APPENDIX G

AQUATIC RESOURCES

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1.0 PURPOSE AND GOALS OF THE APPENDIX

In the Pacific Northwest and Alaska, freshwater aquatic resources often represent an important component of the environment that must be considered in impact assessments for mining projects. Freshwater aquatic resources that typically are addressed in a NEPA document and baseline studies include fish, benthic macroinvertebrates, and physical parameters that define habitat for these communities. These aquatic resources, especially fish, often represent significant issues for the proposed action being evaluated during the NEPA process.

The purpose of this appendix is to provide a summary of the types of information needed to characterize freshwater aquatic resources within the project study area and describe methods that can be used in analyzing impacts of mining projects on freshwater aquatic communities and their habitat. The remaining portions of this Appendix provide information on Issues and Terminology (Section 2.0), Affected Environment Description (Section 3.0), Impact Assessment (Section 4.0), and Literature Cited (Section 5.0). Contacts and other information sources for the topics discussed in this Appendix are included in Section 6.0.

When conducting NEPA impact assessments for mining projects, considerable overlap exists between aquatic resources and surface water and ground water quality and hydrology. Descriptions of methods for conducting NEPA impact assessments on hydrology, sedimentation, and surface and ground water quality are provided in Appendix A, *Hydrology,* Appendix B, *Receiving Waters*, and Appendix H, *Erosion and Sedimentation.*

This appendix addresses only freshwater aquatic resources. Most of the direct impacts of mining operations in EPA Region 10 are to freshwater resources, simply because most mines and mineral deposits are inland, and discharges to marine environments are generally prohibited. In some cases, including cases where there are effects on anadromous fish, there would be indirect effects on marine resources. Although not covered in this appendix, NEPA analyses should address any such impacts to the marine environment and marine aquatic resources, whether direct or indirect.

2.0 ISSUES AND TERMINOLOGY

Resident and anadromous fisheries that are located within a mining project study area represent a concern to the public and governmental agencies such as the National Marine Fisheries Service (NMFS), the Bureau of Land Management (BLM), the U.S. Fish and Wildlife Service (USFWS), the U.S. Forest Service (USFS), the U.S. Army Corps of Engineers (USACE), Tribal Commissions, Tribes, and appropriate state organizations. Fish species, particularly salmonids (trout and salmon), are important because of their recreational, commercial, and/or cultural fishery value. Numerous species also are listed as threatened or endangered (T&E) under the Federal Endangered Species Act or related state statutes. The USFWS, NMFS, and appropriate state agencies should be contacted as part of the scoping and issue identification for a particular project to obtain a list of Federal and state listed species. The

USFS also uses important fish species (usually salmonids) as Management Indicator Species. These species should be included in the NEPA analysis for projects that are located on USFS land.

In addition, the Magnuson-Stevens Act requires Federal lead agencies to consult on Essential Fish Habitat[1] (EFH) that is established by the appropriate fisheries management council and NMFS, as identified in their fishery management plans. The Act is a mandate to conserve marine habitat, but it also includes freshwater habitat for anadromous fish species. In a regulatory context for conserving fish habitat, the Act requires Federal agencies to consult with NMFS when any activity proposed to be permitted, funded, or undertaken by a Federal agency may have adverse impacts on designated EFH. If a project may have adverse effects on EFH, NMFS is required to develop EFH Conservation Recommendations, which will include measures to avoid, minimize, mitigate, or otherwise offset adverse effects on EFH. The consultation process for EFH will be incorporated into interagency procedures previously established under NEPA, ESA, Clean Water Act, Fish and Wildlife Coordination Act, and any other applicable statutes.

Benthic macroinvertebrate communities represent an important biological component of the aquatic environment, since they provide food sources for fish and are indicators of water quality and habitat conditions.

The Clean Water Act (CWA) directs the EPA and states to develop and implement programs that evaluate, restore, and maintain the chemical, physical, and biological integrity[2]. States adopt water quality standards to protect public health and welfare, enhance the quality of water, and protect biological integrity. In general terms, a water quality standard defines the goals of a water body by designating the use or uses to be made of the water, establishing criteria necessary to protect those uses, and preventing degradation of water quality through antidegradation provisions. The fish, macroinvertebrate, and periphyton (attached algae) assemblages are all direct measures of the beneficial use under the CWA. The CWA applies to all species of aquatic life including, but not limited to, “important” fish species.

After reviewing the proposed mining plan for a particular project, the potentially disturbed or impacted areas should be related to the presence of fish species, macroinvertebrate communities, and habitat conditions (including riparian and hyporheic zones) within the project study area. Potential aquatic resource issues for mining projects include:

- Potential adverse effects on water quality and aquatic communities and habitat due to sedimentation, metals, acid generating materials, and other toxic chemical loadings.

[1] Essential Fish Habitat is defined as ". . . those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity."

[2] Biological integrity is "a balanced, integrated, adaptive community of organisms having species composition, diversity, and functional organization comparable to that of natural habitat of the region" (Karr and Dudley 1981).

- Potential effects of transporting and storing fuel and other toxic chemicals that could pose risk of spills and adversely affect aquatic communities and their habitat.
- Potential water use by mining operations that may affect flows in project area water bodies, which could adversely affect habitat for important fish species and macroinvertebrate communities.
- Potential direct disturbance to habitat used by important fish species during life history events such as spawning, rearing, and adult movements.

These issues are discussed in more detail in Section 4.0.

3.0 AFFECTED ENVIRONMENT DESCRIPTION

The initial steps in describing an affected environment include: (1) define the study area and (2) collect and review available information on aquatic resources that are located within the project study area. Information in this appendix focuses on specific aspects of the data collection and review task for aquatic resources and a summary of methods that can be used in conducting additional baseline studies.

The affected environment description should characterize important information on fish communities, macroinvertebrate communities, amphibians and other aquatic and semi-aquatic vertebrates, and aquatic habitat, including the adjacent riparian[3] zone, within the project study area. Fish and macroinvertebrate assemblages are defined as an associations of organisms in a given water body (EPA 1996). The study area for aquatic resources should include potentially affected watersheds. The study area should encompass on-site (project area boundary) and off-site (both upstream and downstream) water bodies and adjacent riparian zones that receive both direct and indirect impacts. The level of detail and analyses need to be commensurate with the importance of the impact (Council on Environmental Quality, 1986). The following types of information are typically needed to characterize aquatic resource topics for the Affected Environment Section of a NEPA document:

Fish (Aquatic Vertebrates) Assemblage Information

- Species list (all species included). This includes any other aquatic vertebrate species (e.g., amphibians) that might be collected in conjunction with the fish.
- Distribution, abundance, and composition of game fish and T&E and candidate species.
- Distribution, abundance, and composition of amphibians and other aquatic and semi-aquatic vertebrates (including aquatic mammals and reptiles)
- List of any critical habitat designations for T&E species, as established by the

[3] *Riparian* is a term that refers to "plant communities contiguous to and affected by surface and subsurface hydrologic features of perennial or intermittent lotic and lentic water bodies (rivers, streams, lakes, or drainage ways). Riparian areas have one or both of the following characteristics: 1) distinctly different vegetative species than adjacent areas, and 2) species similar to adjacent areas but exhibiting more vigorous or robust growth forms. Riparian areas are usually transitional between wetland and upland" (USFWS, 1997). Riparian areas also often include wetlands.

USFWS and/or state agencies.
- List of any Essential Fish Habitat established by regional fisheries management council.
- Seasonal timing of spawning for game and T&E and candidate species.
- Habitat requirements of game and T&E and candidate species.

Fish Tissue Contamination Information

- Species, type of sample (i.e. whole fish, fillet), and number of samples; and
- Metal concentration in sample.

Macroinvertebrate Assemblages Information

- Enumeration and identification of benthic invertebrates to the lowest taxonomic level (Plotnikoff and White 1996).
- Community metric data (e.g., total number of taxa, percent dominance, number of Plecoptera taxa, number of Ephemeroptera taxa, and number of Trichoptera taxa.).

Information on Other Aquatic Organisms (Amphibians and Aquatic/Semi-Aquatic Mammals)

- Species composition and abundance.
- Habitat requirements and seasonal timing of breeding.

Habitat Information

- Streams - Gradient, widths and depths, pool frequency, substrate composition, streambank erosion, existing barriers and/or road crossings, culvert characteristics, large woody debris, percent undercut banks, surface fins, flow characteristics, temperature, and dissolved oxygen.
- Lakes and Reservoirs - Depth, surface area, littoral zone area, presence of aquatic vegetation, and substrate composition.
- Riparian Zone - Width, percent cover and composition of vegetation by strata, and estimated shaded area by seasons.

Project scoping and discussions with Federal and state agency biologists should be used to define the specific list of topics to be covered as part of the Affected Environment Description. Sources of information for the aquatic resource topics can be obtained by searching published literature, unpublished agency file information, and contacts with relevant Federal and state agencies.

Summaries of recommended methodologies to collect baseline data, if needed, are provided below. The summaries focus on field studies for fish, benthic macroinvertebrates, and habitat characterization. For topics such as the life history and habitat requirements of fish, sufficient information is usually available in published literature. Prior to initiating any baseline

studies, the proposed methods should be discussed and approved by appropriate Federal and state agency fishery biologists and/or aquatic ecologists.

3.1 Fish

3.1.1 Distribution, Abundance, and Composition

The timing and frequency of fish surveys largely depend upon the extent of migration or movements exhibited by the important fish species. If the important species are resident (i.e., minimal movement or migrations), one sampling effort in the summer or fall should be adequate to characterize composition and abundance. Additional sampling efforts may be needed to characterize composition and abundance information for more mobile species. If spawning information is needed, one survey should be scheduled to coincide with the peak spawning period for the important species. It also is important to note that surveys of downstream, and in some instances upstream, areas may be appropriate. This is true even if no fish reside within or migrate through the project boundary. Final decisions on the timing and frequency of surveys should be made through discussions with the appropriate agency biologists.

The selection of a sampling method to collect data on the distribution, abundance, and composition of fish communities depends mainly upon the type of water body. Each sampling technique has limitations in terms of its effectiveness in particular types of habitat and behavior and life stages of fish species. In streams and shallow rivers, sampling methods include backpack or shoreline electrofishing, snorkeling, weirs, minnow traps, and seining. Of these methods, electrofishing is the most commonly used technique due to the time efficiency in completing the survey. However, electrofishing has been restricted in some watersheds within the Pacific Northwest that contain federally threatened or endangered salmon or trout species. In deeper rivers, boat electrofishing and hoop nets can be used to collect fish. Possible types of collecting methods for lakes or reservoirs include boat electrofishing, gill nets, fyke nets, and seine nets. Collection permits are required from the USFWS, NMFS, and/or state fish and wildlife agencies for all of these methods except snorkeling. Applications of the various fish sampling methods in terms of general type of habitat and life stage are listed in Table G-1. Brief summaries of these sampling methods are provided below; refer to literature citations in Table G-1 for more detailed descriptions of the sampling methods.

Backpack Electrofishing. In streams and rivers with depths less than about 3 feet, backpack electrofishing is a common method used to collect adult and juvenile fish by producing an electrical field in the water. In addition, some amphibians may be collected along with the fish; they should be enumerated and identified as well. The method is not effective in capturing small-sized fish (i.e. young-of-the-year) because of their relatively small surface area. Prior to initiating the survey, the sampling effort is quantified in terms of linear distance, stream area sampled, or duration of sampling in minutes. The crew moves in an upstream direction and electrofishes all habitat within the reach. All fish species are netted and then processed in the field by identifying and enumerating each fish by species. Species identifications should be made by a qualified fisheries biologist and/or voucher specimens checked by a fish taxonomist at a university, college, or museum. If population studies are required, the upper and lower ends of

the sampling reach are blocked off with nets. Multiple passes through the reach are usually required for estimating fish population numbers.

Shoreline Electrofishing. Shore-based electrofishing can be used in larger wadeable streams and rivers, where backpack electrofishing produces an electrical field that is too small and weak to be effective. In shore-based electrofishing, all equipment (electrical unit and generator) is located on land, except for the lead electrode. A two or three-person crew electrofishes the sampling reach in the manner as described above for backpack electrofishing.

Boat Electrofishing. A flat-bottomed boat equipped with electrofishing equipment can be used to collect fish in slow-moving rivers and standing water environments. The boat design consists of a forward deck that can accommodate two standing adults as dip-netters and one or two booms that extend forward from the bow with an electrode. The sampling procedure involves slow operation of the boat in an upstream direction along shoreline areas with depths less than approximately five feet. Fish are netted as they are stunned and then placed in collecting containers. Field processing is similar to backpack electrofishing.

Snorkeling. As part of the R1/R4 Fish Habitat Inventory procedures that are used on USFS land in the Pacific Northwest, direct counts of game and T&E fish are made by snorkeling (Overton et al., 1997). This technique is not recommended for fish assemblage characterization since some of the small non-game species can be difficult to observe. Typically, one or two snorkelers count all fish in a single pass within the study reach. Sampling criteria required for this technique include: (1) stable flow periods between late June and September; (2) direct sunlight conditions between late morning and early afternoon; (3) water temperatures should exceed 9 °C; and (4) visibility should be greater than 3 to 4 meters. All fish are counted in the entire habitat unit or a portion of the unit using one of the following approaches: (1) proceed up the center of the unit and count fish by zigzagging outward to both banks; (2) proceed up one bank and count all fish towards the other bank if the water is too deep or turbulent to zigzag; or (3) float downstream along the center of the stream in deep water.

Weir. This technique involves the construction of a temporary or permanent barrier across the entire width of the stream to divert fish into a trap. Weirs are best suited for capturing migratory adult and juvenile fish as they move up or down streams. The use of weirs is limited to streams and small rivers because of construction expense, formation of navigation barriers, and tendency to clog with debris and ice.

Minnow Traps. This portable trap captures juvenile fish as they enter through a conical-shaped funnel at both ends. The traps are usually baited with fish eggs when they are used to collect juvenile salmon. Typically, the traps are scattered along a stream or river segment and fished for at least 12 to 24 hours.

Seining. Appropriate-sized seine nets also can be used in slow-moving sections of streams or shallow rivers to collect young-of-the-year and juvenile fish, if bottom substrate is relatively smooth and free of debris and other snags. Beach or haul seines are constructed of

mesh panels hung from a float line with a weighted leadline attached to the lower edge. A mesh bag is often attached to the middle of the net, which collects fish as the seine is dragged along the bottom by two people.

Hoop Nets. This entrapment device is a cylindrical or conical net distended by a series of hoops or frames. The net has one or more internal funnel-shaped throats whose tapered ends are directed inward from the mouth. In riverine habitats, hoop nets are set with the mouth opening downstream and sufficient depths to cover the net. Hoop nets are usually baited and fished for at least 24 hours. This method is selective for bottom-feeding species such as carp, catfish, and suckers.

Fyke Nets. This entrapment device is a modified hoop net with one or two wings or leaders of webbing attached to the mouth to guide fish into the enclosure. Generally, fyke nets are set in shallow areas of ponds, lakes, or reservoirs, with sufficient depths to cover the top f the net. Fyke nets are selective for certain mobile, cover-seeking species such as sunfishes and pike.

Gill Nets. This entanglement gear consists of vertical walls of netting that are typically set out in a straight line in lakes, reservoirs, and ponds. Fish are captured as they swim into the netting and become entangled in the mesh. Gill nets can be set in many different ways, depending on the species desired and types of habitats in the water body. A variety of species can be captured by gill nets, but the gear is most effective for species that exhibit substantial daily movements. This collecting method usually targets adult fish, although juveniles can be captured if smaller mesh sizes are used.

3.1.2 Adult Spawning Counts

The number of spawning salmon that return to freshwater streams or rivers can be estimated by ground counts or aerial helicopter flyovers. These methods are applicable in clear streams with depths less than about six to eight feet. Helicopter surveys are conducted by flying just above tree height along the stream. An observer records the number and location of salmon. A sufficient number of surveys should be conducted to cover the peak spawning period for each of the salmon species. For effective counting, weather conditions should be mostly sunny and clear. Ground counts of spawning salmon can be used to census the number of salmon that reach their spawning areas in a drainage. One or more observers walk along the stream and count the number of spawning salmon. The survey needs to occur during the peak spawning period when most of the salmon have returned to their spawning areas.

3.1.3 Fish Tissue

Definition of metal concentrations in fish tissue can provide important baseline information concerning the background levels in the project study area. If metal contamination in fish tissue is identified as an impact issue, it is important to determine concentrations in the study area prior to the initiation of a new or modified monitoring activity. Numerous problems are typically

Table G-1. Summary of Fish Sampling Techniques

General Type of Water Body/ Sampling Gear	Types of Information					Salmonid Life Stages			References - Descriptions of Sampling Methods
	Species List	Distribution	Abundance/Composition	Population	Adult Spawning Counts	Adults	Juvenile	Young of the Year	
Streams/Shallow Rivers									
Backpack electroshocker, shore-based electroshocker	x	x	x	x		x	x		**Nielsen and Johnson (1983); Klemm et al. (1993)**
Snorkeling						x	x		**Overton et al. (1997)**
Seine net	x	x	x	x			x	x	**Nielsen and Johnson (1983); Klemm et al. (1993)**
Minnow trap	x	x	x				x	x	**Nielsen and Johnson (1983); Klemm et al. (1993)**
Weir	x	x	x			x	x		**Nielsen and Johnson(1983); Klemm et al. (1993)**
Ground survey					x	x			**See Section 3.1.2**
Aerial (helicopter) flyover					x	x			**See Section 3.1.2**
Deep Rivers (Moderate Velocities)									
Hoop net	x	x	x			x	x		**Nielsen and Johnson (1983)**
Deep Rivers (Low Velocities)									
Boat or raft electroshocker	x	x	x			x	x		**Nielsen and Johnson (1983)**
Lakes, Reservoirs, and Ponds									
Boat electroshocker	x	x	x			x	x		**Nielsen and Johnson (1983); Klemm et al. (1993)**
Fyke net	x	x	x			x	x		**Nielsen and Johnson (1983); Klemm et al. (1993)**
Gill net	x	x	x			x	x		**Nielsen and Johnson (1983); Klemm et al. (1993)**
Seine net							x	x	**Nielsen and Johnson (1983); Klemm et al. (1993)**

encountered during the design and implementation of a baseline sampling program for fish tissue analyses. Problem areas include definition of the most meaningful tissue(s) and metals for study, difficulties in collecting the desired samples (i.e., species, numbers, and sizes), proper handling and preparation of samples without contamination, and the interpretation of results. Metals are not evenly distributed among different specimens or within different organs or tissues. Natural variation in metal concentrations also typically exists in fish populations due to a variety of reasons such as movements, feeding habits, and physiological differences. Therefore, a relatively large number of replicates should be collected, if possible, to statistically differentiate various fish populations inhabiting the study area.

The final design for a fish tissue sampling study should be determined through discussions with the appropriate Federal and state agencies. Decisions need to be made regarding the sampling locations, target species, number of replicate samples, composite or individual samples, and tissues or organs to be analyzed. The types of tissues that are typically analyzed for metals include liver, gills, muscle, and whole body. Fish can be collected using any of the methods discussed above. Hook-and line method also is sometimes used to collect fish for tissue analyses.

Specific field and laboratory procedures have been developed to analyze metal concentrations in fish tissue. Field processing techniques, which are described in EPA (1980), involve decontamination of the sampling equipment, double wrapping the fish or tissue in 5 percent nitric acid-rinsed aluminum foil, and then placing the samples on ice during the time of sampling. At a minimum, samples should be kept on ice for no more than 24 hours. Fish or tissues should be frozen prior to shipment to a commercial laboratory for chemical analyses. The procedure for decontaminating sampling equipment consists of the following steps: (1) initial rinse with tap water; (2) wash with biodegradable detergent; (3) rinse with deionized water; (4) rinse with 5 percent nitric acid; and (5) final rinse with analyte-free water. Tissue can be removed from the whole fish in the field or in the laboratory. Latex gloves should be used for each decontamination procedure and field processing of each sample and then discarded.

Additional field data that are recommended for each fish sample include measurements of weight (in grams), length (in millimeters), and the removal of scales for age determination. It is important that the laboratory selected to perform the tissue analyses follows these procedures, including Quality Control/Quality Assurance measures.

3.2 Benthic Macroinvertebrates

Both quantitative and semi-quantitative methods are used to obtain abundance and composition data for macroinvertebrates. Sampling methods should be selected based on the scope and purpose of the overall study. Methods and data should be reviewed for accuracy and their appropriateness for meeting the study's specific objectives. The design of any additional or new studies must decide on whether semi-quantitative or quantitative methods are appropriate, given the purpose of the study and the nature of data from previous investigations (for example, to identify any trends, it might be appropriate to use the same methods as earlier studies even if other methods would provide more complete information).

Semi-quantitative methods typically consist of kick net samplers in streams. After placing the net in a riffle or run, the substrate material in front of the net is rubbed or agitated to remove any macroinvertebrates. The organisms in the sampled area drift into the net. The sampled area is estimated rather than measured. Data analyses usually consist of relative abundance of the various macroinvertebrate taxa present in the sample. Many state environmental agencies and the U.S. Geological Survey use this method in their National Water Quality Assessment Program. The existence of semi-quantitative data from previous surveys make the use of such methods more appropriate than would otherwise be the case.

Quantitative methods are used to provide abundance and composition data per unit area sampled. The sampling methodology depends upon the type of water body. In riffle areas of streams or rivers with depths less than about 18 inches, sieve-type samplers (either Surber or Hess) are the most common devices used to collect macroinvertebrates. The Surber sampler consists of a 1 square foot frame (0.09 square meter) with an attached net and bucket (0.5 millimeter mesh). The Hess sampler is a circular frame with an attached net (0.5 millimeter mesh) that encloses a surface area of approximately 1 square foot or 0.1 square meter. Both methods involve the removal of macroinvertebrates on substrate surfaces by hand. All collected material then is washed and concentrated into the bucket and placed into a labeled sample jar and preserved with formalin and ethanol. Field collection techniques for these methods are described by the following authors: Surber sampler (Surber, 1937; Hughes, 1975, Klemm et al., 1990) and Hess sampler (Hess, 1941; Waters and Knapp, 1961; Jacobi, 1978).

Quantitative sampling in deeper rivers, lakes, reservoirs, or ponds is accomplished using a grab-type device such as a petite Ponar, Peterson, or Eckman. These grab samplers are designed to penetrate the substrate and then enclose bottom substrate material with either spring- or gravity-operated mechanisms. The Eckman grab is relatively light and designed for soft bottoms consisting of sand, clay, silt, and organic material. For clay hardpan and coarse sands, heavier grabs such as the petite Ponar or Petersen are used. The most important criterion in effective grab sampling is to penetrate the bottom material and obtain complete closure of the sides of the sampler. The surface area sampled ranges from 0.25 square foot (0.02 square meter) with the petite Ponar to approximately 1 square foot (0.09 square meter) with the Peterson sampler. Descriptions of sampling techniques for these grab samplers are provided by Weber (1973), Elliott and Drake (1981), Lewis et al. (1982), and Klemm et al. (1990).

The design of a macroinvertebrate sampling program needs to select sampling sites that encompass areas potentially affected by past or future mining operations. If possible, a reference site, which is located outside the influence of the mining activities, should be selected that exhibits similar habitat conditions compared to downstream sites. By comparing sites with similar habitat conditions, the identification of possible causes for differences in macroinvertebrate communities often focuses on water quality. Two to four replicate samples also should be collected at each sampling site to provide sufficient data for statistical analyses, if required. At a minimum, one sampling effort should be conducted in the summer or early fall. Two sampling efforts (spring, summer, or fall) would account for seasonal changes in macroinvertebrate communities that result from developing young and adult hatching. If

previous sampling has been conducted, additional sampling should be scheduled to coincide with the dates as much as possible.

Laboratory processing for all samples consists of sorting and picking all macro-invertebrates into a vial, followed by identification and enumeration of all organisms. If the sample contains a large number of macroinvertebrates, subsampling of 500 organisms can be used (Hayslip, 1993). Identifications should be taken to the lowest possible taxonomic level to provide information on the composition and diversity of macroinvertebrates inhabiting the water body.

Data analyses recommended for a baseline study of macroinvertebrates varies depending upon whether issues were identified during scoping. At a minimum, the number of taxa, abundance, and composition data should be analyzed. However, data analyses are recommended only if at least 50 organisms are present in the sample. Densities are presented as the number of individuals of each taxon per square foot or square meter; composition is presented as percent of each taxon total macroinvertebrate densities at a sampling location. If a more detailed evaluation of sedimentation or metal toxicity are required, the following additional metrics can be analyzed.

- Number of Ephemeroptera (mayflies) taxa.
- Number of Plecoptera (stoneflies) taxa.
- Number of Trichoptera (caddisflies) taxa, whose absence may indicate metals contamination.
- Percent Dominant Taxon - Percent composition of the most abundant taxon in the macroinvertebrate community at a sampling location.
- Percent Baetidae - Percent composition of baetid mayflies (metal sensitive group).
- Species Diversity - Index that indicates taxonomic richness and abundance among the various taxa.
- Metal Tolerance Index - Rating system representing relative sensitivity or tolerance to metals developed by McGuire (1994) for western montane streams.

Information on how to use metric data in evaluating the impacts of mining or other stresses within a water body are discussed in Section 4.0 (Impact Assessment). For the purposes of including these metrics in baseline characterizations of macroinvertebrate communities, procedures are discussed in Plafkin et al. (1989), (Klemm et al. (1990), Wisseman (1996), and Barbour et al. (1997).

3.3 Amphibians

Amphibians are another group of organisms that inhabit aquatic environments. Due to widespread declines of amphibian populations, conservation planning and monitoring efforts have been implemented by Pacific Northwest Federal and state agencies. In the Pacific Northwest, numerous native amphibian species are listed as state "sensitive" or "special concern" species. Federal agencies such as the Forest Service also have targeted certain amphibian species as Forest "sensitive" species.

In general, two groups of amphibian assemblages are associated with aquatic habitats in the Pacific Northwest: (1) stream-dependent species which live in or adjacent to water during all or part of their life cycle (e.g., tailed frogs, *Ascaphus truei*, and giant salamanders, *Dicamptodon* spp.); and (2) pond-breeders which require standing water or lentic habitats for egg-laying and larval development (Olson et al., 1997). The following information describes the more common methods that can be used to collect data on species presence and relative abundance for stream and lentic environments. Detailed descriptions of these and other sampling methods can be found in Heyer et al. (1994) and Olson et al. (1997).

Visual Observations and Dipnetting. The most common method in determining the presence and relative abundance of amphibians in both stream and lentic environments involve visual observations and dipnetting. Species presence and relative abundance can be made by walking and counting amphibians within defined sections of the study area. If relatively large numbers of amphibians are encountered, subsampling can be used. Dipnetting can be used to collect egg masses, larvae, and adults in shallow aquatic areas by making sweeps in front and to the sides at designated stops. Each scoop should include the upper 2 to 3 centimeters of bottom from a sweep approximately 1 meter (3 feet) in length. After each scoop, water and fine sediment should be strained from the net by gently sloshing it back and forth in the surface water. The contents should be examined for adult and larval amphibians. If relative abundance is a study objective, it is important to standardize the distance between stops, as well as the number and length of sweeps. In this situation, abundance data are presented as the number of amphibians per area sampled.

A systematic approach in obtaining relative abundance data can be achieved by using quadrate or transect sampling methods. Quadrate sampling consists of laying out a series of small squares at randomly selected sites within a habitat type and thoroughly searching those squares for amphibians. In the transect method, narrow strip transects are randomly layed out and surveyed for amphibians. Patch sampling, which is a modified form of quadrate sampling, can be used to determine the presence and abundance of amphibians in discrete subunits of an area (i.e, logs, debris jams, etc.). Detailed descriptions of these methods are provided by Heyer et al. (1994).

Funnel Traps. For nocturnal or cryptic species, and habitats that are difficult to sample due to depth or abundance of vegetation, funnel trapping is a useful method. Funnel traps consist of a holding chamber with one or two tapered mouths that channel organisms toward a small entrance to the trap interior. One type of funnel trap that can be used is the commercially available minnow trap, which is constructed of 0.25-inch plastic or galvanized hardware cloth. Other commercial traps are available that are constructed of nylon webbing wrapped around a wire-frame. Traps are sometimes baited to attract amphibians.

Night Surveys. Since some amphibians are more active at night, visual surveys can be conducted using a flashlight. The reflective shine of amphibian eyes are used to record larvae and adults (Olson et al. 1997).

Snorkeling. Visual surveys conducted by snorkeling are useful in deep portions of lakes and wetlands. Visual counts are made along snorkeled transects or defined areas. The number of amphibians also can be recorded per unit of time surveyed.

Electrofishing. Generally, this method is used for fish surveys, but incidental observations of amphibians can be included as part of the fish survey. Pools and backwater areas represent the areas where amphibians may be encountered.

The design and selection of study sites for amphibian surveys are discussed in detail by Olson et al. (1997). Surveys should consider all aquatic habitats within a study area that could be inhabited by amphibians such as streams, rivers, ponds, lakes, meadows, and other wetland areas. If larvae and egg surveys are required, the surveys must be timed to coincide with the breeding and early development of the species (spring and summer).

3.4 Aquatic Habitat and Riparian Zone

The level of detail required for characterizing aquatic habitat within water bodies depends upon numerous factors such as the presence of game fish or T&E fish species, presence of critical habitat for Federally listed fish species, management goals for aquatic resources established by Federal and state agencies, types of potential impacts that could result from the mining project, and the level of concern for habitat impacts as identified during the scoping process. In some instances, existing habitat information may be available for watersheds that support game or T&E fish species. The data should be reviewed and determined whether it would be sufficient to characterize aquatic habitat for the NEPA document. If additional field surveys are required, methods should be used to allow comparisons to future monitoring programs or other watersheds. Examples of methods that are currently being used in the Pacific Northwest are summarized below.

Mining projects that are located on USFS land should use their preferred methods. The USFS Columbia Basin Anadromous Fish Policy and Implementation guidelines directed Columbia Basin Forests to have comparable data within basins to identify existing habitat conditions. The Salmon Conservation Strategy (PACFISH) use habitat variables for monitoring goals and objectives that help protect, maintain, and restore important fish habitat. As a result of these requirements, the R1/R4 habitat procedures were developed by Overton et al. (1997). The following parameters are covered in the R1/R4 manual: general type of habitat designation, discharge, gradient, stream width, stream depth, type and frequency of pools, percent surface fines, substrate composition, percent undercut bank, number of large woody debris, bank stability, vegetative cover, and Rosgen channel classification. The riparian zone provides important habitat values for the aquatic environment. Riparian surveys should include information on width of the zone, percent cover and composition of vegetation, and estimated shaded area. Methods for collecting these data are described by Platts et al. (1983), MacDonald (1991), and Hansen et al. (1995). When designing baseline habitat surveys for a mining project, these parameters should be considered. The final study design should be developed through discussions with the USFS and state agency biologists or habitat specialists.

Specific habitat procedures also may be recommended by state agencies. The appropriate state agency should be contacted prior to designing aquatic habitat studies to determine whether specific procedures are required. Standardized methods for characterizing habitat in western U.S. streams/rivers also are described by Binns (1982), Platts et al. (1983), Hamilton and Bergen (1984), and Rosgen (1985).

4.0 IMPACT ASSESSMENT

Numerous reviews of the effects of mining on aquatic resources are useful in identifying potential issues for a mining project (e.g., Martin and Platts, 1981; Meehan, 1991; Ripley et al., 1995; Waters, 1995; and Starnes and Gasper, 1996). Environmental impact statements (EIS) or environmental assessments (EA) that have been completed for similar mining projects also should be used in the issue identification task. This type of information available from published literature sources in conjunction with the scoping process are used in identifying specific impact issues for a project. Potential aquatic resource issues for a mining project may include the following topics:

- Potential effects of water quality changes on aquatic and semi-aquatic (mammals, amphibians, birds) communities and their habitat that may result from mine operation. Parameters of concern may include heavy metals, pH, and acid-generation materials.
- Potential effects of sedimentation on aquatic and semi-aquatic communities and their habitat due to construction and operation activities.
- Potential effects of physical disturbance or removal of habitat on aquatic and semi-aquatic biota.
- Potential effects of spills on aquatic and semi-aquatic biota that may result from fuel transportation and use (i.e., leaking equipment and refueling) and use of other hazardous materials.
- Potential effects of flow changes on aquatic habitat and riparian zones and their respective biota due to water withdrawals.
- Potential effects of physical blockages or barriers created by mining construction or operation activities on fish movements.

The analysis should encompass potential effects on riparian areas, which can in turn affect aquatic ecosystem health, and on aquatic and semi-aquatic organisms and ecosystems. As required under NEPA regulations, the impact assessment must analyze both direct and indirect impacts (Council on Environmental Quality, 1986). The analyses used in the environmental impact assessment must be scientifically accurate and exhibit scientific integrity. Specific methods used in analyzing impacts and making conclusions must be referenced in the NEPA document. The following information describes methods that can be used in analyzing impacts for the various issues listed above.

4.1 Water Quality Impacts

4.1.1 Comparisons to Aquatic Life Water Quality Criteria

Water quality issues associated with mine exploration, operation and abandonment activities involve the potential discharge of mine water and process solutions; increased loads of metals and other toxic pollutants; and the generation of acid from waste rock, spent ore, and mine workings. If these pollutants reach surface waters, toxic conditions could affect important aquatic species. Potential analytes of concern for mining projects generally include pH, cyanide and associated chemical species, and metals.

Actions and/or measures that can be taken to avoid or reduce water quality impacts from mining activities are discussed in Appendix B, *Receiving Waters*; Appendix C, *Characterization of Ore, Waste Rock, and Tailings*; Appendix D, *Effluent Quality*; Appendix E*, Wastewater Treatment*; and Appendix F, *Solid Waste Management*.

The most common approach used to analyze the effects of water quality changes on aquatic communities is to compare projected post-mining water quality to applicable standards intended to protect aquatic life. Water quality standards are based on three components:

(1) designated beneficial use or uses of water (i.e., aquatic life use)
(2) criteria designed to protect those uses (e.g., pH)
(3) an antidegradation provision.

The fish, macroinvertebrate, and/or periphyton assemblages are all direct measures of the aquatic life beneficial use under the CWA. For many metals, criteria are used to protect aquatic organisms from both acute[4] and chronic[5] toxicity. Standards for metals such as cadmium, chromium III, copper, lead, nickel, and zinc are dependent upon hardness (mg/L as $CaCO_3$), which is reflected in equations that are used to calculate the criterion for each metal. Toxicity is inversely related to hardness and EPA typically uses a conservative hardness (5^{th} or 10^{th} percentile) in determining applicable criteria. It is essential to have representative hardness data for the receiving water. The standards for metals also are based on either total recoverable or dissolved concentrations. The standards used (i.e., total recoverable or dissolved) should be incorporated into a baseline surface water sampling program.

The analysis requires close coordination between the surface water and aquatic resource analyses. The first step in the analysis is to characterize natural background concentrations using available data. Second, water quality conditions during mining and post-closure are projected. The final step in the analysis is to compare the pre-mining and post-mining water quality

[3]Acute toxicity is defined as concentrations that cause mortality or immobilization during a short-term period (usually 48 to 96 hours) of exposure.

[4]Chronic toxicity is defined as concentrations that cause reproductive impairment or other sublethal effects during a long-term period (seven days to greater than one year) of exposure.

concentrations to state water quality standards. It is important to estimate water quality during and after mining for both the proposed operation and alternatives; this would involve analyses both qualitative and quantitative) including various combinations of best management practices and other mitigation measures.

If analytes of concern are identified for the project study area, a qualitative discussion of impacts can be made using available published literature. The discussion should describe the types of effects that the analytes of concern may have on fish and macroinvertebrate communities. If possible, affected water bodies that may exhibit toxic conditions should be identified in terms of their length or surface area.

The issue of sediment water quality effects on aquatic biota is more difficult to evaluate, since standards are not available. The best approach in analyzing this issue is to compare natural background and post-mining sediment quality to benchmark values available in the published literature. These comparisons help identify whether the sediment quality is within background levels reported for areas with no known metal contamination. Examples of information sources for metal concentrations in sediment include Washington State Department of Ecology (1991); EPA (1994a; 1995); and Jones et al. (1996).

4.1.2 Toxicity Studies

Additional site-specific information can be obtained by conducting toxicity studies using surface water or sediment from the project study area. These tests can be used to confirm potential water quality concerns identified as part of the water quality comparisons between post-mining conditions and applicable water quality standards. Typically, microcrustaceans (*Dapnia* or *Ceriodaphnia* species) and fish species are used as test organisms, although test procedures exist for a variety of macroinvertebrates such as midges, mayflies, annelid worms, and amphipods. If additional testing is required, decisions need to be made concerning the test organisms, type of test (acute or chronic), static or flow-through conditions, test medium (surface water or sediment), and concentrations to be tested. Mining companies (or their representatives) are strongly encouraged to consult with the EPA and the appropriate state agency before designing and conducting toxicity tests. The following test procedures should be followed for designing and conducting the tests:

- Acute Toxicity - Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms (Weber, 1993).
- Chronic Toxicity - Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms (Lewis et al., 1994).
- Sediment Toxicity and Bioaccumulation - Methods for Measuring the Toxicity and Bioaccumulation of Sediment-Associated Contaminants with Freshwater Invertebrates (EPA, 1994b) and Standard Test Methods for Measuring the Toxicity of Sediment-Associated Contaminants with Freshwater Invertebrates (American Society for Testing Materials, 1998).

Additional guidance in designing and conducting toxicity testing is provided in *Standard*

Methods for the Examination of Water and Wastewater (American Public Health Association et al., 1989).

4.1.3 Macroinvertebrate Metric Analysis

Macroinvertebrate communities are useful indicators for assessing the effects of various types of environmental stress, as reflected in degraded water quality conditions or habitat. Many benthic macroinvertebrates have limited migration patterns or a sessile mode of life, which makes them well-suited to assess site-specific impacts. Macroinvertebrate assemblages are comprised of a broad range or organisms that exhibit varying levels of tolerance to pollution sources such as sedimentation and metals (Barbour et al., 1997).

The evaluation of impacts on macroinvertebrates typically uses relevant literature pertaining to the effects of sedimentation and metals contamination on macroinvertebrate communities. Previous studies have found that macroinvertebrates often respond to sedimentation or metals contamination by exhibiting reduced densities, reduced taxa richness, and a shift from sensitive to tolerant taxa (Winner et al., 1980; Clements, 1994; Waters, 1995). The absence or low numbers of Ephemeroptera, Plecoptera, and Trichoptera may indicate metal contamination. Predictions of potential impacts can be made using the results of these relevant studies.

Additional analysis of macroinvertebrate data from a project study area can be used to monitor or confirm the projected impacts of mining projects. Numerous types of information or metrics have been used to evaluate the effects of various types of environmental stresses on macroinvertebrate communities. Examples of metrics that have been used to evaluate the effects of metals and sediment on macroinvertebrate communities include total abundance, total number of taxa, number of Ephemeroptera taxa, number of Plecoptera taxa, number of Trichoptera taxa, percent dominant taxon, percent Baetidae, and Metal Tolerance Index (Plafkin et al., 1989; Resh and Jackson, 1993; Wisseman, 1996; Fore et al., 1996; and Barbour et al., 1997). Refer to Section 3.2 for definitions of these metric terms. The final selection of the metric data should be made through discussions with appropriate Federal and state agency biologists. After completing the metric data analyses, comparisons should be made between the reference and downstream sites. Procedures for conducting macroinvertebrate metric data analyses are described by Plafkin et al. (1989), Wisseman (1996), and Barbour et al. (1997).

4.2 Sedimentation

Several types of analyses can be used to evaluate the potential effects of sedimentation on aquatic communities and their habitat. Indicators that can be used to discuss potential sediment-related impacts in streams include change in percent fines or cobble embeddedness. For all types of water bodies, aquatic life water quality standards also may exist for sediment-related parameters such as turbidity or total suspended solids (TSS). Baseline data should be used to characterize the range in values for one or more of these parameters. If possible, percent increases in these values that could occur as a result of project activities should be estimated (see Appendix H, *Erosion and Sedimentation* for a detailed discussion of methods

to quantify sediment loadings). The predicted increase in the sediment-related indicators should then be related to levels that have been reported as limiting fish or macroinvertebrate development. For example, percent fines of 40 percent or greater have been reported to adversely affect salmonid fry development and emergence (Bjornn et al., 1977; McCuddin, 1977). Burton et al. (1991) proposed that no statistically significant increase in natural baseline percent embeddedness should occur in Idaho salmonid rearing habitats.

If quantitative predictions are not possible for the sediment indicators, then a qualitative analysis should be used to discuss potential adverse effects on aquatic communities using published literature. The duration of impacts that have resulted from similar mining projects should be included in the impact discussion. The impact analysis also should estimate the linear length of streams, surface area of lakes/reservoirs that could potentially exhibit increased sediment yield as a result of mining activities. The analysis should focus on the affected aquatic environments that support aquatic communities and habitat.

4.3 Habitat Alteration

The types of information that are needed to evaluate the potential effects of removing or altering habitat for important game and T&E fish species and other aquatic and semi-aquatic species include: (1) identify stream segments or water bodies affected by mining activities; (2) quantify the area of disturbance in square feet or acres; (3) determine list of fish species that utilize the affected areas; (4) characterize the general types of habitat affected; and (5) describe the fish life stages (i.e., spawning, young-of-the-year rearing, etc.) that potentially use the affected areas. The impact discussion should evaluate the significance of altering or removing the habitat for the important species by considering the magnitude (square feet or acres affected) and duration of impacts. The use of the impacted area should be related to the amount of similar types of habitat that are available within the project study area.

Mining activities also may involve the loss of aquatic habitat by physical placement of materials in a portion of a drainage, which may itself need a permit. In this situation, flows are usually diverted from the "affected stream segment" into a newly constructed channel. The impacts of removing and replacing stream segments should be quantified in square feet or acres in relation to the important fish and macroinvertebrate taxa that occur in the affected areas. The recovery of aquatic communities in the newly constructed channels needs to be discussed using published studies that have monitored aquatic biota after flow was returned to a stream.

4.4 Hazardous Material Spills

Transportation of fuel and other toxic chemicals to and from the mine site present potential risks to aquatic communities from spills that enter water bodies. At a minimum, the impact discussion should describe the effects of potential spills on aquatic communities using available literature on toxicity of fuel and the various chemicals being transported and/or stored on-site. The analysis should focus on stream segments or water bodies that are located adjacent to and downstream of the transportation route and project area---all areas where spills may occur. The discussion also should explain that the magnitude and duration of impacts would

depend upon the chemical spilled, volume spilled, toxicity to aquatic species, time of year, weather conditions, and physical characteristics of the water body. Reference should be made to any relevant published studies that have conducted after similar types of spills.

A risk assessment may be used to analyze the impacts from potential spills, if this topic is identified as a significant issue. The following types of information are typically included in a risk assessment:

- Identify the types and volumes of toxic chemicals that are transported to and from, and/or are stored at the mine site;
- Determine the frequency and schedule of transporting toxic chemicals;
- Identify the transportation route;
- Define the spill scenarios to be analyzed;
- Determine the presence of important fish species in water bodies located adjacent to the transportation route;
- Characterize the condition of roads used in transporting toxic chemicals;
- Describe the effects of fuel or chemical spills on aquatic species using available published literature;
- Describe spill risks in terms of probabilities using vehicle accident data; and
- Describe methods (BMPs) for reducing the risk of spills from transport and/or storage of fuels and toxic chemicals.

The contents and methodology to be used in the risk assessment analysis should be discussed with the appropriate Federal and state agencies prior to commencing the work. Guidance documents that can be used in designing the risk assessment include EPA (1992; 1997; 1998).

4.5 Flow Alterations

Water use for mine operations could affect flows in streams that contain important game and T&E fish species. Stream flow and water volumes represent an important aspect of fish habitat. These parameters in combination with other factors such as substrate, depth, and overhanging cover define habitat conditions in a stream.

The type of analysis required to evaluate this issue depends upon the magnitude of flow change and the presence of important species in the affected water bodies. If flow data are lacking, studies may be required to obtain the necessary data. In general, key aspects of the data set (including sources of data, periods of time covered, definitions and descriptions of of data elements) that is used should be fully described. Mining companies (or their representative) should contact hydrologists with the lead Federal agency and appropriate state agency prior to designing flow studies. The simplest approach is to estimate the percent change in flow for the affected streams compared to pre-project or base flow conditions. If possible, the flow data should be summarized on a monthly basis to reflect any seasonal aspects of fish distribution, movements, or life history information. Using the percent flow changes, a qualitative discussion should be made to identify the types of impacts on fish species. For example, a 40 percent

reduction in flows during the spring would reduce available wetted habitat for rainbow trout spawning. Relevant published literature should be used to identify the types of impacts that could result from flow changes. This qualitative approach is appropriate for projects that would result in relatively small flow changes or study areas that do not support important game or T&E species.

If flow alteration is a controversial issue for a project, a quantitative method such as the Instream Flow Incremental Methodology (IFIM) should be used to quantify the effects of flow regimes on fish habitat (Bovee, 1982). IFIM utilizes a hydraulic-simulation technique to predict depths, velocities, and substrates within a stream reach at different flows. Results from the simulation are then combined with microhabitat preferences for the fish species of interest to estimate the amount of suitable habitat. Microhabitat preferences are expressed in the form of habitat-suitability curves for the various life stages for each fish species of interest. Studies have been conducted to develop habitat-suitability curves for a variety of fish species (e.g., Bovee, 1978; Raleigh, 1982; McMahon, 1983; Raleigh et al., 1984; Raleigh and Nelson, 1985; Raleigh et al., 1986a; 1986b). These curves can be used in the habitat simulation analysis. If curves are lacking for the species of interest, curves should be developed for the project study area following techniques described by Bovee and Cochnauer (1977).

Implementation of the IFIM requires the use of a system of computer programs called PHABSIM (Physical Habitat Simulation) (Milhous et al., 1981). The PHABSIM programs simulate the physical habitat of fish as a function of stream flow and transform the hydraulic information (depth, velocity, substrate) into a measure of useable habitat. Field surveys are required to collect flow, depth, and substrate data along transects established in the streams affected by flow changes. After the hydraulic simulation is completed, suitability curves for the target species are used as input to a habitat program, which computes the amount of physical habitat that is available for each target species at a range of flows. This analysis should be completed for both pre- and post-project scenarios. The end product is a quantitative estimate of the change in available habitat in square feet for each target species. A significance level should be established through discussions with appropriate agency biologists or IFIM specialists to interpret the results. For example, a 25 percent reduction in spawning habitat for brown trout could represent a significant impact.

4.6 Obstruction to Fish Movement

If mining activities place materials or structures in a drainage on a temporary or permanent basis, the effects on fish movements need to be addressed. The initial step in the analysis is to identify whether important game or T&E fish species exhibit wide range movements in the affected stream segment. The period of movement then needs to be identified for each species. A particularly important period for trout and anadromous salmon species is spawning, when fish migrate to specific areas to lay eggs. Another critical period for salmon is out-migration of juveniles from their nursery streams to the ocean. Blockages or obstructions to these movements need to be identified in the impact assessment. In most instances, project mitigation is required to eliminate potential blockages to fish movement.

5.0 REFERENCES

American Public Health Association, American Water Works Association, and Water Pollution Control Federation, 1989. *Standard Methods for the Examination of Water and Wastewater, Seventeenth Edition,* American Public Health Association, Washington, D.C.

American Society for Testing Materials, 1998. Standard Test Methods for Measuring the Toxicity of Sediment-Associated Contaminants with Freshwater Invertebrates, Method E 1706-95b. *In: 1998 Annual Book of ASTM Standards,* ASTM, West Conshohocken, Pennsylvania.

Barbour, M.T., Gerritsen, J., Snyder, B.D., and Stribling, J.B., 1997. Revision to Rapid Bioassessment Protocol for Use in Streams and Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, U.S. Environmental Protection Agency Report EPA/841-D-97-002, Washington, D.C.

Binns, N.A., 1982. *Habitat Quality Index Procedures Manual,* Wyoming Game and Fish Department, Cheyenne, Wyoming, 209 pp.

Bjornn, T.C., Brusven, M.A., Molnau, M.P., Milligan, J.H., Klamt, C.E., and Schaye, C., 1977. *Transport of Granitic Sediment in Streams and its Effects on Insects and Fish,* Bulletin 17, University of Idaho, Moscow, Idaho, 43 pp.

Bovee, K.D, 1978. *Probability of Use Criteria for the Family Salmonidae,* Instream Flow Information Paper No. 4, U.S. Fish and Wildlife Service, FWS/OBS-78-07, 53 pp.

Bovee, K.D, 1982. *A Guide to Stream Habitat Analysis Using the Instream Flow Incremental Methodology,* Instream Flow Information Paper No. 12, U.S. Fish and Wildlife Service, FWS/OBS-82-86, 235 pp.

Bovee, K.D. and Cochnauer, T., 1977. *Development and Evaluation of Weighted Criteria, Probability-of-Use Curves for Instream Flow Assessment: Fisheries,* U.S. Fish and Wildlife Service, FWS/OBS-77/63.

Brower, J.E. and Zar, J.H., 1977. Field and Laboratory Methods for General Ecology, Wm. C. Brown Company Publishers, Dubuque, Iowa, 194 pp.

Burton, T.A., Clark, W.H., Harvey, G.W., and Maret, T.R., 1991. Development of Sediment Criteria for the Protection and Propagation of Salmonid Fishes. *In: Biological Criteria: Research and Regulation of Salmonid Fishes, Proceedings of a Symposium,* U.S. Environmental Protection Agency Report EPA-440/5-91-005, Washington, D.C., pp. 142-144.

Clements, W.H., 1994. Benthic Invertebrate Community Responses to Heavy Metals in the Upper Arkansas River Basin, Colorado, *Journal of the North American Benthological Society,* vol. 13, no. 1, pp. 30-44.

Council on Environmental Quality, 1986. *Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act,* Executive Office of the President, 40 CFR Parts 1500-1508.

Elliott, J.M. and Drake, C.M., 1981. A Comparative Study of Seven Grabs Used in Sampling Benthic Macroinvertebrates in Rivers, *Freshwater Biology,* vol. 11, pp. 99-120.

Fore, L.S., Karr, J.R, and Wisseman, R.W., 1996. Assessing Invertebrate Responses to Human Activities: Evaluating Alternative Approaches, *Journal of the North American Benthological* Society, vol. 15, no. 2, pp. 212-231.

Hamilton, K. and Bergen, E.P., 1984. *Methods to Estimate Aquatic Habitat Variables,* Report prepared for the Bureau of Reclamation, Denver, Colorado by Colorado State University and the Colorado Cooperative Fishery Research Unit, Fort Collins, Colorado.

Hansen, P.L., Pfister, R.D., Boggs, K., Cook, B.J., Joy, J., and Hinckley, D.K., 1995. *Classification and Management of Riparian and Wetland Sites*, University of Montana, Miscellaneous Publication No. 54, Missoula, Montana.

Hayslip, G.A., 1993. *EPA Region 10 In-stream Biological Monitoring Handbook (for Wadable Streams in the Pacific Northwest)*, U.S. Environmental Protection Agency, Region 10, Seattle, Washington, Report EPA/910/9-92/013.

Hess, A.D, 1941. *New Limnological Sampling Equipment*, Limnological Society of America Special Publication 6, pp. 1-5.

Heyer, W.R., Donnelly, M.A., McDiarmid, R.W., Hayek, L.C., and Foster, M.S. (Eds), 1994. *Measuring and Monitoring Biological Diversity - Standards and Methods for Amphibians*, Smithsonian Institution Press, Washington, D.C., 364 pp.

Hughes, B.D., 1975. A Comparison of Four Samplers for Benthic Macroinvertebrates Inhabiting Coarse River Deposits, *Water Research*, vol. 9, pp. 61-69.

Jacobi, G.Z., 1978. An Inexpensive Circular Sampler for Collecting Benthic Macroinvertebrates in Streams, *Archives of Hydrobiology,* vol. 83, pp. 126-131.

Jones, D.S., Hull, R.N., and Suter, G.W. II, 1996. *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Sediment-Associated Biota, 1996 Revision,* Oak Ridge National Laboratory Report ES/ER/TM-95/R2, Oak Ridge, Tennessee.

Karr, J.R. and Dudley, D.R., 1981. Ecological Perspective on Water Quality Goals, *Environmental*

Management, vol. 5, pp. 55-68.

Klemm, D.J., Lewis, P.A., Fulk, F., and Lazorchak, J.M., 1990. *Macroinvertebrate Field and Laboratory Methods for Evaluating the Biological Integrity of Surface Waters*, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio, Report EPA/600/4-90/030.

Klemm, D.J., Stober, Q.J., and Lazorchak, J.M., 1993. *Fish Field and Laboratory Methods for Evaluating the Biological Integrity of Surface Waters*, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio, Report EPA/600/R-92/111.

Lewis, P.A., Klemm, D.J., Lazorchak, J.M., Norberg-King, T.J., Peltier, W.H., and Heber, M.A., 1994. *Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms, Third Edition,* Environmental Monitoring Systems Laboratory, U.S. Environmental Protection Agency, Cincinnati, Ohio, Report EPA/600/4-91/002.

Lewis, P.A., Mason, W.T., and Weber, C.I., 1982. Evaluation of Three Bottom Grab Samplers for Collecting River Benthos, *Ohio Journal of Science,* vol. 82, pp. 107-113.

MacDonald, L.H., 1991. *Monitoring Guidelines to Evaluate Effects of Forestry Activities on Streams in the Pacific Northwest and Alaska*, University of Washington, Seattle, Washington, Report EPA/910/9-91/001.

Martin, S.B. and Platts, W.S., 1981. *Influence of Forest and Rangeland Management on Anadromous Fish Habitat in Western North America, Effects of Mining,* USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, General Technical Report PNW-119, 15 pp.

McCuddin, M.E., 1977. *Survival of Salmon and Trout Embryos and Fry in Gravel-Sand Mixtures,* Unpubl. M.S. Thesis, University of Idaho, Moscow, Idaho, 30 pp.

McGuire, D., 1994. *Montana Nonpoint Source Water Quality Investigations: 1992 Macroinvertebrate Assessments,* Montana Department of Health and Environmental Sciences, 18 pp. plus appendices.

McMahon, T.E., 1983. *Habitat Suitability Index Models: Coho Salmon,* U.S. Fish and Wildlife Service Report FWS/OBS-82/10.49, Washington, D.C., 29 pp.

Meehan, W.R., 1991. *Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats,* American Fisheries Society Publication No. 19, 751 pp.

Milhous, R.T., Wegner, D.L., and Waddle, T., 1981. *Users Guide to the Physical Habitat Simulation System (PHABSIM),* Instream Flow Information Paper No. 11, U.S. Fish and Wildlife Service Report FWS/OBS-81/43, 475 pp.

Nielsen, L.A. and Johnson, D.L., 1983. *Fisheries Techniques*, American Fisheries Society, Bethesda, Maryland, 468 pp.

Olson, D.H., Leonard, W.P., and Bury, R.B. (Eds), 1997. *Sampling Amphibians in Lentic Habitats*, Society for Northwest Vertebrate Biology, Olympia, Washington, Northwest Fauna No. 4, 134pp.

Overton, C.K., Wollrab, S.P., Roberts, B.C., and Radko, M.A., 1997. *R1/R4 (Northern/Intermountain Regions) Fish and Fish Habitat Standard Inventory Procedures Handbook,* General Technical Report INT-GTR-346, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, Utah.

Plafkin, J.L., Barbour, M.T., Porter, K.D., Porter, K.D., Gross, S.K., and Hughes, R.M., 1989. *Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish,* U.S. Environmental Protection Agency, Washington, D.C., Report EPA/440/4-89/001.

Platts, W.S, Megahan, W.F., and Minshall, G.W., 1983. *Methods for Evaluating Stream, Riparian, and Biotic Conditions,* U.S. Forest Service, Intermountain Forest and Range Experiment Station General Technical Report INT-138, Ogden, UT, 70 pp.

Plotnikoff, R.W. and White, J.S., 1996. *Taxonomic Laboratory Protocol for Stream Macroinvertebrates Collected by the Washington Department of Ecology*, Ecology Publication No. 96-323. Washington Department of Ecology, Olympia, Washington.

Raleigh, R.F., 1982. *Habitat Suitability Index Models: Brook Trout,* U.S. Fish and Wildlife Service Report FWS/OBS-82/10.24, Washington, D.C., 42 pp.

Raleigh, R.F., Miller, W.J., and Nelson, P.C., 1986a. *Habitat Suitability Index Models and Instream Flow Suitability Curves: Chinook Salmon,* U.S. Fish and Wildlife Service, Washington, D.C., Biological Report 82(10.122), 64 pp.

Raleigh, R.F., Zuckman, L.D. and Nelson, P.C., 1986b. *Habitat Suitability Index Models and Instream Flow Suitability Curves: Brown Trout,* U.S. Fish and Wildlife Service, Washington, D.C., Biological Report 82(10.124), 65 pp.

Raleigh, R.F. and Nelson, P.C., 1985. *Habitat Suitability Index Models and Instream Flow Suitability Curves: Pink Salmon,* U.S. Fish and Wildlife Service, Washington, D.C., Biological Report 82(10.109), 35 pp.

Raleigh, R.F., Hickman, T., Solomon, R.C., and Nelson, P.C., 1984. *Habitat Suitability Information: Rainbow Trout,* U.S. Fish and Wildlife Service, Washington, D.C., FWS/OBS-82/10.60, 64 pp.

Resh, V.H. and Jackson, J.K., 1993. Rapid Assessment Approaches to Biomonitoring Using Benthic Macroinvertebrates. *In:* Resh, V.H. and Rosenberg, D.M., *Freshwater Biomonitoring and Benthic Macroinvertebrates,* Routledge, Chapman, & Hall, Inc., N.Y., N.Y., pp. 40-158.

Ripley, E.A., Redmann, R.E., and Crowder, A.A., 1995. *Environmental Effects of Mining,* St. Lucie Press.

Rosgen, D. L., 1985. A Stream Classification System. *In: Riparian Ecosystems and Their Management: Reconciling Conflicting Uses*, U.S. Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-120, pp. 91-95.

Seber, G.A. and Le Cren, E.D., 1967. Estimating Population Parameters from Catches Large Relative to the Population, *Journal of Animal Ecology,* vol. 36, pp. 631-643.

Starnes, L.B. and Gasper, D.C., 1996. Effects of Surface Mining on Aquatic Resources in North America, *Fisheries,* vol. 21, no. 5, pp. 24-26.

Surber, E.W., 1937. Rainbow Trout and Bottom Fauna Production in One Mile of Stream, *Transactions of the American Fisheries Society*, vol. 66, pp.193-202.

U.S. Environmental Protection Agency (EPA), 1998. *Guidelines for Ecological Risk Assessment. Final,* U.S. EPA Environmental Response Team, Edison, New Jersey.

U.S. Environmental Protection Agency (EPA), 1997. *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments. Interim Final,* U.S. EPA Environmental Response Team, Edison, New Jersey.

U.S. Environmental Protection Agency, 1996. *Biological Criteria: Technical Guidance for Streams - Revised Edition*, U.S. Environmental Protection Agency, Office of Water, Office of Science and Technology, Washington, D.C, Report EPA/822/B-96/001.

U.S. Environmental Protection Agency (EPA), 1995. *National Sediment Inventory: Documentation of Derivation of Freshwater Sediment Quality,* Office of Water, Washington, D.C.

U.S. Environmental Protection Agency (EPA), 1994a. *Briefing Report to the EPA Science Advisory Board on the EqP Approach to Predicting Metal Bioavailability in Sediment and the Derivation of Sediment Quality Criteria for Metals,* U.S. EPA Report EPA 822/D-94/002, Washington, D.C..

U.S. Environmental Protection Agency (EPA), 1994b. *Methods for Measuring the Toxicity and Bioaccumulation of Sediment-Associated Contaminants with Freshwater Invertebrates,* Environmental Monitoring Systems Laboratory, Cincinnati, Ohio, Report EPA/600/R4-94/024.

U.S. Environmental Protection Agency (EPA), 1992. *Framework for Ecological Risk Assessment,* Risk Assessment Forum Report EPA/630/R-92/001.

U.S. Environmental Protection Agency (EPA), 1980. *Interim Methods for the Sampling and Analysis of Priority Pollutants in Sediments and Fish Tissues,* Environmental Monitoring and Support Laboratory, Cincinnati, Ohio.

Washington State Department of Ecology, 1991. *Summary of Criteria and Guidelines for Contaminated Freshwater Sediments,* Environmental Investigations and Laboratory Services, Sediment Management Unit.

Waters, T.F., 1995. *Sediment in Streams: Sources, Biological Effects, and Control,* American Fisheries Society Monograph No. 7, 251 pp.

Waters, T.F. and Knapp, R.J., 1961. An Improved Stream Bottom Fauna Sampler, *Transactions of the American Fisheries Society,* vol. 90, pp. 225-226.

Weber, C.I., 1993. *Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms, Fourth Edition,* Environmental Monitoring Systems Laboratory, U.S. Environmental Protection Agency, Cincinnati, Ohio, Report EPA/600/4-90/027F.

Weber, C.I., (ed.), 1973. *Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents,* Office of Research and Development, Environmental Monitoring Series, U.S. Environmental Protection Agency, Cincinnati, Ohio, Report EPA-670/4-73-001.

Winner, R.W., Boesel, M.W., and Farrell, M.P., 1980. Insect Community Structure as an Index of Heavy-Metal Pollution in Lotic Ecosystems, *Canadian Journal of Fisheries and Aquatic Science,* vol. 37, pp. 647-655.

Wisseman, R.W., 1996. *Benthic Invertebrate Biomonitoring and Bioassessment in Western Montane Streams,* Aquatic Biology Associates, Corvallis, Oregon, 15 pp.

Zippin, C., 1958. The Removal Method of Population Estimation, *Journal of Wildlife Management,* vol. 32, pp. 325-339.

6.0 CONTACTS AND OTHER INFORMATION SOURCES

6.1 Contacts for Fish Information

Alaska Department of Fish and Game, Juneau, AK and appropriate Regional Office

- Commercial Fisheries Management and Development Division
- Division of Subsistence
- Division of Sports Fish

Washington Department of Fish and Wildlife, Olympia, WA and Regional Office

- Fish Management Program

Oregon Department of Fish and Wildlife, Portland, OR and Regional Office

- Fisheries Division

Idaho Department of Fish and Game, Boise, ID and Regional Office

- Fisheries Division

6.2 Contacts for Habitat Information

Alaska Department of Fish and Game, Juneau, AK and appropriate Regional Office

- Habitat and Restoration Division

Washington Department of Fish and Wildlife, Olympia, WA and Regional Office

- Habitat Program

Oregon Department of Fish and Wildlife, Portland, OR and Regional Office

- Habitat Conservation Division

Idaho Department of Fish and Game, Boise, ID and Regional Office

- Fisheries Division

6.3 Contacts for Aquatic Life Water Quality Criteria

Alaska Department of Environmental Conservation, Juneau, AK and appropriate Regional Office

- Division of Environmental Quality

Washington Department of Ecology, Olympia, WA and Regional Office

- Water & Shorelands Division

Oregon Department of Environmental Quality, Portland, OR and Regional Office

- Water Quality Division

Idaho Division of Environmental Quality, Department of Health and Welfare, Boise, ID

- Division of Environmental Quality