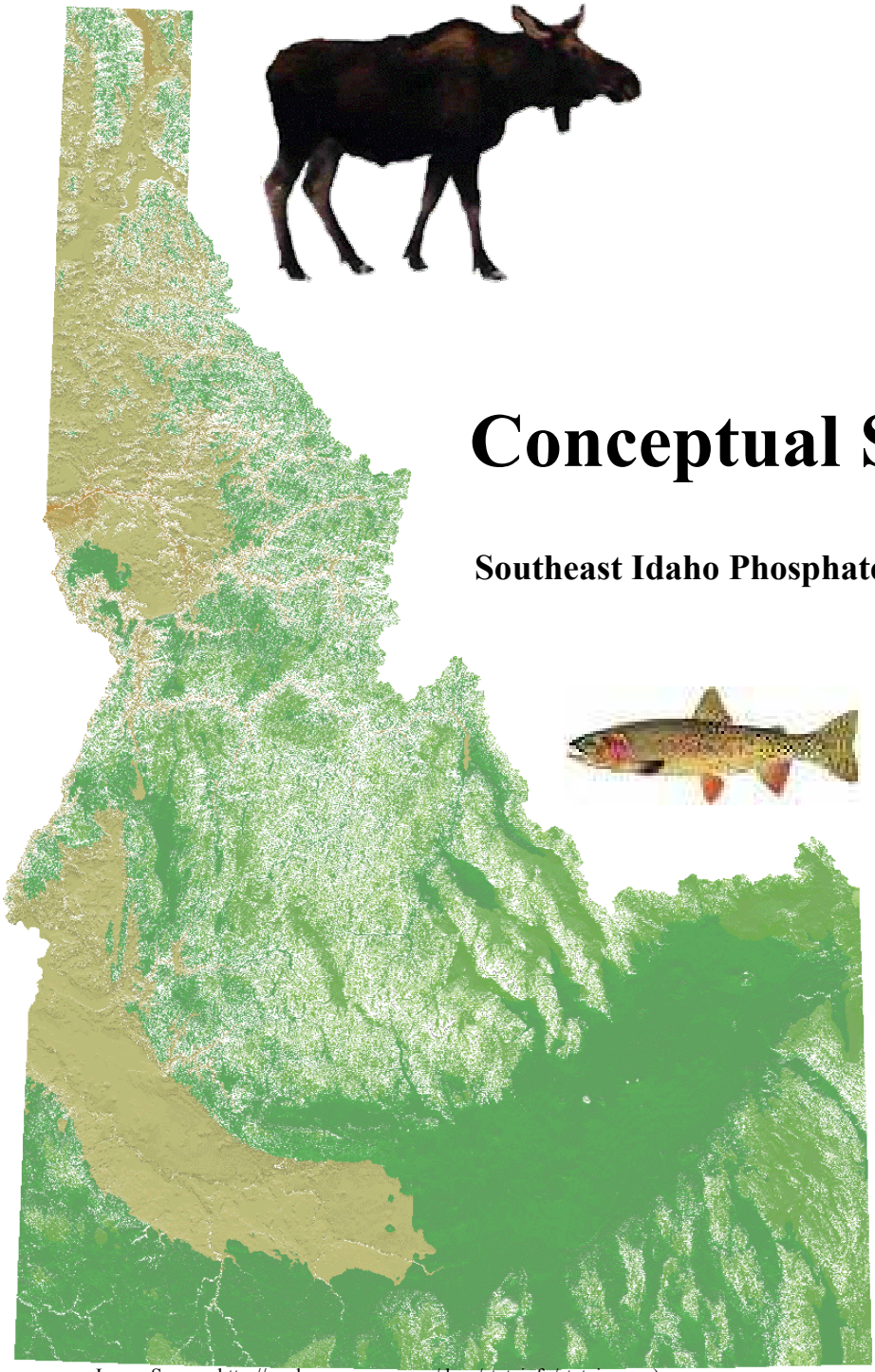

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FINAL

Conceptual Site Models

Selenium Project

Southeast Idaho Phosphate Mining Resource Area

October 2001

State of Idaho Department of Environmental Quality

TETRA TECH EM INC.

AREA WIDE INVESTIGATION
SOUTHEAST IDAHO PHOSPHATE MINING RESOURCE AREA
CONTRACT NUMBER C023
Task Order AWI-00-01

Prepared for

IDAHO DEPARTMENT OF ENVIRONMENTAL QUALITY
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FINAL

CONCEPTUAL SITE MODELS

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October 2001

Prepared by

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1.0 INTRODUCTION

The Idaho Department of Environmental Quality (IDEQ) retained Tetra Tech EM Inc. (TtEMI) in October 2000 to perform an independent review of the existing data and preliminary risk assessment compiled and published by the Idaho Mining Association (IMA) Selenium Committee. TtEMI also will assist the IDEQ in development of final human health and ecological risk assessments associated with past phosphate mining operations in the Southeast Idaho Phosphate Mining Resource Area (Resource Area) to support future agency risk management decisions for the region. This work is being carried out as part of an Area Wide Scope of Work, referenced in the July 2000 *Interagency Memorandum of Understanding concerning Contamination from Phosphate Mining Operations in Southeastern Idaho* (MOU), negotiated between the IDEQ and tribal/federal agencies with jurisdictional responsibilities in the region. The MOU specified the IDEQ as the lead agency for coordinating future activities of the area wide investigation and for establishing regional cleanup guidance to assist lead agencies in implementing future site-specific remedial efforts. The area wide investigation is incorporated as part of an Administrative Order of Consent (AOC) negotiated with the responsible mining companies.

1.1 BACKGROUND

Phosphate mining has been practiced in southeastern Idaho throughout most of the 20th century, starting with the Waterloo Mine in 1907. The major phosphate mines in this region are open pit or contour strip operations that were developed near surface exposures of the Phosphoria Formation. The phosphate ore is transported by truck, rail, and slurry pipeline to local processing facilities in Soda Springs and Pocatello, Idaho. Production from this region represents a significant source of phosphorous for industrial and agricultural applications. Nearly 40 percent of the United States (U.S.) phosphate reserves occur in the Phosphoria Formation in southeastern Idaho, northern Utah, and western Wyoming.

In 1996, isolated livestock losses associated with excessive selenium uptake prompted concerns about potential ecological and human health impacts from past mining operations (Montgomery Watson [MW] 1999b). In response to these concerns, five companies operating mines in the region formed an "*ad hoc*" Selenium Committee with the IMA to characterize the environmental risks and identify mitigation measures associated with phosphate mining. The IMA Selenium Committee, composed of the companies listed in Table 1, was formed in 1997 to voluntarily and jointly address mining related environmental issues from a regional basis. An Interagency/Phosphate Industry Selenium Working Group (SeWG) was subsequently established to facilitate communication and participation by cooperating federal, state, local, and tribal entities.

The SeWG consisted of voluntary representatives, including:

- IDEQ
- Idaho Department of Lands
- Idaho Department of Fish and Game (IDFG)
- Idaho Department of Health (IDH)
- Shoshone-Bannock Tribes
- Southeastern District Health Department (SDHD)
- U.S. Forest Service (FS)
- U.S. Bureau of Land Management (BLM)
- U.S. Bureau of Indian Affairs (BIA)
- U.S. Fish and Wildlife Service (FWS)
- U.S. Environmental Protection Agency (EPA)
- U.S. Geological Survey (USGS)
- Other Interested Stakeholders (i.e. ranchers, Greater Yellowstone Coalition, etc.)

Table 1. List of Area Wide Mines and Operators, Southeast Idaho (MW 1999b)

Company	Mines	
	Active	Inactive
Astaris Production LLC	Dry Valley Mine	Gay Mine[1]
J.R. Simplot Company	Smoky Canyon Mine	Lanes Creek Mine Conda Mine Gay Mine[1]
Nu-West Industries, Inc., and Nu-West Mining, Inc.	Rasmussen Ridge Mine[2]	Mountain Fuel Mine Champ Mine North Maybe Canyon Mine South Maybe Canyon Mine[3] Georgetown Canyon Mine
P4 Production LLC[4]	Enoch Valley Mine	Henry Mine Ballard Mine
Rhodia Inc.		Wooley Valley Mine

Notes:
[1]Gay Mine was leased by FMC Corporation and J.R. Simplot Company, individually and jointly.
[2]Rasmussen Ridge Mine is leased by Nu-West Industries, Inc. (Nu-West), an affiliated company of Nu-West Mining, Inc.
[3]South Maybe Canyon Mine is not included in the scope of the Selenium Project. It is being addressed currently under a consent order with Nu-West and the U.S. Forest Service.
[4]P4 Production LLC is joint venture between Monsanto and Solutia, Inc.

In August 2000, the IDEQ was specified as the lead agency for coordinating the future activities of the area wide investigation and for establishing regional cleanup guidance to assist lead agencies in implementing future site-specific remedial efforts. The IDEQ subsequently established an Interagency Technical Group to coordinate their activities with the other jurisdictional and administrative agencies.

The IDEQ also established the Selenium Area Wide Advisory Committee (SeAWAC) to continue to solicit input from the mining companies, project stakeholders, and other participants in the former SeWG.

Much of the characterization and risk assessment work conducted under the auspices of the IMA Selenium Committee is documented in a series of reports prepared by MW (1998a, 1998b, 1999a, 1999b, 2000). The IMA Selenium Committee implemented a phased approach for investigating potential impacts from phosphate mining activities (MW 1999b). Because of the broad similarities in mining operations and material characteristics, those investigations and corresponding risk assessments were approached from an area-wide perspective. The focus of the investigations is a 2,500–square-mile area in southeastern Idaho that consists of portions of Caribou, Bear Lake, Bonneville, and Bingham counties. This region contains 15 mines previously owned or operated by Astaris Production LLC; J.R. Simplot Company; Nu-West Industries, Inc. and Nu-West Mining, Inc. (Nu-West); Rhodia, Inc.; and P4 Production LLC (see Table 1), as well as numerous "orphaned" mine sites. One of the 15 mines, the South Maybe Canyon Mine, is being addressed separately under a consent order between Nu-West and the FS and is not included in the scope of the Selenium Project.

According to MW (1999b), the overall objectives of the investigations were to:

- Characterize the extent and magnitude of selenium and other target element releases from phosphate mine waste rock in a broad range of environmental media, including surface water, sediments, groundwater, soil, and vegetation
- Characterize the threat of releases of contaminants from waste rock, including selenium and other target elements, to human health, livestock, and aquatic and mammalian wildlife
- Initiate a management study to develop and identify Best Management Practices (BMP) for mitigating potential releases of selenium or other target elements associated with historic, current, and future phosphate mine facilities

Issues and concerns associated with the IMA studies and risk assessments are discussed in the Existing Data and Risk Assessment Review (TtEMI 2001).

Additional studies of the general geology of the Phosphoria Formation and site-specific investigation of selenium biogeochemistry have been or are being conducted by various entities in the SeWG (e.g., USGS, FS, IDFG, USFWS, and individual mine operators). Those investigations are described in more detail in the Existing Data and Risk Assessment Review (TtEMI 2001).

1.2 OBJECTIVES

This report, prepared by TtEMI, represents the second deliverable of a multi-task process outlined in Contract No. CO23, Task Order No. AWI-00-01 (Area Wide Data Review/Risk Assessment). The major objectives of this project as a whole are to:

- Review and assess the existing data and preliminary risk assessment
- Establish the data requirements to support an area-wide ecological and human health risk assessments
- Develop sampling and analysis plans and studies to fill potential data gaps
- Finalize area-wide ecological and human health risk assessments

This second deliverable presents the initial human and ecological conceptual site models (CSM) for the Resource Area as well as supporting information that will be used in scoping the risk assessments. The CSMs will be used to identify data gaps and help scope the final area-wide risk assessments.

Section 2.0 of this report provides a description of the role of the CSM in the risk assessment process. Section 3.0 presents fate and transport information, and Sections 4.0 and 5.0 present the human health and ecological CSMs, respectively.

2.0 PURPOSE OF THE CONCEPTUAL SITE MODEL

Problem formulation represents a critical stage of the risk assessment process, where the goals, breadth, and focus of the assessment are determined. The major goal of the problem formulation step is to develop a CSM that addresses the following major issues:

- Environmental setting and contaminants known or suspected to exist at the site
- Contaminant fate and transport mechanisms that might exist at the site
- Mechanisms of toxicity associated with contaminants and likely categories of receptors that could be affected
- Complete exposure pathways that might exist at the site (a complete exposure pathway is one in which the contaminant can be traced or expected to travel from the source to a receptor)
- Selection of exposed populations for human health risk assessments (HHRA) and selection of assessment and measurement endpoints to screen for ecological risk

In summary the CSM is a visual and written description of the contaminant movement from sources through the ecosystem to receptors that include the assessment and measurement endpoints. Because of differences in exposure, separate CSMs have been developed for human and ecological receptors.

3.0 FATE AND TRANSPORT ASSESSMENT

Key assumptions in developing the CSM involve the fate and transport properties of the various contaminants of potential concern (COPC) or contaminants of potential ecological concern (COPEC) that may pose a risk to receptors. Because of issues concerning the existing COPC and COPEC screening conducted by MW (1999b), significant uncertainty exists concerning which contaminants should be evaluated. Existing data indicates that selenium is definitely a COPC and COPEC, but cadmium, nickel, zinc, and other metals also may be of concern. The following CSMs and associated discussions are based primarily on selenium as the major contaminant. However, these CSMs are broadly applicable to most inorganic contaminants but may require revisions if contaminants are identified with fate and transport properties that are significantly different than selenium. Also note that the fate and transport mechanism for selenium is complex in that selenium has multiple forms for both inorganic and organic species along with its potential for bioaccumulation in aquatic ecosystems. The fate and transport of other metals is not expected to be as complex as selenium.

The fate and transport processes that affect the movement of contaminants through the environment are similar for both human and ecological exposure and are discussed in the following section.

3.1 FATE AND TRANSPORT OF CONTAMINANTS

The primary source of contamination from phosphate mining activities in southeastern Idaho appears to be the waste rock dumps associated with the various mine sites. The primary contaminant release mechanisms for the waste rock dumps are the following:

- Erosion from waste rock dumps to surface soils
- Percolation from waste rock dumps to surface soils, subsurface soils, groundwater, and surface water
- Storm water runoff from waste rock dumps to surface water

Each of these primary release mechanisms results in a potential pathway of exposure of selenium to receptors. The sources of contaminants and each of the primary contaminant release mechanisms are described in the following sections.

3.1.1 Sources of Contaminants

The Phosphoria Formation is the principal sedimentary formation from which all phosphate ore is produced (MW 1999a). The Meade Peak member of the Phosphoria Formation in southeastern Idaho is mined extensively for its phosphate content and is a marine sedimentary deposit of Permian age (MW

1999a; Piper and others 2000). Analyses of this formation indicate that it consists of two fractions: the original marine organic matter and the terrigenous, detrital source fraction. Sources of these fractions appear to include: (1) detrital debris from the terrestrial environment, (2) planktonic debris that settled out of the photic zone of the water column of the ancient sea and onto the ocean floor, and (3) a hydrogenous fraction derived largely from bottom water of the ancient basin by means of inorganic reactions. The origins of these components of the Phosphoria Formation explain the increased levels of many metals, including selenium.

The waste rock resulting from phosphate mining is composed of overburden and underburden materials that have been removed to access the phosphate ore bodies. Waste rock includes alluvium, the middle waste shale of the Meade Park member and overlying Rex Chert and cherty shale of the Phosphoria Formation, the underlying Wells Limestone, and shales of the overlying Dinwoody Formation. The waste rock is typically deposited on the surface, where it is exposed to weathering processes. Weathering of the waste rock results in material that more readily releases contaminants into the environment.

3.1.2 Wind Erosion from Waste Rock Dumps to Surface Soils

In the southeastern Idaho, extensive, wide-open spaces are common and create the potential for strong air currents to occur. Therefore, wind erosion and subsequent deposition may be a significant mechanism of contaminant transportation in the Resource Area.

The potential exists for wind to erode and resuspend surface soil and transport it to other areas, both near and far away, depending on wind speed and other factors. Any selenium closely associated with soil particles also will be transported. Deposition from this mechanism of transport may increase selenium levels at points some distance from the source. In addition, soils transported by wind will settle on leaf surfaces of nearby plants, where they may be directly taken up by the plant or washed onto the ground by rain, thereby making any selenium present available to the plant.

3.1.3 Percolation from Waste Rock Dumps to Groundwater and Surface Water

Precipitation can percolate through the waste rock dumps and carry contaminants into groundwater, or they may be released directly to surface water through seeps, springs, or french drains in the waste dumps. Even though the Resource Area is relatively arid, percolation is one of the major transport mechanisms.

Contaminants may be carried into the groundwater, but based on current information, do not appear to be a problem in the Resource Area at this time. However, any contaminants dissolved in the groundwater

may be carried along until it exiting into a stream, lake, or wetland.

3.1.4 Storm Water Runoff from Waste Rock Dumps to Surface Water

As a result of spring snowmelt and storm events, significant quantities of water may move across the waste dumps as surface runoff. This surface flow will move particles of the waste rock into the adjacent surface soils and then into local streams and ponds. Depending on the topography of the various waste rock dumps, this may be a significant transport mechanism.

3.1.5 Surface Water Transport

Once contaminants enter the local streams or surface water bodies, the material can be transported significant distances from the waste rock dumps. This material can be deposited in terrestrial environments during flood events or in areas where sediment is trapped. In some areas, the contaminants may be deposited in fields or stock ponds by irrigation or pumping. This is a significant transport mechanism for movement of contaminants away from waste rock dumps.

3.1.6 Biotic Uptake

For ecological receptors, the potential exposure pathways for movement of contaminants resulting from the phosphate mining activities in southeastern Idaho include the following:

- Ingestion of windblown particles and dust
- Incidental ingestion of surface soil, sediment, and surface water during grooming, foraging, or feeding
- Dermal uptake of metals
- Dietary uptake of metals through contaminated forage or prey items and surface water ingestion

Some of these exposure pathways are more important than others. The most important exposure pathways for ecological receptors are:

- Incidental ingestion of surface soil and sediment during grooming, foraging, or feeding (assumed to include incidental ingestion of windblown particles and dust)
- Dietary uptake of metals through contaminated forage and prey items and surface water ingestion

These pathways are believed to be the most significant because a high probability exists that ecological receptors will receive direct-contact doses from soils and sediments (given that these are the most contaminated media), as well as potentially contaminated terrestrial and benthic invertebrates that may accumulate selenium. Those two pathways are likely to contribute the greatest percentage of the overall

ecological risks.

The other pathways (although potentially complete) were determined less likely to contribute to the exposure of ecological receptors. Of the potentially complete exposure pathways, dermal absorption was excluded because of a lack of data to assess the effect of dermal adsorption of selenium, which may be negligible because of normal grooming activity and already taken into account through incidental ingestion by the ingestion pathway.

Volatilization of selenium has the potential to be a problem for burrowing mammals in the Resource Area. However, inhalation exposures are poorly understood in an ecological risk context, because no toxicity data are available for comparison.

4.0 HUMAN HEALTH CONCEPTUAL SITE MODEL

As described in the EPA's Risk Assessment Guidance for Superfund (EPA 1989), an exposure pathway consists of four primary elements:

1) Source(s)
2) Release and transport mechanisms
3) Exposure media
4) Receptors

The human health CSM (see Figure 1) depicts human health exposure pathways specific to the Resource Area. Potential contamination in the Resource Area is assumed to originate from a single source, mine waste rock. Contaminants present in the mine waste rock initially are released and transported through the processes of weathering and leaching. As a result of this initial release and transport, contaminants present in the mine waste rock migrate to both surface and subsurface soil, as discussed in Section 3.1.

From surface and subsurface soil, contaminants are transported through a variety of secondary, tertiary, and quaternary release and transport mechanisms into a range of exposure media. The release and transport mechanisms include: wind erosion; runoff; uptake and assimilation; and leaching by percolation, deposition, and irrigation. Potential exposure media include surface and subsurface soil, air, surface water and sediment, food items, and groundwater, as discussed in Section 3.0.

Three potentially exposed human populations are identified for consideration in the HHRA, including recreational hunters and fishers, Native Americans, and subsistence lifestyle receptors. For all three

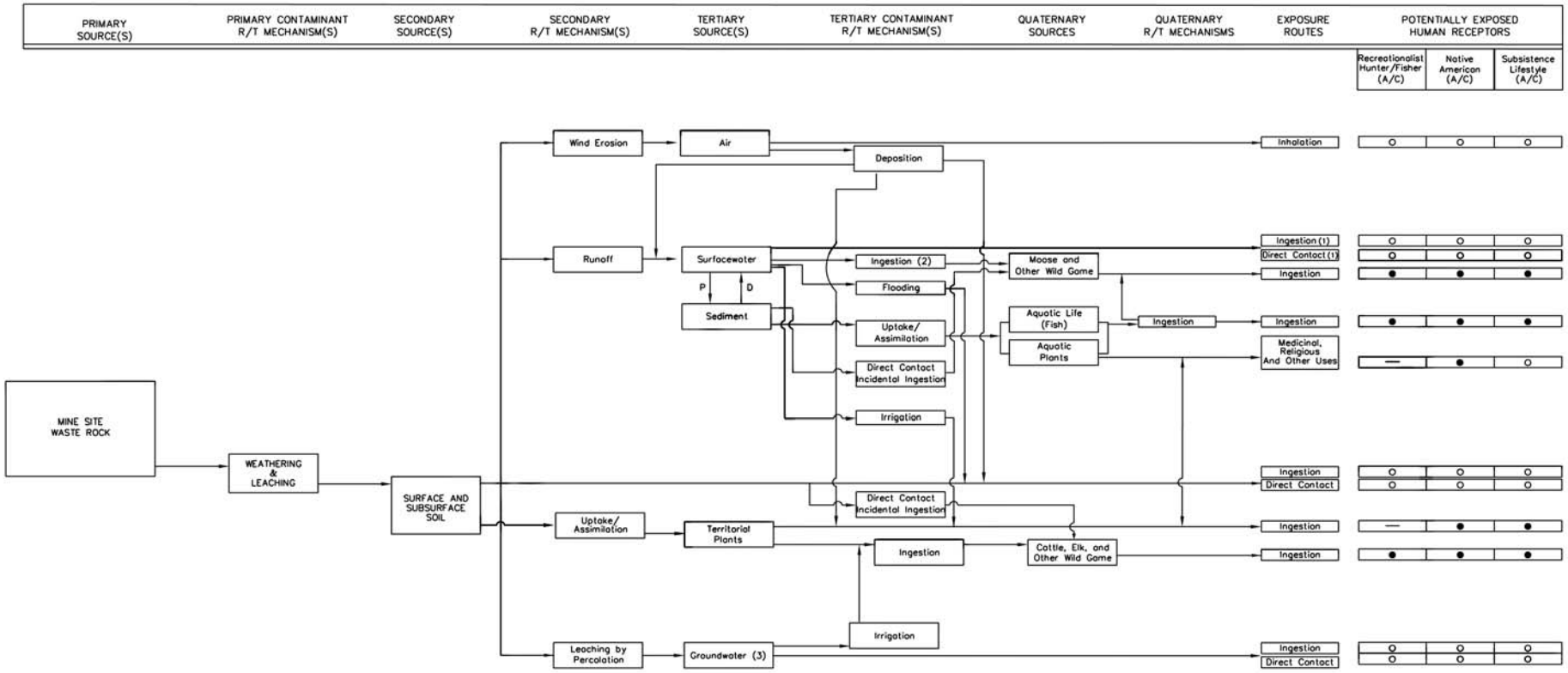
populations, both adult and child receptors will be considered.

As shown in the human health CSM (see Figure 1), some of the exposure pathways are considered to be potentially complete, that is, all four of the required elements are known or assumed to be present. Other exposure pathways are considered to be incomplete, that is, one or more of the required elements – most often the receptor – is missing. Exposure pathways that are considered to be incomplete will not be considered further in the HHRA.

Complete exposure pathways include:

- Ingestion of moose, elk, other wild game, and cattle by recreational hunters and fishers, Native Americans, and subsistence lifestyle receptors
- Ingestion of aquatic life (fish) by recreational hunters and fishers, Native Americans, and subsistence lifestyle receptors
- Ingestion of native terrestrial and aquatic plants by Native American receptors
- Ingestion of homegrown produce by subsistence lifestyle receptors
- Medicinal, religious, and other uses of aquatic and terrestrial plants by Native American receptors

It is recognized that the Native American and subsistence lifestyle receptors are similar in many regards. The most obvious difference between these two receptor groups involves exposures related to plant material. It is assumed that the Native American receptors may be exposed through medicinal, religious, and other uses of plant materials. More specifically, for the purposes of the CSM and the subsequent HHRA, it is assumed that Native American receptors live primarily on the Fort Hall Indian Reservation and are exposed through direct ingestion or ingestion of teas brewed from native plants gathered from the Resource Area. On the other hand, subsistence lifestyle receptors are assumed to live in remote areas in the Resource Area and to ingest homegrown produce grown in riparian areas along streams in the Resource Area.



NOTES

A/C = Adult and Child Receptors

D = Dissolution

P = Precipitation

R/T = Release and Transport

1 = Includes exposure to both surface water and sediment.

2 = Includes ingestion of surface water by moose, elk, cattle, and other wild game.

3 = Ground water may also be hydraulically connected to surface water in the study area. However, this R/T mechanism is expected to be less significant than other R/T mechanisms, and, therefore, is not shown on this figure.

● = Potentially complete exposure pathways – considered quantitatively in the HHRA

o = Potentially complete, but *de minimus* exposure pathway – considered qualitatively in the HHRA

— = Incomplete exposure pathway – not considered further in the HHRA

CONCEPTUAL SITE MODEL
HUMAN HEALTH RISK ASSESSMENT

FIGURE 1
SOUTHEAST IDAHO PHOSPHATE RESOURCE AREA

Tetra Tech EM Inc.

By law, hunting and fishing by non-Native Americans (including subsistence lifestyle receptors) are permitted only during discrete portions of the year. Also, limits on harvests of wild game and fish are enforced for non-Native Americans. However, for the purposes of the CSM and the subsequent HHRA, it is assumed that the subsistence lifestyle receptor may harvest wild game and fish throughout the year and may ignore harvest limits as necessary to meet their subsistence requirements. It is judged that this assumption is reasonable given the size and remoteness of the Resource Area. The uncertainties associated with this and other assumptions will be discussed in the HHRA.

Therefore, while Native American receptors may in fact also be subsistence lifestyle receptors, the Native American and subsistence lifestyle receptors will be evaluated as unique receptor groups.

Of the complete exposure pathways, some will be considered quantitatively in the HHRA. Additional information concerning consumption of domestic livestock is presented in Section 6.0. Other complete exposure pathways are considered to be de minimus or contribute negligibly to total receptor dose and will be evaluated only qualitatively in the HHRA. The complete exposure pathways that are considered to be de minimus and a brief explanation for exposure pathway-specific conclusions regarding these exposure pathways are provided below. It should be noted that while not evaluated quantitatively, de minimus exposure pathways will be qualitatively evaluated in the HHRA. The qualitative evaluation will include, at a minimum, a comparison of medium-specific constituent concentrations to EPA Region 9 preliminary remediation goals (PRG) to ensure that the assumptions discussed below are still accurate. EPA Region 10 uses Region 9 PRGs in lieu of developing specific regional criteria. In most cases, medium-specific EPA Region 9 residential PRGs will be used in the comparisons because the receptors considered in the CSM and the HHRA are engaged in activities more consistent with residential than industrial activities (e.g. ingestion of homegrown produce and wild game). Use of residential PRGs is judged to be appropriately conservative in the context of eliminating exposure pathways from further consideration.

- Inhalation of Fugitive Dusts. Receptors are expected to be exposed to fugitive dusts in the ambient air and not in enclosed spaces. As a result, the contribution to total exposure from inhalation of fugitive dusts is typically small compared with potential exposure through ingestion and direct contact with soil. Also, as noted below, based on comparison of measured soil concentrations to EPA Region 9 PRGs for residential soil, total exposure to constituents in soil is expected to be associated with insignificant risks and hazards.
- Ingestion and Direct Contact with Surface Water. Surface water is not used as a source of drinking or household water in the Resource Area. Therefore, ingestion of constituents in surface water is expected to occur only infrequently (for example, while hiking or hunting in the area or through inadvertent ingestion while swimming in surface water bodies). Also, inorganic constituents are not especially well absorbed through direct contact with surface water (generally,

inorganic constituents dissolved in water are assumed to move through the skin). As with ingestion, direct contact with surface water is expected to be infrequent – because of the cold water temperatures, receptors fishing in area surface water bodies are expected to wear waders most, if not all, of the time.

- Ingestion and Direct Contact with Sediment. Exposure to constituents through incidental ingestion of sediment is expected to be minimal, primarily because most sediment to which receptors are infrequently exposed is expected to be washed off either deliberately or inadvertently with surface water. Exposure to inorganic constituents present in sediment that does manage to adhere to receptor's skin also is expected to be minimal, because these constituents are poorly absorbed through the skin.
- Medicinal, Religious, and Other Uses of Aquatic and Terrestrial Plants by Subsistence Receptors. Subsistence receptors are expected to be exposed to constituents in the tissues of aquatic and terrestrial plants, primarily through ingestion. The contribution to total exposure through medicinal, religious, and other uses of these plants relative to ingestion is expected to be small. To the extent this assumption is incorrect, exposures, risks, and hazards calculated for Native American receptors for this exposure route will provide a reasonable surrogate.
- Ingestion and Direct Contact with Surface and Subsurface Soil. As noted in MW (1999b), the maximum observed concentrations of inorganic constituents in soil are one or more orders of magnitude less than constituent-specific EPA Region 9 industrial soil PRGs. Also, the magnitude of exposure to soil by receptors in the Resource Area is expected to be far less than was assumed in the development of industrial PRGs. Therefore, exposure to constituents present in surface and subsurface soil is expected to be minimal.
- Ingestion and Direct Contact with Groundwater. As noted in MW (1999b), groundwater samples were collected from 20 groundwater wells inventoried in the Resource Area. Maximum concentrations of six inorganic constituents (selenium, cadmium, manganese, nickel, vanadium, and zinc) are between one-half and one order of magnitude (5 to 10 times) lower than the EPA Region 9 tap water PRG. The mean concentrations of these same constituents are almost two orders of magnitude less than their respective PRGs. Therefore, exposure to constituents present in groundwater is expected to be associated with minimal risks and hazards.

5.0 ECOLOGICAL CONCEPTUAL SITE MODEL

Unlike HHRA, which evaluates only one species, the ecological risk assessment (ERA) involves multiple species with different degrees of exposure and toxicological responses. For the purpose of an ERA investigations should focus on receptors most likely to be affected, given the fate and transport mechanisms of the contaminants involved, ecotoxicological properties of the contaminants, habitats at the site, and potential ecological receptors (those species have special status, social significance, or recreational/commercial value)(EPA 1997). Therefore, the ecological CSM is much more complex than the human health CSM. There are two primary food webs that will be assessed in the ERA: terrestrial and riparian/aquatic (see Figure 2).

5.1 ENVIRONMENTAL SETTING

An important part of the problem formulation process is to identify the environmental setting and ecosystems that are potentially at risk. A detailed discussion of the Resource Area is presented in MW (1999b). Using this information and other studies, the following discussion describes the ecosystems potentially at risk.

The vegetation in the Resource Area is transitional between Great Basin vegetation to the south and Rocky Mountain vegetation to the north (MW 1999b).

Six vegetation types are found within the Resource Area and are a result of elevation, moisture, temperature, soil type, slope, and aspect:

- Conifer-aspen Community
- Mountain Brush Community
- Sagebrush-grass Community
- Riparian Community
- Marshland Community
- Agricultural and urban lands

Based on previous investigations, the Resource Area supports or contains habitat for up to 75 species of mammals, 272 species of birds, 16 species of reptiles, 16 species of fish, and 7 species of amphibians (USGS and FS 1977; FS 1985, 1997; Idaho Conservation Center Data Base 1999; all as cited in MW 1999b). A preliminary list of species known to occur in the Resource Area is presented in MW (1999b). All species identified as potential receptors for the ERA are taken from these species lists and information provided by regulatory agencies.

The Resource Area is divided into two major riverine systems, the Bear and the Snake Rivers (MW 1999a). Other major streams in the Resource Area include the Blackfoot, Portneuf, and Salt Rivers, all tributaries of the Snake River. The southern portion of the Resource Area is located in the Bear River watershed. The Blackfoot, Portneuf, Ross, and Salt River watersheds drain the remainder of the Resource Area. All of these streams support abundant aquatic populations of periphyton, benthic macro-invertebrates, and fish.

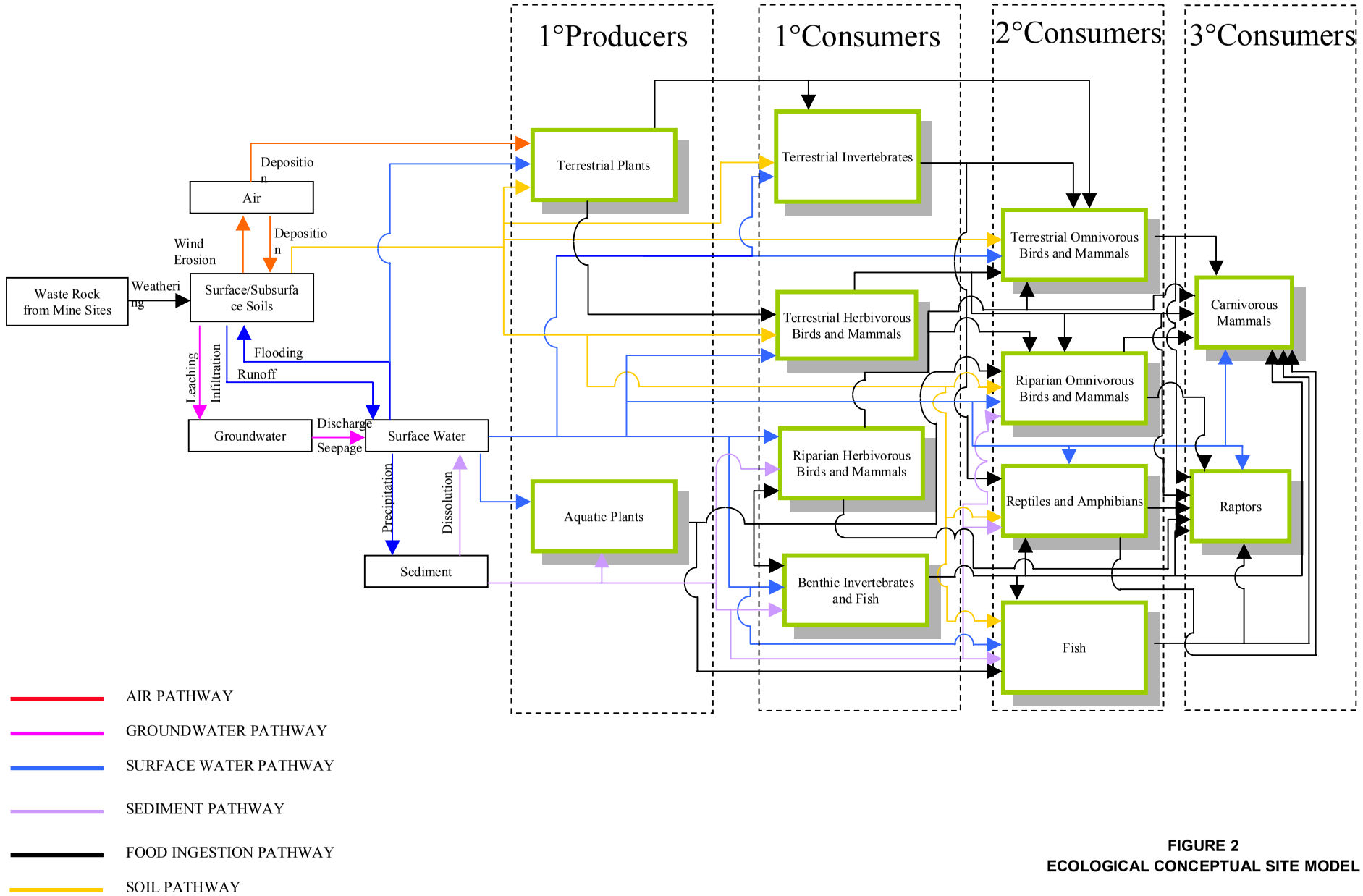


FIGURE 2
ECOLOGICAL CONCEPTUAL SITE MODEL

Tetra Tech EM Inc.

1°Producers

Terrestrial Plants
- Blue joint grass – *Calamagrostis canodensis*
- Blue bunch wheat grass – *Agrophyron spicatum*
- Idaho Fescue – *Festuca idahoensis*
- Meadow milk vetch – *Astragalus diversitollus*
- Big sagebrush – *Artemisia tridentata*
- Antelope bitterbrush – *Purshia tridentata*
- Willow – *Salix* species
- Quaking aspen – *Populus tremuloides*
- Rabbitbrush – *Chrysthamnus viscidiflorus*
- Alfalfa - *Medicago sativa*
- Wheat grass – *Agropyron species*
- Indian paintbrush – *Castelleja* species

Aquatic Plants (Semi-aquatic marsh plants are also listed below
- Periphyton
- Common spike rush – *Eleocharts palustis*
- Bulrush – *Scirpus* species
- Elk Sedge – *Carex geyeri*
- Needle spike rush – *Eleocharis aciculans*

1°Consumers

Terrestrial Invertebrates
- Grasshoppers
- Insect larvae
- Beetle larve

Herbivorous Birds
- Chipping sparrow – *Spizella parrerine*
- House finch – *Carpodacus mexicanus*
- Grey partridge – *Perdix perdix*
- Morning dove – *Zenaida macroura*
- Cassin's finch – *Carpodacus cassinnii*
- Pine grosbeak – *Pinicola enucleator*
- White-winged crossbill – *Loxia leucoptera*

Terrestrial Herbivorous Mammals
- Elk – *Cervus elaphus*
- Moose – *Alces alces*
- Mule Deer – *Odocoileus hemionus*
- Black-tailed jackrabbit – *Lepus californicus*
- Long-tailed Vole – *Microtus longieaudus*
- Yellow-bellied marmot - *Marmota flaviventris*
- Least chipmunk – *Etuarnias minimus*
- Richardson ground squirrel – *Citellus richardsoni*

Benthic Invertebrates
- Insect larvae
- Oligochaetes

Benthic Fish
- Common carp – *Cyprinus carpio*
- Bear Lake Sculpin – *Cottus extensus*
- Longnose Sucker – *Catostomus catostomus*
- Mountain Sucker – *Catostomus platyrhynchus*
- White sucker – *Catostomus commersoni*

Domestic Livestock
- Cattle
- Horses
- Sheep

2°Consumers

Terrestrial Omnivorous Birds
- Western Meadowlark – *Sturnella neglecta*
- Sage Grouse – *Centrocercus urophasianus*
- Sage Thrasher – *Oreoscoptes montanus*
- Sage Sparrow – *Amphispiza belli*
- Loggerhead Shrike – *Lanius ludovicianus*
- Long-billed Curlew – *Numenius americanus*
- Black-billed Magpie – *Pica pica*
- Northern Oriole – *Icterus galbula*
- Ring necked Pheasant – *Phasianus colchicus*
- Red-winged blackbird – *Agelaius phoeniceus*
- Gadwall duck – *Anas strepera*
- Mallard – *Anas platyrhynchas*
- Canada goose – *Branta canadensis*
- American coot – *Fulica americana*

Omnivorous Mammals
- Deer Mouse – *Peromyscus maniculatus*
- Northern pocket gopher – *Thomomys talpoides*
- Great Basin Pocket Mouse – *Perognathis parvus*
- Townsend's ground squirrel – *Spermophilus townsendii*
- Wolverine – *Gulo gulo*
- Raccoon – *Procyon lotor*
- Muskrat – *Ondatra zibethica*
- Deer Mouse – *Peromyscus maniculatus*
- Striped skunk – *Mephitis mephitis*

Reptiles and Amphibians
- Western toad – *Bufo boreas*
- Leopard frog – *Rana pipens*
- Gopher snake – *Pituophies meianoleucus*
- Western garter snake – *Thamnophis elegans*

Fish
- Yellowstone cutthroat trout) – *Salmo clarki bouvieri*
- Rainbow trout – *Onchorhynchus mykiss*
- Mountain whitefish – *Prosopium williamsoni*

3°Consumers

Carnivorous Mammals
- Bobcat – *Lynx rufus*
- Badger – *Taxidea taxus*
- Coyote – *Canis latrans*
- Gray wolf – *Canis lateralis*
- Black bear – *Ursus americanus*

Raptors
- American kestrel – *Falco americanna*
- Peregrine falcon – *Falco peregrinus anatum*
- Red-tailed hawk – *Buteo jamaicensis*
- Golden eagle – *Aquila chrysuetos*

FIGURE 2 (continued)
ECOLOGICAL CONCEPTUAL SITE MODEL

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Several plant and animal species that are classified as threatened or endangered may be present or are thought to be present as seasonal migrants in the Resource Area and are listed in MW (1999b).

The ecological CSM presented in Figure 2 was developed to assist in the identification of specific receptors that might be directly or indirectly exposed to COPECs and to perform the exposure assessment. The ecological CSM illustrates the following:

- The abiotic media (e.g., soil, sediment, and water)
- Trophic levels, primary producers, and primary, secondary, and tertiary consumers
- Trophic-level compartments represented by guilds (that is, a group of species from similar classes that occupy a particular trophic level and exploit similar resources)
- Major dietary relationships between compartments

The ecological CSM illustrates the interlocking patterns of the various inclusive food chains. A food chain is a straight line from a food source to a series of organisms feeding on the source or other organisms feeding on the source. A food web shows how energy or, in this case, contaminants, may be transferred within an ecosystem. A food chain represents a potential COPEC exposure pathway. The importance of the exposure pathway depends on the receptor's dietary habits and the COPEC.

Food webs are organized by class guilds, which are linked together by dietary relationships between them. Food webs are meant to illustrate how contaminants have the potential to be transferred within an ecosystem. The various food chains represent potential COPEC exposure pathways. The importance of a food chain as a dietary exposure pathway depends on receptor dietary habits. The boxes in the ecological CSM represent the expected feeding guilds or communities in each of the ecosystems within the Resource Area. Feeding guilds or communities are groups of organisms that exploit similar resources for food.

5.1.1 Terrestrial Food Web

Figure 2 illustrates the food web interactions for the terrestrial food web for the Resource Area. The primary producers include blue bunch grass (*Agrophyron spicatum*), Idaho fescue (*Festuca idahoensis*), meadow milk vetch (*Astragalus diversitollus*), alfalfa (*Medicago sativa*), and cheat grass (*Bromus tectorum*). Primary consumers are terrestrial invertebrates and herbivorous birds and mammals. Specific species are presented in Figure 2. This generic terrestrial food web may not specifically include every habitat type known to occur in the Resource Area; however, the terrestrial food web adequately represents the entire Resource Area as a whole.

Secondary consumers consist of terrestrial omnivorous birds, mammals, and reptiles. Omnivorous birds and mammals may consume both plants and animals and may feed almost exclusively on one or the other, depending on season and prey population conditions. Specific species are presented in Figure 2.

Tertiary consumers include carnivorous mammals and raptors. These species feed exclusively by preying on other animals. Specific species are presented in Figure 2.

5.1.2 Aquatic and Riparian Food Web

Figure 2 illustrates the food web interactions for aquatic and riparian areas. Primary producers include phytoplankton and aquatic macrophytes. These organisms represent the basis of the food chain. Aquatic and riparian primary producers also provide shelter and habitat for higher-trophic-level species. Specific species are presented in Figure 2.

Primary consumers include zooplankton, benthic invertebrates (insect larvae and freshwater oligochaetes), benthic-feeding fish, and riparian herbivorous birds and mammals. Zooplankton feed primarily on phytoplankton and other zooplankton. Benthic invertebrates, which have the potential to be present in the Resource Area, include insect larvae and freshwater oligochaetes. These organisms feed on detritus composed of dead animals and plants, suspended particulates, and microscopic invertebrates. Benthic-feeding fish tend to be omnivorous and feed on both benthic invertebrates and aquatic plants. Aquatic and riparian herbivorous birds and mammals consume aquatic vegetation. Specific species are presented in Figure 2.

Secondary consumers include fish, amphibians, aquatic and riparian omnivorous birds and mammals, aquatic and riparian piscivorous birds, aquatic and riparian benthic-feeding birds, and aquatic and riparian carnivorous mammals. Specific species are presented in Figure 2.

5.2 ECOLOGICAL EFFECTS OF SELENIUM

An understanding of how selenium adversely affects ecological receptors is required to identify significant potential exposure pathways that should be evaluated in the ERA. This understanding facilitates identification of the most sensitive receptors. A more in-depth discussion of the ecological effects of selenium will be presented in the Area Wide Human Health and Ecological Risk Assessment Work Plan.

Selenium is much less toxic to most plants and invertebrates than to vertebrates (Skorupa 1998). Among vertebrates, reproductive toxicity is one of the most sensitive endpoints. Egg-laying vertebrates, such as birds and fish, seem to have substantially lower thresholds for reproductive toxicity than mammals and there are species-specific differences within the avian and fish groups.

5.2.1 Uptake and Toxicity of Selenium in Terrestrial Ecosystems

The following sections discuss the uptake and toxicity of selenium in terrestrial ecosystems. Additional information concerning domestic livestock is presented in Section 6.0.

5.2.1.1 Uptake of Selenium in Terrestrial Ecosystems

Plants are very effective at removing selenium from contaminated soils (Irwin and others 1997).
Selenium is absorbed by plants as selenite or selenate, which is then converted to the organic form of selenium. It is believed that selenate is taken up actively, while selenite uptake is largely passive (Peterson and Girling 1981). Selenium is translocated to all parts of the plant, including the low-molecular-weight compounds (Broyer and others 1972).

Selenium accumulators can take up and accumulate very high concentrations of selenium (over 1,000 parts per million) in their tissues without injurious effects. Obligate selenium accumulators, which grow only in soils where metabolic needs can be satisfied, include many species of *Astragalus* and some species of *Brassica, Haplopappus, Machaeranthera, Oonopsis, Stanleya,* and *Zylorhiza* (Irwin and others 1997). Facultative selenium accumulators can tolerate, but do not require, elevated soil selenium levels and include many species of *Aster* and some species of *Astragalus, Atriplex, Castelleja, Comandra, Grayia, Grindelia, Gutierrezia, Machaeranthera, and Mentzelia.* These plants take up high levels of selenium and metabolize it into water-soluble selenate: when the plants die, the water-soluble, organic selenium compounds released by decay become more bioavailable to other plants and animals.

5.2.1.2 Toxicity of Selenium in Terrestrial Ecosystems

Selenium toxicity in plants has symptoms that include chlorosis, stunting, and yellowing of leaves. Almost no selenium toxicity data exist for terrestrial invertebrates (Skorupa 1998). No documented field cases exist of fish and other wildlife populations being affected adversely by selenium-induced alterations of various invertebrate population structures, such as invertebrate community structure and density. As indicated for plants, the direct toxic effects of consuming selenium-contaminated invertebrates are more important than any indirect ecological effects, such as changes in population structure (Skorupa 1998). The effects of selenium of particular interest in terrestrial ecosystems include systemic and reproductive

effects, general toxic effects, and mortality.

Consumption of selenium-accumulating forage plants by livestock has induced illness and death from selenium poisoning. Selenium-accumulating plants tend to be deeper-rooted than grasses and survive more arid conditions, therefore remaining as the principal forage for grazing in time of drought (Wilbur 1983, as cited in Eisler 1985).

5.2.2 Uptake and Toxicity of Selenium in Aquatic Ecosystems

The following sections discuss the uptake and toxicity of selenium in aquatic ecosystems.

5.2.2.1 Uptake of Selenium in Aquatic Ecosystems

Selenium, in natural waters, commonly occurs as a mixture of several contaminant species. Two inorganic contaminant species, selenite and selenate, are usually the predominant forms (Masscheleyn and Patrick 1993, as cited in Skorupa 1998). Waterborne selenium partitions between the water column and suspended, detrital particulate matter and to assess risk for waterborne selenium toxicity, unfiltered water samples should be analyzed for both particulate and dissolved selenium (Eastern Research Group 1998, as cited in Skorupa 1998).

Once in the water column, selenium enters the food chain through bioconcentration by phytoplankton, which are then consumed in large quantities by benthic invertebrates, amphibians, and fish. Fish and waterfowl, in turn, eat crustaceans and bivalves. Bioconcentration, bioaccumulation, and biomagnification of selenium can increase selenium levels more than 1,000-fold from water to fish and animals (Saiki and Lowe 1987, as cited in Taylor and others 1992). The greatest increase in concentration occurs between water and phytoplankton and other aquatic plants; subsequent steps in the food chain typically increase selenium concentrations by a factor of 2 to 6 (Lemly and Smith 1987, as cited in Taylor and others 1992).

5.2.2.2 Toxicity of Selenium in Aquatic Ecosystems

Current understanding of selenium toxicology indicates that ecological effects are caused primarily by selenium in the food chain, rather than selenium dissolved in the water column (Philips 1988; Luoma and others 1992, all as cited in Taylor and others 1992). Waterborne selenium, per se, is not very toxic to fish and wildlife (Skorupa 1998). Selenium affects survival, growth, and reproduction of some aquatic invertebrates (Jarvinen and Ankley 1999). The effects of selenium of particular interest in aquatic ecosystems include reproductive and systemic effects and mortality.

5.3 PATHWAYS OF EXPOSURE

For ecological receptors, the potential exposure pathways for movement of contaminants resulting from the phosphate mining activities in southeastern Idaho include the following:

- Ingestion of windblown particles and dust
- Incidental ingestion of surface soil, sediment, and surface water during grooming, foraging, or feeding
- Dermal uptake of metals
- Dietary uptake of selenium through contaminated forage or prey items and surface water ingestion
- Inhalation of volatilized metals by burrowing animals

Some of these exposure pathways are more important than others. The most important exposure pathways for ecological receptors are:

- Incidental ingestion of surface soil and sediment during grooming, foraging, or feeding (assumed to include incidental ingestion of windblown particles and dust)
- Dietary uptake of metals through contaminated forage and prey items

These pathways are believed to be the most significant, because a high probability exists that ecological receptors will receive direct contact doses from soils and sediments (given that these are the most contaminated media), as well as potentially contaminated terrestrial and benthic invertebrates that may accumulate metals. These two pathways are likely to contribute the greatest percentage of the overall ecological risks.

The other pathways (although potentially complete) were determined to be less likely to contribute to the exposure of ecological receptors. MW (1999b) quantified the dermal exposure pathway for the muskrat, since this species had relatively high rates of dermal contact with the sediment, and found the contribution of the dermal pathway to the total exposure dose was insignificant. Therefore, dermal absorption has been excluded. In a number of cases dermal absorption may be negligible because of normal grooming activity and already considered through incidental ingestion by the ingestion pathway. Inhalation exposures also are poorly understood in an ecological risk context, because no toxicity data are available for comparison.

6.0 DOMESTIC LIVESTOCK

Domestic livestock represent a special case of nonhuman receptors. Cattle, horses, and sheep are primary consumers that have the same exposures as all other primary consumers shown in Figure 2. The major difference in exposure potential lies in the fact that humans control areas open for foraging. Exposures to these receptors are controlled largely by human decisions concerning where these receptors are pastured.

Existing literature indicates that significant differences may exist in the resistance to the toxic effects of selenium between cattle, horses, and sheep. Some domestic livestock may accumulate selenium to relatively high tissue levels without exhibiting toxic effects. Additionally, selenium concentrates in some tissues more than others. Therefore, the transfer of contaminants to other receptors through the food chain may be dependent on the species of livestock and the portion of the domestic livestock that is consumed.

Domestic livestock consumption may be a significant pathway for human exposure. IMA conducted a selenium depuration study on cattle, which was presented in the 1999 Regional Investigation Report (MW 2000). The results of this study indicated that selenium was depurated from the cattle at some rate once the animals were removed from selenium-contaminated pastures. Human receptors may also be exposed through consumption of other domestically raised animals such as sheep. Based on limited available information, it is considered unlikely that consumption of sheep represents an exposure pathway anymore significant (and possibly less significant) than consumption of domestic livestock. As part of the HHRA, additional information will be collected regarding sheep grazing and harvesting practices in the Resource Area.

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