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Approach and Strategy for Performing Ecological Risk Assessments for the U.S. Department of Energy's Oak Ridge Reservation: 1994 Revision

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ACRONYMS

BMAP	Biological Monitoring and Assessment Program
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COPC	Contaminants of Potential Concern
DOE	United States Department of Energy
DQO	Data Quality Objectives
EPA	U.S. Environmental Protection Agency
ERA	Ecological Risk Assessment
FFA	Federal Facility Agreement
INM	In Need of Management
LOEC	Lowest-Observed-Effects-Concentration
NAWQC	National Ambient Water Quality Criteria
NPL	National Priorities List
NRDA	Natural Resource Damage Assessment
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
OU	Operable Unit
RI	Remedial Investigation
T&E	Threatened and Endangered

1. PURPOSE

The purpose of this document is to provide guidance for planning and performing ecological risk assessments on the Oak Ridge Reservation (ORR). It is necessitated by the considerable progress that has been made by the parties to the Federal Facility Agreement (FFA) for the ORR in resolving specific issues relating to ecological risk assessment since the publication of previous guidance (Suter et al. 1992). The tiered approach to ecological risk assessment recommended in the prior document (Suter et al. 1992) has been implemented, generic conceptual models have been developed, and a general approach for developing ecological assessment endpoints and measurement endpoints has been agreed upon. The document also includes changes in terminology to agree with the terminology in the U.S. Environmental Protection Agency's (EPA's) framework for ecological risk assessment (Risk Assessment Forum 1992).

Although ecological risks are equal in regulatory importance to human health risks (Reilly 1990, SAB 1990), formal procedures for ecological risk assessment are poorly developed. This state of affairs is reflected in the EPA's risk assessment guidance manual for ecological risk assessments (EPA 1989) which addresses procedures and general philosophy and the fact that the EPA has a framework for guidance on ecological risk assessment (Risk Assessment Forum 1992) but no concrete guidance. This report will provide specific guidance and promote the use of consistent approaches for ecological risk assessments at individual sites on the ORR. The strategy discussed in this report is consistent with the overall strategy for site management and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) compliance developed for the ORR (Environmental Restoration Division 1992) and with relevant EPA guidance (EPA 1989, Warren-Hicks et al. 1989, Risk Assessment Forum 1992). The general approach and strategy presented herein was developed for the ORR, but it should be applicable to other complex CERCLA sites that possess significant ecological resources.

2. SCOPE

2.1 PHYSICAL SCOPE

Because the entire ORR is on the National Priorities List (NPL), the scope of CERCLA activities on the ORR includes the entire reservation and portions of the Melton Hill and Watts Bar Reservoirs that are contaminated by releases from the ORR. The ORR is not uniformly contaminated and cannot be investigated and remediated all at once. Therefore, the ORR was divided into operable units (OUs)—areas that contains wastes in proximity to each other in an locality with (ideally) common physical and hydrological characteristics. The OUs are described in the ORR site management plan (ERD 1994).

Division of the ORR into OUs was not a sufficient solution to the problem of providing an appropriate spatial organization to CERCLA activities because the spatial dynamics of contaminants on the site were not recognized. Contaminants deposited in sites now designated as OUs have moved in leachate into the groundwater and in runoff and leachate into surface waters where they have mixed with contaminants from other sources. In addition, the plant and animal populations of the ORR extend across areas that encompass multiple OUs, and individual organisms may feed on one OU, drink from another, and rest on a third. As a result, four classes of OUs are now recognized: source OUs, aquatic integrator OUs, groundwater OUs, and the terrestrial integrator OU.

The nature of these classes of OUs and the relationships among them are discussed in the following text. In general, each ecological risk assessment for each OU must address the ecological values that are distinct to that OU. However, the Remedial Investigation (RI) for each OU must also characterize its ongoing contributions to risks on other OUs. These risks are due to fluxes of contaminants out of the OU (e.g., leachate or emergent mayflies), use of an OU by animals that are not distinct to that OU (e.g., deer grazing on a waste disposal site), or physical disturbances that extend off the site (e.g., deposition of silt or construction of facilities for the remedial action off the site).

2.1.1 Source Operable Units

Source OUs are sites where wastes were directly deposited. These are the conventional waste sites—areas with trenches, tanks, pits, and drums of waste and areas where wastes have been spilled. Because these source OUs are highly modified systems, they often have low ecological value; some of them are entirely industrialized. Most of the waste burial grounds are vegetated, but the vegetation is maintained as a mowed lawn to prevent erosion while minimizing use of the sites by native plants and animals that might disturb, mobilize, take up, and transport the wastes.

The intensity of effort devoted to ecological risk assessment for a source OU depends on its current character and its assumed future use. A paved OU would have negligible ecological value and would normally require a minimal ecological risk assessment. A waste pond or sump may support aquatic biota, but toxicological risks to that community would not be assessed for the RI because remediation of the wastes would destroy the community. Rather, organisms that drink from the pond or consume aquatic organisms would be the appropriate endpoint species, because they might benefit from removal of a source of toxic exposure. Sites maintained as large lawns may support a distinct plant community (the lawn) and the associated soil heterotrophic community and herbivorous and predatory arthropods characteristic of such plant communities. In such a situation, the ecological risk assessment for the site would address the toxicity of the soil to plants and soil heterotrophs. Wider ranging organisms that occasionally use the site could not be assessed in the RI for the OU because neither their exposure nor their response could be associated with a single OU. However, the sources of exposure of these animals must be characterized.

Some ecological expertise must be applied to evaluating the natural values of these artificial communities. For example, the low-level waste burial grounds at Oak Ridge National Laboratory (ORNL) are frequently mowed so they do not support small mammals except around the edges where adjoining natural vegetation supplies cover (Talmage and Walton 1990). However, other waste sites such as those in Bear Creek OU-1 are seldom mowed, so it is likely that they support small mammal populations.

The appropriate assumptions concerning future states of the source OUs are not well-defined at this time. A land use plan for the reservation, which would help to define future use scenarios, is being considered. Under such a plan, many if not all of these sites are likely to remain industrial. However, loss of institutional control has been a standard scenario for CERCLA baseline risk assessments. Under a loss of institutional control scenario, or under any land use plan that calls for reversion of a source OU to a natural state, natural succession must be assumed leading to establishment on most sites of a deciduous forest. Such scenarios would have more exposure pathways and receptors than the current baseline case; they might include establishment of threatened and endangered species on the site that are not currently present. Appropriate future scenarios for individual source OUs must be determined during the data quality objectives (DQO) process.

Some source OUs are too large and diverse to be assessed and remediated as a unit. In those cases, the OU may be divided into subunits. Although these divisions are likely to be based primarily on the types of wastes present and the manner of their disposal, such divisions should also take ecological differences in the site into consideration. For example, boundaries between distinctly different vegetation types may serve as bounds of subunits.

2.1.2 Aquatic Integrator Operable Units

Aquatic integrator OUs are streams and their associated floodplains. The aquatic integrator OUs include White Oak Creek, Bear Creek, upper and lower East Fork Poplar Creek, Poplar Creek, and upper and lower McCoy Branch. In addition, the Clinch River and lower Watts Bar Reservoir are aquatic integrator OUs for the entire reservation. These OUs receive contaminants from all of the source OUs in their watersheds; incorporate them into sediments, floodplain soils, and biota; and pass them along to the next aquatic integrator OU downstream.

The aquatic integrator OUs generally have much greater ecological value than the source OUs. They support stream communities and, except in reaches that are channelized, riparian communities that are diverse and provide ecosystem services such as hydrologic regulation. Aquatic integrator OUs are likely to be more susceptible to contaminants than the communities of source OUs because the contaminants are in the surface environment including surface waters and because of the greater diversity of biota and routes of exposure. Future land use scenarios may change exposures in some portions of integrator OUs. For example, White Oak Creek through the grounds of Oak Ridge National Laboratory (ORNL) is channelized and riprapped. If it were assumed that ORNL will be removed and no new industrial or residential development is allowed to replace it, then the stream would eventually develop a natural channel and riparian community leading to a more diverse and abundant aquatic community.

In general, aquatic integrator OUs should not be assessed as single units because they are large and vary significantly in their structure and degree of contamination. Rather, they must be divided into reaches. The reaches should be delimited in such a way that they form distinct and reasonably uniform units for assessment and remediation:

- Sources of contamination should be used as bounds on reaches. Examples include contaminated tributaries and sets of seeps associated with drainage from a source OU.
- Tributaries that provide sufficient input to significantly change the hydrology or basic water quality (e.g., pH or hardness) of a stream should serve as bounds of reaches.
- Physical structures that divide a stream, particularly if they limit the movement of animals or trap contaminated sediments, should be used as bounds of reaches. Examples include dams, weirs, and some culverts.
- Changes in land use should be used to delimit reaches. Clearly, ecological risks are different where floodplains have commercial or agricultural land uses than where they are forested.
- Reaches should not be so finely divided that they do not constitute ecological units. Reaches that are too short will contain fish or small mammals that cannot be clearly associated with the reach.

2.1.3 Groundwater Operable Units

Groundwater aquifers receive contaminants in leachate from source OUs and from losing reaches of contaminated streams. The groundwater OUs are aquifers that receive contaminants from multiple sources. Groundwater OUs have not been subject to ecological risk assessments because microbes and micro-invertebrates that make up groundwater communities are not protected in the United States.

2.1.4 Terrestrial Integrator Operable Unit

Most of the ORR lies outside the contaminated sites, streams, and rivers that were originally designated as OUs. However, regulatory and ecological concerns are not limited to such sites. Wildlife and plant populations extend across the reservation, and individual animals visit and use multiple OUs. In addition, the values associated with wetlands and other communities result from their spatial extent and distribution and not just their occurrence on individual contaminated OUs. Therefore, it was necessary to create a terrestrial integrator OU encompassing the entire reservation and addressing risks to those widely distributed populations and communities.

2.2 ADMINISTRATIVE AND REGULATORY SCOPE

Ecological risk assessors must be involved in all stages of the CERCLA investigation and remediation process. That process is diagrammed in Fig. 1, and is briefly discussed in the following paragraphs.

2.2.1 Site Characterization

Before an ecological risk assessment (ERA) can be performed, it is necessary to have a basic understanding of the nature and extent of contamination, potential routes of exposure, and ecological resources present at the site. This involves a site visit and accumulating information pertaining to the state and history of the site. Site characterization involves describing the physical characteristics of the site (e.g., topography, geology, hydrology, etc.) and the types and extent of plant and animal communities present. Previous actions taken at the site that have affected the environment, such as capping of landfills, should also be described.

2.2.2 Screening Assessment

Screening assessments (sometimes termed "preliminary assessments") serve to summarize the existing information (both biotic and abiotic) about a site in terms of risk. That is, they screen contaminants into categories of contaminants of potential concern (COPCs) and contaminants that may be ignored. Similarly, screening assessments partition routes of exposure and receptors into those that require further assessment and those that may be ignored. In this way, a screening assessment provides the basis for the conceptual model and identifies data gaps to be filled by sampling and analysis. In addition, a screening assessment may identify risks that require early remedial actions.

Questions that drive a screening assessment include: 1) Which media (water, sediment, soil, etc.) are contaminated such that they may be toxic?; 2) What chemicals are involved (Which contaminants are COPCs)?; 3) What are the concentrations and spatial and temporal distributions of these contaminants?; 4) What routes of transport may cause additional contamination in the future?; and 5) What organisms are expected to be significantly exposed to the chemicals? Answering these questions works to define the bounds of the problem to be assessed.

Because screening assessments use existing information, they may be performed relatively rapidly. Their primary purpose is to eliminate all nonexistent or clearly insignificant hazards. Only those contaminants that obviously pose no hazard are excluded in these assessments. Screening assessments should therefore be conservative and as broad as is reasonably possible so that no potential hazards are overlooked.

2.2.3 Remedial Investigation Workplan

If, after completion of the screening assessment, additional data are needed to adequately evaluate ecological risk, an RI workplan is developed. Generic ecorisk data needs are discussed in Sect. 6, but the quantity and distribution of samples, the types of analyses required, and the need for additional types of data must be evaluated for each site. In the RI workplan, existing information about the site and data gaps identified through the screening assessment are

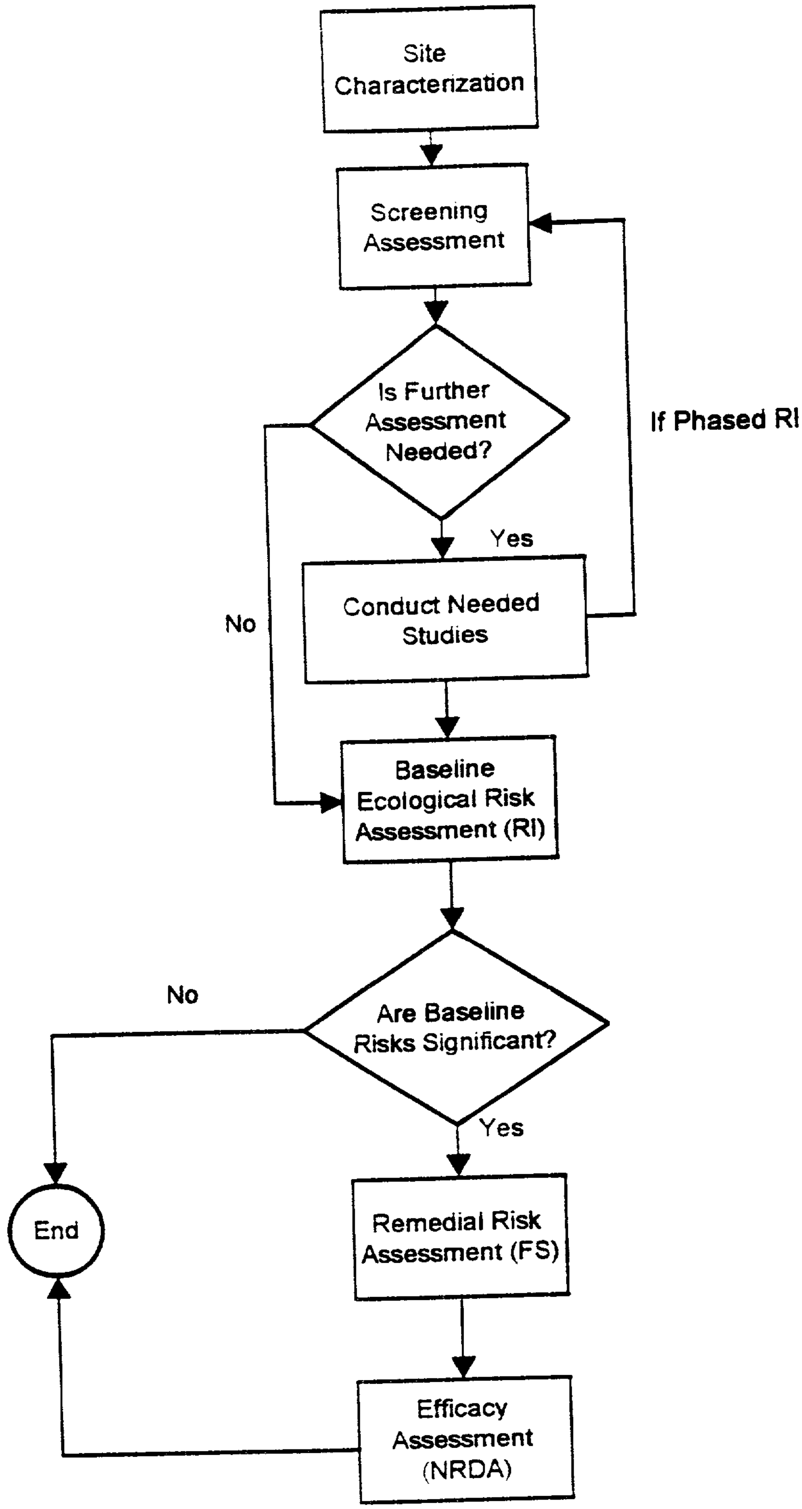

Fig. 1. Ecological Risk Assessment in the RI/FS Process.

summarized. The primary purpose of the RI workplan, however, is to outline the approach and methods that will be used to collect data needed to fill these data gaps. The RI workplan presents a plan for obtaining the data needed for the baseline assessment.

The content of the workplan is based on a process of defining the problems at a site, data needed to resolve the problem, and rules for determining when data are adequate (the DQO process). The DQOs are obtained by a consensus of the FFA parties.

If the OU is poorly characterized by existing data, the RI may be carried out in phases. That is, a Phase 1 sampling and analysis program may be defined and carried out which provides the basis for planning a more focused second phase. This requires that the results of the Phase 1 studies be used to conduct a screening assessment which is used to identify the data gaps that must be filled in Phase 2. See Cook et al. (1993) for an example.

2.2.4 Baseline Ecological Risk Assessment

In contrast to the screening assessment which defines the scope of the baseline assessment, the baseline assessment uses new and existing data to evaluate the risk of leaving the site unremediated. The purposes of the baseline assessment are to determine 1) if significant ecological effects are occurring at the site, 2) the causes of these effects, 3) the source of the causal agents, and 4) the consequences of leaving the system unremediated. The baseline assessment provides the ecological basis for determining the need for remediation.

Because the baseline assessment focuses on a smaller number of contaminants and species than the screening assessment, it can provide a higher level of characterization of toxicity to the species and communities at the site. In the baseline ecological risk assessment, a weight-of-evidence approach is employed to determine if and to what degree ecological effects are occurring or may occur (Sect. 8).

2.2.5 Remedial Alternatives Assessment

A part of the feasibility study for a CERCLA site is an assessment of the degree to which each alternative provides "overall protection of human health and the environment." For the no action alternative and for those alternatives that limit human access to and use of the site, the risks are those identified in the baseline ecological risk assessment. Other remedial alternatives involve some reduction of site contamination or of exposure to contaminants but at a cost of risks due to physical disturbances. These remedial risks include destruction of the biotic communities on the site and on uncontaminated sites for borrow pits, land fills, roads, laydown areas, parking lots, etc. The remedial ERA must consider these direct effects, secondary effects such as erosion and habitat fragmentation, and the expected rate and degree of recovery of the disturbed areas given the site management and expected land uses.

2.2.6 Efficacy Assessments

Ecological risk assessments are performed after completion of remedial actions for two purposes. First, the Natural Resource Damage Assessment (NRDA) provisions of CERCLA require that the residual injuries be assessed so that the natural resource trustees can be compensated for lost natural resource services. Because the DOE is a natural resource trustee for the ORR, it is required to participate in the NRDA along with co-trustees. To be more efficient, it has been recommended that NRDA be integrated with the rest of the CERCLA process (DOE 1991). Second, if the remedial actions leave contaminants in place rather than removing or destroying them, the DOE is required to monitor the remediated site, and, every 5 years, assess the efficacy of the remedial actions in terms of the protection of human health and the environment, until unrestricted use of the site is possible. Both of these assessment goals require collection of data to characterize the post-remedial condition and estimation of levels of effects rather than simply screening contaminants.

3. CONCEPTUAL MODELS

3.1 GENERIC CONCEPTUAL MODELS OF BASELINE ECOLOGICAL RISKS

The generic conceptual models described in this section are provided to illustrate the relationships among the ecological components of the various OUs on the ORR and serve as bases for developing specific conceptual models for particular OUs. The OU-specific models are likely to be simpler than these generic models because individual OUs are unlikely to contain all of the compartments and pathways. The basic conceptual model for the CERCLA baseline ecological risk assessment is presented in Fig. 2. It depicts the movement of contaminants from the source OUs to the groundwater OUs and the terrestrial and aquatic integrator OUs and the exchange of contaminants between the integrator OUs. Fluxes from the groundwater and integrator OUs to source OUs are assumed to be negligible. Contaminant fluxes, exposure, and accumulation within the four types of OUs are discussed in the following text.

The compartments of the model are described in this section in terms of their composition, input, and output. The compartments are composed of groups of taxa that have similar routes of exposure due to their common trophic habits. These trophic groups are not necessarily similar in their sensitivity to contaminant exposures because they may include species from different taxonomic classes. Examples of species assigned to each compartment are presented in the following discussion. In addition, vertebrate species occurring on the ORR or in the Clinch River/Watts Bar Reservoir are listed in Appendix A with the compartment to which they are assigned.

A number of decisions must be made in developing conceptual models. The following list applies to this set of decisions.

- These models are based on the transfer of contaminants and resulting exposures and not on secondary effects such as reduced predator abundance due to loss of prey.

- Recycling of contaminants within an OU is not depicted when it does not increase the number of receptors or routes of exposure. For example, the return of contaminants to the contaminated soil when an herbivore dies on a source OU is not shown.

- "Large" refers to the range of an organism rather than its body size. For example, a vole may be a small herbivore in that the range of a population of voles may be confined primarily to a single OU, but a bird of approximately the same weight, such as a robin, would be categorized as a large soil invertebrate feeder because the high mobility of robins ensures that the range of a robin population will be much larger than a source OU.

- Atmospheric routes of exposure are not included. None are believed to be significant on the ORR, but if evidence is obtained indicating that such routes may be significant at an OU, they should be added.

- Parasites are not included.

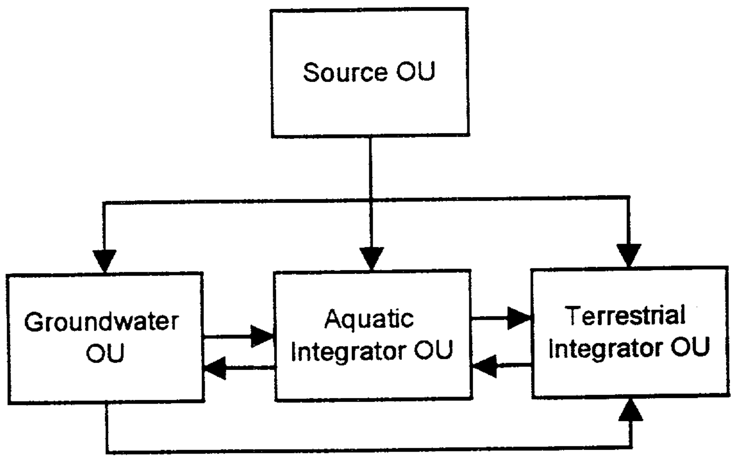

Fig. 2. Contaminant Transfers Among Operable Units.

- Physical effects of waste disposal such as paving or erosion of disturbed soils are not included.

In the diagrams, rectangles represent components of the depicted OU, rounded rectangles represent inputs from other OUs, and circles represent other OUs that receive output from the depicted OU. Shaded rectangles represent compartments containing potential assessment endpoint species or communities.

3.1.1 Source OU Conceptual Model

The generic conceptual model for contaminant fluxes in source OUs is presented in Fig. 3.

Contaminant Sources

Composition—These are the trenches, pits, sumps, tanks, spill sites, and other facilities in which wastes were deposited in the source OU.

Input—It is assumed in this generic conceptual model that wastes are no longer being added, so there is no input. However, if wastes are still being disposed of in the source OU, they must be included in the model.

Output—Waste components enter the soil by direct deposition or by migration out of containers. Wastes enter aqueous systems by leaching into groundwater or by dissolving in runoff.

Surface Soil

Composition—Surface soil is the biologically active upper layer of the soil on the source OU including the litter layer (A_0 horizon). The depth of this compartment varies among sites. This compartment contains contaminants associated with mineral soil, pore water, organic matter, and microbiota. For purposes of this model, contaminants in pits, trenches, etc., that are contacted by plant roots or animals are considered functionally to be contaminated soil.

Input—Waste components enter the soil from the contaminant sources by direct deposition or by migration out of containers.

Output—Soil contaminants enter aqueous systems by leaching into groundwater, by dissolving in runoff, or by being carried with eroded soil. Soil contaminants enter terrestrial plants by root uptake and by leaf uptake following volatilization. Soil contaminants enter animals by direct ingestion either incidentally or deliberately. They also enter animals and microbes by absorption from the pore water.

Groundwater, Runoff, and Eroded Soil

Composition—This compartment represents the contaminants that are in flux in an aqueous phase. It includes all groundwater, surface runoff water, and contaminated soil carried in runoff.

Input—Waste components enter aqueous systems by dissolution into groundwater (leaching) or into runoff. Contaminated soil enters by erosion.

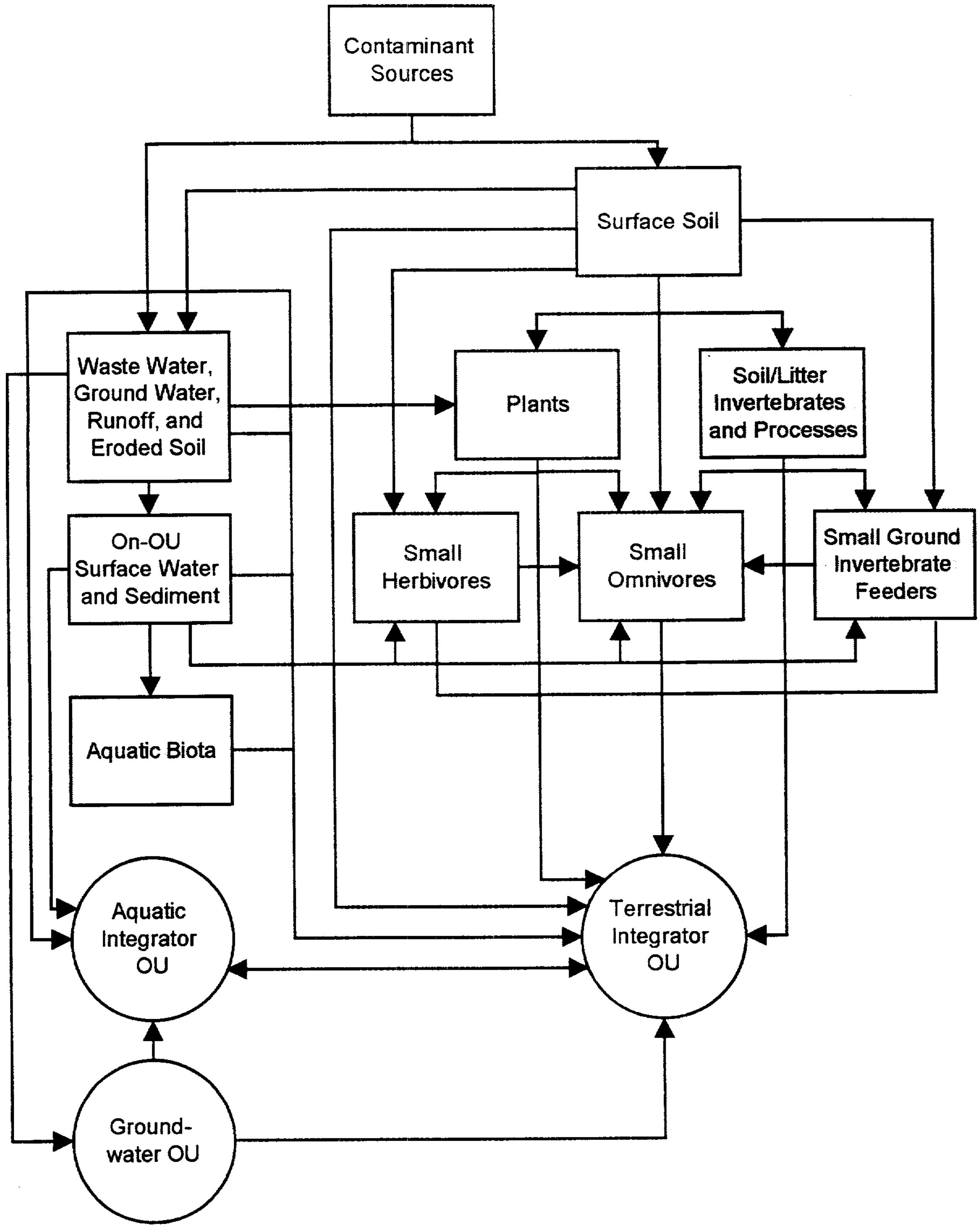

Fig. 3. Transfer of Contaminants Through a Source OU and Into Integrator OUs

Output—Wastes in aqueous phases may be carried to on-site water bodies or to aquatic or groundwater integrator OUs. Plants may take up contaminants in shallow groundwater.

On-OU Surface Water and Sediments

Composition—Some source OUs contain streams or ponds that are distinct to the source OU and are not part of an aquatic integrator OU. These do not include sumps or ponds for aqueous wastes, which are treated as sources to be remediated rather than as ecosystems to be protected. However, they do include ponds that are "waters of the state" which have been contaminated.

Input—These waters receive contaminants in groundwater seeps or springs, runoff, and eroded soil. In addition, some surface waters have received direct discharges of waste waters.

Output—Contaminants in on-OU surface waters and sediments are taken up by any aquatic biota that inhabit them and may be consumed by animals inhabiting the source OU or coming in from the terrestrial integrator. In addition, they may be transported to water and sediments in the aquatic integrator OU.

Aquatic Biota

Composition—This compartment represents the plants, invertebrates, and vertebrates inhabiting the on-OU surface waters. This compartment is described in more detail in Subsect. 3.1.5.

Input—The aquatic biota take up contaminants from water and sediments.

Output—Fish and macroinvertebrates are consumed by piscivores, aquatic invertebrate feeders, and omnivores, and emergent aquatic insects are consumed by flying insectivores. All of these are from the terrestrial integrator OU.

Plants

Composition—This compartment includes terrestrial vascular plants.

Input—Uptake from soil through roots and leaves (leaf uptake includes deposition of contaminated soil and uptake of contaminants volatilized from soil) and from groundwater through roots.

Output—Plants are consumed by herbivores and omnivores. Some of these are not resident on the site and are assessed in the terrestrial integrator OU.

Soil/Litter Invertebrates and Processes

Composition—This compartment includes the heterotrophic invertebrates and microbes that inhabit the soil and litter layers. It does not include soil herbivores. This compartment is commonly represented by earthworms.

Input—Contaminants are taken up by consumption of soil and litter and by absorption from the soil pore water.

Output—Soil invertebrates are consumed by animals that feed primarily on them such as shrews and woodcock and by omnivores such as *Peromyscus*. If there is suitable habitat on the source OU that is sufficiently extensive, these animals may have distinct populations on the source OU. Otherwise, they are part of the terrestrial integrator OU.

Small Herbivores

Composition—Small herbivores include those terrestrial herbivores that are sufficiently small or have sufficiently low mobility to have distinct populations on the OU. The most abundant and ecologically important are insects. However, some vertebrate herbivores such as voles may be included.

Input—Contaminant input includes consumption of contaminated plants and water and incidental consumption of soil.

Output—Contaminant output is consumption by small ground invertebrate feeders and small omnivores on the OU and by flying insectivores, large ground invertebrates feeders, arboreal insectivores (if the OU is wooded), large omnivores, and carnivores from the terrestrial integrator OU.

Small Omnivores

Composition—Small omnivores include those terrestrial omnivores that are sufficiently small or have sufficiently low mobility to have distinct populations on the OU. Examples potentially include *Peromyscus* spp.

Input—Contaminant input includes consumption of contaminated plants, herbivores, soil invertebrates, and water and incidental consumption of soil.

Output—Contaminant output is consumption by large omnivores and carnivores from the terrestrial integrator OU.

Small Ground Invertebrate Feeders

Composition—Small ground invertebrate feeders include those species that feed on soil and litter invertebrates including herbivores that feed on roots and low vegetation and are sufficiently small or have sufficiently low mobility to have distinct populations on the OU. Potential examples include shrews, terrestrial salamanders, lycosid spiders, and centipedes.

Input—Contaminant input includes consumption of contaminated soil invertebrates and water, incidental consumption of soil, and, for amphibians, dermal absorption.

Output—Contaminant output is consumption by small omnivores on the OU and by large omnivores and carnivores from the terrestrial integrator OU.

3.1.2 Aquatic Integrator OU Conceptual Model

The generic conceptual model for contaminant fluxes in aquatic integrator OUs is presented in Fig. 4. These OUs are streams that receive wastes from source OUs plus their floodplains and associated biota. The aquatic biota compartment is presented in Fig. 5.

Wastes Deposited In-OU

Composition—Although hazardous wastes were seldom deliberately deposited in streams or floodplains, the practice is not unknown. This compartment includes wastes disposed of in the aquatic integrator OU either directly or in liquid wastes retained in settling basins. An example is the contaminants deposited in the intermediate pond on White Oak Creek [Waste Area Grouping 2 (WAG 2)].

Input—It is assumed that hazardous wastes are no longer being deposited in the aquatic integrator OUs. All input are from outside the OU in source OUs, point sources (i.e., NPDES sources), or nonpoint sources (e.g., landscaping chemicals).

Output—These wastes directly contaminate the floodplain soils and contaminate water through leachate, runoff, and eroded soil.

Stream, Pond, and Wetland Water

Composition—This compartment includes all persistent surface water in the OU including not only the stream, but also vernal pools, wetlands, and other surface water that persists for sufficient duration to support a community of aquatic macrobiota.

Input—The input to this compartment includes contaminants in runoff from source OUs and in groundwater either from shallow groundwater coming directly off an adjoining source OU or less directly from a groundwater OU. Contaminants may also come from wastes deposited in the aquatic integrator OU.

Output—Surface water contaminants are taken up by the aquatic biota, become sorbed to sediments and floodplain soils, and are consumed by animals inhabiting the aquatic integrator OU or the terrestrial integrator OU.

Stream, Pond, and Wetland Sediments

Composition—This compartment includes all sediments underlying persistent surface water in the OU.

Input—Sediment contaminants come from soil eroded from Source OUs and contaminated floodplain soils and from contaminated surface water and groundwater.

Output—Sediment contaminants are desorbed to the surface water, taken up by aquatic biota, and deposited on the floodplain.

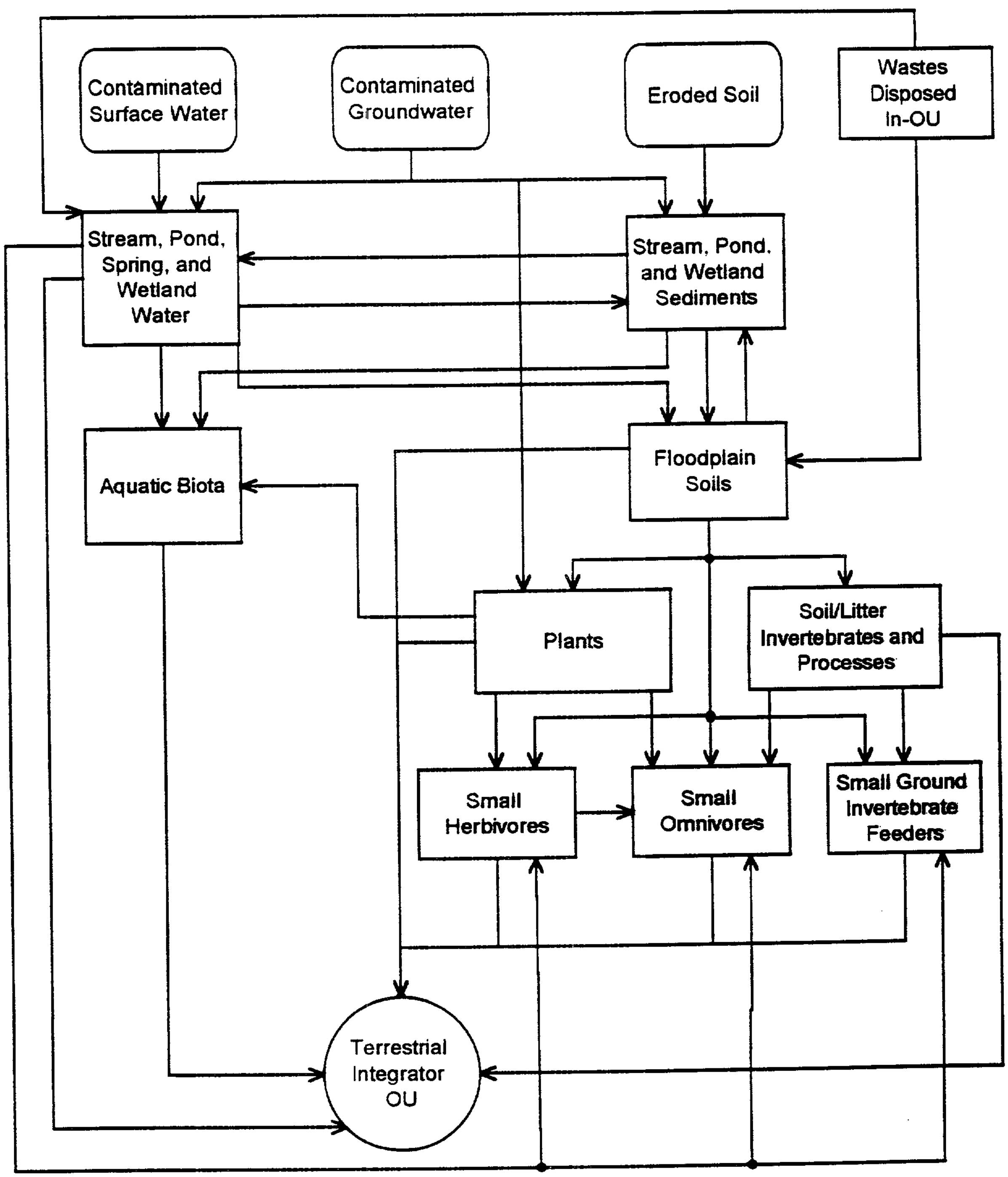

Fig. 4. Transfer of Contaminants Into and Through an Aquatic Integrator OU.

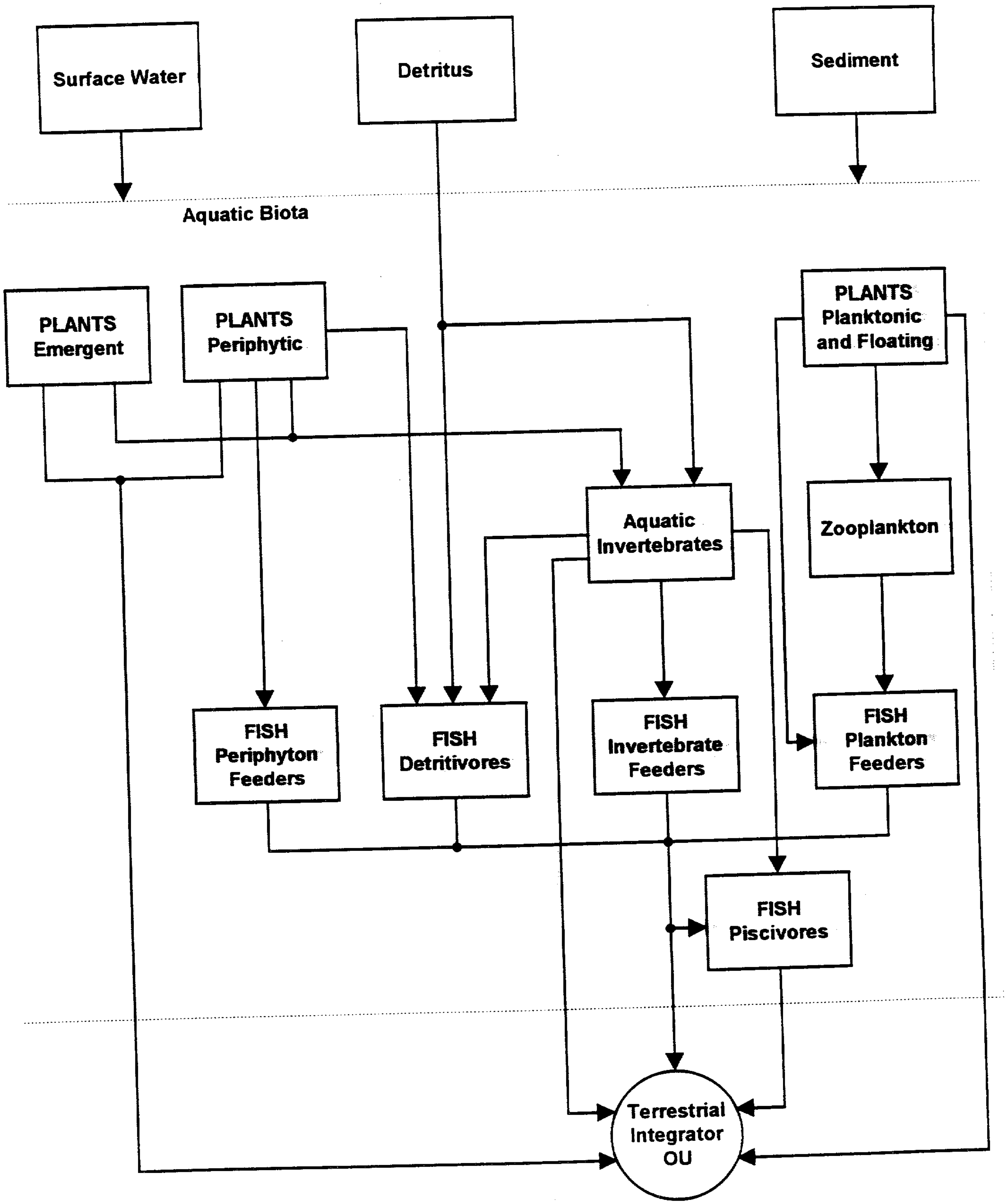

Fig. 5. Transfer of Contaminants Into and Through the Aquatic Biota.

Aquatic Biota

Composition—This compartment represents the plants, invertebrates, and vertebrates inhabiting the on-OU surface waters. This compartment is described in more detail in Subsect. 3.1.5.

Input—The aquatic biota take up contaminants from water and sediments.

Output—Fish and macroinvertebrates are consumed by piscivores, aquatic invertebrate feeders, and omnivores, and emergent aquatic insects are consumed by flying insectivores. All of these are from the terrestrial integrator OU.

Floodplain Soil

Composition—Surface soil is the biologically active upper layer of the soil on the floodplain including the litter layer (A_0 horizon). The depth of contaminated surface soil in floodplains is quite variable because of the dynamics of deposition and erosion.

Input—Waste components enter the soil from the surface water and sediments during flooding or the soils may be contaminated by past waste disposal in the floodplain.

Output—Soil contaminants enter aqueous systems from floodplain soils by leaching into groundwater, by dissolving in runoff, or by being carried with eroded soil. Soil contaminants enter terrestrial plants by root uptake and by leaf uptake following volatilization. Soil contaminants enter animals by direct ingestion either incidentally or deliberately. They also enter animals and microbes by absorption from the pore water.

Plants

Composition—This compartment includes terrestrial vascular plants.

Input—Uptake from soil through roots and leaves (leaf uptake includes deposition of contaminated soil and uptake of contaminants volatilized from soil) and from groundwater through roots.

Output—Plants are consumed by herbivores and omnivores. Some of these are not resident on the site, and are assessed in the terrestrial integrator OU.

Soil/Litter Invertebrates and Processes

Composition—This compartment includes the heterotrophic invertebrates and microbes that inhabit the soil and litter layers. It does not include soil herbivores. This compartment is commonly represented by earthworms.

Input—Contaminants are taken up by consumption of soil and litter and by absorption from the soil pore water.

Output—Soil invertebrates are consumed by animals that feed primarily on them such as shrews and woodcock and by small omnivores such as *Peromyscus* on the OU and by flying insectivores and large ground invertebrates feeders from the terrestrial integrator OU.

Small Herbivores

Composition—Small herbivores include those terrestrial herbivores that are sufficiently small or have sufficiently low mobility to have distinct populations on the OU. The most abundant and ecologically important are insects. However, some vertebrate herbivores such as voles may be included.

Input—Contaminant input includes consumption of contaminated plants and water and incidental consumption of soil.

Output—Contaminant output is consumption by small ground invertebrate feeders and small omnivores on the OU and by flying insectivores, large ground invertebrates feeders, arboreal insectivores (if the OU is wooded), large omnivores, and carnivores from the terrestrial integrator OU.

Small Omnivores

Composition—Small omnivores include those terrestrial omnivores that are sufficiently small or have sufficiently low mobility to have distinct populations on the OU. Examples include *Peromyscus* spp.

Input—Contaminant input includes consumption of contaminated plants, herbivores, soil invertebrates, and water and incidental consumption of soil.

Output—Contaminant output is consumption by large omnivores and carnivores from the terrestrial integrator OU.

Small Soil Invertebrate Feeders

Composition—Small soil invertebrate feeders include those species that are sufficiently small or have sufficiently low mobility to have distinct populations on the OU. Examples include shrews, terrestrial salamanders, and centipedes.

Input—Contaminant input includes consumption of contaminated soil invertebrates and water and incidental consumption of soil.

Output—Contaminant output is consumption by small omnivores on the OU and by large omnivores and carnivores from the terrestrial integrator OU.

3.1.3 Groundwater OU Conceptual Model

The generic conceptual model for contaminant fluxes in the groundwater integrator OUs is presented in Fig. 6.

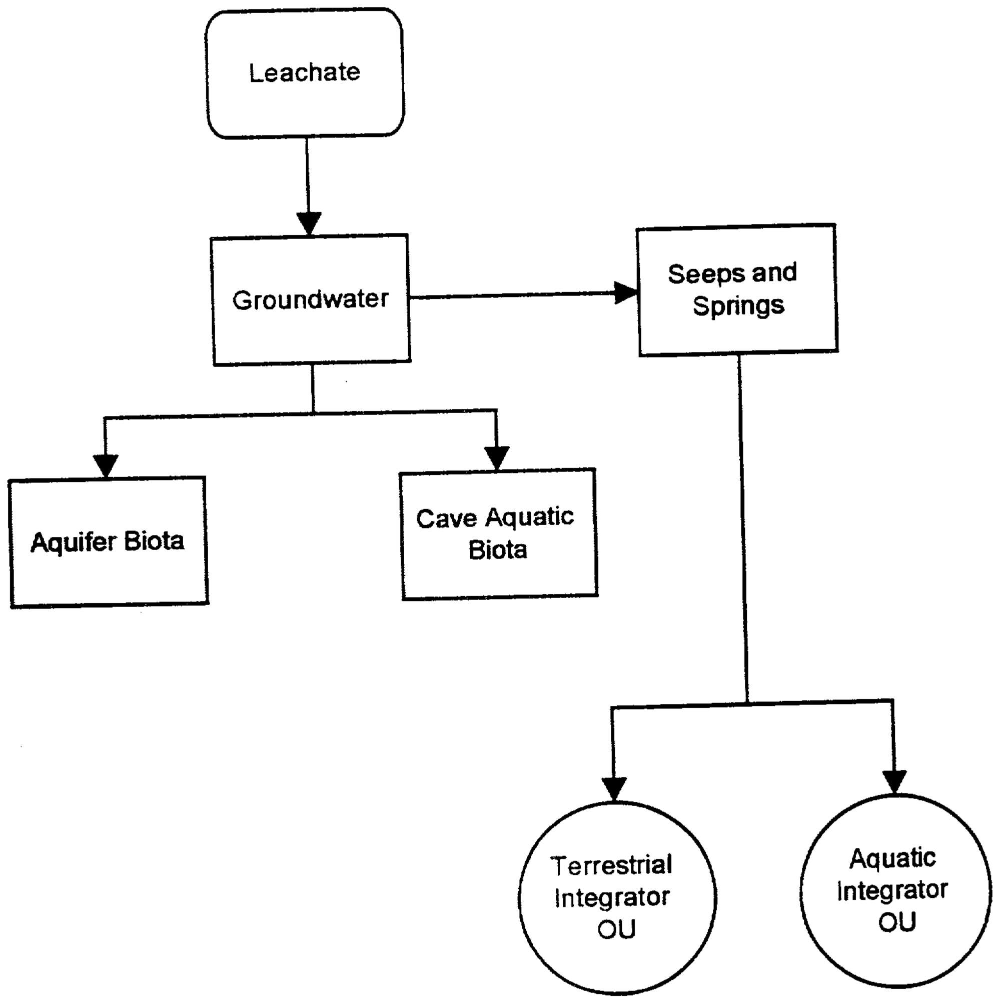

Fig. 6. Transfer of Contaminants Into and Through a Groundwater Integrator OU.

Groundwater

Composition—This compartment consists of contaminated water that occurs in underground aquifers.

Input—Input to this compartment consists of leachates from wastes or contaminated soils.

Output—Contaminant output includes uptake of contaminants by aquifer microbes and invertebrates and by the aquatic biota of caves. It also includes output through seeps and springs to aquatic and terrestrial integrator OUs.

Aquifer Biota

Composition—This compartment includes the invertebrates and microbes that inhabit aquifers. This compartment is not usually considered in ERAs in the U.S., although the contaminant degradation performed by this community may be important to ultimate site remediation.

Input—Contaminants are taken up by absorption from the groundwater.

Output—It is assumed there is no output from this community.

Cave Aquatic Biota

Composition—This compartment includes the vertebrates, invertebrates, and microbes that inhabit cave waters. This compartment is not usually considered in ERAs in the U.S., except when threatened or endangered species are present. It is not clear what species may actually occur in caves on the ORR.

Input—Contaminants are taken up by absorption from the groundwater or through food webs within this compartment. If bats or other surface-feeding species use the caves, they may also serve as an input route. However, the occurrence of such transfers is purely speculative for the ORR.

Output—It is assumed there is no significant output from this community.

3.1.4 Terrestrial Integrator OU Conceptual Model

The generic conceptual model for contaminant fluxes into the terrestrial integrator OUs is presented in Fig. 7. It is assumed there are no contaminant sources in this OU. This figure does not depict contaminant transfers among compartments in the OU. The primary source of contaminants to all compartments is assumed to be contaminants on the source and aquatic integrator OUs. If preliminary assessments suggest there may be significant transfers of contaminants within this OU (e.g., consumption of deer by coyotes or addition of contaminants to soil by defecation), then a model of such internal dynamics of the terrestrial integrator OU will be developed.

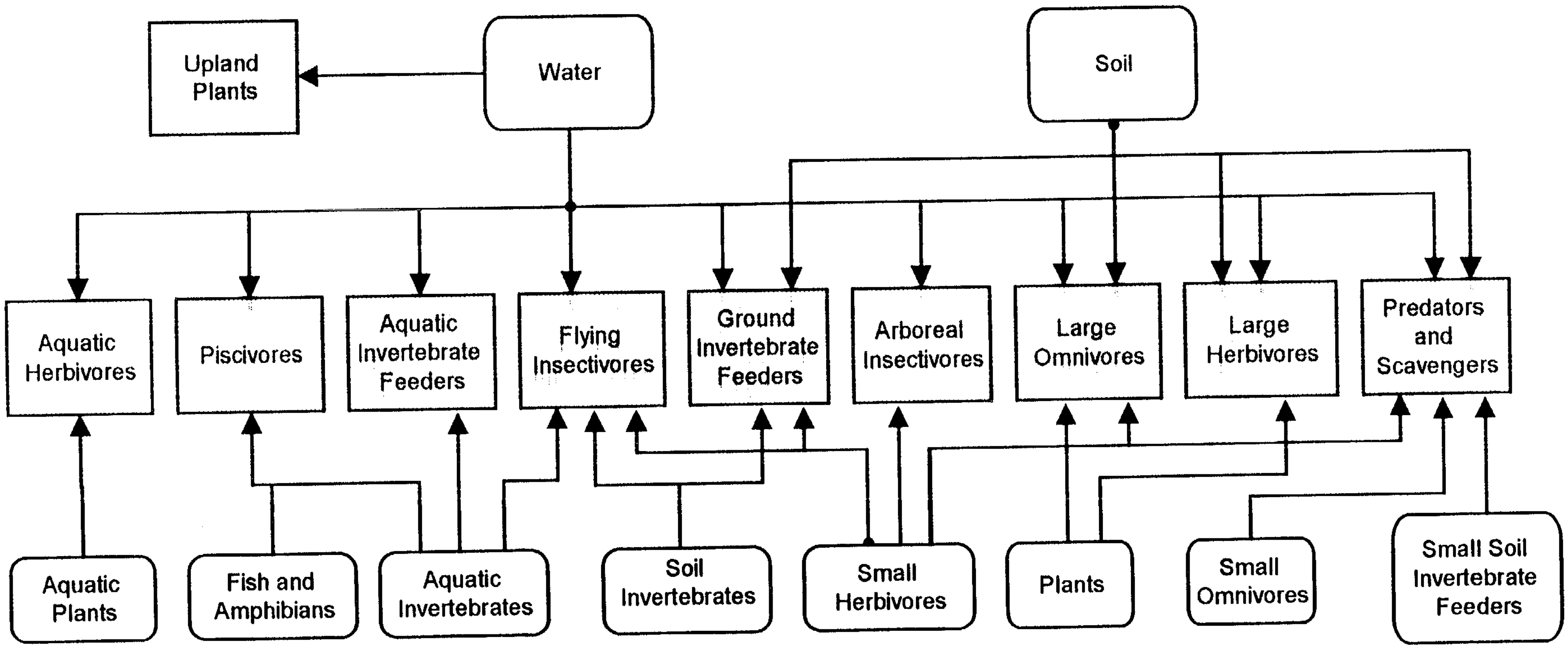

Fig. 7. Transfer of Contaminants From Source and Aquatic Integrator OUs to the Terrestrial Integrator OU.

Upland Plants

Composition—This compartment consists of vascular plants in areas outside source or aquatic integrator OUs.

Input—Upland plants take up contaminants from shallow groundwater that has become contaminated by leachates.

Output—Upland plants are consumed by herbivores and omnivores and may add contaminants to uncontaminated surface soil in litter fall.

Aquatic Herbivores

Composition—This compartment consists of wildlife that consume primarily aquatic plants. Examples include dabbling ducks such as widgeon and gadwall and herbivorous turtles such as pond sliders.

Input—Contaminants are taken up by consumption of aquatic plants and water.

Output—It is assumed that there is no output from this trophic group except decomposition because it would not form a significant component of the diet of any carnivore or scavenger.

Piscivores

Composition—This compartment consists of wildlife that consume primarily fish. Examples include kingfishers, herons, and mink.

Input—Contaminants are taken up by consumption of aquatic biota (fish, amphibians, and aquatic invertebrates) and water.

Output—It is assumed there is no output from this trophic group except decomposition because it would not form a significant component of the diet of any carnivore or scavenger

Aquatic Invertebrate Feeders

Composition—This compartment consists of wildlife that consume primarily aquatic invertebrates. Examples include water fowl such as ruddy duck and pied-billed grebe.

Input—Contaminants are taken up by consumption of aquatic invertebrates and water.

Output—It is assumed that there is no output from this trophic group except decomposition because it would not form a significant component of the diet of any carnivore or scavenger

Flying Insectivores

Composition—This compartment consists of wildlife that consume primarily flying invertebrates. This group is separated from other insectivores primarily because they may consume significant quantities of aquatic insects which would result in different exposure levels from consumption of terrestrial insects. Examples include bats, swallows, and flycatchers.

Input—Contaminants are taken up by consumption of aquatic and terrestrial flying insects and water.

Output—It is assumed there is no output from this trophic group except decomposition because it would not form a significant component of the diet of any carnivore or scavenger. However, bats may act as a route for transferring contaminants to cave ecosystems.

Ground Invertebrate Feeders

Composition—This compartment consists of wildlife that forage on the ground and consume primarily invertebrates. This group consumes soil and litter invertebrates such as earthworms and isopods as well as herbivorous invertebrates that feed on herbaceous vegetation and roots. Examples include robins, woodcock, towhee, skunks, shrews, and toads.

Input—Contaminants are taken up by consumption of herbivorous and soil/litter invertebrates and water and incidental consumption of soil.

Output—Output to this compartment is consumption by predators and scavengers and decomposition.

Arboreal Insectivores

Composition—This compartment consists of wildlife that consume primarily invertebrates that feed on trees. This group is separated from other insectivores primarily because they may consume invertebrates from an almost entirely herbivorous food web and do not consume significant amounts of soil which would result in different exposure levels from consumption of ground-level invertebrates. Examples include vireos, most warblers, and woodpeckers.

Input—Contaminants are taken up by consumption of arboreal invertebrates and water.

Output—Output to this compartment is consumption by predators and scavengers and decomposition.

Large Omnivores

Composition—This compartment consists of wildlife that consume a variety of plant and animal material from terrestrial or aquatic systems. Examples include crows, raccoons, grey fox, and muskrats.

Input—Contaminants are taken up by consumption of plants, animals, and water and incidental consumption of soil.

Output—Output to this compartment is consumption by predators and scavengers and decomposition.

Large Herbivores

Composition—This compartment consists of wildlife that consume primarily plant material from terrestrial systems. Examples include deer, rabbits, and wild turkeys.

Input—Contaminants are taken up by consumption of plants and water and incidental or deliberate consumption of soil.

Output—Output to this compartment is consumption by predators and scavengers and decomposition.

Predators and Scavengers

Composition—This compartment consists of wildlife that consume animal flesh material through predation or scavenging. Examples include weasels, bobcats, hawks, and vultures.

Input—Contaminants are taken up by consumption of animals and water and incidental consumption of soil.

Output—It is assumed there is no output from this trophic group except decomposition because it would not form a significant component of the diet of any carnivore or scavenger.

3.1.5 Aquatic Biota Conceptual Model

The generic conceptual model for contaminant fluxes in the aquatic biota compartment is presented in Fig. 5. This model is an elaboration of the aquatic biota compartment in the conceptual models for source OUs and aquatic integrator OUs. Although aquatic plants, invertebrates, and fish are assessed as a community, they are subdivided in the conceptual model because exposure is dependent on habitat and trophic category. A species list of fishes that identifies their trophic categories is presented in Appendix A, Table A.2. Contaminant fluxes among abiotic compartments (i.e., desorption of sediment contaminants to the surface water) are represented in the conceptual models of the OUs.

Surface Water

Composition—This compartment includes all persistent surface water in the OU which is capable of supporting aquatic macrobiota. This may include streams, ponds, vernal pools and wetlands but not waste sumps or waste ponds, which are treated as sources.

Input—The input to this compartment includes contaminants in runoff and groundwater.

Output—Surface water contaminants are taken up by the aquatic biota. Outputs to abiotic and terrestrial biotic compartments are addressed at the OU level.

Sediment

Composition—This compartment includes all sediments underlying persistent surface water in the source or integrator OU.

Input—The input to this compartment includes contaminants in eroded soil, surface water, and groundwater.

Output—Sediment contaminants are taken up by aquatic biota. Outputs to abiotic compartments are addressed at the OU level.

Detritus

Composition—This compartment represents the nonliving organic matter in the aquatic system.

Input—The primary input is contaminants in allochthanous material from upstream source OUs and riparian communities. Contaminants may be recycled through the decomposition of contaminated aquatic biota resident within the aquatic system.

Output—Contaminants in detritus are taken up through consumption by aquatic biota.

Plants—Emergent

Composition—This compartment represents the vascular aquatic plants rooted in the soft sediments of depositional zones. These plants extend into or above the water column.

Input—Emergent plants take up contaminants from the surface water and sediment.

Output—Emergent plants are consumed by aquatic invertebrates and terrestrial herbivores, such as the pond slider turtle.

Plants—Periphytic

Composition—This compartment represents aquatic vegetation attached to benthic hard substrates in erosional zones (i.e., rocks and submerged logs). These are primarily monocellular and non-vascular assemblages including attached algae, bacteria, and fungi.

Input—The primary contaminant input is from surface water. Uptake from soft sediments is limited by erosion.

Output—Consumers of periphyton include aquatic invertebrates, fish, and terrestrial herbivores.

Plants—Planktonic and Floating

Composition—This compartment represents all unattached vegetation, including simple and vascular plants, suspended in the water column or on the surface. Examples include algae and duckweed.

Input—Planktonic and floating plants take up contaminants from the water column but not from the sediment.

Output—Planktonic and floating plants are consumed by planktonic animals, fish, and terrestrial herbivores.

Zooplankton

Composition—This compartment includes the invertebrates inhabiting the open water zone of slow moving bodies of water. The primary representatives of this group are crustaceans, which may include daphnids, and rotifers.

Input—Planktonic animals take up contaminants from the water and through consumption of phytoplankton.

Output—Contaminant output from this compartment is consumption by planktivorous fish.

Aquatic Invertebrates

Composition—This compartment represents all invertebrates for which the principal habitat of the aquatic life stage is the benthic, or sediment, zone. Potential examples are aquatic insects (including mayflies, stoneflies, and caddisflies which are collectively known as EPT) and crustaceans such as amphipods, isopods, and crayfish.

Input—Benthic invertebrates take up contaminants from the water and sediment and through consumption of detrital and plant material.

Output—Contaminant output to the aquatic system is consumption by fish. Output to the terrestrial integrator OU includes consumption of aquatic life stages by water fowl and consumption of terrestrial life stages by flying insectivores.

Fish—Periphyton Feeders

Composition—This compartment represents fish which primarily consume attached vegetation. Examples include the stoneroller.

Input—Contaminants are taken up from water and sediment and through consumption of periphyton.

Output—Contaminant output is consumption by piscivorous fish and wildlife.

Fish—Detritivores

Composition—This compartment includes fish which consume dead organic matter. Fish in this compartment may intentionally or incidentally consume varying amounts of periphyton and benthic invertebrates. Examples include the carp, spotted sucker, and Tennessee Dace.

Input—Contaminants are taken up from water and sediment and through consumption of detritus, benthic invertebrates, and periphyton.

Output—Contaminant output is consumption by piscivorous fish and wildlife.

Fish—Invertebrate Feeders

Composition—This compartment represents fish which primarily consume aquatic invertebrates. Examples include the bluegill, skipjack herring, and blacknose dace.

Input—Contaminants are taken up from water and sediment and through consumption of invertebrates.

Output—Contaminant output is consumption by piscivorous fish and wildlife.

Fish—Plankton Feeders

Composition—This compartment represents fish which primarily consume phytoplankton and zooplankton. Examples include the paddle fish.

Input—Contaminants are taken up from water and sediment and through consumption of plankton.

Output—Contaminant output is consumption by piscivorous fish and wildlife.

Fish—Piscivores

Composition—This compartment includes fish which consume other fish and invertebrates. Examples include bass, crappie, and channel catfish.

Input—Contaminants are taken up from water and sediment and through consumption of fish and aquatic invertebrates.

Output—Contaminant output is consumption by piscivorous wildlife.

3.2 ADDITIONAL CONCEPTUAL MODELS FOR FEASIBILITY STUDIES

Feasibility studies require assessment of the risks associated with remedial alternatives. For no-action alternatives or alternatives that take no action to remediate ecological risks (e.g., fences, fishing advisories, land use controls), the conceptual models for the baseline risk assessments are applicable. However, the remedial alternatives that involve removal, isolation, or treatment of soil or sediment require disturbance not only of the contaminated areas but also of uncontaminated areas used for roads, structures, laydown areas, borrow pits, landfills, treatment facilities, etc. Generic conceptual models for these activities are presented in Figs. 8-10. These conceptual models for physical disturbance differ from those for contaminants in that the flows are flows of causal influences rather than flows of contaminants. Additionally, the receptors are defined much more broadly because the consequences of physical disturbances tend to be less discriminatory than those of contaminants. These conceptual models of physical disturbance were presented during the DQO meetings for the ORR ecological assessment and were modified in response to comments. However, they were not developed further. They are presented herein as a basis for developing future guidance on ERAs for feasibility studies.

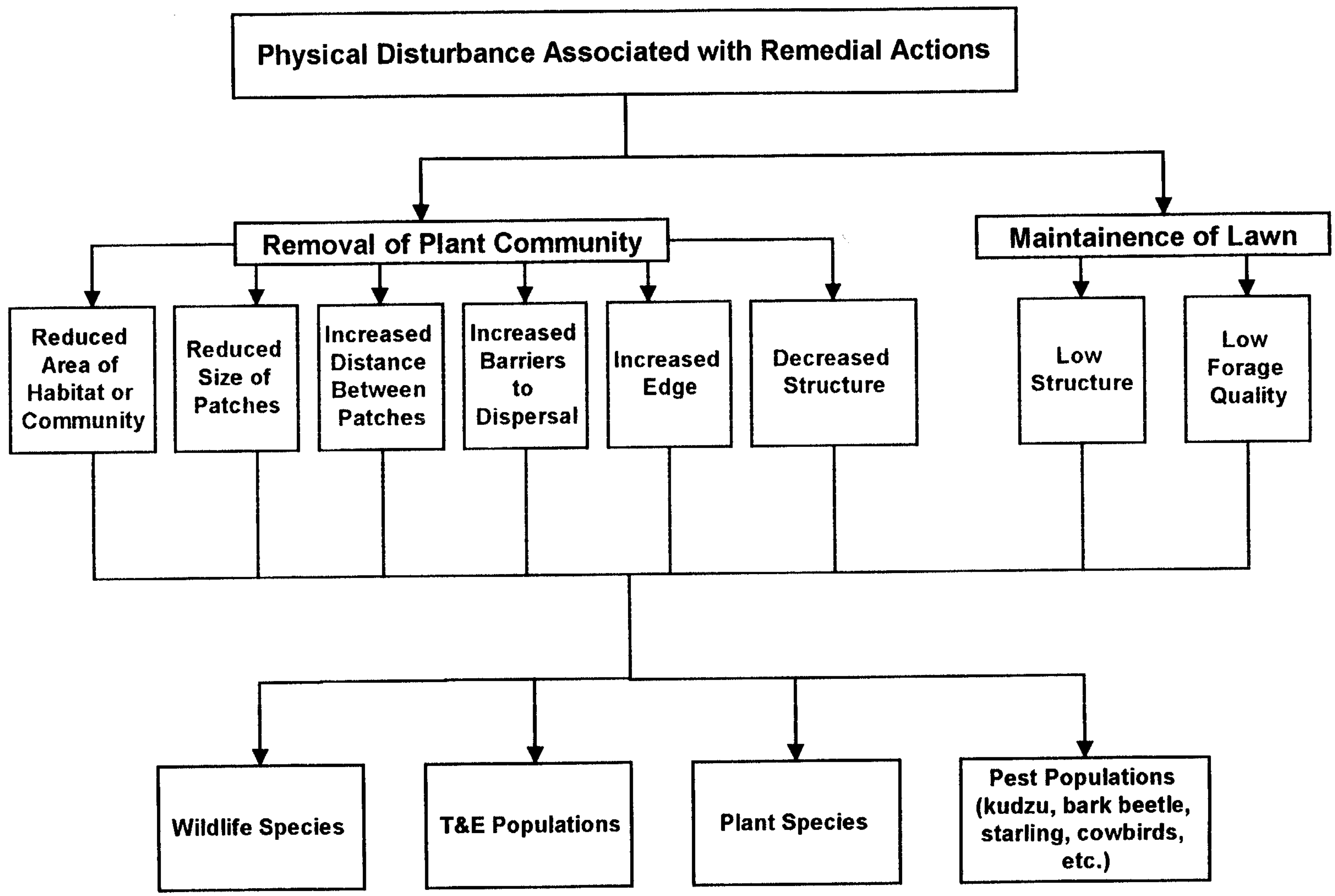

Fig. 8. Generic conceptual model of the effects of physical disturbance on terrestrial ecosystems

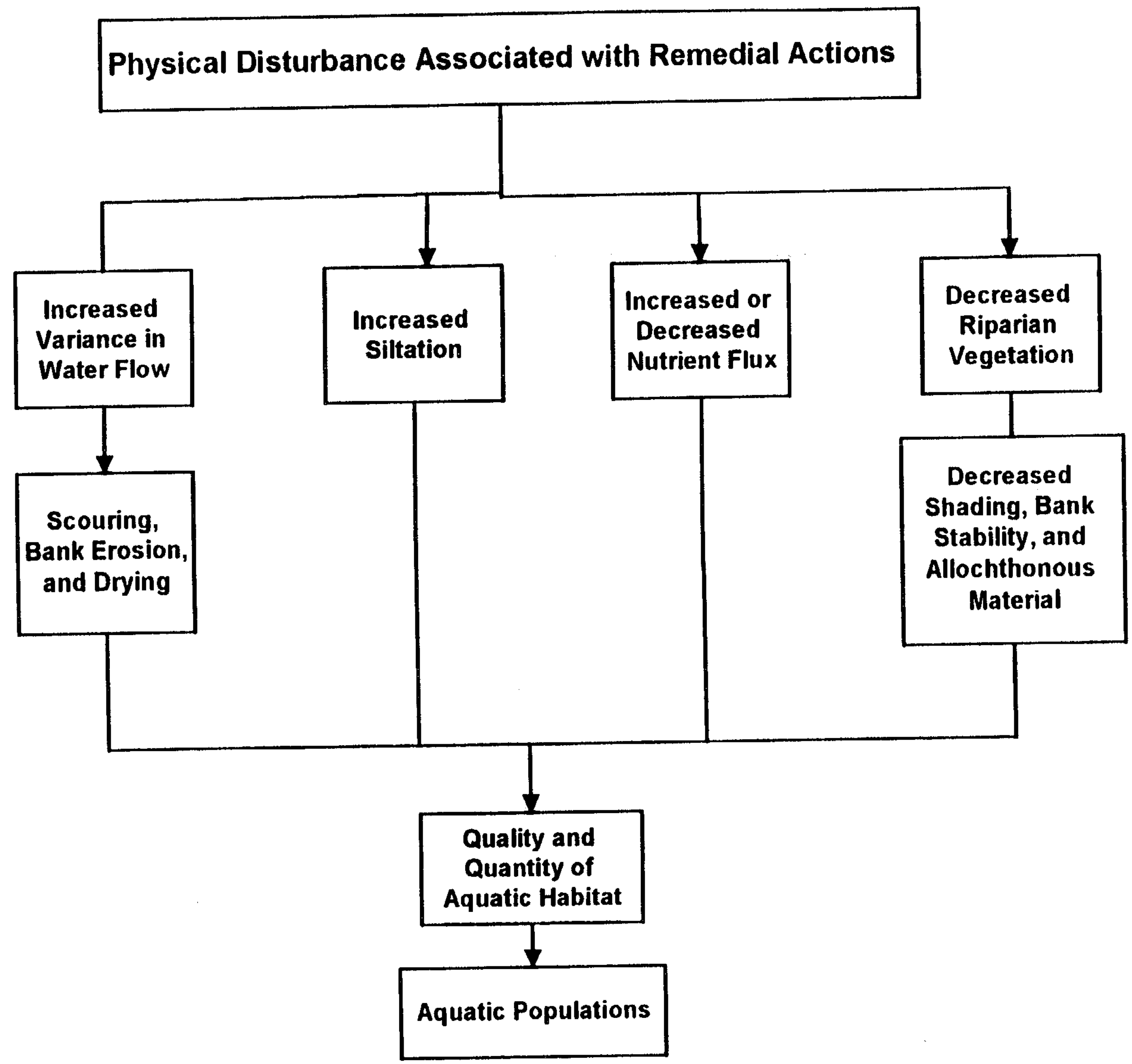

Fig. 9. Generic Conceptual Model of Effects of Physical Disturbance on Aquatic Ecosystems.

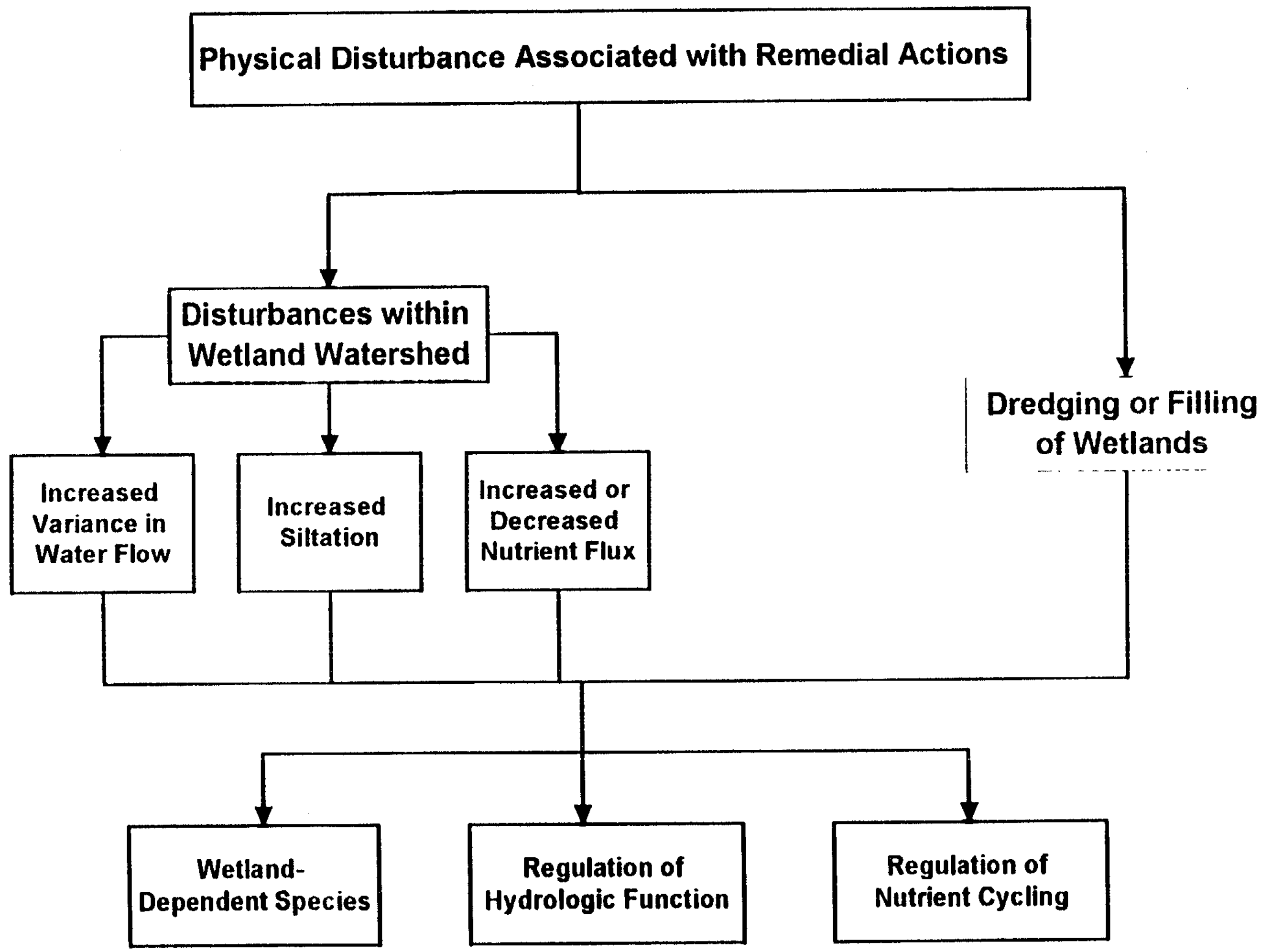

Fig. 10. Generic Conceptual Model of Effects of Physical Disturbance on Wetlands.

4. ECOLOGICAL ENDPOINTS

The problem formulation (also termed hazard identification) phase of an ERA must identify both the assessment endpoints, which are explicit statements of the characteristics of the environment that are to be protected, and the measurement endpoints, which are quantitative summaries of a measurement or series of measurements related to effects on an assessment endpoint (Suter 1989, Risk Assessment Forum 1992). Although endpoints must be derived for each OU, the following generic approach to selecting endpoints has been agreed-upon by the FFA parties for the ORR.

4.1 SELECTING ASSESSMENT ENDPOINTS

The assessment endpoints are explicit statements of the environmental values to be protected. Ecological assessment endpoints consist of an entity, a property of that entity, and a degree of change in the entity that should be detected with some confidence. These are referred to as endpoint entities, endpoint properties, and endpoint effects levels, respectively.

4.1.1 Selection of Endpoint Entities

As agreed by the FFA parties for the ORR, the criteria for selection of the entities are those recommended by the EPA (Risk Assessment Forum 1992), plus considerations of scale and practical considerations.

Susceptibility—Assessment endpoints should be susceptible to the contaminants at the site in that they are potentially exposed and are sensitive to the toxic effects of the contaminants. EPA Region IV considers this to be the most important criterion.

Policy Goals and Societal Values—"Societal concerns can range from protection of endangered or commercially or recreationally important species to preservation of ecosystem attributes for functional reasons (e.g., flood water retention by wetlands) or aesthetic reasons" (Risk Assessment Forum 1992). Additionally, the preferences of the FFA parties expressed in DQO meetings or other situations can constitute policy goals that must be considered in selecting assessment endpoints.

Ecological Relevance—Ecological relevance has been defined as being important to other components of the natural environment, particularly higher levels of organization. EPA Region IV has provided specific criteria (importance in energy flow and mineral or nutrient cycling or acting as keystone species), but they allow other criteria for ecological relevance as appropriate.

Appropriate Scale—Ecological assessment endpoints should have a scale appropriate to the site being assessed to be clearly associated with the site. In particular, organisms that are wide-ranging relative to the scale of an OU should not be used as ecological assessment endpoints for that OU because their contamination or responses could not be clearly associated with the site.

Practical Considerations—Some potential assessment endpoints are impractical because there are not good techniques available to assess risks to them. For example, there are little available toxicity data to assess effects of contaminants on lizards, no standard toxicity tests for any reptile are available, and lizards may be difficult to survey. Therefore, lizards may have a lower priority than other better known taxa. This criterion should be given consideration only after the other criteria are evaluated. If, for example, lizards are included because of evidence of particular sensitivity or societal value (e.g., presence of an endangered lizard species), then some means should be found to deal with the practical difficulties.

4.1.2 Selection of Endpoint Properties

The appropriate properties of the entities selected by these criteria depend on the level of organization of the entity and the criteria that led to their selection.

Organism Level—In general, protection of individual organisms is appropriate only for threatened and endangered species. For those species, individual survivorship or reproductive capacity are appropriate endpoint properties.

Population Level—In general, the appropriate endpoint properties for populations of endpoint species are abundance and production.

Community Level—In general, the appropriate endpoint properties for endpoint communities are species richness and abundance. The measure of abundance will vary among communities. For example, the abundance of the fish community is determined as numbers of all component species, whereas herbaceous plant community abundance may be expressed as biomass per unit area.

Ecosystem Level—Some ecosystems such as wetlands are valued for their properties as ecosystems rather than their composition as communities. Specifically protected properties of wetlands are provisional habitat for wetland dependent species, hydrological regulation, and retention or recycling of nutrients. No other endpoint ecosystem types have been identified. However, some components of ecosystems are clearly ecologically relevant for their role in ecosystem processes but not for their population or community properties. The soil heterotrophic community is a prominent example. Properties of the soil biota that might be endpoint properties include rates of carbon and nitrogen mineralization and rates of transformation of nitrogen and sulfur.

4.1.3 Selection of Levels of Effect on Properties of Endpoint Entities

The levels of effects on endpoint properties that should be detected and may constitute grounds for remedial action have not been specified on a national basis for ERAs as they have been for human health risk assessment. Therefore, they have been inferred on the basis of analysis of EPA and Tennessee regulatory practice (Suter et al. 1992). The clearest ecological criteria for regulation in the U.S. are those developed for the regulation of aqueous effluent under the National Pollution Discharge Elimination System (NPDES). NPDES permitting may be based on any of three types of evidence: water quality criteria, effluent toxicity tests, and biological surveys, and the use of each of these implies that a 20% reduction in ecological parameters is *de minimis*.

1. The Chronic National Ambient Water Quality Criteria (NAWQC) for Protection of Aquatic Life are based on thresholds for statistically significant effects on individual responses of fish and aquatic invertebrates. Those thresholds correspond to approximately 25% reductions in the parameters of fish chronic tests (Suter et al. 1987). Because of the compounding of individual responses across life stages, the chronic NAWQC frequently correspond to much more than 20% effects on a continuously-exposed fish population (Barnthouse et al. 1990).

2. The subchronic tests used to regulate effluent based on their toxicity cannot reliably detect reductions of less than 20% in the test endpoints (Anderson and Norberg-King 1991).

3. Twenty percent is the approximate detection limit of field measurement techniques used in regulating aqueous contaminants based on bioassessment. For example, the community metrics for an exposed benthic macroinvertebrate community must be reduced by more than 20% relative to the best communities within the ecoregion to be considered even slightly impaired in the EPA's rapid bioassessment procedure (Plafkin et al. 1989). Measures for other taxa that are more difficult to sample may be even less sensitive. For example, the number of fish species and individuals must be reduced by 33% to receive less than the top score in the EPA's rapid bioassessment procedure for fish (Plafkin et al. 1989). Finally, some systems, such as large rivers, are more difficult to sample, and some species are inherently highly variable so biological surveys are less sensitive. For example, at least 20 years of data would be necessary to detect a 50% reduction in mean year-class strength of white perch in the Hudson River, even allowing a Type II error of 50% (Vaughan and Van Winkle 1982). The minimum detectable difference varies with species, habitat, and sampling method, but, for mobile species, differences of less than 20% can seldom be reliably detected.

The 20% level is also consistent with practice in assessments of terrestrial effects. The Lowest-Observed-Effects-Concentration (LOEC) for dietary tests of avian reproduction (the most important chronic test endpoint for ecological assessment of terrestrial effects of pesticides and arguably the most applicable test for waste sites) corresponds to approximately a 20% effect on individual response parameters (Office of Pesticide Programs 1982).

Therefore, an effects level for ecological assessment endpoints lower than 20% is generally acceptable based on current EPA regulatory practice and could not be reliably confirmed by field studies. Therefore, it can be considered *de minimis*.

Some exceptions apply to the use of a 20% level of effect to define ecological assessment endpoints. Threatened and endangered species are protected from any adverse effects; therefore, a 20% effect cannot be considered acceptable. Wetlands are protected from any net loss, so a 20% reduction could not be considered acceptable for ecosystems that are so classified. At particular sites there may be other species, communities, or ecosystems that have exceptional importance and therefore require greater protection than is afforded by the 20% level. These exceptions must be identified on a site-by-site basis.

The use of this or any other percent reduction in a population or community requires definition of the area where the reduction occurs. The criterion is stated in terms of the natural units, population, and community, but populations and communities are often difficult to define and delimit. If the limits are set too narrowly, the results will be meaningless (e.g., treating a 5 m^2 plot within a 5 hectare field as a community). On the other hand, if the bounds are too broad, significant effects will be diluted to apparent insignificance (e.g., treating all the short-tailed shrews on the reservation as a single population). The following points are provided as guidance, but each case requires individual consideration.

- Plant communities should be defined using commonly applied categories. Calculations of proportional losses should be based on the area of a distinct occurrence of the community type (e.g., a floodplain hardwood forest on an individual stream or an individual cedar barren) rather than the total area of the community type on the reservation.
- Wetlands should be defined using the U.S. Army Corps of Engineers (1987) manual.
- Fish and other aquatic communities in streams and rivers should be defined by reach. These reaches should have been defined during the development of the RI work plan, but there may need to be some modification of the reaches during the risk characterization to ensure that they are still logical units, given the increased understanding of the system. See Sect. 2.1.2 for criteria for delimiting reaches.
- For colonial animals such as great blue herons, each colony should be treated as a population.
- For animals that have small ranges relative to the size of plant communities (e.g., mice and shrews), the bounds of the animal population may be assumed to correspond to the bounds of the plant community. This suggestion is based on the assumption that the plant communities have habitat qualities that are sufficiently different to support distinct populations, and that they are large enough to support a population. The reasonableness of these assumptions should be determined in each case.

4.2 SELECTING MEASUREMENT ENDPOINTS

Measurement endpoints are "measurable ecological characteristics that are related to the valued characteristic chosen as the assessment endpoint. Measurement endpoints are often expressed as the statistical or arithmetic summaries of the observations that comprise the measurement" (Risk Assessment Forum 1992). Multiple measurement endpoints may exist for a particular assessment endpoint. For example, if the assessment endpoint is a 20% reduction in the species richness or abundance of a fish community, then measurement endpoints would include not only results of fish surveys expressed as densities of fish by species, but also LC50s and other test endpoints for toxicity tests with fish.

To specify the measurement endpoints during the DQO process, it is necessary to provide generic definitions that correspond to the generic definitions of assessment endpoints.

Organism level—Any effect on survivorship, growth or fecundity in a toxicity test of surrogate species for a threatened or endangered species. Any observed death or morbidity of individuals of a threatened or endangered species, or any detectable reduction in the abundance or production of an exposed population of a threatened or endangered species relative to reference populations.

Population level—A 20% effect on survivorship, growth or fecundity in a toxicity test of surrogate species for an endpoint species. A 20% reduction in the abundance or production of an exposed endpoint population relative to reference populations.

Community level—A 20% effect on survivorship, growth or fecundity in a toxicity test of surrogate species for an endpoint community. A 20% reduction in the species richness or abundance of an exposed endpoint community relative to reference communities.

Ecosystem level—A 20% effect on survivorship, growth or fecundity in a toxicity test of surrogate species for an endpoint ecosystem or a 20% or greater reduction in functions of a surrogate ecosystem in a microcosm toxicity test. A 20% reduction in an ecosystem function or a change in 20% of the area of an endpoint ecosystem that is indicative of loss of function. Any net loss of wetlands.

4.3 ECOLOGICAL ASSESSMENT ENDPOINTS FOR THE ORR

The following categories of organisms have been identified by the conceptual model as potential contaminant receptors that occur on the ORR but are not associated with individual source OUs or aquatic integrator OUs. These categories correspond to the compartments in the conceptual model for the terrestrial integrator OU, and they are defined in the conceptual model. This section reviews them in terms of the criteria for selection of assessment endpoints and suggests which species, community, or ecosystem properties are appropriate. Species selected as assessment endpoint species were chosen either because they are common and representative of others within their category or they are species of status (state or federal threatened or endangered or in-need-of-management species or candidate species). The selected species and communities are summarized in Table 1 in terms of the receptor groups in the conceptual models. A subset of these species which may be samples or surveyed is presented in Table 2.

Many species that use the ORR are migratory and are present and potentially exposed to contaminants on the reservation for only a portion of the year. To assess risks to these species, a representative resident species within the same category will be assessed. Because residents may receive year-round exposures, the risk they experience is likely to be substantially greater than that experienced by an ecologically similar migratory species. If it is determined that resident species are not at risk from contaminant exposure, it will be assumed that ecologically similar migratory species are also not at risk. If significant risks are identified for the representative resident species, risks to ecologically similar migrants will be addressed using time-weighted exposure estimates based on the length of time they are resident at the ORR.

Table 1. Reservation-scale ecological assessment endpoint species and communities for ecological risk assessment

Group	Species or Community (species in bold are state or federal T&E or candidate species)
Upland Plants	distribution and abundance of plant community types and T&E plant species
Aquatic Herbivores	Mallard duck and **cumberland slider**
Piscivores	mink, **river otter**, great blue heron, belted kingfisher, **bald eagle, osprey, double-crested cormorant, and black-crowned night heron.**
Aquatic Invertebrate Feeders	pied-billed grebe, leopard frog, and **hellbender**.
Flying Insectivores	rough-winged swallows, **gray bat, Indiana bat, eastern small footed bat, and Rafinesque's big-eared bat.**
Ground Invertebrate Feeders	American woodcock, European starling, American toad, **long-tailed shrew, masked shrew, smokey shrew, southeastern shrew, six-line racerunner, slender glass snake, Tennessee cave salamander and green salamander.**
Arboreal Insectivores	Because arboreal insectivores have low susceptibility to contamination, contaminant risks to these species will not be specifically assessed. Impacts to arboreal insectivores that may occur as a result of remediation-induced habitat alteration will be assessed by monitoring the quality and availability of habitat required by these species.
Large Omnivores	raccoons, wood duck, and muskrat
Large Herbivores	white-tailed deer, wild turkey, Canada goose, groundhog, **grasshopper sparrow, Henslow's sparrow, lark sparrow, and vesper sparrow**
Predators and Scavengers	**golden eagle, northern harrier,** Cooper's hawk, **red-shouldered hawk, sharp-shinned hawk, barn owl, black vulture, cougar,** red fox, snapping turtle, black rat snake, and **northern pine snake**

Table 2. Reservation-scale measurement endpoint species and communities for ecological risk assessment

Group	Species or Community
Upland Plants	distribution and abundance of plant community types and T&E plant species
Aquatic Herbivores	Mallard duck and pond slider
Piscivores	great blue heron, belted kingfisher, northern watersnake
Aquatic Invertebrate Feeders	pied-billed grebe, leopard frog
Flying Insectivores	rough-winged swallows, common bats (e.g., little brown or big brown bat).
Ground Invertebrate Feeders	Short-tailed shrew, European starling, American toad
Arboreal Insectivores	quality and availability of habitat required by these species will be monitored
Large Omnivores	raccoons, wood duck, and muskrat
Large Herbivores	white-tailed deer, wild turkey, Canada goose, and groundhog
Predators and Scavengers	red fox, snapping turtle, and black rat snake

4.3.1 Plants (Upland, Wetland, and Floodplain)

Level of Organization

In general, the most appropriate level of organization at which to address upland plants is the plant community. There is no basis for distinguishing the responses of one plant species from another within a community and no basis to prefer one species over another. However, there are differences among communities in terms of ecological relevance and societal values. For threatened and endangered (T&E) species, it is appropriate to assess effects on both individuals and populations.

Susceptibility

The susceptibility of upland plants to contaminants is not particularly high relative to the various animals. In addition, plants would not wander from the terrestrial integrator OU to the source OUs and aquatic integrator OUs to become exposed. However, there are distinctly different patterns of sensitivity between plants and animals. For example, boron is much more toxic to plants than animals. In addition, plant communities are highly susceptible to physical disturbances.

Policy Goals and Societal Values

Although none of the FFA parties has expressed a particular policy concerning protection of plant communities, their societal values are manifest. In addition, 17 plant species of special concern are currently known to occur on the ORR.

Ecological Relevance

Because they are the primary producers, upland plant communities are of obvious ecological relevance.

Appropriate Scale

The reservation provides the appropriate scale for assessment of risks to upland plants.

Practical Considerations

Although the available data for toxicity of industrial chemicals to terrestrial plants is sparse and of erratic quality, plants are easily surveyed and soil toxicity tests are available.

Conclusions and Recommendations

Data concerning the distribution and abundance of plant community types and T&E plant species should be collected as part of the reservation-wide plan. Contaminant concentrations in plants should be measured by the OUs. These data will be used to assess contaminant exposure to vegetation-consuming wildlife. If contamination is found outside a designated OU (e.g., radionuclide-contaminated trees) or vegetation sampling by an OU is not scheduled until some future date, plant contaminant burden data should be collected as part of the reservation-wide plan.

4.3.2 Aquatic Herbivores

Level of Organization

The appropriate level of organization for an assessment of aquatic herbivorous wildlife is the population. There is no distinct aquatic herbivore community, and toxicity estimates are species-specific for wildlife. For T&E species, it is appropriate to assess effects on both individuals and populations.

Susceptibility

These species are not known to be particularly sensitive to toxic chemicals. However, any wildlife feeding on aquatic biota are likely to be highly exposed and therefore susceptible.

Policy Goals and Societal Values

Most avian aquatic herbivores are protected and have societal value because they are migratory game species. One of the two turtles (e.g., Cumberland slider) is listed as a state In Need of Management (INM) species.

Ecological Relevance

These species are not known to play any particularly significant role in the ecosystems that they inhabit.

Appropriate Scale

The reservation provides the appropriate scale for assessment of risks to aquatic herbivores.

Practical Considerations

— Abundance of avian aquatic herbivores on the reservation has been monitored for the past several years as part of the ongoing waterfowl monitoring program.

This survey provides baseline data and may be used to evaluate temporal trends.

— Individuals of some migratory avian aquatic herbivore species are year-round residents while others are transient. Differential exposures to these groups produces varying levels of risk. Assessment of contribution of ORR to total contaminant-related risk experienced by migrants and their populations is problematic.

— Toxicological data for turtles are limited or lacking.

Conclusions and Recommendations

Mallard duck and Cumberland slider should be retained as assessment endpoints. Toxicological data for turtles should be developed.

4.3.3 Piscivores

Level of Organization

The appropriate level of organization for an assessment endpoint for piscivorous wildlife is the population. There is no distinct piscivore community, and toxicity estimates are species-specific for wildlife. For T&E species, it is appropriate to assess effects on both individuals and populations.

Susceptibility

Piscivores are likely to be highly susceptible to contaminants because of the bioaccumulation and biomagnification that occurs in aquatic food webs and because of the sensitivity of mink to various contaminants including two that occur on the reservation: mercury and PCBs.

Policy Goals and Societal Values

Avian piscivores are conspicuous and aesthetically appealing so they have high societal value. Mink, and possibly future otters, have both commercial value and aesthetic value. In addition, four avian species (bald eagle, osprey, double-crested cormorant, and black-crowned night heron) and one mammal (river otter) are state or federal T&E or INM species.

Ecological Relevance

These species are not known to have any particular importance to the structure or function of the ecosystem of the reservation.

Appropriate Scale

The reservation provides the appropriate scale for assessment of risks to piscivores.

Practical Considerations

- Population surveys of some species (e.g., mink, black-crowned night heron) may be difficult to perform. Populations of great blue herons are relatively easy to survey due to their colonial nesting behavior.

- Abundance of some avian piscivores (e.g., fish-eating ducks) on the reservation has been monitored for the past several years as part of the ongoing waterfowl monitoring program. This survey provides baseline data and may be used to evaluate temporal trends for these species.

— Some species (i.e., bald eagle) are transient on the ORR. Assessment of the ORR's contribution to total contaminant-related risk experienced by migrants and their populations is problematic.

Conclusions and Recommendations

The following should be retained as endpoint species: mink, river otter, great blue heron, belted kingfisher, bald eagle, osprey, double-crested cormorant, and black-crowned night heron.

4.3.4 Aquatic Invertebrate Feeders

Level of Organization

The appropriate level of organization for an assessment endpoint for aquatic invertebrate feeders is the population. There is no distinct aquatic invertebrate feeder community, and toxicity estimates are species-specific for wildlife. For T&E species, it is appropriate to assess effects on both individuals and populations.

Susceptibility

These species are not known to be particularly sensitive to toxic chemicals. However, any wildlife feeding on aquatic biota are likely to be highly exposed and therefore susceptible.

Policy Goals and Societal Values

Most avian aquatic invertebrate feeders are protected and have particular societal value because they are migratory game species. One of the 12 amphibians or reptiles (e.g., hellbender) is listed as a candidate for protection under the federal Endangered Species Act and is a state INM species.

Ecological Relevance

These species are not known to play any particularly significant role in the ecosystems that they inhabit.

Appropriate Scale

The reservation provides the appropriate scale for assessment of risks to aquatic invertebrate feeders.

Practical Considerations

— Abundance of avian aquatic invertebrate feeders on the reservation has been monitored for the past several years as part of the ongoing waterfowl monitoring program. This survey provides baseline data and may be used to evaluate temporal trends.

— Population surveys of some species (e.g., amphibians) may be difficult to perform.

— Toxicological data for amphibians and reptiles are limited or lacking.

— Some species (i.e., waterfowl) are migratory. Assessment of contribution of ORR to total contaminant-related risk experienced by migrants and their populations is problematic.

Conclusions and Recommendations

The following should be retained as endpoint species: pied-billed grebe, leopard frog, and hellbender. Toxicological data for amphibians and reptiles should be developed.

4.3.5 Flying Insectivores

Level of Organization

The appropriate level of organization for an assessment endpoint for flying insectivores is the population. There is no distinct flying insectivore community, and toxicity estimates are species-specific for wildlife. For T&E species, it is appropriate to assess effects on both individuals and populations.

Susceptibility

Many flying insectivores (bats and swallows in particular) forage extensively on emergent aquatic insects. Because they consume large volumes of insects, they are exposed and susceptible to contaminants from aquatic biota.

Policy Goals and Societal Values

Avian flying insectivores are conspicuous and aesthetically appealing so they have high societal value. Several bats potentially present on the ORR are either state and federal endangered species (e.g., gray and Indiana bats) or are state INM and candidates for protection under the federal Endangered Species Act (e.g., eastern small footed bat, Rafinesque's big-eared bat).

Ecological Relevance

These species are not known to play any particularly significant role in the ecosystems that they inhabit. An exception may be the role of bats in cave communities. Use of caves on the ORR by bats is unknown.

Appropriate Scale

The reservation provides the appropriate scale for assessment of risks to flying insectivores.

Practical Considerations

— It is not known if T&E bat species are actually resident on the ORR.

— Population surveys of some species (e.g., bats) may be difficult to perform.

Conclusions and Recommendations

The following should be retained as endpoint species: rough-winged swallows, gray bat, Indiana bat, eastern small-footed bat, and Rafinesque's big-eared bat. A bat survey should be performed to document the occurrence of T&E bat species. Studies of common, non-T&E bat species (e.g., little brown or big brown bats) should be used to assess risks to T&E bat species.

4.3.6 Ground Invertebrate Feeders

Level of Organization

The appropriate level of organization for an assessment endpoint for ground invertebrate feeders is the population. There is no distinct ground invertebrate feeder community, and toxicity estimates are species-specific for wildlife. For T&E species, it is appropriate to assess effects on both individuals and populations.

Susceptibility

Many ground invertebrate feeders consume large volumes of invertebrates; therefore, they are highly exposed and susceptible to contaminants bioaccumulated by ground invertebrates. In addition, shrews, amphibians, and reptiles burrow and are in close physical contact with soil and may take up contaminants directly through ingestion or dermal contact.

Policy Goals and Societal Values

Avian ground invertebrate feeders are conspicuous and aesthetically appealing so they have high societal value. In addition, some are migratory and/or game species. Four shrews (long-tailed, masked, smokey, and southeastern), two lizards (six-line racerunner, slender glass snake), and two salamanders (Tennessee cave salamander and green salamander) are species of status (state T&E or INM or candidates for federal listing).

Ecological Relevance

These species are not known to play any particularly significant role in the ecosystems that they inhabit.

Appropriate Scale

Excluding birds, many ground invertebrate feeders have limited home ranges. However, the reservation provides the most appropriate scale for assessment of risks to populations of ground invertebrate feeders.

Practical Considerations

— Population surveys of some species (e.g., amphibians, reptiles, shrews) may be difficult to perform.

— Toxicological data for amphibians and reptiles are limited or lacking.

— Some species (i.e., birds) are migratory. Assessment of the ORR's contribution to total contaminant-related risk experienced by migrants and their populations is problematic.

Conclusions and Recommendations

The following should be retained as endpoint species: American woodcock, European starlings, American toads, long-tailed shrew, masked shrew, smokey shrew, southeastern shrew, six-line racerunner, slender glass snake, Tennessee cave salamander and green salamander. Toxicological data for amphibians and reptiles should be developed.

4.3.7 Arboreal Insectivores

Level of Organization

The appropriate level of organization for an assessment of arboreal insectivores is the population. There is no distinct arboreal insectivore community, and toxicity estimates are species-specific for wildlife. For T&E species, it is appropriate to assess effects on both individuals and populations.

Susceptibility

While arboreal insectivores are not likely to be highly exposed, sensitive, or susceptible to contamination, they may be greatly impacted by habitat alterations resulting from remediation.

Policy Goals and Societal Values

Avian arboreal insectivores are conspicuous and aesthetically appealing so they have high societal value. In addition, most are migratory species and two (red-headed woodpecker, yellow-bellied sapsucker) are state INM species.

Ecological Relevance

These species are not known to play any particularly significant role in the ecosystems that they inhabit.

Appropriate Scale

The reservation provides the appropriate scale for assessment of risks to arboreal insectivores.

Practical Considerations

— Population surveys of some species (e.g., amphibians and reptiles) may be difficult to perform.

— Toxicological data for amphibians and reptiles are limited or lacking.

— Some species (i.e. birds) are migratory. Assessment of the ORR's contribution to total contaminant-related risk experienced by migrants and their populations is problematic.

Conclusions and Recommendations

Because arboreal insectivores have low susceptibility to contamination and have no particular ecological relevance, contaminant risks to these species will not be specifically assessed. Impacts to arboreal insectivores that may occur as a result of remediation-induced habitat alteration will be assessed by monitoring the quality and availability of habitat required by these species.

4.3.8 Large Omnivores

Level of Organization

The appropriate level of organization for an assessment of large omnivores is the population. There is no distinct large omnivore community, and toxicity estimates are species-specific for wildlife. For T&E species, it is appropriate to assess effects on both individuals and populations.

Susceptibility

While there are no data to suggest that they are particularly sensitive to contaminants, many large omnivores feed extensively on aquatic biota (ducks, raccoons, muskrat) or on soil/litter biota (grackles, opossum, raccoon) that may bioaccumulate contaminants.

Policy Goals and Societal Values

Avian large omnivores are conspicuous and aesthetically appealing so they have high societal value. In addition, most are migratory species. Raccoons and muskrats are valued as furbearers. Raccoons are also a game species.

Ecological Relevance

These species are not known to play any particularly significant role in the ecosystems that they inhabit.

Appropriate Scale

The reservation provides the appropriate scale for assessment of risks to large omnivores.

Practical Considerations

— Population surveys of some species (e.g., turtles) may be difficult to perform.

— Toxicological data for reptiles are limited or lacking.

— Some species (i.e. birds) are migratory. Assessment of the ORR's contribution to total contaminant-related risk experienced by migrants and their populations is problematic.

Conclusions and Recommendations

The following should be retained as endpoint species: raccoons and wood duck. Because muskrats forage almost exclusively on aquatic biota (and may therefore bioaccumulate contaminants) and constitute a substantial portion of the diet of mink, muskrats will also be assessed.

4.3.9 Large Herbivores

Level of Organization

The appropriate level of organization for an assessment of large herbivores is the population. There is no distinct large herbivore community, and toxicity estimates are species-specific for wildlife. For T&E species, it is appropriate to assess effects on both individuals and populations.

Susceptibility

With few exceptions (e.g., consumption of coal ash from the FCAP by deer, groundhogs burrowing in contaminated soils), large herbivores are not highly exposed or highly susceptible to contamination.

Policy Goals and Societal Values

Most mammalian large herbivores are valued game species or furbearers and therefore have high societal value. Avian large herbivores are conspicuous and aesthetically appealing so they have high societal value. In addition, many are migratory, and a few are game species. Four sparrows (grasshopper, Henslow's, lark, and vesper) are species of status (state T&E or INM species or candidates for federal listing).

Ecological Relevance

In general, these species are not known to play any particularly significant role in the ecosystems that they inhabit. However, deer populations at high densities may significantly modify plant communities.

Appropriate Scale

The reservation provides the appropriate scale for assessment of risks to large herbivores.

Practical Considerations

— Some species (i.e., birds) are migratory. Assessment of the ORR's contribution of ORR to total contaminant-related risk experienced by migrants and their populations is problematic.

— Harvesting of deer, trapping of turkey for restocking, and ongoing surveys of Canada goose abundance on the ORR provide an opportunity for monitoring these species.

Conclusions and Recommendations

The following should be retained as endpoint species: white-tailed deer, wild turkey, Canada goose, groundhogs, grasshopper sparrow, Henslow's sparrow, lark sparrow, and vesper sparrow.

4.3.10 Predators and Scavengers

Level of Organization

The appropriate level of organization for an assessment of predators and scavengers is the population. There is no distinct predator and scavenger community, and toxicity estimates are species-specific for wildlife. For T&E species, it is appropriate to assess effects on both individuals and populations.

Susceptibility

Predators and scavengers may be susceptible to contamination because they are at the top of the food web and spatially integrate contaminants bioaccumulated by lower trophic levels.

Policy Goals and Societal Values

Avian predators and scavengers are conspicuous and generally aesthetically appealing so they have high societal value. In addition, many are migratory species. While most mammalian predators are not conspicuous, the status of their populations is a concern to the public. Several predator and scavenger species are also species of status (state or federal T&E or INM species or candidates for federal listing). These include golden eagle, northern harrier, Cooper's hawk, red-shouldered hawk, sharp-shinned hawk, barn owl, black vulture, cougar, and the northern pine snake.

Ecological Relevance

These species are not known to play any particularly significant role in the ecosystems that they inhabit.

Appropriate Scale

The reservation provides the appropriate scale for assessment of risks to predators and scavengers.

Practical Considerations

— Most predators and scavengers are extremely wide-ranging with diffuse populations. Locating sufficient individuals to assess their populations may be difficult.

— Some species (i.e., birds) are migratory. Assessment of the ORR's contribution to total contaminant-related risk experienced by migrants and their populations is problematic.

— Toxicological data for reptiles are limited or lacking.

Conclusions and Recommendations

The following should be retained as endpoint species: golden eagle, northern harrier, Cooper's hawk, red-shouldered hawk, sharp-shinned hawk, barn owl, black vulture, cougar, red fox, snapping turtle, black rat snake, and the northern pine snake. Toxicological data for reptiles should be developed.

4.4 ECOLOGICAL ASSESSMENT ENDPOINTS FOR SOURCE AND AQUATIC INTEGRATOR OUS

Both source OUs and aquatic integrator OUs have relatively limited scales that restrict the choice of assessment endpoints to those organisms having restricted ranges because of their small size, immobility, or restriction to streams or ponds. The process of selecting endpoint species and communities is described in the following text and the results are summarized in Table 3.

4.4.1 Fish

Level of Organization

The appropriate level of organization for an assessment of fish is the community. Fish are sampled as a community, and, in the absence of a sport or commercial fishery on the ORR, no particular populations are more valued than others.

Susceptibility

Fish are susceptible to aqueous contamination because they are intimately exposed to water, integrate effects on lower trophic levels, and assimilate contaminants bioaccumulated by lower trophic levels from both water and sediments.

Policy Goals and Societal Values

Fish are aesthetically appealing, and fish communities have long been used as endpoints for regulation of aqueous contamination.

Ecological Relevance

Fish may play an important role in energy and nutrient dynamics in streams.

Appropriate Scale

Stream or river reaches are the appropriate scale at which to assess effects on fish.

Table 3. Generic measurement endpoint species and communities for source and aquatic integrator OUs

Group	Species or Community
Plants	distribution and abundance of plant community types and T&E plant species
Soil/Litter Invertebrates and Processes	earthworms
Ground Invertebrate Feeders	short-tailed shrew, American toad
Small Omnivores	white-footed mouse
Small Herbivores	none
Fish	species richness and abundance of the fish community
Benthic Invertebrates	species richness and abundance of the invertebrate community
Aquatic Plants	none

Practical Considerations

— Methods for sampling fish are well established.

— Baseline data sets are available for fish communities in most contaminated streams and several reference streams.

— Toxicity tests for effects of ambient waters are well established.

— Baseline data sets are available for toxicity of waters from most contaminated streams and several reference streams.

— Toxicological data for fish are relatively abundant.

Conclusions and Recommendations

The species richness and abundance of fish communities should be used as an assessment endpoint at all sites where fish are present.

4.4.2 Benthic Invertebrates

Level of Organization

The appropriate level of organization for an assessment of benthic invertebrates is the community. Benthic invertebrates are sampled as a community, and no particular populations are more valued than others.

Susceptibility

Benthic invertebrates are susceptible to aqueous contamination because they are intimately exposed to water (epibenthic and riffle species) or sediment (benthic infauna) and because some members are inherently sensitive to many contaminants.

Policy Goals and Societal Values

Benthic invertebrate communities have little inherent societal value, but, because of their ecological importance and relative ease of quantitative characterization, they have long been used as endpoints for regulation of aqueous contamination.

Ecological Relevance

Benthic invertebrates play an important role in energy and nutrient dynamics in streams.

Appropriate Scale

Stream or river reaches are the appropriate scale at which to assess effects on benthic invertebrates.

Practical Considerations

- Methods for sampling benthic invertebrates are well established.
- Baseline data sets are available for benthic invertebrate communities in most contaminated streams and several reference streams.
- Toxicity tests for effects of ambient waters and sediments are well established.
- Baseline data sets are available for toxicity of waters from most contaminated streams and several reference streams.
- Toxicological data for benthic invertebrates are rare relative to fish and planktonic invertebrates.
- Benthic invertebrates are present in streams that are too small or intermittent to support fish.

Conclusions and Recommendations

The species richness and abundance of benthic invertebrate communities should be used as an assessment endpoint at all sites where fish are present.

4.4.3 Aquatic Plants

Level of Organization

The appropriate level of organization for an assessment of aquatic plants is the community. In streams, the plant communities are entirely or primarily in the form of periphyton which is sampled as a community.

Susceptibility

Periphyton is not particularly susceptible to the contaminants released by waste sites.

Policy Goals and Societal Values

In general, algae in streams or lakes is considered to be unaesthetic when it is perceptible. Algal effects are seldom the basis for regulation of aqueous contaminants and have not been included in the EPA's stream bioassessment procedure (Plafkin et al. 1989).

Ecological Relevance

Aquatic plants, along with allochtonous material, form the basis of stream ecosystems.

Appropriate Scale

Stream or river reaches are the appropriate scale at which to assess effects on aquatic plants.

Practical Considerations

- Methods for sampling periphyton are well established.

- Baseline data sets are available for periphyton communities in many contaminated streams and reference streams.

- Toxicity tests for effects of ambient waters are not established and have not been performed on the ORR.

- Periphyton community characteristics are highly sensitive to light, nutrient levels, and grazing levels, which tends to mask any effects of contaminants.

- Toxicological data for aquatic algae are relatively abundant.

Conclusions and Recommendations

Aquatic plants are not good assessment endpoints for streams and ponds relative to fish and benthic invertebrates. However, where data concerning aquatic plants are available, they should be analyzed for evidence of toxic or other effects that may help to interpret risks to fish and benthic invertebrates.

4.4.4 Soil/Litter Invertebrates and Processes

Level of Organization

An appropriate level of organization for an assessment of the soil community is the entire community, because the primary value of this community is its functional role in decomposition and nutrient recycling. However, the EPA has focused on earthworms as representatives of this community, so the entire earthworm fauna (Order *Opisthopora*, Class *Oligochaeta*) is also an appropriate level of organization.

Susceptibility

The soil community is highly exposed to contaminants. The inherent sensitivity of soil processes to contaminants is low, but the sensitivity of particular taxa including earthworms is largely unknown.

Policy Goals and Societal Values

Earthworms are becoming a standard ecological assessment endpoint for the EPA's regulation of contaminants in soils.

Ecological Relevance

The soil community plays a critical role in terrestrial energy and nutrient dynamics.

Appropriate Scale

Because of their small size and relative immobility, soil communities and earthworms can be assessed on the scale of small subunits of OUs.

Practical Considerations

- Methods for sampling earthworms are available, but earthworm taxonomy is relatively difficult, and guidance for interpreting earthworm field data is not available.
- Toxicity tests for earthworms are relatively well established.
- Baseline data sets are not available for toxicity or earthworm abundance in ORR soils.
- Toxicological data for earthworms or soil communities are relatively rare.

Conclusions and Recommendations

The abundance and production of earthworms constitute an appropriate assessment endpoint.

4.4.5 Ground Invertebrate Feeders

Level of Organization

The appropriate level of organization for an assessment endpoint for ground invertebrate feeders is the population. There is no distinct ground invertebrate feeder community, and toxicity estimates are species-specific for wildlife. For T&E species, it is appropriate to assess effects on both individuals and populations.

Susceptibility

Many ground invertebrate feeders consume large volumes of invertebrates; therefore, they are highly exposed and susceptible to contaminants bioaccumulated by ground invertebrates. In addition, shrews, amphibians, and reptiles burrow and are in close physical contact with soil and may take up contaminants directly through ingestion or dermal contact.

Policy Goals and Societal Values

Four shrews (long-tailed, masked, smokey, and southeastern), two lizards (six-line racerunner, slender glass snake), and two salamanders (Tennessee cave salamander and green salamander) are species of status (state T&E or INM or candidates for federal listing).

Ecological Relevance

These species are not known to play any particularly significant role in the ecosystems that they inhabit.

Appropriate Scale

Excluding birds, many ground invertebrate feeders have limited home ranges. Individual OUs provide an appropriate scale for assessment of risks to populations of ground invertebrate feeders if they are found on the OU in significant numbers and have sufficiently low mobility to be associated with the site.

Practical Considerations

- Population surveys of some species (e.g., amphibians, reptiles, shrews) may be difficult to perform.
- Toxicological data for insectivorous mammals, amphibians, and reptiles are limited or lacking.
- Toxicity testing methods for these organisms are poorly developed.

Conclusions and Recommendations

Short-tailed shrews or any more common shrew species should be used as a representative endpoint species for this group.

4.4.6 Small Omnivores

Level of Organization

The appropriate level of organization for an assessment endpoint for small omnivores is the population. There is no small omnivore community, and toxicity estimates are species-specific for wildlife.

Susceptibility

Small omnivorous mammals (e.g., *Peromyscus* spp.) are more exposed to contaminants than herbivores, possibly because of their consumption of ground invertebrates (Talmadge and Walton 1990). In addition, small omnivores burrow and are in close physical contact with soil and may take up contaminants directly through ingestion or dermal contact.

Policy Goals and Societal Values

None of these species has particular societal value or association with policy goals. However, where the EPA has been the lead agency for CERCLA sites, they have routinely used small mammals, including small omnivores, as endpoint species.

Ecological Relevance

Although these species are the most abundant mammalian group on most of the ORR, they are not known to play any particularly significant role in the ecosystems that they inhabit.

Appropriate Scale

Many small omnivores have limited home ranges. Individual OUs provide an appropriate scale for assessment of risks to populations of ground invertebrate feeders if they are found on the OU in significant numbers and have sufficiently low mobility to be associated with the site.

Practical Considerations

- Population surveys of some species are easily performed but the highly variable demographics of these rodents makes interpretation difficult.

- Toxicological data for rodents are abundant.

- Toxicity testing methods for these organisms are well developed.

Conclusions and Recommendations

Peromyscus species should be used as a representative endpoint species for this group.

4.4.7 Small Herbivores

Level of Organization

The appropriate level of organization for an assessment endpoint for small herbivores is the population. There is no distinct small herbivore community, and toxicity estimates are species-specific for wildlife.

Susceptibility

Small herbivorous mammals (e.g., *Microtus* spp.) are less exposed to contaminants than insectivores or omnivores (Talmadge and Walton 1990).

Policy Goals and Societal Values

None of these species has particular societal value or association with policy goals. However, where the EPA has been the lead agency for CERCLA sites, they have routinely used small mammals, including small herbivores, as endpoint species.

Ecological Relevance

These species are not known to play any particularly significant role in the ecosystems that they inhabit.

Appropriate Scale

Many small herbivores have limited home ranges. Individual OUs provide an appropriate scale for assessment of risks to populations of small herbivores if they are found on the OU in significant numbers and have sufficiently low mobility to be associated with the site.

Practical Considerations

- Population surveys of some species are easily performed but the highly variable demographics of these rodents makes interpretation difficult.

- Toxicological data for rodents are abundant.

Conclusions and Recommendations

No endpoint species are recommended for this group.

5. DATA NEEDS AND RESPONSIBILITIES

As part of the RI, each OU is responsible for characterizing:

- risks to the ecological endpoints that are associated with the OU (i.e., occur on the OU and have a scale appropriate to the OU),
- contributions to contaminant inputs to "downstream" integrator OUs, and
- risks resulting from contaminant inputs from "upstream" OUs.

To perform those characterizations, each OU needs estimates of:

- fluxes of contaminants from "upstream" OUs and
- ecological risks resulting from its contributions to downstream OUs.

The needed data would be generated if each OU characterized sources that occurred within the OU, exposures to all endpoint biota on the OU (whether associated with the OU or with a larger scale integrator OU), responses of endpoint biota associated with the OU, and fluxes of contaminants off the OU and into integrator OUs. For example, the RI for a source OU like the WAG 5 low-level waste burial grounds at ORNL would:

- characterize contamination on the OU,
- characterize exposure of endpoint biota associated with the contaminated areas (earthworms and terrestrial plants) and their resulting risks,
- characterize exposure to contaminants on the site of biota associated with the terrestrial integrator OU that use the site but are not associated with the site (e.g., deer and wild turkeys) by characterizing contamination of plants and invertebrates on the OU that are consumed by wildlife from off the OU, and
- characterize contaminant fluxes off the OU in leachates to the Melton Valley Groundwater OU and in seeps and springs to WAG 2 which includes Melton Branch and White Oak Creek (Bechtel 1988, Ashwood and Suter 1993).

The WAG 5 RI could not be completed without characterizing the risks to the integrator OUs to which it contributes contaminants because remedial decisions must be made on the basis of total risk. WAG 2, the aquatic integrator OU for WAG 5, would provide a characterization of the state of the aquatic receptors in terms of its own ecological endpoints. The WAG 5 assessors would obtain that characterization from existing assessments of WAG 2 (Blaylock et al. 1992), Biological Monitoring and Assessment Program (BMAP) reports, or *ad hoc* assessments.

6. SPECIFIC DATA NEEDS

Data needs for ERAs are defined for each OU during the DQO process. The DQO process for individual OUs tends to focus on the problems associated with that OU and the decisions that are necessitated by those problems. However, the ERA strategy for the ORR requires that each OU consider what data it needs from other OUs and what data it must supply to other OUs to which it is functionally linked. This section discusses data needs for each OU in terms of measurements that should be performed for a particular compartment in each OU, given prescribed conditions. These needs are implicit in the generic conceptual models. Like those models, they must be adapted to the individual OUs and should be considered as starting points for the ecorisk portions of DQO workshops.

For all media, chemical analyses should include contaminants of potential concern identified in prior screening assessments. In the absence of an adequate screening assessment, the analyses should include all contaminants that may occur in the OU. Given the incomplete records of waste disposal on most ORR sites, it is often necessary to perform some "full suite" analyses.

For all OUs, data collection must include habitat analyses. Each habitat analysis should include enough information to not only characterize the type of habitat present but to also allow inferences concerning the populations and communities that would be expected to be present and the approximate levels of the endpoint properties.

6.1 SOURCE OUs

Soil Contaminants

Contaminants in the rooting zone of the soil must be characterized. In areas with only herbaceous vegetation, the preponderance of root biomass is likely to be in the top 10–20 cm. If trees are present or may be present in the future, a deep rooting zone down to approximately 3 m should be characterized and assessed separately. In addition, soil particle size distribution, pH, organic matter content, cation exchange capacity, and macronutrient content (N, P, K) should be determined.

Plants

The plant communities of all OUs should be identified and characterized in terms of their structure, major species, and any species of special concern. This characterization need not include a complete species list.

If herbivorous or omnivorous animals are endpoint species for the OU or if such animals from off the OU make significant use of the OU for grazing and if the possibility of toxic levels of contaminants in plants cannot be excluded by a screening assessment based on soil concentrations, the concentrations of contaminants in plants should be determined. For species that are resident on the OU, the sampling design should be based on defining the mean concentration with some specified confidence within an area equal to the range of the least widely ranging endpoint species. If the only endpoint herbivores or omnivores are from off the OU, the sampling should be based on defining the mean concentration for the OU with some specified confidence.

Phytotoxicity tests should be performed on the soil if 1) toxicity to plants is suspected based on a screening assessment, 2) the soil is contaminated but either the soil contamination data or the phytotoxicity data are insufficient to perform a reliable screening assessment, or 3) phytotoxicity is suspected based on the condition of plants on the OU. Plant samples or soil samples for toxicity tests should be collected from sites where soil has been chemically analyzed, or analyses should be performed *ad hoc*.

Soil/Litter Invertebrates

Earthworms are surrogate organisms for all soil invertebrates and are a route of transport of soil contaminants to wildlife. If a screening assessment has not eliminated bioaccumulation of contaminants by soil invertebrates as a hazard, earthworms should be sampled from areas with contaminated soils and analyzed for COPCs that may bioaccumulate. Earthworm toxicity tests should be performed on the soil if 1) toxicity to earthworms is suspected based on a screening assessment, 2) the soil is contaminated, but either the soil contamination data or the oligochaete toxicity data are insufficient to perform a reliable screening assessment, or 3) toxicity is suspected based on the abundance of worms on the OU. Earthworm samples or soil samples for toxicity tests should be collected from sites where soil has been chemically analyzed, or analyses should be performed *ad hoc*.

Small Herbivores, Omnivores, and Soil Invertebrate Feeders

This category includes small mammals, reptiles, and amphibians. Because of the poor habitat quality, these organisms do not occur in significant numbers on many OUs, and mammals are more likely to be present in significant numbers than are reptiles or amphibians.

If the site provides significant habitat for these organisms in areas that have significant soil contamination, small mammals should be sampled and analyzed. The analyses should be performed on whole animals unless toxic effects of particular COPCs can be related to concentrations in specific organs. In such cases, the organ and the remainder of the carcass should be analyzed separately. All captured animals should be counted, aged, sexed, and weighed. However, only selected measurement endpoint species should be chemically analyzed.

Water

If potentially contaminated surface water occurs on the OU, its contamination must be characterized. This should include ponds, wetlands with standing water, streams that are not part of an aquatic integrator OU, and seeps or springs. Water analyses for ERAs should include the dissolved-phase analyses for metals (Prothro 1993). In addition, basic water chemistry should be characterized including pH and hardness.

Aquatic Community

Most source OUs do not possess distinct aquatic communities that require assessment. Most surface water on source OUs is waste water in sumps or waste ponds. Even when these support aquatic life, they are not communities to be protected, but rather sources to be remediated. However, if there are ponds, wetlands, or other surface waters on the site that are not simply waste repositories but may have been contaminated by wastes, they must be characterized. In other words, risks to waters of the state must be assessed but not risks to waste waters. Water bodies on waste sites are so diverse that it is not possible to generalize about data needs. However, the data needs for the aquatic communities in aquatic integrator OUs (discussed in the following text) should be consulted.

6.2 AQUATIC INTEGRATOR OUs

Soil, plants, soil/litter invertebrates, and small herbivores, omnivores, and ground invertebrate feeders should be characterized as described previously for source OUs. The principal difference from source OUs is that the abundance and diversity of animals is likely to be higher on the floodplains of aquatic integrator OUs.

Water

If potentially contaminated surface water occurs on the OU, its contamination must be characterized. In addition to the stream that defines the aquatic integrator OU, this characterization should include ponds, wetlands with standing water, and any seeps or springs not characterized by the source OU. Water analyses for ERAs should include the dissolved-phase analyses for metals. In addition, basic water chemistry should be characterized including pH and hardness. If chemical analyses or other information suggest that the water may be toxic, aqueous toxicity tests should be performed. If significant toxicity is found, follow-up tests should be conducted to determine the cause and the degree to which the source (e.g., a seep or spring) must be diminished to eliminate the toxicity.

Sediment

Sediment should be sampled and analyzed from deposition areas of streams and ponds. The analyses of contaminants should include both whole sediment and pore water. Basic physical/chemical properties of the sediment including pH, organic carbon content, and texture should also be determined. For ERAs, analysis and toxicity testing can be limited to biologically active surface sediments ($\approx$ 10 cm). If sediments are sufficiently contaminated to suggest possible toxicity, toxicity tests of the sediment should be performed.

Benthic Invertebrates

Two distinct communities of benthic invertebrates occur in the streams of the aquatic integrator OUs: riffle communities and pool communities. The riffle communities occur in areas with rapid water flow and stony substrates, so they are exposed to contaminants in the surface water. Because of this, they have been monitored by the BMAP to determine effects of water pollution. If there are COPCs in the water, the BMAP sampling program should be examined to determine if contaminated reaches and suitable reference reaches are being sampled and characterized.

The benthic invertebrates of pools are an endpoint community for these OUs because they are associated with the deposited sediments that may be contaminated and may require remediation. This community is not being characterized by the BMAP program. If sediments are known to be significantly contaminated or if particle associated COPCs occur in the OU, this community should be sampled and characterized in each contaminated reach and at reference sites. The sediment samples for characterization of this community should be taken in areas sampled for sediment analysis either concurrently or at least in the same season and year.

Benthic invertebrates may be sampled for chemical analysis if they may be a significant source of exposure to fish or flying invertebrate feeders. This will be the case if 1) fish are known to be significantly contaminated with a bioaccumulative COPC (e.g., PCBs or mercury) or 2) concentrations of a bioaccumulative COPCs in water or sediment are sufficient to suggest that invertebrates may receive toxic concentrations. In some cases, it may be difficult to obtain a sufficient mass of invertebrates for analysis without unreasonable effort and damage to the community being sampled.

Fishes

Although fish communities include multiple trophic groups, they are sampled and characterized as a community by electrofishing or net. This characterization is being performed by BMAP in most contaminated streams on the ORR and by the CRRI and TVA in the Clinch River/Watts Bar Reservoir. If there are COPCs in the water, the fish sampling programs should be examined to determine if contaminated reaches and suitable reference reaches are being sampled and the communities characterized. This community characterization should include counts by species, size of fish, and observations of gross pathologies and deformities as described in the BMAP procedures.

Most fish analyses have been performed on fillets of game species. For ERAs, analyses should be performed on whole fish and fish species that are likely to be highly exposed or are likely to be major prey species of piscivorous wildlife. When the species analyzed for human health risk assessments fit those criteria, enough carcasses should be analyzed along with the fillets to establish a fillet to whole body ratio for the species.

In addition to the community characterization and chemical analyses, certain organismal and suborganismal properties termed biomarkers or bioindicators are measured by BMAP and other programs. Some of these may be diagnostic of exposure to or effects of particular contaminants. Others may be indicative of the health of individual fish. During the DQO process, the utility of these biomarkers and bioindicators should be considered and a decision made as to the need to extend these measurements to reaches where they are not measured.

Aquatic Plants

Where aquatic herbivores are present (i.e., mallards or pond sliders) or significant habitat for aquatic herbivores is present and COPCs are present that may accumulate in aquatic plants, aquatic plants should be sampled and analyzed.

6.3 GROUNDWATER OUs

If groundwater directly enters surface water in seeps or springs or cave waters that support multicellular organisms, the concentrations of contaminants of potential concern should be determined including dissolved phase analyses of metals, and aquatic toxicity tests should be performed.

6.4 TERRESTRIAL INTEGRATOR OUs

Because only one terrestrial integrator OU exists, there is no need for generic guidance on sampling and analysis. The reader is referred to the sampling and analysis plan for the ORR Environmental Monitoring and Assessment Program (Sample et al. 1994).

7. RISK CHARACTERIZATION

Risk characterization combines information concerning exposure to contaminants with information concerning effects of contaminants to estimate risks. Risk characterization for ERAs is performed by weight of evidence (Risk Assessment Forum 1992). That is, rather than simply modelling risks, ecological risk assessors examine all available data from chemical analyses, toxicity tests, biological surveys, and bioindicators to estimate the likelihood that significant effects are occurring or will occur and describe the nature, magnitude, and extent of effects on the designated assessment endpoints. This section describes the approach for estimating risks based on individual lines of evidence and then combining them through a process of weighing the evidence.

7.1 SINGLE CHEMICAL TOXICITY

This line of evidence uses analyses of individual contaminants in individual media to estimate exposure and uses literature values for effects of individual chemicals to estimate effects (Fig. 11). They are combined in two steps. First, the contaminants are screened against ecotoxicological benchmarks and against background exposures to determine which are COPCs. This may have been done previously in screening assessments for earlier phases in the remedial process such as the RI work plan, but it should be repeated for each new assessment.

For those contaminants that are retained by the screening (the COPCs), exposures must be compared to the full toxicity profile of the contaminant to characterize risk. For example, the distribution of concentrations in water would be compared to the distribution of concentrations of thresholds for chronic toxicity across fish species and across prey species, the nature of the chronic effects would be described, and the exposure durations needed to achieve effects in the laboratory would be compared to temporal dynamics of concentrations in the field. Characteristics of the contaminants that are relevant to risks are also examined such as the influence of metal speciation on toxicity, tendency of the contaminant to accumulate in prey species, etc.

The result of risk characterization for this line of evidence should be statements about:

- are toxic concentrations of contaminants present,
- what effects do these concentrations cause in the laboratory or at well-studied sites,
- how extensive are toxic concentrations,
- how frequent are toxic concentrations,
- are they associated with identifiable sources or contaminants,
- how much must the source be diminished to eliminate toxicity,
- how confident are you concerning your answers?

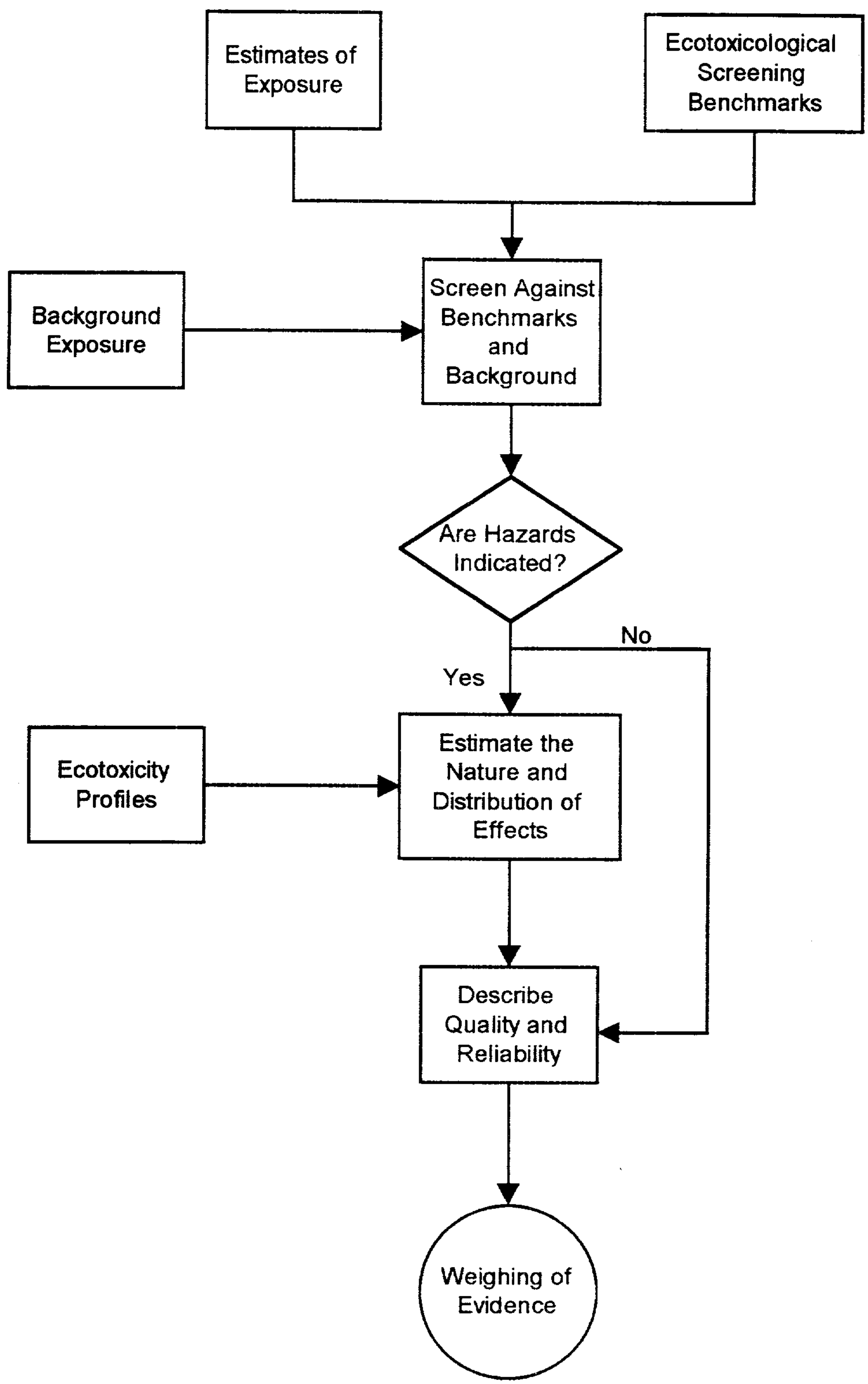

Fig. 11. Risk Characterization Based on Chemical Analyses and Single Chemical Toxicity.

7.2 AMBIENT MEDIA TOXICITY TESTS

Risk characterization for this line of evidence begins by determining whether the tests show significant toxicity (Fig. 12).

- If no significant toxicity was found, the risk characterization consists of determining the likelihood that the result constitutes a false negative. False negatives could result from not collecting samples from the most contaminated sites or at the times with the highest contaminant levels, handling the samples in a way that reduced toxicity, or using tests that are not sufficiently sensitive to detect effects that would cause significant injuries to populations or communities in the field.

- If significant toxicity occurs in the tests, the risk characterization should describe the nature and magnitude of the effects and the consistency of effects among tests conducted with different species in the same medium.

- Toxicity tests may produce ambiguous results in some cases due to poor performance of organisms in control media (e.g., due to diseases, background contamination, inappropriate reference or control media, or poor performance of the test protocol). In such cases, expert judgement by the assessor in consultation with the individuals who performed the test should be used to arrive at an interpretation of the test results.

If significant toxicity is found at any site, then the relationship of toxicity to exposure must be characterized. The first way to do this is to examine the relationship of toxicity to concentrations of contaminants in the media. The manner in which this is done will depend on the amount of data available. If numerous toxicity tests are available, the frequency of tests showing toxic effects could be defined as a function of concentrations of one or more COPCs. An alternative and potentially complementary approach is to determine the relationship between the occurrence of toxicity and sources of contaminants (e.g., springs, seeps, tributaries, spills) or of diluents (i.e., relatively clean water or sediments). Finally, when sources of toxic water have been identified, and tests have been performed on dilution series of those waters, the transport and fate of toxicity can be modelled like that of individual contaminants (DiToro et al. 1991). Such models of toxicity can be used to explain ecological degradation observed in streams and apportion causation among sources.

The result of risk characterization for this line of evidence should be questions such as:

- Is toxicity occurring?

- How severe is it?

- How extensive is it?

- How frequent is it?

- is it associated with identifiable sources or contaminants?

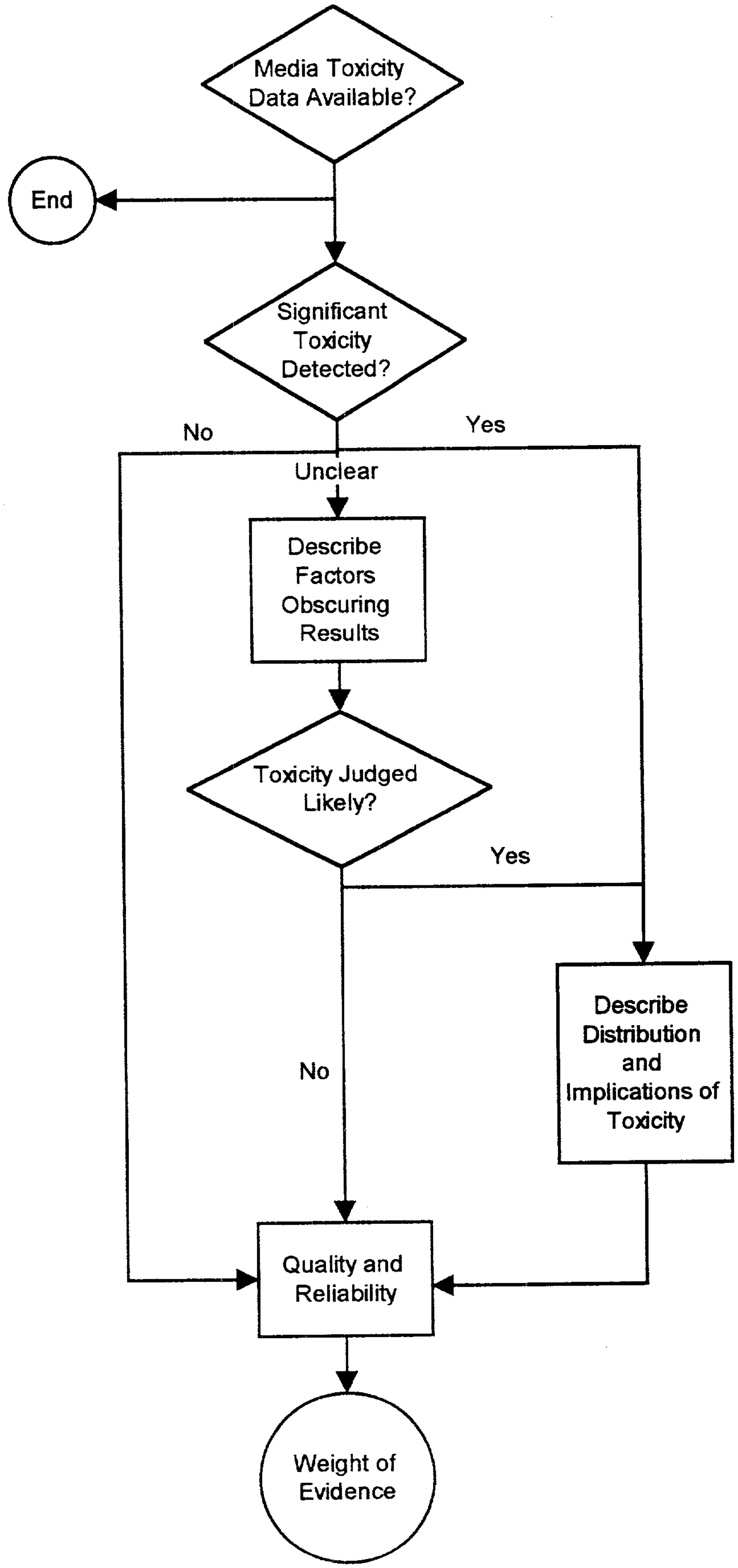

Fig. 12. Risk Characterization Based on Toxicity Testing of Ambient Media.

- how much must the source be diminished to eliminate unacceptable toxicity?

- how confident are you concerning your answers?

7.3 BIOLOGICAL SURVEYS

If biological survey data are available for an endpoint species or community, then the first question to be answered is whether the data suggest that significant effects are occurring (Fig. 13). For some groups, notably fish and benthic invertebrates, there are abundant data from reference streams for comparison. For most other endpoint groups, references must be established *ad hoc* and the lack of temporal or spatial replication may make inference tenuous. For some taxa such as most birds, survey data are not useful for estimating risks from wastes because mobility, territoriality, or other factors obscure demographic effects.

If biological survey data are consistent with significant reductions in abundance, production, or diversity, associations of apparent effects with causal factors must be examined. First, the distribution of apparent effects in space and time must be compared to the distribution of sources or of contaminants. Second, the distribution of apparent effects must be compared to the distribution of habitat factors that are likely to affect the organisms in question such as stream structure and flow. Finally, the natural variability of the endpoint populations and communities and the accuracy of the survey methods must be examined to estimate the likelihood that the apparent effects are due to chance.

The result of risk characterization for this line of evidence should be questions such as:

- Are the endpoint ecological properties significantly reduced?

- How much are they reduced?

- How extensively?

- Is the reduction associated with identifiable sources of contaminants?

- Is the reduction associated with identifiable habitat variables?

- What is the most likely cause of the apparent reduction?

- How confident are you concerning your answers?

7.4 BIOINDICATORS

Biological indicators are seldom useful for estimating risks by themselves, but they can be used to support other lines of inference. The inference begins by asking if the levels of the bioindicators significantly differ from those at reference sites (Fig. 14). If they do, then it is necessary to determine whether they are diagnostic or at least characteristic of any of the COPCs

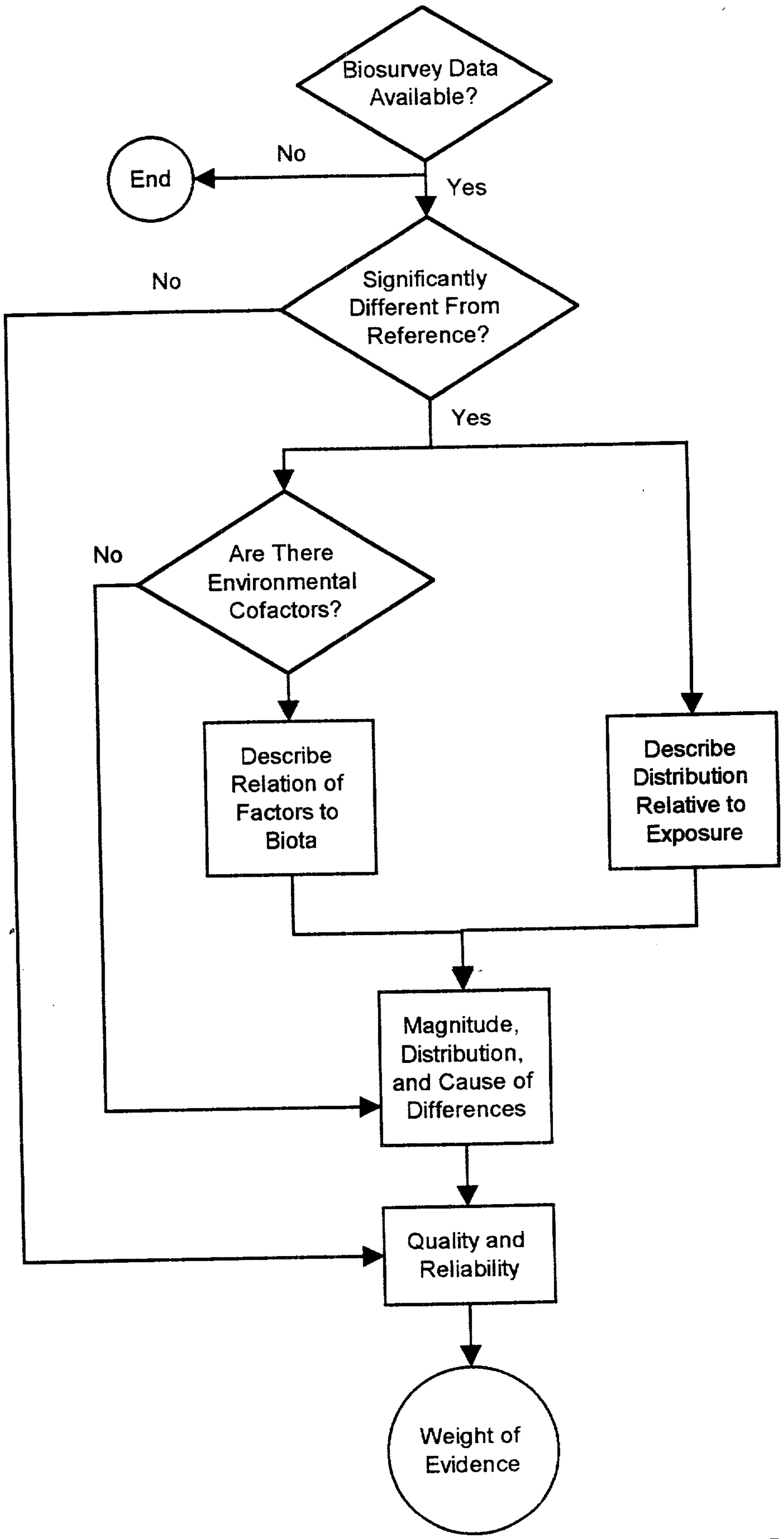

Fig. 13. **Risk Characterization Based on Biological Survey Data.**

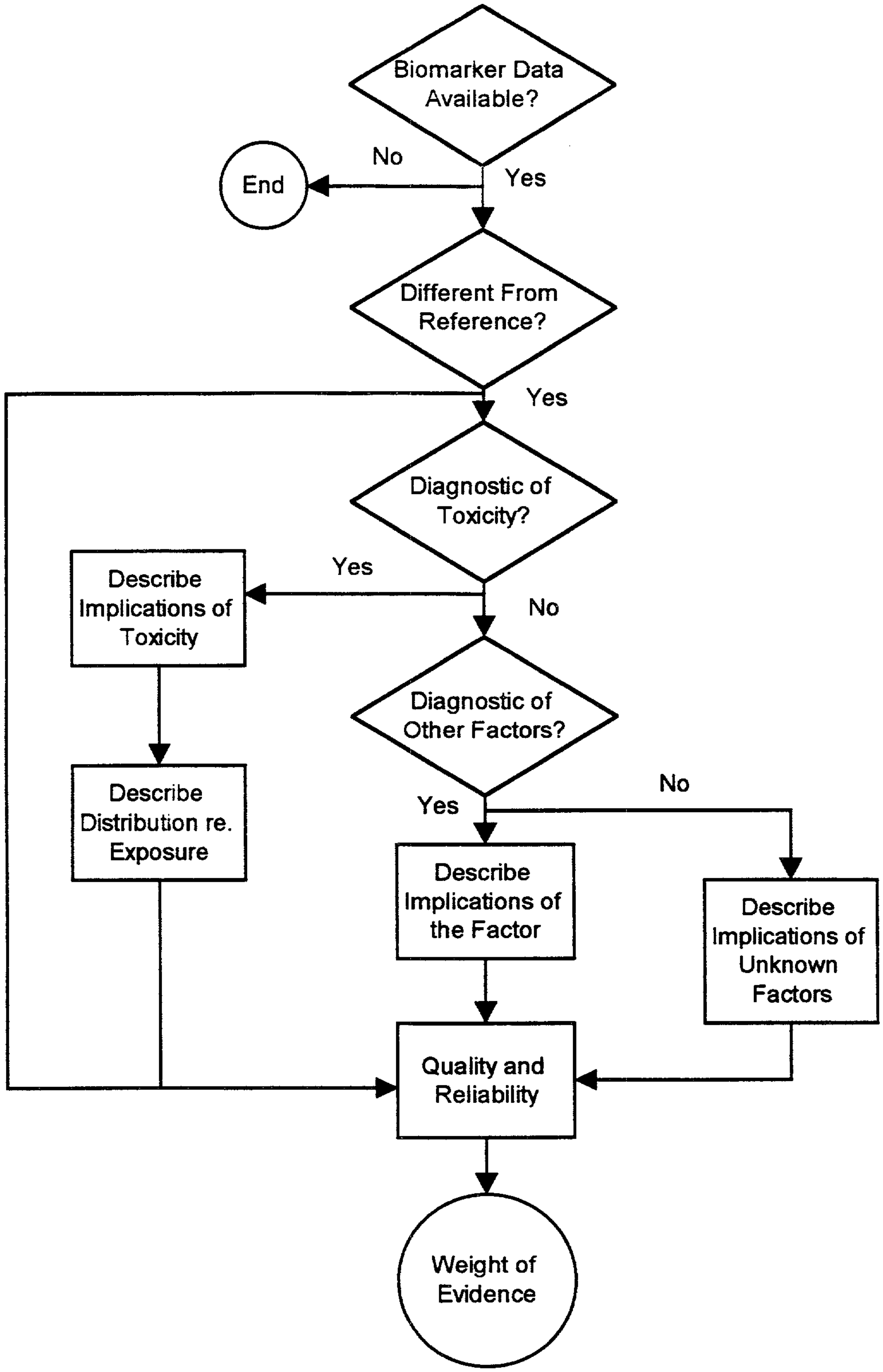

Fig. 14. Risk Characterization Based on Biomarker Data.

or of any of the habitat factors that are thought to affect the endpoint biota. If the bioindicators are characteristic of contaminant exposures, then the distribution and frequency of elevated levels must be compared to the distributions and concentrations of contaminants. Finally, to the extent that the bioindicators are known to be related to overt effects such as reductions in growth, fecundity, or mortality, the implications of the observed bioindicator levels for populations or communities should be estimated.

The result of risk characterization for this line of evidence should be questions such as:

- Are bioindicator levels significantly elevated?
- What are the implications for populations or communities?
- How extensive are the effects?
- Are they spatially or temporally associated with identifiable sources of contaminants?
- Are they spatially or temporally associated with identifiable habitat variables?
- Are they diagnostic or characteristic of a contaminant or a habitat variable?
- What is the most likely cause of the observed levels?
- How confident are you concerning your answers?

7.5 WEIGHT OF EVIDENCE

The weighing of evidence begins by summarizing the available lines of evidence for each endpoint (Fig. 15). The tabular format presented in Table 4 is recommended. The lines of evidence are listed, and a symbol is assigned for each: + if the evidence is consistent with significant effects on the endpoint, - if it is inconsistent with significant effects, and ± if it is too ambiguous to assign to either category. The last column presents a short summary of the results of the risk characterization for that line of evidence. If indirect effects are part of the conceptual model, they should be summarized in their own line of the table. For example, effects on the fish community could be due entirely or in part to toxicity to invertebrate prey species. The last line of the table presents the weight-of-evidence-based conclusion concerning whether significant effects are occurring and a brief statement concerning the basis for the conclusion. This conclusion is not based simply on the relative number of + or - signs. The "weight" component of weight of evidence is the relative credibility and reliability of the conclusions of the various lines of evidence.

In general, the weighing of evidence is best accomplished by beginning with the line of evidence that most directly bears on the actual risks. That is, begin with the risk characterization based on biological survey data, if available. If, for example, the fish community is depauperate downstream of a source, look to the risk characterization based on toxicity data to see if it indicates that aqueous toxicity is responsible. Look to the bioindicators to see if the fish

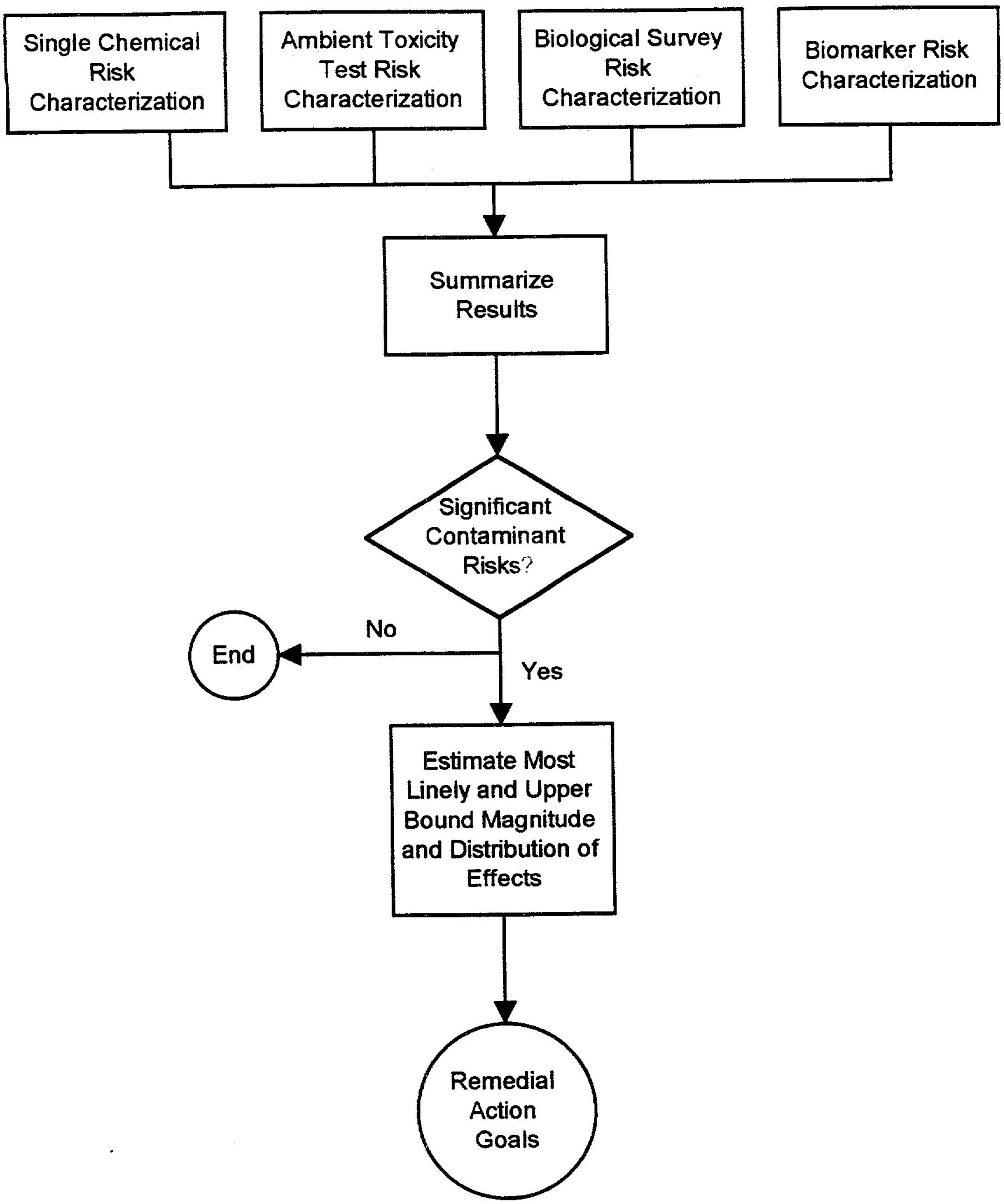

Fig. 15. Risk Characterization Based on Weighing of Multiple Lines of Evidence.

Table 4. Example of a table summarizing the risk characterization for the fish community in a stream at a waste site

Evidence	Result[a]	Explanation
Biological Surveys	-	Fish community productivity and species richness are both high in reaches 2 and 3. Effluents apparently improve community quality.
Toxicity Tests	±	High lethality to fathead minnow larvae in a test at Site 3.3, but variability is too high for standard statistical significance.
Media Analyses	+	Only Zn is believed to be potentially toxic in water and only to highly sensitive species.
Weight-of-Evidence	-	Reaches 2 & 3 support a clearly high quality fish community. Other evidence which suggests toxic risks is much weaker.

a + indicates that the evidence is consistent with the occurrence of the endpoint effect.
- indicates that the evidence is inconsistent with the occurrence of the endpoint effect.
± indicates that the evidence is too ambiguous to interpret.

populations still present bear signs of suborganismal effects. Finally, look to the risk characterization based on analysis of media to determine what contaminants are likely to be responsible for any observed effects or toxicity. This process clearly relies on expert judgement, but that judgement should be presented as clearly as possible to the stakeholders.

If no significant effects are believed to be occurring, the assessment of that particular endpoint ends. However, if significant effects are occurring they must be characterized. That is, the nature, magnitude, and extent of the effects must be estimated. This estimation may also be based on multiple lines of evidence. That is, different lines of evidence may agree in indicating that a significant effect is occurring but may disagree about its magnitude or extent. In general, the estimates will be based on the best evidence—the evidence that provides the clearest and most accurate estimate of effects.

7.6 FUTURE RISKS

Baseline ecological risk assessments for the ORR focus primarily on current risks. However, future risks should be characterized when:

- contaminant exposures are expected to increase in the future (e.g., a contaminated ground water plume will intersect a stream),
- biological succession is expected to increase risks (e.g., a forest will replace a lawn), or
- significant recovery is expected to occur in the near term without remedial actions (i.e., the expense and ecological damage associated with remedial actions may not be justified).

Although these future risks cannot be characterized by measuring effects or by testing future media, all lines of evidence that are useful for estimating current risks may be extended to them. As in human health risk assessments, risk models derived by epidemiological methods can be applied to future conditions and even applied to different sites. For example, if concentrations are expected to change in the future, the exposure-response relationship derived from biosurvey data (e.g., a relationship between contaminant concentration and fish abundance) may supply a better estimate of future effects than a concentration-response relationship derived from laboratory test data. Results of toxicity tests of currently contaminated media may also be used to estimate future effects. The utility of the various risk models depends on their reliability (as suggested by the weight-of-evidence analysis) and their relevance to the future conditions.

7.7 UNCERTAINTIES

Uncertainties should have been identified in the risk characterizations for each line of evidence, but the risk characterization should also include a summary of uncertainties and their implications. The Risk Assessment Forum (1992) indicates that this discussion should include uncertainties due to the conceptual model formulation, incompleteness of information, stochasticity (natural variability), and error. Results of quantitative uncertainty analyses should be presented, but it is important to remember that such analyses do not include all uncertainties.

In particular, while it is possible to quantitatively estimate the uncertainty associated with a single line of evidence, it is not possible to quantify the total uncertainty associated with a conclusion reached by weighing multiple lines of evidence.

It is important to summarize the implications of the listed uncertainties. This summary should include:

- the credible maximum and minimum levels of effects,
- endpoints that were not addressed,
- routes of exposure or indirect modes of action that were not addressed, and
- conditions that were not addressed (e.g., storm events).

8. RELATIONSHIP TO HUMAN HEALTH RISK ASSESSMENT

Because the EPA now places equal emphasis on assessing the potential impacts of hazardous waste sites on human health and the environment, human health assessments and ecological assessments will be performed concurrently at DOE-OR ER. Some information and data are likely to be relevant for assessing both human and environmental threats. Common data needs will be identified during project scoping and sampling plans will be developed in such a way as to avoid duplication of efforts. It is imperative that human health and ecological risk assessors coordinate their activities and communicate throughout the whole process so that all relevant data are accessible to all parties concerned.

Common data needs for human and ecological risk assessments will be determined by the individual characteristics of the site and by the scale of the assessments. In general, the following data are likely to be useful for both human health and ecological risk assessments. Differences between ecological and human health effects data needs are noted in parentheses.

a) Contaminant concentrations in media including:
   - Soils/sediments (concentrations in the pore water will be required for ecological risk assessments)
   - Surface water (concentrations of dissolved forms of contaminants will be required for ERAs)
   - Groundwater
   - Air
   - Biota, including fish (whole body concentrations will be required for ERAs), geese, deer, (plus endpoint species not in the human food chain such as great blue herons)

b) Chemical inventories

c) Operational history and current practices at the site

d) Factors affecting fate and transport of contaminants. For example:
   - Physical parameters, e.g., hydrogeologic setting, soil properties, topography
   - Bioaccumulation factors, particularly for exposure pathways involving indirect exposures to humans via the food chain

e) Background concentration data

All of these factors will be considered as possible common data needs during project scoping.

In some cases, ecological assessments may require samples to be analyzed in a specific way. The list presented previously notes that sediment pore water concentrations are required for ERAs. In addition, minimum required detection limits may be lower for ecological concerns than for human health concerns in some cases. Contaminants that pose a greater ecological than human health risk will need to be analyzed with more precision than would otherwise be required. Certain water quality parameters, such as pH, hardness, and oxygen levels, are also more important for ecological assessments.

The fact that ecological and human health risk assessments have common data needs will be considered during the prioritization of sites for risk assessments. For example, a site of low ecological priority would not normally require an immediate environmental evaluation. If, however, the site is of immediate concern for human health reasons, ecological risks should also be assessed immediately. This is because the analysis of remedial action alternatives must consider both ecological and human health impacts from those alternatives.

When the assessment of risks is completed and remedial action goals are developed, ecological risks must be compared to human health risks to determine which will drive the selection of remedial options. At this point, apparent discrepancies in results will require explanation. Some of these discrepancies will be due to differences in the assessment approaches, and others will be due to unexpectedly greater sensitivities of nonhuman receptors.

8.1 WHY HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT APPROACHES DIFFER

The strategy for ERAs described in this document is more complex than that for human health risk assessment and is fundamentally different in its inferential approach. The greater complexity is largely due to the large number of species and the diversity of routes of exposure that must be considered in ERAs. However, the difference in inferential approach and part of the greater complexity is due to the fact that ERAs for waste sites are based on epidemiological approaches while human health risk assessments for the waste sites are based on modelling. This discrepancy raises the question, why not just model ecological risks as well? The reasons are as follows.

- Epidemiological approaches, when they are feasible, are fundamentally more reliable than modelling, because they address real responses of real receptors. Human health risk assessments are based on epidemiology when possible, but epidemiology is (fortunately) not feasible for the ORR because there are no observable effects in human populations.

- Ecological epidemiology is feasible in practice, because nonhuman organisms are on the OUs and are, in some cases, experiencing observable exposures and effects.

- Ecological epidemiology is feasible in principle because the levels of effects that are deemed to be significant by the regulators and DOE are observable in many species and communities.

- Because of the assumptions that must be made to model risks, the uncertainties in model-generated risk estimates are large. These uncertainties can be accepted in practice by human health assessors because the effects are not observable. However, it is common for modelled ecological risks to be manifestly incorrect because the predicted effects are not occurring or effects occur where they are not predicted. Therefore, it is incumbent to use an epidemiological approach to avoid mistakes and embarrassment.

- Because of the great value placed on human life, remedial actions may be taken on the basis of highly uncertain estimates of hypothetical risks. However, because of the lesser value placed on nonhuman organisms and natural ecosystems, decision makers are somewhat reluctant to spend millions of dollars to remediate highly uncertain ecological risks. Therefore, if ERAs are to be useful they must be compelling.

- Inferences concerning the reality and causation of epidemiological phenomena cannot be made on the basis of epidemiological evidence alone. A concordance between the uncontrolled epidemiological observations and controlled studies such as toxicity tests must be demonstrated (Adams 1963, Woodman and Cowling 1987, Suter 1990, Suter 1993).

- Because biological surveys and ecological toxicity tests are inexpensive relative to chemical analyses and provide more direct evidence concerning ecological risks, they are highly cost effective.

- Even in those cases when ecological epidemiology is not feasible, the process of determining that to be the case is instructive and aids the interpretation of modelled risks. For example, if contaminants on an OU would cause reproductive failure in robins feeding on that OU, counting robins would not reveal that effect because the number of breeding pairs is limited by territory size, and the loss of production on the OU would be easily replaced by birds produced elsewhere. That suggests not only that estimating robin density would not indicate the effects on robins but also that the effects that the hypothesized effect (i.e., reduced reproduction on the OU) would not be significant at the population level.

8.2 WHY ECOLOGICAL ENDPOINTS MAY BE MORE SENSITIVE THAN HUMANS

It is commonly assumed that protection of human health will also result in protection of nonhuman organisms. For this reason, when ecological risks, but not human risks, are estimated to be significant, the apparent discrepancy must be explained. Despite the greater degree of protection afforded humans, nonhuman organisms are often at greater risk for a variety of reasons (Suter 1993). When this greater sensitivity is found, it must be explained. Types of explanations include the following:

- Modes of exposure that do not occur in humans such as respiration of water, consumption of sediment, or drinking from waste sumps.

- Quantitatively greater exposure such as a diet of 100% local fish.

- Inherently greater sensitivity of particular taxa of nonhuman organisms.

- Secondary effects such as loss of primary production.

8.3 SCALE IN HUMAN HEALTH AND ECOLOGICAL RISK

The issue of scale is treated differently in human health and ecological risk assessment. Because human health risks are estimated for hypothetical individuals, they can be calculated for the points in space at which samples are collected. For example, risks from contaminants in the water of White Oak Creek are calculated at an integration point, the weir of the dam, where an individual is assumed to collect his 2 liters of drinking water every day for 30 years. However, the endpoints for ERAs (except for those involving T&E species) are population or community level. Therefore, it is not possible to estimate ecological risks at a specific point, except as a screening technique. For example, one would estimate risks to the fish community in the reaches of White Oak Creek, not at a point at the end of the creek. Similarly for assessments of contaminated soils, the human health assessment may assume that a human lives for 30 years on a small site, but the ERA must acknowledge that vertebrate animal populations have large ranges.

This difference means that the data will be averaged differently and the results will not be point-to-point comparable. However, such comparability is not required by regulations or guidance and is not necessary for risk assessments to be useful. Rather, both human health and ERAs must produce defensible estimates of risks to their respective endpoints.

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APPENDIX A

VERTEBRATE ANIMAL SPECIES OF THE OAK RIDGE RESERVATION AND WATTS BAR RESERVOIR

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Table A.1. Terrestrial[a] animal species on the Oak Ridge Reservation

Common Name	Trophic Category[b]	Special Status[c]
	Birds	
Gadwall	AqH	
Common Gallinule	AqH	
Mallard	AqH	
Pintail	AqH	
Tundra Swan	AqH	
Blue-Winged Teal	AqH	
American Widgeon	AqH	
Bufflehead	AqI	
Black Duck	AqI	
Ruddy Duck	AqI	
Common Goldeneye	AqI	
Pied-Billed Grebe	AqI	
Lesser Scaup	AqI	
Green-Winged Teal	AqI	
Black Tern	AqI	
Carolina Chickadee	ArI	
Brown Creeper	ArI	
Yellow-Billed Cuckoo	ArI	
Yellow-Shafted Flicker	ArI	
Golden-Crowned Kinglet	ArI	
Ruby-Crowned Kinglet	ArI	
Red-Breasted Nuthatch	ArI	
White-Breasted Nuthatch	ArI	
Baltimore Oriole	ArI	
Orchard Oriole	ArI	
American Redstart	ArI	
Yellow-Bellied Sapsucker	**ArI**	**INM**
Scarlet Tanager	ArI	
Summer Tanager	ArI	
Tufted Titmouse	ArI	
Red-Eyed Vireo	ArI	
Solitary Vireo	ArI	

[a]Include water associated animals capable of moving on land.
[b]AqI = aquatic invertebrate feeder; ArI = arboreal invertebrate feeder; FI = flying insectivore; GI = ground invertebrate feeder; LC = predators and scavengers with ORR-wide populations; LH = herbivores with ORR-wide populations; LO = omnivores with ORR-wide populations; P = piscivores; SH = herbivores with populations restricted to source OU-scale; SO = omnivores with populations restricted to source OU-scale.
[c]FC = candidate for federal listing; FE = federally listed as endangered; INM = state listed as in need of management; SE = state listed as endangered; ST = state listed as threatened.

Table A.1. (continued)

Common Name	Trophic Category[b]	Special Status[c]
	Birds (cont.)	
White-Eyed Vireo	ArI	
Yellow-Throated Vireo	ArI	
Bay-Breasted Warbler	ArI	
Black and White Warbler	ArI	
Black-Throated Green Warbler	ArI	
Blackburnian Warbler	ArI	
Blackpoll Warbler	ArI	
Blue-Winged Warbler	ArI	
Cape May Warbler	ArI	
Cerulean Warbler	ArI	
Chestnut-Sided Warbler	ArI	
Hooded Warbler	ArI	
Magnolia Warbler	ArI	
Myrtle Warbler	ArI	
Parula Warbler	ArI	
Pine Warbler	ArI	
Prairie Warbler	ArI	
Prothonotary Warbler	ArI	
Tennessee Warbler	ArI	
Worm-Eating Warbler	ArI	
Yellow Warbler	ArI	
Yellow-Throated Warbler	ArI	
Downy Woodpecker	ArI	
Hairy Woodpecker	ArI	
Pileated Woodpecker	ArI	
Red-Bellied Woodpecker	ArI	
Red-Headed Woodpecker	**ArI**	**INM**
Yellowthroat	ArI	
Eastern Bluebird	FI	
Chuck-Will's-Widow	FI	
Acadian Flycatcher	FI	
Great Crested Flycatcher	FI	
Least Flycatcher	FI	
Blue-Gray Gnatcatcher	FI	
Eastern Kingbird	FI	
Purple Martin	FI	
Common Nighthawk	FI	
Eastern Phoebe	FI	

Table A.1. (continued)

Common Name	Trophic Category[b]	Special Status[c]
	Birds (cont.)	
Bank Swallow	FI	
Barn Swallow	FI	
Cliff Swallow	FI	
Rough-Winged Swallow	FI	
Chimney Swift	FI	
Whip-Poor-Will	FI	
Eastern Wood-pewee	FI	
Red-Winged Blackbird	GI	
Catbird	GI	
Brown-Headed Cowbird	GI	
Cattle Egret	GI	
Common Egret	GI	
Killdeer	GI	
Horned Lark	GI	
Eastern Meadowlark	GI	
Mockingbird	GI	
Ovenbird	GI	
American Robin	GI	
Spotted Sandpiper	GI	
Common Snipe	GI	
Starling	GI	
Brown Thrasher	GI	
Gray-Cheeked Thrush	GI	
Hermit Thrush	GI	
Louisiana Water Thrush	GI	
Swainson's Thrush	GI	
Wood Thrush	GI	
Kentucky Warbler	GI	
Swainson's Warbler	GI	
American Woodcock	GI	
Bewick's Wren	GI	
Carolina Wren	GI	
House Wren	GI	
Winter Wren	GI	
Golden Eagle	LC	SE
Northern Harrier	LC	ST
Broad-Winged Hawk	LC	

Table A.1. (continued)

Common Name	Trophic Category[b]	Special Status
	Birds (cont.)	
Cooper's Hawk	**LC**	**ST**
Red-Shouldered Hawk	**LC**	**INM**
Red-Tailed Hawk	LC	
Sharp-Shinned Hawk	**LC**	**ST**
Sparrow Hawk	LC	
Barn Owl	LC	INM
Barred Owl	LC	
Great Horned Owl	LC	
Screech Owl	LC	
Loggerhead Shrike	LC	
Black Vulture	**LC**	**INM**
Turkey Vulture	LC	
Bobwhite	LH	
Red Crossbill	LH	
Mourning Dove	LH	
Rock Dove	LH	
Purple Finch	LH	
American Goldfinch	LH	
Canada Goose	LH	
Ruffed Grouse	LH	
Ruby-Throated Hummingbird	LH	
Slate-Colored Junco	LH	
Pine Siskin	LH	
Bachman's Sparrow	LH	
Chipping Sparrow	LH	
Field Sparrow	LH	
Fox Sparrow	LH	
Grasshopper Sparrow	**LH**	**ST**
Henslow's Sparrow	**LH**	**FC**
House Sparrow	LH	
Lark Sparrow	**LH**	**INM**
Song Sparrow	LH	
Swamp Sparrow	LH	
Vesper Sparrow	**LH**	**INM**
White-Throated Sparrow	LH	
Wild Turkey	LH	
Cedar Waxwing	LH	
Indigo Bunting	LO	

Table A.1. (continued)

Common Name	Trophic Category[b]	Special Status[c]
	Birds (cont.)	
Canvasback	LO	
Cardinal	LO	
Yellow-Breasted Chat	LO	
American Coot	LO	
Common Crow	LO	
Ring-Necked Duck	LO	
Wood Duck	LO	
Common Grackle	LO	
Blue Grosbeak	LO	
Evening Grosbeak	LO	
Rose-Breasted Grosbeak	LO	
Blue Jay	LO	
Redhead	LO	
Rufous-Sided Towhee	LO	
Double-Crested Cormorant	**P**	**INM**
Bonaparte's Gull	P	
Herring Gull	P	
Ring-Billed Gull	P	
Black-Crowned Night Heron	**P**	**INM**
Great Blue Heron	P	
Green Heron	P	
Belted Kingfisher	P	
Common Loon	P	
Common Merganser	P	
Hooded Merganser	P	
Red-Breasted Merganser	P	
Bald Eagle	**P**	**SE, FE**
Osprey	**P**	**SE**
	Mammals	
Big Brown Bat	FI	
Eastern Small-Footed Bat	**FI**	**FC, INM**
Evening Bat	FI	
Gray Bat	**FI**	**FE, SE**
Hoary Bat	FI	
Indiana Bat	**FI**	**FE, SE**
Little Brown Bat	FI	

Table A.1. (continued)

Common Name	Trophic Category[b]	Special Status[c]
	Mammals (cont.)	
Rafinesque's Big-Eared Bat	**FI**	**FC, INM**
Red Bat	FI	
Silver-Haired Bat	FI	
Keen's Myotis	FI	
Eastern Pipistrelle	FI	
Eastern Mole	GI	
Least Shrew	GI	
Long-Tailed Shrew	**GI**	**FC, INM**
Masked Shrew	**GI**	**INM**
Short-Tailed Shrew	GI	
Smokey Shrew	GI	INM
Southeastern Shrew	GI	INM
Spotted Skunk	GI	
Stripped Skunk	GI	
Bobcat	LC	
Feral Cat	LC	
Cougar[d]	**LC**	**FE**
Coyote	LC	
Feral Dog	LC	
Red Fox	LC	
Mink	LC	
River Otter[e]	**LC**	**ST**
Long-Tailed Weasel	LC	
Beaver	LH	
Eastern Chipmunk	LH	
Eastern Cottontail	LH	
White-Tailed Deer	LH	
Gray Squirrel	LH	
Southern Flying Squirrel	LH	
Woodchuck	LH	
Gray Fox	LO	
Muskrat	LO	
Opossum	LO	
Raccoon	LO	

[d] Reported sightings, but probably does not occur on a regular basis.
[e] Not yet sighted on the ORR, but introduced to area streams, and suitable habitat exists on the ORR.

Table A.1. (continued)

Common Name	Trophic Category[b]	Special Status[c]
	Mammals (cont'd)	
Southern Bog Lemming	**SH**	**INM**
Eastern Harvest Mouse	SH	
Meadow Vole	SH	
Pine Vole	SH	
White-Footed Mouse	SO	
Deer Mouse	SO	
Golden Mouse	SO	
Hispid Cotton Rat	SO	
Rice Rat	SO	
Meadow Jumping Mouse	**SO**	**INM**
Woodland Jumping Mouse	**SO**	**INM**
House Mouse	SO	
Norway Rat	SO	
	Amphibians and Reptiles	
Slider	AqH	INM
Yellow-Bellied Turtle	AqH	
Bronze Frog	AqI	
Bullfrog	AqI	
Leopard Frog	AqI	
Northern Cricket Frog	AqI	
Pickerel Frog	AqI	
Wood Frog	AqI	
Hellbender	**AqI**	**FC, INM**
Mudpuppy	AqI	
Northern Red Salamander	AqI	
Spring Salamander	AqI	
Three-Lined Salamander	AqI	
Map Turtle	AqI	
Gray Tree Frog	ArI	
Spring Peeper Frog	ArI	
Upland Chorus Frog	ArI	
Fence Lizard	ArI	
Green Anole	ArI	
Rough Green Snake	ArI	
Broadhead Skink	GI	
Five-Lined Skink	GI	

Table A.1. (continued)

Common Name	Trophic Category[b]	Special Status[c]
	Amphibians and Reptiles (cont.)	
Ground Skink	GI	
Six-Line Racerunner	**GI**	**INM**
Slender Glass Lizard	**GI**	**INM**
Tennessee Cave Salamander	**GI**	**FC, ST**
Green Salmander	**GI**	**FC, INM**
Red-Backed Salamander	GI	
Slimy Salamander	GI	
Spotted Salamander	GI	
Brown Snake	GI	
Eastern Crowned Snake	GI	
Eastern Worm Snake	GI	
Northern Ringneck Snake	GI	
Red-Bellied Snake	GI	
American-Toad	GI	
Eastern Marrow-Mouthed Toad	GI	
Eastern Spadefoot Toad	GI	
Fowler's Toad	GI	
Black King Snake	LC	
Black Rat Snake	LC	
Corn Snake	LC	
Eastern Hognose Snake	LC	
Eastern Milk Snake	LC	
Garter Snake	LC	
Mole Snake	LC	
Northern Black Racer	LC	
Northern Copperhead	LC	
Northern Pine Snake	**LC**	**FC, ST**
Scarlet Snake	LC	
Timber Rattlesnake	LC	
Eastern Spiny Softshell Turtle	LC	
Snapping Turtle	LC	
Stinkpot Turtle	LC	
Striped-Neck Musk Turtle	LC	
Eastern Box Turtle	LO	
Eastern Painted Turtle	LO	
Northern Water Snake	P	
Queen Snake	P	

Table A.2. Fish species associated[a] with the Oak Ridge Reservation

Common Name	Trophic Catagory[b]	Special Status[c]
Gizzard shad	Dtr	
Goldfish	Dtr	
Carp	Dtr	
Tennessee dace	Dtr	INM
Bluntnose minnow	Dtr	
Fathead minnow	Dtr	
River carpsucker	Dtr	
Quillback	Dtr	
White sucker	Dtr	
Spotted sucker	Dtr	
Black bullhead	Dtr	
Yellow bullhead	Dtr	
Skipjack herring	Inv	
Mooneye	Inv	
Rosefin Shiner	Inv	
Emerald shiner	Inv	
Striped shiner	Inv	
Spotfin shiner	Inv	
Blacknose dace	Inv	
Creek chub	Inv	
Biqeye chub	Inv	
Northern hog sucker	Inv	
Smallmouth buffalo	Inv	
Silver redhorse	Inv	
Black redhorse	Inv	
Golden redhorse	Inv	
Blue catfish	Inv	
Mosquitofish	Inv	
Brook stickleback	Inv	
Redbreast sunfish	Inv	
Green sunfish	Inv	
Warmouth	Inv	
Bluegill	Inv	
Longear sunfish	Inv	
Redear sunfish	Inv	
Greenside darter	Inv	

Table A.2. (continued)

Common Name	Trophic Catagory[b]	Special Status[c]
Black darter	Inv	
Stripetail darter	Inv	
Snubnose darter	Inv	
Logperch	Inv	
Banded sculpin	Inv	
Stoneroller	Peri	
Grass carp	Peri	
Paddlefish	Plnk	
Threadfin shad	Plnk	
Golden shiner	Plnk	
Black buffalo	Plnk	
Brook silverside	Plnk	
Chestnut lamprey	Psc	
Spotted gar	Psc	
Longnose gar	Psc	
Northern Pike	Psc	
Channel catfish	Psc	
Flathead catfish	Psc	
White bass	Psc	
Yellow bass	Psc	
Striped bass	Psc	
Rock bass	Psc	
Smallmouth bass	Psc	
Spotted bass	Psc	
Largemouth bass	Psc	
White crappie	Psc	
Yellow perch	Psc	
Sauger	Psc	
Freshwater drum	Psc	

[a] Species from waters on the ORR and in the Clinch River, as identified in Ryon, M.G., and J. M. Loar. 1988. A checKlist of fishes on the Department of Energy Oak Ridge Reservation. J. Tenn. Acad. Sci. 63 (4): 97-102.

[b] Dtr = Detritivores; Inv = invertebrate feeders; Peri = periphyton feeders; Plnk = plankton feeders; Psc = Piscivores.

[c] INM = state listed as in need of management.

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