Appendix F
Risk Assessment Scoping, Problem Formulation, and Additional Risk Assessment Guidance

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Appendix F
Risk Assessment Scoping, Problem Formulation, and Additional Risk Assessment Guidance

F.1 The Ecological Risk Assessment in the RI/FS

EPA defines ecological risk assessment as "a process that evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors."[1] Ecological risk assessments in Superfund can be divided into three main phases as follows (see Highlight F-1):

Problem Formulation - establishes the goals, breadth, and focus of the ecological risk assessment. This phase includes qualitative evaluation of contaminant release, migration, and fate; identification of contaminants of concern, receptors, exposure pathways, and known ecological effects of the contaminants; identification of assessment and measurement endpoints (see section F.4 of this appendix for a definition of assessment and measurement endpoints) for further study; and development of exposure scenarios.

Analysis - technically evaluates data on the potential exposure and effects of the contaminants.

-- **Characterization of Exposure** - evaluates the interaction of the contaminant with ecological receptors. This step includes contaminant characterization (quantifying release, migration, and fate); ecosystem characterization (characterizing exposure pathways and receptors); and development of an exposure profile that quantifies the magnitude and spatial and temporal distributions of exposure for the scenarios developed during problem formulation (measuring or estimating exposure concentrations).

-- **Characterization of Ecological Effects** - analysis of the relationship between the contaminant and the assessment and measurement endpoints identified during problem formulation. This step may include literature reviews, field studies, and toxicity tests to quantify the contaminant-response relationship and to evaluate evidence for causality.

Risk Characterization - evaluates the likelihood of adverse ecological effects or impacts occurring as a result of exposure to a contaminant; analyzes and summarizes uncertainties; and presents weight-of-evidence discussion. This phase includes risk estimation, risk description, and discussion between the risk assessor and the risk manager allowing full and clear presentation of the results to the risk manager.

Although the elements of exposure characterization and of ecological effects characterization are most pronounced in the analysis phase, aspects of these characterizations are considered also during problem formulation. This is illustrated in Highlight F-1 by the arrows flowing from the problem formulation phase to the analysis phase.

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[1] Environmental Protection Agency (EPA). 1997. *Process for designing and Conducting Ecological Risk Assessments*. EPA/540-R-97/006, June 5, 1997.

F.2 Relationship to Overall Remedial Investigation/Feasibility Study (RI/FS) Process

The ecological problem formulation step described above occurs during the scoping phase of the RI/FS. The ecological assessment described in this appendix occurs during site characterization. Highlight F-2 illustrates the overall RI/FS process and Highlight F-3 provides an overview of the ecological assessment process at Superfund sites.

Many mining waste sites are divided into different operable units to address different areas or sources, and RI/FS investigations for each may proceed in a phased manner. The eight-step process for logical assessments at Superfund sites is described in *Process for Designing and Conducting Ecological Risk Assessments*[2]. More details of the process are described below.

Scoping and ecological problem formulation. RI/FS scoping consists of the components listed in Highlight F-4. The scoping step includes both human health and ecological concerns, and coordination is needed among the scoping team members. The outcome of the ecological problem formulation is a conceptual model of the site. Components of this conceptual site model, potential ARARs, data quality objectives, and remedial action objectives are likely to differ for the human health and ecological assessments; therefore, these need to be integrated throughout scoping. In particular, when identifying operable units and response scenarios, both sets of concerns must be addressed as thoroughly as possible.

Phased approach to site characterization. For most sites, the project plans for site characterization should incorporate a phased approach to the ecological assessment with expert review at each phase. The data or observations from one phase can be used to determine the most appropriate studies for the next phase. Thus, a goal of the scoping phase of the assessment is to establish detailed project plans for the first phase of an ecological assessment. If the results of the first phase so indicate, an additional ecological assessment may be conducted during the site characterization phase.

Scoping the ecological assessment. Highlight F-5 summarizes the steps in scoping a remedial investigation. It shows that a primary objective of scoping is to prepare project plans for the RI/FS, including a work plan (WP), sampling and analysis plan (SAP), and field sampling plan (FSP) for site characterization, (i.e., determine the data required to characterize both human health and ecological threats). The RPM is responsible for a scope or statement of work (SOW). The contractor or other group (e.g., the Potentially Responsible Party (PRP)) performing the field assessment is responsible for project plans that address the elements of the SOW. Highlight F-6 illustrates the elements of these plans.

Site characterization ecological risk assessment. The three primary goals of the site characterization phase are:

> To conduct a field investigation to define the nature and extent of contamination (waste types, concentrations, distributions);
> To conduct the baseline risk assessment to determine if a site poses a current or potential threat to the environment; and
> To help determine remediation goals for site contaminants.

Following the ecological risk assessment, the RPM evaluates whether the data collected are sufficient to make decisions concerning remedial alternatives and cleanup goals or whether additional ecological information is needed.

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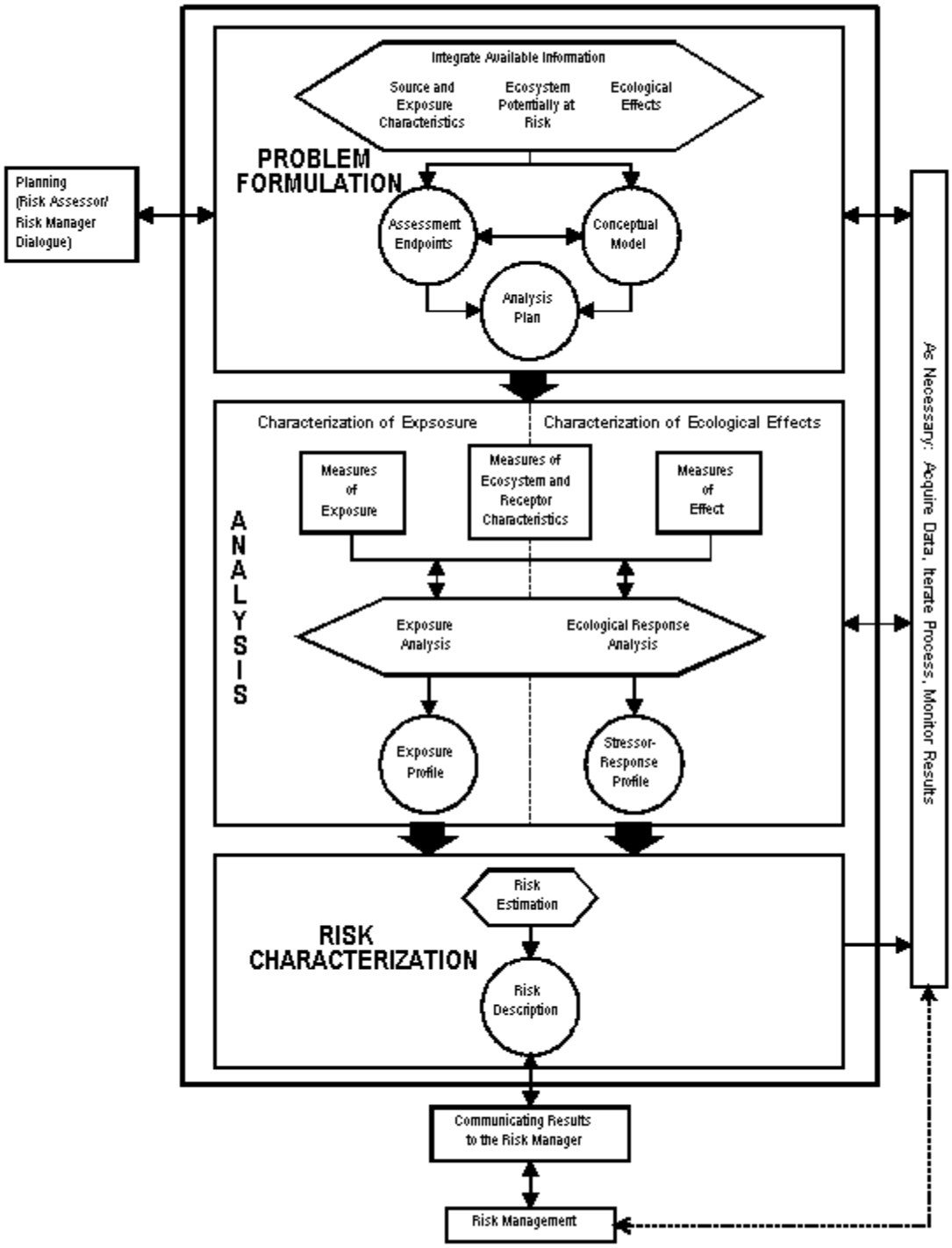
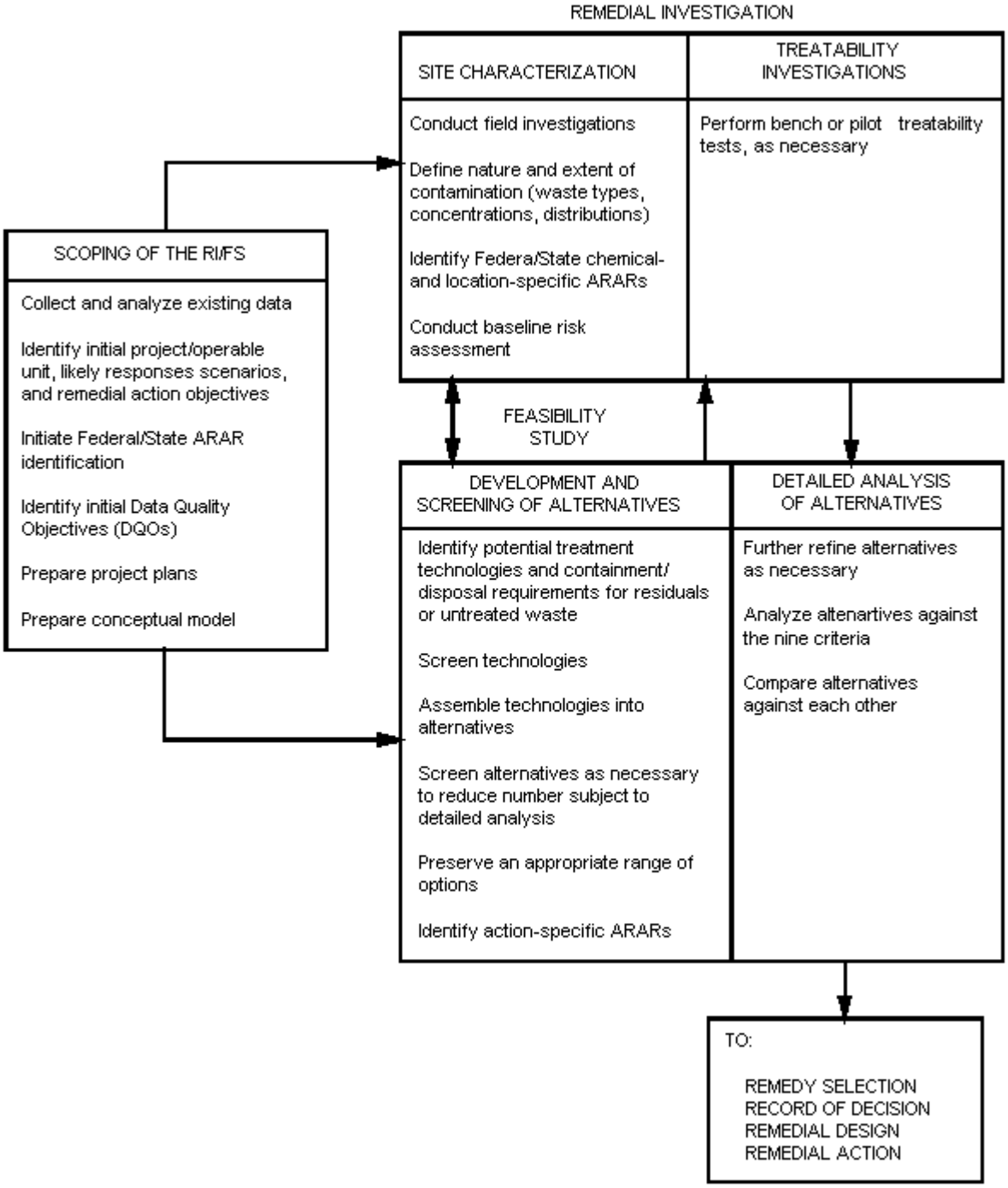
[2] U.S. Environmental Protection Agency (EPA). 1997. *Process for Desgining and Conducting Ecological Risk Assessments.* EPA/540-R-97-006. June 5, 1997.

Highlight F-1
Ecological Risk Assessment Framework



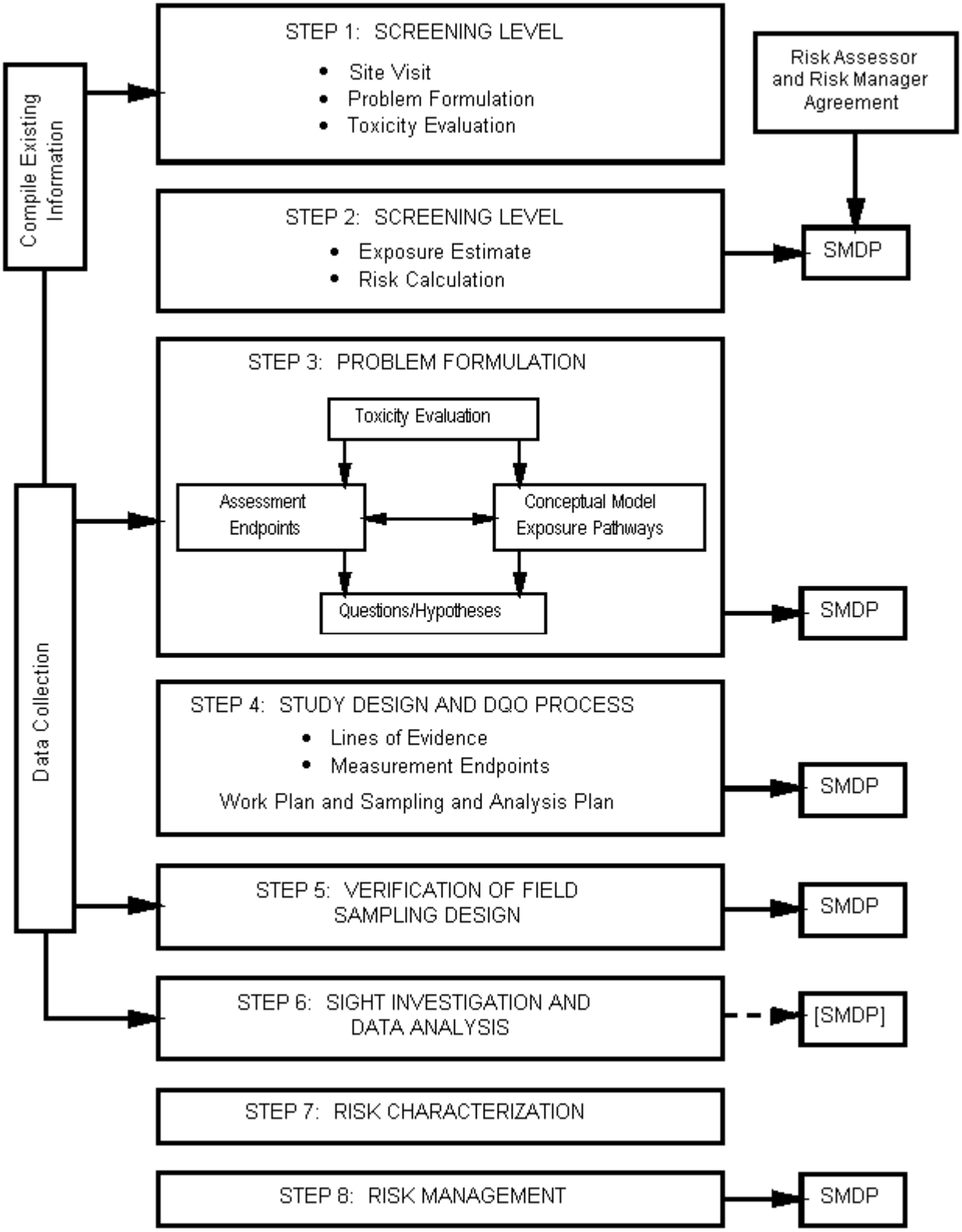
Source: Environmental Protection Agency (EPA) 1998. Guidelines for Ecological Risk Assessment. EPA/630/R-95/003F.

Highlight F-2
Remedial Investigation/Feasibility Study Process



Source: Adapted from Environmental Protection Agency, 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. Office of Emergency and Remedial Response, Washington, D.C. OSWER Directive No. 9355.3-01.

Highlight F-3
Ecological Risk Assessment Process for Superfund



Source: Environmental Protection Agency (EPA) 1997 EPA/540-R-97-006

Highlight F-4:
Components of Scoping an RI/FS

Evaluate existing data
Develop conceptual site model
Identify initial project/operable unit, likely response scenarios, and remedial action objectives
Initiate potential federal/state ARARs identification
Identify initial data quality objectives (DQOs)
Prepare statement of work and project plans for the site characterization phase of study

F.3 General Principles

The following three principles can serve as useful guidelines when planning and conducting ecological risk assessments at Superfund mining sites:

An ecological risk assessment usually requires data in addition to that obtained for a human health risk assessment. While much of the data obtained for a human health risk assessment is useful in an ecological risk assessment, additional information usually is required (e.g., a description of the surrounding habitats and species of concern, additional chemical sampling locations).

Criteria, standards, or other measures for the protection of human health and welfare are not always protective of ecological systems. Many ecological receptors are more sensitive than humans to some chemicals. Moreover, a given environmental concentration of a chemical may result in a greater level of exposure for an ecological receptor than for a human.

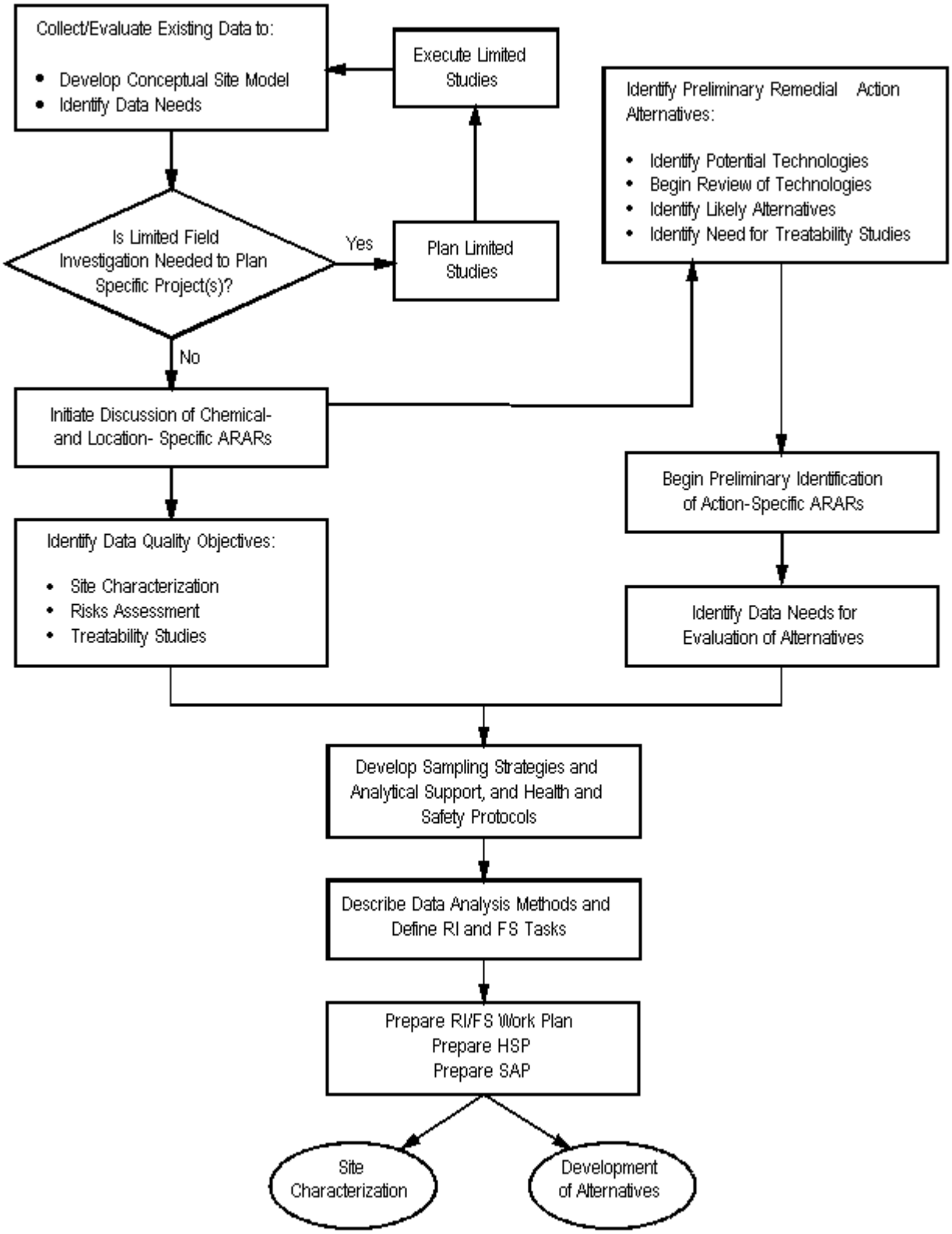
A detailed ecological risk assessment during site characterization will not be necessary or appropriate for every site. The level of detail in an ecological risk assessment should be appropriate to the level of information required to make risk management decisions. A purpose of the ecological assessment is to determine whether additional site investigations will be required before risk management decisions can be made at a particular site.

F.4 RI/FS Scoping and Ecological Problem Formulation

Highlight F-5 shows the steps involved in scoping the remedial investigation. The first step is to collect and evaluate existing data in order to develop a conceptual model of the site and to identify data gaps that will prevent effective formulation of study plans. Highlight F-7 provides a list of useful data sources. For ecological assessments, a site walk-through with a trained ecologist/biologist should be performed. It may be determined at this time that a limited field investigation is required to fully scope the RI. If this is the case, a field sampling plan needs to be formulated and executed.

After collecting data to scope the RI, the assessment team should identify chemical- and location-specific ARARs, preliminary remedial action alternatives, preliminary action-specific ARARs, data quality objectives, and data needs for evaluating alternative remedial strategies. Then the assessors can develop sampling strategies, required analytic support, and data analysis methods for the RI site characterization.

Highlight F-5
Steps in Scoping a Remedial Investigation



Source: Adapted from Environmental Protection Agency (EPA) 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. Office of Emergency and Remedial Response, Washington, D.C. OSWER Directive No. 9355.3-01.

Highlight F-6:
Elements of Project Plans

Elements of a Work Plan (WP)	Elements of the Sampling and Analysis Plan (SAP)
A comprehensive description of the work to be performed, the information needed for each task, the information to be produced during and after each task, and a description of work products submitted to the RPM; The methods that will be used during each activity; A schedule for completing activities; The rational for performing or not performing an activity; A background summary and history of site; A site conceptual model; Identification of preliminary site objectives including preliminary remediation goals; The need for additional data when future site unknowns are identified; The manner of identifying federal and state ARARs; An identification of preliminary alternatives and RI/FS guidance; and A plan for meeting treatability study requirements.	Sampling procedures; Sample custody procedures; Analytical procedures; Data reduction, data validation, and data reporting; Personnel qualifications; The qualifications of each laboratory to conduct work; and The use of internal controls, such as unannounced site, performance, and system audits. **Elements of the Field Sampling Plans (FSP)** The sampling objectives; Sample locations; Sampling frequency and when to sample; Sampling equipment and procedures; Program for sample handling and analysis. **Note: Project Plans also include a health and safety plan (HSP) for the personnel conducting the sampling.**

Source: Adapted from Environmental Protection Agency (EPA). 1991. *Guidance on Oversight of Potentially Resonsible Party Remedial Investigations and Feasibility Studies, Volume 1.* Office of Solid Waste and Emergency Response, Washington, DC. OSWER Directive 9835.1 (c). EPA/540/G-91/010a.

At enforcement lead sites, it is crucial to compile documentation for cost recovery and to make sure that natural resources trustees have been notified of site activities so that they can conduct their investigations.

EPA has published guidance to help develop a scope of work for Ecological Assessments.[3] This guidance provides an overview of the role of the BTAG, points to consider in developing a scope of work, elements of an ecological assessment scope of work, ensuring contractor capability to do the work, and a sample work scope. The remainder of this section provides additional details and sources of information to supplement the existing guidance, emphasizing elements that are likely to be important for mining sites.

[3] Environmental Protection Agency (EPA). 1992b. *Developing a Work Scope for Ecological Assessments. ECO Update*, Intermittent Bulletin, Volume 1, Number 4. Office of Emergency and Remedial Response, Hazardous Site Evaluation Division, Washington, DC. Publication 9345.0-05I.

F.5 Evaluate Existing Data and Visit the Site

The first step of scoping for the RI is evaluating all existing data for the site. As scoping begins for the RI, some data already should be available from previous site studies, studies from similar sites, available aerial photographs, and other sources. Initial site data from the Preliminary Assessment (PA), Site Investigation (SI), Hazard Ranking System (HRS) Scoring Package, and supporting materials included in the docket established as part of the NPL listing process should be obtained. Existing RI/FS studies from similar types of mining waste sites also may be helpful in identifying background information that can help to develop hypotheses about potential problems at the site. During this process, it is critical for the ecological assessment team to work with those conducting the scoping study from the human health perspective. Ten tasks are outlined below.

Task 1: Contact BTAG, Appropriate Agencies and Experts, and Natural Resource Trustees

Contact the Biological Technical Assistance Group (BTAG). The role of BTAGs in ecological assessments at Superfund sites is described in *ECO Update* Volume 1, Numbers 1[4] and 4[5]. If a BTAG or equivalent advisory group exists in the Region (or is otherwise accessible), begin the process of involving group members in the scoping ecological assessment as early as possible. The BTAG can screen the initial site data (e.g., PA, SI, HRS data) to recommend the nature and extent of an ecological assessment that is likely to be needed at the site and to identify the most relevant exposure pathways for further study. BTAG members also can be extremely helpful throughout the ecological assessment, including:

- Assisting the RPM to scope the ecological assessment effort;
- Reviewing the conclusions of the scoping phase;
- Recommending study objectives, field and laboratory protocols, QA/QC requirements, and other elements of the RI SOW; and
- Reviewing draft RI/FS work plans for site characterization.

In some Regions, RPMs present a brief oral description of a site and its history to the BTAG to begin the consultation process. Eco Update Volume 1, Number 5[6] discusses this initial briefing.

Contact appropriate state or local fish and game agencies. Other agencies may have statutory responsibility for involvement in management of the resource(s) of concern (e.g., state Fish and Game Departments). Personnel from these agencies who are familiar with the area should be contacted to determine whether any adverse ecological impacts have been reported that might be attributable to contaminants from the site. Types of impacts that may be expected include fish kills (particularly following storms), reduced or absent fish or wildlife populations, and reduced abundance of particular plant species. Note that these types of impacts may or may not be site-related. It also will be important to determine the state-designated uses of any potentially affected surface waters, whether the surface water quality meets the requirements for the designated use, and if not, the possible causes of use impairment.

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[4] Environmental Protection Agency (EPA). 1991b. *The Role of BTAGs in Ecological Assessment. ECO Update*, Intermittent Bulletin, Volume 1, Number 1. Office of Emergency and Remedial Response, Hazardous Site Evaluation Division, Washington, DC. Publication 9345.0-05I.

[5] Op. Cit. 3.

[6] Environmental Protection Agency (EPA). 1992. *Briefing the BTAG: Initial Description of Setting, History, and Ecology of a Site. ECO Update*, Intermittent Bulletin, Volume 1, Number 5. Office of Emergency and Remedial Response, Hazardous Site Evaluation Division, Washington, DC. Publication 9345.0.05I.

Highlight F-7:
Useful Sources of Existing Data

Federal Sources of Existing Data	State Sources of Existing Data	Local Sources of Existing Data
Preliminary Assessment/Site Inspection Hazardous Ranking Scoring (HRS) documentation PRP search — Section 104(e) letters — waste-in list — data requests to the PRP Records on removals and disposal practices Permits for discharges — Toxic Releases Inventory System (TRIS) National Pollutant Discharge Elimination System (NPDES) Prior Contract Laboratory Program (CLP) work RCRA manifests, notifications, and permit applications and Section 3007 information requests EPA databases (see Appendix A of source)	EPA-equivalent agency Planning board Geological Survey Fish and Wildlife Service Historic Preservation Office Natural Resource Department Natural Heritage Program Department of Conservation	Public library Chamber of Commerce Audubon Society Planning board Town/city hall or court house Water authority Sewage treatment facility Previous site employees/ management Residents near site Universities (information on local areas) Historical societies Newspaper files

Source: Adapted from Environmental Protection Agency (EPA). 1991. *Guidance on Oversight of Potentially Responsible Party Remedial Investigations and Feasibility Studies, Volume 1.* Office of Solid Waste and Emergency Response, Washington, DC. OSWER Directive 9835.1 (c). EPA/540/G-91/010a.

Contact CERCLA natural resource trustees. The NCP outlines formal notification and coordination requirements for EPA and the CERCLA natural resource trustees throughout the RI/FS process. These requirements and recommendations for additional involvement of the natural resource trustees are described in *ECO Update* Volume 1, Number 3[7]. In general, it is important to notify natural resource trustees early and often and always to notify the U.S. Fish and Wildlife Service (FWS; representing the Department of the Interior (DOI)) and the National Oceanic and Atmospheric Administration (NOAA; representing the Department of Commerce). It also may be beneficial to invite trustees' representatives to accompany the assessment team on site visits. Appropriate personnel from FWS, NOAA, and other natural resource trustees can be extremely helpful in identifying and describing signs of exposure or impacts or noting the absence of species expected to be present. In many Regions, natural resource trustee representatives are members of the BTAG.

[7] Environmental Protection Agency (EPA). 1992f. *The Role of Natural Resource Trustees in the Superfund Process. ECO Update*, Intermittent Bulletin, Volume 1, Number 3. Office of Emergency and Remedial Response, Hazardous Site Evaluation Division, Washington, DC. Publication 9345.0-05I.

In accordance with the NCP §300.615(c)(1) and through Memoranda of Understanding between EPA and both DOI and NOAA, the RPM can request a representative of one of the natural resource trustees to conduct a Preliminary Natural Resource Survey (PNRS) or another form of preliminary site survey. A PNRS consists of a site survey and a brief report identifying the natural resources, habitat types, endangered or threatened species, and any potential impacts or injuries to trust resources. The PNRS may be funded by EPA and conducted at any stage of the remedial process, from pre-listing to pre-Record of Decision (ROD). If the PNRS is conducted before RI scoping, it may provide information useful for sampling design and other aspects of the RI ecological assessment.

Other agencies that represent natural resource trustees at many mining sites include the states and the Bureau of Land Management (BLM). Given the large size of many mining sites, potentially affecting large proportions of entire watersheds, it can be helpful to establish a cooperative group to coordinate actions on a watershed basis. The group might be comprised of more than one EPA Office (e.g., Superfund, Office of Water) and appropriate state and other federal agencies (see Highlight F-8).

Task 2: Identify the ecological risk assessment team

Once the principal attributes of the site that may need evaluation have been identified, an ecological assessment team can be identified. Determine which types of technical expertise are required to evaluate the site. The team may be comprised of EPA Superfund staff and include representatives from NOAA, the FWS, or state agencies (see Highlight F-9). The BTAG may be able to recommend appropriate individuals for the team.

Task 3: Map the site

Mapping attributes of the site will assist in formulating a conceptual model for the site. Obtain all available background information on the site and its setting and begin to prepare a map. Specific objectives in this step are to identify and map:

(a) Sources of contaminants and areas of suspected contamination (e.g., deposition areas);
(b) Likely contaminant migration pathways; and
(c) Location and extent of on-site and nearby aquatic, wetland, and terrestrial habitats.

The first two steps (a and b) should be coordinated with the human health assessment team when developing the conceptual site model (section H.6). The final step (c) will be the responsibility of the ecological risk assessment team. For recently listed sites, much of this information should be described in the HRS materials, although additional investigation may be required. The initial map should be consulted or updated in all of the following steps.

Task 4: Develop a history of site operations

In conjunction with the human health assessors, compile information on when mining began, duration of the mining activities, volumes of materials handled, and technologies used in excavation, beneficiation, and refining. This information can indicate what types and how much hazardous waste is present, where it is located on site, and where it has migrated off site. Historical information helps in identifying locations of past activities at which hazardous wastes are likely to be found. Site history should be described in some detail in the HRS materials, although additional investigations may be required.

Highlight F-8:
Example of a Multi-Agency Task Force for a Superfund Mining Site

Water quality of the Upper Arkansas River Basin has been impacted due to mining, beneficiation, post-mill smelting, farming, and urbanization over the past century. Water quality impacts in the Arkansas drainage have been especially acute in the Leadville mining district, including the California Gulch Superfund site, the Leadville mine drainage tunnel discharge, and mine discharges from the Cripple Creek mining district, the Chalk Creek mining district, and miscellaneous mines in the watershed. The primary threat to aquatic life in the Arkansas and its major tributaries is the inflow of dissolved metals (i.e., zinc, manganese, cadmium, lead, copper, iron, and nickel) at levels exceeding the state water quality standards. The majority of the problem creeks are acidic (pH between 2.5 and 3.0). In recent years, toxic metal pollution of Chalk Creek was noted when over 800,000 trout fingerlings died in the spring of 1985 and spring of 1986 after placement in the Colorado Division of Wildlife's Chalk Creek Fish Rearing Unit.

Given the large number of sources impacting the Arkansas drainage, a multi-agency demonstration project has been established to reduce, and possibly eliminate, the existing mining-related nonpoint sources of pollution in Chalk Creek so that the salmonid (i.e., trout) fishery can be returned. EPA has provided grants to the State of Colorado Water Quality Control Division (CWQCD), Department of Health and the State of Colorado Department of Natural Resources, Mine Land Reclamation Division (MLRD) to conduct the Chalk Creek - St. Elmo Nonpoint Source Water Improvement Demonstration Project. At the request of CWQCD, a Colorado Nonpoint Source Task Force (CNSTF) was formed. The Task Force is comprised of four subcommittees, including one on mining. The subcommittee on Abandoned and Inactive Mines is comprised of agencies and individuals involved in efforts to control inactive mine pollution of the Basin. Groups or organizations that are contributing funds or services to the Chalk Creek demonstration project include Coors Pure Water, Cyprus Coal Company, the U.S. Bureau of Mines, the U.S. Bureau of Reclamation, the Soil Conservation Service, and Volunteers for Outdoor Colorado tree planting, among others.

Highlight F-9:
Ecological Risk Assessment Team

The ecological risk assessment team may include personnel from the following resources:

EPA Regional Offices
- Environmental Services Division
- Environmental Response Team
- Water Division

EPA National Offices
- Office of Research and Development

Other Federal Agencies
- US Geological Survey
- US Fish and Wildlife Service
- US Department of Agriculture
- National Oceanic and Atmospheric Administration

States
- State Fish and Wildlife Service

Task 5: Evaluate aerial and other photographs of the site

Aerial photographs are helpful to both the ecological and human health risk assessors for several purposes:

> Verifying the existence and precise location of various site features and determining the spatial extent of waste piles and other sources;
>
> Identifying erosion patterns and other topographic features that can influence contaminant migration pathways and the location of deposition areas;
>
> Locating evidence of past mining operations that are not included in the historical record (or whose existence is uncertain); and
>
> Documenting and/or verifying the site history, if a time series of aerial photographs dating from near the beginning of mining operations to the present is available.

For ecological risk assessors, aerial photographs can provide additional information:

> Delineating the location and extent of various on-site and nearby habitats, although some ground-truthing (i.e., confirming designations by visiting key locations on the ground) usually is required even at the scoping phase (see Task 7); and
>
> Documenting vegetation loss over time and identifying sources that may have caused the losses, if a time series of aerial photographs is available.

Task 6: Evaluate infrared aerial photographs of the site

Infrared aerial photography taken during the growing season can be useful in identifying areas of stressed vegetation. Locating such areas may help identify contaminant sources or areas where hazardous wastes have migrated that otherwise might be overlooked. Although this step can be somewhat expensive (e.g., photointerpretation by a skilled expert is essential), a good series of infrared photographs can save money in the long run by allowing one to identify and bound areas that might require additional investigation. Some ambiguities are possible, however, and ground-truthing usually is necessary. These photographs should not be considered a substitute for a site visit.

Task 7: Plan a site visit

When scoping an ecological assessment, the site and surrounding areas should be visited at least once. Site visits allow the RPM to become familiar with the location, size, and general condition of the site and nearby environments. Some signs of impacts can be observed via careful examination by a trained ecologist/biologist. To be effective, site visits require careful planning, as described in the following paragraphs. The site visit should be coordinated with any site visits planned for scoping the human health assessment.

Ensure that the right personnel are included in the site visits. Ensure that at least one person who is familiar with site-specific fauna and flora takes part in all site visits. No written guidance can replace the expertise of a trained field ecologist/biologist in identifying and describing signs of exposure or impacts, noting the absence of species expected to be present,

and locating appropriate reference habitats. Such an individual also may be helpful in characterizing the overall condition of various habitats and in developing or refining specific hypotheses to be tested. Types of individuals who may be helpful during site visits include:

- Representatives of natural resource trustees (e.g., FWS, NOAA) who have appropriate training and expertise;
- Appropriate representatives of state or local wildlife, fish and game, natural resource, or equivalent agencies; and
- Members of BTAGS (although this is not their usual role).

Prepare a list of areas to visit. Areas to visit should include all main contaminant migration pathways as well as on-site, nearby, and reference habitats and other specific areas that may need to be sampled. Specific areas to visit should include habitats that are:

- Known to be contaminated;
- Located between contaminant sources and areas known to be contaminated;
- Located along known or potential contaminant migration pathways; and
- Appropriate reference areas.

Reference areas. In general, an appropriate reference area is one that includes similar habitats/ecosystems, yet is relatively unimpacted by contaminants from the site. There are two approaches to identifying these areas: (1) trying to identify an area upgradient (e.g., upstream) of the site that is otherwise similar; or (2) trying to locate a similar habitat (e.g., stream order, surrounding vegetation, altitude) elsewhere in the same drainage basin that has not been affected by mining activity. The first approach is preferable because the closer the reference area to the site, the more similar to the site its ecological setting is likely to be. Care must be taken to establish a reference area sufficiently far upgradient that it is unlikely that site contaminants have reached the reference area by any means. Sometimes, however, the upgradient area is significantly different from the area potentially affected by the site (e.g., lower order streams, different stream bottom type, different cover and temperature). If this is the case, the second approach may be preferable. A trained biologist is needed to identify appropriate reference areas or to design alternative studies in the absence of an adequate reference area.

Determine when to visit each area. Timing can be critical for characterizing the overall condition or quality of a given environment. Many plants and animals are markedly seasonal in occurrence or abundance; snow cover and other seasonal events may interfere with observations. During a given season, activity patterns of most animals exhibit diel (i.e., daily) variability (e.g., owls and most mammals are active largely at night, birds sing largely in the early morning, dragonflies are active primarily during the warmer parts of the day). For each area, determine which areas to visit in early morning, mid-day, late afternoon, and/or night.

Task 8: Conduct the site visit

Visit reference areas and habitats first. It may be helpful to visit all known or potential reference environments prior to conducting site visits in order to characterize or become familiar with typical conditions in the area.

Visit all study areas. Visits to each area should include walks down streams or rivers, along the edge of other surface water bodies, and downwind of tailings piles, open landfills, and other large areas of surface contamination. During these visits, the locations of all important habitats should be noted and any previously uncharacterized areas should be mapped.

Document signs of potential impacts. During visits to each area, a trained ecologist/biologist may be able to detect signs of potential impacts and note the location of these observations on the site map. When looking for signs of potential impacts, focus first on those portions of each area that are most likely to be contaminated (e.g., the most likely point at which contaminants would enter a surface water body or a wetland, the portion of an environment closest to the source, deposition areas such as river bends where sediments are likely to accumulate).

Subtle indicators of potential impacts (e.g., changes in community structure or species diversity) may not be evident during relatively brief site visits. However, unusual colors or odors or the *absence* of certain characteristic features of healthy environments can be noted during a site visit and provide evidence of potential impacts. For example, lack of dragonflies or other insects typically found at or near the edges of rivers and streams or lack of insects typically associated with leaf litter may indicate ecological impacts. In shallow streams, fish, crayfish, snails, and aquatic insects often can be seen if present. If definitive documentation of reduced abundance or diversity of species is needed, however, it would be necessary to include a systematic biological survey in the RI.

Task 9: Modify maps and hypotheses

Subsequent steps in scoping will be facilitated by a scale map that identifies the following:

Location and type of sources (e.g., waste rock piles, tailings piles, tunnel entrances);

Hazardous wastes and substances known or suspected to be present in each source;

Potential discharge or release areas (e.g., tunnel discharge areas, groundwater seeps);

Topographic features that would facilitate migration of contaminants from sources to nearby habitats (e.g., drainage ditches, creeks, depressions) and would facilitate deposition of contaminants (e.g., river bend);

Location and areal extent of known adverse impacts that might be site-related (e.g., locations of fish kills, areal extent of stressed vegetation).

Location of on-site and nearby habitats; and

Location of potential reference habitats.

It is important to remember that for most mining sites, the large-scale physical disturbances of the terrain can be responsible for a large proportion of observed impacts on vegetation (e.g., once a hilly terrain is stripped of vegetation and top soil, native plants may not be able to reestablish for decades). Thus, maps also should include indications of where physical disturbance and erosion may have occurred.

At this time, hypotheses about contamination and threats may need to be refined or otherwise modified. In certain areas, observation may confirm contamination, indicate that contamination is unlikely, and/or identify new potential threats.

Task 10: Characterize the ecological setting and potential receptors

Using the results of the previous steps, it now should be possible to identify and characterize the potentially exposed habitats on or near the site and potential species, communities, or functions such as wetlands impacted in these habitats. This task includes several steps:

> Describing and delineating the terrestrial, wetland, and aquatic habitats;
> Identifying the species indicative of the healthy functioning of similar habitats (e.g., top level carnivore, trout in cold water streams, naturally dominant vegetation, aquatic insect larvae);
> Identifying endangered or threatened species potentially on or near the site; and
> Identifying other species protected under federal or state law (e.g., Migratory Bird Treaty Act, Marine Mammal Protection Act).

If contaminants at the site are known to bioaccumulate (e.g., cadmium, mercury), it is important to consider trophic relationships among the wildlife species so that the potential for food-chain effects can be assessed. Descriptions of potentially affected habitats should include as much detail as is necessary to scope the work. For example, stream aquatic communities vary considerably depending on depth, width, flow, type of bottom, and types of vegetation in and adjacent to the stream. These attributes affect both the kinds of studies required to evaluate possible effects and the level of effort needed to conduct the studies.

F.6 Develop Conceptual Site Model

The end product of the ecological problem formulation process is a conceptual site model (Highlight F-10). The model should identify possible contaminant sources, primary and secondary release mechanisms, exposure pathways, and environmental receptors. The model also should identify additional data needs and the analyses to be used. The steps for developing a conceptual model are listed in Highlight F-10 and discussed in the remainder of this section.

Task 1: Qualitatively evaluate contaminant release, migration, and fate

Evaluate contaminant release, migration, and fate in conjunction with the human health assessors. Compile a list of possible contaminants and describe existing information on contaminated media, contaminant migration, and the geographical extent of current and potential contamination.

Identify sources that have released contaminants. Information used to support HRS scoring may include the identity, approximate size, and location of sources known to have released contaminants. Information obtained when developing the history of site operations might help to identify other sources that have released contaminants.

Identify contaminant migration pathways. It is important to identify the key contaminant migration pathways. Considerations at mining sites in particular include the following:

> Runoff from and erosion of contaminated soils, tailings piles, or surficial materials into rivers, streams, and lakes;
>
> Leaching of contaminants in soils and waste piles to groundwater and subsequent discharge to surface water and wetlands;

Collapse of tailings piles into surface waters;

Tunnel surges (e.g., from collapse of a tunnel roof that temporarily dams water until the water pressure is sufficient to break through the debris);

Tunnel seepage (often very acidic);

Surface water transport and redistribution of contaminated sediments;

Air transport of contaminated soils or surficial materials (e.g., flue dust from smelter activities); and

Bioaccumulation and bioconcentration of contaminants in food chains.

Highlight F-10:
Ecological Problem Formulation (Scoping) Conceptual Model

Qualitatively evaluate contaminant release, migration, and fate

Identify:
- contaminants of ecological concern
- potential ecological receptors
- potential exposure pathways
- known effects

Select endpoints of concern

Develop conceptual model; identify:
- scope
- data needs

For surface water contamination, it also is important to determine the critical conditions affecting surface water contaminant loading (e.g., is it low flow during the winter or the spring flush?).

Identify potential or actual areas of contamination. Delineate the spatial extent of known contamination to the extent possible. Sampling efforts used to determine the HRS score for the site may have identified at least some areas known to be contaminated above background levels. For sites scored with the revised HRS, there also may be information on existing contamination of sensitive and other nearby habitats. Identify any habitats known to be contaminated or located within, between, or downgradient of areas of known contamination. Also, identify potential deposition areas for contaminated soils and sediments (e.g., bends in rivers) and other types of hot spots.

Task 2: Identify contaminants of ecological concern

EPA's *ECO Update*, Volume 1, Number 2[8] describes factors to consider in identifying contaminants of ecological concern. We review those factors here. From the list of possible contaminants developed in the qualitative evaluation (Task 1), identify those contaminants that may be of ecological concern, considering the following:

Amount of contaminant:
- Environmental concentrations in media that represent ecological exposure pathways (i.e., soil, surface water, sediment, and biota);
- Known extent of contamination in on-site and off-site media; and
- Background levels, indicating contamination that cannot be attributed to the site.

Attributes of contaminant:
- Physical-chemical properties (e.g., volatility, solubility, and persistence);
- Bioavailability (i.e., presence in a form that can adversely affect organisms);
- Potential for bioaccumulation or bioconcentration (e.g., log K_{ow} between 3 and 7);
- Toxicity (i.e., the amount of toxicant capable of producing adverse effects in organisms)[9];
- Time necessary to produce adverse effects (i.e., days, weeks, years); and
- Type of effects (e.g., lethal or sublethal responses).

Task 3: Identify potential ecological receptors

Ecological receptors include individual organisms, populations, or communities that can be exposed to contaminants. After the fate, migration, and potential release of contaminants have been reviewed, potential receptors can begin to be identified. Identify potentially exposed terrestrial, wetland, and aquatic habitats on or near the site and develop lists of species known or likely to occur in each habitat. Identified receptors should include species on or near the site that are:

Endangered or threatened;
Protected under other federal or state law (e.g., the Migratory Bird Treaty Act);
Rare or unique; or
Considered indicative of the healthy functioning of the community.

The revised Hazard Ranking System (HRS) contains a list of sensitive aquatic and terrestrial environments as shown in Highlight F-11. For NPL sites listed after March 14, 1991, all sensitive environments within the HRS target distance limits (generally a 4-mile radius for terrestrial environments and 15 miles downstream for aquatic environments) should be identified in the HRS scoring package and related materials. At mining sites, however, further distances from the site may need to be considered (e.g., entire drainage basins because of the large quantities of waste present). The HRS scoring package also may provide some information as to whether or not any sensitive environments are contaminated.

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[8] Op. Cit. 2.

[9] One source of information on relative toxicity to aquatic organisms can be EPA's ambient water quality criteria (AWQC) for the protection of aquatic life. See section H.14.

Sources of Information. Several sources of information can be helpful in identifying habitats and species on or near the site:

Aerial photography and satellite imagery;
Site visits;
HRS guidance materials in Regional offices (may include catalogues, maps, or other compilations of some types of sensitive environments);
National Wetland Inventory maps;
U.S. Geological Survey topographic maps;
Natural Resource Trustees;
State or local fish and game agencies (e.g., any history of ecological effects from site);
Water monitoring programs for surface water quality; and
State Natural Heritage Programs.

Task 4: Identify potential exposure pathways

An exposure pathway is the link between a contaminated area and a receptor. Potential exposure pathways for ecological receptors can be identified from the analysis of contaminant release, migration, and fate, and from the receptors present. In evaluating exposure pathways, consider all relevant media (i.e., surface water, sediment, soil, and biota) that are or potentially could be contaminated. For example, organisms may be exposed by direct contact with contaminated media or by indirect contact through the food chain. Consider all potential receptors when identifying exposure pathways. There are several exposure pathways that often are of concern at mining sites:

Direct contact with contaminated sediments for benthic invertebrates, bottom-dwelling fish, fish eggs and fry, and amphibian eggs and tadpoles;
Direct contact with water column contaminants for fish;
Ingestion of contaminated sediments by benthic invertebrates, bottom-dwelling fish, and waterfowl;
Ingestion of contaminated soils by worms, other invertebrates, and burrowing mammals;
Ingestion of contaminated soils and forage plants by grazing herbivores (e.g., deer, domestic livestock);
Ingestion of contaminated aquatic prey by piscivorous birds and mammals and by waterfowl; and
Ingestion of contaminated small mammals by raptors and carnivorous mammals.

Task 5: Identify known effects

In contrast to other types of Superfund sites, the contaminants at mining sites typically are limited to metals and a few other types of substances (e.g., cyanide, sulfuric acid, phosphorus). For aquatic communities, EPA's ambient water quality criteria (AWQC) for the protection of aquatic life can be used to identify contaminant levels in the water column below which adverse effects on aquatic communities are unlikely to occur. It is important to remember that these criteria are not necessarily protective of benthic aquatic communities (i.e., organisms that live in close association with sediments). Possible contaminant effects on terrestrial mammalian species can be identified from the toxicological literature compiled in support of criteria developed for the protection of human health (e.g., EPA Reference Doses (RfDs)). Data on the effects of most of these substances on other terrestrial groups (e.g., birds, amphibians) are available in the published literature.

In the event that an unusual organic or metal compound is of concern, other sources can be consulted. For example, the AQUatic Toxicity Information REtrieval (AQUIRE) data base contains data that can be used to evaluate the effects of contaminants on aquatic organisms. Where appropriate, data on chemicals similar but not identical to site contaminants can help characterize likely effects. Modeling techniques, such as Quantitative Structure Activity Relationships (QSAR), also can be used to estimate the toxicity of untested chemicals. These methods require specialized expertise to ensure proper interpretation of results.

The RPM also should obtain information from appropriate investigations conducted on or near the site to help target the ecological assessment toward the most relevant questions. Examples of useful studies include:

Studies in support of fish or wildlife consumption advisories issued by state or local government agencies;

Corroborative reports of unusual events such as stressed vegetation, fish kills, other mortality events, or absence of species expected in the habitat; and

Field or laboratory studies from previous investigations of the site (e.g., preliminary investigations).

Task 6: Select endpoints of concern

A critical step in selecting endpoints is deciding what effects are important to the remedial decision-making process (i.e., assessment endpoints) and what measurements can be used to evaluate these effects. *An assessment endpoint is any specific value to be protected,* for example, a supply of uncontaminated fish for anglers to catch, survival of an endangered species, or maintenance of a particular population. *A measurement endpoint is a quantifiable characteristic related to an assessment endpoint,* such as the chemical concentration in water that correlates with contaminant levels of concern in fish tissues.

Ideally, measurement and assessment endpoints are the same, but this seldom is possible. For example, one can't trap endangered species and analyze their organs for contaminants. In this case, separate measurement endpoints are needed. Usually several measurement endpoints must be evaluated to determine the status of an assessment endpoint. It must be possible to link clearly the measurement endpoints to their respective assessment endpoints.

In addition, measurement endpoints should provide information about the source of the effects on the assessment endpoint. For example, it is not enough to know that eagles are not reproducing well at a site; a substance that can cause this effect (e.g., DDT) also must be present at the site, and the eagles must be exposed to it in some way (e.g., through contaminated fish). In this example, the assessment endpoint is eagle population maintenance, and the measurement endpoints are DDT residues in site soils and in fish (and perhaps facility records showing releases).

The linkages between the endpoints are as follows: Eagle population maintenance is of concern at the site DDT was produced there and released DDT causes reproductive failure in eagles DDT is found in fish species that the eagles consume within their feeding areas eagles can reasonably consume enough DDT to cause reproductive effects.

It is not uncommon to redefine measurement endpoints during the analysis phase or after the scoping process given the heterogeneity of site habitats and the constraints of our knowledge base. Rationale for any changes should be documented.

Highlight F-11:
List of Sensitive Environments in the Hazard Ranking System.[a]

Critical habitat for Federal designated endangered or threatened species
Marine Sanctuary
National Park
Designated Federal Wilderness Area
Areas identified under the Coastal Zone Management Act
Sensitive areas identified under the National Estuary Program or Near Coastal Waters Program
Critical areas identified under the Clean Lakes Program
National Monument
National Seashore Recreational Area
National Lakeshore Recreational Area

Habitat known to be used by Federal designated or proposed endangered or threatened species
National Preserve
National or State Wildlife Refuge
Unit of Coastal Barrier Resources System
Coastal Barrier (undeveloped)
Federal land designated for protection of natural ecosystems
Administratively Proposed Federal Wilderness Area
Spawning areas critical for the maintenance of fish/shellfish species within river, lake, or coastal tidal waters
Migratory pathways and feeding areas critical for maintenance of anadromous fish species within river reaches or areas in lakes or coastal tidal waters in which the fish spend extended periods of time
Terrestrial areas utilized for breeding by large or dense aggregations of animals
National river reach designated as Recreational

Habitat known to be used by state designated endangered or threatened species
Habitat known to be used by species under review as to its Federal endangered or threatened status
Coastal Barrier (partially developed)
Federal designated Scenic or Wild River

State land designated for wildlife or game management
State designated Scenic or Wild River
Stage designated Natural Areas
Particular areas, relatively small in size, important to maintenance of unique biotic communities

State designated areas for protection or maintenance of aquatic life

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[a] The categories are listed in groups from those assigned higher factor values to those assigned lower factor values in the HRS. See *Federal Register*, Vol. 55, p. 51624 for additional information regarding definitions.

Other examples of assessment endpoints established at some mining sites include the following:

- Reestablishing a self-sustaining trout (or other sport) fishery in affected surface waters;
- Revegetation to control fugitive dust and erosion and to improve wildlife habitat;
- Attainment of designated beneficial use for surface waters (although attainability analysis can indicate use limitations for a variety of reasons unrelated to the mining site); and
- Attainment of the same level of water quality as upstream of the site.

Examples of measurement endpoints include:

- Contaminant concentrations in surface water, sediments, and soils;
- Contaminant concentration in fish tissues or other biota;
- Toxicity of surface waters using surrogate species (e.g., fathead minnow) or assessment species (e.g., trout fry);
- Plant root and shoot elongation bioassays using site soils; and
- Presence/abundance of biological indicators of stream water quality (e.g., insect larvae).

Task 7: Use flow diagrams and maps to help define a conceptual model

In finalizing the conceptual model for the site, establish the following:

(1) A flow chart depicting how contaminants move from sources to receptors, including release mechanisms, secondary sources (e.g., contaminated soil), secondary release mechanisms (e.g., wind erosion), contaminant migration pathways (e.g., air, surface water), receptors (e.g., aquatic community) and routes of exposure (e.g., direct contact, food chain);

(2) A flow chart depicting how the proposed measurement endpoints can be used to infer the status of the assessment endpoints; and

(3) A map of the site depicting contaminant sources, migration pathways, key habitats, and potential exposure areas for receptors of concern. The map will be particularly helpful in establishing the spatial aspects of the field sampling plan.

Flow charts and maps can facilitate discussions among members of the site assessment team and the RPM, help identify gaps in data or logic, and identify the field sampling needs. Highlight F-12 provides an example of a flow chart for a conceptual model for the ecological risk assessment.

F.7 Identify Initial Project/Operable Unit and Remedial Action Objectives

Once the existing site information has been analyzed and a conceptual model of the site developed, the assessment team can identify the project/operable units, likely response scenarios, and remedial action objectives. This step requires close coordination of the ecological and human health assessment teams and is described in detail in EPA's Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA[10]. For each contaminated medium:

Identify potential remedial action technologies;
Begin review of technologies;
Identify likely alternatives; and
Identify need for treatability studies.

This step is particularly important for ecological concerns at mining sites, because restoration to pristine conditions generally is not possible and options for remediation can be limited by the magnitude and scope of the environmental contamination. *The ecological assessment should be focused within these constraints; otherwise, more effort may be expended on the assessment than is necessary or useful.*

Many of the adverse impacts of mining waste sites on terrestrial and aquatic habitats result from non-chemical stressors. The large-scale physical disturbances associated with former surface mining operations in particular can result in severely degraded landscapes. Once vegetation is lost and exposed soils erode for many years, decades may be required for reestablishment of vegetative cover by natural processes. Severe sedimentation of streams also is a common result of surface mining operations. Loss of trees on river banks can cause

[10] Environmental Protection Agency (EPA). 1988. *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*. Office of Emergency and Remedial Response, Washington, DC. OSWER Directive No. 9355.3-01.

bank degradation and increase surface water temperatures. Even for those impacts or potential impacts that can be attributed to mining-related chemical stressors, options for remediation can be limited:

Because of the large areas involved, it generally is not possible to reduce substantially contaminant levels in soils;

Because of residual metal contamination in soils, it often is not possible to reestablish native vegetation; and

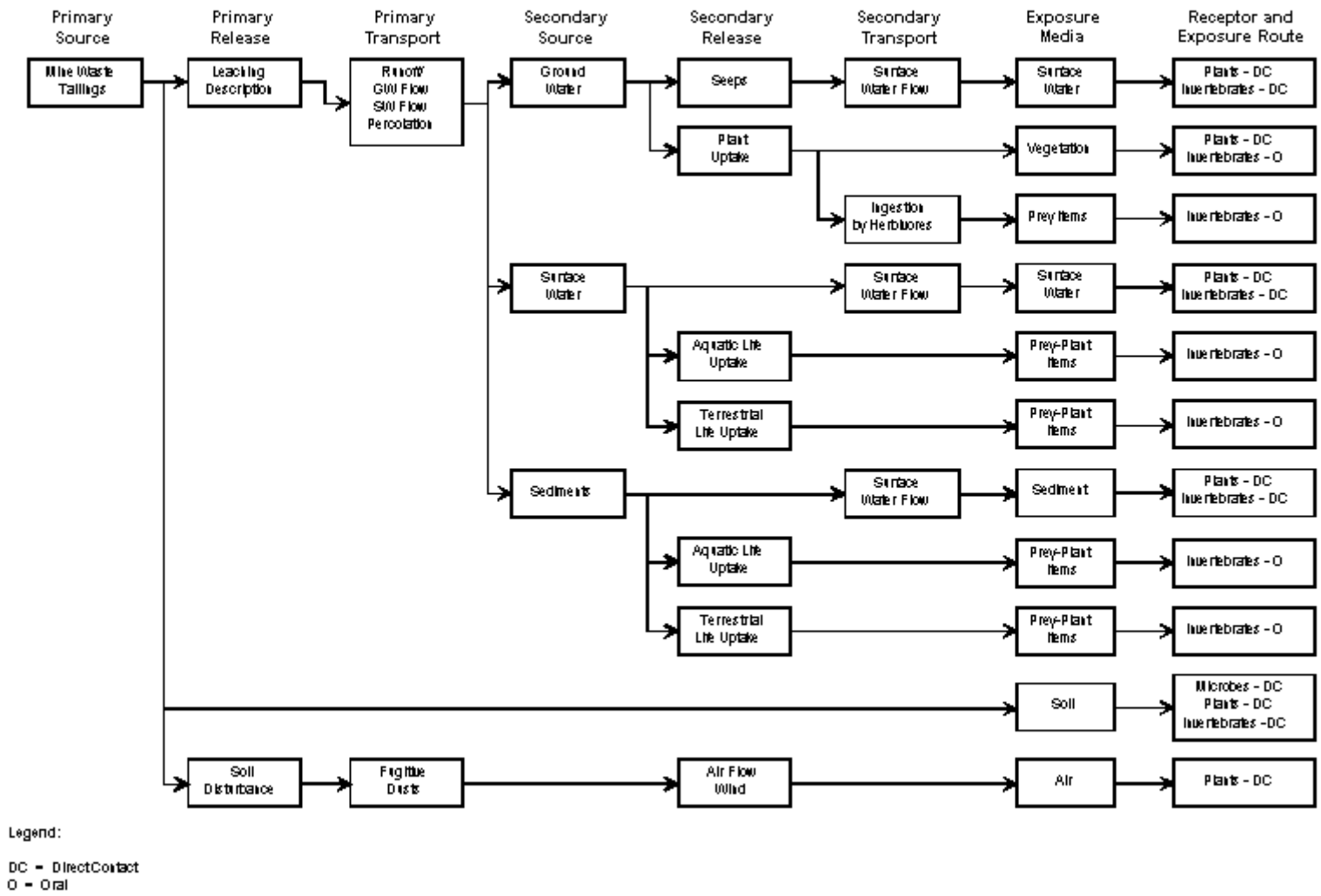
Again, because of the large areas involved, it generally is not possible to excavate contaminated sediments in affected surface waters.

Sometimes more moderate goals can be met:

Containment of sources of contamination to surface waters usually is possible; and
Establishing some type of vegetative ground cover may be possible and important for control of erosion due to wind and precipitation as part of a containment strategy.

For older mining sites at which revegetation already has occurred naturally over waste pile areas, it may be preferable to leave the piles in place rather than to remove or disturb the piles and eliminate the established vegetation.

Highlight F-12
Example Flow Chart for a Conceptual Model for the Ecological Risk Assessment



Legend:

DC = DirectContact
O = Oral

F.8 Initiate Potential Federal/State ARARs Identification

CERCLA requires that Superfund remedial action meet other federal and state standards, requirements, criteria, or limitations that are "applicable or relevant and appropriate" (ARARs). The on-scene coordinator (OSC) or the RPM must identify potential ARARs for each site. EPA's *Risk Assessment for Superfund: Volume 2 - Environmental Evaluation Manual*[11] summarizes ARARs relevant to ecological concerns at Superfund sites.

For mining sites with on-site or nearby surface water or wetlands, state water quality standards for designated uses of rivers, streams, or lakes are ARARs. These may include narrative free from toxics and antidegradation standards. State chemical-specific numeric standards usually are adopted or modified from EPA's Federal Ambient Water Quality Criteria (AWQC), which are ARARs in the absence of state standards for a particular contaminant or water condition. EPA's AWQC include criteria to protect fresh and salt water plants and animals and their habitats from acute and chronic exposures to toxic substances in surface waters (but not in sediments). EPA AWQC were promulgated pursuant to the Federal Water Pollution Control Act, as Amended (Clean Water Act). This law also requires protection of wetlands and other areas and may pertain in several ways to the remediation of mining sites located near wetlands or surface water bodies.

EPA's Storm Water Regulations (40 CFR Part 122) establish requirements for storm water discharges associated with "industrial activity", including inactive mining operations that discharge storm water contaminated by contact with, or that has come into contact with, any overburden, raw material, or waste products located on the site of such operations (inactive mining sites are mining sites that are not being actively mined, but which have an identifiable owner/operator) (40 CFR 122.26(b)(14)). See Appendix E for a further discussion of the implications of this ARAR to mining Superfund sites.

Other federal environmental statutes and regulations that include ecologically relevant ARARs are summarized below:

> ***Endangered Species Act of 1973, as reauthorized in 1988.*** This Act requires federal agencies to ensure that their actions will not jeopardize the continued existence of any endangered or threatened species. Many mining sites are located in otherwise pristine areas that have historically supported a variety of wild flora and fauna, and the ecological assessment should determine if there is a possibility of endangered or threatened species in the vicinity of the site. If there is, EPA must consult with the FWS.
>
> ***Fish and Wildlife Conservation Act of 1980***. This Act requires states to identify significant habitats and develop conservation plans for these areas. The OSC or RPM should consult the responsible state agency to determine whether the mining site is located in one of these significant habitats.
>
> ***Wild and Scenic Rivers Act of 1972***. 0 This Act declares that certain rivers should be preserved. The ecological assessment should determine whether there are any designated Wild or Scenic rivers near the mining site.

[11] Environmental Protection Agency (EPA). 1989. *Risk Assessment Guidance for Superfund: Volume 2 - Environmental Evaluation Manual.* Interim Final. Office of Solid Waste, Office of Emergency and Remedial Response, Washington, DC. EPA/540/1-89/001A.

Fish and Wildlife Coordination Act, as amended in 1965. This Act states that the FWS must be consulted when bodies of water are diverted or modified by another federal agency.

The Migratory Bird Treaty Act of 1972. This statute protects almost all native bird species in the U.S. from unregulated "taking", which can include poisoning at hazardous waste sites. This Act would probably apply at many mining sites.

The Surface Mine Control and Reclamation Act of 1977. This Act requires that excavated surface mines be filled in with the overburden stripped from the mines, returning the area approximately to its original contour.

In addition to federal regulations, other state and local requirements also may be applicable or relevant and appropriate. Consult the *CERCLA Compliance With Other Laws Manual*[12] for more detailed information on ARARs and their relevance to Superfund cleanups of mining sites. Also, consult with the BTAG.

F.9 Identify Initial Data Quality Objectives (DQOs)

Chapter 7, Sampling and Analysis, discusses DQOs. The field data for site characterization must be accurate and amenable to statistical analysis. Consequently, DQO's reflect the statistical design of the study and the level of significance needed to support any conclusion that might be drawn from the study (see also *ECO Update*, Volume 1, Number 4[13]). In particular, the RPM should ensure that minimum sample sizes to allow statistically valid analyses are specified for each type of study or each study area. In general, the more variable the attribute being measured, the more samples will be required to demonstrate significant differences between control and test groups or between reference and study areas. Data quality objectives also should address sampling completeness, comparability, representativeness, precision, and accuracy, as described below.

Completeness. To ensure a complete data set for statistical analysis with acceptable confidence limits, minimum sampling requirements should be described and contingency plans established for problems that might occur and affect the completeness of the field data. For example, some sample locations may be inaccessible, some samples might not be analyzed for certain substances due to matrix interference, and other samples might be invalid due to holding time violations. It also is important to identify the environmental data that need to be collected concurrently with biological or chemical samples (e.g., water temperature, pH, dissolved oxygen, water hardness).

Representativeness. It is important that the sampling locations be representative of the media, habitats, and exposure areas at the site, i.e., that the locations are typical or characteristic of the media/habitat, and not unusual in some way that might bias the results.

Comparability. Combining results from several analytic techniques and sampling events usually is necessary for the baseline risk assessment. When toxicity tests or community surveys are conducted on samples from the site, analytic chemistry should be performed on samples taken from *the same location at the same time*. If sampling is conducted in more than one phase and data from different phases of the study are to be combined, special attention to

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[12] Environmental Protection Agency (EPA). 1988. *CERCLA Compliance with Other Laws Manual, Part 1*. Office of Emergency and Remedial Response, Washington, DC. OSWER Directive 9234.1-01.

[13] Op. Cit. 3.

factors that could affect sample comparability is needed (e.g., detection limits, sample preparation procedures, season or other time-variable attributes that might affect results).

Precision and Accuracy. The contractor's work plan should establish quality control procedures to ensure precision and accuracy for field work and laboratory analyses for activities including sample handling, controls for tests, and numbers of replicate analyses. Use of standardized methods, when appropriate, facilitates quality control; standardized protocols can be found in EPA manuals and are utilized by the contract laboratories that routinely conduct tests for EPA. As described in *ECO Update*, Volume 1, Number 4[14], some laboratories have established standard quality control procedures for aquatic toxicity tests conducted under the National Pollutant Discharge Elimination System (NPDES) (e.g., with fathead minnows, *Daphnia*, algae). Many states have certification programs for these laboratories' tests. For less standardized procedures, appropriate quality control measures need to be specified. For example, an independent taxonomist could enumerate and classify the organisms found in a randomly selected set of benthic invertebrate samples.

F.10 Prepare Statement of Work for the Site Characterization Phase

The project requirements for the RI/FS should be identified and documented in a statement of work (SOW) developed by EPA. The contractor or PRP performing the field investigation then develops project plans including the work plan, sampling and analysis plan, and field sampling plans (Highlight F-6) that address the SOW. The project plans for the ecological assessment need to be developed in conjunction with the human health risk assessment team. The RPM should schedule a review of the contractor or PRP's work plan by the BTAG before field work begins. In several Regions, BTAGs have prepared example SOWs or other guidance materials for RPMs. *ECO Update*, Volume 1, Number 4[15] explains how to develop a SOW.

Overview. The SOW and project plans for the RI should define the objectives of the study, the proposed field or laboratory methods (with appropriate reference to Agency guidelines or other sources), expected sampling locations and sizes, the statistical methods to be used, and data quality objectives and control procedures. The success of a work plan for the RI site characterization and baseline risk assessment may be enhanced considerably by developing preliminary hypotheses regarding:

Contaminant sources and migration pathways;
The nature and extent of existing contamination at the site;
The potential for future releases and further contamination at the site; and
The number and types of habitats that might be contaminated now or in the future.

These preliminary hypotheses, in turn, will assist in identifying or determining:

Specific areas at the site and in the surrounding area that need to be sampled or surveyed; and
The number of chemical samples (and sampling locations) that will be required to adequately characterize the existing or potential future contamination.

The SOW and work plan also should discuss how decisions will be made about the need for additional studies.

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[14] Ibid.

[15] Op. Cit. 3.

Specific tasks. The remainder of this section outlines specific tasks associated with developing initial hypotheses about existing and potential future contamination. As a general rule, it is helpful to focus first on areas of known contamination and sources that have released contaminants, develop hypotheses regarding the magnitude and areal extent of known contamination, and then develop hypotheses regarding the potential for future contamination.

Task 1: Coordinate with human health assessment team

Usually, the ecological assessors identify areas and types of samples that are needed in addition to those identified by the human health team. If the human health assessment team has the lead in developing the field sampling plan, the ecological assessment team must review the plan to determine if additional samples are required for the ecological assessment.

Task 2: Coordinate with natural resource trustees and the BTAG

The success and efficiency of the site sampling effort will be enhanced considerably by close coordination with the natural resource trustees and the BTAG. At a minimum, trustees should be involved in review of the initial and final sampling plans. Because trustees are required to quantify natural resource injury and damage, they might need to conduct sampling beyond what EPA needs for a baseline risk assessment. For example, the trustee may need to demonstrate the areal extent of resource injury, while EPA may need only to demonstrate risk to those resources. Because BTAGs generally include representatives from natural resource trustees as well as provide technical assistance for conducting ecological risk assessments, the BTAG also can help determine which types of samples are likely to be the responsibility of the trustees and which should be collected by EPA.

Task 3: Delineate potential assessment areas

Often, large mining sites are subdivided into several operable units. The conceptual model of the site should provide an overview of the relationship among operable units and the entire watershed. To develop field sampling plans, however, it can be helpful to subdivide the site or operable units into areas that may require different sampling strategies. Using the site map developed with the conceptual model of the site, delineate areas on the map that may require different investigation strategies. Usually, separate "assessment areas" should be delineated *for each combination* of the following factors:

Type of medium being sampled (e.g., sediment, water, fish tissues);
Habitat or ecological receptor;
Contaminants of concern;
Level of contamination (e.g., close to a source, more distant, deposition area in a stream);
Type of remediation likely, and
Expected response (either in terms of speed or type of response, e.g., reduced contaminant concentrations) to potential remedial actions.

Within each assessment area, determine whether any sampling location within the area could be considered representative of the area or if a gradient of contamination is expected. To maximize the efficiency of possible sampling designs, delineate assessment areas that are as large as possible. Potential assessment areas may be refined based on site visits and as hypotheses are accepted or new hypotheses are developed.

If more than one medium is to be sampled in a given type of habitat, the size of the assessment areas may be different for each medium. For example, a set of sediment samples may be

considered representative of only a small portion of the length and width of a river, whereas a set of tissue residue levels taken from fish captured at the same locations may be considered representative of a larger section of the river.

The 1989 Record of Decision for Commencement Bay (Washington state), the Near-shore/Tideflats operable unit, although not a mining site, provides an example of how assessment areas (or segments) can assist in data analysis and identifying areas in need of remediation at large sites. At this site, the waterways leading to Commencement Bay were subdivided into segments based on proximity of sources, length of the waterway, and changes in the waterways' configuration. For each segment, three to ten sampling stations were established to represent the segment. Measures taken at most sampling stations included contaminant concentrations in sediments, sediment toxicity bioassays, and benthic infauna abundances. It was assumed that a segment would require no action unless at least one of the indicators of contamination, toxicity, or biological effects was significantly elevated above reference conditions.

Task 4: Develop specific hypotheses to be tested about the nature and extent of contamination

In order to design an RI sampling plan that will allow attribution of observed contamination to site sources, it is important to develop hypotheses concerning how the contaminants might have migrated from the sources. Use of the site map developed for the conceptual model is helpful in this step. For example, one hypothesis might be that observed contamination in a wetland is the result of runoff or leachate from a mining waste pile. Information required to evaluate the hypothesis might include groundwater and soil samples upgradient of the waste pile and between the waste pile and the wetland, groundwater and soil samples at other points upgradient of the wetland (to determine whether other sources may have contributed to the observed contamination), and the presence of other physical signs of contamination between the waste pile and the wetland (and/or between the wetland and other potential sources).

Task 5: Identify specific data needs for chemical sampling in abiotic media

For each proposed assessment area, identify the specific information that will be provided by chemical and/or other types of samples. Types of information that can be provided by chemical sampling include:

Verifying or delineating contaminant migration pathways;
Delineating areal extent of existing contamination;
Identifying hot spots (e.g., highly contaminated deposition areas);
Verifying known or suspected contamination at specific locations;
Determining background levels; and
Determining gradients of contamination in relation to known sources.

Task 6: Develop specific hypotheses about ecological exposures and effects

Using the site maps, one can overlay the location of various habitats with the expected pattern of contamination. The conceptual model then can be used to identify hypotheses about potential ecological impacts. For example, one hypothesis might be that the metals present in soils and sediments are not bioavailable, and therefore are not toxic to the potential receptor organisms. Another hypothesis might be that surface water toxicity to adult fish is less important than sediment toxicity to the eggs and fry in limiting the resident fish populations.

Task 7: Identify specific biological data needs

There are four general types of biological samples that may assist in testing hypotheses about ecological impacts: tissue residue samples, toxicity tests, biological field surveys, and biomarkers. We discuss circumstances under which each of the biological sampling methods might or might not be recommended for an ecological risk assessment below. *Note that EPA does not need to demonstrate conclusively that site contaminants caused existing impacts; EPA need only demonstrate a **risk** of these impacts now or in the future to justify remedial action.*

Tissue residue samples of fish, invertebrates, or other biota generally should be collected if there is reason to suspect that these biota have been exposed to contaminants that are likely to bioconcentrate (i.e., concentrate in tissues of aquatic organisms at levels higher than the surrounding water). If a contaminant is known or expected to bioaccumulate (i.e., is found at higher concentrations in organisms at each higher step in a food chain), samples should be taken from biota at two or more trophic levels (e.g., plant, herbivore, carnivore) along with the environmental media to which the biota are exposed. This is important because site-specific conditions influence the magnitude of bioaccumulation, and most estimates of bioaccumulation include a large range of uncertainty. Edible tissues (e.g., fillets) generally are sampled for human health risk assessments; however, whole-body samples are more appropriate for ecological risk assessments.

Toxicity tests evaluate the effects of contaminated media on the survival, growth, behavior, reproduction, and/or metabolism of test organisms. Toxicity tests conducted in the laboratory generally use standard laboratory organisms (e.g., *Daphnia*, fathead minnows). Toxicity tests conducted *in situ* (e.g., by caging test animals in the study area) can be used to evaluate toxicity or bioavailability to the particular organisms of interest at the site. Toxicity tests generally are recommended if:

> The bioavailability of contaminants in particular media (e.g., sediments) is unknown, which often is the case with contaminants at mining sites;
>
> The contaminants are toxic below quantitation limits;
>
> The toxicity of a particular site-specific mixture of contaminants in a given area cannot be estimated readily; and
>
> Supporting evidence for a hypothesized link between observed (or potential future) contamination and adverse impacts is needed to make a remedial decision.

Which specific toxicity tests are most appropriate depends on the assessment endpoints. EPA's *Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference*[16] reviews aquatic, terrestrial, and microbial toxicity test methods, including both "off-the-shelf" methods and innovative procedures. Specific toxicity test protocols continue to be developed, and the BTAG should be consulted to ensure that the most up-to-date protocols are used.

Biological field surveys need not be extensive, although they do require matching surveys from an appropriate reference area for their interpretation. Field studies offer direct or

[16] Environmental Protection Agency (EPA). 1989. *Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference*. Office of Research and Development, Environmental Research Laboratory, Corvallis, OR. EPA/600/3-89/013.

corroborative evidence of a link between contamination and existing ecological impacts but are not required for most assessments. For example, field studies can be used to:

Document or verify the absence or reduced abundance of key native species;
Evaluate suitability of habitats for wildlife species of concern;
Identify evidence of stress (e.g., stressed or dead vegetation, bare soil and erosion);
Identify changes in community structure (e.g., reduced biodiversity, altered species composition);
Illustrate an increased incidence of lesions, tumors, or other pathologies; and
Document the presence or increased abundance of species associated primarily with contaminated habitats.

If wetlands exist on or near the site, a functional evaluation of wetlands (e.g., value as wildlife habitat, for pollution abatement, or flood control) might be appropriate. EPA's *Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference*[17] includes a review of field survey methods for aquatic ecosystems and terrestrial vegetation, invertebrates, and vertebrates.

Biomarkers of exposure (e.g., enzyme activity) can be measured to verify that organisms inhabiting contaminated areas actually have been exposed to site contaminants. Given the propensity of some metals to bioaccumulate as well as the availability of sensitive and accurate techniques for routine detection of metals in biological samples, indirect indices for exposure to metals generally are not needed. Erythrocyte ALAD (delta-aminolevulinic acid deyhdratase, a cytosolic enzyme), an indicator of lead exposure, is an exception, because it can be measured in blood samples, which allows non-destructive sampling. The Field and Laboratory Reference[18] gives examples of ALAD's use as an indicator of lead exposure in fish, waterfowl, and mammals.

Highlight F-13 summarizes general types of chemical and biological studies that might be used at Superfund mining sites and the information provided by each type.

Task 8: Coordinate data collection efforts with natural resource trustees

At some sites, natural resource trustees might need to use biological surveys to document and quantify existing damages to trustee resources from site contaminants. It is very important to coordinate data collection activities with the natural resource trustees:

To avoid duplication of effort;
To maximize the usefulness of each type of data collected; and
To maximize the efficiency of data collection.

EPA has developed a Superfund fact sheet that explains in more detail how to coordinate ecological data collection activities with natural resource trustees.

[17] Ibid.

[18] Ibid.

Task 9: Develop initial field sampling plan

In conjunction with the human health assessment team, develop an initial field sampling plan for the site characterization phase of the RI. Sampling locations established in the initial sampling plan should address all relevant sources, existing contaminant migration pathways, potential future contaminant migration pathways, and habitats of concern. Using the conceptual model of the site as a guide, the initial field sampling plan should include at least the following:

A list of specific hypotheses to be tested with sampling;
For each hypothesis, the type of information that would support or reject the hypothesis;
For each hypothesis, the type(s) of samples or observations that will provide the required information;
A preliminary delineation of specific assessment areas to be sampled; and
A listing of available sampling information for each assessment area.

For each proposed assessment area and type of sample (e.g., metals in soils), the field sampling plan should determine the number of samples to collect and the specific locations for each sample. This is one of the most difficult tasks in preparing the project plans. A trade-off exists between the number of samples taken (and hence degree of certainty) versus the time, effort, and expense involved in obtaining and analyzing each sample. Suggestions on how to select the location and number of surface water and sediment samples are contained in the appendices to EPA's *Oversight* document[19] and in EPA's *Standard Operating Procedure Manual*[20]. These documents provide basic rules of thumb for determining number of sampling locations for rivers, streams, and creeks (examples in Highlight F-14); for lakes and ponds (examples in Highlight F-15); for impoundments and lagoons; and for estuaries. Some general suggestions to help in developing a field sampling plan for each assessment area follow.

Hypotheses to test. Begin with the hypotheses identified in Tasks 4 and 6 about contaminant sources, migration pathways, extent of contamination, bioavailability, and other concerns. It may help to redefine some of the assessment areas in light of the hypotheses to be tested.

Sample locations. Within each assessment area, begin with the location where contaminant concentrations are expected to be greatest. These may include the point(s) at which contaminants are most likely to enter the assessment area (e.g., the point of groundwater discharge into surface water), the point(s) in the assessment area closest to key sources, and points where soils, sediments, tailings, or other debris are likely to accumulate (e.g., bends in rivers where sediments accumulate). Second, estimate the potential extent of contamination. Sampling information obtained for HRS scoring and evidence visible in aerial photographs (e.g., tailings, sediment deposits) might help determine tentative sampling distance limits. Third, select sampling locations between the sources and the expected sampling distance limits and just beyond those limits. Where appropriate, use rules of thumb as shown in Highlights F-14 and F-15. If during the field sampling, contamination attributable to the site is found beyond the tentative sampling distance limit, it may be necessary to collect more distant samples to determine the full extent of contamination.

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[19] Environmental Protection Agency (EPA). 1991. *Guidance on Oversight of Potentially Responsible Party Remedial Investigations and Feasibility Studies, Volume 2, Appendices.* Office of Solid Waste and Emergency Response, Washington, DC. OSWER Directive 9835.1 (c). EPA/540/G-91/010b.

[20] Environmental Protection Agency (EPA). 1986. *Engineering Support Branch, Standard Operating Procedures and Quality Assurance Manual*. Region IV, Environmental Services Division.

Highlight F-13:
General Types of Studies and the Information They Provide

Type of Study	Information Provided
Samples of abiotic environmental media (e.g., surface water, soils, sediments)	Concentrations of specific contaminants in environmental media at sampling point Elevated concentrations demonstrate that contaminants have reached sampling point Concentrations can be compared to ecological benchmark levels to assess risk
Tissue residue samples of fish, invertebrates, or other biota (e.g., edible tissues, specific tissues such as liver, whole body)	Concentrations of specific contaminants in specific tissues and/or whole body of organism Elevated concentrations demonstrate that organism has been exposed to contaminants Concentrations can be compared to predicted levels to calibrate bioaccumulation and exposure models Concentrations can be used to directly estimate dietary exposures at the next trophic level
Toxicity tests (laboratory or *in situ*) using soils, sediments, or surface water from the site	Bioavailability of contaminants in environmental medium or media Toxicity of specific mixture of contaminants in environmental medium or media May provide supporting evidence for a link between contamination and adverse impacts
Biological surveys of population abundance or community structure	Documentation or verification of altered populations or communities Absence, abundance, or density of particular species Community structure (e.g., species diversity, species composition)
Biomarkers of exposure or effects (e.g., biochemical or physiological markers; lesions, tumors, or other morphological abnormalities)	Specific biochemical or physiological changes may demonstrate that organism has been exposed to particular contaminants Increased incidence of gross pathologies or morphological changes demonstrates that organisms are experiencing adverse impacts May provide supporting evidence for a link between contamination and adverse impacts.

Task 10: Determine location and number of required samples

Highlight F-14:
Example Rules of Thumb for Sample Collection in Rivers, Streams, and Creeks

To ensure representativeness, samples should be taken immediately downstream of a turbulent area, or downstream of any marked physical change in the stream channel.
At least three locations between any two points of major change in a stream (such as waste discharge or tributary) should be sampled to adequately represent the stream.
Typically, sediment deposits in streams collect most heavily in river bends, downstream of islands, and downstream of obstructions in the water.
Samples should not be taken immediately upstream or downstream from the confluence of two streams or rivers because of the possibility of backflow and inadequate mixing.

Highlight F-15:
Example Rules of Thumb for Sample Collection in Lakes and Ponds

If stratification is present in a lake or pond, each layer of the stratified water column should be sampled separately. Stratification can be determined with temperature, specific conductance, pH, or dissolved oxygen vertical profiles.
In ponds, a single vertical composite at the deepest point may be representative. In naturally formed ponds, the deepest point is usually near the center.
In lakes, several vertical composites should be taken along a transect or grid in order to ensure that the samples are representative.
Sediment samples in lakes, ponds, or reservoirs should be collected approximately at the center of the water mass where contaminated fine-grained materials are most likely to collect.

Sample number. EPA's *Oversight* document[21] and *Standard Operating Procedure Manual*[22] provide some rules of thumb for determining a minimum number of samples to obtain (example in Highlight F-14). The variability in contaminant concentrations among samples will influence the number of samples required to characterize an area within specified statistical confidence limits. Estimate the expected variability among samples. Sampling results from other Superfund mining waste sites might be helpful in determining how much variability may be expected and how many samples are needed per unit area.

Sampling times. Determine the times of year or conditional events (e.g., snow melt) when samples should be collected. It is best to collect media samples during periods when environmental conditions favor the concentration of chemicals in environmental media (e.g., avoid high-flow conditions unless immediately following a storm event that might increase contaminant concentrations in the surface water via runoff).

Reference area. Finally, reference samples should be taken from an appropriate reference area (see section F.5, Task 7) to determine background levels of contamination.

Iterative process. It can be helpful to determine the number and locations of samples iteratively, starting with an initial, general plan for each assessment area, and refining these

[21] Op. Cit. 19.

[22] Op. Cit. 20.

plans based on the specific sampling requirements for the area and how these relate to the requirements for other areas. *ECO Update* Volume 1, Number 4[23], explains this phased approach in more details.

Sampling plan. Once the number of samples that are needed for each assessment area is determined, expected sampling locations (including detailed maps) and sampling dates should be specified (and time of day if important).

Task 11: If needed, plan further site visit(s) to characterize potential ecological receptors

If any questions remain concerning the potential ecological receptors of concern (e.g., species present, habitat characteristics), another site visit with a trained ecologist/biologist(s) should be planned (see section H.5, Tasks 7 and 8). If a Preliminary Natural Resource Survey (PNRS) is needed and has not yet been conducted, the natural resource trustees should be encouraged to conduct the preliminary PNRS at this time.

F.11 Ecological Risk Assessment Guidance

After the initial sampling and studies for the RI are completed, the data are evaluated to determine if the baseline ecological assessment can be completed based on the data. This section describes the steps of the ecological assessment by which this determination is made. Section H.12 describes the objectives and rationale of the ecological assessment. The remaining sections describe the assessment in terms of the three components of ecological risk assessment: exposure assessment (section H.13), ecological effects assessment (section H.14), and risk characterization (section H.15).

F.12 Objectives and Rationale

As described in section H.4, the baseline ecological risk assessment should provide the information to answer key questions:

> Is there a potential for an adverse effect on ecological receptors; and
> If there is, what type of remedy would be needed to be protective?

In addition, the ecological risk assessment should:

> Describe the observed or potential magnitude of adverse ecological effects at the site and the primary cause of the effects; and
> Characterize the ecological consequences of the "no further action" remedial alternative;
> Determine if special measures need to be taken during remediation to protect habitats; and
> Determine what monitoring will be needed to ensure protection of ecological receptors during and after remediation.

During the ecological assessment, the data obtained during the initial RI site studies are used to refine information on the extent and magnitude of existing contamination of soils, other surface

[23] Op. Cit. 3.

substrates, surface waters, and sediments; to determine whether nearby habitats are contaminated; and to determine whether levels of contamination are sufficiently high to pose a reasonable likelihood of ecological risk now or in the future. For enforcement lead sites, a key purpose of the ecological assessment is to determine whether information is sufficient to establish and to defend an endangerment finding. It is not necessary to *prove* that impacts *are occurring* as a result of site contaminants, however (see Highlight F-16).

Highlight F-16:
Objectives of the Baseline Ecological Risk Assessment

The baseline ecological risk assessment summarizes information on contamination and observed impacts to determine whether existing contamination is likely to result in significant risk, and to determine whether additional information is required to identify remedial alternatives and goals that are protective of ecological receptors. For this assessment, it is not necessary to conduct detailed studies to demonstrate a definitive causal link between existing contamination and observed impacts. The ecological risk assessment does not have to prove that impacts are occurring as a result of contamination; instead, the risk assessment need only demonstrate that the release poses a risk of impacts.

Although EPA's remedial measures must eliminate, reduce, or control risks to the environment, it is not necessary for these measures to *restore or replace* affected natural resources. Restoration or replacement generally is the responsibility of the natural resource trustees unless the remedy itself results in injury to natural resources. For example, EPA may need to replace a wetland that is capped to prevent further contaminant migration, but EPA may not need to restore a contaminated wetland if the remedy prevents further migration of contaminants to that wetland.

It can be easier to demonstrate that a community (e.g., aquatic community, soil invertebrate community, terrestrial plant community) is at risk of adverse effects than to demonstrate that a given wildlife population is at risk. If one can delineate areas of a habitat that are contaminated at levels that might harm a proportion of the community or a key community species (e.g., the dominant species of vegetation), one can predict that the portion of the community present within these areas is at risk of adverse effects. Questions for a community-level assessment might include:

> Are the hot spots at the site sufficiently contaminated to impair the community? What proportion of the community is contaminated at levels that could result in chronic adverse effects?

For a population-level (species-specific) assessment, one needs to ask different questions:

> If an animal were to obtain a single prey or a single day's worth of food from a hot spot at the site, would it be at risk of acute poisoning?
>
> If an animal is not at risk of acute poisoning, is a large enough proportion of the home range of a single animal contaminated at sufficient levels that the animal might suffer chronic effects from longer-term exposures?
>
> How many individuals of a species might be exposed above acute and/or chronic toxicity benchmarks?

The remainder of this section outlines specific tasks associated with analyzing the field data to complete the ecological risk assessment (i.e., exposure assessment, ecological effects

assessment, and risk characterization), distinguishing community-level from population-level considerations.

F.13 Exposure Assessment

The exposure assessment quantifies the magnitude and type of actual or potential exposures of ecological receptors to site contaminants. It includes four key elements:

Documenting contaminant release, migration, and fate;
Characterizing receptors;
Measuring or estimating exposure concentrations; and
Analyzing uncertainty.

Quantifying release, migration, and fate For detailed guidance on quantifying contaminant release, migration, and fate, consult EPA's *Risk Assessment Guidance for Superfund: Volumes* 1[24] and 2[25] and the *Exposure Assessment Guidelines*[26]. In addition, the Exposure Factors Handbook, Office of Research and Development (ORD), EPA 1996, should be considered as a source.` Parameters critical for determining the environmental behavior of contaminants, including transport through the environment (e.g., through air or the food chain), include physical transformation (e.g., volatilization, absorption, precipitation), chemical transformation (e.g., photolysis, hydrolysis, oxidation, reduction), biological transformation (e.g., biodegradation), persistence, and bioaccumulation.

Characterizing receptors Although assessment endpoints and receptors were selected during the scoping phase of the RI, new information from the field investigation should be evaluated to determine whether there may be populations, species, or communities exposed other than those that were identified initially. Any gaps in information needed to characterize receptors should be identified. Receptor characterization differs for community-level and population-level assessments, as described below.

Community-level assessments. If terrestrial, wetland, or aquatic communities are components of the assessment endpoint, key attributes of the communities that help define the measurement endpoints need to be characterized (e.g., dominant vegetation; species composition of a cold-water fishery).

Population-level assessments. If populations of selected species (e.g., an endangered species) have been designated as receptors for evaluation, determine the potential relationship that the animals' foraging, drinking, and other activities have to the spatial extent of contamination at the site. If contaminants are known or expected to bioaccumulate, identify the trophic level of the species of concern (i.e., the approximate number of steps in the food chain from primary producers to the animal in question). Initially, it would be appropriate to assume the highest trophic level consistent with a species' dietary habits. EPA's *Great Lakes Water Quality*

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[24] Environmental Protection Agency (EPA). 1989. *Risk Assessment Guidance for Superfund: Volume 1 - Human Health Evaluation Manual.* Interim Final. Office of Solid Waste, Office of Emergency and Remedial Response, Washington, DC. EPA/540/1-89/002.

[25] Op. Cit. 11.

[26] Environmental Protection Agency (EPA). 1992. *Guidelines for Exposure Assessment.* Science Advisory Board, Washington, DC.

Initiative[27] has assumed that mink, kingfishers, and ospreys feed at trophic level 3, that otters obtain half of their diet at trophic level 3 and half at trophic level 4, and that bald eagles feed at trophic level 4. EPA has not yet developed guidance for determining trophic levels. Consult with the BTAG for advice.

Measuring or estimating exposure concentrations EPA's *Framework for Ecological Risk Assessment*[28] defines exposure as the co-occurrence of or contact between a stressor and an ecological component. The receptors of concern dictate how one evaluates patterns of contamination in time and space to predict potential impacts. In this section, we describe approaches to defining exposure concentrations for community-level and population-level assessments.

Community-level assessments. Most community assessments require comparison of chemical concentrations in key media (e.g., surface water, sediments, or soil) to benchmark levels for these media above which adverse community-level effects might be expected. It may be useful to overlay a map of the communities of concern at the site with a map of the contamination pattern found during the field investigation.

The values measured during the initial field sampling of the RI can be used to estimate current exposure levels. Fate-and-transport models are needed to predict the movement of contaminants in the future. In some cases, it may be difficult to measure existing contamination during site visits (e.g., some areas may be flooded, streams may be in high flow, certain locations may be physically inaccessible or too dangerous to sample). In these cases, modeling and estimation techniques can be used in place of field sampling results.

There are two basic options for evaluating current or future environmental concentrations:

> Estimating environmental concentrations only at the point of maximum predicted concentration in each assessment area (or community) to allow a point estimate of risk; and
>
> Estimating the areal extent of contaminant concentrations in each assessment area or community to allow an areal estimate of potential impacts (e.g., 10 stream miles or 5 acres exposed above benchmark levels).

The basic information provided by the point estimate of risk is a quantitative estimate of the number of habitats or areas likely to be contaminated above ecological benchmark levels. The basic information provided by the areal estimate of risk includes a quantitative estimate of the total amount (or proportion) of each habitat or area likely to be contaminated above ecological benchmark levels.

The first of these two options might serve as an initial step to identify assessment areas to which the second option might apply. The second option might be helpful in comparing relative risks. For example, chemical concentrations could be measured at the location(s) where contamination is predicted to be maximal (e.g., point where groundwater discharges into surface water). If these measured concentrations fall below ecological benchmarks, it is unlikely that further evaluation of the pathway(s) will be needed. In contrast, if the measured concentrations exceed ecological benchmarks, it may be useful to estimate the areal extent of the benchmark exceedance. If a benchmark for chronic exposures is exceeded over a small

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[27] Environmental Protection Agency (EPA). 1992. *Great Lakes Water Quality Initiative Procedure for Deriving Criteria for the Protection of Wildlife,* Draft. Office of Research and Development, Environmental Research Laboratory, Duluth, MN.

[28] Op. Cit. 1.

stream reach (e.g., 10 meters), few impacts on a local fish population might be expected. If, on the other hand, chronic benchmarks were exceeded for many miles, significant impacts on the fish population are possible.

Species-level assessments. If one or more species have been designated for evaluation, the home range size of these species should be used in determining the area over which to evaluate contaminant concentrations. When assessing risks to wildlife species exposed to chemicals, potential dose is often the metric used. Potential dose is described as the amount of chemical in food or water ingested, air inhaled, or material applied to the skin[29]. Potential dose is analogous to the administered dose in a toxicity test.

Equation for estimating potential dose. A general equation for estimating potential average daily dose (ADD_{pot}) for chronic exposures (i.e., at least a few weeks) is

$$ADD_{pot} = [C \times IR] / Wt \qquad \text{(equation 1)}$$

where

ADD_{pot} = potential average daily dose (e.g., mg contaminant/kg body weight-day),
C = contaminant concentration in the contacted medium (e.g., mg/kg in food or water),
IR = ingestion rate measured as mass (wet weight) ingested by an animal per unit time (e.g., kg/day), and
Wt = fresh body weight of the animal (e.g., in kg).

This simplified equation assumes that C and IR are constant over time, or averaged over the exposure duration. Highlight F-17 presents two wildlife oral exposure equations corresponding to two patterns of contamination of water or food:

(1) The animal obtains some of its water or food from a contaminated source and the remainder from uncontaminated sources; and

(2) The animal consumes water or food from several sources that are contaminated at different levels.

A frequency term (FR) has been added to the first equation to denote the fraction of time that an animal is exposed to contaminated media (e.g., is present on the site). The concentration (C) equals the mean value of the contaminant concentration in a single water or food source. The second equation can be used when different water or food sources are likely to be contaminated at different levels. In this case, consumption from different sources is weighted by the proportion (P_i) of the animal's total daily intake obtained from each source. FR and P_i in Highlight F-17 are functions of the degree of overlap of the contaminated resources and the animal's home range. EPA's *Wildlife Exposure Factors Handbook*[30] provides a more detailed discussion of these and other equations that can be used to calculate contaminant intakes for species that consume more than one type of food.

For substances that bioaccumulate (see Highlight F-18), if measures of contaminant concentrations in potential prey are unavailable, one should include a food-chain transfer model for receptor species that feed at the higher trophic levels. For piscivorous wildlife (e.g., osprey,

[29] Op. Cit. 24.

[30] Environmental Protection Agency (EPA). 1992. *Wildlife Exposure Factors Handbook*. Prepared for the Office of Research and Development, Office of Emergency and Remedial Response, and Office of Water by ICF Incorporated.

bald eagle, mink, otter), the contaminant concentration in the prey is the concentration in the contacted medium in equation 1. For aquatic food chains,

$$C_{prey} = C_{SW} \times BAF_N \qquad \text{(equation 2)}$$

where

C_{prey} = contaminant concentration in the prey (e.g., in mg contaminant/kg wet weight of the prey),
C_{SW} = contaminant concentration in surface water (e.g., in mg/L), and
BAF_N = trophic level (N)-specific bioaccumulation factor (e.g., L/kg).

Thus, the potential dose can be calculated in one step as shown in Highlight F-19.

Highlight F-17:
Recommended Wildlife Exposure Equations for Oral Exposure

One Source of Contamination:

$$ADD_{pot} = [C \times IR \times FR] / Wt$$

Different Sources with Varying Levels of Contamination:

$$ADD_{pot} = \left[\sum_{i=1}^{n} (C_i \times P_i) \times IR \right] / Wt$$

ADD_{pot} = potential average daily dose (e.g., mg contaminant/kg body weight-day).
C = average contaminant concentration in a single water or food source (e.g., in mg/L or mg/kg).
IR = ingestion rate measured as mass (wet weight) ingested by an animal per unit time (e.g., kg/day).
FR = fraction of intake from contaminated material (unitless).
Wt = fresh body weight of the animal (e.g., in kg).
n = total number of sources.
C_i = contaminant concentration in the ith water or food source (e.g., in mg/L or mg/kg).
P_i = proportion of water or food consumed from the ith source (unitless).

Bioaccumulation potential is the measure of the tendency for chemicals to preferentially concentrate in the tissues of living organisms. There are two general measures: (1) the bioconcentration factor (BCF), i.e., the equilibrium ratio of the concentration of a chemical in the tissue and its concentration in ambient water, in situations where the organism is exposed through the water only; and (2) the bioaccumulation factor (BAF), i.e., the equilibrium ratio of the concentration of a chemical in the tissue to its concentration in an environmental medium where the organism and the food chain both are exposed.

The BAF_N can be estimated in one of three ways (listed in order of preference):

(1) Measured in the field for organisms at trophic level N;

(2) A BCF measured in the laboratory (preferably on a fish species) multiplied by an appropriate food chain multiplier; or

(3) A BCF estimated from the log of the octanol-water partition coefficient (K_{ow}) multiplied by an appropriate food chain multiplier. This method will not work for most metals because their propensity to bioaccumulate is not a function of the lipophilic properties of the compound.

Highlight F-18:
Metals That May Bioaccumulate

Metals for which measured log bioconcentration factors (BCFs) for one or more chemical species exceed 3:

Cadmium	Copper
Lead	Manganese
Mercury	Selenium
Zinc	

For most inorganic substances, BAFs equal BCFs, although bioaccumulation of some trace metals is substantially greater in internal organs than in muscle tissue in fish. For example, BCFs for rainbow trout liver and muscle exposed to cadmium for 178 days were about 325 and 1 respectively.[31] A food chain multiplier greater than one is applicable to most lipophilic organic chemicals with a log K_{ow} of four or more.

BAFs and BCFs can be found in EPA water quality criteria documents, published papers, the AQUIRE data base, and other reliable sources. An uncertainty analysis is particularly important for food chain models because the results of the models are highly sensitive to the magnitude of the BAF used, which may or may not be appropriate for that particular site or prey. The uncertainty can be reduced substantially by measuring contaminant levels in the prey of the assessment species. Generally, whole body contaminant levels are needed, not just fillet contaminant levels as might be measured for the human health assessment.

F.14 Ecological Effects Assessment

Ecological effects assessment consists of quantifying the relationship between exposure concentrations and adverse effects in ecological receptors. Existing ARARs for the protection of aquatic life (i.e., state water quality standards, EPA's AWQC), published studies, biological field studies at the site, and/or toxicity testing can provide the 'dose-response' information. It usually is not necessary to quantify the full dose-response curve; determining what exposure level represents a threshold for an adverse effect can suffice. In this appendix, we refer to this threshold as a toxicity benchmark.

In the remainder of this section, we first discuss both community-level and species-level toxicity benchmarks. By comparing exposure levels with benchmark values developed from available literature, the site assessors can decide whether they need to proceed further with ecological effects investigations such as toxicity tests or field studies.

[31] Giles, M.A. 1988. Accumulation of cadmium by rainbow trout, *Salmo gairdneri*, during extended exposure. Canadian Journal of Aquatic Science 45:1045-1053.

Highlight F-19:
Recommended Wildlife Aquatic Food-Chain Exposure Equations

Prey from One Trophic Level:

$$ADD_{pot} = [C_{SW} \times BAF_N \times IR] / Wt$$

Prey from More than One Trophic Level

$$ADD_{pot} = \left[\sum_{I=1}^{n} (C_{SW} \times BAF_{Ni} \times P_i) \times IR\right] / Wt$$

ADD_{pot} =	average daily potential dose (e.g., mg/kg-day).
C_{SW} =	average contaminant concentration in surface water within the animal's home range (e.g., mg/L).
BAF_N =	trophic level (N)-specific bioaccumulation factor (e.g., L/kg).
IR =	ingestion rate measured as mass (wet weight) ingested by an animal per unit time (e.g., kg/day).
Wt =	fresh body weight of the animal (e.g., in kg).
n =	total number of trophic levels.
BAF_{Ni} =	trophic level (N)-specific bioaccumulation factor (e.g., L/kg) for the ith trophic level.
P_i =	proportion of prey at the ith trophic level (unitless).

Community-level benchmarks

Water quality standards and criteria for the protection of aquatic life. When available, state water quality standards for designated uses of surface waters are ARARs (see Section H.8). When state standards are not available, EPA ambient water quality criteria (AWQC) for the protection of aquatic life are ARARs. These water-concentration benchmarks for the protection of aquatic communities are available for most of the hazardous substances found at mining sites (e.g., metals, cyanide). Most of the state standards have been adopted from or modified from EPA AWQC. These ARARs are available for acute (1-hour) and chronic (4-day) exposures. Many of the criteria for metals depend on water hardness, and a few criteria depend on pH.

Other community-level benchmarks. Highlight F-20 provides examples of community-level benchmarks in addition to water quality ARARs. There is no EPA consensus at this time on use of these other benchmarks; consult with the BTAG to determine if any of these benchmarks are appropriate or if a different approach is needed (e.g., using toxicity tests).

Species-level benchmarks Highlight F-20 also provides examples of species-level benchmarks. It is important to remember that EPA's AWQC, and consequently most state standards, for the protection of aquatic communities are unlikely to be protective of piscivorous (i.e., fish-eating) wildlife if the substance bioaccumulates (e.g., mercury, selenium, cadmium). A food-chain model was *not* used to determine AWQC, even when toxicity to wildlife (e.g., PCB

toxicity to mink) was considered in setting the criterion. If any piscivorous species are of concern in the area, consult with the BTAG for an update on available information and procedures.

EPA's Office of Water/Office of Science and Technology (OW/OST) is developing surface water criteria for the protection of terrestrial piscivorous wildlife. The criteria assume that the exposed species obtains all of its diet from the surface water body in question. EPA has not yet specified what temporal or spatial averaging requirements will apply to the wildlife surface water criteria. We therefore outline an approach consistent with OW/OST's methodology that can be used in the interim to develop surface water benchmarks for piscivorous wildlife. The benchmark is calculated on the basis of two values: (1) an animal's intake of the contaminant that can be attributed to the surface water contamination; and (2) a reference dose of contaminant above which adverse effects on the animal's growth, development, reproduction, or survival can be expected.

Section H.13 described how intakes of contaminants that can be attributed to surface water contamination can be calculated for piscivorous wildlife. For purposes of setting a screening-level benchmark, one can assume that the animal obtains all of its food from the contaminated surface water. The second value required to calculate a surface water benchmark protective of piscivorous wildlife is the reference dose, i.e., a chemical-specific reference toxicity value (TV), as described in the next paragraph.

Determining a reference toxicity value (TV). Toxicity values (TVs) should be developed by a terrestrial wildlife toxicologist. A TV can be estimated from a no-observed-adverse-effect level (NOAEL) multiplied by a species sensitivity factor (SSF), as described below.

From the available literature, a chronic NOAEL is identified. Peer-reviewed field studies of wildlife species are used when available. In the absence of field studies, laboratory studies with surrogate species (e.g., rat, northern bobwhite) can be used. EPA's *Great Lakes Initiative*[32] recommends the following data requirements for chronic studies:

> For laboratory mammals, at least one well-conducted subchronic study consisting of repeated oral exposure for 90 days or longer, or at least one well-conducted reproductive or developmental effects study consisting of repeated oral exposures.
>
> For laboratory birds, at least one well-conducted study of 28 days or greater designed to observe subchronic as well as reproductive or developmental effects.

If a NOAEL is unavailable, it can be extrapolated from a lowest-observed-adverse-effect level (LOAEL) by dividing the LOAEL value by a factor ranging from one to ten. If chronic data are unavailable, a subchronic value can be used, dividing by a factor of up to ten to extrapolate to the longer exposure duration. Finally, the NOAEL is converted to mg/kg-day (i.e., milligrams contaminant eaten per kilograms of consumer organism's body weight per day) basis if it is not already in these units.

[32] Op. Cit. 25.

Highlight F-20:
Types of Ecological Benchmark Values

Type of Benchmark	Examples or Approach
Surface water benchmarks for the protection of aquatic life (i.e., non-benthic aquatic communities)	State water quality standards[a/] EPA ambient water quality criteria (AWQC)[a/] EPA ambient aquatic life advisory concentrations (AALAC) Toxicity values/extrapolation factor(s)[b/]
Sediment benchmarks for the protection of benthic invertebrate communities	EPA interim sediment quality criteria[c/] Apparent effects threshold (AET) Sediment quality triad Screening-level concentration (SLC)
Surface water benchmarks for the protection of fish-eating wildlife species	EPA water quality criteria for the protection of terrestrial wildlife[d/]
Fish flesh benchmarks for the protection of fish-eating wildlife species	New York State fish flesh criteria[e/]
Soil benchmarks protective of plant communities	Toxicity values from PHYTOTOX data base
Soil benchmarks protective of soil invertebrate communities	Toxicity values for selected invertebrate species (e.g., earthworms, amphipods)
Soil benchmarks protective of terrestrial vertebrate species	Soil criteria derived from dietary toxicity values and specific exposure parameters for selected vertebrate species[f/]
Ambient air standards protective of terrestrial plant communities	Some secondary National Ambient Air Quality Standards (NAAQS)

[a/] These ARARs are available for most of the contaminants found at mining sites.
[b/] As an example, a chronic benchmark may be derived by dividing a LOAEL by a numeric factor to account for variation in species sensitivity (see text).
[c/] EPA sediment benchmarks are not available for metals at present. For a review of approaches to developing sediment quality criteria, see Chapman[33]. The BTAG should be consulted to determine which approach(es) is most appropriate for a particular site.
[d/] Back-calculate a benchmark surface water concentration from bioaccumulation factor values for aquatic food items and water consumption, aquatic food consumption, and toxicity for selected avian and mammalian species[34].
[e/] Back-calculate a benchmark fish flesh concentration from fish consumption and toxicity data for selected avian and mammalian species[35].
[f/] Back-calculate a benchmark soil concentration using body mass, dietary intake, bioaccumulation factors, and dietary toxicity values for representative birds and mammals assuming direct contact and food chain exposures[36]. Depending on how receptors and endpoints have been defined (see section 2.2, tasks 3 and 6), one or both of two types of assessments typically are useful: community-level assessments and population-level assessments.

Data rarely are available for the assessment species; therefore, an extrapolation factor to account for differences in species sensitivities to the substance usually is developed. A species sensitivity factor (SSF) typically falls between 1 and 0.01 depending on the amount and quality of data available on the toxicological, physicochemical, and toxicokinetic properties of the substance. An SSF of one is used if the data are from numerous species or if the data are from the only species of concern.

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[33] Chapman, P.M. 1989. Current approaches to developing sediment quality criteria. Environ. Toxicol. Chem. 8:589-599.

[34] Environmental Protection Agency (EPA). 1991. *Assessment and Control of Bioconcentratable Contaminants in Surface Waters*. June 1989 Draft prepared by EPA's National Effluent Toxicity Assessment Center, Environmental Research Laboratory - Duluth, MN; Office of Water Enforcement and Permits, Office of Water Regulations and Standards - Washington, DC; and Office of Health Effects Assessment - Cincinnati, OH

[35] New York State Department of Environmental Conservation (NY DEC). 1987. *Niagara River Biota Contamination Project: Fish Flesh Criteria for Piscivorous Wildlife*. Division of Fish and Wildlife, Bureau of Environmental Protection. DEC Publication, Technical Report 87-3.

[36] Op. Cit. 28.

Estimating a benchmark concentration for surface water (BC_{sw}) for the protection of piscivorous wildlife. The benchmark contaminant concentration in surface water (BC_{sw}) now can be estimated as described in equation 3.

$$Bc_{sw} = [TV \times Wt_A \times SSF] / [IR \times BAF_N] \text{(equation 3)}$$

where

Bc_{sw} =benchmark contaminant concentration in surface water (e.g., mg/L).
TV = wildlife chronic toxicity reference value (e.g., mg/kg-day).
Wt_A = consumer animal's fresh body weight (e.g., kg).
SSF = species sensitivity factor as defined in text.
IR = food ingestion rate of consumer species (e.g., kg/day).
BAF_N = bioaccumulation factor (e.g., L/kg) for the Nth trophic level.

Toxicity tests Toxicity tests on media from the site, in combination with data on chemical concentrations and field studies, can provide important supporting evidence that observed effects are attributable to the presence of hazardous substances. Several factors need to be considered, however, in interpreting (and consequently planning) toxicity tests, as discussed briefly below.

Species sensitivity. Different species show varying sensitivities to different toxic substances. For a community-level assessment, it would be important to encompass the range of species sensitivities likely in the community of concern. There are several approaches to this problem. For some contaminants at some sites, the most sensitive resident species may already be known from previous work at the site. For aquatic communities, EPA's Office of Water has suggested a sliding scale of species-sensitivity extrapolation factors depending on the number of different genera tested.[37] Another approach is described in Highlight F-21. Consult the BTAG for the most appropriate approach for a site.

For a species-level assessment, the choice of number of test organisms and which test organisms to use depends upon how similar the available test species are to the assessment species, what is known about the contaminant's toxicity, and other factors. Again, consultation with the BTAG generally is necessary to ensure that appropriate procedures are applied to plan toxicity tests and interpret their results.

Duration of test. If chronic exposures are of concern, chronic bioassays should be used. To reduce the time and expense of testing, however, it may be possible to substitute one of the short-term (e.g., eight days) tests for estimating chronic toxicity of effluents and receiving waters (EPA 1985[38], 1988[39], 1989[40]). These tests are only suitable for substances that do not bioaccumulate, however. The species used in the short-term tests also may not be as appropriate as other available surrogate test species for a species-level assessment. Again,

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[37] Environmental Protection Agency (EPA). 1987. Guidelines for Deriving Ambient Aquatic Life Advisory Concentrations. Office of Water Regulations and Standards, Washington, DC.

[38] Environmental Protection Agency (EPA). 1985. *Short-term Methods for Estimating the Chronic Toxicity of Effluents in Receiving Waters to Freshwater Organisms.* Office of Research and Development, Office of Environmental Monitoring and Support Laboratory, Cincinnati, OH. EPA/600/4-85/014.

[39] Environmental Protection Agency (EPA). 1988. *Short-term Methods for Estimating the Chronic Toxicity of Effluents in Receiving Waters to Marine and Estuarine Organisms.* Office of Research and Development, Office of Environmental Monitoring and Support Laboratory, Cincinnati, OH. EPA/600/4-87/0928.

[40] Op. Cit. 16.

consult with the BTAG to ensure that appropriate procedures are applied to plan and interpret toxicity tests.

Highlight F-21:
One Approach to Accounting for Varying Species Sensitivities

Use multiple test species and an uncertainty factor. For example, in the context of EPA's National Pollutant Discharge Elimination System (NPDES) permits program, at least three test species (one fish, one invertebrate, and one plant) are required[41]. For toxicity tests on surface waters, analysis of species sensitivity ranges found in EPA AWQC documents indicates the following: If the fathead minnow, *Daphnia magna*, and the bluegill are used for freshwater, the results for the most sensitive of the three test species divided by a factor of 10 encompasses the value for the most sensitive animal species most of the time (i.e., for 71 out of 73 chemicals with data on 4 or more species; Kimerle[42]).

Biological field surveys Biological field surveys can provide direct or corroborative evidence of a link between contamination and ecological effects if an appropriate reference area is surveyed or if a gradient of contamination correlates with a gradient of impacts. The chemical and biological data need to have been collected simultaneously to determine if a correlation exists between contaminant concentrations and ecological effects. *These surveys usually are needed only if a detailed ecological assessment is necessary.*

F.15 Risk Characterization

Ecological risk characterization is primarily a process of comparing the results of the exposure assessment with the results of the ecological effects assessment. The purpose is to answer the following questions:

> Are the ecological receptors of concern currently exposed to site contaminants at levels that can cause adverse effects or is future exposure at such levels likely?
>
> If adverse ecological effects are observed or predicted, what are the types, extent, and severity of the effects?
>
> What are the uncertainties associated with the risk characterization, and are they too large to allow decisions on remedial actions and goals?

All information available by the end of the initial sampling phase of the RI should be used to screen for potential ecological impacts at the site, both present and future. The potential for impacts can be evaluated on the basis of several types of information, considering the weight of evidence provided by each:

> Historical information on impacts (e.g., fish kills following snow melts);
> Comparing ecological benchmarks with contaminant concentrations in environmental media (e.g., surface waters, sediments, soils, plant and animal tissues);

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[41] Environmental Protection Agency (EPA). 1987. *Permit Writer's Guide to Water Quality-Based Permitting for Toxic Pollutants.* Office of Water Regulations and Standards, Washington, DC. EPA 440/4-87-005.

[42] Kimerle, R.A., Werner, A.F., and Adams, W.J. 1984. Aquatic hazard evaluation principles applied to the development of water quality criteria. In: Cardwell, R.D., Purdy, R., and Bahner, R.C. (eds.), *Aquatic Toxicology and Hazard Assessment; Seventh Symposium.* ASTM STP 854. Philadelphia, PA: American Society for Testing and Materials.

Evidence of bioaccumulation (e.g., tissue residue samples compared with exposure media);
Toxicity tests on environmental media;
Results of biological surveys of populations and communities compared with reference areas; and
Biomarkers of exposure or effects.

For any of these evaluations, it generally is helpful to delineate and map areas and habitats within which measured concentrations exceed ecological benchmarks or for which other evidence indicates the potential for adverse ecological impacts.

In the remainder of this section, we focus on the interpretation of exceedances of benchmark levels and species-specific risk estimates. These methods are appropriate for most assessments.

Exceedance of ecological benchmarks

Quotient method. As described earlier, ecological benchmarks are levels of contaminants in environmental media (i.e., surface waters, soils, sediments, or organisms at various trophic levels) that represent a threshold for adverse ecological effects. If an ecological benchmark concentration (BC) is available for the medium sampled (e.g., surface water), one can compare measured or estimated environmental concentrations (EC) with that BC. This approach, also known as the quotient method, assumes that adverse effects are unlikely if the EC is lower than the BC (i.e., EC/BC < 1) and likely if the EC is greater than or equal to the BC (i.e., if EC/BC $\geq$ 1)[43].

Hazard index (HI). A more common situation, however, is for organisms to be exposed to more than one contaminant simultaneously. In this situation, EPA's *Guidelines for the Health Effects Risk Assessment of Chemical Mixtures* can be applied[44]. In this approach, the sum of the quotients developed for individual constituents, is compared with 1. If the sum, known as the hazard index (i.e., HI = EC_i/BC_i), is less than 1, one assumes that ecological impacts are unlikely. If the hazard index is greater than 1, it is reasonable to conclude that a potential for impacts exists, and further study may be required[45]. The HI approach is most appropriate for substances that exhibit the same mode of action and target the same organs; it can underestimate risk if two or more chemicals exert synergistic effects.

Concern level (CL). In applying the quotient or HI approaches, consider the degree of uncertainty associated with both the EC and the BC values and the consequences of falsely concluding there is no risk when, in actuality, adverse effects are likely. If both the EC and the BC have been established using conservative procedures (e.g., upper confidence limits on average values, to encompass a "true" value 95% of the time), then comparing the EC/BC or HI values to 1 might be appropriate (i.e., there is a very small chance that an actual impact would be missed). If, however, both the EC and the BC have been established using "average" values, then the risk assessor must appreciate that the EC/BC or HI could be slightly less than 1 when in fact there is a good chance (e.g., 50%) that adverse effects would occur. In this

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[43] Environmental Protection Agency (EPA). 1988. *Review of Ecological Risk Assessment Methods*. Office of Policy, Planning and Evaluation, Washington, DC. EPA/230-10-88-041.

[44] Environmental Protection Agency (EPA). 1986. *Guidelines for the Health Risk Assessment of Chemical Mixtures*. Office of Health and Environmental Assessment, Washington, DC. EPA/600/8-87/045.

[45] Environmental Protection Agency (EPA). 1989. *Risk Assessment Guidance for Superfund: Volume 1 - Human Health Evaluation Manual*. Interim Final. Office of Solid Waste, Office of Emergency and Remedial Response, Washington, DC. EPA/540/1-89/002.

case, the risk assessor should establish a concern level lower than 1 based on (1) the degree of uncertainty and potential biases in the EC and BC estimates and (2) the consequences of falsely concluding that there are no impacts likely. Given the lack of guidelines on this topic, it is important to consult with the BTAG when setting a CL.

Exceedance of wildlife toxicity reference values In those cases where species of concern can be exposed to contaminants from more than one environmental medium (e.g., contaminated soils and surface waters) or can be exposed to different levels of contamination in different parts of their range, it might be appropriate to estimate a daily average contaminant intake from all sources rather than attempt to develop benchmarks for the environmental media. Section EPA/540/1-89/002. H.14 described how average potential daily intakes (ADD_{pot}) can be estimated for wildlife species of concern, and section H.15 described the development of wildlife toxicity values (TVs). The quotient and hazard index approaches can be used to compare ADD_{pot}s to TVs. The same considerations apply to determining a concern level (CL) as described above.

Interpretation of exceedances It is important to consider both the spatial and temporal applicability of the benchmark when attempting to compare exposure values to toxicity benchmarks. For example, EPA's AWQC and similar state water quality standards are intended to protect aquatic communities, rather than a specified aquatic population. Thus, if either an acute or chronic water quality benchmark is exceeded at any point in a surface water body, the aquatic community at that point can be considered at risk of adverse effects. If often is possible, therefore, to quantify the areal extent of the surface water bodies for which aquatic communities are likely to be impacted (i.e., areal extent of the criterion exceedance) either for acute or chronic exposures. Both the degree of exceedance (i.e., potential severity of the effects) and the areal extent of exceedances are important considerations for evaluating the significance of the estimated effects.

If any portion of a river exceeds an acute water quality criterion for the protection of aquatic life, there is some chance that the mobile members of the aquatic community (e.g., larger fish) will be adversely affected over an area that is larger than the area of exceedance of the criterion. For example, if a portion of a river regularly exceeds acute criteria, it may not be possible for fish to traverse the area without suffering adverse effects. This might divide and isolate the fish populations on either side of the area of exceedance. If anadromous fish used the river, they might be blocked from successfully reaching their spawning grounds upstream.

The RPM should consult with the BTAG if there are questions on how to interpret benchmark exceedances.

F.16 Is Additional Assessment Necessary?

F.16.1 Rationale. When the initial assessment is complete, the RPM needs to evaluate whether the goals of the ecological assessment for the site characterization phase of the RI/FS have been met, or if further site evaluation is warranted. The operative concern is whether ecological risks at the site are understood sufficiently to be adequately considered in selecting a remedial alternative or in establishing remedial goals. At enforcement-lead sites, EPA needs to be able to defend an endangerment finding.

F.16.2 Factors to Consider. Usually, the initial ecological assessment will be sufficient. Sometimes, however, there are problems that require further evaluation. This section identifies and describes several factors that may influence whether further site evaluation is warranted.

ARARs, other statutory requirements, and public concerns. Remedial actions must ensure that all ARARs and other statutory requirements are met or waived. This may require that risks to certain types of environments (e.g., wetlands) or organisms (e.g., endangered species) be eliminated, reduced, or controlled. Public concern also may be high for particular environments or species (e.g., local residents, states, or Native American Tribes may be concerned about trout streams, eagle populations, unique habitats, or other components of nearby ecosystems). Additional site investigation may be warranted if it is not clear how ARARs, other statutory requirements, or public concerns will be addressed by each proposed remedial alternative or cleanup goal.

Ability to link adverse effects to contaminants. EPA must provide sufficient information to reasonably conclude whether or not adverse effects are likely as a result of releases of contaminants from the site. However, EPA need not demonstrate a cause-and-effect linkage between *observed impacts* and site contaminants. Demonstrating a reasonable likelihood of risks to sensitive and other environments generally requires:

> Sufficient understanding of all contaminant migration pathways (i.e., the steps, rates, and processes involved in the migration of contaminants from sources through environmental media to sensitive or other nearby environments);
>
> Reasonably confident measures or estimates of representative environmental concentrations at each key point in all contaminant migration pathways; and
>
> Sufficient understanding of the types of adverse effects that may be associated with observed or estimated environmental concentrations.

For some assessment areas, it may be sufficient to demonstrate that releases can result (or have resulted) in concentrations above ecological benchmark levels, because there is sufficient information in the scientific literature linking such concentrations to adverse ecological effects. AWQC are examples of such ecological benchmark levels. For other assessment areas, toxicity tests and/or other additional investigations may be required to determine whether observed contaminant concentrations have the potential to result in adverse ecological effects. For example, ecological benchmark levels may be below analytic quantitation limits, or contaminants might not be bioavailable.

Most likely remedial alternatives, cleanup goals, or constraints. Additional information may or may not be needed to select a remedy or to evaluate its effectiveness. For example, it may be sufficient to demonstrate that a release has resulted in concentrations above AWQC at the point that contaminants discharge to a surface water body if all of the reasonable remedial alternatives will prevent future releases to that surface water body. In contrast, more complete information on the areal extent of contamination above benchmark levels (or above effect levels in toxicity tests) may be required when remedial alternatives involve removal, treatment, or capping of contaminated media such as soil or sediment that serve as non-point sources of contamination (i.e., it may be necessary to delineate the area that needs to be remediated).

Intended post-remediation uses for assessment areas. The level of information that the ecological risk assessment must provide may depend partially on the intended post-remediation uses for each assessment area. For example, little or no information on ecological risk may be required for areas that are to be capped and revegetated for reasons unrelated to ecological risk (e.g., because of human health risk or other intended use of the land area).

F.16.3 Consultation with the BTAG. The RPM should provide the BTAG with the results of the ecological risk assessment. The BTAG, in turn, should be able to determine if additional field investigations are necessary, and, if so, what investigations are required.

Highlight F-22:
List of Acronyms

ACRs	Acute-to-chronic Ratios
AQUIRE	AQUatic Toxicity Information REtrieval
ARARs	Applicable or Relevant and Appropriate Requirements
AWQC	Ambient Water Quality Criteria
BLM	Bureau of Land Management
BTAG	Biological Technical Assistance Group
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CLP	Contract Laboratory Program
DOI	Department of Interior
DQOs	Data Quality Objectives
EPA	Environmental Protection Agency
FS	Feasibility Study
FWS	US Fish and Wildlife Service
HRS	Hazard Ranking System
LOAEL	Lowest-observed-adverse-effect level
NCP	National Oil and Hazardous Substances Contingency Plan
NOAA	National Oceanic and Atmospheric Administration
NOAEL	No-observed-adverse-effect level
NPDES	National Pollutant Discharge Elimination System
NPL	National Priority List
OSC	On-scene Coordinator
PA	Preliminary Assessment
PNRS	Preliminary Natural Resource Survey
PRP	Potentially Responsible Party
QA/QC	Quality Assurance/Quality Control
QSAR	Quantitative Structure Activity Relationships
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
ROD	Record of Decision
RPM	Remedial Project Manager
SI	Site Investigation
SOW	Statement of Work
SSF	Species Sensitivity Factor
TRIS	Toxics Release Inventory System
TV	Toxicity Value

Glossary:

Bioaccumulation potential	A measure of the tendency for chemicals to preferentially concentrate in the tissues of living organisms; two general measures are the bioconcentration factor (BCF), the equilibrium ratio of the concentration of a chemical in the tissue and its concentration in ambient water, in situations where the organism is exposed through the water only; and the bioaccumulation factor (BAF), the equilibrium ratio of the concentration of a chemical in the tissue to its concentration in an environmental medium where the organism and the food chain both are exposed.
Contaminant migration pathway	The pathway through which a chemical or non-chemical stressor travels from a source to a specified habitat, environment, or ecological receptor; the contaminant migration pathway includes a source, the environmental medium or media through which the stressor moves, and one or more receptor(s).
Ecological benchmark level	Concentrations in environmental media (e.g., surface water, sediment, soils) above which potentially significant adverse effects to ecological receptors are expected to occur; usually derived from toxicity values (e.g., no-adverse-effect levels, lowest-adverse-effect levels, LC_{50}s) for either acute or chronic exposures.
Ecological receptor	An individual organism, population, community, ecosystem, or ecoregion that may be affected by site contaminants or other stressors.
Environmental medium	A component of the environment through which contaminants can move; includes both abiotic components (i.e., soil, groundwater, surface water, air, sediment) and biotic components (e.g., fish, shellfish, plants).
Hazard index (HI)	The sum of the ratios of the estimated environmental concentration of each contaminant (EC) to its ecological benchmark level (EB), calculated using the following formula: $$HI = EC_i/EB_i,$$ where EC_i = the concentration for the ith contaminant; EB_i = the benchmark concentration for the ith contaminant. This approach can also be applied to the ratio of average daily intake of an animal (ADD_{pot}) to a wildlife reference toxicity value (TV) for more than one contaminant.

Nearby habitat	A terrestrial, surface water, or wetland habitat that is actually or potentially exposed to site contaminants; nearby environments may be located anywhere from on site to several tens of miles from the site.
Primary consumers	Organisms that feed primarily on the primary producers (e.g., plants) at the base of a food chain.
Primary producers	Organisms (e.g., green plants and some bacteria) that are autotrophic (i.e., fix energy from the sun or use inorganic compounds for food) and form the base of a food chain or web.
Reference environment	A terrestrial, surface water, or wetland environment that closely resembles the environment of concern in terms of its biotic and abiotic composition and structure and is known not to be exposed to contaminants from the site.
Secondary consumers	Organisms (e.g., carnivores, insectivores) that feed primarily on primary consumers.
Sensitive environment	Environments or habitats that are rare, unique, relic, or otherwise have state, regional, and/or Federal significance or special statutory protection.
Stressor	Any substance that causes an adverse effect (e.g., skin lesions, lethality, decreased growth rate, prenatal mortality) on ecological receptors; stressors may be chemical (e.g., metals) or non-chemical (e.g., pH, turbidity, temperature) and may be natural or anthropogenic.
Trophic level	Any of the feeding levels through which the passage of energy through an ecosystem proceeds. For freshwater aquatic systems, this document assumes that zooplankton are trophic level 2, small fish trophic level 3, top carnivorous fish trophic level 4.