Risk Assessment

Kantishna Gravel Source
Denali National Park and Preserve
Denali Park, Alaska 99755

Prepared for

Denali National Park
National Park Service
U.S. Department of the Interior

and

Federal Highway Administration
U.S. Department of Transportation

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EXECUTIVE SUMMARY

As part of a multidisciplinary study designed to optimize visitor experience along the park road while protecting wildlife, the National Park Service (NPS) initiated a fugitive dust study. In 1998 the Occupational Safety and Health Administration conducted a fugitive dust sampling effort focusing on workers in the Denali National Park and Preserve (DENA) and the fugitive dust along the park road. The results of the fugitive dust sampling revealed no exceedences of the respirable dust or quartz dust standards. In 2005, the NPS sampled potential gravel borrow sources for metals. Results indicated elevated metals content. Prior to utilization of these gravel sources for road maintenance, the NPS wanted to evaluate the potential for the elevated metals content to cause any adverse health effects.

In 2006, the NPS and Federal Highway Administration tasked the U.S. Army Corps of Engineers (USACE) with conducting a risk assessment focusing on the metal content in potential road construction and maintenance material (gravel in the borrow sources). This risk assessment does not consider the risks associated with the existing conditions in Kantishna, such as contact with soil, surface water, and groundwater not associated with the road material. The risk calculated in this assessment are the risks associated with the use of the mineralized gravel on the road surface and do not quantify the risk associated with the highly mineralized background of the Kantishna area. The risk assessment was to focus on the human health issues but include an ecological screening. In support of this effort, USACE conducted additional sampling in the proposed project area. Samples were taken from the proposed gravel borrow source, the existing road material, and background areas. The assessment project area is the section of park road stretching twenty miles east from Kantishna. However, the results of the risk assessment can be applied to any location along the park road.

The human health risk assessment in this document follows the U.S. Environmental Protection Agency (EPA) guidance found in “Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual (Part A), Interim Final,” published in 1989 and related EPA and State of Alaska Department of Environmental Conservation (ADEC) guidance.

The ecological screening follows the ADEC “Ecological Scoping Evaluation Guidance,” published in 2007.

This assessment narrows the chemicals of potential concern down to antimony and arsenic. The exposure pathways that were retained for quantitative evaluation are the incidental ingestion of soil (dust), dermal contact with soil (dust), and inhalation of dust. Receptors include eleven employee groups at DENA. The toxicity assessment evaluated the toxic effects of antimony and arsenic and the carcinogenic effects of arsenic. Antimony is not considered a human carcinogen by the EPA.

The risk characterization indicates that all risks are below the ADEC risk management levels and within the acceptable risk range set by EPA.

The employee group with the highest carcinogenic risk is the Kantishna Air Transport Drivers. The groups with the highest noncarcinogenic risk are the Gravel Processing Crew and the Wonder Lake Grader Operator (cumulative risks from grading and roading activities). The risks for these groups are indicated below.

Maximum Risks

	Hazard Index	Excess Lifetime Cancer Risk
ADEC Risk Management Level	1	1×10^{-5}
EPA Risk Management Level	1	1×10^{-4} to 1×10^{-6}
Kantishna Air Transport Drivers (15 year employment)	0.1	8×10^{-6}
Gravel Processing Crew (2 year employment)	0.2	1×10^{-6}
Wonder Lake Grader Operator (total) (10 year employment)	0.2	7×10^{-6}

The Hazard Index (HI) is an indicator of noncarcinogenic effects and is a summation of separate hazard quotients (HQ). The HQ is calculated by dividing the receptor intake of a chemical by the reference dose (RfD) of a chemical (HQ = intake / RfD). The HQ assumes that there is a level of exposure (i.e., RfD) below which it is unlikely for even sensitive populations to experience adverse health effects. If the Intake/RfD ratio exceeds this threshold (i.e., if intake/RfD exceeds unity), there may be concern for potential noncarcinogenic effects. As a rule, the greater the value of intake/RfD above unity, the greater the level of concern. However, the ratio of intake/RfD is not to be interpreted as a statistical probability; a ratio of 0.001 does not mean that there is a one in a thousand chance of the effect occurring. Further, it is important to emphasize that the level of concern does not increase linearly as the RfD is approached or exceeded because RfDs do not have equal accuracy or precision and are not based on the same severity of toxic effects. Thus, the slopes of the dose-response curve in excess of the RfD can range widely depending on the substance.

The excess lifetime cancer risk (ELCR) is the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen. The slope factor (SF) converts estimated daily intake averaged over a lifetime of exposure directly to incremental risk of an individual developing cancer. The slope of the dose-response curve is assumed linear and thus the SF a constant. Thus the risk is directly related to intake.

The risk assessment uses assumptions that may add uncertainty to the study. For instance, one assumption made for the Kantishna Air Transport Driver is the length of employment. It was assumed the individual would stay in the same driver position for 15 years. This exposure duration affects the carcinogenic risk. If an individual stayed in this position for only five years, the cancer risk would reduce to 3×10^{-6}. Length of exposure duration (employment) has less effect on the noncarcinogenic hazard index.

The ecological screening followed the ADEC "Ecological Scoping Evaluation Guidance" (ADEC 2007c). The potential contamination from the use of gravel with elevated antimony and arsenic is limited in quantity, concentration, mobility, and toxicity. The probability of the antimony and arsenic migrating from the zone of influence is low. There are no valued species or critical habitats in the immediate vicinity (15 - 150 feet) of the roadway. The potential contamination presents no adverse impacts to the environment.

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1 Introduction

1.1 Overview

Elevated metals concentrations have been identified in potential gravel borrow sources (placer tailings) for roadway maintenance on the west end of the Denali National Park and Preserve (DENA) access road (park road). The purpose of this risk assessment is to estimate the human health and ecological risks if this borrow source is used for roadway construction and maintenance activities.

The National Park Service (NPS) and the Federal Highway Administration (FHWA) tasked the U.S. Army Corps of Engineers (USACE) to conduct a focused risk assessment for the proposed maintenance of the park road in 2008 (FHWA 2006).

This risk assessment was conducted following the general procedures in the U.S. Environmental Protection Agency (EPA) “Risk Assessment Guidance for Superfund” (EPA 1989) and related EPA and State of Alaska Department of Environmental Conservation (ADEC) guidance. The results of this risk assessment will provide information to DENA management which will aid in risk management decisions concerning the use of borrow material with elevated metals content.

1.2 Site Background

1.2.1 Site Description

DENA is in interior Alaska. The entrance is located about 237 road miles north of Anchorage and about 124 road miles south of Fairbanks on the Parks Highway. The park road begins at the Parks Highway and winds westward ending at Kantishna. About 15 miles of the road near the entrance is paved, the rest of the road (about 80 miles) is unpaved. The area of this assessment is the last twenty miles of park road beginning in Kantishna and traversing east, past Wonder Lake, and paralleling the McKinley River. (Figures 4 and 5; Pictures 1-7) There are three separate units within Denali National Park and Preserve. These are the former Mt. McKinley National Park, 99% of which has been designated as the Denali Wilderness, Denali National Park additions, and Denali National Preserve.

1.2.2 General History

DENA, established in 1917 as Mount McKinley National Park, is one of the oldest national park units in the United States. Reasons for establishing the park were to stimulate travel to Alaska by tourists and sightseers and to preserve the area's game and natural scenery. The Alaska National Interest Lands Conservation Act of 1980, Section 202 established Denali National Preserve, redesignated Mount McKinley National Park, and significantly expanded the boundaries of the unit.

The implementing language for the original park was retained and the new park and preserve additions were to be managed to protect and interpret the entire mountain massif and additional scenic mountain peaks and formations; to protect fish and wildlife populations and habitat; and to provide continued opportunities, including reasonable access for mountain climbing, mountaineering and other wilderness recreational activities.

The (pre-1980) Mount McKinley National Park boundary line occurs about 2 ½ miles southeast of Kantishna (Figures 4 and 5). The area is closed to sport and subsistence hunting and trapping and is managed to maintain the undeveloped wilderness parkland character. The 1980 park additions include Kantishna and the area of the proposed borrow source. This area is open to traditional subsistence use by local rural residents.

The park road from the park entrance to Kantishna was completed by the Alaska Road Commission in 1938. Local fill material and mining by-products (tailings) have been used for construction and maintenance. Road maintenance is planned for 2008 and beyond. A potential source of gravel is old tailings from placer mining activities near Kantishna. Inspection of these 'tailings' indicates that some or all of them may actually be unprocessed placer material (e.g., stockpiled, excavated earth).

The borrow source material and road segments scheduled for maintenance lie about 90 miles west of the park entrance along the park road (Figure 7; Picture 4). High mineralization occurs in the Kantishna Hills and surrounding areas and strongly elevated lead (Pb), zinc (Zn), silver (Ag), arsenic (As) and antimony (Sb) concentrations have been identified. Anomalous tungsten (W), tin (Sn), copper (Cu), bismuth (Bi), manganese (Mn), molybdenum (Mo), uranium (U), nickel (Ni), thorium (Th) and platinum (Pt) mineralization have also been identified (ADNR 1974, ADNR 1975, ADNR 1976, USGS 1918, USGS 1919, USGS 1933, USGS 1981, and USGS 2000). The proposed borrow source is located about 1,200 feet northwest of the Kantishna Roadhouse and about 6,000 feet southeast of the Kantishna Airstrip.

Sampling by the NPS in 2005 found elevated concentrations of arsenic, antimony and chromium in the proposed borrow source and background soils (FHWA 2006). A fugitive dust study completed by OSHA in 1998 (DPR 1999) provides an initial characterization of the nature and extent of fugitive dust releases from the park road. The OSHA sampling had results for respirable dust and crystalline quartz dust below the permissible exposure level. However, the metals concentrations from the NPS sampling were above acceptable ADEC levels. Therefore, NPS management in consultation with ADEC determined that a risk assessment was necessary to ensure that the proposed action of mining, crushing and placing the mine tailings on the park road did not pose a risk to human health and the environment. This focused risk assessment parallels the larger fugitive dust study.

> In 2006, Denali [National Park] began a multidisciplinary study designed to optimize visitor experience along the park road while protecting wildlife. Since 1972, traffic on the park road has been limited mostly to buses, and since 1986, a use limit of 10,512 vehicle trips annually has been in effect. Faced with increasing visitation and pressure to defend or change the limits to road traffic, park managers have designed a study to develop a greater understanding of the impacts of traffic volume and traffic patterns on the physical, biological, and social environment of the park. (NPS 2007a).

Included in this study is road dust monitoring (NPS 2007f).

1.2.3 General Sampling Locations and Media

Initial 2005 sampling by the NPS occurred along the last twenty miles of the park road. All but one sample was within a half mile of the road. Sampling was at background locations and at the proposed borrow area. All samples were from soil matrix (FHWA 2000, NPS 2006a, b). USACE conducted sampling in 2007 from the same area and soil matrix (USACE 2007a).

1.3 Scope of Risk Assessment

The geographical area for the risk assessment is the proposed road maintenance corridor that starts in the vicinity of the Kantishna Airstrip and proceeds about twenty miles east. The primary concern is exposure to workers; however, other potential receptors are addressed. The human health risk assessment determines the hazard quotient (HQ) (for noncarcinogens) and the excess lifetime cancer risk (ELCR) (for carcinogens). A hazard index (HI) is the sum of two or more HQs. The ecological portion of the assessment is limited to an ecological screening following ADEC's Ecological Scoping Evaluation Guidance (ADEC 2007c).

To accurately assess the human health risks, the assessment looks at background metals concentrations, existing roadway metals concentrations, and the metals concentrations in the proposed gravel borrow source.

1.4 Organization of Risk Assessment Report

The risk assessment follows the EPA suggested outline and uses standard EPA language for a baseline risk assessment report (EPA 1989). In several places EPA guidance is used verbatim. The sections of the risk assessment include:

- Section 1, Introduction
- Section 2, Identification of Chemicals of Potential Concern
- Section 3, Exposure Assessment
- Section 4, Toxicity Assessment
- Section 5, Risk Characterization
- Section 6, Human Health Summary
- Section 7, Ecological Screening
- Section 8, References

Appendices include:

- Appendix A, Human Health Conceptual Site Model

2 Identification of Chemicals of Potential Concern

2.1 General Site-specific Data Collection Considerations

The sources of metals associated with the potential borrow source are the minerals that were processed from previous placer mining in the Kantishna area. These minerals are the result of hydrothermal deposition within the fractured bedrock schist. The results of preliminary discrete sampling of the tailings are illustrated in Table 1[1]. In this document, the term “metals” and “chemicals” are both used interchangeably even though arsenic and antimony are more properly called metalloids.

Table 1 – Metal Concentrations 2005 Sampling

Metal	Borrow Source (mg/kg)	Background (mg/kg)	18 AAC 75 Table B Cleanup Levels (ingestion/inhalation /migration to groundwater) (mg/kg)
Antimony (Sb)			41 / -- / 3.6
Arsenic (As)			5.5 / -- / 2
Barium (Ba)	29 – 100 [67]	16 – 78	7,100 / -- / 1,100
Cadmium (Cd)	nd (0.87) – 1.6 [1.1]	nd (0.5) – 0.85	100 / -- / 5
Chromium (Cr)			300 / -- / 26 *
Lead (Pb)	10 – 30	9.9 – 88	400
Mercury (Hg)	nd (0.042) – 0.081	nd (0.045) – 0.067	-- / 18 / 1.4
Selenium (Se)	nd (8.0) - nd (11)	nd (6.3)	510 / -- / 3.5
Silver (Ag)	nd (1.2) - nd (1.6)	6.1 – 7.9	510 / -- / 21

nd = nondetect with the practical quantitation limits in parenthesis (PQL).

mg/kg = milligrams per kilogram.

indicate results over cleanup levels.

The sampling at the borrow source was 19 discrete samples. The background sampling was 6 discrete samples.

Concentrations in brackets “[ ]” are 95% upper confidence limits calculations using EPA ProUCL software.

*Cleanup levels for chromium are based on the hexavalent toxicity. These values are conservative by at least two orders of magnitude for trivalent chromium.

[1] Information condensed from FHWA 2006.

Preliminary identification of potential human exposure is evaluated through a conceptual site model (CSM). A CSM is a planning tool used for identifying chemical sources, complete exposure pathways, and potential receptors on which to focus the risk assessment. The CSM describes the relationships between chemicals released from a site and the receptors that may be exposed to the chemicals through pathways such as incidental ingestion, dermal contact and inhalation. The CSM evaluates the potential exposure pathways and identifies those that are present and may be important for receptors.

The CSM identifies all:

- Present and future ways people may be exposed (exposure pathways),
- Routes the contaminants may take as they move through soil, groundwater, and/or surface water, (migration routes), and
- Possible categories of people who could be exposed (potential receptors) for further analysis at a site.

A CSM guides the site characterization process, since it helps identify:

- The goals for gathering data to provide clear information (data quality objectives),
- Needs for more sampling, and
- Risk management decisions which may need to be made. This can include cleanup levels and the use of controls placed on the land at the end of active cleanup activities to prevent future exposure to remaining contamination, if any.

The initial and final CSM for potential human exposures related to the use of the proposed borrow source for roadway maintenance in DENA is described below and in Appendix A.

The initial CSM for the Kantishna borrow source has identified six potential exposure pathways. These are:

- incidental soil ingestion,
- dermal absorption of contaminants from soil,
- ingestion of groundwater,
- inhalation of fugitive dust,
- ingestion of surface water, and
- ingestion of wild foods.

The sampling conducted in 2005 identified three metals as being potential risk drivers. These are antimony, arsenic and chromium. The chromium detected during the 2005 sampling was believed to be the less toxic trivalent species and not the more toxic hexavalent species. To validate this assumption, samples were analyzed for total chromium and hexavalent chromium during the 2007 investigation. The 2007 sampling program was designed to support the risk assessment effort and to obtain additional data on arsenic, antimony, and chromium concentrations in the proposed borrow area and background. Information on the sampling methods, quality assurance and quality control methods, and the sampling program are further described in the sampling and analysis plan (USACE 2007a) and the data quality objectives (USACE 2006). The data quality objectives (DQOs) for the 2007 investigation required analytical data on soil and rock concentrations for antimony, arsenic, and chromium from three general areas. The first area was the background areas paralleling the park road. Due to geologic and logistic reasons, this area was further divided into five decision units (DUs) DU1 - DU5. The DQOs called for one-half-inch minus particle size for the sample matrix. The next general area was the proposed borrow source (DU6). The DQOs required sampling all tailing particle sizes from cobbles down to fines (a larger particle size was required since the borrow source material would be crushed as part of the gravel processing). The last general area was the existing roadway (DU7). The DQOs required sampling the one-half-inch minus fraction.

The 2007 sampling was conducted using a multi-incremental sampling method (ADEC 2007a). The sampling design was optimized for obtaining analytical data by controlling the fundamental error to 10%. Each sample consisted of 50 to 100 increments. Each sample was crushed, ground, and/or sieved to produce a 2-millimeter (mm) minus sample matrix. Antimony, arsenic and total chromium were analyzed by EPA Method SW6020. Hexavalent chromium was analyzed with EPA Method SW7195/SW6010B. One multi-increment sample was collected from each DU (DU1 - DU7). Duplicates and triplicates were collected from DU1, DU2, DU6, and DU7 for a total of 15 samples.

2.2 General Site-specific Data Evaluation Considerations

After analysis at the project laboratory (Severn Trent Laboratories of Seattle, Washington), data were reviewed against the Department of Defense Quality Systems Manual for Environmental Laboratories, and data comparability was assessed against the criteria detailed in the ADEC Draft Guidance on Multi-Increment Soil Sampling (ADEC 2007a). The data review included evaluation of sample collection, holding time, field and laboratory blanks (to assess field or laboratory contamination of the samples), sample duplicates (to assess laboratory precision), laboratory control samples (to assess laboratory accuracy), and, where available, matrix spike recoveries (to assess matrix effects).

All data are usable for the purposes of this project. Some data are qualified as “estimated” because of various minor analytical discrepancies, or because the analyte was detected at a concentration below the laboratory’s reporting limit.

Hexavalent chromium was analyzed outside of hold time. The suggested hold time for the method performed by the lab (SW7195/SW6010B) is 24 hours. However, this method is for aqueous samples, not soils. Preparation method SW3060A is for soils, and the suggested hold time for that method is 30 days. However, even that hold time was not met. The samples were analyzed 60 days after collection due to processing delays. The results for hexavalent chromium should be considered low estimates. No other analytical deviations were encountered for this analyte.

2.3 Data from Site Investigation

The 2007 investigation data is shown in Table 2.

Arsenic. The background concentrations of arsenic across DUs appears to vary significantly. Average background concentrations in DU1 and DU2 (260 and 120 mg/kg respectively) were much higher than background for DU3, DU4, and DU5 (average of 22 mg/kg). The DQOs for the 2007 sampling effort deliberately broke out DU1 and DU2 due to a different geologic setting (Figures 6 and 7). The Chemical Data Report (USACE 2007b) indicates the soil matrix was different in these two areas. The soil matrix for DU3 - DU5 was largely mineral soil as opposed to DU1 and DU2 where the matrix was largely organic. The arsenic concentration for the existing park road (average of 34 mg/kg) was only slightly elevated over background of DU3 - DU5 (average of 22 mg/kg). However, the arsenic concentration for the proposed borrow source (average of 66 mg/kg) was about twice that of the existing park road and about three times that of background (in DU3 - DU5).

Table 2 – Data from 2007 Sampling

	Arsenic	Antimony	Chromium (Total)	Hexavalent Chromium
DU1 (Background)	300 250 230 (Average 260)	17 14 13 (Average 15)	8.3 9.9 8.8 (Average 9.0)	0.34 H 0.25 H 0.26 H (Average 0.28)
DU2 (Background)	140 120 100 (Average 120)	31 34 26 (Average 30)	11 12 11 (Average 11)	0.34 H 0.33 H 0.029 H (Average 0.23)
DU3 (Background)	23	2.4	18	0.22 H
DU4 (Background)	19	1.4	15	0.64 H
DU5 (Background)	23	1.5	17	0.35 H
DU3 – DU5 Averages	22	1.8	17	0.40
DU6 (Tailings)	70 66 61 (Average 66)	21 19 19 (Average 20)	8.4 9.9 9.6 (Average 9.3)	0.16 H 0.17 H 0.14 H (Average 0.16)
DU7 (Existing Road)	34 32 35 (Average 34)	6.2 6.6 5.7 (Average 6.2)	20 16 16 (Average 17)	0.24 H 0.22 H 0.18 H (Average 0.21)
All results are mg/kg dry weight; DU = decision unit. DUs with three reported results per analyte are duplicates and triplicates. H – hold time was exceeded (see text). The low hexavalent chromium concentration of 0.029 mg/kg was from a triplicate sample and is suspect since all other hexavalent chromium concentrations reported are in closer agreement.				

Antimony. Antimony concentrations followed a similar pattern as for arsenic. Average background concentrations in DU1 and DU2 (15 and 30 mg/kg respectively) were much higher than background for DU3, DU4, and DU5 (average of 1.8 mg/kg). The antimony concentration for the existing park road (average of 6.2 mg/kg) was elevated over background of DU3 - DU5 (average of 1.8 mg/kg). However, the antimony concentration for the proposed borrow source (average of 20 mg/kg) was more than three times that of the existing park road and about an order of magnitude over that of background (in DU3 - DU5).

Chromium. Chromium concentrations showed a different relationship between the DUs. However, the sampling objective for the 2007 effort was to validate the assumption that the majority of chromium in the study area was the less toxic trivalent (Cr+3) species as opposed to the more toxic hexavalent (Cr+6) species and that neither was a risk problem. This was successfully accomplished. Comparing the highest total chromium result of 20 mg/kg (assuming total chromium is all Cr+3) to the ADEC soil cleanup values of 150,000 mg/kg (ingestion) and over 1,000,000 mg/kg (migration to groundwater) (ADEC 2006) supports dropping total (or Cr+3) from the list of COPC. The same reasoning applies for hexavalent chromium. Comparing the highest hexavalent result of 0.64 mg/kg to the ADEC soil cleanup values of 300 mg/kg (ingestion) and 26 mg/kg (migration to groundwater) (ADEC 2006) supports eliminating Cr+6 as a COPC.

2.4 Summary of Chemicals of Potential Concern (COPC)

Two chemicals remain on the list of COPC, arsenic and antimony. The information in Table 2 is summarized in Table 3.

Table 3 – COPC

	Background DU1 – DU2 (mg/kg)	Background DU3 – DU5 (mg/kg)	Existing Road (mg/kg)	Proposed Borrow Source (Tailings) (mg/kg)
Arsenic	190	22	34	66
Antimony	22	1.8	6.2	20
Note: concentrations are averages.				

3 Exposure Assessment

3.1 Characterization of Exposure Setting

3.1.1 Physical Setting

Denali National Park and Preserve straddles two of the major climatic zones of Alaska — the transitional maritime zone south of the Alaska Range and the continental zone in the interior region, north of the range. The Alaska Range exerts a major influence on the climate of the Interior by blocking much of the moisture that sweeps inland from the Gulf of Alaska.

Therefore, the north side of the park [Kantishna area] is characterized by less precipitation and greater fluctuations in temperature (hotter in summer and colder in winter) than the south side. Temperatures of minus 50 degrees Fahrenheit (°F) and lower are not unusual on the north side of the range during winter, and although summer temperatures can climb to 90°F, they can also fall below the freezing mark.

> Daily weather observations, including minimum and maximum temperatures and precipitation amounts have been recorded at park headquarters since 1923. Temperature extremes at park headquarters range from 91°F to -54°F. Average maximum temperatures at park headquarters are 11°F for January and 66º F for July. The average minimum temperatures for the same months are -7°F and 43°F, respectively. The daily temperature range during the summer months (June through August) averages 22ºF. Much wider daily temperature ranges (up to 68°F) occur during the winter months. (NPS 2007d)

The average total precipitation at the McKinley Park station is 15.29 inches. The amount includes the average total snowfall of 81.5 inches. Precipitation in the Kantishna area may be slightly greater than at McKinley Park station. The Western Region Climate Center shows the Kantishna area receiving up to 19.7 to 23.6 inches of mean annual precipitation (WRCC 2007b).

The area around Kantishna is characterized by tundra-carpeted lowlands, hills, and flat glacial valleys drained by glacier-fed rivers, lakes, and streams. Vegetation in the area is highly varied with many different econiches. Broadly characterized as dominated by boreal forest (or taiga), DENA has at least five major vegetation zones. These are, in order of rising elevation, Low Brush Bog, Bottomland Spruce-Poplar Forest, Upland Spruce-Hardwood Forest, Moist Tundra, and Alpine Tundra.

The ground elevation near the road, Moose Creek and Kantishna airstrip is about 1,690 feet. Wonder Lake has an elevation of about 1,986 feet. The road on the east end of this assessment area rises to 3,000 feet with the elevation of nearby McKinley River at about 2,500 feet. The road continues to rise as it progresses to the east entering mountains with nearby peaks of over 6,000 feet. (Pictures 1-7)

Drinking water for the areas in this study is obtained from surface water and groundwater. Many of the surface water sources are not potable due to high concentrations of heavy metals. The Kantishna area and majority of the park road lie over discontinuous permafrost. Information on depth to groundwater is lacking for the west end of the park road.

3.1.2 Potentially Exposed Populations

Kantishna population is about 135 during the summer but ranges to about 400 when the lodges are fully occupied. Winter population is generally low, limited to lodge caretakers who may stay during the off-season. There are four land uses under consideration for the human health risk assessment.

- Commercial use. The roadway is currently used for commercial and park service tour busses. Several tourist lodges exist in the Kantishna area. These uses are likely to continue into the future.
- Recreational land use. Within the Denali Wilderness, recreational backcountry camping and hiking, bicycle touring and camping at established campgrounds occurs and are expected to continue. Overnight tourist lodges are also available in Kantishna.
- Subsistence hunting, fishing, and gathering. Traditional subsistence uses by local rural residents are allowed in the Kantishna area (but not in the Denali Wilderness). Subsistence uses are likely to continue into the future.
- Residential land use. Although there is no residential land use within the Denali Wilderness, private property exists in the Denali National Park additions (Kantishna area).

3.2 Identification of Exposure Pathways

3.2.1 Sources and Receiving Media

The primary sources and receiving media by which metals from the proposed gravel borrow (placer tailings) would be released into the environment are from processing of the tailings and placement and compaction onto the park road, viewing areas, campgrounds, parking areas, and administrative areas. To utilize the placer tailings from the borrow area for road maintenance purposes, the material would be crushed to ¾ to ½ inch minus.

3.2.2 Fate and Transport in Release Media

There are three main transport mechanisms for the metals contained in the gravel incorporated into road and traffic areas.

Transport Mechanism	Fate
Mechanical or wind generated soil particles (dust or fines) from road surfaces	• suspended dust • plant leaves to food chain • soil • sediment • surface water
Surface water runoff from precipitation or snowmelt containing suspended particles or dissolved metals	• roots, plants to food chain • soil • sediment • surface water

Transport Mechanism	Fate
Migration to groundwater from precipitation or snowmelt of dissolved metals	• soil • groundwater

Mechanical or wind generated soil particles (dust or fines) from road surfaces. The primary mechanism for metals leaving the roadway is the airborne transport of dust generated from the road surface. Dust will remain suspended for a time before settling into or on vegetation, adjacent soil, sediment, or surface water. A secondary mechanism is mechanical generated dust via vehicle tires or spray/splash from road traffic during wet weather. Dust is expected to settle out of the air within 150 feet of the road. The park road is seasonal and is closed during the winter season.

> A study to measure dust accumulation from the Park Road in the Teklanika area found that these effects are greatest within the first 5 meters from the road, and decline rapidly as distance from the road increases until about 50 meters from the road, where conditions are nearly indistinguishable from background dust deposition levels []. (MEG 2005)

During the 2007 investigation, the soil was covered with vegetation in most of the study area. Bare soil was observed along cut banks, fill banks, and on the unpaved roads. Sediment is associated with the numerous streams, rivers, and ponds in the area. Surface water parallels the park road for the entire study area.

Surface water runoff from precipitation or snowmelt containing suspended particles or dissolved metals. Surface water runoff from precipitation and melting snow may transport metals off the roadway. However, total annual precipitation is 15 to 20 inches which includes about 81 inches of snowfall (see section 3.1.1 Physical Setting). This mechanism will be more prevalent in the immediate vicinity of the roadway, but it is not likely to carry soil particles or dissolved metals a long distance compared to windblown transport. Soil particles may also be transported by runoff into streams at road crossings or from the tundra into streams. However, these mechanisms will be inhibited by physical filtration within the tundra or by interacting with the organic material in the tundra.

Transport of the metals in the dissolved state will depend on the form of the metal in the minerals. The Kantishna and Denali areas have 14 minerals that contain arsenic or antimony (Table 4). (MDAT 2007, ADNR 1974, ADNR 1975, ADNR 1976, USGS 1918, USGS 1919, USGS 1933, USGS 1981, USGS 2000). The most prevalent minerals for arsenic and antimony are arsenopyrite and stibnite (Trainor 2007, Sanders 2007).

The environmental behavior and dissolution mechanisms of arsenopyrite and stibnite are not well understood. Reaction rates and pathways vary depending on the pH, bacteria, redox conditions, dissolved oxygen, iron oxides, and organic matter. Within the same soil matrix, mechanisms can vary from one microenvironment to another as conditions change (oxygen content drops, pH changes, etc.). Acid mine drainage results from dissolution of sulfide minerals and the production of sulfuric acid. The metals may be released into surface waters, rendering them non-potable.

Arsenopyrite and stibnite oxidize readily but not fast, and act as a long term source of soluble, oxidized As and Sb. Some sites in interior Alaska have quite high dissolved concentrations in the source regions associated with slow oxidation of tailings (that are over 50 years old and have very high weight percent stibnite), even in well buffered circumneutral pH waters. The dominant sequestration mechanism is adsorption to fine grained (secondary) minerals (iron-oxides primarily). (Trainor 2007)

Table 4 – Antimony and Arsenic Minerals in the Kantishna and Denali Area

Mineral	Chemical Formula	Mineral	Chemical Formula
Arsenopyrite	FeAsS	Proustite (ruby silver)	Ag_3AsS_3
Boulangerite	$Pb_5Sb_4S_{11}$	Pyrargyrite (ruby silver)	Ag_3SbS_3
Bournonite	$PbCuSbS_3$	Scorodite	$Fe^{3+}AsO_4 \cdot 2H_2O$
Freibergite	$(Ag,Cu,Fe)_{12}(Sb,AS)_4S_{13}$	Stephanite	Ag_5SbS_4
Jamesonite	Pb_4FeSb_6S14	Stibiconite (antimony ochre)	$SbSb_2O_6(OH)$
Kermesite	Sb_2S_2O	**Stibnite**	Sb_2S_3
Polybasite	$(Ag,Cu)_{16}(Sb,As)_2S_{11}$	Tetrahedrite	$(Cu,Fe,Ag,Zn)_{12}Sb_4S_{13}$
Bolded text indicates the more prevalent arsenic and antimony minerals in the Kantishna area.			

Figure 1 demonstrates the complexity of stibnite dissolution. Additional oxidation products may also include: $Sb(OH)_3$, $HSb_2S_4^-$, $Sb_2S_4^{2-}$, $Sb(OH)_6^-$, $Sb(OH)_2^+$, and Sb_2O_5. Antimony tends to adsorb to fine grained (secondary) minerals (mainly iron-oxides) under conditions with high iron oxide content, high manganese content, high aluminum content, moderate pH, or organic matter content. (Beak 2002, UONZ 2007, UWM 2003, PNNL 2002, Johnson 2005, Morin 2006, Foley 2004).

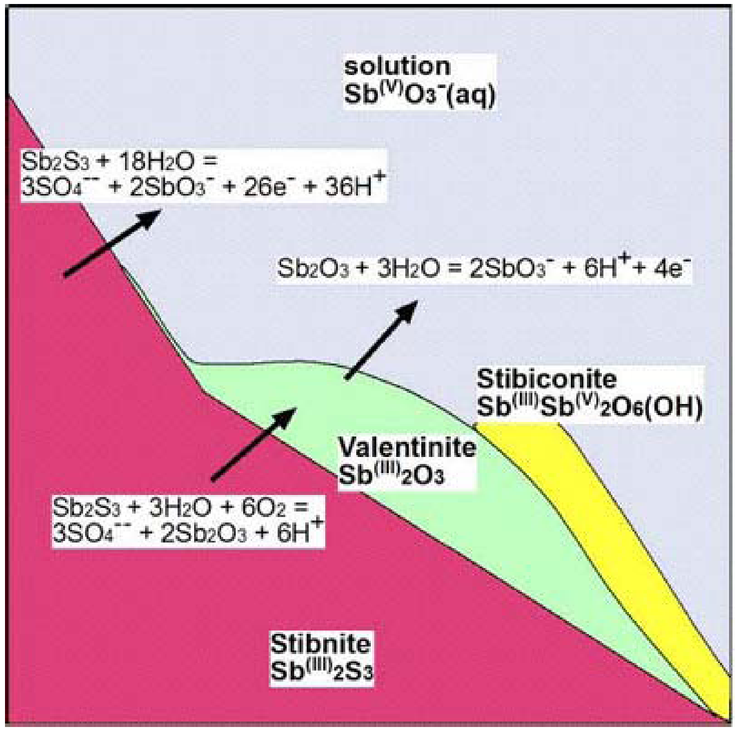

Figure 1 – Stibnite Oxidation (UONZ 2007)

Arsenopyrite also exhibits complicated dissolution processes. A typical dissolution equation is:

$$2FeAsS + 14Fe^{3+} + 3\ H_2O \text{ — } 16\ Fe^{2+} + S_2O_3^{2-}\ (aq) + 6H^+ + 2As^{3+}\ (aq)$$

A rate limiting step may be ferrous – ferric ion pathway,

$$2Fe^{2+} + \tfrac{1}{2}\ O_2 + 2H^+ \text{ — } 2Fe^{3+} + H_2O$$

The thiosulfate ion may further oxidize,

$$S_2O_3^{2-} \text{ — } SO_4^{2-}\ \text{(sulfate)},$$

or to elemental sulfur which is relatively insoluble in water.

Arsenopyrite may also oxidize as:

$$FeAsS + 14Fe^{3+} + 10\ H_2O \text{ — } 14\ Fe^{2+} + SO_4^{2-} + FeAsO_4 \cdot 2\ H_2O\ \text{(scorodite)} + 16H^+$$

Another oxidation pathway is:

$$FeAsS + 5\tfrac{1}{2}\ O_2\ (aq) + 3H_2O \text{ — } 2Fe^{2+}\ (aq) + 2H_3AsO_3\ (aq) + 2\ SO_4^{2-}\ (aq)$$

and with further dissolution,

$$H_3AsO_3 + \tfrac{1}{2}\ O_2\ (aq) \text{ — } H_2AsO_4^- + H^+$$

The dominant sequestration mechanism for arsenopyrite is also adsorption to fine grained (secondary) minerals (iron-oxides primarily).

Although stibnite and arsenopyrite are the primary antimony and arsenic bearing minerals in the Kantishna area, other minerals are also present (Table 4). Each of these has its own dissolution pathways and variables. There is a potential for arsenic and antimony to leach out of the placed borrow material at a greater concentration than that of the surrounding background. However, the mass of arsenic and antimony contained in the placed borrow is insignificant compared to the surrounding soil. For instance, a hypothetical road cross-section of 0.5-ft by 24-ft and a hundred foot length would contain 4.3 kilograms (kg) of arsenic[2] and 1.3 kg of antimony (assuming 100% construction with the proposed borrow material). Taking a road corridor width of 100 feet by 10 feet deep by 100-feet in length, the amount of arsenic would be 120 kg and antimony would be 10 kg.[3] (using background concentrations). The addition of a surface course of gravel with slightly elevated arsenic and antimony concentrations will not measurably impact the transport of dissolved or suspended particles of these two metals.

Migration to groundwater from precipitation or snowmelt of dissolved metals. Migration to groundwater of dissolved metals is a potential transport mechanism. Groundwater depth is not well documented in the study area and the hydrogeology is complicated with surface water bodies and discontinuous permafrost. Areas of leaching would be limited to those directly beneath the placed gravels (road, parking areas, parking areas, etc.). However, the same approach used for surface water runoff can be applied to the dissolved metals migrating to groundwater. A thin layer of gravel with slightly elevated arsenic and antimony concentrations will not significantly add to the amount of arsenic and antimony already leaching from the surrounding terrain.

3.2.3 Exposure Points and Exposure Routes

Receptors may be exposed to arsenic and antimony from the placed borrow material in the air, vegetation, soil, sediment, and surface water within 150 feet of the placed gravel. An additional exposure point may be from wells in the immediate vicinity of the placed gravel. Exposure routes include:

- inhalation of particulates,
- incidental ingestion of soil (dust),
- ingestion of surface water,
- ingestion of groundwater,
- ingestion of edible plants,
- dermal contact with gravel on the road,
- dermal contact with dust settling on exposed skin, and
- dermal contact with surface water.

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[2] Example calculation: (0.5-ft)(24-ft)(100-ft)(120 lb/CF) = 144,000 lb gravel = 65,317 kg gravel; (66 mg/kg As) (65,317 kg gravel) / (10^6 mg/kg) = 4.3 kg As.

[3] Although the dimensions of this road corridor are arbitrary, they point out the small amount of arsenic and antimony in the borrow material compared to the surrounding terrain. See Picture 2.

3.2.4 Integration of Pathway Components

This section integrates the sources, releases, fate and transport mechanisms, exposure points, and exposure routes to determine the complete exposure pathways that may exist. A pathway is complete if there is (1) a source or chemical release from a source, (2) an exposure route by which the chemical is transported to potential receptors, and (3) an exposure point where intake can occur. This is a refinement of the initial CSM and includes all complete exposure pathways (Appendix A).

From all complete exposure pathways at the site, those pathways that will be evaluated further in the exposure assessment are selected. Criteria for eliminating a pathway from detailed analysis include:

- the exposure resulting from the pathway is much less than that from another pathway involving the same medium at the same exposure point;
- the potential magnitude of exposure from a pathway is low; or
- the probability of the exposure occurring is very low and the risks associated with the occurrence are not high (if a pathway has catastrophic consequences, it should be selected for evaluation even if its probability of occurrence is very low). (EPA 1989, p. 6-17)

The final human health CSM (Appendix A) details eight complete exposure pathways.[4] These pathways and potential receptors are shown in Table 5.

Table 5 – Complete Exposure Pathways

Exposure Pathway	Current and Future Receptors
Incidental Soil Ingestion	Residents, Commercial or Industrial Workers, Recreational Users, Construction Workers, Subsistence Harvesters
Dermal Absorption of Contaminants from Soil	Residents, Commercial or Industrial Workers, Recreational Users, Construction Workers, Subsistence Harvesters
Ingestion of Groundwater	Residents, Recreational Users
Inhalation of Fugitive Dust	Residents, Commercial or Industrial Workers, Recreational Users, Construction Workers, Subsistence Harvesters
Ingestion of Surface Water	Residents, Recreational Users
Dermal Absorption of Contaminants in Surface Water	Residents, Recreational Users
Direct Contact with Sediment	Recreational Users
Ingestion of Wild Foods	Subsistence Consumers

[4] The initial CSM contained only six exposure pathways. See Appendix A.

Incidental Soil Ingestion. Current and potential future receptors include residents, commercial or industrial workers, recreational users, construction workers, and subsistence harvesters. The most exposed receptors are the commercial or industrial worker and the construction worker. The incidental soil ingestion would be from the fugitive dust suspended in the air near the park road from traffic. Although the concentration of arsenic and antimony in the proposed borrow source is less than background in DU1 and DU2 (near Kantishna) the use of the gravel on the road creates a new pathway by mobilizing the metals in the fugitive dust from vehicle traffic. The commercial or industrial worker and construction worker would frequently be in the vicinity of the road during work activities. Residents in Kantishna, recreational users, and subsistence harvesters have a much lower potential exposure frequency and duration as they would be in the fugitive dust less often than those working on the road.

Dermal Absorption of Contaminants from Soil. This pathway has the same receptors and similar exposure as for incidental soil ingestion. The most exposed receptors are the commercial or industrial worker and the construction worker. Dermal exposure would be from fugitive dust contact with exposed skin.

Ingestion of Groundwater. Current and potential future receptors include residents and recreational users. The potential magnitude and probability of exposure from this pathway is low. This is due to the low mass of arsenic and antimony in the roadbed (see footnotes page 14). Metals concentrations in groundwater are likely derived from background concentration of metals in the soil.

Inhalation of Fugitive Dust. This pathway is almost identical to the incidental soil ingestion pathway. The only difference is the exposure route into the receptor. The fugitive dust from the dust clouds on the road would be inhaled instead of ingested. As with the ingestion pathway, the most exposed receptors are the commercial or industrial worker and the construction worker.

Ingestion of Surface Water. The current and potential future receptors are the resident and recreational user. Some of the residents in the Kantishna and Wonder Lake area use surface water as a potable water source for drinking. Backcountry campers, bikers, and hikers may use surface water as drinking water. Due to naturally high concentrations of background metals, the NPS already has cautionary warnings posted about this hazard. The same rationale as noted in the ingestion of groundwater pathway applies here. The mass of arsenic and antimony added to the water from placement of the proposed borrow source on roads is negligible compared to natural background concentrations. Although there are surface water sources in the area used for potable water, the mass of arsenic and antimony that may leach from the roadbed material and enter water bodies is low compared to the leaching from the naturally occurring metals concentrations. The potential magnitude and probability of exposure from metals, due to this exposure pathway, in the surface water is low.

Dermal Absorption of Contaminants in Surface Water. The current and potential future receptors are the resident and recreational user. Some of the residents in the Kantishna and Wonder Lake area use surface water as a potable water source for washing. The potential magnitude and probability of exposure is low. Due to the cooler temperatures, swimming and wadding are not popular activities. Also, as noted in the 'ingestion of surface water' description above, the mass of arsenic and antimony that may leach from the roadbed material and enter the water bodies is low compared to the leaching from the naturally occurring metals concentrations.

Direct Contact with Sediment. The cooler climate of the area discourages recreational users from entering the surface water bodies and becoming exposed to sediments or water. The potential magnitude and probability of exposure is low.

Ingestion of Wild Foods. Subsistence harvesting is not allowed within the Denali Wilderness area where most of the park road is located. Subsistence harvesting is allowed in the Denali Park additions (Kantishna area). The natural background levels of arsenic and antimony in the Kantishna area soils are higher than that of the proposed borrow area. The predominant exposure would be from fugitive dust accumulating on plants within 150 feet of the road. Subsistence consumers may be exposed to fugitive dust if plants near the road are harvested and not rinsed off prior to consumption. The potential magnitude and probability of exposure is low.

3.2.5 Summary of Information on All Completed Pathways

This section summarizes pertinent information on all complete exposure pathways in the study area. Potentially exposed populations, exposure media, exposure points, and exposure routes are identified. (See also the CSM, Appendix A.) Table 6 identifies the pathways retained for quantitative evaluation. No change in current land use is expected in the near future.

Table 6 – Exposure Pathway Summarization

Potentially Exposed Population	Exposure Route, Medium and Exposure Point	Pathway Selected for Evaluation?	Reason for Selection or Exclusion
Residents	Incidental ingestion of soil from placed gravel from proposed borrow source	No	The potential for significant exposure via this pathway is low because the potential exposure frequency and duration is also low. Residents would tend to avoid dust clouds as opposed to workers who would be on the road more often. Metals concentrations in the proposed borrow source gravel is less than background in the Kantishna area.
Residents	Dermal absorption of contaminants from placed gravel from proposed borrow source	No	The potential for significant exposure via this pathway is low because of lower traffic in the Kantishna area which produces less fugitive dust. Potential exposure frequency and duration is also low. Metals concentrations in the proposed borrow source gravel is less than background in the Kantishna area.

Potentially Exposed Population	Exposure Route, Medium and Exposure Point	Pathway Selected for Evaluation?	Reason for Selection or Exclusion
Residents	Ingestion of Groundwater	No	The potential for significant exposure via this pathway is low because the mass of arsenic and antimony added by placement of the gravel from the proposed borrow source is less than the naturally occurring background concentrations in the Kantishna area.
Residents	Inhalation of fugitive dust from placed gravel from proposed borrow source	No	The potential for significant exposure via this pathway is low because of lower traffic in the Kantishna area which produces less fugitive dust. Potential exposure frequency and duration is also low. Metals concentrations in the proposed borrow source gravel is less than background in the Kantishna area.
Residents	Ingestion of surface water	No	The potential for significant exposure via this pathway is low because the mass of arsenic and antimony added by placement of the gravel from the proposed borrow source is less than the naturally occurring background concentrations in the Kantishna area.
Residents	Dermal absorption of contaminants in surface water	No	The potential for significant exposure via this pathway is low because the mass of arsenic and antimony added by placement of the gravel from the proposed borrow source is less than the naturally occurring background concentrations in the Kantishna area.
Commercial or Industrial Workers	Incidental ingestion of soil from placed gravel from proposed borrow source	Yes	Placement of gravel from the proposed borrow source on traffic areas will result in fugitive dust to which workers may be exposed. Previous studies indicate significant dust exposure to workers (FHWA 2006).
Commercial or Industrial Workers	Dermal absorption of contaminants from placed gravel from proposed borrow source	Yes	Placement of gravel from the proposed borrow source on traffic areas will result in fugitive dust to which workers may be exposed. Previous studies indicate significant dust exposure to workers (FHWA 2006).
Commercial or Industrial Workers	Inhalation of fugitive dust from placed gravel from proposed borrow source	Yes	Placement of gravel from the proposed borrow source on traffic areas will result in fugitive dust to which workers may be exposed. Previous studies indicate significant dust exposure to workers (FHWA 2006).

Potentially Exposed Population	Exposure Route, Medium and Exposure Point	Pathway Selected for Evaluation?	Reason for Selection or Exclusion
Recreational Users	Incidental ingestion of soil from placed gravel from proposed borrow source	No	The potential for significant exposure via this pathway is low because potential exposure frequency and duration is low.
Recreational Users	Dermal absorption of contaminants from placed gravel from proposed borrow source	No	The potential for significant exposure via this pathway is low because potential exposure frequency and duration is low.
Recreational Users	Ingestion of Groundwater	No	The potential for significant exposure via this pathway is low because potential exposure frequency and duration is low. Also, the mass of arsenic and antimony added by placement of the gravel from the proposed borrow source is insignificant compared to the mass of the background metals that are naturally occurring.
Recreational Users	Inhalation of fugitive dust from placed gravel from proposed borrow source	No	The potential for significant exposure via this pathway is low because potential exposure frequency and duration is low. Recreational users will tend to avoid fugitive dust clouds when possible.
Recreational Users	Ingestion of surface water	No	The potential for significant exposure via this pathway is low because potential exposure frequency and duration is low. Also, the mass of arsenic and antimony added by placement of the gravel from the proposed borrow source is insignificant compared to the mass of the background metals that are naturally occurring.
Recreational Users	Dermal absorption of contaminants in surface water	No	The potential for significant exposure via this pathway is low because potential exposure frequency and duration is low. Also, the mass of arsenic and antimony added by placement of the gravel from the proposed borrow source is insignificant compared to the mass of the background metals that are naturally occurring.

Potentially Exposed Population	Exposure Route, Medium and Exposure Point	Pathway Selected for Evaluation?	Reason for Selection or Exclusion
Recreational Users	Direct contact with sediment	No	The potential for significant exposure via this pathway is low because potential exposure frequency and duration is low. Also, the mass of arsenic and antimony added by placement of the gravel from the proposed borrow source is insignificant compared to the mass of the background metals that are naturally occurring.
Construction Workers	Incidental ingestion of soil from placed gravel from proposed borrow source	Yes	Placement of gravel from the proposed borrow source on traffic areas will result in fugitive dust to which workers will be exposed. Previous studies indicate significant dust exposure to workers (FHWA 2006).
Construction Workers	Dermal absorption of contaminants from placed gravel from proposed borrow source	Yes	Placement of gravel from the proposed borrow source on traffic areas will result in fugitive dust to which workers will be exposed. Previous studies indicate significant dust exposure to workers (FHWA 2006).
Construction Workers	Inhalation of fugitive dust from placed gravel from proposed borrow source	Yes	Placement of gravel from the proposed borrow source on traffic areas will result in fugitive dust to which workers will be exposed. Previous studies indicate significant dust exposure to workers (FHWA 2006).
Subsistence Harvesters	Incidental ingestion of soil from placed gravel from proposed borrow source	No	The potential for significant exposure via this pathway is low because of lower traffic in the Kantishna area which produces less fugitive dust. Potential exposure frequency and duration is also low. Metals concentrations in the proposed borrow source gravel is less than background in the Kantishna area.
Subsistence Harvesters	Dermal absorption of contaminants from placed gravel from proposed borrow source	No	The potential for significant exposure via this pathway is low because of lower traffic in the Kantishna area which produces less fugitive dust. Potential exposure frequency and duration is also low. Metals concentrations in the proposed borrow source gravel is less than background in the Kantishna area.

Potentially Exposed Population	Exposure Route, Medium and Exposure Point	Pathway Selected for Evaluation?	Reason for Selection or Exclusion
Subsistence Harvesters	Inhalation of fugitive dust from placed gravel from proposed borrow source	No	The potential for significant exposure via this pathway is low because of lower traffic in the Kantishna area which produces less fugitive dust. Potential exposure frequency and duration is also low. Metals concentrations in the proposed borrow source gravel is less than background in the Kantishna area.
Subsistence Consumers	Ingestion of wild foods in the vicinity of the gravel from the proposed borrow source	No	The potential magnitude and probability of exposure is low. The natural background of arsenic and antimony in the Kantishna area is higher than that of the proposed borrow area. The only exposure would be from fugitive dust from the road settling on plants within 150 feet of the road. Subsistence consumers may be exposed to the fugitive dust if plants from near the road were harvested and the dust not rinsed prior to consumption.

3.3 Quantification of Exposure

The next step in the exposure assessment process is to quantify the magnitude, frequency and duration of exposure for the populations and exposure pathways selected for quantitative evaluation.

3.3.1 Exposure Concentrations

Exposure concentrations are derived directly from the multi-incremental sampling conducted in 2007. These concentrations are shown in Table 7.

Table 7 – Summary of Exposure Concentrations

Pathways	Exposure Concentration	Comments
Incidental soil ingestion and dermal absorption of metals from soil:		
Arsenic	66 mg/kg	Concentrations are the average of borrow source from 2007 multi-incremental sampling based on a fundamental error of 10%.
Antimony	20 mg/kg	
Inhalation of dust:		
Arsenic	0.0066 ug/m^3	Concentrations based on measured respirable dust level (0.1 mg/m^3) (FHWA 2006) and 2007 sampling results of proposed borrow area.
Antimony	0.0020 ug/m^3	

3.3.2 Estimation of Chemical Intakes

Exposure is defined as the contact of an organism with a chemical or physical agent. If exposure occurs over time, the total exposure can be divided by a time period of interest to obtain an average exposure rate per unit time. This average exposure rate also can be expressed as a function of body weight. Therefore, exposure normalized for time and body weight is termed "intake," and is expressed in units of mg chemical/kg body weight · day.

3.3.2.1 Chemical Intake for Incidental Ingestion of Soil

The equation for calculating intake of chemicals from soil ingestion is shown in Table 8 (EPA 1989). Table 11 shows the workers that may be present in the area where gravel from the proposed borrow source may be used on the road. Table 12 shows the calculated intakes for the various workers for arsenic (both non-carcinogenic and carcinogenic effects) and antimony. Intakes were calculated for both the average exposure duration and the maximum expected exposure duration.

Table 8 –Standard Equation and Parameters for Soil Ingestion

$$\text{Intake (mg/kg} \cdot \text{day)} = \frac{CS \times IR \times CF \times FI \times EF \times ED}{BW \times AT}$$

Parameters:		
CS	=	chemical concentration; the average concentration contacted over the exposure period (mg/kg soil)
IR	=	ingestion rate (mg soil/day)
CF	=	conversion factor (10^{-6} kg/mg)
FI	=	fraction ingested from contaminated source (unitless)
EF	=	exposure frequency (days/years)
ED	=	exposure duration (years)
BW	=	body weight; the average body weight over the exposure period (kg)
AT	=	averaging time; period over which exposure is averaged (days)
Values:		
CS	=	66 mg/kg for arsenic (site-specific measured value) 20 mg/kg for antimony (site-specific measured value)
IR	=	100 mg/day (EPA 2001)
CF	=	10^{-6} kg/mg
FI	=	pathway-specific value; considered 1 for this study with the assumption that the entire road is topped with gravel from the proposed borrow source
EF	=	numbers from Table 11 (days per week x weeks/year)

Table 8 (cont.)			
		Kantishna Air Transport Driver	78 days/yr
		Kantishna VTS Shuttle Bus Drivers	52 days/yr
		Kantishna Business Bus Drivers	52 days/yr
		Wonder Lake Grader Operator (roading)	68 days/yr
		Wonder Lake Grader Operator (grading)	13 days/yr
		Brush Crew	28 days/yr
		Wonder Lake Laborer	25 days/yr
		Wonder Lake Rangers	64 days/yr
		Gravel Processing Crew	48 days/yr
		Dump truck drivers	32 days/yr
		Denali Backcountry lodge employees	32 days/yr
ED	=	numbers from Table 11 average (extreme)	
		Kantishna Air Transport Driver	5 (15) years
		Kantishna VTS Shuttle Bus Drivers	3 (20) years
		Kantishna Business Bus Drivers	3 (10) years
		Wonder Lake Grader Operator (roading)	5 (10) years
		Wonder Lake Grader Operator (grading)	5 (10) years
		Brush Crew	1 (5) years
		Wonder Lake Laborer	5 (10) years
		Wonder Lake Rangers	1 (5) years
		Gravel Processing Crew	1 (2) years
		Dump truck drivers	1 (5) years
		Denali Backcountry lodge employees	1 (3) years
BW	=	70 kg (EPA 1989, EPA 2001)	
AT	=	pathway-specific period of exposure for Noncarcinogenic effects (ED x 365 days/year); and 70 year lifetime for carcinogenic effects (70 years x 365 days/year); (EPA 1989, EPA 2001)	

3.3.2.2 Chemical Intake for Dermal Absorption of Contaminants from Soil

The standard equation and parameters for dermal contact with chemicals in soil are shown in Table 9.

> As with other contact rates (e.g., soil ingestion), the recommended default value is a conservative, health protective value. To maintain consistency with this approach (i.e., recommending a high-end of a mean), two options exist when recommending default weighted AFs [adherence factor]: (1) select a central tendency (i.e., typical) soil contact activity and use the high-end weighted AF (i.e., 95th percentile) for that activity; or (2) select a high-end (i.e., reasonable but higher exposure) soil contact activity and use the central tendency weighted AF (i.e., 50th percentile) for that activity. (EPA 2004, p. 3-14)

Option 2 was used for this study. The type of worker (e.g., driver, brush crew, lodge employees) is well documented and their soil contact can be reasonably well estimated.

Table 9 – Standard Equation and Parameters for Dermal Contact

$$DAD = \frac{DA_{event} \times EF \times ED \times EV \times SA}{BW \times AT}$$ (EPA 2004, Eqn. 3.11)

where:

Parameter		Definition (units)	Value
DAD	=	Dermal Absorbed Dose (mg/kg·event)	--
DA_{event}	=	Absorbed dose per event (mg/cm^2·day)	see below
SA	=	Skin surface area available for contact (cm^2)	2,479 cm^2 (EPA 2004, Eqn. 3.14)
EV	=	Event frequency (events/day)	1 (EPA 2004, Exhibit 3-5)
EF	=	Exposure frequency (days/year)	(same as for ingestion, Table 8)
ED	=	Exposure duration (years)	(same as for ingestion, Table 8)
BW	=	Body weight (kg)	70 kg (EPA 2004)
AT	=	Averaging time (days)	(same as for ingestion, Table 8)

$$DA_{event} = CS \times CF \times AF \times ABS_d$$ (EPA 2004, Eqn. 3.12)

where:

Parameter		Definition (units)	Value
DA_{event}	=	Absorbed dose per event (mg/cm^2·event)	--
CS	=	Chemical concentration in soil (mg/kg)	66 mg/kg for As; 20 mg/kg for Sb
CF	=	Conversion factor (10^{-6} kg/mg)	10^{-6} kg/mg
AF	=	Adherence factor of soil to skin (mg/cm^2·event)	(EPA 2004, Exhibit 3-3)
		Kantishna Air Transport Driver	0.1
		Kantishna VTS Shuttle Bus Drivers	0.1
		Kantishna Business Bus Drivers	0.1
		Wonder Lake Grader Operator (roading)	0.2
		Wonder Lake Grader Operator (grading)	0.2
		Brush Crew	0.1
		Wonder Lake Laborer	0.1
		Wonder Lake Rangers	0.02
		Gravel Processing Crew	0.6
		Dump truck drivers	0.2
		Denali Backcountry lodge employees	0.02
ABS_d	=	Dermal absorption fraction	0.03 (As, EPA 2004, Exhibit 3-4)
			0.001 (Sb, ORNL 2007)

3.3.2.3 Chemical Intake from Inhalation of Fugitive Dust

The intake equation for fugitive dust is modified after EPA 1989 (p. 6-44) and is shown in Table 10.

Table 10 – Standard Equation and Parameters for Inhalation Contact

$$\text{Intake (mg/kg·day)} = \frac{CA \times IR \times ET \times EF \times ED}{BW \times AT}$$

Where:			
	CA	=	Contaminant Concentration in Air (mg/m^3)
			(chemical concentration in soil / particulate emission factor)
	IR	=	Inhalation Rate (m^3/hour)
	ET	=	Exposure Time (hours/day)
	EF	=	Exposure Frequency (days/year)
	ED	=	Exposure Duration (years)
	BW	=	Body Weight (kg)
	AT	=	Averaging Time (period over which exposure is averaged, days)
Variable Values:			
	CA:		As: 66 mg/kg / 1E+7 m^3/kg = 0.0000066 mg/m^3
			Sb: 20 mg/kg / 1E+7 m^3/kg = 0.0000020 mg/m^3
			(soil As & Sb conc.; OSHA measurement in FHWA 2006)
	IR:		1.1 m^3/hour (outdoor worker slow activities);
			1.5 m^3/hour (outdoor worker moderate activities);
			2.5 m^3/hour (outdoor worker heavy activities);
			(EPA 1997, Table 5-23)
			Assume slow activities for all workers except for grader operators, rangers, and dump truck drivers (moderate); brush crew, Wonder Lake laborer, gravel processing crew (all heavy);
	ET:		6 hours/day;
			4 hours/day: Denali Backcountry lodge employees, Wonder Lake Rangers;
			10 hours/day: grader operator, gravel processing crew, dump truck drivers;
			Conservative assumption based on type of work (see Table 11) and probability of worker breathing in the fugitive dust (dust cloud from road traffic).
	EF:		(same as for ingestion, Table 8)
	ED:		(same as for ingestion, Table 8)
	BW:		70 kg (EPA 2004)
	AT:		(same as for ingestion, Table 8)

Table 11 – Worker Exposures

Job	Trips/Day	AvgHrs /Day	Days /Wk	Weeks	Multi Year?	Possible Seasons of Exposure average(extreme)	
Kantishna Air Transport Driver	6	5.5	6	13	Yes	5 (15)	All driving done within affected section. Continuously transports clients from Kantishna lodges to Kantishna airstrip.
Kantishna VTS Shuttle Bus Drivers	1 RT	3	4	13	Yes	3 (20)	Most are much less, one long time driver.
Kantishna Business Bus Drivers	1 RT	2.5	4	13	Yes	3 (10)	Most are much less.
Wonder Lake Grader Operator (roading)	1 RT	2	4	17	Yes	5 (10)	Traveling through affected section to work on other sections.
Wonder Lake Grader Operator (grading)	Continuous	10	0.75 average	17	Yes	5 (10)	Grading within the affected section 4 days every three weeks. Significant dust generation/exposure from grading operation. Dust travels with machine and infiltrates the cab. Should be factored to exposure.
Brush Crew	Continuous	10	7	4	Yes	1 (5)	Work is outside adjacent to the road. Much more concentrated exposure then being in a vehicle. Very heavy exposure from every passing vehicle and from dust on brush.
Wonder Lake Laborer	1 RT	6	2.5	16	Yes	5 (10)	Works on roadside within the affected section approx 2.5 days a week. Exposed to dust generated by all vehicles.
Wonder Lake Rangers	2 RT	3	4	16	Yes	1 (5)	
Gravel Processing Crew	Continuous	8	4	12	No	1 (2)	Excavating, screening, crushing of gravel.
Dump truck drivers	Continuous	8	4	8	No	1 (5)	Generates and exposed to road dust on a daily basis while working within affected section.
Denali Backcountry Lodge employees	N/A	8	4	8	No	1 (3)	Approx. 1/4 mile downwind from gravel processing operations. Plumes will be diluted by the time they reach DBL housing.

Assumptions: 1) These positions/personnel would have the highest exposure to dust generated from Kantishna gravel. 2) Gravel would be used on twelve miles of road between mile 78 and 92. 3) Times and exposures are based on exposure to only the affected section of road. 4) Assumes worst case scenario: Dry, dusty conditions 100% of the time and no dust palliatives to encapsulate dust. 5) Wonder Lake Grader Operator is same individual with two exposure scenarios itemized. RT = roundtrip; N/A = not applicable; Source: NPS 2007b.

Table 12 – Incidental Soil Ingestion Intakes

Worker	EF d/yr	ED yr (avg ED)	ED yr (max ED)	Intake mg/kg-day As (noncar)	As (car) (avg ED)	As (car) (max ED)	Sb (noncar)
Kantishna Air Transport Driver	78	5	15	2.0149E-05	1.4392E-06	4.3176E-06	6.1057E-06
Kantishna VTS Shuttle Bus Drivers	52	3	20	1.3432E-05	5.7568E-07	3.8379E-06	4.0705E-06
Kantishna Business Bus Drivers	52	3	10	1.3432E-05	5.7568E-07	1.9189E-06	4.0705E-06
Wonder Lake Grader Operator (roading)	68	5	10	1.7566E-05	1.2547E-06	2.5094E-06	5.3229E-06
Wonder Lake Grader Operator (grading)	13	5	10	3.3581E-06	2.3987E-07	4.7973E-07	1.0176E-06
Brush Crew	28	1	5	7.2329E-06	1.0333E-07	5.1663E-07	2.1918E-06
Wonder Lake Laborer	25	5	10	6.4579E-06	4.6128E-07	9.2256E-07	1.9569E-06
Wonder Lake Rangers	64	1	5	1.6532E-05	2.3618E-07	1.1809E-06	5.0098E-06
Gravel Processing Crew	48	1	2	1.2399E-05	1.7713E-07	3.5426E-07	3.7573E-06
Dump truck drivers	32	1	5	8.2661E-06	1.1809E-07	5.9044E-07	2.5049E-06
Denali Backcountry lodge employees	32	1	3	8.2661E-06	1.1809E-07	3.5426E-07	2.5049E-06

EF = Exposure Frequency; ED = Exposure Duration; noncar = noncarcinogenic; car = carcinogenic; avg = average; max = maximum; As = arsenic; Sb = antimony;

The intake for carcinogenic effects varies depending on the exposure duration. The average exposure duration is based on the average seasons of exposure from Table 11. The maximum exposure duration is based on the extreme seasons of exposure from Table 11.

Example Calculation: Kantishna Air Transport Driver:

(arsenic, noncarcinogen, maximum (extreme) exposure duration scenario; see Tables 8 and 11):

$$\text{Intake (mg/kg·day)} = \frac{CS \times IR \times CF \times FI \times EF \times ED}{BW \times AT} = \frac{(66\text{ mg/kg})(100\text{ mg/day})(1E\text{-}6\text{ kg/mg})(1)(78\text{ days/yr})(15\text{ yrs})}{(70\text{ kg})(15\text{ yrs} \times 365\text{ days/yr})} = 2.0149E\text{-}5$$

Table 13 – Dermal Absorbed Doses

Worker	EF	ED	ED	AF	DAD mg/kg-day			
	d/yr	yr (avg ED)	yr (max ED)	mg/(cm^2-event)	As (noncar)	As (car) (avg ED)	As (car) (max ED)	Sb (noncar)
Kantishna Air Transport Driver	78	5	15	0.1	1.4985E-06	1.0703E-07	3.2110E-07	1.5136E-08
Kantishna VTS Shuttle Bus Drivers	52	3	20	0.1	9.9897E-07	4.2813E-08	2.8542E-07	1.0091E-08
Kantishna Business Bus Drivers	52	3	10	0.1	9.9897E-07	4.2813E-08	1.4271E-07	1.0091E-08
Wonder Lake Grader Operator (roading)	68	5	10	0.2	2.6127E-06	1.8662E-07	3.7324E-07	2.6391E-08
Wonder Lake Grader Operator (grading)	13	5	10	0.2	4.9949E-07	3.5678E-08	7.1355E-08	5.0453E-09
Brush Crew	28	1	5	0.1	5.3791E-07	7.6844E-09	3.8422E-08	5.4334E-09
Wonder Lake Laborer	25	5	10	0.1	4.8028E-07	3.4305E-08	6.8611E-08	4.8513E-09
Wonder Lake Rangers	64	1	5	0.02	2.4590E-07	3.5129E-09	1.7564E-08	2.4839E-09
Gravel Processing Crew	48	1	2	0.6	5.5328E-06	7.9040E-08	1.5808E-07	5.5887E-08
Dump truck drivers	32	1	5	0.2	1.2295E-06	1.7564E-08	8.7822E-08	1.2419E-08
Denali Backcountry lodge employees	32	1	3	0.02	1.2295E-07	1.7564E-09	5.2693E-09	1.2419E-09

EF = Exposure Frequency; ED = Exposure Duration; noncar = noncarcinogenic; car = carcinogenic; avg = average; max = maximum; DAD = Dermal Absorbed Dose; As = arsenic; Sb = antimony;

The intake for carcinogenic effects varies depending on the exposure duration. The average exposure duration is based on the average seasons of exposure from Table 11. The maximum exposure duration is based on the extreme seasons of exposure from Table 11.

Example Calculation: Kantishna Air Transport Driver:

(arsenic, non-carcinogen, maximum (extreme) exposure duration scenario; see Tables 9 and 11):

DA_{event} (mg/cm^2·event) = CS x CF x AF x ABS_d = (66 mg/kg)(1E-6 kg/mg)(0.1 mg/cm^2·event)(0.03) = 1.98E-7

$$DAD\ (mg/kg\cdot day) = \frac{DA_{event} \times EF \times ED \times EV \times SA}{BW \times AT} = \frac{(1.98E\text{-}7\ mg/cm^2\cdot event)(78\ days/yr)(15\ yrs)(1\ event/day)(2{,}479\ cm^2)}{(70\ kg)(15\ yr \times 365\ days/yr)} = 1.4985E\text{-}6$$

Table 14 – Intake from Inhalation of Fugitive Dust

Worker	EF	ED	ED	ET	IR	Intake (mg/kg-day)			
	d/yr	yr (avg ED)	yr (max ED)	hr/d	m3/hr	As (noncar)	As (car) (avg ED)	As (car) (max ED)	Sb (noncar)
Kantishna Air Transport Driver	78	5	15	6	1.1	1.3298E-07	9.4987E-09	2.8496E-08	4.0297E-08
Kantishna VTS Shuttle Bus Drivers	52	3	20	6	1.1	8.8654E-08	3.7995E-09	2.5330E-08	2.6865E-08
Kantishna Business Bus Drivers	52	3	10	6	1.1	8.8654E-08	3.7995E-09	1.2665E-08	2.6865E-08
Wonder Lake Grader Operator (roading)	68	5	10	10	1.5	2.6348E-07	1.8820E-08	3.7640E-08	7.9843E-08
Wonder Lake Grader Operator (grading)	13	5	10	10	1.5	5.0372E-08	3.5980E-09	7.1960E-09	1.5264E-08
Brush Crew	28	1	5	6	2.5	1.0849E-07	1.5499E-09	7.7495E-09	3.2877E-08
Wonder Lake Laborer	25	5	10	6	2.5	9.6869E-08	6.9192E-09	1.3838E-08	2.9354E-08
Wonder Lake Rangers	64	1	5	4	1.5	9.9194E-08	1.4171E-09	7.0853E-09	3.0059E-08
Gravel Processing Crew	48	1	2	10	2.5	3.0998E-07	4.4283E-09	8.8566E-09	9.3933E-08
Dump truck drivers	32	1	5	10	1.5	1.2399E-07	1.7713E-09	8.8566E-09	3.7573E-08
Denali Backcountry lodge employees	32	1	3	4	1.1	3.6371E-08	5.1959E-10	1.5588E-09	1.1022E-08

EF = Exposure Frequency; ED = Exposure Duration; noncar = noncarcinogenic; car = carcinogenic; avg = average; max = maximum;
As = arsenic; Sb = antimony; ET = exposure time; IR = inhalation rate;

Example Calculation: Kantishna Air Transport Driver:

(arsenic, non-carcinogen, maximum (extreme) exposure duration scenario; see Tables 10 and 11):

$$\text{Intake (mg/kg·day)} = \frac{\text{CA x IR x ET x EF x ED}}{\text{BW x AT}} = \frac{(6.6\text{E-6 mg/m}^3)(1.1\text{ m}^3\text{/hr})(6\text{ hrs/day})(78\text{ day/yr})(15\text{ yrs})}{(70\text{ kg})(15\text{ yrs x }365\text{ days/yr})} = 1.3298\text{E-7}$$

3.4 Identification of Uncertainties

The first step in discussion of the exposure uncertainty is a tabular summary of the values used to estimate exposure and the range of these values. See Table 15.

Table 15 – Exposure Uncertainties

Variable	Range	Midpoint	Value Used this Assessment	Brief Rationale
As concentration in soil (proposed borrow source) (mg/kg)	61, 66, 70	66	66	Average of three multi-incremental sample results.
Sb concentration in soil (proposed borrow source) (mg/kg)	19, 19, 20	20	20	Average of three multi-incremental sample results.
Soil ingestion rate , IR (mg/day)	0.56 – 480	240	100	Value recommended by EPA 2001 for outdoor worker. Recommended indoor worker IR is 50 mg/day. Range from EPA 1997.
Fraction ingested from contaminated source, FI (unitless)			1	Pathway specific value that should consider contaminant location and population activity patterns. One (1) used as conservative default assuming all exposure is to gravel from proposed borrow source.
Exposure frequency, EF (days/year)	200 - 365	282	13 - 78	ADEC 2005b list a low of 200 days/year. EPA 1989 lists a high of 365 days/year. EPA 2001 states to use a site-specific value which was done here according to Table 11. Table 11 values are conservative as number of wet days not accounted for in exposure.
Exposure duration, ED (years)	9 – 70	40	3 – 20	Professional judgment based on average and extreme lengths of employment (Table 11).
Body weight, BW (kg)	67.2 – 74.5	70.8	70	Range is from EPA 1990 (means of men and women). Value used from EPA 1989, EPA 1990, EPA 2001.
Averaging time, AT (years), non-carcinogen			ED x 365	Pathway-specific period of exposure for Noncarcinogenic effects (i.e., ED x 365 days/year). (EPA 1989)
Averaging time, AT (years), carcinogen			70	70 year lifetime for carcinogenic effects (i.e., 70 years x 365 days/year). (EPA 1989)

Variable	Range	Midpoint	Value Used this Assessment	Brief Rationale
Skin surface area available for contact, SA (cm^2)	1,841 – 3,027	2434	2,479	Range from EPA 1997, Table 6-4; Value used from EPA 2004, Eqn. 3.14 which uses a commercial/Industrial surface area equal to surface areas of head, forearms and hands. Areas are 50th percentile of average of male and female.
Event frequency, EV (events/day)			1	EPA 2004 uses 1 as default. This is reasonable as OSHA fugitive dust study (FHWA 2006) was totaled over entire work day.
Adherence factor of soil to skin, AF ($mg/cm^2 \cdot event$)	0.021 – 0.630	0.33	0.02 – 0.2	Range from EPA 2004 geometric means for industrial/commercial workers. Values used from EPA 2004, Exhibit 3-3 (matching DENA workers with workers in EPA 2004). Geometric mean used (see section 3.3.2.2 above.)
Dermal absorption fraction, ABS_d (unitless)			0.03 As 0.001 Sb	As value used is average absorption value for arsenic from EPA 2004. Sb value used is antimony specific from ORNL 2007.
Inhalation rate, IR (m^3/hour)	0.6 – 3.6	2.1	1.1, 1.5, 2.5	Range from EPA 1997, Table 5-25 for light to heavy activities. Values used from EPA 1997, Table 5-23, means for outdoor workers.
Exposure time, ET (hours/day)			4, 6, 10	Pathway specific. Professional judgment based on conservative assumption according to type of work (see Table 11) and probability of worker breathing in fugitive dust.

The second part of the uncertainty discussion is the summarization of the major assumptions of the exposure assessment, discussion of the uncertainty associated with each, and a description of how this uncertainty is expected to affect the estimate of exposure. Sources of uncertainty addressed include 1) the monitoring data, which may or may not be representative of actual conditions at the site; 2) the exposure models, assumptions and input variables used to estimate exposure concentrations (not applicable in this study); and 3) the values of the intake variables used to calculate intakes. Table 16 summarizes this information.

Table 16 – Exposure Assessment Uncertainty Table

	EFFECT ON EXPOSURE*		
ASSUMPTION	**Potential Magnitude for Over-Estimation of Exposure**	**Potential Magnitude for Under-Estimation of Exposure**	**Potential Magnitude for Over- or Under Estimation of Exposure**
Environmental Sampling and Analysis			
Sufficient analytical samples may not have been taken to characterize the media being evaluated.			Low
Systemic or random errors in the chemical analyses may yield erroneous data.			Low
Sufficient air monitoring samples may not have been taken to characterize the fugitive dust.			Low
Exposure Parameter Estimation			
The standard assumptions regarding body weight, life expectancy, population characteristics, and lifestyle may not be representative of any actual exposure situation.			Moderate
The study-specific assumptions regarding exposure frequency and exposure duration may not be representative of actual exposure situation.			Low
The amount of media intake is assumed to be constant and representative of the exposed population.	Moderate		

* As a general guideline, assumptions marked as "low," may affect estimates of exposure by less than one order of magnitude; assumptions marked "moderate" may affect estimates of exposure by between one and two orders of magnitude; and assumptions marked "high" may affect estimates of exposure by more than two orders of magnitude.

3.5 Summary of Exposure Assessment

The summary of exposure assessment is presented in Table 17. The chemical-specific intakes for each pathway are listed. No distinction is made between current and future use categories as the current use is not expected to change.

Table 17 – Summary of Exposure Assessment

Population	Exposure Pathway	Chemical	Intake (mg/kg-day)		
			Carcinogenic Effects (average exposure duration)	Noncarcinogenic Effects	Carcinogenic Effects (extreme exposure duration)
Kantishna Air Transport Driver	Incidental Soil Ingestion	Arsenic	1.4392E-06	2.0149E-05	4.3176E-06
		Antimony	--*	6.1057E-06	--*
	Dermal Absorption of Contaminants from Soil	Arsenic	1.0703E-07	1.4985E-06	3.2110E-07
		Antimony	--*	1.5136E-08	--*
	Inhalation of Fugitive Dust	Arsenic	9.4987E-09	1.3298E-07	2.8496E-08
		Antimony	--*	4.0297E-08	--*
Kantishna VTS Shuttle Bus Drivers	Incidental Soil Ingestion	Arsenic	5.7568E-07	1.3432E-05	3.8379E-06
		Antimony	--*	4.0705E-06	--*
	Dermal Absorption of Contaminants from Soil	Arsenic	4.2813E-08	9.9897E-07	2.8542E-07
		Antimony	--*	1.0091E-08	--*
	Inhalation of Fugitive Dust	Arsenic	3.7995E-09	8.8654E-08	2.5330E-08
		Antimony	--*	2.6865E-08	--*
Kantishna Business Bus Drivers	Incidental Soil Ingestion	Arsenic	5.7568E-07	1.3432E-05	1.9189E-06
		Antimony	--*	4.0705E-06	--*
	Dermal Absorption of Contaminants from Soil	Arsenic	4.2813E-08	9.9897E-07	1.4271E-07
		Antimony	--*	1.0091E-08	--*
	Inhalation of Fugitive Dust	Arsenic	3.7995E-09	8.8654E-08	1.2665E-08
		Antimony	--*	2.6865E-08	--*

Population	Exposure Pathway	Chemical	Intake (mg/kg-day)		
			Carcinogenic Effects (average exposure duration)	Noncarcinogenic Effects	Carcinogenic Effects (extreme exposure duration)
Wonder Lake Grader Operator (roading)	Incidental Soil Ingestion	Arsenic	1.2547E-06	1.7566E-05	2.5094E-06
		Antimony	--*	5.3229E-06	--*
	Dermal Absorption of Contaminants from Soil	Arsenic	1.8662E-07	2.6127E-06	3.7324E-07
		Antimony	--*	2.6391E-08	--*
	Inhalation of Fugitive Dust	Arsenic	1.8820E-08	2.6348E-07	3.7640E-08
		Antimony	--*	7.9843E-08	--*
Wonder Lake Grader Operator (grading)	Incidental Soil Ingestion	Arsenic	2.3987E-07	3.3581E-06	4.7973E-07
		Antimony	--*	1.0176E-06	--*
	Dermal Absorption of Contaminants from Soil	Arsenic	3.5678E-08	4.9949E-07	7.1355E-08
		Antimony	--*	5.0453E-09	--*
	Inhalation of Fugitive Dust	Arsenic	3.5980E-09	5.0372E-08	7.1960E-09
		Antimony	--*	1.5264E-08	--*
Brush Crew	Incidental Soil Ingestion	Arsenic	1.0333E-07	7.2329E-06	5.1663E-07
		Antimony	--*	2.1918E-06	--*
	Dermal Absorption of Contaminants from Soil	Arsenic	7.6844E-09	5.3791E-07	3.8422E-08
		Antimony	--*	5.4334E-09	--*
	Inhalation of Fugitive Dust	Arsenic	1.5499E-09	1.0849E-07	7.7495E-09
		Antimony	--*	3.2877E-08	--*

Population	Exposure Pathway	Chemical	Intake (mg/kg-day)		
			Carcinogenic Effects (average exposure duration)	Noncarcinogenic Effects	Carcinogenic Effects (extreme exposure duration)
Wonder Lake Laborer	Incidental Soil Ingestion	Arsenic	4.6128E-07	6.4579E-06	9.2256E-07
		Antimony	--*	1.9569E-06	--*
	Dermal Absorption of Contaminants from Soil	Arsenic	3.4305E-08	4.8028E-07	6.8611E-08
		Antimony	--*	4.8513E-09	--*
	Inhalation of Fugitive Dust	Arsenic	6.9192E-09	9.6869E-08	1.3838E-08
		Antimony	--*	2.9354E-08	--*
Wonder Lake Rangers	Incidental Soil Ingestion	Arsenic	2.3618E-07	1.6532E-05	1.1809E-06
		Antimony	--*	5.0098E-06	--*
	Dermal Absorption of Contaminants from Soil	Arsenic	3.5129E-09	2.4590E-07	1.7564E-08
		Antimony	--*	2.4839E-09	--*
	Inhalation of Fugitive Dust	Arsenic	1.4171E-09	9.9194E-08	7.0853E-09
		Antimony	--*	3.0059E-08	--*
Gravel Processing Crew	Incidental Soil Ingestion	Arsenic	1.7713E-07	1.2399E-05	3.5426E-07
		Antimony	--*	3.7573E-06	--*
	Dermal Absorption of Contaminants from Soil	Arsenic	7.9040E-08	5.5328E-06	1.5808E-07
		Antimony	--*	5.5887E-08	--*
	Inhalation of Fugitive Dust	Arsenic	4.4283E-09	3.0998E-07	8.8566E-09
		Antimony	--*	9.3933E-08	--*

Population	Exposure Pathway	Chemical	Intake (mg/kg-day)		
			Carcinogenic Effects (average exposure duration)	Noncarcinogenic Effects	Carcinogenic Effects (extreme exposure duration)
Dump truck drivers	Incidental Soil Ingestion	Arsenic	1.1809E-07	8.2661E-06	5.9044E-07
		Antimony	--*	2.5049E-06	--*
	Dermal Absorption of Contaminants from Soil	Arsenic	1.7564E-08	1.2295E-06	8.7822E-08
		Antimony	--*	1.2419E-08	--*
	Inhalation of Fugitive Dust	Arsenic	1.7713E-09	1.2399E-07	8.8566E-09
		Antimony	--*	3.7573E-08	--*
Denali Backcountry lodge employees	Incidental Soil Ingestion	Arsenic	1.1809E-07	8.2661E-06	3.5426E-07
		Antimony	--*	2.5049E-06	--*
	Dermal Absorption of Contaminants from Soil	Arsenic	1.7564E-09	1.2295E-07	5.2693E-09
		Antimony	--*	1.2419E-09	--*
	Inhalation of Fugitive Dust	Arsenic	5.1959E-10	3.6371E-08	1.5588E-09
		Antimony	--*	1.1022E-08	--*

* Intake for carcinogenic effects not calculated for chemicals not considered by EPA to be potential human carcinogens.

4 Toxicity Assessment

The purpose of the toxicity assessment is to weigh available evidence regarding the potential for particular contaminants to cause adverse effects in exposed individuals and to provide, where possible, an estimate of the relationship between the extent of exposure to a contaminant and the increased likelihood and/or severity of adverse effects.

EPA gathers evidence from a variety of sources regarding the potential for a substance to cause adverse health effects (carcinogenic and noncarcinogenic) in humans. These sources may include controlled epidemiologic investigations, clinical studies, and experimental animal studies. Supporting information may be obtained from sources such as in vitro test results and comparisons of structure-activity relationships.

The EPA hierarchy for toxicity values is:

- Integrated Risk Information System (IRIS) and cited references. Changes are made in this database as new chemicals or chemical information becomes available, but there may be data gaps (EPA 2007c)
- The Provisional Peer Reviewed Toxicity Values (PPRTV) and cited references developed for the EPA OSWER Office of Superfund Remediation and Technology Innovation (OSRTI) programs
- Other toxicity values

The "other" level of the hierarchy includes several sources of toxicity values that are commonly consulted by the EPA Superfund program when a relevant toxicity value is not available from either IRIS or the PPRTV database. They include:

- California Environmental Protection Agency (Cal EPA) toxicity values, available on Cal EPA's internet website (CALEPA 2007);
- The Agency for Toxic Substances and Disease Registry (ATSDR) Minimal Risk Levels (MRLs, addressing noncarcinogenic effects only), available on ATSDR's internet website (ATSDR 2007b);
- The EPA Superfund Health Effects Assessment Summary Tables (HEAST) database and cited references; and
- Additional sources of toxicity values.

4.1 Toxicity Information for Noncarcinogenic Effects

EPA uses a reference dose, or RfD, as the toxicity value to evaluate noncarcinogenic effects. A chronic RfD is defined as an estimate (with uncertainty spanning perhaps an order of magnitude or greater) of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime. Chronic RfDs are specifically developed to be protective for long-term exposure to a compound. As a guideline, chronic RfDs generally are used to evaluate the potential noncarcinogenic effects associated with exposure periods between 7 years and a lifetime. More recently, EPA has begun developing subchronic RfDs which are useful for characterizing potential noncarcinogenic effects associated with shorter-term exposures. Subchronic RfDs are used to evaluate the potential noncarcinogenic effects of exposure periods between two weeks and seven years. All DENA workers in this study have subchronic exposure for the average possible seasons of employment. All but the Brush Crew, Wonder Lake Rangers, Gravel Processing Crew, Dump Truck Drivers, and Denali Backcountry Lodge employees have chronic exposure for the maximum (extreme) periods of employment (see Table 11).

For many noncarcinogenic effects, protective mechanisms are believed to exist that must be overcome before an adverse effect is manifested. For example, where a large number of cells perform the same or similar function, the cell population may have to be significantly depleted before an effect is seen. As a result, a range of exposures exists from zero to some finite value that can be tolerated by the organism with essentially no chance of expression of adverse effects. In developing a toxicity value for evaluating noncarcinogenic effects (i.e., an RfD), the approach is to identify the upper bound of this tolerance range (i.e., the maximum subthreshold level). Because variability exists in the human population, attempts are made to identify a subthreshold level protective of sensitive individuals in the population. For most chemicals, this level can only be estimated; the RfD incorporates uncertainty factors indicating the degree or extrapolation used to derive the estimated value. RfD summaries in IRIS also contain a statement expressing the overall confidence that the evaluators have in the RfD (high, medium, low). The RfD is generally considered to have uncertainty spanning an order of magnitude or more, and therefore the RfD should not be viewed as a strict scientific demarcation between what level is toxic and nontoxic. References doses are calculated by using an experimentally derived dose called a no-observed-adverse-effect-level (NOAEL) or a lowest-observed-adverse-effect-level (LOAEL). These doses are adjusted by uncertainty factors (UF) and a modifying factor (MF).

$$RfD = NOAEL \text{ or } LOAEL / (UF_1 \times UF_2 \ldots \times MF)$$

Uncertainty factors are similar to engineering safety factors. Typical uncertainty factors include:

- A UF of 10 is used to account for variation in the general population and is intended to protect sensitive subpopulations (e.g., elderly, children).
- A UF of 10 is used when extrapolating from animals to humans. This factor is intended to account for the interspecies variability between humans and other mammals.
- A UF of 10 is used when a NOAEL derived from a subchronic instead of a chronic study is used as the basis for a chronic RfD.
- A UF of 10 is used when a LOAEL is used instead of a NOAEL. This factor is intended to account for the uncertainty associated with extrapolating from LOAELs to NOAELs.

In addition to the UFs listed above, a modifying factor (MF) is applied.

- A MF ranging from >0 to 10 is included to reflect a qualitative professional assessment of additional uncertainties in the critical study and in the entire data base for the chemical not explicitly addressed by the preceding uncertainty factors. The default value for the MF is 1.[5]

The RfDs for antimony and arsenic are shown in Table 18. A reference concentration (RfC) is similar to an RfD but based on contaminants dispersed in air.

4.1.1 Antimony

Oral RfD (chronic) is 4E-4 mg/kg·day.

The chronic RfD is from IRIS. Principal and Supporting Studies:

Schroeder, H.A., M. Mitchner and A.P. Nasor. 1970. Zirconium, niobium, antimony, vanadium and lead in rats: Life term studies. J. Nutrition. 100: 59-66.

Critical study effect: An experimental group of 50 male and 50 female rats was administered 5 ppm potassium antimony tartrate in water. Over the period of study, growth rates of treated animals were not affected, but male rats survived 106 and females 107 fewer days than did controls at median lifespans. Nonfasting blood glucose levels were decreased in treated males, and cholesterol levels were altered in both sexes. Since there was only one level of antimony administered, a NOAEL was not established in this study. A decrease in mean heart weight for the males was noted. No increase in tumors was seen as a result of treatment. Although not precisely stated, the concentration of 5 ppm antimony was expressed as an exposure of 0.35 mg/kg/day by the authors.

Ten additional studies were also listed.

Uncertainty and Modifying Factors:

UF — An uncertainty factor of 1000 (10 for interspecies conversion, 10 to protect sensitive individuals, and 10 because the effect level was a LOAEL and no NOAEL was established) was applied to the LOAEL of 0.35 mg/kg bw/day.

MF — None

Oral RfD (subchronic) is 2E-4 mg/kg·day.

The subchronic RfD is a provisional value obtained from EPA by the Oak Ridge National Laboratory (ORNL). Supporting documentation and uncertainty factors are not available but can be assumed similar to the chronic studies.

Dermal RfD (chronic) is 8E-6 mg/kg·day and (subchronic) is 4E-6 mg/kg·day.

These values are calculated from the oral RfDs (See Table 18).

Inhalation RfC (chronic) is 2E-4 mg/m^3.

The chronic inhalation RfC is from the California Environmental Protection Agency (CAL 2005).

The RfD and the RfC have the following relationship.

$$RfD_i \text{ (mg/kg·day)} = RfC \text{ (mg/m}^3\text{)} \times 20 \text{ (m}^3\text{/day)} / 70 \text{ (kg)}$$

Inhalation RfC (subchronic) is 4E-4 mg/m^3.

The subchronic RfC is a provisional value obtained from EPA by the ORNL.

[5] The MF is set less than one for a small number of substances to account for nutritional essentiality.

Table 18 – Toxicity Factors for Antimony and Arsenic

The Risk Assessment Information System http://rais.ornl.gov/tox/tox_values.shtml (modified by USACE)

Chemical	CAS #	Date Withdrawn	Absorption Factor, Dermal	Ref.	Dermal RfD - Chronic (mg/kg-day)	Ref.	Dermal RfD - Subchronic (mg/kg-day)	Ref.	Dermal SF $(mg/kg\text{-}day)^{-1}$	Ref.	GI Absorption Factor	Ref.	Inhalation Unit Risk $(mg/m^3)^{-1}$	Ref.	Oral Unit Risk $(mg/L)^{-1}$	Ref.
Antimony (metallic)	7440360		0.001	14_1	8.00E-06	CALC	4.00E-06	CALC			0.02	9_85				
Arsenic, Inorganic	7440382	01/98	0.03	14_4	1.23E-04	CALC	1.23E-04	CALC	3.66E+00	CALC	0.41	9_7	4.3E+00	IRIS	5.0E-02	IRIS

Chemical	Inhalation RfC - Chronic (mg/m^3)	Ref.	Inhalation RfC - Subchronic (mg/m^3)	Ref.	Inhalation RfD - Chronic (mg/kg-day)	Ref.	Inhalation RfD - Subchronic (mg/kg-day)	Ref.	Oral RfD - Chronic (mg/kg-day)	Ref.	Oral RfD - Subchronic (mg/kg-day)	Ref.	Inhalation SF $(mg/kg\text{-}day)^{-1}$	Ref.	Oral SF $(mg/kg\text{-}day)^{-1}$	Ref.
Antimony (metallic)	**2E-4**	**CA**	4.00E-04	PROV	**5.7E-5**	CALC	1.1E-04	CALC	4.00E-04	IRIS	2.00E-04	PROV				
Arsenic, Inorganic	**3E-5**	**CA**			**8.6E-6**	CALC			3.00E-04	IRIS	3.00E-04	HEAST	1.51E+01	u	1.50E+00	IRIS

REFERENCES:

9_7 Bettley, F.R., O'Shea, J.A. 1975. The absorption of arsenic and its relation to carcinoma. Br. J. Dermatology. 92:563. (Cited in Hindmarsh and McCurdy, 1986). **(Cited in ORNL 2007)**

9_85 Gerber, G.B., J. Maes and B. Eykens. 1982. Transfer of antimony and arsenic to the developing organism. Arch. Toxicol. 49:159-168. **(Cited in ORNL 2007)**

14_1 United States Environmental Protection Agency. 1995. Supplemental Guidance to RAGS: Region 4 Bulletins, Human Health Risk Assessment (Interim Guidance). Waste Management Division, Office of Health Assessment. **(Cited in ORNL 2007)**

14_4 Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Final. July 2004. **(Cited in ORNL 2007)**

CALC - These calculations are performed when there isn't a reference for the desired toxicity value.

1) Oral Slope Factor (OSF) to Dermal Slope Factor (DSF). OSF / GIABS=DSF.
2) Oral Reference Dose (RfDo) to Dermal Reference Dose (RfDd). RfDo* GIABS=RfDd.
3) Inhalation Reference Concentration (RfCi) to Inhalation Reference Dose (RfDi). **(RfC mg/m^3)(20 m^3/day)(1/70 kg) = RfD**
4) Oral Unit Risk (OUR) to OSF. OUR*(70 kg/2L/d)=OSF.
5) Inhalation Unit Risk (IUR) to Inhalation Slope Factor (ISF). IUR*(70 kg/20 m3)=ISF.

Note: These work for chronic and subchronic. GIABS is the gastrointestinal absorption factor (unitless).

HEAST - Values listed were taken from the EPA's Health Effects Summary Tables. **(Cited in ORNL 2007)**

IRIS - Values listed were taken from the EPA's Integrated Risk Information System.

PROV - Values listed are provisional. Other occuring sources are Superfund Health Risk Technical Support Center or draft IRIS assessments. **(Cited in ORNL 2007)**

CA - California EPA (CALEPA 2005).

u - **The Inhalation Slope Factor was calculated from inhalation unit risk as described in Supplemental Guidance from RAGS: Region 4 Bulletins, Human Health Risk Assessment (Interim Guidance) (November 1995). (Cited in ORNL 2007)**

4.1.2 Arsenic

Oral (chronic) RfD is 3E-4 mg/kg·day.

The chronic RfD is from IRIS. Principal and Supporting Studies:

Tseng, W.P. 1977. Effects and dose-response relationships of skin cancer and blackfoot disease with arsenic. Environ. Health Perspect. 19: 109-119.

Tseng, W.P., H.M. Chu, S.W. How, J.M. Fong, C.S. Lin and S. Yeh. 1968. Prevalence of skin cancer in an endemic area of chronic arsenicism in Taiwan. J. Natl. Cancer Inst. 40: 453-463.

Critical study effect: The data reported in Tseng (1977) show an increased incidence of blackfoot disease that increases with age and dose. Blackfoot disease is a significant adverse effect. The prevalences (males and females combined) at the low dose are 4.6 per 1000 for the 20-39 year group, 10.5 per 1000 for the 40-59 year group, and 20.3 per 1000 for the >60 year group. Moreover, the prevalence of blackfoot disease in each age group increases with increasing dose. However, a recent report indicates that it may not be strictly due to arsenic exposure. The data in Tseng et al. (1968) also show increased incidences of hyperpigmentation and keratosis with age. The overall prevalences of hyperpigmentation and keratosis in the exposed groups are 184 and 71 per 1000, respectively. The text states that the incidence increases with dose, but data for the individual doses are not shown. These data show that the skin lesions are the more sensitive endpoint. The low dose in the Tseng (1977) study is considered a LOAEL.

The control group described in Tseng et al. (1968; Table 3) shows no evidence of skin lesions and presumably blackfoot disease, although this latter point is not explicitly stated. This group is considered a NOAEL.

Ten additional studies were also listed.

Uncertainty and Modifying Factors:

UF — The UF of 3 is to account for both the lack of data to preclude reproductive toxicity as a critical effect and to account for some uncertainty in whether the NOAEL of the critical study accounts for all sensitive individuals.

MF — None

Oral RfD (subchronic) is 3E-4 mg/kg·day.

The subchronic RfD value is from the EPA Health Effects Summary Tables (HEAST). Supporting documentation and uncertainty factors are not available but can be assumed similar to the chronic studies.

Dermal RfD (chronic) is 1.23E-4 mg/kg·day and (subchronic) is 1.23E-4 mg/kg·day.

These values are calculated from the oral RfDs (See Table 18).

Inhalation RfC (chronic) is 3E-5 mg/m^3.

The chronic inhalation RfC is from the California Environmental Protection Agency (CAL 2005). Principle study:

Nagymajtényi L, Selypes A, and Berencsi G. 1985. Chromosomal aberrations and fetotoxic effects of atmospheric arsenic exposure in mice. J. Appl. Toxicol. 5:61-63.

Critical study effect: Reduction in fetal weight; increased incidences of intrauterine growth retardation and skeletal malformations.

Uncertainty and Modifying Factors:

UF – An uncertainty factor of 1000 (10 because the effect level was a LOAEL, 1, for subchronic uncertainty, 10 for interspecies conversion, and 10 for Intraspecies uncertainty).

Inhalation RfD (subchronic) is not available.

The chronic RfD will be used for the subchronic RfD.

4.1.3 Absorption Efficiency

The EPA has determined, from experimental results, recommended dermal absorption factors The amount of chemical absorbed from soil is dependent on a number of chemical, physical and biological factors of both the soil and the receptor. The recommended dermal absorption factor for antimony is 0.001 and for arsenic is 0.03.

The gastrointestinal absorption factor was used to calculate the dermal RfD from the oral RfD. The recommended GI absorption factor for antimony is 0.02 and for arsenic is 0.41 (see Table 18).

4.2 Toxicity Information for Carcinogenic Effects

Carcinogenesis, unlike many noncarcinogenic health effects, is generally thought to be a phenomenon for which risk evaluation based on presumption of a threshold is inappropriate. For carcinogens, EPA assumes that a small number of molecular events can evoke changes in a single cell that can lead to uncontrolled cellular proliferation and eventually to a clinical state of disease. This hypothesized mechanism for carcinogenesis is referred to as "nonthreshold" because there is believed to be essentially no level of exposure to such a chemical that does not pose a finite probability, however small, of generating a carcinogenic response. That is, no dose is thought to be risk-free. Therefore, in evaluating cancer risks, an effect threshold cannot be estimated. For carcinogenic effects, EPA uses a two-part evaluation in which the substance first is assigned a weight-of-evidence classification, and then a slope factor is calculated.

EPA normally uses the cumulative dose received over a lifetime, expressed as average daily exposure prorated over a lifetime (typically 70 years) as the appropriate measure of exposure to a carcinogen. That is, the assumption is made that a high dose of a carcinogen received over a short period of time is equivalent to a corresponding low dose spread over a lifetime.

4.2.1 Weight-Of-Evidence Classification

The first step of the toxicity assessment for carcinogenic effects is the determination of the likelihood that the chemical is a human carcinogen. The EPA uses the following classification system.

Group	Description
A	Human carcinogen
B1 or B2	Probable human carcinogen
	B1 indicates that limited human data are available.
	B2 indicates sufficient evidence in animals and inadequate or no evidence in humans.
C	Possible human carcinogen
D	Not classifiable as to human carcinogenicity
E	Evidence of noncarcinogenicity for humans

The EPA in the IRIS database classified antimony as Group D and arsenic as Group A.

4.2.2 Slope Factors

The second part of the toxicity assessment for carcinogenic effects, based on the evaluation that the chemical is a known or probable human carcinogen, is determination of a toxicity value that defines quantitatively the relationship between dose and response (i.e., the slope factor). Generally, the slope factor is a plausible upper-bound estimate of the probability of a response per unit intake of a chemical over a lifetime. The slope factor is used in risk assessments to estimate an upper-bound lifetime probability of an individual developing cancer as a result of exposure to a particular level of a potential carcinogen. A number of mathematical models and procedures have been developed to extrapolate from carcinogenic responses observed at high doses (experimental studies) to responses expected at low doses. In general, after the data are fit to the appropriate model, the upper 95th percent confidence limit of the slope of the resulting dose-response curve is calculated. This value is known as the slope factor and represents an upper 95th percent confidence limit on the probability of a response per unit intake of a chemical over a lifetime (i.e., there is only a 5 percent chance that the probability of a response could be greater than the estimated value on the basis of the experimental data and model used). The slope factor is expressed as $(\text{mg/kg}\cdot\text{day})^{-1}$.

$$\text{Slope factor} = \text{risk per unit dose}$$
$$= \text{risk per mg/kg}\cdot\text{day}$$

Toxicity values for carcinogenic effects also can be expressed in terms of risk per unit concentration of the substance in the medium where human contact occurs. For instance, in air,

$$\text{air unit risk} = \text{risk per mg/m}^3$$

4.2.3 Arsenic

Arsenic is a group A carcinogen based on sufficient evidence from human data. Increased lung cancer mortality was observed in multiple human populations exposed primarily through inhalation (smelter workers, pesticide manufacturing workers, populations near pesticide plants). Also, increased mortality from multiple internal organ cancers (liver, kidney, lung, and bladder) and an increased incidence of skin cancer were observed in populations consuming drinking water high in inorganic arsenic.

The oral slope factor is 1.5E+0 (mg/kg·day)$^{-1}$.

The slope factor is from IRIS.

Principle and supporting studies:

Tseng W.P., H.M. Chu, S.W. How, J.M. Fong, C.S. Lin, and S. Yen. 1968. Prevalence of skin cancer in an endemic area of chronic arsenicism in Taiwan. J. Natl. Cancer Inst. 40(3): 453-463.

Tseng W.P. 1977. Effects and dose-response relationships of skin cancer and Blackfoot disease with arsenic. Environ. Health Perspect. 19: 109-119.

Dermal slope factor is 3.66E+0.

The dermal slope factor was calculated from the oral slope factor (see Table 18).

The inhalation unit risk is 4.3E+0 (mg/m^3)$^{-1}$.

The inhalation unit risk is from IRIS. (The inhalation SF can be calculated from the unit risk as (4.3E+0 (mg/m^3)$^{-1}$) x ((70 kg) / (20 m^3/day)) = 1.51E+1 (mg/kg·day)$^{-1}$).

Principle and supporting studies:

Brown, C.C. and K.C. Chu. 1983a. Approaches to epidemiologic analysis of prospective and retrospective studies: Example of lung cancer and exposure to arsenic. In: Risk Assessment Proc. SIMS Conf. on Environ. Epidemiol. June 28-July 2, 1982, Alta, VT. SIAM Publications.

Brown, C.C. and K.C. Chu. 1983b. Implications of the multistage theory of carcinogenesis applied to occupational arsenic exposure. J. Natl. Cancer Inst. 70(3): 455-463.

Lee-Feldstein, A. 1983. Arsenic and respiratory cancer in man: Follow-up of an occupational study. In: Arsenic: Industrial, Biomedical, and Environmental Perspectives, W. Lederer and R. Fensterheim, Ed. Van Nostrand Reinhold, New York.

Higgins, I. 1982. Arsenic and respiratory cancer among a sample of Anaconda smelter workers. Report submitted to the Occupatinal Safety and Health Administration in the comments of the Kennecott Minerals Company on the inorganic arsenic rulemaking. (Exhibit 203-5)

Higgins, I., K. Welch and C. Burchfield. 1982. Mortality of Anaconda smelter workers in relation to arsenic and other exposures. University of Michigan, Dept. Epidemiology, Ann Arbor, MI.

Enterline, P.E. and G.M. Marsh. 1982. Cancer among workers exposed to arsenic and other substances in a copper smelter. Am. J. Epidemiol. 116(6): 895-911.

Eastern Research Group, under contract to EPA, convened an Expert Panel on Arsenic Carcinogenicity on May 21 and 22, 1997. The Expert Panel believed that, "it is clear from epidemiological studies that arsenic is a human carcinogen via the oral and inhalation routes." They also concluded, "that one important mode of action is unlikely to be operative for arsenic". The panel agreed that arsenic and its metabolites do not appear to directly interact with DNA." In addition, the panel agreed that, "for each of the modes of action regarded as plausible, the dose-response would either show a threshold or would be nonlinear". The panel agreed, however, "that the dose-response for arsenic at low doses would likely be truly nonlinear, i.e., with a decreasing slope as the dose decreased. However, at very low doses such a curve might be linear but with a very shallow slope, probably indistinguishable from a threshold." Therefore, the arsenic slope factor will be conservative at very low doses.

4.3 Uncertainties Related to Toxicity Information

Toxicity information for many chemicals is often limited. Consequently, there are varying degrees of uncertainty associated with the toxicity values calculated. Table 19 summarizes the toxicity uncertainties.

IRIS documentation for Antimony, oral RfD (chronic):

The confidence in the oral RfD:

- Study — Low
- Database — Low
- RfD — Low

"Confidence in the chosen study is rated as low because only one species was used, only one dose level was used, no NOAEL was determined, and gross pathology and histopathology were not well described. Confidence in the data base is low due to lack of adequate oral exposure investigations. Low confidence in the RfD follows." (EPA 2007c)

IRIS documentation for Arsenic, oral RfD (chronic):

The confidence in the oral RfD:

- Study — Medium
- Database — Medium
- RfD — Medium

"Confidence in the chosen study is considered medium. An extremely large number of people were included in the assessment (> 40,000) but the doses were not well-characterized and other contaminants were present. The supporting human toxicity database is extensive but somewhat flawed. Problems exist with all of the epidemiological studies. For example, the Tseng studies do not look at potential exposure from food or other source. A similar criticism can be made of the Cebrian et al.

(1983) study. The U.S. studies are too small in number to resolve several issues. However, the database does support the choice of NOAEL. It garners medium confidence. Medium confidence in the RfD follows." (EPA 2007c)

CALEPA documentation for Arsenic, inhalation RfD (chronic):

"The major strength of the REL for arsenic is the identification of an animal LOAEL that is supported by data from other studies. The major uncertainties are the lack of adequate human inhalation data, the lack of a NOAEL observation, the lack of comprehensive, long-term, multiple-dose, multiple-species studies, and the possibly marginal significance of the findings in the low dose group in the Nagymajtényi et al. (1985) study." (CALEPA 2000)

IRIS documentation for Arsenic, oral SF:

"This assessment is based on prevalence of skin cancer rather than mortality because the types of skin cancer studied are not normally fatal. However, competing mortality from Blackfoot disease in the endemic area of Taiwan would cause the risk of skin cancer to be underestimated. Other sources of inorganic arsenic, in particular those in food sources have not been considered because of lack of reliable information. There is also uncertainty on the amount of water consumed/day by Taiwanese males (3.5 L or 4.5 L) and the temporal variability of arsenic concentrations in specific wells was not known. The concentrations of arsenic in the wells was measured in the early 1960s and varied between 0.01 and 1.82 ppm. For many villages 2 to 5 analyses were conducted on well water and for other villages only one analysis was performed; ranges of values were not provided. Since tap water was supplied to many areas after 1966, the arsenic-containing wells were only used in dry periods. Because of the study design, particular wells used by those developing skin cancer could not be identified and arsenic intake could not be assigned except by village. Several uncertainties in exposure measurement reliability existed and subsequent analysis of drinking water found fluorescent substances in water that are possible confounders or caused synergistic effects. Uncertainties have been discussed in detail [in U.S. EPA (1988)]. Uncertainties in exposure measurement can affect the outcome of dose- response estimation." (EPA 2007c)

IRIS documentation for Arsenic, inhalation SF:

"Overall a large study population was observed. Exposure assessments included air measurements for the Anaconda smelter and both air measurements and urinary arsenic for the ASARCO smelter. Observed lung cancer incidence was significantly increased over expected values. The range of the estimates derived from data from two different exposure areas was within a factor of 6." (EPA 2007c)

Valence State of Antimony and Arsenic

Inorganic arsenic and antimony normally will be present in either valence states of 3+ or 5+. For both metals, the 3+ is more toxic than the 5+ state. However, the distinctions have not been emphasized in this assessment because, " (1) in most cases, the differences in the relative potency are reasonably small (about 2–3-fold), often within the bounds of uncertainty regarding NOAEL or LOAEL levels; (2) different forms of arsenic may be interconverted, both in the environment . . . and the body . . . ; and (3) in many cases of human exposure (especially those involving intake from water or soil, which are of greatest concern to residents near wastes sites), the precise chemical speciation is not known." (ATSDR 2007a)

Table 19 – Toxicity Assessment Uncertainty Table

ASSUMPTION	EFFECT OF TOXICITY		
	Potential Magnitude for Over-Estimation of Toxicity	Potential Magnitude for Under-Estimation of Toxicity	Potential Magnitude for Over- or Under-Estimation of Toxicity
Antimony Oral RfD IRIS confidence in the RfD study is low, database is low, RfD is low.			high
Antimony Dermal RfD Dermal RfD is calculated from oral using GI absorption factor			moderate
Antimony Inhalation RfD Values are provisional from EPA, assume confidence similar to oral.			high
Arsenic Oral RfD IRIS confidence in the RfD study is medium, database is medium, RfD is medium.			moderate
Arsenic Dermal RfD Dermal RfD is calculated from oral using GI absorption factor			moderate
Arsenic Inhalation RfD Derived by CALEPA			moderate
Arsenic Oral SF IRIS weight-of-evidence classification is "A."	low		
Arsenic Dermal SF Dermal SF is calculated from oral using GI absorption factor			moderate
Arsenic Inhalation SF IRIS weight-of-evidence classification is "A."	low		
Arsenic and antimony valence states vary depending on the mineral.			low

4.4 Summary of Toxicity Information

The toxicity factors and references are shown in Table 18. General descriptions of toxic effects of the two metals are below.

4.4.1 Arsenic

The following information is taken from ATSDR 2007a.

> Inorganic arsenic has been recognized as a human poison since ancient times, and large oral doses (above 60,000 ppb in water which is 10,000 times higher than 80% of U.S. drinking water arsenic levels) can result in death. If you swallow lower levels of inorganic arsenic (ranging from about 300 to 30,000 ppb in water; 100–10,000 times higher than most U.S. drinking water levels), you may experience irritation of your stomach and intestines, with symptoms such as stomachache, nausea, vomiting, and diarrhea. Other effects you might experience from swallowing inorganic arsenic include decreased production of red and white blood cells, which may cause fatigue, abnormal heart rhythm, blood-vessel damage resulting in bruising, and impaired nerve function causing a "pins and needles" sensation in your hands and feet.
>
> Perhaps the single-most characteristic effect of long-term oral exposure to inorganic arsenic is a pattern of skin changes. These include patches of darkened skin and the appearance of small "corns" or "warts" on the palms, soles, and torso, and are often associated with changes in the blood vessels of the skin. Skin cancer may also develop. Swallowing arsenic has also been reported to increase the risk of cancer in the liver, bladder, and lungs. The Department of Health and Human Services (DHHS) has determined that inorganic arsenic is known to be a human carcinogen (a chemical that causes cancer). The International Agency for Research on Cancer (IARC) has determined that inorganic arsenic is carcinogenic to humans. EPA also has classified inorganic arsenic as a known human carcinogen.
>
> If you breathe high levels of inorganic arsenic, then you are likely to experience a sore throat and irritated lungs. You may also develop some of the skin effects mentioned above. The exposure level that produces these effects is uncertain, but it is probably above 100 micrograms of arsenic per cubic meter (ug/m^3) for a brief exposure. Longer exposure at lower concentrations can lead to skin effects, and also to circulatory and peripheral nervous disorders. There are some data suggesting that inhalation of inorganic arsenic may also interfere with normal fetal development, although this is not certain. An important concern is the ability of inhaled inorganic arsenic to increase the risk of lung cancer. This has been seen mostly in workers exposed to arsenic at smelters, mines, and chemical factories, but also in residents living near smelters and arsenical chemical factories. People who live near waste sites with arsenic may have an increased risk of lung cancer as well.

If you have direct skin contact with high concentrations of inorganic arsenic compounds, your skin may become irritated, with some redness and swelling. However, it does not appear that skin contact is likely to lead to any serious internal effects.

4.4.2 Antimony

The following information is taken from ATSDR 1992.

Exposure to 9 milligrams per cubic meter of air (mg/m^3) of antimony for a long time can irritate your eyes, skin, and lungs. Breathing 2 mg/m^3 of antimony for a long time can cause problems with the lungs (pneumoconiosis) heart problems (altered electrocardiograms), stomach pain, diarrhea, vomiting and stomach ulcers. People who drank over 19 ppm of antimony once, vomited. We do not know what other health effects would occur to people who swallow antimony. We do not know if antimony can cause cancer or birth defects, or affect reproduction in humans. Antimony can have beneficial effects when used for medical reasons, It has been used as a medicine to treat people infected with parasites. Persons who have had too much of this medicine or are sensitive to it when it was injected into their blood or muscle have experienced adverse health effects. These health effects include diarrhea, joint and/or muscle pain, vomiting, problems with the blood (anemia) and heart problems (altered electrocardiograms).

Rats and guinea pigs that breathed very high levels of antimony for a short time died. Rats breathing high levels of antimony for several days had lung, heart, liver, and kidney damage. Breathing very low levels of antimony for a long time has resulted in eye irritation, hair loss, and lung damage in rats. Dogs and rats that breathed low levels of antimony for a long period had heart problems (changes in EKGs). Problems with fertility have been observed in rats that breathed very high levels of antimony for a couple of months. Lung cancer has been observed in some studies of rats breathing high concentrations of antimony. Antimony has not been classified for cancer effects by the Department of Health and Human Services, the International Agency for Research on Cancer or the Environmental Protection Agency.

Dogs that drank very high levels of antimony for several weeks lost weight and had diarrhea. Rats that drank very low levels of antimony for most of their lives died sooner than rats not drinking antimony. Rats eating high levels of antimony for a long time had liver damage and fewer red blood cells.

Rabbits that had very small amounts of antimony placed on their skin for less than 1 day had skin irritation. Small amounts of antimony placed in rabbit eyes resulted in eye irritation. Large amounts of antimony placed on rabbit's skin resulted in death.

5 Risk Characterization

Future land-use risks are not separately calculated in this assessment. The current land-use is not expected to change and thus the current land-use risk estimates are also the future land-use risk estimates.

5.1 Carcinogenic Risk

For carcinogens, risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen (i.e., incremental or excess lifetime cancer risk (ELCR)).

The slope factor (SF) converts estimated daily intakes averaged over a lifetime of exposure directly to incremental risk of an individual developing cancer. Because relatively low intakes (compared to those experienced by test animals) are most likely from environmental exposures at contaminated sites, it generally can be assumed that the dose-response relationship will be linear in the low-dose portion of the multistage model dose-response curve. Under this assumption, the slope factor is a constant, and risk will be directly related to intake. Thus, the linear form of the carcinogenic risk equation is usually applicable for estimating site risks. This linear low-dose equation is described in Table 20.

Table 20 – Carcinogenic Risk Equation

LINEAR LOW-DOSE CANCER RISK EQUATION		
Risk (ELCR) = Intake x SF		
Risk	=	a unitless probability (e.g., 2×10^{-5}) of an individual developing cancer;
Intake	=	chronic daily intake averaged over 70 years (mg/kg·day); and
SF	=	slope factor, expressed in $(mg/kg \cdot day)^{-1}$
For instance, an ELCR of 2E-5 (2×10^{-5}) is translated to mean that there is a possibility that 2 individuals out of 100,000 *may* develop cancer.		

Because the slope factor is often an upper 95th percentile confidence limit of the probability of response based on experimental animal data used in the multistage model, the carcinogenic risk estimate will generally be an upper-bound estimate. This means that EPA is reasonably confident that the "true risk" will not exceed the risk estimate derived through use of this model and risk is likely to be less than that predicted.

It is appropriate to combine the risk from the three exposure pathways (incidental ingestion, dermal contact, and inhalation) in this assessment. The exposure is from contact with fugitive dust originating from the park road and can reasonably be expected to occur simultaneously. The cumulative ELCR would then equal the sum of the ELCR from each of the pathways.

$$ELCR_{total} = ELCR_{pathway\ 1} + ELCR_{pathway\ 2} + ELCR_{pathway\ 3}$$

Arsenic is the only carcinogen of the two COPC. Table 21 shows the ELCRs for the receptor groups at DENA. The ELCRs are shown for both the average exposure durations and the extreme exposure durations. The total ELCR is shown to one significant figure (as per EPA guidance). Any total risk shown to more than one significant figure would give unwarranted accuracy to the risk calculations.

The group with the lowest ELCR (both average and extreme employment duration) is the Denali Backcountry Lodge employees. The ELCR for the average employment duration (1 year) is 2E-7, for the extreme employment duration (3 years) it is 6E-7. Both of these are well below the ADEC risk standard of 1E-5.

The group with the highest ELCR (both average and extreme employment duration) is Kantishna Air Transport drivers. The ELCR for the average employment duration (5 years) is 3E-6, for the extreme employment duration (15 years) it is 8E-6. Both of these are below the ADEC risk standard of 1E-5.

Table 21 – Excess Lifetime Cancer Risks (ELCR) from Arsenic

Population	Exposure Pathway	Intake (mg/kg-day) (average exposure duration)	Intake (mg/kg-day) (extreme exposure duration)	Slope Factor 1/(mg/kg-day)	ELCR (unitless) (average exposure duration)	ELCR (unitless) (extreme exposure duration)
Kantishna Air Transport Driver	Incidental Soil Ingestion	1.4392E-06	4.3176E-06	1.5	2.1588E-06	6.4764E-06
	Dermal Absorption of Contaminants from Soil	1.0703E-07	3.2110E-07	3.66	3.9174E-07	1.1752E-06
	Inhalation of Fugitive Dust	9.4987E-09	2.8496E-08	15.1	1.4343E-07	4.3029E-07
	Total Pathway ELCR				**3E-06**	**8E-06**
Kantishna VTS Shuttle Bus Drivers	Incidental Soil Ingestion	5.7568E-07	3.8379E-06	1.5	8.6352E-07	5.7568E-06
	Dermal Absorption of Contaminants from Soil	4.2813E-08	2.8542E-07	3.66	1.5670E-07	1.0446E-06
	Inhalation of Fugitive Dust	3.7995E-09	2.5330E-08	15.1	5.7372E-08	3.8248E-07
	Total Pathway ELCR				**1E-06**	**7E-06**
Kantishna Business Bus Drivers	Incidental Soil Ingestion	5.7568E-07	1.9189E-06	1.5	8.6352E-07	2.8784E-06
	Dermal Absorption of Contaminants from Soil	4.2813E-08	1.4271E-07	3.66	1.5670E-07	5.2232E-07
	Inhalation of Fugitive Dust	3.7995E-09	1.2665E-08	15.1	5.7372E-08	1.9124E-07
	Total Pathway ELCR				**1E-06**	**4E-06**
Wonder Lake Grader Operator (roading)	Incidental Soil Ingestion	1.2547E-06	2.5094E-06	1.5	1.8820E-06	3.7640E-06
	Dermal Absorption of Contaminants from Soil	1.8662E-07	3.7324E-07	3.66	6.8303E-07	1.3661E-06
	Inhalation of Fugitive Dust	1.8820E-08	3.7640E-08	15.1	2.8419E-07	5.6837E-07
	Total Pathway ELCR				**3E-06**	**6E-06**

Population	Exposure Pathway	Intake (mg/kg-day) (average exposure duration)	Intake (mg/kg-day) (extreme exposure duration)	Slope Factor 1/(mg/kg-day)	ELCR (unitless) (average exposure duration)	ELCR (unitless) (extreme exposure duration)
Wonder Lake Grader Operator (grading)	Incidental Soil Ingestion	2.3987E-07	4.7973E-07	1.5	3.5980E-07	7.1960E-07
	Dermal Absorption of Contaminants from Soil	3.5678E-08	7.1355E-08	3.66	1.3058E-07	2.6116E-07
	Inhalation of Fugitive Dust	3.5980E-09	7.1960E-09	15.1	5.4330E-08	1.0866E-07
	Total Pathway ELCR				**5E-07**	**1E-06**
Wonder Lake Grader Operator (total)	Incidental Soil Ingestion				2.2418E-06	4.4836E-06
	Dermal Absorption of Contaminants from Soil				8.1361E-07	1.6273E-06
	Inhalation of Fugitive Dust				3.3852E-07	6.7703E-07
	Total Pathway ELCR				**3E-06**	**7E-6**
Brush Crew	Incidental Soil Ingestion	1.0333E-07	5.1663E-07	1.5	1.5499E-07	7.7495E-07
	Dermal Absorption of Contaminants from Soil	7.6844E-09	3.8422E-08	3.66	2.8125E-08	1.4062E-07
	Inhalation of Fugitive Dust	1.5499E-09	7.7495E-09	15.1	2.3404E-08	1.1702E-07
	Total Pathway ELCR				**2E-07**	**1E-06**
Wonder Lake Laborer	Incidental Soil Ingestion	4.6128E-07	9.2256E-07	1.5	6.9192E-07	1.3838E-06
	Dermal Absorption of Contaminants from Soil	3.4305E-08	6.8611E-08	3.66	1.2556E-07	2.5112E-07
	Inhalation of Fugitive Dust	6.9192E-09	1.3838E-08	15.1	1.0448E-07	2.0896E-07
	Total Pathway ELCR				**9E-07**	**2E-06**
Wonder Lake Rangers	Incidental Soil Ingestion	2.3618E-07	1.1809E-06	1.5	3.5426E-07	1.7713E-06
	Dermal Absorption of Contaminants from Soil	3.5129E-09	1.7564E-08	3.66	1.2857E-08	6.4286E-08
	Inhalation of Fugitive Dust	1.4171E-09	7.0853E-09	15.1	2.1398E-08	1.0699E-07
	Total Pathway ELCR				**4E-07**	**2E-06**

Population	Exposure Pathway	Intake (mg/kg-day) (average exposure duration)	Intake (mg/kg-day) (extreme exposure duration)	Slope Factor 1/(mg/kg-day)	ELCR (unitless) (average exposure duration)	ELCR (unitless) (extreme exposure duration)
Gravel Processing Crew	Incidental Soil Ingestion	1.7713E-07	3.5426E-07	1.5	2.6570E-07	5.3140E-07
	Dermal Absorption of Contaminants from Soil	7.9040E-08	1.5808E-07	3.66	2.8929E-07	5.7857E-07
	Inhalation of Fugitive Dust	4.4283E-09	8.8566E-09	15.1	6.6867E-08	1.3373E-07
	Total Pathway ELCR				**6E-07**	**1E-06**
Dump truck drivers	Incidental Soil Ingestion	1.1809E-07	5.9044E-07	1.5	1.7713E-07	8.8566E-07
	Dermal Absorption of Contaminants from Soil	1.7564E-08	8.7822E-08	3.66	6.4286E-08	3.2143E-07
	Inhalation of Fugitive Dust	1.7713E-09	8.8566E-09	15.1	2.6747E-08	1.3373E-07
	Total Pathway ELCR				**3E-07**	**1E-06**
Denali Backcountry lodge employees	Incidental Soil Ingestion	1.1809E-07	3.5426E-07	1.5	1.7713E-07	5.3140E-07
	Dermal Absorption of Contaminants from Soil	1.7564E-09	5.2693E-09	3.66	6.4286E-09	1.9286E-08
	Inhalation of Fugitive Dust	5.1959E-10	1.5588E-09	15.1	7.8458E-09	2.3537E-08
	Total Pathway ELCR				**2E-07**	**6E-07**

Example Calculation: Kantishna Air Transport Driver:

(arsenic, carcinogen, maximum (extreme) exposure duration scenario; see Tables 11 and 17):

ELCR = Intake x SF = (4.3176E-6 mg/kg·day)(1.5/(mg/kg·day) = 6.4764E-6

5.2 Hazard Quotients

To assess the overall potential for noncarcinogenic effects posed by more than one chemical, EPA has developed a hazard index (HI) approach. This approach assumes that simultaneous subthreshold exposures to several chemicals could result in an adverse health effect. It also assumes that the magnitude of the adverse effect will be proportional to the sum of the ratios of the subthreshold exposures to acceptable exposures. The hazard index is equal to the sum of the hazard quotients (HQ), as described in Table 22 below, where E and the RfD represent the same exposure period (e.g., subchronic, chronic, or shorter-term). When the HI exceeds unity, there may be concern for potential health effects. While any single chemical with an exposure level greater that the toxicity value will cause the hazard index to exceed unity, for multiple chemical exposure, the HI can also exceed unity even if no single chemical exposure exceeds its RfD.

Table 22 – Noncarcinogenic Hazard Index

$$\text{Hazard Index} = E_1/RfD_1 + E_2/RfD_2 + \ldots + E_i/RfD_i$$

where:

E_i	=	exposure level (or intake) for the i^{th} toxicant;
RfD_i	=	reference dose for the i^{th} toxicant; and

E and RfD are expressed in the same units and represent the same exposure period (i.e., chronic, subchronic, or shorter-term).

It is important to calculate the hazard index separately for chronic, subchronic, and shorter-term exposure periods. For each chronic exposure pathway (i.e., seven years to lifetime exposure), a separate chronic hazard index is calculated from the ratios of the chronic daily intake (CDI) to the chronic reference dose for individual chemicals. For each subchronic exposure pathway (i.e., two weeks to seven years exposure), a separate subchronic hazard index is calculated from the ratios of the subchronic daily intake (SDI) to the subchronic reference dose (RfD_s) for individual chemicals.

There are several limitations to this approach that must be acknowledged. The level of concern does not increase linearly as the reference dose is approached or exceeded because the RfDs do not have equal accuracy or precision and are not based on the same severity of effect. Moreover, hazard quotients are combined for substances with RfDs based on critical effects of varying toxicological significance. Also, it will often be the case that RfDs of varying levels of confidence that include different uncertainty adjustments and modifying factors will be combined (e.g., extrapolation from animals to humans, from LOAELs to NOAELs, from one exposure duration to another).

Another limitation with the hazard index approach is that the assumption of dose additivity is most properly applied to compounds that induce the same effect by the same mechanism of action. Consequently, application of the hazard index equation to a number of compounds that are not expected to induce the same type of effects or that do not act by the same mechanism, although appropriate as a screening-level approach, could overestimate the potential for effects. This possibility is generally not of concern if only one or two substances are responsible for driving the HI above unity. If the HI is greater than unity as a consequence of summing many hazard quotients of similar value, it would be appropriate to segregate the compounds by effect and by mechanism of action and to derive separate hazard indices for each group.

The hazard quotients from the three exposure pathways (incidental ingestion, dermal contact, and inhalation) can be combined in this assessment. The exposure is from contact with the dust clouds originating from the park road and can reasonably be expected to occur simultaneously. The hazard index would then equal the sum of the hazard indexes from each of the pathways.

$$HI_{total} = (HQ_{Sb} + HQ_{As})_{ingestion} + (HQ_{Sb} + HQ_{As})_{Dermal} + (HQ_{Sb} + HQ_{As})_{Inhalation}$$

Antimony and arsenic both have noncarcinogenic, toxic effects. Tables 23 – 25 show the HQs for each pathway. Both the average and maximum ED (seasons of employment) are shown. Table 26 shows the HI_{total} for the subject populations at DENA. The total pathway HIs are shown to one significant figure (as per EPA guidance). Any HIs shown to more than one significant figure would give unwarranted accuracy to the calculations.

The group with the lowest HI is the Wonder Lake Grader Operator (while grading) for both the average ED and the extreme ED. The HI for the average employment duration (5 years) is 3E-2 (0.03) and for the maximum employment duration (10 years) is 2E-2 (0.02). Both of these values are well below the ADEC risk standard of 1.

The groups with the highest HI are the Gravel Processing Crew and the Wonder Lake Grader Operator (total exposure or summation of grading and roading activities). The HI for the average employment duration (1 year and 5 years respectively) is 2E-1 (0.2) and for the maximum employment duration (2 years and 10 years respectively) is 2E-1 (0.2). Both of these values are well below the ADEC risk standard of 1.

Table 23 – Incidental Ingestion of Soil Pathway Hazard Quotients

Worker	Antimony Intake mg/kg-day	Average ED Antimony RfD mg/kg-day	Average ED Antimony HQ (unitless)	Maximum ED Antimony RfD mg/kg-day	Maximum ED Antimony HQ (unitless)
Kantishna Air Transport Driver	6.1057E-06		3.0528E-02		1.5264E-02
Kantishna VTS Shuttle Bus Drivers	4.0705E-06		2.0352E-02		1.0176E-02
Kantishna Business Bus Drivers	4.0705E-06		2.0352E-02		1.0176E-02
Wonder Lake Grader Operator (roading)	5.3229E-06		2.6614E-02		1.3307E-02
Wonder Lake Grader Operator (grading)	1.0176E-06		5.0881E-03		2.5440E-03
Brush Crew	2.1918E-06		1.0959E-02		1.0959E-02
Wonder Lake Laborer	1.9569E-06		9.7847E-03		4.8924E-03
Wonder Lake Rangers	5.0098E-06		2.5049E-02		2.5049E-02
Gravel Processing Crew	3.7573E-06		1.8787E-02		1.8787E-02
Dump truck drivers	2.5049E-06		1.2524E-02		1.2524E-02
Denali Backcountry lodge employees	2.5049E-06		1.2524E-02		1.2524E-02
Worker	Arsenic Intake mg/kg-day	Average ED Arsenic RfD mg/kg-day	Average ED Arsenic HQ (unitless)	Maximum ED Arsenic RfD mg/kg-day	Maximum ED Arsenic HQ (unitless)
Kantishna Air Transport Driver	2.0149E-05		6.7162E-02		6.7162E-02
Kantishna VTS Shuttle Bus Drivers	1.3432E-05		4.4775E-02		4.4775E-02
Kantishna Business Bus Drivers	1.3432E-05		4.4775E-02		4.4775E-02
Wonder Lake Grader Operator (roading)	1.7566E-05		5.8552E-02		5.8552E-02
Wonder Lake Grader Operator (grading)	3.3581E-06		1.1194E-02		1.1194E-02
Brush Crew	7.2329E-06		2.4110E-02		2.4110E-02
Wonder Lake Laborer	6.4579E-06		2.1526E-02		2.1526E-02
Wonder Lake Rangers	1.6532E-05		5.5108E-02		5.5108E-02
Gravel Processing Crew	1.2399E-05		4.1331E-02		4.1331E-02
Dump truck drivers	8.2661E-06		2.7554E-02		2.7554E-02
Denali Backcountry lodge employees	8.2661E-06		2.7554E-02		2.7554E-02

ED = exposure duration; RfD = reference dose; HQ = hazard quotient;

Example Calculation, Kantishna Air Transport Driver:

(antimony, non-carcinogen, average exposure duration scenario; see Tables 11, 17 and 18):

HQ = Intake / RfD = (6.1057E-6 mg/kg·day) / (2E-4 mg/kg·day) = 3.052E-2

Table 24 – Dermal Absorption Pathway Hazard Quotients

Worker	Antimony Intake mg/kg-day	Average ED Antimony RfD mg/kg-day	Average ED Antimony HQ (unitless)	Maximum ED Antimony RfD mg/kg-day	Maximum ED Antimony HQ (unitless)
Kantishna Air Transport Driver	1.5136E-08		3.7840E-03		1.8920E-03
Kantishna VTS Shuttle Bus Drivers	1.0091E-08		2.5227E-03		1.2613E-03
Kantishna Business Bus Drivers	1.0091E-08		2.5227E-03		1.2613E-03
Wonder Lake Grader Operator (roading)	2.6391E-08		6.5977E-03		3.2989E-03
Wonder Lake Grader Operator (grading)	5.0453E-09		1.2613E-03		6.3067E-04
Brush Crew	5.4334E-09		1.3584E-03		1.3584E-03
Wonder Lake Laborer	4.8513E-09		1.2128E-03		6.0641E-04
Wonder Lake Rangers	2.4839E-09		6.2096E-04		6.2096E-04
Gravel Processing Crew	5.5887E-08		1.3972E-02		1.3972E-02
Dump truck drivers	1.2419E-08		3.1048E-03		3.1048E-03
Denali Backcountry lodge employees	1.2419E-09		3.1048E-04		3.1048E-04

Worker	Arsenic Intake mg/kg-day	Average ED Arsenic RfD mg/kg-day	Average ED Arsenic HQ (unitless)	Maximum ED As RfD mg/kg-day	Maximum ED Arsenic HQ (unitless)
Kantishna Air Transport Driver	1.49846E-06		1.2183E-02		1.2183E-02
Kantishna VTS Shuttle Bus Drivers	9.98974E-07		8.1217E-03		8.1217E-03
Kantishna Business Bus Drivers	9.98974E-07		8.1217E-03		8.1217E-03
Wonder Lake Grader Operator (roading)	2.6127E-06		2.1241E-02		2.1241E-02
Wonder Lake Grader Operator (grading)	4.99487E-07		4.0609E-03		4.0609E-03
Brush Crew	5.37909E-07		4.3732E-03		4.3732E-03
Wonder Lake Laborer	4.80276E-07		3.9047E-03		3.9047E-03
Wonder Lake Rangers	2.45901E-07		1.9992E-03		1.9992E-03
Gravel Processing Crew	5.53278E-06		4.4982E-02		4.4982E-02
Dump truck drivers	1.22951E-06		9.9960E-03		9.9960E-03
Denali Backcountry lodge employees	1.22951E-07		9.9960E-04		9.9960E-04

ED = exposure duration; RfD = reference dose; HQ = hazard quotient;

Example Calculation, Kantishna Air Transport Driver:

(antimony, non-carcinogen, average exposure duration scenario; see Tables 11, 17 and 18):

HQ = Intake / RfD = (1.5136E-8 mg/kg·day) / (4E-6 mg/kg·day) = 3.7840E-3

Table 25 – Inhalation Pathway Hazard Quotient

Worker	Antimony Intake mg/kg-day	Average ED Antimony RfD mg/kg-day	Average ED Antimony HQ (unitless)	Maximum ED Antimony RfD mg/kg-day	Maximum ED Antimony HQ (unitless)
Kantishna Air Transport Driver	4.02975E-08		3.66E-04		7.07E-04
Kantishna VTS Shuttle Bus Drivers	2.6865E-08		2.44E-04		4.71E-04
Kantishna Business Bus Drivers	2.6865E-08		2.44E-04		4.71E-04
Wonder Lake Grader Operator (roading)	7.98434E-08		7.26E-04		1.40E-03
Wonder Lake Grader Operator (grading)	1.52642E-08		1.39E-04		2.68E-04
Brush Crew	3.28767E-08		2.99E-04		2.99E-04
Wonder Lake Laborer	2.93542E-08		2.67E-04		5.15E-04
Wonder Lake Rangers	3.00587E-08		2.73E-04		2.73E-04
Gravel Processing Crew	9.39335E-08		8.54E-04		8.54E-04
Dump truck drivers	3.75734E-08		3.42E-04		3.42E-04
Denali Backcountry lodge employees	1.10215E-08		1.00E-04		1.00E-04

Worker	Arsenic Intake mg/kg-day	Average ED Arsenic RfD mg/kg-day	Average ED Arsenic HQ (unitless)	Maximum ED Arsenic RfD mg/kg-day	Maximum ED Arsenic HQ (unitless)
Kantishna Air Transport Driver	1.32982E-07		1.55E-02		1.55E-02
Kantishna VTS Shuttle Bus Drivers	8.86544E-08		1.03E-02		1.03E-02
Kantishna Business Bus Drivers	8.86544E-08		1.03E-02		1.03E-02
Wonder Lake Grader Operator (roading)	2.63483E-07		3.06E-02		3.06E-02
Wonder Lake Grader Operator (grading)	5.03718E-08		5.86E-03		5.86E-03
Brush Crew	1.08493E-07		1.26E-02		1.26E-02
Wonder Lake Laborer	9.68689E-08		1.13E-02		1.13E-02
Wonder Lake Rangers	9.91937E-08		1.15E-02		1.15E-02
Gravel Processing Crew	3.0998E-07		3.60E-02		3.60E-02
Dump truck drivers	1.23992E-07		1.44E-02		1.44E-02
Denali Backcountry lodge employees	3.6371E-08		4.23E-03		4.23E-03

ED = exposure duration; RfD = reference dose; HQ = hazard quotient;

Example Calculation, Kantishna Air Transport Driver:

((antimony, non-carcinogen, average exposure duration scenario; see Tables 11, 17 and 19):

HQ = Intake / RfD = (4.02975E-8 mg/kg·day) / (5.7E-5 mg/kg·day) = 3.6634E-4

Table 26 – All Chemicals All Pathways Hazard Index (HI)

Worker	Average ED Hazard Index	Maximum ED Hazard Index
Kantishna Air Transport Driver	1E-01	1E-01
Kantishna VTS Shuttle Bus Drivers	9E-02	8E-02
Kantishna Business Bus Drivers	9E-02	8E-02
Wonder Lake Grader Operator (roading)	1E-01	1E-01
Wonder Lake Grader Operator (grading)	3E-02	2E-02
Wonder Lake Grader Operator (total)	2E-01	2E-01
Brush Crew	5E-02	5E-02
Wonder Lake Laborer	5E-02	4E-02
Wonder Lake Rangers	9E-02	9E-02
Gravel Processing Crew	2E-01	2E-01
Dump truck drivers	7E-02	7E-02
Denali Backcountry lodge employees	5E-02	5E-02
Hazard Index = sum of Hazard Quotients		

5.3 Uncertainties

The previous sections on the Identification of Chemicals of Potential Concern, Exposure Assessment, and Toxicity Assessment all have uncertainties attached to the assessment. The risk characterization section utilizes the information from these three previous sections and thus the uncertainties are carried into this section.

The sensitivity of the risk characterization to the exposure and toxicity assessments is a direct relationship. The cancer risk equation is:

$$ELCR = Intake \times SF$$

The noncarcinogenic hazard quotient equation is:

$$\text{Hazard Quotient} = Intake/RfD$$

The risk and hazard quotient are directly proportional to the exposure (amount of chemical intake) and toxicity (slope factor or reference dose). When dealing with a single substance, this direct proportionality is a simple tool to see how a doubling of the intake (for instance - twice as much soil ingested, or concentration of arsenic is twice what is expected) impacts the risk or hazard. It simply doubles the risk. However, if the exposure duration is increased, say from 5 years to 10 years, no change occurs for the noncarcinogenic hazard quotient (unless the chronic reference dose is different from the subchronic reference dose). This is because the intake is based on a daily rate averaged over the exposure duration (see Table 8). However, for calculating the ELCR, doubling the exposure duration would increase the intake proportionally. In the case above, the intake, and thus the risk, would double when exposure duration went from 5 years to 10 years. (See the definition for AT in Table 8.)

Combining more than one chemical and more than one pathway increases the uncertainty due to different intakes and different slope factors or reference doses.

5.4 Summary Discussion of the Risk Characterization

This section highlights the potential risks if the proposed gravel borrow source is used for road maintenance in DENA.

The group with the highest potential carcinogenic risk if the proposed gravel borrow source is utilized on the park road is the Kantishna Air Transport drivers. Other groups had the same risk with this group in one or two scenarios. However, the Kantishna Air Transport drivers have the highest risk for both average and maximum exposure (employment) duration.

The potential risk of cancer (15 year employment duration) from the arsenic in the proposed borrow material for this group is 8E-6, or eight in a million. The ADEC risk standard is one in a hundred thousand. The EPA standard is a range of 1E-4 to 1E-6. At a risk of 1E-4 remedial action is generally warranted, however, this is not a concrete departure point and is subject to site-specific considerations.

The group with the highest potential noncarcinogenic risk if the proposed gravel borrow source is utilized on the park road is the Gravel Processing crew. The hazard index from the arsenic and antimony in the proposed borrow material for this group is 0.2. The ADEC and EPA risk standard is 1.

The use of the proposed borrow material for road construction and maintenance should not adversely impact workers. Figure 2 and 3 show the contributions of each pathway and the individual metals to each workers risk. In all cases, the incidental ingestion of soil containing arsenic and antimony produced the greatest risk. In the majority of cases, inhalation produced the next greatest risk.

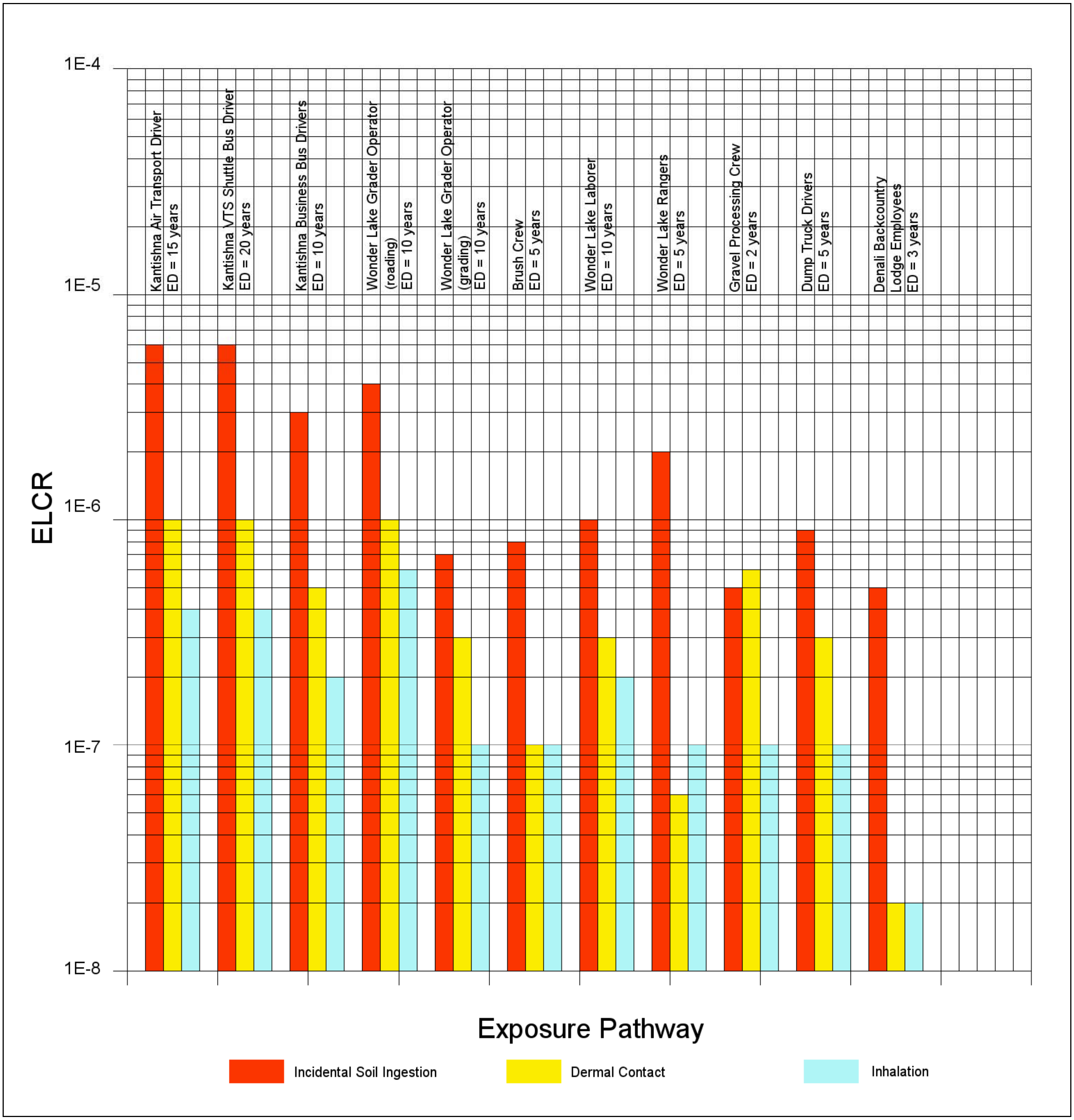

Figure 2 – Contribution of Pathways to Arsenic Cancer Risk (Max ED)

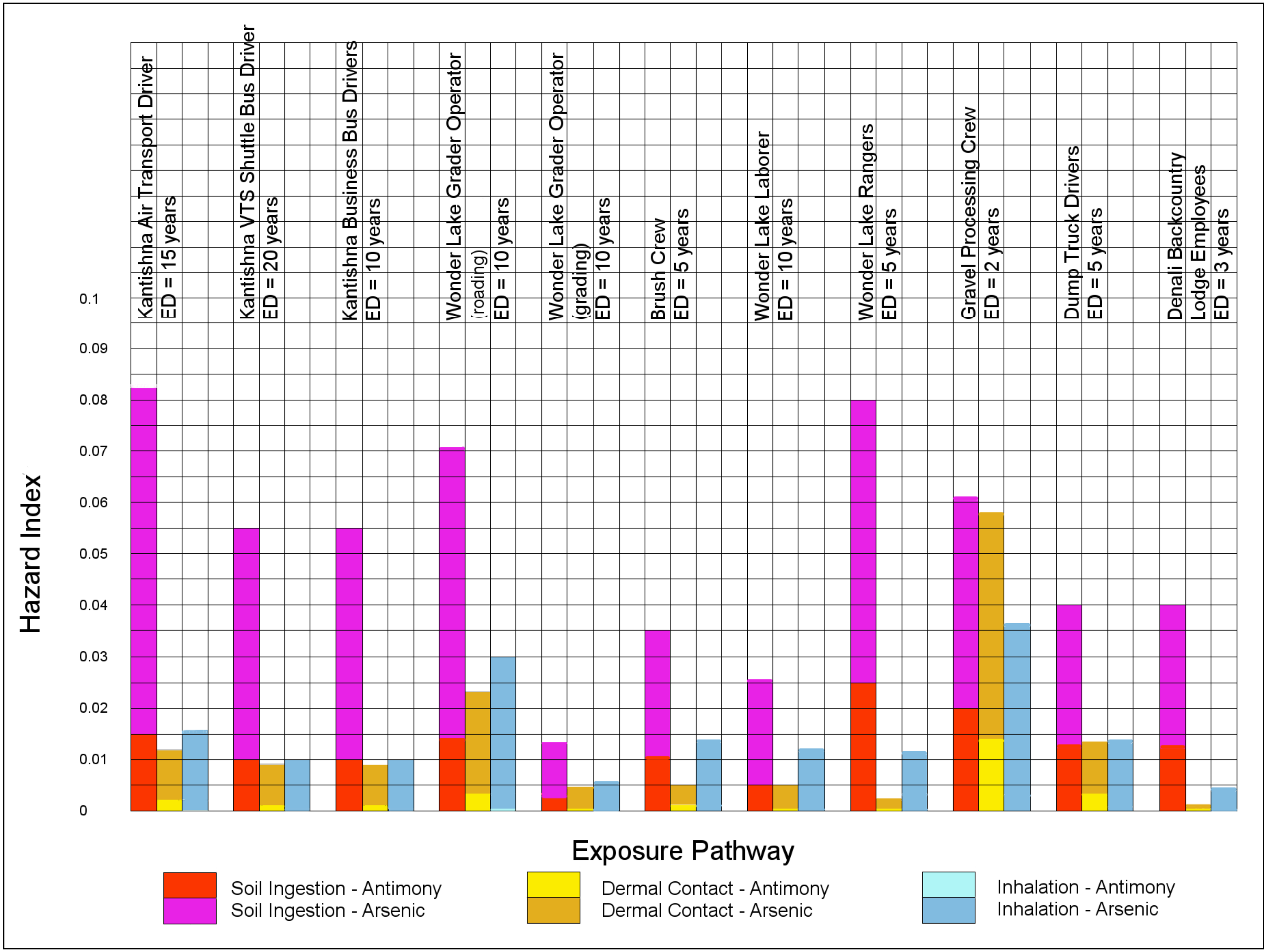

Figure 3 – Contribution of Pathways to Antimony and Arsenic Noncarcinogenic Hazard Index (Max ED)

6 Human Health Summary

6.1 Chemicals of Potential Concern

The Kantishna area is heavily mineralized. This is one of the reasons it became a mining district. Sampling and testing reduced the list of COPC to two chemicals. The levels of antimony and arsenic in the proposed borrow source warranted further evaluation in a risk assessment. Although the antimony and arsenic content in the proposed borrow source is less than two background areas along the park road near Kantishna, the potential increased exposure warranted including the entire project road length in the study. Antimony is not considered a carcinogen by the EPA and only contributes toxic effects. However arsenic is considered a carcinogen and contributes both a carcinogenic effect and a toxic effect. The proposed borrow source contains an average 20 mg/kg (0.0020 %) antimony and 66 mg/kg (0.0066 %) arsenic.

6.2 Exposure Assessment

The exposure pathways that were quantitatively assessed (see CSM) are the incidental ingestion of soil (dust) pathway, the dermal contact pathway, and the inhalation pathway. These three pathways were considered the primary or most significant exposure pathways. The receptors of concern are the employees who would be working in DENA in the vicinity of the road and other areas receiving gravel from the proposed borrow source (see Table 11). The employee group with the largest exposure is the Kantishna Air Transport Driver. Since intake is normalized to a daily rate, a longer employment duration (exposure duration) does not change the intake for noncarcinogenic effects. However, the carcinogenic exposure is averaged over a lifetime and thus that rate changes. The Kantishna Air Transport Driver would have a higher arsenic carcinogenic intake per day for an employment period of 15 years than that over a 5 year employment period. The largest exposure comes from the incidental ingestion of soil (dust) pathway.

6.3 Toxicity Assessment

Antimony and arsenic have similar toxicities under the oral route (within one order of magnitude). Under the dermal route, antimony is the more toxic by two orders of magnitude. The inhalation route has arsenic more toxic than antimony by one order of magnitude. Antimony is not classified as a human carcinogen. Arsenic is classified as a human carcinogen.

6.4 Risk Characterization

The receptors with the largest potential toxic risk (for both the average and maximum employment durations) are the Gravel Processing Crew and Wonder Lake Grader Operator (cumulative from roading and grading), each with a hazard index of 0.2. The Kantishna Air Transport Driver has the highest potential carcinogenic risk (for both the average and maximum employment durations) at 3 in a million (5 year exposure) and 8 in a million (15 year exposure).

6.5 Uncertainties

The risk approaches used in most environmental risk assessments are usually not fully probabilistic estimates of risk, but conditional estimates given a considerable number of assumptions about exposure and toxicity. Thus, it is important to fully specify the assumptions and uncertainties inherent in the risk assessment to place the risk estimates in proper perspective. Another use of uncertainty characterization can be to identify areas where a moderate amount of additional data collection might significantly improve the basis for selection of a remedial alternative.

Highly quantitative statistical uncertainty analysis is usually not practical or necessary for environmental risk assessments for a number of reasons, not the least of which are the resource requirements to collect and analyze site data in such a way that the results can be presented as valid probability distributions. As in all environmental risk assessments, it already is known that uncertainty about the numerical results is generally large (i.e., on the range of at least an order of magnitude or greater). Consequently, it is more important to identify the key site-related variables and assumptions that contribute most to the uncertainty than to precisely quantify the degree of uncertainty in the risk assessment.

The data collection for this assessment was designed to keep the fundamental error to 10% by using multi-incremental sampling, grinding of the samples, and controlling the minimum sample size. Uncertainty related to this segment of the assessment is considered low.

Uncertainties related to the exposure assessment are considered low except for the standard assumptions regarding body weight, life expectancy, population characteristics, and lifestyle. The uncertainty here is considered moderate. Likewise the assumption on media intake has a moderate uncertainty.

The toxicity assessment uncertainties are high for the antimony oral and inhalation reference dose. Moderate uncertainty characterizes the antimony dermal reference dose, arsenic oral, dermal and inhalation reference doses and dermal slope factor.

7 Ecological Screening

The ecological screening follows the 'Ecological Scoping Evaluation Guidance,' (ADEC 2007c).

7.1 Direct Visual Impacts and Acute Toxicity

No direct impacts were observed during the 2007 sampling efforts. Direct impacts include visibly stressed or dead biota and can be associated with acute toxicity. Observations were made of the proposed gravel borrow area itself, the existing road, and background (see Pictures 2 - 7). DU1 and DU2 on the west end of the study area (3-4 miles east of Kantishna) had antimony and arsenic background concentrations above those of the proposed gravel borrow area (see Pictures 6 and 7).

Decision Point – Since no direct impacts were observed, evaluation continues with the remaining scoping factors, taking off-ramps as appropriate.

7.2 Receptor-Pathway Interactions

Receptor-pathway interactions describe the many ways that contaminants are transported to and can be taken up by plants or animals. Ecological receptors may be present at a contaminated site without there being receptor-pathway interactions.

7.2.1 Terrestrial Pathway

The circumstances surrounding the environmental pathways from the use of the proposed gravel borrow area are directly connected to the naturally occurring background levels of antimony and arsenic. There is a potential for arsenic and antimony to leach out of the placed borrow material at a greater concentration than that of the surrounding background. However, the mass of arsenic and antimony contained in the placed borrow is insignificant compared to the surrounding soil. For instance, a hypothetical road cross-section of 0.5-ft by 24-ft and a hundred foot length would contain 4.3 kilograms (kg) of arsenic[6] and 1.3 kg of antimony (assuming 100% construction with the proposed borrow material). Taking a road corridor width of 100 feet by 10 feet deep by 100-feet in length, the amount of arsenic would be 120 kg and antimony would be 10 kg.[7] (using background concentrations). The addition of a surface course of gravel with slightly elevated arsenic and antimony concentrations will not impact the transport of dissolved or suspended particles of these two metals. As with the human health assessment, it is the mobilization of the antimony and arsenic by the road dust that is significant.

Potentially complete pathways include:

- Particulates deposited on plants directly or from traffic wheel splash or spray.
- Inhalation of fugitive dust from road traffic.
- Ingestion of fugitive dust from road traffic.
- Arsenic is bioaccumulative and should be mentioned. However, due to the naturally occurring antimony and arsenic, the added mass from potential use of the gravel borrow source is insignificant.

7.2.2 Aquatic Pathway Interactions

There are no significant aquatic pathways and exposure routes. The mass of added antimony and arsenic to the local environment is insignificant compared to the naturally occurring background concentrations (see discussion above).

7.2.3 Contaminant Fate and Transport

The primary mechanism for metals leaving the roadway is the airborne transport of dust generated from the road surface. Dust will remain suspended for a time before settling into or on vegetation, adjacent soil, sediment, or surface water. Secondary is mechanical generated transport via vehicle tires or spray from road traffic. Deposition of

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[6] Example calculation: (0.5-ft)(24-ft)(100-ft)(120 lb/CF) = 144,000 lb gravel = 65,317 kg gravel; (66 mg/kg As) (65,317 kg gravel) / (10^6 mg/kg) = 4.3 kg As.

[7] Although the dimensions of this road corridor are arbitrary, they point out the small amount of arsenic and antimony in the borrow material compared to the surrounding terrain. See Picture 2.

dust is expected to diminish within 150 feet of the road. "A study to measure dust accumulation from the Park Road in the Teklanika area found that these effects are greatest within the first 5 meters from the road, and decline rapidly as distance from the road increases until about 50 meters from the road, where conditions are nearly indistinguishable from background dust deposition levels []." (MEG 2005)

7.2.4 Decision Point

Since there are potentially complete terrestrial pathways present, evaluation proceeds to the habitat determination scoping factor.

7.3 Habitat Determination

7.3.1 Valued Species

There are no threatened or endangered species in the Kantishna area (ADF&G 2007c, USFWS 2007). Alaska special species of concern that may be in the Kantishna area include: the American Peregrine Falcon, Arctic Peregrine Falcon, Northern Goshawk, and Olive-sided Flycatcher (ADF&G 2007d).

Subsistence species that may be present or pass through DENA include caribou, moose, brown bear, salmon, whitefish, Arctic grayling, trout, geese, swan, pintail, teal, shoveler ducks, blueberries, salmonberries, cranberries, raspberries, and rhubarb. The Denali Wilderness is closed to sport and subsistence hunting and trapping and is managed to maintain the undeveloped wilderness parkland character. North of this border (which includes Kantishna and the area of the proposed borrow source) is the Denali National Park additions which were established in 1980. This area is open to traditional subsistence use by local rural residents.

Species of ceremonial importance in DENA include the raven, wolves, wolverines, fox, ermine, martin, ptarmigan, and grouse.

Species of commercial value include wolves, wolverines, fox, marten, beaver, mink, muskrat, otter, ermine, hare, coyote, Dall sheep, lynx, marmot, and weasel. However, DENA is closed to hunting and trapping.

Species important to recreational activities include salmon, whitefish, grayling, caribou, and waterfowl. DENA is closed to hunting but recreational fishing is allowed. Due to the silt-containing characteristic of the rivers in the area, fishing quality is limited.

7.3.2 Critical Habitats and Anadromous Streams

The study area is not in or near any state refuge, state critical habitat area, state sanctuary, or state range (ADF&G 2007b). The Fish Distribution Database Atlas, Mt. McKinley, C-2 shows an anadromous stream, Moose Creek, passing through Kantishna generally east-west (ADF&G 2007a). Moose Creek is classified as an anadromous stream with Chum salmon present.

7.3.3 Other Important Habitats

Significant aquatic or terrestrial habitats are not within the influence of traffic areas that may be maintained with the gravel from the proposed borrow area. The road corridor is a small area within the larger ecosystem of DENA. In addition, there is abundant, high quality habitat throughout the area. The localized road corridor areas are not in a critical or sensitive microcosm.

7.3.4 Parks, Preserves, and Wildlife Refuges

The study area is within the Denali National Park and Preserve. DENA is to be managed to protect and interpret the entire mountain massif, and additional scenic mountain peaks and formations; and to protect fish and wildlife populations and habitat; and to provide continued opportunities, including reasonable access for mountain climbing, mountaineering and other wilderness recreational activities.

7.3.5 Decision Point

There is low probability that the additional antimony and arsenic from the proposed gravel borrow area will impact habitats supporting valued species of wildlife, critical habitats or other habitats identified as important for the region. Scoping stops at this point. Although DENA is a national park and preserve managed to protect fish and wildlife populations and habitat, the use of gravel with elevated antimony and arsenic has little likelihood of impacting the environment. This is due to two main points. First is there is already high naturally occurring background concentrations of these two metals in the area. Second, the exposure pathway for the fugitive dust is limited to about 150 feet from the road with the majority of exposure being in the first 15 feet. The chance for exposure to subpopulations of flora and fauna is extremely low due to the relatively small footprint of the roadway area.

7.4 Ecological Evaluation Conclusion

The potential contamination from the use of gravel with elevated antimony and arsenic concentrations is limited in quantity, concentration, mobility, and toxicity. The probability of the antimony and arsenic migrating from the zone of influence is low. There are no other valued species or critical habitats in the immediate vicinity (15 - 150 feet) of the roadway. The potential contamination presents no adverse impacts to the environment.

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Picture 1 – Denali National Park Road (NPS 2007a)

Picture 2 – Park Road in Study Area (USACE file photograph)

Picture 3 – Park Road in Study Area (USACE file photograph)

Picture 4 – Proposed Gravel Borrow Source (USACE file photograph)

Picture 5 – Mt. McKinley and Terrain in Study Area (USACE file photograph)

Picture 6 – DU1 Overview from Mining Road North of Park Road (USACE file photograph)

Picture 7 – DU2 Overview (USACE file photograph)

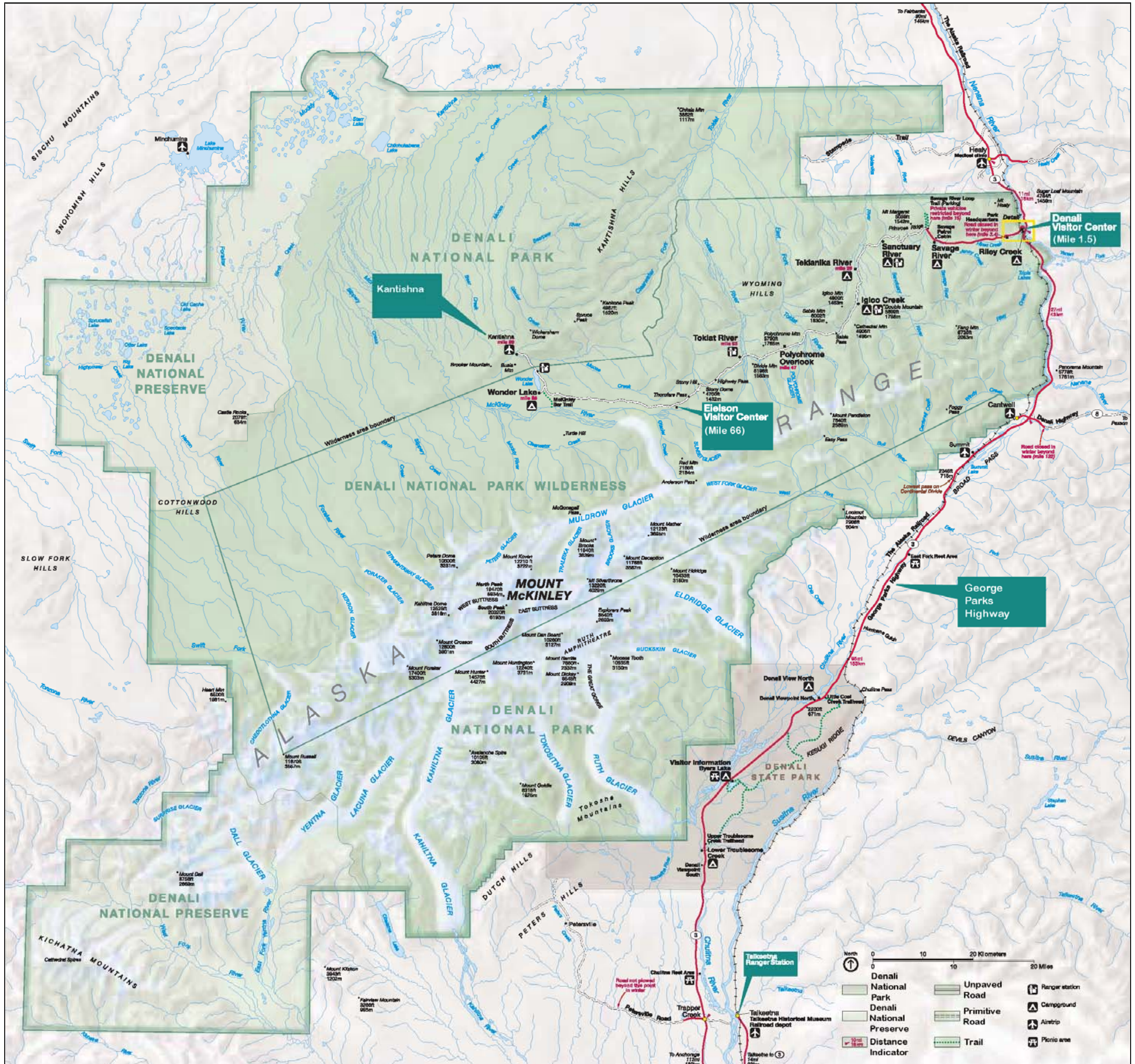

Figure 4 – Map of Denali National Park and Preserve

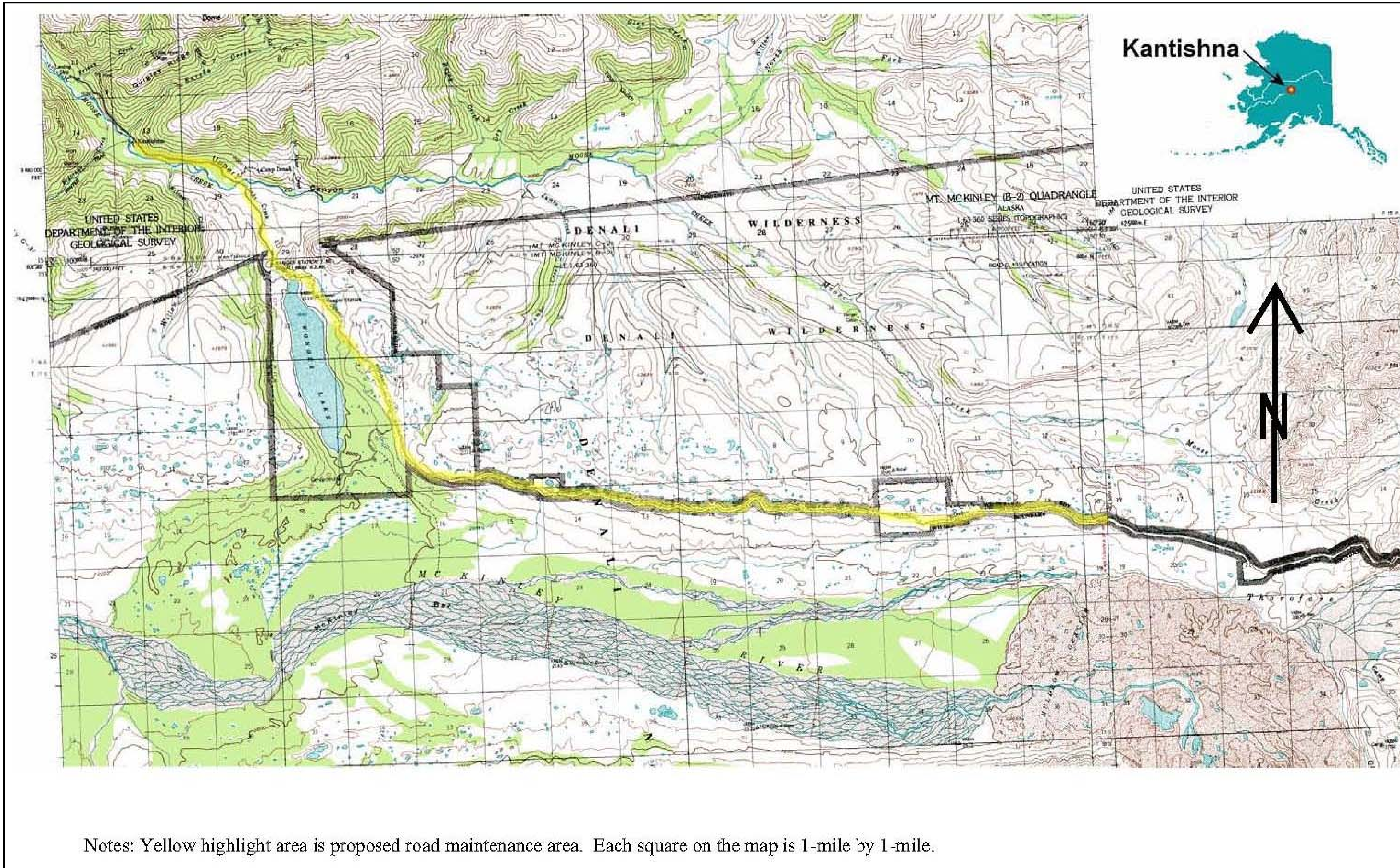

Figure 5 – USGS Map (USGS 1982, USGS 1994) of the Study Area

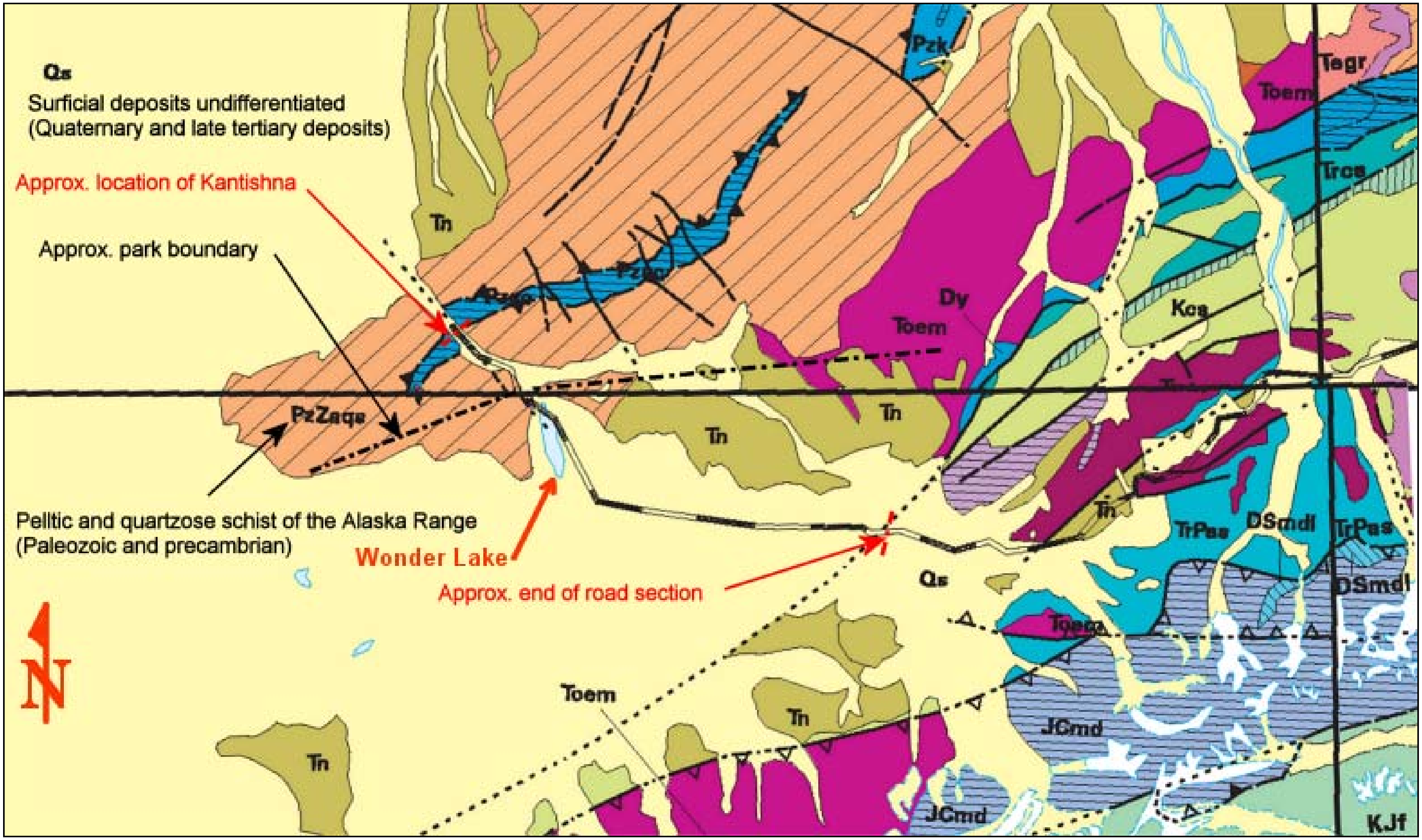

Figure 6 – Geologic Map of Study Area

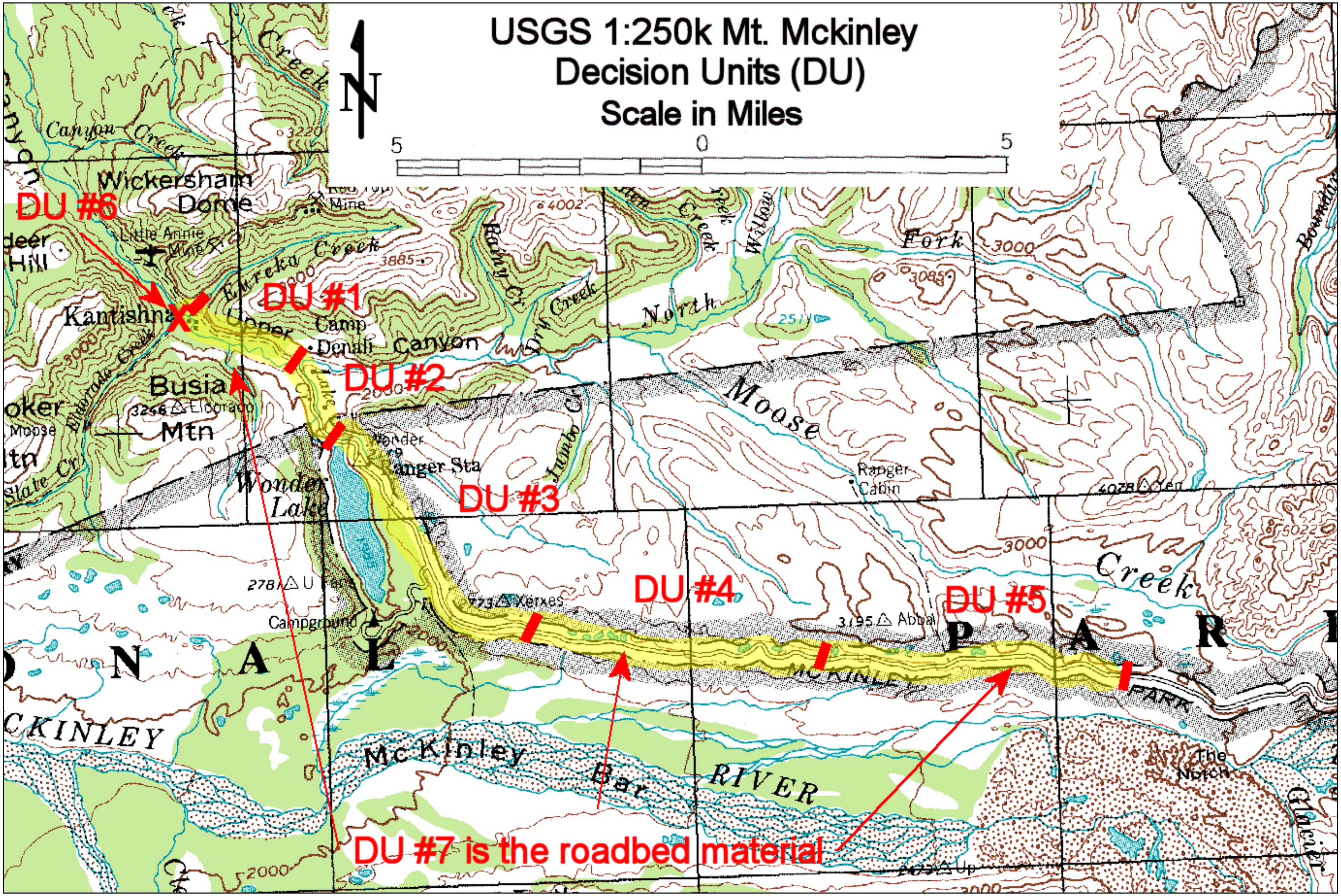

Figure 7 – USGS Topographic Map (USGS 1982) Showing Decision Units

APPENDIX A: HUMAN HEALTH CONCEPTUAL SITE MODEL

The Human Health Conceptual Site Model is based on the draft Guidance on Developing Conceptual Site Models (ADEC 2005a).

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INITIAL HUMAN HEALTH CONCEPTUAL SITE MODEL

Site: Kantishna Gravel Source
Denali National Park and Preserve

Completed By: USACE
Date Completed: ____

Follow the directions below. Do not consider engineering or land use controls when describing pathways.

(1) *Check the media that could be directly affected by the release.*

(2) *For each medium identified in (1), follow the top arrow and check possible transport mechanisms. Briefly list other mechanisms or reference the report for details.*

(3) *Check exposure media identified in (2).*

(4) *Check exposure pathways that are complete or need further evaluation. The pathways identified must agree with Sections 2 and 3 of the CSM Scoping Form.*

(5) *Identify the receptors potentially affected by each exposure pathway: Enter "C" for current receptors, "F" for future receptors, or "C/F" for both current and future receptors.*

Media	Transport Mechanisms
☑ Surface Soil (0-2 ft bgs)	Direct release to surface soil — check soil
	☑ Migration or leaching to subsurface — check soil
	☑ Migration or leaching to groundwater — check groundwater
	☐ Volatilization — check air
	☑ Runoff or erosion — check surface water
	☑ Uptake by plants or animals — check biota
	☑ Other (list): Fugitive Dust
☐ Subsurface Soil (2-15 ft bgs)	Direct release to subsurface soil — check soil
	☐ Migration to groundwater — check groundwater
	☐ Volatilization — check air
	☐ Other (list):
☐ Ground-water	Direct release to groundwater — check groundwater
	☐ Volatilization — check air
	☐ Flow to surface water body — check surface water
	☐ Flow to sediment — check sediment
	☐ Uptake by plants or animals — check biota
	☐ Other (list):
☐ Surface Water	Direct release to surface water — check surface water
	☐ Volatilization — check air
	☐ Sedimentation — check sediment
	☐ Uptake by plants or animals — check biota
	☐ Other (list):
☐ Sediment	Direct release to sediment — check sediment
	☐ Resuspension, runoff, or erosion — check surface water
	☐ Uptake by plants or animals — check biota
	☐ Other (list):

Current & Future Receptors

Exposure Media	Exposure Pathways	Residents (adults or children)	Commercial or industrial workers	Site visitors, trespassers, or recreational users	Construction workers	Farmers or subsistence harvesters	Subsistence consumers	Other
☑ soil	☑ Incidental Soil Ingestion	C/F	C/F	C/F	C/F	C/F		
	☑ Dermal Absorption of Contaminants from Soil	C/F	C/F	C/F	C/F	C/F		
☑ groundwater	☑ Ingestion of Groundwater	C/F		C/F				
	☐ Dermal Absorption of Contaminants in Groundwater							
	☐ Inhalation of Volatile Compounds in Tap Water							
☑ air	☐ Inhalation of Outdoor Air							
	☐ Inhalation of Indoor Air							
	☑ Inhalation of Fugitive Dust	C/F	C/F	C/F	C/F	C/F		
☑ surface water	☑ Ingestion of Surface Water			C/F				
	☐ Dermal Absorption of Contaminants in Surface Water							
	☐ Inhalation of Volatile Compounds in Tap Water							
☐ sediment	☐ Direct Contact with Sediment							
☑ biota	☑ Ingestion of Wild Foods						C/F	

FINAL HUMAN HEALTH CONCEPTUAL SITE MODEL

Site: Kantishna Gravel Source
Denali National Park and Preserve

Completed By: USACE
Date Completed: November 28, 2007

Follow the directions below. Do not consider engineering or land use controls when describing pathways.

(1) *Check the media that could be directly affected by the release.*

(2) *For each medium identified in (1), follow the top arrow and check possible transport mechanisms. Briefly list other mechanisms or reference the report for details.*

(3) *Check exposure media identified in (2).*

(4) *Check exposure pathways that are complete or need further evaluation. The pathways identified must agree with Sections 2 and 3 of the CSM Scoping Form.*

(5) *Identify the receptors potentially affected by each exposure pathway: Enter "C" for current receptors, "F" for future receptors, or "C/F" for both current and future receptors.*

Media / Transport Mechanisms

Media	Transport Mechanisms	
[x] Surface Soil (0-2 ft bgs)	Direct release to surface soil	check soil
	[x] Migration or leaching to subsurface	check soil
	[x] Migration or leaching to groundwater	check groundwater
	[ ] Volatilization	check air
	[x] Runoff or erosion	check surface water
	[x] Uptake by plants or animals	check biota
	[x] Other (list): Fugitive Dust [air; sediment]	
[ ] Subsurface Soil (2-15 ft bgs)	Direct release to subsurface soil	check soil
	[ ] Migration to groundwater	check groundwater
	[ ] Volatilization	check air
	[ ] Other (list):	
[ ] Ground-water	Direct release to groundwater	check groundwater
	[ ] Volatilization	check air
	[ ] Flow to surface water body	check surface water
	[ ] Flow to sediment	check sediment
	[ ] Uptake by plants or animals	check biota
	[ ] Other (list):	
[ ] Surface Water	Direct release to surface water	check surface water
	[ ] Volatilization	check air
	[ ] Sedimentation	check sediment
	[ ] Uptake by plants or animals	check biota
	[ ] Other (list):	
[ ] Sediment	Direct release to sediment	check sediment
	[ ] Resuspension, runoff, or erosion	check surface water
	[ ] Uptake by plants or animals	check biota
	[ ] Other (list):	

Exposure Media / Exposure Pathways / Current & Future Receptors

Exposure Media	Exposure Pathways	Residents (adults or children)	Commercial or industrial workers	Site visitors, trespassers, or recreational users	Construction workers	Farmers or subsistence harvesters	Subsistence consumers	Other
[x] soil	[x] Incidental Soil Ingestion	C/F	C/F	C/F	C/F	C/F		
	[x] Dermal Absorption of Contaminants from Soil	C/F	C/F	C/F	C/F	C/F		
[x] groundwater	[x] Ingestion of Groundwater	C/F		C/F				
	[ ] Dermal Absorption of Contaminants in Groundwater							
	[ ] Inhalation of Volatile Compounds in Tap Water							
[x] air	[ ] Inhalation of Outdoor Air							
	[ ] Inhalation of Indoor Air							
	[x] Inhalation of Fugitive Dust	C/F	C/F	C/F	C/F	C/F		
[x] surface water	[x] Ingestion of Surface Water			C/F				
	[x] Dermal Absorption of Contaminants in Surface Water			C/F				
	[ ] Inhalation of Volatile Compounds in Tap Water							
[x] sediment	[x] Direct Contact with Sediment			C/F				
[x] biota	[x] Ingestion of Wild Foods						C/F	

Initial
Human Health Conceptual Site Model
Scoping Form

Site Name: Kantishna Gravel Source

File Number:

Completed by: USACE

Introduction
The form should be used to reach agreement with the Alaska Department of Environmental Conservation (DEC) about which exposure pathways should be further investigated during site characterization. From this information, a CSM graphic and text must be submitted with the site characterization work plan.

General Instructions: Follow the italicized instructions in each section below.

1. *General Information:*

Sources *(check potential sources at the site)*

- ☐ USTs
- ☐ ASTs
- ☐ Dispensers/fuel loading racks
- ☐ Drums
- ☐ Vehicles
- ☐ Landfills
- ☐ Transformers
- ☑ Other: Gravel

Release Mechanisms *(check potential release mechanisms at the site)*

- ☐ Spills
- ☐ Leaks
- ☐ Direct discharge
- ☐ Burning
- ☑ Other: Road maintenance

Impacted Media *(check potentially-impacted media at the site)*

- ☑ Surface soil (0-2 feet bgs*)
- ☑ Subsurface Soil (>2 feet bgs)
- ☑ Air
- ☐ Groundwater
- ☑ Surface water
- ☐ Other:

Receptors (*check receptors that could be affected by contamination at the site)*

- ☑ Residents (adult or child)
- ☑ Commercial or industrial worker
- ☑ Construction worker
- ☑ Subsistence harvester (i.e., gathers wild foods)
- ☑ Subsistence consumer (i.e., eats wild foods)
- ☑ Site visitor
- ☐ Trespasser
- ☑ Recreational user
- ☐ Farmer
- ☐ Other:

* bgs – below ground surface

2. *Exposure Pathways:* *(The answers to the following questions will identify complete exposure pathways at the site. Check each box where the answer to the question is "yes".)*

a) Direct Contact –

1 Incidental Soil Ingestion

Is soil contaminated anywhere between 0 and 15 feet bgs? ☑

Do people use the site or is there a chance they will use the site in the future? ☑

If both boxes are checked, label this pathway complete: Complete

2 Dermal Absorption of Contaminants from Soil

Is soil contaminated anywhere between 0 and 15 feet bgs? ☑

Do people use the site or is there a chance they will use the site in the future? ☑

Can the soil contaminants permeate the skin? (Contaminants listed below, or within the groups listed below, should be evaluated for dermal absorption). ☑

Arsenic	Lindane
Cadmium	PAHs
Chlordane	Pentachlorophenol
2,4-dichlorophenoxyacetic acid	PCBs
Dioxins	SVOCs
DDT	

If all of the boxes are checked, label this pathway complete: Complete

b) Ingestion –

1 Ingestion of Groundwater

Have contaminants been detected or are they expected to be detected in the groundwater, OR are contaminants expected to migrate to groundwater in the future? ☑

Could the potentially affected groundwater be used as a current or future drinking water source? *Please note, only leave the box unchecked if ADEC has determined the groundwater is not a currently or reasonably expected future source of drinking water according to 18 AAC 75.350.* ☑

If both the boxes are checked, label this pathway complete: Complete

2 Ingestion of Surface Water

Have contaminants been detected or are they expected to be detected in surface water OR are contaminants expected to migrate to surface water in the future? ☑

Could potentially affected surface water bodies be used, currently or in the future, as a drinking water source? *Consider both public water systems and private use (i.e., during residential, recreational or subsistence activities).* ☑

If both boxes are checked, label this pathway complete: Complete

3 Ingestion of Wild Foods

Is the site in an area that is used or reasonably could be used for hunting, fishing, or harvesting of wild food? ☑

Do the site contaminants have the potential to bioaccumulate (*see* Appendix A)? ☑

Are site contaminants located where they would have the potential to be taken up into biota? (i.e. the top 6 feet of soil, in groundwater that **could be** connected to surface water, etc.) ☑

If all of the boxes are checked, label this pathway complete: Complete

c) Inhalation

1 Inhalation of Outdoor Air

Is soil contaminated anywhere between 0 and 15 feet bgs? ☑

Do people use the site or is there a chance they will use the site in the future? ☑

Are the contaminants in soil volatile (*See Appendix B*)? ☐

If all of the boxes are checked, label this pathway complete: ______

2 Inhalation of Indoor Air

Are occupied buildings on the site or reasonably expected to be placed on the site in an area that could be affected by contaminant vapors? (i.e., within 100 feet, horizontally or vertically, of the contaminated soil or groundwater, or subject to "preferential pathways" that promote easy airflow, like utility conduits or rock fractures) ☐

Are volatile compounds present in soil or groundwater (*See Appendix C*)? ☐

If both boxes are checked, label this pathway complete: ______

3. *Additional Exposure Pathways:* *(Although there are no definitive questions provided in this section, these exposure pathways should also be considered at each site. Use the guidelines provided below to determine if further evaluation of each pathway is warranted.)*

Dermal Exposure to Contaminants in Groundwater and Surface Water

Exposure from this pathway may need to be assessed only in cases where DEC water-quality or drinking-water standards are not being applied as cleanup levels. Examples of conditions that may warrant further investigation include:

- Climate permits recreational use of waters for swimming,
- Climate permits exposure to groundwater during activities, such as construction, without protective clothing, or
- Groundwater or surface water is used for household purposes.

Check the box if further evaluation of this pathway is needed: ☐

Comments:

Inhalation of Volatile Compounds in Household Water

Exposure from this pathway may need to be assessed only in cases where DEC water-quality or drinking-water standards are not being applied as cleanup levels. Examples of conditions that may warrant further investigation include:

- The contaminated water is used for household purposes such as showering, laundering, and dish washing, <u>and</u>
- The contaminants of concern are volatile (common volatile contaminants are listed in Appendix B)

Check the box if further evaluation of this pathway is needed: ☐

Comments:

Inhalation of Fugitive Dust

Generally DEC soil ingestion cleanup levels in Table B1 of 18 AAC 75 are protective of this pathway, although this is not true in the case of chromium. Examples of conditions that may warrant further investigation include:

- Nonvolatile compounds are found in the top 2 centimeters of soil. The top 2 centimeters of soil are likely to be dispersed in the wind as dust particles.
- Dust particles are less than 10 micrometers. This size can be inhaled and would be of concern for determining if this pathway is complete.

Check the box if further evaluation of this pathway is needed: ☑

Comments:

The size of the dust particles from the OSHA dust sampling in 1998 is not available.

Direct Contact with Sediment

This pathway involves people's hands being exposed to sediment, such as during recreational or some types of subsistence activities. People then incidentally **ingest** sediment from normal hand-to-mouth activities. In addition, **dermal absorption of contaminants** may be of concern if people come in contact with sediment and the contaminants are able to permeate the skin (see dermal exposure to soil section). This type of exposure is rare but it should be investigated if:

- Climate permits recreational activities around sediment, and/or
- Community has identified subsistence or recreational activities that would result in exposure to the sediment, such as clam digging.

ADEC soil ingestion cleanup levels are protective of direct contact with sediment. If they are determined to be over-protective for sediment exposure at a particular site, other screening levels could be adopted or developed.

Check the box if further evaluation of this pathway is needed: ☐

Comments:

4. Other Comments *(Provide other comments as necessary to support the information provided in this form.)*