FINAL

MIDNITE MINE HUMAN HEALTH RISK ASSESSMENT REPORT

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September 2005

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ABBREVIATIONS AND ACRONYMS

AESE	Associated Environmental Scientists and Engineers
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COPC	chemical of potential concern
CSF	cancer slope factor
CSM	conceptual site model
DMC	Dawn Mining Company
EPA	Environmental Protection Agency
EPC	exposure point concentration
HEAST	Health Effects Assessment Summary Tables
HHRA	Human Health Risk Assessment
HI	hazard index
HQ	hazard quotient
IRIS	Integrated Risk Information System
MCL	Maximum Contaminant Level
NAREL	National Air and Radiation Environmental Laboratory
NPL	National Priorities List
PCi	picoCuries
PRG	preliminary remediation goals
RAGS	Risk Assessment Guidelines for Superfund
RfD	reference dose
RI	remedial investigation
RI/FS	remediation investigation/feasibility study
RME	reasonable maximum exposure
SMI	Shepherd Miller, Inc
95%UCL	95 percent upper confidence limit of the mean
µg	microgram
µrem	microrem
µR	microRoentgen
UTL	upper tolerance limit

1.0 INTRODUCTION

This report presents the baseline risk assessment for the Midnite Mine Superfund site. A risk assessment evaluates the likelihood of adverse effects occurring in human populations potentially exposed to contaminants released in the environment.

According to U.S. Environmental Protection Agency (EPA) guidance, human health risk assessments (HHRAs) are composed of four basic steps, which are the basis for the organization of this HHRA. The steps are:

1. **Data Evaluation/Selection of Chemicals of Potential Concern (COPCs).** The sampling data are initially screened to select the applicable data set for humans and, within that data set, to select contaminants that could be a health concern.

2. **Exposure Assessment.** Contaminant sources, pathways, receptors, exposure duration and frequency, and routes of exposure are evaluated to assess the amount of exposure to the COPCs quantitatively.

3. **Toxicity Assessment.** A toxicity assessment summarizes the carcinogenic and non-carcinogenic effects associated with the COPCs and provides toxicity values that are used to estimate the dose-response relationship.

4. **Risk Characterization.** A risk characterization integrates the quantitative and qualitative results of the data evaluation, exposure, and toxicity assessment sections.

The accuracy of the information presented in a risk assessment depends in large part on the quality and representativeness of the available sample, exposure, and toxicological data. Where information is incomplete, health protective assumptions have been made so that risk to human health is unlikely to be underestimated. A discussion of uncertainties in the HHRA is presented in Section 5.7. This report was prepared in accordance with current EPA guidelines for risk assessment (EPA 1989a, 1991a, 1997a, and 1998a).

1.1 SITE DESCRIPTION AND BACKGROUND INFORMATION

Midnite Mine is an inactive open pit uranium mine located on the Spokane Indian Reservation in Washington. Dawn Mining Company (DMC) mined the site between 1955 and 1981. Mining has released radionuclides and other metals into the environment. Midnite Mine was added to the National Priorities List (NPL) in May of 2000. The location and primary features of the site are shown on Figure 1-1. This HHRA is part of an EPA-funded remedial investigation/feasibility study (RI/FS).

The Spokane Indian Reservation occupies approximately 157,000 acres in Stevens County, Washington. The reservation is bounded by water on three sides: to the south and west by the Spokane and Columbia arms of Franklin D Roosevelt Lake, to the east by Chamokane Creek, and to the north by the 48th parallel. The Tribe manages the majority of the reservation for

timber production. The balance of the land has been developed for pasture, agricultural, municipal, and approximately 529 residences. The population residing in the reservation was 1,502 in 1990; 83 percent identified themselves as American Indians (Spokane Tribe of Indians, 2003). As of 1997, the Spokane Tribe had 2,258 registered Tribal members. Compared with Stevens County, population growth on the Reservations is greater and the population is younger (Spokane Tribe of Indians, 2003).

In 1955, DMC excavated several open pits in an area approximately one mile north-south by one-half mile east-west. The site was managed for timber prior to 1955. The DMC ceased uranium mining operations in 1981, but continues to operate a plant to treat acid mine drainage intercepted from the open pits, seeps, and drainages. Waste rock was used to backfill some of the pits, to create several large piles above grade, and to fill portions of natural surface drainages. Groundwater flows closely follow surface topography, due to extensive fractures in the bedrock. The filled drainages continue to act as conduits for shallow groundwater flow and the open pits intercept significant groundwater flows.

The approximately 350-acre Mined Area is defined by visible disturbances at the ground surface (e.g., an absence or paucity of native vegetation and topsoil, bare rock, obvious grading, and stockpiled ore, waste rock, and topsoil). Approximately 2.4 million tons of ore and rock remain stockpiled in the Mined Area. Outside of the Mined Area, the remedial investigation (RI) of the site initially included a relatively large additional area primarily south and southeast of the Mined Area in order to evaluate the nature and extent of mining impacts. This additional area is referred to in the RI as the "Potentially Impacted Area (PIA)" and is shown on Figure 1-1. Based on the information provided in the RI, not all of the investigated area was found to be impacted by mining activities. The "Mining Affected Area (MAA)" is a subset of the Potentially Impacted Area and is indicated by shading on Figure 1-1. In general the Mining Affected Area is limited to the streams and stream floodplains that drain the Mined Area, and to the roads and roadsides which were used to haul material from the mine. For the purposes of the risk assessment, the site comprises the Mined Area and the Mining Affected Area. These areas are evaluated separately in the risk assessment to delineate different levels of impact and associated risk based on different exposures and anticipated future uses. Currently, the closest residents live approximately three miles from the site.

1.2 PURPOSE AND SCOPE

The purpose of the baseline risk assessment is to facilitate EPA's decision-making by identifying the most important exposure pathways and site-related chemicals that should be reduced or eliminated. Because the site is located on land owned by the Spokane Tribe of Indians and individual members of the Tribe, the focus of the risk assessment is exposures to tribal members. In this risk assessment, exposure factors and pathways representative of tribal subsistence activities were used, based largely on recommendations from the Spokane Tribe of Indians (Harper et al. 2002).

In the assessment, risk from exposure to external radiation and contaminants in air, water, soil, plants, or meat are quantified. The exposure scenarios, exposure pathways, exposure factors, and toxicity values are used to estimate potential cancer risks and non-cancer hazards. The HHRA

follows EPA risk assessment guidance to address unique aspects of the site and the surrounding community (EPA 1989a).

Risk assessments encompass many uncertainties, which are discussed in Section 5. Risk assessments are needed to determine if current or potential risks are sufficient to warrant Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) remedial actions (EPA 1991b). In the case of the site, risks clearly warrant remedial action.

Spokane Mountain

Sand Creek

Northwest Ridge

PIT 4

Northeastern Drainage

Middle Fork

West Fork

East Fork

East Branch (ND)

Middle Branch (ND)

West Branch (ND)

PIT 3

West Fork

Mined Area (MA) Boundary

East Haul Road

Upper Eastern Drainage

Central Drainage

Western Drainage

West Haul Road

Southwestern Drainage

Ford - Wellpinit Rd.

Blue Creek

BIA Hwy 55

Mining Affected Area

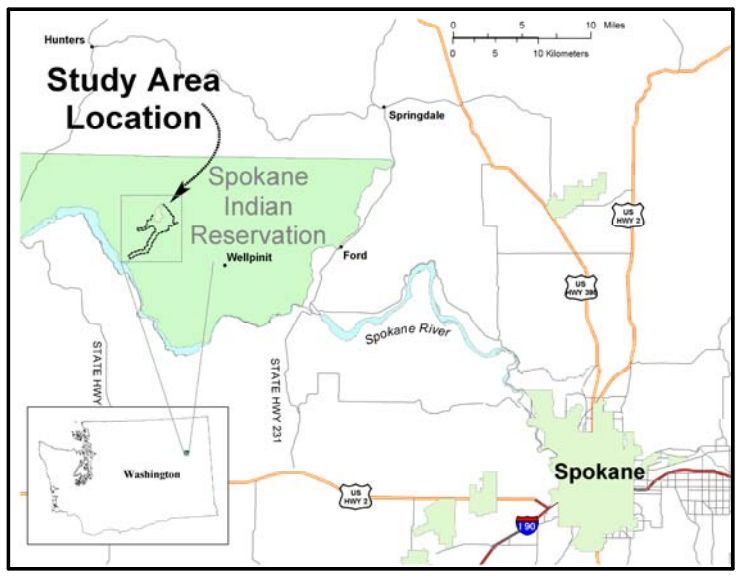
Blue Creek

Oyachen Creek

BIA Hwy 55

Blue Creek

Franklin D. Roosevelt Lake



LEGEND

- Mined Area Boundary
- Potentially Impacted Area Boundary
- Stream
- Road
- Shaded areas represent the Mining Affected Areas evaluated in the risk assessment

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Midnite Mine Human Health Risk Assessment

EPA REGION 10

Overview of the Midnite Mine Superfund Site

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DOCUMENT CONTROL NO.	DSGN.	CHK.

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EDIT DATE: 09/27/04 AT: 12:23

2.0 DATA EVALUATION/SELECTION OF CHEMICALS OF POTENTIAL CONCERN

This initial step in the risk assessment reviews the available sampling data and site information to identify contaminants and affected environmental media (e.g., soil, groundwater) that are potential health concerns and that require a more detailed assessment. The relevant sampling investigations for the site are summarized below, followed by the selection of the COPCs.

2.1 SAMPLING INVESTIGATIONS

An early step in the risk assessment process is to evaluate historical data and data generated during the remedial investigation to determine whether they are of adequate quality to quantify risks and to identify any remaining critical data gaps. At Midnite Mine, levels of numerous metals and radionuclides were analyzed. Radionuclides were selected for analysis based on the nature of the site (a uranium mine), as well as radionuclide decay series, half-lives, and mobility. Radionuclide mobility is particularly important in the case of radon, which is a gas and is part of the uranium decay series.

Sample locations for the data used in the HHRA are depicted on Figures 2-1 through 2-5. A complete list of all of the sample locations and data sources is included as Appendix A.

The following data sources were evaluated for use in the HHRA:

- Data collected by URS, EPA's contractor for the Midnite Mine RI/FS
- Data collected by Ecology and Environment, Inc., in support of the EPA Expanded Site Investigation
- Data collected by Shepherd Miller, Inc. (SMI), on behalf of DMC
- 1995 Midnite Mine radiation survey data collected by the U.S. Bureau of Mines

During the data evaluation process, EPA found that data collected before 1998 was not suitable for the risk assessment because the quality of these older historical data could not be determined. There were a variety of reasons the data quality could not be adequately assessed, including inadequate documentation of well construction methods or sampling procedures, unacceptable field data collection procedures, or failure to meet laboratory quality assurance and quality control requirements (URS 1999, 2000a and b).

In addition to the data eliminated due to quality issues, essential human nutrients were eliminated from the data set, in accordance with guidance (EPA 1989a). The following essential nutrients and generally non-toxic elements were excluded: calcium, iron, magnesium, potassium, and sodium.

2.2 DATA QUALITY EVALUATION

Chemical and radiochemical data used in quantifying risk have undergone review to evaluate data quality (URS 1999, 2000a, b and c). Data quality is maintained through standard operating

procedures during sample collection and sample analysis, quality control checks, data review, and validation. Radionuclide analyses were performed by the EPA National Air and Radiation Environmental Laboratory (NAREL) in Montgomery, Alabama. The data validation process consisted of an independent technical assessment of the reported radiological and inorganic metals analytical data (URS 1999, 2000a, b, and c). This process included the assignment of data qualifiers to analytical results based on the results of the reported quality control data, other appropriate technical criteria, and the professional judgment of the data evaluator. Validation followed the format and guidelines of Laboratory Data Validation Guidelines for Evaluating Radionuclide Analyses (SAIC 1993), as specified by the July 12, 1999 draft Quality Assurance Project Plan for the Midnite Mine Phase 1 RI/FS (URS 1999).

Full validation was performed only on the data collected by EPA or its contractors. SMI did not perform full validation on their data set; however, quality control split samples were collected by SMI and analyzed by separate laboratories to evaluate the comparability of SMI and EPA data. The evaluation of the SMI and EPA quality control split sample data generally found that the two data sets were comparable (a more complete discussion of data quality and comparability can be found in the Remedial Investigation Report, ref). In addition, EPA performed full validation on a subset of the SMI data. The EPA validation found the SMI data usable.

2.3 SELECTION OF CHEMICALS OF POTENTIAL CONCERN

Typically, a limited number of contaminants pose the primary health risk at a site, while other chemicals or radionuclides detected at a site may not pose significant health risks or may not contribute significantly to the overall site risk (EPA 1989a). The EPA guidelines (1989) therefore recommend focusing on a group of contaminants of potential concern (COPCs) based on inherent toxicity, site concentration, and behavior of the contaminants in the environment. To identify COPCs for the Midnite Mine human health risk assessment, risk-based screening values and natural background values were compared to site concentrations of contaminants. If site concentrations of a contaminant exceeded its respective screening and/or background concentration, then the contaminant was retained as a COPC for further evaluation in the risk assessment. All metals and radionuclides found at the site were present prior to mining; hence, comparison of site concentrations to background levels (as an approximation of pre-mining conditions, for which no data are available) was an important step. The COPCs were selected for groundwater, surface and subsurface soil, sediments, surface water, plants, and animal tissue, or meat. The screening process consisted of the steps listed below and Table 2-1 summarizes the results. Appendix B contains the tables that provide details of the selection process using the format provided in Risk Assessment Guidelines for Superfund (RAGS) Part D, Table 2 Series (EPA 2001a).

Quantitative risk estimates are developed only for chemicals selected as COPCs, because the COPC selection process focuses the risk assessment on chemicals and radionuclides that pose the greatest risks to human health. Chemicals not selected as COPCs may present some risk. However, inclusion of a larger number of contaminants in the risk assessment is not likely to affect site decisions if the additional contaminants do not contribute significantly to the total risk. Focusing efforts towards those chemicals that drive risk facilitates risk assessment and supports remedial decisions. General selection criteria are described in the Risk Assessment Guidance for

Superfund Human Health Evaluation Manual Part A (EPA 1989a), in Soil Screening Guidance: Technical Background Document (EPA 1996a), and Soil Screening Guidance: User's Guide (EPA 1996b).

Selecting COPCs is a multi-step process. The steps are described in this section and are depicted on Figures 2-6 through 2-8. The major steps are as follows:

- Step 1 – Select and group available data applicable to human exposures
- Step 2 – Select background and risk-based screening values
- Step 3 – Compare maximum site data to screening values and select COPCs in primary media (e.g., water, soil)
- Step 4 – Select COPCs in secondary media (e.g., plants, meat, air)

The selection process differed depending on whether a contaminant was a (non-radioactive) chemical or a radionuclide and whether the medium was a primary medium or a secondary medium. The COPCs were selected first for primary media such as surface/subsurface material, sediments, and water. Primary media included the following media directly affected by mining: soil, groundwater, surface water, and sediments. For purposes of COPC selection, secondary media generally are those that are affected by the primary media. Where sampling results were not available for secondary media (e.g., animal tissue and air), modeling was used. The COPCs selected for primary media also were included as COPCs for plants and meat, except as discussed in Section 2.3.4.

Risk-based screening levels were used for non-radionuclides in soil, sediment, and water. For soil and sediment, risk-based screening levels were equal to one-tenth of the Region 9 EPA residential soil preliminary remediation goals (PRGs) (Smucker 2003). The Region 9 PRGs for water were modified to reflect the assumption of greater water ingestion rate of the Spokane Tribe. Radionuclides were selected on the basis of relative contribution to risk to retain a subset of radionuclides accounting for 85 percent or more of the total radionuclide cancer risk.

2.3.1 Step 1 – Group Data Applicable to Human Health

Section 2.1 indicated which data sets were included and which were excluded from the risk assessment evaluation. This section describes the rationale for grouping the selected data sets prior to screening for COPC selection.

Data groupings were used in COPC selection, if the human exposure was likely to be similar across different affected areas. For example, surface water data for the East, Central, and Western Drainages and seeps were combined because people living in the Mining Affected Area could potentially drink surface water from drainages near the mine. Sediment data were similarly grouped based on likely exposure. Data from affected areas of Blue Creek were treated separately from data from the mine drainages, both for sediment and surface water. Groundwater was not segregated by area for screening, because groundwater could be consumed at any location (assuming a well could be drilled at many places within the site); therefore, all groundwater data were pooled for screening to provide the most inclusive COPC list. Pit 3 and Pit 4 data were pooled because there is an equal possibility of a swimmer using one or the other pit. Since maximum site values were used in the screening, combining

sampling into larger groups resulted in a more inclusive COPC list. The data groupings are listed below along with the Appendix B table that provides the media-specific COPC selection details:

Affected Area/Media:	**Appendix B Table:**
Mined Area: Surface and Subsurface Material	Table 2-1
Mined Area: Pit Surface Water	Table 2-7
Mined Area: Pit Sediments	Table 2-10
Mined Area: Terrestrial Plants	Table 2-12
Mining Affected Area: Surface and Subsurface Material on Haul Roads	Table 2-2
Mining Affected Area: Surface Material adjacent to the Haul Roads	Table 2-3
Mining Affected Area: Blue Creek Surface Water	Table 2-5
Mining Affected Area: Surface Water in Drainages & Seeps	Table 2-6
Mining Affected Area: Blue Creek Sediments	Table 2-8
Mining Affected Area: Drainage & Seep Sediments	Table 2-9
Mining Affected Area: Riparian and Aquatic Plants in the Drainages	Table 2-13
Mining Affected Area: Riparian and Aquatic Plants in Blue Creek	Table 2-14
Both Areas: Groundwater	Table 2-4
Both Areas: Airborne Radon and External Radiation	Table 2-11

In the Mined Area, affected media included surface and subsurface materials, groundwater, and both sediment and water in Pits 3 and 4. In the Mining Affected Area, surface and subsurface materials on and adjacent to the gravel haul roads were affected, as well as groundwater, sediment and surface water (including seeps) in the East, Central, and Western Drainages directly down gradient of the Mined Area. In Blue Creek, surface water was affected in both the middle and lower segments, and sediments in the middle segment of Blue Creek were affected.

2.3.2 Step 2 – Select Screening Values

Two sets of screening values were used to select COPCs: background values and values based on human health risks.

Background Screening Values

The chemicals and radionuclides at the site are naturally occurring throughout the study area, and their concentrations prior to mining are unknown. To determine whether mining activities are the cause of elevated concentrations in environmental media, background (pre-mining) concentrations of the chemicals and radionuclides are used as a basis for comparison.

Details of the process used to characterize background areas, select background reference values, and identify mine-affected areas and media were presented in Draft Technical Memorandum for Suitability of Background Sampling Used to Establish Site Impacts on the Midnite Mine Superfund Site (URS 2003a).

Background data were also used in the selection of COPCs for the risk assessment. The background data were used to calculate 95 percent upper tolerance limits (UTLs) for each contaminant, in accordance with EPA guidance (EPA 2002b). The use of the 95 percent UTL as a screening value was intended to reduce the likelihood of falsely concluding that site levels are above background levels (EPA 2002b).

Risk-Based Screening Values

The EPA's Region 9 PRGs are widely used risk-based screening values for residential exposures to non-radioactive COPCs. The PRGs are based on a target hazard quotient of 1 for non-carcinogens or a cancer risk of 10^{-6} for carcinogens. The Region 9 PRGs reflect the assumption that people live at one location and are exposed to contaminants there for 30 years (EPA 1996a and b, Smucker 2003, EPA 1989a). Additional details about the Region 9 PRGs can be found on the web at the following address:
http://www.epa.gov/region09/waste/sfund/prg/files/background.pdf.

The Spokane Tribe subsistence lifestyle results in more contact-intensive soil exposures than the residential exposures used to develop the Region 9 PRGs. It also includes some exposure pathways not addressed by the PRGs, such as routine consumption of locally harvested plants and animals (Harper et al. 2002). Rather than develop a soil screening level that would account for both direct soil contact and the plants and meat tissue affected by soil, EPA used one tenth of the Region 9 soil PRG as a screening level for soil and sediments. This approach reduces the impact of uncertainties in Tribal exposures while considering the higher contact rate compared with a more typical residential population. It also focuses the risk assessment on risk-driving chemicals.

Screening levels were similarly adjusted for water, based on the water ingestion rate for Spokane Tribe subsistence exposures. This rate is twice the water ingestion rate of two liters per day in the Region 9 residential PRGs (EPA 1991c, Smucker 2003). Risk-based screening levels specific to the Spokane Tribe were developed for water ingestion by using the Region 9 PRG equation in conjunction with an adult tribal ingestion rate of four liters per day (the Region 9 PRG calculations assume two liters per day) (Smucker 2003, Harper et al. 2002).

2.3.3 Step 3 – Select Contaminants of Potential Concern for Primary Media

Once the data sets and screening levels were selected, the process of selecting chemical and radionuclide COPCs could begin. In this step, maximum site concentrations of chemicals and radionuclides within each primary media data group were compared to background concentrations. If the maximum site concentration of a given chemical exceeded the background concentration by a factor of two or more, and if 10 percent or more of the sample locations in the data group exceeded background, then the chemical or radionuclide was identified as a preliminary COPC.

Following the background comparison, the chemicals and radionuclides were compared to human health risk-based concentrations. Chemicals were evaluated by comparing their maximum site concentrations to one tenth of the Region 9 PRGs. Radionuclides were evaluated by assessing the percent contributions of risk from individual radionuclides relative to risk from all radionuclides combined. The chemical and radionuclide selection process are further described below. The COPCs selected for each medium are summarized in Table 2-1.

Chemicals

The selection processes for chemicals are depicted as "decision trees" on Figure 2-6 (surface/subsurface material and sediment) and Figure 2-7 (surface water and groundwater). Details are provided in tables in Appendix B, which generally follow the format of EPA Part D Tables 2 series (EPA 2001a). The tables include the following information:

- Basic chemical data (i.e., minimum, maximum, detection frequency, location of maximum, range of detection limits) for each chemical/radionuclide, by area/media data grouping.
- The 95 percent UTL background value for each chemical/radionuclide and measures of the frequency and magnitude of background exceedances. If fewer than 10 background samples were available, then the maximum background value was used in place of the UTL.
- Risk-based screening values and the ratio of the maximum site value to one-tenth of the risk-based screening value.
- Rationale for selection or deletion of each chemical/radionuclide as a COPC.

Radionuclides

Radionuclide concentrations in background exceed risk-based PRGs. For radionuclides, EPA included an additional step that evaluated the relative contribution of each radionuclide to the total risk posed by radionuclides for a given medium and exposure pathway. As a group, radionuclides that were retained as COPCs contributed at least 85 percent or more of the total radionuclide risk associated with specific media and exposure pathways. This screening criterion was developed based on site-specific data and media concentrations for the purpose of optimizing COPC risk calculation efforts. The decision tree for radionuclides is presented on Figure 2-8. Details of the screening process are depicted in Table C-1 in Appendix C.

The process for selecting radionuclide COPCs was developed using standard risk assessment practices and site-specific data (EPA 1989a). The radionuclide analyses focused on the three primary, naturally occurring radioactive decay series (uranium-238, uranium-235, and thorium-232). Each of these series contains distinct subchains of radionuclide decay products.

The sub-chains, listed below, are determined by the relative half-lives and physical states of the radionuclides within the sub-chain.

(1) Subchains of uranium-238:
   a) Uranium-238+D
   b) Uranium-234
   c) Thorium-230
   d) Radium-226+D
   e) Lead-210+D

(2) Subchains of uranium-235:
   a) Uranium-235+D
   b) Protactinium-231
   c) Actinium-227+D (based on analysis of thorium-227)

(3) Subchains of thorium-232:
   a) Thorium-232
   b) Radium-228+D
   c) Thorium-228+D

There are many additional radionuclides within the subchains, many of which present practical analytical difficulties. Radionuclides for laboratory analysis of samples were selected to provide data for the radionuclide at the head of each subchain. Risks from the individual subchains are generally characterized by using the "+D" entries for risk-slope factors, where +D accounts for the decay products within the subchain which were not analyzed. Summing the risks for the subchains then gives total risk in each decay series (EPA 1999a, 2002c). The +D approach assumes secular equilibrium among the radioactive decay products. Secular equilibrium is a condition characteristic of radioactive decay chains where the parent radionuclide has a half-life that is much longer than that of the decay product. Under conditions of secular equilibrium, the activity of the decay product builds up to a level where it is the same as the parent. The use of +D slope factors may not be appropriate where members of the subchain have been separated or isolated (e.g., during processing at a uranium mill site) unless sufficient time has passed to allow equilibrium to be reestablished. Using +D slope factors is a bounding assumption in undisturbed media. In the case of Midnite Mine, the use of +D slope factors is supported by site-specific evaluations of radionuclide ratios using site data (URS 2003a), which showed that the assumption of secular equilibrium was unlikely to underestimate concentrations of decay products in the subchains.

In naturally occurring decay chains, and particularly with uranium and thorium ores, not all subchains contribute equally to risk. Depending on the exposure pathway, radionuclide risks are generally dominated by a limited number of subchains. For instance, in the case of external radiation exposure, the uranium-238 subchain headed by radium-226 poses the majority of the risk due to the significant gamma-emitting radionuclides it contains. For this reason, regulatory analyses of the external radiation pathway are frequently limited to radium-226 based on the Uranium Mill Tailings Radiation Control Act of 1978, Section 7901-7942: http://uscode.house.gov/usc.htm.

Although the suite of radionuclides used in analyzing site samples provides a basis for a complete risk evaluation of all subchains, EPA performed a comparative risk analysis and eliminated radionuclide subchains that did not contribute significantly to risk. The comparative risk analysis for radionuclides was performed for all the radionuclide subchains in each of the three decay series, as follows:

- Secular equilibrium was assumed with each subchain.
- Polonium-210 analyses were assumed to be protectively incorporated in the lead-210 subchain.

- Concentrations used for the comparative risk analysis were maximum values for each grouping of site data (e.g., Mined Area soils, Mining Affected Area sediments).
- Slope factors were used to estimate subchain risks. For water samples, risks were based on the water-ingestion pathway. For surface/subsurface materials and sediment, risks were estimated for the direct-ingestion pathway and external radiation exposure.
- The percent contribution of each subchain was calculated for each case and pathway.
- Approximately 85 percent of total risk in each case was made up of the combined risks from subchains that contributed at least 5 percent to the total.
- Subchains were retained as COPCs if they both contributed 5 percent or more to the total estimated risk (from at least one pathway for a given data grouping) and were flagged based on the background comparison.

The results of this comparative analysis show that in most cases the primary radionuclide contributions to risk are from uranium, radium, radon, and radioactive lead. See Table C-1 in Appendix C.

2.3.4 Step 4 – Select Chemicals of Potential Concern for Plants, Meat, and Fugitive Dust

Secondary media include plants, meat, and air. Generally, COPCs in surface/subsurface materials and sediments also were evaluated in plants and meat. There are no published human health risk-based screening criteria for plants or meat. There are published criteria for air, but air data were available only for radon and gamma radiation.

Plants

Terrestrial plant data for the Mined Area, and riparian and aquatic plant data from the Mining Affected Area were available, as well as plant data from background reference areas. All COPCs selected for soil or sediment were automatically selected as COPCs for terrestrial and aquatic/riparian plants, respectively. Where plant data were not available for a COPC (lead-210, radium-226, and in one area vanadium), soil data were used to model plant concentrations. Uranium isotopes, though not COPCs for MA soil based on their contribution to risk, were included as plant COPCs given the availability of plant data and the potential for different relative concentrations in plants compared to soil.

Meat

Modeled concentrations of COPCS in meat from cattle were used to represent concentrations in animal protein sources. The COPCS selected for meat included all COPCS selected for soil or surface water in any area of the site, because cattle and other animals could ingest soil and water while foraging in affected areas.

Fugitive Dust

No COPCs were selected for the fugitive dust inhalation pathway.

Most inhaled dust does not reach the lungs but is removed from the nasal passages. Of the dust that does reach the lungs, a significant portion is removed via the mucociliary escalator and swallowed (Klaassen 2001). Smaller particles are deposited more deeply and are less likely to be cleared from the lungs. Dust particles from soil and rock tend to be larger than dust particles generated by combustion processes (Klaassen 2001). Fugitive dust at Midnite Mine is likely to be from surface soil and rock.

For radionuclides, inhalation of fugitive dust is not considered a significant source of risk relative to inhalation of radon gas. Risks from inhalation of radon gas were calculated for Midnite Mine. For non-radionuclides, soil concentrations protective of soil ingestion are generally protective for dust inhalation.

Chemicals in soil that pose cancer risk through inhalation, such as beryllium, cadmium, and cobalt, had maximum site concentrations in surface material that were well below values protective of dust inhalation alone, ingestion, and the combined pathways. (Table 2-2) (Smucker 2004). For this reason, risk from fugitive dust inhalation was not calculated.

2.4 SPECIAL CASES: LEAD, RADON, AND DIRECT RADIATION EXPOSURE

Because of its unique characteristics, lead was evaluated using a separate process, as were radon in air and external radiation. The variations are discussed below.

2.4.1 Lead in Surface/Subsurface Material and Sediment

Data for lead in surface/subsurface material and sediment were evaluated according to the selection steps described above, with one important exception. Unlike the screening levels for other chemicals, which were based on Region 9 PRGs divided by ten, the screening level used for lead was the unadjusted value from EPA national guidance (EPA 1994a, 1998b).

Lead risk estimates combine all potential exposures, regardless of exposure medium or origin. Unlike the Region 9 PRGs, the soil screening level for lead is not based on exposure to soil only. Rather, the lead screening level includes exposure from non-site-related exposures (e.g., air, food, water, and house dust). The EPA screening level, 400 mg/kg, is therefore significantly lower than it would be for soil exposure pathways only.

The lead risk assessment methods used to develop the national screening level are based on central tendency measures of exposure (e.g., the arithmetic mean) as opposed to reasonable maximum exposures (e.g., the upper 95^{th} percentile confidence limit on the mean) (White et al. 1998). Thus, for lead, comparing the site maxima to one tenth of the screening level would be more protective than for other chemicals.

Levels of lead in site surface/subsurface materials were well below both the national screening level of 400 mg/kg and background levels for the site and Spokane Basin (EPA 1998b, Ecology

1994). The maximum concentration of lead in site surface/subsurface materials was 86 mg/kg. Average lead levels in surface materials and sediment were 18 mg/kg and 12 mg/kg, respectively. The maximum is below the unadjusted screening level of 400 mg/kg, and averages are below one tenth of the screening level, 40 mg/kg. The average levels are also substantially below national average lead levels as well as the default level of lead in soil (200 mg/kg) used to assess risk in the EPA IEUBK lead model (EPA 2001b).

In light of the low levels at the site relative to the national screening and background levels, EPA did not select lead as a COPC in surface material.

2.4.2 Radon in Air and Direct Radiation Exposure

Airborne radon and its decay products result from the decay of naturally occurring uranium and constitute the most significant source of radiation exposure in the United States (NCRPM 1987). Since uranium occurs at the site in concentrations significantly greater than those generally present in background concentrations in the United States, radon concentrations are expected to be higher than normal, due both to the natural levels of uranium present and to the disturbance of natural ores by mining operations. For this reason, airborne radon measurements at the site were compared to local background measurements. For the Mined Area, radon exceeded background in 14 out of 16 samples, with a maximum value approaching eight times background. For the Mining Affected Area, radon exceeded background in three out of four samples. Although the maximum was less than two times background in this area, EPA selected radon as an air-pathway COPC for both the Mined Area and the Mining Affected Area due to its contribution to risk.

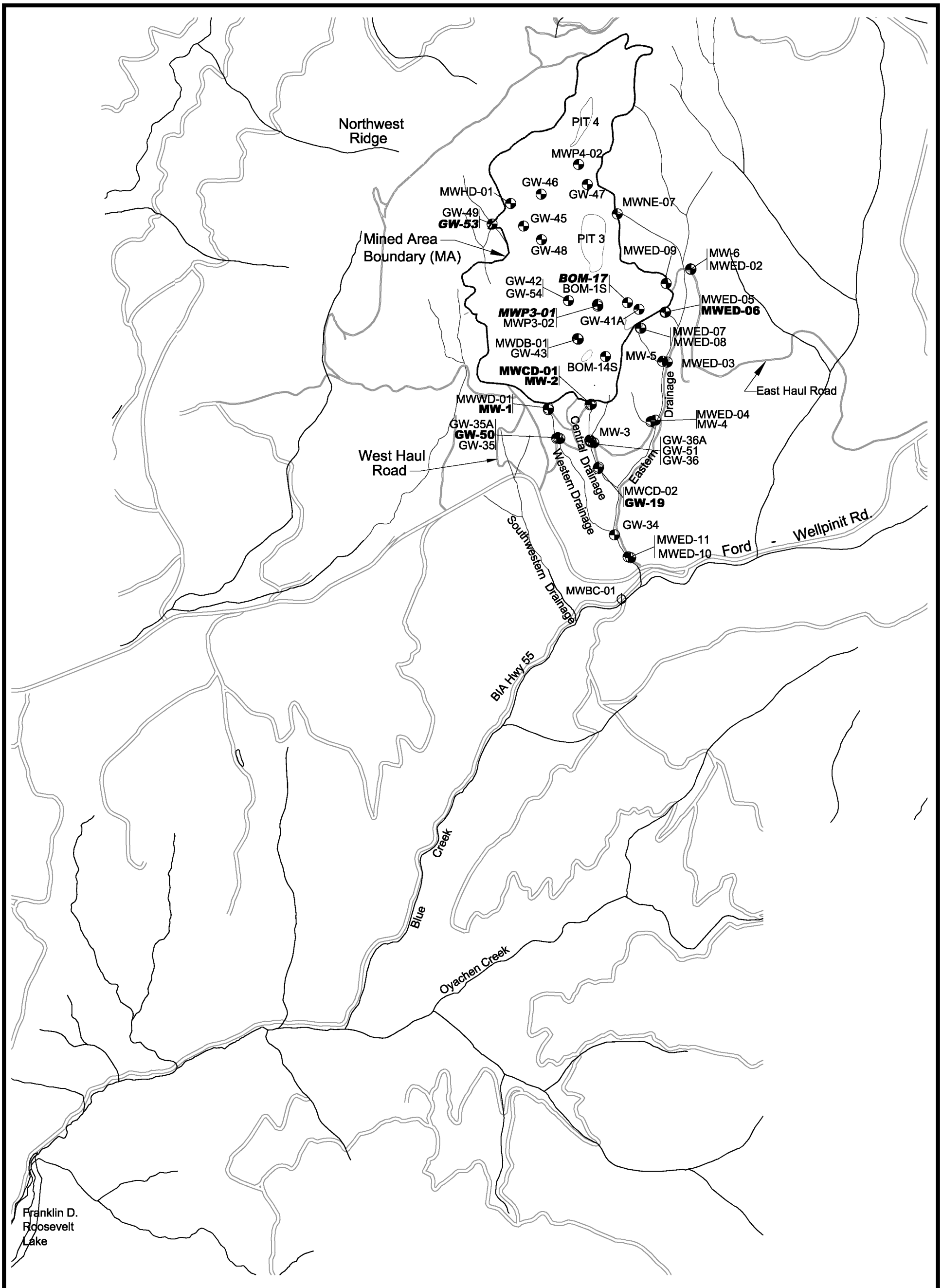
Gamma radiation levels were also elevated at the site relative to background levels. Although not a specific chemical or radionuclide, external gamma radiation was considered a COPC because it contributes to cancer risk separately from risks due to ingestion or inhalation of radionuclides.

2.5 SUMMARY OF SELECTED CHEMICALS OF POTENTIAL CONCERN

After selecting and grouping the applicable data sets, screening criteria were developed to select or eliminate contaminants. These criteria were based on frequency of detection, the frequency and magnitude of exceedance of background levels, and exceedance of risk-based levels. If contaminant concentrations were above screening values, they were considered for selection as COPCs. Contaminants with concentrations below screening values were not selected because they are either present within the expected range of natural background concentrations or are unlikely to present a health concern. Both chemical and radionuclide data were compared to background concentrations to determine whether contaminants were site-related (i.e., present due to mining-related activities), and, in addition, chemical data were compared to risk-based screening levels while the percent contribution of individual radionuclides to the combined risk from radionuclides was evaluated.

The results of screening, presented in Table 2-1, show that groundwater has the most COPCs (4 radionuclides, 11 metals), followed by water in the mine drainages (4 radionuclides, 9 metals) and in Pits 3 and 4 (2 radionuclides, 9 metals). Soils, including the haul roads, and sediments

had fewer COPCs than water. Blue Creek (water and sediments), and soils adjacent to the haul roads had the fewest COPCs. The COPCs for plants were selected based on COPCs in soil and sediment. The COPCs in animal tissue were selected based on soil and surface water. Radon in air and gamma radiation were also included as COPCs.



Midnite Mine Human Health Risk Assessment

EPA REGION 10

Human Health Assessment Groundwater Sample Locations

FILE/DRAWING NO.	DATE: Sept. 2005	Figure 2-1
DOCUMENT CONTROL NO.	DSGN. CK	CHK.

FILENAME: Q:\Geo\Midnite Mine\HumanHealth\HHfinal\Alluvial Bedrock GW Fig 2-1.dwg
EDIT DATE: 09/27/05 AT: 10:18

Spokane Mountain
Sand Creek
Northwest Ridge
PIT 4
Northeastern Drainage
Middle Fork
West Fork
PIT 3
Mined Area (MA) Boundary
East Haul Road
West Haul Road
Central Drainage
Upper Eastern Drainage
Western Drainage
Southwestern Drainage
Ford - Wellpinit Rd.
BC09SW/BC09SD
SW-5
RSBC-01
BC08SW/BC08SD
RSBC-02
BC07SW/BC07SD
Creek
BC06SW/BC06SD
RSBC-03
Blue
BC05SW/BC05SD
RSBC-04
Oyachen Creek
BC04SW/BC04SD
SW-7
BIA Hwy 55
BC03SW/BC03SD
BC02SW/BC02SD
RSBC-05
BC01SW/BC01SD
SDBC-02/SWBC-02
Franklin D. Roosevelt Lake

Reach Area Sampling Sites

MMSED-BD3-D05-981026
MMSED-BD3-D20-981026
MM-AQP-BD3-26OCT
MMROO-BD3P1-25OCT98
MMROO-BD3P2-25OCT98
MMROO-BD3P3-25OCT98
MMROO-BD3P4-25OCT98
MMROO-BD3P5-25OCT98
MMROO-BD3P6-25OCT98

Reach Area Sampling Sites

MMSED-BD1/BD2-D05
MMSED-BD1/BD2-D20
MM-SED-BD1/BU3
MM-SED-BD1-D05-26
MM-SED-BD1-D20-26
MM-AQP-BD1/BD2-25OCT
MM-AQP-BD1-26SEP98
MMROO-BD1P1-26OCT98
MMROO-BD1P2-26OCT98
MMROO-BD1P3-26OCT98
MMROO-BD1P4-26OCT98
MMROO-BD1P5-26OCT98
MMROO-BD1P6-26OCT98

Reach Area Sampling Sites

MMSED-BD2/BD3-D05
MMSED-BD2/BD3-D20
MMSED-BD2-D05-981025
MMSED-BD2-D1-981025
MMSED-BD2-D20-981025
MM-AQP-BD2/BD3-25OCT
MM-AQP-BD2-25SEP98
MMROO-BD2P1-25OCT98
MMROO-BD2P2-25OCT98
MMROO-BD2P3-25OCT98
MMROO-BD2P4-25OCT98
MMROO-BD2P5-25OCT98
MMROO-BD2P6-25OCT98

Note:

Reach areas are approximate sampling sites for the listed sampling locations. Individual sample locations are not available.

N

0 1000 2000

SCALE IN FEET

Surface Water and Sediment Sample

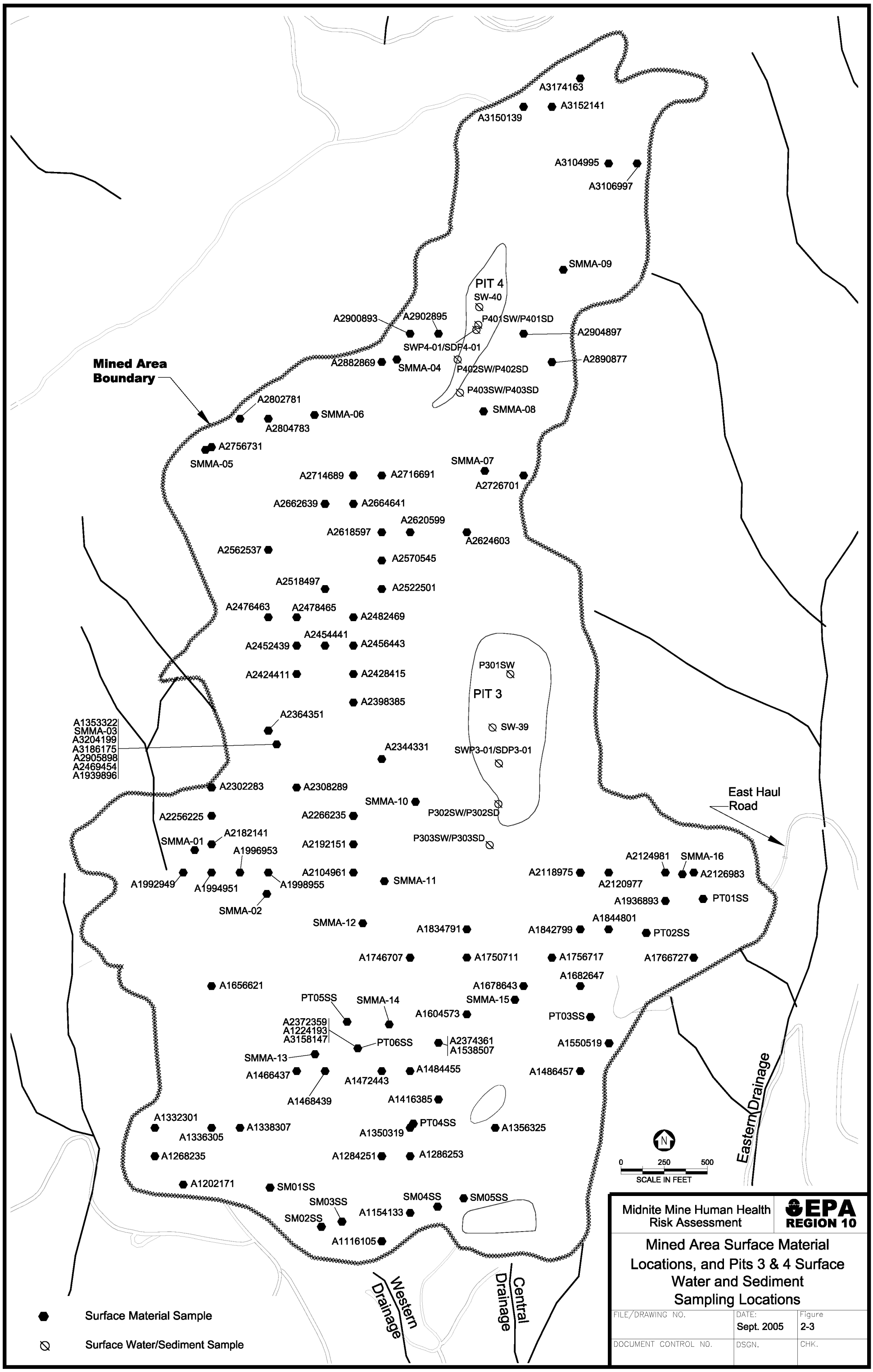
Midnite Mine Human Health Risk Assessment

EPA REGION 10

Blue Creek Sediment, Surface Water, and Plant Sampling Locations

FILE/DRAWING NO.	DATE: Sept. 2005	Figure 2-2
DOCUMENT CONTROL NO.	DSGN.	CHK.

FILENAME: Q:\Geo\Midnite Mine\HumanHealth\HHfinal\Bluecreek Fig 2-2.dwg
EDIT DATE: 09/27/05 AT: 15:37



Midnite Mine Human Health Risk Assessment

EPA REGION 10

Mined Area Surface Material Locations, and Pits 3 & 4 Surface Water and Sediment Sampling Locations

FILE/DRAWING NO.	DATE:	Figure
	Sept. 2005	2-3
DOCUMENT CONTROL NO.	DSGN.	CHK.

FILENAME: Q:\Geo\Midnite Mine\HumanHealth\HHfinal\MAsoil pits3-4SW_PA pits3-4 SD Fig 2-3.dwg
EDIT DATE: 09/27/05 AT: 15:55

MM-SOI-US3-P1-D05-980924
MM-SOI-US3-P1-D20-980924
MM-SOI-US3-P2-D05-980924
MM-SOI-US3-P2-D20-980924
MM-SOI-US3-P3-D05-980923
MM-SOI-US3-P3-D20-980923
MM-SOI-US3-P4-D05-980923
MM-SOI-US3-P4-D20-980923
MM-SOI-US3-P5-D05-980923
MM-SOI-US3-P5-D20-980923
MM-SOI-US3-P6-D05-980924
MM-SOI-US3-P6-D20-980924
MM-ROO-US3P1-24SEP98
MM-ROO-US3P2-24SEP98
MM-ROO-US3P3-23SEP98
MM-ROO-US3P4-23SEP98
MM-ROO-US3P5-23SEP98
MM-ROO-US3P6-23SEP98

PIT 4

Mined Area Boundary

PIT 3

MM-SOI-US2-P1-D05-980923
MM-SOI-US2-P1-D20-980923
MM-SOI-US2-P2-D05-980923
MM-SOI-US2-P2-D20-980923
MM-SOI-US2-P3-D05-980923
MM-SOI-US2-P3-D20-980923
MM-SOI-US2-P4-D05-980923
MM-SOI-US2-P4-D20-980923
MM-SOI-US2-P5-D05-980923
MM-SOI-US2-P5-D20-980923
MM-SOI-US2-P6-D05-980923
MM-SOI-US2-P6-D20-980923
MM-ROO-US2P1-23SEP98
MM-ROO-US2P2-23SEP98
MM-ROO-US2P3-23SEP98
MM-ROO-US2P4-23SEP98
MM-ROO-US2P5-23SEP98
MM-ROO-US2P6-23SEP98

East Haul Road

MM-SOI-US1-P1-D05-980922
MM-SOI-US1-P1-D20-980922
MM-SOI-US1-P2-D05-980922
MM-SOI-US1-P2-D20-980922
MM-SOI-US1-P3-D05-980922
MM-SOI-US1-P3-D20-980922
MM-SOI-US1-P4-D05-980922
MM-SOI-US1-P4-D20-980922
MM-SOI-US1-P5-D05-980922
MM-SOI-US1-P5-D20-980922
MM-SOI-US1-P6-D05-980922
MM-SOI-US1-P6-D20-980922
MM-ROO-US1P1-22SEP98
MM-ROO-US1P2-22SEP98
MM-ROO-US1P3-22SEP98
MM-ROO-US1P4-22SEP98
MM-ROO-US1P5-22SEP98
MM-ROO-US1P6-22SEP98

N

0 250 500
SCALE IN FEET

Eastern Drainage

Western Drainage

Central Drainage

Note:
Hatched boxes are approximate sampling site areas for the listed sampling locations. Individual sample locations are not available.

Midnite Mine Human Health Risk Assessment

EPA REGION 10

Mined Area Plant Tissue Sampling Locations

FILE/DRAWING NO.	DATE: Sept. 2005	Figure 2-4
DOCUMENT CONTROL NO.	DSGN.	CHK.

FILENAME: Q:\Geo\Midnite Mine\HumanHealth\HHfinal\MA surface material plant tissue Fig 2-4.dwg
EDIT DATE: 09/27/05 AT: 15:58

Note:
Shaded boxes are approximate sampling site areas for the listed sampling locations.
Individual sample locations are not available.

SDND-01/SWND-01
SDNE-01/SWNE-01
PIT 4
Mined Area (MA) Boundary
PIT 3
SDNE-02/SWNE-02
OF01SW/OF01SD
SDED-07
SDED-01
ED05SW/ED05SD
SMEHR-01
TH225
EAST SEEP/SDED-05
SW-02/SDED-6
ED04-SD/ED-2A
SMEHR-02
TI400
TG175
ES02SP/ES02SD
ES01SP/ES01SD
ED04SW/ED04SD
ED-4A/SDE02
RSED-05
RSED-01
SMEHR-03
ED03SW/ED03SD
RSED-04
CD SEEP/SDCD-01
CD03SD
RSCD-01
CD01SD
WD02SD
RSWD-01
WDSEEP/SDWD-01/SW10
WDJWEST
SDFW-01/SWFW-01
SMWHR-02
TM250
SMWHR-01
SMWHR-03
SMWHR-04
WD01SD
SWWD-01/SDWD-02
West Haul Road
SDCD-03
RSWD-04
SDCD-02/SW-12
RSWD-02
RSWD-03
Central Drainage
Eastern Drainage
Western Drainage
RSED-02
RSCD-02
SWED-01/SDED-03
SW-11
CD-11
CD02SD
ED02SW/ED02SD
SWED-02/SDED-04
SW-06/ED01-SD/ED01SW
RSED-03
East Haul Road
SMEHR-07
SMEHR-06
SMEHR-04
SMEHR-05
SDBK-03/SWBK-03
SMEHR-08
SMEHR-12
SMEHR-09
SMEHR-11
SMEHR-10
Ford - Wellpinit Rd.
SWEHR/SDEHR-01

MM-ROO-C1AP1-27SEP98
MM-ROO-C1AP2-27SEP98
MM-ROO-C1AP3-27SEP98
MM-ROO-C1BP4-27SEP98
MM-ROO-C1BP5-27SEP98
MM-ROO-C1BP6-27SEP98

MM-ROO-C2P1-01OCT98
MM-ROO-C2P2-30SEP98
MM-ROO-C2P3-01OCT98
MM-ROO-C2P4-01OCT98
MM-ROO-C2P5-01OCT98
MM-ROO-C2P6-30SEP98

MM-SED-W1/W2-D05-01
MM-SED-W1/W2-D20-01
MM-SED-W1-D05-980925
MM-SED-W1-D20-980925
MM-AQP-W1/W2-01OCT98
MM-AQP-W1-27SEP98
MM-ROO-W1P1-25SEP98
MM-ROO-W1P2-25SEP98
MM-ROO-W1P3-25SEP98
MMROO-WD1P4-27OCT98
MMROO-WD1P5-26OCT98
MMROO-WD1P6-25OCT98

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MM-SED-W2-D20-981001
MM-AQP-W2-01OCT98
MMROO-WD2P1-26OCT98
MMROO-WD2P2-26OCT98
MMROO-WD2P3-26OCT98
MMROO-WD2P4-26OCT98
MMROO-WD2P5-27OCT98
MMROO-WD2P6-27OCT98

MM-SED-E1/E2-D05-30
MM-SED-E1/ED-D20-30
MM-SED-E1-D05-980929
MM-SED-E1-D20-980929
MM-AQP-E1/E2-30SEP98
MM-AQP-E1-29SEP98
MMROO-ED1P1-27OCT98
MMROO-ED1P2-27OCT98
MMROO-ED1P3-27OCT98
MMROO-ED1P4-27OCT98
MMROO-ED1P5-27OCT98
MMROO-ED1P6-27OCT98

MM-SED-E2-D05-980930
MM-SED-E2-D20-980930
MM-AQP-E2-30SEP98
MMROO-ED2P1-27OCT98
MMROO-ED2P2-27OCT98
MMROO-ED2P3-27OCT98
MMROO-ED2P4-27OCT98
MMROO-ED2P5-27OCT98
MMROO-ED2P6-27OCT98

N
0 500 1000
SCALE IN FEET

Seep Sample
Surface Material Sample
River Sample
Outfall Sample

Midnite Mine Human Health Risk Assessment

EPA REGION 10

Mining Affected Area Haul Roads Soil and Drainage Sediment, Surface Water, and Plant Sampling Locations

FILE/DRAWING NO.	DATE: Sept. 2005	Figure 2-5
DOCUMENT CONTROL NO.	DSGN.	CHK.

FILENAME: C:\Geo\Midnite Mine\HumanHealth\HHfinal\PIA haulrds-soil_Drain-SD-SW Fig 2-5.dwg
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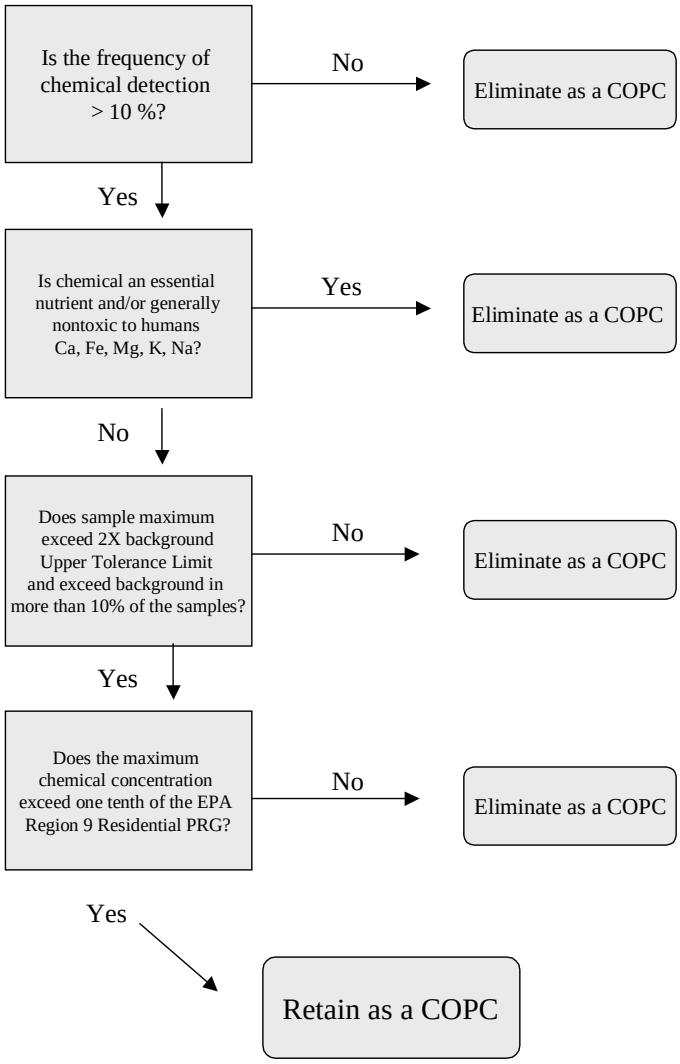


Figure 2-6 Selection of Non-Radionuclide Chemicals of Potential Concern in Surface/Subsurface Material and Sediment

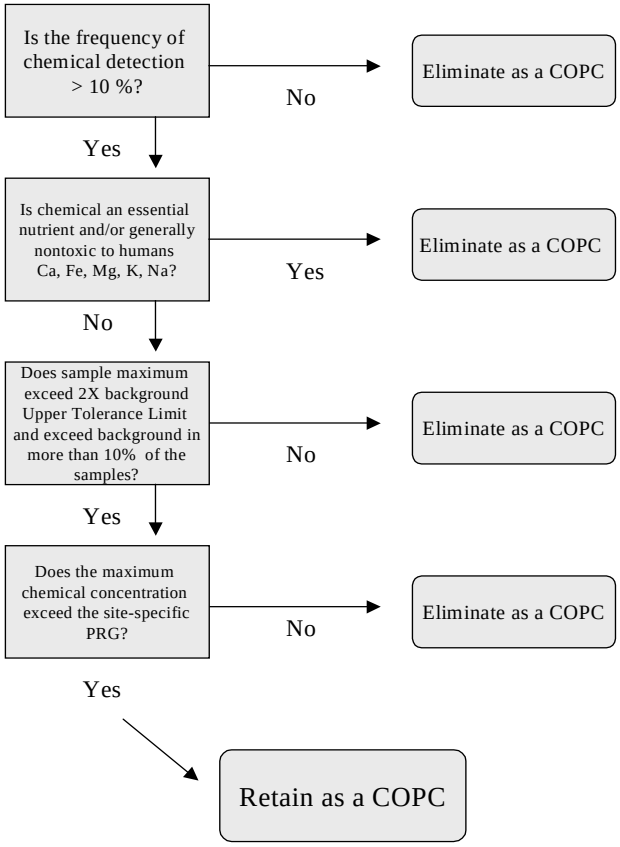


Figure 2-7 Selection of Non-Radionuclide Chemicals of Potential Concern in Surface Water and Groundwater

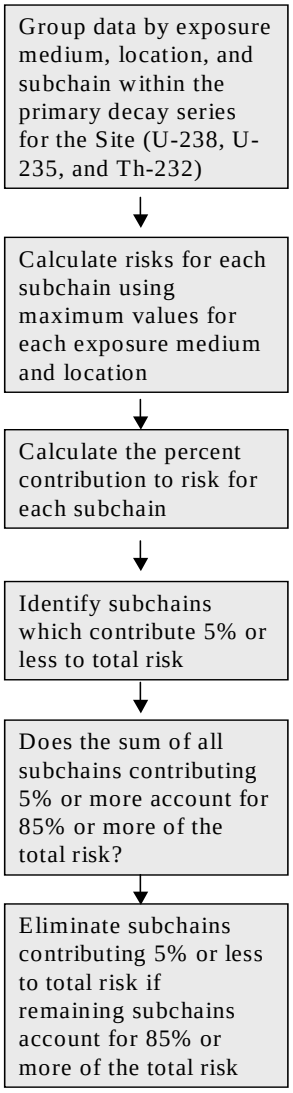


Figure 2-8 Selection of Radionuclide Chemicals of Potential Concern

Table 2-1
Chemicals of Potential Concern in Soil, Groundwater, Surface Water, Sediment, and Plants

Medium	Soil			Groundwater	Surface Water			Sediment			Plants		
RAGS D Table	Table 2-1	Table 2-2	Table 2-3	Table 2-4	Table 2-5	Table 2-6	Table 2-7	Table 2-8	Table 2-9	Table 2-10	Table 2-12	Table 2-13	Table 2-14
Chemicals of Potential Concern	Surface Material (Mined Area)	Haul Roads (MAA)	Soil Adjacent to Haul Roads (MAA)	Mined Area and MAA	Blue Creek (MAA)	Mine Drainages (MAA)	Pits 3 and 4 (Mined Area)	Blue Creek (MAA)	Mine Drainages (MAA)	Pits 3 and 4 (Mined Area)	Terrestrial(Mined Area)	Riparian & Aquatic Mine Drainages (MAA)	Riparian & Aquatic Blue Creek (MAA)
Radionuclides													
Gross Alpha				X		X							
Lead 210	X	X	X		X				X	X	X	X	
Radium 226	X	X	X	X					X	X	X	X	
Radon 222						X							
Uranium 234				X	X	X	X		X	X	X	X	
Thorium 228		X											
Uranium 238				X	X	X	X		X	X	X	X	
Total Metals													
Aluminum						X	X						
Antimony					X								
Arsenic	X										X		
Beryllium				X			X						
Cadmium				X		X	X	X	X			X	X
Chromium	X										X		
Cobalt				X		X	X		X			X	
Lead						X	X						
Manganese				X	X	X	X	X	X			X	X
Nickel				X		X	X	X	X			X	X
Selenium	X										X		
Thallium	X									X	X		
Silver				X									
Uranium	X	X	X	X	X		X		X	X	X	X	
Vanadium	X										X		
Zinc				X			X						
Dissolved Metals													
Aluminum				X		X							
Antimony						X							
Beryllium				X									
Cadmium				X		X							
Chromium						X							
Cobalt				X		X							
Copper				X		X							
Lead				X		X							
Manganese				X	X	X							
Nickel				X		X							
Silver				X									
Zinc				X									

Note:
MAA: Mining Affected Area

Table 2-2
Evaluation of Inhalation Pathway for Soil

COPC[a]	Site Maximum Soil Concentration (mg/kg)	Region 9 EPA Residential Soil risk-based concentrations (Inhalation Pathway Only) (mg/kg)		Region 9 EPA Residential Soil Preliminary Remediation Goals All Pathways (mg/kg)
		Cancer	Non-cancer	
Beryllium	6.41	1,100	12,000	154 non-cancer
Cadmium	3.5	1,400	no value	37 non-cancer
Cobalt	19.9	900	12,000	900 cancer

Note:
[a] The COPCs listed are carcinogens for the inhalation pathway only. Site maximum soil concentrations are well below levels protective of all pathways (and both cancer and non-cancer) and of inhalation specifically.

3.0 EXPOSURE ASSESSMENT

This section evaluates sources, pathways, receptors, exposure duration and frequency, and routes of exposure to assess overall human exposure to the substances of concern at the site. An exposure assessment is used to quantify the dose of chemical per body weight per day for each COPC, receptor, and exposure pathway combination. Three elements are required to calculate a dose: first, a conceptual site model (CSM) must be developed that identifies exposure pathways and populations; second, estimates of media concentrations at the exposure point must be developed; and third, contact rates must be selected to quantify the amount of exposure. These exposure factors are then combined with the media concentrations to quantify a dose for each chemical.

3.1 CONCEPTUAL SITE MODEL

A CSM describes the sources of site chemicals, their passage through environmental media (e.g., soil and water), and the locations and means where people may contact the chemicals. This section briefly describes where environmental media have been impacted by chemical releases, the site's land uses, and a characterization of the exposed populations under both current and future conditions, as is required by EPA guidance (EPA 1989a). The goal of the CSM is to provide an understanding of where the site-related chemicals are present, how they were released and moved through environmental media, and how people may be exposed to the chemicals. The pathways of exposure for these populations can then be selected for quantitative evaluation of health risks.

3.1.1 Affected Media and Land Use

The following media have been sampled and identified as containing chemicals above risk-based screening levels and/or background concentrations associated with former mining activities:

- Soil
- Groundwater
- Surface water
- Sediment
- Plants

Animal tissue was not included on the above list because it was not sampled. Radon in air and external radiation were measured. Potential COPC concentrations in animal tissue are discussed in Section 3.2.2.

Figures 3-1 through 3-6 depict the impacted media and the environmental transport mechanisms that resulted in movement of COPCs throughout the site. Currently, land use at the site (apart from environmental sampling and seasonal water treatment system operations) consists of intermittent traditional and subsistence activities, particularly outside the Mined Area. The

Spokane Tribe of Indians has expressed a desire to be able to use the site without restrictions in the future.

At Midnite Mine, radionuclides are significant contaminants. Geologic materials containing radionuclides occur naturally in the area. Concentrations of uranium and its decay products in unimpacted areas near the mine are approximately twice average U.S. values. Nationally, estimated risks from background levels of radionuclides generally exceed the upper end of EPA's risk range. This is also the case for background at Midnite Mine. High background risks are considered in the assessment of site-related contributions to risk because the same constituents are present both in background and at the site. Background concentrations are discussed further in Sections 5.5 and 5.7.

3.1.2 Selected Populations

Based on the site's location, members of the Spokane Tribe of Indians were assumed to be the current and potential future users of the Mined Area and Mining Affected Area. Risks were evaluated for the following four Tribal populations: 1) future residents living in the Mined Area, 2) non-residents visiting to swim in the pits in the Mined Area, 3) future residents living in the Mining Affected Area, and 4) non-residents using the Mining Affected Area for subsistence activities. Apart from the swimming scenario, all scenarios included use of the site for traditional and subsistence activities.

3.1.3 Identification of Exposure Pathways

Several possible pathways of exposure exist at this site. An exposure pathway is the mechanism by which a person is exposed to chemicals from a source. The following four elements constitute a complete exposure pathway:

- A source and mechanism of chemical release
- A retention or transport medium (e.g., soil)
- A point of potential human contact with the affected medium
- A means of entry into the body (e.g., ingestion) at the contact point

Only complete pathways containing all four elements result in exposures. However, in some circumstances, an exposure pathway may be considered complete (i.e., meet all four elements outlined above), but insignificant. An exposure pathway is considered complete but insignificant if one or more of the following conditions is met (EPA 1989a):

- The exposure resulting from the pathway is much less than that from another pathway involving the same medium
- The potential magnitude of exposure from the pathway has low toxicological importance
- The probability of the exposure occurring is very low and the risks associated with the occurrence are not high

Only complete and significant pathways of exposure are evaluated quantitatively in this risk assessment. Complete but insignificant pathways of exposure do not require quantitative evaluation. The CSM (Figures 3-1 through 3-6) depicts the complete pathways. Complete and significant pathways are depicted by a closed circle while complete and insignificant pathways are depicted by an open circle.

In some cases, a pathway was selected for evaluation, but the risks were not quantified. For example, dermal exposure to metals in pit sediments was selected as a complete and significant exposure pathway but, because the only two metals with dermal absorption values (arsenic and cadmium) were not COPCs for this exposure area, risk estimates were not calculated (EPA 2004). Quantified exposure pathways included those typical of residential exposure, pathways associated with radioactive COPCs, and pathways specific to traditional Tribal activities. Typical residential exposure pathways include soil ingestion, dermal soil absorption, and water ingestion. Tribal residents were assumed to live a traditional subsistence lifestyle, so contact rates used for some residential pathways, such as soil and water ingestion, were higher than for typical residential scenarios (Harper et al. 2002). Pathways associated with radioactive COPCs included inhalation of radon gas and absorption of gamma radiation (i.e., external radiation). Specific Tribal pathways include consumption of site plants and meat (using beef to represent all animal protein sources), and sweat lodge use. The four populations and the pathways evaluated for them are listed below:

- Residents of the Mined Area, are exposed to contaminants through:
  - Incidental ingestion and dermal exposures to COPCs in Mined Area surface soil. The dermal pathway is quantified only for arsenic and cadmium, which are the only two COPCs that have sufficient information on dermal absorption (EPA 2004). See Appendix H.
  - Water ingestion. Residents are assumed to drink groundwater from residential wells in the Mined Area. The only surface water in the Mined Area is in the open pits, which are unlikely to be used as a drinking water source.
  - Inhalation of water vapor during sweat lodges. The source of water for the sweat lodges is assumed to be groundwater from a well. Water from the open pits is unlikely to be used for this purpose. The water vapor would contain COPCs dissolved in the groundwater.
  - Exposure to gamma radiation and airborne radon, both indoors and outdoors.
  - Ingestion of plants and meat.
- Residents of the Mining Affected Area, assumed to live next to the haul roads, exposed to contaminants through:
  - Incidental ingestion and dermal exposure to soil and sediment. The soil is in affected areas adjacent to the haul roads, and the sediment is in the mine drainages.

  - Ingestion of water. The Mining Affected Area resident was assumed to obtain drinking water either from a well or from surface water in the drainages south of the Mined Area.
  - Inhalation of COPCs in water vapor during sweat lodges. The source of water is assumed to be either groundwater or surface water from the mine drainages
  - Exposure to gamma radiation and airborne radon both indoors and outdoors.
  - Ingestion of plants and meat.
- People who visit the Mined Area to swim in Pits 3 and 4, exposed to COPCs through:
  - Incidental ingestion of water while swimming in the pits.
  - Incidental ingestion of sediment in the pits.
  - Exposure to gamma radiation and airborne radon outdoors.
- People who visit the Mining Affected Area for traditional and subsistence activities and are exposed to COPCs through:
  - Ingestion of soil while using the haul roads (use of the haul roads may occur for the other scenarios as well, but is assessed only for this scenario).
  - Ingestion of sediment during subsistence activities (either along Blue Creek or in the mine drainages).
  - Inhalation of water vapor during sweat lodges, using water from Blue Creek.
  - Exposure to gamma radiation and airborne radon outdoors.
  - Ingestion of plants and meat.

For health risks from eating meat, it was assumed that the entire meat diet came from animals that forage only in the Mined Area and Mining Affected Area. Beef tissue concentrations of COPCs were modeled as a surrogate for all animal protein sources. Actual meat diets may include some non-site meat (purchased or hunted off-site) or meat from animals that forage across areas in addition to site areas).

For health risks from eating plants, it was assumed that the entire plant diet came from the site, and that people harvest in only one area of the site. Specifically, Mined Area residents were assumed to eat plants only from the Mined Area, Mining Affected Area residents to eat plants only from the drainages south of the mine, and non-residents to eat plants only growing in and beside Blue Creek. Actual plant ingestion may consist of a mixture of different plant types from different areas, including non-site sources.

3.2 EXPOSURE POINT CONCENTRATIONS

To calculate a cancer risk or a non-cancer hazard, an estimate must be made of the chemical concentration to which an individual may be exposed. According to EPA (EPA 1992a, 1992b), the exposure point concentration (EPC) should be an estimate of the average concentration to which an individual would be exposed over a significant part of a lifetime. Because of the uncertainties surrounding the true average, EPCs will be the 95 percent upper confidence limit of the mean (95%UCL) as the appropriate estimate of the average site concentration for an RME scenario (EPA 2002). The results of the EPC calculations for each COPC are summarized in Tables 3-1 to 3-3, and additional details of the calculations are included in Appendix D. A draft version of the results of the EPC calculations was released in January 2003 (EPA 2003). The EPCs used in this risk assessment include several values that were recalculated following the January 2003 draft.

3.2.1 Exposure Point Concentrations in Sampled Media

For sampled media, EPCs were direct estimates based on the analytical results of the sampling. Sampled media were: soils, sediment, plants, surface water (drinking use), groundwater (drinking use). Radon in air and gamma radiation were also measured.

The formula used to calculate a 95%UCL depends on the distribution of the data, i.e., the "shape" of the curve (EPA 2002d). A statistical test was performed for each COPCs data set to determine the best distribution assumption for the data set. A statistical add-in to Microsoft Excel, titled MTCAStat 3.0, provided by Washington State Department of Ecology, was used to determine distributions (http://www.ecy.wa.gov/programs/tcp/tools/toolmain.html). The results of the distribution test indicated whether the data are normally distributed, lognormally distributed, or neither normal nor lognormal. If the data set distribution was normal or lognormal, then MTCAStat 3.0 was used to calculate a corresponding 95%UCL value. If the MTCAStat 3.0 results indicated a "neither" distribution of the data set, then a one-sided 95%UCL was calculated using the bootstrap method as recommended by EPA (EPA 2002d).

Statistical tests were not used for data sets with fewer than 10 samples. If the data set had fewer than 10 samples, then the maximum concentration was used as the estimate of the EPC for that chemical. The summary statistical tables in Appendix D indicate the distribution of the individual EPC data set and whether the EPC is a maximum or 95%UCL value.

In accordance with EPA guidance (1989a), half the sample quantitation limit was used as a surrogate concentration for non-detected contaminants. In general, very few samples contained COPCs that were not detected.

Specific data groupings/data subsets were used for the following EPC calculations:

- All plant EPC calculations used root data only (Mined Area terrestrial plants, Blue Creek aquatic and riparian plants, drainages aquatic and riparian plants).
- Surface water EPCs calculated for the drainages included samples identified as "seeps."

- Groundwater data were not pooled. Rather, EPCs were estimated for nine individual wells that represented a range of concentrations and locations across the site, including three wells within the Mined Area, and six wells within the Mining Affected Area (Figure 2-1 and Table E-1 in Appendix E).
- For all sweat lodge scenarios, EPCs (for either groundwater or surface water data) used dissolved metals concentrations. The EPC calculations for the drinking water pathways used total metals concentrations.
- Mined Area and Mining Affected Area soil and surface water data were pooled to calculate the EPCs used to model contaminant concentrations in meat.

External Radiation

External radiation exposure at the site was determined in two ways. First, gamma radiation was measured with a 1 inch x 1 inch unshielded sodium iodide detector giving results in counts per minute (cpm). Calibration constants from the site were used to convert cpm to microRoentgen (µR)/h. Site-specific factors were used to convert µR/hr to microrem (µrem)/hr. This dose was multiplied by the total exposure duration in hours to determine the lifetime exposure dose in µrem (EPA 1999a, 2002c). Because detectors were not shielded to minimize interference from background, background levels were subtracted from the cpm measurements.

In the second method, soil concentrations of radionuclides were measured in samples, and risks were calculated from soil concentrations using the standard EPA methods described above. Both methods are based on direct measurements. Each method has advantages and limitations, and comparison of the results provides a qualitative indicator of the uncertainties in the estimates of external radiation risk. Both were used in calculating risk from site soils, as shown in Appendix 1, but summary risk tables show the results for the second method only.

Outdoor Radon

The decay products of radon, rather than radon itself, pose health risks from inhalation. When radon gas initially forms from the decay of radium-226, radon decay products (progeny) are not present. Radon has a half-life of a few days, so in a closed system radioactive decay soon leads to equilibrium between radon and its progeny. Equilibrium cannot be achieved in the open air, however, so risk estimates for outdoor radon exposure are adjusted to reflect the degree of equilibrium. For radon in ambient air, an equilibrium factor of 0.8 is generally applied (UNSCEAR 1993).

At Midnite Mine, the air contains both ambient radon and radon formed locally by the decay of uranium on site. Radon from the site has had less time to approach equilibrium. To reflect the combination of radon sources at the site, EPA compared background radon levels with site radon levels and assumed the difference was radon formed at the site. The ambient component was corrected with an equilibrium factor of 0.8, while the site component was adjusted with an equilibrium factor of 0.1. The factor of 0.1 is based on an estimate of 1 km transport distance and a wind speed of 2.5 m/s, which are reasonable estimates for this site.

3.2.2 Exposure Point Concentrations in Media Not Sampled

The evaluated media that were not sampled included: radon concentrations in indoor air, vapor concentrations in a sweat lodge, concentrations of plant COPCs for which plant sample data were not available (i.e., lead-210, radium-226, and vanadium), and meat. Modeled EPCs are described in the following sections.

Water Vapor in a Sweat Lodge

In a sweat lodge, water is poured over heated rocks, generating water vapor (water droplets suspended in air). If the water contains dissolved COPCs, then the water droplets are also assumed to contain COPCs. This principle was applied to the sweat lodge scenarios for the Hanford site in Richland, Washington (Washington Department of Health 1999). It was assumed that the water droplets in vapor would contain COPCs at the same concentrations as in the water poured on the rocks. The Hanford risk assessment used a volatilization factor of 0.1 L water/m^3 air based on a saturation level for water in air at 130 ° F.

For Midnite Mine, a sweat lodge temperature of 150° F was used (Harris and Harper 1997; Lide 2002), leading to a volatilization factor of 0.15 L water/m^3 value based on saturation conditions. Exposure point concentrations for inhalation of COPCs in water vapor were calculated using the following equation:

Concentration mg or pCi COPC/m^3 in sweat lodge air = COPC in water (mg or pCi of COPC/liter water) x 0.15 L water/m^3 air

For COPC concentrations in water, total radionuclide concentrations were used (no dissolved data were available), while for metals, dissolved concentrations were used.

Indoor Radon

Air concentrations of radon in the residence were estimated using soil concentrations of radium-226. A single radon concentration was used for all residential radon exposure, based on aggregated soil data for the Mined Area and Mining Affected Area. The radon estimate is based on an empirical relationship observed for typical homes (EPA 1992b). On average, 1 pCi/g of radium-226 in soil will result in 1.25 pCi/L of indoor air. For indoor air, therefore:

Indoor Air Radon Concentration (pCi/l) = Radium-226 concentration in soil (pCi/g) x 1.25

While air in a sweat lodge would include some radon from soil emanation, soil would contribute little risk relative to radon and other radionuclides in water vapor.

Plant Tissue Concentrations

Concentrations of a subset of contaminants in plants were available from plant sampling (SMI 1999a). The sampling included terrestrial plants in the Mined Area, riparian and aquatic plants in the Western, Central, and Eastern Drainages (SMI 1999a), and riparian and aquatic plants in Blue Creek near the confluence with the Eastern Drainage. For COPCs without analytical data (e.g., lead 210, radium 226, and vanadium), plant concentrations were predicted using soil-to-

plant uptake ratios developed by the Oak Ridge National Laboratory (Oak Ridge National Laboratory 2002). Model inputs are presented in Table E-2 in Appendix E. Because Tribal preferences and utilization patterns were not used to select plant species for sampling, the representativeness of the plant data to Tribal harvesting and consumption is uncertain. Therefore, as a health protective measure, all exposure point concentrations were based on concentrations in plant roots, which have higher concentrations than above-ground portions of the plants. This pattern has been observed in garden plants analyzed for radium, uranium, and lead (Finster et al. 2003). The concentrations of contaminants in plant roots are expected to account for a significant source of soil ingestion because of soil adhered to root surfaces (Tracy et al. 1983).

Ingestion of Meat

Although a traditional Tribal diet would include wild game, samples of game were not available and modeled concentrations of radionuclides and metals in wild game are highly uncertain. Therefore, COPC concentrations in wild game were represented by modeled concentrations in cattle assumed to forage on site and to take up contaminants through exposure to water, soil, and pasture. Meat concentrations were calculated using the Food Chain Models for Risk Assessment (Oak Ridge National Laboratory 2002). Inputs to the model include COPC concentrations in water and soil. Model inputs are presented in Table E-3 in Appendix E.

3.3 CALCULATION OF CHEMICAL DOSE

This section defines the magnitude, frequency, and duration of exposure for the populations and pathways selected for quantitative evaluation. Doses were calculated assuming the "reasonable maximum exposure" (RME) as defined by EPA. Contact rates for central tendency exposures were not provided by the Spokane Tribe (Harper 2002). The RME is defined as "...the highest exposure that is reasonably expected to occur at a site" (EPA 1989a, 1991a). The goal is to quantify risk based on a high level of exposure to ensure an adequate, but reasonable level of protection (EPA 1989a, 1990a). EPA distinguishes between scenarios that are possible, but highly improbable, and those that are more likely to occur within a population, with the latter being favored in risk assessment. The RME estimate is not an upper-bound estimate (i.e., an upper limit on what is possible) because it must occur within the realm of reasonable likelihood (EPA 1989a, 1990a).

In practice, estimating an RME entails considerable uncertainty. The exposure assessment must develop levels of exposure that ensure an adequate level of protection while remaining reasonable. Uncertainties in the exposure assessment are described along with other uncertainties inherent to conducting a risk assessment to meet the transparency, clarity, consistency, and reasonableness criteria (Browner 1995, EPA 2000a).

The formulas and exposure factors that are used in concert with the EPCs to quantify the dose for each of the complete pathways at each site are presented in Tables 3-4 through 3-10, which also indicate the sources of the factors.

The traditional lifestyle, as practiced in their ancestral homeland, defines the Spokane Tribe of Indians. The exposure assessment developed for this risk assessment is intended to represent

traditional activities practiced by the Spokane Tribe of Indians. The exposure assessment relies primarily on exposure factors developed by the Spokane Tribal Council, the Spokane Cultural Resources Program, and technical representatives to the Tribe. Many of the exposure factors used differ from standard default exposure factors and exposure factors developed for other tribes.

EPA worked closely with the Tribe during the planning of the risk assessment. Concurrently, the Tribe developed The Spokane Tribe's Multipathway Subsistence Exposure Scenario and Screening Level RME (Harper et al. 2002) specific to the subsistence activities and traditions of the Spokane. This document is included as Appendix F to this document. Certain Tribal exposure factors proposed by Associated Environmental Scientists and Engineers (AESE) for the Spokane Tribe, could not be evaluated because the underlying data are proprietary or otherwise unavailable for review and concurrence. EPA recognizes the Spokane Tribal Council as the authority on the subject of Spokane Tribe traditional knowledge. However, EPA revised aspects of the Spokane exposure assessment based on CERCLA requirements and other sources of information cited in this assessment.

The following exposure factors were modified from the recommendations received from the Tribe: soil ingestion rate, inhalation rate, sweat lodge water vapor volatilization factor, and duration of sweat lodge use by children.

Specific exposure factors are described in the following sections. Generally, the exposures occur 365 days per year over a 70 year lifetime. Exposure factors differ for the following age ranges: infants (0-24 months), children (2 – 6 years), and adults (7-70 years).

3.3.1 Soil and Dust Ingestion

A soil ingestion rate of 300 mg per day was used for adults and children. For infants, a rate of 200 mg per day was used, because ingestion rates are believed to be lower during this time (Table 3-4) (EPA 1997b, van Wijnen et al. 1990). These ingestion rates are applicable to long-term (i.e., chronic) exposures arising from inadvertent soil ingestion. The soil ingestion rates account for both outdoor soil ingestion and ingestion of soil in house dust. Concentrations of COPCs in house dust were assumed to be the same as in soil outside the house. Non-residents were assumed to ingest 300 mg per day of haul road soil, although some of that amount would be from ingestion of soil and dust at the home.

Because soil ingestion studies have not been conducted for tribal subsistence populations, the soil ingestion rate encompasses considerable uncertainty. The 300 mg per day ingestion rate used for children and adults is based on the 90^{th} percentile estimate for children in a campground setting (van Wijnen et al. 1990).

Although EPA Region 10 guidance recommends using the 300 mg per day rate for exposure scenarios of short duration (e.g., a few weeks per year) rather than a lifetime, the guidance is not specific to tribal populations (EPA 2001c). However, because this soil ingestion rate represents a 90^{th} percentile value from a soil tracer study of children, it is likely to be protective applied to a lifetime of exposure, assuming young children, on average, ingest more soil on a daily basis than adults. It is possible that the 300 mg per day rate may be exceeded on an occasional basis, but it

is less likely to be exceeded on average over a 70-year lifetime. For comparison, Superfund RME default ingestion rates are 200 and 100 mg per day for children and adults, respectively (EPA 1991a).

3.3.2 Dermal Absorption of Metals in Soil and Sediment

Clothing was assumed to limit exposed skin surface areas for contact with soil and sediment (EPA 2001a). Exposed surface areas were 1,800 cm^2, 2,800 cm^2, and 5,700 cm^2 for infants, children, and adults, respectively, using the most recent exposure guidance from EPA (EPA 1997b, 2001a). Body surface areas are central tendency estimates, to be consistent with central tendency estimates of body weight (e.g., 9.1, 17.2, and 70 kg for infants, children, and adults, respectively). For children, the exposed surface areas represented the head, hands, forearms, lower legs, and feet. Exposed surface areas for adults were calculated similarly to children, although feet were not included (EPA 1997b, 2001a).

A soil-to-skin adherence factor of 0.2 mg/cm^2 was used for all ages. This adherence factor corresponds to both the 95^{th} percentile of children at a daycare facility and the 50^{th} percentile of children playing in wet, bare soil (Kissel et al. 1998a, EPA 2001a). The fraction absorbed is 3 percent for arsenic and 0.1 percent for cadmium (Wester et al. 1992 and 1993, EPA 2001a). Studies of the fraction absorbed for other metals were lacking and consequently were not quantified (EPA 2001a).

3.3.3 Drinking Water

Daily drinking water ingestion rates for infants, children, and adults were 0.9, 2, and 4 liters to account for increased water ingestion necessary to maintain hydration for a lifestyle with a high level of physical activity and daily sweat lodge use (Harper et al. 2002).

3.3.4 Sweat Lodge Exposure Duration

Estimated sweat lodge exposure for children aged 2–6 was 0.25 hours per day 365 days per year based on pediatric heat stress recommendations from the American Academy of Pediatrics (2000) included as Appendix G. Sweat lodge use by young children is likely to be less than adults because they are more susceptible to heat stress than adults (Jokinen et al. 1990, American Academy of Pediatrics 2000). For the 7–70 age range, sweat lodge use was assessed for 2 hours of use per day (Table 3-6) (Harper et al. 2002). Infants, 0–24 months, were not included in the sweat lodge exposure scenarios.

3.3.5 Surface Water Ingestion During Swimming in Pits 3 and 4

Swimming in Pits 3 and 4 was assumed to occur for 1 hour per day during the summer for a total of 112 days per year (EPA 1997b). Swimmers were estimated to ingest 30 mL of water per hour while swimming (EPA 1998a).

3.3.6 Plant Ingestion

Plant ingestion was assessed using ingestion rates up to 720 and 1,600 grams per day for children and adults, respectively (Table 3-9). These rates were based on daily caloric needs of 2,500-

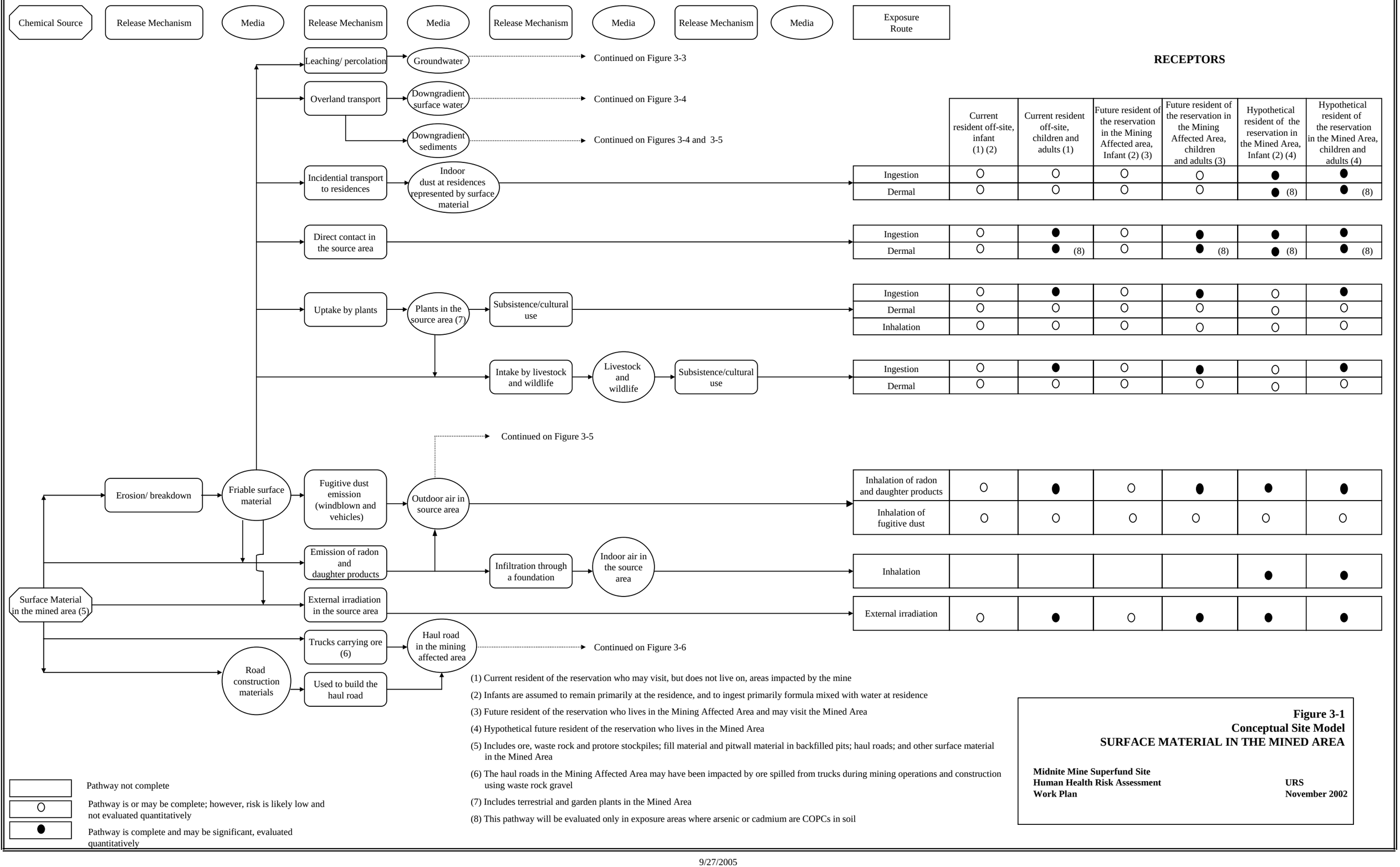
3,000 kcal. The caloric need was divided approximately equally between plants and animal protein (Harper et al. 2002).

3.3.7 Meat Ingestion

Meat ingestion was assessed using ingestion rates up to 593 and 1,185 grams per day for children and adults, respectively (Table 3-10). Similar to plant ingestion, these rates were based on daily caloric needs of 2,500-3,000 kcal divided between plant and animal sources (Harper et al. 2002).

3.3.8 Inhalation Rate

The risk assessment used the EPA default inhalation rates of 10 and 20 m^3 per day for children and adults, respectively (EPA 1991a). The Spokane Tribe recommended an adult inhalation rate of 30 m^3 per day. EPA and the Tribe each submitted correspondence supporting their preferred inhalation rate to the journal *Risk Analysis*, which had previously published The Spokane Tribe's Multipathway Subsistence Exposure Scenario and Screening Level RME. The original publication and follow-up letters to the editor are included as Appendix F (Harper et al. 2002; Harper et al. 2003; Stifelman 2003b).



(1) Current resident of the reservation who may visit, but does not live on, areas impacted by the mine

(2) Infants are assumed to remain primarily at the residence, and to ingest primarily formula mixed with water at residence

(3) Future resident of the reservation who lives in the Mining Affected Area and may visit the Mined Area

(4) Hypothetical future resident of the reservation who lives in the Mined Area

(5) Includes ore, waste rock and protore stockpiles; fill material and pitwall material in backfilled pits; haul roads; and other surface material in the Mined Area

(6) The haul roads in the Mining Affected Area may have been impacted by ore spilled from trucks during mining operations and construction using waste rock gravel

(7) Includes terrestrial and garden plants in the Mined Area

(8) This pathway will be evaluated only in exposure areas where arsenic or cadmium are COPCs in soil

Pathway not complete

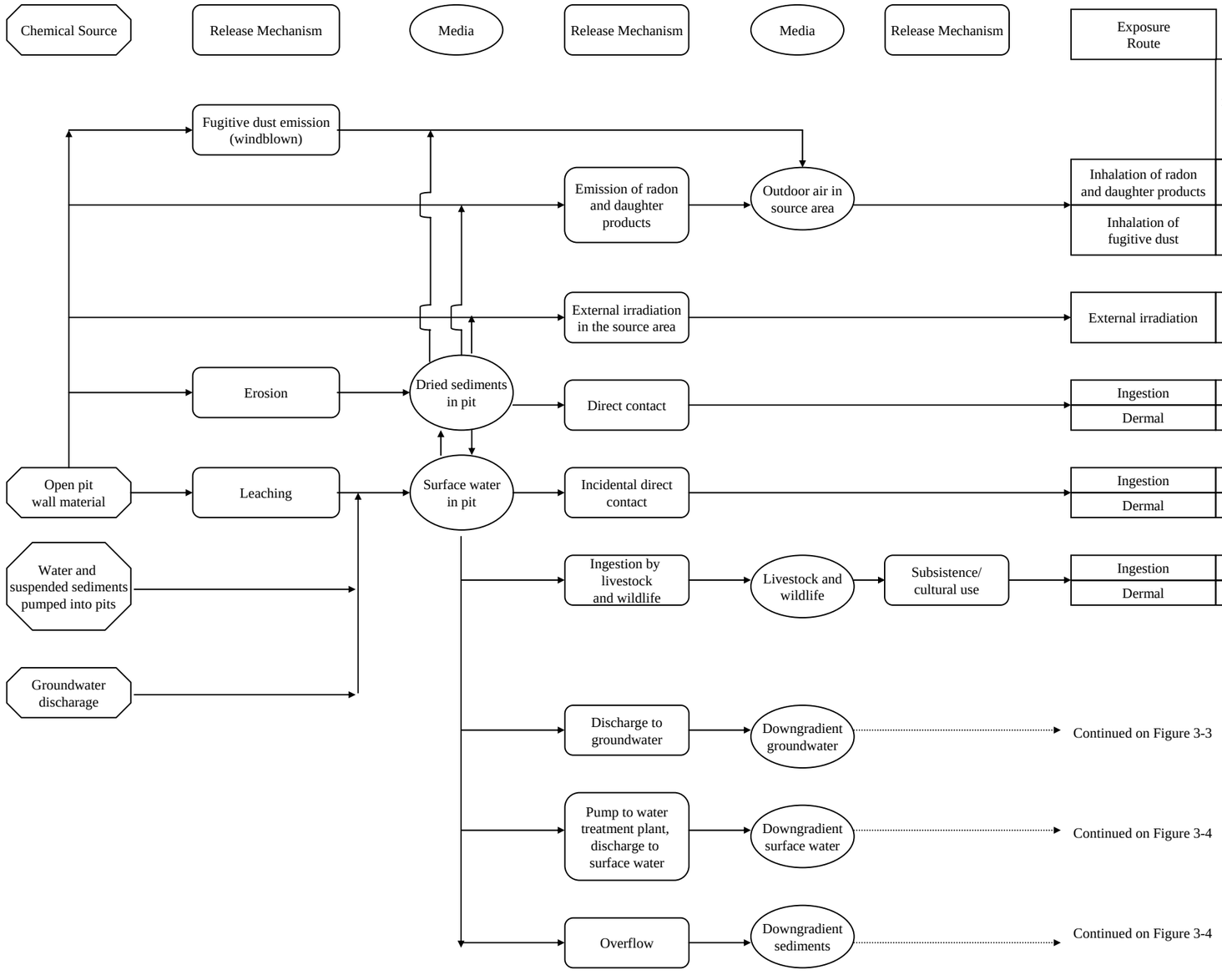
Pathway is or may be complete; however, risk is likely low and not evaluated quantitatively

Pathway is complete and may be significant, evaluated quantitatively

Figure 3-1
Conceptual Site Model
SURFACE MATERIAL IN THE MINED AREA

Midnite Mine Superfund Site
Human Health Risk Assessment
Work Plan

URS
November 2002



RECEPTORS

Exposure Route	Current resident off-site, infant (1) (2)	Current resident off-site, children and adults (1)	Future resident of the reservation in the Mining Affected Area, Infant (2) (3)	Future resident of the reservation in the Mining Affected Area, children and adults (3)	Hypothetical resident of the reservation in the Mined Area, infant (2) (4)	Hypothetical resident of the reservation in the Mined Area, children and adults (4)	Swimming scenario, children and adults (6)
Inhalation of radon and daughter products		(5)		(5)		(5)	●
Inhalation of fugitive dust		(5)		(5)		(5)	○
External irradiation		(5)		(5)		(5)	●
Ingestion		(5)		(5)		(5)	●
Dermal		(5)		(5)		(5)	● (7)
Ingestion		(5)		(5)		(5)	●
Dermal		(5)		(5)		(5)	○
Ingestion	○	●	○	●	○	●	
Dermal	○	○	○	○	○	○	

(1) Current resident of the reservation who may visit, but does not live on, areas impacted by the mine

(2) Infants are assumed to remain primarily at the residence, and to ingest primarily formula

(3) Future resident of the reservation who lives in the Mining Affected Area and may visit the Mined Area

(4) Hypothetical future resident of the reservation who lives in the Mined Area

(5) These routes of exposure for children and adults will be evaluated in the swimming scenario

(6) A swimming scenario for children and adults in the two open pits will be evaluated separately from other scenarios

(7) This pathway will be evaluated only in exposure areas where arsenic or cadmium are COPCs in sediment

▭ Pathway not complete

○ Pathway is or may be complete; however, risk is likely low and not evaluated quantitatively

● Pathway is complete and may be significant, evaluated quantitatively

Figure 3-2
Conceptual Site Model
TWO OPEN PIT SOURCES IN THE MINED AREA

Midnite Mine Superfund Site
Human Health Risk Assessment
Work Plan

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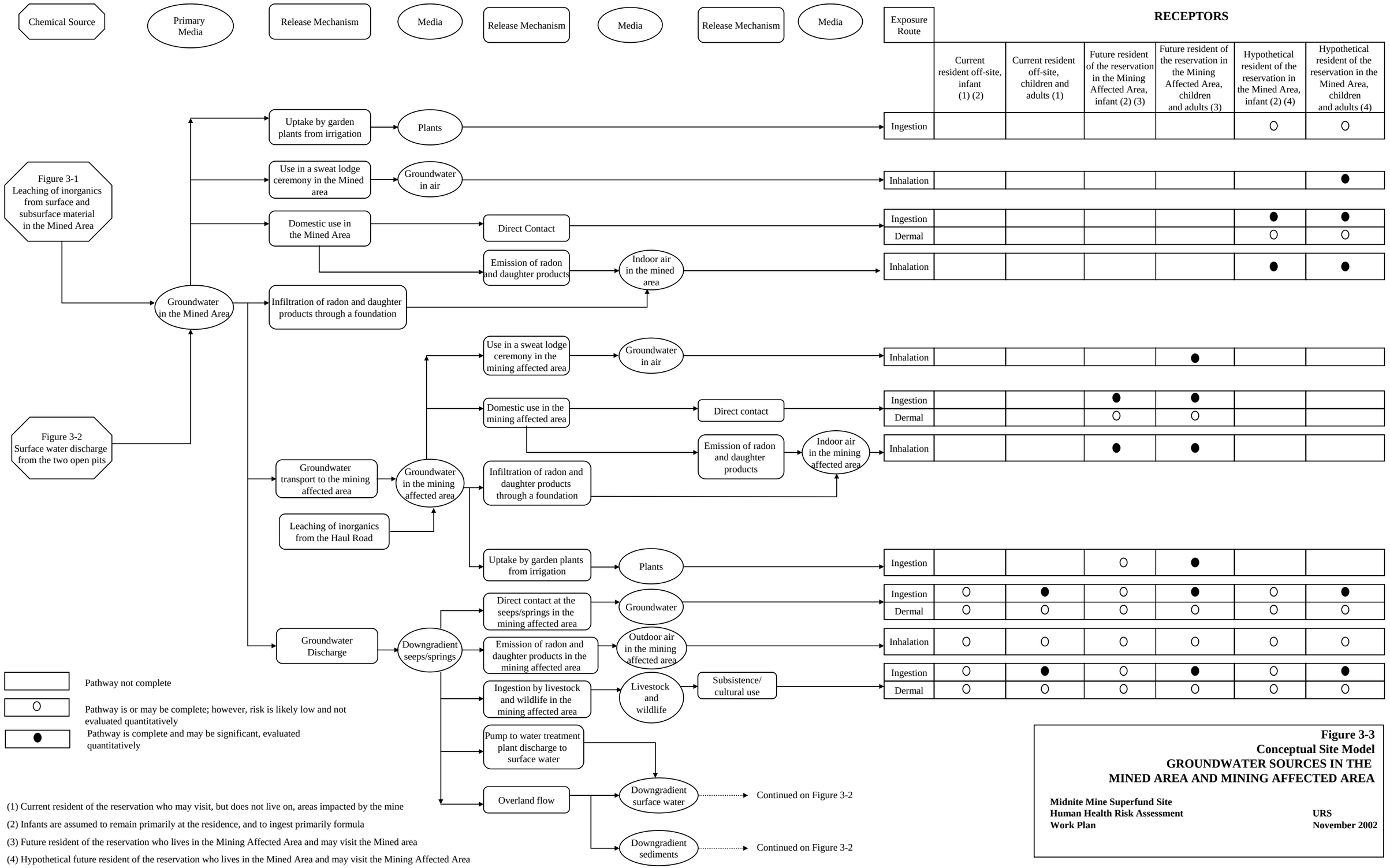

(1) Current resident of the reservation who may visit, but does not live on, areas impacted by the mine

(2) Infants are assumed to remain primarily at the residence, and to ingest primarily formula

(3) Future resident of the reservation who lives in the Mining Affected Area and may visit the Mined area

(4) Hypothetical future resident of the reservation who lives in the Mined Area and may visit the Mining Affected Area

Figure 3-3
Conceptual Site Model
GROUNDWATER SOURCES IN THE MINED AREA AND MINING AFFECTED AREA

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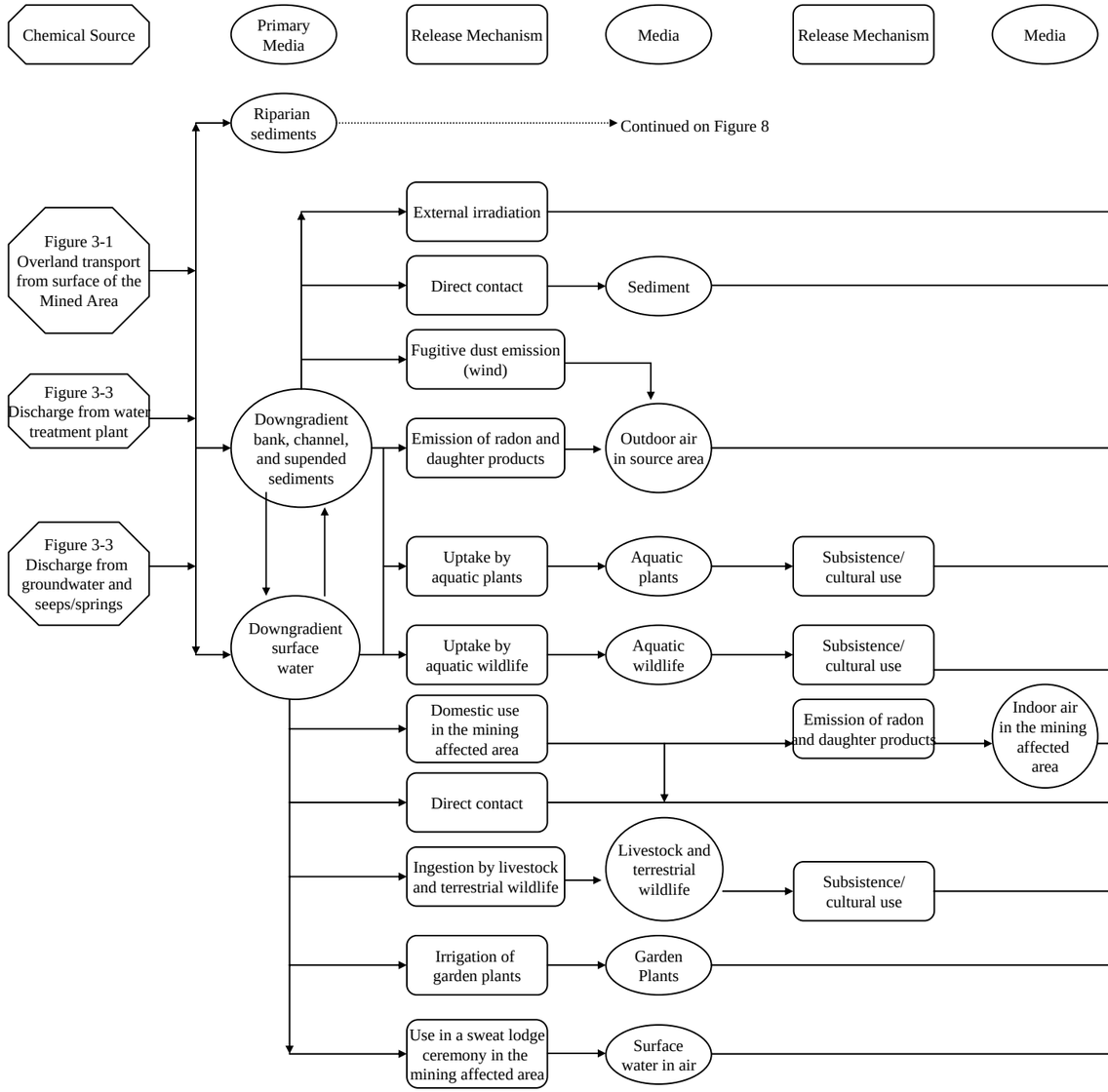


RECEPTORS

Exposure Route	Current resident off-site, infant (1) (2)	Current resident off-site, children and adults (1)	Future resident of the reservation in the Mining Affected Area, infant (2) (3)	Future resident of the reservation in the Mining Affected Area, children and adults (3)	Hypothetical resident of the reservation in the Mined Area, infant (2) (4)	Hypothetical resident of the reservation in the Mined Area, children and adults (4)
External irradiation	○	○ (5)	○	○ (5)	○	○ (5)
Ingestion	○	●	○	●	○	●
Dermal	○	● (7)	○	● (7)	○	● (7)
Inhalation of radon and daughter products	○	○ (6)	○	○ (6)	○	○ (6)
Inhalation of fugitive dust	○	○ (6)	○	○ (6)	○	○ (6)
Ingestion	○	●	○	●	○	●
Dermal	○	○	○	○	○	○
Inhalation	○	○	○	○	○	○
Ingestion	○	○	○	○	○	○
Dermal	○	○	○	○	○	○
Inhalation			●	●		
Ingestion	○	●	●	●	○	●
Dermal	○	○	○	○	○	○
Ingestion	○	●	○	●	○	●
Dermal	○	○	○	○	○	○
Ingestion			○	●		
Inhalation				●		

(1) Current resident of the reservation who may visit, but does not live on, areas impacted by the mine

(2) Infants are assumed to remain primarily at the residence, and to ingest primarily formula

(3) Future resident of the reservation who lives in the Mining Affected Area and may visit the Mined Area

(4) Hypothetical future resident of the reservation who lives in the Mined Area and may visit the Mining affected area

(5) External irradiation emitted from bank, channel, and suspended sediments in creeks in the Mining Affected area is considered to be potentially complete, but insignificant because the source area is small relative to riparian sediments in the Mining affected area

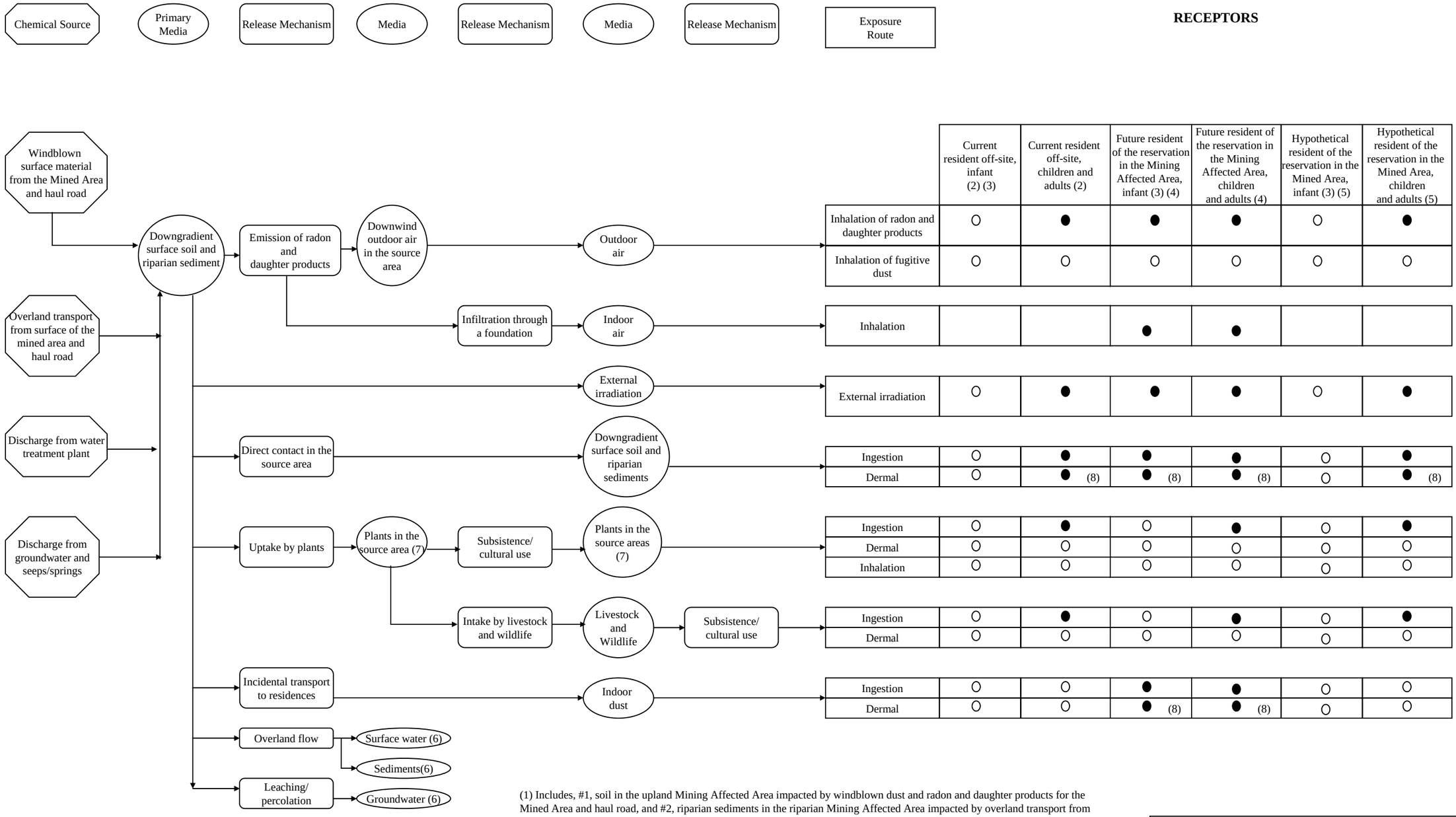
(6) Inhalation of radon and dust particulates in outdoor air emitted from bank, channel, and suspended sediments in creeks in the mining affected area is considered to be potentially complete, but insignificant because of the small amount of radon and dust emitted from bank, channel, and suspended sediments would probably not contribute measurably to levels in outdoor air in the mining affected area

(7) This pathway will be evaluated only in exposure areas where arsenic or cadmium are COPCs in soil

	Pathway not complete
○	Pathway is or may be complete; however, risk is likely low and not evaluated quantitatively
●	Pathway is complete and may be significant, evaluated quantitatively

Figure 3-4
Conceptual Site Model
SURFACE WATER/SEDIMENT SOURCES IN THE MINING AFFECTED AREA

Midnite Mine Superfund Site
Human Health Risk Assessment **URS**
Work Plan **November 2002**



(1) Includes, #1, soil in the upland Mining Affected Area impacted by windblown dust and radon and daughter products for the Mined Area and haul road, and #2, riparian sediments in the riparian Mining Affected Area impacted by overland transport from the Mined area

(2) Current resident of the reservation who may visit, but does not live on, areas impacted by the mine

(3) Infants are assumed to remain primarily at the residence, and to ingest primarily formula mixed with water at the residence

(4) Future resident of the reservation who lives in the Mining Affected Area and may visit the Mined area

(5) Hypothetical future resident of the reservation who lives in the Mined Area and may visit the Mining affected area

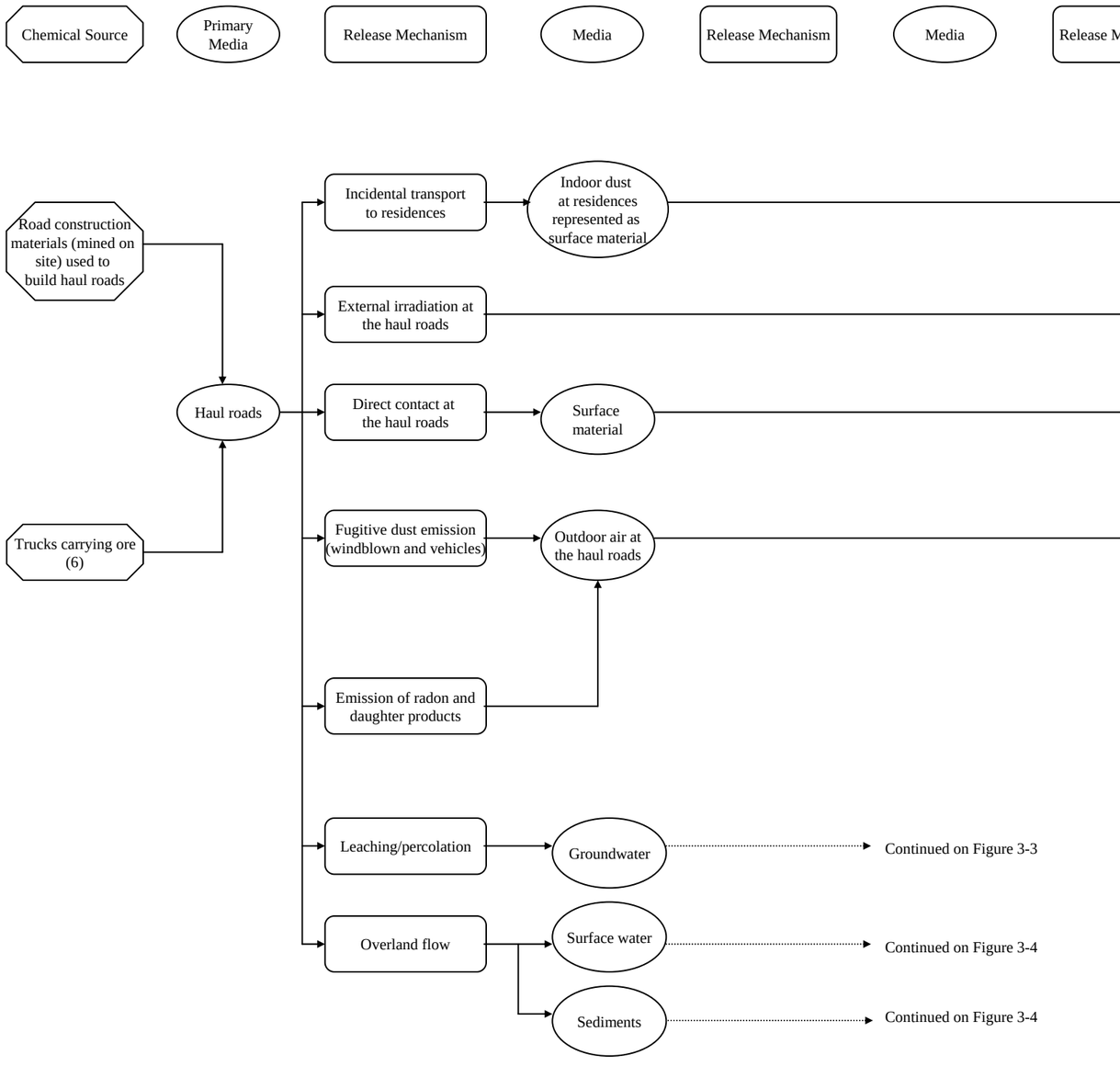
(6) Pathway may be minor due to small volume of source

(7) Includes terrestrial and garden plants in the upland Mining Affected Area and riparian plants in the riparian Mining affected area

(8) This pathway will be evaluated only in exposure areas where arsenic or cadmium are COPCs in soil

Figure 3-5
Conceptual Site Model
SOILS AND RIPARIAN SEDIMENT SOURCES IN THE MINING AFFECTED AREA (1)

Midnite Mine Superfund Site
Human Health Risk Assessment **URS**
Work Plan **November 2002**



Exposure Route	RECEPTORS: Current resident off-site, infant (2) (3)	Current resident off-site, children and adults (2)	Future resident of the reservation in the Mining Affected Area, infant (3) (4)	Future resident of the reservation in the Mining Affected Area, children and adults (4)	Hypothetical resident of the reservation in the Mined Area, infant (3) (5)	Hypothetical resident of the reservation in the Mined Area, children and adults (5)
Ingestion	○	○	○	○	○	○
Dermal	○	○	○	○	○	○
External irradiation	○	●	○	●	○	●
Ingestion	○	●	○	●	○	●
Dermal	○	● (7)	○	● (7)	○	● (7)
Inhalation of radon and daughter products	○	●	○	●	○	●
Inhalation of fugitive dust	○	○	○	○	○	○

(1) Direct exposures while using the haul roads for transportation
(2) Current resident of the reservation who may visit, but does not live on, areas impacted by the mine
(3) Infants are assumed to remain primarily at the residence, and to ingest primarily formula
(4) Future resident of the reservation who lives in the Mining Affected Area and may visit the haul roads
(5) Hypothetical future resident of the reservation who lives in the Mined Area and may visit the haul roads
(6) The haul roads may have been impacted by ore lost from trucks during mining operations
(7) This pathway will be evaluated only in exposure areas where arsenic or cadmium are COPCs in soil

	Pathway not complete
○	Pathway is or may be complete; however, risk is likely low and not evaluated quantitatively
●	Pathway is complete and may be significant, evaluated quantitatively

Figure 3-6
Conceptual Site Model
HAUL ROADS SOURCE (1)

Midnite Mine Superfund Site
Human Health Risk Assessment
Work Plan

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Table 3-1
Summary of Exposure Point Concentrations for Soil, Sediment, Plants, and Livestock

Geographical Area		Mined Area			Mining Affected Area			Dietary Pathways (various areas)					
Sub-Area			Pits 3 & 4	Haul Road	Adj. Haul Road	Blue Creek	Mining Drainages Including Seeps	Site-wide	Mined Area	Blue Creek		Mining Drainages Including Seeps	
Exposure Point													
Chemical of Potential Concern	EPC Units	Surface Soil	Sediment	Surface Soil	Surface Soil	Sediment	Sediment	Livestock[a]	Terrestrial Plants	Riparian Plants	Aquatic Plants	Riparian Plants	Aquatic Plants
Radionuclides													
Lead 210	pCi/g	110.49	130	70	21.26		18.03	1.56	3.89[b]			0.64[b]	0.76[b]
Radium 226	pCi/g	84.53	122	54.54	33.09		25.3	4.41	5.3[b]			2.39[b]	1.78[b]
Thorium 228	pCi/g	--	--	13.7	--	--	--	1.59	--	--	--	--	--
Uranium 234	pCi/g	--	342	--	--	--	148	0.18	11.4	--	--	10.58	72
Uranium 238	pCi/g	--	305	--	--	--	143	0.27	11.4	--	--	10.33	62.4
Total Metals													
Aluminum	mg/kg							62.85	--				
Antimony	mg/kg							0.00008	--				
Arsenic	mg/kg	74.20						0.28	1.49				
Beryllium	mg/kg							0.0037	--				
Cadmium	mg/kg					1.32	2.99	0.0012	--	0.97	2.06	0.96	0.61
Chromium	mg/kg	17.08						0.41	1.53				
Cobalt	mg/kg						25.94	0.0044	--			7.55	4.45
Manganese	mg/kg					6,194	4,388	6.61	--	569	6,208	1648	2,752
Nickel	mg/kg					55.83	73.79	0.98	--	13.32	22	16.41	11.4
Selenium	mg/kg	13.96						5.82	0.03				
Thallium	mg/kg	0.77	2.1					0.07	0.02				
Uranium	mg/kg	219	917	262	44.26		332	0.49	136			674	188
Vanadium	mg/kg	47	--					2.51	0.04[b]				
Zinc	mg/kg							87.94	--				

Notes:

a. Livestock (beef) EPCs were calculated using soil and water COPC chemical concentrations to estimate beef chemical concentrations.

b. Plant EPCs were modeled for those COPCs without analytical data; see Section 3.2.2 for additional information. Model inputs are presented on Table E-2 in Appendix E.

-- = Chemical is not a COPC for this medium.

pCi/g = picoCuries per gram

mg/kg = milligram per kilogram

Table 3-2
Summary of Exposure Point Concentrations for Surface Water, Drinking Water, and Sweat Lodge

Geographical Area		MA	Mining Affected Area				MA and MAA	
Sub-geographical Area		Pits 3 & 4	Blue Creek		Drainages Including Seeps		Groundwater	
Exposure Point / Chemical of Potential Concern	EPC Units	Surface Water	Drinking Water	Sweat Lodge	Drinking Water (Resident & Non-Resident)	Sweat Lodge	Drinking Water	Sweat Lodge
Radionuclides								
Lead 210	pCi/L	--	4.97	4.97	--	--	--	--
Radium 226	pCi/L	--	--	--	--	--	0.302-427	0.302-427
Radon 222	pCi/L	--	--	--	12,311	12,311	--	--
Uranium 234	pCi/L	4,211	12.4	12.4	7,632	7,632	14.3-18,241	14.3-18,241
Uranium 238	pCi/L	4,281	10.51	10.51	8,703	8,703	14-18,141	14-18,141
Total Metals								
Aluminum	ug/L	43,973	--	--	11,392	--	--	--
Antimony	ug/L	--	4.06	--	--	--	--	--
Beryllium	ug/L	25.39	--	--	--	--	0.11-170	--
Cadmium	ug/L	30.2	--	--	17.68	--	0.25-140	--
Cobalt	ug/L	1,820	--	--	166	--	0.6-4,000	--
Lead	ug/L	6.76	--	--	2.37	--	--	--
Manganese	ug/L	62,133	367	--	35,380	--	37.6-537,000	--
Nickel	ug/L	1,136	--	--	524	--	2.7-6,400	--
Silver	ug/L	--	--	--	--	--	0.4-25	--
Uranium	ug/L	13,518	33.91	--	--	--	41-54,000	--
Zinc	ug/L	2,498	--	--	--	--	3.1-8,030	--
Dissolved Metals								
Aluminum	ug/L	--	--	--	--	5,751	--	4.2-255,749
Antimony	ug/L	--	--	--	--	2.8	--	--
Beryllium	ug/L	--	--	--	--	--	--	0.05-214
Cadmium	ug/L	--	--	--	--	65.3	--	0.2-184
Chromium	ug/L	--	--	--	--	4.53	--	--
Cobalt	ug/L	--	--	--	--	188	--	0.6-4,400
Copper	ug/L	--	--	--	--	153.6	--	0.4-802
Lead	ug/L	--	--	--	--	6.16	--	0.05-25.98
Manganese	ug/L	--	--	929	--	37,923	--	30-568,425
Nickel	ug/L	--	--	--	--	565	--	1.2-7,848
Silver	ug/L	--	--	--	--	--	--	0.4-385
Zinc	ug/L	--	--	--	--	--	--	2.6-10,106

Notes:
MA = Mined Area
MAA = Mining Affected Area
-- = Chemical is not a COPC for this medium
pCi/L = picoCuries per liter
ug/L = micrograms per liter

Table 3-3

Summary of Exposure Point Concentrations for Air and External Radiation

Geographical Area		MA	MAA	Site-Wide	Site-Wide
Exposure Point		Outdoor/	Outdoor/		
Chemical of Potential Concern	EPC Units	Indoor Air	Indoor Air	Outdoor Air	Indoor Air
Radionuclides					
External Gamma Radiation	pCi/g	84.53[b]	33.09[b]		
Radon	pCi/L	--	--	9.09	135.88[c]

Notes:

a. Site-wide = Pooled data from the MA and the MAA.

b. External gamma radiation is estimated from soil concentrations

c. The concencentration of radon in indoor air was estimated by assuming that 1 pCi/g of Radium 226 in soil results in 1.25 pCi/L of radon in indoor air. Therefore, the 95 percent upper confidence limit (95UCL) of Radon 226 in all residential soil was multiplied by 1.25 to derive the concentration of radon in indoor air, as follows: 108.7 (pCi/g) x 1.25 (pCi/L / pCi/g) = 135.88 pCi/L

-- = Chemical is not a COPC for this medium.

MA = Mined Area

MAA = Mining Affected Area

uR/hr = microrems per hour

pCi/L = picoCuries per liter

Table 3-4
Soil and Sediment Exposure Factors

Equation: Chemical intake (mg/kg-day) = CS x SIF [a, b]

$$SIF_{ing} = \frac{IR \cdot CF \cdot EF \cdot ED}{BW \cdot AT} \qquad SIF_{derm} = \frac{CF \cdot SA \cdot AF \cdot ABS \cdot EF \cdot ED \cdot FC}{BW \cdot AT}$$

Where:

SIF_{ing} $(day)^{-1}$ = summary intake factor for ingestion of soil/sediment

SIF_{derm} $(day)^{-1}$ = summary intake factor for dermal contact with soil/sediment

Parameter	Definition	Infant Value	Child Value	Adult Value	Units	Source
CS	Chemical concentration in soil/sediment	chemical specific	Chemical specific	chemical specific	mg/kg	Analytical data
IR	Ingestion rate	200	300	300	mg/day	Contact-intensive for child/adult (EPA 1999b); infant value is child default (EPA 1991a)
CF	Conversion factor	1.00E-06	1.00E-06	1.00E-06	kg/mg	
SA	Surface area	1,800	2,800	5,700	cm^2/day	EPA 2001a
AF	Soil to skin adherence factor	0.2	0.2	0.2	mg/cm^2	EPA 2001a
ABS	Absorption factor	chemical specific	Chemical specific	chemical specific	unitless	EPA 2001a
FC	Fraction of day for dermal exposure	1	1	1	unitless	Tribal-specific (Harper et al. 2002)
EF	Exposure frequency	365	365	365	days/year	Tribal-specific (Harper et al. 2002)
ED	Exposure duration	2	4	64	year	Tribal-specific (Harper et al. 2002)
BW	Body weight	9.1	17.2	70	kg	EPA 1991a
ATnc	Averaging time for noncarcinogenic effects	ED x 365	ED x 365	ED x 365	days	EPA 1991a
ATc	Averaging time for carcinogenic effects	25,550	25,550	25,550	days	EPA 1991a

Notes:

a. Exposure factors are combined for infant/child/adults when calculating lifetime cancer intakes, non-cancer intakes are calculated separately for each age group.

b. For the radioactive chemicals, the BW and AT terms are not used when calculating cancer intakes.

Table 3-5
Surface Water and Groundwater Ingestion Exposure Factors

Equations:

Chemical intake (mg/kg-day) = CW x SIF [a, b]

$$SIF_{ing} = \frac{IR \cdot CF \cdot EF \cdot ED}{BW \cdot AT}$$

Where: SIF_{ing} (L-mg/µg-kg-day) = summary intake factor for ingestion of groundwater/surface water

Parameter	Definition	Infant Value	Child Value	Adult Value	Units	Source
CW	Chemical concentration in Groundwater/surface water	chemical specific			µg/L	Analytical data
CF	Conversion factor	1.00E-03			mg/µg	
IR	Ingestion rate	0.9	2	4	L/day	Tribal-specific (Harper et al. 2002)
EF	Exposure frequency	365	365	365	days/year	Tribal-specific (Harper et al. 2002)
ED	Exposure duration	2	4	64	year	Tribal-specific (Harper et al. 2002)
BW	Body weight	9.1	17.2	70	kg	EPA 1991 and 1997b
ATnc	Averaging time for noncarcinogenic effects	ED x 365	ED x 365	ED x 365	days	EPA 1989a
ATc	Averaging time for carcinogenic effects	25,550	25,550	25,550	days	EPA 1989a

Notes:

a. Factors are combined for infant/child/adults when calculating cancer intakes, non-cancer intakes are calculated separately for each age group.

b. For the radioactive chemicals, the BW and AT terms are not used when calculating cancer intakes.

Table 3-6
Sweat Lodge Inhalation Exposure Factors

Equations: Chemical intake (mg/kg-day) = CW x SIF [a, b]

$$SIFinh = \frac{CF \bullet InhR \bullet EF \bullet ED \bullet ET \bullet VF}{BW \bullet AT}$$

Where: SIF_{inh} (L-mg/µg-kg-day) = summary intake factor for inhalation metals dissolved in water

Parameter	Definition	Child Value	Adult Value	Units	Source
CW	Chemical concentration in groundwater/surface water	chemical specific		µg/L	Analytical data
CF	Conversion factor	1.00E-03		mg/µg	
InhR	Inhalation rate	0.42	0.83	m^3/hour	Pro-rated from daily inhalation of 10 m^3/day child 20 m^3/day adult (EPA 1991a)
VF	Volatilization factor for water	0.15		L/m^3	Water vapor saturation at 150 degrees F sweat lodge temperature (Harris and Harper 1997)
EF	Exposure frequency	365		days/year	Tribal-specific (Harper et al. 2002)
ET	Exposure time	0.25	2	hours/day	Tribal-specific (Harper et al. 2002)
ED	Exposure duration	4	64	years	Tribal-specific (Harper et al. 2002)
BW	Body weight	17.2	70	kg	EPA 1991 and 1997b
ATnc	Averaging time for noncarcinogenic effects	ED x 365		days	EPA 1989a
ATc	Averaging time for carcinogenic effects	25,550		days	EPA 1989a

Notes:

a. These are simplified formulas. Factors are combined for infant/child/adults when calculating cancer intakes, non-cancer intakes are calculated separately for each age group.

b. For the radioactive chemicals, the BW and AT terms are not used when calculating cancer intakes.

Table 3-7
Water Ingestion Exposure Factors While Swimming in Pits 3 and 4

Equations: Chemical intake (mg/kg-day) = CW x SIF [a, b]

$$SIF_{ing} = \frac{IR \bullet CF \bullet EF \bullet ED \bullet ET}{BW \bullet AT}$$

Where: SIF_{ing} (L-mg/µg-kg-day) = summary intake factor for ingestion of surface water

Parameter	Definition	Child Value	Adult Value	Units	Source
CW	Chemical concentration in surface water	chemical specific		µg/L	Analytical data
IR	Ingestion rate	0.03		L/hour	EPA 1998a
CF	Conversion factor	1.00E-03		mg/µg	
ET	Exposure time	1		hours/day	EPA 1997b
EF	Exposure frequency	112		days/year	Site-specific [c]
ED	Exposure duration	4	64	year	Tribal-specific (Harper et al. 2002)
BW	Body weight	17.2	70	kg	EPA 1991a, 1997b
Atnc	Averaging time for noncarcinogenic effects	ED x 365		days	EPA 1989a
Atc	Averaging time for carcinogenic effects	25,550		days	EPA 1989a

Notes:

a. These are simplified formulas. Factors are combined for infant/child/adults when calculating cancer intakes, non-cancer intakes are calculated separately for each age group.

b. For the radioactive chemicals, the BW and AT terms are not used when calculating cancer intakes.

c. Assumes daily exposure of 16 weeks during from June through September.

Table 3-8
Sediment Ingestion Exposure Factors While Swimming in Pits 3 and 4

Equations: Chemical intake (mg/kg-day) = Csed x SIF [a, b]

$SIF_{ing} = \frac{IR \cdot CF \cdot EF \cdot ED}{BW \cdot AT}$

Where: SIF_{ing} $(day)^{-1}$ = summary intake factor for ingestion of sediment

Parameter	Definition	Child Value	Adult Value	Units	Source
Csed	Chemical concentration in sediment	chemical specific		mg/kg	Analytical data
IR	Ingestion rate	300		mg/day	Contact-intensive for child/adult (EPA 2001c)
CF	Conversion factor	1.00E-06		kg/mg	
ABS	Absorption factor	chemical specific		unitless	EPA 2001a
EF	Exposure frequency	112		days/year	Site-specific [c]
ED	Exposure duration	4	64	year	Tribal-specific (Harper et al. 2002)
BW	Body weight	17.2	70	kg	EPA 1991a, 1997b
ATnc	Averaging time for noncarcinogenic effects	ED x 365		days	EPA 1991a
ATc	Averaging time for carcinogenic effects	25,550		days	EPA 1991a

Notes:

a. Factors are combined for infant/child/adults when calculating cancer intakes, non-cancer intakes are calculated separately for each age group.

b. For the radioactive chemicals, the BW and AT terms are not used when calculating cancer intakes.

c. Assumes daily exposure of 16 weeks during June through September.

Table 3-9
Plant Consumption Exposure Factors

Equations: Chemical intake (mg/kg-day) = CTi x SIF [a, b]

$$SIF_{ing} = \frac{IR \cdot CF \cdot EF \cdot ED \cdot FC}{BW \cdot AT}$$

Where: SIF_{ing} $(day)^{-1}$ = summary intake factor for ingestion of plant tissue

Parameter	Definition	Child Value	Adult Value	Units	Source
CTi	Chemical concentration in plant tissue	chemical specific		mg/kg	Analytical data
IR	Ingestion rate	720	1,600	g/day	Tribal-specific (Harper et al. 2002)
CF	Conversion factor	1.00E-03		kg/g	
FC	Fraction of plant from contaminated source	1		unitless	Site-specific
EF	Exposure frequency	365		days/year	Site-specific
ED	Exposure duration	4	64	year	Tribal-specific (Harper et al. 2002)
BW	Body weight	17.2	70	kg	EPA 1991a, 1997b
ATnc	Averaging time for noncarcinogenic effects	ED x 365		days	EPA 1991a
ATc	Averaging time for carcinogenic effects	25,550		days	EPA 1991a

Notes:
a. Factors are combined for infant/child/adults when calculating cancer intakes, non-cancer intakes are calculated separately for each age group.
b. For the radioactive chemicals, the BW and AT terms are not used when calculating cancer intakes.

Table 3-10
Meat Consumption Exposure Factors

Equations: Chemical intake (mg/kg-day) = CTi x SIF [a, b]

$$SIF_{ing} = \frac{IR \bullet CF \bullet EF \bullet ED \bullet FC}{BW \bullet AT}$$

Where: SIF_{ing} $(day)^{-1}$ = summary intake factor for ingestion of animal tissue

Parameter	Definition	Child Value	Adult Value	Units	Source
CTi	Chemical concentration in meat	chemical specific		mg/kg	Modeled value [c]
IR	Ingestion rate	593	1,185	g/day	Tribal-specific (Harper et al. 2002)
CF	Conversion factor	1.00E-03		kg/g	
FC	Fraction of meat from contaminated source	1		Unitless	Site-specific
ED	Exposure duration	4	64	years	Tribal-specific (Harper et al. 2002)
BW	Body weight	17.2	70	kg	EPA 1991a, 1997b
ATnc	Averaging time for noncarcinogenic effects	ED x 365		Days	EPA 1991a
ATc	Averaging time for carcinogenic effects	25,550		days	EPA 1991a

Notes:
a. These are simplified formulas. Factors are combined for infant/child/adults when calculating cancer intakes, non-cancer intakes are calculated separately for each age group.
b. For the radioactive chemicals, the BW and AT terms are not used when calculating cancer intakes.
c. Modeled value based on equations from Oak Ridge National Laboratory Risk Assessment Information Web Site: http://rais.ornl.gov/prg/equations/ag_cc_bef.shtml and site-specific soil and surface water concentrations

4.0 TOXICITY ASSESSMENT

The toxicity assessment describes the potential for contaminants to cause adverse health effects and provides a quantitative estimate of the relationship between the magnitude of exposure and the likelihood of cancer (EPA 1989a). This section describes the types of toxicity criteria used in the HHRA. Profiles for each radionuclide or metal are included as Appendix H. Table 4-1 presents the toxicity criteria used in this assessment and the associated health effects for each COPC.

4.1 SOURCES OF TOXICITY VALUES USED IN RISK ASSESSMENT

The individual chemical profiles in Appendix H were prepared with information gathered from the EPA Integrated Risk Information System (IRIS) (EPA 2003), Agency for Toxic Substances and Disease Registry Toxicological Profiles (ATSDR 1992a), Institute of Medicine Dietary Intake Reports (Institute of Medicine 2000 and 2001), reports prepared by the EPA Superfund Technical Support Center, and *Casarett & Doull's Toxicology-The Basic Science of Poisons, 6th Ed*. (Klaassen 2001). Toxicity values specific to the oral and inhalation pathways were obtained from the sources listed below using the following sources:

- IRIS on-line database http://www.epa.gov/iris/ (EPA 2003)
- The EPA National Center for Environmental Assessment Superfund Technical Support Center
- The Radionuclide Table, formerly known as HEAST Table 4, available from the EPA/ORIA website at http://www.epa.gov/radiation/heast/download.htm
- Federal Guidance Report No. 13 Cancer Risk Coefficients for Environmental Exposure to Radionuclides with supplemental (EPA 1999a, 2002c)

4.2 DOSE-RESPONSE RELATIONSHIP

The relationship between the dose of a chemical and the incidence of adverse health effects is the dose-response. Dose-response data are typically graphed with dose plotted on the X-axis (i.e., the independent variable) and the response on the Y-axis (i.e., the dependent variable). The rate of response is represented by the slope of the curve. Toxicity values are derived from dose-response data and are used to estimate the potential for adverse health effects as a function of the rate of exposure. Toxicity values are combined with the summary intake factors (i.e., dose) calculated in Section 3 and are used to calculate risks for various exposure scenarios presented in Section 5. For more background on the dose-response relationship, see *Casarett & Doull's Toxicology* (Klaassen 2001).

Exposure to chemicals may cause cancer or non-cancer effects, which are characterized differently. The cancer slope factor (CSF) is the relevant toxicity criterion for assessing cancer risks. The reference dose (RfD) is the relevant toxicity criterion for assessing non-cancer effects by comparing dose with a threshold. The criteria for non-radionuclides were primarily from the EPA's online database, Integrated Risk Information System, http://www.epa.gov/iris/. The

criteria for radionuclides were from the CSFs for Environmental Exposure to Radionuclides document (EPA 1999a and 2003).

4.3 NON-CANCER TOXICITY CRITERIA

The RfD is an exposure-route-specific (e.g., oral, inhalation, or dermal) estimate of a chronic daily chemical intake per unit body weight that is likely to be without adverse effects (i.e., a threshold) (EPA 1989a). The EPA has developed RfDs to protect sensitive populations from adverse health effects resulting from long-term, chronic exposures (e.g., from 7 years to a lifetime) (EPA 2003). Chronic oral RfDs are currently available for aluminum, antimony, arsenic, beryllium, cadmium, chromium, cobalt, copper, manganese, nickel, selenium, silver, thallium, total uranium, vanadium, and zinc (Table 4-1). Chronic inhalation RfDs are available for aluminum, beryllium, cadmium, and manganese (Table 4-2).

4.4 CANCER RISK ASSESSMENT

CSFs used to estimate cancer risks for non-radionuclides are typically upper 95^{th} percentile confidence limits of the increased probability of contracting cancer per unit of dose over a lifetime. CSFs are based on human studies (e.g., observational epidemiology often from exposed workers), or more frequently, from experimental animal data. Because cancer risks are unitless probabilities, the slope factors are expressed in the inverse units as chemical intake, i.e., mg chemical intake per kg body weight per day $(mg/kg\text{-}day)^{-1}$. Because slope factors are typically high-end estimates, actual cancer potency of COPCs are likely lower than estimated. The slope factor for arsenic is a notable exception, because it is based on a maximum likelihood estimate for skin cancer (EPA 1998c). Exposure to arsenic also may cause internal cancers in addition to skin cancer. Internal cancers were described in recent studies reviewed in the arsenic drinking water reports conducted by the National Academy of Sciences (National Academy of Sciences 2000 and 2001, EPA 1998c). The current EPA slope factor for arsenic does not address the additional risk of internal cancers from arsenic exposure (EPA 1998c).

Oral route cancer slope factors were available for arsenic and all radionuclides except radon-220 and radon-222 (risks from radon are dominated by the inhalation pathway so missing oral values are not a concern). Inhalation route CSFs were available for arsenic, beryllium, cadmium, chromium-6, cobalt, and all radionuclides. External radiation slope factors are available for all radionuclides except radon-222 (EPA 1999a, 2002c). CSFs are summarized in Table 4-1.

Cancer Risk from Radionuclides

The EPA has classified all radionuclides as known human carcinogens based on epidemiological studies of radiogenic cancers in humans (EPA 1999a, 2002c). Cancer slope factors for radionuclides are central tendency estimates of the age-averaged increased lifetime cancer risk. These estimates are expressed in units of risk per unit of radionuclide intake or radiation dose.

Risks for individual radionuclides were calculated using Health Effects Assessment Summary Table (HEAST) (EPA 2001d). This update of the HEAST for radionuclides incorporates all new values, based on Federal Guidance Report No. 13 (EPA 1999a). Report No. 13 incorporates

state-of-the-art models and methods that take into account age and gender dependence of radionuclide intake, metabolism, dosimetry, radiogenic cancer risk, and competing risks.

The radionuclide CSFs used take into account the age dependence of the biological behavior and internal dosimetry of ingested or inhaled radionuclides. The radionuclide CSFs characterize the effects of age and gender dependence in radiogenic risk models, U.S. cancer mortality rates, and competing risks from non-radiogenic causes of death in the U.S. Finally, these CSFs take into account the age and gender dependence in the usage of contaminated environmental media.

Many of the radionuclides of concern are members of important naturally-occurring decay chains (e.g., radium-226 series, thorium-228 series). For these radionuclides, risks were calculated based on risk from the entire decay series in secular equilibrium. Risk CSFs representing the entire decay series (identified with "+D" designation) were applied.

Radionuclide Decay Chains

In some cases, CSFs for radionuclides include the contributions from their short-lived decay products assuming secular equilibrium. EPA recommends using site-specific analytical data to establish the degree of equilibrium between each parent radionuclide and its decay products for each medium sampled. In case of non-equilibrium, EPA recommends using slope factors for sub-chains or individual radionuclides (EPA 1999a, 2002c). Data were collected at the site to evaluate equilibrium in the uranium and thorium decay series. These analytical data have been evaluated to determine the site-specific degree of equilibrium between parent radionuclides and decay members of contiguous decay chains (URS 2003a). The results indicate that the assumption of secular equilibrium within uranium decay sub-chains is not likely to significantly underestimate concentrations of radionuclide decay products. Figures 4-1 through 4-3 depict the important decay chains for the site.

Radon Inhalation Slope Factor

The radon inhalation slope factor (7.57×10^{-12} risk/pCi) is based on an assumption of 50 percent equilibrium of radon decay products. Because radon risk depends on the equilibrium fraction, the radon slope factor was adjusted for expected ambient outdoor equilibrium values (which will be higher than 50 percent) and equilibrium from site-related radon (which will be lower). The slope factor for ambient background radon, with an assumed equilibrium fraction of 0.8, was 1.21×10^{-11} risk/pCi. For site radon, with an assumed equilibrium fraction of 0.1, the resulting slope factor was 1.51×10^{-12} risk/pCi. The weighted average slope factor was 2.83×10^{-12} risk/pCi, based on a weighted average of background radon, site radon, and their respective slope factors.

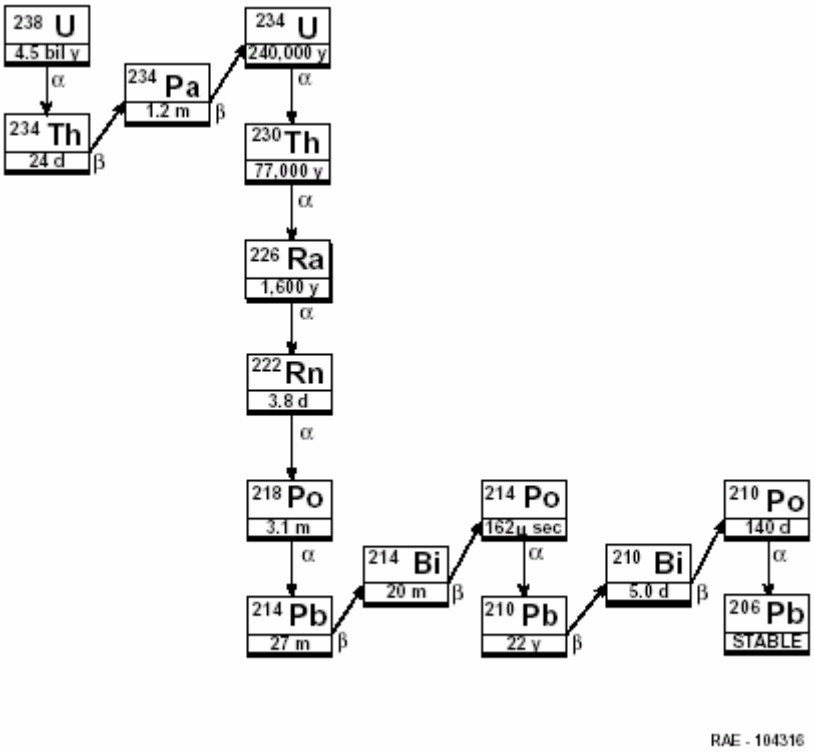
4.5 DERMAL TOXICITY CRITERIA

There are currently no RfDs or CSFs specific for dermal route exposures. Risks and hazards associated with dermal exposure are evaluated using an oral toxicity factor (route-to-route extrapolation) corrected for percutaneous absorption (EPA 1992c and 2004a). Only arsenic and cadmium were evaluated for dermal toxicity in this risk assessment because only these chemicals

have sufficient data to quantify percutaneous absorption (EPA 2004). Lack of knowledge regarding dermal absorption of other metals is likely to underestimate site risks to a small degree.

Route-to-route extrapolation assumes that on the basis of absorbed (as opposed to administered) dose, the toxicity of a hazardous constituent is the same once it enters the blood, regardless of the route of exposure (EPA 1989a). The administered dose is the dose applied at the point of contact, including the mouth, skin, and nose. The absorbed dose is the fraction of the administered dose that enters the body's general circulation. Because the skin forms an effective barrier to inorganic metal compounds, only a small fraction of the dose administered on the skin's surface is absorbed through the skin into the bloodstream (Wester et al. 1992 and 1993). Neither the CSF nor the RfD for arsenic was adjusted from an administered dose, to an absorbed dose, because the RfD and CSF are based on arsenic in drinking water rather than food. Because most of the arsenic ingested in water is absorbed through the gastrointestinal tract, the orally administered dose is considered equivalent to the absorbed dose.

For cadmium, the administered oral RfD of 0.001 mg/kg-day in food was multiplied by the gastrointestinal absorption fraction of 0.025 to derive a dermal RfD of 0.000025 mg/kg-day (EPA 2004). This adjustment was necessary for cadmium because only a small fraction of ingested cadmium is absorbed into the bloodstream (EPA 1989a).

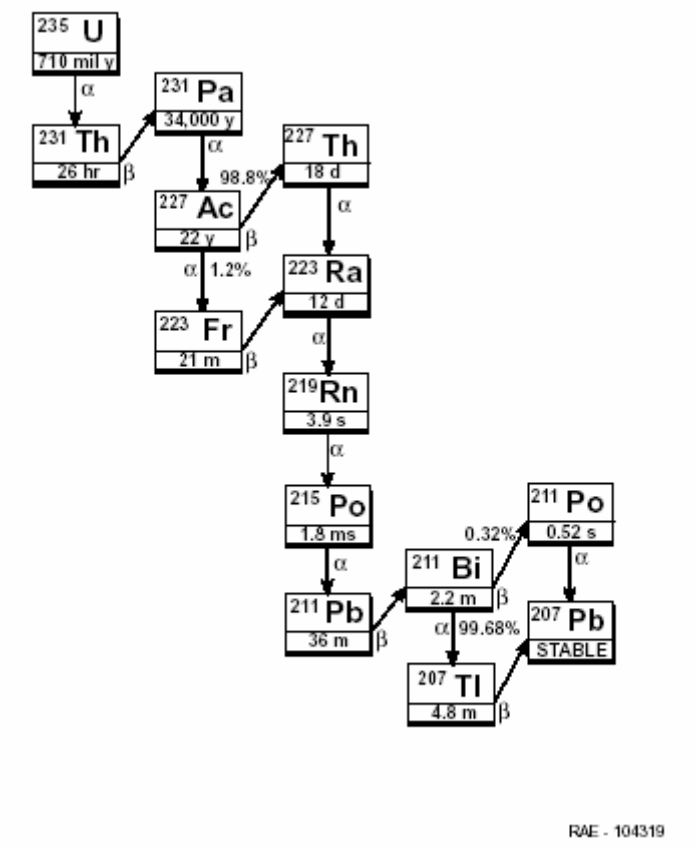


Notes

Notation explanation: $\frac{238\,U}{4.5\,bll\,y}$ indicates that uranium (U) isotope 238 has a half life of 4.5 billion years

Bi: bismuth
Pa: protactinium
Pb: lead
Po: polonium
Ra: radium
Rn: radon
Th: thorium
U: uranium

Figure 4-1 Uranium-238 Decay Series

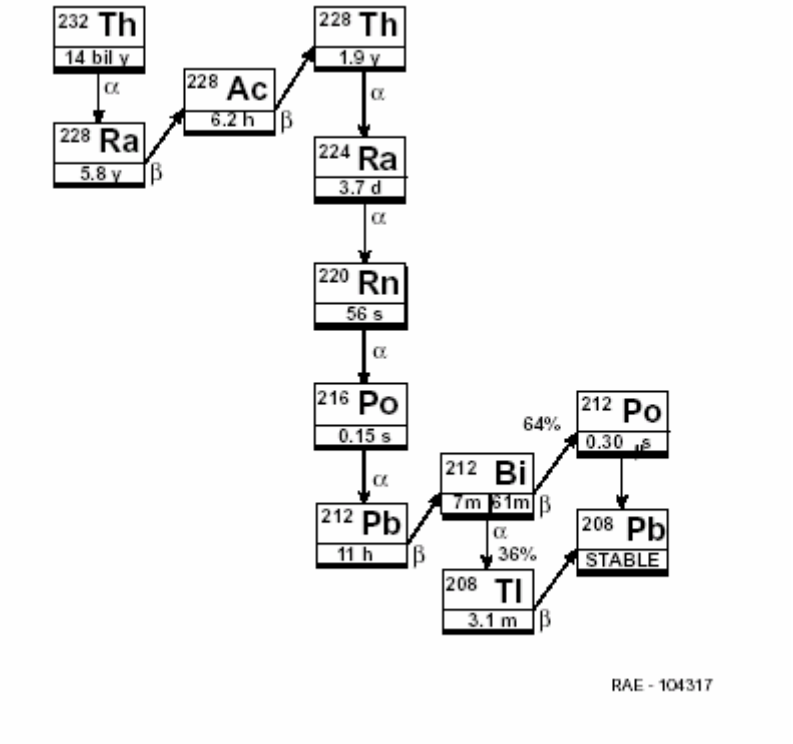


Notes

Notation explanation: $\frac{235\,U}{710\,mil\ y}$ indicates that uranium (U) isotope 235 has a half life of 710 million years

Ac: actinium
Bi: bismuth
Fr: francium
Pa: protactinium
Pb: lead
Po: polonium
Ra: radium
Rn: radon
Th: thorium
Tl: thallium
U: uranium

Figure 4-2 Uranium-235 Decay Series



Notes

Notation explanation: $\frac{232\ Th}{14\ bll\ y}$ indicates that thorium (Th) isotope 232 has a half life of 14 billion years

Ac: actinium
Bi: bismuth
Pb: lead
Po: polonium
Ra: radium
Rn: radon
Th: thorium
Tl: thallium

Figure 4-3 Thorium-232 Decay Series

Table 4-1
Summary of Oral Toxicity Values

Chemical	CSF[a]	RfD (mg/kg-day)	Critical Effect Observed	Level of Confidence	Product of Uncertainty and Modifying Factors	Reference
Radionuclides						
Lead-210 +D	3.4×10^{-9} (food) 2.7×10^{-9} (soil 1.3×10^{-9} (water)	None	Radiogenic cancers	High	None	EPA 1999a
Radium-226	5.2×10^{-10} (food) 7.3×10^{-10} (soil) 3.9×10^{-10} (water)	None	Radiogenic cancers	High	None	EPA 1999a
Thorium-228 +D	4.2×10^{-10} (food) 8.1×10^{-10} (soil) 3.0×10^{-10} (water)	None	Radiogenic cancers	High	None	EPA 1999a
U-234	9.6×10^{-11} (food) 1.6×10^{-10} (soil) 7.1×10^{-11}(water)	None	CSF: radiogenic cancers	High	None	EPA 1999a
U-238 +D	1.2×10^{-10} (food) 2.1×10^{-10} (soil) 8.7×10^{-11} (water)	None	CSF: radiogenic cancers	High	None	EPA 1999a
Non-Radionuclides						
Aluminum	None	1.0	Neurotoxicity-mice	Low	100	Gawron 2001
Antimony	None	0.0004	Reduced lifespan, altered cholesterol levels	Low	1,000	EPA 1991d
Arsenic	1.5	0.0003	CSF-human skin cancer RfD-human dermal & vascular	Medium	3	EPA 1998c
Beryllium	None	0.002	Gastrointestinal lesions-dogs	Medium-Low	300	EPA 1998d
Cadmium	None	0.001 (food); 0.0005 (water)	Renal proteinuria-human	High	10	EPA 1994b
Chromium-3	None	1.5	Reduction in organ weights-rats	Low	1,000	EPA 1998e and f
Chromium-6	None	0.003	No LOAEL-rats	Low	1,000	EPA 1998e
Cobalt	None	0.06	Increased hemoglobin Increased erythrocytes-human	Medium-Low	10	STSC 2001
Copper	None	0.037	Gastrointestinal irritation-human	High	2	EPA 1985a
Lead	None	None	Neurological deficits in children	High confidence	None	Centers for Disease Control and Prevention 1991
Manganese	None	0.14 food 0.047 other	None-RfD based on high-end estimates of human intakes	Medium	Food: None Other: 3	EPA 1989a
Nickel	None	0.002	Reduction in organ weights-rats	Medium	300	EPA 1996c
Selenium	None	0.005	Selenosis (liver, hair and nails) human	High	3	EPA 1993A
Silver	None	0.005	Argyia (skin discoloration) Human	Low-Medium	3	EPA 1996d
Thallium	None	0.000066	Elevated liver enzymes-rats	Low	3,000	EPA 1990a
Uranium soluble salts	None	0.0002	Weight loss and nephrotoxicity-rabbits	Medium	1,000	EPA 1989a
Vanadium	None	0.007	Decreased hair cystine-rats	Low	100	EPA 1997c
Zinc	None	0.3	Anemia	Medium	3	EPA 1992a

Notes:

[a] The CSF is in risk/picoCuries for radionuclides, and in mg/kg-day^{-1} for non-radionuclides

CSF: cancer slope factor

+D: CSF includes the toxicity of daughter products of the radionuclide decay chain.

LOAEL: lowest observed adverse effect level

RfD: Reference Dose

STSC: Superfund Technical Support Center

Table 4-2
Summary of Inhalation Toxicity Values

Chemical	CSF[a]	RfD (mg/kg-day)	Critical Effect Observed	Level of Confidence	Product of Uncertainty and Modifying Factors	Reference
Radionuclides						
Lead-210 +D	1.4×10^{-8}	None	Radiogenic cancers	High	None	EPA 1999a
Radon-222 +D	7.6×10^{-12}	None	Radiogenic cancers	High	None	EPA 1999a
Radium-226 +D	1.2×10^{-8}	None	Radiogenic cancers	High	None	EPA 1999a
Thorium-228 +D	1.4×10^{-7}	None	Radiogenic cancers	High	None	EPA 1999a
U^{234}	1.1×10^{-8}	None	Radiogenic cancers	High	None	EPA 1999a
$U^{238 +D}$	9.4×10^{-9}	None	Radiogenic cancers	High	None	EPA 1999a
Non-Radionuclides						
Aluminum	None	0.0014	NA	NA	NA	EPA Region 9 2002 PRG list[b]
Arsenic	15	None	Human lung cancer	NA	NA	EPA 2003
Beryllium	8.4	5.7×10^{-6}	CSF: lung cancer; RfD: sensitization & progress to CBD	Medium	10	EPA 2003
Cadmium	6.3	None	Lung cancer	NA	NA	EPA 2003
Chromium-6	290	2.2×10^{-6}	CSF: lung cancer; RfD: nasal septum atrophy	Low	90	EPA 2003
Cobalt	9.8	5.7×10^{-6}	NA	NA	NA	EPA Region 9 2002 PRG list[b]
Manganese	None	0.000014	Impairment of neurobehavioral function	Medium	1000	EPA 2003

Note:

a. The CSF is in risk/picoCuries for radionuclides, and in mg/kg-day-1 for non-radionuclides

b. Toxicity Value was obtained from EPA's Region 9 PRG list, which cites the source of the value as EPA's National Center for Environmental Assessment, no other detail provided.

CBD: chronic beryllium disease

CSF: Cancer Slope Factor

+D: CSF includes the toxicity of daughter products of the radionuclide decay chain.

NA: Not available. Note that "level of confidence" and "product of uncertainty and modifying factors" only apply to RfDs.

RfD: Reference Dose

5.0 RISK CHARACTERIZATION

Risk characterization is the summarizing step of risk assessment (Browner 1995, EPA 2000a). In the risk characterization step, the exposure point concentrations of COPCs (Sections 2 and 3), the exposure factors used to calculate intakes (Section 3) are applied in conjunction with the toxicity values (Section 4) to estimate health hazards and cancer risks.

Non-cancer hazards and cancer risk were calculated for RME scenarios as described in Section 3.3. By design, the estimated RME is higher than the exposure experienced by most of the population. The summary of the risk assessment results are presented in Tables 5-1 through 5-7 and more detailed spreadsheets are included in Appendix I. Risk estimates for cancer effects are expressed as an increased probability of contracting cancer. Risk estimates for non-cancer effects are expressed as hazard quotients (HQs) and hazard indices (HIs). For the COPCs evaluated in this HHRA, the following have the potential for both non-cancer and cancer health effects: arsenic, beryllium, cadmium, chromium, cobalt, and uranium.

5.1 METHOD FOR EVALUATING NON-CANCER HAZARDS

The potential for non-cancer health effects was calculated by dividing estimated chemical intakes by chemical-specific RfDs. The resulting ratio is the hazard quotient (HQ), derived as follows:

$$HQ = \frac{\text{Chemical Intake (mg/kg-day)}}{\text{RfD (mg/kg-day)}}$$

An RfD is the intake level that represents a threshold below which it is unlikely that even sensitive individuals, such as children, will experience adverse health effects following a chronic exposure. An HQ is the ratio of a specified intake relative to an acceptable intake (i.e., the RfD). If the average daily intake exceeds the RfD (i.e., if the HQ exceeds 1), then there may be cause for concern. The level of concern for a particular adverse effect increases with size of the HQ, but the HQ does not represent the *probability* of an adverse health effect. Therefore, the level of concern does not increase linearly as the RfD is approved or exceeded. Since the HQ does not define a dose-response relationship, its numerical value cannot be construed as a direct estimate of risk. In addition, the level of concern must consider the severity of the potential adverse effect as well as the magnitude of the HQ. Hazard quotients exceeding 1 may trigger actions to limit exposure to the media of concern (EPA 1986 and 1989a).

HQ for each COPC are summed to yield a Hazard Index (HI) to integrate hazards from multiple chemicals. The assumption of additive health effects inherent in the HI is most appropriate for substances that induce a common adverse effect by a shared mechanism (EPA 1986 and 1989a). Similarly, hazards from exposure to multiple COPCs from multiple pathways are characterized by adding HIs from the relevant pathways to calculate an integrative HI. If the HI is less than or equal to 1, then multiple-pathway exposures to COPCs at the site are considered unlikely to result in an adverse effect. If the total hazard index is greater than 1, then further evaluation of exposure assumptions and toxicity, including consideration of the specific affected target organs and the mechanisms of toxic actions of COPCs, is warranted to ascertain whether the cumulative exposure would in fact be likely to harm exposed individuals.

IRIS defines the RfD as

> "... an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime" (EPA 1998c).

Because of the uncertainty inherent in the RfD estimate, HIs are more appropriately interpreted as an "order of magnitude" measure of concern.

5.2 METHOD FOR EVALUATING CANCER RISKS

Carcinogenic risks are characterized as an excess probability of developing cancer over a lifetime (i.e., an increased risk of developing cancer attributable to exposures to site-related contaminants). Cancer risk estimates are the product of exposure assumptions (i.e., intake) and the chemical specific CSF. The CSF typically represents an upper 95^{th} percentile estimate of the dose-response relationship. However, arsenic and radiological CSFs are based on central tendency estimates of cancer potency.

An impossible event has a probability of 0 and a certain event has a probability of 1. Most events are possible, but are less than certain, meaning the probability is between 0 and 1. The increased likelihood of cancer from exposure to a particular chemical is defined as an excess individual lifetime cancer risk, as distinct from risks that are not associated from a particular exposure scenario on the site. Excess individual lifetime cancer risk is typically estimated by multiplying the estimated chemical intake by the CSF, as follows:

$$\text{Cancer Risk} = \text{Chemical Intake (mg/kg-day)} \times \text{CSF (mg/kg-day)}^{-1}$$

The linear equation is valid only for risks below one in a hundred (10^{-2}). For risks above 10^{-2}, the following *one-hit* equation was used (EPA 1989a). The one-hit model is based on the concept that a cancer can be induced after a single susceptible target or receptor has been exposed to a single effective dose unit of a carcinogen (EPA 1996c).

$$\text{Cancer Risk} = 1-\{e^{-(\text{Chemical Intake} \times \text{CSF})}\}$$

The risk from exposure to multiple carcinogens is assumed to be additive, but is bounded by 1, corresponding to a 100 percent risk or certainty of developing cancer. The total cancer risk is estimated by adding together the estimated risk for each COPC and for each exposure pathway. This approach may overestimate the excess cancer risk, especially if several carcinogens are present, because the 95^{th} percentile estimates are not strictly additive (EPA 1989a). The EPA's target acceptable excess cancer risk range is 10^{-6} to 10^{-4} (1 in 1,000,000 to 1 in 10,000) (EPA 1991b). On Superfund sites, cancer risks below 10^{-6} are considered acceptable and are not evaluated further. Cancer risks above 10^{-4} are unacceptable and generally warrant remedial action.

Because of differences in the methodology used to estimate their CSFs, radiological and non-radiological cancer risks are tabulated separately, as well as summed, on the summary cancer risk tables, Tables 5-1, 5-4, 5-5, and 5-7 (EPA 1989a). For most chemical (non-radiological) carcinogens, laboratory experiments and animal data are the basis for estimates of risk (arsenic is an exception). In the case of radionuclides, however, the data come primarily from epidemiological studies of exposure to humans. Another important difference is that the CSFs used for chemical carcinogens are biased high. They generally represent an upper bound or 95th percent upper confidence level of risk (arsenic is an exception), while radionuclide CSFs are unbiased estimates. See also the discussions regarding cancer estimates for radionuclides in Sections 4 and 5.7.

5.3 RISK CHARACTERIZATION RESULTS

Risk estimates from various exposure media and pathways are presented for each of the four exposure scenarios. These require close review. EPA did not weight or pro-rate exposures from a given pathway. Rather, risks were always calculated using 100 percent of the intake, even if the exposure pathway could apply in different media or areas.

For example, for the non-residential scenario in the Mining Affected Area, risk is shown for 300 mg/day of haul road soil, 300 mg/day of drainage sediment, and 300 mg/day of Blue Creek sediment. Since the total intake is 300 mg/day, these risks cannot be added. For the Mining Affected Area resident, risks are shown for drinking 4 liters per day of surface water and for 4 liters per day of ground water from individual wells. Again, these risks would not be additive as the total intake is 4 liters per day. For plants in different areas of the site, risks are shown for the total plant ingestion rate of 1,600 grams/day in each area and should not be added.

As an exception, risks from meat consumption were the same for non-residents, Mined Area residents, and Mining Affected Area residents, because they were based on aggregated data for these areas. Risks for groundwater ingestion were the same for Mined Area and Mining Affected Area residents, as they were calculated using data from wells in both areas to show the variation in contaminant concentrations.

In general, cancer risks calculated for the Mined Area were approximately an order of magnitude greater than comparable cancer risks for the Mining Affected Area. Cancer risks from radioactive contaminants exceeded cancer risks from non-radioactive contaminants, but both occurred in the same rank order of exposure media and pathways (i.e., the same media and pathways had the highest and lowest cancer risks for both radioactive and non-radioactive chemicals). Non-cancer hazards were generally the highest at the same locations and in the same media as the highest cancer risks.

In terms of exposure media in the Mined Area, most of the risk is from groundwater ingestion and inhalation during daily sweat lodge use, followed by plant consumption, radon in indoor air, meat consumption, external gamma radiation from soil, and soil ingestion. Although risks from plant consumption, meat consumption, and sweat lodge use are substantial, site risks from external gamma radiation or radon inhalation alone exceeded upper limits of acceptable risk by a

large margin. Risks from gamma and radon are independent of exposure assumptions other than exposure frequency and duration (Tables 5-2 and 5-5).

Relatively few elements were responsible for most of the non-cancer hazards and cancer risk. Uranium (non-radiological toxicity) and manganese accounted for the majority of the non-cancer hazards (Tables 4-1 and 4-2), while lead-210, radium-226, and uranium isotopes, radon, and gamma radiation were generally the risk drivers for cancer risks (Tables 5-2 and 5-4). Specific chemicals and risk estimates are discussed below by area and land use.

5.3.1 Mined Area Risks: Residential Use

The risk and hazard estimates for residential use of the Mined Area assume that people will spend all their time within the Mined Area and that all their food needs will be met by food from the site (plants grown in affected soil, and cattle, as a surrogate for wild game, that forage exclusively in affected areas). Currently, there are no residents of the Mined Area. However, if the area were to be used by residents to supply 100 percent of their food, then risks and hazards would be well above EPA's target risk goals. Cancer risks would approach 100 percent, and hazard indices would exceed 10,000 for the majority of the exposure pathways (Table 5-1).

The pathways contributing the largest percentage of the cancer risks were groundwater vapor inhalation (sweat lodge) and plant ingestion. The majority of the risks from plant ingestion were due to modeled concentrations of lead-210 (71 percent, see Tables 5-4 and 5-8). The other pathways all exceeded a 10^{-4} cancer risk, with meat ingestion, and indoor radon inhalation each contributing cancer risks in excess of 10^{-1} (Table 5-4).

The pathway contributing the largest percentage of the non-cancer hazards (excluding groundwater) was also plant ingestion, with uranium (chemical toxicity) accounting for 99 percent of the non-cancer hazards (Tables 5-2 and 5-8). The pathway with both the lowest risks and the lowest hazards was residential soil (Table 5-1). For this pathway, lead-210 and uranium contributed the largest percentage of risks and hazards, respectively (Table 5-9).

The risks and hazards associated with potential future exposure from the groundwater pathways were extremely variable due to large differences in concentrations of radionuclides and chemicals between wells. Concentrations in three wells within the Mined Area were selected for risk calculations as representative of the ground water supply within this area (Section 3). Total groundwater cancer risk (which included both drinking water and sweat lodge inhalation pathways) for the most contaminated well (BOM-17) was 1 (i.e., 100 percent). At the lower end of the range, the total groundwater risk calculated for well MWP3-01 was 2×10^{-3}. Risks were primarily due to radionuclides. Non-radiological groundwater risk was insignificant by comparison, but nonetheless generally exceeded 10^{-4}.

The majority of the groundwater non-cancer hazard was from inhalation of manganese during sweat lodge use. Inhaled manganese is 10,000 times more toxic than ingested manganese (EPA 1996f). The percent contributions of the groundwater COPCs to overall risks and hazards are shown on Table 5-10 by individual well.

5.3.2 Mined Area: Recreational Use

The calculated risk and hazard estimates for recreational use of the Mined Area were based on swimming in the pits and spending time in the Mined Area. People would be exposed to both the water and the sediments during swimming, and for the duration of their visit would be exposed to radon and external radiation. Cancer risks were derived assuming 112 hours/year spent outdoors at the site, using a sitewide radon exposure concentration and an exposure concentration specific to the MA for external radiation. Excess cancer risks were primarily due to direct radiation exposure (Table 5-13).

Risks and hazards for the recreational pathways are summarized in Table 5-5, while Tables 5-6 and 5-7 show the hazards and the risks, respectively, by contaminant. Risks for swimming exceeded the target cancer risk range and were estimated at 10^{-3}. Non-cancer hazards exceeded one, with HIs of 15 for adults and 62 for children aged 2 to 6 years (Table 5-5). Lead 210 and uranium were the contaminants contributing the largest percentages to risk and hazard estimates, respectively, for exposure to pit sediments and water. The percent contributions of the various COPCs to overall risks and hazards for the pits exposures are shown in Tables 5-11 and 5-12 for sediment and water, respectively.

5.3.3 Mining Affected Area: Residential Use

Currently no one is living in the Mining Affected Area. Similar to residential risk and hazard estimates for the Mined Area, Mining Affected Area risks and hazards assume that a person would spend 24 hours a day within contaminated areas (at a home near affected soils adjacent to the haul roads), eat plants growing nearby, eat meat raised in the area (using cattle as a surrogate for wild game), and use water from either groundwater or the mine drainages. Risks and hazards from eating meat are the same for both residential use of the Mined Area and residential use of the Mining Affected Area (Section 3). Percent contributions of individual COPCs to overall risks and hazards for the meat consumption pathway are shown on Table 5-14. The other site-wide pathways were radon in indoor and outdoor air (Table 5-1).

As noted above, risk and hazard estimates are lower for residential use of the Mining Affected Area than for the Mined Area; however, all estimates still greatly exceed target health goals with many cancer risk estimates in the 10^{-1} range and HIs in the thousands (Tables 5-1, 5-3, and 5-4).

As noted above for risks and hazards in the Mined Area, the range of risks associated with the groundwater pathways is large because the concentrations of COPCs vary widely from well to well. Concentrations in six down-gradient wells from the Mined Area were selected as representative of concentrations in wells within this area (Section 3 and Appendix D). Calculated groundwater risks (which include both drinking water and sweat lodge pathways) for the most contaminated well, MW-1, are 2×10^{-1}. At the lower end of the range, the total groundwater risk calculated for well MWCD-01 is 1×10^{-2}. Risks were primarily due to radionuclides. Non-radiological groundwater cancer risks were insignificant by comparison, but nonetheless generally exceed 10^{-4}. Most non-cancer hazards from groundwater were from inhalation of manganese during sweat lodge use.

5.3.4 Mining Affected Area: Non-Resident Subsistence Use

Risks and hazards for non-residents who visit the Mining Affected Area for subsistence or traditional uses were quantified for several pathways:

- Walking every day on the haul roads (ingesting haul road soil)
- Using Blue Creek for drinking (water ingestion) and sweat lodges (vapor inhalation)
- Harvesting plants in Blue Creek or the mine drainages (sediment ingestion)
- Eating the plants (aquatic or riparian) and meat
- Radon and external radiation

Risks and hazards by chemical for these pathways are summarized in Table 5-5, while Tables 5-6 and 5-7 show the hazards and the risks, respectively. Estimated risks and hazards exceeded target health goals for nearly all pathways, although risks and hazards are lower than for residential use. Radon and external radiation contribute significantly to the risk. The external radiation EPC was based on Mining Affected Area data, and the radon EPC was based on the combined data for the Mined Area and Mining Affected Area. Figure 5-4 shows decreasing cancer risks from external radiation with decreasing time of exposure. The same would be true of risks from radon.

As with terrestrial plant exposures for the Mined Area, the estimated cancer risks were due primarily to the plant ingestion pathway, assuming 100 percent of a person's plant diet comes from aquatic or riparian plants in the mine drainages. Although the diet may include Blue Creek plants, there were no cancer-causing COPCs for Blue Creek plants). The risk driving chemicals for non-residential pathways were similar to those for the residential pathways: uranium and manganese for non-cancer hazards and lead-210 for cancer risks, except aquatic plants (Tables 5-6 through 5-12). For aquatic plants in the drainages, uranium-234 and uranium-238 were the largest contributors to cancer risks (Tables 5-7 and 5-8).

Blue Creek exposures have some of the lowest hazards and risks evaluated in this assessment. Risk from sediment ingestion barely exceeded target health goals, assuming 100 percent of a person's soil exposure would be Blue Creek sediment; consequently, less than 100 percent exposure on a less frequent basis than daily would be unlikely to represent a health risk. The COPCs in Blue Creek sediment did not include any carcinogens. While the other pathways evaluated for Blue Creek (drinking the water, sweat lodges using the water, and plant ingestion) had higher hazards, a reduction in the 100 percent assumption could lower some of the risks/hazards to acceptable levels (see discussion in the uncertainty section). Manganese is the driver for non-cancer hazards from Blue Creek exposures (Table 5-6) and lead-210 was the cancer risk driver assuming the Creek water is the sole drinking water source and sweat lodge use occurs daily (Table 5-7).

5.4 COMBINED CANCER RISKS FROM RADIONUCLIDES AND CONVENTIONAL CHEMICALS OF POTENTIAL CONCERN

Estimated cancer risks were one or more orders of magnitude above EPA's acceptable upper-bound cancer risk of 10^{-4} for each exposure pathway in all areas of the site. The lowest risks were 2×10^{-3} for groundwater well MWP3-01, located south of Pit 3, and from ingestion of soils located adjacent to the haul roads with risks of 6×10^{-4}. Tables 5-1 through 5-7 show total non-cancer hazards, non-radionuclide cancer risks, radionuclide cancer risks, and combined cancer risks.

For uranium-related constituents, radon inhalation and external gamma radiation from rocks and soils are significant contributors to cancer risks. Both of these are closely related to the concentrations of uranium-derived radionuclides (primarily radium-226) present in the soil. Estimates of risk from external radiation in Tables 5-15 through 5-18 are based on concentrations of radium-226 in soil.

Because cancer risks from radioactive contaminants generally exceeded non-radioactive cancer risks by an order of magnitude or more, the combined cancer risks, expressed to one significant figure, often appear the same as the uncombined cancer risks. In some cases, cancer risks exceeded 1 for a single pathway (e.g., inhalation of groundwater) or when multiple contaminants or pathways were summed. In these instances, the summed cancer risks were expressed as 1.

5.5 RISKS DUE TO BACKGROUND CONCENTRATIONS OF CHEMICALS OF POTENTIAL CONCERN

All the selected COPCs in this assessment were present on the site prior to mining activities. EPA calculated risks using the 95% UCL of background concentrations (as an approximation of pre-mining conditions). Estimated cancer risks associated with exposure to background concentrations exceeded EPA's target health goals for most of the pathways evaluated in this assessment (Tables 5-15 through 5-18). However, risks from background concentrations were typically a small percentage of the "total risk" from COPCs at Midnite Mine, indicating that mining activities have had a significant effect on concentrations of COPCs at the site. The percentage of risk due to background varies for groundwater depending on which site groundwater well is selected. On Table 5-14 results for only the most contaminated (BOM-17) and least contaminated (MWP3-01) site wells are presented.

Remedial action objectives are not typically established at concentrations below background levels (EPA 2002a). Risks due to background concentrations of chemicals at Midnite Mine are well above EPA's target health goals. If remedial action objectives are established at natural background concentrations, then health risks for the exposures used in this risk assessment may remain above EPA's target health goals after cleanup. Radiation background levels are further discussed in Section 5.7.

Because health risks of COPCs at background levels exceed EPA's target health goals, a qualitative summary of background contaminants and concentrations is useful for comparison. For example, in the Mined Area soils, the concentrations of radium-226 were approximately 40 times that of background. In the Mining Affected Area, radium-226 concentrations were

approximately 15 times background levels. For perspective, risks estimated based on background levels exceeded 10^{-4} (the upper end of the CERCLA risk range). Concentrations of key radionuclides in terrestrial plant tissues are 30 to 50 times higher in the Mined Area than in background areas. In the Mining Affected Area, radionuclide concentrations in aquatic and riparian plant tissues are 5-10 times levels in corresponding samples from background areas.

Measured radiation dose rates are direct estimates of exposure in radiation fields resulting from the radionuclides present in the soil, and external radiation fields are significant contributors to risk at the site. In the Mined Area, radiation levels are approximately 3 times background levels, while in the Mining Affected Area, radiation levels are approximately 1.5 times greater than background. Risk estimates based on measured radiation fields are more certain than other measurements because they are more direct measures of exposure than other types of data (e.g., plant concentrations) and require fewer human activity assumptions to estimate risk.

The following sections summarize site-related increases in indicator metals and radionuclides by exposure medium, based on a comparison of the geometric mean concentrations of indicator parameters for site samples and background reference areas (URS 2005b). A more detailed discussion of elevated concentrations of COPCs and maps depicting the spatial extent of contamination appears in Section 5 of the Remedial Investigation Report (URS 2005b).

5.5.1 Surface Water

Elevated concentrations of uranium and associated decay products, as well as cadmium, chromium, nickel, zinc and sulfate, indicative of acid mine drainage, were observed in all down-gradient surface drainages. The geometric mean levels of uranium-238 in drainages in the Mining Affected Area were over 4,000 times greater than in the background reference areas. Uranium-238 was highly correlated with all other isotopes of uranium and other risk drivers, including lead-210 and manganese. Exceedance ratios decreased with distance from source areas.

5.5.2 Groundwater

Uranium and sulfate were elevated in wells screened in alluvium, unconsolidated materials, and bedrock relative to background wells. Uranium in alluvial and unconsolidated materials on the site exceeded background levels by a factor of 200-500; in bedrock the exceedance factor was approximately 45. Manganese was elevated in wells screened in alluvium and unconsolidated materials by a factor of approximately 80, but not in bedrock. Concentrations of analytes decreased with distance from the Mined Area. In wells installed south of the confluence of the Eastern Drainage and Blue Creek, sulfate was the only indicator parameter that exceeded background levels. Uranium and manganese are risk drivers for cancer and non-cancer effects, respectively, and concentrations of these metals were correlated.

5.5.3 Seeps

In seeps, concentrations of uranium, cobalt, manganese, nickel, zinc, and sulfate were elevated above background levels.

5.5.4 Sediments

Concentrations of uranium and associated decay products, cadmium, cobalt, manganese, zinc, and sulfate were elevated relative to background levels in sediments upstream from the confluence of the Eastern Drainage and Blue Creek. Risk drivers in sediment included uranium and its decay products, specifically lead-210 and radium-226. Uranium exceeded background levels by a factor of approximately 9. In Blue Creek below the confluence with the Eastern Drainage, a similar pattern of elevated concentrations was observed, but the number of indicators and the ratio of exceedances were lower. Uranium was not significantly elevated above background levels in this area. Manganese, nickel, zinc, and sulfate were approximately twice as high as background levels. Manganese, nickel, and zinc were highly correlated in sediments.

5.5.5 Surface Soil

In the Mined Area, concentrations of the risk drivers (uranium-234, uranium-238, lead-210, and radium-226) exceeded background levels by a factor of approximately 15-20 in surface soil. Arsenic exceeded background levels by a factor of 5. All of these metals were strongly correlated. A similar, but weaker pattern of exceedances was observed on the haul roads where isotopes of uranium, and its decay products, exceeded background by a factor of approximately 5. Arsenic was not elevated on the haul roads. None of the site-related indicator parameters were elevated in areas downwind of the Mined Area, to the southwest and the northeast.

5.5.6 Radon and Gamma Radiation

Radon and gamma radiation measurements in the Mined Area and Mining Affected Area were above background levels. In the Mining Affected Area, the maximum radon level exceeded the screening level by slightly less than two, but was retained for detailed evaluation. Levels rapidly decreased with distance from these areas.

5.6 CHEMICALS EVALUATED BY COMPARISON WITH STANDARDS

Gross alpha and lead were selected as COPCs in groundwater and drainages surface water, (Table 2-1). There are no toxicity criteria for either gross alpha radiation or lead, however, so they cannot be evaluated using standard risk assessment methodology. Instead, both were evaluated by a direct comparison of site concentrations to drinking water maximum contaminant levels (MCLs). For alpha radiation, all concentrations at the site exceeded the MCL (Table 5-19). Lead concentrations did not exceed the MCL for lead in surface water. However, dissolved lead concentrations in groundwater exceeded the MCL for one (GW-53) of the nine groundwater wells that were evaluated (Table 5-20).

5.7 UNCERTAINTIES IN RISK ESTIMATES

When presenting risk estimates, it is important to reiterate the scope of the assessment and to discuss uncertainties to provide a context for interpretation. The purpose of this baseline risk assessment is to estimate cancer risks and hazards and to support development of remedial alternatives.

Estimating health risks from exposure to environmental contaminants is a complex process with inherent uncertainties. Uncertainty reflects limitations in knowledge and data collection, and reliance on simplifying assumptions necessary to quantify health risks. Uncertainty can be classified into lack of knowledge, natural variability, and measurement or model errors (Finkel 1990, Hattis and Burmaster 1994, EPA 1997a).

Variability is the underlying and relatively stable distribution of some parameter that can be empirically characterized. Variability can be measured through systematic sampling, but that does not eliminate its contribution to overall uncertainty.

In this assessment, the major uncertainties were primarily associated with:

Land-use assumptions	lack of knowledge
Exposure point concentrations	natural variability
Exposure assessment	lack of knowledge and natural variability
Toxicity assessment	lack of knowledge

Additional areas of uncertainty discussed in this section are those due to large estimates of risk and some special issues pertaining to radiological risk assessments. Table 5-21 summarizes the uncertainties.

5.7.1 Land Use Assumptions

Land use assumptions are a fundamental uncertainty, because assumptions about the future use of the site defined the exposure scenarios used in the risk assessment. The exposure scenarios used, based on residential and traditional subsistence activities, will overestimate risks if the future use of the site is less exposure intensive..

5.7.2 Delineation of the Nature and Extent of Contamination

Background levels can be used to delineate the nature and extent of contamination, identify COPCs, define exposure areas for risk assessment, and in some cases estimate areas and cleanup levels for remediation. Estimates of background are of particular importance at mining sites, where the contaminants of concern were present prior to mining but, as a result of mining activities, were exposed, mobilized, or concentrated at higher rates than those that occur under natural conditions. As with any study, sample data can only approximate the actual distribution of concentrations in site and background media. Where concentrations are naturally variable, the distribution of concentrations in the sample data may not encompass the true range of conditions.

Uncertainties in determining background affect COPC selection and the definition of exposure areas. These uncertainties include lack of data for pre-mining concentrations of naturally occurring contaminants, selection of a background reference area which cannot perfectly replicate pre-mining conditions at the site, reliance on a finite number of samples from this area to represent conditions with high natural variability, and the use of a statistical threshold to distinguish background from mine-affected areas.

Prior to mining, the spatial distribution of naturally occurring metals and radionuclides in surface and ground water, sediments, surface materials, plants, and air were not quantitatively assessed

at Midnite Mine and in downgradient environmental media. The RI/FS characterized the mined area (MA) and potentially impacted areas (PIA), as well as nearby areas that EPA considers unaffected by mining and that have similar hydrogeologic and geochemical conditions. For remediation purposes, conditions in these background areas represent the range of conditions at and near Midnite Mine.

To define areas potentially needing cleanup, EPA compared site data to an upper statistical threshold of the data from the background areas. The comparison relied on a statistical approach intended to balance the chance of overestimating impacts (where an unaffected area appears affected) against the chance of underestimating impacts (where an affected area appears unaffected). Generally, however, near the edges of a contaminated area, site conditions approach background conditions, increasing the uncertainty in comparing the two. EPA may thus have underestimated areas at the periphery of Midnite Mine where concentrations of metals increased due to mining.

Selection of different areas to represent site background conditions, collection of additional or different samples in the area used, and use of different statistical thresholds for assessing change in conditions due to mining could result in different but similarly valid conclusions. As required by CERCLA, EPA is focusing on areas where, despite natural variability, the data demonstrate that mining impacts have occurred and that the associated risks to human health and the environment warrant response actions.

EPA reviewed data from the area around Midnite Mine to select background sample locations, which were identified in sampling and analysis plans. The data were evaluated statistically and EPA considers them reasonably representative of background conditions. EPA used a sample-by-sample comparison between site data and background data to identify potentially impacted locations, applying knowledge of site characteristics, mining practices, and professional judgment in determining mining affected areas. This sample-by-sample approach was followed by a population comparison. Both comparisons demonstrate the mined area concentrations are markedly higher than background, while concentrations further from the source become increasingly difficult to distinguish from those in nearby unaffected areas.

5.7.3 Exposure Point Concentrations

There are two types of uncertainties in the exposure point concentrations. The first type arises from the use of a limited number of environmental samples to infer *true* media concentrations. Uncertainties of this type include spatial, temporal, and analytical uncertainties. Measurement errors and random and/or systematic errors arise from the inability to measure variables precisely and accurately (equipment and laboratory protocol problems), or because the quantity being measured varies spatially or temporally. Chemical/radiological measurement errors were minimized by use of standardized Contract Lab Program requirements and other data quality assurance and quality control programs. Greater uncertainty is associated with sampling representativeness given spatial and temporal variability. As a protective measure, if 10 or more samples were available, then exposure point concentration were based on the lesser of the 95^{th} percentile upper confidence limits on the average or the maximum value sampled. For data sets with fewer than 10 samples, the exposure point concentration was the maximum value sampled.

The second type of uncertainty concerns obtaining the *relevant* media concentration needed to estimate exposure point concentrations based on anticipated activities governing exposure. This greater uncertainty arises from lack of knowledge of how, where, and when people contact contaminants in the environment. Generally, it is desirable to randomize environmental samples to avoid systematic sampling bias. However, when sampling for an exposure assessment, the goal is to sample in a manner that reproduces the way people contact contaminants in the environment.

The magnitude of the uncertainty varies with the sampling media. Gamma radiation represents very little uncertainty because it varies little over time and because exposure to gamma radiation is largely independent of behavior. On the other hand, estimates of exposure from consuming plants were highly uncertain. COPC concentrations in plants vary within an area, people may gather plants from a combination of areas (rather than all from one area), and the plants sampled do not reflect the Tribe's dietary preferences. For example, arrow leaf balsamroot is known to be used by Tribal members, but was not sampled preferentially. (SMI 1999a, b, and c, Abeyta 2002). To address this uncertainty, EPCs for plants were based entirely on data for plant roots, which had higher concentrations of contaminants than the aboveground portions of the sampled plants. The higher concentrations of metals in root samples are believed to be caused by two factors: soil particles adhered to root surfaces (roots were washed but not peeled prior to analysis), and the fact that, generally, concentrations of metals in plant tissue decrease with increasing distance from the root (Finster et al. 2003, Tracy et al. 1983).

Radiation Background Levels

Because the contaminants associated with Midnite Mine derive from uranium-related sources, and because so much of the risk is driven by uranium and radionuclides, an examination of these constituents and of radiation sources as they occur naturally is important to risk assessment and risk characterization. For the United States as a whole, the average radiation dose from background sources is approximately 300 mrem/year. Of that, approximately 200 mrem/year is from radon inhalation. Radon emanates from the uranium decay series naturally present in soil and rock. The remaining 100 mrem/year is from other sources, primarily radioactive potassium-40 in the human body, cosmic rays, and direct exposure from radioactive sources in soils and rocks. The background total varies with altitude (cosmic radiation increases with altitude) and geology (determines radon and gamma sources at the ground surface). Background radiation doses in the United States vary widely and are estimated to range from 100 to 1,000 mrem/year. At Midnite Mine, the background soil concentrations of radium-226 are approximately twice the estimated United States average of 1 pCi/g. Background radiation doses are also approximately twice the national average, or about 500-600 mrem/year, within the range of national background exposures. For comparison, the upper end of the CERCLA risk range within which CERCLA cleanup objectives are typically established corresponds to dose rates that are less than 15 mrem/year above background.

Studies have not been able to relate variations in health effects to variations in background radiation doses. Based on international studies, the National Research Council reports that in areas of high natural background radiation an increased frequency of chromosomal aberrations has been noted. However, no consequent increase in the frequency of cancer has been

documented in populations residing in areas of high natural background radiation (National Academy of Sciences 1990).

Gamma Radiation

In developing exposure point concentrations for external radiation exposure, EPA used both soil sample results and direct gamma radiation measurements obtained by SMI (1999d). The uncertainties associated with corrections to existing field data for instrument calibrations are recognized. Soil analytical results, were used with cancer slope factors to estimate risk from exposure to external radiation. Radiation exposure risk estimates in the summary tables are based on this method. Risk estimates based on direct measurements of gamma radiation are provided in the appendix as a supplement to these estimates. A conversion factor of 0.7 was used to convert exposure rates measured in roentgens (R) to effective dose equivalent (rem), based on Federal Guidance 12 (EPA 1993b). The gamma shielding factor used is 0.4, based on the EPA Soil Screening Guidance for Radionuclides, Technical Background Document (EPA 2000b). This factor accounts for the shielding that buildings provide to occupants. It was applied both to exposure rates calculated from soil concentrations and to directly measured exposure rates.

Modeled Exposure Point Concentration Estimates for Unsampled Media

Uncertainty was greater for exposure media which could not be sampled because they do not currently exist at the site. Media not sampled include water vapor in sweat lodges, radon in indoor air, house dust, and meat (concentrations were modeled in beef as a surrogate for wild game and other meat). Additionally, measured concentrations of lead-210, radium-226, and vanadium in plant roots were not available. Concentrations of these analytes were modeled using soil uptake factors developed by the Oak Ridge National Laboratory (2002).

5.7.4 Exposure Factors

Certain exposure factors proposed by AESE for the Spokane Tribe could not be critically evaluated because the underlying data are proprietary or otherwise unavailable for review and concurrence. EPA recognizes the Spokane Tribal Council as the authority on the subject of Spokane Tribe traditional knowledge. However, in applying recommendations from the Spokane Tribe, EPA also considered relevant information available from peer-reviewed publications and applicable Agency guidance. EPA revised aspects of the Spokane exposure assessment based on CERCLA requirements and other sources of information cited in this assessment. The following exposure factors were modified from the recommendations received from the Tribe: the soil ingestion rate, inhalation rate, sweat lodge water vapor volatilization factor, and the duration of sweat lodge use by children. Exposure factors and sources of information are listed in Tables 3-4 through 3-10 in Section 3.

Some of the differences in defining RME exposures may arise from the differences in objectives among the Spokane Tribe, its technical representative (AESE), and EPA. AESE described their exposure scenario as a screening level assessment, in contrast to a comprehensive baseline CERCLA risk assessment prepared as a component of an RI/FS. A screening level assessment typically includes more intensive exposure assumptions to ensure that the results safely

determine whether additional study is needed. In a baseline risk assessment, where exceeding risk thresholds may lead to remedial action, the exposure assumptions are more realistic.

Two types of modifications were made to the exposure scenario developed by AESE and the Tribe. In the first case, if sufficient information was available from Agency sources or peer-reviewed literature to support a revised value, then the AESE point estimate exposure factor was replaced with a revised point estimate. These included the following exposure factors: soil ingestion, inhalation rate, sweat lodge water vapor volatilization factor, and the duration of sweat lodge use by children.

In the second case, some exposure factors provided by AESE represent upper-bound values (i.e., what is possible, but not necessarily reasonable), but insufficient information is available to define an alternative RME point estimate. Examples include an exposure frequency of 365 days per year over a lifetime exposure duration of 70 years, meat ingestion of 1,185 grams per day, plant ingestion of 1,600 grams per day, and two hours of daily sweat lodge use by adults. For these exposure factors, the RME likely occurs below the values provided by Harper (2002). For these exposure factors, risk estimates were also presented graphically for a range of exposure assumptions up to and including the assumptions recommended by the Tribe (Figures 5-1 through 5-12). Specific modifications to the AESE scenario are described in detail in the following paragraphs.

We note that the estimated risks based on the selected exposure factors are very high (with non-cancer hazard quotients exceeding 100,000 and cancer risks approaching a value of 1). Using even higher values for the Tribal exposure factors would not change the conclusions of the risk assessment. Typically, using higher estimates of exposure results in a more protective estimate of risk. However, when estimating risks from natural resources that provide benefits, an over-estimate of risk may cause loss of those benefits through resource avoidance. Although risk estimates at site background levels exceed CERCLA risk and hazard targets, individuals should weigh the risks and benefits of subsistence practices against the alternative of avoiding subsistence resources.

Fraction of Food Derived from Site

Plant and meat consumption rates and exposure point concentrations were not reduced to account for food consumed from sources outside of impacted areas of the site. This health-protective assumption will overestimate risks incurred by people whose diets are not limited exclusively to food sources within Midnite Mine.

Exposure Frequency

The 365 day per year exposure frequency is an upper bound value that is likely to overestimate site risks for people who travel, attend school, work in locations outside of the site, or otherwise do not spend 24 hours at the site every day. The Superfund default exposure frequency for residential exposure scenarios is 350 days per year based on a two week vacation or travel from the site (rounded to 15 days) (EPA 1991a). Increasing the frequency from the default of 350 days to 365 days increased risks by about 4 percent. The impact of exposure frequency on risk

estimates is depicted on Figures 5-1 through 5-12, which show risks as a function of exposure frequency between 0 and 365 days per year.

Exposure Duration

An exposure duration of 70 years represents a 2.3-fold increase above the default 30-year exposure duration. The 30-year default is based on the 90th percentile of time spent at a single residence, using data representative of the entire United States (EPA 1991a). The 70-year duration was selected because tribal members are more likely to remain in one area (the reservation) than the general population.

Sweat Lodge Radon

Uncertainties associated with estimating radon concentrations indoors are large. Exposure models are based on typical structural parameters, but little is known about radon levels within sweat lodges (Argonne National Laboratory 2001). Given the large uncertainties and lack of data, sweat lodge radon concentrations were estimated based on the same assumptions used for residential structures. This assumption is likely to overestimate risk. Residential structures typically concentrate radon because of limited air circulation and a negative air pressure gradient. A sweat lodge is likely to be less air tight than a residence, and the steam generated in a sweat lodge would create a positive pressure gradient, which would disperse radon.

Sweat Lodge Volatilization Rate

Inhalation of contaminants in water during sweat lodge use was based an assumption that concentrations of the non-volatile COPCs would be limited by the saturation of water vapor in the sweat lodge. Assuming concentrations occur at the saturation point is likely to overestimate sweat lodge risks, especially for the non-volatile COPCs which occur at Midnite Mine.

Meat Consumption Rates

Risk from meat consumption was assessed using ingestion rates of 593 grams per day and 1,185 grams per day for children and adults, respectively (Table 3-10). These rates are based on daily caloric needs of 2,500-3,000 kcal, rather than current consumption or resource availability (Harper et al. 2002). These rates overestimate exposure for people who eat meat from sources other than Midnite Mine. With regard to availability and sustainability of food sources, a recent study calculated per capita land area requirements for sustained harvest of food, timber, and energy (Wackernagel et al. 2002). These estimates convey, on a global scale, land areas utilized to meet basic human needs. The estimates are useful to gauge the land areas required to support various levels of human consumption. Based on protective estimates of current use patterns, per capita land demands were estimated at 6, 12, and 24 acres per person for the entire world, the United Kingdom and Germany, and the United States, respectively.

Although exposure patterns may differ, land use requirements for subsistence activities assessed at the Hanford Department of Energy Reservation (located approximately 100 miles southwest of the site) may be relevant to Midnite Mine. Using the exposure factors developed for the Hanford facility, required land areas were estimated to be approximately 100 acres per person. Adjusting the Hanford land use assumptions to reflect Spokane Tribe consumption rates for meat and plants

yields a land requirement of approximately 60 acres per person (Appendix J). The Midnite Mine land requirements are less than those estimated at Hanford due to the relatively high plant intakes and lack of dairy products in the Spokane diet (dairy cows use more forage than beef cattle). This does not account for the likely difference in productivity between the Hanford land and Midnite Mine. The Midnite Mine site would thus either fully supply the caloric needs for a small number of people or would support a larger number of people who obtained some of their food from non-site sources. Figures 5-5 and 5-6 depict cancer risks and non-cancer hazards, respectively, from consuming meat from animals raised on the site at various consumption rates.

Plant Ingestion Rates

Similar to meat ingestion, plant ingestion was assessed using ingestion rates of 720 grams per day and 1,600 grams per day for children and adults, respectively (Table 3-9). These rates are based on caloric need rather than current consumption or the availability of food plants at the site. (Harper et al. 2002). Accordingly, these rates represent upper bound, rather than reasonable maximum exposure, values. A range of consumption rates and frequencies, and associated risk estimates, are presented on Figure 5-7.

Soil and Dust Ingestion Rates

The HHRA used a soil ingestion rate of 300 mg per day for adults and children over 24 months old. An ingestion rate of 200 mg per day was used for infants (0-24 months) because soil contact is believed to be less frequent in this age range. The 300 mg per day ingestion rate is based on high-end (i.e., approximating the 90^{th} percentile) estimates from soil tracer studies in young children in a camping scenario (van Wijnen et al. 1990). The 300 mg per day soil ingestion rate has been recommended for intensive soil contact scenarios (Stanek et al. 1997, Simon 1998, EPA 2001c). Because data specific to soil ingestion in a tribal or subsistence setting is lacking, the soil ingestion rate carries considerable uncertainty.

Soil tracer studies are based on a mass balance approach (i.e., all tracer mass found in fecal matter is assumed to have originated from soil sources). This approach cannot distinguish direct soil ingestion from ingestion of soil in house dust or with dietary sources (e.g., soil adhered to plants). A 300 mg per day ingestion rate was assumed to account for soil, house dust and sediment ingestion. Because a substantial portion of house dust comes from surface soil near the residence (TerraGraphics 2000), site soil concentrations were used to represent soil and house dust interchangeably.

Risks were also estimated for ingestion of 300 mg per day of sediment using site sediment data. Thus, the risk estimates for soil and sediment ingestion should not be added. Ingestion of haul road surface materials was not separately evaluated for site residents, but risks were based on 300 mg per day ingestion for non-residents using the site. Like soil and sediment, ingestion of haul road soils should not be added to soil or sediment ingestion risk estimates.

Although Region 10 guidance recommends using the 300 mg per day rate for exposures of short duration (e.g., a few weeks per year) rather than a lifetime, the 300 mg per day rate was used here to represent daily soil ingestion averaged over a lifetime of tribal exposure (EPA 2001c). Because this soil ingestion rate represents a high-end value obtained from a soil tracer study, it is

likely to be protective applied to a lifetime of exposure, assuming that young children, on average, ingest more soil on a daily basis than adults. It is possible that the rate may be exceeded on an occasional basis, but as an average it is less likely to be exceeded over the course of a 70-year exposure.

For comparison, Superfund RME default ingestion rates are 200 and 100 mg per day for children and adults, respectively (EPA 1991a). These ingestion rates are applicable to long-term (i.e., chronic) exposures arising from inadvertent soil ingestion.

Inhalation Rate

The Superfund default inhalation rate of 20 m^3 per day was used in this assessment instead of the 30 m^3 per day rate recommended by the Spokane Tribe (Harper et al. 2002). Use of the lower default inhalation rate nevertheless resulted in risks which exceed acceptable levels of risk by several orders of magnitude.

Divergent viewpoints regarding the appropriate inhalation rate for Midnite Mine were published in a series of letters subsequent to the publication of The Spokane Tribe's Multipathway Subsistence Exposure Scenario and Screening Level RME in the journal, *Risk Analysis* (Harper et al. 2002; Harper et al. 2003; Stifelman 2003b). The original publication and follow-up letters to the editor are included as Appendix F.

5.7.5 Toxicity Criteria

Contaminants at Midnite Mine include radionuclides and metals, including arsenic. Toxicity values used in this assessment are discussed in detail in Appendix H and summarized in Tables 4-1 and 4-2. Toxicity values frequently involve extrapolation from highdose studies to low-dose exposures, and are often derived from animal, rather than human, data. Uncertainty regarding toxicity is addressed by using modifying and uncertainty factors and by deriving slope factors using protective assumptions (e.g., no thresholds for carcinogens). Because larger safety factors are applied in response to increasing levels of uncertainty, there is a tendency to overestimate risk. However, uncertainties for many Midnite Mine COPCs are low, because toxicity values used to estimate cancer risks for arsenic and radionuclides are based on human data and are less uncertain than values used for many other contaminants (EPA 1998c and 1999a).

Considerable uncertainty is associated with risks from inhalation of manganese during sweat lodge use. Exposure conditions in sweat lodges are not well documented. In addition, toxicological data are limited for inhalation of manganese in water vapor. Most cases of manganese toxicity have occurred from occupational exposures to miners, ore processors, and welders, through inhalation of metal dust or fumes (Levy and Nassetta 2003). There have been limited cases of manganese toxicity attributed to ingestion of water with high levels of manganese and other metals, but manganese health effects from water vapor inhalation remain an potential yet uncertain health concern (EPA 1996f; Elsner & Spangler, 2005).

5.7.6 Uncertainties Associated with Large Estimates of Risk

CERCLA risk assessments estimate cancer risks that can be compared to the target risk range of 1 in 10,000 to 1 in 1,000,000. However, when risk estimates are very high, the results are subject to additional uncertainties and technical limitations.

For most environmental exposures at Superfund sites, exposures fall in the low-dose portion of the multistage model dose-response curve. In such cases, the dose-response relationship is linear, the cancer slope factor is a constant, and risk is directly related to intake. However, the linear relationship is valid only at risk levels below 1 in 100. For risks above this level, alternative calculations must be used. Because risk is an estimate of cancer probability, and probabilities can only be between 0 and 1, risks greater than 1 have no meaning (EPA 1989a).

In addition to uncertainties in assuming dose-response linearity, there is uncertainty in estimating cancer risks for high radiation doses. The radionuclide CSFs are based on radiation risk models developed for low doses or dose rates. These models assume that the age distribution of the population is not affected by cancer deaths. (EPA 1999a). This may not be the case for risks calculated based on large cumulative doses. A third uncertainty is the effect of multiple contaminants. Standard risk assessment practice is to add the estimated cancer risks from carcinogenic contaminants. These risk summation techniques assume that exposures to individual contaminants are small, that there are no synergistic or antagonistic interactions among contaminants, and that all contaminants have the same effect (cancer). This approximation is useful when the total estimated cancer risk is less than one in 10. However, because CSFs are often 95^{th} percentile estimates of potency, and because upper 95^{th} percentiles of probability distributions are not strictly additive, the cancer risk may be overestimated when risks from multiple carcinogens are summed. If the risks from individual contaminants are large, or if the number of contaminants is large, or if the assumptions applied are otherwise incorrect, simple risk summation may result in large estimates of cumulative cancer risk that lose some usefulness (EPA 1989a).

5.7.7 Uncertainties in Radiation Risk Assessment

The uncertainty associated with radiation risks calculated in this assessment includes the analytical uncertainties of the reported results and uncertainty in the CSFs applied. The analytical uncertainties associated with the laboratory results are reported at the two standard deviation level. For radionuclide analyses, uncertainties related to counting statistics depend on the number of counts obtained, which varies with the analytical technique used as well as the concentration of radionuclide in the sample. As a percentage of the reported result, their magnitude typically varies from a few percent (in the case of gamma results which are significantly above detection limits) to 20-40 percent for uranium isotopes, to more than 100 percent of the detection limit where results are reported as non-detect. Some analytical results are qualified as estimated values due to interferences from other radionuclides in the analysis. Additional uncertainty results from the use of some radionuclides as surrogates for others in a decay series, the assumption of secular equilibrium, and the use of minimum detectable concentration data in calculating risk. The assumptions made in these cases were designed to be protective. These uncertainties are therefore unlikely to result in underestimates of risk and may result in overestimates of risk.

Risks from surface material are due primarily to external radiation exposure. External radiation exposure risks were calculated two ways: (1) based on radionuclide soil concentrations and appropriate slope factors, and (2) based on measured external radiation levels and conversion factors from radiation dose to risk. There are uncertainties inherent in both approaches. Slope factors for soil concentrations assume effectively infinite (both depth and horizontal extent) and uniform distributions of contaminants in soil. These assumptions will tend to overestimate risks in some circumstances. Gamma radiation measurements are subject to uncertainties associated with the field instruments used and conversion of results to radiation dose, as well as conversion of dose to risk.

Comparing the results obtained from Midnite Mine, risks calculated from soil concentrations are generally 2 to 4 times higher than those calculated from corresponding field radiation measurements. Because the field measurement-based risks cannot be shown to be significantly more certain than the soil concentration-based risks, the soil concentration-based risks were used in this summary with the understanding that they may be biased high.

The uncertainties associated with CSFs are likely to be larger than those due to analytical uncertainties. Federal Guidance 13 does not provide specific quantitative uncertainty estimates of the cancer CSFs (EPA 1999a). Report 126, Uncertainties in Fatal Cancer Risk Estimates Used in Radiation Protection, examined the question of uncertainties in risk estimates for the relatively simple case of external exposure to gamma radiation (NCRP 1997). The conclusion was that the 90 percent confidence interval spans a range from about 1/3 to almost three times the median risk estimate. Since estimates of risk from ingestion of food necessarily involve the added complexity of modeling of physiological processes to determine dose and risk, the uncertainties in this context are likely to be even greater.

The report Health Effects of Exposure to Low Levels of Ionizing Radiation BEIR V addressed the issue of uncertainty in risk estimates for low doses from gamma radiation (National Academy of Sciences 1990). The report considered the assumptions inherent in modeling such risks and concluded that, due to high uncertainty, at low doses and dose rates the range of risk estimates includes zero.

Limitations on Use of the Cancer Slope Factors

Based on Federal Guidance Report No. 13, risk analyses involving the CSFs in this report should be limited to estimation of risks in large populations (EPA 1999a). The CSFs are not intended for application to individuals or small groups and should not be used for that purpose.

External radiation CSFs are cancer risk estimates per unit exposure to a specified radionuclide concentration in soil. These factors are calculated using volume and surface dose factors derived using the computer code DFSOIL (EPA 1999a, 2002c). External radiation slope factors assume infinite thickness and distribution of a source. External radiation slope factors used in this risk assessment were not corrected for site-specific values for surface area and thickness of contamination, and thus may overestimate exposure.

Because radiation can alter DNA, it has been classified as a *known human carcinogen* (EPA 1999a). The equations to estimate risk from radiation exposure assume that at low levels of

exposure, the probability of incurring cancer increases linearly with dose and does not have a threshold (EPA 1999a).

The CSFs for external radiation exposure are based on estimated dose rates for a reference adult male, standing outdoors with no shielding. Activity distributions in air, on the ground surface, or in soil are assumed to be of infinite extent. Appropriate reduction factors are used to account for the finite nature of the activity distribution in the environment, shielding by buildings during time spent indoors, or other factors encountered in the real world. As noted previously, the CSFs are based on radiation risk models developed for application either to low doses (defined as acute absorbed doses less than 20 rad) or to low dose rates (defined as dose rates less than 10 mrad/min).

All of the epidemiological studies used in the development of radiation risk models involve high radiation doses delivered over relatively short periods of time. The response from external radiation may be overestimated if extrapolations are made from short term, high doses. For this reason, a dose rate effectiveness factor is used to adjust risks observed from high doses and dose rates for the purpose of estimating risks from exposures at environmental levels. The EPA models for radiation risk include a dose and dose rate effectiveness factor of 2, applicable to most external radiation exposure. For alpha particle exposure, the differences in relative biological effect are accounted for in weighting factors applied in the calculation of dose and risk.

The CSFs used in this risk assessment are morbidity CSFs. They represent an estimate of the average risk of experiencing a cancer due to radiation exposure, whether or not the cancer is fatal. These CSFs are appropriate for use in estimating exposure over a lifetime, since they take into account the different sensitivities to radiation as a function of age. The CSFs in this assessment were used to assess the risk due to chronic lifetime exposure of an average individual to a constant environmental concentration. In addition to cancer risk, radiation exposure can increase the risk of hereditary effects. Radiation-induced genetic effects have not been observed in human populations, however, and extrapolation from animal data reveals that risks of hereditary effects in offspring per unit exposure are smaller than, or comparable to, the risk of cancer (EPA 1989a). While the risk of severe mental retardation from radiation exposure to the fetus is estimated to be greater per unit dose than the risk of cancer in the general population, the period of susceptibility is very much shorter. Based on these considerations, EPA uses the risk of cancer as the sole basis for assessing radiation-related human health risks (EPA 1999a).

Uncertainties in External Dosimetry Models

The greatest uncertainties in the modeled external radiation fields as predictors of real-world situations generally arise from oversimplifications in the exposure scenarios rather than from inadequacies in the dosimetry models per se. For example, there will often be considerable differences between the simplified, infinite exposure geometries and real, finite exposure geometries. An important example is exposure to contaminated ground surface, for which the source region is assumed to be a smooth plane. In the real world, external dose rates from sources on the ground surface generally are reduced by shielding provided by "ground roughness," including irregularities in the terrain and surface vegetation.

The CSFs for exposure to contaminated soil assume that exposed individuals spend all of the time outdoors and have no shielding from the radiation. One of the largest uncertainties in the external dose rates as applied in the present report is the question of whether a uniform reduction factor or radionuclide-specific reduction factors should be used to account for shielding during indoor residence. Based on Superfund guidance (EPA 2000b and 2000c), this report uses a uniform reduction factor to avoid overestimation of actual dose rates for external exposures.

Uncertainties in the Effects of Radiation at Low Dose and Dose Rate

For purposes of radiation protection, it is assumed that the probability of inducing radiogenic cancers in a human population is proportional to the radiation dose received, even for extremely low doses and dose rates. This "linear, no-threshold" model is a major source of uncertainty, and controversy, in radiogenic cancer risk estimation.

Carcinogenesis is understood to be a multistage process in which a single cell gives rise to a tumor, with mutation of DNA required in one or more of the steps leading to malignancy. Since cancer is a common disease, the background rate for each of these steps is greater than zero and any biological mechanism for destroying pre-cancerous cells must be imperfect. Movement of a single ionizing track through a cell appears to be capable of causing DNA damage that cannot always be faithfully repaired. Thus, it is reasonable to assume that any exposure that increases the rate of mutation of DNA may cause cancer. On the other hand, scientific evidence does not rule out the possibility that the risk per unit dose may be zero at typical environmental exposure levels or that there may be a net beneficial effect of low dose radiation (i.e., hormesis).

Arguments for and against the existence of an effective threshold for radiation effects have been made on the basis of epidemiological data, but conclusions appear to depend on the population and cancer type considered, the nature of the exposure, and the assumptions underlying the analysis. It is doubtful that human epidemiological data can be used to determine the existence or absence of a threshold for radiogenic cancer, due to the statistical uncertainties inherent in such data and the high incidence of cancer relative to low regulatory thresholds.

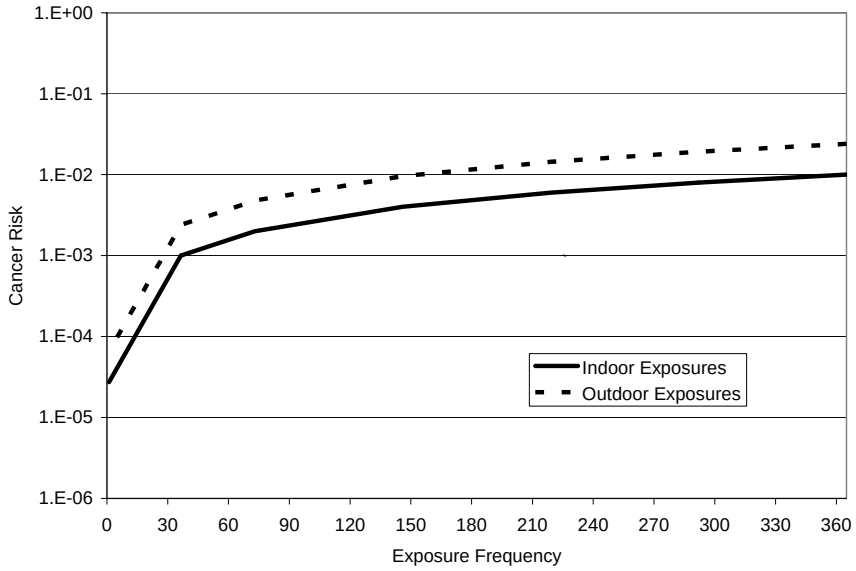


Figure 5-1 Cancer Risk from External Radiation in the Mined Area at Various Exposure Frequencies

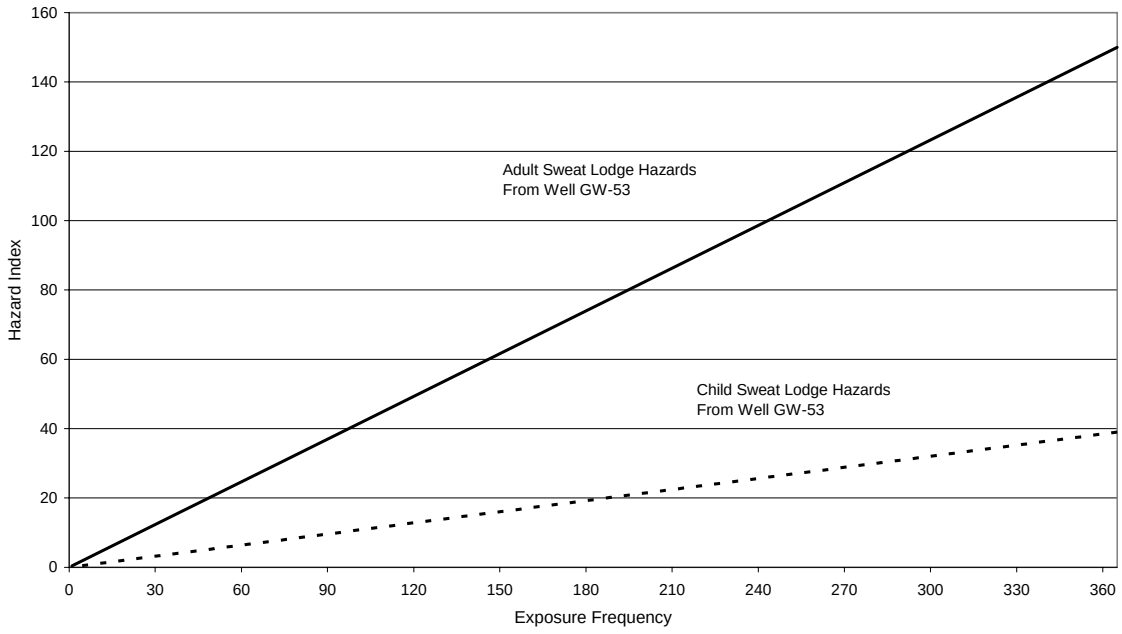


Figure 5-2 Sweat Lodge Hazards at Various Exposure Frequencies at MA Well GW-53

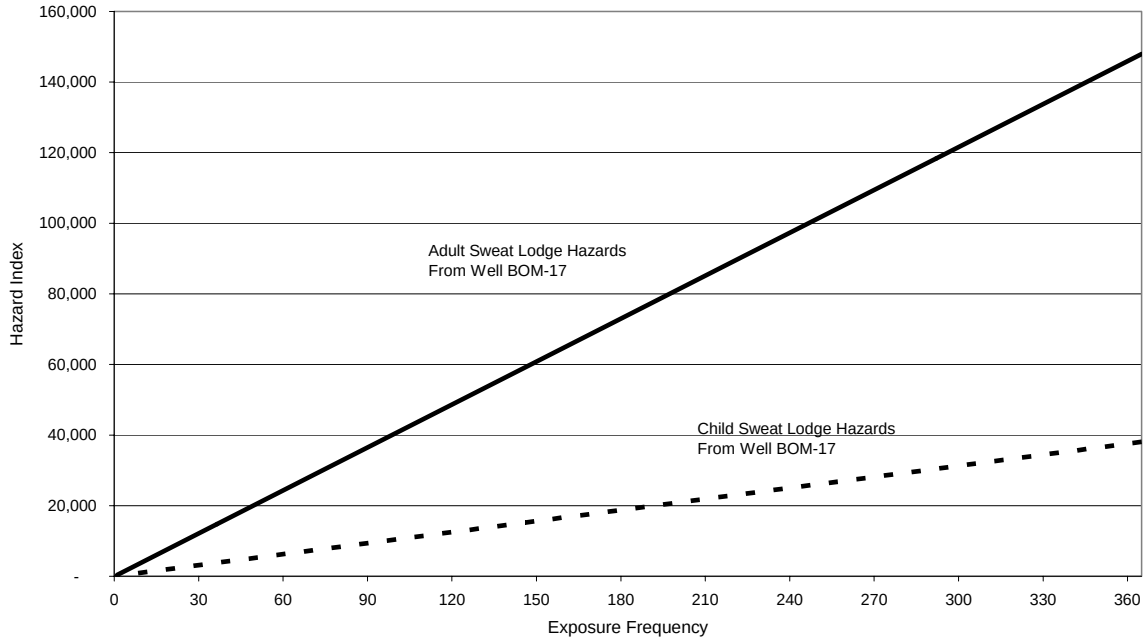


Figure 5-3 Sweat Lodge Hazards at Various Exposure Frequencies at MA Well BOM-17

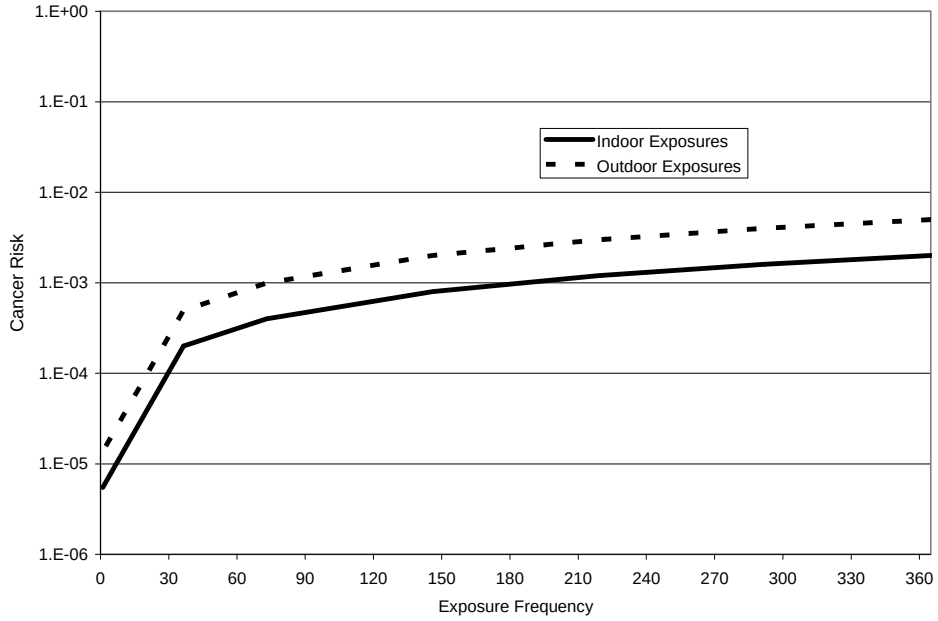
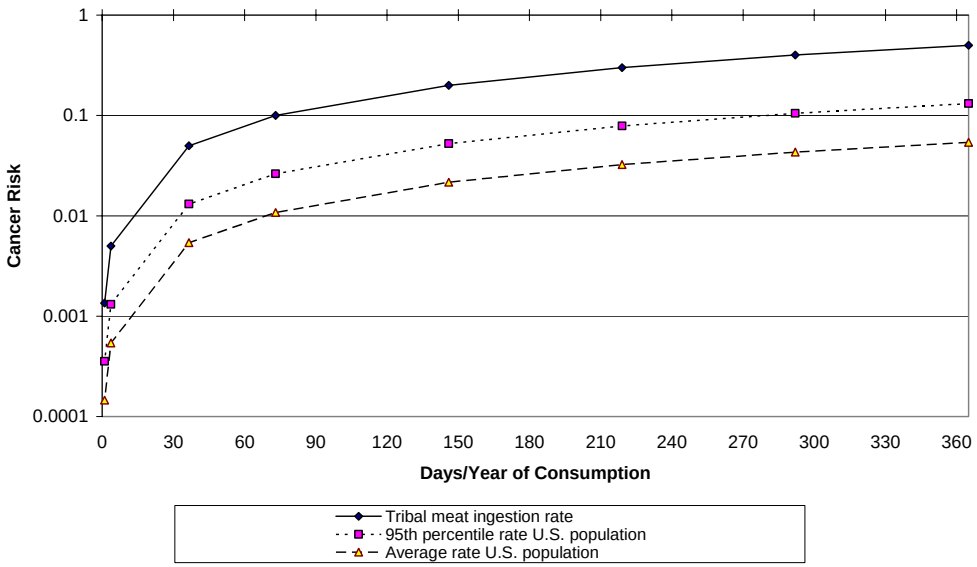
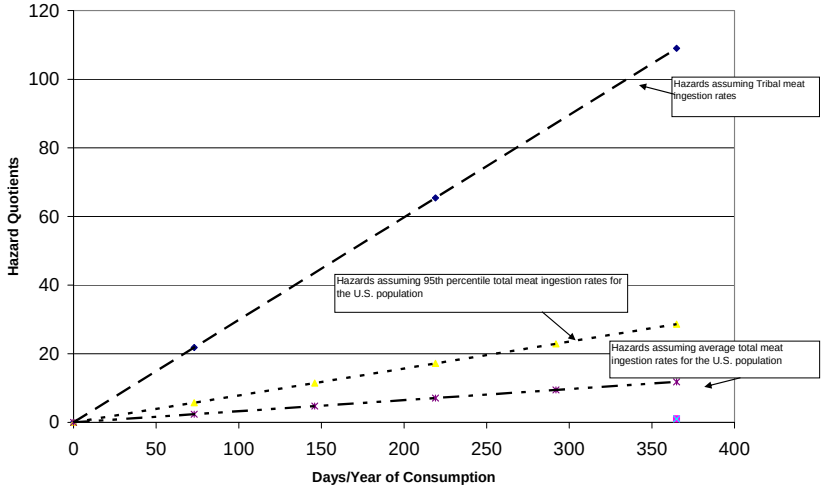


Figure 5-4 Cancer Risk from External Radiation in the Mining Affected Area at Various Exposure Frequencies



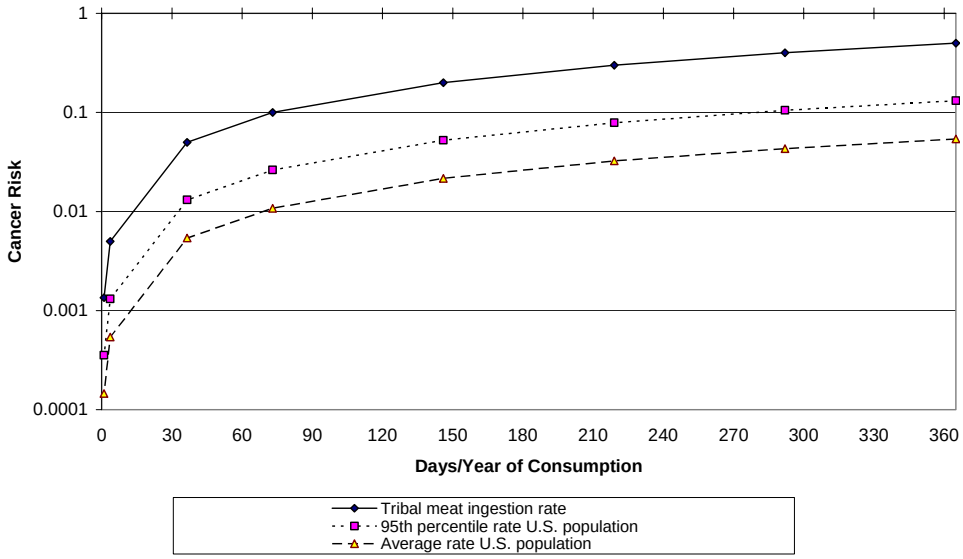
Notes:
1185 g/day equals 2.6 pounds per day
306 g/day equals 10 ounces per day
126 g/day equals 4 ounces per day

Figure 5-5 Cancer Risk from Meat Ingestion at Various Rates and Frequencies



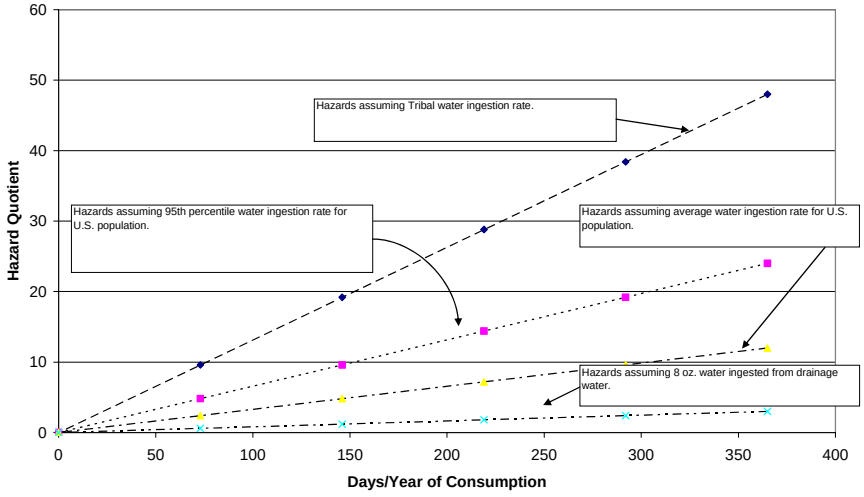
Notes:
1185 g/day equals 2.6 pounds (41.6 ounces) per day
306 g/day equals 0.6 pound (10 ounces) per day
126 g/day equals 0.25 pound (4 ounces) per day

Figure 5-6 Hazards from Meat Ingestion at Various Rates and Frequencies



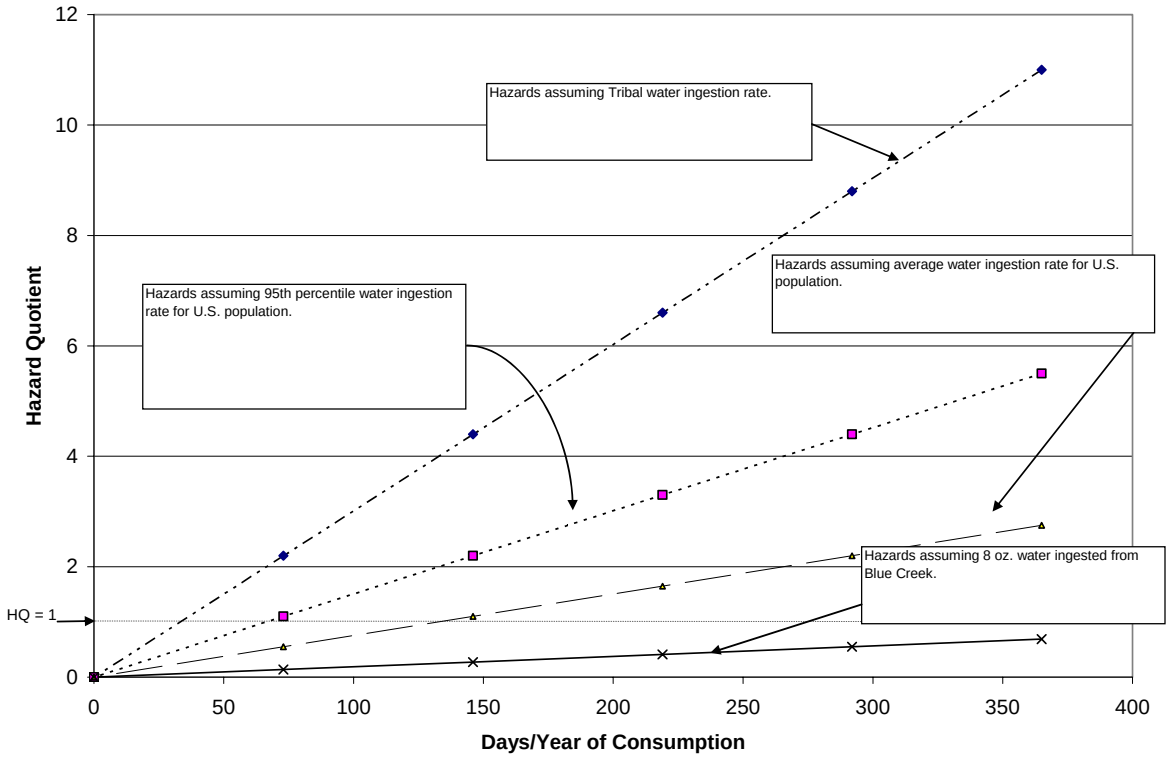
Notes:
1600 g/day equals 3.5 pounds (56 oz) per day
606 g/day equals 1.3 pounds (30.8 oz) per day
258 g/day equals ½ pound (8 oz) per day

Figure 5-7 Hazards from Ingestion of Riparian Plants in the Mine Drainages at Various Rates and Frequencies



Notes:
1 Liter is approximately equal to 4 cups

Figure 5-8 Hazards from Drinking Water from Mine Drainages at Various Ingestion Rates and Frequencies



Notes:
1 Liter is approximately equal to 4 cups

Figure 5-9 Hazards from Drinking Water from Blue Creek at Various Ingestion Rates and Frequencies

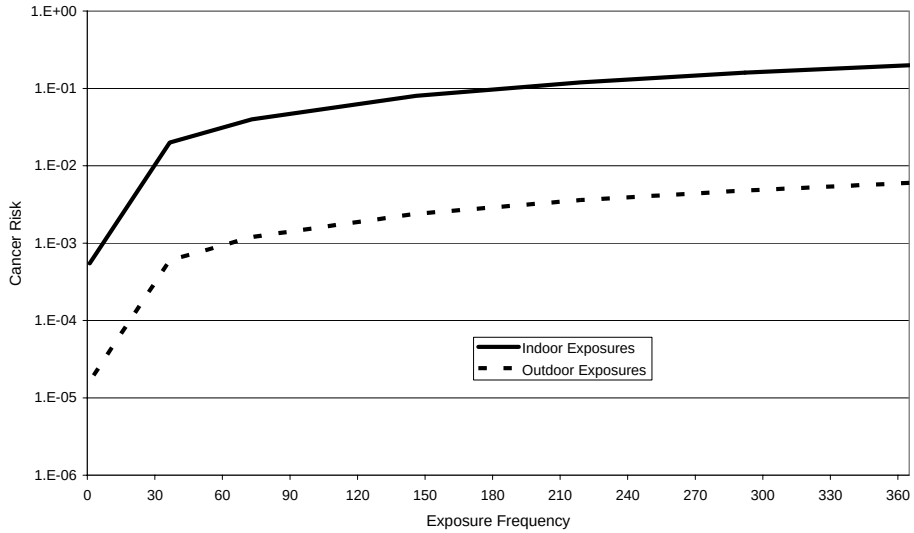


Figure 5-10 Cancer Risk from Radon Inhalation in Mined Area and Mining Affected Area at Various Exposure Frequencies

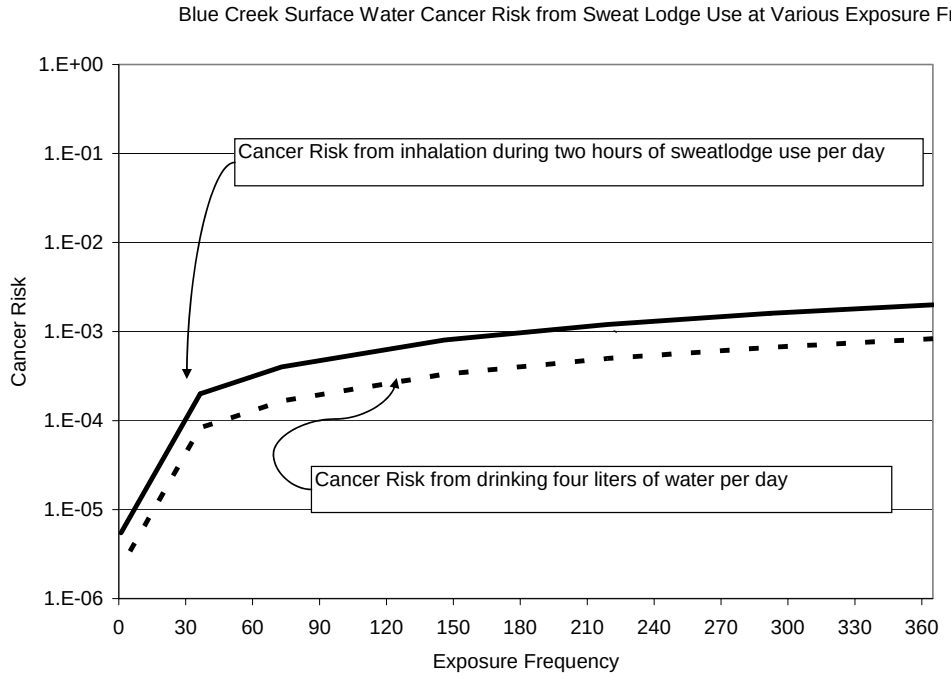


Figure 5-11 Blue Creek Surface Water Cancer Risk from Sweat Lodge and Drinking Water Use

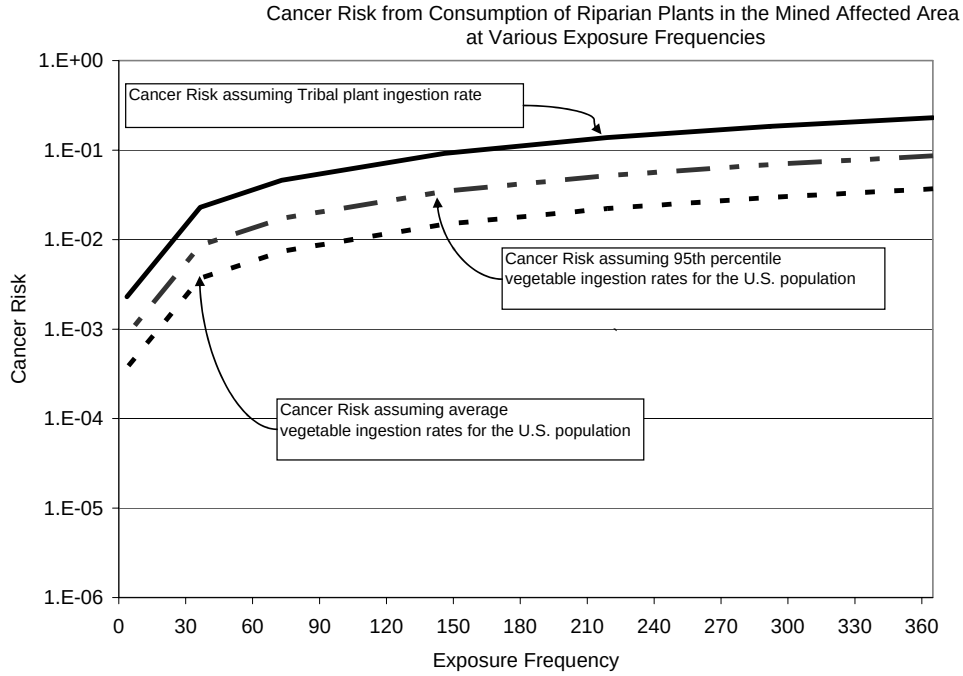


Figure 5-12 Cancer Risk from Ingestion of Riparian Plants in the Mining Affected Area at Various Exposure Frequencies

Table 5-1
Summary of Total Risks and Hazards for Residential Exposures

Area / Exposure Point		Non-Radionuclides				Radionuclides Cancer Risk	Combined Rad and Non-Rad Cancer Risk
		Hazard Index			Cancer Risk		
		Infant	Child	Adult			
Mined Area[a]	Soil (MA)	28	22	6	4E-04	3E-03	3E-03
	Groundwater (Drinking Water)[b]	0.087 - 26,749	0.1 - 31,449	0.05 - 15,455	nc	2E-04 - 3E-01	2E-04 - 3E-01
	Groundwater (Sweat Lodge)[b]	--	39 - 38,087	150 - 147,956	2E-04 - 2E-01	2E-03 – 1E+00[f]	2E-03 - 1E+00[f]
	External Radiation (Outdoors)	na	na	na	na	2E-02	2E-02
	External Radiation (Indoors)	na	na	na	na	1E-02	1E-02
	Plants (MA terrestrial)**	--	28,686	15,664	5E-02	6E-01	7E-01
	Meat	--	221	109	7E-03	2E-01	2E-01
	Radon (Outdoor Air)	na	na	na	na	6E-03	6E-03
	Radon (Indoor Air)	na	na	na	na	2E-01	2E-01
Total[c]		**28 - 26,777**	**28,968 - 98,465**	**15,929 – 179,190**	**6E-02 –3E-01**	**9E-01 – 1E+00[f]**	**1E+00[f]**
Mining Affected Area	Soil (Adjacent to Haul Roads)*	5	4	0.9	nc	6E-04	6E-04
	Sediment	na	31	8	na	9E-04	9E-04
	Mine Drainages (Drinking Water)	83	98	48	nc	1E-01	1E-01
	Mine Drainages (Sweat Lodge)	--	2,514	9,767	1E-02	8E-01	8E-01
	Groundwater (Drinking Water)[d,g]	47 - 3,453	55 - 4,060	27 - 1,995	nc	1E-03 – 2E-02	1E-03 - 2E-02
	Groundwater (Sweat Lodge)[d,g]	--	2 - 3,941	8 - 15,309	3E-05 - 9E-03	8E-03 – 1E-01	8E-03 - 1E-01
	External Radiation (Outdoors)	na	na	Na	na	9E-03	9E-03
	External Radiation (Indoors)	na	na	Na	na	4E-03	4E-03
	Plants (Drainages, Aquatic/Riparian)**	--	40,230-141,653	21,967-77,347	nc	2E-01 - 7E-01	2E-01 - 7E-01
	Meat	--	221	109	7E-03	2E-01	2E-01
	Radon (Outdoor Air)	na	na	Na	na	6E-03	6E-03
	Radon (Indoor Air)	na	na	Na	na	2E-01	2E-01
Total[e]		**52 - 3,458**	**40,512 – 149,879**	**22,112 – 94,761**	**7E-03 – 2E-02**	**6E-01 - 1E+00[f]**	**6E-01 - 1E+00[f]**

Notes:
Cancer risk notation explanation: 1E-02 equals a cancer risk of 1×10^{-2}
-- Infants were not evaluated for these pathways
na - not applicable
nc – COPCs evaluated for these pathways were not carcinogenic
* - Haul road soil ingestion risks are shown under the non-residential scenario.
** - Plants are assumed to be gathered in the exposure area where the residence is located.
a. Assumed that 100% of the day (24 hours) and 365 days per year is spent on the site, and 100% of diet is from the site (i.e., fraction from site FC=1).
b. Risks from exposure to groundwater were evaluated on a well by well basis representing a range of concentrations in the Mined Area. The results are reported as a range of risks and hazards calculated from wells GW-53, BOM-17, and MWP3-01.
c. Totals are presented as a range to include the low and high concentrations in groundwater and plants.
d. Risks from exposure to groundwater were evaluated on a well by well basis representing a range of concentrations in the Mining Affected Area. The results are reported as a range of risks and hazards calculated from wells MW-1, MW-2, GW-19, MWCD-01, GW-50, and MWED-06. Risks calculated for ground water exposures can be exchanged for risks calculated for surface water exposures.
e. One drinking water and one sweat lodge exposure point were selected for totals. Totals are presented as a range to include the low and high groundwater values.
f. The probability of contracting cancer cannot be greater than 1 (i.e. a 100% chance). Thus, the maximum cancer risk value reported is 1, although the sum may be greater than 1.
g. Risks and hazards for use of surface water as a drinking water supply and sweat lodge water source represent the same pathways as groundwater (e.g., water ingestion and inhalation), so the values should not be added together. Surface water risks and hazard values are bounded by the range for groundwater in MAA wells.

Table 5-2
Residential Hazards in the Mined Area by Contaminant

Area	Media	Pathway	HQ	Al	Sb	As	Be	Cd	Cr	Co	Cu	Mn	Ni	Se	Ag	Tl	U	V	Zn	Total
Mined Area	Soil	Ingestion	Infant	a	a	3	a	a	0.0003	a	a	a	a	0.06	a	0.3	24	0.1	a	**28**
			Child	a	a	3	a	a	0.0002	a	a	a	a	0.05	a	0.2	19	0.1	a	**22**
			Adult	a	a	0.6	a	a	0.00005	a	a	a	a	0.01	a	0.05	5	0.03	a	**6**
		Dermal	Infant	a	a	0.3	a	a	b	a	a	a	a	b	a	b	b	b	a	**0.3**
			Child	a	a	0.2	a	a	b	a	a	a	a	b	a	b	b	b	a	**0.2**
			Adult	a	a	0.1	a	a	b	a	a	a	a	b	a	b	b	b	a	**0.1**
	Plants (terrestrial)	Ingestion	Child	a	a	208	a	a	0.04	a	a	a	a	0.3	a	13	28,465	0.2	a	**28,686**
			Adult	a	a	114	a	a	0.02	a	a	a	a	0.1	a	7	15,543	0.1	a	**15,664**
	Meat[c]	Ingestion	Child	2	0.007	32	0.06	0.04	0.009	0.008	a	2	2	40	a	37	84	12	10	**221**
			Adult	1	0.003	16	0.03	0.02	0.005	0.004	a	0.8	0.8	20	a	18	41	6	5	**109**
	Groundwater[d]	Ingestion (BOM-17)	Infant	a	a	a	0.2	0.7	a	0.05	a	40	5	a	0.2	a	26,703	a	0.1	**26,749**
			Child	a	a	a	0.3	0.8	a	0.06	a	47	5	a	0.3	a	31,395	a	0.1	**31,449**
			Adult	a	a	a	0.1	0.4	a	0.03	a	23	3	a	0.1	a	15,429	a	0.07	**15,455**
		Inhalation (GW-53) (Sweat lodge) [e]	Child	167	a	a	34	b	a	707	b	37,179	b	a	b	a	a	a	b	**38,087**
			Adult	650	a	a	134	b	a	2,746	b	144,426	b	a	b	a	a	a	b	**147,956**
Total Hazards Residents in Mined Area[d]			Infant	--	--	4	0.2	1	0.0003	0.05	--	40	5	0.06	0.2	0.3	26,727	0.1	0.1	**26,777**
			Child	169	0.007	243	35	1	0.05	707	--	37,228	7	40	0.3	49	59,964	13	10	**98,465**
			Adult	651	0.003	130	134	0.4	0.03	2,746	--	144,450	3	20	0.1	25	31,018	6	5	**179,190**

Notes:

Al - aluminum
Sb - antimony
As - arsenic
Be - beryllium
Cd - cadmium
Cr - chromium
Co - cobalt
Cu - copper
Mn - manganese
Ni - nickel
Se - selenium
Ag - silver
Tl - thallium
U - uranium
V - vanadium
Zn - zinc

HQ - Hazard quotient
-- Not summed because there are no values to sum.
a. Chemical not selected as a COPC in this media
b. Chemical not associated with non-carcinogenic effects by this pathway.
c. Selenium and thallium did not exceed target health goals in soil but were evaluated in meat.
d. Risks and hazards shown are based on data from individual wells in the MAA. Risks and hazards from other wells are listed in Appendix I.
e. Sweat lodge risks and hazards for non-radionuclides are based on dissolved concentrations.

Table 5-3
Hazards for Mining Affected Area Residents by Contaminant

Area	Media	Pathway	HQ	Al	Sb	As	Be	Cd	Cr	Co	Cu	Mn	Ni	Se	Ag	Tl	U	V	Zn	Total
Mining Affected Area	Soil	Ingestion	Infant	a	a	a	a	a	a	a	a	a	a	a	a	a	5	a	a	**5**
			Child	a	a	a	a	a	a	a	a	a	a	a	a	a	4	a	a	**4**
			Adult	a	a	a	a	a	a	a	a	a	a	a	a	a	1	a	a	**0.9**
	Surface Water	Ingestion	Infant	1	a	a	a	3	a	0.8	a	75	3	a	a	a	a	a	a	**83**
			Child	1	a	a	a	4	a	1	a	88	3	a	a	a	a	a	a	**98**
			Adult	0.7	a	a	a	2	a	0.5	a	43	1	a	a	a	a	a	a	**48**
	Surface Water	Vapor Inhalation Sweat lodge	Child	4	b	a	a	b	b	30	b	2,480	b	a	a	a	a	a	a	**2,514**
			Adult	15	b	a	a	b	b	117	b	9,636	b	a	a	a	a	a	a	**9,767**
	Plants (riparian and aquatic)	Ingestion	Child	a	a	a	a	25-40	a	9-16	a	493-823	24-34	a	a	a	39,349 - 141,070	a	a	**40,230 - 141,653**
			Adult	a	a	a	a	14-22	a	5-9	a	269-449	13-19	a	a	a	21,486-77,029	a	a	**21,967 - 77,347**
	Meat[c]	Ingestion	Child	2	0.007	32	0.06	0.04	0.009	0.008	a	2	2	40	a	37	84	12	10	**221**
			Adult	1	0.003	16	0.03	0.02	0.005	0.004	a	0.8	0.8	20	a	18	41	6	5	**109**
	Groundwater[d]	Ingestion (MWED-06)	Infant	a	a	a	0.001	0.4	a	0.05	a	3,442	2	a	0.008	a	7	a	3	**3,453**
			Child	a	a	a	0.001	0.4	a	0.06	a	4,047	2	a	0.009	a	8	a	3	**4,060**
			Adult	a	a	a	0.0003	0.2	a	0.03	a	1,989	1	a	0.005	a	4	a	2	**1,995**
	Groundwater[d]	Vapor Inhalation Sweat lodge[e] (GW-19)	Child	0.7	a	a	0.8	B	a	2	b	3,938	b	a	b	a	a	a	b	**3,941**
			Adult	3	a	a	3	B	a	7	b	15,296	b	a	b	a	a	a	b	**15,309**
Total residential hazards for the Mining Affected Area depend on the source of water and the type of plants used; therefore, the values were not summed.																				

Notes:
Al - aluminum
Sb - antimony
As - arsenic
Be - beryllium
Cd - cadmium
Cr - chromium
Co - cobalt
Cu - copper
Mn - manganese
Ni - nickel
Se - selenium
Ag - silver
Tl - thallium
U - uranium
V - vanadium
Zn - zinc

HQ- Hazard quotient
-- Not summed because there are no values to sum.
a. Chemical not selected as a COPC in this media. For MAA soil, dermal exposure not evaluated, as COPCs did not have dermal toxicity.
b. Chemical not associated with non-carcinogenic effects by this pathway.
c. Selenium and thallium did not exceed target health goals in soil but were evaluated in meat.
d. Risks and hazards shown are based on data from two wells in the MAA. Risks and hazards from other wells are listed in Appendix I.
e. Sweat lodge risks and hazards for non-radionuclides are based on dissolved concentrations.

Table 5-4
Cancer Risks for Residential Exposures by Contaminant

Area	Media	Pathway	Lifetime Cancer Risk													
			As	Be	Cd	Cr	Co	Pb210	Ra226	Rn222	Th228	U234	U238	External Radiation	Airborne Radon	Total
Mined Area	Soil	Ingestion[d]	4E-04	a	a	b	a	2E-03	5E-04	a	a	a	a	a	a	**3E-03**
	Plants (mined area)	Ingestion	5E-02	a	a	b	a	4E-01	1E-01	a	a	4E-02	6E-02	a	a	**7E-01**
	Meat	Ingestion	7E-03	b	b	b	b	1E-01	7E-02	a	2E-02	5E-04	1E-03	a	a	**2E-01**
	Groundwater[c]	Ingestion (BOM-17)	a	b	b	a	b	a	1E-05	a	a	1E-01	1E-01	a	a	**3E-01**
	Groundwater[c]	Inhalation (GW-53) (Sweat lodge)	a	7E-03	4E-03	a	1E-01	a	3E-02	a	a	7E-01	6E-01	a	a	**1E+00[e]**
	Outdoor Air	radon/gamma	a	a	a	a	a	a	a	a	a	a	a	2E-02	6E-03	**2E-02**
	Indoor Air	radon/gamma	a	a	a	a	a	a	a	a	a	a	a	1E-02	2E-01	**2E-01**
Total Residential Cancer Risk - Mined Area			6E-02	7E-03	4E-03	--	1E-01	6E-01	2E-01	--	2E-02	8E-01	8E-01	2E-02	2E-01	**1E+00[e]**
Mining Affected Area[f]	Soil Adjacent to Haul Roads	Ingestion	a	a	a	a	a	4E-04	2E-04	a	a	a	a	a	a	**6E-04**
	Sediment (Mine Drainages)	Ingestion	a	a	a	a	a	4E-04	1E-04	a	a	2E-04	2E-04	a	a	**9E-04**
	Surface Water (Mine Drainages)	Ingestion	a	a	b	a	b	a	a	2E-02	a	5E-02	7E-02	a	a	**1E-01**
		Vapor Inhalation Sweat lodge	a	a	2E-03	5E-03	7E-03	a	a	6E-04	a	4E-01	4E-01	a	a	**8E-01**
	Groundwater[c]	Ingestion (MWED-06)	a	a	b	a	b	a	4E-05	a	a	8E-03	1E-02	a	a	**2E-02**
		Vapor Inhalation Sweat lodge (GW-19)	a	2E-04	8E-04	a	4E-04	a	2E-04	a	a	8E-03	6E-03	a	a	**2E-02**
	Plants (drainages)	Ingestion	a	a	a	a	a	9E-02 - 1E-02	5E-02 - 4E-02	a	a	4E-02 - 2E-01	5E-02 - 3E-0)	a	a	2E-01 - 6E-01
	Meat	Ingestion	7E-03	b	b	b	b	1E-01	7E-02	a	2E-02	5E-04	1E-03	a	a	**2E-01**
	Outdoor Air	radon/gamma	a	a	a	a	a	a	a	a	a	a	a	9E-03	6E-03	**2E-02**
	Indoor Air	radon/gamma	a	a	a	a	a	a	a	a	a	a	a	4E-03	2E-01	**2E-01**
Total Residential Cancer Risk for the Mining Affected Area depends on the source of water and soil/sediment exposures; therefore, these values were not summed. .																

Notes:
As - arsenic
Be - beryllium
Cd - cadmium
Cr - chromium
Co - cobalt
Pb - lead
Ra - radium
Rn - radon
Th - thorium
U – uranium

-- There are no values to sum.
a. Chemical not selected as a COPC in this media
b. Chemical not associated with carcinogenic effects by this pathway.
c. Risks and hazards are based on data from two wells in the MAA. Risks and hazards from other wells are listed in Appendix I.
d. Arsenic was also evaluated by the dermal pathway in soil. The value reported for arsenic is the combined risk from the ingestion and dermal pathways.
e. The probability of contracting cancer cannot be greater than 1 (100% chance). The maximum cancer risk value reported is therefore 1, although the sum may be greater than 1.

Table 5-5
Risks and Hazards for Non-Residential Exposures

Area	Exposure Point	Non-Radionuclides			Radionuclides Cancer Risk
		Hazard Index		Cancer Risk	
		Child	Adult		
Mined Area Swimmer	Pit Surface Water[a] (Ingestion)	37	9	na	2E-04
	Pit Sediment[a] (Ingestion)	25	6	na	1E-03
	Outdoor Radon (Inhalation)[a]	na	na	na	2E-04
	External Radiation[a]	na	na	na	6E-04
Totals		**62**	**15**	--	**2E-03**
Mining Affected Area Visitor	Haul Road Soil (Ingestion)[b]	23	6	na	2E-03
	Blue Creek Water (Vapor Inhalation)	61	236	na	2E-03
	Blue Creek Water (Ingestion)	22	11	na	8E-04
	Blue Creek Sediment (Ingestion)[b]	2	0.6	na	na
	Blue Creek Plants (Ingestion)[c]	239 - 1989	130 -1,086	na	na
	Meat (Ingestion)[d]	221	109	7E-03	2E-01
Totals[b]		566 -141,980	382 -77,599	7E-03	**2E-01**

Notes:
na - COPCs in area/media not applicable for effect (cancer versus non-cancer) for this pathway.
a. Assumed that 1 hour per day for 112 days per year is spent at Pits 3 and 4.
b. Risks and hazards for sediment ingestion are for the same pathway as haul road soil ingestion. The risks and hazards should not be added together; therefore, Blue Creek Sediment values are not included in total.
c. Calculated hazard or risk differs for aquatic and riparian plants in Blue Creek.
d. Risks related to meat consumption are based on modeled COPC uptake from soil values and are the same for all subsistence scenarios.

Table 5-6
Summary of Non-Residential Hazards by Contaminant

	Sub Area	Media	Exposure Pathway	HQ	Al	Sb	Be	Cd	Co	Mn	Ni	Tl	U	Zn	Total
Mined Area	Pits 3 and 4	Surface Water	Ingestion	Child	0.02	a	0.01	0.03	0.05	0.7	0.03	a	36	0.004	**37**
				Adult	0.01	a	0.002	0.01	0.01	0.2	0.01	a	9	0.001	**9**
		Sediment	Ingestion	Child	a	a	a	a	a	a	a	0.2	25	a	**25**
				Adult	a	a	a	a	a	a	a	0.04	6	a	**6**
	Mined Area Swimming Exposures (Total)			Child	0.02	--	0.01	0.03	0.05	1	0.03	--	61	0.004	**62**
				Adult	0.01	--	0.002	0.01	0.01	0.2	0.01	--	15	0.001	**15**
Mining Affected Area	Haul Roads	Soil	Ingestion	Child	a	a	a	a	a	a	a	a	23	a	**23**
				Adult	a	a	a	a	a	a	a	a	6	a	**6**
	Blue Creek	Vapor	Inhalation (Sweat lodge)	Child	a	a	a	a	a	61	a	a	a	a	**61**
				Adult	a	a	a	a	a	236	a	a	a	a	**236**
		Surface Water	Ingestion	Child	a	1	a	a	a	0.9	a	a	20	a	**22**
				Adult	a	0.6	a	a	a	0.4	a	a	10	a	**11**
		Sediment	Ingestion	Child	a	a	a	0.05	a	2	0.05	a	a	a	**2**
				Adult	a	a	a	0.01	a	0.6	0.01	a	a	a	**0.6**
			Dermal	Child	a	a	a	0.002	a	b	b	a	a	a	**0.002**
				Adult	a	a	a	0.0009	a	b	b	a	a	a	**0.0009**
			Cumulative (Ingestion and Dermal)	Child	a	a	a	0.05	a	2	0.05	a	a	a	**2**
				Adult	a	a	a	0.01	a	1	0.01	a	a	a	**1**
		Riparian Plants	Ingestion	Child	a	a	a	41	a	170	28	a	a	a	**239**
				Adult	a	a	a	22	a	93	15	a	a	a	**130**
		Aquatic Plants		Child	a	a	a	86	a	1,856	47	a	a	a	**1,989**
				Adult	a	a	a	47	a	1,014	26	a	a	a	**1,086**
	Site wide	Meat	Ingestion	Child	2.2	0.007	0.06	0.04	0.008	1.6	1.7	37	84	10	**221**[d]
				Adult	1.1	0.003	0.03	0.02	0.004	0.8	0.8	18	41	5	**109**[d]
Mining Affected Area Residential Exposures (total) [c]															

Notes:

Al - aluminum
Sb - antimony
Be - beryllium
Cd - cadmium
Co - cobalt
Mn - manganese
Ni - nickel
Tl - thallium
U - uranium
Zn - zinc
HQ - Hazard quotient

a. Chemical not selected as a COPC in this media

b. Chemical not associated with non-carcinogenic effects by this pathway

c. Total non-residential exposures for the Mining Affected Area will vary depending on which water sources and which plant sources are used; therefore, the values were not summed.

d. Total as listed on Table 22 in Appendix I; however, not all COPCs are listed on this summary table.

Table 5-7
Summary of Non-Residential Cancer Risks

Area	Sub Area	Media	Pathway of Exposure	Lifetime Cancer Risk							
				Pb210	Ra226	Th228	U234	U238	External Radiation	Airborne Radon	Total
Mined Area	Pits 3 and 4	Surface Water	Ingestion	a	a	a	7E-05	9E-05	a	a	**2E-04**
		Sediment	Ingestion	8E-04	2E-04	a	1E-04	2E-04	a	a	**1E-03**
		Outdoor air	Radon/gamma	a	a	a	a	a	6E-04	2E-04	**8E-04**
Mined Area Total Non-Residential Cancer Risks (swimming in pits)				8E-04	2E-04	--	2E-04	2E-04	6E-04	2E-04	**8E-04**
MAA	Haul Roads	Soil	Ingestion	1E-03	3E-04	8E-05	a	a	a	a	**2E-03**
	Blue Creek	Surface Water	Ingestion	6E-04	a	a	9E-05	9E-05	a	a	**8E-04**
		Vapor	Sweat Lodge Inhalation	4E-04	a	a	9E-04	6E-04	a	a	**2E-03**
		Sediment	Ingestion	a	a	a	a	a	a	a	**na**
		Riparian Plants	Ingestion	a	a	a	a	a	a	a	**na**
		Aquatic Plants	Ingestion	a	a	a	a	a	a	a	**na**
	Site-wide	Meat	Ingestion	2E-01	7E-02	2E-02	5E-04	1E-03	a	a	**2E-01**
Total residential exposures for the Mining Affected Area will vary depending on which water sources and which plant sources are is used; therefore, the values were not summed.											

Notes:
MAA - Mining Affect Area
na - COPCs in area/media not applicable for effect (cancer versus non-cancer) for this pathway.
a. Chemical not selected as a COPC in this media

Table 5-8
Plants Percent Contribution to Noncancer Hazards and Cancer Risks

Exposure Area	Mined Area		Blue Creek[a]		Mining Affected Area Drainages and Mined Area Seeps			
Plant Type	Terrestrial		Riparian Noncancer	Aquatic Noncancer	Riparian		Aquatic	
Chemical	Noncancer	Cancer			Noncancer	Cancer	Noncancer	Cancer
Lead 210	**na**	**72.9**	--	--	**na**	**38.2**	**na**	**15.6**
Radium 226	**na**	**18.3**	--	--	**na**	**21.8**	**na**	**5.7**
Uranium 234	--	--	--	--	**na**	**18.0**	**na**	**37.8**
Uranium 238	--	--	--	--	**na**	**22.1**	**na**	**40.9**
Arsenic	0.7	8.8	--	--	--	--	--	--
Cadmium	--	--	**17.0**	**4.3**	**0.0**	**na**	**0.1**	**na**
Chromium	0.0	na	--	--	--	--	--	--
Cobalt	--	--	--	--	0.0	na	0.0	na
Manganese	--	--	**71.3**	**93.3**	**0.3**	**na**	**2.0**	**na**
Nickel	--	--	11.7	2.4	0.0	na	0.1	na
Selenium	0.0	na	--	--	--	--	--	--
Thallium	0.0	na	--	--	--	--	--	--
Uranium	**99.2**	**na**	--	--	**99.6**	**na**	**97.8**	**na**
Vanadium	0.0	na	--	--	--	--	--	--

Notes:
-- Chemical was not a COPC in this area.
na: Not applicable. Toxicity criteria is not relevant or is unavailable for cancer or noncancer effect.
a. No carcinogens were selected as COPCs for Blue Creek sediments or plants
Risk drivers appear in bold text.

Table 5-9
Surface Soil Percent Contribution to Noncancer Hazards and Cancer Risks

Exposure Area	Mined Area		Mining Affected Area Adjacent to Haul Roads		Haul Roads	
Chemical	**Noncancer**	**Cancer**	**Noncancer**	**Cancer**	**Noncancer**	**Cancer**
Lead 210	**na**	**71.4**	**na**	**70.1**	**na**	**78.5**
Radium 226	**na**	**15.0**	**na**	**29.9**	**na**	**16.8**
Thorium 228	na	--	--	--	na	4.7
Arsenic	13.7	13.6	--	--	--	--
Chromium	0.0	na	--	--	--	--
Selenium	0.2	na	--	--	--	--
Thallium	0.9	na	--	--	--	--
Uranium	**84.7**	**--**	**100.0**	**--**	**100.0**	**--**
Vanadium	0.5	na	--	--	--	--

Notes:
-- Chemical was not a COPC in this area.
na: Not applicable. Toxicity criteria is not relevant or is unavailable for cancer or noncancer effects
Risk Drivers appear in bold text.

Table 5-10
Groundwater Percent Contribution to Total Risk for Each Monitoring Well

Pathway	Drinking Water		Sweat Lodge Inhalation		Total	
Chemical	**Noncancer**	**Cancer**	**Noncancer**	**Cancer**	**Noncancer**	**Cancer**
Monitoring Well BOM-17						
Radium 226	na	0.0%	na	0.0	na	0.0
Uranium 234	**na**	**45.3%**	**na**	**52.6%**	**na**	**51.4%**
Uranium 238	**na**	**54.7%**	**na**	**47.3%**	**na**	**48.5%**
Aluminum	--	--	0.0%	na	0.0	na
Beryllium	0.0%	Na	0.1%	0.0	0.0	0.0
Cadmium	0.0%	Na	Na	0.0	0.0	0.0
Cobalt	0.0%	na	0.1%	0.0	0.0	0.0
Manganese	**0.1%**	**na**	**99.8%**	**na**	**4.0%**	**na**
Nickel	0.0%	na	Na	na	0.0	na
Silver	0.0%	na	Na	na	0.0	na
Uranium	**99.8%**	**na**	**--**	**--**	**95.9%**	**na**
Zinc	0.0%	na	na	na	0.0	na
Monitoring Well GW-19						
Radium 226	na	5.7%	na	1.2%	na	1.7%
Uranium 234	**na**	**44.9%**	**na**	**52.0%**	**na**	**51.3%**
Uranium 238	**na**	**49.3%**	**na**	**38.0%**	**na**	**39.2%**
Aluminum	--	--	0.0	na	0.0	na
Beryllium	0.0	Na	0.0	1.0%	0.0	0.9%
Cadmium	2.0%	Na	na	5.1%	0.1	4.6%
Cobalt	0.0	Na	0.0	2.6%	0.0	2.4%
Manganese	**41.2%**	**Na**	**99.9%**	**na**	**97.1%**	**na**
Nickel	1.6%	Na	na	na	0.1	na
Silver	0.0	Na	na	na	0.0	na
Uranium	**55.0%**	**Na**	**--**	**--**	**2.7%**	**na**
Zinc	0.1%	Na	na	na	0.0	na
Monitoring Well GW-50						
Radium 226	na	10.6%	na	2.3%	na	3.2%
Uranium 234	**na**	**69.4%**	**na**	**81.0%**	**na**	**79.8%**
Uranium 238	**na**	**20.1%**	**na**	**15.6%**	**na**	**16.1%**
Aluminum	--	--	0.0	na	0.0	na
Beryllium	0.0	na	0.4%	0.3%	0.1%	0.2%
Cadmium	0.0	na	na	0.1%	0.0	0.0
Cobalt	0.0	na	1.1%	0.8%	0.2%	0.7%
Manganese	**99.8%**	**na**	**98.5%**	**na**	**99.5%**	**na**
Nickel	0.0	na	na	na	0.0	na
Silver	0.0	na	na	na	0.0	na
Uranium	0.1%	na	--	--	0.1	na
Zinc	0.0	na	na	na	0.0	na

Table 5-10 (Continued)
Groundwater Percent Contribution to Total Risk for Each Monitoring Well

Pathway	Drinking Water		Sweat Lodge Inhalation		Total	
Chemical	**Noncancer**	**Cancer**	**Noncancer**	**Cancer**	**Noncancer**	**Cancer**
Monitoring Well GW-53						
Radium 226	na	6.1%	na	2.0%	na	2.6%
Uranium 234	**na**	**42.8%**	**na**	**46.4%**	**na**	**45.9%**
Uranium 238	**na**	**51.1%**	**na**	**41.3%**	**na**	**42.8%**
Aluminum	--	--	0.4%	na	0.4%	na
Beryllium	0.7%	na	0.1%	0.4%	0.1%	0.4%
Cadmium	2.3%	na	na	0.3%	0.1%	0.2%
Cobalt	1.6%	na	1.9%	9.6%	1.8%	8.1%
Manganese	92.6%	na	97.6%	na	97.4%	na
Nickel	2.6%	na	na	na	0.1%	na
Silver	0.0	na	na	na	0.0	na
Monitoring Well MW-1						
Radium 226	na	1.0%	na	0.2%	na	0.3%
Uranium 234	**na**	**46.7%**	**na**	**53.8%**	**na**	**53.0%**
Uranium 238	**na**	**52.3%**	**na**	**40.5%**	**na**	**41.8%**
Aluminum	--	--	0.3%	na	0.1%	na
Beryllium	0.0	na	0.1%	0.3%	0.1%	0.3%
Cadmium	0.1%	na	na	0.2%	0.0	0.2%
Cobalt	0.1%	na	1.3%	5.0%	0.7%	4.5%
Manganese	**4.2%**	**na**	**98.3%**	**na**	**53.6%**	**na**
Nickel	0.1%	na	na	na	0.1%	na
Silver	0.0	na	na	na	0.0	na
Uranium	**95.5%**	**na**	**--**	**--**	**45.4%**	**na**
Zinc	0.0	na	na	na	0.0	na
Monitoring Well MW-2						
Radium 226	na	0.3%	na	0.1%	na	0.1%
Uranium 234	**na**	**44.6%**	**na**	**54.6%**	**na**	**53.5%**
Uranium 238	**na**	**55.1%**	**na**	**45.1%**	**na**	**46.3%**
Aluminum	--	--	0.0	na	0.0	na
Beryllium	0.0	na	0.2%	0.1%	0.0	0.1%
Cadmium	0.0	na	na	0.0	0.0	0.0
Cobalt	0.0	na	0.2%	0.1%	0.0	0.1%
Manganese	**0.5%**	**na**	**99.6%**	**na**	**10.5%**	**na**
Nickel	0.0	na	na	na	0.0	na
Silver	0.0	na	na	na	0.0	na
Uranium	99.4%	na	--	--	89.4%	na
Zinc	0.0	na	na	na	0.0	na

Table 5-10 (Continued)
Groundwater Percent Contribution to Total Risk for Each Monitoring Well

Pathway	Drinking Water		Sweat Lodge Inhalation		Total	
Chemical	**Noncancer**	**Cancer**	**Noncancer**	**Cancer**	**Noncancer**	**Cancer**
Monitoring Well MWCD-01						
Radium 226	na	5.7%	na	1.2%	na	1.7%
Uranium 234	**na**	**70.2%**	**na**	**80.1%**	**na**	**79.1%**
Uranium 238	**na**	**24.1%**	**na**	**18.3%**	**na**	**18.9%**
Aluminum	--	--	4.0%	na	0.2%	na
Beryllium	0.0	na	0.4%	0.0	0.0	0.0
Cadmium	0.1%	na	na	0.1%	0.1%	0.1%
Cobalt	0.0	na	4.5%	0.3%	0.2%	0.2%
Manganese	**0.2%**	**na**	**91.1%**	**na**	**3.6%**	**na**
Nickel	0.0	na	na	na	0.0	na
Silver	0.0	na	na	na	0.0	na
Uranium	**99.7%**	**na**	**--**	**--**	**95.9%**	**na**
Zinc	0.0	na	na	na	0.0	na
Monitoring Well MWED-06						
Radium 226	na	0.2%	na	0.1%	na	0.1%
Uranium 234	**na**	**44.7%**	**na**	**54.5%**	**na**	**53.4%**
Uranium 238	**na**	**55.1%**	**na**	**45.0%**	**na**	**46.1%**
Aluminum	--	--	0.0	na	0.0	na
Beryllium	0.0	na	0.1%	0.1%	0.0	0.1%
Cadmium	0.0	na	na	0.1%	0.0	0.1%
Cobalt	0.0	na	0.1	0.2%	0.1%	0.2%
Manganese	**99.7%**	**na**	**99.8%**	**na**	**99.7%**	**na**
Nickel	0.1%	na	na	na	0.0	na
Silver	0.0	na	na	na	0.0	na
Uranium	0.2%	na	--	--	0.1	na
Zinc	0.1%	na	na	na	0.0	na
Monitoring Well MWP3-01						
Uranium 234	**Na**	**45.3%**	**na**	**50.3%**	**na**	**49.8%**
Uranium 238	**Na**	**54.7%**	**na**	**40.4%**	**na**	**41.8%**
Aluminum	--	--	0.0	na	0.0	na
Beryllium	--	--	0.0	0.2%	0.0	0.1%
Cadmium	--	--	na	0.2%	na	0.2%
Cobalt	--	--	2.1%	8.9%	2.1%	8.0%
Manganese	**--**	**--**	**97.8%**	**na**	**97.6%**	**na**
Uranium	**100.0%**	**na**	**--**	**--**	**0.3%**	**na**
Zinc	0.0	na	na	na	0.0	na

Notes:
-- Chemical was not a COPC in this area.
na: Not applicable. Toxicity criterion is not relevant or is unavailable for cancer or noncancer effects.
Risk Drivers appear in bold text.

Table 5-11
Sediment Percent Contribution to Noncancer Hazards and Cancer Risks

Exposure Area	Mined Area (Pits)		Blue Creek	Mining Affected Area Drainages and Mined Area Seeps	
Chemical	**Noncancer**	**Cancer**	**Noncancer**	**Noncancer**	**Cancer**
Lead 210	**na**	**62.5%**	--	**na**	**40%**
Radium 226	**na**	**16.1%**	--	**na**	**15.4%**
Uranium 234	**na**	**9.8%**	--	**na**	**19.5%**
Uranium 238	**na**	**11.6%**	--	**na**	**25.1%**
Cadmium	--	--	2%	0.4%	na
Cobalt	--	--	--	0.1%	na
Manganese	--	--	**96%**	**5.3%**	**na**
Nickel	--	--	2%	0.2%	na
Thallium	1%	na	--	--	--
Uranium	**99%**	--	--	**94%**	**na**

Notes:
-- Chemical was not a COPC in this area.
na: Not applicable. Toxicity criterion is not relevant or is unavailable for cancer or noncancer effects.
Risk Drivers appear in bold text.

Table 5-12
Surface Water Percent Contribution to Noncancer Hazards and Cancer Risks

Exposure Area	Pits 3 and 4		Blue Creek						Mining Affected Area Drainages and Mined Area Seeps					
Exposure Pathway	Incidental Swimming Ingestion		Drinking Water		Sweat Lodge Inhalation		Total		Drinking Water		Sweat Lodge		Total	
Chemical	noncancer	Cancer	noncancer	cancer	noncancer	cancer	noncancer	cancer	noncancer	cancer	noncancer	cancer	noncancer	cancer
Aluminum	0.1%	na	--	--	--	--	--	--	1.4%	na	0.1%	na	0.2%	na
Antimony	--	--	5.4%	na	--	--	1.4%	na	--	--	na	na	na	na
Beryllium	0.0	na	--	--	--	--	--	--	--	--	--	--	--	--
Cadmium	0.1%	--	--	--	--	--	--	--	4.2%	na	na	0.2%	0.2%	0.2%
Chromium	--	--	--	--	--	--	--	--	--	--	na	0.6%	na	0.5%
Cobalt	0.1%	--	--	--	--	--	--	--	1.0%	na	1.2%	0.8%	1.2%	0.7%
Lead 210	--	--	**na**	**77.9%**	**na**	**22.4%**	**na**	**38.8%**	--	--	--	--	--	--
Manganese	**1.9%**	--	**4.2%**	**na**	**100.0%**	**na**	**74.7%**	**na**	**90.3%**	**na**	**98.6%**	**na**	**98.3%**	**na**
Nickel	0.1%	--	--	--	--	--	--	--	3.1%	na	na	na	0.1%	na
Radon 222	--	--	--	--	--	--	--	--	--	--	na	0.1%	na	0.1%
Uranium	**97.7%**	--	**90.4%**	**na**	--	--	**23.9%**	**na**	--	--	--	--	--	--
Uranium 234	**na**	**44.4%**	**na**	**10.8%**	**na**	**45.8%**	**na**	**35.4%**	**na**	**41.9%**	**na**	**50.4%**	**na**	**49.3%**
Uranium 238	**na**	**55.6%**	**na**	**11.3%**	**na**	**31.8%**	**na**	**25.7%**	**na**	**58.1%**	**na**	**47.9%**	**na**	**49.3%**
Zinc	0.0	--	--	--	--	--	--	--	--	--	--	--	--	--

Notes:
-- Chemical was not a COPC in this area.
na - Not applicable. Toxicity criterion is not relevant or is unavailable for cancer or noncancer effects.
Risk Drivers appear in bold text.

Table 5-13
Excess Risks From External Radiation and Radon Exposures

Chemical	Units	EPC used to Calculate Total Risk	EPC used to Calculate Background	Cancer Risk					
				Residential Scenario			Nonresidential Scenario [b]		
				Total Risk	Background Risk	Excess Risk [a]	Total Risk	Background Risk	Excess Risk [a]
Mined Area Radiation									
External Radiation[c]	pCi/g	84.53	2.32	3.4E-02	9.5E-04	3.3E-02	6.4E-04	1.8E-05	6.2E-04
Mining Affected Area Radiation									
External Radiation[c]	pCi/g	33.09	2.32	1.3E-02	9.5E-04	1.2E-02	NA	NA	NA
Combined Mined Area and Mining Affected Area Radon									
Radon (outdoor)	pCi/L	9.09	1.13	6.3E-03	7.8E-04	5.5E-03	1.7E-04	2.1E-05	1.5E-04
Radon (indoor)	pCi/L	135.88	2.9	2.2E-01	5.3E-03	2.1E-01	NA	NA	NA

Notes:
EPC - exposure point concentration (the 95% UCL)
NA - not applicable
NE - not established
pCi/g - picoCuries per gram
pCi/L - picoCuries per liter
UCL - upper confidence limit of the mean
uR/hr - microRoentgens
a. Excess risks are equal to total risks minus the risks present at background (pre-mining) levels of COPCs. Excess risks are those ascribed to impacts at the site.
b. Assumes 112 hr/yr outdoors for recreation exposure in Pits 3 and 4. See Tables 45 and 46 (Appendix I) for the recreational exposures in the MA.
c. External radiation exposure includes both indoor and outdoor exposure for residential scenarios, but only outdoor exposure for non-residential exposures.

Table 5-14
Meat Percent Contribution to Noncancer Hazards and Cancer Risks

COPC	Noncancer	Cancer
Lead 210	**na**	**61.1%**
Radium 226	**na**	**27.1%**
Thorium 228	na	8.2%
Uranium 234	na	0.2%
Uranium 238	na	0.4%
Aluminum	1.0%	na
Antimony	0.0	na
Arsenic	**14.5%**	**3.0%**
Beryllium	0.0	na
Cadmium	0.0	na
Chromium	0.0	na
Cobalt	0.0	na
Manganese	0.7%	na
Nickel	0.8%	na
Selenium	**18.1%**	**na**
Thallium	**16.5%**	**na**
Uranium	**38.1%**	**na**
Vanadium	5.6%	na
Zinc	4.6%	na

Notes:
na: Not applicable. Toxicity criterion is not relevant or is unavailable for cancer or noncancer effects.
Risk Drivers appear in bold text.

Table 5-15
Excess Risks for Residential Land Use in the Mined Area

	Total Risk	Background Risk	Excess Risk[a]	Percentage of Total Risk due to Background
Ingestion of Surface material (soil)	3.2×10^{-3}	3.2×10^{-4}	2.9×10^{-3}	10
Ingestion of Groundwater (BOM-17)	1	1.5×10^{-3}	1	0
Ingestion of Groundwater (MWP3-01)	2.0×10^{-3}	1.5×10^{-3}	5.8×10^{-4}	75
External radiation (indoor and outdoor)	3.4×10^{-2}	9.5×10^{-4}	3.3×10^{-2}	3
Radon (indoor and outdoor)	2.3×10^{-1}	6.1×10^{-3}	2.2×10^{-1}	4
Ingestion of Plants (MA terrestrial)	6.3×10^{-1}	1.9×10^{-2}	6.1×10^{-1}	3
Ingestion of Meat (site-wide)	2.4×10^{-1}	7.4×10^{-4}	2.4×10^{-1}	0

Notes:

a. Excess risks are equal to total risks minus the risks present at background (pre-mining) levels of COPCs. Excess risks are those ascribed to impacts at the site.

Table 5-16
Excess Risks for Swimming in Pits

	Total risk	Background Risk	Excess Risk[a]	Percentage of Total Risk due to Background
Ingestion of Pit Surface Water	1.6×10^{-4}	7.1×10^{-8}	1.6×10^{-4}	0
Ingestion of Pit Sediment	1.3×10^{-3}	4.0×10^{-5}	1.3×10^{-3}	3%
Radon (outdoor)	1.7×10^{-4}	2.1×10^{-5}	1.5×10^{-4}	12%
External Radiation (outdoor)	6.4×10^{-4}	1.8×10^{-5}	6.2×10^{-4}	3%

Notes: *check values for radon/radiation

a Excess risks are equal to total risks minus the risks present at background (pre-mining) levels of COPCs. Excess risks are those ascribed to impacts at the site.

Table 5-17
Excess Risks for Residential Exposures in the Mining Affected Area

	Total risk	Background Risk	Excess Risk[a]	Percentage of Total Risk due to Background
Ingestion of Surface Material (soil adjacent to haul roads)	6.2×10^{-4}	8.2×10^{-5}	5.4×10^{-4}	13
Ingestion of Surface Water (drainages)	9.6×10^{-1}	2.9×10^{-4}	9.5×10^{-1}	0
Ingestion of Sediment (drainages)	9.2×10^{-4}	1.3×10^{-4}	7.9×10^{-4}	14
Ingestion of Plants (drainages, aquatic)	6.5×10^{-1}	9.5×10^{-2}	5.6×10^{-1}	15
Ingestion of Meat (site-wide)	2.4×10^{-1}	7.4×10^{-4}	2.4×10^{-1}	0
Ingestion of Groundwater (MW-1)	1.5×10^{-1}	1.5×10^{-3}	1.5×10^{-1}	1
Ingestion of Groundwater (MWCD-01)	8.7×10^{-3}	1.5×10^{-3}	7.2×10^{-3}	17
External radiation (indoor and outdoor)	1.3×10^{-2}	9.5×10^{-4}	1.2×10^{-2}	8
Inhalation of Radon (indoor and outdoor)	2.3×10^{-1}	6.1×10^{-3}	22×10^{-1}	4

Notes:

a. Excess risks are equal to total risks minus the risks present at background (pre-mining) levels of COPCs. Excess risks are those ascribed to impacts at the site.

Table 5-18
Excess Risks for Non-Residential Exposures in the Mining Affected Area

	Total risk	Background Risk	Excess Risk[a]	Percentage of Total Risk due to Background
Ingestion of Soil (Haul Road)	1.8×10^{-3}	8.1×10^{-5}	1.7×10^{-3}	4
Ingestion of Surface Water (Blue Creek)	2.8×10^{-3}	7.1×10^{-4}	2.1×10^{-3}	25
Ingestion of Sediment (Blue Creek)	9.2×10^{-4}	1.3×10^{-4}	8.0×10^{-4}	14
Ingestion of Plants (Blue Creek aquatic)	nc	nc	nc	nc
Ingestion of Meat	2.4×10^{-1}	7.4×10^{-4}	2.4×10^{-1}	0

Notes:
nc - not calculated because cancer risks are not applicable for this pathway.
a. Excess risks are equal to total risks minus the risks present at background (pre-mining) levels of COPCs. Excess risks are those ascribed to impacts at the site.

Table 5-19
Summary of Gross Alpha Concentrations Compared to
MCL and Background in Surface Water and Groundwater

Area and Exposure Point	Units	Background [a]	MCL	EPC	Min	Max	Ave
All Residential Groundwater Wells (b)	pCi/L	189.27	15	81.5 - 40,743	23	52,000	11,617
Mining Affected Area Drainages Including MA Seeps	pCi/L	51.97	15	11,812	8.4	22,000	2,564

Notes:
a. Background concentration is 95% UTL of water values from the applicable reference area.
b. EPC concentrations are presented as a range for the wells selected for groundwater evaluation.
MCL - Maximum contaminant level. Gross alpha drinking water action level (http://www.epa.gov/waterscience).
Ave - Average concentration of data set
EPC - Exposure point concentration
MA - Mined Area
Max - Maximum concentration of data set
Min - Minimum concentration of data set

Table 5-20
Summary of Lead Concentrations Compared to
MCL and Background in Surface Water and Groundwater

Area and Exposure Point	Units	Background [a]	MCL	EPC	Min	Max	Ave
Total Lead							
Mined Area Pits 3 & 4 - Surface Water	ug/L	4.7	15	6.76	0.18	39.4	6.76
Mining Affected Area Drainages Including MA Seeps	ug/L	4.7	15	2.37	0.2	34.7	2.37
Groundwater	ug/L	25	15	--(b)	1	19.8	--[b]
Dissolved Lead							
Mining Affected Area Drainages Including MA Seeps	ug/L	1.2	15	6.16	0.2	130	6.16
Groundwater	ug/L	0.9	15	0.05 - 25.98 [c]	0.1	72.9	5.52

Notes:

[a] Background concentration is 95% UTL of water values from the applicable reference area.

[b] Lead was not selected as a COPC in these media because 10% of concentrations did not exceed background; therefore, EPCs and average values were not calculated.

[c] EPC concentrations are presented as a range for the wells selected for groundwater evaluation. Only the well with the maximum concentration (GW-53) exceeded the MCL.

MCL - Maximum contaminant level. Lead drinking water action level (http://www.epa.gov/waterscience).
EPC - Exposure point concentration
Min - Minimum concentration of data set
Max - Maximum concentration of data set
Ave - Average concentration of data set

Lead concentrations in Blue Creek surface water (both total and dissolved) were below both the surface water background concentrations.

Table 5-21
Summary of Uncertainties

Category	Comment	Probable Direction of Bias
Future Land Use	Unrestricted land use is not likely	Overestimate for uses less intensive than traditional tribal subsistence activities
Exposure Point Concentrations	Judgmental sampling and use of UCL or maximum sampled value	Overestimate
Exposure Pathways	Not all potential exposure pathways were evaluated	Underestimate (examples include dermal absorption for metals other than cadmium and arsenic)
Limiting COPCs	Chemicals not selected as COPCs contribute to risk	Underestimate
Groundwater	Monitoring wells were not always located to represent drinking water exposures	Overestimate
Surface water	Seeps from waste rock and ore piles were included in exposure estimates	Overestimate
	Samples included areas downstream from treatment out fall	Underestimate for untreated water exposure
Sweat lodge vapor	Protective assumptions were used because empirical data to quantify sweat lodge exposures is unavailable	Overestimate
Soil and Sediment	Sampling included material from highly-contaminated drainage ditches and pits	Overestimate
Plants	Roots used to represent all plant material	Overestimate
	Plant samples did not include Tribal preferences	Unknown
Meat	Wild game was represented by modeled cattle values	Unknown
	Cattle remain on site all the time	Overestimate
Radon	Indoor radon levels were modeled	Unknown for permanent structures May overestimate sweat lodge concentrations
Gamma Radiation	Gamma levels were based on soil radium concentrations rather than direct readings	Overestimate
Exposure Factors	Quantifying traditional tribal exposure is highly uncertain because little empirical data are available.	Unknown
Exposure Frequency	365-day exposure frequency is an upper-bound value	Overestimate
Exposure Duration	A 70-year exposure duration was assumed for a 343 acre area	Overestimate
Sweat Lodge Use	Assumed 25 hours and 2 hours per day for children and adults, respectively	Overestimate
Plant Ingestion	Assumed all caloric needs were met from site	Overestimate
Meat Ingestion	Assumed all caloric needs were met from site	Overestimate
Soil Ingestion	Used 200 mg/day for infants and 300 mg/day for children and adults; Spokane Tribe recommended 400 mg/day	Unknown; rates used are higher than Superfund default values
Inhalation rate	Used 20 m^3 per day; Spokane Tribe recommended 30 m^3	Unknown; see (Harper et al., 2002; Barbara L. Harper et al., 2003; Marc Stifelman, 2003b)
Toxicity criteria	Varies with COPC. Generally less uncertainty associated with radionuclides than conventional metals.	Toxicity criteria are often likely to overestimate risk. Cancer risks from radionuclides/ionizing radiation are less likely to overestimate risk compared to other COPCs Arsenic cancer risks may be underestimated

6.0 SUMMARY AND CONCLUSION

A baseline risk assessment was performed for the site as part of the RI/FS being conducted to assess whether remedial actions are required to address potential health risks at the site.

Midnite Mine is an inactive, open-pit uranium mine located on the Spokane Indian Reservation in Washington. The mine operated between 1955 and 1981. The site comprises two major areas: the Mined Area of 350 acres, which has been visibly affected by mining activities, and the Mining Affected Area, which includes:

- Down gradient groundwater
- Down gradient surface water that drains the site and the sediments associated with this surface water
- The haul roads, which were used to haul ore
- The immediate vicinity of the haul roads

6.1 SELECTION OF CHEMICALS OF POTENTIAL CONCERN

The first step in an HHRA is to evaluate the data in order to select COPCs for human health. Of the total available data, data collected before 1998 was excluded from the risk assessment because it was of insufficient quality. All data collected after 1998 were included.

After selecting the applicable data sets, data were grouped by media (i.e., soil, sediment, surface water, air, or plants) and by area (Mined Area or Mining Affected Area). Surface water and sediments in the Mining Affected Area were further segregated to separate Blue Creek data from data collected from the water and sediments in the East, Central, and Western Drainages and seeps (collectively referred to as "the drainages"). Groundwater data were not separated by area for screening, because a groundwater well can be drilled at any location. The COPCs were then selected for each media in each area based on whether they exceeded background levels and, if background concentrations were exceeded, whether concentrations also exceeded a health-based level (non-radionuclides), or contributed significantly to total expected site risks (radionuclides). As part of the selection process, the frequency of detection of contaminants and the frequency and magnitude of exceedance of site concentrations above background levels were evaluated.

Site-wide, six radionuclides and 17 non-radionuclides were selected in at least one medium. Depending on the media, between 15 and three COPCs were selected. Water appeared to be the most impacted, based on the number of COPCs selected. Groundwater had the most COPCs (15), followed by surface water in the drainages (13) and surface water in the open pits in the Mined Area (11). Soil in the Mined Area (eight COPCs) and sediment in the drainages (nine COPCs) were the most impacted surface materials. Relatively few COPCs were selected for the haul roads and the soils adjacent to the haul roads (four and three COPCs, respectively), and Blue Creek impacts also appeared to be lower than in other areas (six COPCs selected for surface water and three in sediment). Uranium and manganese were the non-radionuclides that were selected in the most media (10 and eight, respectively). Lead-210 and radium-226 were the

radionuclides selected in the most media (eight), followed by uranium-238 and uranium-234 (seven).

6.2 EXPOSURE ASSESSMENT

Once COPCs are selected, the second step in risk assessment is to evaluate the exposure pathways by which people can encounter chemicals. The exposure assessment identifies the populations potentially exposed to chemicals at the site, the means by which exposure occurs, and the amount of chemical received from each exposure medium (i.e., the dose). Only complete exposure pathways are quantitatively evaluated. Complete pathways consist of four elements: (1) a source and mechanism of chemical release, (2) a retention or transport medium (e.g., groundwater), (3) a point of potential human contact with the affected medium, and (4) a means of entry into the body at the contact point.

The site is currently used for intermittent hunting and gathering. While there is no planned development for the site, the Spokane Tribe has expressed a desire to be able to use the site without restrictions in the future. Because the site is located on land owned by the Spokane Tribe of Indians, the focus of the risk assessment is exposures to tribal members. In this risk assessment, exposure factors and pathways representative of tribal subsistence activities were based on recommendations from the Spokane Tribe of Indians. The following populations and exposure pathways were selected for quantitative evaluation:

- Residents of the Mined Area who are exposed to chemicals through:
  - Incidental ingestion and dermal exposures to COPCs in Mined Area soil.
  - Ingestion of water used for drinking (groundwater).
  - Inhalation of chemical in water vapor during a sweat lodge (dissolved chemicals in groundwater).
  - Ingestion of plants (terrestrial plant data), assuming all plant needs are met by food grown in the Mined Area.
  - Ingestion of wild game, assuming all meat needs are met by animals that forage within the boundaries of the site (both Mining and Mining Affected Areas). Cattle raised within the site boundaries were used as a surrogate for wild game.
  - Exposure to radon and gamma radiation in air.
- Residents of the Mining Affected Area who are exposed to chemicals through:
  - Incidental ingestion and dermal exposures to COPCs in soil adjacent to the haul roads.
  - Ingestion of water used for drinking (either groundwater or drainages surface water).
  - Inhalation of COPCs in water vapor during a sweat lodge (dissolved chemicals in either groundwater or drainages surface water).

  - Exposure to radon and gamma radiation in air.
  - Ingestion of aquatic or riparian plants from drainages.
- Non-residential populations who are exposed to chemicals in the Mined Area during use of the Pits for water recreation through:
  - Incidental ingestion of Pit water during swimming
  - Incidental ingestion of Pit sediment during recreational activities adjacent to the water
  - Inhalation of radon
  - External radiation
- Non-residential populations who are exposed to chemicals in the Mining Affected Area during subsistence activities through:
  - Ingesting plants present in the riparian and aquatic environments of Blue Creek (assuming 100 percent of plant needs are met by Blue Creek plants)
  - Ingesting soil along the haul roads
  - Ingesting sediment during plant harvesting activities (Blue Creek sediment)
  - Inhaling vapors from Blue Creek water used for a sweat lodge
  - Ingesting Blue Creek water as a drinking water source
  - Ingestion of wild game, assuming all meat needs are met by animals that forage within the boundaries of the site (both Mining and Mining Affected Areas). Cattle raised within the site boundaries were used as a surrogate for wild game.

6.3 TOXICITY ASSESSMENT

The third step in risk assessment is to evaluate the toxicity of the COPCs by assessing the relationship between the dose of a chemical and the occurrence of toxic effects. Chemical toxicity criteria, which are based on this relationship, consider both cancer effects and effects other than cancer (noncancer effects). The toxicity criteria are required in order to quantify the potential health risks due to the COPCs. All radionuclides were evaluated for cancer effects. For the non-radionuclides, arsenic, beryllium, cadmium, chromium, cobalt, and uranium have the potential for both non-cancer and cancer health effects. The remaining non-radionuclides had the potential only for non-cancer effects.

6.4 RISK CHARACTERIZATION

The last step in an HHRA is to characterize the health risks. The exposure factors, media concentrations, and toxicity criteria are combined to calculate health risks. Health risks are calculated differently for chemicals that cause cancer and for chemicals that cause noncancer effects. The calculation of cancer risk assumes that no level of the chemical is without some risk, whereas for chemicals with noncancer effects, a "threshold" dose exists. Risks (for cancer) and hazards (for noncancer effects) are calculated for the RME for each pathway, a calculation that overestimates risks for the majority of the population in order to ensure that public health is protected. Cancer risk estimates represent the potential for cancer effects by estimating the probability of developing cancer over a lifetime due to site exposures. Noncancer hazards assume there is a level of chemical intake that is not associated with an adverse health effect even in sensitive individuals.

Cancer risks and hazards for all pathways (except adult exposure to Blue Creek sediment) greatly exceeded 10^{-4} (the upper end of EPA's target risk range) and the hazard quotient of 1 (the health goal for noncarcinogens). For many pathways, risks approached 1 (a 100 percent chance of developing cancer) and hazard quotients were in the thousands. Cancer risks calculated in the Mined Area were approximately an order of magnitude greater than comparable cancer risks in the Mining Affected Area. Cancer risks from radioactive contaminants exceeded cancer risks from non-radioactive contaminants. Non-cancer hazards generally were the highest at the same locations and in the same media as the highest cancer risks.

In terms of exposure media in the Mined Area, most of the risk is from groundwater ingestion and inhalation during daily sweat lodge use, followed by plant consumption, radon in indoor air, meat consumption, and external gamma radiation from soil. Although substantial risks are incurred from plant consumption, meat consumption, and sweat lodge use, site risks from external gamma radiation or radon inhalation alone exceed upper limits of acceptable risk by a large margin. Relatively few elements are responsible for most of the noncancer hazards and cancer risk. Uranium (non-radiological toxicity) and manganese account for the majority of the non-cancer hazards, while lead-210, radium-226, radon-222, and uranium isotopes are generally the risk drivers for cancer risks. Risks from gamma radiation and radon are independent of exposure assumptions other than exposure frequency and duration. Gamma radiation and radon risks depend solely on how much time is spent on the site.

Blue Creek had some of the lowest hazards and risks evaluated in this assessment. Sediment exposure hazards marginally exceeded a hazard quotient of 1 for children aged 2 to 6 years, assuming daily exposure and assuming that 100 percent of the soil ingested would be Blue Creek sediment. The adult sediment exposure did not exceed a hazard quotient of 1. Other pathways evaluated for Blue Creek (drinking Blue Creek water, using Blue Creek water in sweat lodges, and ingesting Blue Creek plants) had higher risks and hazards than sediment exposure. For people using Blue Creek less frequently than daily, or obtaining less than 100 percent of their exposure there, the risks would be reduced accordingly, to the point where the pathways evaluated could fall within EPA's target risk range and below the non-cancer health goal. All the selected COPCs in this assessment occur naturally in the area and were present on the site

prior to mining activities. Estimates of the cancer risks associated with exposure to background concentrations of the COPCs show cancer risks for the background area that exceed the upper end of EPA's target risk range for most of the pathways evaluated in this assessment. However, because COPC levels are significantly higher at the site, risks from background levels of COPCs are a small percentage of the risk at Midnite Mine, indicating that mining activities have resulted in significant site-related risks.

This risk assessment contains multiple sources of uncertainty. Simplifying assumptions were made so that health risks could be estimated quantitatively. Despite the uncertainties in the process, this risk assessment is intended to overestimate rather than underestimate risk.

6.5 CONCLUSIONS

- Health risks and hazards clearly warrant remedial action for all areas of the site, although risks and hazards associated with Blue Creek exposures are significantly lower than for other areas.
- Risks and hazards are estimated for a scenario assuming future residential land use and subsistence practices. Current use of the Mined Area and Mining Affected Areas other than Blue Creek appears to be intermittent.
- For the exposure scenarios used, risks in background areas exceed EPA's target risk range for all carcinogens; however, when background risks are subtracted from site risks, site risks still exceed the target risk range by a considerable margin for most media.
- The risk drivers for non-cancer effects were uranium and manganese.
- The risk drivers for cancer effects were radionuclides consisting of uranium isotopes and their decay products. Radium-226, radon-222, and lead-210 were the primary radionuclides of concern. Significant exposure pathways for radionuclides included exposure to external radiation, inhalation exposure to radon, and ingestion of radionuclides in water, soil, and food.
- Tribal subsistence exposures assumed higher exposure rates than the typical RME exposure scenario evaluated for Superfund sites; however, for most pathways even typical Superfund RME or average rates would result in risks that exceed EPA's target risk range for most areas of the site.
- Subsistence exposure pathways in Blue Creek assumed daily exposure and complete reliance on Blue Creek plants, water, and sediments for subsistence. Less intensive exposures may fall within EPA's target risk range at Blue Creek.
- Although risk estimates at site background levels exceed EPA risk and hazard targets, individuals should weigh the risks/benefits of subsistence practices against the alternative of avoiding subsistence resources. Estimating risks from chemicals in natural resources that provide certain benefits may cause loss of those benefits through resource avoidance.

7.0 REFERENCES

Abeyta, C. Biologist, AESE. Personal communication during site visit with M. Stifelman, EPA. August, 13, 2002.

Agency for Toxic Substances and Disease Registry (ATSDR). 1992a. Toxicological Profile for Antimony and Compounds. U.S. Department of Health and Human Services: Atlanta, GA. PB/93/110641/AS. September. http://www.atsdr.cdc.gov/toxprofiles/tp23.pdf

American Academy of Pediatrics. 2000. Climatic heat stress and the exercising child and adolescent. American Academy of Pediatrics. Committee on Sports Medicine and Fitness. *Pediatrics*, 106, 158-9. http://www.aap.org/policy/re9845.html

Argonne National Laboratory. 2001. RESRAD. V. 6. U.S. Department of Energy. Argonne, IL. http://web.ead.anl.gov/resrad/home2/resrad.cfm

Associated Environmental Scientists and Engineers (AESE). 2001. Spokane Tribe Subsistence Exposure Scenario.

Browner, C.M. 1995. Policy for Risk Characterization at the U.S. Environmental Protection Agency. EPA: Washington, DC. March. http://www.epa.gov/osp/spc/rcpolicy.htm

Centers for Disease Control and Prevention. 1991. Preventing Lead Poisoning in Young Children: A Statement on Preventing Lead Poisoning in Young Children by the Centers for Disease Control. Centers for Disease Control and Prevention: Atlanta, GA. October 1. http://aepo-xdv-www.epo.cdc.gov/wonder/prevguid/p0000029/p0000029.asp

Ecology – see Washington State Department of Ecology

Elsner, R.J. & Spangler, J.G. (2005). Neurotoxicity of inhaled manganese: public health danger in the shower? *Med Hypotheses*, **65,** 607-16. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=15913899

EPA – see United States Environmental Protection Agency

Finkel, A.M. 1990. Confronting uncertainty in risk management : a guide for decision-makers. Center for Risk Management, Resources for the Future: Washington, DC.

Finster, Mary E., Kimberly A. Gray, and Helen J. Binns. 2003. Lead levels of edibles grown in contaminated residential soils: a field survey. *The Science of the Total Environment.*

Friedmann, A. 2002. Technical Update: Calculation of an Enhanced Soil Ingestion Rate. Massachusetts Department of Environmental Protection: Boston, MA. April. http://www.state.ma.us/dep/ors/files/Soiling.doc

Gawron, R. 2001. Superfund Technical Support Center Request for Surrogate Toxicity Values. Bailey, M., Vol. Superfund Technical Support Center: May 1. Cincinnati, OH.

Harper, B.L., Flett, B., Harris, S., Abeyta, C. & Kirschner, F. (2003). Response to letter to the editor: Regarding The Spokane Tribe's multipathway subsistence exposure scenario and screening level RME. Risk Anal, 23, 861-4. http://www.blackwell-synergy.com/links/doi/10.1111/1539-6924.00364/abs

Harper, B.L., B. Flett, S. Harris, C. Abeyta, and F. Kirschner. 2002. The Spokane Tribe's Multipathway Subsistence Exposure Scenario and Screening Level RME. *Risk Anal*, 22, 513-26. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=12088230

Harris, S.G. and B.L. Harper. 1997. A Native American exposure scenario. *Risk Anal*, 17, 789-95. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=9463932

Hattis, D. and D.E. Burmaster. 1994. Assessment of variability and uncertainty distributions for practical risk analysis. *Risk Analysis*, 14, 713-730.

Hawley, J.K. 1985. Assessment of health risk from exposure to contaminated soil. *Risk Anal*, 5, 289-302. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=3843688

Holmes, K.K., Jr., J.H. Shirai, K.Y. Richter, and J.C. Kissel. 1999. Field measurement of dermal soil loadings in occupational and recreational activities [In Process Citation]. *Environ Res*, 80, 148-57. http://www.ncbi.nlm.nih.gov/cgi-bin/Entrez/referer?http://www.idealibrary.com/cgi-bin/links/citation/0013-9351/80/148

Institute of Medicine. 2000. Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids. A report of the Panel on Dietary Antioxidants and Related Compounds, Subcommittees on Upper Reference Levels of Nutrients and of Interpretation and Use of Dietary Reference Intakes, and the Standing Committee on the Scientific Evaluation of Dietary Reference Intakes, Food and Nutrition Board, Institute of Medicine. National Academy Press, Washington, DC. http://www.nap.edu/catalog/9810.html

———. 2001. Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc. Standing Committee on the Scientific Evaluation of Dietary Reference Intakes, Panel on Micronutrients, Food and Nutrition Board, Institute of Medicine. National Academy Press, Washington, DC. http://www.nap.edu/catalog/10026.html

Jokinen, E., I. Valimaki, K. Antila, A. Seppanen, and J. Tuominen. 1990. Children in sauna: cardiovascular adjustment. *Pediatrics*, 86, 282-288. http://pediatrics.aappublications.org/cgi/content/abstract/86/2/282

Kissel, J., J.H. Shirai, K.Y. Richter, and R. Fenske. 1998a. Investigation of Dermal Contact with Soil in Controlled Trials. *J. Soil Contamination*, 7, 737-752.

Kissel, J.C., J.H. Shirai, K.Y. Richter, and R.A. Fenske. 1998b. Empirical investigation of hand-to-mouth transfer of soil. *Bull Environ Contam Toxicol*, 60, 379-86. http://www.ncbi.nlm.nih.gov/htbin-post/Entrez/query?db=m&form=6&dopt=r&uid=9528696

Klaassen, C.D. 2001. *Casarett and Doull's Toxicology : The Basic Science of Poisons.* McGraw-Hill Health Professions Division: New York.

Levy, B.S. and W.J. Nassetta. 2003. Neurologic effects of manganese in humans: a review. *Int J Occup Environ Health*, 9, 153-63. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=12848244

Lide, D. 2002. *CRC Handbook of Chemistry and Physics, 2002-2003.* CRC Press: Boca Raton, FL.

National Academy of Sciences. 1990. Health Effects of Exposure to Low Levels of Ionizing Radiation. Committee on the Biological Effects of Ionizing Radiation (BEIR V): Washington, DC. BRER-K-97-01-A 1990.

———. 2000. Copper in Drinking Water. National Research Council: Washington, DC. http://www.nap.edu/catalog/9782.html

———. 2001. Arsenic in Drinking Water: 2001 Update pp. 244. National Research Council: Washington, DC.

National Council on Radiation Protection and Measurements (NCRP). 1987. Ionizing Radiation Exposure of the Population of the United States (NCRP Report No. 93. Bethesda, MD. September 1. http://www.ncrp.com/rpt93.html
———. 1997. Report 126: Uncertainties in Fatal Cancer Risk Estimates Used in Radiation Protection. Bethesda, MD. October. http://www.ncrp.com/rpt126.html

Oak Ridge National Laboratory. 2002. Risk Assessment Information System. Accessed September and November 2002. http://risk.lsd.ornl.gov/prg/prg_document.shtml

Science Applications International Corporation (SAIC). 1993. Laboratory Data Validation Guidelines for Evaluating Radionuclide Analyses - Revision 5A. Science Applications International Corporation (SAIC). April.

Shepard Miller Inc. (SMI). 1999a. Midnite Mine Data Transmittal Report RA-4 (Vegetation Sampling Results). Prepared for Dawn Mining Company for Submittal to the Bureau of Land Management. SMI: Fort Collins, CO. April 23.

———. 1999b. Midnite Mine Data Transmittal Report RA-3 (Vegetation Composition Survey). Prepared for Dawn Mining Company for Submittal to the Bureau of Land Management. SMI: Fort Collins, CO. April 16. http://www.shepmill.com

———. 1999c. Midnite Mine Data Transmittal Report RA-1 (Upland Vegetation Soil Sample Results). Submitted by Dawn Mining Company to the Bureau of Land Management. SMI: Fort Collins, CO. January 29.

———. 1999d. Technical Memorandum R-B: Gamma-226Ra Concentration Correlation. Prepared for Dawn Mining Company. SMI: Fort Collins, CO. June 16.

Simon, S.L. 1998. Soil ingestion by humans: a review of history, data, and etiology with application to risk assessment of radioactively contaminated soil. *Health Phys,* 74, 647-72. http://www.ncbi.nlm.nih.gov/htbin-post/Entrez/query?db=m&form=6&dopt=r&uid=9600298

Smucker, S.J. 2004. Region 9 PRGs Table 2003 Update. Accessed December 20, 2004. http://www.epa.gov/region09/waste/sfund/prg/index.htm

Spokane Tribe of Indians. 2003. The Spokane Tribe of Indians Home Page. Accessed October 8, 2003. http://www.spokanetribe.com/

Spokane Tribe of Indians. (2003). The Spokane Tribe of Indians Home Page. Accessed: October 8, 2003. Revised: 2003. http://www.spokanetribe.com/

Stanek, E.J., 3rd, E.J. Calabrese, R. Barnes, and P. Pekow. 1997. Soil ingestion in adults--results of a second pilot study. *Ecotoxicol Environ Saf,* 36, 249-57. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=9143453

Stifelman, M. 2003a. Equations Used to Calculate Area Needed to Support a Subsistence Farmer Adapted to Midnite Mine Diet. Region 10 EPA: Seattle, WA.

Stifelman, M. 2003b. Letter to the Editor: Response to Harper et al. 30 m-3/day Inhalation Rate. Risk Anal, 23, 859-860. http://www.blackwell-synergy.com/links/doi/10.1111/1539-6924.00363/abs

Superfund Technical Support Center. 2001. Risk Assessment Issue Paper for: Oral RfD, Inhalation RfC and Cancer Assessment for Compounds of Natural Uranium (CASRN 7440-61-0). EPA, National Center for Exposure Assessment: Cincinnati, OH. May.

TerraGraphics. 2000. Final 1999 Five-Year Review Report Bunker Hill Site. Idaho Department of Health and Welfare Division of Environmental Quality and EPA Region 10: Moscow, ID. April.

TerraGraphics, URS and CH2M Hill. 2001. Final Human Health Risk Assessment for the Coeur d'Alene Basin. EPA Region 10 and Idaho Department of Health and Welfare Division of Environmental Quality: Moscow, ID. June. http://yosemite.epa.gov/r10/cleanup.nsf/sites/cda#HHrisk

Tracy, B.L., F.A. Prantl, and J.M. Quinn. 1983. Transfer of 226 Ra, 210Pb and uranium from soil to garden procedure: assessment of risk. *Health Phys.* 44, 469-77.

U N. Scientific Committee on the Effects of Ionizing Radiation (UNSCEAR). 1993. Sources and Effects of Ionizing Radiation. United Nations Publications: New York, NY.

United States Environmental Protection Agency (EPA). 1985a. Drinking Water Criteria Document on Copper. Final draft. Office of Drinking Water: Washington DC. EPA/600/X-84/190-1; ECAO-CIN-417; PB86-118239. February. http://yosemite.epa.gov/water/owrccatalog.nsf/0/9f8b0459a0d9bc1785256b0600724cb3?OpenDocument

———. 1986. Guidelines for Health Risk Assessment of Chemical Mixtures. 51 Federal Register 34014. EPA: Washington, DC. September 24.

———. 1989a. Risk Assessment Guidance for Superfund Human Health Evaluation Manual Part A. Interim Final. Office of Solid Waste And Emergency Response: Washington, DC. 9285.701A. July. http://www.epa.gov/superfund/programs/risk/ragsa/index.htm

———. 1990a. IRIS Toxicity Profile for Thallium Sulfate. Accessed August 7, 2003. Last revised September 1990. http://www.epa.gov/iris/subst/0116.htm#top

———. 1990b. National Oil and Hazardous Substances Pollution Contingency Plan (NCP). Final Rule. *Federal Register* 6670-8852. March 8.

———. 1991a. Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors. Office of Emergency and Remedial Response: Washington, DC. OERR Publication 9285.6-03 NTIS PB91-921314.

———. 1991b. Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions. Office of Emergency and Remedial Response: Washington, DC. OSWER Directive 9355.0-30 April 22. http://www.epa.gov/superfund/programs/risk/baseline.pdf

———. 1991c. Risk Assessment Guidance for Superfund - Volume I: Human Health Evaluation Manual, Part B, Development of Risk-based PRGs. Office of Emergency and Remedial Response: Washington, DC. EPA/540/R-92/003 Pub 9285.7-01B. December. http://www.epa.gov/superfund/programs/risk/ragsb/index.htm

———. 1991d. IRIS Toxicity Profile for Antimony. Accessed 2003. Last revised February 1991. http://www.epa.gov/iris/subst/0006.htm#top

———. 1992a. IRIS Toxicity Profile for Zinc and Compounds. Accessed August 2003. Last revised October 1992. http://www.epa.gov/iris/subst/0426.htm

———. 1992b. National Residential Radon Survey. EPA-4-2-R-92-011.

———. 1992c. Dermal Exposure Assessment: Principles and Applications Interim Report. EPA: Washington, DC.

———. 1993a. IRIS Toxicity Profile for Selenium and Compounds. EPA: Washington, DC. Last revised July 1993. http://www.epa.gov/iris/subst/0472.htm

———. 1993b. Federal Guidance Report 12: External Exposure to Radionuclides In Air, Water, and Soil. EPA. Office of Radiation and Indoor Air; Oak Ridge National Laboratory: Oak Ridge, TN. EPA 402-R-93-081. September. http://www.epa.gov/radiation/federal/docs/fgr12.pdf

———. 1994a. OSWER Directive #9355.4-12 Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities. EPA: Washington, DC. EPA/540/F-94/043. July 14. http://www.epa.gov/superfund/programs/lead/prods.htm#guidance

———. 1994b. IRIS Toxicity Profile for Cadmium. Accessed 2003. Last revised February 1994. http://www.epa.gov/iris/subst/0141.htm

———. 1996a. Soil Screening Guidance: Technical Background Document. Office of Radiation and Indoor Air: Washington, DC. EPA/540/R-95/128 PB96-963502. July. http://www.epa.gov/superfund/resources/soil/ssg496.pdf

———. 1996b. Soil Screening Guidance: User's Guide. Office of Radiation and Indoor Air: Washington, DC. 9355.4-23. July. http://www.epa.gov/superfund/resources/soil/ssg496.pdf

———. 1996c. IRIS Toxicity Profile for Nickel Soluble Salts. EPA: Washington, DC. Last revised December 1996. http://www.epa.gov/iris/subst/0271.htm

———. 1996d. IRIS Toxicity Profile for Silver (CASRN 744-22-4). Accessed August 7, 2003. Last revised October 1, 1996. http://www.epa.gov/iris/subst/0099.htm

———. 1996e. Proposed Guidelines for Carcinogen Risk Assessment. Office of Research and Development: Washington, DC. EPA/600/P-92/003C. April. http://www.epa.gov/ORD/WebPubs/carcinogen/carcin.pdf

———. 1996f. IRIS Toxicity Profile for Manganese. Accessed 2003. Last revised May 1996. http://www.epa.gov/iris/subst/0373.htm

———. 1997a. Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments Interim Final. Office of Solid Waste and Emergency Response: Washington, DC. EPA 540-R-97-006, PB97-953211. June. http://www.epa.gov/superfund/programs/risk/ecorisk/ecorisk.htm

———. 1997b. Exposure Factors Handbook. Office of Research and Development: Washington, DC. EPA/600/P-95/002Fc. August. http://www.epa.gov/ncea/exposfac.htm

———. 1997c. Health Effects Assessment Summary Table (HEAST) - FY 1997 Update. Office of Research and Development: Washington, DC. July.

———. 1998a. Ambient Water Quality Criteria Derivation Methodology: Human Health Technical Support Document Final Draft. Office of Science and Technology:

Washington, DC. EPA/822/B-98/005. July. http://www.epa.gov/waterscience/humanhealth/awqc-tsd.pdf

———. 1998b. OSWER Directive #9200.4-27P Clarification to the 1994 Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities. EPA: Washington, DC. EPA/540/F-98/030. August. http://www.epa.gov/superfund/programs/lead/prods.htm#guidance

———. 1998c. IRIS Toxicity Profile for Arsenic. Accessed August 2003. Last revised April 1998. http://www.epa.gov/iris/subst/0278.htm

———. 1998d. IRIS Toxicity Profile for Beryllium and Compounds. Accessed 2003. Last revised April 1998. http://www.epa.gov/iris/subst/0012.htm

———. 1998e. Toxicological Review of Hexavalent Chromium (CAS No. 18540-29-9) In Support of Summary Information on the Integrated Risk Information System (IRIS). Accessed 2003.

———. 1998f. Toxicological Review of Trivalent Chromium (CAS No. 16065-83-1) In Support of Summary Information on the Integrated Risk Information System (IRIS). August.

———. 1999a. Federal Guidance Report No. 13 Cancer Risk Coefficients for Environmental Exposure to Radionuclides. Office of Radiation and Indoor Air. Oak Ridge National Laboratory: Oak Ridge, TN. EPA 402-R-99-001. September.

———. 1999b. Region 10 Supplemental Guidance. Assessing childhood exposures for non-carcinogens. Draft. Seattle, WA. November.

———. 2000a. Risk Characterization Handbook. EPA Science Policy Council: Washington, DC. EPA 100-B-00-002. December. http://www.epa.gov/osp/spc/rchandbk.pdf

———. 2000b. Soil Screening Guidance for Radionuclides: Technical Background Document. Office of Radiation and Indoor Air, Office of Solid Waste and Emergency Response: Washington, DC. 9355.4-16, EPA/540-R-00-006, PB2000 963306. October. http://www.epa.gov/oerrpage/superfund/resources/radiation/radssg.htm#guide

———. 2000c. Soil Screening Guidance for Radionuclides: User's Guide. EPA/540/R-00-007. Office of Radiation and Indoor Air, Office of Solid Waste and Emergency Response. October 2000.

———. 2001a. Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Interim Review Draft for Public Comment. EPA/540/R/99/005 OSWER 9285.7-02EP PB99-963312. September. http://www.epa.gov/superfund/programs/risk/ragse/index.htm

———. 2001b. User's Guide for the Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK) Windows version. Office of Emergency and Remedial Response: Washington, DC. OSWER #9285.7-42 2001.

———. 2001c. Region Supplemental Human Health Risk Assessment Guidance, Soil Ingestion Rates. EPA Region 10, Office of Environmental Assessment: Seattle. January.

———. 2001d. New HEAST Radionuclide Slope Factors Table. Office of Radiation and Indoor Air: Washington, DC. April.

———. 2002a. Guidance for Characterizing Background Chemicals In Soil at Superfund Sites. Office of Emergency and Remedial Response: Washington, DC. OSWER 9285.7-41 EPA 540-R-01-003. November. http://www.epa.gov/superfund/programs/risk/background.pdf

———. 2002b. Role of Background in the CERCLA Cleanup Program. Office of Solid Waste and Emergency Response, Office of Emergency and Remedial Response: Washington, DC. OSWER 9285.6-07P. April. http://www.epa.gov/oerrpage/superfund/programs/risk/bkgpol_jan01.pdf

———. 2002c. CD Supplement: Federal Guidance Report No. 13 Cancer Risk Coefficients for Environmental Exposure to Radionuclides. Office of Radiation and Indoor Air. Accessed April 2002. http://www.epa.gov/rpdweb00/federal/techdocs.htm#cd_supplement

———. 2002d. Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites. Office of Emergency and Remedial Response. OSWER 9285.6-10.

———. 2003. The Integrated Risk Information System (IRIS). Accessed 2003. http://www.epa.gov/iris/

———. 2004. Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Final. Prepared for EPA: Washington, DC. EPA/540/R/99/005 OSWER 9285.7-02EP PB99-963312 July, 2004. http://www.epa.gov/superfund/programs/risk/ragse/

URS Corporation (URS). 1999. Quality Assurance Project Plan for the Midnite Mine Phase 1A RI/FS. Region 10 EPA: Denver, CO. August.

———. 2000a. Midnite Mine Existing Data Summary. Technical Memorandum. Region 10 EPA: Denver, CO. June.

———. 2000b. Midnite Mine Focused Historical Data Assessment. Draft Technical Memorandum. Region 10 EPA: Denver, CO. July 25.

———. 2000c. Quality Assurance Project Plan for the Midnite Mine, Phase 2A/1B, RI/FS. Region 10 EPA: Denver, CO. November 30.

———. 2001. Draft Work Plan Human Health Risk Assessment for the Midnite Mine Superfund Site. Prepared for EPA Region 10: Denver, CO. October 29.

———. 2003a. Draft Technical Memorandum for Suitability of Background Sampling Used to Establish Site Impacts on the Midnite Mine Superfund Site. EPA Region 10: Seattle, WA. Work Assignment No. 018-RI-CO-102Q. August.

———. 2003b. Draft Midnite Mine Superfund Remedial Investigation Report. Region 10 EPA: Seattle, WA. Work Assignment No. 018-RI-CO-102Q. August.

Uranium Mill Tailings Radiation Control Act. 1978. United States Code. 42 USC Chapter 88 Section: 7901-7942. http://uscode.house.gov/usc.htm

van Wijnen, J.H., P. Clausing, and B. Brunekreef. 1990. Estimated soil ingestion by children. *Environ Res*, 51, 147-62. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=2335156

Wackernagel, M., N.B. Schulz, D. Deumling, A.C. Linares, M. Jenkins, V. Kapos, C. Monfreda, J. Loh, N. Myers, R. Norgaard, and J. Randers. 2002. Tracking the ecological overshoot of the human economy. *Proc Natl Acad Sci USA*, 99, 9266-71. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=12089326

Washington Department of Health. 1999. Radiochemical Risk Assessment for the Low-Level Radioactive Waste Disposal Facility, Richland, WA. Division of Radiation Protection: Olympia, WA.

Washington State Department of Ecology. 1994. Natural background soil metals concentrations in Washington State. http://www.ecy.wa.gov/pubs/94115.pdf

Wester, R.C., H.I. Maibach, L. Sedik, J. Melendres, S. DiZio, and M. Wade. 1992. In vitro percutaneous absorption of cadmium from water and soil into human skin. *Fundam Appl Toxicol*, 19, 1-5.

Wester, R.C., H.I. Maibach, L. Sedik, J. Melendres, and M. Wade. 1993. In vivo and in vitro percutaneous absorption and skin decontamination of arsenic from water and soil. *Fundam Appl Toxicol,* 20, 336-40.

White, P.D., P. Van Leeuwen, B.D. Davis, M. Maddaloni, K.A. Hogan, A.H. Marcus, and R.W. Elias. 1998. The conceptual structure of the integrated exposure uptake biokinetic model for lead in children. *Environ Health Perspect*, 106 Suppl 6, 1513-30. http://www.ncbi.nlm.nih.gov/htbin-post/Entrez/query?db=m&form=6&dopt=r&uid=9860910

APPENDIX A

Sample Locations and Data Sources Retained in the Risk Assessment

APPENDIX B

Chemicals of Potential Concern Selection Process Tables

APPENDIX C

Radionuclides Screening Based on Contribution to Risk

APPENDIX D

Exposure Point Concentration Tables

APPENDIX E

Monitoring Wells With COPC Exceedances, Plant and Beef Tissue Modeling

APPENDIX F

The Spokane Tribe's Multipathway Subsistence Exposure Scenario and Screening Level RME and Follow-Up Letters

APPENDIX G

Climatic Heat Stress and the Exercising Child and Adolescent

APPENDIX H

Toxicity Profiles

APPENDIX I

Risk Tables

APPENDIX J

Land Use Requirements for the Hanford Reservation

APPENDIX K

Calculations Comparing Total and Background Risks and Hazards