AREA WIDE INVESTIGATION

SOUTHEAST IDAHO PHOSPHATE MINING RESOURCE AREA

Contract Number C023

Task Order AWI-00-01

FINAL
AREA WIDE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT

SELENIUM PROJECT
SOUTHEAST IDAHO PHOSPHATE MINING RESOURCE AREA

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Prepared for

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ACRONYMS AND ABBREVIATIONS

µ/day	Microgram per day
µ/kg/day	Microgram per kilogram per day
µ/L	Microgram per liter
ADD	Average daily dose
ADI	Average daily intake
ATSDR	Agency for Toxic Substances and Disease Registry
AWAC	Area-weighted average concentration
AWERA	Area Wide Ecological Risk Assessment
AWHHRA	Area Wide Human Health Risk Assessment
AWQC	Ambient water quality criteria
AWRA	Area wide risk assessment
BIA	U.S. Bureau of Indian Affairs
BLM	U.S. Bureau of Land Management
BTF	Biotransfer factor
BW	Body weight
C	Concentration
CCC	Chronic criterion concentration
COPC	Chemical of potential concern
COPEC	Chemical of potential ecological concern
CSM	Conceptual site model
CTE	Central tendency exposure
EcoSSL	Ecological soil screening level
ELCR	Excess lifetime cancer risk
EPA	U.S. Environmental Protection Agency
EPC	Exposure point concentration
ERA	Ecological risk assessment
FCM	Food chain model
FDA	U.S. Food and Drug Administration
FI	Fraction ingested
FS	U.S. Forest Service
g/day	Gram per day
GMU	Game management unit
HI	Hazard index
HHRA	Human health risk assessment
HQ	Hazard quotient
IDEQ	Idaho Department of Environmental Quality
IDFG	Idaho Department of Fish and Game
IDH	Idaho Department of Health
IDL	Idaho Department of Lands
IMA	Idaho Mining Association

ACRONYMS AND ABBREVIATIONS (continued)

IR	Ingestion rate
IRIS	Integrated Risk Information System
LADD	Lifetime average daily dose
LOAEL	Lowest observed adverse effect level
MDL	Method detection limits
mg/day	Milligram per day
mg/kg	Milligram per kilogram
mg/kg/day	Milligram per kilogram per day
mg/L	Milligram per liter
MOU	Memorandum of understanding
MS/MSD	Matrix spike and matrix spike duplicate
MW	Montgomery Watson
NA	Not applicable
Navy	U.S. Department of the Navy
NCP	Nation Oil and Hazardous Substances Pollution Contingency Plan
NOAA	National Oceanic and Atmospheric Administration
NOAEL	No observed adverse effect level
Nu-West	Nu-West Industries, Inc.
ORD	Office of Research and Development
OSWER	Office of Solid Waste and Emergency Response
PEL	Probable effects level
PRG	Preliminary remediation goal
QC	Quality control
RA	Residential area
RAGS	Risk Assessment Guidance for Superfund
RCRA	Resource Conservation and Recovery Act
Resource Area	Southeast Idaho Phosphate Mining Resource Area
RfD	Reference dose
RME	Reasonable maximum exposure
SDHD	Southeastern District Health Department
SeAWAC	Selenium Area Wide Advisory Committee
SeWG	Selenium Working Group
SF	Slope factor
SQL	Sample quantitation limits
SQuiRT	Screening Quick-Reference Tables
SUF	Site use factor
TEC	Threshold effect concentration
TEL	Threshold effect level
TMDL	Total maximum daily loading
TRV	Toxicity reference value

ACRONYMS AND ABBREVIATIONS (continued)

TTC	Trophic transfer coefficient
TtEMI	Tetra Tech EM Inc.
UCL_{95}	95 percent upper confidence limit
UET	Upper effect threshold
UF	Uncertainty factor
USGS	U.S. Geological Survey
WW	Wet weight

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EXECUTIVE SUMMARY

This executive summary is provided to report the findings and conclusions of the Final Area Wide Human Health and Ecological Risk Assessment report for the Southeast Idaho Phosphate Resource Area developed by Tetra Tech EM Inc. (TtEMI) under the direction of the Idaho Department of Environmental Quality (IDEQ or Agency). The assessment was focused on potential regional impacts resulting from historic mining releases in the Southeast Idaho Phosphate Mining Resource Area (Resource Area). A draft risk assessment was published in April 2002 for stakeholder review and released in July 2002 for a formal 45-day public comment period. Comments and responses are appended in the final document. The following major conclusions resulted from the assessment efforts:

- There is a low probability of significant human health effects in the region based on current conditions, existing exposure pathways, and observed concentrations of chemicals. Potentially significant human health risks are indicated only in the case of subsistence use of resources in a limited number of highly impacted areas identified during previous area wide investigations. Based on regional observations, subsistence-level use by human receptors is considered highly unlikely.
- There is a low probability of population level impacts to regional wildlife based on current conditions and the low percentage of impacted zones in comparison to unaffected surrounding habitat.
- There is a high probability of subpopulation and/or individual effects occurring for ecological receptors residing in the vicinity of highly impacted areas.
- There is a potential for risks to aquatic and riparian ecological receptors residing in highly impacted areas as indicated by significant exceedances of conservative benchmarks for surface water, sediment and fish tissue concentrations.
- The contaminants of concern (COC) for future site-specific activities have been identified as cadmium, chromium, copper, nickel, selenium, vanadium and zinc. Selenium and cadmium are considered to be the primary hazard drivers on a regional basis.

PROJECT BACKGROUND

In 1996, isolated livestock deaths associated with excessive selenium uptake in the vicinity of historic phosphate mines in southeast Idaho prompted concerns regarding potential human health and ecological effects from past mining operations. In response to these concerns, the primary mine operators in the region formed the Idaho Mining Association (IMA) Selenium Committee, an "*ad hoc*" organization, to jointly and voluntarily investigate and address any mining-related environmental and public health issues associated with past operations. Similarly, an Interagency/Phosphate Industry Selenium Working Group (SeWG) consisting of voluntary participants from federal, state and tribal agencies, as well as other stakeholder groups, was established to collaborate on these efforts.

Since 1997, the IMA Selenium Committee's contractor, Agency investigators, and regional academic scholars and scientists have conducted numerous phased investigations. Due to the similarities in operations and mine design, and to provide some level of cost effectiveness, the investigations were initially directed at a limited number of constituents and conducted on an "Area Wide" basis.

In July 2000, the IDEQ was formally assigned the role of Lead Agency for the Selenium Area Wide Investigation through voluntary agreements with the companies and interagency participants. An Area Wide Investigation scope of work was developed and formalized through the agreements requiring IDEQ to review the previous data, conduct a data gaps analysis, and collect any remaining critical data to support an independent risk assessment effort by the IDEQ, and to develop regional risk management guidance for the performance of future mine-specific evaluations. The IDEQ retained TtEMI in October 2000 as their contractor for technical assistance and support in the implementation of the Area Wide Investigation scope of work.

The IDEQ established an Interagency Technical Group, comprised of other federal, state and tribal technical representatives with overlapping jurisdictions and interest in the Resource Area, to coordinate investigative activities and ensure collaborative efforts by all regulatory parties as specified in the July 2000 *Interagency Memorandum of Understanding Concerning Contamination from Mining Operations in Southeastern Idaho*. The IDEQ also formed a Selenium Area Wide Advisory Committee (SeAWAC) to continue to solicit input from mining company representatives, project stakeholders and other participants in the former SeWG.

GENERAL APPROACH

The focus of the Area Wide Investigation is a 2,500-square mile area, referred to as the Southeast Idaho Phosphate Mining Resource Area, comprised of portions of Caribou, Bear Lake and Bingham Counties. This region contains 15 major open pit mines previously owned or operated by the members of the IMA Selenium Committee consisting of FMC Corporation, J.R. Simplot Company, Nu West Industries, Inc., Rhodia, Inc., and P4 Production LLC. One of the sites, South Maybe Canyon Mine, is being addressed separately under an existing Consent Order between Nu West and the U.S. Forest Service. The region also contains 14 historic "orphaned" mine sites, primarily of underground design, that are not currently subject to future comprehensive site-specific investigations but are under independent review by the Interagency Technical Group using a preliminary assessment process to determine appropriate disposition.

Previous area wide investigations have indicated the presence of selenium and other mining-related metals at elevated levels in the environment as a result of mining activities in the Resource Area. The Agency's highest priority objectives were to identify any regional public health or wildlife population impacts requiring immediate action. The Area Wide Human Health Risk Assessment (AWHHRA) and the Area Wide Ecological Risk Assessment (AWERA) are intended to evaluate baseline risks to human receptors using regional resources and to assess the potential for population-level risks to ecological receptors in the region, respectively. Subsequent mine-specific investigations will be conducted under regulatory oversight to comprehensively identify and control localized sources, releases and exposures at each mine site, and to select and implement necessary remedial activities. The regional risk assessment results will provide supplemental information to support regulatory risk management decision-making processes resulting from site-specific activities.

The AWHHRA and AWERA were conducted using a tiered approach with conservative assumptions to ensure a high level of protectiveness for individual human receptors and regional wildlife populations. The assessments used deterministic methods, which are typically conservative, leading to risk estimates somewhat greater than those likely to be encountered by receptors. Deterministic methods require the development of discrete values to represent each exposure parameter. The parameters were used to calculate an estimated receptor dose that is compared to toxicological reference values by reporting a ratio referred to as a hazard quotient (HQ) or hazard index (HI) for combined risks. HQs/HIs less than 1.0 indicate exposure estimates below the no effects risk threshold while values above 1.0 may indicate a potential for risk but not a definitive statement that effects will occur. For this effort, the selected reference value was the no observed adverse effects level (NOAEL) consisting of the highest dose reported in the scientific literature that was administered to an applicable receptor group without causing any observed adverse effects. Due to the variations in developing model parameters and reference values, it is extremely important that risk assessment results be evaluated in context to actual conditions and not strictly on the basis of numeric outcomes in reaching risk conclusions.

The primary data used for risk estimates was collected in 2001, following a comprehensive data gaps analysis, although previous data was utilized for evaluation of temporal variations. The 2001 target analyte list consisted of 21 potential mining-related constituents identified through review of current and historic mining operation monitoring requirements, literature review, and results of U.S. Geological Survey site-specific analysis of regional geologic formations. All media samples were analyzed for the full target analyte list and the results were used to perform a comprehensive screening for the initial list of chemicals of potential concern (COPC) for human health risk and chemicals of potential ecological concern (COPEC) for ecological risks, to be evaluated in the risk assessment process. Constituents below analytical detection limits, at background levels, or significantly less than conservative benchmarks were eliminated from formal risk assessment consideration.

Both the human health and the ecological risk assessments consist of three tiers. The first tier is a very conservative screening step using the highest observed media-specific concentrations from any location and the most conservative parameters to eliminate constituents that did not present a significant risk even under these hypothetical "worst case" conditions. In the second tier, more realistic exposure assumptions were used for human exposures, based on both reasonable maximum and central tendency parameters. Tier 2 ecological exposures were based on area- or watershed-weighted averages to represent population level conditions. The final tier was used to evaluate temporal variation, parameter sensitivity, and for watershed specific analysis.

AREA WIDE HUMAN HEALTH RISK ASSESSMENT

The four COPCs identified for human health risk evaluation were arsenic, cadmium, chromium and selenium. The receptor groups selected for evaluation were recreational hunters and fishers, Native Americans, and modified subsistence lifestyle users representing ranchers or residents within the boundaries of the Resource Area. Adult and child receptors were evaluated in each receptor group.

Tier 1 was designed as a screening step using maximum detected, medium-specific concentrations for each COPC to develop hypothetical "upper bound" risk estimates. The exposure pathways considered for all three receptor groups included inhalation of particulates; ingestion of impacted beef, elk and fish tissue; and ingestion of surface water. Additionally, subsistence receptor pathways included ingestion of homegrown produce and incidental soil ingestion, while the Native American scenario included ingestion of aquatic and terrestrial plants, and teas brewed from terrestrial plants. Pathways associated with carcinogenic risks of less than 1E-06 or toxic HIs less than 1.0, and individual COPCs associated with risks less than 1E-07 or HIs less than 0.1 were eliminated from further consideration.

The Tier 1 efforts identified ingestion of aquatic life as a potential risk for all receptors based on selenium and cadmium concentrations in fish, primarily driven by the high concentrations observed in fish tissues samples collected from East Mill Creek. HI exceedances were also observed for child subsistence lifestyle receptors for selenium from ingestion of surface water based on concentrations in samples from East Mill Creek, and for incidental soil ingestion from arsenic based on a maximum concentration observed in a sample from adjacent to Rasmussen Creek. Chromium was retained for further evaluation because HIs exceeded 0.1. Elk and beef tissue ingestion were retained for further evaluation due to public interest in regional hunting and fishing.

Tier 2 of the human health risk assessment focused on further evaluation of the hazards identified in the Tier 1 screening using both reasonable maximum exposure (RME) and central tendency exposure (CTE) approaches. The RME approach estimates risks occurring in the area of highest impact while the CTE approach uses more realistic human health risk parameters and area-weighted average exposure point concentrations for each watershed. Tier 2 results indicated that threshold exceedances (HIs ranging from 1.5 to 5.3) occurred for ingestion of fish by all subsistence lifestyle users under the RME approach and for ingestion of soil (HI = 1.6) by the subsistence lifestyle child as summarized in Table 6-26 of the report. Under the CTE approach summarized in Table 6-27 of the report, exceedances (HI = 1.1) occurred only for ingestion of fish by the child subsistence user in the Blackfoot/Little Blackfoot watershed.

Tier 3 consisted of additional analysis of ingestion of fish and surface water pathways to evaluate the temporal variability in risks resulting from observed changes in media concentrations as affected by climatic and meteorological conditions. Tier 3 results indicated that the significant fluctuations observed in transitory media, such as surface water, has minimal effect on the overall risk estimates. The primary risk contributors consist of the more stable medias such as soil, plants and prey species; therefore, the overall risk estimates are similar regardless of temporal effects. On a watershed-specific basis, only the Blackfoot/Little Blackfoot watershed resulted in an RME risk exceedance for subsistence lifestyle receptors based on concentrations observed in samples from East Mill Creek, and all CTE estimates were below risk thresholds.

In evaluating the human health risk estimates presented, only subsistence lifestyle users were identified as exceeding risk thresholds. The subsistence lifestyle scenario was included in the assessment as a conservative upper-bound risk estimate to ensure the protection of lesser users who may supplement their dietary needs with regional resources. Under the subsistence lifestyle scenario, it is assumed that the receptor resides in the vicinity of the impacted media, as in the case of incidental soil ingestion, and that the only source of some component of their diet, as in the case of fish ingestion, is from a single area over an extended period of time; 30 years for the adult and 6 years for the child. While this type of exposure is theoretically possible, it is extremely unlikely in this application for numerous reasons. The areas of high impacts are very limited and occur primarily on public lands where a residential scenario cannot occur. This is particularly the case for the soil sample from Rasmussen Ridge and fish samples from East Mill Creek that are solely responsible for the reported risk threshold exceedances. East Mill Creek is a first order stream that does not support a highly productive fish population and at which fishing has never been observed during frequent visits by site inspectors, let alone subsistence level use. While the region is sparsely populated by ranchers, it is highly unlikely that any residents rely solely on area resources for all their dietary needs or that those needs would only be met through the use of impacted areas that represent less than 5 percent of the total Resource Area, including mining disturbed lands such as pits and waste rock piles. Based on knowledge of the regional population and area resource use, the conservatism of the model, and the marginal level of risk exceedances presented by the subsistence use evaluation, it is concluded that regional human health effects are not likely to occur based on current conditions.

However, it should be noted that the Idaho Division of Health and Idaho Department of Fish and Game previously issued consumption advisories to area hunters recommending moderate ingestion of elk liver based on results from regional surveys. Calculations using the maximum detected concentrations indicated that mild gastrointestinal effects (i.e. diarrhea, nausea, etc.) could occur if large and persistent portions of liver containing these high levels of selenium were consumed. Similarly, the Idaho Fish Consumption Advisory Program Committee is in the process of issuing a temporary fish consumption advisory for East Mill Creek as a precautionary action. Their exposure calculations also indicate potential risk to child subsistence level users based on selenium concentrations, although they also agree that subsistence use of this area is considered highly unlikely.

Not all exposure pathways and risks are amenable to quantitative assessment procedures. The human health risk assessment contains some qualitative risk discussions, particularly for Native American use of the Resource Area under existing off-reservation treaty rights. Technical representatives of the Shoshone Bannock Tribes have collaborated on this effort and provided their general concurrence on the direct physical hazard estimates developed within the context of formal risk assessment procedures. However, they continue to have concerns that lie outside the realm of current standard practices for risk assessment, particularly in the area of unspecified traditional uses, spiritual health and cultural consequences. These caveats have been provided in the final document for future consideration in decision-making processes. A qualitative risk evaluation is included to discuss some of the potential pathways not included in the quantitative assessment such as traditional gardens, ceremonial uses and medicinal applications that are considered either proprietary in nature or are too diverse for comprehensive consideration. The Native American scenario included in the risk assessment does quantify risks using direct ingestion pathways for several plant species of common traditional use as identified by the Tribal Risk Assessment Committee, and other allowances have been made in using whole-body fish concentrations for ingestion and developing estimates for ingestion of native plant-based teas. These exposure pathways are believed to represent the most significant traditional use dose contributions to a Native American receptor and resulted in HIs less than 1.0. However, a potential for increased risk could exist from the other undisclosed uses.

AREA WIDE ECOLOGICAL RISK ASSESSMENT

The primary objective of the AWERA was to evaluate the likelihood of population-level effects on regional wildlife based on current conditions. A population-level effect is defined as a significant decline or toxicological effect in the area-wide population of a particular species. Multiple lines of evidence were used to evaluate risks to ecological receptors including development of HQs for various receptors based on modeled doses, comparisons of tissue concentrations with literature values, comparisons of impacted versus reference area concentrations, and media concentration comparisons with reference benchmarks. HQs were developed for numerous ecological receptors representing various communities and feeding guilds using data collected in 2001 with a three-tiered, deterministic approach.

Tier 1 consisted of a screening level assessment to evaluate chemicals under worst-case conditions. Tier 1 used the maximum detected concentrations and most conservative parameters to calculate HQs for each target species and COPEC. The COPECs identified for evaluation were cadmium, chromium, copper, nickel, selenium, vanadium and zinc. The results summarized in Tables 7-7 through 7-14 of the report indicate threshold exceedances to mammalian and avian species for cadmium, copper, nickel, selenium and vanadium, and to avian receptors only for chromium based on maximum observed media concentrations.

Tier 2 consisted of an evaluation of regional ecological risks using area-weighted averages for exposure point concentrations of each media, and mean values for model parameters intended to represent an estimate of the average population-level exposures. Each medium was represented by average values for impacted and unimpacted areas, and was area weighted based on surface area ratios, stream segment lengths and other applicable weighting criteria. HQs were developed for each surrogate species using NOAELs and are summarized in Tables 7-15 through 7-22 of the report. Aquatic populations were assessed through direct comparisons with tissue and media concentration benchmarks and are summarized in Tables 7-23 and 7-24 of the report.

Tier 2 results indicate a significant decrease in HQs when viewed in the perspective of population-level risks, which is expected considering less than 5 percent of the overall Resource Area can be characterized as impacted. Selenium and cadmium are the only COPECs that appear to present a significant risk on a regional basis; however, Tier 1 results clearly indicate that the other COPECs may present significant risks to individual or subpopulation receptors in specific localized areas. Aquatic benchmark comparisons also indicated exceedances for surface water, sediments, and fish tissue benchmarks in impacted areas.

Tier 3 consisted of an evaluation of temporal effects employing 1998 and 1999 surface water and fish tissue data. The Tier 3 results did not indicate a significant difference in risks as compared with Tier 2 results because the major portion of the dose for all receptors comes from media less transitory than surface water.

The AWERA concludes that population-level effects for ecological receptors are unlikely based on Tier 2 estimates; however, the high risk values reported in Tier 1 indicate a high probability of significant risks to individual and/or subpopulation ecological receptors in localized areas. Tier 3 indicates that while large fluctuations in surface water concentrations may occur temporally, these variations are dampened because the most significant dose contributors are in non-transitory media that serve as reservoirs and do not vary at the same rate as surface water. The evaluation of risks to aquatic receptors is inconclusive due to the lack of scientific consensus and the diversity in outcomes of selenium-related studies. However, concentrations for surface water, sediments, and fish tissue in impacted areas do exceed the conservative benchmarks published in reference literature.

1.0 INTRODUCTION

The Idaho Department of Environmental Quality (IDEQ) retained Tetra Tech EM Inc. (TtEMI) in October 2000 for an independent review of the existing data and preliminary risk assessment compiled and published by the Idaho Mining Association (IMA) Selenium Committee. TtEMI was also asked to assist IDEQ in developing final area wide 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 risk management decisions by the agency 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 IDEQ and the tribal and federal agencies with jurisdictional responsibilities in the region. The MOU specified IDEQ as the lead agency for coordinating future activities of the area wide investigation and for establishing regional guidance cleanup 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 negotiated with the responsible mining companies.

1.1 PURPOSE AND OBJECTIVES

This Area Wide Risk Assessment (AWRA) report, prepared by TtEMI, represents the sixth deliverable in a multitask 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 data requirements to support area wide human health and ecological risk assessments
- Develop sampling and analysis plans and studies to fill potential data gaps
- Finalize an area wide human health and ecological risk assessment

The Area Wide Human Health Risk Assessment (AWHHRA) and Area Wide Ecological Risk Assessment (AWERA) follow a tiered approach to evaluating the risk of mining to human health and ecological receptors. Both the AWHHRA and AWERA follow a deterministic approach to developing doses for the risk assessment. Overall risk to ecological receptors was calculated based on a weight-of evidence approach.

The key EPA guidance documents that were used to prepare the AWHHRA are listed below.

- EPA. 1989. "Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part A) (RAGS)." Interim Final. Office of Emergency and Remedial Response (OERR). Washington, DC. EPA/540/1-89/002. December.
- EPA. 1991. "RAGS, Volume I: Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors." Interim Final. Office of Solid Waste and Emergency Response (OSWER) Directive 9285.6-03. March 25.
- EPA. 1997. "Exposure Factors Handbook." Volumes 1 through 3. Office of Research and Development (ORD). EPA/600/P-95/002Fa, -Fb, and –Fc. August.

For the AWERA, U.S. Environmental Protection Agency's (EPA) "Ecological Risk Assessment (ERA) Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments, Interim Draft Final" (EPA 1997b) (ERA Guidance for Superfund) was followed as opposed to EPA's "Guidelines for Ecological Risk Assessment, Final" (EPA 1998). EPA's ERA Guidance for Superfund is most widely employed for ERAs as opposed to the "Guidelines for Ecological Risk Assessment." Both use the same basic principles for conducting an ERA, but the terminology is different in some cases. For instance, EPA (1998) uses "measurement effect" for "measurement endpoint" (EPA 1997b). The outcome is the same regardless of the terminology used

1.2 REPORT ORGANIZATION

This report is organized into eight sections and includes figures, tables, eight appendices, and one compact disk containing analytical data. The report is presented in two volumes:

Volume 1 of 2:

- Area Wide Human Health and Ecological Risk Assessment Report
  - Section 1.0 – Introduction
  - Section 2.0 – Location, Environmental Setting, and Background
  - Section 3.0 – Data Quality Assessment
  - Section 4.0 – General Conceptual Site Model
  - Section 5.0 – Screening of Chemicals of Concern
  - Section 6.0 – Area Wide Human Health Risk Assessment
  - Section 7.0 – Area Wide Ecological Risk Assessment
  - Section 8.0 – References
  - Figures
  - Tables

- Appendices A – G
  - Appendix A Glossary
  - Appendix B Chemical of Potential Concern Screening
  - Appendix C Medium-specific Exposure Point Concentration Calculations
  - Appendix D Human Health Toxicity Profiles
  - Appendix E Human Health Tier-specific Exposure, Risk, and Hazard Calculations
  - Appendix F Ecological Toxicity Profiles
  - Appendix G Area Wide Ecological Risk Assessment Hazard Calculations

Volume 2 of 2:

- Appendices H and I
  - Appendix H 2001 Data Summary Report
  - Appendix I Responses to Comments on the Draft Area Wide Human Health and Ecological Risk Assessment

- Compact disk containing 2001 sampling analytical data

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2.0 LOCATION, ENVIRONMENTAL SETTING, AND BACKGROUND

This section presents the location, environmental setting, and background information for this report.

2.1 SOUTHEAST IDAHO PHOSPHATE MINING HISTORY

Phosphate mining has been practiced in southeastern Idaho throughout most of the Twentieth 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 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 2-1, was formed in 1997 to voluntarily and jointly addresses 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 (IDL)
- 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 (USFWS)
- U.S. EPA
- U.S. Geological Survey (USGS)
- Other Interested Stakeholders (such as ranchers and the Greater Yellowstone Coalition)

In August 2000, IDEQ was specified 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. IDEQ subsequently established an Interagency Technical Group to coordinate its activities with the other jurisdictional and administrative agencies. 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.

Although IDEQ has been designated as the lead for the area wide assessments, other agencies such as FS, BLM, and IDL are responsible for specific mine sites and are the lead agencies for the site-specific work to be conducted at certain mines.

Much of the characterization and risk assessment conducted under the auspices of the IMA Selenium Committee is documented in a series of reports prepared by MW (MW 1998a, 1998b, 1999a, 1999b, 2000, 2001). The IMA Selenium Committee implemented a phased approach for investigating potential impacts from phosphate mining (MW 1999b). Because of the broad similarities in mining operations and material characteristics, those investigations and the 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 comprises portions of Caribou, Bear Lake, Bonneville, and Bingham Counties (Figure 1). This region contains 15 mines previously owned or operated by FMC Corporation; J.R. Simplot Company; Nu-West Industries, Inc., and Nu-West Mining, Inc. (Nu-West); Rhodia, Inc.; and P4 Production LLC (see Table 2-1), as well as numerous "orphaned" mine sites, primarily of underground design. One of the 15 mines, the South Maybe Canyon Mine, is being addressed separately under a consent order between Nu-West and FS and is not included in the scope of the Selenium Project.

Issues and concerns associated with the IMA studies and risk assessments are discussed in the "Final Existing Data and Risk Assessment Review" (TtEMI 2001a). The additional information deemed necessary to complete the AWHHRA and AWERA are discussed in the "Final Data Gap Technical Memorandum" (TtEMI 2001b) and the guidance followed was presented in the "Final Area Wide Human Health and Ecological Risk Assessment Work Plan" TtEMI 2002a), referred to as the Work Plan.

Additional studies of the general geology of the Phosphoria Formation and site-specific investigation of biogeochemistry of selenium have been or are being conducted by the various entities in SeWG (that is, USGS, FS, IDFG, USFWS, and individual mine operators). These investigations are described more fully, as appropriate, in the "Final Existing Data and Risk Assessment Review" (TtEMI 2001a).

2.2 REGIONAL ENVIRONMENTAL SETTING

The Resource Area covers about 2,500 square miles in the southeastern part of Idaho. The regional environmental setting is discussed in the following sections and is adapted primarily from MW (1999b).

2.2.1 Climate

The topography of southeastern Idaho influences wind patterns, temperature, and precipitation in the Resource Area (MW 1999b). The north-to-south-trending mountain ranges west of the Resource Area create a natural barrier for water-bearing Pacific air masses. Because of this rainshadow effect, the Snake River Plain region is semiarid, with a middle-latitude steppe climate. The southeastern part of the Resource Area is wetter and cooler than the other parts because of the increasing elevation (MW 1999b). Fall and winter are dominated by cold, dry continental air and cyclonic storms. In the cooler months, precipitation is generally from snow, while in the springtime, cool marine air from the south brings precipitation. In the summer, precipitation is associated with localized, orographic thunderstorms (MW 1999b). Average precipitation increases in an easterly direction, with 12 inches in the west and 25 to 35 inches in the central and eastern districts.

2.2.2 Regional Geology

The Resource Area is situated within the northern region of the Basin and Range Physiographic province. The mountain ranges in southeastern Idaho generally are composed of deformed Paleozoic and Mesozoic sedimentary rocks, including thick marine clastic units, cherts, and limestones (MW 1999b). The valleys are largely filled with Quaternary alluvium and colluvium that overlay Pleistocene basalt flows. Thick rhyolite flows of the Snake River Plain region, and rhyolite domes, located south of the Blackfoot Reservoir, make up the remaining volcanic sequences in the area. Large accumulations of marine sediment occurred during the Paleozoic era over a large area of eastern Idaho, southwestern Montana, northern Utah, and western Idaho (MW 1999b). The Phosphoria Formation was deposited during Permian time, forming the western phosphate field, part of which is located in the Resource Area. Additional information on stratigraphy and concentrations of target elements in ore-bearing units is provided in MW (1999b). MW (1999b) also provides additional information on soils and vegetation; water resources, including surface water and discussions on each major watershed located in the Resource Area; and groundwater.

2.2.3 Regional Ecology

This section briefly discusses the biological resources in the Resource Area. MW (1999b) presents a detailed discussion of the regional ecology.

2.2.3.1 Ecological Characteristics

The vegetation in the Resource Area is transitional between the Great Basin vegetation to the south and the Rocky Mountain vegetation to the north (MW 1999b). Six vegetation types within the Resource Area are a result of elevation, moisture, temperature, soil type, slope, and aspect. A list of plant species found in the Resource Area is presented in Table A.1 of Appendix A of MW (1999b). Based on previous investigations, the Resource Area contains or supports about 75 species of mammals, 272 species of birds, 16 species of reptiles, 16 species of fish, and seven species of amphibians (USGS and USFWS 1977; USFWS 1985, 1997; and Idaho Conservation Center Data Base (ICCDB) 1999, all as cited in MW 1999b). In MW (1999b), Table A.2 presents a list of mammals, Table A.3 presents a list of birds, and Table A.4 presents a list of reptiles and amphibians known or believed to reside in the Resource Area.

2.2.3.2 Threatened and Endangered Species

Several threatened and endangered species may live full time or are seasonal migrants in the Resource Area (MW 1999b): bald eagle, gray wolf, whooping crane, the Canada lynx, and Ute ladies' tresses, (listed species). Several species are classified as sensitive by federal and state agencies: northern goshawk, Columbian sharp-tailed grouse, trumpeter swan, Harlequin duck, great gray owl, flammulated owl, boreal owl, three-toed woodpecker, western big-eared bat, wolverine, spotted bat, spotted frog, Snake River finespotted cutthroat, Yellowstone and Bonneville cutthroat trout, Idaho sedge, slick-spot peppergrass, starveling milkvetch, Payson's bladderpod, and Cache beardtongue (MW 1999b).

2.3 HUMAN POPULATIONS

The Resource Area consists of about 2,500 square miles in Caribou, Bingham, Bannock, and Bear Lake Counties in southeastern Idaho. As stated in the "Final 1998 Regional Investigation Report" (MW

1999b), "a significant portion of the project area land is within the Caribou National Forest, the Fort Hall Indian Reservation, or is administered by the BLM." The Resource Area is sparsely populated. The largest nearby population centers are located in Pocatello, Fort Hall, Montpelier, and Soda Springs, Idaho, and Afton, Wyoming. Farming and ranching are the dominant land uses in the Resource Area (MW 1999b).

2.4 SUMMARY OF PREVIOUS INVESTIGATIONS AND ASSESSMENTS

This section presents a summary of the previous investigations and assessments that pertain to human health risk assessments (HHRA) and ERAs that have been conducted in the Resource Area.

A wide range of environmental media and facilities were sampled and analyzed, including biotic and abiotic media. Overall, the investigations were conducted using a phased approach, where preliminary sampling was used to help define the requirements for future investigations.

IMA Fall 1997 Interim Surface Water Survey: The 1997 survey represents the initial effort by SeWG to assess surface water quality in the Resource Area. The 1997 water quality survey was intended as a preliminary investigation that would lay the foundation for subsequent regional investigations. The results of the 1997 survey are documented in the "Fall 1997 Interim Surface Water Survey Report" (MW 1998a). The results showed that surface water samples collected from or near many of the mine facilities contained elevated concentrations of selenium.

1998 Regional Investigation: In 1998, the media represented were increased to include groundwater, stream sediments, soil and vegetation on waste rock piles, water from waste rock pile seeps, and background uplands (Phosphoria outcrops) soils, and trout fillets. The frequency of stream sampling also was increased to include the spring runoff (May), as well as the September low-flow event. The data collected in 1998 were used in the preliminary ecological and human health risk assessments and are documented in the "Final 1998 Regional Investigation Report" (MW 1999b). The preliminary assessments were intended to be refined based on new data gathered during future investigations. Samples were analyzed for a limited set of inorganic chemicals that included selenium, cadmium, copper, chromium, cobalt, manganese, nickel, vanadium, zinc, calcium, iron, magnesium, potassium, and sodium.

IMA 1999 Interim Regional Investigation: In 1999, additional investigations were conducted to collect time-critical data and implement special studies on selected biotic components in the Resource Area. Surface water was the primary environmental medium sampled outside of the special studies, and the list of target elements was reduced to selenium and cadmium. The results of the 1999 interim regional investigation are documented in the “1999 Interim Investigation Data Report” (MW 2000).

Additionally, IMA initiated four special studies in 1999 to obtain information on selected biotic components in the Resource Area:

(1) Bird eggs
(2) Cutthroat trout
(3) Elk tissue
(4) Cattle tissue

IMA 1999-2000 Regional Investigation: This report presented data for surface water, sediment, and aquatic biological samples collected in September and October 1999, and May 2000. Media sampled included surface water, sediment, periphyton, plankton, submerged macrophytes, benthic macroinvertebrates, forage fish, salmonids, and riparian vegetation. Samples were analyzed for a limited set of inorganic chemicals. The results of the 1999-2000 regional investigation are documented in the “1999-2000 Regional Investigation Data Report for Surface Water, Sediment, and Aquatic Biota Sampling Activities, Draft” (MW 2001).

IMA 2001 Waste Pile, Seep, and On-site Pond Investigations: IMA collected samples from the waste rock piles, seeps, and on-site ponds at 14 of the mine sites during Spring 2001. These samples were analyzed for a comprehensive list of inorganic chemicals.

IMA 2001 Terrestrial Invertebrate, Terrestrial Plant, Soil, and Small Mammal Investigation: The IMA collected small mammals along with collocated terrestrial invertebrates, soils, and vegetation samples from waste rock piles, upland background areas (Phosphoria outcrops), impacted riparian zones, and background riparian areas during Summer 2001. These samples were analyzed for a comprehensive list of inorganic chemicals.

IDEQ 2001 Surface Water and Sediment Investigation: As part of the Total Daily Maximum Load (TMDL) program for the Resource Area and the AWRA, IDEQ collected surface water and sediment samples for analysis from selected segments of various streams where there was a potential for impacts from phosphate mining. These data can be used to support the AWHHRA and ERA and also will be used to provide baseline data to establish TMDL requirements for streams in the Resource Area. These samples were analyzed for a comprehensive list of inorganic chemicals. The results of the 2001 surface water and sediment investigation are documented in the "Final 2001 TMDL Baseline Monitoring Report" (TtEMI 2002b).

IDEQ Summer 2001 Risk Assessment Sampling: IDEQ initiated an extensive sampling effort for the Spring and Summer of 2001 to collect a variety of media, including surface water, sediment, soil, vegetation, and biota for laboratory analysis. These data were used to support the AWHHRA and ERA for the Resource Area and the analytical results were used to help refine the list of chemicals of potential ecological concern (COPEC) and to identify potential exposure scenarios. These samples were analyzed for a comprehensive list of inorganic chemicals. Results of the Summer 2001 risk assessment sampling are provided in Appendix H.

Additional Studies: A number of additional studies have been conducted by various government agencies including, but not limited to, USFWS, FS, and USGS. These additional studies varied in the type of samples collected, types of analyses, and collection locations. These additional studies will be evaluated to obtain supporting information for the risk assessment.

Table 2-2 presents the numbers and type of data that were used to conduct the AWHHRA and AWERA.

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3.0 DATA QUALITY ASSESSMENT

The AWERA and AWHHRA are based primarily on data collected during calendar year 2001. The IMA and TtEMI collected the data as a joint effort. The breakdown of responsibility for data collection was as follows.

- Waste Rock – IMA
- On-site Surface Water and Sediment – IMA
- Off-site Surface Water and Sediment – TtEMI
- Aquatic Plants – TtEMI
- Fish – TtEMI
- Aquatic Invertebrates – TtEMI
- Terrestrial Plants and Invertebrates – IMA
- Small Mammals – IMA
- Riparian and Upland Soil – IMA

TtEMI did not evaluate the quality of the data collected by IMA. However, both groups used the same laboratories, and the data are therefore assumed to be of comparable quality. The following sections discuss the overall quality of the data collected by TtEMI but are assumed to apply to all data collected by both groups.

The laboratory analyses were performed according to EPA methods, as described in the "Final Sampling and Analysis Plan" (TtEMI 2001d). However, the information reported by the laboratory was not adequate to validate the data according to EPA functional guidelines. An overall assessment of the available information was therefore used to assess the quality of the laboratory data. This evaluation included a review of quality control (QC) information in the raw data package, analytical methods, and discussions with laboratory staff. In particular, the following data from the sampling events were evaluated:

- Check standards
- Blanks
- Matrix spike and matrix spike duplicate (MS/MSD) samples
- Laboratory control samples
- Standard reference material
- Sensitivity

The laboratory quality assessment was restricted to selenium, boron, and other constituents analyzed using the EPA Methods 200.7 and 200.8.

3.1 CHECK STANDARDS

Check standards were consistently reported for all constituents. The check standard recoveries were generally within 95 to 100 percent. The recoveries were never outside of the QC guidance limits of 85 and 115 percent. The recoveries for check samples indicate that the instruments maintained calibration throughout the analytical runs.

3.2 BLANKS

The results for method blank results were generally below method detection limits (MDL). With the exception of blank samples with detectable concentrations of aluminum and boron, constituents were rare. In such cases, concentrations of the detected constituents only slightly exceeded the MDL. These elevated levels are probably related to normal analytical variability rather than to significant laboratory contamination. Normal analytical variability is exacerbated by the very low detection limits that were selected for the project. Aluminum and boron tended to occur in the blanks more regularly than the other elements and at somewhat higher concentrations. The source of aluminum and boron is problematic. However, dust could be the source for aluminum in the blanks, whereas glassware was the probable source for boron. Thus, the results for method blank samples suggest that laboratory contamination was minimal.

3.3 MATRIX SPIKES AND MATRIX SPIKE DUPLICATES

Matrix spikes were determined only for selenium and cadmium. Matrix spike recoveries for cadmium were always within the QC guidance limits of 75 to 125 percent. The recoveries for selenium were generally within the desired range but were low in some cases. Thus, the analysis of selenium may be affected by matrix interference in some instances.

3.4 LABORATORY CONTROL SAMPLES

Blank spikes were reported for selenium and cadmium, but not for other constituents. Laboratory control sample (blank spike) recoveries were generally within the QC guidance of 80 to 120 percent. These data indicate that analytical precision was reasonable and generally within acceptable analytical bounds.

3.5 STANDARD REFERENCE MATERIALS

Standard reference materials were included with the analytical runs for all elements, except for uranium. The standard reference materials are prepared by external sources and provide a measure of laboratory accuracy. Recoveries for the external standards were generally good. Analytical methods used in the source laboratory that developed the standard reference materials may vary from those used in the reporting laboratory, so it is not uncommon for recoveries to deviate from the true values. The recoveries were almost always within acceptable limits, indicating good precision and high accuracy.

3.6 SENSITIVITY

The detection limits were below proposed regulatory benchmarks, and the data are adequate from this perspective. Notably, the detection limits reported are generally lower than in previous investigations in the Resource Area (TtEMI 2001a). The relatively high sensitivity associated with the low detection limits resulted in low magnitude, but high proportional, variation.

3.7 OVERALL ASSESSMENT OF LABORATORY DATA

Overall, only minor and isolated problems were noted with calibrations, blanks, matrix spikes, laboratory control samples, and standard reference materials. No apparent and consistent bias was detected in the analysis. The primary limitation of the data from a quality perspective is that matrix spikes, duplicates, and laboratory control samples were not consistently analyzed for all elements. Nonetheless, the data are considered both accurate and precise based on the results of the analysis for check standard, blank, and standard reference materials. The detection limits are much improved from previous investigations and are appropriate for the proposed regulatory comparisons and use in the risk assessment.

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4.0 GENERAL 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 conceptual site model (CSM) that addresses the following major issues:

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

Because of differences in exposure, separate CSMs have been developed for human health and ecological receptors and are discussed in more detail in the following sections (see Figures 3 and 6).

4.1 FATE AND TRANSPORT OF CHEMICALS OF POTENTIAL CONCERN

The primary source of contamination from phosphate mining in the Resource Area appears to be the waste rock piles associated with the various mine sites. Primary chemical release mechanisms for the piles are as follows:

- Erosion from waste rock piles to surface soils
- Percolation from waste rock piles to surface soils, subsurface soils, groundwater, and surface water
- Biotic uptake from contaminated soils or sediments
- Storm water runoff from waste rock piles to surface water

Each of these primary release mechanisms results in a pathway of exposure of various metals from mining to human health and ecological receptors. The primary chemical is selenium, but other chemicals were identified as posing a potential concern in the screening process discussed in Section 5.0. The sources of chemicals and each of the primary chemical release mechanisms for metals are described in the following sections. These processes may vary, depending on the specific metal.

4.1.1 Sources of Chemicals

The Dinwoody, Phosphoria, and Wells Formations, the “phosphate sequence,” are the principal sedimentary formations mined to produce all phosphate ore (MW 1999a). The Meade Peak member of the Phosphoria Formation in southeastern Idaho is extensively mined for its phosphate content and is a marine sedimentary deposit of Permian age (MW 1999a; Piper and others 2000). An analysis of the formation indicated 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.

The waste rock that results from phosphate mining is composed of overburden and underburden materials that have been removed to reach the bodies of phosphate ore. The waste rock typically is deposited on the surface, where it’s exposed to the elements. Weathering of the waste rock results in material that more readily releases chemicals into the environment.

4.1.2 Wind Erosion from Waste Rock Piles to Surface Soils

In southeastern Idaho, extensive, wide-open spaces are common and create the potential for strong air currents. Therefore, wind erosion and subsequent deposition may be a significant mechanism of chemical transportation in the Resource Area, particularly at locations that may be frequented by recreational users and no longer actively managed by site operators.

The potential exists for wind to erode and re-suspend surface soil and transport it to other areas, both near and far away, depending on wind speed and other factors. Any metals that are closely associated with soil particles also will be transported. Deposition from this mechanism of transport may increase levels of metals 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, washed onto the ground by rain, or eaten by herbivores or omnivores, thereby making any metals present available to the plants and animals in the vicinity.

4.1.3 Percolation from Waste Rock Piles to Groundwater and Surface Water

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

Chemicals may be carried into the groundwater, but based on current information, they do not appear to create a significant problem in the Resource Area. However, any chemicals dissolved in groundwater may be carried along until exiting into a stream, lake, or wetland.

4.1.4 Storm Water Runoff from Waste Rock Piles to Surface Water

As a result of spring snowmelt and storms, significant quantities of water may move across the waste piles as surface runoff. This surface flow will move particles of the waste rock into the local streams and ponds or onto adjacent terrestrial areas. Depending on the topography of the various waste rock piles, storm water runoff may be a significant transport mechanism.

4.1.5 Surface Water Transport

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

4.1.6 Biotic Uptake

Plants may take up metals in significant quantities. The rate of uptake depends on the species and chemical and can vary significantly between species. In terrestrial systems, humans and animals can ingest various metals in water or food or through incidental ingestion of dust, soil, or sediment.

Metals also maybe taken up in significant quantities by aquatic plants. The rate of uptake depends on the species and can vary significantly among species. Similar to terrestrial systems, uptake by aquatic animals can occur by ingestion of food, water, and sediments. However, direct absorption from the surrounding media may be significant for some receptors in aquatic systems.

4.2 HUMAN HEALTH RISK ASSESSMENT

The preliminary CSM links potential or actual releases to potential human exposures. Specifically, the CSM identifies (1) potential chemical sources and mechanisms of potential release, (2) potential receptors and exposure pathways, and (3) exposure scenarios. These three elements were first presented in the "Draft Conceptual Site Model" (TtEMI 2001c) (referred to as the Draft CSM) and are repeated here.

As described in the EPA's RAGS (EPA 1989), an exposure pathway consists of four primary elements:

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

The human health CSM (see Figure 3) depicts human health exposure pathways specific to the Resource Area.

4.3 ECOLOGICAL RISK ASSESSMENT

For the AWERA, investigations are focused on ecological receptors most likely to be affected, given the fate and transport mechanisms of the chemicals involved, the ecotoxicological properties of the chemicals, and habitats at the site (EPA 1997b). The CSM for the AWERA is presented in Figure 6. The expected and potential primary producers and the primary, secondary, and tertiary consumers are presented. Assessment endpoints are highlighted for each trophic level that is included in the CSM. The CSM for the AWERA is discussed in more detail in Section 7.4.3.

5.0 SCREENING OF CHEMICALS OF CONCERN

Screening the data to select chemicals of potential concern (COPC) for humans and COPECs for ecological receptors involved the following steps:

- Tier 1 – The results of analysis of the waste rock were compared with data on the naturally occurring levels found in background soils in the western U.S. If the maximum concentration detected in waste rock was less than 2 times the mean background level for the western U.S., the chemical was considered for elimination as a COPC or COPEC. Data for sediment, surface water, and soil were evaluated for chemicals present at background levels in the waste rock. If the concentrations were not elevated in the other media, the chemical was eliminated from consideration. This evaluation resulted in the elimination of barium, lead, manganese, and thallium from further consideration. All other chemicals were evaluated in Tiers 2 and 3.
- Tier 2 – The concentrations of chemicals that passed the Tier 1 assessment were evaluated for riparian soils, surface water, and sediment against area-specific background concentrations. If the maximum detected concentration for the medium was less than 2 times the mean area-specific background level for the chemical, it was eliminated from consideration as a COPC or COPEC for that media. All chemicals retained after this comparison were evaluated on a media specific basis in Tier 3.
- Tier 3 – The maximum detected concentrations of chemicals for each medium that remained after the Tier 2 assessment was compared with media-specific benchmarks. The Tier 3 screening was conducted separately for COPCs for human health and COPECs for ecological receptors. For human COPCs, sediments were not considered because the exposure was evaluated as de minimis for the exposure scenarios under consideration.

The following benchmarks were used for selection of human health COPCs:

- Soils – EPA Region 9 residential preliminary remediation goals (PRG)
- Surface Water – EPA Region 9 tap water PRGs

If the maximum detected concentration did not exceed the applicable benchmark, the chemical was eliminated from consideration for that medium as a human health COPC.

The following benchmarks were used for ecological COPEC selection:

- Soils – EPA ecological soil screening levels (EcoSSL) were given priority when they were available for a chemical. For chemicals without EPA EcoSSLs, EPA Region 4 soil screening levels were used (see Table 7-1).

- Sediments – The lowest available benchmark from the threshold effects level (TEL), probable effects level (PEL), or upper effects threshold (UET) values were used for the comparisons (see Table 7-1).
- Surface Water – The ambient water quality criterion (AWQC) chronic criterion concentrations (CCC) were used for the comparisons (see Table 7-1).

If the maximum detected concentration did not exceed the applicable benchmark, the chemical was dropped from consideration for that medium as an ecological COPEC. After all media were screened, any chemical retained for any medium was retained for Tier 3 as an ecological COPEC for all media.

- Tier 4 - After all media were screened, a full evaluation was conducted of the information on each chemical based on the results of the medium-specific screening. The individual data sets were evaluated to identify any additional information that would provide an additional weight of evidence for retaining or rejecting a chemical as a human health COPC or COPEC. Based on this evaluation, a COPC or COPEC was selected or rejected for the AWRA.

The following chemicals were retained as COPCs for evaluation of risk to humans:

- Arsenic
- Cadmium
- Chromium
- Selenium

The following chemicals were retained as COPECs for evaluation of risk to ecological receptors:

- Cadmium
- Chromium
- Copper
- Nickel
- Selenium
- Vanadium
- Zinc

A more detailed discussion of how the chemicals of concern were selected is provided in Appendix B.

6.0 AREA WIDE HUMAN HEALTH RISK ASSESSMENT

The overall scope of this AWHHRA is to evaluate potential exposures to COPCs in multiple media and characterize the associated risks and hazards across the entire Resource Area for several receptor groups. The specific objectives of the AWHHRA are to (1) identify exposure scenarios (receptor and exposure pathway combinations), locations (for example, particular watersheds or stream segments), and COPCs that are associated with or contribute significantly to cancer risks and hazards greater than acceptable levels; and (2) focus ongoing and subsequent field investigations on the exposure scenarios, locations, and COPCs associated with or contributing significantly to unacceptable risks and hazards.

As described in EPA's RAGS, a risk assessment is typically conducted in the following four basic steps: (1) data evaluation and identification of COPCs, (2) exposure assessment, (3) toxicity assessment, and (4) risk and hazard characterization (EPA 1989).

The AWHHRA is organized as follows: Section 6.1 discusses the technical approach and identifies primary guidance documents used in the AWHHRA; Section 6.2 presents the analytical data selection procedures; Section 6.3 discusses selection of COPCs; Sections 6.4 and 6.5 discuss exposure and toxicity assessments, respectively; Section 6.6 discusses characterization of risk and hazard; Sections 6.7 through 6.9 present the Tier 1, 2 and 3 assessments, respectively; Section 6.10 discusses the uncertainty assessment, and Section 6.11 presents the AWHHRA summary and conclusions.

6.1 AREA WIDE HUMAN HEALTH RISK ASSESSMENT APPROACH

The AWHHRA was conducted following a tiered approach (see Figure 5). The objectives of the tiered approach were two-fold:

(1) To identify exposure scenarios (receptor and exposure pathway combinations) and locations (for example, particular watersheds or stream segments) that were associated with cancer risks and noncancer hazards greater than acceptable levels and

(2) To focus ongoing and subsequent field investigations on the exposure scenarios and locations associated with unacceptable risks and hazards.

The tiered approach consisted of three tiers. Sections 6.1.1 to 6.1.3 present descriptions of each tier.

TtEMI used the following the key EPA guidance documents in the AWHHRA:

- EPA. 1989. "Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part A)." Interim Final. OERR. Washington, DC. EPA/540/1-89/002. December.
- EPA. 1991. "RAGS, Volume I: Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors." Interim Final. OSWER Directive 9285.6-03. March 25.
- EPA. 1992. "Supplemental Guidance to RAGS: Calculating the Concentration Term." OSWER Publication 9285.7-081. May.
- EPA. 1997d. "Exposure Factors Handbook." Volumes 1 through 3. ORD. EPA/600/P-95/002Fa, - Fb, and - Fc. August.

6.1.1 Tier 1 Assessment

Purpose: Tier 1 was the first screening step for all potentially complete exposure scenarios identified in the human health CSM (see Figure 3). Other complete (or potentially complete) exposure pathways were considered to be de minimus or contribute only a negligible part of the total dose to the receptor. A qualitative discussion regarding why these exposure pathways are considered de minimus is presented in Section 6.4.2. It should be noted that no gardens, residential or otherwise, have been observed in any riparian areas in the Resource Area. Therefore, ingestion of homegrown produce from such a garden is a theoretical exposure scenario.

Detail: Exposure pathways resulting in cancer risks and noncancer hazards lower than acceptable levels (defined as hazard index [HI] = 1.0 and one in a million incremental cancer risk, see Section 6.1.2) were eliminated from further evaluation in the AWHHRA, except for exposure pathways that were deemed to be common in the Resource Area and were likely to be of particular concern to the general public (for example, ingestion of elk and beef cattle tissue associated with hunting and ranching). These and all other exposure pathways resulting in cancer risk and noncancer hazards greater than acceptable levels were carried forward in the Tier 2 quantitative evaluation.

Data: Tier 1 evaluated medium-specific analytical data collected by TtEMI in 2001 (referred to hereafter as 2001 data) (see Appendix H).

Exposure Point Concentrations (EPC): TtEMI used maximum detected concentrations of COPCs (see Section 6.3 for a discussion on COPC identification) in all media to quantify cancer risks and noncancer hazards for all exposure scenarios, except in cases where maximum detected concentrations were measured in an exposure medium which did not correlate with the corresponding exposure scenario. For instance, the subsistence lifestyle receptor was not evaluated using maximum observed concentrations from the Resource Area stream segments, such as values from East Mill Creek, that cannot reasonably be expected to have the potential to support that scenario. Similarly, maximum soil concentrations for homegrown produce models did not use waste rock pile soils where it is indisputable that residential gardens do not and will not occur. Instead, fluvial or riparian soils were used to represent areas where residential gardens could occur. Soil chemical concentration data from these areas are considered relevant to the evaluation of the subsistence scenario, and the maximum detected concentration was used.

Exposure Parameters: Reasonable maximum exposure (RME) conditions, as defined by EPA (EPA 1989) were used in Tier 1.

6.1.2 Tier 2 Assessment

Purpose: Tier 2 was an area-wide evaluation of exposure pathways and COPCs carried over from the Tier 1 assessment, based on a watershed-, stream-, or riparian area-specific exposure area.

Detail: Tier 2 assessments consisted of two categories, Tier 2a and Tier 2b, based on the following exposure area definitions:

- Tier 2a: This tier involved evaluation of all exposure pathways associated with exposure areas that extend (or could extend) beyond stream-specific areas. For example, to account for ingestion of fish that may have been caught by receptors in a variety of streams, fish tissue EPCs were calculated on a watershed-specific basis (an exposure area that extends beyond stream-specific areas). Tier 2a addressed six exposure scenarios, including ingestion of (1) fish, (2) wild game (represented by elk), (3) beef cattle, (4) aquatic and terrestrial plants, (5) teas brewed from aquatic and terrestrial plants, and (6) surface water.
- Tier 2b: This tier involved evaluation of exposure pathways associated with stream-, riparian area-, and mine-specific exposure areas, including ingestion of homegrown produce, ingestion of surface soil, and inhalation of particulates.

In general, exposure scenarios and pathways associated with risks and hazards lower than acceptable levels were eliminated from further evaluation in the AWHHRA.

The following exposure pathways were not evaluated beyond Tier 2:

- Ingestion of wild game (as represented by elk) and ingestion of beef cattle (considered under Tier 2a): these exposure pathways were evaluated using data sets that could not be further broken down (see Section 6.3). Also, additional elk and beef tissue data sets are unavailable for comparison.
- Ingestion of homegrown produce, ingestion of surface soil, and inhalation of particulates: these exposure pathways were already evaluated on a stream- or mine-specific basis in Tier 2b. Also, it was assumed that there is little temporal variation of COPC concentrations in plant tissue, surface soil, and waste rock. Additional details regarding the proposed exposure scenario-specific application of the tiered approach are presented in Sections 6.4.2.

Data: Tier 2 evaluated medium-specific 2001 data (See Appendix H).

EPCs: For the fish and surface water ingestion exposure pathways, EPCs were calculated under RME and central tendency exposure (CTE) conditions as watershed-specific averages weighted by the relative presence of impacted and unimpacted stream segments as described in Appendix C. For all other exposure pathways, EPCs were calculated as the lower of the maximum detected concentration and 95 percent upper confidence limit of the mean (UCL_{95}) for RME conditions and the mean value for CTE conditions, consistent with EPA guidance (EPA 1992). Appendix C details the procedures used to calculate media-specific COPCs.

Exposure Parameters: In addition to evaluating RME conditions, Tier 2 evaluated CTE conditions (see Tables 6-1 and 6-2 for RME and CTE exposure parameters, respectively). Exposure parameters for CTE conditions represented central tendency values (for example, mean or fiftieth percentile), consistent with EPA guidance (EPA 1992). In general, CTE values were generally consistent with EPA guidance based on area-specific knowledge.

6.1.3 Tier 3 Assessment

Purpose: Tier 3 consisted of evaluating fish ingestion exposure scenarios in order to assess the impact of temporal changes in COPC concentrations.

Detail: Cancer risks and noncancer hazards were calculated on a watershed-specific basis. As necessary, this exposure pathway could also be evaluated on a stream-specific basis in the future as part of mine-specific risk assessments. As part of these future stream-specific evaluations, the potential for each stream to support a particular exposure scenario should be considered. For example, some streams in the

Resource Area (for example, Maybe Creek) have been shown to currently support little if any aquatic life – ingestion of fish from impacted stretches of these streams is unlikely to occur under current conditions. The potential for each stream to support the fish ingestion exposure scenario could be characterized through the use of stream-specific fraction-ingested (FI) values. These FI values should reflect the productivity of each stream and should be developed using a variety of criteria including, but not limited to, order; the number, type, size and species of fish present; and whether spawning has been observed in the stream. It should be noted, however, that (1) it is considered unlikely that receptors will be exposed exclusively to fish and surface water from individual streams and (2) based on the large number of fishable streams in each watershed, each of the three watersheds evaluated in the AWHHRA was assumed to be productive enough to support the alluvial ingestion rates (in other words, the FI for each watershed was assumed to be 1).

Data: Tier 3 evaluated medium-specific 2001 data and historical data (see Appendix H and MW [1999b]).

EPCs: EPCs were calculated in the same manner as for Tier 2.

Exposure Parameters: Tier 3 evaluated RME and CTE conditions, as described in Tier 2.

6.2 SELECTION OF ANALYTICAL DATA

This section presents analytical data selection procedures for evaluation of receptor-specific exposures. The medium-specific data sets used as the basis for the AWHHRA are discussed in detail in Section 7.2.1 of the Work Plan (TtEMI 2002a). In general, the AWHHRA is based on medium-specific analytical results associated primarily with samples collected in 2001 and supplemented by historical data. More specifically, Tiers 1 and 2 of the AWHHRA are based primarily on analytical data for 2001 (see Appendix H), as well as on data for elk and beef cattle presented in MW (2000), although Tier 3 is based on historical analytical data collected in 1998 (MW 1999b). Medium-specific analytical data sets that form the basis of Tiers 1 and 2 of the AWHHRA (with the exception of data sets for elk and beef tissue) are summarized in Table 6-3 (including the number and location of medium-specific samples). All medium-specific analytical data sets (waste rock, surface water, plant tissue, soil, game, beef cattle, and historical sample results) are briefly discussed in the following sections.

6.2.1 Waste Rock

MW, a consultant to IMA, collected samples of waste rock in Summer 2001 (TtEMI 2001e). Samples were collected from all or a portion of the waste piles at each of 14 mines. Samples of waste rock were analyzed for a comprehensive list of metals. Analytical results for waste rock are summarized in Appendix H. The locations of waste rock samples are shown in Figure 7. It should be noted that the samples were collected from black shale areas and may not be representative of the entire waste rock pile at each site.

6.2.2 Surface Water

TtEMI and IDEQ personnel collected surface water samples in May, June, July, and September 2001 (TtEMI 2001d; see also Appendix H). In total, surface water samples were collected from 39 locations associated with 24 different streams at locations upstream (uncontaminated) and downstream (potentially contaminated) of various mining sites. Surface water samples were analyzed for the list of parameters presented in Table 6-4. Figure 7 shows the location of the 2001 surface water samples that were used to form the basis for Tiers 1 and 2 of the AWHHRA.

6.2.3 Fish Tissue

TtEMI and IDEQ personnel collected fish tissue samples in July 2001 (TtEMI 2001d). In total, samples of fish tissue were collected from six sampling locations associated with both impacted and unimpacted reaches of the stream (see Table 6-3). The location, species, and weight of fish samples are summarized in Table 6-5. Samples of fish tissue were analyzed for a comprehensive list of metals (see Table 6-4). Figure 7 shows the locations of fish tissue samples considered in Tiers 1 and 2 of the AWHHRA.

6.2.4 Plant Tissue

TtEMI and IDEQ personnel collected samples of both aquatic and terrestrial plants in May and July 2001 (TtEMI 2001d). Specifically, tissue samples were collected from two aquatic species – watercress (*Nasturtium officinale*) and water buttercup (*Cara photomycetin*), and from four terrestrial species – wild onion (*Allium canadense*), bitterroot (*Camus spp.*), golden sage (*Artemesia spp.*), and red willow (*Salix spp.*). These plants represent species that members of the Shoshone Bannock Tribe either ingest or use to brew teas (TtEMI 2001f). Samples of plant tissue were collected in streams or riparian areas downstream of specific mines (impacted reaches) and from unimpacted (background) zones. The number and location of plant tissue samples collected by TtEMI are summarized in Table 6-3. Figure 7 shows the locations of plant tissue samples TtEMI collected in Summer 2001 and considered in the AWHHRA.

Samples of bitterroot were collected only from unimpacted zones; therefore, receptor-specific exposure to contaminants in bitterroot was not considered in the AWHHRA. It was judged that human receptors were more likely to ingest watercress than water buttercup; therefore, receptor-specific exposures to contaminants in water buttercup were not considered in the AWHHRA. Contaminant concentrations in water buttercup are similar to levels detected in watercress samples (see Appendix H).

IMA collected additional samples of plant tissue in Summer 2001. However, the sampling methodology followed by IMA did not specify that samples be collected of the plant species mentioned above. Rather, samples were collected of whatever vegetation was present in selected locations. Therefore, the analytical results from plant tissue samples collected by IMA in Summer 2001 were not considered in the AWHHRA because samples of plant species likely to be ingested by human receptors were not collected.

6.2.5 Soil

Analytical results from soil samples collected in riparian areas along streams in the Resource Area were used to (1) assess potential receptor-specific exposure through incidental ingestion of soil, and (2) estimate the concentration of COPCs in homegrown produce from gardens planted in riparian areas. It should be noted that no gardens, residential or otherwise, have been observed on any riparian areas in the Resource Area. Therefore, ingestion of homegrown produce from such a garden should be considered a theoretical exposure scenario.

IMA collected soil samples from riparian areas in Summer 2001. Soil samples were collected from locations both upstream and downstream of mining facilities. Riparian areas upstream of mining facilities are referred to as unimpacted (or background) reaches and riparian areas downstream of mining facilities are referred to as impacted reaches. The number and locations of riparian area soil samples are summarized in Table 6-3; the locations of riparian soil samples are shown in Figure 7.

6.2.6 Game

Analytical results from skeletal muscle and liver samples (used to represent offal) collected from elk harvested from Idaho Game Management Units (GMU) 76 and 66A, as reported in MW's "1999 Interim

Investigation Data Report" (MW 2000), were used to represent the concentrations of COPCs in game tissue potentially ingested by human receptors.

6.2.7 Beef Cattle

Fifteen steers were confined on a seleniferous pasture for 9 weeks on a reclaimed overburden pile at the Henry Mine in July and August 1999 were included as part of a feedlot depuration study in Fall 1999 (MW 2000). Skeletal muscle and liver (as well as kidney and heart) samples were collected post-mortem. Analytical results associated with these samples were used to represent beef tissue potentially ingested by human receptors; as for elk, liver samples were used to represent offal. While cattle are not typically penned on a waste rock pile, the reclaimed areas present the most palatable forage in the Resource Area and appear to attract free-ranging animals; therefore, sufficient evidence does not exist to conclude that this study represents a "worst-case" scenario.

6.2.8 Historical Surface Water and Fish Tissue

Samples of surface water and fish tissue were collected by IMA throughout the Resource Area in May and September 1998 (MW 1999b). In total, surface water samples were collected from 51 sampling locations associated with 20 streams (in the three study watersheds) at locations upstream (unimpacted) and downstream (impacted) of different mining sites. Surface water samples were analyzed for selenium, cadmium, copper, chromium, cobalt, manganese, nickel, vanadium, zinc, calcium, iron, magnesium, potassium, and sodium, as well as a variety of water quality parameters such as sulfate and total alkalinity. Figure 7 shows the locations of the surface water samples collected by IMA in 1998. Similarly, samples of fish tissue were collected from three sampling locations associated with three streams at locations upstream (unimpacted) and downstream (impacted) of various mining sites. The number, species, and size of the fish IMA collected are summarized in Table 6-5. Samples of fish tissue were analyzed for six metals. Figure 7 shows the locations of the fish tissue samples collected by IMA in 1998.

6.3 SELECTION OF CHEMICALS OF POTENTIAL CONCERN

This section presents the COPC selection process and the medium-specific COPCs that are evaluated in the tiered risk assessment approach described in Section 6.1.

Appendix B presents a description of the process used to select medium-specific COPCs. This process is briefly summarized below.

(1) Chemicals detected in waste rock at a maximum concentration less than twice the mean background level found in soils in the western U.S. were eliminated from further consideration in the AWHHRA (Shacklette and Boerngen 1984) unless found to be elevated in other media.

(2) Remaining chemicals were evaluated subsequently on a medium-specific basis against area-specific background concentrations. Chemicals with maximum detected concentrations for the specific medium less than twice the mean area-specific background level were eliminated from further consideration.

(3) For the remaining chemicals, maximum detected concentrations in soil were compared with EPA Region 9 residential PRG. The maximum detected concentration in water was compared with EPA Region 9 PRGs for tap water (EPA 2000d). Chemicals with maximum detected concentrations equal to or lower than applicable PRGs were eliminated from further consideration.

(4) Finally, each chemical and individual data set were evaluated to identify any additional information that would provide a weight-of-evidence basis for retaining or rejecting a chemical as a COPC (for example, association with historical operations, of particular concern to the public, etc.).

Generally, the chemicals retained as COPCs for evaluation of risk to humans include arsenic, cadmium, chromium, and selenium. Additional chemicals were retained as COPCs in waste rock, aquatic and terrestrial plants, and homegrown produce. The following sections identify the COPCs retained for each medium. Details providing rationale for the selection or rejection of COPCs are presented in Appendix B.

6.3.1 Riparian Area Surface Soil

Arsenic, cadmium, chromium, and selenium were retained as COPCs for evaluation of exposures to surface soil in riparian areas.

6.3.2 Waste Rock Pile Surface Soil

All chemicals detected at elevated concentrations in waste rock piles were retained as COPCs to be evaluated for potential exposure through inhalation of fugitive dust only. Those chemicals are listed below.

- Aluminum
- Antimony
- Arsenic
- Beryllium

- Boron
- Cadmium
- Chromium
- Cobalt
- Copper
- Mercury
- Molybdenum
- Nickel
- Selenium
- Uranium
- Vanadium
- Zinc

6.3.3 Surface Water

Arsenic, cadmium, chromium, and selenium were retained as COPCs for evaluation of exposures to surface water.

6.3.4 Terrestrial Vegetation

There are no PRGs for ingestion of plant tissue. Therefore, chemicals present in soil and terrestrial plant tissue at concentrations greater than twice the average terrestrial plant background levels were retained for evaluation as COPCs. The chemicals retained for evaluation of terrestrial vegetation are listed below.

- Aluminum
- Antimony
- Arsenic
- Cadmium
- Chromium
- Cobalt
- Nickel
- Selenium
- Vanadium
- Zinc

6.3.5 Aquatic Vegetation

There are no PRGs for ingestion of plant tissue. Therefore, chemicals present in sediment and aquatic plant tissue at concentrations greater than twice the average aquatic plant background levels were retained for evaluation as COPCs. The chemicals retained for evaluation of aquatic vegetation include the metals and other inorganic chemicals listed for terrestrial vegetation, with the addition of copper.

6.3.6 Freshwater Fish

Arsenic, cadmium, chromium, and selenium were retained as COPCs for evaluation of exposure to freshwater fish.

6.3.7 Beef Cattle

Cadmium and selenium were retained as COPCs for evaluation of ingestion of beef cattle tissue. Skeletal muscle and liver samples from beef cattle were not analyzed for arsenic and chromium (MW 2000).

6.3.8 Elk

Cadmium and selenium were retained as COPCs for evaluation of ingestion of elk tissue. Samples of skeletal muscle and liver from elk were not analyzed for arsenic and chromium (MW 2000).

6.3.9 Homegrown Produce

There are no PRGs for ingestion of plant tissue. Therefore, chemicals present in soil and terrestrial plant tissue at concentrations greater than twice the average terrestrial plant background levels were retained for evaluation as COPCs. The chemicals retained for evaluation of homegrown produce include the substances listed for terrestrial vegetation.

6.4 EXPOSURE ASSESSMENT

This section discusses the methods used to quantify exposure associated with each complete exposure pathway in the Resource Area.

6.4.1 Human Receptors Evaluated Quantitatively

Three receptor groups were selected for quantitative evaluation in the AWHHRA: recreational hunter/fishers, Native Americans, and subsistence lifestyle. These receptor groups were selected primarily to allow for evaluation of a range of potential exposure and to address particular public and stakeholder concerns. No studies have been conducted regarding the potential presence of subsistence lifestyle receptors in the Resource Area. Therefore, no statements can be made regarding the potential presence or specific number of such receptors in the Resource Area. However, it is acknowledged that the Resource Area is very sparsely populated by ranchers, none of who rely solely on study area resources for subsistence. While selected numbers of the local population may rely on area resources for a significant supplement to their diets, a true subsistence lifestyle is unlikely within the Resource Area. Therefore, for the purpose of the AWHHRA, the subsistence lifestyle receptor should be considered a conservative, theoretical receptor.

6.4.2 Exposure Pathways Evaluated Quantitatively

Figure 3 presents the human health CSM that depicts human health exposure pathways specific to the Resource Area that are considered in the AWHHRA. Only complete exposure pathways (that is, exposure pathways that contain or potentially contain the four primary elements identified by EPA – source or sources, release and transport mechanisms, exposure media, and receptors) were considered in the AWHHRA.

The complete exposure pathways considered in the AWHHRA include:

- Ingestion of wild game (represented by elk) and beef cattle by receptors that include the recreational hunter and fisher, Native American, and subsistence lifestyle
- Ingestion of aquatic life (fish) by receptors that include the recreational hunter and fisher, Native American, and subsistence lifestyle
- Ingestion of teas brewed using aquatic and terrestrial plants by Native American receptors
- Ingestion of aquatic and terrestrial plants by Native American receptors and homegrown produce by subsistence lifestyle receptors. It should be noted that no home gardens associated with subsistence lifestyle receptors have been identified in the Resource Area and no resources have been expended for the purpose of such identification.
- Ingestion of surface soil by subsistence lifestyle receptors
- Ingestion of surface water by receptors that include the recreational hunter and fisher, Native American, and subsistence lifestyle
- Inhalation of fugitive dusts by receptors that include the recreational hunter and fisher, Native American, and subsistence lifestyle receptors while hunting by tracking on foot or using all-terrain vehicles near or on waste rock piles

Other complete (or potentially complete) exposure pathways are considered to be de minimus or contribute only a negligible part of the total dose to the receptor and were considered only qualitatively in the AWHHRA. These exposure pathways include: direct contact with surface water; ingestion and direct contact with sediment; ingestion and medicinal, religious, and other uses (for example, medicinal or ceremonial) of aquatic and terrestrial plants by Native American and subsistence lifestyle receptors; ingestion and direct contact with surface and subsurface soil by Native American and recreational hunter and fisher receptors; direct contact with surface and subsurface soil by subsistence lifestyle receptors; and ingestion and direct contact with groundwater.

An explanation of the basis for concluding these exposure pathways contribute only a negligible part of the total dose to the receptor (qualitative analysis) is provided below.

- 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 chemicals 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 chemicals are not especially well absorbed through direct contact with surface water. 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. Therefore, ingestion of surface water was only evaluated by for the hunter scenario and not for subsistence lifestyle receptors.
- Ingestion and Direct Contact with Sediment: Exposure to chemicals 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 chemicals present in sediment that does manage to adhere to receptor's skin is also expected to be minimal because these chemicals are poorly absorbed through the skin.
- Ingestion and Medicinal, Religious, and Other Uses of Aquatic and Terrestrial Plants by Subsistence Receptors: Subsistence receptors are expected to be exposed to chemicals in the tissues of aquatic and terrestrial plants primarily through ingestion, and potentially through medicinal, religious, and other uses of these plants. The contribution to total exposure for the subsistence receptor associated with exposures to terrestrial and aquatic plants relative to ingestion of homegrown produce was expected to be small. As necessary, however, risks and hazards associated with exposures to terrestrial and aquatic plants as calculated for Native American receptors provide a reasonable surrogate and were used to provide estimates of the contribution to total exposure associated with these exposure routes for the subsistence receptor.
- Ingestion and Direct Contact with Surface and Subsurface Soil by Recreational Hunter/Fisher and Native American Receptor: As noted in MW (1999b), the maximum observed concentrations of inorganic chemicals in soil are one or more orders of magnitude less than chemical-specific EPA Region 9 industrial soil PRGs. Also, the magnitude of exposure to soil by recreational hunter/fisher and Native American receptors in the Resource Area was expected to be less than was assumed in the development of the industrial PRGs. Also, inorganic chemicals are poorly absorbed through the skin. Therefore, exposure through ingestion and direct contact to chemicals present in surface and subsurface soil for recreational hunter/fisher and Native American receptors was expected to be minimal.
- Direct Contact with Surface and Subsurface Soil by Subsistence Receptors: The maximum observed concentrations of inorganic chemicals in soil (as presented in Table 5-1 in MW [1999b]) exceed their respective residential PRGs for cadmium, manganese, nickel, and vanadium (EPA 2001). As defined by EPA Region 9, residential PRGs are based on potential exposure through both ingestion and direct contact. However, inorganic chemicals in soil are poorly absorbed through the skin. Therefore, potential exposure through direct contact with surface and subsurface soil does not contribute significant to total exposure for subsistence receptors and was not quantitatively evaluated.

- Ingestion and Direct Contact with Groundwater: As noted in MW (1999b), groundwater samples were collected from 20 groundwater wells inventoried in the Resource Area. The maximum concentrations of six inorganic chemicals (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 chemicals are almost two orders of magnitude less than their respective PRGs. Therefore, exposure to chemicals present in groundwater was expected to be associated with minimal risks and hazards. However, additional samples were collected by the Idaho Department of Health and were evaluated to ensure that groundwater is not an exposure pathway of concern.
- Inhalation of Fugitive Dust: Inhalation of fugitive dusts is generally expected associated with minimal risks and hazards. However, in Southeastern Idaho, extensive, wide-open spaces are common and create the potential for strong air currents to occur. Therefore, wind erosion may be a significant mechanism of chemical transportation in the Resource Area, particularly at locations potentially frequented by recreational users and no longer actively managed by site operators. Therefore, potential exposure to hunters through inhalation of fugitive dusts at or near waste rock piles was evaluated.
- Ingestion of Surface Water by Recreational Receptors: Hunting, fishing, and camping are popular recreational activities in the Resource Area. Recreational receptors are expected to get some or all of their drinking water while engaged in these activities from Resource Area streams. Therefore, in order to be health protective, potential ingestion of surface water by receptors engaged in recreational activities (including hunting and fishing) were evaluated in the AWHHRA.

6.4.3 Human Receptors Evaluated Qualitatively

The Native American traditional and subsistence lifestyle is a specific and separate receptor group. This receptor group was identified to evaluate Shoshone Bannock Tribal resource usage on aboriginal territory, ceded and federal lands. While quantitative assessment is provided for this group within the scope of standard risk assessment protocols, additional qualitative evaluation is required to outline potential exposure pathways and address particular Tribal concerns that are not conducive to formal risk assessment practices due to the diversity and breadth of traditional uses and cultural confidentialities.

6.4.4 Tribal Exposure Pathways Evaluated Qualitatively

The following exposure pathways, identified by the Shoshone Bannock Tribal technical representatives, can be considered complete pathways that contain or may contain the four elements identified by EPA: (1) source or sources, (2) release and transport mechanisms, (3) exposure media, and (4) receptors. Conservative assumptions were used in the quantitative risk assessment approach to attempt to compensate for uncertainties and counterpoise unspecified exposure paths. However, due to the breadth and diversity of traditional practices and the proprietary nature of Tribal medicines, ceremonies, and materials, etc., the following pathways are evaluated in qualitative and comparative terms. Therefore, the contribution to the total dose of an individual Tribal receptor from these pathways could have the potential for increased risk to this receptor group under varying conditions. Several of these pathways are also discussed in Section 7.3.2.2 of the Work Plan (TtEMI 2002a).

- Ingestion of Plants and Animals in Traditional and Ceremonial Practices: The quantitative risk estimates include calculations for ingestion of selected plants and animals based on common Tribal uses, as designated by Tribal representatives during the scoping process. While these ingestion estimates result in negligible human health risks, the plant and animal surrogate species lists used are not comprehensive enough to represent every potential traditional or ceremonial use or exposure. The existing quantitative risk estimate approach contains a high level of conservatism in the selection of ingestion rates, media concentrations, exposure durations and other parameters, thought to be protective of potential unspecified Tribal uses. However, an increased potential for risks could exist from this pathway under varying conditions.
- Ingestion of Homegrown Produce and Traditional Gardens: The quantitative risk assessment includes a model for ingestion of homegrown produce for subsistence receptors, and a scenario for ingestion of selected traditional plants by Native Americans. Both scenarios result in minimal Tier 1 risks using the highest observed plant concentrations and include conservative assumptions thought to be protective of potential unspecified Tribal uses. However, there could exist a potential for increased risks from plants or locations that were not subject to identification and testing.
- Ingestion of Surface Soil: The quantitative risk assessment includes an ingestion of surface soil pathway for subsistence lifestyle receptors that resulted in minimal Tier 1 risk using the highest observed concentrations. The EPA Region 9 Industrial Soil PRGs also indicate risk thresholds for incidental soil ingestion and contact that are well above those observed in the Resource Area. This pathway is not expected to provide a significant risk to the Native American receptor; however, a potential for increased risk may exist for any unspecified practices that could result in substantially higher soil ingestion rates than those modeled.
- Dermal Absorption from Plants used for Medicinal, Traditional and Ceremonial Purposes: The quantitative risk assessment provides risk estimates based on direct ingestion of impacted media, which is the most direct and complete route for the accumulation of inorganics. While dermal exposure can occur, inorganic chemicals are typically poorly absorbed through the skin and are not expected to present a significant health risk to the Tribal receptor. However, these effects can vary based on solvent carriers and constituents; therefore, a potential for increased risks may exist for unspecified uses.
- Inhalation of Fugitive Dust and Particulates by Native American Range Riders and Herders: The quantitative risk assessment includes inhalation of fugitive dust and particulates pathways for all receptors which resulted in minimal risks. While Native American range riders and herders may have longer exposure periods than those modeled, the Tier 1 risk estimates assumed the highest observed concentrations for particulates and are so low that an increased exposure duration would still result in an estimate below human health hazard thresholds. This pathway is not expected to present a significant risk to Native American receptors.

It should be acknowledged that the Shoshone Bannock Tribes do not endorse current risk assessment standard practices. Tribal representatives have indicated that a more holistic risk approach should be developed that considers spiritual health, cultural losses and other areas of concern for Native American receptors and is not solely based on comparisons with toxicological thresholds. The Tribes have provided IDEQ with a general concurrence on the regional risk assessment effort within the limitations of estimating the likelihood of direct physical human health effects but reserve their right to discuss other Tribal considerations in subsequent decision-making processes.

6.4.5 Equations Used to Quantify Exposures

Exposure is defined as the contact of an organism with a chemical or physical agent. The magnitude of potential chemical exposure, which depends on the amount of a chemical available at human exchange boundaries (skin, lungs, and gut) during a specified period of time, are quantitatively assessed for the human receptors discussed in Section 6.4.

Exposure dose equations that consider contact rate, receptor body weight, and frequency and duration of exposure were used to estimate the intake or dose of each COPC for each receptor. Under Tier 1, exposures were calculated using the maximum detected medium-specific concentration of each COPC under RME exposure parameters. Under Tiers 2 and 3, exposures were calculated under both RME and CTE conditions.

An exposure can occur over a period of time. The total exposure can be divided by time to calculate an average exposure per unit of time. An average exposure can be expressed in terms of body weight. All exposures quantified in the AWHHRA were normalized for time and body weight and presented in units of milligrams of chemical per kilogram of body weight per day (mg/kg/day). These exposures are termed "intakes." Equation 6-1 is a generic equation for calculating chemical intake (EPA 1989).

$$D = \frac{C \times CR \times EF \times ED}{BW \times AT} \tag{6-1}$$

where

D = Dose: the amount of chemical at the exchange boundary (mg/kg/day); to evaluate exposure to noncarcinogenic chemicals, the intake is referred to as the average daily dose (ADD); to evaluate exposure to carcinogenic chemicals, the intake is referred to as the lifetime average daily dose (LADD)

C = Chemical concentration: the average concentration (referred to as the EPC) contacted over the exposure period (for example, milligram per kilogram [mg/kg] fish tissue [fish tissue results are initially reported as dry weight and are converted to wet weight]). All other media, except surface water, chemical wet weight concentrations are provided in dry weight.

CR = Contact rate: the amount of contaminated medium contacted per unit of time or event (for example, g/day for fish ingestion)

EF = Exposure frequency: how often the exposure occurs (days per year)

ED = Exposure duration: how long the exposure occurs (years)

BW = Body weight: the average body weight of the receptor over the exposure period (kilogram [kg])

AT = Averaging time: the period over which exposure is averaged (days); for carcinogens, the averaging time is 25,550 days based on a lifetime exposure of 70 years; for noncarcinogens, the averaging time is calculated as exposure duration (years) times 365 days/year

Variations of Equation 6-1 were used to calculate pathway-specific exposures to COPCs. The equations used for each exposure pathway are presented in Figure 4 of the Work Plan (TtEMI 2002a). The exposure parameter values considered under RME and CTE conditions are presented in Tables 6-1 and 6-2. The EPC calculations, pathway-specific intake equations and parameters, and evaluation of background and supplemental exposures are discussed below.

The equations used to estimate receptor-specific exposures are presented in Figure 4. The exposure parameters used to estimate receptor-specific exposures under RME and CTE exposure conditions are presented in Tables 6-1 and 6-2, respectively. For both RME and CTE evaluations, LADD and ADD are quantified. The LADD defines a dose level that is distributed (averaged) over an entire lifetime rather than a specific incremental exposure period; LADDs are the measure of exposure used to characterize risks associated with exposure to potential carcinogens. Unlike the LADD, the ADD is averaged over specified exposure duration rather than over an entire lifetime; ADDs are the measure of exposure used to characterize hazards associated with exposure to noncarcinogens.

The intake equations and exposure parameter values used in the AWHHRA were taken or adapted from EPA guidance documents, including RAGS (EPA 1989); “Exposure Factors Handbook” (EPA 1997d); and “RAGS, Volumes I: Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors” (EPA 1991). These documents provide guidance for selecting exposure parameter values and were used, along with Resource Area- and state-specific information (such as fish and game regulations), information from peer-reviewed scientific literature, and professional judgment, to identify appropriate parameter values. The basis for the value selected for each exposure parameter under RME and CTE conditions is detailed in the footnotes to Tables 6-1 and 6-2, respectively.

Equations used to calculate the LADD and ADD are presented in Figure 4. Tables 6-9 to 6-14 present the chemical-specific factors used in these equations.

6.4.6 Calculation of Medium-specific Exposure Point Concentrations

The EPC is defined as the concentration of a COPC that a human receptor is exposed to at an exposure point. This section summarizes how medium-specific EPCs were derived for use in the AWHHRA. Summaries of medium-specific EPCs are presented in Table 6-6 for Tier 1 and Tables 6-7 to 6-8 for Tier 2. Refer to Appendix E for tables specific to receptors and exposure pathways.

Duplicate analytical results were averaged and represented by a single value, and each analytical result reported as a nondetect was replaced with a value equal to one-half of the sample quantitation limit (SQL) to calculate background concentrations and EPCs. These procedures are consistent with EPA guidance (EPA 1989, 2000c). As discussed in EPA's "Guidance for Data Quality Assessment, Practical Methods for Data Analysis, EPA QA/G-9, QA00 Version," (EPA 2000c) replacement of a nondetect analytical result with a value equal to one-half the SQL is most appropriate for data sets in which the frequency of censored or nondetect values is less than 15 percent.

Under Tier 1 of the tiered approach (see Section 6.1.1), the maximum detected medium-specific concentration of each COPC, applicable to the specific scenario based on area-specific knowledge, was used as the EPC. Tier 1 EPCs are summarized in Table 6-6. Under Tiers 2 and 3, and in accordance with EPA's "Supplemental Guidance to RAGS: Calculating the Concentration Term" guidance, the UCL_{95} of the mean or the maximum medium-specific concentration (whichever is lower) was used as the EPC under RME conditions and the mean concentration was used as the EPC under CTE conditions (EPA 1992).

As discussed in Section 6.1.2 and summarized in Figure 4, EPCs were calculated under Tiers 2 and 3 on (1) a watershed-specific basis for Category 2a exposure pathways retained from Tier 1 (ingestion of fish and surface water), (2) a Resource Area-wide basis for ingestion of beef cattle and elk tissue, and (3) a riparian area-specific basis for ingestion of surface soil. As will be discussed in Section 6.6, risks and hazards associated with inhalation of particulates, ingestion of terrestrial and aquatic plants, ingestion of tea brewed from terrestrial and aquatic plants, and ingestion of homegrown produce were determined to be insignificant under Tier 1; therefore, these exposure pathways were not retained for assessment under Tier 2.

Appendix C presents the equations, procedures, and assumptions used to calculate EPCs under Tiers 2 and 3. With the exception of EPCs for beef cattle and elk tissue (which were calculated based on data generated in 1999 [MW 2000]), Tier 2 EPCs were based entirely on medium-specific analytical data for samples collected in 2001. Under Tier 3, EPCs were calculated for surface water and fish tissue based on analytical data for samples collected in 1998 (MW 1999b). Medium-specific Tier 2 EPCs are presented in Tables 6-9 through 6-16 and are summarized in Tables 6-7 and 6-8. Medium-specific Tier 3 EPCs are presented in Tables 6-17 through 6-20.

6.4.7 Evaluation of Background and Supplemental Exposure

In addition to the intakes specific to exposure pathways associated with complete (or potentially complete) exposure pathways, receptors may also receive additional exposure to COPCs through background exposures and through ingestion of dietary supplements. As described in the "National Oil and Hazardous Substances Pollution Contingency Plan" (NCP) (EPA 1990) and in EPA RAGS (EPA 1989), potential exposure to carcinogenic COPCs is evaluated in terms of incremental exposure. As interpreted by IDEQ, incremental exposure refers to exposures through complete (or potentially complete) exposure pathways, but does not include exposure through background exposures and ingestion of dietary supplements. However, characterization of hazards associated with exposures to noncarcinogenic COPCs is based on an assessment of whether the dose to a receptor has exceeded an exposure threshold (see Section 6.5.1). Background exposures and exposures through ingestion of dietary supplements must be considered in addition to exposures through complete exposure pathways to evaluate whether an exposure threshold has been exceeded.

As discussed in Section 6.4.5, for the purpose of assessing potential exposures to carcinogenic COPCs, the AWHHRA considered only exposures related to complete (or potentially complete) exposure pathways. However, for the purpose of characterizing hazards associated with exposure to COPCs, receptor-specific total exposures were estimated as the sum of (1) exposure related to complete (or potentially complete) exposure pathways, (2) background exposures, and (3) supplemental exposures.

As described in Section 6.1.1, the purpose of Tier 1 of the AWHHRA is to identify those exposure pathways and COPCs associated with potentially significant risks and hazards and to eliminate from further consideration, those exposure pathways and COPCs associated with insignificant risks and hazards. Therefore, Tier 1 addresses exposures related only to complete (or potentially complete) exposure pathways and does not consider total exposures (e.g. factoring in background and supplemental exposure). Under Tier 2, receptor-specific total exposures, risks, and hazards including exposures, risks, and hazards associated with background and supplemental exposure to arsenic, cadmium, chromium, and selenium are considered (see Section 6.8.3.7). Similarly, as described in Section 6.1.3, the purpose of Tier 3 of the AWHHRA is to compare the impact of temporal variations in COPC concentrations on the calculated exposures associated with ingestion of fish tissue and surface water. Therefore, background and supplemental exposures are addressed indirectly as part of revised receptor-specific total exposures, risks, and hazards.

6.4.7.1 Background Exposure

The primary source of information on background exposure to COPCs was chemical-specific toxicity profiles prepared by the Agency for Toxic Substances and Disease Registry (ATSDR). However, the information provided in these profiles is insufficient to develop a precise estimate of background exposure (in addition to exposure through potentially complete exposure pathways – which in turn includes exposure to naturally occurring chemical concentrations). For example, information is available on estimates of average daily intake (ADI) and intake through ingestion of food in general. Information is also available on the concentration of specific COPCs in various foodstuffs (such as fish, beef, and dairy products). However, information is not available for all potential background exposures or for all potential foodstuffs.

The greatest receptor-specific exposures (and, therefore, risks and hazards) are associated with ingestion of fish and surface soil (see Section 6.6 and 6.7). For both of these exposure pathways, an FI value of 1 was used for all receptors under both RME and CTE conditions. Receptor-specific exposure through ingestion of fish was evaluated on a watershed-specific basis. Therefore, the use of a FI value of 1 assumes that receptors ingest fish only from watersheds within the Resource Area and that enough fish are present in each of the watersheds to meet the receptor-specific intake assumptions. Exposure through ingestion of soil was evaluated for subsistence lifestyle receptors on a residential area- (RA) specific basis. Therefore, the use of a FI value of 1 assumes that receptors (young children and the elderly) remain on residential property throughout the assumed period of exposure (exposure duration). The use of a FI value of 1 also assumes that these receptors do not receive any background exposure through these two pathways.

Therefore, in an effort to estimate the impact of background exposure, the ADI for each COPC was identified and summed with the ADD based on complete exposure pathways for each receptor. It is acknowledged that there is some degree of overlap (in some cases, significant overlap) in this approach because some portion of the ADI for a receptor is related to exposures associated with complete exposure pathways (such as ingestion of fish, elk, beef cattle, terrestrial and aquatic plants, homegrown produce, and surface water, and inhalation of particulates).

6.4.7.2 Supplement Exposure

Chromium and selenium are typically present in dietary supplements; however, arsenic and cadmium are not. Therefore, potential exposure to chromium and selenium through ingestion of dietary supplements was estimated and summed with the ADD and background exposure. Supplement exposure (such as exposure through dietary supplements) to selenium used was compared with the supplement exposure for selenium obtained from MW (1999b) and in IMA (2002). Supplement exposure to chromium was estimated by comparison to the selenium results.

Information on ADIs (obtained primarily from ATSDR toxicity profiles) and supplement exposure (obtained [or extrapolated] from MW [1999b]) is summarized below for each of the four core COPCs: arsenic, cadmium, chromium, and selenium.

Arsenic

As stated above, arsenic is not typically present in dietary supplements. The total mean daily intake of inorganic arsenic ranges from 0.3 to 2.4 micrograms per kilogram body weight per day (µg/kg/day) for children 0.5 to 4 years old (ATSDR 2000a; see Table 5-4). These children are assumed to weight about 13 kg, which is similar to the 15-kg body weight assumed in the AWHHRA. The midpoint of this range, 13.5 µg/kg/day (1.35E-02 mg/kg/day) was used as an estimate of the ADI for children. The total mean daily intake of inorganic arsenic ranges from 0.1 to 0.7 µg/kg/day for adults (ATSDR 2000a, see Table 5-4). The midpoint of this range, 0.4 µg/kg/day (4.0E-04 mg/kg/day) was used as an estimate of the ADI for adults.

Cadmium

As stated above, cadmium is not typically present in dietary supplements. Estimates of the total mean daily intake of cadmium were not identified. However, ATSDR notes that the adult intake of cadmium from food in the U.S. was estimated to be about 30 µg/day based on the Total Diet Study (ATSDR 1999). The largest contribution to this intake was from grain, cereal products, potatoes, and other vegetables (Gartrell and others 1986, as cited in ATSDR 1999). Based on an assumed adult body weight of 70 kg, this daily intake from food can be converted to an intake of 4.3E-04 mg/kg/day. This value was used as a measure of the ADI for cadmium for both adult and child receptors.

Chromium

Estimates of the total mean daily intake of chromium were not identified. However, ATSDR notes that the adult intake of chromium from consumption of selected diets (diets with 25 and 43 percent fat) in the U.S. was estimated to be about 76 µg/day (with a range of 25 to 224 µg/day) (Kumpulainen and others 1979, as cited in ATSDR 2000b). Based on an assumed adult body weight of 70 kg, this daily intake from food can be converted to an intake of 1.1E-03 mg/kg/day. This value was used as a measure of the ADI for chromium for both adult and child receptors.

As discussed below, the ADI of selenium through ingestion of supplements is 1.4E-03 mg/kg/day. Based on a review at a typical pharmacy (Walgreens – 5002 Bellaire Boulevard in Bellaire, Texas), the concentration of chromium and selenium is similar in supplements and multivitamins. In addition, as with selenium, chromium is not present in all supplements and multivitamins. Therefore, based on these two observations, it was assumed that the ADI of selenium through ingestion of supplements could also be used as an estimate of the ADI of chromium through ingestion of supplements. Therefore, an ADI of selenium through ingestion of supplements of 1.4E-03 mg/kg/day was used for both adult and child receptors.

Selenium

As discussed in ATSDR's toxicity profile, estimates of selenium intake for Americans ranges from about 0.071 to 0.152 mg/day (ATSDR 1996). This range is based on a variety of studies that estimated intake from a review of concentrations of selenium in various foodstuffs (U.S. Food and Drug Administration [FDA] 1982; Levander 1987; Pennington and others 1989; Schrauzer and White 1978; Schubert and others 1987; and Welsh and others 1981, all as cited in ATSDR 1996). The midpoint of this range, 0.111 mg/day, compares favorably with the mean dietary intake of selenium (0.108 mg/day) presented in MW (1999b). For the AWHHRA, therefore, the daily intake of 0.111 mg/day for selenium was converted to a body-weight basis using the assumed adult body weight of 70 kg; this conversion resulted in an ADI of

1.6E-03 mg/kg/day. This value was used as a measure of the ADI for selenium for both adult and child receptors.

MW (1999b) presents a modeled lower exposure for a receptor taking a “low-dose, inorganic Se [selenium] multi-vitamin,” of 0.0006 mg/day and an upper bound of 0.04 mg/day for an individual taking “two high-dose supplement tablets (200 µg) per day.” MW also notes that, on average, only about 40 percent of adults “routinely take vitamins or mineral supplements and not all vitamins contain Se [selenium]” (MW 1999b). Based on probabilistic techniques, the mean ADI of selenium in supplements was calculated as 1.00E-01 mg/day (MW 1999b; see Attachment H-2). MW subsequently refined its analysis of selenium intake through ingestion of supplements and multivitamins (IMA 2002). The refined analyses considered additional information gathered regarding usage of mineral supplements containing selenium. When the two forms of supplementation (mineral supplements and multivitamins) were added together, and considering the likelihood of individuals taking these supplements, the total selenium intake has a distribution with a mean of 0.0188 mg/day. For the AWHHRA, therefore, this intake value was converted to a body-weight basis using the assumed adult body weight of 70 kg. The resulting intake value of 2.7E-04 mg/kg/day was used as a measure of the intake of selenium through ingestion of supplements for both adult and child receptors.

6.5 TOXICITY ASSESSMENT

This section identifies toxicity values used to quantify potential adverse effects on human health that are associated with potential exposure to COPCs. Toxicity profiles are prepared for each of the COPCs (see Appendix D). The toxicity profiles discuss the pathway-specific dose responses for each COPC focusing on the identification of no observed adverse effect levels (NOAEL) and lowest observed adverse health effect level (LOAEL) that were used to establish the pathway-specific toxicity values. Toxicity values include reference doses (RfD) for noncarcinogenic COPCs and slope factors (SF) for carcinogenic COPCs. Toxicity values used to assess the effects for noncarcinogenic and carcinogenic COPCs are discussed in Sections 6.5.1 and 6.5.2. Section 6.5.3 briefly discusses the toxicological profiles prepared for the COPCs.

6.5.1 Toxicity Values for Noncarcinogenic Chemicals of Potential Concern

Standard risk assessment models assume that noncarcinogenic effects, unlike carcinogenic effects, exhibit a threshold; that is, a level of exposure exists below which no adverse effects are observed. The potential for noncarcinogenic health effects to result from exposure to a COPC was assessed by comparing an exposure estimate for intake with an RfD. The RfD represents an estimated daily intake rate for a noncarcinogenic COPC that is believed to pose no appreciable risk of adverse effects on human health, including sensitive populations, during a lifetime. RfDs also apply to the noncarcinogenic effects of potential carcinogens. An RfD is specific to a chemical and a route of exposure, such as ingestion or inhalation. The AWHHRA considered only exposure through ingestion and inhalation.

EPA workgroups review all human and animal studies relevant to a chemical and select the study or studies pertinent to derive the RfD. RfDs are often derived from a measured NOAEL. The NOAEL corresponds to the dose (in mg/kg/day) that was administered during the toxicity study without inducing observable adverse effects. If a NOAEL cannot be established, the LOAEL is used. The LOAEL corresponds to the lowest daily dose administered in the toxicity study that induces an observable adverse effect. The toxic effect characterized by the LOAEL is referred to as the "critical effect."

The NOAEL or LOAEL is divided by uncertainty factors to ensure that the RfD derived will be protective of human health. Uncertainty factors usually occur in multiples of 10, and each factor represents a specific area of uncertainty inherent in the extrapolation from available data. Uncertainty factors account for (1) variations in the general population to protect sensitive subgroups such as child and the elderly, (2) extrapolation of data from animals to humans (interspecies extrapolation), (3) derivation of a chronic RfD based on a subchronic rather than a chronic study, and (4) derivation of an RfD based on a LOAEL instead of a NOAEL. Modifying factors may be applied to reflect additional uncertainties associated with the data. Modifying factors range from 0 to 10.

Additionally, chronic and subchronic RfDs are developed for different periods of exposure. Chronic RfDs are generally used to evaluate exposures that occur over periods of more than 7 years, and subchronic RfDs are used to evaluate exposures that occur over periods of 2 weeks to 7 years. Based on the exposure durations assumed, chronic RfDs were used to characterize the hazards associated with all receptor-specific exposures. COPC-specific chronic RfDs were identified from the following hierarchical list of sources:

- EPA's Integrated Risk Information System (IRIS) (EPA 2002)
- EPA's Health Effects Assessment Summary Tables (HEAST) (EPA 1997c)
- EPA's National Center for Environmental Assessment

Table 6-22 summarizes the RfDs used in the AWHHRA, along with the confidence level, critical effect, and source.

6.5.2 Toxicity Values for Carcinogenic Chemicals of Potential Concern

The potential for exposure to a specific chemical to result in carcinogenic effects is evaluated differently than for noncarcinogenic effects. The upper-bound excess lifetime cancer risk (ELCR) is calculated by multiplying the dose from a specific route of exposure by an SF. An SF is an upper-bound estimate of the probability of a carcinogenic response per unit dose of a chemical over a lifetime. SFs are derived through mathematical models based on a high-to-low dose extrapolation and assume that no threshold exists for initiation of cancer. Because of the use of the nonthreshold assumption and the UCL_{95} of the slope of the dose-response curve, SFs provide a conservative, upper-bound estimate of potential cancer risks. The actual response to a dose of a chemical is therefore probably less than the predicted response (EPA 1989).

EPA assigns weight-of-evidence designations to indicate the likelihood that a chemical agent is a carcinogen in humans. These designations are defined as (EPA 1989):

- "A" indicates that a chemical is considered a proven carcinogen in humans.
- "B" indicates that a chemical is considered a probable human carcinogen. "B1" indicates that suggestive but inconclusive evidence of carcinogenicity in humans is associated with the chemical, and "B2" indicates that conclusive evidence of a chemical's carcinogenicity is documented in repeated animal studies but that evidence of carcinogenicity in humans is inconclusive.
- "C" indicates that a chemical is a possible human carcinogen, either because a single high-quality animal study demonstrates carcinogenicity or because several low-quality animal studies indicate carcinogenicity.
- "D" indicates that evidence of a chemical's carcinogenicity in animals or humans is inconclusive.
- "E" indicates that no evidence of a chemical's carcinogenicity is available from adequate human or animal studies.

SFs are specific to a chemical and a route of exposure and are generally available for both the oral (ingestion or gavage) and inhalation routes. The potentially complete exposure pathways evaluated in the AWHHRA involve ingestion and inhalation exposures. In accordance with EPA guidance, SFs were identified using the same hierarchical list of sources presented in Section 6.5.1. Table 6-23 identifies the oral and inhalation SFs used in the AWHHRA.

6.5.3 Toxicity Profiles

A brief description of the toxic effects of each COPC is presented in the toxicological profiles in Appendix D of this report. The toxicological profiles focus on the effects most likely to be observed at environmental exposure levels that form the basis for the toxicity values. Toxic effects other than the carcinogenic and noncarcinogenic effects quantitatively assessed include reproductive, teratogenic, and mutagenic effects. The toxicity values, critical effects, and any uncertainty factors used in calculating the toxicity values are also summarized in the toxicological profiles.

6.6 CHARACTERIZATION OF RISK AND HAZARD

This section characterizes the carcinogenic risks and noncarcinogenic hazards associated with the exposure pathways identified in Section 6.4.2. Risks and hazards are characterized for individual COPCs, multiple COPCs within each exposure pathway, and exposures attributable to multiple exposure pathways, as appropriate. Sections 6.6.1 and 6.6.2 discuss the methodologies used to characterize noncarcinogenic hazards and carcinogenic risks.

6.6.1 Methodology for Hazard Characterization

The potential for receptors to develop noncancerous health effects is characterized by comparing an intake for a specific exposure period (the ADD) with an RfD developed for a similar exposure period. When performed for a single chemical, this comparison yields a ratio known as the hazard quotient (HQ), which is calculated as shown in Equation 6-2.

$$HQ = ADD/RfD \tag{6-2}$$

where

HQ	=	Hazard quotient
ADD	=	Average daily dose (mg/kg/day)
RfD	=	Reference dose (mg/kg/day)

Adverse health effects are not expected at an HQ of 1 or lower. An HQ greater than 1 indicates a potential for adverse noncarcinogenic health effects (EPA 1989). RfDs for chronic exposure were used in the AWHHRA to characterize noncarcinogenic hazards for all receptor-exposure pathway combinations.

Within a given exposure pathway, a receptor may be exposed to multiple chemicals associated with noncarcinogenic health effects. The procedures outlined in "Guidelines for the Health Risk Assessment of Chemical Mixtures" and RAGS (EPA 1986, 1989) were used in the AWHHRA to estimate the total noncarcinogenic hazards for each exposure pathway. The total noncarcinogenic hazard that can be attributed to exposure to multiple COPCs through a single pathway is calculated as shown in Equation 6-3.

$$HI_{EP} = HQ_1 + HQ_2 + \ldots + HQ_i \qquad (6\text{-}3)$$

where

HI_{EP} = Total hazard index for a given exposure pathway

HQ_i = Hazard quotient for the i^{th} COPC

This methodology assumes that the effects of the various COPCs to which a receptor is exposed are additive.

Receptors may be exposed through a number of exposure pathways at specific exposure points (see the human health CSM, Figure 3). At each exposure point, the total exposure for a receptor equals the sum of the exposures through the various exposure pathways to which the receptor is exposed. Exposure pathway combinations were developed for each receptor under each exposure scenario. Initially, the combinations were based on the highest receptor-specific total HI for each exposure pathway regardless of their relative location. The total noncarcinogenic hazard posed to a receptor through a combination of exposure pathways is calculated as shown in Equation 6-4.

$$\text{Total HI} = HI\,(EP_1) + HI\,(EP_2) + \ldots + HI\,(EPj) \qquad (6\text{-}4)$$

where

$HI\,(EP_j)$ = Hazard index that results from the j^{th} exposure pathway

As part of Tier 2, care was taken to ensure that the same receptor would consistently face multiple exposure pathways before summing the HIs associated with these different exposure pathways. Clearly, it is inappropriate to combine HIs that are associated with location-specific maxima calculated assuming that the entire exposure to a receptor takes place at each location. Summing location-specific maxima under Tier 1 is consistent with a screening-level approach.

In accordance with EPA guidance, all total HIs that exceed 1 were evaluated further (EPA 1989). In some cases, a refined assessment can include development of separate total HIs based on specific target organs and systems. Typically, target organs and systems affected by each COPC are identified based on (1) effects (termed "critical effects" by EPA) that occur at levels of exposure that correspond to LOAELs, or (2) effects at exposure levels that slightly exceed LOAELs, as appropriate. However, as discussed in Sections 6.6 through 6.8, receptor-specific total HIs greater than 1 are associated with at least 1 COPC-specific HI greater than 1; total HIs are driven by exposure to one or two COPCs. Therefore, segregated (or target organ-specific) HIs were not calculated as part of the AWHHRA. The uncertainty associated with this approach is discussed in Section 6.10.

The hazard characterization was completed following the tiered approach described in Section 6.1. Total hazards were estimated as described above for the exposure pathways that have been retained to that point under each step of this tiered approach. The Tier 1 assessment resulted in elimination of specific exposure scenarios and COPCs from further consideration because they were associated with hazards less than 1 (and risks less than 1E-06). In addition, specific COPCs were eliminated from further consideration because they were associated with HIs less than 0.1 (and risks less than 1E-07). Tiers 2 and 3 (as described in Sections 6.1.2 and 6.1.3) provide for more detailed assessment of exposure scenarios that are associated with hazards greater than or equal to 1 as calculated in Tier 1.

6.6.2 Methodology for Risk Characterization

For carcinogenic COPCs, risk estimates represent the incremental probability that an individual will develop cancer over a lifetime as a result of exposure to the COPC (EPA 1989). The ELCR is calculated as shown in Equation 6-5.

$$\text{ELCR (Risk)} = \text{LADD} \times \text{SF} \qquad (6\text{-}5)$$

where

LADD = Lifetime average daily dose (mg/kg/day)

SF = Slope factor $(\text{mg/kg/day})^{-1}$

Risk is expressed as a probability. For example, a risk of 1E-06 indicates one additional case of cancer in an exposed population of 1 million. The SF in almost all cases represents a UCL_{95} of the probability of a carcinogenic response based on experimental data used in a linear zed multistage model. The resulting estimate therefore represents an upper-bound estimate of the carcinogenic risk. The actual risk probably does not exceed the estimate and is likely to be less (EPA 1989).

In the revised NCP (EPA 1990), EPA has established an "acceptable" range for carcinogenic risk associated with exposure at Superfund sites of 1E-06 to 1E-04 (one case of cancer in an exposed population of 10,000). In general, EPA uses a potential upper-bound risk of 1E-06 as a point of departure for setting remediation goals. Though the Resource Area is not a Superfund site, EPA's range is relevant and appropriate for use in evaluating risk levels.

Within a given exposure pathway, receptors may be exposed to more than one chemical. The total upper-bound risk associated with exposure to multiple chemicals through a single pathway is estimated as shown in Equation 6-6.

$$Risk_{EP} = Risk_1 + Risk_2 + \ldots + Risk_i \qquad (6\text{-}6)$$

where

$Risk_{EP}$ = Total risk for a given exposure pathway

$Risk_i$ = Risk estimate for the i^{th} COPC

As discussed in Section 6.5.1 for noncarcinogenic COPCs, combinations of exposure pathways were initially developed for receptors by summing the maximum risks associated with each exposure pathway, regardless of the locations of these maximums. The total risk posed to a receptor through a combination of pathways is calculated as shown in Equation 6-7.

$$\text{Total Risk} = \text{Risk}(EP_1) + \text{Risk}(EP_2) + \ldots + \text{Risk}(EP_i) \qquad (6\text{-}7)$$

where

Total Risk = Risk resulting from multiple exposure pathways

Risk (EPj) = Risk resulting from the j^{th} exposure pathway

The approach described above is consistent with the widely held belief that the total carcinogenic risk associated with exposure to multiple carcinogenic COPCs can be estimated as the sum of the carcinogenic risks posed by individual COPCs (EPA 1986). The risk characterization was completed following the tiered approach described in Section 6.1. Total risks were estimated as described above for the exposure scenarios retained to that point under each step of this tiered approach. The Tier 1 assessment resulted in elimination of specific exposure scenarios from further consideration because they were associated with risks less than 1E-06. In addition, specific COPCs were eliminated from further consideration because they were associated with risks less than 1E-07 (and HIs less than 0.1). Tiers 2 and 3 (as described in Sections 6.1.2 and 6.1.3) provide more detailed analyses of exposure scenarios that were associated with risks greater than or equal to 1E-06 as calculated in Tier 1.

6.7 TIER 1 SCREENING ASSESSMENT

The Tier 1 methodology is presented in Section 6.1.1. This section presents cancer risks and noncancer hazards for all receptors. Tables 6-24 and 6-25 present summaries of noncancer hazards and cancer risks, respectively.

Section 6.7.1 presents the Tier 1 cancer risk and noncancer hazard results for all receptors. Section 6.7.2 presents an evaluation of the results.

6.7.1 Tier 1 Cancer Risk and Noncancer Hazard Results

This section presents the results of the Tier 1 calculations. RME exposure parameters (along with the maximum detected medium-specific concentrations) were used to calculate risks and hazards for each receptor including all COPCs at the entire site. These site-wide receptors include the recreational hunters and fishers (see Section 6.7.1.1), Native Americans (see Section 6.7.1.2), and the subsistence lifestyle receptors (see Section 6.7.1.3). Tier 1 hazard and risk summaries are listed in Tables 6-24 and 6-25.

6.7.1.1 Recreational Hunter and Fisher Receptors

Adult and child recreationalists hunting or fishing on or near the site are expected to be potential receptors. Tables E-16 to E-25 in Appendix E present Tier 1 results for exposure, hazard and risk for the adult and child recreationalist receptors.

Adult Recreationalist

The total HI of 1.0 for adult recreationalists equals an HI of 1.0. The total HI is driven by potential ingestion of aquatic life (0.81). All of the individual exposure pathways resulted in an HI less than 1.0 and generally do not warrant any further consideration in terms of the adult recreationalist:

- Ingestion of aquatic life (0.81)
- Ingestion of surface water (1.3E-01)
- Ingestion of beef cattle – skeletal (8.2E-02)
- Ingestion of beef cattle – offal (1.8E-02)
- Ingestion of elk and wild game – skeletal (5.6E-03)
- Ingestion of elk and wild game – offal (1.7E-03)
- Inhalation of particulates (1.2E-04)

The total risk of 4.3E-07, including all pathways for adult recreationalists, was less than 1E-06.

Child Recreationalist

The total HI of 2.0 for child recreationalists exceeds an HI of 1.0. The total HI is driven by potential ingestion of aquatic life (1.4) associated with selenium (0.93) and cadmium (0.42). This hazard resulted from data for fish samples collected from East Mill Creek. The following exposure pathways resulted in an HI less than 1.0 and, generally, do not warrant any further consideration:

- Ingestion of surface water (3.8E-01)
- Ingestion of beef cattle – skeletal (1.5E-01)
- Ingestion of beef cattle – offal (8.6E-02)
- Ingestion of elk and wild game – skeletal (8.1E-03)
- Ingestion of elk and wild game – offal (7.0E-03)
- Inhalation of particulates (4.2E-04)

The total risk of 3.0E-07, including all pathways for child recreationalists, was less than 1E-06. The grand total risk of 7.3E-07 (the sum of adult and child risks) is less than 1E-06.

6.7.1.2 Native American Receptors

Adult and child Native Americans who hunt, fish, and gather on or near the site are expected to be potential receptors. Tables E-1 to E-15 in Appendix E present Tier 1 results for exposure, hazard, and risk for adult and child Native American receptors.

Adult Native American

The total HI of 2.4 for adult Native Americans exceeds an HI of 1.0. The total HI is driven by potential ingestion of aquatic life (1.2) associated with selenium (0.83) and cadmium (0.38). This hazard resulted from data for fish samples collected from East Mill Creek.

The following exposure pathways resulted in an HI less than 1.0 and, generally, do not warrant any further consideration:

- Ingestion of tea (8.7E-01)
- Ingestion of surface water (1.3E-01)
- Ingestion of beef cattle – skeletal (1.0E-01)
- Ingestion of beef cattle – offal (5.1E-02)
- Ingestion of aquatic and terrestrial plants (2.0E-02)
- Ingestion of elk and wild game – skeletal (5.2E-04)
- Ingestion of elk and wild game – offal (4.2E-04)
- Inhalation of particulates (1.2E-04)

The total risk of 1.1E-06, including all pathways for adult Native Americans slightly exceeds 1E-06.

Child Native American

The total HI of 3.2 for child Native Americans exceeds an HI of 1.0. The total HI is driven by potential ingestion of aquatic life (2.0) associated with selenium (1.4) and cadmium (0.64). This hazard resulted from data for fish samples from East Mill Creek. The following exposure pathways resulted in HIs less than 1.0 and, generally, do not warrant any further consideration:

- Ingestion of surface water (3.8E-01)
- Ingestion of beef cattle – skeletal (1.9E-01)

- Ingestion of tea (4.8E-01)
- Ingestion of beef cattle – offal (9.2E-02)
- Ingestion of aquatic and terrestrial plants (2.0E-02)
- Ingestion of elk and wild game – skeletal (7.5E-04)
- Ingestion of elk and wild game – offal (6.1E-04)
- Inhalation of particulates (4.2E-04)

The total risk of 4.1E-07, including all pathways for child Native Americans, was less than 1E-06. The grand total risk of 1.5E-06 (the sum of adult and child risks) slightly exceeds 1E-06.

6.7.1.3 Subsistence Lifestyle Receptors

The adult and child subsistence lifestyle receptors include individuals who live near the site and maintain gardens and fish and hunt near the site for subsistence. Table E-26 to E-39 in Appendix E present Tier 1 results for exposure, hazard, and risk for adult and child subsistence lifestyle receptors.

Adult Subsistence Lifestyle Receptor

The total HI of 6.4 for adult subsistence lifestyle receptors exceeds an HI of 1.0. The total HI is driven by potential ingestion of aquatic life (5.5) associated with selenium (3.8) and cadmium (1.7). This hazard resulted from data for fish samples collected from East Mill Creek. All other pathways resulted in HIs less than 1.0, which are considered insignificant. They are listed below.

- Ingestion of surface water (3.6E-01)
- Ingestion of surface soil (3.5E-01)
- Ingestion of beef cattle – skeletal (8.2E-02)
- Ingestion of beef cattle – offal (1.8E-02)
- Ingestion of elk and wild game – skeletal (6.9E-02)
- Ingestion of aboveground produce (1.0E-02)
- Ingestion of elk and wild game – offal (1.7E-03)
- Ingestion of homegrown produce (1.1E-02)
- Inhalation of particulates (3.4E-04)

The total risk of 2.7E-05 for adult subsistence lifestyle receptors exceeds a risk of 1E-06. The risk is driven by potential exposure to arsenic through ingestion of surface soil. The following exposure pathways resulted in risks that slightly exceed or are less than 1.0E-06 and do not warrant any further consideration:

- Inhalation of particulates (1.2E-06) – based on the conservative assumption that all chromium in waste piles is in the hexavalent form
- Ingestion of homegrown produce (2.0E-09)

Child Subsistence Lifestyle Receptor

The total HI of 14 for child subsistence lifestyle receptors is driven by several exposure pathways. The HI of 9.2 for child subsistence lifestyle receptors who ingest aquatic life is driven by selenium (6.3) and cadmium (2.9). This hazard resulted from data for fish samples collected from East Mill Creek. The HI of 3.2 for child subsistence lifestyle receptors who ingest surface soil is driven by cadmium (1.6) and arsenic (1.2). This hazard resulted from data for a single surface soil sample collected along Rasmussen Creek in the Blackfoot River/Little Blackfoot watershed. The total HI of 1.1 for child subsistence lifestyle receptors who ingest surface water is driven by selenium. This hazard resulted from data for surface water samples collected from East Mill Creek. The following exposure pathways resulted in HIs less than 1.0 and, generally, do not warrant any further consideration:

- Ingestion of beef cattle – skeletal (1.5E-01)
- Ingestion of beef cattle – offal (8.6E-02)
- Ingestion of elk and wild game – skeletal (1.8E-02)
- Ingestion of elk and wild game – offal (7.0E-03)
- Ingestion of homegrown produce (1.4E-02)
- Inhalation of particulates (1.2E-03)

The risk of 4.8E-05 for child subsistence lifestyle receptors that ingest surface soil exceeds a risk of 1.0E-06. The risk is driven by arsenic. All other pathways resulted in risks that slightly exceed or are less than 1E-06, which are considered insignificant. They are listed below.

- Inhalation of particulates (1.2E-06)
- Ingestion of homegrown produce (5.3E-10)

The grand total risk (the sum of adult and child risks) for subsistence lifestyle receptors is 7.6E-05.

6.7.2 Results of Tier 1 Assessment

This section lists the COPCs and exposure pathways that were eliminated from further assessment and that were retained for Tier 2 assessment. Only exposure pathways that result in an HI greater than 1.0 and a risk greater than 1E-06 and only the COPCs that drive these exposure pathways (associated with total HIs greater than or equal to 0.1 and risks greater than or equal to 1E-07) were retained. The COPCs and exposure pathways remain receptor-specific, whether they are eliminated or retained for further analysis.

6.7.2.1 Chemicals of Potential Concern and Exposure Pathways Eliminated from Further Consideration

As discussed in Section 6.1.1, all exposure pathways that result in an HI less than 1.0 and a risk less than 1E-06 were eliminated from further analysis. The exposure pathways that were eliminated from further consideration include:

- Inhalation of particulates
- Ingestion of aquatic and terrestrial plants
- Ingestion of tea
- Ingestion of homegrown produce

Ingestion of elk and beef cattle tissues (skeletal muscle and offal [represented by liver]) were found to be associated with risks less than 1E-06 and HIs less than 1. Nonetheless, these exposure pathways were retained for assessment under Tier 2 because hunting and ranching are common to the Resource Area. Therefore, it was assumed that these exposure pathways might be of particular concern to the public.

In addition, the COPCs that do not drive the exposure pathways retained were eliminated. COPCs that drive the exposure pathway pose a hazard or risk of greater than 0.1 or 1E-07. For the exposure pathways retained, the COPCs that were eliminated from further consideration include:

- Aluminum
- Antimony
- Barium
- Beryllium
- Boron
- Cobalt
- Copper
- Cyanide
- Iron
- Lead
- Magnesium
- Manganese

- Mercury
- Molybdenum
- Nickel
- Silver
- Thallium
- Uranium
- Vanadium
- Zinc

For all receptors, chromium resulted in an HI less than 1.0 and risks slightly greater than 1E-06 (associated with inhalation of particulates). The risks obtained were based on a worst-case scenario. Although no data on speciation are available, it was conservatively assumed that the concentrations consisted only of hexavalent chromium. EPA Region 9 assumes a ratio of 1 (hexavalent chromium) to 6 (trivalent chromium) when no speciation data are available. This assumption would further reduce the risk to all receptors.

6.7.2.2 Chemicals of Potential Concern and Exposure Pathways Retained for Tier 2 Assessment

As stated in Section 6.6.1, only exposure pathways associated with total risks and HIs equal to or greater than 1E-06 and 1 under Tier 1 were retained for consideration. This requirement was conservatively applied in that exposure pathways retained were considered for all three receptor groups even if receptor-specific risks and hazards were found to be insignificant for one or more of the receptor groups. It should be noted that risks associated with inhalation of particulates slightly exceeded 1E-06 for adult and child subsistence lifestyle receptors. These risks were calculated based on the conservative assumption that all chromium present in waste piles is in the hexavalent form. Because chromium is expected to be present almost entirely in the trivalent form, the actual risks associated with the inhalation of particulates is expected to be less than 1E-06. Therefore, inhalation of particulates was not retained for Tier 2 assessment. In addition, as discussed elsewhere, ingestion of elk and beef cattle were retained for Tier 2 because these exposure pathways may be of particular concern to the public.

Similarly, only COPCs associated with total risks greater than 1E-07 and HIs greater than or equal to 0.1 under Tier 1 were retained for consideration under Tier 2. Once again, this requirement was conservatively applied. That is, COPCs must be associated only with total risks and HIs greater than 1E-07 and 0.1 for a single receptor to be retained and considered under Tier 2 for all three receptor groups. The following exposure pathways and COPCs were retained for consideration under Tier 2:

Exposure Pathways

- Ingestion of aquatic life
- Ingestion of surface water
- Ingestion of surface soil
- Ingestion of elk tissue (skeletal muscle and offal [represented by liver])
- Ingestion of beef cattle tissue (skeletal muscle and offal [represented by liver])

COPCs

- Arsenic
- Cadmium
- Chromium
- Selenium

6.8 TIER 2 AREA WIDE HUMAN HEALTH RISK ASSESSMENT

The Tier 2 methodology is presented in Section 6.1.2. This section presents cancer risks and noncancer hazards for all receptors. Sections 6.8.1 and 6.8.2 present exposure pathways evaluated in Tiers 2a and 2b. Section 6.8.3 presents Tier 2 risk and hazard results. Section 6.8.4 presents an evaluation of Tier 2 results.

6.8.1 Tier 2a Exposure Pathways

Tier 2a evaluated exposure pathways that could extend beyond areas specific to streams. The pathways evaluated include (1) ingestion of aquatic life, (2) ingestion of wild game (represented by elk), (3) ingestion of beef cattle, (4) and ingestion of surface water.

The ingestion of fish and surface water exposure pathways were evaluated on watershed-specific basis. Results are discussed for the following three watersheds: Blackfoot/Little Blackfoot, Salt, and Georgetown. The ingestion of elk and beef cattle exposure pathways were evaluated on a Resource Area-wide basis.

6.8.2 Tier 2b Exposure Pathways

Tier 2b evaluated the single exposure pathway with exposure areas specific to riparian areas – ingestion of surface soil. The ingestion of surface soil exposure pathway was separated based on exposure areas specific to riparian areas. These exposure areas were labeled RA1 through RA8.

6.8.3 Tier 2 Cancer Risk and Noncancer Hazard Results

This section includes the results of the Tier 2 calculations. RME- and CTE-specific EPCs and exposure parameters were used to assess risks and hazards for each receptor for the exposure pathways and COPCs retained from Tier 1. Results are organized and presented as follows:

- Exposure pathways evaluated on a watershed-specific basis (ingestion of fish and surface water) – Sections 6.8.3.1 (Blackfoot/Little Blackfoot watershed), 6.8.3.2 (Salt watershed), and 6.8.3.3 (Georgetown watershed)
- Ingestion of beef cattle tissue – Section 6.8.3.4
- Ingestion of elk tissue – Section 6.8.3.5
- Results specific to riparian areas (ingestion of surface soil) – 6.8.3.6

RME and CTE results are presented for recreationalist, Native American, and subsistence lifestyle receptors in each section. For the purpose of the AWHHRA, COPCs contributing significantly to total risk and hazards are referred to as "risk and hazard drivers." Risk and hazard drives are defined for the AWHHRA as those COPCs that alone or in combination with other COPCs contribute about 90 percent or greater of the total calculated risk or hazard.

Tables 6-26 and 6-27 present summaries of the hazard results for all receptors under RME and CTE conditions, respectively. Table 6-28 presents a summary of the risk results for all receptors under both RME and CTE conditions. Appendix E presents receptor-, exposure pathway-, and COPC-specific exposure, risk, and hazard results.

6.8.3.1 Blackfoot/Little Blackfoot Watershed

Ingestion of aquatic life in the Blackfoot/Little Blackfoot watershed was associated with an HI of greater than 1.0 under RME conditions but not under CTE conditions (with the exception of the subsistence lifestyle child). EPCs for fish tissue in the Blackfoot/Little Blackfoot watershed are included in

Table 6-9. The hazards resulting from RME and CTE conditions are presented in Tables 6-26 and 6-27, respectively, and are listed below.

Adult Recreationalist

- RME (0.35)
- CTE (7.8E-02)

Child Recreationalist

- RME (0.58)
- CTE (0.13)

Adult Native American

- RME (0.52)
- CTE (0.12)

Child Native American

- RME (0.87)
- CTE (0.20)

Adult Subsistence Lifestyle Receptor

- RME (2.4) driven by selenium (2.0) and cadmium (0.35)
- CTE (0.68)

Child Subsistence Lifestyle Receptor

- RME (4.0) driven by selenium (3.4) and cadmium (0.59)
- CTE (1.1) driven by selenium (0.97)

Ingestion of surface water in the Blackfoot/Little Blackfoot watershed was not associated with an HI of greater than 1.0 for RME or CTE conditions. EPCs for surface water in the Blackfoot/Little Blackfoot watershed are included in Table 6-10. The hazards are presented in Tables 6-26 and 6-27 under RME and CTE conditions, respectively, and are listed below.

- Adult recreationalist: RME (1.6E-03); CTE (2.3E-04)
- Child recreationalist: RME (4.8-03); CTE (5.7E-04)
- Adult Native American: RME (1.6E-03); CTE (2.3E-04)
- Child Native American: RME (4.8E-03); CTE (5.7E-04)
- Adult subsistence lifestyle receptor: RME (4.6E-03); CTE (6.2E-04)
- Child subsistence lifestyle receptor: RME (1.4E-02); CTE (1.5E-03)

Of the four COPCs retained for Tier 2 assessment, only arsenic is considered a potential carcinogen through ingestion. However, arsenic was not detected in either fish tissue or surface water samples. Therefore, risks were not calculated for these exposure pathways.

6.8.3.2 Salt Watershed

Ingestion of aquatic life in the Salt watershed was associated with an HI of greater than 1.0 under RME conditions only for subsistence lifestyle receptors but not under CTE conditions for any receptors. EPCs for fish tissue in the Salt watershed are included in Table 6-11. The hazards calculated under RME and CTE conditions are presented in Tables 6-26 and 6-27, respectively, and are listed below.

Adult Recreationalist

- RME (0.22)
- CTE (5.2E-02)

Child Recreationalist

- RME (0.37)
- CTE (8.7E-02)

Adult Native American

- RME (0.33)
- CTE (7.7E-02)

Child Native American

- RME (0.55)
- CTE (0.13)

Adult Subsistence Lifestyle Receptor

- RME (1.5) driven by selenium (1.3)
- CTE (0.45)

Child Subsistence Lifestyle Receptor

- RME (2.5) driven by selenium (2.3)
- CTE (0.76)

Ingestion of surface water in the Salt watershed was not associated with an HI of greater than 1.0 for RME or CTE conditions. Surface water EPCs in the Salt watershed are included in Table 6-12. The hazards are presented in Tables 6-26 and 6-27 under RME and CTE conditions, respectively, and are listed below.

- Adult recreationalist: RME (5.7E-04); CTE (6.4E-05)
- Child recreationalist: RME (1.7E-03); CTE (1.6E-04)
- Adult Native American: RME (5.7E-04); CTE (6.4E-05)
- Child Native American: RME (1.7E-03); CTE (1.6E-04)
- Adult subsistence lifestyle receptor: RME (1.6E-03); CTE (1.7E-04)
- Child subsistence lifestyle receptor: RME (4.8E-03); CTE (4.2E-04)

Of the four COPCs retained for Tier 2 assessment, only arsenic is considered a potential carcinogen through ingestion. However, arsenic was not detected in either fish tissue or surface water samples. Therefore, risks were not calculated for these exposure pathways.

6.8.3.3 Georgetown Watershed

Ingestion of aquatic life in the Georgetown watershed generally associated with an HI of greater than 1.0 under RME conditions for the Native American child and both adult and child subsistence lifestyle receptors, but not under CTE conditions for any receptors. EPCs for fish tissue in the Georgetown watershed are included in Table 6-13. The hazards calculated under RME and CTE conditions are presented in Tables 6-26 and 6-27, respectively, and are listed below.

Adult Recreationalist

- RME (0.47)
- CTE (6.0E-02)

Child Recreationalist

- RME (0.79)
- CTE (0.10)

Adult Native American

- RME (0.70)
- CTE (9.0E-02)

Child Native American

- RME (1.2) driven by selenium (0.96) and cadmium (0.22)
- CTE (0.15)

Adult Subsistence Lifestyle Receptor

- RME (3.2) driven by selenium (2.6) and cadmium (0.58)
- CTE (0.52)

Child Subsistence Lifestyle Receptor

- RME (5.3) driven by selenium (4.4) and cadmium (0.98)
- CTE (0.88)

Ingestion of surface water in the Georgetown watershed was not associated with an HI of greater than 1.0 for RME or CTE conditions. EPCs for surface water in the Georgetown watershed are included in Table 6-14. The hazards are presented in Tables 6-26 and 6-27 under RME and CTE conditions, respectively, and are listed below.

- Adult recreationalist: RME (2.7E-04); CTE (5.8E-05)
- Child recreationalist: RME (7.9E-04); CTE (1.4E-04)
- Adult Native American: RME (2.7E-04); CTE (5.8E-05)
- Child Native American: RME (7.9E-04); CTE (1.4E-04)
- Adult subsistence lifestyle receptor: RME (7.5E-04); CTE (1.6E-04)
- Child subsistence lifestyle receptor: RME (2.2E-03); CTE (3.8E-04)

Of the four COPCs retained for Tier 2 assessment, only arsenic is considered a potential carcinogen through ingestion. However, arsenic was not detected in either fish tissue or surface water samples. Therefore, risks were not calculated for these exposure pathways.

6.8.3.4 Beef Cattle Tissue

Ingestion of beef cattle, both skeletal and offal, was not associated with an HI of greater than 1.0 for RME or CTE conditions. EPCs for beef cattle are included in Table 6-15. The hazards are presented in Tables 6-26 and 6-27 under RME and CTE conditions, respectively, and are listed below.

Adult Recreationalist

- Skeletal: RME (5.5E-02); CTE (5.4E-03)
- Offal: RME (2.2E-03); CTE (3.1E-04)

Child Recreationalist

- Skeletal: RME (0.1); CTE (1.0E-02)
- Offal: RME (1.0E-02); CTE (1.5E-03)

Adult Native American

- Skeletal: RME (6.7E-02); CTE (6.6E-03)
- Offal: RME (6.0E-03); CTE (6.1E-04)

Child Native American

- Skeletal: RME (0.12); CTE (1.2E-02)
- Offal: RME (1.1E-02); CTE (1.1E-03)

Adult Subsistence Lifestyle Receptor

- Skeletal: RME (5.5E-02); CTE (5.4E-03)
- Offal: RME (2.3E-03); CTE (3.1E-04)

Child Subsistence Lifestyle Receptor

- Skeletal: RME (0.1); CTE (1.0E-02)
- Offal: RME (1.0E-02); CTE (1.5E-03)

Of the four COPCs retained for consideration under Tier 2, only arsenic is considered potentially carcinogenic through ingestion. However, samples of beef cattle tissue were not analyzed for arsenic. Therefore, risks were not calculated for this exposure pathway.

6.8.3.5 Elk Tissue

Ingestion of elk and wild game, both skeletal and offal, was not associated with an HI of greater than 1.0 under RME or CTE conditions. Refer to Table 6-15 for elk EPCs. The hazards are presented in Tables 6-26 and 6-27 under RME and CTE conditions, respectively, and are listed below.

Adult Recreationalist

- Skeletal: RME (2.6E-03); CTE (9.4E-04)
- Offal: RME (5.8E-04); CTE (2.3E-03)

Child Recreationalist

- Skeletal: RME (3.8E-03); CTE (1.4E-03)
- Offal: RME (2.3E-03); CTE (8.6E-04)

Adult Native American

- Skeletal: RME (2.4E-04); CTE (8.6E-05)
- Offal: RME (1.4E-04); CTE (4.8E-05)

Child Native American

- Skeletal: RME (3.6E-04); CTE (1.4E-04)
- Offal: RME (2.0E-04); CTE (7.6E-05)

Adult Subsistence Lifestyle Receptor

- Skeletal: RME (3.2E-02); CTE (9.4E-04)
- Offal: RME (5.8E-04); CTE (2.3E-03)

Child Subsistence Lifestyle Receptor

- Skeletal: RME (8.4E-02); CTE (1.4E-03)
- Offal: RME (2.3E-03); CTE (8.6E-04)

Of the four COPCs retained for consideration under Tier 2, only arsenic is considered potentially carcinogenic through ingestion. However, samples of elk tissue were not analyzed for arsenic. Therefore, risks were not calculated for this exposure pathway.

6.8.3.6 Results Specific to Residential Areas

Hazards and risks were calculated for data on surface soil samples specific to RAs for the subsistence lifestyle receptor only. Ingestion of surface soil was not associated with an HI of greater than 1.0 under RME or CTE conditions, except for the child subsistence lifestyle receptor that ingests surface soil from RA1 (HI of 1.6) (see Tables 6-26 and 6-27). The hazard is driven by cadmium (0.73), arsenic (0.68), and selenium (0.17). EPCs specific to soil in potential RAs are included in Table 6-16. The ranges of hazards for ingestion of surface soil are listed below for the subsistence lifestyle receptor.

Adult Subsistence Lifestyle Receptor

- RME (2.3E-02 - 0.17)
- CTE (1.1E-02 - 8.4E-02)

Child Subsistence Lifestyle Receptor

- RME (0.22 – 1.6)
- CTE (0.11 - 0.80)

Ingestion of surface soil resulted in risks greater than 1E-06 for all riparian areas sampled. The risks were all driven by arsenic. See Table 6-28 for a list of risks for each riparian area. It should be noted that the risk from ingestion of surface soil in the riparian areas was approximately the same as the risks associated with ingestion of arsenic in surface soil in unimpacted areas of the Resource Area and for the western U.S. (Table 6-28).

6.8.3.7 Receptor-specific Total Results

The total hazards for each receptor (without consideration of background and supplement exposures) are listed below. The range of total hazards presented for the subsistence lifestyle receptors represents the impact of the range of hazards associated with ingestion of surface soil (as presented in Section 6.7.1.3).

Adult Recreationalist

- Blackfoot/Little Blackfoot watershed: RME (0.41); CTE (8.7E-02)
- Salt watershed: RME (0.28); CTE (6.1E-02)
- Georgetown watershed: RME (0.53); CTE (6.9E-02)

Child Recreationalist

- Blackfoot/Little Blackfoot watershed: RME (0.71); CTE (0.15)
- Salt watershed: RME (0.49); CTE (0.10)

- Georgetown watershed: RME (0.91); CTE (0.12)

Adult Native American

- Blackfoot/Little Blackfoot watershed: RME (0.60); CTE (0.12)
- Salt watershed: RME (0.40); CTE (8.5E-02)
- Georgetown watershed: RME (0.78); CTE (9.7E-02)

Child Native American

- Blackfoot/Little Blackfoot watershed: RME (1.0); CTE (0.21)
- Salt watershed: RME (0.69); CTE (0.14)
- Georgetown watershed: RME (1.3); CTE (0.16)

Adult Subsistence Lifestyle Receptor

- Blackfoot/Little Blackfoot watershed: RME (2.5 to 2.6); CTE (0.71 to 0.78)
- Salt watershed: RME (1.6 to 1.8); CTE (0.47 to 0.55)
- Georgetown watershed: RME (3.3 to 3.4); CTE (0.54 to 0.62)

Child Subsistence Lifestyle Receptor

- Blackfoot/Little Blackfoot watershed: RME (4.4 to 5.8); CTE (1.3 to 2.0)
- Salt watershed: RME (2.9 to 4.3); CTE (0.88 to 1.6)
- Georgetown watershed: RME (5.8 to 7.1); CTE (1.0 to 1.7)

Background and supplement exposures to arsenic, cadmium, chromium, and selenium were estimated for adult and child receptors (see Section 6.4.7). Table 6-29 presents background and supplement exposures. These exposures were divided by the oral RfD to calculate the background and supplement HIs listed below.

Arsenic

- Adult background HI (1.33)
- Child background HI (45)

Cadmium

- Adult/child background HI (0.86)

Chromium

- Adult/child background HI (7.33E-04)
- Adult/child supplemental HI (9.33E-04)

Selenium

- Adult/child background HI (0.32)
- Adult/child supplemental HI (5.4E-02)

The most significant hazard associated with exposure through background and supplement sources is a hazard of 45 associated with background exposure to arsenic in soils by a child receptor. It is assumed that the background exposure to arsenic may be overestimated by taking the midpoint of the range of ADIs as the child background exposure. Watershed-specific risks were all driven by incidental soil ingestion.

Also, a hazard of 1.33 is associated with background exposure to arsenic by an adult receptor which is greater than 1. It should also be noted that background exposure to cadmium by adult and child receptors is nearly significant at 0.86. Finally, a hazard of 0.32 is associated with background exposure to selenium by adult and child receptors, which is notable. The hazards associated with background exposure to chromium and supplement exposure to both chromium and selenium are negligible.

The total hazards for each receptor including hazards associated with background and supplement exposure are listed below. The range of total hazards presented for the subsistence lifestyle receptors represents the impact of the range of hazards associated with ingestion of surface soil (as presented in Section 6.7.1.3).

Adult Recreationalist

- Blackfoot/Little Blackfoot watershed: RME (3.0); CTE (2.7)
- Salt watershed: RME (2.9); CTE (2.6)
- Georgetown watershed: RME (3.1); CTE (2.6)

Child Recreationalist

- Blackfoot/Little Blackfoot watershed: RME (46.9); CTE (46.4)
- Salt watershed: RME (46.7); CTE (46.3)
- Georgetown watershed: RME (47.1); CTE (46.3)

Adult Native American

- Blackfoot/Little Blackfoot watershed: RME (3.2); CTE (2.7)
- Salt watershed: RME (3.0); CTE (2.7)
- Georgetown watershed: RME (3.4); CTE (2.7)

Child Native American

- Blackfoot/Little Blackfoot watershed: RME (47.2); CTE (46.4)
- Salt watershed: RME (46.9); CTE (46.3)
- Georgetown watershed: RME (47.5); CTE (46.4)

Adult Subsistence Lifestyle Receptor

- Blackfoot/Little Blackfoot watershed: RME (5.1 to 5.2); CTE (3.3 to 3.4)
- Salt watershed: RME (4.2 to 4.4); CTE (3.0 to 3.1)
- Georgetown watershed: RME (5.9 to 6.0); CTE (3.1 to 3.2)

Child Subsistence Lifestyle Receptor

- Blackfoot/Little Blackfoot watershed: RME (50.6 to 52); CTE (47.5 to 48.2)
- Salt watershed: RME (49.1 to 50.5); CTE (47.1 to 47.8)
- Georgetown watershed: RME (52 to 53.3); CTE (47.2 to 47.9)

These totals are dominated by COPC-specific hazards greater than 1 associated with background exposure to arsenic and to a lesser extent cadmium.

The total risk was calculated for the subsistence lifestyle receptor based on results for both the watershed and RAs. The risk was the same for each watershed. The range of risks based on data for the RAs is listed below. See Table 6-28 for the risk calculated for each RA.

Adult Subsistence Lifestyle Receptor

- RME (3.8E-06 – 1.4E-05)
- CTE (5.7E-07 – 2.1E-06)

Child Subsistence Lifestyle Receptor

- RME (7.2E-06 – 2.6E-05)
- CTE (3.6E-06 – 1.3E-05)

Again, the risks calculated for each RA are similar to the risks calculated based on the concentration of arsenic in uncontaminated soil in the Resource Area and in soil from the western U.S. (see Table 6-28).

6.8.4 Evaluation of Tier 2 Results

This section includes a summary of the results for each receptor, a comparison of the RME and CTE results, and the exposure pathways that were evaluated under the Tier 3 assessment.

6.8.4.1 Summary of Receptor-specific Results

Total hazards in each watershed for receptors that include the recreationalist, Native American, and adult subsistence lifestyle are driven by background exposure to arsenic and, to a lesser extent, cadmium. Resource Area-related hazards (that is, hazards without consideration of background and supplement exposures) are driven by selenium, and to a lesser extent, cadmium through ingestion of aquatic life (and ingestion of soil for subsistence lifestyle receptors). The hazard in each watershed for the child subsistence lifestyle receptor is driven by data for selenium and cadmium through ingestion of aquatic life; and by selenium, cadmium, and arsenic through ingestion of surface soil. The selenium EPCs in fish tissue are similar to the concentration of selenium found in fish from uncontaminated reaches (see Table 6-30).

It should be noted that the only hazards greater than 1.0 for receptors other than subsistence lifestyle receptors are for the child Native American receptor. Specifically, the child Native American receptor has a total hazard (not considering background and supplement exposures) of 1.0 and 1.3 for the Blackfoot/Little Blackfoot and Georgetown watersheds, respectively.

For the Blackfoot/Little Blackfoot watershed, no COPC-specific hazard is greater than 1.0. The total hazard of 1.0 is driven by selenium (0.88) and cadmium (0.13). Therefore, this total was further evaluated focusing on the target organs and systems affected by these two COPCs. As noted in Appendix D, both cadmium and selenium are known to impact the gastrointestinal system. Therefore, it is appropriate to sum the COPC-specific hazards for these two COPCs. However, for the Georgetown watershed, the total hazard associated with selenium alone is 1.1. Since a single constituent caused the HQ to exceed 1.0, no further assessments necessary to establish that a potential risk exists. Therefore, the total hazard for Georgetown watershed was not subjected to detailed analysis of affected target organs and systems consistent with EPA guidance (EPA 1989).

With regard to the subsistence lifestyle receptors, all total hazards under RME conditions are associated with a COPC-specific hazard greater than 1.0. Under CTE conditions, no adult hazards are greater than 1.0. However, total hazards in all three watersheds are greater than 1.0 for the child subsistence lifestyle receptor.

In the Blackfoot/Little Blackfoot watershed, the total hazard is driven by a COPC-specific total for selenium greater than 1.0; therefore, this total was not further evaluated. In both the Salt and Georgetown watersheds, the totals are associated with no COPC-specific hazards greater than 1.0; therefore, these totals were further evaluated. As discussed above for the child Native American receptor, cadmium and selenium both affect the gastrointestinal system (among other organs and systems). Therefore, it is appropriate to sum the hazards for cadmium and selenium. Summing only the hazards for cadmium and selenium, the total hazards exceed 1.0 only when considering exposure of RA1; 1.2 (Salt watershed) and 1.3 (Georgetown watershed).

The risk in each watershed for the subsistence lifestyle receptor is driven by arsenic through ingestion of surface soil. Riparian area-specific concentrations of arsenic are similar to background levels found in the Resource Area specifically and in the western U.S. in general (see Table 6-28).

6.8.4.2 Comparison of Reasonable Maximum Exposure and Central Tendency Exposure Results

The hazard and risk RME results were approximately 4 to 6 times higher than the CTE results. For example, the HI for the adult subsistence lifestyle receptor through ingestion of aquatic life from the Blackfoot/Little Blackfoot watershed was 2.4 under RME conditions and 0.68 under CTE conditions. This difference resulted in several pathways with significant hazards and risks under RME conditions but not under CTE conditions. The pathways with an HI greater than 1.0 or a risk greater than 1.0E-06 under RME conditions include:

Ingestion of Aquatic Life

- Blackfoot/Little Blackfoot watershed – adult and child subsistence lifestyle receptors
- Salt watershed – adult and child subsistence lifestyle receptors
- Georgetown watershed – child Native American and adult and child subsistence lifestyle receptors

Ingestion of Surface Soil

- All riparian areas – subsistence lifestyle receptors

The pathways with an HI greater than 1.0 or a risk greater than 1.0E-06 under CTE conditions are listed below.

Ingestion of Aquatic Life

- Blackfoot/Little Blackfoot watershed – child subsistence lifestyle

Ingestion of Surface Soil

- Residential area 1 – adult subsistence lifestyle receptor (1.4E-05) driven by arsenic
- All residential areas – child subsistence lifestyle receptor (1.1E-05 – 7.2E-06) – driven by arsenic

There are no pathways with an HI greater than 1.0 or a risk greater than 1.0E-06 under CTE conditions for the recreational or Native American receptor.

TtEMI believes that the CTE results associated with watershed-specific exposure pathways are more representative of the receptors' exposure because:

(1) The large size of the unimpacted areas of the watersheds in the Resource Area. Receptors are most likely to spend much more time in the unimpacted areas of the watershed as compared to the impacted areas simply due to large difference in size between these areas. Impacted stream reaches represent only about 27 percent of the total stream reaches in the Blackfoot/Little Blackfoot watershed, and less than 10 percent in the other two watersheds. As such, receptors will most likely be exposed under conditions that more closely resemble CTE, rather than RME conditions.

(2) The small sample sizes in unimpacted areas and the EPC calculation methodology confound the magnitude of exposure of each receptor in Resource Area. For example, there was a relatively small fish sample size in unimpacted areas as compared to impacted areas. As such, all unimpacted reaches were considered as a single area represented by a single mean concentration. The representation of data from the unimpacted reaches in the statistical derivation of EPCs, therefore, was disproportionately lower than the representation of data from impacted areas. As such, EPCs for RME conditions in most cases represented the maximum detected concentration or concentrations near maximum detected concentrations. Maximum detected concentrations were invariably located in impacted areas of the watershed. Therefore, RME conditions represented exposures that occurred mostly within impacted areas, which, in turn, represent a small percentage of the overall Resource Area. Receptors are more likely to spend time in unimpacted rather than impacted areas due to the differences in sizes between these areas.

6.8.4.3 Exposure Pathways Retained for Tier 3 Assessment

The pathways evaluated under Tier 3 include ingestion of aquatic life and ingestion of surface soil. Each receptor was evaluated under these pathways.

6.9 TIER 3 ASSESSMENT – WATERSHED-SPECIFIC ANALYSES BASED ON HISTORICAL DATA

Tier 3 methodology was presented in Section 6.1.3. This section presents cancer risks and noncancer hazards for all receptors exposed to COPCs by ingestion of aquatic life and surface soil. Section 6.9.1 presents Tier 3 cancer risk and noncancer hazard results. Section 6.9.2 presents an evaluation of Tier 3 results.

6.9.1 Tier 3 Cancer Risk and Noncancer Hazard Results

This section includes the results from the Tier 3 calculations. The ingestion of aquatic life and ingestion of surface water pathways were evaluated, accounting for the temporal variation in concentration and length of contaminated reaches for all receptors using both RME and CTE conditions. Tables E-134 to E-169 in Appendix E present the results.

6.9.1.1 Reasonable Maximum Exposure Case

The total exposure in the Blackfoot/Little Blackfoot watershed resulted in an HI less than 1.0 for adult (0.46) and child (0.80) subsistence lifestyle receptors under RME conditions. EPCs for fish tissue and surface water used for the Tier 3 evaluation of the Blackfoot/Little Blackfoot watershed are presented in Tables 6-17 and 6-18, respectively.

In the Salt watershed, ingestion of surface water resulted in an HI less than 1.0 for adult (2.9E-02) and child (8.7E-02) subsistence lifestyle receptors. EPCs for surface water used for the Tier 3 assessment of the Salt watershed are included in Table 6-19.

In the Georgetown watershed, ingestion of surface water resulted in an HI less than 1.0 for adult (4.2E-03) and child (1.3E-02) subsistence lifestyle receptors. EPCs for surface water used for the Tier 3 assessment of the Georgetown watershed are included in Table 6-20.

The total exposure in each watershed resulted in an HI less than 1.0 for all other receptors under RME conditions. The range of hazards is listed below. See Tables E-140 to E-145, E-152 to E-157, and E-164 to E-169 in Appendix E for Native American, recreational, and subsistence lifestyle receptor-specific results, respectively.

- Adult recreational receptor (1.5-03 to 7.2E-02)
- Child recreational receptor (4.4E-03 to 0.13)
- Adult Native American receptor (1.5E-03 to 0.10)
- Child Native American receptor (4.4E-03 to 0.18)

6.9.1.2 Central Tendency Exposure Case

The total exposure in each watershed resulted in an HI less than 1.0 for all receptors under CTE conditions. See Tables E-134 to E-139, E-146 to E-151, and E-158 to E-163 in Appendix E for individual results.

The range of hazards is listed below.

- Adult recreational receptor (3.5E-04 to 1.3E-02)
- Child recreational receptor (8.6E-04 to 2.2E-02)
- Adult Native American receptor (3.5E-04 to 1.9E-02)
- Child Native American receptor (8.6E-04 to 3.1E-02)
- Adult subsistence lifestyle receptor (9.4E-04 to 1.1E-03)
- Child subsistence lifestyle receptor (4.6E-03 to 7.0E-03)

6.9.2 Evaluation of Tier 3 Results

This section includes a summary of receptor-specific results and a comparison of the results based on 2001 and historical data.

6.9.2.1 Summary of Receptor-specific Results

No exposure pathway-specific or total hazards or risks for any of the three receptor groups equaled or exceeded an HI of 1.0 or a risk of 1E-06.

6.9.2.2 Comparison of Results Based on 2001 and Historical Data

Table 6-30 shows fish tissue EPCs based on data collected in 2001. Table 6-17 shows fish tissue EPCs based on data collected in 1998. The 2001 data has concentrations that are approximately 5 to 6 times greater than the 1998 data for both cadmium and selenium. For example, the UCL_{95} concentration of cadmium in fish tissue is 7.29E-02 mg/kg wet weight (WW) based on the 2001 data and 1.26E-02 mg/kg WW based on the 1998 data.

Tables 6-10, 6-12, and 6-14 show surface water EPCs based on data collected in 2001 for the Blackfoot/Little Blackfoot, Salt, and Georgetown watersheds, respectively. Tables 6-18, 6-19, and 6-20 show surface water EPCs based on data collected in 1998 for the Blackfoot/Little Blackfoot, Salt, and Georgetown watersheds, respectively. Generally, the 2001 data are approximately one order of magnitude lower than the 1998 data for cadmium. The cadmium area-weighted average concentration (AWAC) in the Blackfoot/Little Blackfoot watershed was 0.27 micrograms per liter (µg/L) in 2001 and 1.9 µg/L in 1998 for the Blackfoot/Little Blackfoot and Salt watersheds and about one-fourth the 1998 data for the Georgetown watershed. For chromium, the 2001 data is approximately two orders of magnitude higher than the 1998 data. The chromium AWAC in the Blackfoot/Little Blackfoot watershed was 1.07 µg/L in 2001 and 6.21E-03 µg/L in 1998. For selenium, the 2001 data is similar to the 1998 data. The selenium AWAC in the Blackfoot/Little Blackfoot watershed was 11.97 µg/L in 2001 and 4.37 µg/L in 1998.

6.10 UNCERTAINTY ASSESSMENT

The estimates of exposure, risk, and hazard presented in the AWHHRA are subject to varying degrees of uncertainty from a variety of sources. The potential sources of uncertainty are discussed for each step in the risk assessment. Uncertainties associated with data evaluation and selection of COPCs; exposure assessment; toxicity assessment; and risk and hazard characterization are discussed in the following sections.

6.10.1 Data Evaluation and Chemical of Potential Concern Selection

Uncertainties associated with data evaluation and selection of COPCs result from a variety of sources. This section briefly discusses some of the more significant sources of uncertainty, including the assumption of steady-state conditions, the number and type of samples collected, and the methodology for selection of COPCs. The uncertainties may result in overestimation or underestimation of risks and hazards, as discussed in the following sections.

6.10.1.1 Assumption of Steady-state Conditions

Medium-specific concentrations are used to select COPCs and to calculate EPCs based on the assumption of steady-state conditions. That is, the concentrations measured from about 1998 through 2001 are assumed to remain constant and representative of exposure throughout the receptor-specific durations of exposure. This assumption ignores the variable introduction of additional contamination into the environment in the future. The introduction of contamination from mine-specific waste rock piles into the environment is expected to be variable and depend in large part on annual precipitation and subsequent runoff. The use of data for surface water and fish tissue collected in 1998 (a year of high precipitation and runoff) under Tier 3 and comparison to Tier 2 results based data for surface water and fish tissue collected in 2001 (a year of lower precipitation and runoff) was an attempt to quantify the impact of variable medium-specific concentrations.

In general, metals do not degrade substantially in the environment and are not significantly metabolized in biological systems. Selenium, on the other hand, can significantly metabolize and be incorporated into proteins. Therefore, the concentration of COPCs in waste rock, surface soil, the tissues of plants growing in contaminated surface soil, and fish tissue may not vary significantly over time for individual sample locations. However, the concentration of COPCs in surface water can clearly vary significantly over time. It is expected that the variability of medium-specific COPC concentrations may be affected to a greater extent by the number and location of medium-specific samples as compared with the assumption of steady-state conditions. Therefore, the potential magnitude and direction of the uncertainty associated with the assumption of steady-state conditions is likely to vary by medium and over time.

6.10.1.2 Number and Type of Samples Collected

The Resource Area as a whole and the individual watersheds considered in the AWHHRA are very large. For all media, attempts were made to collect samples from both impacted and unimpacted stream reaches and riparian areas. Given the relatively small number of impacted locations as compared with unimpacted locations in the Resource Area and throughout each watershed, a greater percentage of samples were collected from impacted locations than from unimpacted locations. However, even for impacted locations, limited numbers of samples were collected. For example, limited numbers of fish tissue samples were collected for some stream stretches based on a concern that collection of a greater number of samples could impair the stream's fish population.

The use of area-weighted concentrations factored in the relative sizes of impacted and unimpacted areas throughout the Resource Area and individual watersheds. However, the inputs to these area-weighted concentrations depend on the limited number of samples. In general, the variability of medium-specific concentrations within both unimpacted and impacted locations may not be adequately characterized in some cases.

In addition, samples were not collected from some media to which receptors may be exposed. For example, no samples were collected of homegrown produce. Soil-to-plant uptake factors were used to extrapolate concentrations in plant tissue from concentrations in soil. An undetermined level of uncertainty is associated with the use of these generalized literature values.

In general, the low number of medium-specific samples means that there is uncertainty associated with characterization of COPC-specific concentrations for each medium. The direction and magnitude of the uncertainty (for example, were medium-specific EPCs over- or underestimated) is unknown.

6.10.1.3 Chemical of Potential Concern Selection Methodology

In general, the methodology for selection of COPCs (see Appendix B) is expected to be conservative. This means that it is unlikely that that COPC selection methodology would overlook a chemical that should be a COPC. The conservatism in the COPC selection process is illustrated as follows:

(1) At all steps in the process, the maximum detected medium-specific concentration of each chemical is compared with either a measure of background or a screening criterion. If that concentration exceeds both the background measure and screening criterion, the chemical is retained as a COPC.

(2) The background used to compare against these maximum detected medium-specific concentrations was set equal to twice the mean background concentration. As noted in Section 7.2.3.1 of the Work Plan (TtEMI 2002a), similar nonstatistical methods have been accepted for background comparisons for EPA Region 4 and FS Region 3 using higher numerical multipliers (such as 3 times background) in some cases. In addition, the common industry practice for establishing background levels for industrial sites under the Resource Conservation and Recovery Act (RCRA) consists of collecting three to five directed samples in areas assumed to represent pre-industry conditions to calculate UCL_{95} concentrations. A UCL_{95} typically results in a background comparison level that is 1.5 to 3 times the mean value of the data set, depending on variability in the data. Therefore, use of a numerical multiplier of 2 is expected to be conservative in most cases.

(3) A chemical retained as a COPC in one medium was retained as a COPC for all media. Therefore, a chemical that may not be present at elevated concentrations in a specific medium was considered to be a COPC because the concentration of the chemical was elevated in another medium (possibly on the basis of a single sample).

Therefore, it is expected that, in general, the COPC selection methodology may (1) include chemicals as COPCs that may be detected at elevated concentrations at only a limited number of locations within the Resource Area, and (2) is unlikely to overlook a chemical that should be a COPC.

6.10.2 Exposure Assessment

Uncertainties associated with exposure assessment result from a variety of sources. This section briefly discusses some of the more significant sources of uncertainty, including development of EPCs, identification of exposure pathways, exposure parameters and assumptions, calculating total exposures, and incorporating background and supplemental exposure. The uncertainties may result in overestimation or underestimation of risks and hazards as discussed below.

6.10.2.1 Exposure Point Concentrations

The uncertainty associated with the calculation of EPCs varies by medium. For example, riparian area-specific EPCs for surface soil are based on the results from a single impacted soil sample and a limited number of unimpacted soil samples. Therefore, the uncertainty associated with these COPCs depends on the relative lack of information on the variability of COPC-specific concentrations in that riparian area. In addition, as discussed in Appendix C, EPCs for surface soil were calculated assuming that a 0.5-acre residential area was located in part within the riparian zone. This assumption is expected to be conservative, especially along larger streams, because residents are not expected to develop heavily within flood plains. However, in the end, the uncertainty associated with concentrations in surface soil is not significant because the calculated EPCs (especially for arsenic, which drives the risks associated with exposure to surface soil) are similar to the concentration of COPCs in unimpacted portions of the Resource Area and in soils from the western U.S. in general.

The EPCs for fish tissue and surface water are affected by the limited number of medium-specific samples. Under CTE conditions, the EPCs were calculated as area-weighted concentrations. This approach took into account the lack of impact to much of the Resource Area and the individual watersheds from mining-related activities. Therefore, EPCs calculated under CTE conditions for fish tissue and surface water largely reflect the concentrations of COPCs from unimpacted portions of the Resource Area and the individual watersheds.

However, under RME conditions, the EPCs for fish tissue and surface water were calculated as UCL_{95} incorporating a number of simplifying assumptions. These simplifying assumptions include: (1) it was assumed that an arithmetic mean is appropriate to represent the true average concentration of each chemical in each reach (in cases where only a single measurement is available, this measurement is used as a surrogate for the mean concentration); (2) possible spatial or serial correlations in the data were ignored; (3) the distribution of the means for all reaches follows a normal distribution (note that this assumption applies to the distribution of means, rather than individual measurements within each reach); and (4) potential complications introduced by nondetect data were ignored. The overall impact (direction and magnitude) of these assumptions on the calculated EPCs cannot be readily qualified. Beyond these assumptions, the greatest amount of uncertainty is probably introduced by the limited number of samples used to represent each watershed (particularly for fish tissue). For example, concentrations in fish tissue for the Salt and Georgetown watersheds were each based on two reach-specific concentrations (one impacted reach and one unimpacted reach). The concentration of COPCs in impacted and unimpacted reaches was different for some COPCs. This result led to significant variation which, coupled with the low number of samples, resulted in calculated UCL_{95} concentrations that exceeded the maximum detected concentration. Therefore, in these cases, the maximum detected medium-specific concentration was selected as the EPC consistent with EPA guidance (EPA 1992).

As described in Appendix C, EPCs were calculated substituting a value equal to one-half the detection limit for results reported as nondetect. This process is consistent with EPA guidance (EPA 1989, 2000c) as well as industry practices. However, this process does introduce uncertainty into the calculation of EPCs. The magnitude of the uncertainty increases with the percentage of nondetect results in a data set.

In response to the lack of fish tissue data from particular watersheds (for example, no fish tissue samples were collected by TtEMI for streams in the Georgetown watershed in 2001), an additional assumption was made. Specifically, in the absence of watershed-specific fish tissue data, EPCs for these watersheds were estimated as the average of the fish tissue concentrations for watersheds with fish tissue data, weighted by the relative presence of impacted and unimpacted streams in the watershed to which the assumption was applied (for example, the Georgetown watershed in the example above).

This assumption introduces uncertainty about the calculation of EPCs because data from outside a particular watershed are being used to represent that watershed. However, the impact of the uncertainty is expected to be tempered by two factors: (1) average concentrations were applied; this will reduce the impact of particularly high or low concentrations that might not be representative and (2) the surrogate concentrations were weighted by the relative presence of impacted and unimpacted reaches in the subject watershed.

Additional uncertainty is introduced by the decision to not use analytical results associated with fish tissue and surface water samples collected by IMA in September 1999 and May 2000. The IMA data were not included for two primary reasons. First, the 2000 data represents the most recent analytical data, while the 1998 data represents data from a "high flow" year and is useful for evaluation of temporal concentration changes. Second, the 1999 and 2001 data collected by IMA represents a relatively small data set that did not provide results substantially different from the data used in the AWHHRA. Therefore, the uncertainty introduced by not using the 1999 and 2001 IMA data is not expected to be significant.

Therefore, in general, the EPCs for fish tissue and surface water calculated under RME conditions are expected to be artificially elevated. This assumption must be interpreted in the context that, while unlikely, it is possible that individual receptors may fish from or draw drinking water from individual impacted stream reaches a significant amount of the time, rather than being exposed throughout individual watersheds. Overall, TtEMI believes that the EPCs calculated under CTE conditions for fish tissue and surface water provide a more reasonable estimate of the medium-specific COPC concentrations to which receptors may be exposed.

EPCs for beef cattle and elk tissue are calculated based on the results of 14 beef cattle samples and 26 elk samples. These numbers in general should provide a reasonable amount of confidence on the variability of chemical concentrations in individual tissues. However, the results for beef cattle tissue are from a single depuration study when cattle were grazed on a single seleniferous pasture near the Henry Mine. Concentration of COPCs in cattle that are grazed on other impacted pastures or that graze at least partially on unimpacted pastures may be different. Use of analytical data from beef cattle that have undergone depuration does not account for potential exposure to COPCs in beef cattle tissue from animals taken directly from the pasture. This practice is not considered to be widely used, but can occur and may result in somewhat higher tissue concentrations.

The data for elk tissue were collected from animals taken throughout much of the Resource Area. Therefore, the analytical results from these animals are expected to provide a reasonable estimate of the concentrations of COPCs in elk tissue.

The concentration of COPCs in aquatic and terrestrial plant tissue depends on a limited number of samples. Specifically, the EPCs for COPCs in aquatic plants are based on two impacted samples and one unimpacted sample, and the EPCs for COPCs in terrestrial plants are based on four impacted and four unimpacted samples. Both of these pathways were eliminated after Tier 1. It is uncertain whether the maximum detected COPC-specific concentrations used in Tier 1 calculations adequately represent actual concentrations in plant tissue.

Finally, the concentration of COPCs in homegrown produce were calculated based on soil-to-plant uptake factors from the literature and a single surface soil sample from each impacted riparian area. Uncertainties associated with the concentration of COPCs from the individual surface samples and the use of literature-based uptake factors have already been discussed. These uncertainties also apply to the concentration of COPCs in homegrown produce, an exposure pathway that was dropped after Tier 1.

6.10.2.2 Exposure Pathway Identification

Relatively little uncertainty is associated with identification of potentially complete exposure pathways considered in the AWHHRA, with the exception of ingestion of homegrown produce and the ingestion by Native American receptors of aquatic and terrestrial plants and tea brewed from terrestrial plants. All other exposure pathways considered in the AWHHRA have been observed within the Resource Area.

Currently, TtEMI is unaware of any residences located along or within riparian areas in the Resource Area. In addition, for evaluation of the ingestion of homegrown produce exposure pathway it was assumed that a home garden was located within the riparian area. This assumption is considered very conservative because the size of the riparian area, along many streams within the Resource Area, may not be large enough to support a home garden. Furthermore, residents may not develop gardens within the riparian area for fear that they may be flooded. Nonetheless, the ingestion of homegrown produce exposure pathway was retained and was eliminated after Tier 1.

Details on the precise nature of exposure scenarios specific to Native Americans are limited. In general, all that is known is that it is possible that Native American receptors use aquatic and terrestrial plants from the Resource Area. It is also known that some Native American populations ingest native plants and also brew teas from native plants. Therefore, because the precise nature of exposure pathways for Native Americans was unknown, exposure pathways related to the ingestion of native aquatic and terrestrial plants were considered in the AWHHRA because they could be quantified and for completeness. However, significant uncertainty is associated with the actual presence of these exposure pathways in the Resource Area.

6.10.2.3 Exposure Parameters and Assumptions

Standard assumptions on exposure parameters were made for population characteristics such as body weight, life expectancy, and exposure duration. Uncertainties associated with these assumptions on exposure parameters are likely to be insignificant when the entire potentially exposed population is considered because population characteristics used in the AWHHRA are based on national averages of large samples.

However, assumptions associated with exposure characteristics such as exposure frequency and contact rate may not represent actual exposure conditions. In other words, the characteristic values used in the AWHHRA may not accurately represent all individuals who may be exposed at or near the Resource

Area. For example, beef tissue EPCs were based on a study of cattle raised exclusively on a seleniferous pasture. The number of cattle in the Resource Area that are raised exclusively on seleniferous pastures is not expected to be large. Therefore, the use of tissue concentrations from beef cattle raised exclusively on a seleniferous pasture may overestimate receptor-specific exposures.

In general, parameter values for exposure characteristics under RME conditions are selected to represent some of the most highly exposed individuals. Therefore, receptor-specific exposure estimates calculated under RME conditions are expected to overestimate the exposure of the majority of receptors potentially exposed in the Resource Area. However, consistent with EPA guidance (EPA 1989), RME exposure parameters do not typically represent the most exposed receptors. For example, it is possible that some receptors, primarily Native American receptors, but also individual subsistence lifestyle and recreational receptors may live in or near the Resource Area for a period of time greater than the allowed 30 years. Exposure, risk, and hazard estimates for these individuals may be underestimated (at least with regard to this specific parameter). However, any underestimation is expected to relatively small because of the impact of other exposure parameter assumptions. Primary among these additional assumptions is the use of conservative fraction ingested values. For example, the AWHHRA assumed all fish ingested were caught from a particular watershed. This is a conservative assumption. To further assume that a receptor would ingest all of his or her fish from a single watershed over an entire estimated lifetime of 70 years is unwarranted. Parameter values selected to represent CTE conditions are intended to be less conservative and better represent average exposure conditions.

6.10.2.4 Estimating Total Exposures

Total site-related exposures are estimated by summing exposure pathway-specific exposures. It is unlikely that any individual is actually exposed at RME levels to all potentially complete exposure pathways. Therefore, total site-related exposures (and, subsequently, total site-related hazards and risks) calculated under RME conditions are likely to overestimate actual values. The degree of uncertainty (and overestimation) is less under CTE conditions. Receptor-specific risks are driven almost entirely by a single exposure pathway – ingestion of surface soil. Therefore, the amount of overestimation resulting from summing risks related to all potentially complete exposure pathways is not considered insignificant. Similarly, receptor-specific hazards are driven by two exposure pathways: ingestion of fish tissue and surface water. Of these two exposure pathways, ingestion of fish tissue contributes the majority of the total hazard. Therefore, the amount of overestimation is not expected to be significant.

6.10.2.5 Incorporation of Background and Supplemental Exposure

As discussed in Section 6.4.7, background and supplemental exposures were conservatively estimated due to a lack of specific information regarding COPC exposure from background dietary and supplemental sources. As a result, a degree of double counting (in some cases significant) is associated with summing total site-related exposures with background and supplemental exposures. However, as discussed in Section 6.8.4.1, with the exception of background exposure to arsenic for children, COPC-specific background and supplemental exposures are generally insignificant and do not contribute much to total exposures and hazards.

It is very likely that the estimated background exposure to arsenic for children overestimates the actual degree of background exposure for the entire exposed population. There may be some individuals with this amount of background exposure, but it is very unlikely that the majority of the population is exposed to this level. In addition, the hazard associated with the estimated background exposure to arsenic for children so outweighs the site-related total hazard as to render site-related hazards meaningless. In summary, the estimated background and supplemental exposures are either low enough or so high as to have little bearing on the interpretation of site-related exposures and hazards.

6.10.3 Toxicity Assessment

Uncertainties associated with the toxicity assessment resulted primarily from the methodology used to quantify various toxicological effects. In most instances, these uncertainties may result in overestimation of risk and hazard. Sources of uncertainty include (1) extrapolation of animal data to humans, (2) limited availability of chemical-specific data, and (3) modeling of SFs. Each of these sources of uncertainty is discussed in the following sections.

6.10.3.1 Extrapolation of Animal Data to Humans

EPA makes several assumptions to develop toxicity values that may result in overestimation of the actual hazard or risk to human health that results from exposure to a COPC. One assumption involves the use of animal study data to extrapolate high doses administered to laboratory animals to much lower doses expected to be experienced by humans. The dose-response relationship may not be the same at these lower doses and their extrapolation may therefore result in overestimation of risk and hazard. EPA acknowledges the limitations associated with current evaluation procedures and plans to revise the procedures for estimating the carcinogenic effects of chemicals. EPA plans to evaluate a broader range of health effects than those addressed by the current procedures, which are based on observations of tumors in animals exposed to large doses of chemicals in laboratory experiments. The additional health effects to be evaluated are the effects on human cells and genetic material.

6.10.3.2 Limited Availability of Chemical-specific Data

Overestimation of risks and hazards may result from the use of SFs to derive RfDs when data from animal studies are used to predict adverse health effects in humans. The limited availability of toxicity information on some chemicals affects the use of uncertainty and modifying factors in development of the RfDs. In some cases, only limited data are available; in others, a greater number of data are available but are to some degree contradictory.

6.10.3.3 Modeling of Safety Factors

An upper confidence limit on the dose-response relationship is calculated to develop an SF and is used as the final toxicity value. Use of this mathematical model results in a conservative estimate of the potential carcinogenic response and may overestimate the true health effects associated with exposure to a chemical.

6.10.4 Risk and Hazard Characterization

The risk and hazard estimates presented in the AWHHRA are subject to various degrees of uncertainty from a variety of sources. Uncertainties related to data evaluation and selection of COPCs, the exposure assessment, and the toxicity assessment (see above) contribute to the overall uncertainty associated with risk and hazard results. In general, it is unlikely that the AWHHRA risk and hazard results underestimate the true receptor-specific risks and hazards.

Two specific areas of uncertainty were raised in comments received on the draft AWHHRA. These areas of uncertainties are (1) the assumption that chromium is present entirely as hexavalent chromium and (2) the process used to calculate hazard indexes.

First, the assumption that chromium is present entirely as hexavalent chromium (Cr^{+6}) is very conservative. In the environment, chromium is expected to be present almost entirely in the trivalent form (Cr^{+3}). This form of chromium is not carcinogenic (hexavalent chromium is considered a potential inhalation carcinogen) and is less toxic than the hexavalent form. Therefore, this assumption contributes to an overestimation of the risks and hazards associated with exposure to chromium.

Second, consistent with EPA guidance (EPA 1989), HIs are initially calculated by summing chemical- and exposure pathway-specific HQs. If a single chemical is associated with a HQ of greater than 1.0, the HI is not further evaluated. However, in the case where no single chemical is associated with a HQ greater than 1.0, than the HI is reviewed focusing on the target organ or system impacted by each COPC.

Revised HIs are calculated as sums of HQs for COPCs having similar target organs or systems.

Uncertainty is introduced by the fact that HIs with at least one COPC-specific HQ greater than 1.0 are not refined to look at target organs or systems. Therefore, these HIs are likely to overestimate the hazard associated with exposure to multiple COPCs because the COPCs may impact different target organs or systems.

6.11 SUMMARY AND CONCLUSIONS

The AWHHRA for the Resource Area was prepared to evaluate potential exposures to COPCs in multiple media and characterize the associated risks and hazards across the entire Resource Area for several receptor groups. The AWHHRA was completed following a tiered approach (see below) with two primary objectives:

- Identify exposure scenarios (receptor and exposure pathway combinations), locations (for example, particular watersheds or stream segments), and COPCs which are associated with or contribute significantly to cancer risks and hazards greater than acceptable levels
- Focus ongoing and subsequent field investigations on the exposure scenarios, locations, and COPCs associated with or contributing significantly to unacceptable risks and hazards

The AWHHRA was completed in accordance with the final Work Plan TtEMI submitted to IDEQ in April 2002 (TtEMI 2002a). The remainder of this section summarizes the tiered approach followed in completing the AWHHRA (Section 6.11.1), selection of COPCs (Section 6.11.2), the human health CSM and associated receptor groups and complete (or potentially complete) exposure pathways considered quantitatively in the AWHHRA (Section 6.11.3), tier-specific results (Section 6.11.4), and final conclusions (Section 6.11.5).

6.11.1 Tiered Risk Assessment Approach

The risk assessment was completed following a three-step tiered approach (see Figure 2). The purpose of each of the tiers is briefly summarized below.

- Tier 1 was designed as a screening step and used maximum detected medium-specific COPC concentrations and RME exposure parameters to screen out exposure pathways associated with risks less than 1E-06 and HIs less than 1; and COPCs associated with risks less than 1E-07 and HIs less than 0.1.
- Tier 2 focused on the exposure pathways and COPCs retained from Tier 1 and calculated receptor-specific exposures, risks, and hazards under both RME and CTE conditions to provide risk managers with a range of results that can be used to make decisions.
- Tier 3 evaluated two exposure pathways – ingestion of fish tissue and surface water – that were considered to be altered by temporal variations in medium-specific COPC concentrations as a result of varying environmental conditions related to total precipitation and the mass of COPCs introduced into the environment. The Tier 3 assessment employed historical data (from 1998 and 1999) to contrast with the more analytical data for fish tissue and surface water from 2001 that were used in Tier 2. As with Tier 2, Tier 3 was designed to give risk managers a range of results that can be used to make decisions.

6.11.2 Selection of Chemicals of Potential Concern

COPCs were selected following a conservative process in which the maximum detected medium-specific concentration of each chemical was compared against a value equal to twice the average medium-specific background concentration and a medium-specific screening criterion. Chemicals that were found to exceed the background and toxicity screening (if available) concentrations in at least one sample for at least one medium were retained as COPCs in all media with some exceptions. These exceptions are summarized below:

- All chemicals found to be present in waste rock at concentrations that exceeded a value equal to twice the average concentration in soil for the western U.S. were retained as COPCs for waste rock (only)
- Chemicals found to be present at concentrations in aquatic and terrestrial plants greater than twice the mean concentrations in unimpacted aquatic and terrestrial plants and were found at concentrations greater than twice the mean background concentration in the base medium (soil for terrestrial plants and sediment for aquatic plants) were retained as COPCs for terrestrial and aquatic plants
- Chemicals identified as COPCs for terrestrial plants were also selected as COPCs for homegrown produce

COPCs retained for the AWHHRA were:

- Aluminum – Aquatic plants only
- Antimony – Aquatic plants only
- Arsenic – All media
- Cadmium – All media
- Chromium – All media
- Cobalt – Aquatic plants only
- Copper – Aquatic plants only
- Nickel – Terrestrial plants only
- Selenium – All media
- Uranium – Terrestrial plants only
- Vanadium – Aquatic and terrestrial plants
- Zinc – Aquatic and terrestrial plants

6.11.3 Human Health Conceptual Site Model

The human health CSM links potential or actual releases of chemicals from waste rock piles to potential human exposures. Figure 3 presents the human health CSM for the AWHHRA. Three receptor groups were considered as potential receptors in the AWHHRA: (1) recreational hunters and fishers; (2) Native Americans; and (3) subsistence lifestyle. Both adults and children were considered for each receptor group. Only those exposure pathways that are considered complete (or potentially complete) were retained for quantitative evaluation in the AWHHRA. These exposure pathways are identified in Figure 3 and are summarized below:

- Inhalation of particulates – all three receptor groups
- Ingestion of beef cattle tissue (skeletal muscle and offal) – all three receptor groups
- Ingestion of elk tissue (skeletal muscle and offal) – all three receptor groups
- Ingestion of fish tissue – all three receptor groups
- Ingestion of surface soil – subsistence lifestyle receptors only
- Ingestion of aquatic and terrestrial plants – Native American receptors only
- Ingestion of tea brewed from terrestrial plants – Native American receptors only
- Ingestion of homegrown produce – subsistence lifestyle receptors only

6.11.4 Tier-specific Results

The tiered risk assessment approach summarized in Section 6.11.1 was completed for the COPCs selected as summarized in Section 6.11.2, for the complete (or potentially complete) exposure pathways identified in Section 6.11.3 following standard exposure assessment, toxicity assessment, and risk characterization algorithms and procedures. The tier-specific results are summarized in Sections 6.11.4.1 through 6.11.4.3.

6.11.4.1 Tier 1 Results

Based on Tier 1 calculations, the following exposure pathways were identified as being potentially associated with risks greater than or equal to 1E-06 and HIs greater than or equal to 1 and were retained for consideration under Tier 2:

- Ingestion of fish tissue
- Ingestion of surface water
- Ingestion of surface soil

In addition to these three exposure pathways, ingestion of elk and beef cattle tissue were retained for consideration under Tier 2 because hunting and ranching are common and popular activities in the Resource Area and these exposure pathways may be of particular concern to the public.

Also, based on Tier 1 calculations, the following four COPCs were identified as being potentially associated with risks greater than or equal to 1E-07 and HIs greater than or equal to 0.1 and were retained for consideration under Tier 2:

- Arsenic
- Cadmium
- Chromium
- Selenium

6.11.4.2 Tier 2 Results

Under Tier 2, potential exposures to the four COPCs retained from Tier 1 were evaluated under both RME and CTE conditions for the exposure pathways retained from Tier 1. Receptor-specific hazards calculated under RME and CTE conditions are summarized in Tables 6-26 and 6-27. Receptor-specific risks are summarized in Table 6-28 for both RME and CTE conditions. The Tier 2 results are discussed below as follows: RME results first, followed by CTE results.

RME Results

RME hazards are discussed first, followed by risks. Under RME conditions, significant hazards were identified associated with two exposure pathways: ingestion of fish tissue, and ingestion of surface soil. Hazards associated with ingestion of beef cattle and elk tissues remained insignificant and did not exceed 1.0E-01 (beef cattle) and 8.4E-02 (elk) for any receptor. Significantly, no significant hazards were identified associated with ingestion of surface water for any receptor; all hazards were less than 0.1 for the Blackfoot/Little Blackfoot watershed and less than 1E-02 for the other two watersheds.

Hazards associated with potential ingestion of fish tissue are significant only for adult and child subsistence lifestyle receptors for all three watersheds, with one exception. Significant hazards associated with potential exposure to the child Native American were identified only in the Georgetown watershed. Hazards associated with potential ingestion by all receptors were driven by selenium and cadmium, with about 75 percent of the hazard posed by selenium and most of the remaining 25 percent attributable to cadmium. The greatest receptor-specific hazards were identified associated with potential ingestion of fish from the Georgetown watershed, followed by the Blackfoot/Little Blackfoot watershed, and the Salt watershed; however, the watershed-specific hazards did not exceed 7.1 (maximum for the child subsistence lifestyle receptor for the Georgetown watershed) and did not vary by more than a factor of 2.

Hazards associated with ingestion of surface soil were found to be significant (1.6) only for the child subsistence lifestyle receptor at a single location (RA1) near the Rasmussen Mine.

Consistent with these results, the total receptor-specific hazards (based on exposure to all complete [or potentially complete] exposure pathways) are driven almost entirely by ingestion of fish tissue.

Finally, the most significant hazard associated with exposure to background and supplement exposure is the hazard associated with background exposure to arsenic by a child receptor (45). It is assumed that this value may be an overestimate associated with selecting the midpoint of the range of ADIs as the child background exposure. Also, a hazard of 1.33 is associated with background exposure to arsenic by an adult receptor and is greater than 1.0. Hazards associated with background exposure to cadmium by adult and child receptors (0.86) and selenium by adult and child receptors (0.32) are also notable. The hazards associated with background exposure to chromium and supplement exposure to chromium and selenium are negligible.

Significant risks were identified only associated with ingestion of surface soil. The risks ranged about three-fold across the eight locations evaluated: 3.8E-06 to 1.4E-05 for the subsistence lifestyle adult and 7.2E-06 to 2.6E-05 for the child subsistence lifestyle receptor. However, these receptor-specific risks are similar to the risks calculated based on potential exposure to arsenic at concentrations present in unimpacted Resource Area soil and in soil from the western U.S.

CTE Results

Under CTE conditions, no significant hazards or risks were identified for adult and child recreationalists, Native American receptors, or adult subsistence lifestyle receptors. Significant total hazards were identified only for the child subsistence lifestyle receptor (1.6 to 2.0) and were driven by ingestion of fish tissue and soil. Based on a comparison of the watershed-specific EPCs for fish tissue to the concentration of COPCs in fish from unimpacted reaches and the concentration of COPCs in riparian areas to unimpacted Resource Area soils, these receptor-specific hazards are similar to those that would be calculated if it were assumed that receptors ingested only fish from unimpacted reaches or soil from unimpacted areas.

Significant risks were identified only associated with ingestion of surface soil. The risks ranged about three-fold across the seven locations evaluated: 5.7E-07 to 2.1E-06 for the subsistence lifestyle adult and 3.6E-06 to 1.3E-05 for the child subsistence lifestyle receptor. Again, these receptor-specific risks are similar to the risks calculated based on potential exposure to arsenic at concentrations present in unimpacted Resource Area soil and in soil from the western U.S.

6.11.4.3 Tier 3 Results

Under Tier 3, two exposure pathways – ingestion of fish tissue and ingestion of surface water – were reevaluated based on medium-specific EPCs developed from samples collected in 1998 (as compared to Tier 2 in which these exposure pathways were evaluated based on medium-specific EPCs developed from samples collected in 2001). Risks and hazards were characterized based on 1998 analytical data to evaluate any impacts from temporal variations in medium-specific COPC concentrations. Annual precipitation was higher in 1998 than in 2001, and it was postulated that the higher precipitation might have released a greater mass of chemicals from waste rock piles to the environment. The increased chemical loading may have resulted in changes in COPC concentrations in fish tissue and surface water.

Based on the limited amount of data on fish tissue collected in 1998, only ingestion of fish from the Blackfoot/Little Blackfoot watershed was evaluated under Tier 3. Under RME conditions, hazards based on 1998 analytical data were 5 to 6 times lower than calculated in Tier 2 and were determined to be insignificant. Similarly, under CTE conditions, all hazards were determined to be insignificant. It is unclear how the increased precipitation in 1998 may have altered (if at all) the concentration of COPCs in fish tissue. Although similar species of fish were caught and analyzed in 1998 and 2001, the difference in concentrations of COPCs may result more from the collection and analysis of tissue samples from different subpopulations of fish. In any case, comparison of the results under Tiers 2 and 3 illustrate the variability in results over time.

All hazards associated with ingestion of surface water remained insignificant under Tier 3 for all three watersheds.

6.11.5 Final Conclusions

Ingestion of surface soil and fish tissue were the only two exposure pathways associated with risks and hazards greater than acceptable levels.

Hazards associated with ingestion of surface soil were found to exceed 1 only slightly (1.6) at a single location (RA1, near Rasmussen Mine) for the child subsistence lifestyle receptor. No single COPC contributing to this hazard was found to be associated with an HI greater than or equal to 1 (cadmium [0.73], arsenic [0.68], and selenium [0.17]). These three COPCs affect different target organs (see Appendix D). Therefore, it is appropriate to sum only the hazards for cadmium and selenium for the COPC-specific HIs. Because the total HI based on cadmium and selenium (0.90) and each COPC-specific HI is less than 1, the hazard associated with ingestion of surface soil at location RA1 is considered to be insignificant.

The receptor-specific risks associated with ingestion of surface soil were found to be significant (greater than or equal to 1E-06) but within EPA's acceptable risk range (1E-06 to 1E-04) (EPA 1990). In addition, these risks were found to be comparable to risks associated with exposure to concentrations of arsenic in unimpacted Resource Area soil and in soil from the western U.S. Therefore, the arsenic concentrations in riparian area soils do not contribute significantly to incremental cancer risks for all receptors evaluated in the AWHHRA.

No cancer risk was associated with ingestion of fish because arsenic (the only COPC considered potentially carcinogenic through ingestion) was not detected in any samples of fish tissue. Ingestion of fish tissue was found to be associated with hazards greater than 1 only for subsistence lifestyle receptors (all three watersheds) and the child Native American receptor for the Georgetown watershed, based on 2001 data. All hazards associated with ingestion of fish tissue were determined to be less than 1.0 based on 1998 data.

CTE conditions more accurately reflect receptor-specific hazards due to the following reasons:

(1) The large size of the unimpacted area of watersheds in the Resource Area. Receptors are most likely to spend much more time in the unimpacted areas of the watershed as compared to the impacted areas simply due to large difference in size between these areas. Impacted stream reaches represent only about 27 percent of the total stream reaches in the Blackfoot/Little Blackfoot watershed, and less than 10 percent in the other two watersheds. As such, receptors will most likely be exposed under conditions that more closely resemble CTE, rather than RME conditions.

(2) The small sample sizes in unimpacted areas and the EPC calculation methodology confound the magnitude of exposure of each receptor in Resource Area. For example, there was a relatively small fish sample size in unimpacted areas as compared to impacted areas. As such, all unimpacted reaches were considered as a single area represented by a single mean concentration. The representation of data from the unimpacted reaches in the statistical derivation of EPCs, therefore, was disproportionately lower than the representation of data from impacted areas. Therefore, EPCs for RME conditions in some cases represented the maximum detected concentration or concentrations near maximum detected concentrations. Maximum detected concentrations were invariably located in impacted areas of the watershed. Therefore, RME conditions represented exposures that occurred mostly within impacted areas, which, in turn, represent a small percentage of the overall Resource Area. Receptors are more likely to spend time in unimpacted rather than impacted areas due to the differences in sizes between these areas.

It is possible that individual receptors may selectively fish only from impacted stream reaches and catch only fish with elevated concentrations of COPCs in tissue. However, it is considered unlikely that this situation will persist for long or occur in many individuals. Accordingly, the hazards calculated under CTE conditions (based on COPC-specific EPCs calculated entirely on a area-weighted basis that takes into account that the majority of all three watersheds appear to be unimpacted by mining activities) more accurately reflect actual receptor-specific hazards.

As noted above, the receptor-specific hazards calculated under CTE range were found to be significant only for the child subsistence lifestyle receptor and range from 1.6 to 2.0. Although still significant, these hazards are similar to the hazards associated with ingestion of fish only from unimpacted reaches and soil for unimpacted areas. Therefore, ingestion of fish tissue and soil are expected to be associated with only a limited hazard that can be expected to increase to the extent that receptors fish more frequently in impacted stream reaches or are exposed to soil in unimpacted areas.

7.0 AREA WIDE ECOLOGICAL RISK ASSESSMENT

Typically, the ERA conducted by MW (1999b) would be equivalent to a screening-level ERA. This assessment is equivalent to a baseline ERA. However, EPA (EPA 1997b) guidance on ERA is based on evaluating single waste sites or areas of relatively limited aerial extent. This process was adapted to allow assessment of a site the size of the Resource Area.

The risk assessment process uses multiple tiers of assessment that represent different bounding conditions to provide adequate information for the risk managers. The process used is discussed in the following sections.

7.1 AREA WIDE ECOLOGICAL RISK ASSESSMENT APPROACH

The aerial extent of the Resource Area is large, with multiple mine sites across the area. Chemicals from mining may impact a wide variety of habitats and receptors. No single line of evidence will adequately assess the potential risks to ecological receptors in the area from mining-related releases. Therefore, multiple lines of evidence were used to assess the potential risk to ecological receptors. These lines of evidence are described fully in Section 7.5.2 but consist of: (1) development of HQs for various receptors based on modeled doses; (2) comparison of concentrations in tissue to literature data on effects; (3) comparisons of chemical concentrations between impacted and reference areas; and (4) comparison of concentration on media to accepted benchmarks. The primary line of evidence was development of HQs for the representative receptors and effects. Because of issues concerning the quality and comparability of historical data, only data collected during calendar year 2001 was used to develop the HQs. This primary line of evidence was supplemented by information from the other lines of evidence. The strategy for evaluating HQs for various receptors for the Resource Area is described in the following sections and shown in Figure 5.

7.1.1 Tier 1 Assessment

The first tier is a "worst-case" screening-level activity directed at eliminating any chemicals that present negligible risks, chemicals that occur at background levels with no increased concentrations associated with mining, or chemicals that occur near or below the detection limits of laboratory instrumentation. In this step, the highest observed concentration for each medium and chemical and the most conservative exposure parameters (see Table 7-4) were used to calculate an HQ for each target species and COPEC.

Any chemicals that do not present a potential risk using this worst-case scenario can then be safely removed from further consideration on a receptor-specific basis (see Figure 5).

7.1.2 Tier 2 Assessment

In the second tier, chemicals and receptors that were not eliminated in Tier 1 were evaluated on an area-wide basis using area-weighted EPCs for each medium and mean exposure parameters for each receptor intended to represent an estimate of the average population-level exposures (see Figure 5). IDEQ chose to use a targeted sampling approach to support development of area-weighted EPCs. IDEQ deemed this approach scientifically valid and it provides a cost-effective method within the accepted tolerances of typical risk assessment processes without collecting the excessive number of samples associated with purely statistical approaches.

Each medium was represented by average values from impacted and unimpacted data sets for the riparian areas (examining the aquatic and riparian receptors restricted to this ecosystem) and the overall area (including both riparian and terrestrial areas) for wide-ranging receptors (all other receptors that may be found in both the aquatic and riparian and terrestrial areas). These values were area-weighted based on surface area ratios, lengths of stream segments other applicable weighting criteria (see Appendix C). HQs were developed based on NOAEL benchmarks as will be discussed in Section 7.6.3. The dose calculation and development of HQs for each species was conducted as described in Section 7.6.

Although the mines occupy a large area, the combined area of the mine sites is about only 3 percent of the total Resource Area. Therefore, HQs were calculated for the following data sets to place the results in the appropriate context.

- Aquatic and Riparian Areas – All data were used to calculate EPCs using an area-weighted approach for both impacted and background areas. HQs developed from this data set represent the potential risk to overall populations of the selected receptors (red-winged blackbird, great blue heron, mallard duck, and mink).
- Overall Aquatic, Riparian, and Terrestrial Areas – All data were used to calculate EPCs using an area-weighted approach for both impacted and background areas for the aquatic, riparian, and terrestrial ecosystems. HQs developed from this data set represent the potential risk to overall populations of the selected receptors (all other receptors that are not included above).

The HQs derived from these data sets provide sufficient information to place the calculated risks in an appropriate context to represent the average risk in the Resource Area.

7.1.3 Tier 3 Assessment

For an area the size of the Resource Area, the data available for the risk assessment are limited in nature and extent. Therefore, significant uncertainties are inherent in the risk assessment. These uncertainties include temporal components of chemical releases to surface water, EPCs used in the calculations, and actual exposure experienced by the various receptors. Tier 3 provided additional assessment to assess the uncertainties of various parameter values used in the risk assessment calculations (see Figure 5). This included running separate calculations based on the mean concentrations of COPECs from historical data and assessing uncertainties in the exposure parameters to evaluate their effects on the HQ values calculated in Tier 2. The results of the risk characterization were also analyzed in terms of other lines of evidence described in Section 7.5.2.

7.2 IDENTIFICATION AND PRIORITIZATION OF CHEMICALS OF POTENTIAL ECOLOGICAL CONCERN

Chemicals detected in the various media sampled were subjected to a screening process to focus the ERA on chemicals that are site-specific and that pose the greatest risk to ecological receptors (see Figure 5). Screening factors consist of the following:

Surface Water

- Frequency of detection
- EPA. 1999. "National Recommended Water Quality Criteria – Corrected." EPA/822/2-99/001. April.
- For background screening comparisons, an average concentration was calculated for each chemical using data collected from streams upgradient to and in the undisturbed region of the Resource Area (considered to be representative of pre-mining conditions). Average and single-point concentrations that are more than 2 times the calculated background average were considered impacted and were evaluated in the risk assessment process.

Freshwater Sediments

- Frequency of detection
- Comparison to background concentrations
- Consensus-Based Freshwater Sediment Quality Guidelines (MacDonald and others 2000)
- Selected freshwater threshold effects levels from National Oceanic and Atmospheric Administration (NOAA) Screening Quick-Reference Tables (SQuiRT) (EPA 1999)

- Suggested toxicity threshold for selenium taken from Van Derveer and Canton (1997), San Joaquin Valley Drainage Program (1990), and Lemly and Smith (1990, all as cited in Skorupa 1998)

Soils

- Frequency of detection
- Comparison to background concentrations
- Soil screening criteria as provided for limited inorganics from Ecological Soil Screening Level Guidance (EPA 2000a); Kapustka and others (2000); and EPA (2001)

Table 7-1 presents the screening benchmarks and criteria for surface water, sediment, and soil. The screening process is summarized in Section 5.0 and is described in detail in Appendix B. The method used for weighting of the data is presented in Appendix C. Retained chemicals are referred to as COPECs.

7.3 ECOLOGICAL FOOD WEB IN RESOURCE AREA

Food webs are organized by class guilds, which are linked based on dietary relationships. Food webs are meant to illustrate how chemicals have the potential to be transferred within an ecosystem. The various food chains represent potential exposure pathways to COPECs. The importance of a food chain as a dietary exposure pathway depends on dietary habits of the receptor. The boxes in the ecological CSM represent the expected feeding guilds in each of the ecosystems in the Resource Area (see Figure 6). Feeding guilds are groups of organisms that exploit similar resources for food.

7.3.1 Terrestrial Food Web

Figure 6 illustrates the food web interactions for the terrestrial food web for the Resource Area. The primary producers include wheatgrass (*Agrophyron* spp.), alfalfa (*Medicago sativa*), and brome grass (*Bromus* spp.).

The primary consumers are composed of terrestrial invertebrates and herbivorous birds and mammals. Diets of birds can vary greatly, and numerous bird species may also be considered herbivorous either all or part of the year, depending on conditions such as availability of prey and life stage. Terrestrial invertebrates include plant-eating insects such as grasshoppers, insect larvae, and beetle larvae. Other primary consumers include herbivorous mammals and herbivorous birds. Specific species of each of these guilds are presented in Figure 6, and the assessment endpoints are highlighted.

The secondary consumers consist of terrestrial omnivorous birds and 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 population of the prey. Specific species of each of these guilds are presented in Figure 6, and the assessment endpoints are highlighted.

Tertiary consumers include carnivorous mammals and raptors. These species feed exclusively by preying on other animals. Specific species of each of these guilds are presented in Figure 6, and the assessment endpoints are highlighted.

7.3.2 Aquatic and Riparian Food Web

Figure 6 illustrates the interactions within the food web for freshwater and riparian areas. Primary producers include phytoplankton and aquatic macrophytes. These organisms represent the basis of the food chain. Emergent and riparian primary producers also provide shelter and habitat for higher trophic level species. Specific species of each of these guilds are presented in Figure 6, and the assessment endpoints are highlighted.

Primary consumers include zooplankton, benthic invertebrates, 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. These organisms are closely associated with the sediments and are exposed to the contamination in the sediment dermally and through direct and incidental ingestion. Benthic-feeding fish tend to be omnivorous and feed on both benthic invertebrates and aquatic plants. Aquatic and riparian herbivorous birds and mammals consume vegetation found in the aquatic or riparian environment. Specific species of each of these guilds are presented in Figure 6, and the assessment endpoints are highlighted.

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 of each of these guilds are presented in Figure 6, and the assessment endpoints are highlighted.

7.4 ECOLOGICAL EFFECTS, COMPLETE EXPOSURE PATHWAYS, AND ECOSYSTEMS POTENTIALLY AT RISK

This section discusses the fate and transport and the complete exposure pathways for the COPEC, and the ecosystems potentially at risk. Based on the initial, the COPECs are cadmium, chromium, copper, nickel, selenium, vanadium, and zinc.

7.4.1 Ecological Effects of Chemicals of Potential Ecological Concern

An understanding of how the COPECs adversely affect 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. Toxicity profiles for each of these COPECs are presented in Appendix F.

7.4.2 Complete Exposure Pathways

For ecological receptors, the potential exposure pathways for movement of chemicals that results from phosphate mining 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, surface water, 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 selenium. These two pathways are likely to contribute the greatest percentage of the overall ecological risks.

The other pathways (although potentially complete) were deemed 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. In addition, it was already taken into account through incidental ingestion by the ingestion pathway. Inhalation exposures are also poorly understood in an ecological risk context because no toxicity data are available for comparison.

7.4.3 Ecosystems Potentially at Risk

An important part of the problem formulation process is to identify the environmental setting and the 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 project area is transitional between the Great Basin vegetation to the south and the Rocky Mountain vegetation to the north (MW 1999b). Six vegetation types are found within the project 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
- Lotic Aquatic Community

Based on previous investigations, the project 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 seven species of amphibians (USGS and FS 1977; FS 1985, 1997; Idaho Conservation Center Data Base [(ICCDB) 1999; all as cited in MW 1999b]. A 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 lists.

The Resource Area is divided into two major riverine systems: the Bear River, and the Snake River (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, and Ross Fork, 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.

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 6, was developed to assist in identifying specific receptors that might be directly or indirectly exposed to COPECs and to carry out the exposure assessment. The ecological CSM illustrates the following:

- The abiotic media (that is, 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 that feed on the source or other organisms that feed on the source. A food web shows how energy or, in this case, chemicals, may be transferred within an ecosystem. A food chain represents a potential exposure pathway to a COPEC. The importance of the exposure pathway depends on the dietary habits of the receptor and the COPEC.

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

7.5 ASSESSMENT AND MEASUREMENT ENDPOINTS

To assess ecological risks, identification of potential assessment and measurement endpoints are presented as one of the components of problem formulation. Assessment endpoints represent potentially significant ecological impacts and are selected based on the ecosystems, communities, and species that are of particular concern at the site under study. For each assessment endpoint, one or more measurement endpoints are selected to integrate modeled or field data with the individual assessment endpoint. Measurement endpoints are measurable responses to a stressor that are related to the valued assessment endpoint (Suter 1993). Table 7-2 presents the assessment endpoints for each guild in the terrestrial and aquatic and riparian ecosystems and the associated assessment receptor.

7.5.1 Assessment Endpoints

Assessment endpoints should be accepted depending on whether the exposure pathway is complete, whether the metal is bioavailable, and whether the assessment endpoint is expected to be the most toxicological sensitive to exposure to the metal.

7.5.1.1 Assessment Endpoints for the Terrestrial Food Web Ecosystem

Using the terrestrial habitat-specific food web, assessment endpoints may be selected to focus the risk assessment and characterization (see Figure 6 and Table 7-2). Herbaceous plant abundance, habitat, and productivity are attributes to be preserved in a terrestrial ecosystem. As food, herbaceous plants provide an important pathway for energy and nutrient transfer from soil to herbivorous and omnivorous receptors. Herbaceous plants also provide critically important habitat for terrestrial animals. Woody plant habitat and productivity are critical attributes to be protected. Herbivore productivity is an attribute to be protected in the terrestrial ecosystem because herbivores incorporate energy and nutrients from plants and transfer it to higher trophic levels. Herbivores are integral to the success of terrestrial plants, because they disperse plants seeds.

Productivity and function of soil invertebrates as decomposers are attributes to be preserved in a terrestrial ecosystem. They provide a mechanism for the physical breakdown of detritus for microbial decomposition, which is a vital function. Soil invertebrates function as a major source of food for omnivorous birds and mammals and reptiles.

Productivity of omnivores is an important attribute to be protected because omnivores incorporate energy and nutrients from lower trophic levels and transfer them to higher-level omnivores and carnivores.

Based on knowledge of the toxicity of metals and metalloids, site-specific terrestrial assessment endpoints would include the following terrestrial guilds:

- Terrestrial plants
- Terrestrial invertebrates
- Terrestrial herbivorous birds
- Terrestrial herbivorous mammals
- Terrestrial omnivorous birds
- Terrestrial omnivorous mammals
- Reptiles
- Terrestrial carnivorous mammals
- Terrestrial carnivorous birds

Although some individual receptors exhibit a greater potential for exposure than others, each assessment endpoint is toxicologically sensitive to metals and is expected to have a complete exposure pathway.

Terrestrial Plants

Some terrestrial plants are highly effective in removing various metals from contaminated soil. Some metals are not essential for plant growth, but in some plants can cause toxicity, as exemplified by chlorosis, stunting, and yellowing of leaves. Plants that bioaccumulate metals may transform them into organic forms that become highly bioavailable when the plant is eaten or dies. Terrestrial invertebrates, terrestrial herbivorous birds and mammals, and terrestrial omnivorous birds and mammals that consume plants are potentially at risk. Terrestrial plants were not directly assessed; however, protection of terrestrial plants will be afforded through the protection of the guilds that use this resource, as defined below.

Terrestrial Invertebrates

The terrestrial invertebrates include soil invertebrates, such as earthworms, and other invertebrates, such as various insects that feed directly on plants. These receptors are important in stabilization of the soil and are an important source of food for omnivorous birds and mammals, thereby providing for the transfer of energy to higher trophic levels. Significant exposure is predicted for terrestrial insects that feed on plants. However, metals may not be directly toxic to terrestrial invertebrates, but consumers of these terrestrial invertebrates are highly susceptible to toxic effects of accumulated metals. For example, there is no data on the toxicity of selenium for terrestrial invertebrates, and the toxic effects of directly consuming selenium-contaminated invertebrates are more important than any indirect ecological effects. Omnivorous birds and mammals are most at risk from consuming terrestrial invertebrates. Terrestrial invertebrates were not directly assessed; however, protection of terrestrial invertebrates will be afforded through the protection of the guilds that use this resource, as defined below.

Terrestrial Herbivorous Birds and Associated Assessment Endpoints

Terrestrial herbivorous birds are expected to be highly exposed to metals based on their expected diet requirements and through incidental ingestion of soil contaminated by metals. As an example, exposure to selenium in the diet of terrestrial herbivorous birds is associated with reproductive abnormalities, congenital malformations, selective bioaccumulation, and growth retardation. The following assessment endpoint was defined for terrestrial herbivorous birds.

- Protection of terrestrial herbivorous birds that may ingest contaminated plants and surface water and incidental ingestion of associated soil from potentially lethal, reproductive, systemic, or general toxic effects of metals that result from phosphate mining.

Assessment endpoints and associated receptors are presented in Table 7-2.

Terrestrial Herbivorous Mammals and Associated Assessment Endpoints

Excessive metals in the herbivorous mammal's food source may cause systemic or general toxic effects. The following assessment endpoint was defined for terrestrial herbivorous mammals.

- Protection of terrestrial herbivorous mammals that may ingest contaminated plants and surface water and incidental ingestion of associated soil from potentially systemic or general toxic effects of metals that result from phosphate mining.

Assessment endpoints and associated receptors are presented in Table 7-2.

Terrestrial Omnivorous Birds and Associated Assessment Endpoints

Terrestrial omnivorous birds are expected to be highly exposed to metals based on their expected dietary requirements (terrestrial plants and invertebrates) and through incidental ingestion of soil contaminated by metals. As an example, exposure to selenium in the diet of terrestrial omnivorous birds and incidental ingestion of associated soil is associated with reproductive abnormalities, congenital malformations, selective bioaccumulation, and growth retardation.

The following assessment endpoint was defined for terrestrial omnivorous birds.

- Protection of terrestrial omnivorous birds that may ingest contaminated food and surface water and associated soil or sediment from potentially lethal, mutagenic, reproductive, systemic, or general toxic effects of metals resulting from phosphate mining.

Assessment endpoints and associated receptors are presented in Table 7-2.

Terrestrial Omnivorous Mammals and Associated Assessment Endpoints

Excessive metals in the omnivorous mammal's food source may cause systemic or general toxic effects. As an example, there have been no well-documented cases of widespread selenosis reported for wild mammals, including terrestrial omnivorous mammals, and selenium does not biomagnify at this level in the food chain. Terrestrial omnivorous mammals are a potential assessment endpoint as follows:

- Protection of terrestrial omnivorous mammals that may ingest contaminated plants, prey, and surface water and incidental ingestion of associated soil and sediment from potentially systemic or general toxic effects of metals resulting from phosphate mining.

Assessment endpoints and associated receptors are presented in Table 7-2.

Reptiles

Mortality in reptiles caused by metal intoxication has not been reported (Linder and Grillitsch 2000). Ambient levels of metals in free-ranging reptiles have rarely been reported in the literature. Ingestion of food is the major cause of exposure to metals in reptiles. Based on the available data, reptiles do not seem to biomagnify metals to the extent that would correspond to their trophic level (Linder and Grillitsch 2000). Reptiles will not be directly assessed because of the indication that this guild is not affected by the presence of excess levels of metals nor is an adequate database available for proper comparison to assess risk. It is assumed that protection of the terrestrial ecosystem for the other guilds will confer some protection for reptiles.

7.5.1.2 Assessment Endpoints for the Aquatic or Riparian Food Web Ecosystem

As in the terrestrial ecosystem, phytoplankton and aquatic macrophytes transfer energy from the sediments to herbivorous invertebrates, herbivorous birds and mammals, and omnivorous birds and mammals. Productivity and function of benthic invertebrates as decomposers are attributes to be preserved in an aquatic ecosystem. They provide a mechanism for the physical breakdown of detritus for microbial decomposition, which is a vital function. Benthic invertebrates function as a major source of food for benthic-feeding fish, amphibians, and omnivorous birds. Omnivore productivity is an important attribute to be protected because omnivores incorporate energy and nutrients from lower trophic levels and transfer it to higher-level omnivores and carnivores.

Based on knowledge of the toxicity of various metals, site-specific aquatic or riparian assessment endpoints would include the following:

- Phytoplankton and aquatic macrophytes
- Zooplankton and benthic invertebrates
- Aquatic and riparian herbivorous birds
- Aquatic and riparian herbivorous mammals
- Benthic fish
- Aquatic and riparian omnivorous birds
- Aquatic and riparian omnivorous mammals
- Aquatic and riparian piscivorous birds
- Aquatic and riparian benthic-feeding birds
- Aquatic and riparian omnivorous mammals
- Aquatic and riparian carnivorous mammals
- Fish
- Amphibians

Although some individual receptors exhibit a greater potential for exposure than others, each assessment endpoint is toxicologically sensitive to various metals and is expected to have a complete exposure pathway.

Phytoplankton and Aquatic Macrophytes

Phytoplankton and aquatic macrophytes are highly effective at removing metals from sediment contaminated by metals. As an example, selenium is not essential for plant growth. Plants that bioaccumulate selenium transforms the selenium into organic forms that become highly bioavailable when the plant is eaten or dies. Benthic invertebrates, herbivorous birds and mammals, and terrestrial omnivorous birds and mammals that consume plants are potentially at risk from contamination by metals. Phytoplankton and aquatic macrophytes will not be directly assessed; however, protection of phytoplankton and aquatic macrophytes will be afforded through the protection of the guilds that use this resource, as defined below.

Zooplankton and Benthic Invertebrates

Significant exposure is predicted for zooplankton and benthic invertebrates. Invertebrates are an important source of protein for various fish and omnivorous and benthic-feeding birds. As an example of toxicity of the metals, selenium appears to affect the survival of zooplankton (rotifers and cladocerans) and benthic invertebrates (midge larvae) (Jarvinen and Ankley 1999), and consumers of these invertebrates are highly susceptible to toxic effects of accumulated selenium. There is some data on the toxicity of selenium for benthic invertebrates, and the toxic effects that occur from directly consuming selenium-contaminated invertebrates are important. Amphibians, benthic-feeding fish, fish, and benthic-feeding birds are most at risk from the toxicity of metals from consuming benthic invertebrates. Zooplankton and benthic invertebrates will not be directly assessed; however, protection of zooplankton and benthic invertebrates will be afforded through the protection of the guilds that use this resource, as defined below.

Aquatic and Riparian Herbivorous Birds and Associated Assessment Endpoints

Aquatic and riparian herbivorous birds are expected to be highly exposed to metals based on their expected dietary requirements and through incidental ingestion of metal-contaminated sediment or soil. As an example, selenium exposure in the diet and drinking water of aquatic and riparian herbivorous birds is associated with reproductive abnormalities, congenital malformations, selective bioaccumulation, and growth retardation.

Aquatic and riparian herbivorous birds are a potential assessment endpoint as follows:

- Protection of riparian herbivorous birds that may ingest contaminated plant food and incidental ingestion of associated soil, sediment, and surface water from potentially lethal, reproductive, systemic, or general toxic effects of metals resulting from phosphate mining.

Assessment endpoints and associated receptors are presented in Table 7-2.

Aquatic and Riparian Herbivorous Mammals and Associated Assessment Endpoints

Excessive metals in the aquatic and riparian herbivorous mammal's food source may cause systemic or general toxic effects. As an example, there have been no well-documented cases of widespread selenosis reported for wild mammals, and selenium does not biomagnify at this level in the food chain. Aquatic and riparian herbivorous mammals are a potential assessment endpoint as follows:

- Protection of aquatic and riparian herbivorous mammals that may ingest contaminated plant food and incidental ingestion of associated soil, sediment, or surface water from potentially systemic or general toxic effects of metals resulting from phosphate mining.

Assessment endpoints and associated receptors are presented in Table 7-2.

Benthic Fish and Associated Assessment Endpoints

Protection of benthic fish is imperative since aquatic and riparian piscivorous birds, aquatic and riparian benthic-feeding birds, aquatic and riparian omnivorous mammals and birds, and amphibians feed on adult and young benthic fish. As an example, elevated levels of selenium can cause reproductive failure in fish, anemia, reduced hatch, reduced growth, reduced swimming rate, and chromosomal aberrations (Hodson and others 1980; Adams 1976; Bovee and O'Brien 1982; and Krishnaja and Rege 1982; all as cited Eisler 1985). Lemly (1993a and 1996a, as cited in Skorupa 1998) concluded that the most precise way to assess risk associated with exposure of fish to selenium was to measure the selenium levels in gravid ovaries. Benthic fish are a potential assessment endpoint as follows:

- Protection of benthic fish from contaminated food and associated sediments form potentially lethal, mutagenic, reproductive, systemic or general toxic effects of metals resulting from phosphate mining.

Assessment endpoints and associated receptors are presented in Table 7-2.

Aquatic and Riparian Omnivorous Birds and Associated Assessment Endpoints

Aquatic and riparian omnivorous birds are expected to be highly exposed to metals based on their expected diet requirements (aquatic and terrestrial plants and invertebrates) and through incidental ingestion of soil, sediment, or water contaminated by metals. As an example, exposure to selenium in the diet and drinking water of aquatic and riparian omnivorous birds is associated with reproductive abnormalities, congenital malformations, selective bioaccumulation, and growth retardation. Aquatic and riparian omnivorous birds are a potential assessment endpoint as follows:

- Protection of aquatic and riparian omnivorous birds that may ingest contaminated food and associated soil, sediment, or water from potentially lethal, mutagenic, reproductive, systemic, or general toxic effects of metals resulting from phosphate mining.

Assessment endpoints and associated receptors are presented in Table 7-2.

Aquatic and Riparian Piscivorous Birds and Associated Assessment Endpoints

Aquatic and riparian omnivorous birds are expected to be highly exposed to metals based on their expected diet requirements (benthic fish and other fish species) and through incidental ingestion of sediment or water contaminated by metals. As an example, exposure to selenium in the diet and drinking water of aquatic and riparian piscivorous birds is associated with reproductive abnormalities, congenital malformations, selective bioaccumulation, and growth retardation.

Aquatic and riparian piscivorous birds are a potential assessment endpoint as follows:

- Protection of aquatic and riparian piscivorous birds that may ingest contaminated food and associated sediment or water from potentially lethal, mutagenic, reproductive, systemic, or general toxic effects of metals resulting from phosphate mining.

Assessment endpoints and associated receptors are presented in Table 7-2.

Aquatic and Riparian Benthic-Feeding Birds and Associated Assessment Endpoints

Aquatic and riparian benthic-feeding birds are expected to be highly exposed to metals based on their expected dietary requirements (benthic invertebrates) and through incidental ingestion of sediment or water contaminated by metals. As an example, exposure to selenium in the diet and drinking water of aquatic and riparian benthic-feeding birds is associated with reproductive abnormalities, congenital malformations, selective bioaccumulation, and growth retardation.

Aquatic and riparian benthic-feeding birds are a potential assessment endpoint as follows:

- Protection of aquatic and riparian benthic-feeding birds that may ingest contaminated food and associated sediment or water from potentially lethal, mutagenic, reproductive, systemic, or general toxic effects of metals resulting from phosphate mining.

Assessment endpoints and associated receptors are presented in Table 7-2.

Aquatic and Riparian Omnivorous Mammals and Associated Assessment Endpoints

Excessive metals in the omnivorous mammal's food source may cause systemic or general toxic effects. As an example, there have been no well-documented cases of widespread selenosis reported for wild mammals, including aquatic and riparian omnivorous mammals, and selenium does not magnify at this level in the food chain. Aquatic and riparian omnivorous mammals are a potential assessment endpoint as follows:

- Protection of aquatic and riparian omnivorous mammals that may ingest contaminated plant food and incidental ingestion of associated soil, sediment, or water from potentially systemic or general toxic effects of metals resulting from phosphate mining.

Assessment endpoints and associated receptors are presented in Table 7-2.

Riparian Carnivorous Mammals and Associated Assessment Endpoints

Excessive ingestion of metals by aquatic and riparian carnivorous mammals may cause systemic or general toxic effects. Aquatic and riparian carnivorous mammals are a potential assessment endpoint as follows:

- Protection of aquatic and riparian carnivorous mammals that may ingest contaminated prey and incidental ingestion of associated soil, sediment, and water from potentially systemic or general toxic effects of metals resulting from phosphate mining.

Assessment endpoints and associated receptors are presented in Table 7-2.

Fish and Associated Assessment Endpoints

Protection of fish is imperative since aquatic and riparian piscivorous birds, benthic-feeding birds, aquatic and riparian omnivorous mammals and birds, and amphibians feed on adult and young fish. As an example, elevated levels of selenium can result in reproductive failure, anemia, reduced hatch, reduced growth, reduced swimming rate, and chromosomal aberrations (Hodson and others 1980; Adams 1976; Bovee and O'Brien 1982; and Krishnaja and Rege 1982; all as cited Eisler 1985). Lemly (1993a and 1996a, as cited in Skorupa 1998) concluded that the most precise way to assess risk associated with exposure of fish to selenium was to measure the selenium levels in gravid ovaries. Fish are a potential assessment endpoint as follows:

- Protection of fish from contaminated food and associated sediments or water from potentially lethal, mutagenic, reproductive, systemic or general toxic effects of metals resulting from phosphate mining.

Assessment endpoints and associated receptors are presented in Table 7-2.

Amphibians

Amphibians may be an important source of food for riparian omnivorous birds and mammals and riparian carnivorous mammals. There are little data on the toxicity of metals to amphibians (Sparling and others 2000). As an example of the toxicity of metals, Skorupa (1998) suggests that based on the similarity of the toxic threshold values for fish and bird eggs (two other classes of egg-laying vertebrates) it is probably safe to assume the following for amphibians:

- Reproductive impairment is among the most sensitive response variables
- Populations producing eggs with equal to or greater than 10 mg/kg selenium are reproductively impaired

Amphibians will not be directly assessed because of the paucity of data on the toxicity of metals; however, protection to amphibians will be afforded through the protection of the guilds that use this resource as defined above.

There may be some overlap between the habitat requirements of the species listed for the aquatic and riparian ecosystem and the terrestrial ecosystem.

7.5.1.3 Assessment Endpoints for Tertiary Consumers

Productivity of carnivores is an attribute to be protected because they provide food to other carnivores, omnivores, scavengers, and microbial decomposers. In addition, carnivores affect the abundance, reproduction, and recruitment of lower trophic levels, such as herbivores and omnivores, through predation.

Based on knowledge of the toxicity of metals, site-specific tertiary consumer endpoints include the following:

- Carnivorous mammals
- Raptors

Although some individual receptors exhibit a greater exposure potential than others, each assessment endpoint is toxicologically sensitive to metals and is expected to have a complete exposure pathway.

Carnivorous Mammals and Associated Assessment Endpoints

Excessive metals in the carnivorous mammal's food source may cause systemic or general toxic effects. However, there have been no well-documented cases of widespread selenosis reported for wild mammals, including carnivorous mammals, and selenium does not magnify at this level in the food chain. Carnivorous mammals are a potential assessment endpoint as follows:

- Protection of carnivorous mammals that may ingest contaminated prey and incidental ingestion of associated soil, sediment, or water from potentially systemic or general toxic effects of metals resulting from phosphate mining.

Assessment endpoints and associated receptors are presented in Table 7-2.

Raptors and Associated Assessment Endpoints

Raptors are expected to be exposed to metals based on their expected dietary requirements and through incidental ingestion of contaminated soil, sediment, or water. As an example, exposure to selenium in the diet and drinking water of raptors is associated with reproductive abnormalities, congenital malformations, selective bioaccumulation, and growth retardation (Eisler 1985).

Raptors are a potential assessment endpoint as follows:

- Protection of raptors that may ingest contaminated prey and associated soil, sediment, or water from potentially lethal, mutagenic, reproductive, systemic, or general toxic effects of metals resulting from phosphate mining.

Assessment endpoints and associated receptors are presented in Table 7-2.

7.5.2 Measurement Endpoints

After assessment endpoints are identified for each guild, possible measurement endpoints can be established. Measurement endpoints are measurable responses to a stressor that are related to the valued assessment endpoint (Suter 1993).

Multiple lines of evidence, which serve as measurement endpoints, have been considered for integration to assess ecological risk for the various identified guilds:

- Collect, analyze, and evaluate data on residues in tissue
- Compare concentrations of COPECs in tissues with levels that are reported in scientific literature to be harmful
- Measure concentrations of COPECs in selected food items
- Compare concentrations in food items to levels from areas not impacted by phosphate mining
- Model chemical levels in food items to calculate a potential dose and compare this dose with appropriate toxicity threshold values

Table 7-3 presents the list of measurement endpoints used to evaluate each assessment endpoint receptor.

The tissues of terrestrial plants, aquatic macrophytes, terrestrial invertebrates, benthic invertebrates, small herbivorous and omnivorous mammals, and benthic and other fish have been collected and analyzed. Data on residues in tissue are a strong indicator of chemical bioavailability. These concentrations in tissue can then be compared with similar concentration levels in the literature to ascertain if there is a potential risk to these respective guilds. In addition, these data can be used to model a daily dose ingested by higher-level mammals and birds.

The exposure dose was compared with a toxicity reference value (TRV). TRVs are available for birds and mammals. There are some uncertainties associated with this measurement endpoint:

- The assumption that the chosen receptor adequately represents the guild of interest
- The assumption that food items chosen for collection and analysis of tissues are those most commonly consumed by the receptor
- May be difficult to find adequate area free of impacts from phosphate mining for comparison
- TRVs are developed from laboratory data and may not be accurate surrogates for wildlife

There are adequate TRVs that can be used to assess risk to birds and mammals. Therefore, the use of tissue residue data was to model doses to upper trophic level receptors.

7.6 METHODOLOGY FOR EVALUATION OF EXPOSURE AND EFFECTS TO VERTEBRATE RECEPTORS

The total exposure from ingestion for each receptor of concern was calculated as the sum of the estimates of the dietary and soil, sediment, or surface water exposure for each COPEC. The resultant exposure dose was compared with a TRV to assess whether there is a hazard to the receptor for a COPEC.

7.6.1 Development of Exposure Estimates

The following generic equation was customized for each terrestrial and aquatic and riparian assessment endpoint:

$$Dose_{Total} = (SUF) \text{ x } \frac{[(C_{media} \text{ x } IR_{media}) + (C_{prey})(IR_{prey})]}{BW} \qquad (7\text{-}1)$$

where

$Dose_{Total}$	=	Daily dose resulting from ingestion of terrestrial or riparian soil and or sediment and prey (milligrams COPEC per kilogram body weight per day [mg COPEC/kg BW/Day])
C_{media}	=	Concentration of chemical in terrestrial or riparian soil, sediment, or surface water (mg/kg or milligram per liter [mg/L]) during incidental ingestion of that media
C_{prey}	=	(C_{prey}), prey may consist of aquatic invertebrates, riparian insects, riparian insects and worms, terrestrial insects, fish, riparian mammals, terrestrial mammals

		(mg/kg). Actual concentrations were used since no BTF was calculated for these prey types (see Section 7.6.2).
C_{prey}	=	(C_{media}) (BTF), tissue concentration factor used for aquatic plants, riparian plants, and terrestrial plants where a BTF was calculated, see Section 7.6.2.
BTF	=	Biotransfer factor, calculated for sediment to aquatic plants, riparian soil to riparian plants, and terrestrial soil to terrestrial plants (see Section 7.6.2)
IR	=	Ingestion rate (the amount of prey items, surface water, sediment, and soil ingested per day) (kg/day, kg/kg/day)
BW	=	Body weight of receptor species (kg)
SUF	=	Site use factor to account for the amount of time that the organism spends using the site, always set as 1.0 for this AWERA based on the size of the Resource Area

The resulting dose is then compared with a dose that serves as the TRV, and the ratio (presented as an HQ) is indicative of potential risks to ecological receptors.

For the AWERA, the same equation was used to calculate an exposure dose for each assessment endpoint. A dose that represents the most conservative exposure was used for the Tier 1 assessment (see Table 7-4). For the Tier 2 assessment, a dose that represents a site-specific exposure scenario was calculated using mean exposure parameters along with area-weighted EPCs of COPECs in soil; sediment; surface water; terrestrial, riparian, or aquatic plants; terrestrial or riparian insects; and tissues of aquatic invertebrates; fish, and riparian and terrestrial small mammals (see Table 7-5). General procedures and assumptions used for development of EPCs for use in the dose equations for the AWERA are presented and discussed in Appendix C.

The Tier 1 assessment presents a worst-case scenario (using conservative exposure parameters), and the Tier 2 assessment presents a more site-specific scenario (using mean exposure parameters), which then can be used in a risk management process to arrive at a risk value that can be applied to manage levels of metals in appropriate media that resulted from phosphate mining in the Resource Area.

The following sections present the dose models specific to each of the assessment endpoints based on the general model equation presented above.

7.6.1.1 Terrestrial Herbivorous Birds – Northern Bobwhite

The dose equation for the terrestrial herbivorous birds is as follows:

$$Dose_{Total} = (SUF)\times\frac{\left[(C_{soil}\times IR_{soil})+\left\{\begin{matrix}83.8\%(C_{terrestrid\ plants}\times IR_{prey})+\\14.1\%(C_{terrestrid\ insects}\times IR_{prey})\end{matrix}\right\}\right]}{BW} \qquad (7\text{-}2)$$

where

$Dose_{Total}$	=	Total quantity of a chemical received by a receptor from all sources (mg/kg/day)
$C_{terrestrial\ insects}$	=	Concentration of chemical in terrestrial invertebrates (mg/kg)
$C_{terrestrial\ plants}$	=	($C_{terrestrial\ soil}$) x ($BTF_{terrestrial\ plants}$) (mg/kg)
C_{soil}	=	Concentration of chemical in soil (mg/kg)
$BTF_{terrestrial\ plant}$	=	BTF of terrestrial soil to terrestrial plant calculated as indicated in Section 7.6.2
IR_{soil}	=	Ingestion rate of soil (kg/day)
IR_{prey}	=	Ingestion rate of prey (kg/day)
BW	=	Body weight of receptor species (kg)
SUF	=	Site use factor to account for the amount of time that the organism spends using the site, always set as 1.0 for this AWERA due to the size of the Resource Area

Input consists of data for terrestrial soils, terrestrial plants, and terrestrial insects. It is assumed that the water requirement for the northern bobwhite is obtained from its food source. Exposure parameters used in the dose model are presented in Tables 7-4 and 7-5, and were adjusted to kg.

7.6.1.2 Terrestrial Herbivorous Mammals – Eastern Cottontail

The dose equation for the terrestrial herbivorous mammal is as follows:

$$Dose_{Total} = (SUF)\times\frac{[(C_{soil}\times IR_{soil})+97.6\%(C_{terrestrid\ plants}\times IR_{prey})]}{BW} \qquad (7\text{-}3)$$

where

$Dose_{Total}$	=	Total quantity of a chemical received by a receptor from all sources (mg/kg/day)
$C_{terrestrial\ plants}$	=	($C_{terrestrial\ soil}$) x ($BTF_{terrestrial\ plants}$) (mg/kg)
C_{soil}	=	Concentration of chemical in soil (mg/kg)
$BTF_{terrestrial\ plant}$	=	BTF of terrestrial soil to terrestrial plant calculated as indicated in Section 7.6.2
IR_{soil}	=	Ingestion rate of soil (kg/day)
IR_{prey}	=	Ingestion rate of prey (kg/day)
BW	=	Body weight of receptor species (kg)
SUF	=	Site use factor to account for the amount of time that the organism spends using the site, always set as 1.0 for this AWERA due to the size of the Resource Area

Input consists of data for terrestrial soils and terrestrial plants. It is assumed that the water requirement for the eastern cottontail is obtained from its food source. Exposure parameters used in the dose model are presented in Tables 7-4 and 7-5, and were adjusted to kg.

7.6.1.3 Terrestrial Omnivorous Birds– American Robin

The dose equation for terrestrial omnivorous birds is as follows:

$$Dose_{Total} = (SUF) \times \frac{\left[(C_{soil} \times IR_{soil}) + \left\{ \begin{matrix} 49.0\%(C_{terrestrid\ plants} \times IR_{prey}) + \\ 49.0\%(C_{terrestrid\ insects} \times IR_{prey}) \end{matrix} \right\} \right]}{BW} \qquad (7\text{-}4)$$

where

$Dose_{Total}$	=	Total quantity of a chemical received by a receptor from all sources (mg/kg/day)
$C_{terrestrial\ insects}$	=	Concentration of chemical in terrestrial invertebrates (mg/kg)
$C_{terrestrial\ plants}$	=	($C_{terrestrial\ soil}$) x ($BTFT_{terrestrial\ plants}$) C_{soil} = Concentration of chemical in soil (mg/kg)
$BTF_{terrestrial\ plant}$	=	BTF of terrestrial soil to terrestrial plant calculated as indicated in Section 7.6.2
IR_{soil}	=	Ingestion rate of soil (kg/day)

IR_{prey}	=	Ingestion rate of prey (kg/day)
BW	=	Body weight of receptor species (kg)
SUF	=	Site use factor to account for the amount of time that the organism spends using the site, always set as 1.0 for this AWERA due to the size of the Resource Area

Input consists of data for terrestrial soils, terrestrial plants, and terrestrial insect data. It is assumed that the water requirement for the American robin is obtained from its food source. Exposure parameters used in the dose model are presented in Tables 7-4 and 7-5, and were adjusted to kg.

7.6.1.4 Terrestrial Omnivorous Mammals – Deer Mouse

The dose equation for terrestrial omnivorous mammals is as follows:

$$Dose_{Total} = (SUF) \times \frac{\left[(C_{soil} \times IR_{soil}) + \left\{ \begin{matrix} 53.4\%(C_{terrestrial\ plants} \times IR_{prey}) + \\ 44.6\%(C_{terrestrial\ insects} \times IR_{prey}) \end{matrix} \right\} \right]}{BW} \quad (7\text{-}5)$$

where

$Dose_{Total}$	=	Total quantity of a chemical received by a receptor from all sources (mg/kg/day)
$C_{terrestrial\ insects}$	=	Concentration of chemical in terrestrial invertebrates (mg/kg)
$C_{terrestrial\ plants}$	=	$(C_{terrestrial\ soil})$ x $(BTF_{terrestrial\ plants})$ (mg/kg)
C_{soil}	=	Concentration of chemical in soil (mg/kg)
$BTF_{terrestrial\ plant}$	=	BTF of terrestrial soil to terrestrial plant calculated as indicated in Section 7.6.2
IR_{soil}	=	Ingestion rate of soil (kg/day)
IR_{prey}	=	Ingestion rate of prey (kg/day)
BW	=	Body weight of receptor species (kg)
SUF	=	Site use factor to account for the amount of time that the organism spends using the site, always set as 1.0 for this AWERA due to the size of the Resource Area

Input consists of data for terrestrial soils, terrestrial plants, and terrestrial insect data. It is assumed that the water requirement for the deer mouse is obtained from its food source. Exposure parameters used in the dose model are presented in Tables 7-4 and 7-5, and were adjusted to kg.

7.6.1.5 Aquatic and Riparian Herbivorous Birds – Song Sparrow

The dose equation for aquatic and riparian omnivorous birds is as follows:

$$Dose_{Total} = (SUF) \times \frac{\left[\left(C_{riparian soil} \times IR_{soil}\right) + 98.0\%\left(C_{riparian plants} \times IR_{prey}\right)\right]}{BW} \quad (7\text{-}6)$$

where

$Dose_{Total}$	=	Total quantity of a chemical received by a receptor from all sources (mg/kg/day)
$C_{riparian\ plants}$	=	($C_{riparian\ soil}$) x ($BTF_{riparian\ plants}$) (mg/kg)
$C_{riparian\ soil}$	=	Concentration of chemical in riparian soil (mg/kg)
$BTF_{riparian\ plant}$	=	BTF of riparian soil to riparian plants calculated as indicated in Section 7.6.2
IR_{soil}	=	Ingestion rate of soil (kg/day)
IR_{prey}	=	Ingestion rate of prey (kg/day)
BW	=	Body weight of receptor species (kg)
SUF	=	Site use factor to account for the amount of time that the organism spends using the site, always set as 1.0 for this AWERA due to the size of the Resource Area

Input consists of data for riparian soils and riparian plants. It is assumed that the water requirement for the song sparrow is obtained from its food source. Exposure parameters used in the dose model are presented in Tables 7-4 and 7-5, and were adjusted to kg.

7.6.1.6 Aquatic and Riparian Herbivorous Mammals – Meadow Vole

The dose equation for aquatic and riparian herbivorous mammals is as follows:

$$Dose_{Total} = (SUF) \times \frac{\left[\begin{array}{l} (C_{riparian soil} \times IR_{soil}) + 95.6\%(C_{riparian plants} \times IR_{prey}) \\ + 1.96\%(C_{riparian invertebrates} \times IR_{prey}) \end{array} \right]}{BW} \tag{7-7}$$

where

$Dose_{Total}$	=	Total quantity of a chemical received by a receptor from all sources (mg/kg/day)
$C_{riparian\ invertebrates}$	=	Concentration of chemical in riparian invertebrates (mg/kg)
$C_{riparian\ plants}$	=	$(C_{riparian\ soil})$ x $(BTF_{riparian\ plants})$ (mg/kg)
$C_{riparian\ soil}$	=	Concentration of chemical in riparian soil (mg/kg)
$BTF_{riparian\ plant}$	=	BTF of riparian soil to riparian plants calculated as indicated in Section 7.6.2
IR_{soil}	=	Ingestion rate of soil (kg/day)
IR_{prey}	=	Ingestion rate of prey (kg/day)
BW	=	Body weight of receptor species (kg)
SUF	=	Site use factor to account for the amount of time that the organism spends using the site, always set as 1.0 for this AWERA due to the size of the Resource Area

Input consists of data for riparian soils, riparian plants, and riparian insects. It is assumed that the water requirement for the meadow vole is obtained from its food source. Exposure parameters used in the dose model are presented in Tables 7-4 and 7-5, and were adjusted to kg.

7.6.1.7 Aquatic and Riparian Omnivorous Birds – Red-winged Blackbird

The dose equation for aquatic and riparian omnivorous birds is as follows:

$$Dose_{Total} = (SUF) \times \frac{\left[(C_{riparian soil} \times IR_{soil}) + \left\{ \begin{array}{l} 78.4\%(C_{riparian plants} \times IR_{prey}) + \\ 21.5\%(C_{riparian invertebrates} \times IR_{prey}) \end{array} \right\} \right]}{BW} \tag{7-8}$$

where

$Dose_{Total}$	=	Total quantity of a chemical received by a receptor from all sources (mg/kg/day)
$C_{riparian\ invertebrates}$	=	Concentration of chemical in riparian invertebrates (mg/kg)
$C_{riparian\ plants}$	=	$(C_{riparian\ soil})$ x $(BTF_{riparian\ plants})$ (mg/kg)
$C_{riparian\ soil}$	=	Concentration of chemical in riparian soil (mg/kg)
$BTF_{riparian\ plant}$	=	BTF of riparian soil to riparian plants calculated as indicated in Section 7.6.2
IR_{soil}	=	Ingestion rate of soil (kg/day)
IR_{prey}	=	Ingestion rate of prey (kg/day)
BW	=	Body weight of receptor species (kg)
SUF	=	Site use factor to account for the amount of time that the organism spends using the site, always set as 1.0 for this AWERA due to the size of the Resource Area

Input consists of data for riparian soils, riparian plants, and riparian insects. It is assumed that the water requirement for the red-winged blackbird is obtained from its food source. Exposure parameters used in the dose model are presented in Tables 7-4 and 7-5, and were adjusted to kg.

7.6.1.8 Aquatic and Riparian Piscivorous Birds – Great Blue Heron

The exposure assumptions for prey items for the great blue heron were varied between the Tier 1 and Tier 2 assessment. The following sections discuss each tier.

Tier 1

The dose equation for aquatic and riparian piscivorous birds is as follows:

$$Dose_{Total} = (SUF) \times \frac{\left[\begin{array}{l} (C_{\text{sediments}} \times IR_{se\dim emts}) + (C_{surface\ water} \times IR_{water}) \\ + 99.3\% (C_{fish} \times IR_{prey}) \end{array} \right]}{BW} \qquad (7\text{-}9)$$

where

$Dose_{Total}$	=	Total quantity of a chemical received by a receptor from all sources (mg/kg/day)

C_{fish}	=	Concentration of chemical in fish (mg/kg)
$C_{sediments}$	=	Concentration of chemical in sediments (mg/kg)
$C_{surface\ water}$	=	Concentration of chemical in surface water (mg/kg)
$IR_{sediments}$	=	Ingestion rate of soil (kg/day)
IR_{prey}	=	Ingestion rate of prey (kg/day)
$IR_{surface\ water}$	=	Ingestion rate of surface water (kg per day)
BW	=	Body weight of receptor species (kg)
SUF	=	Site use factor to account for the amount of time that the organism spends using the site, always set as 1.0 for this AWERA due to the size of the Resource Area

Input consists of data for aquatic sediments, surface water, and fish. Exposure parameters used in the dose model are presented in Tables 7-4 and 7-5, which were adjusted to kg.

Tier 2

The dose model was modified to include a mixed diet that included invertebrates:

$$Dose_{Total} = (SUF) \times \frac{\left[\begin{array}{l}(C_{\text{sediments}} \times IR_{sediments}) + (C_{surface\ water} \times IR_{water}) \\ + 82.4\%(C_{fish} \times IR_{prey}) + 16.9\%(C_{triparian\,invertebrates} \times IR_{prey})\end{array}\right]}{BW} \quad (7\text{-}10)$$

where

$Dose_{Total}$	=	Total quantity of a chemical received by a receptor from all sources (mg/kg/day)
C_{fish}	=	Concentration of chemical in fish (mg/kg)
$C_{riparian\ invertebrates}$	=	Concentration of chemical in riparian invertebrates (mg/kg)
$C_{sediments}$	=	Concentration of chemical in sediments (mg/kg)
$C_{surface\ water}$	=	Concentration of chemical in surface water (mg/kg)
$IR_{sediments}$	=	Ingestion rate of soil (kg/day)
IR_{prey}	=	Ingestion rate of prey (kg/day)
$IR_{surface\ water}$	=	Ingestion rate of surface water (kg/day)
BW	=	Body weight of receptor species (kg)
SUF	=	Site use factor to account for the amount of time that the organism spends using the site, always set as 1.0 for this AWERA due to the size of the Resource Area

Input consists of data for aquatic sediments, surface water, fish, and riparian insects. Exposure parameters used in the dose model are presented in Tables 7-4 and 7-5, and were adjusted to kg.

7.6.1.9 Aquatic and Riparian Benthic-feeding Birds – Mallard Duck

The dose equation for aquatic and riparian benthic-feeding birds is as follows:

$$Dose_{Total} = (SUF) \times \frac{\left[\begin{array}{l} (C_{sediments} \times IR_{sediment}) + (C_{surface\ water} \times IR_{water}) \\ + \left\{ \begin{array}{l} 24.5\%(C_{aquatic\ plants} \times IR_{prey}) \\ + 72.2\%(C_{aquatic\ invertebrates} \times IR_{prey}) \end{array} \right\} \end{array} \right]}{BW} \qquad (7\text{-}11)$$

where

$Dose_{Total}$	=	Total quantity of a chemical received by a receptor from all sources (mg/kg/day)
$C_{aquatic\ plants}$	=	$(C_{sediments})$ x $(BTF_{aquatic\ plants})$ x $(C_{aquatic\ invertebrates})$ = Concentration of chemical in aquatic invertebrates (mg/kg)
$C_{sediments}$	=	Concentration of chemical in sediments (mg/kg)
$C_{surface\ water}$	=	Concentration of chemical in surface water (mg/kg)
$BTF_{aquatic\ plant}$	=	BTF of sediment to aquatic plants calculated as indicated in Section 7.6.2
$IR_{sediment}$	=	Ingestion rate of sediment (kg/day)
IR_{prey}	=	Ingestion rate of prey (kg/day)
$IR_{surface\ water}$	=	Ingestion rate of surface water (kg/day)
BW	=	Body weight of receptor species (kg)
SUF	=	Site use factor to account for the amount of time that the organism spends using the site, always set as 1.0 for this AWERA due to the size of the Resource Area

Input consists of data for sediments, surface water, aquatic plants, and aquatic invertebrates. Exposure parameters used in the dose model are presented in Tables 7-4 and 7-5, and were adjusted to kg.

7.6.1.10 Aquatic and Riparian Omnivorous Mammals– Raccoon

The dose equation for aquatic and riparian omnivorous mammals as follows:

$$Dose_{Total} = (SUF) \times \frac{\left[\left(C_{\text{sediments}} \times IR_{sediment}\right) + \left(C_{surface\,water} \times IR_{water}\right) + \left\{ \begin{array}{l} 24.0\%\left(C_{aquatic\,plants} \times IR_{prey}\right) \\ +24.0\%\left(C_{riparian\,plants} \times IR_{prey}\right) \\ +31.7\left(C_{aquatic\,invertebrates} \times IR_{prey}\right) \\ +9.1\%\left(C_{small\,mammals} \times IR_{prey}\right) \\ +1.8\%\left(C_{fish} \times IR_{prey}\right) \end{array} \right\} \right]}{BW} \quad (7\text{-}12)$$

where

$Dose_{Total}$	=	Total quantity of a chemical received by a receptor from all sources (mg/kg/day)
$C_{aquatic\ plants}$	=	$(C_{sediment})$ x $(BTF_{aquatic\ plants})$ x $(C_{aquatic\ invertebrates})$ = Concentration of chemical in aquatic invertebrates (mg/kg)
$C_{riparian\ plants}$	=	$(C_{riparian\ soil})$ x $(BTF_{riparian\ plants})$ x $(C_{sediments})$ = Concentration of chemical in sediments (mg/kg)
$C_{small\ mammals}$	=	Concentration of chemical in small mammals (mg/kg)
$C_{surface\ water}$	=	Concentration of chemical in surface water (mg/kg)
$BTF_{riparian\ plant}$	=	BTF of riparian soil to riparian plants calculated as indicated in Section 7.6.2
$BTF_{aquatic\ plant}$	=	BTF of sediments to aquatic plants calculated as indicated in Section 7.6.2
$IR_{sediment}$	=	Ingestion rate of sediment (kg/day)
IR_{prey}	=	Ingestion rate of prey (kg/day)
IR_{water}	=	Ingestion rate of surface water (kg/day)
BW	=	Body weight of receptor species (kg)
SUF	=	Site use factor to account for the amount of time that the organism spends using the site, always set as 1.0 for this AWERA due to the size of the Resource Area

Input consists of data for sediments, surface water, aquatic and riparian plants, aquatic invertebrates, riparian mammals, and fish. Exposure parameters used in the dose model are presented in Tables 7-4 and 7-5, and were adjusted to kg.

7.6.1.11 Aquatic and Riparian Carnivorous Mammals – Mink

The basic equation for aquatic and riparian carnivorous mammals is as follows:

$$Dose_{Total} = (SUF)(TTC) \times \frac{\left[\begin{array}{l} (C_{\text{sediments}} \times IR_{sediment}) + (C_{surface\,water} \times IR_{water}) + (C_{riparian soil} \times IR_{soil}) \\ + \left\{ \begin{array}{l} 3.86\%(C_{aquatic\,plants} \times IR_{prey}) \\ 3.86\%(C_{riparian\,plants} \times IR_{prey}) \\ +6.4\%(C_{aquatic invertebrates} \times IR_{prey}) \\ +4.7\%(C_{small\ mammals} \times IR_{prey}) \\ +62.4\%(C_{fish} \times IR_{prey}) \end{array} \right\} + \end{array} \right]}{BW} \quad (7\text{-}13)$$

where

$\text{Dose}_{\text{Total}}$	=	Total quantity of a chemical received by a receptor from all sources (mg/kg/day)
$\text{C}_{\text{aquatic plants}}$	=	$(\text{C}_{\text{sediment}})$ x $(\text{BTF}_{\text{aquatic plants}})$ x $(\text{C}_{\text{aquatic invertebrates}})$ = Concentration of chemical in aquatic invertebrates (mg/kg)
C_{fish}	=	Concentration of chemical in fish (mg/kg)
$\text{C}_{\text{riparian plants}}$	=	$(\text{C}_{\text{riparian soil}})$ x $(\text{BTF}_{\text{riparian plants}})$ x $(\text{C}_{\text{riparian soil}})$ = Concentration of chemical in riparian soil (mg/kg)
$\text{C}_{\text{sediments}}$	=	Concentration of chemical in sediments (mg/kg)
$\text{C}_{\text{small mammals}}$	=	Concentration of chemical in small mammals (mg/kg)
$\text{C}_{\text{surface water}}$	=	Concentration of chemical in surface water (mg/kg)
$\text{BTF}_{\text{riparian plant}}$	=	BTF of riparian soil to riparian plants calculated as indicated in Section 7.6.2
$\text{BTF}_{\text{aquatic plant}}$	=	BTF of sediments to aquatic plants calculated as indicated in Section 7.6.2
$\text{IR}_{\text{sediment}}$	=	Ingestion rate of sediment (kg/day)
IR_{soil}	=	Ingestion rate of soil (kg/day)
IR_{prey}	=	Ingestion rate of prey (kg/day)
IR_{water}	=	Ingestion rate of surface water (kg/day)
BW	=	Body weight of receptor species (kg)
SUF	=	Site use factor to account for the amount of time that the organism spends using the site, always set as 1.0 for this AWERA due to the size of the Resource Area

Input consists of data for sediments, surface water, aquatic and riparian plants, aquatic invertebrates, riparian mammals, and fish. Exposure parameters used in the dose model are presented in Tables 7-4 and 7-5, and were adjusted to kg.

7.6.1.12 Carnivorous Mammals – Coyote

The dose equation for carnivorous mammals is as follows:

$$Dose_{Total} = (SUF)(TTC) \times \frac{\left[\begin{array}{l} (C_{\text{soils}} \times IR_{soils}) + (C_{surface\,water} \times IR_{water}) \\ + \left\{ \begin{array}{l} 9.7\% (C_{terrestrid\ plants} \times IR_{prey}) \\ + 87.5\% (C_{small\,mammals} \times IR_{prey}) \end{array} \right\} \end{array} \right]}{BW} \quad (7\text{-}14)$$

where

$Dose_{Total}$	=	Total quantity of a chemic al received by a receptor from all sources (mg/kg/day)
$C_{small\ mammals}$	=	Concentration of chemical in small mammals (mg/kg)
$C_{terrestrial\ plants}$	=	($C_{terrestrial\ soil}$) x ($BTF_{terrestrial\ plants}$) x ($C_{soil}$) = Concentration of chemical in soil (mg/kg)
$C_{surface\ water}$	=	Concentration of chemical in surface water (mg/kg)
$BTF_{terrestrial\ plant}$	=	BTF of terrestrial soil to terrestrial plants calculated as indicated in Section 7.6.2
IR_{prey}	=	Ingestion rate of prey (kg/day)
IR_{soil}	=	Ingestion rate of soil (kg/day)
IR_{water}	=	Ingestion rate of surface water (kg/day)
BW	=	Body weight of receptor species (kg)
SUF	=	Site use factor to account for the amount of time that the organism spends using the site, always set as 1.0 for this AWERA due to the size of the Resource Area

Input consists of data for terrestrial soils, surface water, terrestrial plants, and terrestrial mammal. Exposure parameters used in the dose model are presented in Tables 7-4 and 7-5, and were adjusted to kg.

7.6.1.13 Carnivorous Birds - Northern Harrier

The dose equation for carnivorous birds is as follows:

$$Dose_{Total} = (SUF)(TTC)\times\frac{\left[\begin{array}{l}(C_{\text{soils}}\times IR_{soils})\\ +\left\{\begin{array}{l}2.5\%(C_{terrestrial\ invertebrates}\times IR_{prey})\\ +96.8\%(C_{small\ mammals}\times IR_{prey})\end{array}\right\}\end{array}\right]}{BW} \qquad (7\text{-}15)$$

where

$Dose_{Total}$	=	Total quantity of a chemical received by a receptor from all sources (mg/kg/day)
$C_{small\ mammals}$	=	Concentration of chemical in small mammals (mg/kg)
$C_{terrestrial\ invertebrates}$	=	Concentration of chemical in terrestrial invertebrates (mg/kg)
C_{soil}	=	Concentration of chemical in soil (mg/kg)
IR_{prey}	=	Ingestion rate of prey (kg/day)
IR_{soil}	=	Ingestion rate of soil (kg/day)
BW	=	Body weight of receptor species (kg)
SUF	=	Site use factor to account for the amount of time that the organism spends using the site, always set as 1.0 for this AWERA due to the size of the Resource Area

Input consists of data for terrestrial soils, terrestrial invertebrate, and terrestrial mammal. Exposure parameters used in the dose model are presented in Tables 7-4 and 7-5, and were adjusted to kg.

7.6.2 Biotransfer Factor Calculations

Actual concentrations of COPECs in the tissues invertebrates and plants were collected and analyzed. This information was used to develop BTFs that can be used to model from one trophic level to the next.

Site-specific BTFs for soil-to-plant and soil-to-invertebrate transfer factors were originally intended to be calculated using data for collocated samples of soil, plants, and invertebrates. However, based on difficulties in collecting soil-dwelling invertebrates in various areas, only soil-to-plant BTFs were developed. Actual tissue concentration levels were used in the dose equation for all other tissue types. Calculation of the actual EPC is presented in Appendix C.

BTFs were calculated for plants using the following ratio:

$$BTF_{plant} = \frac{C_{plant}}{C_{soil\,or\,sediment}} \qquad (7\text{-}16)$$

where

BTF_{plant}	=	Chemical specific soil-to-plant BTF
C_{plant}	=	Concentration in plant tissues (mg/kg)
$C_{sediment}$	=	Concentration of chemical in sediment (mg/kg)
C_{soil}	=	Concentration of chemical in soil (mg/kg)

The following BTFs were calculated for plants:

- Sediment to aquatic plants
- Riparian soil to riparian plants
- Terrestrial soil to terrestrial plants

Each calculated BTF is used as a multiplier for the concentration in the respective media, thus providing for a measure of the fraction of the contaminant that is absorbed by the receptor from the consumed media.

7.6.3 Toxicity Reference Values and Associated Uncertainty

TRVs are screening-level, benchmark values for higher-trophic-level receptors such as birds and mammals. In general, a TRV is a dose at which a specific biological effect may occur in an organism based on the results of laboratory toxicological investigations. For bird and mammal receptors, TRVs are compared with estimates of site-specific, daily chemical doses ingested from food and media in the HQ approach to model potential risk. All TRVs used in the assessments were based on NOAELs reported in the literature. The proposed TRVs for both mammals and birds that are being used for this project are presented in Table 7-6. The TRVs were taken from two sources, primarily the U.S. Department of the Navy (Navy) (1998) “Development of Toxicity Reference Values for Conducting Ecological Risk Assessments at Naval Facilities in California, Interim Final Technical Memorandum” and secondarily from Sample and others (1996) “Toxicological Benchmarks for Wildlife: 1996 Revision.” There was one exception, lead. There have been inherent problems with the use of the published TRV for lead

(Navy 1998). Presently the EPA Region 9 Biological Technical Assistance Group is considering revising the lead TRV. In an effort to minimize these problems, the lead TRVs published by Sample and others (1996) were used. In all other cases, preference was given to the values found in Navy 1998.

Published methods for conducting ecological assessments differ in the way they address uncertainty, including the magnitude and type of uncertainty factors recommended (Opresko and others 1993; Suter 1993; and Calabrese and Baldwin 1993; all as cited in Navy 1998). One method of accounting for the uncertainty inherent in the derivation of TRVs is to use uncertainty factors (UF). The TRV is divided by the UF to overlay a level of conservatism to data that are, for one reason or another, incomplete. For example, uncertainty that results from the lack of data on chronic exposure has been addressed traditionally by dividing the proposed TRV by a number, usually 10. UFs were applied originally to the TRVs used for this ERA (Navy 1998). No TRVs were developed specifically for this assessment.

7.6.4 Allometric Conversions

In cases where the species that represents the measurement endpoint was different from the species used to develop the TRV, dietary concentrations were converted to dose (that is, mg COPEC/kg BW/day) for comparison with estimated ingestion rates of COPEC in receptor species. All TRVs were adjusted based on the difference in body weights between the study organisms used as the basis for the literature values and the body weight of the measurement endpoint receptor. For example, when toxicological data and dose levels were available for laboratory rats but were needed for the deer mouse, an allometric conversion estimates a similar dose level for the deer mouse. The underlying assumption of allometric conversion is that a given effect on a species of small mammal is similar to the effect on a species of larger mammal, per unit body weight, and vice versa.

The recommendations of Sample and Arenal (1999) were followed for allometric conversions. Sample and Arenal (1999) investigated the allometric relationships for acute avian and mammalian toxicity data across a wide variety of chemicals to assess the applicability of existing allometric factors and to evaluate whether allometric relationships differ between birds and mammals. A total of 194 chemicals for birds and 167 chemicals for mammals were reviewed. The range of chemicals included alkaloids, inorganics, organochlorines, and drugs. The mean, chemical-specific scaling factor calculated was 1.20 for birds and 0.94 for mammals (Sample and Arenal 1999).

These scaling factors were expressed as follows:

For mammals:

$$TRV_{receptor} = TRV_{test\ organism}\left(body\ weight_{test\ organism} / body\ weight_{receptor}\right)^{1-0.94} \qquad (7\text{-}17)$$

For birds:

$$TRV_{receptor} = TRV_{test\ organism}\left(body\ weight_{test\ organism} / body\ weight_{receptor}\right)^{1-1.2} \qquad (7\text{-}18)$$

7.7 TIER 1 SCREENING ASSESSMENT

Tier 1 is a "worst-case" screening-level activity directed at eliminating any chemicals that present negligible risks. In this step, the highest concentration observed for each medium and chemical and the most conservative exposure parameters were used to calculate an HQ for each target species and COPEC.

The first tier of the AWERA focused on the assessment endpoints identified in Section 7.5 and evaluated exposure through the ingestion pathway. Target receptors evaluated that may range the entire Resource Area included the northern bobwhite, eastern cottontail, American robin, northern harrier, deer mouse, raccoon, and coyote. Target receptors that range only in the aquatic and riparian habitat included the song sparrow, meadow vole, red-winged black bird, great blue heron, mallard, mink, and raccoon.

Based on life history and foraging habits, an estimated daily dose for each COPEC (cadmium, chromium, copper, nickel, selenium, vanadium, and zinc [see Appendix B for COPEC selection]) was calculated for each receptor. Estimated doses were calculated for each COPEC and target receptor. Doses were based on maximum site-specific concentrations in media and prey collected from mining impacted areas, regardless of the habitat range of the receptor.

Estimated daily doses for each COPEC and target receptor were compared to the respective TRVs to calculate an HQ; calculations are presented in their entirety in Appendix G. The following sections discuss the results of the risk calculations by COPEC and for each target receptor.

7.7.1 Evaluation of Potential Risk to Birds and Mammals from Exposure to Cadmium

Target receptors for which HQs for cadmium were greater than 1.0, are presented in Table 7-7. A complete list of HQs for all target receptors is provided in Appendix G.

The results of the food chain model (FCM) indicated potential risk resulting from exposure to maximum concentrations of cadmium to both avian and mammalian receptors. Potential risk was highest to avian receptors that range in the riparian habitat, with a maximum HQ of 419 for the song sparrow and 321 for the red-winged blackbird. The maximum mammalian HQ of 212 was for the meadow vole in the riparian habitat. Potential risk was also significant to mammalian receptors that range the overall habitat with a HQ of 147 for the deer mouse. The HQs for the northern harrier, great blue heron, and mallard duck were all less than 1.0, which indicated minimal potential risk to these receptors. Receptors for which HQs were less than 1.0 were not carried forward to Tier 2. The receptors listed in Table 7-7 were further evaluated in Tier 2 for potential risk resulting from exposure to cadmium.

7.7.2 Evaluation of Potential Risk to Birds and Mammals from Exposure to Chromium

Target receptors for which HQs for chromium were greater than 1.0, are presented in Table 7-8. A complete list of HQs for all target receptors is provided in Appendix G.

The results of the FCM indicated potential risk to avian receptors from exposure to maximum concentrations of chromium. Potential risk was highest in the riparian habitat, with a HQ of 44 for the song sparrow. The HQs for all mammalian receptors and the great blue heron were less than 1.0, which indicated minimal potential risk. Receptors for which the HQ was less than 1.0 were not carried forward to Tier 2. All receptors listed in Table 7-8 were further evaluated in Tier 2 for potential risk resulting from exposure to chromium.

7.7.3 Evaluation of Potential Risk to Birds and Mammals from Exposure to Copper

Target receptors for which HQs for copper were greater than 1.0, are presented in Table 7-9. A complete list of HQs for all target receptors is provided in Appendix G.

The results of the FCM indicated potential risk resulting from exposure to maximum concentrations of copper to both avian and mammalian receptors. Potential risk was highest to receptors that range the riparian habitat with a maximum HQ of 18.8 for the song sparrow. The maximum mammalian HQ was

6.4 for the meadow vole, also in the riparian habitat. The HQs for the northern harrier, coyote, great blue heron, and mallard duck were less than 1.0, which indicated minimal potential risk to these receptors. Receptors for which the HQ was less than 1.0 were not carried forward to Tier 2. All receptors listed in Table 7-9 were further evaluated in Tier 2 for potential risk resulting from exposure to copper.

7.7.4 Evaluation of Potential Risk to Birds and Mammals from Exposure to Nickel

Target receptors for which HQs for nickel were greater than 1.0, are presented in Table 7-10. A complete list of HQs for all target receptors is provided in Appendix G.

The results of the FCM indicated potential risk resulting from exposure to maximum concentrations of nickel to both avian and mammalian receptors. Potential risk was highest to small mammalian receptors that range in the riparian habitat, with a maximum HQ of 48.4 for the meadow vole. The maximum HQ for an avian receptor was 13 for the song sparrow. The HQs for the American robin, northern harrier, and great blue heron were less than 1.0, which indicated minimal potential risk to these receptors. Receptors for which the HQs were less than 1.0 were not carried forward to Tier 2. The receptors listed in Table 7-10 were further evaluated in Tier 2 for potential risk resulting from exposure to nickel.

7.7.5 Evaluation of Potential Risk to Birds and Mammals from Exposure to Selenium

Target receptors for which HQs for selenium were greater than 1.0, are presented in Table 7-11. A complete list of HQs for all target receptors is provided in Appendix G.

The results of the FCM indicated potential risk resulting from exposure to maximum concentrations of selenium to both avian and mammalian receptors. Potential risk was highest to small mammalian receptors, with a maximum HQ of 2,302 for the meadow vole in the riparian habitat and 1,423 for the eastern cottontail in the overall habitat. The maximum HQ for an avian receptor was 1,442 for the song sparrow. The HQs for all receptors were greater than 1.0. The receptors listed in Table 7-11 were further evaluated in Tier 2 for potential risk resulting from exposure to selenium.

7.7.6 Evaluation of Potential Risk to Birds and Mammals from Exposure to Vanadium

Target receptors for which HQs for vanadium were greater than 1.0, are presented in Table 7-12. A complete list of HQs for all target receptors is provided in Appendix G.

The results of the FCM indicated potential risk resulting from exposure to maximum concentrations of vanadium to mammalian receptors, the song sparrow, and the red-winged blackbird. Potential risk was highest to small mammalian receptors that range in the riparian habitat, with a maximum HQ of 45 for the meadow vole. The HQs for the song sparrow and red-winged blackbird were 2.4 and 2.3, respectively. The HQs for all other avian receptors (northern bobwhite, American robin, great blue heron, mallard, and northern harrier) were all less than 1.0, which indicated minimal potential risk to these receptors. Receptors for which the HQs were less than 1.0 were not carried forward to Tier 2. The receptors listed in Table 7-12 were further evaluated in Tier 2 for potential risk resulting from exposure to vanadium.

7.7.7 Evaluation of Potential Risk to Birds and Mammals from Exposure to Zinc

Target receptors for which HQs for zinc were greater than 1.0, are presented in Table 7-13. A complete list of HQs for all target receptors is provided in Appendix G.

The results of the FCM indicated potential risk resulting from exposure to maximum concentrations of zinc to both avian and mammalian receptors. Potential risk was highest to the song sparrow, with a maximum HQ of 28. The maximum HQ for a mammalian receptor was 18.3 for the meadow vole. The HQs for the northern harrier, coyote, mallard, and great blue heron were less than 1.0, which indicated minimal potential risk to these receptors. Receptors for which the HQs were less than 1.0 were not carried forward to Tier 2. The receptors listed in Table 7-13 were further evaluated in Tier 2 for potential risk resulting from exposure to zinc.

7.7.8 Summary of Tier 1 Risk Evaluation for Birds and Mammals

Tier 1 was a “worst-case” screening-level activity that used the highest observed concentration in media and prey, and the most conservative exposure parameters to calculate an HQ for each target species and COPEC. Table 7-14 summarizes the results of the Tier 1 assessment. COPECs and target receptors for which a potential risk was indicated in Tier 1 are represented with a check (✓). Blank cells represent target species and COPECs that did not present a potential risk, and were therefore removed from further consideration in Tier 2. Target species and COPECs removed from further consideration in Tier 2 were those for which HQs calculated using maximum COPEC concentrations in media and prey were less than 1.0.

For cadmium, Tier 1 results indicated potential risk resulting from exposure to maximum concentrations of cadmium to both avian and mammalian receptors. Potential risk was highest to avian receptors, with a maximum HQ of 419 for the song sparrow.

For chromium, Tier 1 results indicated potential risk to avian receptors that was highest for the song sparrow with an HQ of 44. The HQs for all mammalian receptors were less than 1.0.

For copper, Tier 1 results indicated potential risk resulting from exposure to maximum concentrations of copper to both avian and mammalian receptors. Potential risk was highest to the song sparrow, with a maximum HQ of 18.8. The maximum mammalian HQ was 6.4 for the meadow vole.

For nickel, Tier 1 results indicated potential risk to both avian and mammalian receptors. Potential risk was highest to small mammalian receptors, with a maximum HQ of 48.4 for the meadow vole. The maximum HQ for an avian receptor was 13 for the song sparrow.

For selenium, Tier 1 results indicated potential risk to both avian and mammalian receptors. Potential risk was highest to small mammalian receptors, with a maximum HQ of 2,302 for the meadow vole. The maximum HQ for an avian receptor was 1,442 for the song sparrow.

For vanadium, Tier 1 results indicated potential risk to mammalian receptors, song sparrow, and red-winged blackbird. Potential risk was highest to small mammalian receptors, with a maximum HQ of 45 for the meadow vole. The maximum HQ for avian receptors was 2.4 for the song sparrow.

For zinc, Tier 1 results indicated potential risk to both avian and mammalian receptors. Potential risk was highest to the song sparrow, with a maximum HQ of 28. The maximum HQ for a mammalian receptor was 18.3 for the meadow vole.

7.8 TIER 2 AREA WIDE ECOLOGICAL RISK ASSESSMENT

In Tier 2, receptors not eliminated in Tier 1 were evaluated on an area-wide basis using approximated EPCs for each media and mean exposure parameters for each receptor to represent average population-level exposures. While the mines occupy a large area, the combined area of the mine sites is about only 3 percent of the total Resource Area. Therefore, development of HQs for the Resource Area as a whole was based on a watershed approach. EPCs were calculated for three watersheds (1) the Blackfoot/Little Blackfoot, (2) Georgetown, and (3) Salt. Background EPCs were also calculated using data collected from non-mining impacted areas. The EPCs are area-weighted based on surface area ratios, stream segment lengths and other applicable weighting criteria as described in Appendix C. The dose calculation and development of HQs for each species was conducted as described in Section 7.6.

Target receptors evaluated in Tier 2 that range in the riparian habitat included the song sparrow, red-winged blackbird, great blue heron, mallard duck, meadow vole, mink, and raccoon. Receptors that range the overall habitat included the northern Bobwhite, American robin, northern harrier, deer mouse, eastern cottontail, and coyote.

Based on life history and foraging habits, an estimated daily dose for each COPEC (cadmium, chromium, copper, nickel, selenium, vanadium, and zinc [see Appendix B for COPEC selection]) was calculated for each receptor and watershed area. The following sections discuss the results of the risk calculations, by COPEC for each target receptor and watershed area.

7.8.1 Tier 2 Evaluation of Potential Risk to Birds and Mammals from Exposure to Cadmium

Target receptors for which HQs for cadmium were greater than 1.0 are presented in Table 7-15. A complete list of HQs for all Tier 2 target receptors is provided in Appendix G.

The results of the FCM indicated potential risk resulting from exposure to AWACs of cadmium to both avian and mammalian receptors. Potential risk was highest to avian receptors in the riparian habitat, with a maximum HQ of 9.2 for the red-winged blackbird in the Georgetown watershed. In general, avian HQs were only slightly elevated above background, with ratios of watershed HQs divided by background HQs ranging from 1 to 1.42. For mammalian receptors the maximum HQ was 8.0 for the deer mouse in the Blackfoot/Little Blackfoot watershed. As with avian receptors, mammalian HQs were only slightly elevated above background, with ratios of impacted to background HQs ranging from 1 to 1.38.

7.8.2 Tier 2 Evaluation of Potential Risk to Birds and Mammals from Exposure to Chromium

Target receptors for which HQs for chromium were greater than 1.0 are presented in Table 7-16. A complete list of HQs for all target receptors is provided in Appendix G.

The results of the FCM indicated potential risk resulting from exposure to AWACs of chromium to avian receptors. Potential risk was highest to the song sparrow in the Georgetown watershed, and American robin in the Blackfoot/Little Blackfoot watershed, both with a HQ of 1.9. Overall, avian HQs were only slightly elevated above background, with ratios of impacted to background HQs ranging from 1 to 1.20. HQs for mammalian receptors were all less than 1.0.

7.8.3 Tier 2 Evaluation of Potential Risk to Birds and Mammals from Exposure to Copper

Target receptors for which HQs for copper were greater than 1.0 are presented in Table 7-17. A complete list of HQs for all target receptors is provided in Appendix G.

The results of the FCM indicated potential risk resulting from exposure to average concentrations of copper to both avian receptors. However, watershed HQs were similar to background HQs, indicating negligible incremental risk from mining related copper. The maximum ratio of impacted to background HQs, was 1.04 for the song sparrow in the Georgetown watershed. HQs for mammalian receptors were all less than 1.0.

7.8.4 Tier 2 Evaluation of Potential Risk to Birds and Mammals from Exposure to Nickel

Target receptors for which HQs for nickel were greater than 1.0, are presented in Table 7-18. A complete list of HQs for all target receptors is provided in Appendix G.

The results of the FCM indicated potential risk resulting from exposure to AWACs of nickel to mammalian receptors and the song sparrow. Potential risk was highest to the meadow vole in the Georgetown watershed with a HQ of 3.3. The Georgetown watershed HQ for the song sparrow was equal to one. The two other watershed HQs for the song sparrow were less than one. Overall, HQs were only slightly elevated above background with impacted to background ratios for all watersheds ranging from 1.0 to 1.15.

7.8.5 Tier 2 Evaluation of Potential Risk to Birds and Mammals from Exposure to Selenium

Target receptors for which HQs for selenium were greater than 1.0 are presented in Table 7-19. A complete list of HQs for all target receptors is provided in Appendix G.

The results of the FCM indicated potential risk resulting from exposure to AWACs of selenium to both avian and mammalian receptors. Potential risk was highest to small mammalian receptors, with a maximum HQ of 19.4 for the deer mouse. The maximum HQ for an avian receptor was 9.1 for the American robin. Risk to both avian and mammalian receptors was highest in the Blackfoot/Little

Blackfoot watershed. In general, HQs for selenium are elevated above background more than the other COPECs. Impacted to background HQ ratios ranged from 1.0 to 2.62 for mammals and from 1.0 to 3.2 for avian receptors.

7.8.6 Tier 2 Evaluation of Potential Risk to Birds and Mammals from Exposure to Vanadium

Target receptors for which HQs for vanadium were greater than 1.0 are presented in Table 7-20. A complete list of HQs for all target receptors is provided in Appendix G.

The results of the FCM indicated potential risk resulting from exposure to AWACs of vanadium to mammalian receptors. Potential risk was highest to the deer mouse, with a maximum HQ of 5.5. However, all watershed HQs were similar to background HQs, indicating negligible incremental risk from mining related vanadium. The maximum ratio of impacted to background HQs was 1.05 for the raccoon in the Salt watershed. HQs were all less than 1.0 for avian receptors.

7.8.7 Tier 2 Evaluation of Potential Risk to Birds and Mammals from Exposure to Zinc

Target receptors for which HQs for zinc were greater than 1.0 are presented in Table 7-21. A complete list of HQs for all target receptors is provided in Appendix G.

The results of the FCM indicated potential risk resulting from exposure to average concentrations of zinc to avian receptors and the deer mouse. Potential risk was highest to the American robin, with a maximum HQ of 2.2. However, all watershed HQs for avian receptors were similar to background HQs, indicating negligible incremental risk to birds from mining related zinc. The maximum ratio of impacted to background HQs for birds was 1.12 for the song sparrow in the Georgetown watershed. For the deer mouse, the maximum HQ was 1.9 in all watersheds. The background HQ was 1.0 indicating no potential risk from mining related zinc to the deer mouse. HQs for other mammalian receptors were all less than 1.0.

7.8.8 Summary of Tier 2 Risk Evaluation for Birds and Mammals

Tier 2 was an evaluation on an area-wide basis using approximated EPCs for each medium and mean exposure parameters for each receptor to represent average population-level exposures. EPCs were evaluated for the three watersheds (1) Blackfoot/Little Blackfoot, (2) Georgetown, and (3) Salt. Background EPCs were also calculated using non-mining impacted data.

Sections 7.8.1 through 7.8.7 discuss all COPECs and receptors for which HQs exceed 1.0. Table 7-22 summarizes the results of the Tier 2 assessment while taking background HQs into consideration. HQs greater than 1.0 for the COPECs and receptors shown on Table 7-22 are likely associated with some increased level of risk due to mining related activities in the watershed. COPECs and receptors were selected based on the watershed specific HQ being at least 0.5 higher than the background HQ(an arbitrary, yet conservative value). Receptors for which the difference was less than 0.5 were not included in the summary table.

Tier 2 results indicated potential risk to avian and mammalian receptors resulting from exposure to cadmium and selenium. Selenium by far affects the greatest number of receptors throughout the three watersheds. Potential risk from exposure to selenium was highest to small mammalian receptors with watershed HQs ranging from 18.5 to 19.4 for the deer mouse. For mammalian receptors, the highest ratio of impacted to background HQs was 2.62 for the eastern cottontail in the Blackfoot/Little Blackfoot watershed. For avian receptors, the highest impacted to background HQ ratios were for the song sparrow and the mallard duck (2.8 and 3.2, respectively).

For cadmium, potential risk was indicated to the song sparrow, red-winged blackbird, and meadow vole. Potential risk was highest to the red-winged blackbird in the Georgetown watershed with a HQ of 9.2. The ratios of impacted to background HQs was 1.4 for the song sparrow, 1.2 for the red-winged blackbird, and 1.4 for the meadow vole.

7.9 TIER 3 ASSESSMENT – ADDITIONAL LINES OF EVIDENCE

An evaluation of the data collected by the IMA and TtEMI indicates that significant variations occur in the concentrations of COPECs in surface water not only from year-to-year but also from month-to-month. Current data indicate that COPEC release from the mining areas is related to the volume of water released. Therefore, data collected in previous years was evaluated to determine variations in risk from year-to-year.

The Tier 1 and Tier 2 assessments in this AWERA only address higher trophic levels of aquatic and riparian and terrestrial mammals and birds. While some of these receptors are mainly found around and feed primarily from the benthic and fishery guilds, assessment of these higher trophic level receptors does not directly provide information concerning potential risks to aquatic receptors such as fish or benthic invertebrates. Because of limited scientific information, the dose assessment approach used for aquatic and riparian and terrestrial higher trophic level receptors is not usable with an acceptable degree of certainty. Therefore, other approaches must be used to evaluate potential risks to benthic and fish guilds. For this AWERA, the selected additional lines-of-evidence were compared to media-specific benchmarks for surface water and sediment and fish tissue concentrations were compared to literature reported tissue concentrations at which effects have been documented.

7.9.1 Comparison to Historical Data Concentrations

This section addresses variations of the data analysis based on different data sets, such as those collected by IMA prior to 2001 in comparison to the data collected by IMA and TtEMI in 2001. An arbitrary definition of impacted areas was developed for surface water based on an evaluation of the 1998 and 2001 data sets. Any stream segment with selenium concentrations that exceeded AWQC for selenium (the most widespread COPEC) at any time during the year was considered to be impacted. Based on this definition, extreme variation in the extent of impacted surface water occurs from year-to-year. For example, based on 1998 data, 27 percent of the Blackfoot/Little Blackfoot watershed would have been classified as impacted; whereas, based on 2001 data, only 0.7 percent would have been classified as impacted. To evaluate this temporal fluctuation in COPEC concentrations, an additional set of risk calculations was conducted using the surface water results from 1998.

The Tier 2 and Tier 3 assessments were conducted using area weighting for impacted areas based on the extent of impact defined by the 1998 data. The only difference in the calculations was the input parameter for the area-weighted surface water concentrations. The results indicated little difference in potential risk between 1998 and 2001 based on the assumptions used. The results of these Tier 2 and 3 assessments are presented in Appendix G.

A sensitivity analysis of the assessment indicates that the dose contributed by surface water is a minor portion of the dose for most receptors. The major contributors to dose for all terrestrial receptors were sediment or soil ingestion and concentrations of COPECs in prey. The more transitory surface water changes are less important than the residual COPECs in soils, sediments, and prey.

7.9.2 Comparison of Surface Water and Sediment Concentrations to Benchmarks

The detected concentrations of COPECs in surface water and sediment samples were compared to media specific benchmarks. The primary benchmark selected for surface water comparisons was the National AWQC continuous chronic criterion (CCC) for freshwater. These benchmarks have been developed to be protective of sensitive aquatic life. The following sections discuss the surface water concentrations of each COPEC. Detailed information is provided in Appendix B.

7.9.2.1 Cadmium

The selected ecological screening criterion was based on the CCC as reported in the NOAA SQuiRT tables (EPA 1999). The reported CCC was 2.20 micrograms per liter (µ/L) but the actual benchmark is based on a hardness-adjusted value. The maximum detected concentration of cadmium in impacted off-site surface water during the 2001 sampling was 1.25 µ/L. During the IMA sampling conducted in 1998 (MW 1999b), a maximum concentration of 4.70 µ/L was reported. Based on these comparisons, the maximum detected concentrations in the impacted areas did not exceed the benchmark in 2001 but did in 1998. The average concentrations in the impacted reaches were not reported by MW (1999b). However, comparisons of the 2001 impacted area data to background area data indicated that the average concentrations were not significantly different.

The maximum detected concentration of cadmium in impacted sediments was 14.0 mg/kg with an average impacted area concentration of 5.47 mg/kg. These values were compared to the average background area concentration of 1.06 mg/kg. The maximum detected value in the impacted area exceeded the average background area concentration by a factor of 13.

The selected freshwater sediment criterion for cadmium was the threshold effects concentration (TEC) reported in MacDonald and others (2000). The reported TEC was 0.99 mg/kg. The maximum detected and average concentrations in impacted sediments exceeded this concentration by a significant factor.

7.9.2.2 Chromium

The maximum detected concentration of chromium in impacted surface water was 4.60 µ/L with an average impacted area concentration of 1.20 µ/L. These values were compared to the average background area concentration of 0.62 µ/L. The maximum detected value in the impacted area exceeded the average background area concentration by a factor of 7.

The selected ecological screening criterion was based on the freshwater CCC for chromium. The reported CCC was 74.0 µ/L. Based on this comparison, the maximum detected and average concentrations in the impacted areas did not exceed the benchmark.

The maximum detected concentration of chromium in impacted sediments was 191 mg/kg with an average impacted area concentration of 73.7 mg/kg. These values were compared to the average background area concentration of 35.4 mg/kg. The maximum detected value in the impacted area exceeded the average background area concentration by a factor of 5.

The selected freshwater sediment criterion for chromium was the TEC reported in MacDonald and others (2000). The reported TEC was 43.4 mg/kg. The maximum detected and average concentrations in impacted sediments exceeded this concentration.

7.9.2.3 Copper

The maximum detected concentration of copper in impacted surface water was 15.0 µ/L with an average impacted area concentration of 0.57 µ/L. These values were compared to the average background area concentration of 1.30 µ/L for background areas. The maximum detected value in the impacted area exceeded the average background area concentration by a factor of 12. However, the average impacted area concentration was less than the average background concentration.

The selected ecological screening criterion was based on the freshwater CCC for copper. The reported CCC was 9.00 µ/L. Based on this comparison, the maximum detected concentration in the impacted areas exceeded the benchmark, but not the average.

The maximum detected concentration of copper in impacted sediments was 102 mg/kg with an average impacted area concentration of 17.8 mg/kg. These values were compared to the average background area concentration of 10.5 mg/kg. The maximum detected value in the impacted area exceeded the average background area concentration by a factor of 10.

The selected freshwater sediment criterion for copper was the TEC reported in MacDonald and others (2000). The reported TEC was 31.6 mg/kg. The maximum detected concentration in impacted sediments exceeded this concentration. However, the average impacted area concentration did not exceed the TEC.

7.9.2.4 Nickel

The maximum detected concentration of nickel in impacted surface water was 43 µ/L with an average impacted area concentration of 3.13 µ/L. These values were compared to the average background area concentration of 0.978 µ/L. The maximum detected concentration in the impacted area exceeded the average background area concentration by a factor of 44.

The selected ecological screening criterion was based on the freshwater CCC for nickel. The reported CCC was 52.0 µ/L. Based on this comparison, the maximum detected and average concentrations in the impacted areas did not exceed the CCC.

The maximum detected concentration of nickel in impacted sediments was 164 mg/kg with an average of 64 mg/kg. These values were compared to the average background area concentration of 14 mg/kg. The maximum detected value and the average in the impacted area exceeded the average background area concentration by a factor of 12.

The selected freshwater sediment criterion for nickel was the TEC reported in MacDonald and others (2000). The reported TEC was 22.7 mg/kg. The maximum detected and average concentration in impacted sediments exceeded this concentration.

7.9.2.5 Selenium

The maximum detected concentration of selenium in impacted surface water was 1,140 µ/L with an average impacted area concentration of 66.68 µ/L. These values were compared to the average background area concentration of 0.745 µ/L. The maximum detected concentration in the impacted area greatly exceeded the average background area concentration by a factor of 1,530.

The selected ecological screening criterion was based on the freshwater CCC for selenium. The reported CCC was 5.00 µ/L. Based on this comparison, the maximum detected and average concentrations in the impacted areas exceeded the CCC.

The maximum detected concentration of selenium in impacted sediments was 188 mg/kg with an average of 19.7 mg/kg. These values were compared to the average background area concentration of 1.57 mg/kg. The maximum detected value in the impacted area exceeded the average background area concentration by a factor of 119.

There is no standard freshwater sediment criterion for selenium; therefore the value used for screening selenium is 4.0 mg/kg dry weight taken from National Irrigation Water Quality Program Guidelines

(Skorupa 1998). The maximum detected and average concentrations for the impacted areas exceed this criterion.

7.9.2.6 Vanadium

The maximum detected concentration of vanadium in impacted surface water was 6.2 µ/L with an average impacted area concentration of 1.43 µ/L. These values were compared to the average background area concentration of 0.92 µ/L. The maximum detected concentration in the impacted area exceeded the average background area concentration by a factor of 6. There were no applicable ecological benchmarks.

The maximum detected concentration of vanadium in impacted sediments was 133 mg/kg with an average impacted area concentration of 62.57 mg/kg. These values were compared to the average background area concentration of 30.3 mg/kg. The maximum detected value in the impacted area exceeded the average background area concentration by a factor of 4. There were no applicable ecological benchmarks.

7.9.2.7 Zinc

The maximum detected concentration of zinc in impacted surface water was 110 µ/L with an average impacted area concentration of 24.18 µ/L. These values were compared to the average background area concentration of 15.05 µ/L. The maximum detected concentration in the impacted area exceeded the average background area concentration by a factor of 7.

The selected ecological screening criterion was based on the freshwater CCC for zinc. The reported CCC was 120 µ/L. Based on this comparison, the maximum detected and average concentrations in the impacted areas did not exceed the CCC.

The maximum detected concentration of zinc in impacted sediments was 866 mg/kg with an average impacted area concentration of 251.73 mg/kg. These values were compared to the average background area concentration of 75.50 mg/kg. The maximum detected value in the impacted area exceeded the average background area concentration by a factor of 11.

The freshwater sediment criterion for zinc was the TEL concentration reported in the NOAA SQuiRT tables (EPA 1999). The reported TEL was 123.1 mg/kg. The maximum detected and average concentration in impacted sediments exceeded the TEL.

7.9.3 Comparison of Fish Tissue Concentrations to Literature Reported Effects Values

A limited body of scientific literature exists that presents tissue concentrations in fish to effects. Fish tissue concentrations in both impacted and background areas were evaluated against no observed effect levels for trout. With the exception of vanadium, the average concentrations in fish from impacted reaches exceeded the reference values. However, in some cases the average concentrations in fish collected from background locations also exceeded the reference values. The data is presented in Tables 7-23 through 7-25.

7.10 UNCERTAINTIES

This section discusses uncertainty associated with the exposure parameters in conducting an AWERA. Because the same methodology, models, and model parameters were used to estimate potential risks in the Tier 1 and Tier 2 assessments, this analysis discusses general uncertainties associated with the AWERA performed for the Resource Area. The uncertainties described for Tier 2 also apply for the Tier 3 assessments. Uncertainties arise due to the application of those methodologies, models, parameters, and parameter values.

7.10.1 Tier 1 Assessment Uncertainty

The Tier 1 assessment, designed to address uncertainty by over estimating risk, serves to increase the level of confidence within the AWERA that risk to a specific ecological receptor will not be removed from further assessment when in fact risk to the ecological receptors actually exists. Therefore, a conservative approach was employed to conduct the Tier 1 AWERA using biological and chemical information that leads to risk calculation results that have a high potential to exceed what is actually present in the study area. The parameters that were used in the dose assessments and risk calculations are listed in Table 7-26, which contains their conservative assumption and influences on the risk calculation results.

All of the parameters utilized in the Tier 1 assessment lead to an overestimate of risk, so that no COPEC with any possibility of posing a risk to the ecological receptors of concern were excluded.

7.10.2 Tier 2 Assessment Uncertainty

The following sections discuss uncertainties that remain after conducting the Tier 2 assessment; these are termed "residual uncertainties." The discussion of residual uncertainties associated with dose modeling for this study is organized as follows:

(1) Input parameters to the dose assessment
(2) TRVs

7.10.2.1 Dose Assessment Input Parameters

Residual uncertainties associated with input parameters used in the dose assessment for the receptors of concern are sub-divided into the following categories:

- Body weight and ingestion rate
- Diet composition
- Estimation of EPCs
- Representativeness of site EPCs for media and tissue data
- COPEC Bioavailability
- Prey species variation in COPEC uptake
- SUFs

Body Weight and Ingestion Rate

Dose parameters used in the Tier 2 assessment were mean values derived from existing literature. Although literature data exist for inputs to the dose calculation such as body weight, ingestion rate, and dietary composition for the receptors in this risk assessment, there is a natural level of variability in these parameters within a population of organisms. Uncertainty is inherent in the use of these values because they were generated from literature sources, rather than being empirically measured in the study area. Therefore, using literature-derived exposure parameters from investigations conducted outside of the study area adds an unknown degree of uncertainty that may over- or under-estimate exposure.

Diet Composition

The percent composition and type of prey ingested by the various receptors was based on literature studies that were not site-specific. Additionally the models were simplified to assume a limited diet, consistent with the literature data. Receptors from the Resource Area may consume food items in percentages that differ from the dose model.

Estimation of EPCs

Calculation of EPCs for receptors evaluated in the Tier 1 assessment involved uncertainties that were not eliminated in the Tier 2 assessment. Residual uncertainties associated with estimation of EPCs include:

- Representativeness of the data that were used to calculate EPCs for sediment, soil, and surface water
- Representativeness of the data that were used to calculate EPCs for tissue

Representativeness of Site EPCs for Media and Tissue Data

Uncertainty related to representativeness of the data is associated with the location and number of samples evaluated which may not adequately cover each stream reach, impacted area, or background area. Therefore, the EPCs for media and tissue may under- or over-estimate the concentration of COPECs to which the ecological receptors may be exposed.

An additional area of uncertainty associated with the data for tissue relates to the taxonomic composition of benthic invertebrates, insects, small mammal, and plant species collected for this assessment. The uncertainty is related to the potential for differential uptake of COPECs based on taxonomic differences between different species.

Representativeness of the Chosen Assessment Receptor

This AWERA assumed that the species chosen adequately represents its guild. In actuality, the assessment endpoint was chosen based on the availability of adequate information for calculating the necessary dose parameters required for the exposure assessment.

COPEC Bioavailability

This AWERA conservatively assumed that each COPEC is 100 percent bioavailable when that is not the case. Depending on the COPEC and receptor, bioavailability may be significantly less than 100 percent.

Prey Species Variation in COPEC Uptake

Each species or organism absorbs and processes COPECs in a different manner that will affect the exposure of to a higher-level receptor. As stated above, uncertainty associated with combining tissue from multiple species is related to the potential for differential uptake of COPECs based on taxonomic differences between species.

SUFs

The Resource Area is a large and complex ecosystem that supports a variety of habitats and numerous species of plants and animals that coexist in a complex and widespread food web. Assumptions on home or foraging ranges for all receptors were based on literature-derived information, which may not truly reflect actual distribution. No site-specific studies were available for the receptors assessed. SUFs for both Tier 1 and Tier 2 were assumed to be 1.0, which may overestimate exposure and does not account for variability in home ranges for each receptor.

7.10.2.2 Toxicity Reference Values

Development of TRVs requires acquisition and integration of toxicity data from numerous sources in an attempt to define a daily dose (mg/kg/day) that is protective of a specific receptor. Because toxicity studies vary, a certain level of uncertainty is associated with the TRV chosen to represent a species. Sources of uncertainty with the TRVs included:

- Quantity and quality of the toxicity data used to derive the TRVs
- Exposure conditions of literature-derived TRVs
- Use of data for surrogate species
- Conversion of laboratory TRVs to receptor TRVs

Quantity and Quality of Toxicity Data Used to Derive the TRVs

Potential uncertainties exist in the quantity and quality of literature-derived toxicity data. TRVs were taken from Sample and others (1996) and Navy (1998). Both documents have been extensively reviewed and the data are based on extensive searches of the primary, peer-reviewed literature and on secondary literature, such as government reports and proceedings from technical conferences. Therefore, it was assumed that sufficient data of reasonably high quality were used to derive the TRVs used in this assessment.

Exposure Conditions of Literature-derived TRVs

The majority of the toxicity data evaluated and used to generate the TRVs were derived from laboratory studies and not from the receptors used in this study. Laboratory settings do not mimic true field conditions. Laboratory studies typically control various factors to isolate one parameter. For example, to establish a dose-response relationship, animals of the same genetic strain and body weight may be administered a chemical in the same medium through the same route of exposure for the same exposure duration, with only the concentration of the chemical varied. Although the controlled experiments result in a more valid interpretation of the isolated parameters or relationship, uncertainty is associated with assuming laboratory exposure conditions are equivalent to exposure conditions in the field. Even extrapolation of field conditions associated with a literature study to exposure conditions in the Resource Area is associated with uncertainty. Exposure duration and toxicity characterization are two parameters that exemplify the difficulty in translating literature-derived data to data that represent exposure conditions for receptors in the Resource Area.

In general, uncertainty is associated with extrapolation of literature-derived toxicity endpoints (especially laboratory-based studies) to equivalent endpoints for receptors in the Resource Area as a result of discrepancies in exposure conditions.

Use of Data for Surrogate Species

The primary source of uncertainty associated with avian TRVs stems from the need to develop TRVs based on data from surrogate species that may or may not appropriately reflect the sensitivity of the receptors used in this AWERA. Developing TRVs based on toxicity values for surrogate species is necessary because appropriate data on the effects of COPECs on the specific receptors of concern are not available.

Conversion of Laboratory TRVs to Receptor TRVs

Allometric conversions are used to convert test species TRVs to receptor TRVs based on a mathematical relationship that uses the ratio of body weights for the test species and receptor species. The practice is based on scaling theory and is applied to correct for different food ingestion rates and metabolism rates that depend on the size of the organism. This theory, as applied to absorption, transport, metabolism, and excretion, assumes that all receptors, physiologically and biochemically, treat all chemicals in the same fashion. However, tremendous differences occur in all of these areas that relate to the metabolic activity and physiological processes of the individual organisms and species. Therefore, a degree of unknown uncertainty exists whenever an allometric conversion is applied to adjust a TRV from a test organism to a receptor species. This uncertainty is not quantifiable without conducting toxicity studies on the specific receptors that the AWERA assesses.

7.11 AREA WIDE ECOLOGICAL RISK ASSESSMENT CONCLUSIONS

The Tier 1, or "worst-case", assessment indicated potentially significant risk from all COPECs. Various COPECs affected different receptors. In some cases, those receptors that use only riparian areas were predicted to be most affected while in other cases the receptors that use the overall Resource Area were more impacted (see Table 7-14). However, the Tier 1 results do not present a realistic assessment of probable risk at a single location. The maximum media concentrations used in the Tier 1 assessment were found at different locations. These results present a bounding estimate of maximum potential risk in the Resource Area for the endpoints selected. However, the extremely high HQs (>2,000) for some receptors indicate that there is a high probability of significant risk to terrestrial receptors occurring in some localized areas.

The Tier 2 assessment was designed to evaluate an "average" risk to the selected endpoints in the Resource Area. Instead of maximum detected concentrations for each media, an area-weighted average was developed for each media. These "average" EPCs were designed to predict the average exposure for the entire receptor population in the Resource Area. To place the potential risks in the appropriate context, HQs were developed based on background only samples as well as the area-weighted EPCs for the entire area.

Based on the Tier 2 assessment, the only significant area-wide risks to ecological receptors are presented by selenium and cadmium. While the other COPECs may present a significant risk in some localized areas, the assessment indicates that they do not pose a significant risk to populations in the Resource Area as a whole. While selenium and cadmium risks are elevated, they are less than three times the background risk for the Resource Area. Therefore, the risk to overall populations of terrestrial receptors in the Resource Area is expected to be low. However, the risks calculated from the Tier 2 assumptions may significantly underestimate exposure to localized subpopulations of various species.

The Tier 3 assessment did not indicate a significant difference in risk when 1998 surface water data was used instead of 2001 data. The significantly higher concentrations detected in 1998 did not create a significant additional risk because the major portion of the dose for all receptors comes from other media not as transitory as surface water. These other media serve as a "sink" for the various COPECs that move with the surface water. The major effect of the surface water concentrations is to add COPECs into the other media, which serve as a more permanent reservoir of chemicals for exposure to the various receptors.

The Tier 1, 2, and 3 assessments evaluated exposure to terrestrial, aquatic, and riparian receptors. Data concerning effects on aquatic receptors is less well developed and has a higher level of uncertainty. Surface water concentrations of cadmium, copper, and selenium exceeded their respective benchmarks. Sediment concentrations of cadmium, chromium, copper, nickel, selenium, and zinc exceeded their respective benchmarks. There was no available benchmark for vanadium for surface water or sediments. For all COPECs, impacted fish tissue concentrations exceeded the conservative benchmarks except for vanadium.

Based on the Tier 3 assessment, all of the contaminants except nickel and vanadium were a risk to the aquatic/riparian omnivorous birds (red-winged blackbird)(see Table G-6, Appendix G). For the aquatic/riparian herbivorous birds (song sparrow), all contaminants except nickel and vanadium also posed a risk in all three watersheds. All COPECs posed a risk to the aquatic/riparian herbivorous mammals (meadow vole) except for chromium and copper. Selenium was the only COPEC that appeared to impact the piscivorous bird guild (great blue heron) in all three watersheds. Selenium also was the only COPEC that posed a risk to aquatic/riparian benthic-feeding birds (mallard) in the Blackfoot/Little Blackfoot and Georgetown watersheds, but not in the Salt watershed. Nickel, selenium, and vanadium posed a risk to the aquatic/riparian carnivorous mammals (mink) in all three watersheds. Cadmium also posed a risk to the mink in the Blackfoot/Little Blackfoot and Georgetown watersheds. The same COPECs also were found to affect aquatic/riparian omnivorous mammals (raccoon). Only cadmium and selenium posed a risk to the terrestrial herbivorous birds (represented by the northern bobwhite) in all three watersheds (see Table G-68, Appendix G). Nickel posed a risk to the terrestrial herbivorous mammals (cottontail rabbit) in all three watersheds, while selenium only posed a risk in the

Blackfoot/Little Blackfoot watershed. For the terrestrial omnivorous birds (American robin), all COPECs posed a risk in all three watersheds except for nickel and vanadium. For the terrestrial omnivorous mammals (deer mouse), all COPECs posed a risk in all watersheds except for chromium and copper. Based on the Tier 3 assessment, there does not appear to be any impact to the terrestrial carnivore guild (coyote) and the raptors (northern harrier). The primary conclusion of the study is that there is some potential risks to aquatic and riparian receptors, but the data is not sufficient to be definitive.

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