OWRS with a list of priority substances or groups of substances found most frequently at high concentrations. The opportunity also exists for OSWER to support development of generic risk-based benchmarks for ecological receptors, analogous to EPA's reference doses used in the assessment of noncarcinogenic human health risks. Such ecological

protection benchmarks could serve as Agency-approved, core values that could be adjusted as needed to fit the needs of specific EPA programs. The development or expansion of ecological benchmarks would be useful for the removal program, conducting pre-remedial activities, selecting remedial actions, and implementing remedial actions.

Develop Guidance for Receptor Characterization. Characterization of actual and potential ecological impacts at Superfund sites would be made more accurate, consistent, and comprehensive by delineating a standard set of organisms and endpoints for evaluating threats in particular ecosystems caused by particular substances. Along with this guidance, it would be useful to develop a standard set of exposure/intake assumptions for the selected organisms, guidance in interpreting the ecological significance of observed changes in the endpoints, and clarification on whether the selection of appropriate receptors and endpoints should be based on a program-wide or site-specific basis. Such guidance is particularly important to the remedial action selection phase of the Superfund program.

Develop Guidance for Assessing Threats to Terrestrial Ecosystems. Threats to terrestrial ecosystems also appear to be a high priority ecological problem in the Superfund program, mainly because such a threat exists at many sites (virtually all of the sites reviewed in this study have soil contamination) and because the exact nature and extent of terrestrial impacts often are not well understood. There are currently no EPA criteria for the protection of terrestrial life, although in some cases site-specific criteria have been developed on an ad hoc basis. Although several factors will make it difficult to develop such criteria in the near future, guidance for assessing terrestrial threats could facilitate protection in lieu of official criteria. In particular, it would be useful to develop guidance for selecting terrestrial organisms and endpoints to study and a standard set of exposure/intake assumptions for these organisms. A compilation of information on critical parameters of physiology, metabolism, and natural history for these species would facilitate quantitative estimates of exposures. It also would be useful to develop guidance on methods to predict chronic no-effect levels in terrestrial organisms from acute or chronic toxicity data for laboratory animals and agricultural crops. Such guidance would be most useful for the remedial action evaluation and selection phase of the Superfund program.

Establish Guidance for Addressing Contaminated Surface Water Sediments. Contamination of surface water sediments appears to be a high priority ecological problem at Superfund sites because such contamination: (1) exists at a large number of sites and is sometimes spread over large areas, as evidenced in the 52-site sample analyzed for this study; (2) may persist for extended periods; and (3) has the potential to affect commercially and/or recreationally important species (i.e., shellfish and fish). Sediment contamination also presents the problem of being difficult to remedy, as cleanup measures such as dredging may be equally or more disruptive to aquatic ecosystems. EPA has recently developed a method for determining ecologically based sediment criteria for organic compounds, and has developed interim criteria for 12 organic compounds. However, EPA is just now starting to develop an approach for determining ecologically based sediment criteria for heavy metals. Therefore, there are very few widely accepted criteria for evaluating surface water sediment contamination, no official guidance on how to use available AWQC or toxicity data for assessing sediment contamination in lieu of widely accepted criteria, and no Superfund policy identifying circumstances when it may be useful or necessary to remove contaminated sediments. Guidance in this area is needed for implementing the removal program and essentially all phases of the remedial program.

Develop and Test An Ecological Threat Screening Model. Given the large number of NPL and non-NPL sites that have the potential for significant ecological impacts, there appears to be a real need for a rapid screening model separate from the HRS to identify and possibly prioritize sites with the greatest potential for ecological impacts. An ecological threat screening model also would be a useful tool for states to use in assessing and prioritizing Superfund sites that are not eligible for federally funded response actions. Such a model could be intermediate in detail and data input requirements between the HRS and the site screening model used by the National Oceanic and Atmospheric Administration, and it could be designed exclusively to evaluate ecological concerns. Once developed, an ecological threat screening model would be most useful in the pre-remedial phase of the Superfund program.

Develop Guidance for Conducting and Implementing Toxicity Tests. Toxicity tests were used at a number of Superfund sites to determine whether mixtures of contaminants in soils, leachate, sediments, and the water column are potentially toxic to site-specific aquatic or terrestrial organisms. Several standard toxicity test protocols exist, and others are under development by EPA's laboratories. However, at no site reviewed was there a clear statement as to what was considered a "significant" ecological hazard based on a media toxicity test result. Characterizing ecological hazard based on media toxicity tests could be standardized by (1) summarizing the types of media toxicity tests available, the species to which they can be applied, the endpoints they measure, and the ecological significance of changes in those endpoints, and (2) developing guidance for using toxicity test results to determine ecological benchmark levels, and denoting levels of concern for each toxicity test. Such guidance has been developed for the NPDES permitting process, and it could possibly be adopted directly by OSWER to establish levels of concern and cleanup criteria for some aquatic ecosystems. Because media toxicity tests are most likely to be conducted as part of the remedial program, guidance in this area would be most useful for conducting pre-remedial activities, selecting remedial actions, and implementing/completing remedial actions.

Establish a Formal Communications Network for Biological Technical Assistance Groups. During discussions with personnel in EPA Region 3, the Region expressed an interest in expanding the extent to which biological technical assistance groups and ecological experts in other Regions share information, lessons learned, and experiences. EPA's Emergency Response Team currently supports communications among biological technical assistance groups by, among other activities, sponsoring a workshop to assist in the development of such groups and for presentation of individual case studies. It would be useful to investigate the feasibility of a formal communications network to complement these existing channels of communication and if appropriate, an efficient and effective way to implement it. For example, it may be helpful to compile and distribute a set of case studies of sites where certain assessment methods have been used successfully in the past. This enhanced communication would be useful in implementing all programs and activities under Superfund, but it would probably most facilitate the remedial action selection process.

Investigate Mechanisms for Coordinating Ecological Evaluations in the Superfund and RCRA Programs. With the growth of biological technical assistance groups and the recent (and forthcoming) policy and guidance related to ecological assessments under Superfund, ecological considerations are receiving increased attention within the Superfund program. There are several areas of the RCRA program that also involve the evaluation of ecological issues, such as the development of RCRA regulations, hazardous waste definition, permitting, and corrective action (see Part II of this report for additional discussion of the RCRA program). In general, it appears that ecological evaluations under RCRA are currently less formalized than under

Superfund, and that certain programs under RCRA that involve the consideration of ecological risk could benefit from increased coordination with the Superfund program. For example, the RCRA corrective action program is just getting started, but eventually it will have to overcome many of the same difficulties encountered in Superfund's program. EPA could identify the potential difficulties that pertain to ecological analyses and provide a forum for the Superfund experience to be conveyed to RCRA permit writers. EPA also could investigate the feasibility of various policy or program implementation options to assure that ecological concerns are being considered in a consistent manner across the Superfund and RCRA programs.

In conclusion, the extent to which ecological considerations are taken into account in the Superfund program has increased significantly in the recent past, partly due to the formation of regional biological technical assistance groups and the growing awareness of ecological issues created by new EPA guidance and policy in this area. There are, however, important areas for further program improvements to help assure that Superfund site responses are appropriately protective of the environment as well as human health. The opportunities for further study and program improvements listed above appear to be, based on the findings of this study, areas of work that are needed and that would produce useful results.

PART II: RCRA

1. INTRODUCTION

This part of the report summarizes the U.S. Environmental Protection Agency/ Office of Policy Analysis (EPA/OPA) assessment of the characterization and management of ecological risks at facilities subject to the Resource Conservation and Recovery Act (RCRA). The OPA ecological risk project was initiated to develop policy and guidance for ecological risk assessment and management in RCRA. The goals of this project include:

- improving ecological risk assessment and management in the RCRA program,
- improving the balance between human health and environmental concerns in Agency decision-making,
- encouraging consistency across programs,
- developing capabilities to conduct efficient and cost-effective ecological risk analyses tailored to program needs, and
- improving understanding of ecosystem functions.

This summary is divided into six sections. First, this introduction contains an overview of the four principal RCRA ecological risk issue areas examined during the course of the project. Section 2 describes the sources of information used to develop the analyses. Sections 3, 4, and 5 present the conclusions reached during the examination of these issue areas with regard to the nature and extent of ecological risks at RCRA facilities, the methods used to evaluate ecological risk, and the management of ecological risk in the RCRA program, respectively. Section 6 outlines ecological risk and management needs for the RCRA program.

Overview of the RCRA Ecological Risk Project

In response to increasing concern that EPA has focused insufficient attention on the ecological threats posed at RCRA facilities, EPA undertook this project to enhance its understanding of these ecological threats and to identify ecological risk assessment methods and management issues. As part of the detailed reports cited at the beginning of this summary, the Agency prepared separate analyses for each of three RCRA ecological risk issue areas:

- **Nature and Extent of Ecological Threats at RCRA Facilities** -- This analysis provides a rough estimate of the extent of ecological damage at RCRA facilities and describes examples of such damage. The analysis focuses mainly on Subtitle C facilities, but also discusses other practices subject to RCRA, such as municipal and special waste facilities. Both predictive modeling to support regulatory activity and site-specific ecological assessments of RCRA facilities and activities were investigated in developing this analysis.
- **RCRA Ecological Risk Assessment Methods** -- This analysis summarizes and evaluates methods used to characterize ecological impacts resulting from releases of hazardous constituents and wastes at RCRA facilities. The analysis also assesses methods used to evaluate ecological impacts addressed by rulemakings.

- **RCRA Ecological Risk Management Issues** -- This analysis discusses the extent to which ecological concerns have been used as a basis for decision making in the RCRA program. The analysis focuses on both rulemaking and site-specific decisions.

These analyses are included as sections of the three reports cited in the overview section of this summary.

2. STUDY APPROACH

2.1 Information Sources Used

OPA directed its efforts toward gathering information from two primary sources. First, OPA collected and reviewed program analysis and regulatory development documents discussing ecological effects at RCRA facilities. Second, OPA contacted an extensive network of EPA Regional and State RCRA professionals familiar with specific facilities to identify sites where ecological threats had been characterized and used in the RCRA decision-making process. OPA also collected and summarized documentation for facilities identified by these personnel.

2.2 Interviews with EPA Regional and State RCRA Professionals

OPA's interviews of 51 EPA Regional and State RCRA professionals provided preliminary results about the nature and extent of site-specific ecological threats, ecological impact assessment methods, and the use of ecological threat information in RCRA decision making.

- The EPA Regional and State professionals identified 52 RCRA Subtitle C facilities with known, suspected, or potential ecological damages. We were able to obtain documentation of the site conditions and history for 16 of these 52 facilities.

- Nearly 20 percent of the professionals responded to questions concerning the use of ecological assessments in RCRA investigations. The remaining interviewees were not sufficiently familiar with the topic to offer their opinions. Those individuals who did respond to the questions generally stated that ecological threats at RCRA facilities are not commonly investigated or that no standard methods exist to aid in the assessment of ecological threats. Assessment methods mentioned by the professionals included toxicity testing, observation of vegetative cover, contaminant body burden, community structure, key species biomonitoring, fish/shellfish kill observation, bioaccumulation, and proximity of sensitive or endangered habitat.

- In general, the interviewees stated that ecological threats at RCRA facilities are given inadequate consideration. This inadequacy was attributed to a lack of appropriate assessment methods, a lack of guidance, the impression that ecological concerns are "too big to deal with," program emphasis on human health, and an inability to address terrestrial threats. Only one interviewee suggested that current considerations of ecological threats in RCRA were adequate.

- The professionals identified a number of uses of ecological information in RCRA decision making. Specific RCRA decisions relying on ecological risk information, to a limited extent at least, include Alternate Concentration Limit (ACL) determinations, setting permit requirements (e.g., determining ground-water

protection requirements on the basis of observed ecological body burden data), determining appropriate cleanup levels, and siting hazardous waste facilities. One interviewee stated that ecological risk information had little or no role in RCRA decision making. The primary barriers to using ecological information in RCRA decision making include the infancy of the corrective action program, program emphasis on human health, the lack of ecological risk guidance for corrective action, the lack of support for risk assessment, State restrictions for on-site investigations, and the lack of resource commitment to ecological risk assessment.

- The primary ecological risk assessment and management needs identified by the interviewees included determining appropriate protection levels, developing an understanding of and investigative methods to assess terrestrial effects, providing guidance for description of community structure and other ecological measures, evaluating the effects of mixtures of contaminants in the environment, and balancing program emphasis between protection of human health and the environment.

3. NATURE AND EXTENT OF ECOLOGICAL RISKS

The analysis of the nature and extent of ecological threats at RCRA facilities involved an investigation of six RCRA program areas: Subtitle C, Municipal Subtitle D, Mining Waste, Coal-Fired Utilities, Oil and Gas, and Smelting and Refining. OPA evaluated the extent of the ecological threats at these facilities based on a variety of broad regulatory and policy analyses conducted by the Office of Solid Waste and the EPA Regional Offices. OPA's examination of the nature of these threats also included a review of various OSW studies, and was further enhanced through the development and analysis of damage case studies developed for each RCRA program area. Exhibit II-1 illustrates the number and type of RCRA case studies that OPA analyzed for this project.

3.1 Extent of Ecological Threats at RCRA Facilities

The extent of ecological threats at RCRA facilities has been generally described in Regulatory Impact Analyses, Reports to Congress, Background Documents, and special reports prepared by OSW and the Regions. Although few of these sources investigate the extent of ecological impacts in great detail, they do provide some indication of the problem. For example, hundreds of incidents of releases from Subtitle C and D land disposal facilities to soil, ground water, surface water, and air have been identified during the last three years, and OSW expects that cleanup of these media at thousands of RCRA Subtitle C TSDFs will be required. Furthermore, roughly 11 million barrels of oil and gas drilling wastes are released annually from over 9,000 spills. In addition, an estimated 26 percent of the active mining and 32 percent of the coal-fired utility facilities are within 5 km of sensitive environmental areas. Seventy-eight percent of the phosphate mines sampled were within 5 km of wetlands, and 60 percent of mining waste management case studies reported effects on non-human biota. Although little is presently known concerning the characteristics of ecological damage resulting from these releases, waste management activities conducted under all of these RCRA program areas appear to pose a substantial potential threat to the environment.

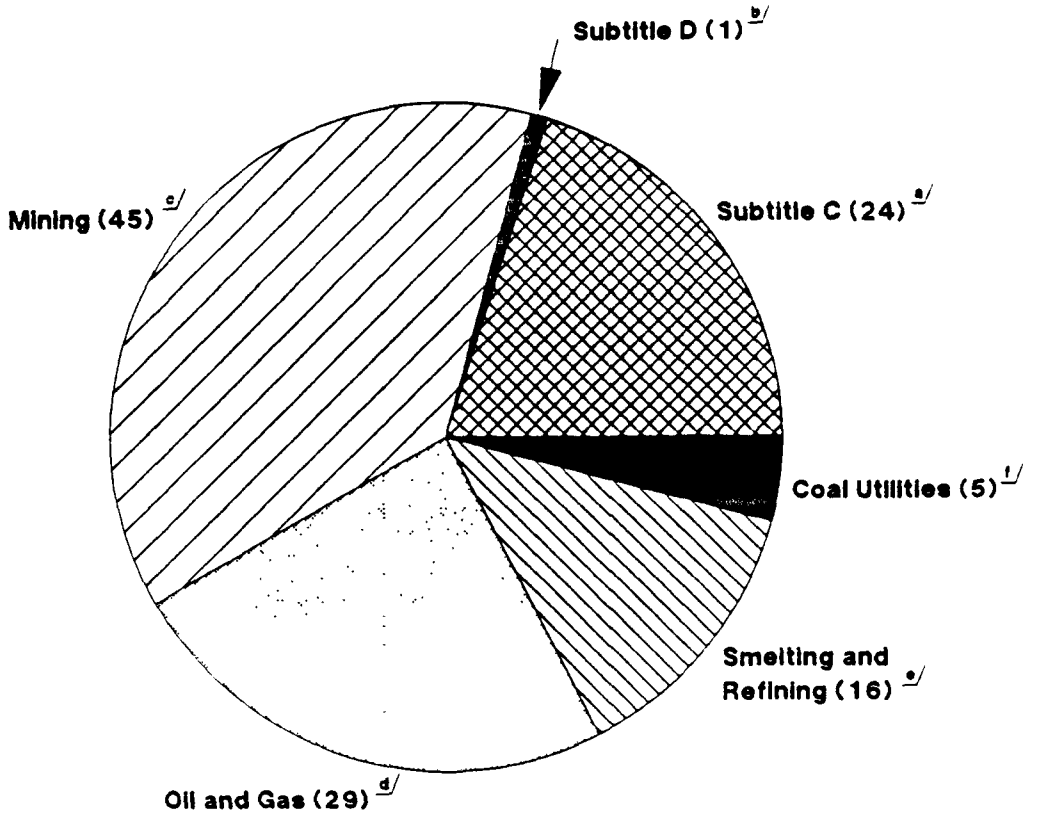
3.2 Nature of Ecological Threats at RCRA Facilities

The precise nature of the ecological threats at RCRA facilities is not well understood, but OPA identified and analyzed a number of examples of observed and predicted ecological damages at RCRA facilities. Exhibit II-2 presents a summary, prepared by OPA, of the observed ecological threat characteristics of each RCRA program area in terms of the observed ecological damages, waste management practices, environmental settings, and principal waste types.

The severity of ecological threats depends on environmental setting (e.g., wetlands), facility size (i.e., quantity of wastes released), toxicity characteristics of the constituents released, and the nature of the release event itself (e.g., flooding or leaching to soil). The observed ecological damages from these releases are both long- and short-term in nature, and include fish kills, diseased benthic invertebrates or desecrated benthic habitats, chronic or behavioral effects on aquatic and terrestrial plant and animal species, and reduced floral and faunal species diversity. Other observed impacts include reduced productivity in wetland habitats and increased contaminant body burdens in aquatic species. Concentrations in water and soil have been observed to exceed water quality criteria or other measures of aquatic toxicity at a number of sites, and sparse vegetation and contaminated soils are also reported at some facilities. In

EXHIBIT II-1

RCRA CASE STUDIES EXAMINED BY OPA



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[a] 16 of the 24 Subtitle C case studies were obtained through phone interviews and meetings with personnel in Regions 3 and 4. These 16 facilities were screened from a total of 52 identified facilities that may have been evaluated for ecological damage. The remaining 8 case studies are derived from damage cases contained in Subtitle C Location Standards Background Information Documents/RIAs.

[b] Obtained from an OSWER document, "Ecological Evaluation of a Municipal Landfill in the Superfund Program," written by John Bascietto, OWPE (undated).

[c] Selected from 68 damage cases presented in the SCS Summary of Environmental Incidents. Selected sites have experienced contaminant releases resulting in threats to terrestrial and aquatic plant and animal species.

[d] Selected from 61 damage cases presented in the Oil and Gas Report to Congress. Selected sites contain documented evidence of ecological damage.

[e] Obtained from 16 damage cases included in the Smelting and Refining Report to Congress.

[f] Selected from 14 damage cases presented in the Coal Utilities Report to Congress. Selected sites contain documented evidence of existing or potential ecological damage.

EXHIBIT II-2

OBSERVED ECOLOGICAL THREAT CHARACTERISTICS OF RCRA PROGRAM AREAS

Program Area	Observed Ecological Damages	Waste Management Practices	Environmental Settings	Waste Types
Subtitle C	▪ Mortality - fish and vegetation kills ▪ Decreased species richness and diversity ▪ Increased body burden of toxicants ▪ Decreased productivity ▪ Altered life cycles ▪ Habitat alteration	▪ Landfills ▪ Surface impoundments (unlined) ▪ Container storage ▪ Wastewater discharge ▪ Waste piles	▪ Near surface waters ▪ Wetlands ▪ Special habitats (i.e., endangered and protected species habitat, and wildlife refuge)	▪ Metals - Cr, As, Pb, Hg ▪ Aromatic hydrocarbons and substituted aromatic compounds ▪ Solvents ▪ Other VOCs ▪ Creosote ▪ PCBs ▪ Acids ▪ Alkali ▪ Pesticides
Subtitle D	▪ Impaired overall health and fertility of freshwater and estuarine fish and macro-invertebrates ▪ Potential for contamination to all environmental media and thus widespread effects to terrestrial and aquatic species	▪ Uncontained disposal (e.g., dumping to surface waters) of combustion fly ash ▪ Storage in unlined landfills of all municipal wastes	▪ Limited available data ▪ 13 percent of facilities in 100-year floodplain ▪ 6 percent in wetland areas	▪ Particulates ▪ BOD ▪ Microbes ▪ Heavy Metals ▪ Pesticides ▪ VOCs ▪ PCDFs ▪ PCDDs
Mining	▪ Fish kills ▪ Impairment and reduction in bird, benthic and other aquatic organisms population ▪ Bioaccumulation in terrestrial organisms	▪ Tailings ponds ▪ Waste storage piles ▪ Waste hauling ▪ Surface impoundment ▪ Cyanide wash stored in drums	▪ Near surface waters	▪ Tailings, overburden, leachate solution, and mine water containing: cyanide, arsenic, copper, zinc, cadmium, lead, cobalt, silver, chromium, iron, TSS, pH
Oil and Gas	▪ Chronic and acute damages ▪ Fish kills, benthic invertebrate population reductions ▪ Reduced fertility and growth in aquatic species ▪ Vegetation damage ▪ Bioaccumulation ▪ Alteration of community structure	▪ Drilling operations ▪ Storage and disposal of drilling wastes in faulty surface impoundments ▪ Injection or discharge of process waters to ground surface	▪ Near surface waters ▪ Desert or tundra environment	▪ Drilling muds, production brines, wastewater, and oil field effluents and fracturing fluids containing: chlorides, benzene, lead, phenanthrene, barium, arsenic, fluoride, antimony
Coal-Fired Utility	▪ Fish kills ▪ Eradication of bottom-dwelling organisms and other aquatic and terrestrial plant and animal life ▪ Chronic effects also likely	▪ Improper storage or mishandling of waste sludges and fly ash wastes ▪ Illegal or improper dumping of wastes ▪ Failure of surface impoundments	▪ Limited available data ▪ Predominantly near surface water bodies	▪ Fly ash wastes containing heavy metals (aluminum, arsenic, barium, cadmium, chromium, copper, lead, mercury, selenium and silicon)
Smelting and Refining	▪ Chronic and acute damages to aquatic organisms ▪ Surface water contaminant concentrations >400 times AWQC	▪ On-site wastewater settling ponds ▪ Cryolite sludge lagoons ▪ Storage and disposal of spent potliners	▪ Over 70 percent within 2,000 feet of surface water	▪ Spent potliners, cryolite slurries, cryolite sludges, slags, and process fluids containing: zinc, copper, cyanide, lead, cadmium and fluoride

addition, more specific measures of ecological impact, such as oyster mortality and impacts on bird nesting behavior, are occasionally reported.

Ecological damage was most often caused by the improper disposal or storage of wastes in unlined landfills or surface impoundments. Storage in waste piles and application of wastewaters to the land have also been noted as significant sources of damage. Exhibit II-3 summarizes the predominant release/exposure pathways associated with Subtitle C damage cases.

Most ecological damage was characterized in aquatic ecosystems and included fish kills and reduced community diversity and structure. It is not clear, however, whether most ecological damage does actually occur in aquatic habitats, or is simply easier, and therefore more common, to characterize impacts in this medium. Reported chronic terrestrial habitat damage includes impaired health and fertility of plant and animal species. Exhibit II-4 illustrates the types of ecosystems most commonly threatened or damaged in the RCRA Subtitle C case studies.

The contaminants associated with ecological damage include virtually all waste types managed at RCRA facilities. For example, the heavy metal wastes found at large volume waste facilities have been implicated in a number of damage cases.

3.3 Conclusions

Although this analysis of facility characteristics suggests some patterns concerning practices, settings, and wastes that pose the most severe ecological threats, it is questionable whether quantitative projections based on these results can be made for the RCRA facility population as a whole. Such extrapolations are tenuous, mainly due to the limited nature of the available data characterizing the RCRA facilities and the lack of representativeness (in a statistical sense) of the sites examined. Sufficient data to characterize the nature and extent of ecological impacts at RCRA facilities accurately are generally not available. Nonetheless, perhaps the most significant conclusion to be drawn from this analysis is that the wide range of hazardous and non-hazardous substances managed at RCRA facilities, the numerous release and ecological exposure pathways, and the diverse nature of the observed ecological impacts indicate that releases from these facilities have the potential to affect all environmental media and major ecosystem types. Hence, releases in wetlands, floodplains, surface waters, or in ecologically vital or sensitive habitats should be considered a potential source of ecological damage.

EXHIBIT II-3

SUBTITLE C CASE STUDY RELEASE/
EXPOSURE PATHWAYS

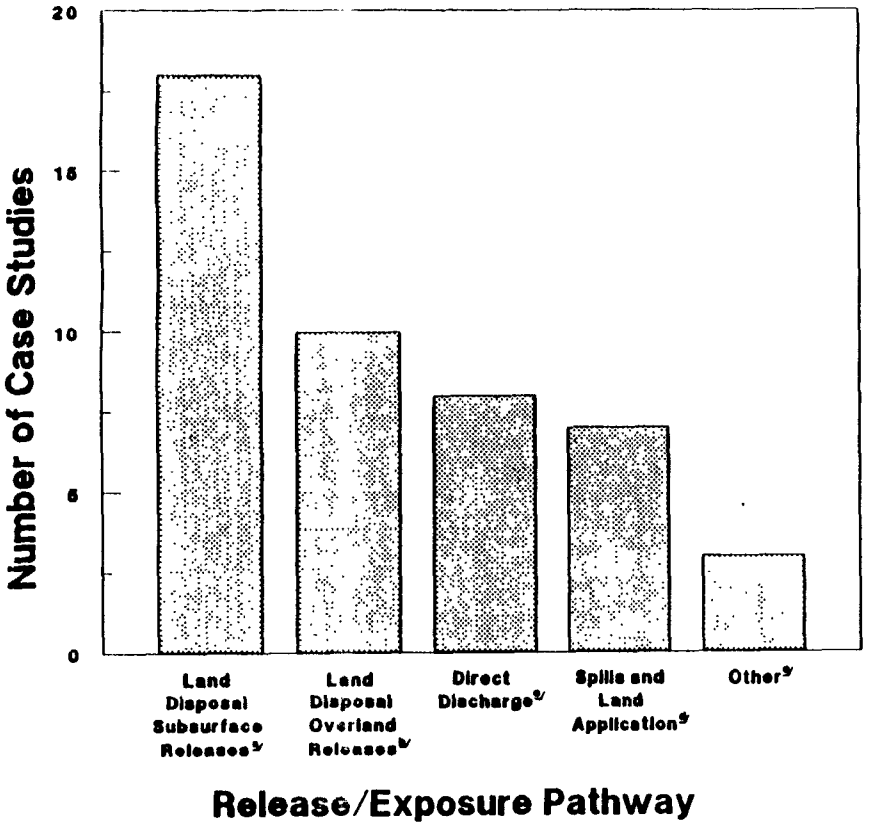
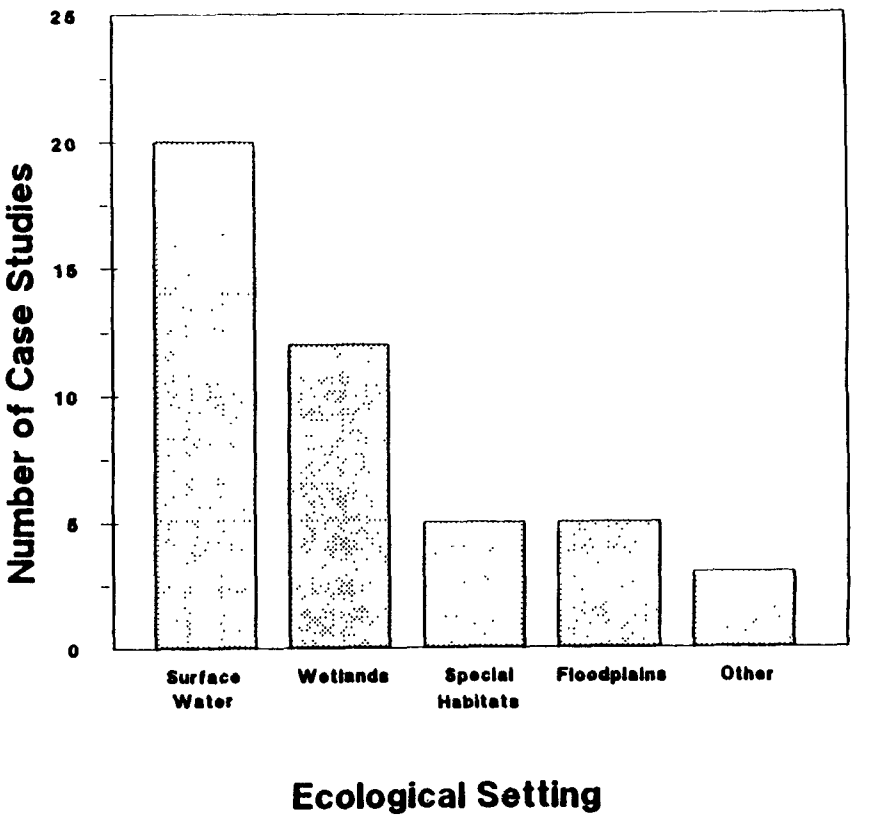


EXHIBIT II-4

ECOLOGICAL SETTING OF SUBTITLE C
CASE STUDY FACILITIES



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[a] Land disposal subsurface releases refers to leaching of wastes or constituents from landfills, lagoons, pits, or ponds and subsequent migration to ecological receptors.

[b] Land disposal overland releases refers to runoff from landfills, lagoons, pits, or ponds to ecological receptors.

[c] Direct discharge of wastes or wastewaters to ecosystems (usually surface waters).

[d] Spills and land application refers to migration of spilled or land applied wastes or constituents to ecological receptors.

[e] Other release/exposure pathways include volatilization and no release of hazardous constituents.

4. ECOLOGICAL RISK ASSESSMENT METHODS

OPA's review of ecological risk assessment methods focused on describing and evaluating the broad approaches that have been used to characterize impacts at RCRA facilities. OPA described and evaluated each major approach based on the types of ecological impacts characterized, the success in measuring those impacts, the main limitations and assumptions underlying the approach, and the types of information provided for risk management. This section summarizes the assessment methods used in analyses supporting RCRA rulemakings, as well as those methods used in characterizing specific RCRA facilities.

4.1 Rulemaking Analyses

EPA has relied on screening-level analyses of diverse problem areas, facility types, or waste management practices for evaluating ecological impacts in RCRA policy and regulatory studies. Screening level analyses include: (1) evaluation of the proximity of waste sites to sensitive environments, (2) survey of damage case studies, (3) quantitative modeling of potential impacts based on damage case studies, and (4) comparative risk estimation. Specific methods utilizing a comparison of environmental concentrations of contaminants to ecological benchmarks include: (1) computing a hazard index for multiple contaminants, and (2) modeling ecosystem exposure-response. These six methods are summarized and evaluated in Exhibit II-5.

In the first approach, the assessment consists of determining how many facilities are located within, or in proximity to, environments that are ecologically critical or vulnerable, have a particular cultural significance, or have been set aside for conservation. Information from sources such as the Natural Heritage Program data base of sensitive or critical habitats is typically used in these analyses. For example, the analysis of mining waste practices relied on this approach.

Developing surveys of damage case studies involves identifying specific facilities where damages have been noted, collecting and reviewing documentation for these facilities, and combining the various damage case descriptions into one or more "typical" damage case scenarios according to geographic area, specific waste types, affected media, and waste management practices. Several RCRA analyses have relied on this case study approach, including the Smelting and Refining and Oil and Gas Reports to Congress, and the Location Standards Regulatory Impact Analysis (RIA).

The quantitative modeling used in support of rulemaking generally involves evaluating potential ecological impacts that might result from "typical" damage case scenarios. In the modeling approach used in the Draft Smelting and Refining Report to Congress reviewed by OPA, EPA compared modeled concentrations of contaminants in receiving waters to ecological benchmarks (i.e., ambient water quality criteria).

EPA has also used comparative risk estimation to rank the relative ecological impacts associated with widely diverse facilities or problem areas. This approach derives a qualitative or semi-quantitative relative risk ranking for each type of facility or problem area by assimilating information on exposure levels and/or potential, types and societal value of ecological receptors, hazards of constituents to receptors, and the areal extent and reversibility of potential impacts.

EXHIBIT II-5

SUMMARY EVALUATION OF APPROACHES USED TO CHARACTERIZE POTENTIAL IMPACTS AT RCRA FACILITIES

Approach or Technique	Information Provided by This Approach or Technique	Information Not Provided by This Approach or Technique	Information Gained by Adding This Approach or Technique
Qualitative Evaluation of Exposure Potential	Types of ecosystems and receptors potentially exposed to contaminants	Likelihood or severity of potential impacts	Identification of sites with potential ecological impacts Identification of potential exposure pathways
Contaminant Concentration vs. Ecological Benchmark	Yes/no information as to whether impacts are likely	Quantitative measure of severity of impacts if benchmarks are exceeded	Ecologically based cleanup criteria for single contaminants
	Impacts resulting from direct exposures to contaminated media and indirect exposures via food chains	Impacts to communities or the ecosystem (unless benchmarks specifically account for these)	
Evaluation of Hazard Potential (Media Toxicity Tests)	Quantification of likelihood and severity of impacts to populations of test organisms	Impacts to communities or the ecosystem	Ecologically based cleanup criteria for mixtures of contaminants[a/]
	Identification of hazards to site-specific populations		Ecologically based cleanup criteria for contaminants in soils and sediments
	Areal extent of impacts (if media tested at sufficient number of locations)		

[a/] NPDES permit guidelines (EPA/OW 1985, 1987) define bioassay-based cleanup criteria for some ecosystems.

The Office of Solid Waste and Emergency Response and Regions I, III, and X have performed such analyses.

4.2 Site-Specific Analyses

OPA's review of site-specific methodological approaches is based on a limited sample of RCRA facilities. Only 16 RCRA facilities were documented by OPA as having undergone ecological assessments beyond a screening level, and all of these facilities are regulated under the Subtitle C program. Actual impacts were evaluated at nine of these 16 Subtitle C facilities, and potential impacts were estimated at 11 facilities. The methods used for these RCRA facilities are summarized below.

EPA has used three primary approaches to characterize actual ecological impacts at specific RCRA facilities: (1) evaluation of biotic community structure, (2) analysis of the morphological and/or physiological condition of individual organisms, and (3) comparison of environmental concentrations of contaminants to ecological benchmark levels. These methods were generally used in association with corrective action analyses. Exhibit II-6 summarizes and evaluates these methods.

Evaluations of biotic community structure have focused on species diversity indices for benthic macroinvertebrates and fish in aquatic ecosystems and the absence of vegetation in terrestrial ecosystems. Two major types of community structure evaluations include qualitative surveys and quantitative measures. In general, qualitative surveys are low-effort techniques used to document large, readily apparent changes in community structure, while quantitative techniques (including indices of community structure and aerial photography) require more detailed analyses offering greater ability to distinguish subtle impacts.

Analyses of the morphological and/or physiological condition of individual organisms have concentrated on fish and shellfish in aquatic ecosystems and birds and plants in terrestrial ecosystems. (Most of these analyses have focused on tissue residue levels, although, strictly speaking, elevated tissue residue levels do not indicate the presence of adverse biological effects unless coupled with independent evidence of such effects.) At one facility, investigators used an histopathological examination to determine whether there was a greater incidence of abnormalities in fish exposed to contaminants than in fish in a reference environment.

A final method used to characterize actual ecological impacts at RCRA sites involves comparing environmental concentrations of contaminants to ecological benchmark levels derived from toxicity tests on laboratory organisms. The purpose of this approach is to determine whether contaminant concentrations have reached levels known to result in adverse effects in the tested organisms. When the ecological benchmarks are designed to be protective of biota, such as AWQC (the most frequently used ecological benchmarks), this comparison is a surrogate measure of actual impacts. However, this approach serves mainly to document the nature and extent of contamination at a site and does not establish the existence of actual ecological impacts.

OPA has identified three main approaches used to characterize potential ecological impacts at the RCRA facilities reviewed: (1) comparison of environmental concentrations of contaminants to ecological benchmark levels, (2) qualitative evaluation of potential impacts from

EXHIBIT II-6

SUMMARY EVALUATION OF APPROACHES AND TECHNIQUES USED TO CHARACTERIZE ACTUAL IMPACTS AT RCRA FACILITIES

Approach or Technique	Information Provided by This Approach or Technique	Information Not Provided by This Approach or Technique	Information Gained by Adding This Approach or Technique
Evaluation of Biotic Community Structure			
Qualitative Survey	Identification of large, readily-apparent impacts	Identification of subtle impacts	Identification of sites with major impacts to biotic communities
	Areal extent of impacts	Impacts to individuals or or populations	
		Severity of impacts (unless obvious)	
Quantitative Measure	Quantification of small, subtle impacts	Impacts to individuals or populations	Identification of sites with minor impacts to biotic communities
	Severity of impacts[a/]		
	Areal extent of impacts		
Evaluation of Individual Morphology or Physiology			
Examination of Specimens	Direct evidence of injury to individual organisms	Impacts to populations, communities or the ecosystem	Identification of sites with major impacts to individual organisms
	Areal extent or magnitude of impacts		
Detailed Field Studies	Quantification of small, subtle impacts to individuals or populations	Impacts to communities or the ecosystem	Identification of sites with minor impacts to individuals or populations
Comparison of Contaminant Concentration to Ecological Benchmark			
Field Sampling	Nature and areal extent of contamination	Direct evidence of actual impacts	Identification of exposure pathways

[a/] The Ohio Environmental Protction Agency (Ohio EPA 1988) has developed guidelines that define severity of impacts for some ecosystems.

estimates of exposure potential, and (3) qualitative evaluation of potential impacts from estimates of hazard potential based on media bioassays. Exhibit II-7 summarizes and compares these three approaches to characterizing potential impacts.

The first approach, also known as the quotient method, was used exclusively for aquatic ecosystems. EPA's ambient water quality criteria were the most frequently-used ecological benchmark; State standards and acute toxicity values (LC_{50}s) also were used at some facilities.

EPA used qualitative evaluations of potential impacts for terrestrial ecosystems and the terrestrial component of wetland ecosystems. These evaluations focused on acute mortality or altered community structure resulting from estimated exposure potential for mammals, birds, reptiles, and plants.

Investigators used media bioassays for fish, daphnids, and algae to evaluate hazards in a freshwater and a wetland ecosystem. Specific hazards identified in the bioassays included acute mortality and depressed reproduction.

4.3 Conclusions

The methods used to characterize ecological impacts identified in this review varied considerably in approach, level of effort, and the manner of data utilization, presentation, and evaluation. Exhibits II-8 and II-9 illustrate the types of ecological assessment methods used at the 16 Subtitle C case study facilities to assess actual and potential ecological damages. The variety of methods applied appears to result primarily from a lack of policy and guidance rather than a lack of either appropriate methods or ecological expertise among the investigators. Because there are no clear guidelines for conducting ecological assessments at RCRA facilities, there is no established methodology for screening sites for potential ecological impacts and assessing actual or potential impacts at particular sites. Moreover, there is no widely accepted method for quantifying ecological risks at RCRA facilities for the purpose of risk management decisions. Hence, an investment of resources to develop guidance, modify and standardize current approaches, and further develop promising techniques and methods should improve the consistency, accuracy, and comprehensiveness of ecological assessments at RCRA facilities. The implications of OPA's findings about ecological assessment methods for the RCRA program are discussed in Section 6 of this part of the report.

EXHIBIT II-7

SUMMARY EVALUATION OF APPROACHES USED TO CHARACTERIZE ECOLOGICAL IMPACTS IN POLICY AND REGULATORY STUDIES

Approach or Technique	Information Provided by This Approach or Technique	Information Not Provided by This Approach or Technique	Information Gained by Adding This Approach or Technique
Screening-Level Analyses			
Proximity of Waste Sites to Sensitive Environments	Number of sites located in or in close proximity to sensitive environments	Types of impacts possible Likelihood of impacts	Screening-level identification of types of sites with potential for ecological impacts
Survey of Damage Case Studies	Types of impacts associated with activities under review Contaminants and settings associated with impacts	Estimate of the extent of actual impacts associated with activities under review	Identification of types of facilities and settings that have resulted in the greatest amount of ecological damage in the past or at present
Quantitative Modeling Based on Damage Case Studies	Potential impacts associated with activities under review Types of contaminants and releases associated with potential impacts	Estimate of the extent of potential ecological impacts associated with activities under review	Identification of types of facilities that pose the greatest potential for ecological impacts
Comparative Risk Estimation	Estimate of relative ecological risks/impacts associated with problem areas under review	New information about ecological impacts Quantitative estimates of ecological risks	Identification of problem areas that pose the greatest (and least) ecological risks

EXHIBIT II-8

METHODS USED TO ASSESS ACTUAL IMPACTS
AT RCRA FACILITIES

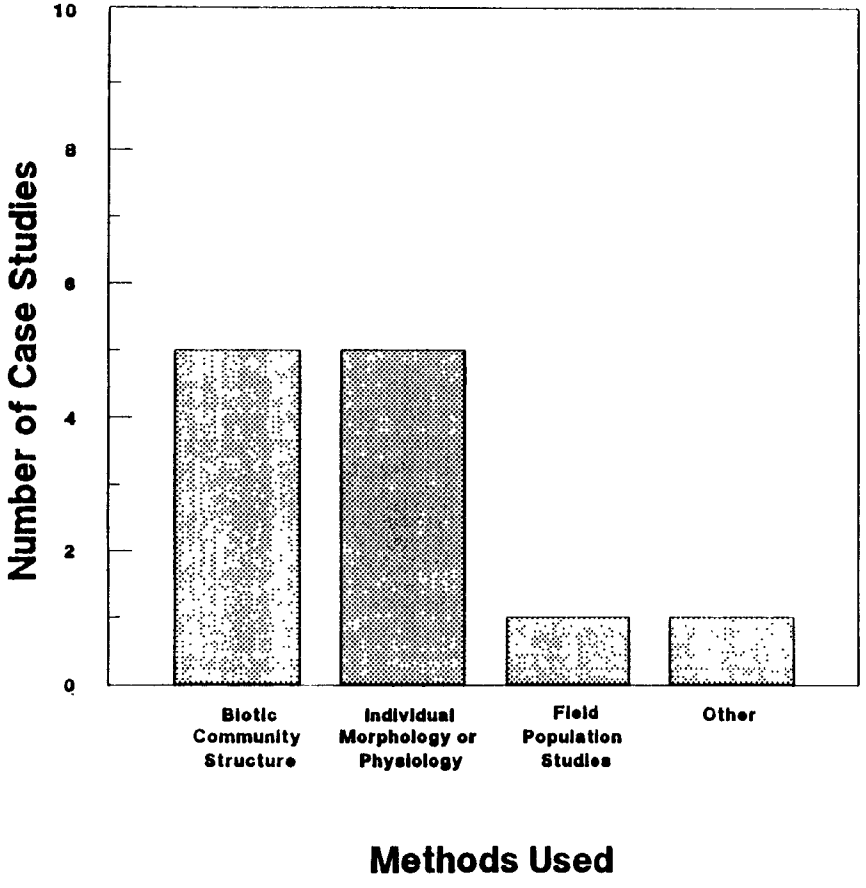
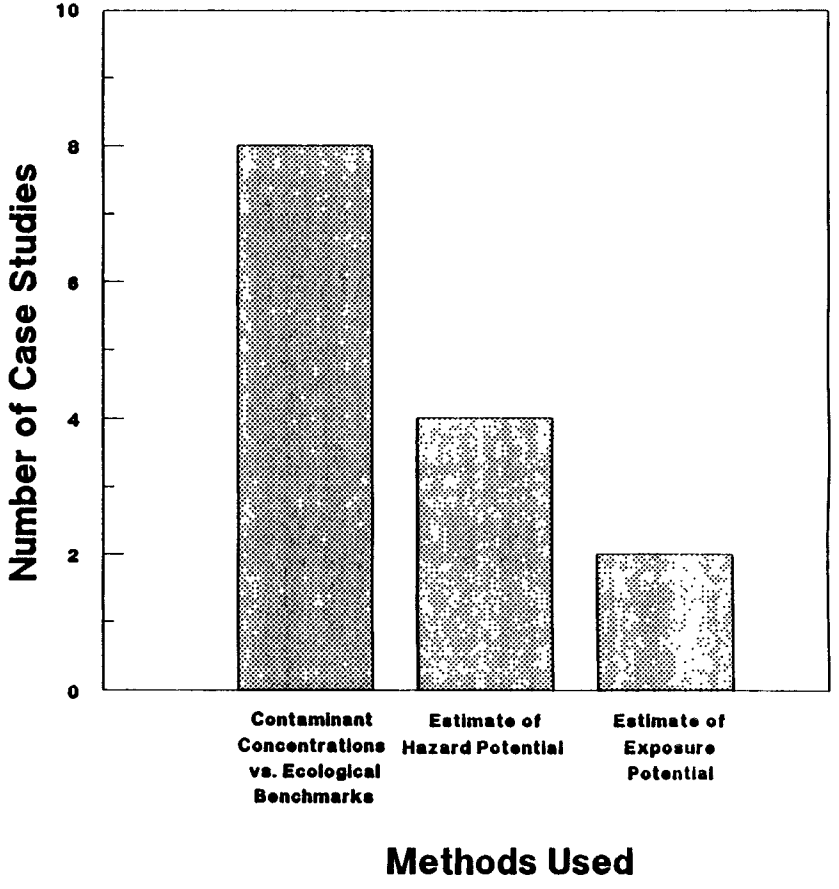


EXHIBIT II-9

METHODS USED TO ASSESS POTENTIAL IMPACTS
AT RCRA FACILITIES



5. RCRA ECOLOGICAL RISK MANAGEMENT ISSUES

The Office of Policy Analysis investigated the use of ecological impact and risk assessment information to support rulemaking activities and site-specific decision making. OPA reviewed eight RIAs to assess the use of ecological information in the rulemaking process:

- Subtitle D Criteria Revisions RIA;
- Corrective Action RIA;
- Land Disposal Restrictions for Solvent Wastes RIA;
- Small Quantity Generator Rule RIA;
- Location Standards RIAs (including floodplains and wetlands background documents);
- Smelting and Refining RIA;
- Mining Waste RIA; and
- Oil and Gas RIA.

Each of these RIAs was prepared within the last several years and, therefore, provides a good indication of the type of information currently being collected and evaluated by OSW in the RCRA rulemaking process. OPA also evaluated site-specific decision making in the RCRA program in four broad areas: hazardous waste definition determinations, Subtitle C permitting, Subpart F corrective action, and Subpart S corrective action. Documentation for specific RCRA sites involved in one or more of these processes served as the basis for the analysis of site-specific decision making. Based upon a review of this RIA and facility documentation, OPA sought to determine how ecological risk information is currently being used to support decisions in the RCRA program and to identify approaches for improving the use of such impact information.

5.1 Review of RIAs

The RIAs indicate that most RCRA rulemakings are justified in terms of their benefits to human health, rather than protection of the environment. This conclusion is supported by a review of Federal Register notices for rulemakings from 1979 to the present, which indicates that the threat of ecological damage is rarely used as the primary basis of support for rules affecting RCRA facilities. Although some actions are based on a combination of ecological and human health risks, they usually rely on human health risk assessments for any quantitative determinations and discuss ecological benefits in a qualitative or descriptive fashion.

5.2 Site-Specific Decisions

With regard to site-specific decisions, OSW is engaged in a growing number of waste definition, permitting, and corrective action decisions that may involve ecological impacts.

Under the hazardous waste definition process, ecological concerns are generally not considered because the criteria for listing hazardous waste (at 40 CFR 261.11) focus exclusively on physical and chemical waste characteristics and toxic effects to humans. However, the criteria do provide an indirect means by which a waste can be listed for ecological concerns; a waste can be listed if it contains any of the constituents in Appendix VIII, some of which are included because they are toxic to environmental receptors. In practice, however, the listing rationale for individual hazardous waste streams are virtually always based upon human health endpoints.

The extent to which ecological threats are addressed in permitting decisions depends largely on the status of the facility seeking a permit. Under current permitting practices, ecological information is not requested from the owner or operator of most facilities. Such information is deemed unnecessary because the permitting standards are designed to ensure that facilities do not release hazardous wastes or constituents to the environment, thereby protecting surrounding ecosystems. Nonetheless, certain types of facilities do experience permitted releases to the environment, such as air emissions from thermal treatment facilities or incinerators. Ecological concerns are addressed consistently only when past releases or impacts are observed at a facility seeking a permit or permit modification. The ecological evaluations performed at such facilities, therefore, are generally for the purpose of evaluating the level of cleanup required to address a past release, rather than the controls needed to prevent future damage.

Corrective action for releases of hazardous constituents at RCRA facilities is currently addressed under Part 264, Subpart F. Corrective action under Subpart F is triggered when constituent concentrations in ground water exceed background concentrations or MCLs. There is little opportunity for any type of ecological (or human health) risk assessment or management in this process. Ecological receptors are implicitly protected by requiring cleanup when background levels are exceeded. The exception is for the handful of constituents with MCLs; approximately 50 percent of the MCLs are higher than ecological reference concentrations and thus may not be protective of aquatic life. In addition, however, the ACL process provides an important regulatory tool within the RCRA program to implement ecological risk management. Facility owner/operators may petition for ACLs for specific constituents. These ACLs would then serve as the target level for cleanup of the constituent in ground water. The guidance and regulations for the ACL process clearly require that ecological impacts, as well as human health impacts, must be considered when setting ACLs. In fact, petitioners often base their requested ACLs on ecological toxicity data for the constituents in question because environmental exposures are more likely than human exposures in most facility settings.

Under HSWA, the Agency is developing a new approach to corrective action to address hazardous constituent releases from all solid waste management units to all environmental media. Under this new approach, implemented in the pending Subpart S corrective action regulations, all RCRA Subtitle C facilities will undergo a RCRA Facility Assessment (RFA) to identify past releases. If releases are discovered, the facility may undergo a RCRA Facility Investigation (RFI) to characterize the release. If the impacts of the release are significant, the owner/operator must conduct a Corrective Measures Study (CMS) to identify an appropriate cleanup alternative.

5.3 Conclusions

OPA's analysis indicates that, in general, ecological concerns have not played a significant role in past regulatory development or site-specific decision making in the RCRA program. RCRA program needs associated with incorporating ecological considerations in the decision-making process are discussed in Section 6 of this part of the report.

6. ECOLOGICAL RISK ASSESSMENT AND MANAGEMENT NEEDS FOR THE RCRA PROGRAM

This section outlines the various ecological risk assessment and management needs for the RCRA program identified by OPA in the preceding analyses. OPA has identified policy, guidance, methods, data, and training/expertise needs that apply to the RCRA program in general as well as specific RCRA program areas. The general RCRA needs apply to all major areas of the RCRA program, including corrective action activities and ACL petitions; Subtitle C permitting activities; listing, delisting, and hazardous waste identification; special waste programs; and regulatory analysis. Following the discussion of general needs, we present specific needs for Subtitle C facility permitting, corrective action, and closure; regulatory analysis; hazardous waste listing/delisting; special waste programs; and the Subtitle D program.

6.1 General Needs

Although the Agency is mandated under RCRA to protect human health and the environment, it has not described the manner in which environmental impacts should be identified and addressed. Resolution of four major policy and guidance issues would clarify the role of ecological damage information in RCRA:

- Identify the ecological endpoints of concern and levels of ecological impact that warrant Agency action (i.e., the damage level that constitutes a "significant effect");
- Address the manner in which actions to minimize human and ecological impacts should be balanced;
- Provide direction on when ecological threats must be considered and the appropriate scope and level of effort of ecological risk analyses; and
- Develop procedures for involving personnel from other agencies or EPA Program Offices who possess specific ecological assessment expertise in the RCRA ecological risk decision-making process.

In light of the difficulties and importance of accurately determining the severity of ecological impacts through evaluations of exposure levels and toxicity of specific constituents, there is a need for the development of standard qualitative and quantitative methods for measuring ecological damage. Five specific methods development needs are listed below:

- Create site screening methods to quickly and inexpensively gather information on the areal extent and reversibility of ecological damage at a site by using commonly available toxicity data and benchmarks;
- Develop methods for using and interpreting qualitative measures of ecological damage resulting from releases of single and multiple chemicals;

- Develop a standard set of organisms and endpoints for evaluating impacts in particular ecosystems and for particular substances and develop procedures for measuring and interpreting the ecological significance of observed changes in these endpoints;

- Develop methods for determining standard uptake/exposure levels for different ecological receptors to hazardous substances in different environments; and

- Establish standard procedures for developing and applying acute and chronic ambient water quality criteria for the protection of freshwater and marine life.

Due to the variety of ecological receptors, hazardous constituents, and environmental settings that must be considered in ecological assessments, the data requirements to support such assessments can be extensive. OPA has identified four primary ecological risk assessment data needs:

- Develop a queriable data base containing peer-reviewed ecological toxicity data and information;

- Adopt a list of ecological toxicity thresholds for key RCRA constituents and for different species and environments;

- Compile existing information and data bases describing habitat and species information into a queriable data base; and

- Communicate organism- and chemical-specific data needs to other programs, offices, and agencies to focus research on chemicals and organisms most useful to the RCRA program.

With regard to the training/expertise needs of the OSWER ecological risk assessment and management program, OPA identified three basic needs:

- Create bioassessment groups in Headquarters and Regions to serve as nuclei for ecological assessment expertise;

- Improve cooperation/integration with other State and Federal Agencies and EPA Offices to gain access to ecological assessment expertise; and

- Institute training for current personnel and hire additional staff trained in ecological assessment techniques.

In addition to these general RCRA program needs, more program-specific needs are outlined below.

6.2 Subtitle C Facility Permitting, Corrective Action, and Closure Needs

Ecological risk considerations in RCRA Subtitle C permitting, corrective action, and closure can be improved by:

- Consistently gathering ecological impact data;
- Setting constituent concentration action levels at thresholds that are protective of human health and ecological receptors;
- Relying on ecological assessment expertise early enough in the decision-making process to characterize ecological threats accurately; and
- Developing approaches for expanding or modifying cleanups or remedial actions to mitigate ecological (and human health) impacts, and procedures for verifying this mitigation;

OPA has identified several needs for ecological risk management in the proposed Subpart S corrective action program. Resolution of these major policy and/or guidance issues would clarify the role of ecological threat information in Subpart S corrective action.

- Policy and/or guidance for incorporating ecological risk information when setting priorities for RFIs. Given the limited resources available to the Regions and States and the large number of sites with past releases that will require RFIs, the Regions must set priorities. As a result, the Regions are developing their own priority setting schemes.
- Policy and/or guidance for collecting information appropriate for ecological risk assessment during the RFI, when most of the detailed information for use in decision making concerning corrective action is collected. Only a handful of RFIs have been completed at RCRA facilities, and it is therefore difficult to assess the extent to which ecological concerns are addressed.
- Policy and/or guidance for utilizing ecological risk information in determining when corrective actions should be conducted. Under the pending draft Subpart S rules, corrective action is triggered if pollutant concentrations in air, water, and/or soil exceed action levels that are identified for several constituents. These action levels are based primarily on human health risk. Cleanup levels are also based on human risk assessment. Damage to ecosystems may serve as sufficient reason to trigger corrective action, but this decision is left to the discretion of the permit writer.
- Policy and/or guidance for considering ecological concerns in the CMS. At present very few facilities have reached this point in the process. As a result, it is difficult to assess the extent to which ecological risk management will occur in the selection of corrective measures.

6.3 Regulatory Analysis Needs

The consideration of ecological concerns in RCRA rulemakings could be enhanced through developing the following:

- clear statements of policy requiring the analysis of ecological impacts in benefits and impacts assessments;
- protocols for incorporating qualitative measures of ecological impacts in rulemaking decisions;
- guidance and methods for improving the quantitative measurement of ecological impacts; and
- clear identification of the threshold levels of ecological impacts that warrant rulemaking action.

An important reason for the lack of rigorous ecological risk assessment to support rulemaking decisions appears to be the absence of a resource commitment to develop methods for quantifying and valuing ecological damages on the national level. Although EPA has described the types of ecological impacts that occur at RCRA sites through case studies, this largely descriptive information cannot readily be assimilated and weighed in the decision-making process.

6.3.1 Hazardous Waste Listing and Delisting

The Listing program identifies wastes and waste constituents which are hazardous to either human health or the environment. Any waste or waste constituent identified as hazardous is subject to regulation under RCRA. RCRA listings apply to specific or non-specific processes, or specific wastestreams. Individual wastestreams may vary, however, depending on raw materials, industrial processes, and other factors. Thus, while a waste that is described in 40 CFR §261.31, 261.32, and 261.33 generally is hazardous, a specific waste from an individual facility meeting the listing description may not be. For this reason, 40 CFR §260.20 and §260.22 provide an exclusion procedure, allowing persons to demonstrate that a specific waste from a particular generating facility should not be regulated as a hazardous waste. Delisting petitions are submitted to the Agency for evaluation in order to demonstrate whether the wastestream or waste constituent meets the criteria of the RCRA listing.

The consideration of ecological risk in the RCRA listing and delisting programs can be improved by the following:

- Developing a policy requiring the consideration of ecological toxicity data for constituents in the listing and delisting process;
- Collecting data or information describing ecological damage from management of the waste constituent during the listing process, rather than simply focusing on human health damage;
- Providing access to ecological assessment personnel during the listing process;

- Developing guidance to petitioners describing the type of ecological impact data to be reported in delisting petitions;

- Expanding the Vertical and Horizontal Spread (VHS) modeling approach for evaluating delisting petitions to consider exposures other than through the consumption of contaminated drinking water;

- Evaluating predicted downgradient wastestream concentrations using ecological criteria, as well as human health criteria.

6.3.2 Special Wastes

Under RCRA, certain special or large volume wastes are specifically exempted from Subtitle C management requirements. These wastes include mining, utility, and oil and gas extraction residues. Because many of these special wastes are generated in rural areas, ecological impacts at these sites may be a significant concern. However, because these sites are not presently required to obtain operating permits under RCRA, data describing ecological impacts at these sites are scarce.

Managing and assessing ecological risks at special waste sites could be improved by the following:

- Expanding ongoing programs to collect data characterizing the ecological impacts at special waste sites to support policy and rulemaking development;

- Developing requirements mandating the submission of ecological impact monitoring data by site owners and operators;

- Determining ecological impact threshold levels for constituents that are primarily found at special waste sites (e.g., chloride); and

- Investigating the need for siting criteria or facility technical standards to limit ecological degradation at special waste sites.

6.3.3 Subtitle D Waste Facilities

Program needs specific to the Subtitle D program, which can improve the analysis of ecological risk, include the following:

- Investigate or evaluate the potential applications of biological standards, biological monitoring, or other innovative approaches at Subtitle D facilities, in addition to ongoing ground-water and soil monitoring activities;

- Establish a data base to track ecological monitoring data for Subtitle D facilities to support policy development and regulatory activities;

- Review and, if necessary, develop ecological impact thresholds for regulatory action for relevant constituents of concern at Subtitle D facilities (e.g., BOD);

- Investigate the need for additional or revised siting criteria or facility technical standards to limit ecological degradation at Subtitle D facilities.

In sum, the program needs OPA has described above represent activities that can improve the collection and management of ecological impact and threat information in the RCRA program.