# K3.18 WATER AND SEDIMENT QUALITY

This appendix contains supplemental technical information on the following topics related to baseline surface water, groundwater, and substrate/sediment quality discussed in Section 3.18, Water and Sediment Quality:

- Water and sediment quality criteria used to compare to existing and predicted future conditions.
- Geochemistry sampling program, rationale, data summaries, and time period predictions.
- Surface water data tables and trend analyses for the mine site, north access route, and Iliamna Lake.
- Water quality information for Cook Inlet at Iliamna/Iniskin estuary north of Amakdedori port.
- Groundwater well completions and data summary for the mine site.
- Sediment quality data for the mine site and north access route.

## K3.18.1 Criteria

This section provides a description of water and sediment quality criteria used in comparison to baseline and predicted future data to assess where conditions might exceed standards for protection of aquatic resources or human health.

### K3.18.1.1 Surface Water Quality Criteria

In Alaska, surface water quality is regulated by Alaska Department of Environmental Conservation (ADEC) under 18 Alaska Administrative Code (AAC) 70, Water Quality Standards (WQS). Table K3.18-1 provides a list of the most stringent applicable WQS.

US Environmental Protection Agency (EPA) provides oversight of WQS selection under the Clean Water Act (CWA 40 Code of Federal Regulation [CFR] Part 131). In 2004, EPA partially approved revisions to the WQS, while taking no action on Alaska's proposed acute and chronic freshwater aquatic life criteria for mercury and selenium. Therefore, the new aquatic life criteria for mercury and selenium will not be in effect for CWA purposes until a decision is made by EPA about whether these criteria can be approved. In the interim, the previously approved aquatic life criteria for mercury (2.4 micrograms per liter [µg/l] acute and 0.012 µg/l chronic, both as total recoverable) and selenium (20 µg/l acute and 5 µg/l chronic, both as total recoverable) will remain the applicable CWA standards.

In instances where the Alaska WQS (AWQS) have been approved by EPA, water quality in this section is described in relation to AWQS. These include use classifications, numeric and narrative water quality criteria, and an anti-degradation policy. The usage classification system designates the beneficial uses that each waterbody in the state of Alaska is expected to support. These include freshwater and marine water use for water supply (including drinking water, irrigation, aquaculture, and industrial use), recreation, and protection of fish. In Alaska, waterbodies are designated for all protected water uses unless otherwise stated (18 AAC 70.050). The water quality data presented in this appendix are compared to the most stringent applicable State of Alaska water and sediment quality standards (for all designated water uses) listed in Table K3.18-1.

**Table K3.18-1: Criteria Used for Comparison to Water and Sediment Quality Data**

| Water Quality[a] | | | | Sediment Quality[b,c] | |
|---|---|---|---|---|---|
| **Parameter[d]** | **Unit** | **Most Stringent Criteria** | **Basis** | **TEL** | **PEL** |
| Aluminum (Total) | mg/L | 0.087 | WQBEL-ALC | - | - |
| Antimony (Total) | mg/L | 0.006 | WQBEL-DW | - | - |
| Arsenic (Total) | mg/L | 0.01 | WQBEL-DW | 5,900 | 17,000 |
| Barium (Total) | mg/L | 2 | WQBEL-HH | - | - |
| Beryllium (Total) | mg/L | 0.004 | WQBEL-HH | - | - |
| Boron (Total) | mg/L | 0.75 | WQBEL-HH | - | - |
| Cadmium (H) (Total) | mg/L | 0.00008 | WQBEL-ALC | 596 | 3,530 |
| Chloride | mg/L | 230 | WQBEL-ALC | - | - |
| Residual Chlorine (Total) | mg/L | 0.011 | WQBEL-ALC | - | - |
| Chromium (Total) | mg/L | 0.1 | WQBEL-DW | 37,300 | 90,000 |
| Chromium III (H) (Total) | mg/L | 0.01918 | WQBEL-ALC | - | - |
| Chromium VI (Dissolved) | mg/L | 0.011 | WQBEL-ALC | - | - |
| Cobalt (Total) | mg/L | 0.05 | WQBEL-IR | - | - |
| Copper (H) (Total) | mg/L | 0.00219 | WQBEL-ALC | 35,700 | 197,000 |
| Cyanide (WAD)[e] | mg/L | 0.0052 | WQBEL-ALC | - | - |
| Fluoride | mg/L | 1 | WQBEL-IR | - | - |
| Iron (Total) | mg/L | 1 | WQBEL-ALC | - | - |
| Lead (H) (Total) | mg/L | 0.00039 | WQBEL-ALC | 35,000 | 91,300 |
| Lithium (Total) | mg/L | 2.5 | WQBEL-IR | - | - |
| Manganese (Total) | mg/L | 0.05 | WQBEL-HH | - | - |
| Mercury (Total) | mg/L | 0.000012 | WQBEL-ALC | 174 | 486 |
| Molybdenum (Total) | mg/L | 0.01 | WQBEL-IR | - | - |
| Nickel (H) (Total) | mg/L | 0.01287 | WQBEL-ALC | 18,000 | 36,000 |
| Nickel (dissolved) | mg/L | 0.0082 | AWQS | | |
| Nitrate ($NO_3$) | mg/L | 10 | WQBEL-DW | - | - |
| Nitrite ($NO_2$) | mg/L | 1 | WQBEL-DW | - | - |
| Nitrate+Nitrite (Total) | mg/L | 10 | WQBEL-DW | - | - |
| Selenium (Total) | mg/L | 0.005 | WQBEL-ALC | - | - |
| Silver (H) (Total) | mg/L | 0.0011 | WQBEL-ALA | - | - |
| Thallium (Total) | mg/L | 0.0017 | WQBEL-HH | - | - |
| Vanadium (Total) | mg/L | 0.1 | WQBEL-HH | - | - |
| Zinc (H) (Total) | mg/L | 0.02895 | WQBEL-ALA | 123,000 | 315,000 |

**Table K3.18-1: Criteria Used for Comparison to Water and Sediment Quality Data**

| Water Quality[a] | | | | Sediment Quality[b,c] | |
|---|---|---|---|---|---|
| **Parameter[d]** | **Unit** | **Most Stringent Criteria** | **Basis** | **TEL** | **PEL** |
| Total Dissolved Solids | mg/L | 500 | WQBEL-HH | - | - |
| pH | - | 6.5 - 8.5 | WQS-GP | - | - |
| Total Suspended Solids[f] | mg/L | 20 | ELG-MA | - | - |
| Dissolved Oxygen | mg/L | > = 7.0 | WQS-GP | - | - |
| Turbidity (NTU) | NTU | <= 5 NTU above natural turbidity | WQS-WS | - | - |
| Total Alkalinity | mg/L | > = 20 | WQBEL-ALC | - | - |
| Ammonia ($NH_3$) as Nitrogen (N) | mg/L | 4.36 | WQBEL-ALC | - | - |
| Sulfate | mg/L | 250 | WQS | - | - |
| Alkalinity as $CaCO_3$ | mg/L | > = 20 | ALC | - | - |
| Total Ammonia as N[g] | mg/L | 0.18 | ALC | - | - |
| Temperature[h] | °C | 13 | WQS | - | - |
| Hardness (as CaCO3)[i,j] | mg/L | ~=100 | | - | - |

Notes:
[a] Water quality limits are based on the lowest 15th percentile hardness of the three proposed discharge locations.
[b] Sediment quality units = parts per billion
[c] Based on NOAA Freshwater Sediment criteria
[d] WQBEL is the most stringent among total and dissolved criteria for all metals, unless otherwise specified.
[e] ADEC has determined that the WAD cyanide method is to be used for analysis and the result is to be applied to the free cyanide criterion.
[f] There is no state water quality standard for total suspended solids (TSS).
[g] Ammonia: acute criterion is pH dependent; chronic criterion is temperature and pH dependent. Estimate based on pH 7.5 and temperature 14 degrees Celsius (°C). Temperatures below 14°C do not change the criterion.
[h] Temperature limits are dependent on habitat and seasonal considerations. Temperature criteria for spawning areas are included in table.
[i] There is no criterion for hardness in the State of Alaska WQS. Hardness value indicates the most stringent condition of the three proposed discharge locations.
[j] Hardness-dependent criteria (cadmium, copper, chromium III, lead, nickel, silver, zinc) are calculated using the estimated 15th percentile conditions for the receiving streams. The most stringent of the three proposed discharge locations is included in the table.
Abbreviations:
WQBEL = Water Quality Based Effluent Limit
(H) = Hardness dependent criterion
WQS: Water Quality Standards
ALA = Aquatic Life, Acute
DW = Drinking Water
GP = Growth and Propagation of Fish
WS = Water supply
WAD: Weak Acid Dissociable
$CaCO_3$ = calcium carbonate
ELG = Effluent Limitation Guideline
(S) = Selenite + Selenate dependent criterion
HH = Human Health
ALC = Aquatic Life, Chronic
MA = Monthly Average
IR = Irrigation water
NTU: Nephelometric Turbidity Units
mg/L = milligrams per liter
AWQS = Alaska Water Quality Standard
Source: Knight Piésold 2018a; HDR 2018; Schlumberger et al. 2011a; Buchman 2008; ADEC 2018b

Criteria for some dissolved metals, including cadmium, chromium, copper, lead, nickel, silver, and zinc, are hardness-dependent, meaning that the acceptable concentrations of these metals depend on the hardness of the water. Hardness is a measure of the concentration of polyvalent cations in the water, such as calcium ($Ca^{2+}$) and magnesium ($Mg^{2+}$). The polyvalent cations that contribute to water hardness reduce the bioavailability of certain trace metals by competing with the trace metal ions for binding sites within organisms. The extent of this effect varies according to which dissolved metals are present, and their oxidation states. To account for the influence of

water hardness on the bioavailability and potential toxicity of certain dissolved metals, the numeric water quality criteria for those metals are calculated so that the allowable concentrations of the metals increase in proportion to the hardness of the water (ADEC 2008a). Therefore, the numeric water quality criteria for hardness-dependent parameters vary depending on the measured (or predicted) hardness value for the specific water in question. Hardness parameters are based on the lowest 15$^{th}$ percentile of hardness measured at the three proposed discharge locations for the project, which are located in tributaries to the North Fork Koktuli (NFK), South Fork Koktuli (SFK), and Upper Talarik Creek (UTC) (Figure 2-3).

The ADEC numeric water quality standard for ammonia depends on both the temperature and the pH of the water, but not hardness.

### K3.18.1.2 Groundwater Quality Criteria

As specified in 18 AAC 70.050(a)(2), groundwater is protected for all uses in Class (1)(A), including drinking, culinary, and food processing; agriculture, including irrigation and stock watering; aquaculture; and industrial uses. ADEC also regulates discharges to groundwater under 18 AAC 72 (wastewater disposal); releases to groundwater from contaminated sites under 18 AAC 75 (oil and hazardous substances); and discharge of domestic and/or non-domestic wastewater to groundwater, or discharge of groundwater to surface water, under 18 AAC 83 (APDES program).

Drinking water from groundwater sources is regulated by 18 AAC 80 (ADEC 2012c) and by EPA (2013k, 2017c). EPA sets standards for approximately 90 contaminants in drinking water. These standards include National Primary Drinking Water Regulations, which become legally enforceable Maximum Contaminant Levels (MCLs) for public water systems in Alaska once adopted by 18 AAC 80. Primary standards protect public health by limiting the levels of contaminants in drinking water. Secondary Drinking Water Standards are unenforceable federal guidelines regarding taste, odor, color, and certain other effects of drinking water. EPA MCLs for certain constituents (e.g., aluminum, chloride, iron, manganese, pH, sulfate, total dissolved solids [TDS], and zinc) are Secondary Drinking Water Regulations that set non-mandatory water quality standards.

Because groundwater at the mine site is intended to be extracted and discharged to surface waterbodies, or could migrate to surface waterbodies or groundwater drinking water sources, the most stringent of either WQS aquatic life criteria or drinking water standards (Table K3.18-1) are used for the purposes of comparison to existing and future groundwater conditions.

### K3.18.1.3 Sediment Quality Criteria

There are no regulations established for chemical concentrations in sediment. Sediment Quality Guidelines (SQGs) recommended by ADEC (2013d) for use at contaminated sites were used for comparison purposes to project area data (Table K3.18-1). These include Threshold Effects Levels (TELs) and Probable Effects Levels (PELs) published in National Oceanic and Atmospheric Administration (NOAA) Screening Quick Reference Tables for both fresh and marine water sediment (Buchman 2008). TELs are concentrations below which adverse effects of benthic organisms are expected to occur rarely, and PELs represent concentrations above which effects are expected to be frequent.

## K3.18.2 Geochemistry

This section contains additional technical information on the following topics related to geochemical characterization of the Pebble deposit and its potential for weathering and release of constituents to water and sediment resources:

- Geochemical data summary
- Waste rock characteristics
- Tailings analyses
- Construction rock fill
- Open pit block model

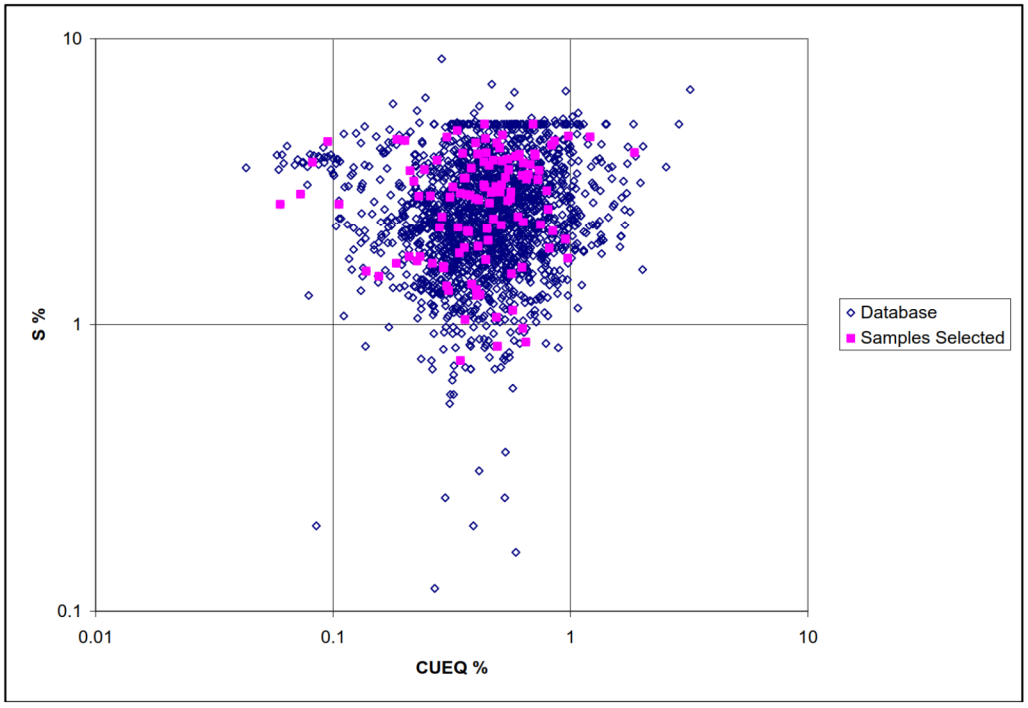
The geochemical evaluation presented in Section 3.18, Water and Sediment Quality, primarily relies on data presented in SRK (2011a, 2018a, 2018b, 2018c, 2018d). These data were developed using representative overburden, rock cores, and metallurgical waste (tailings) samples from the Pebble east and west zones (PEZ and PWZ), and rock core samples from borings drilled in three proposed construction rock quarry areas. Geochemical characterization includes sample mineralogy and static and kinetic tests including acid base accounting (ABA), metal mobility, humidity cell, subaqueous leach columns, stored bag weathering, and field barrel tests. Based on consistent mineralization style and host rocks between the PEZ and PWZ, a combined dataset was used to fully leverage the data available (SRK 2018f). Characteristics of samples tested for geochemical analyses were compared to the complete range of characteristics shown by that lithological group. A visual analysis was performed to ensure that samples were representative across all geochemical variations. Additionally, a gap analysis was performed and additional samples were selected manually to ensure a representative sampling pattern was used (SRK 2011a). Figure K3.18-1 provides an example distribution of samples selected for analysis compared to the breadth of samples in terms of copper, sulfur, and calcium content (SRK 2011a).

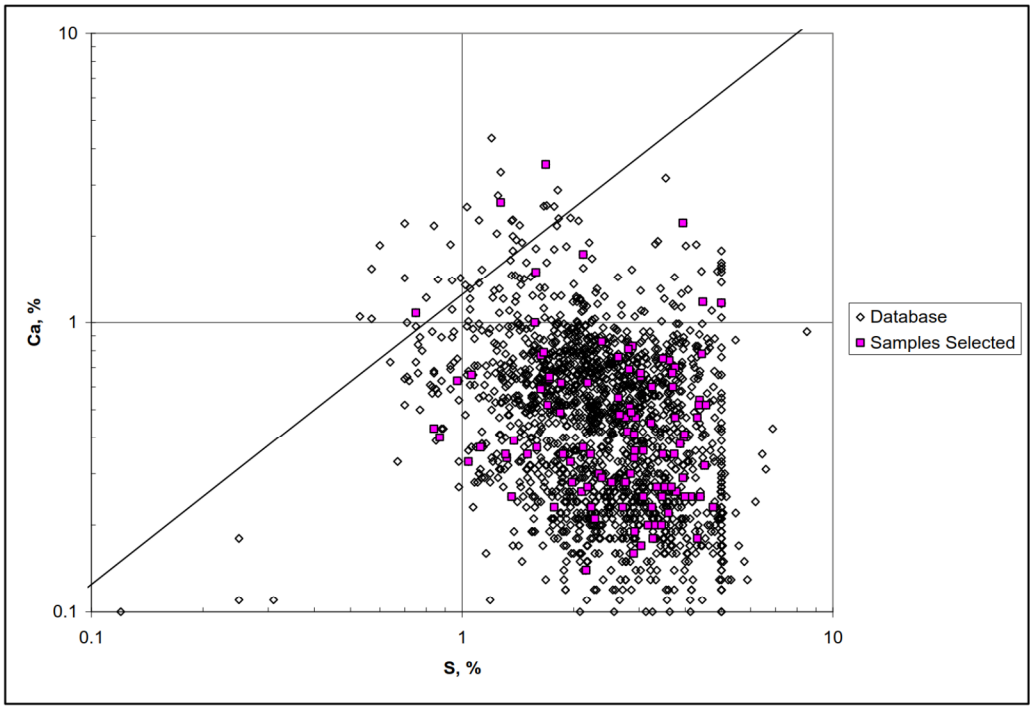
A total of 1,049 overburden and pre-Tertiary and Tertiary rock core samples from various rock and alteration types within the Pebble deposit, 64 tailings samples from metallurgical process test runs, and 138 rock core samples from boreholes drilled at the proposed construction quarries have been tested to date. Of the 1,049 rock samples tested, 685 were assigned by Pebble Limited Partnership (PLP) geologists to a hydrothermal alteration zone within the deposit. A summary of the rock and tailings samples geochemically characterized is provided in Table K3.18-2.

### K3.18.2.1 Waste Rock Geochemical Characteristics

The objectives of the geochemical characterization program were to predict the weathering and leaching behavior of rock, tailings, and other materials that would be produced during mining and processing. Data produced from geochemical testing were used to predict the chemistry of waters that contact the rock exposed in the open pit, and the waste rock and tailings stored in the tailings storage facilities, and determine their acid rock drainage/metal leaching (ARD/ML) potential.

Samples for geochemical testing were selected from the numerous exploration cores drilled to outline the deposit. The samples included all the main Pebble deposit rock types, and adjacent rock types that might be removed during mining. As of 2018, the program had included analysis of 1,023 rock samples from the Pebble deposit, and 26 samples of overburden materials from the PEZ and PWZ. In addition, 64 tailings samples composed mostly of rougher, cleaner scavenger, pyritic, and gold plant tails, from test processing of ore composites have also been characterized. To date, limited geochemical testing has been performed on the representative concentrate because metallurgical process designs are still being evaluated.




Source: SRK 2011a, Figure 11-2

Notes: 'Database' refers to all available data in the NDM Pebble Project Drill-Core Database at the time of sampling, while 'Samples selected' refers to data specific to the samples selected for detailed geochemical characterization.

The diagonal line on the lower graph indicates equivalent AP and NP if sulfur (S) and calcium (Ca) are used as AP and NP surrogates.

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**GEOCHEMICAL CHARACTERIZATION – REPRESENTATIVE SAMPLE DISTRIBUTION**

**PEBBLE PROJECT EIS**

**FIGURE K3.18-1**

**Table K3.18-2: Summary of Rock and Tailings Geochemical Testing Program**

| Test | Waste Rock Test Count | | | | | Tailings Test Count | |
|---|---|---|---|---|---|---|---|
| | PWZ | | PEZ | | Overburden | | |
| | Pre-Tertiary | Tertiary | Pre-Tertiary | Tertiary | | PWZ | PEZ |
| Acid-base Accounting | 429 | 56 | 249 | 289 | 26 | 46 | 18 |
| Mineralogy | 17 | 7 | 12 | 15 | 0 | 10 | 9 |
| Shake-flask Extractions | 27 | 4 | 0 | 0 | 0 | 0 | 0 |
| NAG | 27 | 4 | 0 | 0 | 0 | 0 | 0 |
| MWMP | 0 | 27 | 0 | 0 | 9 | 0 | 0 |
| Humidity Cell | 27+1[a] | 15+3[b] | 19+1[a] | 14+3[b] | 0 | 11 | 9 |
| Stored Bag | 0 | 0 | 8 | 12 | 0 | 0 | 0 |
| Subaqueous Columns | 6 | 0 | 0 | 4 | 0 | 2 | 0 |
| Aerated Columns | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| Field (Barrel) | 5+1[a] | 2+3[b] | 1[a] | 1+3[b] | 0 | 1[c] | |

Notes:
One of these tests comprised material from both the Pebble East and Pebble West zones.
[a] Three of these tests comprised material from both the Pebble East and Pebble West zones.
[b] Tailings from XPS mini pilot plant (zone not documented).
MWMP = Meteoric Water Mobility Procedure
NAG = net acid generation
PEZ = Pebble East Zone
PWZ = Pebble West Zone
Source: PLP 2018-RFI 105

For the project, neutralization potential (NP) and acidification potential (AP) terms were developed through extensive study of the chemistry and mineralogy of the various rock types at the site. This included ABA using the modified Sobek et al. (1978) method on 1,023 rock samples collected from drill holes blanketing the PWZ and PEZ of the mine site. The rock samples were tested for mineral abundance using transmitted and reflected light microscopy, and ARD potential, bulk chemical composition, and constituent mobility. Geochemical tests have included ABA, sequential net acid generation, shake flask extractions, meteoric water mobility, humidity cells, subaqueous (saturated) leach columns, and on-site field weathering (barrel and bag) tests to evaluate rates of oxidation, acid generation, acid neutralization, and element leaching.

In some mineralized deposits, rock type alone can be a good indicator of whether a rock will potentially produce ARD and/or ML. There are two main geological divisions at the proposed mine site. The mineralization is hosted by sedimentary and volcanic rocks of pre-Tertiary age. After the pre-Tertiary occurrence of mineralization, those rocks were partially eroded, then covered by other sedimentary and volcanic rock later in the Tertiary period. The later Tertiary age rocks at the mine site generally do not contain copper, gold, or other metals that would be economically viable to recover at the present time (SRK 2011a, 2011b, 2018a).

The mineralogical characterization included analysis of samples by thin section, Rietveld X-ray diffraction (XRD), and/or ion microprobe to determine carbonate and sulfide mineral compositions. Based on mineralogical analysis, the NP in the pre-Tertiary rocks was found to be mainly dolomite, with lesser amounts of calcite, ankerite, and magnesite. NP in Tertiary rocks is primarily derived from calcite. Siderite was found in both the pre-Tertiary and Tertiary rocks, but

does not contribute to NP. The AP was found to be mainly pyrite and chalcopyrite, and lesser amounts of molybdenite. Pyrite is the predominant source of acidity in both pre-Tertiary and Tertiary rocks.

ABA is a series of laboratory tests designed to estimate a rock's AP and NP. Both AP and NP are expressed in units of tons of calcium carbonate ($CaCO_3$) equivalent per 1,000 tons of material ($tCaCO_3/kt$) to allow direct comparisons. Corrections are made when the respective minerals are not all pyrite or calcite. Table K3.18-3 provides a summary of the ABA results for waste rock grouped by lithologic type. ABA determined that the pre-Tertiary mineralized sedimentary and plutonic rocks at the proposed mine site are predominantly potentially acid generating (PAG). The AP of these rocks is relatively high because they contain several percent pyrite, as indicated by the total sulfur content of greater than 1 percent, and they have limited NP. The distribution of pyrite (and consequently acid generating potential) was found to be influenced by the hydrothermal alteration zones overprinted on the deposit.

In contrast, the majority of the Tertiary age and younger rocks that comprise the cover and overburden materials at the proposed mine site are considered non-PAG because they have less than 1 percent pyrite, low total sulfur concentrations less than 0.1 percent, and excess NP because carbonate minerals are abundant. However, a small proportion of the Tertiary volcanic rocks were found to be PAG.

The most common measure of whether a rock is non-PAG or PAG is the NP/AP ratio. To develop an understanding of weathering and leaching processes that might affect rocks exposed during mining (e.g., pit walls and stockpiled waste rock and tailings), additional laboratory and field geochemical tests were conducted. Laboratory tests included humidity cell, subaqueous (saturated) column, stored bag, and field barrel tests.

Humidity cell test results were used to confirm ABA criteria for segregating PAG from non-PAG rocks and waste, based on the NP/AP ratio. The average duration of these tests was approximately 3 years and ranged from 27 weeks up to 8 years (SRK 2011a; PLP 2018a). Analysis of the ABA and humidity cell data indicates that PAG and NAG rocks can be distinguished using an NP/AP ratio of 1.4 (PLP 2018a), and is applicable to pre-Tertiary, Tertiary, and overburden materials. Humidity cell test data obtained for periods up to 8 years allow interpretation of long-term acid generation potential and neutralization rates as the rocks are oxidized and leached during wet and dry cycles. Humidity cell tests also help to estimate the potential lag or delay in the onset of ARD using the sulfide oxidation and release rates and pH profiles. The delay occurs because acid-neutralizing minerals (e.g., calcite, feldspars, and micas) are not depleted instantly as acid is formed, but are consumed at different rates depending on their reactivity and abundance.

Results show that pre-Tertiary rocks with low NP/AP ratios (less than 0.3) have little neutralization potential and are estimated to generate acid within 1 to 6 years (PLP 2018a). Pre-Tertiary rocks with NP/AP ratios of 1 have higher neutralization potential, which delays the estimated onset of acid generation to 8 to 20 years (PLP 2018a). These estimated times to onset of ARD are considered underestimates because they are based on data developed under controlled laboratory conditions. Paste pH results for aged rock cores stored at the site suggest that acidification may be delayed up to 40 years. Given differences in the test conditions, laboratory and field tests suggest that oxidized pre-Tertiary mineralized rock may take up to several decades for acidification to occur.

**Table K3.18-3: Summary of ABA Results for Waste Rock**

| Number of Samples | Litho Code | Mean Paste pH | Mean S(T), % | Mean S(SO4), % | Mean S(S-2), % | Mean AP, $kgCaCO_3/t$ | Mean NP (Sobek), $kgCaCO_3/t$ | Mean Modified NP, $kgCaCO_3/t$ | Mean TIC, $kgCaCO_3/t$ | Mean TIC, % | NP/AP[a] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Waste Rock (PEZ)** | | | | | | | | | | | |
| 9 | D | 7.92 | 1.11 | 0.03 | 1.10 | 34.31 | 9.00 | 12.44 | 9.45 | 0.08 | 0.36 |
| 19 | G | 6.76 | 3.45 | 0.06 | 3.40 | 106.12 | - | 16.14 | 21.31 | - | 0.15 |
| 2 | G^c | 5.36 | 1.28 | 0.03 | 1.26 | 39.22 | - | 2.90 | - | - | 0.07 |
| 79 | Gp | 7.97 | 0.90 | 0.06 | 0.86 | 26.80 | 8.36 | 15.81 | 11.42 | 0.09 | 0.59 |
| 5 | Gpk | 8.54 | 0.55 | 0.01 | 0.54 | 16.94 | - | 29.18 | 22.27 | - | 1.72 |
| 62 | Gs | 5.30 | 7.76 | 0.17 | 7.61 | 237.96 | 15.84 | 4.49 | 12.52 | 0.13 | 0.02 |
| 2 | Gs/D | 8.19 | 0.31 | 0.02 | 0.30 | 9.22 | - | 16.25 | 15.91 | - | 1.76 |
| 1 | GZ | 5.41 | 0.72 | 0.07 | 0.65 | 20.31 | - | 7.40 | <4.5 | - | 0.36 |
| 1 | P | 9.55 | 0.12 | <0.01 | 0.12 | 3.75 | - | 7.90 | 6.82 | - | 2.11 |
| 45 | TA | 8.98 | 0.59 | 0.02 | 0.60 | 18.90 | 85.34 | 33.15 | 55.39 | 0.95 | 1.75 |
| 1 | TA d | 8.24 | 2.58 | 0.03 | 2.55 | 79.69 | - | 34.60 | 34.09 | - | 0.43 |
| 1 | TA/TD | 7.98 | 0.88 | 0.01 | 0.87 | 27.19 | - | 17.20 | 74.09 | - | 0.63 |
| 2 | TA+TB | 9.13 | 0.07 | 0.02 | 0.04 | 1.25 | - | 43.70 | 36.37 | - | 34.96 |
| 1 | Tabt | 9.23 | <0.01 | <0.01 | <0.01 | <0.3 | - | 10.10 | 9.09 | - | >33.6 |
| 3 | TAD | 8.47 | 0.20 | 0.03 | 0.19 | 5.84 | - | 66.43 | 56.06 | - | 11.38 |
| 2 | Tap | 9.02 | 0.67 | 0.02 | 0.66 | 20.63 | 41.80 | 17.20 | 23.98 | 0.52 | 0.83 |
| 1 | TAwx | 9.18 | 0.10 | <0.01 | 0.10 | 3.13 | - | 27.50 | 13.64 | - | 8.79 |
| 1 | TAx | 8.99 | 0.99 | 0.01 | 0.98 | 30.63 | - | 20.90 | 13.64 | - | 0.68 |
| 46 | TB | 8.69 | 0.07 | 0.01 | 0.07 | 2.12 | - | 56.47 | 38.74 | - | 26.66 |
| 1 | TBh | 8.82 | 0.01 | <0.01 | 0.01 | 0.31 | - | 35.30 | 13.64 | - | 113.87 |
| 3 | TBTBx | 8.66 | 0.16 | 0.01 | 0.16 | 5.00 | - | 52.77 | 43.18 | - | 10.55 |
| 1 | TBv | 8.23 | <0.01 | 0.01 | 0.01 | 0.31 | - | 63.10 | 31.82 | - | 203.55 |
| 1 | TBx | 8.46 | 0.01 | <0.01 | 0.01 | 0.31 | - | 126.30 | 111.36 | - | 407.42 |
| 68 | TC | 8.91 | 0.26 | 0.02 | 0.26 | 8.05 | 87.27 | 69.80 | 71.15 | 1.00 | 8.67 |
| 5 | TC/TF | 9.20 | 0.07 | 0.01 | 0.08 | 2.58 | 84.70 | 60.30 | 75.55 | 0.96 | 23.37 |

**Table K3.18-3: Summary of ABA Results for Waste Rock**

| Number of Samples | Litho Code | Mean Paste pH | Mean S(T), % | Mean S(SO4), % | Mean S(S-2), % | Mean AP, $kgCaCO_3/t$ | Mean NP (Sobek), $kgCaCO_3/t$ | Mean Modified NP, $kgCaCO_3/t$ | Mean TIC, $kgCaCO_3/t$ | Mean TIC, % | NP/AP[a] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | TC/TW | 7.34 | 0.72 | 0.05 | 0.67 | 20.94 | - | 26.50 | 20.45 | - | 1.27 |
| 1 | TC/TY | 8.99 | 0.11 | 0.01 | 0.10 | 3.13 | - | 125.10 | 120.45 | - | 39.97 |
| 6 | TD | 8.89 | 0.34 | 0.02 | 0.34 | 10.57 | 106.80 | 50.28 | 75.54 | 1.26 | 4.75 |
| 1 | TDd | 8.80 | 0.04 | 0.02 | 0.02 | 0.63 | - | 75.80 | 9.09 | - | 120.32 |
| 5 | TDm | 8.91 | 0.01 | 0.01 | 0.01 | 0.39 | - | 17.83 | 10.61 | - | 45.71 |
| 29 | TF | 8.83 | 0.22 | 0.02 | 0.23 | 7.13 | 101.79 | 59.06 | 76.32 | 1.22 | 8.28 |
| 1 | TF/TC | 8.93 | 0.33 | <0.01 | 0.33 | 10.31 | 100.00 | - | 103.41 | 1.24 | 0.00 |
| 1 | TFf | 8.90 | <0.01 | <0.01 | <0.01 | <0.3 | - | 3.00 | <0.1 | - | >10 |
| 4 | TFw | 8.75 | 0.01 | 0.01 | 0.01 | 0.31 | - | 57.58 | 53.41 | - | 185.73 |
| 5 | TMd | 8.52 | 0.06 | 0.01 | 0.04 | 1.37 | - | 33.50 | 27.27 | - | 24.38 |
| 4 | TT | 8.80 | 0.03 | 0.02 | 0.04 | 1.25 | - | 60.95 | 50.00 | - | 48.76 |
| 1 | TTbu | 8.78 | 0.01 | <0.01 | 0.01 | 0.31 | - | 19.20 | 9.09 | - | 61.94 |
| 16 | TW | 8.86 | 0.26 | 0.03 | 0.24 | 7.58 | 79.85 | 60.15 | 75.77 | 0.91 | 7.94 |
| 1 | TW(TF) | 8.78 | 0.13 | 0.01 | 0.12 | 3.75 | - | 81.20 | 79.55 | - | 21.65 |
| 3 | TW/TC | 8.73 | 0.17 | 0.01 | 0.16 | 5.00 | 78.63 | - | 88.03 | 1.06 | 15.73 |
| 2 | TW/TF | 9.21 | 0.11 | 0.02 | 0.10 | 2.97 | 95.65 | - | 94.43 | 1.13 | 32.21 |
| 4 | TW/TY | 8.86 | 0.22 | 0.01 | 0.22 | 6.72 | 69.05 | - | 66.31 | 0.80 | 10.28 |
| 10 | TWc | 8.92 | 0.07 | 0.01 | 0.06 | 1.97 | - | 47.62 | 21.14 | - | 24.20 |
| 1 | TWc(TWf) | 8.49 | 0.01 | <0.01 | 0.01 | 0.31 | - | 23.40 | 4.55 | - | 75.48 |
| 1 | TWcm | 9.00 | 1.05 | 0.02 | 1.03 | 32.19 | - | 91.30 | 63.64 | - | 2.84 |
| 2 | TX | 8.77 | 0.01 | 0.01 | 0.01 | 0.16 | - | 26.95 | 25.00 | - | 173.87 |
| 4 | TXc | 8.80 | 0.05 | 0.01 | 0.05 | 1.67 | - | 24.45 | 18.18 | - | 14.67 |
| 1 | TXH | 8.58 | 0.01 | <0.01 | 0.01 | 0.31 | - | 6.90 | <4.5 | - | 22.26 |
| 17 | TY | 8.65 | 0.28 | 0.02 | 0.26 | 8.11 | 57.75 | 54.50 | 63.53 | 0.66 | 6.72 |
| 7 | W | 7.85 | 0.74 | 0.03 | 0.71 | 22.28 | - | 11.34 | 10.46 | - | 0.51 |
| 52 | Y | 7.42 | 2.24 | 0.04 | 2.21 | 69.00 | 6.70 | 9.38 | 8.45 | 0.05 | 0.14 |

**Table K3.18-3: Summary of ABA Results for Waste Rock**

| Number of Samples | Litho Code | Mean Paste pH | Mean S(T), % | Mean S(SO4), % | Mean S(S-2), % | Mean AP, $kgCaCO_3/t$ | Mean NP (Sobek), $kgCaCO_3/t$ | Mean Modified NP, $kgCaCO_3/t$ | Mean TIC, $kgCaCO_3/t$ | Mean TIC, % | NP/AP[a] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Y/W | 8.07 | 2.61 | 0.04 | 2.57 | 80.31 | 5.80 | - | 3.86 | 0.05 | 0.07 |
| 2 | Y0 | 8.74 | 0.30 | 0.01 | 0.29 | 9.07 | - | 18.45 | 14.77 | - | 2.04 |
| 8 | Y2L | 6.23 | 7.01 | 0.14 | 6.87 | 214.69 | - | 14.56 | 20.46 | - | 0.07 |
| 7 | Z | 8.18 | 1.01 | 0.04 | 0.98 | 30.67 | 81.90 | 26.50 | 25.00 | - | 0.86 |
| 26 | N/A | 7.81 | 0.03 | 0.01 | 0.03 | 0.97 | - | 23.25 | 28.76 | - | 23.92 |
| **Waste Rock (PWZ)** | | | | | | | | | | | |
| 1 | B | 7.29 | 0.14 | 0.07 | - | 2.19 | - | 1.88 | 0.83 | 0.01 | 0.86 |
| 44 | D | 7.46 | 4.37 | 0.06 | 6.42 | 134.55 | 40.09 | 28.38 | 46.56 | 0.57 | 0.21 |
| 2 | D/D | 8.15 | 5.11 | 0.10 | - | 158.13 | - | 34.63 | 32.92 | 0.40 | 0.22 |
| 2 | D/G | 7.28 | 3.40 | 0.14 | - | 102.04 | - | 26.26 | 58.75 | 0.71 | 0.26 |
| 2 | D/N | 6.41 | 2.75 | 0.13 | - | 81.88 | - | 13.25 | 66.26 | 0.80 | 0.16 |
| 1 | D/N-.#b | 8.37 | 2.00 | 0.02 | - | 61.88 | - | 47.00 | 129.18 | 1.55 | 0.76 |
| 1 | D/R | 8.82 | 3.29 | 0.11 | - | 99.38 | - | 49.50 | 52.50 | 0.63 | 0.50 |
| 1 | D / Dp | 8.72 | 4.88 | <0.01 | - | 152.50 | 50.30 | 41.75 | 42.50 | 0.51 | 0.27 |
| 1 | Dp | 9.00 | 3.39 | 0.01 | - | 105.63 | - | 51.00 | 54.17 | 0.65 | 0.48 |
| 1 | Dxq/D | 6.95 | 4.16 | 0.09 | - | 127.19 | - | 11.38 | 23.33 | 0.28 | 0.09 |
| 2 | F.F-DY | 8.10 | 2.19 | 0.02 | - | 67.66 | - | 8.50 | 31.26 | 0.38 | 0.13 |
| 1 | F.H(FDY) | 8.59 | 2.77 | <0.01 | - | 86.56 | - | 13.00 | 33.34 | 0.40 | 0.15 |
| 2 | Fc | 7.11 | 0.12 | 0.09 | - | 1.88 | - | 1.57 | 0.83 | 0.01 | 0.83 |
| 5 | Fh | 8.18 | 2.27 | 0.02 | - | 70.31 | 36.50 | 31.58 | 55.67 | 0.67 | 0.45 |
| 21 | G | 7.04 | 2.47 | 0.09 | - | 74.48 | 39.60 | 16.42 | 20.68 | 0.27 | 0.22 |
| 4 | G/D/N | 8.32 | 3.87 | 0.08 | 3.66 | 114.22 | - | 25.23 | 34.09 | - | 0.22 |
| 1 | G/N | 4.69 | 5.20 | 0.13 | - | 158.44 | - | 2.31 | 6.67 | 0.08 | 0.01 |
| 6 | G^c | 8.08 | 1.36 | 0.01 | - | 42.35 | 50.00 | 33.90 | 27.64 | 0.33 | 0.80 |
| 2 | G^f | 5.58 | 4.27 | 0.04 | - | 132.35 | - | 3.03 | 8.33 | 0.10 | 0.02 |
| 1 | G^fp | 8.02 | 2.36 | 0.01 | - | 73.44 | - | 11.50 | 49.17 | 0.59 | 0.16 |

**Table K3.18-3: Summary of ABA Results for Waste Rock**

| Number of Samples | Litho Code | Mean Paste pH | Mean S(T), % | Mean S(SO4), % | Mean S(S-2), % | Mean AP, $kgCaCO_3/t$ | Mean NP (Sobek), $kgCaCO_3/t$ | Mean Modified NP, $kgCaCO_3/t$ | Mean TIC, $kgCaCO_3/t$ | Mean TIC, % | NP/AP[a] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | G^m | 7.76 | 2.13 | 0.03 | - | 65.52 | 13.40 | 4.73 | 1.11 | 0.01 | 0.07 |
| 3 | G^p | 5.71 | 1.80 | 0.24 | - | 48.55 | - | 0.44 | 0.83 | 0.01 | 0.01 |
| 11 | Gp | 6.28 | 2.98 | 0.05 | 2.39 | 91.59 | 1.50 | 8.43 | 9.17 | 0.12 | 0.09 |
| 11 | G-p | 6.85 | 3.18 | 0.09 | - | 96.53 | 12.30 | 8.15 | 19.92 | 0.26 | 0.08 |
| 4 | Gph | 8.28 | 1.76 | 0.02 | - | 54.93 | - | 18.28 | 31.05 | 0.37 | 0.33 |
| 1 | GpK | 7.57 | 1.95 | 0.03 | - | 60.00 | - | 5.13 | 10.00 | 0.12 | 0.09 |
| 2 | Gp-k | 7.98 | 1.87 | 0.06 | - | 56.72 | 11.90 | 14.01 | 36.67 | 0.44 | 0.25 |
| 1 | Gp-Pl | 7.86 | 3.50 | 0.03 | - | 108.44 | - | 6.88 | 25.84 | 0.31 | 0.06 |
| 1 | G-q | 8.43 | 0.87 | 0.07 | - | 25.00 | - | 17.63 | 10.83 | 0.13 | 0.71 |
| 9 | Gs | 7.40 | 2.33 | 0.03 | 2.30 | 72.01 | 12.88 | 3.50 | 24.43 | 0.29 | 0.05 |
| 1 | Gs? | 5.45 | 0.38 | 0.36 | 0.02 | 0.63 | 0.30 | - | 1.82 | 0.02 | 0.48 |
| 1 | GxN | 8.04 | 1.45 | 0.01 | - | 45.00 | - | 8.00 | 25.84 | 0.31 | 0.18 |
| 2 | Kgde | 6.11 | 5.23 | 0.05 | - | 161.72 | - | 3.16 | 0.83 | 0.01 | 0.02 |
| 1 | Kqs | 7.07 | 4.16 | 0.04 | - | 128.75 | - | 4.38 | 0.83 | 0.01 | 0.03 |
| 2 | M | 8.26 | 1.55 | 0.04 | - | 47.35 | - | 37.75 | 54.17 | 0.65 | 0.80 |
| 1 | M.ky/X.mk | 7.54 | 1.70 | 0.08 | - | 50.63 | - | 6.50 | 38.34 | 0.46 | 0.13 |
| 1 | M/P | 5.11 | 2.33 | 0.02 | - | 72.19 | - | -1.13 | 0.83 | - | -0.02 |
| 1 | M? | 9.08 | 1.32 | 0.02 | - | 40.63 | 25.00 | 21.50 | 40.84 | 0.49 | 0.53 |
| 1 | M-k | 7.56 | 1.29 | 0.01 | - | 40.00 | - | 5.19 | 4.17 | 0.05 | 0.13 |
| 1 | Mk.Y | 8.47 | 1.64 | 0.03 | - | 50.31 | - | 20.00 | 14.17 | 0.17 | 0.40 |
| 1 | Mkp-x | 8.41 | 1.19 | 0.02 | - | 36.56 | - | 37.50 | 109.17 | 1.31 | 1.03 |
| 2 | Mp-k | 8.02 | 0.89 | 0.02 | - | 27.19 | - | 26.50 | 70.01 | 0.84 | 0.97 |
| 1 | Mpk / M-k | 7.30 | 1.87 | 0.01 | - | 58.13 | - | 4.38 | 0.83 | - | 0.08 |
| 1 | MpK-N | 7.58 | 0.76 | 0.01 | - | 23.44 | - | 2.75 | 14.17 | 0.17 | 0.12 |
| 14 | N | 6.80 | 2.61 | 0.10 | 2.33 | 78.17 | 12.45 | 13.17 | 27.91 | 0.36 | 0.17 |
| 1 | N / F.FD | 5.98 | 3.24 | 0.03 | | 100.31 | | -0.25 | 0.83 | 0.01 | 0.00 |

**Table K3.18-3: Summary of ABA Results for Waste Rock**

| Number of Samples | Litho Code | Mean Paste pH | Mean S(T), % | Mean S(SO4), % | Mean S(S-2), % | Mean AP, $kgCaCO_3/t$ | Mean NP (Sobek), $kgCaCO_3/t$ | Mean Modified NP, $kgCaCO_3/t$ | Mean TIC, $kgCaCO_3/t$ | Mean TIC, % | NP/AP[a] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | N or Gp.YD-M | 7.63 | 2.51 | 0.04 | - | 77.19 | - | 7.50 | 34.17 | 0.41 | 0.10 |
| 1 | N or Gp.YM | 7.80 | 1.52 | 0.05 | - | 45.94 | - | 9.13 | 37.50 | 0.45 | 0.20 |
| 1 | N or Gp-p.YM | 7.24 | 1.73 | 0.02 | - | 53.44 | - | 6.06 | 25.00 | 0.30 | 0.11 |
| 1 | N.DyM | 7.61 | 2.25 | 0.03 | - | 69.38 | - | 3.88 | 12.50 | 0.15 | 0.06 |
| 1 | N.FDZ / N/DX | 6.13 | 3.59 | 0.12 | - | 108.44 | - | 11.25 | 12.50 | 0.15 | 0.10 |
| 4 | N.H | 7.02 | 2.46 | 0.04 | - | 75.71 | - | 6.36 | 10.42 | 0.13 | 0.08 |
| 2 | N.M | 7.02 | 1.81 | 0.11 | - | 53.29 | 5.30 | 17.82 | 40.00 | 0.48 | 0.33 |
| 1 | N.MH | 7.32 | 2.52 | 0.08 | - | 76.25 | - | 5.94 | 13.33 | 0.16 | 0.08 |
| 1 | N.MY/ TBd | 8.66 | 0.15 | 0.01 | - | 4.38 | - | 67.75 | 159.18 | 1.91 | 15.47 |
| 1 | N.NM / N.YM | 6.65 | 2.18 | 0.04 | - | 66.88 | - | 6.38 | 7.50 | 0.09 | 0.10 |
| 1 | N.Y | 5.43 | 2.76 | 0.09 | - | 83.44 | - | 0.87 | 0.83 | 0.01 | 0.01 |
| 1 | N-.Y | 7.78 | 1.48 | 0.03 | - | 45.31 | - | 10.38 | 80.84 | 0.97 | 0.23 |
| 1 | N.Y-D | 8.87 | 1.03 | 0.02 | - | 31.56 | - | 116.13 | 150.01 | 1.80 | 3.68 |
| 1 | N.YM | 7.48 | 1.90 | 0.04 | - | 58.13 | - | 5.63 | 37.50 | 0.45 | 0.10 |
| 1 | N/D | 8.60 | 1.08 | 0.02 | - | 33.13 | - | 44.25 | 105.01 | 1.26 | 1.34 |
| 1 | N/D.-YM | 6.69 | 2.99 | 0.16 | - | 88.44 | - | 30.75 | 64.17 | 0.77 | 0.35 |
| 1 | N/F-D.Y | 4.50 | 5.10 | 0.12 | - | 155.63 | - | 0.00 | 0.83 | 0.01 | 0.00 |
| 2 | N/P | 8.41 | 2.33 | 0.03 | - | 71.72 | - | 7.32 | 2.92 | 0.04 | 0.10 |
| 2 | N/P / N | 8.04 | 1.93 | 0.02 | - | 59.69 | 11.10 | 4.88 | 1.67 | 0.02 | 0.08 |
| 1 | Np | 6.58 | 2.51 | 0.09 | - | 75.63 | - | 9.31 | 5.00 | 0.06 | 0.12 |
| 3 | N-p | 6.13 | 1.82 | 0.02 | - | 56.36 | - | 5.38 | 10.28 | 0.35 | 0.10 |
| 1 | Np-.#b D | 8.53 | 2.01 | 0.03 | - | 61.88 | - | 26.38 | 79.17 | 0.95 | 0.43 |
| 1 | N-p-.Y / N-.Y-D | 8.14 | 1.86 | 0.06 | - | 56.25 | - | 20.50 | 34.17 | 0.41 | 0.36 |
| 1 | O/B | 5.95 | 0.66 | 0.64 | - | 0.63 | - | 1.75 | 0.83 | 0.01 | 2.78 |
| 7 | OB | 7.40 | 0.51 | 0.12 | - | 12.63 | - | 12.43 | 6.43 | 0.09 | 0.98 |
| 4 | P | 7.82 | 2.51 | 0.03 | - | 77.58 | - | 23.72 | 42.09 | 0.51 | 0.31 |

**Table K3.18-3: Summary of ABA Results for Waste Rock**

| Number of Samples | Litho Code | Mean Paste pH | Mean S(T), % | Mean S(SO4), % | Mean S(S-2), % | Mean AP, $kgCaCO_3/t$ | Mean NP (Sobek), $kgCaCO_3/t$ | Mean Modified NP, $kgCaCO_3/t$ | Mean TIC, $kgCaCO_3/t$ | Mean TIC, % | NP/AP[a] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | P.DF | 8.17 | 2.46 | 0.02 | - | 76.10 | - | 26.07 | 25.42 | 0.31 | 0.34 |
| 1 | P/N.DN/p | 8.27 | 2.50 | 0.01 | - | 77.81 | - | 42.25 | 45.00 | 0.54 | 0.54 |
| 2 | P-k | 7.52 | 0.78 | 0.16 | - | 39.06 | - | 10.13 | 27.09 | 0.64 | 0.26 |
| 2 | Pp | 6.95 | 1.36 | 0.30 | - | 33.28 | - | 2.16 | 0.83 | 0.01 | 0.06 |
| 1 | Ppk | 6.20 | 1.73 | 0.04 | - | 52.81 | - | 10.00 | 14.17 | 0.17 | 0.19 |
| 1 | Ppk / P-k | 6.32 | 1.62 | 0.04 | - | 49.38 | - | 6.25 | 0.83 | 0.01 | 0.13 |
| 1 | q | 4.70 | 4.20 | 0.10 | - | 128.13 | - | -0.63 | 0.83 | 0.01 | 0.00 |
| 9 | R | 8.56 | 3.55 | 0.03 | - | 109.93 | 16.50 | 31.31 | 16.30 | 0.20 | 0.28 |
| 1 | R / qp | 7.85 | 11.65 | 0.05 | - | 362.50 | - | 25.75 | 19.17 | 0.23 | 0.07 |
| 7 | R/Db | 6.47 | 4.88 | 0.18 | - | 146.88 | - | 15.16 | 38.93 | 0.47 | 0.10 |
| 1 | TA pd | 8.53 | 0.40 | 0.02 | - | 11.88 | - | 66.25 | 175.85 | 2.11 | 5.58 |
| 2 | Tad | 8.57 | 0.32 | 0.01 | 0.38 | 9.85 | 23.10 | 60.25 | 31.59 | 0.38 | 6.12 |
| 2 | TB | 8.65 | 0.37 | 0.01 | - | 11.10 | - | 81.00 | 60.84 | 0.73 | 7.30 |
| 11 | TBd | 8.24 | 0.24 | 0.02 | - | 7.53 | 67.53 | 73.15 | 119.40 | 1.43 | 9.71 |
| 11 | TBd-.MY | 7.98 | 0.74 | 0.02 | 0.72 | 22.64 | 28.97 | - | 28.72 | 0.34 | 1.28 |
| 1 | TBpd | 8.41 | 0.41 | 0.03 | - | 11.88 | - | 72.50 | 160.01 | 1.92 | 6.10 |
| 1 | TC | 7.87 | 0.25 | 0.05 | - | 6.25 | 86.90 | 29.00 | 88.34 | 1.06 | 4.64 |
| 6 | TC - And/Volc cng | 8.70 | 0.04 | 0.01 | - | 1.04 | 123.80 | 85.11 | 118.90 | 1.43 | 81.57 |
| 1 | TC - Arkose | 7.41 | 0.60 | 0.30 | - | 9.38 | - | 41.38 | 81.67 | 0.98 | 4.41 |
| 1 | TC - basalt | 8.01 | 0.09 | 0.02 | - | 2.19 | - | 85.31 | 109.17 | 1.31 | 38.95 |
| 1 | TC-Cng | 8.07 | 0.41 | 0.08 | - | 10.47 | 152.50 | 76.94 | 137.93 | 1.66 | 7.35 |
| 1 | TC - Cng/mdst | 8.14 | 0.36 | 0.10 | - | 8.13 | - | 97.00 | 155.84 | 1.87 | 11.93 |
| 1 | TC - Slst | 8.20 | 0.11 | 0.04 | - | 2.19 | - | 56.75 | 129.18 | 1.55 | 25.91 |
| 2 | TC - Volc cng | 8.42 | 0.04 | 0.03 | - | 0.94 | - | 96.63 | 140.43 | 1.69 | 102.79 |
| 1 | TC- Arkose | 7.71 | 0.37 | 0.08 | - | 9.06 | 90.00 | 36.75 | 62.50 | 0.75 | 4.06 |
| 1 | TC- Oxidized | 7.02 | 0.05 | 0.01 | - | 1.25 | 15.30 | 3.00 | 1.67 | 0.02 | 2.40 |

**Table K3.18-3: Summary of ABA Results for Waste Rock**

| Number of Samples | Litho Code | Mean Paste pH | Mean S(T), % | Mean S(SO4), % | Mean S(S-2), % | Mean AP, $kgCaCO_3/t$ | Mean NP (Sobek), $kgCaCO_3/t$ | Mean Modified NP, $kgCaCO_3/t$ | Mean TIC, $kgCaCO_3/t$ | Mean TIC, % | NP/AP[a] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | TC/TF/TX | 9.01 | 0.34 | 0.03 | 0.30 | 9.38 | - | 92.53 | 142.05 | - | 9.87 |
| 1 | TC^k - Basalt | 8.37 | 0.12 | 0.01 | - | 3.44 | 141.30 | 76.25 | 195.85 | 2.35 | 22.17 |
| 4 | TC^k - Volc Cng | 8.80 | 0.07 | 0.03 | - | 2.08 | - | 78.00 | 79.38 | 0.95 | 37.44 |
| 1 | TD | 9.12 | 0.01 | 0.01 | - | <0.3 | - | 28.38 | 20.00 | 0.24 | >94.6 |
| 1 | TF | 7.42 | 3.80 | 0.06 | 3.74 | 116.88 | - | 21.90 | 324.09 | - | 0.19 |
| 2 | W | 5.30 | 3.33 | 0.09 | - | 101.41 | - | 2.72 | 1.25 | 0.02 | 0.03 |
| 1 | WC? | 9.16 | 1.49 | 0.02 | - | 45.94 | 32.00 | 30.75 | 45.84 | 0.55 | 0.67 |
| 5 | WY | 6.73 | 2.59 | 0.13 | - | 76.94 | 11.80 | 8.44 | 13.83 | 0.17 | 0.11 |
| 2 | X | 8.45 | 1.94 | 0.02 | - | 60.16 | - | 19.00 | 42.09 | 0.51 | 0.32 |
| 1 | X.Db GN | 7.74 | 3.67 | 0.13 | - | 110.63 | - | 45.00 | 66.67 | 0.80 | 0.41 |
| 1 | X.DbGY | 5.84 | 1.56 | 0.06 | - | 46.88 | - | 2.44 | 0.83 | - | 0.05 |
| 1 | X.DFxN/P/N/P.DF | 7.82 | 3.76 | 0.02 | - | 116.88 | - | 39.38 | 46.67 | 0.56 | 0.34 |
| 1 | X.DFxN/P\P/N.DF | 7.37 | 1.85 | 0.02 | - | 57.19 | - | 6.75 | 1.67 | 0.02 | 0.12 |
| 1 | X.DPYxN | 7.54 | 3.74 | 0.09 | - | 114.06 | 20.80 | 17.13 | 32.50 | 0.39 | 0.15 |
| 2 | X.FDM/pxn/p^f | 7.03 | 2.71 | 0.03 | - | 83.60 | - | 4.50 | 6.67 | 0.08 | 0.05 |
| 2 | X.H(DNNxY) | 8.08 | 4.56 | 0.11 | - | 138.91 | 15.30 | 21.82 | 25.84 | 0.31 | 0.16 |
| 1 | X.HGDN-YxN/D | 5.39 | 2.11 | 0.08 | - | 63.44 | 9.30 | 4.06 | 3.33 | 0.04 | 0.06 |
| 1 | X.HxN/X.YxN | 9.13 | 2.13 | <0.01 | - | 66.56 | - | 30.00 | 35.00 | 0.42 | 0.45 |
| 1 | X.HxN^f | 8.35 | 1.47 | 0.05 | - | 44.38 | 103.80 | 45.50 | 50.00 | 0.60 | 1.03 |
| 1 | X.M/Mx | 7.67 | 0.05 | 0.06 | - | <0.3 | - | 1.13 | 0.83 | 0.01 | >3.8 |
| 2 | X.MD#b | 7.99 | 1.94 | 0.03 | - | 59.54 | - | 9.16 | 25.42 | 0.31 | 0.15 |
| 1 | X.MDbxN | 6.74 | 2.98 | 0.05 | - | 91.56 | - | 5.63 | 10.00 | 0.12 | 0.06 |
| 1 | X.MDxN | 7.42 | 0.99 | 0.02 | - | 30.31 | - | 8.00 | 19.17 | 0.23 | 0.26 |
| 5 | X.MD-YxN | 6.21 | 3.84 | 0.06 | 3.78 | 118.07 | 7.66 | - | 15.59 | 0.19 | 0.06 |
| 1 | X.YM-DxN | 6.76 | 2.61 | 0.03 | - | 80.63 | - | 2.13 | 0.83 | 0.01 | 0.03 |
| 1 | X.YMzN(?) / X.YM- | 6.41 | 1.64 | 0.17 | - | 45.94 | - | 1.13 | 0.83 | 0.01 | 0.02 |

**Table K3.18-3: Summary of ABA Results for Waste Rock**

| Number of Samples | Litho Code | Mean Paste pH | Mean S(T), % | Mean S(SO4), % | Mean S(S-2), % | Mean AP, $kgCaCO_3/t$ | Mean NP (Sobek), $kgCaCO_3/t$ | Mean Modified NP, $kgCaCO_3/t$ | Mean TIC, $kgCaCO_3/t$ | Mean TIC, % | NP/AP[a] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | DxN | | | | | | | | | | |
| 1 | X.YP | 8.24 | 1.89 | 0.01 | - | 58.75 | - | 92.50 | 114.17 | 1.37 | 1.57 |
| 1 | X.YxN | 8.62 | 1.23 | 0.01 | - | 38.13 | - | 49.75 | 59.17 | 0.71 | 1.30 |
| 9 | X2 | 7.38 | 2.74 | 0.08 | - | 83.02 | 20.15 | 13.37 | 27.41 | 0.37 | 0.16 |
| 11 | X2.DYF | 7.26 | 3.44 | 0.05 | 3.39 | 105.80 | 12.62 | - | 34.30 | 0.41 | 0.00 |
| 1 | X2xx2qpw | 7.87 | 2.87 | 0.02 | - | 89.06 | - | 16.00 | 36.67 | 0.44 | 0.18 |
| 108 | Y | 7.00 | 2.88 | 0.07 | 3.56 | 90.08 | 10.19 | 11.30 | 16.88 | 0.22 | 0.13 |
| 1 | Y/Gs? | 6.16 | 0.29 | 0.31 | <0.01 | <0.3 | 0.20 | - | 1.36 | 0.02 | >0.67 |
| 1 | Yb | 7.74 | 3.22 | 0.06 | - | 98.75 | - | 15.63 | 30.00 | 0.36 | 0.16 |
| 1 | YW | 4.66 | 3.61 | 0.11 | - | 109.38 | - | 1.38 | 0.83 | 0.01 | 0.01 |
| 3 | Y-W | 8.19 | 2.73 | 0.03 | - | 84.58 | - | 19.98 | 39.17 | 0.47 | 0.24 |
| 1 | Y-x | 7.05 | 2.26 | 0.16 | - | 65.63 | - | 16.13 | 25.84 | 0.31 | 0.25 |
| 1 | Yxbp(l) | 9.06 | 2.23 | 0.02 | - | 69.06 | - | 20.50 | 22.50 | 0.27 | 0.30 |
| 1 | Y-xk-pd | 8.23 | 2.65 | 0.02 | - | 82.19 | - | 6.00 | 5.83 | 0.07 | 0.07 |
| 1 | YxN/N.Y / YXNYxq | 8.29 | 1.47 | 0.02 | - | 45.31 | - | 88.75 | 115.84 | 1.39 | 1.96 |
| 1 | YxP/M | 8.72 | 1.34 | 0.01 | - | 41.56 | - | 21.00 | 27.50 | 0.33 | 0.51 |
| 1 | YxP\P/M-k / Y-x | 8.41 | 1.93 | 0.04 | - | 59.06 | - | 34.75 | 57.50 | 0.69 | 0.59 |
| 1 | Yxq | 8.43 | 2.57 | 0.03 | - | 79.38 | - | 15.00 | 13.33 | 0.16 | 0.19 |
| 1 | Yxqd | 7.24 | 1.42 | 0.04 | - | 43.13 | - | 7.25 | 31.67 | 0.38 | 0.17 |
| 1 | Yxq-p | 7.09 | 3.09 | 0.04 | - | 95.31 | 8.50 | 4.50 | 1.67 | 0.02 | 0.05 |
| 1 | Yxqp / Yxq-p\ | 7.56 | 3.48 | 0.04 | - | 107.50 | - | 12.88 | 23.33 | 0.28 | 0.12 |
| 3 | Z | 6.67 | 4.59 | 0.08 | - | 140.83 | - | 37.69 | 32.50 | 0.39 | 0.27 |
| 1 | Z / Gp | 6.99 | 1.80 | 0.07 | - | 54.06 | - | 10.75 | 25.00 | 0.30 | 0.20 |
| 1 | Z.N | 7.34 | 2.30 | 0.06 | - | 70.00 | - | 9.50 | 55.84 | 0.67 | 0.14 |
| 1 | Z.NPY | 7.66 | 2.83 | 0.08 | - | 85.94 | - | 19.00 | 17.50 | 0.21 | 0.22 |
| 1 | Z.TBd / Z | 8.77 | 1.79 | 0.01 | - | 55.63 | - | 83.63 | 59.17 | 0.71 | 1.50 |

**Table K3.18-3: Summary of ABA Results for Waste Rock**

| Number of Samples | Litho Code | Mean Paste pH | Mean S(T), % | Mean S(SO4), % | Mean S(S-2), % | Mean AP, $kgCaCO_3/t$ | Mean NP (Sobek), $kgCaCO_3/t$ | Mean Modified NP, $kgCaCO_3/t$ | Mean TIC, $kgCaCO_3/t$ | Mean TIC, % | NP/AP[a] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Z.Y | 7.70 | 0.89 | 0.29 | - | 18.75 | - | 56.50 | 126.68 | 1.52 | 3.01 |
| 1 | Z.Y / Y | 4.40 | 4.88 | 0.19 | - | 146.56 | - | -2.94 | 0.83 | - | -0.02 |
| 1 | No LithoCode | 7.19 | 4.14 | 0.01 | 4.13 | 129.06 | - | 14.20 | - | - | 0.11 |
| 1 | No LithoCode | 6.56 | 6.65 | 0.03 | 6.62 | 206.88 | - | 11.60 | - | - | 0.06 |
| **Waste Rock (PEZ+PWZ)** | | | | | | | | | | | |
| 2 | TW | 9.29 | 0.24 | 0.04 | 0.20 | 6.10 | - | 80.55 | 103.41 | - | 13.15 |
| 2 | TY | 8.64 | 0.38 | 0.07 | 0.31 | 9.53 | - | 57.55 | 59.09 | - | 8.48 |
| 2 | TD | 9.38 | 0.13 | 0.02 | 0.11 | 3.44 | - | 50.45 | 46.59 | - | 19.40 |
| 2 | No LithoCode | 8.2 | 2.2 | 0.0 | 2.2 | 68.1 | - | 21.6 | - | - | 0.3 |
| **Waste Rock (Pebble-North)** | | | | | | | | | | | |
| 1 | G/N | 7.37 | 10.10 | 0.05 | - | 314.06 | - | 40.13 | 38.34 | 0.46 | 0.13 |
| 2 | Y | 8.2 | 5.6 | 0.0 | - | 173.3 | - | 16.9 | 13.8 | 0.2 | 0.10 |
| 1 | G | 8.07 | 7.43 | 0.01 | - | 231.88 | - | 30 | 29.17 | 0.35 | 0.13 |
| 2 | Kq | 8.36 | 1.99 | 0.01 | - | 61.875 | - | 17.875 | 9.165 | 0.11 | 0.29 |
| **Waste Rock (Others)** | | | | | | | | | | | |
| 1 | Gp | 7.04 | 0.08 | 0.08 | - | <0.3 | - | 2.19 | 0.83 | 0.01 | >7.3 |
| 1 | Pp | 7.1 | 0.61 | 0.3 | - | 9.69 | - | 3.63 | 0.83 | 0.01 | 0.37 |
| 3 | No LithoCode | 5.28 | 4.25 | 0.06 | - | 130.84 | - | 4.09 | 4.16 | 0.05 | 0.03 |
| Ore | | - | - | - | - | - | - | - | - | - | - |
| 1 | No LithoCode | 8.09 | 2.41 | 0.05 | 2.36 | 73.75 | - | 6.9 | 4.55 | - | 0.09 |
| **Tailings** | | | | | | | | | | | |
| 94 | Tailings | 7.88 | 1.36 | 0.04 | 1.13 | 41.31 | - | 12.18 | 22.23 | 0.38 | 0.29 |

Notes:
[a] Mean NP (Sobek) was used when mean Modified NP was not available
TIC = Total Inorganic Carbon
$kgCaCO_3/t$ = kilograms calcium carbonate per ton
Source: PLP 2018a

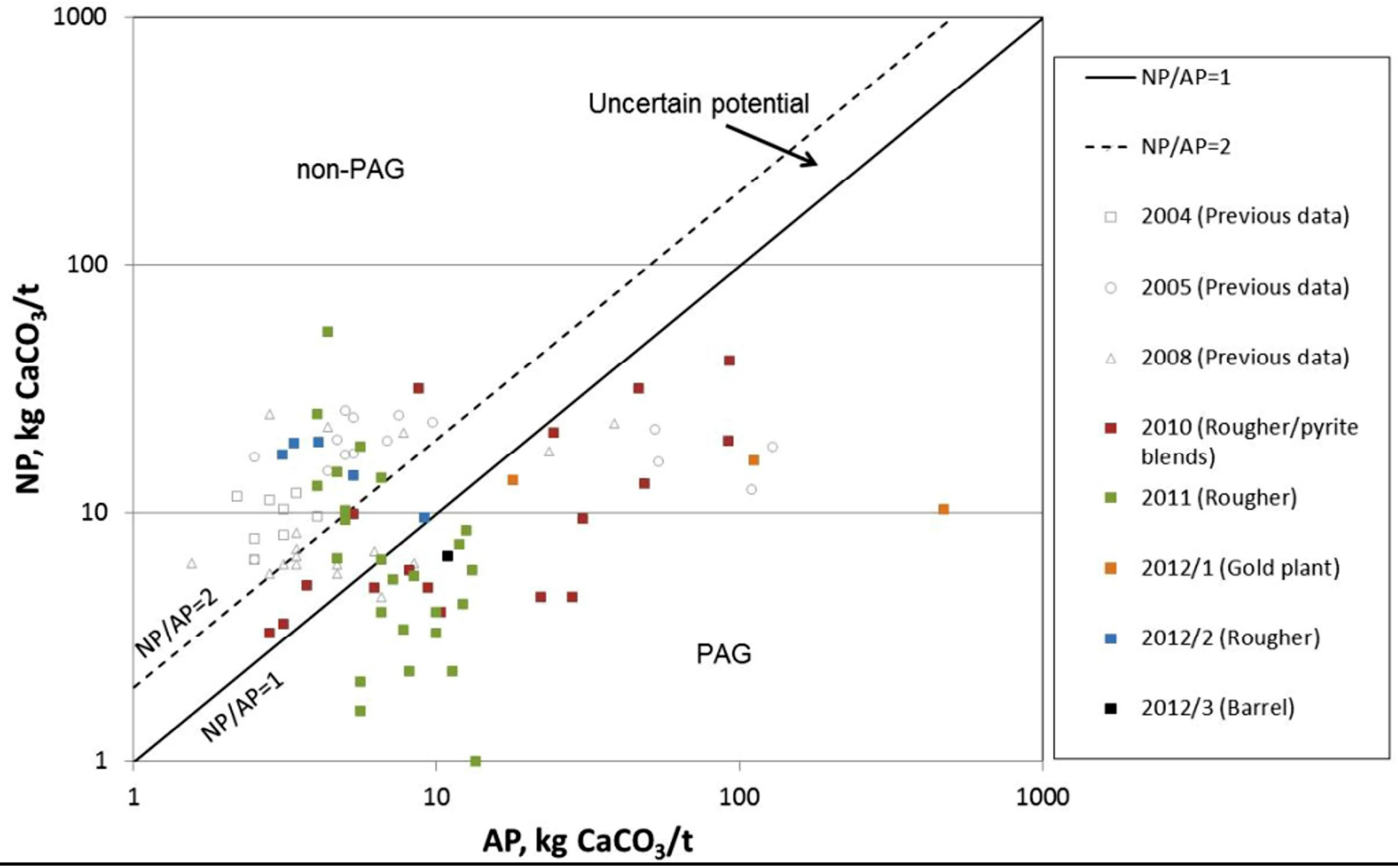
Element release rates determined from kinetic tests did not correlate well to the trace element content of the samples, and other parameters such as pH were observed to have stronger influence on release rates for many metals (PLP 2018a). Leaching of copper accelerated as pH decreased; therefore, the potential for metal release is linked to the potential for acid generation, and ABA data can be used to assess the potential for copper leaching. However, for some elements (e.g., arsenic, molybdenum, and selenium), release can be environmentally significant under neutral pH conditions. Tests on some samples of Tertiary rock showed elevated leaching of these elements under non-acidic conditions. These leaching data, along with baseline water quality data, are being used with other inputs to develop geochemical source terms for water quality modeling and water treatment planning (SRK 2018a).

### K3.18.2.2 Tailings and Supernatant Geochemical Characteristics

A total of 64 tailings samples from concurrent metallurgical process test runs have been geochemically characterized. Samples analyzed included rougher tails and rougher tail blends from various hydrothermal alteration zones, blends of rougher and pyritic tails, and first cleaner scavenger, pyrite rougher, combined rougher, and gold plant tails that are representative of anticipated mine tails during operations. Most of the tailings samples tested represent rougher tails, which will be the most volumetrically abundant tailings. All of the tailings samples were analyzed using ABA and total metals methods. ABA tests included paste pH, total, sulfate, and sulfide sulfur, AP, Sobek and modified NP, fizz test, total inorganic carbon (TIC), and carbon dioxide. Total metals were determined using a four-acid digestion. A subset of samples were analyzed using optical mineralogy and x-ray diffraction methods and humidity cell, subaqueous column leach column, and field barrel tests.

Mineralogy determinations indicate that the rougher tailings are dominated by potassium and plagioclase feldspars (about 67 percent), quartz (about 12 percent), muscovite and biotite (about 13 percent), carbonate minerals (about 4 percent), and trace hematite, pyrite, and rutile. ABA tests indicate that the rougher tails have total sulfur contents ranging between 0.3 and 1.3 percent, primarily as sulfide sulfur. Other tailings products (pyritic tails, blends with pyritic tails, and gold plant tails) had total sulfur contents up to 31.6 percent (gold plant tails), which are also dominated by sulfide sulfur. AP ranged from 0.9 to 980 kilograms $CaCO_3$ per ton ($kgCaCO_3/t$). NP was generally less than 20 $kgCaCO_3/t$, with a maximum NP of 54 $kgCaCO_3/t$.

Figure K3.18-2 provides an AP versus NP graph for the tailings. While some tailings samples are classified as non-PAG, a large number of samples are considered PAG. The sulfide sulfur content of the tailings exerts a strong control on the NP/AP ratio, where NP/AP values below 2 are associated with sulfide sulfur contents greater than 0.2 percent. The rougher tails typically have low to moderate total sulfur and are predicted to be non-PAG, provided the sulfide content remains below 0.2 percent. The pyritic and gold plant tailings have higher sulfide contents and are often classified as PAG.




Source: SBD Chapter 11 (SRK 2018a), Figure 11-34

US Army Corps of Engineers

AP = acid potential
NP = neutralizing potential
PAG = potentially acid generating
kg $CaCO_3$/t = kilograms calcium carbonate/ton

**NP PLOTTED AS FUNCTION OF AP FOR TAILINGS**

Tailings supernatant analyses are summarized in Table K3.18-4. Results indicate that the supernatants have a pH of 8, are dominated by major ions (Ca, Mg, Na, K, sulfate, and alkalinity), and generally low trace metal concentrations (Mn, As, Co, Cu, Mo, Ni, Sb, Se, and Zn). For mercury, most of the supernatant mercury results (69 percent) were not detected at a detection limit (10 nanograms per liter [ng/L]) less than the applicable water quality standard (12 ng/L). Several higher concentration samples (14 percent) were diluted for analysis, which resulted in elevated detection limits ranging from 50 to 500 ng/L. Mercury was only detected in 18 percent of the supernatant samples analyzed, and ranged in concentration from 12 to 450 ng/L. The 50$^{th}$ percentile supernatant mercury concentration is 10 ng/L, which is less than the water quality standard. These results were used to establish reasonable source term concentrations for the bulk tailings water in the water quality model as described in SRK (2018f), discussed under "Surface Water Quality Criteria," above, and shown on Table K4.18-2.

### K3.18.2.3 Construction Rockfill Geochemical Characteristics

Construction rockfill will be obtained from quarries in Cretaceous age granodiorite located outside of the footprint of the proposed mine. To evaluate the potential needs to manage the rock geochemistry and to estimate contact water quality, PLP tested rock from boreholes in three proposed quarry locations designated A, B, and C. The first phase of testing involved continuous sampling of core by PLP at 10-foot intervals from two boreholes drilled in each quarry, for a total of six boreholes. The core was tested using a multi-element scan (including sulfur) following a four-acid digestion. A total of 138 samples were analyzed: 50 samples from quarry A, 41 samples from quarry B, and 47 samples from quarry C. The results obtained to date are summarized in SRK (2018d) and provided in Table K3.18-5.

The results demonstrate that the quarry rock, which has low metal leaching and ARD potential, is dominated by unmineralized granodiorite, which would be geochemically suitable for use as construction fill, and is classified as non-PAG (SRK 2018d). It is expected that weathering of the granodiorite would be expected to yield contact water chemistry comparable to that observed in natural surface water and groundwater. However, hydrothermally altered zones with elevated metal concentrations may have the potential for leaching of metals and possibly ARD potential, and would need to be segregated using an operational monitoring program and not used as construction fill.

### K3.18.2.4 Open Pit Block Model

Because of the geochemical variability in the rocks, assessment of impacts resulting from geochemical processes requires consideration of the disposition and fate of the material that would be mined each year. The annual area mined can be estimated by developing an open pit block model. A block model is a computer model that shows the three-dimensional distribution of rock types and their likely order of excavation within the open pit as mining progresses. The mined rock is assessed based on its PAG and non-PAG characteristics, and whether the material would be processed and end up in tailings, or would not be processed and set aside as waste rock.

**Table K3.18-4: Analytical Results for Representative Tailings Supernatants**

| Sample ID | Product | pH | $SO_4$ | Alkalinity | Thiosalts | Al | Sb | As | Ag | Cd | Ca | Cr | Co | Cu | Fe | Pb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (mg/L) | ($mgCaCO_3$/L) | ($mgS_2O_3$/L) | (all elements in mg/L) | | | | | | | | | | |
| **Batches Tested During Period 2010 to 2012** | | | | | | | | | | | | | | | | |
| ***2010 set*** | | | | | | | | | | | | | | | | |
| LCT-25 | Rougher/ pyrite blend | 8.0 | 166 | 135.1 | - | 0.020 | 0.007 | 0.002 | 0.00004 | -0.0002 | 52.6 | 0.0006 | 0.0002 | 0.002 | -0.03 | 0.00005 |
| LCT-26 | Rougher/ pyrite blend | 8.0 | 117 | 115.2 | - | 0.016 | 0.007 | 0.003 | -0.00001 | -0.0001 | 35.3 | -0.0005 | 0.0002 | 0.002 | -0.03 | -0.00005 |
| LCT-27 | Rougher/ pyrite blend | 8.0 | 110 | 113.6 | - | 0.016 | 0.002 | 0.001 | 0.00024 | -0.0001 | 53.3 | -0.0005 | -0.0001 | -0.002 | -0.03 | -0.00005 |
| LCT-28 | Rougher/ pyrite blend | 8.2 | 199 | 147.3 | - | 0.014 | 0.003 | 0.002 | 0.00102 | -0.0001 | 48.5 | -0.0005 | 0.0001 | 0.021 | -0.03 | -0.00005 |
| LCT-29 | Rougher/ pyrite blend | 8.0 | 134 | 117.7 | - | 0.012 | 0.005 | 0.002 | 0.00002 | -0.0001 | 52.1 | -0.0005 | 0.0002 | 0.001 | -0.03 | 0.00009 |
| LCT-30 | Rougher/ pyrite blend | 8.0 | 281 | 102.0 | - | 0.003 | 0.004 | 0.005 | -0.00001 | -0.0001 | 78.5 | -0.0005 | 0.0016 | 0.002 | -0.03 | -0.00005 |
| LCT-31 | Rougher/ pyrite blend | 8.0 | 153 | 90.8 | - | 0.015 | 0.008 | 0.001 | -0.00001 | 0.0001 | 36.8 | -0.0005 | 0.0014 | 0.003 | -0.03 | 0.00005 |
| LCT-32 | Rougher/ pyrite blend | 8.0 | 215 | 88.7 | - | 0.010 | 0.009 | 0.029 | -0.00001 | 0.0001 | 67.2 | -0.0005 | 0.0007 | 0.002 | -0.03 | -0.00005 |
| LCT-33 | Rougher/ pyrite blend | 8.0 | 163 | 93.7 | - | 0.010 | 0.004 | 0.001 | 0.00010 | 0.0005 | 44.1 | -0.0005 | 0.0018 | 0.029 | -0.03 | -0.00005 |
| LCT-34 | Rougher/ pyrite blend | 7.8 | 288 | 81.4 | - | 0.004 | 0.003 | 0.002 | -0.00001 | 0.0025 | 87.5 | -0.0005 | 0.0033 | 0.038 | -0.03 | 0.00032 |
| LCT-35 | Rougher/ pyrite blend | 7.9 | 155 | 89.9 | - | 0.009 | 0.001 | 0.002 | 0.00001 | -0.0001 | 58.1 | -0.0005 | 0.0023 | 0.037 | -0.03 | -0.00005 |
| LCT-36 | Rougher/ pyrite blend | 7.9 | 182 | 95.7 | - | 0.013 | 0.019 | 0.015 | 0.00013 | -0.0001 | 55.9 | -0.0005 | 0.0002 | 0.003 | -0.03 | -0.00005 |
| LCT-37 | Rougher/ pyrite blend | 8.0 | 153 | 90.1 | - | 0.004 | 0.001 | 0.001 | 0.00003 | 0.0001 | 48.3 | -0.0005 | 0.0012 | 0.007 | -0.03 | -0.00005 |
| LCT-38 | Rougher/ pyrite blend | 7.9 | 155 | 82.8 | - | 0.059 | 0.026 | 0.005 | 0.00021 | 0.0001 | 66.2 | -0.0005 | 0.0002 | 0.055 | -0.03 | -0.00005 |
| LCT-39 | Rougher/ pyrite blend | 8.1 | 79.9 | 120.8 | - | 0.031 | 0.002 | 0.001 | 0.00002 | -0.0001 | 24.6 | -0.0005 | -0.0001 | 0.001 | -0.03 | -0.00005 |
| LCT-40 | Rougher/ pyrite blend | 7.9 | 237 | 69.9 | - | 0.019 | 0.005 | 0.002 | 0.00016 | 0.0010 | 77.9 | -0.0005 | 0.0012 | 0.060 | -0.03 | -0.00005 |
| LCT-41 | Rougher/ pyrite blend | 7.8 | 180 | 82.9 | - | 0.057 | 0.002 | 0.003 | 0.00075 | 0.0002 | 82.4 | -0.0005 | 0.0004 | 0.062 | -0.03 | -0.00005 |
| LCT-42 | Rougher/ pyrite blend | 8.0 | 341 | 95.4 | - | 0.006 | 0.002 | 0.001 | 0.00003 | 0.0015 | 119 | 0.0006 | 0.0027 | 0.020 | -0.03 | 0.00005 |
| ***2011 set*** | | | | | | | | | | | | | | | | |
| Illite Pyrite Cu Ro Tail | Rougher | 8.1 | 361 | 118.6 | - | 0.008 | 0.002 | 0.005 | -0.00001 | 0.0005 | 101 | -0.0005 | 0.0007 | 0.014 | -0.03 | -0.00005 |
| K-Silicate Cu Ro Tail | Rougher | 8.1 | 340 | 97.4 | - | 0.009 | 0.002 | 0.005 | -0.00001 | -0.0001 | 95.9 | -0.0005 | 0.0006 | 0.010 | -0.03 | -0.00005 |
| Sodic Potassic Cu Ro Tail | Rougher | 8.0 | 516 | 133.4 | - | 0.008 | 0.001 | 0.005 | -0.00001 | 0.0001 | 121 | -0.0005 | 0.0006 | 0.008 | -0.03 | -0.00005 |
| Supergene Cu Ro Tail | Rougher | 8.0 | 518 | 104.8 | - | 0.010 | 0.002 | 0.004 | -0.00001 | 0.0007 | 149 | -0.0005 | 0.0029 | 0.033 | -0.03 | 0.00006 |
| ***2012 set*** | | | | | | | | | | | | | | | | |
| 1st Cleaner Scav Tails | Gold plant tails | 9.0 | - | 51.3 | 360 | 0.106 | 0.003 | 0.007 | 0.00541 | -0.0001 | 273 | -0.001 | -0.0002 | 0.550 | -0.03 | 0.00063 |
| Pyrite Rougher Tails | Gold plant tails | 8.5 | - | 35.6 | 250 | 0.098 | 0.004 | 0.005 | 0.00087 | -0.0001 | 238 | -0.001 | -0.0002 | 0.130 | -0.03 | -0.00010 |
| Combined Rougher Tails | Gold plant tails | 8.1 | - | 173.2 | < 2 | 0.011 | 0.002 | 0.001 | -0.00001 | 0.0001 | 122 | -0.0005 | 0.0006 | 0.019 | -0.03 | 0.00024 |
| Gold Plant Tails | Gold plant tails | 7.6 | - | 52.7 | < 2 | 0.017 | 0.005 | 0.005 | -0.00005 | -0.0003 | 382 | -0.0025 | 0.0119 | 0.011 | -0.03 | -0.00025 |
| **Summary Statistics for Samples 2004 – 2008**[a] | | | | | | | | | | | | | | | | |
| Minimum | - | 7.0 | 35 | 30 | -10 | 0.01 | -0.0001 | 0.001 | -0.00001 | -0.00001 | 36.1 | -0.001 | -0.0001 | -0.001 | -0.03 | -0.0001 |
| Median | - | 8.0 | 292 | 77 | 5 | 0.05 | 0.005 | 0.013 | 0.000004 | 0.00005 | 116 | 0.0005 | 0.0001 | 0.00813 | 0.015 | 0.00015 |
| Average | - | 7.9 | 319 | 75 | 46.86 | 0.07 | 0.006 | 0.017 | 0.00004 | 0.0001 | 116 | 0.001 | 0.000 | 0.008 | 0.064 | 0.0003 |
| Maximum | - | 8.3 | 2436 | 111 | 826 | 0.37 | 0.040 | 0.117 | 0.00170 | 0.0005 | 707 | 0.005 | 0.001 | 0.0171 | 2.15 | 0.0033 |

**Table K3.18-4: Analytical Results for Representative Tailings Supernatants – Part 2**

| Sample ID | Product | Mg | Mn | Hg | Mo | Ni | K | Se | Na | Tl | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (all elements in mg/L) | | | | | | | | | |
| **Batches Tested During Period 2010 to 2012** | | | | | | | | | | | |
| ***2010 set*** | | | | | | | | | | | |
| LCT-25 | Rougher/pyrite blend | 16.1 | 0.13 | -0.00001 | 0.07 | 0.005 | 33.6 | 0.005 | 46.8 | -0.0001 | 0.001 |
| LCT-26 | Rougher/pyrite blend | 13.7 | 0.08 | -0.00001 | 0.03 | 0.002 | 23.8 | 0.013 | 40.7 | 0.0001 | -0.001 |
| LCT-27 | Rougher/pyrite blend | 11.6 | 0.05 | -0.00001 | 0.02 | 0.002 | 29.0 | 0.004 | 28.4 | -0.0001 | -0.001 |
| LCT-28 | Rougher/pyrite blend | 11.2 | 0.04 | 0.00002 | 0.03 | 0.001 | 26.6 | 0.008 | 86.9 | -0.0001 | -0.001 |
| LCT-29 | Rougher/pyrite blend | 13.5 | 0.10 | -0.00001 | 0.02 | 0.002 | 21.2 | 0.006 | 26.1 | -0.0001 | 0.003 |
| LCT-30 | Rougher/pyrite blend | 25.4 | 0.76 | -0.00001 | 0.01 | 0.005 | 26.7 | 0.006 | 24.9 | 0.0003 | -0.001 |
| LCT-31 | Rougher/pyrite blend | 15.4 | 1.53 | -0.00001 | 0.02 | 0.007 | 34.0 | 0.006 | 26.1 | -0.0001 | -0.001 |
| LCT-32 | Rougher/pyrite blend | 6.8 | 0.26 | -0.00001 | 0.05 | 0.004 | 18.3 | 0.006 | 30.9 | 0.0001 | 0.005 |
| LCT-33 | Rougher/pyrite blend | 15.8 | 1.83 | 0.00002 | 0.05 | 0.005 | 38.4 | 0.005 | 29.9 | 0.0001 | 0.004 |
| LCT-34 | Rougher/pyrite blend | 18.2 | 1.30 | -0.00001 | 0.07 | 0.003 | 30.9 | 0.015 | 27.1 | 0.0001 | 0.055 |
| LCT-35 | Rougher/pyrite blend | 11 | 0.85 | -0.00001 | 0.05 | 0.001 | 20.5 | 0.008 | 27.0 | -0.0001 | 0.028 |
| LCT-36 | Rougher/pyrite blend | 17.1 | 0.13 | -0.00001 | 0.04 | 0.003 | 31.4 | 0.007 | 28.7 | 0.0001 | -0.001 |
| LCT-37 | Rougher/pyrite blend | 17.4 | 1.32 | -0.00001 | 0.05 | 0.002 | 18.6 | 0.018 | 21.9 | -0.0001 | 0.004 |
| LCT-38 | Rougher/pyrite blend | 5.18 | 0.27 | 0.00045 | 0.02 | -0.001 | 31.3 | 0.005 | 18.5 | 0.0001 | 0.001 |
| LCT-39 | Rougher/pyrite blend | 5.25 | 0.03 | -0.00001 | 0.04 | 0.001 | 11.4 | 0.003 | 60.1 | -0.0001 | -0.001 |
| LCT-40 | Rougher/pyrite blend | 15.6 | 1.81 | 0.00004 | 0.02 | 0.001 | 34.1 | 0.006 | 20.1 | 0.0002 | 0.001 |
| LCT-41 | Rougher/pyrite blend | 9.85 | 1.01 | -0.00001 | 0.04 | -0.001 | 13.9 | 0.006 | 23.2 | 0.0001 | 0.001 |
| LCT-42 | Rougher/pyrite blend | 22 | 0.35 | -0.00001 | 0.02 | 0.005 | 36.5 | 0.019 | 25.6 | 0.0001 | 0.008 |
| ***2011 set*** | | | | | | | | | | | |
| Illite Pyrite Cu Ro Tail | Rougher | 26.4 | 1.20 | -0.00001 | 0.05 | 0.002 | 42.4 | 0.008 | 29.6 | 0.0002 | 0.003 |
| K-Silicate Cu Ro Tail | Rougher | 14 | 0.17 | -0.00001 | 0.15 | 0.002 | 39.6 | 0.015 | 47.7 | 0.0001 | 0.003 |
| Sodic Potassic Cu Ro Tail | Rougher | 40.6 | 1.07 | -0.00001 | 0.06 | 0.003 | 52.3 | 0.003 | 49.1 | 0.0001 | 0.004 |
| Supergene Cu Ro Tail | Rougher | 35.1 | 2.77 | -0.00001 | 0.08 | 0.002 | 42.8 | 0.028 | 24.9 | 0.0002 | 0.023 |
| ***2012 set*** | | | | | | | | | | | |
| 1st Cleaner Scav Tails | Gold plant tails | 0.149 | 0.00 | 0.00008 | 0.13 | -0.001 | 40.9 | 0.020 | 42.9 | -0.0001 | -0.002 |
| Pyrite Rougher Tails | Gold plant tails | 0.248 | 0.00 | -0.00005 | 0.09 | -0.001 | 31.0 | 0.013 | 29.6 | -0.0001 | -0.002 |
| Combined Rougher Tails | Gold plant tails | 33.8 | 0.56 | -0.00001 | 0.02 | 0.002 | 32.4 | 0.004 | 29.6 | 0.0001 | 0.008 |
| Gold Plant Tails | Gold plant tails | 13.9 | 0.06 | -0.00005 | 0.11 | -0.003 | 21.8 | 0.019 | 482.0 | -0.0003 | -0.005 |
| **Summary Statistics for Samples 2004 – 2008[a]** | | | | | | | | | | | |
| Minimum | - | 0.15 | 0.002 | -0.00001 | 0.018 | -0.0005 | 4.47 | -0.01 | 7 | -0.00001 | -0.002 |
| Median | - | 6.12 | 0.060 | 0.00001 | 0.06 | 0.0005 | 26.5 | 0.008 | 16.9 | 0.000113 | 0.0027 |
| Average | - | 8.0 | 0.072 | 0.00002 | 0.07 | 0.001 | 26.0 | 0.009 | 43.8 | 0.0001 | 0.005 |
| Maximum | - | 27.3 | 0.288 | 0.00025 | 0.35 | 0.005 | 40.5 | 0.017 | 757 | 0.0005 | 0.037 |

Notes:
[a] Where concentrations were below the method detection limit, average values were calculated using half the method detection limit value.
negative values = concentration of the element was below the method detection limit.
" - " values in an otherwise empty cell = not measured.
Table includes data for various tailings products, including gold plant tails that may not be a waste stream during mine operations.
Source: SRK 2018a, Table 11-31

L = Liter
$mgS_2O_3$ = milligrams thiosulfate
$mgCaCO_3$ = milligrams calcium carbonate
mg/L = milligrams per liter

**Table K3.18-5: Statistical Summary by Quarry for Selected Elements**

| Quarry | n | Statistic (percentiles) | As (mg/kg) | Cu (mg/kg) | Mo (mg/kg) | S (%) | Se (mg/kg) | Zn (mg/kg) |
|---|---|---|---|---|---|---|---|---|
| A | 50 | Min | 1 | 11 | 0.89 | 0.005 | 0.5 | 48 |
| | | P5 | 1 | 12 | 1 | 0.005 | 0.5 | 54 |
| | | P50 | 1.4 | 18 | 1.6 | 0.01 | 0.5 | 64 |
| | | P95 | 3.4 | 35 | 2.7 | 0.01 | 1 | 92 |
| | | Max | 6.4 | 43 | 16 | 0.07 | 1 | 300 |
| B | 41 | Min | 0.1 | 7.7 | 1.1 | 0.005 | 0.5 | 51 |
| | | P5 | 0.6 | 10 | 1.2 | 0.005 | 0.5 | 57 |
| | | P50 | 1.7 | 15 | 1.6 | 0.01 | 1 | 61 |
| | | P95 | 2.7 | 33 | 2 | 0.01 | 1 | 72 |
| | | Max | 6.3 | 140 | 2.2 | 0.02 | 1 | 160 |
| C | 47 | Min | 0.8 | 6.3 | 0.71 | 0.005 | 0.5 | 42 |
| | | P5 | 1.2 | 15 | 1.2 | 0.005 | 0.5 | 47 |
| | | P50 | 1.9 | 23 | 1.7 | 0.01 | 0.5 | 63 |
| | | P95 | 25 | 53 | 3.1 | 0.26 | 1 | 78 |
| | | Max | 600 | 75 | 8.6 | 4.4 | 4 | 94 |

Notes:
As = arsenic
Cu = copper
mg/kg = milligrams per kilogram
Mo = molybdenum
S = sulfur
Se = selenium
Zn = zinc
Source: SRK 2018d

PLP has developed an open pit block model that incorporates available geological data collected to date; however, the block model does not currently contain geochemical characterization data. Evaluation of the geologic data in the block model indicates that the two mineralized zones (PWZ and PEZ) are part of the same porphyry copper system and intruded the same host rocks. The dominant hydrothermal alteration overprint is potassic in both zones with the same assemblage of sulfide (dominantly pyrite and chalcopyrite) and carbonate minerals. The main difference between the two zones is that the PWZ has been naturally oxidized to a depth of several tens of meters; however, this oxidation acted on the primary mineral assemblage producing chalcocite, covellite, and iron oxides. The overlying unmineralized Tertiary rocks do not show any significant geological differences between the PWZ and PEZ; the Tertiary rocks covering the PEZ simply extend over part of the PWZ. The similar geological, mineralization, and alteration characteristics of the PWZ and PEZ suggest that data from both zones can be combined to provide a robust data set to characterize the waste rock and tailings geochemistry. Given consistent mineralization style and pre-Tertiary host rocks of the Pebble deposit and the stratigraphic continuity of the Tertiary cover rocks, the PWZ and PEZ geochemical datasets were combined to evaluate the geochemistry and source terms for the waste rock, tailings, and rocks exposed on the open pit walls.

The geologic block model was used to confirm the representativeness of the geochemical characterization data by estimating the percentage of samples from the pre-Tertiary mineralized zone and overlying non-mineralized Tertiary rock formations. Table K3.18-6 provides a summary of the major waste rock categories and the proportions of samples geochemically

tested from the PWZ (46 percent) and PEZ (52 percent). Of the PWZ samples tested, 89 percent of the pre-Tertiary rock samples were statically tested using ABA and 63 percent of the pre-Tertiary rock samples were tested using kinetic humidity cell tests (HCTs).

**Table K3.18-6: Comparison of Waste Rock Categories and Proportions of Samples Tested**

| Parameter | PWZ | | PEZ | |
|---|---|---|---|---|
| | Pre-Tertiary | Tertiary | Pre-Tertiary | Tertiary |
| Million Tons | 50.6 | 13.0 | Mining will not extend into the PEZ | |
| Proportion of Waste (in percent) | 80 | 20 | | |
| Proportion of Samples Tested (Static)[a] | 41 | 5 | 24 | 28 |
| Proportion of Samples Tested (Kinetic)[b] | 35 | 21 | 25 | 20 |

Notes:
[a] Static test proportions based on acid base accounting
[b] Kinetic test proportions based on humidity cell testing
Source: PLP 2018-RFI 105

## K3.18.3 Surface Water Quality

### K3.18.3.1 Data Tables

This section contains baseline surface water data for parts of the project area that would be most affected by project activities. These include:

- Table K3.18-7 through Table K3.18-10: surface water data for the NFK and SFK watersheds, UTC, and Frying Pan Lake, respectively. These waterbodies would receive discharge from mine site water treatment plants (WTPs).
- Table K3.18-11 and Table K3.18-12: surface water data for the western and eastern parts of the north access route transportation corridor, respectively.
- Table K3.18-13: water quality data for Iliamna Lake, which would be crossed by project ferry traffic.

Baseline data for other mine area surface waterbodies are available in Pebble Environmental Baseline Documents (EBDs) (ERM [2018: Tables 9.1-15 through 9.1-24] and Schlumberger et al. [2011: Tables 9.1-31 through 9.1-36]), and incorporated here by reference.

**Table K3.18-7: Surface Water Data Summary – NFK River, Mine Site**

| Analyte | Number of Samples | Range of Detects (Min-Max) [a] | Mean[a,b] |
|---|---|---|---|
| **Field and Physical parameters (mg/L, except where noted)** | | | |
| Total Dissolved Solids | 327 | 3.10 - 72.5 | 36.6 |
| pH (Field, Standard Units) | 348 | **3.31** - 8.36 | 6.65 |
| Dissolved Oxygen | 342 | **5.75** - 14.6 | 9.89 |
| Water Temperature ($^0$C) | 347 | -0.30 - **19** | 4.17 |
| Specific Conductivity (Field, uS/cm) | 345 | 7.0 - 710 | 47.9 |
| Turbidity (NTU) | 319 | 0.10 - **8.8** | 1.04 |
| Total Suspended Solids | 325 | 0.15 - 10.8 | 1.19 |

**Table K3.18-7: Surface Water Data Summary – NFK River, Mine Site**

| Analyte | Number of Samples | Range of Detects (Min-Max) [a] | Mean[a,b] |
|---|---|---|---|
| Oxidation Reduction Potential (mV) | 343 | -248 - 349 | 137 |
| **Major Ions (mg/L)** | | | |
| Calcium (dissolved) | 230 | 1.82 - 10.1 | 5.16 |
| Calcium (Total) | 235 | 1.79 - 9.88 | 5.12 |
| Magnesium (Dissolved) | 231 | 0.38 - 2.66 | 1.33 |
| Magnesium (Total) | 235 | 0.37 - 2.86 | 1.32 |
| Sodium (Dissolved) | 231 | 0.99 - 3.41 | 2.41 |
| Sodium (Total) | 235 | 1.18 - 3.58 | 2.39 |
| Potassium (Dissolved) | 226 | 0.096 - 1.15 | 0.41 |
| Potassium (Total) | 236 | 0.081 - 1.10 | 0.40 |
| Alkalinity (total) | 336 | **3.10** - 49.1 | 21.4 |
| Sulfate | 234 | 0.53 - 9.56 | 2.21 |
| Chloride | 237 | 0.20 - 1.38 | 0.65 |
| Fluoride | 237 | 0.031 - 0.14 | 0.039 |
| Hardness as $CaCO_3$ | 327 | 5.90 - 36.4 | 18.1 |
| **Nutrients, (mg/L)** | | | |
| Total Ammonia as Nitrogen (N) | 291 | 0.031 - 0.17 | 0.050 |
| Nitrate-Nitrite | 229 | 0.031 - 3.94 | 0.19 |
| Total Phosphorous (P) | 233 | 0.0031 - 0.17 | 0.023 |
| Total Orthophosphate (as P) | 40 | 0.031 - 0.10 | 0.079 |
| **Total Metals (mg/L)** | | | |
| Aluminum | 325 | 0.0036 - **0.42** | 0.034 |
| Arsenic | 236 | 0.000099 - 0.00079 | 0.00034 |
| Barium | 287 | 0.0013 - 0.013 | 0.0034 |
| Cadmium | 323 | 0.0000062 - **0.000094** | 0.000020 |
| Chromium | 234 | 0.000062 - 0.0010 | 0.00029 |
| Copper | 324 | 0.00015 - **0.0036** | 0.00042 |
| Iron | 326 | 0.015 - **1.05** | 0.22 |
| Lead | 324 | 0.000022 - **0.0024** | 0.00012 |
| Manganese | 323 | 0.00088 - **0.096** | 0.013 |
| Molybdenum | 235 | 0.000015 - 0.00055 | 0.00018 |
| Nickel | 308 | 0.000030 - 0.00093 | 0.00025 |
| Selenium | 154 | 0.000029 - 0.00031 | 0.00027 |
| Silver | 232 | 0.0000029 - 0.000020 | 0.0000064 |

**Table K3.18-7: Surface Water Data Summary – NFK River, Mine Site**

| Analyte | Number of Samples | Range of Detects (Min-Max) [a] | Mean[a,b] |
|---|---|---|---|
| Zinc | 324 | 0.00044 - 0.015 | 0.0023 |
| **Dissolved Metals (mg/L)** | | | |
| Aluminum | 325 | 0.002 - 0.063 | 0.013 |
| Arsenic | 233 | 0.000081 - 0.00067 | 0.00031 |
| Barium | 254 | 0.0014 - 0.0072 | 0.0031 |
| Cadmium | 325 | 0.0000062 - 0.000078 | 0.000020 |
| Chromium | 216 | 0.000062 - 0.00094 | 0.00028 |
| Copper | 237 | 0.00016 - 0.0017 | 0.00041 |
| Iron | 326 | 0.0062 - 0.44 | 0.11 |
| Lead | 285 | 0.000022 - 0.00037 | 0.000070 |
| Manganese | 314 | 0.00048 - **0.054** | 0.0082 |
| Molybdenum | 210 | 0.0000062 - 0.00078 | 0.00019 |
| Nickel | 184 | 0.000077 - 0.0012 | 0.00033 |
| Selenium | 236 | 0.000029 - 0.00078 | 0.00028 |
| Silver | 236 | 0.0000029 - 0.000016 | 0.0000062 |
| Zinc | 230 | 0.00068 - 0.0075 | 0.0025 |
| **Cyanides (mg/L)** | | | |
| Cyanide (total) | 210 | 0.0015 - 0.0050 | 0.0020 |
| Cyanide (WAD) | 327 | 0.0015 - **0.012** | 0.0024 |
| **Organic Compounds, (mg/L)** | | | |
| Dissolved Organic Carbon | 201 | 0.17 - 4.83 | 1.58 |

Notes:
[a] Bold values indicate fields that exceed the most stringent water quality criteria.
[b] When calculating the mean, non-detects with "U" or "UJ" qualifiers were included as a concentration of one-half the reported detection limit (RDL).
$CaCO_3$ = calcium carbonate
uS/cm = Microsiemens per centimeter
mV = millivolts
mg/L = milligrams per liter
NTU = Nephelometric Turbidity Units
Source: ERM 2018a

**Table K3.18-8: Surface Water Data Summary – SFK River, Mine Site**

| Analyte | Number of Samples | Range of Detects (Min-Max) [a] | Mean[a,b] |
|---|---|---|---|
| **Field and Physical parameters (mg/L, except where noted)** | | | |
| Total Dissolved Solids | 493 | 3.1 - 96.2 | 39.4 |
| pH (Field, Standard Units) | 603 | 3.54 - **8.85** | 6.63 |
| Dissolved Oxygen | 597 | **3.53** - 18.2 | 9.89 |

**Table K3.18-8: Surface Water Data Summary – SFK River, Mine Site**

| Analyte | Number of Samples | Range of Detects (Min-Max) [a] | Mean[a,b] |
|---|---|---|---|
| Water Temperature ($^0$C) | 607 | -0.33 - **23.4** | 4.33 |
| Specific Conductivity (Field, uS/cm) | 600 | 20 - 133 | 52.3 |
| Turbidity (NTU) | 484 | 0.080 - **23** | 1.34 |
| Total Suspended Solids | 492 | 0.15 - 16 | 1.69 |
| Oxidation Reduction Potential (mV) | 587 | -259 - 516 | 128 |
| **Major Ions (mg/L)** | | | |
| Calcium (Dissolved) | 330 | 2.28 - 13.4 | 6.18 |
| Calcium (Total) | 333 | 2.34 - 13.8 | 6.17 |
| Magnesium (Dissolved) | 329 | 0.35 - 3.9 | 1.4 |
| Magnesium (Total) | 333 | 0.28 - 3.9 | 1.4 |
| Sodium (Dissolved) | 330 | 1.09 - 4.67 | 2.33 |
| Sodium (Total) | 333 | 1.1 - 5.23 | 2.32 |
| Potassium (Dissolved) | 326 | 0.12 - 1.07 | 0.36 |
| Potassium (Total) | 333 | 0.11 - 0.96 | 0.35 |
| Alkalinity (Total) | 500 | **3.1** - 40 | **18** |
| Sulfate | 333 | 0.90 - 28.8 | 8 |
| Chloride | 333 | 0.14 - 1.45 | 0.69 |
| Fluoride | 334 | 0.031 - 0.23 | 0.044 |
| Hardness as $CaCO_3$ | 493 | 7.91 - 52.9 | 20.5 |
| **Nutrients, (mg/L)** | | | |
| Total Ammonia as Nitrogen (N) | 423 | 0.031 - 0.16 | 0.052600 |
| Nitrate-Nitrite | 322 | 0.031 - 1.21 | 0.17 |
| Total Phosphorous (P) | 330 | 0.0031 - 0.095 | 0.019 |
| Total Orthophosphate (as P) | 68 | 0.031 - 0.10 | 0.070 |
| **Total Metals (mg/L)** | | | |
| Aluminum | 491 | 0.0019 - **1.09** | 0.039 |
| Arsenic | 330 | 0.00016 - 0.0010 | 0.00033 |
| Barium | 417 | 0.0013 - 0.016 | 0.0041 |
| Cadmium | 487 | 0.0000062 - 0.000073 | 0.000019 |
| Chromium | 333 | 0.000062 - 0.0011 | 0.00027 |
| Copper | 473 | 0.00011 - **0.0090** | 0.0014 |
| Iron | 493 | 0.0062 - **2.41** | 0.29 |
| Lead | 488 | 0.000022 - **0.0030** | 0.00011 |
| Manganese | 493 | 0.00011 - **0.20** | 0.024 |

**Table K3.18-8: Surface Water Data Summary – SFK River, Mine Site**

| Analyte | Number of Samples | Range of Detects (Min-Max) [a] | Mean[a,b] |
|---|---|---|---|
| Molybdenum | 331 | 0.000015 - 0.0017 | 0.00051 |
| Nickel | 477 | 0.000062 - 0.0013 | 0.00033 |
| Selenium | 260 | 0.000058 - 0.00062 | 0.00029 |
| Silver | 327 | 0.000003 - 0.000031 | 0.0000064 |
| Zinc | 491 | 0.00031 - 0.022 | 0.0027 |
| **Dissolved Metals (mg/L)** | | | |
| Aluminum | 464 | 0.0020 - 0.040 | 0.0098 |
| Arsenic | 329 | 0.00012 - 0.00091 | 0.00031 |
| Barium | 388 | 0.0010 - 0.0096 | 0.0039 |
| Cadmium | 485 | 0.0000062 - 0.000074 | 0.000019 |
| Chromium | 306 | 0.000062 - 0.0010 | 0.00025 |
| Copper | 418 | 0.00015 - **0.0049** | 0.0011 |
| Iron | 488 | 0.0062 - **1** | 0.12 |
| Lead | 427 | 0.000022 - **0.00042** | 0.000072 |
| Manganese | 474 | 0.000056 - **0.12** | 0.019 |
| Molybdenum | 313 | 0.000031 - 0.0017 | 0.00051 |
| Nickel | 292 | 0.000090 - 0.0012 | 0.00042 |
| Selenium | 334 | 0.000047 - 0.00062 | 0.00029 |
| Silver | 333 | 0.000003 - 0.000013 | 0.0000062 |
| Zinc | 366 | 0.00047 - 0.011 | 0.0028 |
| **Cyanides (mg/L)** | | | |
| Cyanide | 330 | 0.0015 - 0.016 | 0.0024 |
| Cyanide (WAD) | 469 | 0.0015 - **0.0078** | 0.0022 |
| **Organic Compounds, (mg/L)** | | | |
| Dissolved Organic Carbon | 305 | 0.15 - 4.76 | 1.27 |

Notes:
[a] Bold values indicate fields that exceed the most stringent water quality criteria.
[b] When calculating the mean, non-detects with "U" or "UJ" qualifiers were included as one-half the RDL.
mg/L = milligrams per liter
mV = millivolts
uS/cm = Microsiemens per centimeter
NTU = Nephelometric Turbidity Units
WAD = Weak Acid Dissociable
Source: ERM 2018a

**Table K3.18-9: Surface Water Data Summary – UTC, Mine Site**

| Analyte | Number of Samples | Range of Detects (Min-Max) [a] | Mean[a,b] |
|---|---|---|---|
| **Field and Physical parameters (mg/L, except where noted)** | | | |
| Total Dissolved Solids | 590 | 3.75 - 115 | 52.8 |
| pH (Field, Standard Units) | 764 | **4.5** - **9.33** | 6.9 |
| Dissolved Oxygen | 757 | **2.69** - 18.6 | 9.7 |
| Water Temperature ($^0$C) | 767 | -0.93 - **15.7** | 3.89 |
| Specific Conductivity (Field, uS/cm) | 760 | 10 - 750 | 77.6 |
| Turbidity (NTU) | 570 | 0.0 - **16.3** | 1.39 |
| Total Suspended Solids | 584 | 0.15 - **25.8** | 3.21 |
| Oxidation Reduction Potential (mV) | 729 | -180 - 519 | 115 |
| **Major Ions (mg/L)** | | | |
| Calcium (Dissolved) | 443 | 2.37 - 17.3 | 8.92 |
| Calcium (Total) | 445 | 2.12 - 16.7 | 8.95 |
| Magnesium (Dissolved) | 442 | 0.64 - 4.73 | 2.1 |
| Magnesium (Total) | 444 | 0.66 - 5 | 2.1 |
| Sodium (Dissolved) | 443 | 1.02 - 6.73 | 2.77 |
| Sodium (Total) | 444 | 0.95 - 6.84 | 2.77 |
| Potassium (Dissolved) | 435 | 0.11 - 1.2 | 0.45 |
| Potassium (Total) | 443 | 0.19 - 1.36 | 0.45 |
| Alkalinity (Total) | 601 | **3.73** - 74 | 31.6 |
| Sulfate | 444 | 0.90 - 41.6 | 6.28 |
| Chloride | 443 | 0.031 - 1.15 | 0.70 |
| Fluoride | 429 | 0.0060 - 0.16 | 0.044 |
| Hardness as $CaCO_3$ | 591 | 7.25 - 62.2 | 32 |
| **Nutrients, (mg/L)** | | | |
| Total Ammonia as Nitrogen (N) | 526 | 0.0050 - **0.25** | 0.042 |
| Nitrate-Nitrite | 435 | 0.0050 - 1.74 | 0.21 |
| Total Phosphorous (P) | 442 | 0.0031 - 0.11 | 0.019 |
| Total Orthophosphate (as P) | 47 | 0.031 - 0.10 | 0.068 |
| **Total Metals (mg/L)** | | | |
| Aluminum | 584 | 0.0032 - **0.66** | 0.073 |
| Arsenic | 445 | 0.00012 - 0.0028 | 0.00095 |
| Barium | 528 | 0.0012 - 0.018 | 0.0053 |
| Cadmium | 578 | 0.0000030 - **0.00010** | 0.000017 |
| Chromium | 445 | 0.000062 - 0.0012 | 0.00036 |

**Table K3.18-9: Surface Water Data Summary – UTC, Mine Site**

| Analyte | Number of Samples | Range of Detects (Min-Max) [a] | Mean[a,b] |
|---|---|---|---|
| Copper | 590 | 0.000050 - **0.0054** | 0.00061 |
| Iron | 588 | 0.015 - **1.3** | 0.24 |
| Lead | 586 | 0.0000050 - **0.0028** | 0.000089 |
| Manganese | 587 | 0.00068 - **0.16** | 0.026 |
| Molybdenum | 427 | 0.000015 - 0.00053 | 0.00025 |
| Nickel | 575 | 0.000030 - 0.0040 | 0.00061 |
| Selenium | 441 | 0.000030 - 0.00040 | 0.00030 |
| Silver | 438 | 0.0000029 - 0.000032 | 0.0000076 |
| Zinc | 588 | 0.00020 - 0.016 | 0.0025 |
| **Dissolved Metals (mg/L)** | | | |
| Aluminum | 564 | 0.0020 - **0.14** | 0.013 |
| Arsenic | 441 | 0.000089 - 0.0027 | 0.00082 |
| Barium | 517 | 0.0011 - 0.013 | 0.0049 |
| Cadmium | 573 | 0.0000030 - 0.000073 | 0.000017 |
| Chromium | 416 | 0.000050 - 0.0011 | 0.00031 |
| Copper | 473 | 0.000030 - **0.0026** | 0.00047 |
| Iron | 587 | 0.0034 - 0.43 | 0.090 |
| Lead | 524 | 0.0000030 - 0.00037 | 0.000057 |
| Manganese | 580 | 0.00025 - **0.15** | 0.020 |
| Molybdenum | 403 | 0.000015 - 0.00057 | 0.00025 |
| Nickel | 436 | 0.000070 - 0.0038 | 0.00068 |
| Selenium | 445 | 0.000029 - 0.0010 | 0.00030 |
| Silver | 441 | 0.0000029 - 0.000044 | 0.0000068 |
| Zinc | 488 | 0.00020 - 0.0084 | 0.0025 |
| **Cyanides (mg/L)** | | | |
| Cyanide | 433 | 0.00090 - 0.0081 | 0.0022 |
| Cyanide (WAD) | 573 | 0.00090 - **0.021** | 0.0022 |
| **Organic Compounds, (mg/L)** | | | |
| Dissolved Organic Carbon | 438 | 0.15 - 9.38 | 1.52 |

Notes:
[a] Bold values indicate fields that exceed the most stringent water quality criteria.
[b] When calculating the mean, non-detects with "U" or "UJ" qualifiers were included as one-half the RDL.
mg/L = milligrams per liter
mV = millivolts
uS/cm = Microsiemens per centimeter
NTU = Nephelometric Turbidity Units
Source: ERM 2018a

**Table K3.18-10: Surface Water Data Summary – Frying Pan Lake, Mine Site**

| Analyte | Number of Samples | Range of Detects (Min-Max) | Mean [a,b] |
|---|---|---|---|
| **Field and Physical Parameters (mg/L, except where noted)** | | | |
| Total Dissolved Solids | 11 | 20.0 - 68.1 | 44.3 |
| pH (Field, Standard Units) | 10 | **4.74** - **8.61** | 6.32 |
| Dissolved Oxygen | 10 | **5.65** - 8.85 | 7.37 |
| Water Temperature (°C) | 10 | 3.16 - **13.8** | 9.09 |
| Specific Conductivity (Field, uS/cm) | 10 | 0.017 - 0.064 | 0.038 |
| Turbidity (NTU) | 10 | 0.25 - **7.44** | 1.98 |
| Total Suspended Solids | 11 | 0.40 - 14.8 | 4.27 |
| Oxidation Reduction Potential (mV) | 10 | -77.8 - 223 | 128 |
| **Major Ions (mg/L)** | | | |
| Calcium (Dissolved) | 11 | 2.52 - 7.37 | 4.78 |
| Calcium (Total) | 11 | 2.59 - 7.77 | 5.02 |
| Magnesium (Dissolved) | 11 | 0.42 - 1.92 | 1.05 |
| Magnesium (Total) | 11 | 0.43 - 1.96 | 1.09 |
| Sodium (Dissolved) | 10 | 1.74 - 2.98 | 2.18 |
| Sodium (Total) | 11 | 1.67 - 3.17 | 2.19 |
| Potassium (Dissolved) | 11 | 0.073 - 0.46 | 0.20 |
| Potassium (Total) | 11 | 0.079 - 0.48 | 0.20 |
| Alkalinity (Total) | 11 | **10.0** - 29.9 | **19.8** |
| Sulfate | 11 | 0.36 - 11.2 | 3.56 |
| Chloride | 11 | 0.39 - 0.76 | 0.54 |
| Fluoride | 11 | 0.041 - 0.070 | 0.038 |
| Hardness as $CaCO_3$ (Not Filtered) | 11 | 8.23 - 27.5 | 17.0 |
| **Cations (mg/L, except where noted)** | | | |
| Nitrogen (N), Ammonia (as N) | 11 | 0.016 - 0.20 | 0.071 |
| Nitrogen (N), Nitrate-Nitrite | 11 | 0.032 - 1.19 | 0.28 |
| Total Phosphorus (P) | 11 | 0.0070 - 0.059 | 0.023 |
| Total Orthophosphate (as P) | 10 | NA - NA | 0.043 |
| **Total Metals (mg/L)** | | | |
| Aluminum | 11 | 0.020 - 0.19 | 0.053 |
| Barium | 11 | 0.0021 - 0.0073 | 0.0040 |
| Iron | 11 | 0.064 - **1.03** | 0.40 |
| Copper | 11 | 0.00018 - **0.0038** | 0.0013 |
| Zinc | 11 | 0.0010 - 0.0057 | 0.0032 |

**Table K3.18-10: Surface Water Data Summary – Frying Pan Lake, Mine Site**

| Analyte | Number of Samples | Range of Detects (Min-Max) | Mean [a,b] |
|---|---|---|---|
| Lead | 11 | 0.000042 - **0.00044** | 0.00011 |
| Cadmium[c] | 11 | 0 - 0 | 0.000018 |
| Arsenic | 11 | 0.00049 - 0.0013 | 0.00048 |
| Nickel | 11 | 0.00024 - 0.00047 | 0.00022 |
| Molybdenum | 11 | 0.00020 - 0.00073 | 0.00035 |
| Manganese | 11 | 0.0022 - **0.074** | 0.035 |
| **Dissolved Metals (mg/L)** | | | |
| Aluminum | 11 | 0.0025 - 0.025 | 0.015 |
| Barium | 11 | 0.0010 - 0.0058 | 0.0033 |
| Iron | 11 | 0.029 - 0.44 | 0.16 |
| Copper | 10 | 0.00020 - 0.0021 | 0.00083 |
| Zinc | 9 | 0.0013 - 0.0039 | 0.0027 |
| Lead | 4 | 0.00010 - 0.00028 | 0.00016 |
| Cadmium[c] | 11 | 0 - 0 | 0.000018 |
| Arsenic | 11 | 0.00035 - 0.00091 | 0.00036 |
| Nickel | 2 | 0.00027 - 0.00046 | 0.00036 |
| Molybdenum | 11 | 0.00017 - 0.00070 | 0.00035 |
| Manganese | 11 | 0.00029 - **0.051** | 0.017 |
| **Cyanides (mg/L)** | | | |
| Cyanide (Total)[c] | 11 | 0 - 0 | 0.00075 |
| Cyanide (WAD) | 11 | 0.0016 - 0.0050 | 0.0013 |

Notes:
[a] Bold values indicate fields that exceed the most stringent water quality criteria.
[b] When calculating the mean, non-detects with "U" or "UJ" qualifiers were included as one-half the RDL.
[c] Zeros represent constituents that were not detected (constituent concentrations fall below the detection limits). Non-detect results of zero without a “U” or “UJ” qualifiers were included as one-half the method detection limit (MDL).
NTU = Nephelometric Turbidity Units
uS/cm = Microsiemens per centimeter
mV = millivolts
mg/L = milligrams per liter
Source: Schlumberger et al. 2011a, Table 9.1-32

**Table K3.18-11: Surface Water Data Summary – North Access Route, West Part**

| Analyte | Number of Samples | Range of Detects (Min-Max) [a] | Mean [a,b] |
|---|---|---|---|
| **Total Metals (mg/L)** | | | |
| Aluminum | 82 | 0.00486 - **0.925** | **0.095** |
| Antimony | 82 | 0.0000016 - 0.0019 | 0.00011 |
| Arsenic | 82 | 0.00002 - 0.0081 | 0.00084 |
| Barium | 82 | 0.00128 - 0.01100 | 0.00491 |
| Beryllium | 82 | 0 - NA | 0.00001 |
| Bismuth | 65 | 0 - 0.00075 | 0.00033 |
| Boron | 81 | 0.0013 - 0.005 | 0.00279 |
| Cadmium | 80 | 0 - **0.0022** | 0.00004 |
| Calcium | 82 | 2.34 - 14 | 7.13915 |
| Chromium | 82 | 0.00003 - 0.0010 | 0.00027 |
| Cobalt | 82 | 0 - 0.0001 | 0.00006 |
| Copper | 82 | 0.00011 - 0.0014 | 0.00063 |
| Iron | 82 | 0.00310 - **2.110** | 0.2081 |
| Lead | 82 | 0.00002 - **0.0011** | 0.00013 |
| Magnesium | 82 | 0.18000 - 1.27000 | 0.8786 |
| Manganese | 82 | 0.0005 - **0.1560** | 0.0128 |
| Mercury | 82 | 0.00015 - 0.00001 | 0 |
| Molybdenum | 82 | 0.00016 - 0.00153 | 0.00064 |
| Nickel | 82 | 0.00005 - 0.00063 | 0.00029 |
| Potassium | 82 | 0.11300 - 0.8650 | 0.3142 |
| Selenium | 82 | 0.00001 - 0.00026 | 0.00011 |
| Silver | 82 | 0 - 0.00003 | 0 |
| Thallium | 82 | 0 - 0.00001 | 0.00001 |
| Tin | 79 | 0.00003 - 0.00050 | 0.00014 |
| Vanadium | 82 | 0.00010 - 0.0032 | 0.00042 |
| Zinc | 82 | 0.00050 - 0.0129 | 0.0028 |
| **Dissolved Metals (mg/L)** | | | |
| Aluminum | 81 | 0.00100 - 0.057 | 0.0151 |
| Antimony | 78 | 0.0000016 - 0.00028 | 0.00005 |
| Arsenic | 81 | 0.00004 - 0.00585 | 0.00046 |
| Barium | 81 | 0.00126 - 0.0135 | 0.0042 |
| Beryllium | 81 | 0 - 0.000040 | 0.00001 |
| Bismuth | 72 | 0 - 0.00075 | 0.00033 |
| Boron | 76 | 0.00155 - 0.0119 | 0.0024 |

**Table K3.18-11: Surface Water Data Summary – North Access Route, West Part**

| Analyte | Number of Samples | Range of Detects (Min-Max) [a] | Mean [a,b] |
|---|---|---|---|
| Cadmium | 81 | 0.0000031 - 0.00006 | 0.00002 |
| Calcium | 79 | 2.34 - 12.9 | 6.989 |
| Chromium | 71 | 0.00003 - 0.00143 | 0.0002 |
| Cobalt | 76 | 0 - 0.0004 | 0.00004 |
| Copper | 72 | 0.00019 - 0.0021 | 0.00043 |
| Iron | 81 | 0.00400 - 0.215 | 0.0554 |
| Lead | 62 | 0.00002 - 0.00035 | 0.00013 |
| Magnesium | 81 | 0.1810 - 1.340 | 0.8590 |
| Manganese | 81 | 0.00025 - 0.0332 | 0.0052 |
| Molybdenum | 78 | 0.00016 - 0.00159 | 0.00065 |
| Nickel | 48 | 0.00005 - 0.00056 | 0.00035 |
| Potassium | 72 | 0.1120 - 0.855 | 0.3099 |
| Selenium | 81 | 0.00001 - 0.00021 | 0.00011 |
| Silicon | 81 | 2.240 - 6.570 | 4.219 |
| Silver | 81 | 0 - 0.00001 | 0 |
| Thallium | 80 | 0 - 0.00001 | 0.00001 |
| Tin | 81 | 0.00003 - 0.00085 | 0.00011 |
| Vanadium | 81 | 0.00008 - 0.00074 | 0.00022 |
| Zinc | 69 | 0.00075 - 0.0143 | 0.00239 |
| **Anions (mg/L, except where noted)** | | | |
| Chloride | 82 | 0.42 - 2.33 | 0.961 |
| Fluoride | 82 | 0.016 - 0.12 | 0.041 |
| Cyanide | 82 | 0.0013 - 0.0066 | 0.002 |
| Cyanide (WAD) | 82 | 0.0013 - **0.0077** | 0.0018 |
| Nitrogen (N), Nitrate+Nitrite (as Nitrogen) | 81 | 0.016 - 8.09 | 0.840 |
| Phosphorus (P), Total Orthophosphate (as P) | 82 | 0.0017 - 0.445 | 0.048 |
| Sulfate | 82 | 0.91 - 59.1 | 6.06 |
| **Cations (mg/L, except where noted)** | | | |
| Ammonia as Nitrogen (N) | 82 | 0.015 - **0.464** | 0.045 |
| Sodium (dissolved) | 77 | 1.03 - 3.9 | 1.952 |
| Sodium (total) | 82 | 0.987 - 4.13 | 1.968 |
| **Miscellaneous Parameters (mg/L, except where noted)** | | | |
| Acidity (total) | 82 | 0.79 - 9.5 | 2.6 |
| Alkalinity (total) | 82 | **1.60** - 33.0 | **19** |

**Table K3.18-11: Surface Water Data Summary – North Access Route, West Part**

| Analyte | Number of Samples | Range of Detects (Min-Max) [a] | Mean [a,b] |
|---|---|---|---|
| Hardness as $CaCO_3$ (Not Filtered) | | - | |
| pH (Field, Standard Units) | | - | |
| Specific Conductivity (Field, uS/cm) | 82 | 21.00 - 600 | 70.00 |
| Total Dissolved Solids | 82 | 10 - 126 | 4.350 |
| Total Suspended Solids | 82 | 0.075 - **56** | 4.2 |
| Water Temperature (°C) | 80 | 0.08 - **22.7** | 7.42 |

Notes:
[a] Bold values indicate fields that exceed the most stringent water quality criteria.
[b] When calculating the mean, non-detects with "U" or "UJ" qualifiers were included as one-half the RDL. Non-detect results of zero without a "U" or "UJ" qualifiers were included as one-half the method detection limit (MDL).
$CaCO_3$ = calcium carbonate
uS/cm = Microsiemens per centimeter
mg/L = milligrams per liter
Source: Schlumberger et al. 2011a

**Table K3.18-12: Surface Water Data Summary – North Access Route, East Part**

| Analyte | Number of Samples | Range of Detects (Min-Max) [a] | Mean [a,b] |
|---|---|---|---|
| **Total Metals (mg/L)** | | | |
| Aluminum | 50 | 0.00735 - **1.36** | **0.1530** |
| Antimony | 50 | 0.0000016 - 0.0000630 | 0.000129 |
| Arsenic | 50 | 0.000020 - **0.021100** | 0.00067 |
| Barium | 50 | 0.00062 - 0.02130 | 0.00814 |
| Beryllium | 50 | 0.0000015 - 0.0000342 | 0.0000084 |
| Bismuth | 50 | 0.0000016 - 0.0007500 | 0.0002730 |
| Boron | 50 | 0.00143 - 0.01400 | 0.00427 |
| Cadmium | 50 | 0.0000031 - 0.0000683 | 0.0000192 |
| Calcium | 50 | 1.030 - 9.210 | 3.290 |
| Chromium | 50 | 0.0000310 - 0.0006920 | 0.000210 |
| Cobalt | 50 | 0.0000050 - 0.0005990 | 0.0001290 |
| Copper | 50 | 0.000114 - **0.034600** | 0.004310 |
| Iron | 50 | 0.0013 - 0.8260 | 0.1080 |
| Lead | 50 | 0.000016 - **0.0012** | 0.000145 |
| Magnesium | 50 | 0.1000 - 0.6480 | 0.3010 |
| Manganese | 50 | 0.00025 - **0.05450** | 0.01120 |
| Mercury | 50 | 0.0000001 - **0.0000320** | 0.00000084 |
| Molybdenum | 50 | 0.000017 - 0.000997 | 0.000375 |
| Nickel | 50 | 0.000031 - 0.000678 | 0.000213 |
| Potassium | 50 | 0.1030 - 0.5130 | 0.2510 |

**Table K3.18-12: Surface Water Data Summary – North Access Route, East Part**

| Analyte | Number of Samples | Range of Detects (Min-Max) [a] | Mean [a,b] |
|---|---|---|---|
| Selenium | 50 | 0.0000143 – 0.0001550 | 0.0000966 |
| Silver | 50 | 0.0000014 – 0.0000205 | 0.0000036 |
| Thallium | 50 | 0.0000021 – 0.0000210 | 0.0000067 |
| Tin | 50 | 0.000030 – 0.002290 | 0.000155 |
| Vanadium | 50 | 0.000052 – 0.001830 | 0.000322 |
| Zinc | 50 | 0.00075 – 0.01850 | 0.00436 |
| **Dissolved Metals (mg/L)** | | | |
| Aluminum | 49 | 0.0035 – 0.058 | 0.0133 |
| Antimony | 45 | 0.0000016 – 0.0001120 | 0.000064 |
| Arsenic | 48 | 0.000006 – 0.007760 | 0.000406 |
| Barium | 50 | 0.00060 – 0.01510 | 0.00662 |
| Beryllium | 50 | 0.0000015 – 0.0000162 | 0.0000068 |
| Bismuth | 48 | 0.0000016 – 0.0007500 | 0.0002720 |
| Boron | 46 | 0.00134 – 0.01300 | 0.00405 |
| Cadmium | 49 | 0.0000031 – 0.0000754 | 0.0000179 |
| Calcium | 50 | 1.020 – 9.760 | 3.330 |
| Chromium | 50 | 0.0000310 – 0.0008890 | 0.000179 |
| Cobalt | 48 | 0.0000050 – 0.0005810 | 0.0000947 |
| Copper | 45 | 0.000198 – 0.026 | **0.00042**[c] |
| Iron | 50 | 0.0013 – 0.1230 | 0.0247 |
| Lead | 33 | 0.000016 – **0.000414** | 0.000131 |
| Magnesium | 50 | 0.968 – 0.5990 | 0.2740 |
| Manganese | 50 | 0.00010 – 0.03150 | 0.00666 |
| Molybdenum | 42 | 0.000050 – 0.000881 | 0.000412 |
| Nickel | 28 | 0.000083 – 0.000521 | 0.000286 |
| Potassium | 50 | 0.1000 – 0.4560 | 0.2390 |
| Selenium | 50 | 0.0000143 – 0.0001550 | 0.0000970 |
| Silicon | 50 | 1.050 – 4.320 | 2.510 |
| Silver | 50 | 0.0000014 – 0.0000158 | 0.0000035 |
| Thallium | 50 | 0.0000021 – 0.0000304 | 0.0000067 |
| Tin | 50 | 0.000030 – 0.000155 | 0.000076 |
| Vanadium | 49 | 0.000025 – 0.000584 | 0.000174 |
| Zinc | 41 | 0.00000 – 0.01700 | 0.00378 |
| **Anions (mg/L, except where noted)** | | | |
| Chloride | 50 | 0.31 – 1.7 | 0.861 |

**Table K3.18-12: Surface Water Data Summary – North Access Route, East Part**

| Analyte | Number of Samples | Range of Detects (Min-Max) [a] | Mean [a,b] |
|---|---|---|---|
| Fluoride | 50 | 0.016 - 0.088 | 0.035 |
| Cyanide | 50 | 0.0013 - 0.0066 | 0.0016 |
| Cyanide (WAD) | 50 | 0.0013 - 0.0037 | 0.0015 |
| Nitrogen (N), Nitrate+Nitrite (as N) | 49 | 0.0395 - **26.4** | 1.39 |
| Phosphorus (P), Total Orthophosphate (as P) | 50 | 0.0 - 0.60 | 0.04 |
| Sulfate | 49 | 0.53 - 33.9 | 5.39 |
| **Cations (mg/L, except where noted)** | | | |
| Nitrogen (N), Ammonia (as N) | 50 | 0.020 - 0.03 | 0.040 |
| Sodium (dissolved) | 45 | 0.620 - 2.36 | 1.220 |
| Sodium (total) | 50 | 0.770 - 2.73 | 1.250 |
| **Miscellaneous Parameters (mg/L, except where noted)** | | | |
| Acidity (Total) | 50 | 0.79 - 10.0 | 1.78 |
| Alkalinity (Total) | 50 | **1.55** - 20.8 | **5.9** |
| Hardness as $CaCO_3$ (Not Filtered) | 50 | 2.98 - 25.5 | 9.46 |
| pH (Field, Standard Units) | 50 | **4.69** - **8.59** | **6.43** |
| Specific Conductivity (Field, uS/cm) | 50 | 10.5 - 270 | 43 |
| Total Dissolved Solids | 50 | 1.55 - 110 | 24.5 |
| Total Suspended Solids | 50 | 0.08 - **34.8** | 3.50 |
| Water Temperature (°C) | 50 | 0.09 - **22.0** | 6.84 |

Notes:
[a] Bold values indicate fields that exceed the most stringent water quality criteria.
[b] When calculating the mean, non-detects with "U" or "UJ" qualifiers were included as one-half the RDL. Zeros represent constituents that were not detected (constituent concentrations fall below the detection limits). Non-detect results of zero without a "U" or "UJ" qualifiers were included as one-half the method detection limit (MDL).
[c] Median value as provided in PLP 2019-RFI 111
$CaCO_3$ = calcium carbonate
NTU = Nephelometric Turbidity Units
uS/cm = Microsiemens per centimeter
mg/L = milligrams per liter
Source: Schlumberger 2011a, Table 9.3-2; PLP 2019-RFI 111

**Table K3.18-13: Surface Water Data Summary – Iliamna Lake, Transportation Corridor**

| Parameters | Upper Talarik Creek | | | Iliamna Village Area | | | Pedro Bay Area | | | Pile Bay | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Range of Detects [a,b] | | | Range of Detects [a,b] | | | Range of Detects [a,b] | | | Range of Detects [a,b] | | |
| | Min | Max | Mean [a,c] | Min | Max | Mean [a,c] | Min | Max | Mean [a,c] | Min | Max | Mean [a,c] |
| **Total Metals (mg/L)** | | | | | | | | | | | | |
| Aluminum | 0.00221 | 0.0156 | 0.006133 | 0.00369 | **1.26** | 0.04005 | 0.0028 | **0.202** | 0.01532 | 0.00555 | **0.85** | 0.06563 |
| Antimony | 0.000014 | 0.00005 | 0.000028 | 0.000005 | 0.000061 | 0.000026 | 0.000008 | 0.000033 | 0.000022 | 0.000002 | 0.00015 | 0.000028 |
| Arsenic | 0.000125 | 0.000511 | 0.000189 | 0.000125 | 0.000916 | 0.000228 | 0.000125 | 0.000397 | 0.000157 | 0.000125 | 0.000585 | 0.000187 |
| Barium | 0.00482 | 0.00628 | 0.00545 | 0.000713 | 0.0217 | 0.005428 | 0.00455 | 0.00928 | 0.006188 | 0.00487 | 0.0143 | 0.006253 |
| Beryllium | 0.000008 | 0.000013 | 0.00001 | 0.000008 | 0.000013 | 0.000011 | 0.000008 | 0.000013 | 0.000011 | 0.000008 | 0.000013 | 0.00001 |
| Bismuth | 0.000002 | 0.000022 | 0.000006 | 0.000002 | 0.000039 | 0.000006 | 0.000002 | 0.000013 | 0.000006 | 0.000002 | 0.000008 | 0.000005 |
| Boron | 0.00155 | 0.005 | 0.00361 | 0.00125 | 0.0068 | 0.003217 | 0.00125 | 0.0079 | 0.00295 | 0.00155 | 0.0056 | 0.00374 |
| Cadmium | 0.000008 | 0.000029 | 0.000009 | 0.000008 | 0.000033 | 0.000013 | 0.000008 | 0.000025 | 0.000013 | 0.000008 | 0.000025 | 0.00001 |
| Calcium | 5.37 | 6.51 | 5.95 | 2.63 | 7.46 | 5.689 | 3.9 | 6.21 | 5.302 | 4.41 | 6.55 | 5.497 |
| Chromium | 0.00005 | 0.000454 | 0.000197 | 0.000031 | 0.000663 | 0.000219 | 0.000031 | 0.000672 | 0.00033 | 0.000031 | 0.000642 | 0.000216 |
| Cobalt | 0.000005 | 0.000031 | 0.000015 | 0.000005 | 0.00038 | 0.000028 | 0.000005 | 0.000064 | 0.00002 | 0.000011 | 0.000387 | 0.000057 |
| Copper | 0.000423 | 0.0007 | 0.000497 | 0.00038 | **0.00269** | 0.00058 | 0.000345 | 0.00164 | 0.000578 | 0.000572 | **0.00787** | 0.001957 |
| Iron | 0.0031 | 0.0257 | 0.01313 | 0.00993 | **1.06** | 0.08431 | 0.0031 | **1.56** | 0.06564 | 0.00672 | 0.884 | 0.06803 |
| Lead | 0.000016 | 0.00005 | 0.000019 | 0.000016 | **0.00065** | 0.000077 | 0.000016 | 0.00035 | 0.000122 | 0.000016 | **0.000415** | 0.00006 |
| Magnesium | 0.724 | 0.942 | 0.846 | 0.596 | 1.15 | 0.8408 | 0.559 | 0.833 | 0.753 | 0.582 | 0.985 | 0.755 |
| Manganese | 0.000674 | 0.00248 | 0.001153 | 0.000694 | 0.0304 | 0.003244 | 0.0001 | 0.00947 | 0.003944 | 0.000352 | **0.0815** | 0.00815 |
| Mercury | 0 | 0.000003 | 0 | 0 | 0.000003 | 0.000001 | 0 | 0.000003 | 0.000001 | 0 | 0.000003 | 0.000001 |
| Molybdenum | 0.000627 | 0.00111 | 0.00076 | 0.000089 | 0.00116 | 0.000702 | 0.000533 | 0.000894 | 0.000678 | 0.000499 | 0.000923 | 0.000707 |
| Nickel | 0.0001 | 0.000283 | 0.000203 | 0.0001 | 0.00227 | 0.000237 | 0.0001 | 0.000532 | 0.000194 | 0.0001 | 0.00104 | 0.000254 |
| Potassium | 0.47 | 0.593 | 0.538 | 0.24 | 1.86 | 0.5337 | 0.336 | 0.655 | 0.5202 | 0.433 | 0.649 | 0.5117 |
| Selenium | 0.000078 | 0.00025 | 0.000122 | 0.000078 | 0.00025 | 0.000137 | 0.000078 | 0.00025 | 0.000141 | 0.000078 | 0.00025 | 0.000126 |
| Silver | 0.000003 | 0.000007 | 0.000003 | 0.000003 | 0.000035 | 0.000005 | 0.000003 | 0.000012 | 0.000005 | 0.000003 | 0.000007 | 0.000003 |
| Thallium | 0.000003 | 0.000005 | 0.000004 | 0.000003 | 0.000014 | 0.000004 | 0.000003 | 0.000005 | 0.000004 | 0.000003 | 0.000022 | 0.000003 |

**Table K3.18-13: Surface Water Data Summary – Iliamna Lake, Transportation Corridor**

| Parameters | Upper Talarik Creek | | | Iliamna Village Area | | | Pedro Bay Area | | | Pile Bay | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Range of Detects [a,b] | | | Range of Detects [a,b] | | | Range of Detects [a,b] | | | Range of Detects [a,b] | | |
| | Min | Max | Mean [a,c] | Min | Max | Mean [a,c] | Min | Max | Mean [a,c] | Min | Max | Mean [a,c] |
| Tin | 0.000031 | 0.00005 | 0.00004 | 0.000031 | 0.00005 | 0.000043 | 0.000031 | 0.00005 | 0.000044 | 0.000031 | 0.000071 | 0.00004 |
| Vanadium | 0.0001 | 0.000247 | 0.000134 | 0.0001 | 0.00268 | 0.000211 | 0.0001 | 0.00025 | 0.00018 | 0.0001 | 0.00137 | 0.000217 |
| Zinc | 0.000233 | 0.0152 | 0.002427 | 0.000233 | 0.0164 | 0.002445 | 0.000233 | 0.0137 | 0.002818 | 0.000233 | 0.0134 | 0.00308 |
| **Dissolved Metals (mg/L)** | | | | | | | | | | | | |
| Aluminum | 0.00031 | 0.00461 | 0.00213 | 0.00031 | **0.114** | 0.01566 | 0.001 | 0.00889 | 0.004406 | 0.00273 | 0.0176 | 0.00586 |
| Antimony | 0.000007 | 0.000058 | 0.00003 | 0.000002 | 0.000068 | 0.000028 | 0.000005 | 0.000059 | 0.000021 | 0.000005 | 0.00005 | 0.000027 |
| Arsenic | 0.000125 | 0.000461 | 0.00017 | 0.000125 | 0.000564 | 0.000246 | 0.000125 | 0.00031 | 0.00016 | 0.000125 | 0.000492 | 0.000166 |
| Barium | 0.00326 | 0.0069 | 0.005401 | 0.0001 | 0.00755 | 0.005028 | 0.00454 | 0.00764 | 0.005772 | 0.00466 | 0.00633 | 0.0056 |
| Beryllium | 0.000008 | 0.000013 | 0.00001 | 0.000008 | 0.000034 | 0.000011 | 0.000008 | 0.000013 | 0.000011 | 0.000008 | 0.000013 | 0.00001 |
| Bismuth | 0.000002 | 0.000008 | 0.000005 | 0.000002 | 0.000017 | 0.000006 | 0.000002 | 0.000008 | 0.000006 | 0.000002 | 0.000008 | 0.000005 |
| Boron | 0.00155 | 0.00528 | 0.00335 | 0.00125 | 0.0102 | 0.003136 | 0.00125 | 0.0052 | 0.002318 | 0.00155 | 0.0067 | 0.0035 |
| Cadmium | 0.000008 | 0.00005 | 0.00001 | 0.000008 | 0.000063 | 0.000011 | 0.000008 | 0.000035 | 0.000014 | 0.000008 | 0.000025 | 0.000009 |
| Calcium | 3.92 | 6.85 | 5.803 | 0.00775 | 7.34 | 5.586 | 4.03 | 6.43 | 5.232 | 3.97 | 6.49 | 5.47 |
| Chromium | 0.000031 | 0.000634 | 0.00018 | 0.000031 | 0.000511 | 0.000173 | 0.000031 | 0.000524 | 0.000284 | 0.000031 | 0.000552 | 0.000199 |
| Cobalt | 0.000002 | 0.000026 | 0.000014 | 0.000002 | 0.000029 | 0.000016 | 0.000005 | 0.000025 | 0.000017 | 0.000005 | 0.000094 | 0.000024 |
| Copper | 0.000328 | 0.00059 | 0.00043 | 0.00005 | 0.000714 | 0.00049 | 0.000313 | 0.000707 | 0.000522 | 0.00053 | 0.00269 | 0.000943 |
| Iron | 0.0031 | 0.0235 | 0.01033 | 0.0031 | 0.249 | 0.04118 | 0.0031 | 0.0641 | 0.02034 | 0.0031 | 0.0254 | 0.0116 |
| Lead | 0.000016 | **0.00218** | 0.000167 | 0.000016 | 0.000146 | 0.000052 | 0.000016 | 0.000133 | 0.000035 | 0.000016 | 0.000129 | 0.000045 |
| Magnesium | 0.552 | 1.05 | 0.8583 | 0.000775 | 1.01 | 0.8341 | 0.559 | 0.878 | 0.7518 | 0.558 | 0.885 | 0.759 |
| Manganese | 0.0001 | 0.00129 | 0.000376 | 0.000031 | 0.00334 | 0.000784 | 0.000066 | 0.00277 | 0.001007 | 0.000195 | 0.00619 | 0.00119 |
| Mercury | - | - | - | - | - | - | - | - | - | - | - | - |
| Molybdenum | 0.000395 | 0.000901 | 0.000716 | 0.000003 | 0.00101 | 0.000681 | 0.00048 | 0.000814 | 0.000674 | 0.000536 | 0.000839 | 0.000712 |

**Table K3.18-13: Surface Water Data Summary – Iliamna Lake, Transportation Corridor**

| Parameters | Upper Talarik Creek | | | Iliamna Village Area | | | Pedro Bay Area | | | Pile Bay | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Range of Detects [a,b] | | | Range of Detects [a,b] | | | Range of Detects [a,b] | | | Range of Detects [a,b] | | |
| | Min | Max | Mean [a,c] | Min | Max | Mean [a,c] | Min | Max | Mean [a,c] | Min | Max | Mean [a,c] |
| Nickel | 0.000169 | 0.000424 | 0.000259 | 0.000016 | 0.000432 | 0.000236 | 0.0001 | 0.000442 | 0.000243 | 0.0001 | 0.000731 | 0.000276 |
| Potassium | 0.352 | 0.612 | 0.5307 | 0.00775 | 0.686 | 0.5053 | 0.344 | 0.579 | 0.4912 | 0.432 | 0.613 | 0.514 |
| Selenium | 0.000078 | 0.000155 | 0.000116 | 0.000078 | 0.000165 | 0.000127 | 0.000078 | 0.00025 | 0.000141 | 0.000078 | 0.00025 | 0.000131 |
| Silicon | 0.797 | 1.39 | 1.04 | 0.075 | 2.39 | 1.155 | 0.831 | 11.2 | 3.17 | 1.04 | 1.46 | 1.207 |
| Silver | 0.000003 | 0.000009 | 0.000003 | 0.000003 | 0.000014 | 0.000004 | 0.000003 | 0.000003 | 0.000003 | 0.000003 | 0.000003 | 0.000003 |
| Thallium | 0.000003 | 0.000005 | 0.000004 | 0.000003 | 0.000012 | 0.000004 | 0.000003 | 0.000005 | 0.000004 | 0.000003 | 0.000005 | 0.000004 |
| Tin | 0.000031 | 0.000123 | 0.000044 | 0.000031 | 0.000106 | 0.000044 | 0.000031 | 0.000112 | 0.000046 | 0.000031 | 0.00005 | 0.00004 |
| Vanadium | 0.0001 | 0.000262 | 0.000135 | 0.0001 | 0.000479 | 0.000182 | 0.0001 | 0.00025 | 0.000187 | 0.0001 | 0.000243 | 0.000142 |
| Zinc | 0.000233 | 0.0144 | 0.003203 | 0.000233 | 0.0196 | 0.001666 | 0.000233 | 0.0146 | 0.002478 | 0.0005 | 0.0156 | 0.001897 |
| **Anions (mg/L, except where noted)** | | | | | | | | | | | | |
| Chloride | 0.542 | 1.17 | 1.037 | 0.413 | 5.38 | 1.05 | 0.823 | 1.23 | 1.044 | 0.866 | 1.08 | 0.987 |
| Fluoride | 0.034 | 0.089 | 0.05 | 0.032 | 0.086 | 0.051 | 0.033 | 0.088 | 0.05 | 0.016 | 0.083 | 0.044 |
| Cyanide (Total) | 0.001 | 0.001 | 0.001 | 0.001 | 0.003 | 0.001 | 0.001 | 0.002 | 0.001 | 0.001 | 0.003 | 0.001 |
| Cyanide (WAD) | 0.001 | 0.004 | 0.001 | 0.001 | 0.003 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.003 | 0.001 |
| Thiocyanate | 0.155 | 0.5 | 0.36 | 0.155 | 0.5 | 0.327 | 0.03 | 0.5 | 0.258 | 0.03 | 0.5 | 0.316 |
| Total Nitrate + Nitrite (as Nitrogen) | 0.016 | 0.91 | 0.113 | 0.016 | 1.93 | 0.219 | 0.016 | 0.218 | 0.086 | 0.016 | 0.259 | 0.128 |
| Nitrite (as Nitrogen) | - | - | - | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | - | - | - |
| Nitrate (as Nitrogen) | - | - | - | 0.032 | 1.93 | 0.981 | 0.039 | 0.045 | 0.042 | - | - | - |
| Total Phosphorus (P) | 0.001 | 0.7 | 0.035 | 0.001 | 0.12 | 0.009 | 0.001 | 0.052 | 0.008 | 0.001 | 0.241 | 0.02 |
| Orthophosphate | - | - | - | 0.016 | 0.04 | 0.028 | 0.016 | 0.016 | 0.016 | - | - | - |
| Sulfate | 2.17 | 5.74 | 3.917 | 0.914 | 5.93 | 3.692 | 3.1 | 4.74 | 3.766 | 3.45 | 4.38 | 3.89 |
| **Cations (mg/L, except where noted)** | | | | | | | | | | | | |
| Ammonia (as Nitrogen) | 0.016 | 0.05 | 0.022 | 0.016 | 0.164 | 0.029 | 0.016 | 0.132 | 0.03 | 0.016 | 0.148 | 0.026 |

**Table K3.18-13: Surface Water Data Summary – Iliamna Lake, Transportation Corridor**

| Parameters | Upper Talarik Creek | | | Iliamna Village Area | | | Pedro Bay Area | | | Pile Bay | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Range of Detects [a,b] | | | Range of Detects [a,b] | | | Range of Detects [a,b] | | | Range of Detects [a,b] | | |
| | Min | Max | Mean [a,c] | Min | Max | Mean [a,c] | Min | Max | Mean [a,c] | Min | Max | Mean [a,c] |
| Sodium (total) | 1,340 | 2,090 | 1,707 | 1,410 | 4,100 | 1,974 | 1,360 | 1,990 | 1,710 | 1,350 | 1,850 | 1,573 |
| Sodium | 1,130 | 2,230 | 1,720 | 15.5 | 4,120 | 1,969 | 1,350 | 2,120 | 1,724 | 1,300 | 1,790 | 1,587 |
| **Miscellaneous Parameters (mg/L, except where noted)** | | | | | | | | | | | | |
| Acidity | 0.785 | 1.57 | 1.18 | 0.785 | 2.63 | 1.37 | 0.785 | 2.5 | 1.416 | 0.785 | 5 | 1.403 |
| Alkalinity | **14** | **17** | **15.67** | **12** | **29.6** | 15.58 | **10** | **16** | **13.26** | **10.5** | **15** | **13.57** |
| Hardness (as $CaCO_3$) | 16.4 | 20 | 18.33 | 9.03 | 22.6 | 17.68 | 12.4 | 18.9 | 16.34 | 13.4 | 20.1 | 16.83 |
| pH (field measurement, pH Units) | **6.01** | 7.34 | 6.857 | **6.25** | 7.8 | 7.143 | **6.11** | 8.17 | 7.314 | **4.5** | 7.67 | 6.657 |
| Conductivity (µmhos/cm) | - | - | - | - | - | - | - | - | - | - | - | - |
| Total Dissolved Solids | 13.8 | 52.5 | 26.4 | 5 | 71.3 | 28.74 | 13.8 | 35 | 27.52 | 12.5 | 56 | 27.47 |
| Total Suspended Solids | 0.075 | 1.09 | 0.353 | 0.075 | **22.7** | 0.963 | 0.075 | 8.56 | 0.936 | 0.075 | **77.6** | 4.497 |
| Temperature (Field Measurement, °C) | 4 | 16.28 | 8.666 | 4.57 | **17.86** | 10.74 | 3.81 | **16.78** | 10.76 | 4 | **16.31** | 8.176 |
| Total Organic Carbon | 0.617 | 1.01 | 0.84 | 0.462 | 0.96 | 0.74 | 0.333 | 0.662 | 0.516 | 0.35 | 0.825 | 0.611 |

Notes:
[a] Bold values indicate fields that exceed the most stringent water quality criteria.
[b] Range of Detects includes the minimum and maximum measurements from multiple sample locations in the area (1 sample location for Upper Talarik Creek, 4 locations for Iliamna Village Area, 3 sample locations for Pedro Bay Area, and 1 sample location for Pile Bay).
[c] Mean values for each area represent the average of mean values for measurements made at each sample location in the respective area
$CaCO_3$ – calcium carbonate
µmhos/cm = micromhos per centimeter
mg/L = milligrams per liter
WAD = Weak Acid Dissociable
Source: HDR 2011a

To ensure the representativeness of data, sample locations were selected to provide documentation of naturally occurring conditions, based on the following considerations (Schlumberger et al. 2011a):

- Characterization of drainage areas within the report study area.
- Historical baseline sample locations.
- Groundwater and surface water interactions.
- Location relative to the deposit area.
- Surface water in the vicinity of the Pebble deposit area.
- Relationship to other potentially affected resources, including fish and aquatic resources.

Table K3.18-7 through Table K3.18-12 provide the range of detected results, along with the mean and standard deviation of each detected analyte. Table K3.18-13 provides a summary of the Iliamna Lake data as a range of mean values for groups of sampling stations in the following locations: north ferry terminal, south ferry terminal, Iliamna village area, and eastern end of Iliamna Lake. Results exceeding the most stringent criteria listed in Table K3.18-1 are shown in bold on the data tables.

### Mine Site

Table K3.18-7 through Table K3.18-10 summarize data used for characterization of surface water quality at the mine site.

### Transportation Corridor

Table K3.18-11 and Table K3.18-12 summarize data used for characterization of surface water quality along the upland area of the west and east parts of the north access road, respectively, which are pertinent to Alternative 2 and Alternative 3. The samples were divided on the basis of geology: samples west of GS-11A (Figure 3.18-4) are located in an area of Quaternary surficial deposits over volcanic and sedimentary rocks, while samples to the east are located in an area of exposed intrusive bedrock (Schlumberger et al. 2011a).

Table K3.18-13 summarizes surface water quality data for Iliamna Lake, which are grouped as follows: near the mouth of UTC (Alternative 1 in the north ferry terminal area), Iliamna village area (pertinent to Alternative 1, and Alternative 2 in the Eagle Bay ferry terminal area), Pedro Bay area (pertinent to Alternative 2 and Alternative 3 natural gas pipeline and road routes, respectively), and Pile Bay (pertinent to Alternative 2 in the Pile Bay ferry terminal area) (Figure 3.18-5).

## K3.18.3.2 Trend Analysis at Mine Site

Some differences in water quality between watersheds and trends in water quality along streams were noted. Table K3.18-14 through Table K3.18-16 summarize observed spatial trends in the NFK, SFK, and UTC, respectively. A combination of the Mann-Kendall test and Theil Sen Line regression was used to analyze data for trends and compute tau values, p-values (probability values), slope magnitude of the trend, and y-intercept (ERM 2018a). Tau values represent the correlation coefficient, or how strongly the data trend. Negative tau values indicate an inverse relationship between constituents and distance downstream, and positive tau values indicate that constituents increase in concentration as distance downstream increases.

Statistical methods employed determined whether spatial trends in constituents increase or decrease in a statistically significant way, or remain stable (no significant trend in data). P-values, or probability values, represent the probability that the null hypothesis (i.e., no significant trend in data for a given model) is true. When analyzing data, a p-value of 0.05 is the threshold for statistical significance. Trends with a p-value calculated to be less 0.05 are statistically significant, indicating that observed spatial trends are real. Field and physical parameters with p-values calculated to be greater than 0.05 display trends that are not statistically significant, and indicate a stable spatial distribution of data.

**Table K3.18-14: Spatial Regression Analysis, NFK River[a]**

| Analyte | tau | p-value | Spatial Trend | Regression Significantly Different? |
|---|---|---|---|---|
| **Field and Physical Parameters (mg/L, except where noted)** | | | | |
| Total Dissolved Solids | -0.194 | 0.0000862 | **Decreasing** | **YES** |
| pH (Field, Standard Units) | -0.013 | 0.786 | Stable | NO |
| Dissolved Oxygen | 0.117 | 0.0152 | **Increasing** | **YES** |
| Water Temperature ($^0$C) | 0.00615 | 0.899 | Stable | NO |
| Specific Conductivity (Field, uS/cm) | -0.304 | 3.57E-10 | **Decreasing** | **YES** |
| Turbidity (NTU) | -0.276 | 2.54E-08 | **Decreasing** | **YES** |
| Total Suspended Solids | -0.233 | 0.00000224 | **Decreasing** | **YES** |
| Oxidation Reduction Potential (mV) | 0.0517 | 0.281 | Stable | NO |
| **Major Ions (mg/L)** | | | | |
| Calcium (Total) | -0.378 | 1.11E-10 | **Decreasing** | **YES** |
| Magnesium (Total) | -0.44 | 6.34E-14 | **Decreasing** | **YES** |
| Sodium (Total) | 0.0262 | 0.656 | Stable | NO |
| Potassium (Total) | -0.456 | 7.22E-15 | **Decreasing** | **YES** |
| Alkalinity (Total) | -0.368 | 3.31E-14 | **Decreasing** | **YES** |
| Sulfate | 0.0625 | 0.288 | Stable | NO |
| Chloride | 0.141 | 0.0157 | **Increasing** | **YES** |
| Fluoride | -0.0668 | 0.293 | Stable | NO |
| Hardness as $CaCO_3$ | -0.398 | 4.29E-16 | **Decreasing** | **YES** |
| **Nutrients, (mg/L)** | | | | |
| Nitrogen (N), Nitrate-Nitrite | 0.000892 | 0.989 | Stable | NO |
| **Total Metals (mg/L)** | | | | |
| Aluminum | -0.0594 | 0.227 | Stable | NO |
| Arsenic | -0.426 | 1.43E-11 | **Decreasing** | **YES** |
| Barium | 0.0522 | 0.322 | Stable | NO |
| Chromium | -0.166 | 0.00505 | **Decreasing** | **YES** |
| Copper | 0.0286 | 0.573 | Stable | NO |
| Iron | -0.519 | 0 | **Decreasing** | **YES** |

**Table K3.18-14: Spatial Regression Analysis, NFK River[a]**

| Analyte | tau | p-value | Spatial Trend | Regression Significantly Different? |
|---|---|---|---|---|
| Manganese | -0.255 | 2.33E-07 | **Decreasing** | **YES** |
| Molybdenum | 0.362 | 0 | **Increasing** | **YES** |
| Nickel | -0.307 | 2.87E-09 | **Decreasing** | **YES** |
| Zinc | -0.0509 | 0.319 | Stable | NO |

Notes:
[a] For 4 sample locations along NFK River
mV = millivolts
$CaCO_3$ = calcium carbonate
uS/cm = Microsiemens per centimeter
mg/L = milligrams per liter
Source: ERM 2018a

**Table K3.18-15: Spatial Regression Analysis, SFK River[a]**

| Analyte | tau | p-Value | Spatial Trend | Regression Significantly Different? |
|---|---|---|---|---|
| **Field and Physical parameters (mg/L, except where noted)** | | | | |
| Total Dissolved Solids | -0.257 | 1.05E-11 | **Decreasing** | **YES** |
| pH (Field, Standard Units) | -0.067 | 0.0523 | Stable | No |
| Dissolved Oxygen | 0.182 | 0.000000119 | **Increasing** | **YES** |
| Water Temperature ($^0$C) | -0.0338 | 0.325 | Stable | No |
| Specific Conductivity (Field, uS/cm) | -0.268 | 1.39E-14 | **Decreasing** | **YES** |
| Turbidity (NTU) | -0.406 | 0 | **Decreasing** | **YES** |
| Total Suspended Solids | -0.194 | 2.13E-07 | **Decreasing** | **YES** |
| Oxidation Reduction Potential (mV) | 0.164 | 2.62E-06 | **Increasing** | **YES** |
| **Major Ions (mg/L)** | | | | |
| Calcium (Total) | -0.308 | 2.06E-12 | **Decreasing** | **YES** |
| Magnesium (Total) | -0.367 | 6.44E-17 | **Decreasing** | **YES** |
| Sodium (Total) | -0.312 | 1.39E-12 | **Decreasing** | **YES** |
| Potassium (Total) | -0.285 | 8.51E-11 | **Decreasing** | **YES** |
| Alkalinity (Total) | -0.0246 | 0.508 | Stable | No |
| Sulfate | -0.556 | 0 | **Decreasing** | **YES** |
| Chloride | 0.157 | 0.000358 | **Increasing** | **YES** |
| Fluoride | -0.271 | 6.43E-09 | **Decreasing** | **YES** |
| Hardness as $CaCO_3$ | -0.296 | 2.81E-15 | **Decreasing** | **YES** |
| **Nutrients, (mg/L)** | | | | |
| Nitrogen (N), Nitrate-Nitrite | -0.0383 | 0.393 | Stable | No |
| **Total Metals (mg/L)** | | | | |

**Table K3.18-15: Spatial Regression Analysis, SFK River[a]**

| Analyte | tau | p-Value | Spatial Trend | Regression Significantly Different? |
|---|---|---|---|---|
| Aluminum | -0.194 | 2.12E-07 | **Decreasing** | **YES** |
| Arsenic | -0.16 | 0.0012 | **Decreasing** | **YES** |
| Barium | -0.685 | 0 | **Decreasing** | **YES** |
| Chromium | -0.0613 | 0.169 | Stable | No |
| Copper | -0.614 | 0 | **Decreasing** | **YES** |
| Iron | -0.604 | 0 | **Decreasing** | **YES** |
| Manganese | -0.624 | 0 | **Decreasing** | **YES** |
| Molybdenum | -0.558 | 0 | **Decreasing** | **YES** |
| Nickel | -0.418 | 0 | **Decreasing** | **YES** |
| Zinc | -0.185 | 1.32E-06 | **Decreasing** | **YES** |

Notes:
[a] For 10 sample locations along SFK River
mV = millivolts
CaCO3 = calcium carbonate
uS/cm = Microsiemens per centimeter
mg/L = milligrams per liter
NTU = Nephelometric Turbidity Units
Source: ERM 2018a

**Table K3.18-16: Spatial Regression Analysis, UTC[a]**

| Analyte | tau | p-Value | Spatial Trend | Regression Significantly Different? |
|---|---|---|---|---|
| **Field and Physical parameters (mg/L, except where noted)** | | | | |
| Total Dissolved Solids | -0.35 | 2.49E-23 | **Decreasing** | **YES** |
| pH (Field, Standard Units) | -0.0154 | 0.62 | Stable | NO |
| Dissolved Oxygen | 0.00816 | 0.793 | Stable | NO |
| Water Temperature ($^0$C) | -0.0161 | 0.604 | Stable | NO |
| Specific Conductivity (Field, uS/cm) | -0.0154 | 0.62 | Stable | NO |
| Turbidity (NTU) | -0.0174 | 0.625 | Stable | NO |
| Total Suspended Solids | 0.439 | 0 | **Increasing** | **YES** |
| Oxidation Reduction Potential (mV) | 0.0466 | 0.14 | Stable | NO |
| **Major Ions (mg/L)** | | | | |
| Calcium (Total) | -0.382 | 3.27E-21 | **Decreasing** | **YES** |
| Magnesium (Total) | -0.661 | 0 | **Decreasing** | **YES** |
| Sodium (Total) | -0.488 | 0 | **Decreasing** | **YES** |
| Potassium (Total) | -0.532 | 0 | **Decreasing** | **YES** |
| Alkalinity (Total) | -0.449 | 0 | **Decreasing** | **YES** |

**Table K3.18-16: Spatial Regression Analysis, UTC[a]**

| Analyte | tau | p-Value | Spatial Trend | Regression Significantly Different? |
|---|---|---|---|---|
| Sulfate | -0.45 | 0 | **Decreasing** | **YES** |
| Chloride | 0.165 | 5.14E-05 | **Increasing** | **YES** |
| Fluoride | -0.291 | 2.64E-12 | **Decreasing** | **YES** |
| Hardness as $CaCO_3$ | -0.481 | 0 | **Decreasing** | **YES** |
| **Nutrients, (mg/L)** | | | | |
| Nitrogen (N), Nitrate-Nitrite | -0.215 | 1.44E-07 | **Decreasing** | **YES** |
| **Total Metals (mg/L)** | | | | |
| Aluminum | 0.115 | 0.00112 | **Increasing** | **YES** |
| Arsenic | 0.452 | 0 | **Increasing** | **YES** |
| Barium | -0.41 | 0 | **Decreasing** | **YES** |
| Chromium | 0.101 | 0.0128 | **Increasing** | **YES** |
| Copper | -0.188 | 1.29E-07 | **Decreasing** | **YES** |
| Iron | -0.0475 | 0.175 | Stable | NO |
| Manganese | -0.0473 | 0.177 | Stable | NO |
| Molybdenum | 0.418 | 0 | **Increasing** | **YES** |
| Nickel | -0.224 | 5.15E-10 | **Decreasing** | **YES** |
| Zinc | -0.0891 | 0.0147 | **Decreasing** | YES |

Notes:
[a] For 10 sample locations along UTC
mV = millivolts
CaCO3 = calcium carbonate
uS/cm = Microsiemens per centimeter
mg/L = milligrams per liter
NTU = Nephelometric Turbidity Units
Source: ERM 2018a

### K3.18.3.3 Cook Inlet: Iliamna/Iniskin Estuary

This section contains additional water quality information for the portion of Cook Inlet north of Kamishak Bay that pertains to the port area for the north access route under Alternative 2 and Alternative 3.

**Salinity Gradient.** Water quality in the Iliamna/Iniskin estuary, located about 30 miles north of the Amakdedori port site, was studied in 2004 through 2012 by Pentec/Hart Crowser and SLR (2011) and Hart Crowser (2015a). Water quality in this area appeared to be dominated by tidal exchange with Cook Inlet and Kamishak Bay, with smaller, localized effects from freshwater inputs and local wind waves. Observed gradients in salinity between the inner (lower salinity) and outer (higher salinity) portions of Iliamna Bay are consistent with this conclusion. Average salinity was observed to decrease from the outer stations of Iliamna Bay to the inner stations. This is likely a result of freshwater inputs at the head of Iliamna Bay. Salinity decreases from spring to late summer, and increases again in the fall, thereby providing an additional indicator of the influence of regional water on the bays. A certain amount of stratification was observed

during both the spring snowmelt season and during the warmer summer months, particularly during calmer weather and in more sheltered portions of the bays.

Snowmelt or significant rain events create a freshwater surface lens a few inches deep in areas adjacent to freshwater inputs; these lenses rapidly diminish as a result of tidal and wind driven mixing.

**Suspended Particulates/Turbidity**. Analysis of available data indicates that turbidity is generally moderate, and does not exhibit any obvious trends that indicate point-source inputs. Average turbidity for the Iliamna/Iniskin stations ranged between 3.1 and 75 Nephelometric Turbidity Units (NTU). Monthly mean turbidity was relatively constant over the study period, with occasional high turbidity corresponding to months in which generally windy conditions prevailed.

**Organics and Inorganics.** Analyses of hydrocarbon concentrations in marine water from the Iliamna/Iniskin estuary in 2004, and of metal and trace element concentrations in 2008 to 2012, showed little to no connection to anthropogenic effects. With the exception of boron and iron, concentrations of inorganic constituents were less than water quality criteria recommended by the EPA and others for marine habitat (Buchanan 2008), many by orders of magnitude. Boron exceeded the chronic marine water quality criterion at all sample stations, and iron was elevated at one of four sample locations in bottom waters only. Organic constituents were similarly at low levels, and appeared to be derived from biologic, petrogenic, and anthropogenic sources.

The data provide some support for a relationship between increased concentrations of inorganic constituents and total suspended solids, but demonstrate no strong patterns with respect to depth in the water column, to geography, or to tidal elevation.

## K3.18.4 Groundwater Quality

The following baseline groundwater data tables are provided in this appendix:

- Table K3.18-17 provides a list of wells completed within and outside of the deposit area, along with watershed, screened intervals, and lithologies.
- Table K3.18-18 provides the results of groundwater quality testing summarized as a range of mean values for individual wells within each lithologic group. Results exceeding the most stringent criteria listed in Table K3.18-1 are shown in bold.

**Table K3.18-17: Groundwater Well Completions and Sample Numbers**

| Area | Target Zone | Watershed | Well Nest ID[a] | Well ID (Depth)[b,c] | Lithology[d] | Total Number of Samples Collected |
|---|---|---|---|---|---|---|
| DEPOSIT AREA | Overburden | SFK | P-08-56 | S (20) | Clay, Silty Clay | 13 |
| | | | | M (97) | Gravel, Gravelly Sand | 13 |
| | | | P-4A | S (50) | Sand, Silty Sand | 17 |
| | | | | D (90) | Sand, Silty Sand | 14 |
| | | | SRK-5 | S (18) | Sand with Gravel | 22 |
| | | | | M (51) | Sand with Gravel | 22 |
| | | | KP-P4 | D (54) | Gravel, Gravelly Sand | 16 |
| | | UT | SRK-2 | D (134) | Sand, Silty Sand | 19 |
| | Bedrock | SFK | PQ-4 | D (133) | Bedrock Contact | 17 |
| | | | SRK-3 | D (73) | Bedrock Contact | 17 |

**Table K3.18-17: Groundwater Well Completions and Sample Numbers**

| Area | Target Zone | Watershed | Well Nest ID[a] | Well ID (Depth)[b,c] | Lithology[d] | Total Number of Samples Collected |
|---|---|---|---|---|---|---|
| | | | SRK-5 | D (78) | Bedrock Contact | 8 |
| | Deep Bedrock | UT | DH-8417 | B (640-795) | Deep Bedrock | 2 |
| | | | | C (950-1,470) | Deep Bedrock | 1 |
| | | | | E (1,900-2,350) | Deep Bedrock | 1 |
| | | | | F (2,356-2,900) | Deep Bedrock | 1 |
| | | | | G (2,900-3,300) | Deep Bedrock | 1 |
| | | | | H (3,300-3,700) | Deep Bedrock | 1 |
| | | | | I (3,700-4,050) | Deep Bedrock | 3 |
| OUTSIDE DEPOSIT AREA | Overburden | NFK | MW-6D | D (91) | Gravel with Sand | 22 |
| | | | MW-8 | S (18) | Gravel with Sand | 19 |
| | | | | M (47) | Gravelly Sand | 23 |
| | | | | D (97) | Gravelly Sand | 22 |
| | | | P-08-69 | S (19) | Clay, Silty Clay | 2 |
| | | | P-08-77 | S (23) | Gravel, Gravelly Sand | 9 |
| | | | | D (89) | Gravel, Gravelly Sand | 12 |
| | | | P-08-79 | S (16) | Gravel, Gravelly Sand | 6 |
| | | | | M (69) | Sand, Silty Sand | 6 |
| | | | | D (150) | Gravel, Gravelly Sand | 5 |
| | | | P-08-81 | S (16) | Gravel, Gravelly Sand | 11 |
| | | SFK | MW-1 | S (25) | Gravel with Sand | 21 |
| | | | | M (72) | Gravel with Sand | 22 |
| | | | MW-11 | S (71) | Sandy Gravel | 19 |
| | | | | M (112) | Sandy Gravel | 21 |
| | | | | SS (25) | Gravel | 8 |
| | | | MW-12 | S (41) | Sand, Silty Sand | 29 |
| | | | MW-13 | S (30) | Gravel, Gravelly Sand | 29 |
| | | | MW-14 | S (46) | Gravel, Gravelly Sand | 16 |
| | | | MW-3 | D (194) | Gravelly Sand | 20 |
| | | | MW-5 | M (65) | Gravelly Sand | 33 |
| | | | | S (41) | Silty Sand | 32 |
| | | | MW-7 | S (30) | Gravel with Sand | 16 |
| | | | MW-9D | D (72) | Sand | 11 |
| | | | P-08-54 | S (47) | Gravel, Gravelly Sand | 8 |
| | | | P-08-61 | S (71) | Gravel, Gravelly Sand | 8 |

**Table K3.18-17: Groundwater Well Completions and Sample Numbers**

| Area | Target Zone | Watershed | Well Nest ID[a] | Well ID (Depth)[b,c] | Lithology[d] | Total Number of Samples Collected |
|---|---|---|---|---|---|---|
| | | | P-08-84 | S (32) | Sand, Silty Sand | 12 |
| | | UT | MW-2 | D (135) | Gravel with Sand | 22 |
| | | | P-05-28 | S (75) | Gravel, Gravelly Sand | 15 |
| | | | | D (160) | Gravel, Gravelly Sand | 14 |
| | | | P-05-33D | D (44) | Sand, Silty Sand | 15 |
| | | | P-05-35D | D (57) | Sand, Silty Sand | 15 |
| | | | P-06-37 | S (25) | Gravel with Sand | 24 |
| | | | P-06-40 | S (19) | Sand, Silty Sand | 6 |
| | | | P-06-41 | S (41) | Sand, Silty Sand | 11 |
| | | | P-08-75 | S (41) | Gravel, Gravelly Sand | 13 |
| | | | | M (129) | Gravel, Gravelly Sand | 13 |
| | | | P-08-88 | S (30) | Sand, Silty Sand | 7 |
| | Bedrock | NFK | MW-10 | D (40) | Bedrock Contact | 21 |
| | | | P-08-69 | D (54) | Bedrock Contact | 12 |
| | | | P-08-70 | S (19) | Bedrock Contact | 13 |
| | | | | D (54) | Bedrock Contact | 13 |
| | | | P-08-81 | D (55) | Weathered Bedrock | 11 |
| | | | P-08-72 | D ( 48) | Bedrock Contact | 12 |
| | | SFK | MW-1 | D (134) | Bedrock Contact | 22 |
| | | | MW-11 | D (135) | Bedrock Contact, Sand with Gravel | 21 |
| | | | MW-12 | D (122) | Bedrock Contact | 28 |
| | | | MW-13 | D (110) | Bedrock Contact | 29 |
| | | | MW-14 | D (101) | Bedrock Contact | 17 |
| | | | MW-5 | D (105) | Bedrock Contact | 27 |
| | | | MW-7 | D (71) | Bedrock Contact | 22 |
| | | | P-08-54 | D (114) | Bedrock Contact | 8 |
| | | | P-08-61 | D (88) | Bedrock Contact | 9 |
| | | | P-08-84 | D (74) | Bedrock Contact | 12 |
| | | UT | P-06-37 | M (90) | Bedrock Contact | 24 |
| | | | | D (200) | Bedrock Contact | 23 |
| | | | P-06-38 | M (68) | Bedrock Contact | 4 |
| | | | | D (170) | Bedrock Contact | 6 |
| | | | P-06-40 | D (145) | Bedrock Contact | 8 |

**Table K3.18-17: Groundwater Well Completions and Sample Numbers**

| Area | Target Zone | Watershed | Well Nest ID[a] | Well ID (Depth)[b,c] | Lithology[d] | Total Number of Samples Collected |
|---|---|---|---|---|---|---|
| | | | P-06-41 | M (63) | Bedrock Contact | 11 |
| | | | | D (200) | Bedrock Contact | 11 |
| | | | P-07-45 | D (60) | Bedrock Contact | 15 |
| | | | P-08-75 | D (173) | Bedrock Contact | 13 |
| | | | P-08-85 | S (32) | Bedrock Contact | 9 |
| | | | | D (137) | Bedrock Contact | 11 |
| | | | P-08-88 | D (106) | Bedrock Contact | 12 |
| | Deep Bedrock | NFK | GH 10-220 | P14 (210) | Deep Bedrock | 7 |
| | | | | P04 (510) | Deep Bedrock | 7 |
| | | | | P02 (575) | Deep Bedrock | 7 |

Notes:
[a] Nested wells refer to multiple screened wells residing within a single borehole at varying depths.
[b] Relative depth: D=deep, M=medium, S=shallow
[c] Numbers in parentheses represent depth to the bottom of the well in feet. Screen length is typically 10 feet.
[d] Bedrock contact refers to the disturbed and weathered region of bedrock which can be up to 50 feet thick. These regions have been documented under the lower slopes and valley bottoms throughout the project area (Knight Piésold 2018a).
[e] Sample locations are shown in Schlumberger 2015b and Knight Piésold 2018c.
Source: Schlumberger 2015b

**Table K3.18-18: Groundwater Data Summary – Mine Site**

| Analyte | Outside Deposit Area | | | | Deposit Area | | | | | Deposit Area Groundwater Source Terms[b] |
|---|---|---|---|---|---|---|---|---|---|---|
| | Range of Detects | | Overburden | Bedrock Contact | Range of Detects | | Overburden | Bedrock Contact | Deep Bedrock | |
| | Min[a] | Max[a] | Mean[a] | Mean[a] | Min[a] | Max[a] | Mean[a] | Mean[a] | Mean[a] | |
| **Total Metals (mg/L)** | | | | | | | | | | |
| Aluminum | 0.00031 | **74.8** | **0.44** | **2.19** | **0.00031** | **9.59** | **0.432** | 0.0751 | **0.258** | 0.0034 |
| Antimony | 1.55E-06 | **0.0199** | 0.0000606 | 0.000168 | 1.55E-06 | 0.0367 | 0.0000425 | 0.0000675 | 0.00465 | 0 |
| Arsenic | 0.0000518 | **0.101** | 0.00178 | 0.00411 | 0 | 0.0532 | 0.00211 | 0.00195 | 0.00801 | 0.0004 |
| Barium | 0.000125 | 0.847 | 0.0182 | 0.0411 | 0.00025 | 1.36 | 0.0271 | 0.0974 | 0.0985 | 0.0064 |
| Beryllium | 0.0000015 | 0.00247 | 0.000037 | 0.000109 | 0 | 0.000201 | 0.0000278 | 0.0000156 | 0.0000168 | 0.00002 |
| Bismuth | 1.55E-06 | 0.000819 | 0.0000359 | 0.0000443 | 0 | 0.00075 | 0.0000274 | 0.0000305 | 0.0000234 | 0.00002 |
| Boron | 0.00075 | 0.0832 | 0.00563 | 0.00723 | 0.00075 | 0.0707 | 0.00823 | 0.002 | 0.0252 | 0.0015 |
| Cadmium | 0.0000031 | **0.000917** | 0.0000193 | 0.0000287 | 0 | 0.00134 | 0.0000163 | 0.0000631 | 0.0000636 | 0.00002 |
| Calcium | 0.65 | 90.9 | 13.2 | 17.1 | 1.67 | 317 | 21.4 | 15.1 | 102 | 13.8 |
| Chromium | 0.000031 | 0.0717 | 0.00203 | 0.00391 | 0 | 0.0177 | 0.0022 | 0.000363 | 0.00123 | 0.0005 |
| Cobalt | 4.76E-06 | 0.0432 | 0.00045 | 0.00132 | 0 | 0.00456 | 0.000684 | 0.000877 | 0.000521 | 0.0001 |
| Copper | 0.000025 | **0.342** | **0.00267** | **0.0138** | **0.000117** | **1.18** | **0.0099** | **0.248** | **0.00732** | 0.0004 |
| Iron | 0.00133 | **87.6** | 0.713 | **2.54** | **0** | **33.9** | **4.46** | 0.226 | **2.07** | 0.02 |
| Lead | 0.000011 | **0.0485** | **0.000553** | **0.00155** | **0** | **0.0084** | 0.000318 | 0.000188 | **0.000734** | 0.0001 |
| Magnesium | 0.0881 | 41 | 4.47 | 4.81 | 0.0501 | 26.7 | 6.91 | 6.02 | 7.49 | 1.07 |
| Manganese | 0.000025 | **3.55** | **0.0709** | **0.172** | **0.000367** | **1.11** | **0.264** | 0.0472 | **0.136** | 0.441 |
| Mercury | 1.7E-07 | **0.00176** | 0.0000105 | 5.73E-06 | 0 | **0.0001** | 0.0000105 | 4.37E-06 | 2.28E-06 | 0.000001 |
| Molybdenum | 0.0000031 | **0.0242** | 0.00108 | 0.00265 | 0.0000941 | **0.0754** | 0.0017 | 0.00309 | **0.0349** | 0.000256 |
| Nickel | 0.0001 | **0.0566** | 0.00167 | 0.00306 | 0.000111 | 0.0127 | 0.00225 | 0.00113 | 0.00257 | 0.000647 |
| Potassium | 0.0709 | 8.47 | 0.759 | 1.38 | 0.171 | 11.4 | 1.23 | 0.665 | 4.09 | 0.342 |
| Selenium | 0.0000143 | 0.00404 | 0.00022 | 0.000354 | 0 | 0.0019 | 0.000184 | 0.000452 | 0.000389 | 0.00109 |
| Silver | 1.44E-06 | 0.000491 | 7.99E-06 | 0.0000178 | 0 | 0.000841 | 5.95E-06 | 0.0000161 | 0.0000866 | 0.000006 |

**Table K3.18-18: Groundwater Data Summary – Mine Site**

| Analyte | Outside Deposit Area | | | | Deposit Area | | | | | Deposit Area Groundwater Source Terms[b] |
|---|---|---|---|---|---|---|---|---|---|---|
| | Range of Detects | | Overburden | Bedrock Contact | Range of Detects | | Overburden | Bedrock Contact | Deep Bedrock | |
| | Min[a] | Max[a] | Mean[a] | Mean[a] | Min[a] | Max[a] | Mean[a] | Mean[a] | Mean[a] | |
| Thallium | 2.13E-06 | 0.000661 | 0.0000101 | 0.0000194 | 0 | 0.000445 | 7.11E-06 | 0.0000158 | 0.0000248 | 0.00001 |
| Tin | 0.0000155 | 1.06 | 0.000282 | 0.00658 | 0 | 0.00557 | 0.000133 | 0.0000955 | 0.000155 | 0.0001 |
| Vanadium | 0.0000804 | **0.143** | 0.00175 | 0.00532 | 0 | 0.0154 | 0.0016 | 0.000207 | 0.00147 | 0.00055 |
| Zinc | 0.000155 | **4.13** | 0.0287 | 0.0095 | 0.000155 | **5.36** | 0.00343 | 0.0112 | **0.12** | 0.0015 |
| **Dissolved Metals (mg/L)** | | | | | | | | | | |
| Aluminum | 0.00031 | **8.92** | 0.0271 | **0.174** | **0.00031** | **1.99** | **0.0896** | 0.0473 | - | - |
| Antimony | 1.55E-06 | 0.00197 | 0.0000309 | 0.000123 | 1.55E-06 | 0.000275 | 0.0000238 | 0.0000647 | - | - |
| Arsenic | 0.000048 | **0.053** | 0.0012 | 0.00361 | 0.00002 | **0.011** | 0.00196 | 0.00196 | - | - |
| Barium | 0.000125 | 0.151 | 0.0128 | 0.0202 | 0.000392 | 0.478 | 0.0235 | 0.1 | - | - |
| Beryllium | 0.0000015 | 0.000812 | 0.0000131 | 0.0000223 | 0.0000015 | 0.0000998 | 0.0000164 | 0.0000144 | - | - |
| Bismuth | 1.55E-06 | 0.00075 | 0.0000285 | 0.00002 | 1.55E-06 | 0.00075 | 0.0000252 | 0.0000295 | - | - |
| Boron | 0.00075 | 0.0907 | 0.00564 | 0.00702 | 0.00075 | 0.037 | 0.00821 | 0.00201 | - | - |
| Cadmium | 0.0000031 | **0.000136** | 0.0000107 | 0.0000123 | 0.0000031 | **0.000308** | 0.000013 | 0.0000649 | - | - |
| Calcium | 0.63 | 95 | 12.6 | 16 | 1.99 | 72.2 | 20.8 | 15.2 | - | - |
| Chromium | 0.000031 | 0.0188 | 0.000524 | 0.000672 | 0.000031 | 0.00295 | 0.000689 | 0.000194 | - | - |
| Cobalt | 4.76E-06 | 0.00773 | 0.0000685 | 0.00023 | 4.76E-06 | 0.00382 | 0.000448 | 0.000873 | - | - |
| Copper | 0.000025 | **0.328** | 0.0011 | **0.0102** | **0.0000645** | **1.21** | **0.00754** | **0.248** | - | - |
| Iron | 0.00133 | **6.68** | 0.0415 | 0.246 | 0.00133 | **33.9** | **4.05** | 0.214 | - | - |
| Lead | 0.000011 | **0.0127** | 0.000078 | 0.000157 | 0.000011 | **0.000912** | 0.0000702 | 0.0000457 | - | - |
| Magnesium | 0.0598 | 37 | 4.27 | 4.27 | 0.355 | 26.3 | 6.69 | 6.12 | - | - |
| Manganese | 0.0000075 | **1.31** | 0.0441 | **0.0854** | **0.000208** | **1.12** | **0.249** | 0.0484 | - | - |
| Mercury | 4.8E-07 | **0.000116** | 4.57E-06 | 2.94E-06 | 4.75E-07 | **0.0001** | 5.48E-06 | 5.87E-06 | - | - |
| Molybdenum | 0.0000031 | **0.0269** | 0.00111 | 0.00277 | 0.0000745 | **0.0104** | 0.00178 | 0.00304 | - | - |

**Table K3.18-18: Groundwater Data Summary – Mine Site**

| Analyte | Outside Deposit Area | | | | Deposit Area | | | | | Deposit Area Groundwater Source Terms[b] |
|---|---|---|---|---|---|---|---|---|---|---|
| | Range of Detects | | Overburden | Bedrock Contact | Range of Detects | | Overburden | Bedrock Contact | Deep Bedrock | |
| | Min[a] | Max[a] | Mean[a] | Mean[a] | Min[a] | Max[a] | Mean[a] | Mean[a] | Mean[a] | |
| Nickel | 0.0000755 | 0.0126 | 0.000832 | 0.00109 | 0.0001 | 0.00614 | 0.00155 | 0.00111 | - | - |
| Potassium | 0.0721 | 8.04 | 0.684 | 1.24 | 0.208 | 3.19 | 1.19 | 0.676 | - | - |
| Selenium | 0.0000143 | 0.00431 | 0.000212 | 0.000334 | 0.0000143 | 0.00136 | 0.000168 | 0.000448 | - | - |
| Silicon | 1.06 | 42.2 | 7.12 | 7.47 | 3.05 | 15 | 8.25 | 6.43 | 5.04 | 5.88 |
| Silver | 1.44E-06 | 0.000101 | 0.0000034 | 4.21E-06 | 1.44E-06 | 0.0000239 | 3.93E-06 | 0.0000042 | - | - |
| Thallium | 2.13E-06 | 0.000171 | 4.92E-06 | 0.0000077 | 2.13E-06 | 0.0000718 | 5.36E-06 | 0.0000161 | - | - |
| Tin | 0.0000155 | 0.0814 | 0.0000948 | 0.00123 | 0.0000155 | 0.00122 | 0.0000623 | 0.000052 | - | - |
| Vanadium | 0.0000135 | 0.0287 | 0.00062 | 0.00133 | 0.0000047 | 0.00477 | 0.000849 | 0.000182 | - | - |
| Zinc | 0.000155 | **0.303** | 0.0053 | 0.00227 | 0.000155 | **0.0433** | 0.00229 | 0.0113 | - | - |
| **Anions (mg/L, except where noted)** | | | | | | | | | | |
| Chloride | 0.213 | 32.9 | 0.769 | 1.74 | 0.502 | 37.3 | 0.862 | 0.552 | 11.8 | 0.804 |
| Fluoride | 0.0155 | 0.705 | 0.0741 | 0.101 | 0 | 2.3 | 0.105 | 0.0543 | 0.698 | 0.072 |
| Cyanide (Total) | 0.00075 | 0.0067 | 0.00104 | 0.00105 | 0 | 0.05 | 0.000993 | 0.000855 | 0.00616 | - |
| Cyanide (WAD) | 0.00075 | **0.006** | 0.00102 | 0.00104 | 0 | **0.01** | 0.00104 | 0.000785 | 0.00151 | - |
| Thiocyanate | 0.0295 | 5.2 | 0.195 | 0.274 | 0 | 1.3 | 0.203 | 0.156 | 0.0676 | - |
| Nitrate/ Nitrite | 0.0031 | **196** | 0.156 | 0.595 | 0 | 6.53 | 0.262 | 0.0774 | 0.0473 | - |
| Nitrite | 0.0155 | 0.0885 | 0.0178 | 0.0203 | 0.0155 | 0.05 | 0.0155 | 0.0145 | - | - |
| Nitrate | 0.0155 | 0.568 | 0.112 | 0.0913 | 0.0155 | 0.697 | 0.228 | 0.0301 | - | - |
| Total Phosphorus | 0.0011 | 5.27 | 0.0617 | 0.144 | 0 | 1.73 | 0.125 | 0.0617 | 0.0271 | - |
| Orthophosphate | 0.0155 | 0.37 | 0.0382 | 0.081 | 0.0155 | 0.17 | 0.0328 | 0.0697 | - | - |
| Sulfate | 0.371 | 216 | 10.5 | 16.1 | 0.058 | **1,330** | 48.4 | 12.7 | **428** | 4.9 |

**Table K3.18-18: Groundwater Data Summary – Mine Site**

| Analyte | Outside Deposit Area | | | | Deposit Area | | | | | Deposit Area Groundwater Source Terms[b] |
|---|---|---|---|---|---|---|---|---|---|---|
| | Range of Detects | | Overburden | Bedrock Contact | Range of Detects | | Overburden | Bedrock Contact | Deep Bedrock | |
| | Min[a] | Max[a] | Mean[a] | Mean[a] | Min[a] | Max[a] | Mean[a] | Mean[a] | Mean[a] | |
| **Cations (mg/L, except where noted)** | | | | | | | | | | |
| Ammonia | 0.0155 | **5.69** | 0.0288 | 0.0965 | 0 | **5.38** | 0.0869 | 0.0244 | 1.56 | - |
| Sodium (dissolved) | 1,030 | 133,000 | 8,410 | 17,600 | 31 | 48,300 | 12,400 | 3,390 | - | - |
| Sodium | 986 | 139,000 | 8,500 | 17,800 | 0.752 | 49,400 | 12,900 | 3,350 | 154 | 2.47 |
| **Miscellaneous Parameters (mg/L, except where noted)** | | | | | | | | | | |
| Acidity | 0.785 | 150 | 5.62 | 5.78 | 0 | 77.3 | 10.1 | 8.43 | 2.93 | 7.5 |
| Alkalinity | **1.55** | 479 | 59.1 | 79.9 | **1.55** | 236 | 66.1 | 59.3 | 68.3 | 33 |
| Hardness | 2 | 368 | 51.3 | 62.4 | 5.66 | 882 | 82 | 62.1 | 297 | - |
| Field pH (pH Units) | **2.84** | **12** | 6.74 | 7.33 | **3.98** | **11.5** | 6.82 | **4.44** | 7.87 | 6.7 |
| Field Specific Conductivity (µmhos/cm) | 7 | 1,500 | 131 | 209 | 15 | 3020 | 224 | 125 | 1,070 | - |
| Lab Conductivity (µmhos/cm) | 10.9 | 1,100 | 136 | 205 | 23 | 900 | 226 | 149 | - | - |
| Field Oxidation Reduction Potential (mV) | -369 | 423 | 118 | 66.5 | -399 | 350 | 78.2 | 93.5 | - | - |
| Total Dissolved Solids | 1.55 | **593** | 87.3 | 122 | 1.55 | **2,370** | 151 | 86.2 | **835** | - |
| Total Suspended Solids | 0.072 | **5,750** | **34.4** | **105** | 0 | **281** | **21.4** | 0.633 | **27.8** | - |
| Field Water Temperature | 0.12 | 92 | 3.59 | 3.63 | 0.66 | 8.04 | 3.28 | 2.02 | - | - |

**Table K3.18-18: Groundwater Data Summary – Mine Site**

| Analyte | Outside Deposit Area | | | | Deposit Area | | | | | Deposit Area Groundwater Source Terms[b] |
|---|---|---|---|---|---|---|---|---|---|---|
| | Range of Detects | | Overburden | Bedrock Contact | Range of Detects | | Overburden | Bedrock Contact | Deep Bedrock | |
| | Min[a] | Max[a] | Mean[a] | Mean[a] | Min[a] | Max[a] | Mean[a] | Mean[a] | Mean[a] | |
| (°C) | | | | | | | | | | |
| Field Dissolved Oxygen | **-0.37** | 73.6 | 9.1 | 4.88 | **-0.02** | 15.9 | 5.36 | 2.61 | - | - |
| Dissolved Organic Carbon | 0.075 | 51 | 0.861 | 1.3 | 0.075 | 64.4 | 1.71 | 0.28 | 13.2 | - |

Notes:
[a] Bold values indicate fields that exceed the most stringent water quality criteria.
[b] Groundwater from deposit area used as source terms for WTP design, provided for comparison purposes; based on the median of 103 measured concentrations for samples collected from pit area wells KPP4, MW12D, MW12S, P4S, SRK2, SRK 5D, SRK5M, and SRK5S between 2005 and 2007 (SRK 2018a)
mV = millivolts
µmhos/cm = micromhos per centimeter
WAD: Weak Acid Dissociable
Source: Schlumberger 2015b; Knight Piésold 2018c

## K3.18.5 Sediment Quality

The following baseline sediment data tables are provided in this appendix:

- Table K3.18-19 provides a summary of the sediment quality data collected at the mine site.
- Table K3.18-20 provides a summary of the sediment quality data collected in Iliamna Lake as a range of mean values for sampling stations in the following areas: Iliamna village area, and Pedro and Pile bays at the east end of the lake (Alternative 2 and Alternative 3).

**Table K3.18-19: Sediment Data Summary – Mine Site**

| Analyte[a] | Number of Samples | Range of Detects (mg/kg) (Min - Max)[b] | Mean (mg/kg)[b] |
|---|---|---|---|
| **Trace Elements** | | | |
| Aluminum | 197 | 1,820 – 25,200 | 11,218 |
| Antimony | 197 | 0.03 - 2.30 | 0.23 |
| Arsenic | 197 | 1.23 - **270** | **14.2** |
| Barium | 197 | 12.3 - 239 | 74.7 |
| Beryllium | 197 | 0.079 - 0.97 | 0.35 |
| Bismuth | 197 | 0.063 - 3.10 | 1.11 |
| Boron | 196 | 0.59 - 11.5 | 6.78 |
| Cadmium | 197 | 0.068 - 2.60 | 0.26 |
| Calcium | 197 | 583 – 23,400 | 3,773 |
| Chromium | 197 | 0.43 - 105 | 15.4 |
| Cobalt | 197 | 0.51 - 49.1 | 7.86 |
| Copper | 197 | 1.3 - **200** | 27.3 |
| Iron | 197 | 2,670 – 83,400 | 21,617 |
| Lead | 197 | 1.46 - **40.3** | 6.90 |
| Magnesium | 197 | 410 - 7970 | 3,586 |
| Manganese | 197 | 28.7 - 6970 | 623 |
| Mercury | 197 | 0.011 - **0.42** | 0.040 |
| Molybdenum | 197 | 0.28 - 22.0 | 2.02 |
| Nickel | 197 | 0.64 - **46.9** | 8.95 |
| Potassium | 197 | 75 - 1770 | 545 |
| Selenium | 197 | 0.018 - 13.1 | 1.15 |
| Silver | 197 | 0.0341 - 2.54 | 0.12 |
| Thallium | 197 | 0.0079 - 0.45 | 0.11 |
| Tin | 197 | 0.16 - 46.2 | 1.21 |
| Vanadium | 197 | 2.2 - 143 | 44.9 |
| Zinc | 197 | 9.9 - **313** | 61.8 |
| **Anions and Cations** | | | |
| Ammonia (as Nitrogen) | 196 | 3.9 - 1730 | 235 |
| Chloride | 184 | 0.327 - 223 | 5.31 |
| Cyanide (Total) | 194 | 0.03 - 2.10 | 0.39 |

**Table K3.18-19: Sediment Data Summary – Mine Site**

| Analyte[a] | Number of Samples | Range of Detects (mg/kg) (Min - Max)[b] | Mean (mg/kg)[b] |
|---|---|---|---|
| Cyanide (WAD) | 12 | 0.13 - 0.96 | 0.54 |
| Fluoride | 183 | 0.11 - 118 | 2.24 |
| Sodium | 197 | 18 - 630 | 194 |
| Sulfate | 184 | 0.499 – 2,600 | 51.8 |

Notes:
[a] All data is presented on a dry weight basis.
[b] Bold values indicate fields that exceed the most stringent sediment quality criteria.
mg/kg = milligrams per kilogram
WAD = Weak Acid Dissociable
Source: SLR et al. 2011a

**Table K3.18-20: Sediment Data Summary – Iliamna Lake, Transportation Corridor**

| Analyte[a] Unit: mg/kg | Iliamna Village | | Pedro Bay | | Pile Bay | |
|---|---|---|---|---|---|---|
| | Range of Detects Min[b,c] - Max[b,c] | Mean[b,d] | Range of Detects Min[b,c] - Max[b,c] | Mean[b,d] | Range of Detects Min[b,c] - Max[b,c] | Mean[b,d] |
| **Trace Elements** | | | | | | |
| Aluminum | 4,800 - 12,600 | 8,020 | 3,380 - 11,200 | 5940 | 8,360 - 10,700 | 9,530 |
| Antimony | 0.0225 - 0.188 | 0.0908 | 0.0228 - 0.127 | 0.0812 | 0.0929 - 0.107 | 0.1 |
| Arsenic | 4.47 - 7.28 | 5.67 | 0.706 - **7.71** | 2.99 | 4.22 - 5.48 | 4.85 |
| Barium | 64.3 - 138 | 94.9 | 19 - 59.7 | 35.1 | 97.8 - 123 | 110 |
| Beryllium | 0.12 - 0.417 | 0.211 | 0.0905 - 0.262 | 0.151 | 0.0648 - 0.111 | 0.0879 |
| Bismuth | 0.0302 - 0.154 | 0.0856 | 0.03 - 0.253 | 0.114 | 0.116 - 0.156 | 0.136 |
| Boron | 1.14 - 6.33 | 3.09 | 1.07 - 6.19 | 3.27 | 1.54 - 3.23 | 2.38 |
| Cadmium | 0.0449 - **22.3** | **2.94** | 0.0653 - 0.253 | 0.148 | 0.157 - 0.158 | 0.158 |
| Calcium | 2,670 - 5,600 | 3,930 | 1,940 - 5,000 | 3,100 | 3,630 - 4,670 | 4,150 |
| Chromium | 4.35 - 10.5 | 6.53 | 1.23 - 6.34 | 2.61 | 7.21 - 9.23 | 8.22 |
| Cobalt | 1.86 - 4.58 | 3.41 | 0.51 - 2.68 | 1.74 | 4.76 - 6.66 | 5.71 |
| Copper | 4.61 - 23.6 | 13.5 | 6.67 - 16.1 | 11.6 | 56.9 - 90.6 | **73.8** |
| Iron | 8,290 - 15,400 | 10,900 | 1,850 - 26,400 | 10,100 | 17,000 - 24,100 | 20,600 |
| Lead | 2.09 - **79.1** | 13.2 | 1.29 - 7.76 | 3.36 | 5.75 - 6.01 | 5.88 |
| Magnesium | 1,730 - 4,080 | 2,800 | 483 - 2,400 | 1,070 | 3,860 - 4,510 | 4,190 |
| Manganese | 150 - 292 | 227 | 38.6 - 279 | 137 | 307 - 591 | 449 |
| Mercury | 0.00595 - 0.0637 | 0.0234 | 0.00595 - 0.0492 | 0.0258 | 0.0118 - 0.0191 | 0.0155 |
| Molybdenum | 0.225 - 5.02 | 2.56 | 0.228 - 8.47 | 3.58 | 2.23 - 2.93 | 2.58 |
| Nickel | 2.3 - 6.43 | 4.62 | 1.55 - 5.91 | 2.85 | 4.02 - 6.07 | 5.05 |
| Potassium | 486 - 1,590 | 768 | 106 - 572 | 338 | 1,150 - 1,580 | 1,370 |
| Selenium | 0.13 - 6.64 | 2.12 | 0.0725 - 12.5 | 3.39 | 0.145 - 0.63 | 0.388 |

**Table K3.18-20: Sediment Data Summary – Iliamna Lake, Transportation Corridor**

| Analyte[a] Unit: mg/kg | Iliamna Village | | Pedro Bay | | Pile Bay | |
|---|---|---|---|---|---|---|
| | Range of Detects | Mean[b,d] | Range of Detects | Mean[b,d] | Range of Detects | Mean[b,d] |
| | Min[b,c] - Max[b,c] | | Min[b,c] - Max[b,c] | | Min[b,c] - Max[b,c] | |
| Silver | 0.0151 - 0.077 | 0.0428 | 0.015 - 0.127 | 0.0569 | 0.0154 - 0.0807 | 0.048 |
| Thallium | 0.00535 - 0.0773 | 0.0334 | 0.00455 - 0.0815 | 0.0367 | 0.0282 - 0.0606 | 0.0444 |
| Tin | 0.487 - 6.78 | 1.56 | 0.484 - 3.42 | 1.19 | 0.496 - 0.965 | 0.73 |
| Vanadium | 20.2 - 40.8 | 30.4 | 3.21 - 42.3 | 19.9 | 37.8 - 48.8 | 43.3 |
| Zinc | 23.2 - 88.2 | 42 | 12.6 - 43.7 | 27.4 | 45.2 - 58.3 | 51.8 |
| **Anions and Cations** | | | | | | |
| Ammonia (as Nitrogen) | 37.2 - 512 | 222 | 58.6 - 570 | 345 | 40.3 - 86.7 | 63.5 |
| Chloride | 7.32 - 97.6 | 47.3 | 2.37 - 18.5 | 11.9 | 1.53 - 3.11 | 2.32 |
| Cyanide (Total) | 0.016 - 0.4 | 0.144 | 0.014 - 0.43 | 0.128 | 0.0135 - 0.058 | 0.0358 |
| Fluoride | 0.643 - 13 | 3.29 | 0.76 - 53.7 | 12.4 | 0.98 - 3.99 | 2.49 |
| Sodium | 277 - 971 | 477 | 154 - 636 | 416 | 428 - 591 | 510 |
| Sulfate | 3.31 - 146 | 43 | 2.66 - 426 | 144 | 19.7 - 88.8 | 54.3 |
| **Miscellaneous** | | | | | | |
| Total Solids (%, Wet) | 19.2 - 66.8 | 38.7 | 12.1 - 65.6 | 26.8 | 50.8 - 55.6 | 53.2 |
| Total Organic Carbon (%) | 0.621 - 10.8 | 4.72 | 0.684 - 13.9 | 6.28 | 0.945 - 1.08 | 1.01 |

Notes:
[a] Data presented on dry weight basis unless otherwise noted.
[b] Bold values indicate fields that exceed the most stringent sediment quality criteria.
[c] Range of detects includes minimum and maximum measurements from multiple sample locations in the area (4 locations for Iliamna Village Area, 3 sample locations for Pedro Bay Area, and 1 sample location for Pile Bay)
[d] Mean values for each area represent the average of mean values at each sample location within the respective area.
mg/kg = milligrams per kilogram
Source: HDR 2011a

# K3.26 VEGETATION

The following tables show the relationship of field-verified vegetation types and Alaska Center for Conservation Science (ACCS) land cover types to the vegetation types applied in Section 3.26 and Section 4.26, Vegetation.

Table K3.26-1 lists details on the 48 field-verified vegetation types (3PPI and HDR 2011). Table K 3.26-2 lists details on the 101 detailed land cover types from ACCS (Boggs et al. 2016).

The tables include definitions of each type, and identifies whether the type occurs predominantly in wetlands or uplands.

**Table K3.26-1: Relationship of Section 3.26 and Section 4.26 Vegetation Type to Field-Verified Vegetation Type**

| Vegetation Type | Field-Verified Vegetation Type | Abbreviation | Definition[1] | Predominantly Occurs in Wetlands or Uplands |
|---|---|---|---|---|
| **Forest (≥10% cover of trees over 10 feet in height)** | | | | |
| Open Closed Forest | Closed White Spruce Forest | CWSF | Closed forest dominated by white spruce trees where the canopy cover is ≥ 60%. | Upland |
| | Open White Spruce Forest | OWSF | Open forest dominated by white spruce where the canopy cover ranges from 25 to 59%. | Upland |
| | White Spruce Woodland | WSW | Woodlands dominated by white spruce.<br>Sparse stands of white spruce trees that have a total tree cover of 10 to 24%.<br>Most of the white spruce trees are taller than 10 feet. The openings between the trees may be dominated by mosses and lichens, herbs, and/or shrubs. | Upland |
| | Black Spruce Woodland | BSW | Woodlands dominated by black spruce. The openings between the trees may be dominated by mosses and lichens, herbs, and/or shrubs.<br>Sparse stands of black spruce trees that have a total tree cover of 10 to 24%.<br>Most of the black spruce are taller than 10 feet. | Wetland |
| | Closed Broadleaf Forest | CBF | Forests dominated by broadleaf tree species where tree canopy coverage is ≥ 60%. More than 75% of the total tree cover consists of | Upland |

**Table K3.26-1: Relationship of Section 3.26 and Section 4.26 Vegetation Type to Field-Verified Vegetation Type**

| Vegetation Type | Field-Verified Vegetation Type | Abbreviation | Definition[1] | Predominantly Occurs in Wetlands or Uplands |
|---|---|---|---|---|
| | | | broadleaf species. | |
| | Open Broadleaf Forest | OBF | Forests dominated by broadleaf tree species where tree canopy coverage ranges from 25 to 59%. Over 75% of the total tree cover consists of broadleaf species. | Upland |
| | Broadleaf Woodland | BW | Sparse stands of broadleaf trees that have a total tree cover of 10 to 24%. | Wetland/Upland |
| | Closed Mixed Forest | CMF | Forests dominated by a mix of broadleaf and needleleaf trees where tree canopy coverage is ≥ 60%. Both tree types must contribute 25 to 75% of the total canopy cover. | Upland |
| | Open Mixed Forest | OMF | Forests dominated by a mix of broadleaf and needleleaf trees where tree canopy coverage ranges from 25 to 59%. Both tree types must contribute 25 to 75% of the total canopy cover. | Upland |
| Open Closed Forest | Mixed Forest Woodland | MFW | Sparse trees stands consisting of a mix of black and/or white spruce and broadleaf trees that have a total tree cover of 10 to 24%. Most of the trees are taller than 10 feet. Both tree types must contribute at least 25% of the total canopy cover. | Upland |
| | Dwarf White Spruce Scrub | DWSS | Black spruce stands where the trees are less than 10 feet | Upland |

**Table K3.26-1: Relationship of Section 3.26 and Section 4.26 Vegetation Type to Field-Verified Vegetation Type**

| Vegetation Type | Field-Verified Vegetation Type | Abbreviation | Definition[1] | Predominantly Occurs in Wetlands or Uplands |
|---|---|---|---|---|
| | | | tall. This vegetation type includes woodland cover (10 to 24%) and open cover (25 to 59%). If trees 10 feet or taller cover at least 10% of the area, the scrub class does not apply. | |
| **Scrub (<10% cover of trees over 10 feet in height, >25% shrub cover)** | | | | |
| Open Closed Tall Shrub | Closed Willow Tall Shrub | CWTS | Thickets of tall willows. These communities have a cover of willow species ≥ 75%. Trees provide less than 10% cover. The height of the willow is ≥ 5 feet. In some sites, shrub birch may be mixed with the willow. | Upland |
| | Closed Alder Tall Shrub | CATS | Dense stands of tall alder where the canopy cover is ≥ 75% and the shrub height is ≥ 5 feet. Trees provide less than 10% cover. | Upland |
| | Closed Alder-Willow Tall Shrub | CAWTS | Mixed species thickets of tall alders and willows. Dense shrub stands consisting of a mix of alder and willow where the canopy cover is ≥ 75% and the shrub height is ≥ 5 feet. Both shrub types must contribute 25 to 75% of the total shrub canopy cover. Trees provide less than 10% cover. | Wetland/Upland |
| Open Closed Tall Shrub | Open Alder Tall Shrub | OATS | Open stands of tall alder. These communities have a shrub canopy cover of 25 to 74% that consists primarily of | Upland |

**Table K3.26-1: Relationship of Section 3.26 and Section 4.26 Vegetation Type to Field-Verified Vegetation Type**

| Vegetation Type | Field-Verified Vegetation Type | Abbreviation | Definition[1] | Predominantly Occurs in Wetlands or Uplands |
|---|---|---|---|---|
| | | | alder species. Trees provide < 10% cover. The height of the alder is ≥ 5 feet. | |
| | Open Alder-Willow Tall Shrub | OAWTS | Tall, open shrub stands co-dominated by alder and willow. Shrub stands consisting of a mix of alder and willow where the canopy cover is ≥ 25% and < 75%. The shrub height is > 5 feet. Both shrub types must contribute 25 to 75% of the total shrub canopy cover. Trees provide less than 10% cover. | Upland |
| | Open Willow Tall Shrub | OWTS | Open stands of tall willow. These communities have a shrub canopy cover of 25 to 74% that consists primarily of willow species. In some sites, shrub birch may be mixed with the willow. Trees provide < 10% cover. The height of the willow is ≥ 5 feet. | Upland |
| Open Closed Low Shrub | Closed Willow Low Shrub | CWLS | Thickets of low willow. These communities have a cover of willow species ≥ 75%. Trees provide less than 10% cover. The height of the willow is ≥ 8 inches and < 5 feet. Shrubs ≥ 5 feet are absent or provide less than 25% cover. In some sites, shrub birch may be mixed with the willow. | Wetland |
| | Closed Alder-Willow Low Shrub | CAWLS | Mixed-species thickets of low alder and willows. Dense shrub stands consisting of a | Wetland/Upland |

**Table K3.26-1: Relationship of Section 3.26 and Section 4.26 Vegetation Type to Field-Verified Vegetation Type**

| Vegetation Type | Field-Verified Vegetation Type | Abbreviation | Definition[1] | Predominantly Occurs in Wetlands or Uplands |
|---|---|---|---|---|
| | | | mix of alder and willow where the canopy cover is ≥ 75% and the shrub height is < 5 feet. Both shrub types must contribute 25 to 75% of the total shrub canopy cover. Trees provide less than 10% cover. | |
| | Closed Alder Low Shrub | CALS | Thickets of low alder. Dense stands of alder where the canopy cover is ≥ 75% and the shrub height is < 5 feet. Trees provide less than 10% cover. | Upland |
| Open Closed Low Shrub | Open Sweetgale-Graminoid Bog | OSGB | Bogs and fens dominated by sweetgale. These communities have 25 to 74% cover of shrubs ≥ 8 inches and < 5 feet. The shrubs are primarily *Myrica gale*. Tree canopy cover is < 10%. Graminoids have at least 25% cover. These communities occur on peat that is usually at least 8 inches thick. | Wetland |
| | Open Mixed Shrub-Sedge Tussock | OMSST | Tussock tundra co-dominated by low shrubs and tussock-forming graminoids. These communities have 25 to 74% cover of low shrubs (≥ 8 inches and < 5 feet tall) mixed with tussock-forming sedges, usually *Eriophorum vaginatum*, but sometimes *Carex bigelowii*. The tussock species have ≥ 25% cover. Trees are absent or very | Wetland |

**Table K3.26-1: Relationship of Section 3.26 and Section 4.26 Vegetation Type to Field-Verified Vegetation Type**

| Vegetation Type | Field-Verified Vegetation Type | Abbreviation | Definition[1] | Predominantly Occurs in Wetlands or Uplands |
|---|---|---|---|---|
| | | | scarce. | |
| | Open Dwarf Birch-Ericaceous Shrub Bog | ODBESB | Bogs with abundant mosses, ericaceous shrubs, and dwarf birch. These communities have 25 to 74% cover of shrubs at least 8 inches tall. Tree cover is < 10% and tall shrubs (≥ 5 feet) provide less than 25% cover. Common dominants include *Betula glandulosa*, *B. nana*, *Vaccinium uliginosum*, *V. vitis-idaea*, *Ledum decumbens*, *Empetrum nigrum*, and *Andromeda polifolia*. The combined cover of *Betula glandulosa* and *B. nana* is ≥ 10%. These communities occur on peat that is at least 8 inches thick. Sphagnum spp. are abundant at most sites, but occasionally may be absent. | Wetland |
| | Ericaceous Shrub Bog | ESB | Bogs with abundance mosses and ericaceous shrubs, but only sparse dwarf birch. These communities are dominated by ericaceous shrubs such as *Empetrum nigrum*, *Vaccinium uliginosum*, *V. vitis-idaea*, *V. oxycoccos*, *Andromeda polifolia*, and *Ledum decumbens*. The shrubs have a cumulative cover ≥ 25%, and range in height from 8 inches to < 5 feet. Ericaceous shrub bogs occur on organic | Wetland |

**Table K3.26-1: Relationship of Section 3.26 and Section 4.26 Vegetation Type to Field-Verified Vegetation Type**

| Vegetation Type | Field-Verified Vegetation Type | Abbreviation | Definition[1] | Predominantly Occurs in Wetlands or Uplands |
|---|---|---|---|---|
| | | | soil (thickness of peat ≥ 16 inches). Sphagnum spp. are always present and usually dominate the moss layer. Other mosses, such as feather mosses, also may be common. | |
| | Low Ericaceous Shrub Tundra | LEST | Treeless areas dominated by low ericaceous shrubs, including *Empetrum nigrum*, *Vaccinium uliginosum*, *V. vitis-idaea*, *V. oxycoccos*, *Andromeda polifolia*, *Ledum decumbens*, and *L. groenlandicum*. The sites have mineral soils (thickness of surface organic horizons < 16 inches). The shrubs have a cumulative cover ≥ 25%, and range in height from 8 inches to < 5 feet. | Upland |
| | Open Dwarf Birch Scrub | ODBS | Open shrub stands dominated by *Betula nana* and *B. glandulosa* that have a shrub cover ≥ 25% and < 75%. While most of these areas consist of low shrubs (≥ 8 inches and < 5 feet), the vegetation type should also be used for the occasional stand of tall (≥ 5 feet) *B. glandulosa*. | Wetland/Upland |
| | Shrub Birch-Willow | SBW | Open or dense low shrub (≥ 8 inches and < 5 feet tall) stands dominated by shrub birch and willow species. These low shrubs have 25 to | Upland |

**Table K3.26-1: Relationship of Section 3.26 and Section 4.26 Vegetation Type to Field-Verified Vegetation Type**

| Vegetation Type | Field-Verified Vegetation Type | Abbreviation | Definition[1] | Predominantly Occurs in Wetlands or Uplands |
|---|---|---|---|---|
| | | | 74% cover. Both shrub types must contribute at least 25% of the total shrub canopy cover. | |
| | Open Willow Low Shrub | OWLS | Open stands of low shrub stands dominated by low willow (≥ 8 inches and < 5 feet tall) that have 25 to 74% cover. Shrubs 5 feet or taller provide < 25% cover and trees overtopping the shrubs provide < 10% cover. These communities usually occur on a mineral soil and are drier than Open Willow Low Shrub Fen communities. | Wetland |
| | Open Willow Low Shrub Fen | OWLSF | Fens characterized by open stands of shrubs dominated by low willow (≥ 8 inches and < 5 feet tall) that have 25 to 74% cover. These communities usually occur on peat that is at least 8 inches thick, and the sites are wetter than Open Willow Low Shrub areas. Most OWLSF areas are classified as Slope wetlands and have wetland hydrology that is maintained by groundwater. | Wetland |
| | Open Alder-Willow Low Shrub | OAWLS | Low, open shrub stands consisting of a mix of alder and willow where the canopy cover is ≥ 25% and < 75%. The shrub height is < 5 feet. Both shrub types must contribute 25 to 75% of the | Wetland |

**Table K3.26-1: Relationship of Section 3.26 and Section 4.26 Vegetation Type to Field-Verified Vegetation Type**

| Vegetation Type | Field-Verified Vegetation Type | Abbreviation | Definition[1] | Predominantly Occurs in Wetlands or Uplands |
|---|---|---|---|---|
| | | | total shrub canopy cover. Trees provide less than 10% cover. | |
| | Open Alder Low Shrub | OALS | Open stands of low alder with a shrub canopy cover of 25 to 74% that consists primarily of alder species. Trees provide < 10% cover. The height of the alder is ≥ 8 inches and < 5 feet. Shrubs ≥ 5 feet are absent or provide less than 25% cover. | Upland |
| Dwarf Shrub | Dwarf Ericaceous Shrub Tundra | DEST | Treeless areas dominated by shrubs < 8 inches in height. The shrubs are primarily ericaceous species, including *Arctostaphylos* spp., *Vaccinium* spp., *Empetrum nigrum*, *Phyllodoce aleutica*, and *Cassiope* spp. Lichens are often common but cover < 60% of the site. If lichen cover is ≥ 60%, the DEST vegetation type should be used. | Upland |
| | Dwarf Ericaceous Shrub Tundra - Hummocks | DEST-H | Dwarf ericaceous shrublands growing on moderate to large hummocks (> 6 inches tall). Treeless areas dominated by shrubs < 8 inches in height. The shrubs are primarily ericaceous species, including *Arctostaphylos* spp., *Vaccinium* spp., *Empetrum nigrum*, *Phyllodoce aleutica*, and *Cassiope* spp. The ground surface consists | Upland |

**Table K3.26-1: Relationship of Section 3.26 and Section 4.26 Vegetation Type to Field-Verified Vegetation Type**

| Vegetation Type | Field-Verified Vegetation Type | Abbreviation | Definition[1] | Predominantly Occurs in Wetlands or Uplands |
|---|---|---|---|---|
| | | | mostly of moderate hummocks (5.9 to 17.7 inches) and large hummocks (> 17.7 inches). | |
| | Dwarf Ericaceous Shrub Tundra - Equisetum | DEST-EQ | Dwarf ericaceous shrublands with abundant horsetails (>25% coverage). Treeless areas dominated by shrubs <8 inches in height. The shrubs are primarily ericaceous species, including *Arctostaphylos* spp., *Vaccinium* spp., *Empetrum nigrum*, *Phyllodoce aleutica*, and *Cassiope* spp. Equisetum spp. covers at least 25% of the area. | Upland |
| | Dwarf Ericaceous Shrub Tundra - Carex | DEST-C | Dwarf ericaceous shrublands with abundant sedges (>25% coverage). Treeless areas dominated by shrubs < 8 inches in height. The shrubs are primarily ericaceous species, including *Arctostaphylos* spp., *Vaccinium* spp., *Empetrum nigrum*, *Phyllodoce aleutica*, and *Cassiope* spp. Carex spp. covers at least 25% of the area. | Upland |
| | Dwarf Ericaceous Shrub-Lichen Tundra | DESLT | Dwarf ericaceous shrublands on lichen dominated (>60% coverage) ground. Treeless areas dominated by shrubs < 8 inches in height. The shrubs are primarily ericaceous species, including | Upland |

**Table K3.26-1: Relationship of Section 3.26 and Section 4.26 Vegetation Type to Field-Verified Vegetation Type**

| Vegetation Type | Field-Verified Vegetation Type | Abbreviation | Definition[1] | Predominantly Occurs in Wetlands or Uplands |
|---|---|---|---|---|
| | | | *Arctostaphylos* spp., *Vaccinium* spp., *Empetrum nigrum*, *Phyllodoce aleutica*, and *Cassiope* spp. Lichens cover at least 60% of the area. | |
| **Herbaceous (<10% of tree cover and <25% of shrub cover)** | | | | |
| Dry to Moist Herbaceous | Halophytic Dry Graminoids | HDG | These herbaceous communities are dominated by species of the genus Leymus. They are characteristic of coastal sand dunes and the upper parts of coastal flats and beaches. Many communities grade seaward into halophytic herb communities. While the dune communities are usually no-wetlands, some *Leymus* communities on the upper portions of coastal flats are wetland. | Upland |
| | Bluejoint Tall Grass | BTG | Abundant bluejoint reedgrass; other herbs and grasses may be present but are not co-dominant. Bluejoint tall grass communities are dominated by bluejoint. Other grasses and herbs may be present but are not co-dominant. The canopy is usually about 2.5 to 5 feet tall. Woody plants are absent or scarce, although in some sites low or trailing shrubs may occur as a low layer below the tall bluejoint grass stratum. | Upland |

**Table K3.26-1: Relationship of Section 3.26 and Section 4.26 Vegetation Type to Field-Verified Vegetation Type**

| Vegetation Type | Field-Verified Vegetation Type | Abbreviation | Definition[1] | Predominantly Occurs in Wetlands or Uplands |
|---|---|---|---|---|
| | Bluejoint-Herb | BH | Abundant bluejoint reedgrass interspersed with other low-growing species. Bluejoint herb communities are dominated by bluejoint and various herbs. Sedges and other grasses may be present in significant amounts. The canopy is usually about 2.5 to 5 feet tall. Woody plants are absent, scattered, or may occur as a low layer below the tall bluejoint herb stratum. | Upland |
| | Mesic Herbs | MH | Herb-dominated communities that occur on mesic sites and do not satisfy the requirements of other project vegetation types. These communities are dominated by herbs. This type is also used for drier alpine herb communities, which include a wide variety of species. | Upland |

**Table K3.26-1: Relationship of Section 3.26 and Section 4.26 Vegetation Type to Field-Verified Vegetation Type**

| Vegetation Type | Field-Verified Vegetation Type | Abbreviation | Definition[1] | Predominantly Occurs in Wetlands or Uplands |
|---|---|---|---|---|
| Wet Herbaceous | Subarctic Sedge-Moss Wet Meadow | SSMWM | This vegetation type is used as a lumped mapping type that includes numerous wet graminoid herbaceous communities. The lumped mapping class is used because of the difficulty in separating the specific Viereck types on aerial photography. These types include Sub-arctic Lowland Sedge-Moss Bog Meadow, Subarctic Lowland Sedge Bog Meadow, Subarctic Lowland Sedge Wet Meadow, Wet Sedge-Herb Meadow Tundra, and Sub-arctic Lowland Herb Bog Meadow. In general, the SSMWM type represents communities dominated or co-dominated by graminoids that occupy wet sites. Forbs may be co-dominant in some areas, and shrubs may be present, but provide < 25% cover. In some sites, low trailing shrubs may form a layer below the herbaceous layer. Dense moss is abundant on many of the sites. Soils are saturated or may have shallow surface water. Most sites have peat ≥8 inches in depth. | Wetland |
| | Fresh Sedge Marsh | FSM | Dominated by members of the sedge family (e.g., sedges, cottongrass) rooted in standing water, and often | Wetland |

**Table K3.26-1: Relationship of Section 3.26 and Section 4.26 Vegetation Type to Field-Verified Vegetation Type**

| Vegetation Type | Field-Verified Vegetation Type | Abbreviation | Definition[1] | Predominantly Occurs in Wetlands or Uplands |
|---|---|---|---|---|
| | | | near open water. This vegetation type is dominated by sedges, bulrush, spikerush, and/or rushes. The vegetation occurs in deep water (≥ 6 inches). Standing water persists throughout the growing season in most years. Trees, shrubs, and lichens are absent; aquatic mosses may be present, but are not abundant. The community is often found at the edge of ponds, lakes, and sluggish streams. | |
| | Fresh Herb Marsh | FHM | Dominated by emergent in persistent standing water | Wetland |
| | Aquatic Herbaceous | AH | These are herbaceous communities dominated by plants with leaves that float on the water surface or grow primarily below the surface of the water. In general, standing or flowing water persists throughout the growing season (permanently flooded). | Wetland |
| **Other** | | | | |
| Other | Partially Vegetated | PV | This type is used for areas that have sparse vegetation cover (≥ 10% and < 25%). It is usually applied to temporarily flooded pond basins that lose water early in the growing season. These areas are unvegetated when water recedes, but develop sparse | Upland |

**Table K3.26-1: Relationship of Section 3.26 and Section 4.26 Vegetation Type to Field-Verified Vegetation Type**

| Vegetation Type | Field-Verified Vegetation Type | Abbreviation | Definition[1] | Predominantly Occurs in Wetlands or Uplands |
|---|---|---|---|---|
| | | | cover by pioneering annual plants as the growing season progresses. The type can also apply to sparsely vegetated rubble and scree fields, mountaintops, or revegetating gravel bars. | |
| | Barren | BARE | This type is used for areas devoid or nearly devoid of vegetation, such as unvegetated gravel bars, beaches, seasonal pond bottoms, rubble fields, and scree slopes. Vegetation cover is < 10% vascular plants. | Wetland / Upland |
| | Snow | SNOW | This type is used for areas devoid of visible vegetation and covered entirely by snow. These areas are generally snow covered for the majority or all of a given year. | Upland |
| Open Water[2] | Open Water | OW | Unvegetated to very sparsely vegetated open water, including streams, rivers, lakes, and ponds. | Waters |

Notes:
[1] Forest density classes (closed, open, woodland) are differentiated base on tree canopy coverage (>60%, 25-59%, 10-24%, respectively). Shrub density classes (closed thickets, open) are differentiated based on shrub canopy cover (>75%, 25-75%, respectively). Shrub height classes (tall, low, dwarf) are differentiated based on average shrub height (>5 feet tall, 5 feet to 8 inches tall, <8 inches tall, respectively).
[2] As noted in Section 3.26 and Section 4.26, the open water type is included in vegetation type pie charts showing proportion of types in Section 3.26, but is not included in impact analysis in Section 4.26.
Plant names are generally given as scientific names and are not italicized. This format may differ from other places in this document.
Source: 3PPI and HDR 2011

**Table K3.26-2: Relationship of Section 3.26 and Section 4.26 Vegetation Type to ACCS Land Cover Type**

| Vegetation Type | ACCS Land Cover Type | ACCS Land CoverType (Fine Filter) | Definition | Predominantly Occurs in Wetlands or Uplands |
|---|---|---|---|---|
| Open Closed Forest | Alaska Sub-boreal White Spruce-Hardwood Forest | White Spruce or Black Spruce-Deciduous (Open-Closed) | The White Spruce or Black Spruce-Deciduous Forest (Open-Closed) landcover class is defined by at least 25% (sometimes more than 10%) tree cover, but neither needleleaf nor deciduous trees make up more than 75% of the tree cover. This class occurs on floodplains, inactive terraces, rolling hills and mountain sideslopes and is common on all aspects except north. Soils are typically well-drained. Permafrost is rare on most sites Vegetation: Canopy is dominated by *Picea glauca* and *Betula papyrifera* and typically ranges from 25% to 80%. *Populus tremuloides* or *Populus balsamifera* may be co-dominant in the hardwood component. Some sites are dominated or co-dominated by *Picea mariana*. The understory is open shrub or herbaceous. Common understory species include *Alnus* spp., *Rhododendron* spp., *Vaccinium vitis-idaea*, *Betula nana*, *Rosa acicularis*, *Shepherdia canadensis*, *Viburnum edule*, *Calamagrostis canadensis* and *Equisetum* spp. Feathermosses such as *Hylocomium splendens* and *Pleurozium schreberi* are common (Boggs and Sturdy 2005; Jorgenson et al. 1999). | Upland |
| | Closed Mix Forest | White Spruce-Deciduous Forest (Closed) | | Upland |
| | Closed Mixed Needleleaf/Deciduous | Needleleaf-Deciduous Forest (Closed) (Southern Alaska) | | Upland |
| | Closed Mixed Needleleaf/Deciduous | White Spruce or Black Spruce-Deciduous Forest (Closed) | | Upland |
| | Mixed forest | Needleleaf-Deciduous Forest | | Upland |
| | Alaskan Pacific Maritime Sitka Spruce Forest | White Spruce or Black Spruce (Open-Closed) | The White Spruce or Black Spruce (Open-Closed) landcover class is defined by 25-100% cover of trees where more than 75% of the trees are needleleaf, and lichen covers less than 20% of the ground surface. White spruce (*Picea glauca*) and black spruce (*Picea mariana*) are either co-dominant or dominant, and the soils are typically dry to mesic. Forested Wetlands | Upland |
| | Closed Needleleaf | White Spruce or Black Spruce (Closed) | | Upland |
| | Open Needleleaf | White Spruce or Black Spruce (Open) | | Upland |

**Table K3.26-2: Relationship of Section 3.26 and Section 4.26 Vegetation Type to ACCS Land Cover Type**

| Vegetation Type | ACCS Land Cover Type | ACCS Land CoverType (Fine Filter) | Definition | Predominantly Occurs in Wetlands or Uplands |
|---|---|---|---|---|
| | Open Spruce | White Spruce or Black Spruce (Open) | (i.e. tussock, bogs or fens) are included in the White Spruce or Black Spruce (Woodland) class. | Upland |
| | White/Lutz/Sitka spruce | White Spruce-Lutz Spruce-Sitka Spruce | | Upland |
| | Closed Birch | Paper Birch (Closed) | This class is common on well-drained Upland terrain on south, west and east aspects in Interior Alaska, and is widespread in the Cook Inlet basin. Soils are well-drained and develop on residual material or reworked deposits including glacial till, loess, and colluvium. Permafrost is rare on most sites. *Betula papyrifera* is typically dominant in the canopy, but other dominants or subdominants include *Populus balsamifera* and *Populus tremuloides*. Stands are often closed-canopied with an open shrub or herbaceous understory. Common understory species include *Alnus viridis* ssp. *sinuata*, *Rhododendron* spp., *Vaccinium vitis-idaea*, *Betula nana*, *Rosa acicularis*, *Ribes triste*, *Linnaea borealis*, *Shepherdia canadensis* and *Viburnum edule*. *Salix scouleriana* is locally common. Common herbaceous species include *Calamagrostis canadensis*, *Chamerion angustifolium*, *Gymnocarpium dryopteris*, and *Cornus canadensis*. Feathermosses such as *Hylocomium splendens* and *Pleurozium schreberi* are common in the ground layer (Boggs and Sturdy 2005). | Upland |
| | Closed Birch | Paper Birch (Closed) | | Upland |
| | Closed Deciduous | Deciduous Forest (Closed) | The Deciduous Forest (Open-Closed) landcover class is defined by at least 25% (sometimes more than 10%) tree cover | Upland |
| | Closed Deciduous | Deciduous Forest (Closed) | | Upland |

**Table K3.26-2: Relationship of Section 3.26 and Section 4.26 Vegetation Type to ACCS Land Cover Type**

| Vegetation Type | ACCS Land Cover Type | ACCS Land CoverType (Fine Filter) | Definition | Predominantly Occurs in Wetlands or Uplands |
|---|---|---|---|---|
| | | (Southern Alaska) | where more than 75% of the trees are deciduous. There is generally a needleleaf component to this class though it is less than 25%. Dominant or co-dominant tree species include paper birch (*Betula papyrifera*), balsam poplar (*Populus balsamifera*) and quaking aspen (*Populus tremuloides*). | |
| | Closed Poplar | Balsam Poplar (Closed) | | Upland |
| | Closed Poplar | Balsam Poplar (Closed) | | Upland |
| | Closed Populus Forest | Balsam Poplar (Closed) | | Upland |
| | Deciduous forest | Deciduous Forest (Open-Closed) | | Upland |
| | Open Birch | Paper Birch (Open) | This class is common on well-drained Upland terrain on south, west and east aspects in Interior Alaska, and is widespread in the Cook Inlet basin. Soils are well-drained and develop on residual material or reworked deposits including glacial till, loess, and colluvium. Permafrost is rare on most sites. *Betula papyrifera* is typically dominant in the canopy, but other dominants or subdominants include *Populus balsamifera* and *Populus tremuloides*. Stands are often closed-canopied with an open shrub or herbaceous understory. Common understory species include *Alnus viridis* ssp. *sinuata*, *Rhododendron* spp., *Vaccinium vitis-idaea*, *Betula nana*, *Rosa acicularis*, *Ribes triste*, *Linnaea borealis*, *Shepherdia canadensis* and V*iburnum edule*. *Salix scouleriana* is locally common. Common herbaceous species include *Calamagrostis canadensis*, *Chamerion angustifolium*, *Gymnocarpium dryopteris*, and *Cornus canadensis*. Feathermosses such as *Hylocomium splendens* and *Pleurozium schreberi* are common in the | Upland |
| | Open Birch | Paper Birch (Open) | | Upland |

**Table K3.26-2: Relationship of Section 3.26 and Section 4.26 Vegetation Type to ACCS Land Cover Type**

| Vegetation Type | ACCS Land Cover Type | ACCS Land CoverType (Fine Filter) | Definition | Predominantly Occurs in Wetlands or Uplands |
|---|---|---|---|---|
| | | | ground layer (Boggs and Sturdy 2005). | |
| | Open Deciduous | Deciduous Forest (Open) | The Deciduous Forest (Open-Closed) landcover class is defined by at least 25% (sometimes more than 10%) tree cover where more than 75% of the trees are deciduous. There is generally a needleleaf component to this class though it is less than 25%. Dominant or co-dominant tree species include *Betula papyrifera*, *Populus balsamifera* and *Populus tremuloides*. | Upland |
| | Open Deciduous | Deciduous Forest (Open) (Southern Alaska) | | Upland |
| | Open Mix Forest | White Spruce Deciduous Forest (Open) | The White Spruce or Black Spruce-Deciduous Forest (Open-Closed) landcover class is defined by at least 25% (sometimes more than 10%) tree cover, but neither needleleaf nor deciduous trees make up more than 75% of the tree cover. This class occurs on floodplains, inactive terraces, rolling hills and mountain sideslopes and is common on all aspects except north. Soils are typically well-drained. Permafrost is rare on most sites. Canopy is dominated by *Picea glauca* and *Betula papyrifera* and typically ranges from 25% to 80%. *Populus tremuloides* or *Populus balsamifera* may be co-dominant in the hardwood component. Some sites are dominated or co-dominated by *Picea mariana*. The understory is open shrub or herbaceous. Common understory species include *Alnus* spp., *Rhododendron* spp., *Vaccinium vitis-idaea*, *Betula nana*, *Rosa acicularis*, *Shepherdia Canadensis*, *Viburnum edule*, *Calamagrostis canadensis* and *Equisetum* spp. Feathermosses such as *Hylocomium splendens* and *Pleurozium schreberi* are | Upland |

**Table K3.26-2: Relationship of Section 3.26 and Section 4.26 Vegetation Type to ACCS Land Cover Type**

| Vegetation Type | ACCS Land Cover Type | ACCS Land CoverType (Fine Filter) | Definition | Predominantly Occurs in Wetlands or Uplands |
|---|---|---|---|---|
| | | | common (Boggs and Sturdy 2005; Jorgenson et al. 1999). | |
| | Open Mixed Needleleaf/Deciduous | Needleleaf-Deciduous Forest (Open) (Southern Alaska) | This class occurs on moraines, bedrock, colluvium and glacial till deposits. Elevation ranges from sea level to treeline. Patch size is small to matrix forming. Slopes are generally mesic although wet inclusions are common. This class does not include seasonally flooded sites such as floodplain and outwash plains. Vegetation: *Picea sitchensis* is the dominant tree species, although *Tsuga mertensiana* or *Tsuga heterophylla* may be minor canopy associates. Common species in the shrub layer include *Alnus viridis* ssp. *sinuata*, *Oplopanax horridus*, *Rubus spectabilis*, and *Vaccinium ovalifolium* (DeMeo et al. 1992; Martin et al. 1995; DeVelice et al. 1999). Common herbaceous species include *Maianthemum dilatatum*, *Tiarella trifoliata*, *Dryopteris expansa*, and *Gymnocarpium dryopteris*. *Calamagrostis nutkaensis* may be common on exposed sites near the coast. In the northern portion of the temperate rainforest (Kodiak Island, Kenai Fjords, and Prince William Sound), *Picea sitchensis* is frequently the dominant canopy tree from sea level to treeline on productive sites. In the southern portion of the Alaskan rainforest, *Tsuga heterophylla* is often the dominant canopy tree across productive sites and *Picea sitchensis* is linked more closely with disturbance (e.g., very steep sites, recently de-glaciated landscapes, outer coast headlands) | Upland |
| | Woodland Needleleaf | Needleleaf Forest (Woodland) (Southern Alaska) | | Upland |

**Table K3.26-2: Relationship of Section 3.26 and Section 4.26 Vegetation Type to ACCS Land Cover Type**

| Vegetation Type | ACCS Land Cover Type | ACCS Land CoverType (Fine Filter) | Definition | Predominantly Occurs in Wetlands or Uplands |
|---|---|---|---|---|
| | | | (DeMeo et al. 1992; Martin et al. 1995). | |
| | Open Mixed Needleleaf/Deciduous | White Spruce or Black Spruce-Deciduous Forest (Open) | The White Spruce or Black Spruce-Deciduous Forest (Open-Closed) landcover class is defined by at least 25% (sometimes more than 10%) tree cover, but neither needleleaf nor deciduous trees make up more than 75% of the tree cover. This class occurs on floodplains, inactive terraces, rolling hills and mountain sideslopes and is common on all aspects except north. Soils are typically well-drained. Permafrost is rare on most sites. Canopy is dominated by *Picea glauca* and *Betula papyrifera* and typically ranges from 25% to 80%. *Populus tremuloides* or *Populus balsamifera* may be co-dominant in the hardwood component. Some sites are dominated or co-dominated by *Picea mariana*. The understory is open shrub or herbaceous. Common understory species include *Alnus* spp., *Rhododendron* spp., *Vaccinium vitis-idaea*, *Betula nana*, *Rosa acicularis*, *Shepherdia Canadensis*, *Viburnum edule*, *Calamagrostis canadensis* and *Equisetum* spp. Feathermosses such as *Hylocomium splendens* and *Pleurozium schreberi* are common (Boggs and Sturdy 2005; Jorgenson et al. 1999). | Upland |
| | Open Needleleaf | Needleleaf Forest (Open) (Southern Alaska) | This class occurs on moraines, bedrock, colluvium and glacial till deposits. Elevation ranges from sea level to treeline. Patch size is small to matrix forming. Slopes are generally mesic although wet inclusions are common. This class does not include seasonally flooded sites such | Wetland |

**Table K3.26-2: Relationship of Section 3.26 and Section 4.26 Vegetation Type to ACCS Land Cover Type**

| Vegetation Type | ACCS Land Cover Type | ACCS Land CoverType (Fine Filter) | Definition | Predominantly Occurs in Wetlands or Uplands |
|---|---|---|---|---|
| | | | as floodplain and outwash plains. Vegetation: *Picea sitchensis* is the dominant tree species, although *Tsuga mertensiana* or *Tsuga heterophylla* may be minor canopy associates. Common species in the shrub layer include *Alnus viridis* ssp. *sinuata*, *Oplopanax horridus*, *Rubus spectabilis*, and *Vaccinium ovalifolium* (DeMeo et al. 1992; Martin et al. 1995; DeVelice et al. 1999). Common herbaceous species include *Maianthemum dilatatum*, *Tiarella trifoliata*, *Dryopteris expansa*, and *Gymnocarpium dryopteris*. *Calamagrostis nutkaensis* may be common on exposed sites near the coast. In the northern portion of the temperate rainforest (Kodiak Island, Kenai Fjords, and Prince William Sound), *Picea sitchensis* is frequently the dominant canopy tree from sea level to treeline on productive sites. In the southern portion of the Alaskan rainforest, *Tsuga heterophylla* is often the dominant canopy tree across productive sites and *Picea sitchensis* is linked more closely with disturbance (e.g., very steep sites, recently de-glaciated landscapes, outer coast headlands) (DeMeo et al. 1992; Martin et al. 1995). | |
| | Open Needleleaf - Lichen | White Spruce or Black Spruce/Lichen (Open) | The White Spruce or Black Spruce/Lichen (Woodland-Open) landcover class is defined by 10-60% cover of trees where more than 75% of the trees are needleleaf. *Picea glauca* and *Picea mariana* are either co-dominant or dominant. Lichen cover is more than 20%. This class is generally found along ridgetops or on riparian benches. These | Upland |
| | Woodland Ndl. - Lichen | White Spruce or Black Spruce/Lichen (Woodland) | | Upland |
| | Woodland Needleleaf - Lichen | Needleleaf Forest-Lichen (Woodland) (Southern Alaska) | | Upland |

**Table K3.26-2: Relationship of Section 3.26 and Section 4.26 Vegetation Type to ACCS Land Cover Type**

| Vegetation Type | ACCS Land Cover Type | ACCS Land CoverType (Fine Filter) | Definition | Predominantly Occurs in Wetlands or Uplands |
|---|---|---|---|---|
| | | | are cool dry sites on well-drained to excessively well-drained substrates. Soils are thin and develop on gravels, sandy loess deposits, or bedrock. *Picea glauca* or *Picea mariana* dominate or co-dominate. The shrub layer is open and typically includes *Betula nana*, *Shepherdia canadensis*, *Vaccinium uliginosum* or *Empetrum nigrum*. Lichens (primarily *Cladina* spp.) often occur in small round patches between trees. | |
| | Woodland Needleleaf | White Spruce or Black Spruce (Woodland) | The White Spruce or Black Spruce (Woodland) landcover class is defined by 10-24% of cover of trees, where more than 75% of the trees are needleleaf, and lichen covers less than 20% of the ground surface. *Picea glauca* and *Picea mariana* are either co-dominant or dominant. Forested Wetlands (i.e. tussock, peatlands) are typically woodlands and included in this class. | Upland |
| | Tall Shrub | Tall Shrub (Southern Alaska) | The Tall Shrub (Open-Closed) landcover class is defined by 25-100% cover of shrubs and either more than 25% of the site consists of shrubs taller than 1.3 m in height or shrubs taller than 1.3 m are the most common shrubs. Note that some maps used 1.5 m in height as the tall shrub cut-off. To help define this class, two of the more common fine-scale classes are described:<br>• Alder-Willow (Open-Closed)<br>• Alder-Willow (Floodplain) | Upland |
| | Tall Shrub | Tall Shrub | | Upland |
| | Willow shrub | Tall Salix alaxensis-S. glauca | | Upland |
| Open Closed Tall Shrub | Alder | Alder (Open-Closed) | This fine-scale class is widespread on | Upland |

**Table K3.26-2: Relationship of Section 3.26 and Section 4.26 Vegetation Type to ACCS Land Cover Type**

| Vegetation Type | ACCS Land Cover Type | ACCS Land CoverType (Fine Filter) | Definition | Predominantly Occurs in Wetlands or Uplands |
|---|---|---|---|---|
| | Closed Alder | Alder (Closed) | mountain and hill slopes throughout Northern, Western and Interior Alaska, and is matrix forming above treeline and on avalanche slopes in the Cook Inlet Basin (Viereck 1979). Soils are typically mesic. Common tall shrubs include *Alnus viridis* ssp. *crispa*, *A. viridis* ssp. *sinuata*, *Salix glauca*, *S. barclayi* and *S. pulchra*. Additional species include *Sambucus racemosa*, *Vaccinium uliginosum*, *V. vitis-idaea*, *Betula nana*, *Rhododendron tomentosum*, *Empetrum nigrum*, *Spiraea stevenii*, *Dryas* spp. and *Cassiope tetragona*. Mosses include *Hylocomium splendens* and *Dicranum* spp. In Northern, Western and Interior Alaska, this fine-scale class is often mosaicked with low shrub tundra and dwarf shrubs. In the Cook Inlet basin region, it is typically mosaicked with the herbaceous (mesic) class. | Upland |
| | Open Alder | Alder-Herbaceous (Mesic) Mosaic | | Upland |
| | Tall Alder Shrub | Alder (Open-Closed) | | Upland |
| Open Closed Low Shrub | Low Shrub | Low Shrub (Southern Alaska) | The Low Shrub landcover is defined by 25-100% cover of shrubs, where shrubs taller than 1.3 m make up less than 25% of the site, and either more than 25% of the site consists of shrubs 0.2-1.3 m in height or shrubs 0.2-1.3 m are the most common shrubs. Note that some maps used 1.5 m as the tall shrub cut-off. Lichen cover is less than 20%. To help define this class, three of the more common fine-scale classes are described:<br>• Low Willow (Open-Closed)<br>• Low *Betula nana* and Ericaceous Shrub (Mesic)<br>• *Betula nana-Vaccinium uliginosum* (Peatland) | Upland |
| | Scrub shrub | Low Shrub | | Upland |
| | Shrub/Scrub | Low-Tall Shrub (<5 m Tall) (>20% Cover) (Aleutians) | | Upland |

**Table K3.26-2: Relationship of Section 3.26 and Section 4.26 Vegetation Type to ACCS Land Cover Type**

| Vegetation Type | ACCS Land Cover Type | ACCS Land CoverType (Fine Filter) | Definition | Predominantly Occurs in Wetlands or Uplands |
|---|---|---|---|---|
| | Low Shrub | Low Betula nana-Low Willow | Low Willow Fine Class: Willow-dominated sites are widespread and common on wet and mesic mountain slopes, hillslopes, flats, and adjacent to streams. It also occurs along water tracts in Northern and Western Alaska. Patch size is small to large and often linear along small streams. *Salix pulchra*, *S. glauca*, *S. niphoclada*, *S. chamissonis* and *S. bebbiana* dominate or co-dominate with *Alnus viridis* ssp. *crispa*, *Betula nana*, *Vaccinium uliginosum* and *Rhododendron tomentosum*.<br>Low *Betula nana* Fine Scale class: This class is common on mesic mountain slopes, hillslopes and flats. Patch size is small to matrix-forming. Soils are mesic and mineral with a well-decomposed organic layer 5-30 cm thick (Viereck et al. 1992).<br>Low *Betula nana*, *Vaccinium uliginosum*, or *Rhododendron tomentosum* typically dominate or co-dominate. Salix species (*Salix barclayi* and *S. pulchra*) do not dominate but may co-dominate. This fine-scale class does not include tussock-dominated (more than 35% tussocks) sites. | Upland |
| | Low shrub - Lichen | Low Shrub-Lichen (Southern Alaska) | The Low Shrub/Lichen landcover class is defined by 25-100% cover of shrubs, more than 20% cover of lichen and either 25% of the site consists of shrubs 0.2-1.3 m in height or shrubs 0.2-1.3 m are the most common shrubs.<br>This class is found at mid to high elevations, on mesic mountain slopes, hillslopes and flats. Patch size is small. | Upland |
| | Low shrub - Lichen | Low Shrub-Lichen | | Upland |

**Table K3.26-2: Relationship of Section 3.26 and Section 4.26 Vegetation Type to ACCS Land Cover Type**

| Vegetation Type | ACCS Land Cover Type | ACCS Land CoverType (Fine Filter) | Definition | Predominantly Occurs in Wetlands or Uplands |
|---|---|---|---|---|
| | | | Soils are mesic.<br>The shrub species in this class is nearly always *Betula nana*. Lichens (primarily *Cladina* spp.) typically occur in large patches between shrubs. | |
| | Low Shrub-Tussock Tundra | Low Shrub/Tussock Tundra (Open) | The Tussock Tundra (Low Shrub or Herbaceous) landcover class is defined by more than 35% cover of tussocks and trees have less than 10% cover. These sites may have more than 25% cover of low shrubs 0.2-<br>1.3 m tall, or a combination of low and dwarf shrubs. To help define this class, two fine-scale classes are described:<br>• Low Shrub/Tussock Tundra<br>• Herbaceous Tussock Tundra<br>Low shrub tussock tundra is common in valleys and slopes throughout Northern, Western and Interior Alaska. These sites are cold, poorly drained, and underlain by mesic, silty mineral soils with a shallow surface organic layer surrounding the tussocks (Viereck et al. 1992). It often occurs on high-centered polygons. Permafrost is present. Patch size is small to matrix-forming. | Upland |
| | Low Shrub-Tussock Tundra | Low Shrub-Tussock Tundra | | Upland |
| Dwarf Shrub | Dwarf Shrub | Dwarf Shrub | The Dwarf Shrub landcover class is defined by more than 25% of the cover is shrub (more than 40% on some maps) and either 25% of the site consists of shrubs less than 0.2 m in height or shrubs less than 0.2 m tall are the most common shrubs. Lichen cover is less than 20%. | Upland |
| | Dwarf Shrub Tundra | Dwarf Shrub | | Upland |
| | Prostrate Shrub Tundra | Dwarf Shrub | | Upland |
| | Shrubby Tundra | Dwarf Shrub | | Upland |

**Table K3.26-2: Relationship of Section 3.26 and Section 4.26 Vegetation Type to ACCS Land Cover Type**

| Vegetation Type | ACCS Land Cover Type | ACCS Land CoverType (Fine Filter) | Definition | Predominantly Occurs in Wetlands or Uplands |
|---|---|---|---|---|
| | Dwarf Shrub | Dwarf Shrub | The Vegetation mapping for Southern Alaska provides a separate description of this class:<br>The Dwarf Shrub landcover class occurs from low to high elevations in the Aleutian Islands and primarily on alpine and subalpine sites in Southern Alaska. It occurs on sideslopes, shoulder slopes, and low summits, and the terrain varies from gently sloping to steep.<br>The vegetation can be a mosaic of herbaceous meadow and dwarf shrublands or continuous dwarf shrub cover. In the mountains, this class often grades upslope into sparsely vegetated sites (10-25% cover). Patch size is small to matrix forming. Shrubs less than 0.2 m tall with at least 25% cover. This is a diverse and species rich class, and lichen and moss cover are often high. Dominant dwarf shrub species include *Arctostaphylos alpina*, *Empetrum nigrum*, *Harrimanella stelleriana*, *Loiseleuria procumbens*, *Luetkea pectinata*, *Phyllodoce aleutica*, *Phyllodoce glanduliflora*, *Vaccinium uliginosum*, and *Vaccinium vitis-idaea*. Common willows include *Salix rotundifolia*, *Salix arctica* and *Salix reticulata*. Scattered low and tall shrubs and dwarf trees may be present. Common herbaceous species include *Aconitum delphiniifolium*, *Anemone narcissiflora*, *Artemisia arctica*, *Carex macrochaeta*, *Castilleja unalaschcensis*, *Geranium erianthum*, *Lupinus nootkatensis*, *Sanguisorba canadensis*, *Valeriana sitchensis*, and *Viola* species. *Nephrophyllidium crista- galli* may co- | Upland |

**Table K3.26-2: Relationship of Section 3.26 and Section 4.26 Vegetation Type to ACCS Land Cover Type**

| Vegetation Type | ACCS Land Cover Type | ACCS Land CoverType (Fine Filter) | Definition | Predominantly Occurs in Wetlands or Uplands |
|---|---|---|---|---|
| | | | dominate. | |
| | Dwarf Shrub-Lichen | Dwarf Shrub-Lichen (Southern Alaska) | The Dwarf Shrub-Lichen landcover class is defined by 25-100% cover of shrub where more than 20% of the cover is lichen and either 25% of the site consists of shrubs less than 0.2 m in height or shrubs less than 0.2 m tall are the most common shrubs. | Upland |
| | Dwarf Shrub-Lichen | Dwarf Shrub-Lichen | | Upland |
| Dry to Moist Herbaceous | Dwarf Shrub/Mesic Herbaceous | Tussock Tundra | The Tussock Tundra (Low Shrub or Herbaceous) landcover class is defined by more than 35% cover of tussocks and trees have less than 10% cover. These sites may have more than 25% cover of low shrubs 0.2-1.3 m tall, or a combination of low and dwarf shrubs. | Upland |
| | Grasslands | Bluejoint (Mesic) | The Herbaceous (Mesic) (Interior Alaska, Cook Inlet Basin) landcover class is defined by its occurrence on mesic to dry sites with more than 25% cover of herbaceous species. Dominant and co-dominant species include sedges, grasses and forbs including ferns. This is a diverse class occurring throughout Interior Alaska and Cook Inlet Basin. North of the Alaska Range, alpine sites are commonly dominated by *Carex bigelowii*, *Luzula confusa* and lichens. Dwarf shrubs (≤ 0.2 m tall) such as *Arctostaphylos alpina*, *Empetrum nigrum*, *Salix pulchra* and *Betula nana* are usually present, but contribute less than 25% to the canopy cover. It often forms a mosaic with dwarf and low shrub classes. On drier slopes, species such as *Festuca altaica*, *Calamagrostis purpurascens*, *Leymus* | Upland |
| | Mesic/Dry Graminoid | Graminoid (Mesic) | | Upland |
| | Mesic/Dry Grass Meadow | Grass (Mesic) | | Upland |
| | Mesic/Dry Sedge Meadow | Sedge (Mesic) | | Upland |
| | Sedge Dominated Mesic Tundra | Sedge (Mesic) | | Upland |
| | Sedge graminoid | Sedge (Mesic) | | Upland |
| | Sparse Vegetation | Herbaceous (Mesic) >20%, Bareground >50% | | Upland |

**Table K3.26-2: Relationship of Section 3.26 and Section 4.26 Vegetation Type to ACCS Land Cover Type**

| Vegetation Type | ACCS Land Cover Type | ACCS Land CoverType (Fine Filter) | Definition | Predominantly Occurs in Wetlands or Uplands |
|---|---|---|---|---|
| | | | *innovatus*, *Artemisia frigida* and *Achillea* spp. are common.<br>The alpine in the Cook Inlet Basin and other regions with a mild climate support lush and often species-rich herbaceous communities. Species include *Calamagrostis canadensis*, *Chamerion angustifolium*, *Festuca altaica*, *Heracleum maximum*, *Veratrum viride*, *Angelica lucida*, *Athyrium filix-femina*, *Dryopteris expansa* and *Equisetum arvense* (Viereck et al. 1992). It typically occurs near treeline mosaicked with alder patches, and is uncommon north of the Alaska Range. *Chamerion angustifolium* often dominates recently burned forests, whereas *Calamagrostis canadensis* often dominates spruce-beetle killed forests in the Cook Inlet Basin.<br>Sites dominated or co-dominated by *Leymus* | |
| | Mesic/Dry Graminoid | Graminoid (Mesic) | The Herbaceous (Mesic) (Northern and Western Alaska) landcover class is defined by its occurrence on mesic to dry sites with more than 25% cover of herbaceous species and includes the NLCD 'Sedge/Herbaceous' class of (Homer et al. 2004), which occurs exclusively on the Bering Sea Islands. Dwarf shrubs (less than 0.2 m tall) may exceed 25% under the herbaceous layer. It occurs in Northern and Western Alaska.<br>These mesic-dry herbaceous communities occur throughout Northern and Western Alaska on hill and mountain slopes, upper drainages, and lowlands including drained lake basins. It typically occurs as small | Upland |
| | Mesic/Dry Grass Meadow | Grass (Mesic) | | Upland |
| | Mesic/Dry Sedge Meadow | Sedge (Mesic) | | Upland |
| | Sparse Vegetation | Herbaceous (Mesic) >20%, Bareground >50% | | Upland |

**Table K3.26-2: Relationship of Section 3.26 and Section 4.26 Vegetation Type to ACCS Land Cover Type**

| Vegetation Type | ACCS Land Cover Type | ACCS Land CoverType (Fine Filter) | Definition | Predominantly Occurs in Wetlands or Uplands |
|---|---|---|---|---|
| | | | patches and is more common in western Alaska.<br>Herbaceous species include *Carex microchaeta* ssp. *nesophila* (dominant sedge in higher elevations), *Chamerion angustifolium*, *Alopecurus magellanicus*, *Artemisia arctica*, *Polygonum bistorta*, *Valeriana capitata*, *Pedicularis* spp. and *Polemonium acutiflorum*. Collapsed acidic lowland snowbeds that support *Phippsia algida* and *Alopecurus magellanicus* and drained lake basins dominated by *Calamagrostis canadensis* (Western Alaska) are also included in this fine-scale class. | |
| | Mesic/Dry Graminoid | Graminoid (Mesic-Dry) (Southern Alaska) | The Herbaceous (Mesic) class occurs on mesic to dry sites with more than 25% cover of herbaceous species. Dwarf shrubs (less than 0.2 m tall) may exceed 25% under the herbaceous layer. To help define this class, we describe two of the more common fine-scale classes:<br>• Alpine and subalpine mesic herbaceous<br>• Beach and dune mesic herbaceous<br>In Southern Alaska, the herbaceous (mesic) class occurs in subalpine and alpine herbaceous meadows and sideslopes. The slope position is often above the tall shrub zone and below alpine dwarf shrub tundra. The substrate is colluvium, residuum, volcanic ash or glacial till. The dominant disturbances are snow avalanche, soil creep and freeze-thaw action. Patch size is small to matrix-forming.<br><br>Species composition is diverse and | Upland |

**Table K3.26-2: Relationship of Section 3.26 and Section 4.26 Vegetation Type to ACCS Land Cover Type**

| Vegetation Type | ACCS Land Cover Type | ACCS Land CoverType (Fine Filter) | Definition | Predominantly Occurs in Wetlands or Uplands |
|---|---|---|---|---|
| | | | species richness is often high, and typically no single species is dominant. Common graminoids include *Calamagrostis canadensis* and *Carex microchaeta*. Common forbs include *Aconitum delphiniifolium*, *Anemone narcissiflora*, *Athyrium filix- femina*, *Castilleja unalaschcensis*, *Chamerion angustifolium*, *Chamerion latifolium*, *Geranium erianthum*, *Lupinus nootkatensis*, *Nephrophyllidium crista-galli*, *Polemonium acutiflorum*, *Sanguisorba canadensis*, *Senecio triangularis*, *Valeriana sitchensis*, and *Veratrum viride* (DeVelice et al. 1999). On the Aleutian Islands, *Leymus mollis* may also be co-dominant with the above species and occur far inland. | |
| | Mesic/Dry Grass Meadow | Grass (Mesic-Dry) (Southern Alaska) | | Upland |
| | Lichen | Lichen | The Lichen landcover class is defined by less than 25% cover of herbaceous species, and more than 50% lichen species.<br><br>Common slope positions include sideslopes, summits and ridges. Sites are typically acidic and mesic to dry. It is also common on volcanic lava flows with little soil development. Patch size is small to large.<br>Foliose and fruticose lichens dominate and include *Umbilicaria* spp., *Rhizocarpon geographicum*, *Cladina stellaris*, *Racomitrium lanuginosum*, *Flavocetraria* spp. and *Alectoria ochroleuca*. Common | Upland |

**Table K3.26-2: Relationship of Section 3.26 and Section 4.26 Vegetation Type to ACCS Land Cover Type**

| Vegetation Type | ACCS Land Cover Type | ACCS Land CoverType (Fine Filter) | Definition | Predominantly Occurs in Wetlands or Uplands |
|---|---|---|---|---|
| | | | dwarf shrubs include *Loiseleuria procumbens*, *Betula nana*, *Rhododendron tomentosum*, *Empetrum nigrum* and *Vaccinium uliginosum*. | |
| | Lichen Tundra | Lichen | | Upland |
| Wet Herbaceous | Aleutian Freshwater Marsh | Herbaceous (Wet-Marsh) | The Herbaceous (Marsh) (Interior Alaska, Cook Inlet Basin) landcover class is defined by sites, which are periodically wet or continually flooded and dominated by emergent herbaceous plants such as sedges, cattails and rushes.<br>In Interior Alaska and Cook Inlet Basin, fresh water marshes occur as small to large patches, typically on the margins of ponds and lakes. They are semipermanently flooded, but some have seasonal flooding and the water depth typically exceeds 10 cm. Soils are muck or mineral and water can be nutrient- rich. Vegetation is dominated by emergent vegetation such as *Carex utriculata*, *Schoenoplectus tabernaemontani*, *Typha latifolia*, *Menyanthes trifoliata*, *Equisetum fluviatile*, *Eleocharis palustris*, *Comarum palustre* and *Hippuris vulgaris*. *Arctophila fulva* becomes more common in the northern portions of Interior Alaska. | Wetland |
| | Wet Graminoid | Graminoid (Wet) | | Wetland |
| | Wet tundra | Herbaceous (Wet) | | Wetland |
| | Wetland - graminoid | Graminoid (Wet) | | Wetland |

**Table K3.26-2: Relationship of Section 3.26 and Section 4.26 Vegetation Type to ACCS Land Cover Type**

| Vegetation Type | ACCS Land Cover Type | ACCS Land CoverType (Fine Filter) | Definition | Predominantly Occurs in Wetlands or Uplands |
|---|---|---|---|---|
| | Wet Sedge Meadow | Carex utriculata-C. aquatilis | This fine-scale class is common in wet depressions, low-lying areas, and shallow drainage ways. It is minerotrophic with high nutrient levels and high rates of decomposition. Soils are mineral or muck and saturated at some point during the growing season, but standing water is ephemeral.<br>Wet sedge meadows typically have a well-developed organic mat but not deep enough to be considered peatlands. | Wetland |
| | Sedge & Shrub Bog Meadow | Sedge/Sphagnum (Peatland) | This fine-scale class includes hydrologically closed bogs and poor fens with thick (more than 40 cm) peat deposits. It includes basin and blanket bogs.<br>It is dominated by peat-forming sedges including *Trichophorum cespitosum*, *Carex pluriflora*, *C. chordorrhiza*, *C. livida* and *Eriophorum russeolum* (Viereck et al. 1992). Dwarf and low shrubs include *Vaccinium oxycoccos*, *Andromeda polifolia*, *Vaccinium uliginosum*, *Rhododendron tomentosum* and *Empetrum nigrum*. Sphagnum species are usually abundant in the ground layer. | Wetland |
| | Emergent | Forb (Wet) | The Herbaceous (Wet) (Northern and Western Alaska) landcover class is defined by more than 20% herbaceous cover, 5-25% water or more than 20% *Carex aquatilis*; it occurs in Northern and Western Alaska. This class represents sites, which are wet or seasonally flooded by freshwater. | Wetland |
| | Wet Graminoid | Graminoid (Wet) | | Wetland |
| | Wet herbaceous | Herbaceous (Wet or Tidal) | | Wetland |

**Table K3.26-2: Relationship of Section 3.26 and Section 4.26 Vegetation Type to ACCS Land Cover Type**

| Vegetation Type | ACCS Land Cover Type | ACCS Land CoverType (Fine Filter) | Definition | Predominantly Occurs in Wetlands or Uplands |
|---|---|---|---|---|
| | Moss | Herbaceous-Moss (Wet) | The Moss landcover class is defined by less than 25% cover of herbaceous species and more than 50% cover of bryoid species of which more than 50% are mosses or liverworts.<br>Sites range from peatlands, lake edges, floodplains, mountain ridges and volcanic ash.<br>This class includes Sphagnum spp.-dominated peatlands, moss covered ridges and floodplains, and cryptobiotic crusts found on volcanic pyroclastic flows. | Wetland |
| | Moss | Herbaceous-Moss (Wet) | | Wetland |
| | Moss | Moss (Southern Alaska) | The Moss (Southern Alaska) landcover class is uncommon. It occurs on wet and dry active floodplains where herbs and shrubs have not yet colonized, alpine seeps, and alpine slopes. Patch size is small to medium. Slope ranges from flat on floodplains to steep alpine slopes. The elevation ranges from near sea level to alpine.<br>Biological crusts or moss dominate or co-dominates with lichen. In the alpine, it occurs as a mosaic within a matrix of dwarf shrub classes. | Wetland |
| | Sedge & Shrub Bog Meadow | Sedge/Sphagnum (Peatland) | This fine-scale class includes hydrologically closed bogs and poor fens with thick (more than 40 cm) peat deposits. It includes basin and blanket bogs.<br>It is dominated by peat-forming sedges including *Trichophorum cespitosum*, *Carex pluriflora*, *C. chordorrhiza*, *C. livida* and *Eriophorum russeolum* (Viereck et al. 1992). Dwarf and low shrubs include *Vaccinium oxycoccos*, *Andromeda* | Wetland |

**Table K3.26-2: Relationship of Section 3.26 and Section 4.26 Vegetation Type to ACCS Land Cover Type**

| Vegetation Type | ACCS Land Cover Type | ACCS Land CoverType (Fine Filter) | Definition | Predominantly Occurs in Wetlands or Uplands |
|---|---|---|---|---|
| | | | *polifolia*, *Vaccinium uliginosum*, *Rhododendron tomentosum* and *Empetrum nigrum*. Sphagnum species are usually abundant in the ground layer. | |
| | Shallow marsh | Herbaceous (Marsh) | The Herbaceous (Marsh) (Northern and Western Alaska) landcover class is defined by sites, which are periodically wet or continually flooded and dominated by emergent herbaceous plants such as sedges.<br>In Northern and Western Alaska, freshwater marshes occur as small to large patches, typically on the margins of ponds, lakes (thaw-lakes), low-centered polygons and beaded streams. They are semi permanently flooded, but some have seasonal flooding, and the water depth typically exceeds 10 cm. Soils are muck or mineral, and water can be nutrient-rich. It is often dominated by monocultures of *Arctophila fulva*, *Carex aquatilis* or *Eriophorum angustifolium*. Other emergent species may occur, including *Comarum palustre*, *Hippuris vulgaris*, *Carex utriculata*, *Menyanthes trifoliata*, *Lysimachia thyrsiflora* and *Equisetum fluviatile*. Species diversity is low. | Wetland |
| | Wet Graminoid | Graminoid (Wet) (Southern Alaska) | The Herbaceous (Wet-Marsh) landcover class is represented by the following National Wetlands Inventory (NWI) Subclasses:<br>• Lacustrine, Littoral, Emergent<br>• Palustrine, Emergent<br>Site is not a peatland. Freshwater Wetlands and marshes are mostly small patch, found at all elevations but mostly | Wetland |

**Table K3.26-2: Relationship of Section 3.26 and Section 4.26 Vegetation Type to ACCS Land Cover Type**

| Vegetation Type | ACCS Land Cover Type | ACCS Land CoverType (Fine Filter) | Definition | Predominantly Occurs in Wetlands or Uplands |
|---|---|---|---|---|
| | | | confined to limited areas in suitable floodplain or basin topography along the borders of ponds and lakes or wet depressions. The water table for most of the growing season ranges from just below the ground surface, to at the ground surface, to above the ground surface in marshes. Soils are mineral soil or muck over mineral soil, or have an organic layer less than 40 cm thick. It may be composed of Sphagnum, sedge, or other organic material and can occur over mineral soil or may be a floating root mat.<br>In sites where the water table is typically above the ground surface (i.e. marsh), plant associations include *Carex aquatilis*, *Carex utriculata*, *Comarum palustre*, *Equisetum fluviatile*, *Equisetum palustre*, *Hippuris tetraphylla*, *Hippuris vulgaris*, *Menyanthes trifoliata*, and *Scirpus microcarpus*. Species diversity is often low. In drier sites where the water table is typically below the ground surface, common associations include *Carex aquatilis* var. *dives*, *Carex aquatilis*, *Carex lyngbyei*, *Carex macrochaeta*, *Carex pyrenaica* ssp. *micropoda*, *Carex rostrata*, *Carex saxatilis*, *Comarum palustre*, *Equisetum variegatum* var. *alaskanum*, *Eriophorum angustifolium* ssp. *angustifolium*, and *Trichophorum cespitosum*. Sphagnum may be common. | |
| | Wet Sedge Meadow | Carex utriculata-C. aquatilis | This fine-scale class is common in wet depressions, low-lying areas, and shallow drainage ways. It is minerotrophic with high nutrient levels and high rates of decomposition. Soils are mineral or muck | Wetland |

**Table K3.26-2: Relationship of Section 3.26 and Section 4.26 Vegetation Type to ACCS Land Cover Type**

| Vegetation Type | ACCS Land Cover Type | ACCS Land CoverType (Fine Filter) | Definition | Predominantly Occurs in Wetlands or Uplands |
|---|---|---|---|---|
| | | | and saturated at some point during the growing season, but standing water is ephemeral.<br>Wet sedge meadows typically have a well-developed organic mat but not deep enough to be considered peatlands. | |
| Open Water[1] | Clear Water | Clear Water | The Freshwater or Saltwater landcover class is defined by aquatic sites where the cover of vegetation is less than 10%. | Wetland |
| | Clear Water | Clearwater | | Wetland |
| | Open Water | Freshwater or Saltwater | | Wetland |
| | Turbid Water | Freshwater or Saltwater | | Wetland |
| | Turbid Water | Turbid Water | | Wetland |
| | Water | Freshwater or Saltwater | | Wetland |
| Other | Barren - wet | Bareground | The Bareground (Norther, Western, and Interior Alaska) landcover class is defined by more than 90% cover of unvegetated ground. This class includes sand along the major rivers, high-elevation rock/gravel areas, cliffs, tidal mud flats, unvegetated sand dunes, and large piles of driftwood found on the west coast in the Innoko (Unalakleet) area.<br>The Bareground (Southern Alaska) landcover class is defined by vegetation cover less than 10%. This type includes sand along the major rivers, high-elevation rock/gravel areas, and cliffs. | Wetland |
| | Barren Land | Bareground | | Upland |
| | Non-veg bare | Bareground (<10% vegetation) | | Upland |
| | Rock/Gravel | Bareground (Rock or Gravel) | | Upland |
| | Rock/Gravel | Bareground (Rock-Gravel; <20% vegetation) | | Upland |
| | Rock-Talus | Rock-Talus | | Upland |
| | Sparse Vegetation | Sparse Vegetation (10-25%) | | Upland |

**Table K3.26-2: Relationship of Section 3.26 and Section 4.26 Vegetation Type to ACCS Land Cover Type**

| Vegetation Type | ACCS Land Cover Type | ACCS Land CoverType (Fine Filter) | Definition | Predominantly Occurs in Wetlands or Uplands |
|---|---|---|---|---|
| | Sparse Vegetation | Sparse Vegetation (Southern Alaska) | The Sparse Vegetation (Northern and Western Alaska) landcover class is defined by at least 50% cover of unvegetated ground and vascular vegetation with more than 10% cover. On acidic substrates (pH typically less than 6) common dwarf shrubs (less than 0.2 m tall) include *Dryas octopetala*, *D. integrifolia*, *Empetrum nigrum*, *Vaccinium uliginosum*, *Loiseleuria procumbens* and *Salix phlebophylla*. Herbaceous species may include *Antennaria alpina*, *Hierochloe alpina*, *Minuartia obtusiloba*, *Carex scirpoidea*, *C. podocarpa*, *C. microchaeta* and *Festuca altaica*. Lichens include *Cladina* spp., *Sphaerophorus globosus*, *Nephroma arcticum*, *Flavocetraria* spp. and *Alectoria ochroleuca*. | Upland |
| | Urban/Cultural | Urban, Agriculture, Road | The Urban, Agriculture, Road landcover class is defined by sites where at least 50% of the area has been developed. | Upland |
| | Urban/Developed | Urban | | Upland |

Notes:
Landcover classes were pulled from ACCS Vegetation Mapping for the State of Alaska. The User Guides for both regions (Boggs et al. 2016) provides the definitions for each class as presented above. Some landcover types were described differently for different geographical locations in Alaska. If no separate description was provided in the User guide then it was grouped together despite geographic distinction.
1 As noted in Section 3.26, Vegetation and Section 4.26, Vegetation, the open water type is included in vegetation type pie charts showing proportion of types in Section 3.26, Vegetation but is not included in impact analysis in Section 4.26, Vegetation.
Plant names are generally given as scientific names and are not italicized. This format may differ from other places in this document.
Source: Boggs et al. 2016

# K4.10 HEALTH AND SAFETY

The evaluation of impacts on human health and safety is a required component of the National Environmental Policy Act (NEPA) as it pertains to negative and beneficial consequences of a proposed project on potentially affected communities. This appendix supports the health evaluation for Section 4.10, Health and Safety.

The Alaska Department of Health and Social Services (ADHSS) defines health as "the reduction in mortality, morbidity and disability due to detectable disease or disorder and an increase in the perceived level of health," as discussed in Sections 3.10 and 4.10, Health and Safety (ADHSS 2015). Because health is a multi-dimensional concept with physical, mental, and social aspects, the proposed project could affect aspects of health at a localized or individual level, a community level, a regional level, or a state-wide level, depending on the nature of the effect.

Human health impacts were evaluated in accordance with NEPA practice, and generally followed the ADHSS methodology. The terminology used for descriptions and rankings of health impacts in this section generally correspond to the terms and ratings used in the ADHSS Health Impact Assessment (HIA) guidance. This guidance uses the concept of Health Effect Categories. A Health Effect Category (HEC) groups similar health effects so that they can be discussed and evaluated more easily and efficiently. A health effect can be a health outcome (e.g., a documented health event, such as a clinic visit, the birth of an infant, or an incidence of a disease), or a health determinant (a social, environmental, or economic reality that influences health outcomes, such as education level, income, or access to healthcare). By evaluating both determinants and outcomes, the HIA can develop an assessment of health status, health needs, health impacts, and mitigation/monitoring recommendations (if warranted) that are based on a good understanding of the proposed project and its connections with the affected communities.

A characteristic of this guidance is that the individual dimensions of health impacts (i.e., nature of health effect, duration, magnitude, extent, and likelihood) are each given their own descriptive terms for the estimated relative degree of occurrence; and a final consolidated health impact rating for each health metric or HEC is numerical (Category 1 through 4). The guidance suggests that impact ratings of 2 or higher may markedly increase or decrease illness and injury rates, and may warrant interventions, if negative (ADHSS 2015).

In accordance with NEPA practice and ADHSS (2015), the scope of this assessment is limited to affected communities "outside of the fence," (outside the mine site and other mine-related components). Accordingly, this assessment does not include a direct evaluation of the anticipated workforce safety and health issues ("inside the fence") because the project would be governed by the Occupational Safety and Health Administration (OSHA) and the Mine Safety and Health Administration (MSHA) regulations in the areas where project activities would occur. However, this assessment does consider "crossover issues," such as areas where workers are housed, or where workforce behaviors result in interactions/overlap with the affected communities.

The analysis of potential consequences to human health for the affected communities using ADHSS (2015) criteria is consistent with the principles of analysis required by NEPA. The first step is to determine the impact score, which takes into consideration four impact dimensions: severity of potential health effects (which can be positive or negative, and considers the need for intervention if the impact is negative), duration, magnitude, and extent of the impact (Table K4.10-1). Each component of the impact dimension is assigned a score of 0, 1, 2, or 3 to derive the overall impact rating score.

**Table K4.10-1: Step 1 – Impact Dimensions**

| Step 1 | | | | |
|---|---|---|---|---|
| **Impact Rating Score** | **A – Health Effect (+/-)** | **B – Duration** | **C – Magnitude** | **D – Extent** |
| 0 | Effect is not perceptible | Less than 1 month | Minor | Individual cases |
| 1 | (+/-) minor benefits or risks to injury or illness patterns (no intervention needed) | Short-term: 1 to 12 months | Those impacted would:<br>1) be able to adapt to the impact with ease and maintain pre-impact level of health; or<br>2) see noticeable but limited and localized improvements to health conditions. | Local: small; limited impact to households |
| 2 | (+/-) moderate benefits or risks to illness or injury patterns (intervention needed, if negative) | Medium-term: 1 to 6 years | Those impacted would:<br>1) be able to adapt to the health impact with some difficulty and would maintain pre-impact level of health with support; or<br>2) experience beneficial impacts to health for specific populations; some maintenance may still be required. | Entire Potentially Affected Communities; village level |
| 3 | (+/-) severe benefits or risks: marked change in mortality and morbidity patterns (intervention needed, if negative) | Long-term: more than 6 years/life of project and beyond | Those impacted would:<br>1) not be able to adapt to the health impact or to maintain pre-impact level of health; or<br>2) see noticeable major improvements in health and overall quality of life. | Extends beyond Potentially Affected Communities; regional and state-wide levels |

Source: ADHSS 2015

Next, the severity and likelihood of each type of impact is evaluated, and those ratings are used to develop an overall significance impact rating category of 1, 2, 3, or 4 (Table K4.10-2). Recommended actions for negative impacts are listed by category below:

- Category 1: Actions to reduce negative impacts are not needed.
- Category 2: Recommend that decision-makers assess whether actions to reduce negative impacts would be helpful for negative impacts.
- Category 3: Recommend that decision-makers develop and implement actions to reduce negative impacts.
- Category 4: Strongly recommend that decision-makers develop and implement actions to reduce negative impacts.

**Table K4.10-2: Steps 2, 3, and 4 – Likelihood and Overall Impact Ratings**

| Step 2 | Step 3 | | | | | | |
|---|---|---|---|---|---|---|---|
| Impact Severity Level (Sum Scores from Step 1 to choose range) | Likelihood Rating | | | | | | |
| | Extremely Unlikely (<1%) | Very Unlikely (1-10%) | Unlikely (10-33%) | About as likely as Not (33-66%) | Likely (66-90%) | Very Likely (90-99%) | Virtually Certain (>99%) |
| 1 to 3 | ♦ | ♦ | ♦ | ♦ | ♦♦ | ♦♦ | ♦♦ |
| 4 to 6 | ♦ | ♦ | ♦ | ♦♦ | ♦♦ | ♦♦ | ♦♦♦ |
| 7 to 9 | ♦♦ | ♦♦ | ♦♦ | ♦♦♦ | ♦♦♦ | ♦♦♦ | ♦♦♦♦ |
| 10 to 12 | ♦♦♦ | ♦♦♦ | ♦♦♦ | ♦♦♦♦ | ♦♦♦♦ | ♦♦♦♦ | ♦♦♦♦ |
| **Step 4** | **Impact Rating** | | | | | | |
| | Category 1 = ♦ | | Category 2 = ♦♦ | | Category 3 = ♦♦♦ | | Category 4 = ♦♦♦♦ |

Source: ADHSS 2015

Although the framework used for the evaluation of health impacts is generally consistent with ADHSS guidance, and the data are considered sufficient for analysis in this Environmental Impact Statement (EIS), it is important to note that any assessment of potential impacts is subject to several types of uncertainty, as summarized below.

- Baseline data used to describe current health status and conditions vary along the spatial and temporal scales; the reported data may range from current, to several years since data were collected; some data are available at the level of individual communities, while others are regional or state-level in scale. For example, Lake and Peninsula Borough (LPB) regional-level baseline data (from 2016-2017) are available for leading causes of hospitalizations by diagnosis, leading causes of non-fatal injuries, and leading causes of death (see Section 3.10, Health and Safety, HECs 2 and 7), while similar regional-level data are not available for the Nushagak/Bristol Bay communities. In other cases, Iliamna Lake/Lake Clark community-level baseline data are available for unintentional injury death rates (2016), but are not available for the Nushagak/Bristol Bay communities (see Section 3.10, Health and Safety, HEC 2). For many health status indicators such as adult alcohol consumption, infectious diseases, and chronic diseases and others, baseline health data are available only at the regional or state level, and are reported at the larger scale. Therefore, not all health conditions are described or evaluated at the same level of precision and timeliness.
- Health consequences related to changes in environmental conditions—such as soil quality and water quality, which can potentially lead to bioaccumulation in foods—are subject to uncertainties. Although the concentrations of chemicals in environmental media under baseline conditions may be known, future concentrations (e.g., as related to end-of-mine life and closure) are evaluated by using conservative modeling approaches that meet NEPA requirements (see Section 4.20, Air Quality; Section 4.14, Soils; and Section 4.18, Water and Sediment Quality). It is likely that these modeling approaches lead to overestimation of the potential for impacts, but do not necessarily represent "worst-case scenarios."
- Although the presentation of baseline health conditions may be based on data of varying levels of completeness and quality, the evaluation of health impacts is generally more qualitative; and some potential health consequences, by their very nature, are complex, and not easily quantifiable. The evaluation of social

determinants of health is particularly subject to uncertainty, because many of the choices that affect social and mental health and behavioral risk factors are made at the level of the individual, and many of the choices may have both beneficial and negative aspects associated with them. Two individuals exposed to the same situation may make very different behavioral choices; therefore, there is uncertainty in trying to predict the aggregate of individual choices at a community level in terms of overall severity, likelihood, and impact rating. The evaluation uses published literature, where feasible, to provide context for this type of uncertainty. In addition, effects related to communicable and non-communicable diseases typically cannot be quantified, because their prevalence depends on numerous environmental, behavioral, and genetic factors. The potential for these indirect health effects to occur is included in the assessment, based on reports of their occurrence at other projects and sites, but the severity and likelihood of their occurrence in relation to the project cannot be precisely estimated.

Where quantifiable evaluations are not possible, qualitative evaluations strive for transparency in professional judgement. To this end, the components of the severity ranking system and the likelihood ranking system follow the gradations described in the ADHSS guidance, and the final impact ratings are based on a combination of severity and likelihood considerations. This allows the reader to clearly understand the basis of the ratings for project-related health consequences.

- Another source of uncertainty is the rating system for "likelihood" of impacts that is employed by the ADHSS guidance. Uncertainties regarding the reliability of impact ratings and the methodology have been pointed out by several authors (Thomson 2008; Petticrew et al. 2007). Uncertainty in estimating likelihood is easier to describe and quantify for certain types of health impacts such as exposure to potentially hazardous materials; and more difficult for other kinds of impacts such as social determinants of health, or diseases (both infectious and non-communicable). For this health assessment, estimation of likelihood is based on a general understanding of baseline health status and trends; project description, including proposed programs and measures to avoid or minimize health impacts; the detailed evaluation of certain types of impacts in other sections of the EIS (e.g., air quality, water quality, socioeconomics, subsistence, and transportation); and publicly available literature regarding these impacts on other, similar projects. The actual likelihood of the impacts may vary from the estimated level.

For each alternative, the consequences of the project activities are described with regard to relevant issues and concerns associated with the eight HECs described in the HIA guidance (ADHSS 2015). Although all components were considered, the project was primarily analyzed as a whole, because effects could not be attributed to a single component (i.e., there was overlap of affected communities for multiple components). Finally, the health consequences are summarized by HEC, and for each alternative as a whole; and expressed as Category 1, 2, 3, or 4. ADHSS does not provide narrative descriptions for these numeric impact category rankings, and only suggests that they be used to propose recommendations for actions.

For the purposes of this assessment, the EIS analysis area is defined as an area that may be affected by physical releases, or changes in economic, subsistence, and health resources and activities. Overall, it includes eight communities in the LPB, seven communities in the Dillingham Census Area, three communities in the Kenai Peninsula Borough (KPB), two communities in Bristol Bay, as well as the surrounding regions and the Municipality of Anchorage. Not all communities are assessed for all health effects, because some effects may be more relevant to some communities than others. A complete listing of the communities in the

EIS analysis area and the HECs for which they are evaluated is provided in Section 3.10, Health and Safety.

### K4.10.1 No Action Alternative

The current baseline condition is assumed as a reasonable proxy to qualitatively evaluate the future in the No Action Alternative. Although there may be some uncertainty associated with the many factors and variables that could impact the health of communities in the EIS analysis area in the future, current trends can be reasonably assumed to continue in the absence of the proposed project. The purpose of this health impact assessment is to evaluate the impacts of the proposed project and its alternatives against baseline conditions, as represented by the No Action Alternative. As a result, no independent quantitative impact discussion (i.e., impact rating) is presented for the No Action Alternative.

The No Action Alternative would have direct impacts related to the Pebble Limited Partnership (PLP) exploration activities, as discussed in Section 4.3, Needs and Welfare of the People—Socioeconomics. PLP exploration-related employment and income—which were realized in the Bristol Bay region over the previous decade—would cease. The PLP employed around 100 to 150 local community members annually at the site during the pre-development phase of the project, which ended in 2012 (Loeffler and Schmidt 2017). Since then, PLP has had a minimal number of workers at the site for exploration and maintenance activities. The exploratory phase of the project revealed that the income earned by residents employed by the project was an important part of the total income earned in local communities, especially those communities close to the mine site; and the income earned by residents close to the mine was greater than the income earned for commercial fishing, indicating that even the limited employment during the exploratory phase had large impacts on the communities. In communities that were further from the mine site, commercial fishing was a larger part of total income. Overall, the current number of direct and indirect jobs would remain roughly the same, and there would be no impact to the regional economy.

Human health impacts associated with the loss of employment opportunities (and subsequent decrease in median household income) primarily concern potential impacts on social determinants of health (SDH) (e.g., income, psychosocial stress, substance abuse, and family stability). Any expected changes in SDH would be relatively minor in magnitude, relative to the baseline, and would largely be confined to the communities closest to the mine site (Nondalton, Iliamna, and Newhalen).There would be no impact to more distant communities in the lower Bristol Bay watershed, such as Dillingham, other than removing uncertainty about the fate of this project. Other health factors would likely be similar to current conditions (baseline), such as potential rates of accidents and injuries, communicable and non-communicable diseases, exposure to hazardous constituents, and access to healthcare services.

Health impacts from the No Action Alternative would not be perceptible, or those impacted would be able to adapt to the impact with ease, and not require medical intervention. Direct effects would be largely similar to baseline levels of health. Current health conditions and trends, as described in Section 3.10, Health & Safety, would continue in the EIS analysis area.

### K4.10.2 Alternative 1 – Applicant's Proposed Alternative

This section presents the environmental consequences to community health for Alternative 1. This evaluates potential impacts (both positive and negative) to the affected communities from the project during all three phases. The HIA includes summaries of the more extensive health and safety evaluations provided in Section 4.27, Spills Risk, regarding human health impacts from potential spills or failures. The potential health impacts from exposure to chemicals due to

a spill or failure are of low likelihood, and are typically short-term, acute exposures, but may also lead to chronic exposure depending on the nature, duration, and migration of the spill. Impacts from potential spills or failures are evaluated in detail in Section 4.27, Spill Risk. Hypothetical spills of diesel fuel, natural gas, copper-gold ore concentrate, chemical reagents, bulk and pyritic tailings, and untreated contact water are assessed using estimates of release rates, volume, and likelihood of occurrence, based on their spill potential and potential spill consequences. Project design measures, standard permit conditions, and best management practices would be implemented for preventing and reducing impacts from potential spills (see Section 4.27, Spill Risk; and Chapter 5, Mitigation). Health impacts related to spills may include psychosocial stress and anxiety regarding the possible or actual occurrence of spills; potential temporary releases of hazardous chemicals to air, water and soil; and possible exposures to chemicals by subsistence resources that are ultimately consumed by humans. Planned measures to address these potential impacts include prompt measures for spill containment, rapid community outreach and notifications, and testing and monitoring of environmental media such as air, water, and subsistence food resources. Additional details are provided in Section 4.27, Spill Risk.

The communities potentially affected by the project range from small, remote, and rural communities to larger regional and urban centers, as discussed in Section 3.10, Health and Safety. The eight communities identified in that section in the LPB would be most closely affected by multiple project components. In addition, three Nushagak/Bristol Bay communities in the Dillingham Census Area were also identified as potentially affected by project components. The Kenai Peninsula Borough and Anchorage would also be potentially affected economically by all components of the project, at a relatively minor level, due to their larger population size, as noted in Section 4.3, Needs and Welfare of the People—Socioeconomics. In addition, more communities have been identified as using the EIS analysis area for subsistence; therefore, these communities could also be potentially affected by all of the components of the project (see Section 3.9, Subsistence).

The consequences (described below per HEC) for all project components would be expected to be more noticeable in smaller, rural communities, and less perceptible in the Municipality of Anchorage. The following HECs were evaluated for potential negative (adverse) and positive impacts from the project.

### K4.10.2.1 HEC 1: Social Determinants of Health

The following sections present the evaluation of potential health impacts, both beneficial and adverse, that are often correlated with SDH. Table K4.10-3 summarizes the potential impact levels and categories for the SDH, including the health effect consequences, magnitude, duration, and geographic extent of the impact, and likelihood of the impact occurring.

**Table K4.10-3: Summary of HEC 1 Impacts: Social Determinants of Health**

| Potential Impact | Project Phase | Negative/ Positive | Health Effect | Magnitude | Duration | Geographic Extent | Severity Ranking | Likelihood Rating | Impact Rating | Impact Category |
|---|---|---|---|---|---|---|---|---|---|---|
| Increase in household incomes, employment, and education attainment | Construction | + | 1 | 2, beneficial impacts to health for affected population during construction and operation | 2, medium-term | 2, entire small communities and limited households in large communities that benefit from regional economic opportunities | **7** | 66 to 90% | ♦♦♦ | **3** |
| | Operations | + | 1 | | 3, long-term | | **8** | 66 to 90% | ♦♦♦ | **3** |
| | Closure | - | 1 | 1, negative impacts due to reduced income, but able to adapt to the change during closure | 3, long-term | 1, limited number of households | **6** | 66 to 90% | ♦♦ | **2** |
| Psychosocial stress | Construction | +/- | 2 | 2, able to maintain pre-impact levels of health with support; negative and beneficial impacts to health for affected population during construction and operation | 2, medium-term | 2, entire small communities and limited households in large communities | **8** | 33 to 66% | ♦♦♦ | **3** |
| | Operations | +/- | 2 | | 3, long-term | | **9** | 33 to 66% | ♦♦♦ | **3** |
| | Closure | +/- | 1 | 1, negative impacts, but would expect and adapt to the change during closure | 3, long-term | | **7** | 33 to 66% | ♦♦ | **2** |
| Family stress and stability | Construction | +/- | 1 | 2, able to maintain pre-impact levels of health with support; beneficial impacts to health for specific population | 2, medium-term | 1, limited number of households | **6** | 10 to 33% | ♦ | **1** |
| | Operations | | | | 3, long-term | | **7** | 10 to 33% | ♦♦ | **2** |
| | Closure | | | | 3, long-term | | **7** | 1 to 10% | ♦♦ | **2** |

## Household Incomes, Employment, and Education Attainment

Increases in household incomes, employment rates, and education attainment would likely result in an improvement to the overall health and well-being of residents living in the communities from which the workforce for the project would be employed, and where ancillary municipal tax revenue might be spent during construction and operations. The economic impacts of household incomes, employment rates, and education attainment are discussed in Section 4.3, Needs and Welfare of the People—Socioeconomics. The following summarizes the findings:

- The project would result in 2,000 jobs during the construction phase, and 850 jobs during the operations phase, and some jobs would continue during closure. PLP has stated that its objective is to maximize opportunities for local hire; first, directly to residents of the EIS analysis area, or those with close ties to the area; and then to Alaska residents in general. It is estimated that 250 employees would come from surrounding communities, and the remaining 600 would be flown to the project from Anchorage or Kenai. However, it is likely that during the construction phase, significant non-Alaskan labor would be required to fill the anticipated 2,000 jobs; potentially as high as 50 percent of hires (PLP 2018-RFI 027). In addition, indirect employment would increase from the services that would be needed to support construction and operation activities (e.g., air services, goods, and supplies). These activities could potentially create a large number of direct and indirect jobs in the region, relative to the population.
- Because mining jobs pay higher than most industry categories, the wages earned would likely be higher than the median household incomes of the potentially affected communities.
- Additional impacts could include potentially stemming the current trend of out-migration, increasing or maintaining the number of schools in the region, and other indirect economic benefits (e.g., taxes, sales/revenue, and other fiscal effects to the regional and local communities).
- The benefits would be more apparent in the small, rural communities closest to the mine site (LPB communities), where even small changes in their economies could have a measureable impact on their overall health and well-being.
- The benefits of these employment opportunities would be felt most in the households of those employees, but the ancillary sales and taxes would benefit the communities, regions, and state as a whole. However, it cannot be assumed that the economic benefits to the communities and region would directly correspond to increased healthcare spending or enhancement or development of community healthcare facilities, because these decisions may require involvement from multiple levels of government.
- During the closure phase, there would be negative impacts related to job losses and decreased income for communities and households, who would then need to adjust to this change.
- Under the Summer-Only Ferry Operations Variant, communities may wish to stockpile food, fuel, and other supplies, or receive shipments via air when the ferry is not operating. In addition, more mine site employees (e.g., truck drivers, ferry/terminal workers) would be needed seasonally during summer operations, but fewer year-round employees would be needed (PLP 2018-RFI 065). This variant would likely lower the income earned by community members in the EIS analysis area, especially those who are in the smaller, rural communities closest to the mine

site, for whom alternative income streams may not be readily available. Overall, the high cost of living for the communities near the transportation corridor would still be lowered under this variant, but not to the extent of the proposed year-round ferry operations.

The positive relationship between educational attainment and income or wealth status is well known (Wolla and Sullivan 2017). The summary impact to human health due to increased household incomes, employment rates, and education attainment for the potentially affected communities would be Category 3 (beneficial) for the construction and operations phases (see Table K4.10-3), because health benefits are expected to result in perceptible minor benefits, and more apparent benefits in the small rural communities, although they may extend to a state-wide level. The duration ratings for this potential impact, as well as all potential impacts/HECs, would correlate with the expected duration of the three phases of the project. The likelihood of this benefit occurring is considered high, because PLP has committed to filling as many positions as possible within the region. The summary impact is considered Category 2 (adverse) for the closure phase, because the affected households would need to replace or adjust to reduced employment and income.

## Psychosocial Stress

As defined by ADHSS (2015), the term psychosocial refers "to social situations that produce psychological distress or psychological relief." Adverse health behaviors may be adopted by people to cope with psychological stress; and likewise, beneficial health behaviors may be fostered during times of perceived optimism and hopefulness (e.g., change in economic and education status; increased food security, improved infrastructure, and access to healthcare services). Poverty, lack of employment, rural and urban isolation, impacts to subsistence practices, cultural change, family instability, and outward and inward migration are some of the social factors that may impact psychological stress. An example would be a community's fear that a proposed project could impact their environment and subsistence resources. Increased stress could also occur from increased exposure to physical stressors such as noise, vibration, and light.

Mine site activities during all phases would increase noise levels above existing outdoor ambient concentrations in proximity of the mine, which could lead to sleep disturbance for recreational or subsistence hunters sleeping outdoors, as discussed in Section 4.19, Noise, and Section 4.5, Recreation; however, beyond 10 miles from the mine site, noise impacts would be well below the existing outdoor sound level. Similarly, the transportation corridor, Amakdedori port, and natural gas pipeline could result in noise impacts that may result in sleep disturbance for overnight recreational and subsistence receptors, depending on their location and proximity to these features, particularly during construction and operations. The noise generated by these activities would also likely displace wildlife from the vicinity of the noise-impacted area, thereby reducing the likelihood of hunting success close to project components. Therefore, subsistence and recreational users would likely stop using these noise-impacted areas. It would result in minimal displacement to other areas with similar habitats during construction, operation, and closure activities. In addition, noise impacts may also be realized for inhabited structures near the Kokhanok spur road, depending on their potential location. Vibration and light could be increased at the mine site, particularly during construction and closure, but the nearest communities (Nondalton, Iliamna, and Newhalen) would be approximately 17 miles away. Overall, noise impacts to communities would be expected to be minimal. Therefore, physical stressors could increase psychosocial stress for individuals on overnight recreational or subsistence trips. However, it is also possible that

recreational and subsistence receptors would adapt and sleep outside the noise-impacted areas, and therefore not experience an increase in psychosocial stress.

Although it is difficult to predict changes in the direction and magnitude of psychosocial stresses and indicators, it is considered that both positive and negative impacts may occur in the area of psychosocial stress. Although the nature of the positive (e.g., financial security) and negative (e.g., increased cultural alienation and depression) effects are well-known and can be qualitatively described, quantitative predictions of the level of change are difficult to estimate. Because the same household and/or individual may be impacted by both positive and negative factors resulting from the project, the nature of the impacts would vary among different populations; and as a result, the likelihood of the different impacts would also be expected to be variable for the project phases.

Some potential health outcomes of psychosocial stress (i.e., indicators) may include substance abuse, suicide (overlaps with HEC 2), and mental health issues. The potential for decreases in psychosocial stress could occur from improved economic opportunities and employment (see Section 3.10, Health and Safety). The project would likely have a drug- and alcohol-free workplace, with a zero-tolerance policy and targeted and random drug testing. Such workplace programs may assist in decreasing existing incidence or habits of drug or alcohol overuse among employees, thereby providing a secondary benefit to their families and communities. Potential decreases in rates of psychosocial stress could also occur, due to the increase in jobs available in the region. New jobs and increased income could contribute to increased family stability, and subsequently lead to decreased rates of poor mental health and lower rates of substance abuse.

There is also the potential for increases in psychosocial stress in the potentially affected communities, related to fear of changes in lifestyle and cultural practices, land encroachment, impact to the environment, and food security and quality associated with both commercial and recreational fishing, and with subsistence activities. Increased travel time and distances to subsistence resources may add to the difficulty of maintaining a subsistence-oriented diet and lifestyle, and could result in an increase in psychosocial stress. The addition of new stressors to the populations in the EIS analysis area could potentially worsen existing mental health conditions, primarily for those individuals that are susceptible and who are not benefiting from increased economic security related to the project or accessory economic development. In the area of the affected communities, there are currently shortages of mental health professionals as a contributing factor to its Medically Underserved Area/Population and Health Professional Shortage Area designations, as noted in Section 3.10, Health and Safety. Any substantial increases in mental health disorders would further strain an already underserved system.

The summary impact to human health due to changes in psychosocial stress for the potentially affected communities is rated as Category 2 (beneficial and adverse) for construction, operations, and closure (see Table K4.10-3). The health effect is expected to result in moderate benefits and risks. However, the likelihood of this impact occurring is considered unlikely for all phases, because it is a multi-dimensional aspect that is influenced by many factors, and the probability of a significant contribution from any one factor would be low.

## Family Stress and Stability

As with psychosocial stress, there may be both decreases and increases in family stress and instability, with different potential causes and effects in different segments of the community. Increases in family stress and instability could occur due to long-term work rotations (i.e., living at the mine site while working, and going home during off periods). Rotational work schedules can increase stress and instability in families, put a strain on relationships and child care, and

may increase feelings of fatigue, anxiety, worry, and jealousy, contributing to domestic violence, extra-marital affairs, and unwanted sexual harassment—particularly of women (Czyewski et al. 2014; Diavik 1999). However, potential decreases in family stress and increases in family stability could also occur due to the increase in jobs available in the region, and increase in household income. Proportions of adverse and beneficial effects cannot be predicted, because the causes and effects would vary among different portions of the population.

The summary impact on human health due to increased family stress for the potentially affected communities is rated as Category 1 (beneficial and adverse) for construction; and Category 2 (beneficial and adverse) for the operations and closure (see Table K4.10-3). The health effect is expected to result in minor benefits and risks. Similar to psychosocial stress, the nature and likelihood of project effects on family stress and stability may be highly variable and unpredictable. Construction and operation are assigned a slightly higher likelihood than closure because it would be expected that individuals in the potentially affected communities would be more directly and extensively affected during the initial phases of the project.

**Summary**

The Category Impact ratings for SDH range from 1 to 3 for the construction and operations phases, and 1 to 2 for the closure phase, and may include both positive and negative impacts. Therefore, it is recommended that decision-makers develop and implement plans and actions to reduce negative impacts for SDH, such as monitoring for exclusion from project-related economic benefits; and increases in psychosocial stress, family stress, and instability.

### K4.10.2.2 HEC 2: Accidents and Injuries

Accidents (e.g., motor vehicle crashes, falls, and fires) can result in unintentional injuries. Unintentional injury (e.g., falls, poisoning, drowning, motor vehicle crashes) is the third leading cause of death in the state and most regions (ADHSS 2017a; ANTHC 2017i). Intentional injuries include homicide and suicide (note: suicide overlaps with HEC 1, psychosocial stress). Non-fatal and fatal intentional and unintentional injuries can place a substantial burden on available healthcare resources (such as hospitals, clinics, and ambulances).

#### Transportation Accidents

Project impacts may be related to surface, water, or air transportation. Transportation-related unintentional accidents and injuries are a leading cause of hospitalizations in the state and in the EIS analysis area (Section 3.10, Health and Safety). Land transportation and motor vehicle incidents are among the three leading causes of hospitalization in the LPB, the Dillingham Census Area, and Bristol Bay Borough, as noted in Appendix K3.10. This is also similar to the state as a whole, although reliable data on actual rates of transportation-related accidents and injury are not readily available for the small rural communities among the potentially affected communities.

The evaluation of potential impacts from transportation (air, surface, and water) and navigation (water) activities is presented in Section 4.12, Transportation and Navigation. Road and ferry terminals would be sited to avoid environmentally sensitive areas, archaeological resources, and areas of known high subsistence use. During project construction, operations, and closure, public access to or through the mine site would be restricted for safety. Along the transportation corridor, spur roads would be gated to prevent traffic on the mine and port access roads. Known trail crossings would be marked, and traffic controls would be implemented for safety (PLP 2018-RFI 027). Additional public access, if any, would be coordinated between the State of Alaska, the LPB, PLP, and landowners.

Potential surface transportation impacts to the public from the project could occur related to taking alternate routes, crossing the access roads at marked crossing points, or other potential community uses such as potential shared use of the project roads and potential use of the ferry to transport the public and snow machines. It should be noted that state and local authorizations may affect final road alignment and uses. Increased travel distances in pursuit of more distant or alternative subsistence resources may also increase the potential for accidents and injuries for community members engaging in subsistence activities.

When Iliamna Lake is frozen, it is used as a travel way for the public on snowmachines. Open water created by the ice-breaking ferry would disrupt some cross-lake snowmachine routes, and could potentially create a safety hazard. PLP would work with communities (and supply funding) to provide for the marking and maintenance of snowmachine trails between communities across Iliamna Lake, when lake ice is thick enough to support such traffic (PLP 2018-RFI-071a). Alternate, marked routes would avoid the ferry path, but would have the potential to add to travel time and distance. The construction of the natural gas pipeline corridor would impact a high-traffic area of Cook Inlet, and could cause navigational hazards for vessels passing nearby on Cook Inlet and Iliamna Lake. Traffic in the community of Kokhanok would see an increase between the airport and the ferry terminal site.

If the Kokhanok East Ferry Terminal Variant were to be built, differences in impacts would occur relative to the proposed south ferry terminal. The Kokhanok East Ferry Terminal Variant has thicker ice for a longer duration than the proposed south ferry terminal. There is a substantial amount of winter traffic between Kokhanok and Sid Larson Bay (to the east of the community), and winter travel routes would cross the Kokhanok east ferry route. However, the creation of an alternate winter travel route along the Kokhanok east spur road with an access point to the lake east of the terminal would mitigate this impact by creating a marked safe route that would not cross ferry traffic, but may add travel time, distance, and fuel costs (PLP 2018-RFI 078) (Section 4.12, Transportation and Navigation). Navigation on Iliamna Lake at the Kokhanok east ferry terminal site would be more sheltered from wind and waves, but would contain more navigational hazards such as shallow water and a longer ferry route (PLP 2018-RFI 078).

If the ferry were to only operate in the summer, the concentrate would be stockpiled in the winter, and truck and ferry trips would double in the summer. This would mean that winter snowmachine traffic across the lake would not be interrupted by an ice-breaking ferry, but vessels on the lake in the summer would experience double the ferry traffic.

Accidents and injuries (mortality and morbidity rates) could occur for mine site workers and for the public at surface access road crossings (at a minimum), if alternate safe routes or mitigation measures were not taken across Iliamna Lake; and from navigation hazards during pipeline construction (see Section 4.12, Transportation and Navigation). For transportation-related accidents and injury, the summary impact to human health due to air, surface, and water transportation are rated Category 2 for all phases (Table K4.10-4). The health effect is assigned a score of 3 (severe) due to the potential for serious health injury and loss of life for all modes of transportation. The magnitude of the effect is assigned a score of 2 for surface and water accidents, because those affected may require medical intervention to maintain pre-impact level of health; while air accidents are assigned a score of 3, because air accidents have a higher likelihood of death, and those affected may be unable to maintain pre-impact level of health. The geographic extent of potential transportation and navigation impacts is assigned a score of 0, because impacts would be limited to individual cases, although the individuals may come from any of the communities in the EIS analysis area. The likelihood of these accidents occurring range from extremely unlikely for air transport (they generally occur rarely), to unlikely for surface transportation (given the currently planned potential for limited public access except at designated crossings, and that service capacity of roadways are expected to be below

capacity, even if final use designation of certain transportation corridor segments also become available to the public), to unlikely for water navigation (given low nautical speeds, but shared waterbodies).

## Other Unintentional Injuries

Unintentional injuries from falls are the primary leading causes of hospitalizations in Alaska, the LPB, and the Dillingham Census Area, as well as the second leading cause in Bristol Bay Borough (Section 3.10, Health and Safety). It is difficult to predict changes in direction and magnitude of these types of injuries due to their unintentional nature. The project would provide safety training (as required by OSHA and MSHA) for all employees; health and safety plans would be developed and implemented; and public access would be prohibited in industrial facilities. Therefore, it is assumed that the project workforce would adhere to the project's safety procedures when traveling or operating in the public domain, and promote the safety culture outside of standard work operations as well (i.e., "outside the fence"). Based on this, the summary impact to human health due to increases in non-transportation unintentional injury rates would be Category 2 for all project phases (Table K4.10-4). The health effect would be considered severe due to the potential for serious health injury and loss of life. The likelihood of this impact occurring is considered very low, because of the potential for promotion of safety awareness and culture, and its likely limited scale.

## Intentional Injury: Suicide Rate

Suicide mortality rates vary by region but are based on rates of less than 20 cases/counts and may not be statistically reliable, as discussed in Section 3.10, Health and Safety. Suicide was the fourth leading cause of death among Alaska Native people during the period 2012 to 2015 (ANTHC 2017f). Suicide, in general, is considered to be an action of low likelihood but high consequence. Similar to psychosocial stress and family stability (HEC 1), it is difficult to predict changes in the direction and magnitude of impacts to suicide rates because it is influenced by complex, multi-dimensional contributing factors. Increases in suicide rates could potentially occur due to increases in psychosocial stress and decreases in family stability. Conversely, decreases in psychosocial stress and increases in family stability may also occur, and could potentially result in decreased suicide rates. Note that although baseline suicide rates for the Bristol Bay region and the Kenai region may appear to be higher than the state average, the data may not be statistically significant due to the low number of reported cases, and any interpretations should be viewed with caution.

The summary impact to human health due to increases in suicide rates would be Category 2 for all project phases (Table K4.10-4). The health effect would be considered severe due to the potential for loss of life. The magnitude of the effect is assigned a score of 3, because those affected would not maintain pre-impact level of health; that is, the negative health effects of suicide are permanent. The geographic extent of this potential impact is assigned a score of 0, because impacts would be limited to individual cases. The likelihood of this impact occurring is considered very low on a large scale (1 to 10 percent). Because the overall impact rating is Category 2, monitoring for noticeable changes in selected key indicators of accidents and injuries, such as surface, water, and air-related accidents, and rates of homicide and suicide is recommended to assist decision-makers assess whether actions to reduce negative impacts would be helpful for negative impacts.

**Table K4.10-4: Summary of HEC 2 Impacts: Accidents and Injuries**

| Potential Impact | Project Phase | Negative/ Positive | Health Effect | Magnitude | Duration | Geographic Extent | Severity Ranking | Likelihood Rating | Impact Rating | Impact Category |
|---|---|---|---|---|---|---|---|---|---|---|
| Increase in unintentional accidents and injuries, morbidity, and mortality rates due to air, surface, and water transportation (same rating unless otherwise noted) | Construction | - | 3 | air = 3, unable to maintain pre-impact level of health<br><br>surface and water = 2, able to maintain pre-impact level of health with medical intervention | 2, medium-term | 0, individual cases | 8 (air)<br>7 (water/ surface) | <1 % (air)<br><br>10 to 33% (surface)<br><br>10 to 33% (water) | ♦♦ | **2** |
| | Operations | | | | 3, long-term | | 9 (air)<br>8 (water/ surface) | | ♦♦ | **2** |
| | Closure | | | | 3, long-term | | 9 (air)<br>8 (water/ surface) | | ♦♦ | **2** |
| Increase in other unintentional injury (e.g., falls, cuts, poisoning) | Construction | +/- | 3 | 2, able to maintain pre-impact level of health with medical intervention | 2, medium-term | 0, individual cases | 7 | 1 to 10% | ♦♦ | **2** |
| | Operations | | | | 3, long-term | | 8 | | ♦♦ | **2** |
| | Closure | | | | 3, long-term | | 8 | | ♦♦ | **2** |
| Increase in Intentional injury: suicide rate | Construction | - | 3 | 3, unable to maintain pre-impact level of health with medical intervention | 2, medium-term | 0, individual cases | 8 | 1 to 10% | ♦♦ | **2** |
| | Operations | | | | 3, long-term | | 9 | | ♦♦ | **2** |
| | Closure | | | | 3, long-term | | 9 | | ♦♦ | **2** |

### K4.10.2.3 HEC 3: Exposure to Potentially Hazardous Materials

This section evaluates the health determinants and outcomes from potential exposure to project-related hazardous materials, relative to baseline conditions, consistent with ADHSS (2015) and NEPA practice. A qualitative evaluation of the potential for human exposures to project-related chemicals to occur is discussed, followed by a screening-level assessment of the magnitude of the exposures and potential for adverse health effects, relative to baseline conditions. As noted above, this section does not independently evaluate human health impacts from potential spills or failures, but does include a summary of the hazardous materials evaluation from Section 4.27, Spills Risk.

The key health outcomes considered are the potential for increases and decreases in illnesses or exacerbation of illnesses commonly associated with exposure to chemicals of potential concern (COPCs) through inhalation, physical (dermal) contact, and direct or indirect ingestion (e.g., direct exposure through incidental soil ingestion, indirect exposure through ingestion of subsistence foods that have the potential to bioaccumulate COPCs).

The nature of the health effects are grouped as non-cancer (e.g., reproductive, developmental, and metabolic effects) and cancer effects, in the context of the Alaska Department of Environmental Conservation's (ADEC's) and US Environmental Protection Agency's (EPA's) commonly used conceptual frameworks to evaluate exposures to hazardous chemicals. Many chemicals may exert adverse noncancer effects on humans, but only a few are considered to be known or probable carcinogens. To simplify initial evaluations of exposure to hazardous chemicals, ADEC, EPA, and other agencies have developed health-protective "screening levels" for a variety of chemicals. These values represent concentrations of each chemical in a medium such as soil, water, or air, where long-term exposure by people would have extremely low likelihood of adverse cancer or noncancer health effects (including adults and sensitive sub-groups such as children, infants, nursing mothers, etc.). The values are intentionally biased to include a large margin of safety. One can understand whether there is potential for a health concern by comparing concentrations at a particular site to these screening levels. The potential for cancer-related health effects is expressed as a statistical probability or "risk"; and the potential for noncancer effects is expressed as a ratio to a safe dose, called a hazard quotient. If the screening levels are exceeded, it does not mean that health effects would occur—only that some additional evaluation may be warranted. The non-cancer screening levels used for comparison were adjusted to one-tenth the acceptable level to be protective of simultaneous exposure to multiple chemicals.

#### Exposure-Based Evaluation

The first step in the HIA evaluation is the exposure pathway identification. This step includes the identification of the primary potential project-related sources of contamination, COPCs, determination of exposure pathway completeness, and an assessment of the likelihood of exposure (e.g., complete but insignificant). The presence of a complete exposure pathway is established when there is an unbroken chain from a project-related COPC source to exposure point for a receptor. If a pathway is incomplete, then there is no exposure and no associated risk.

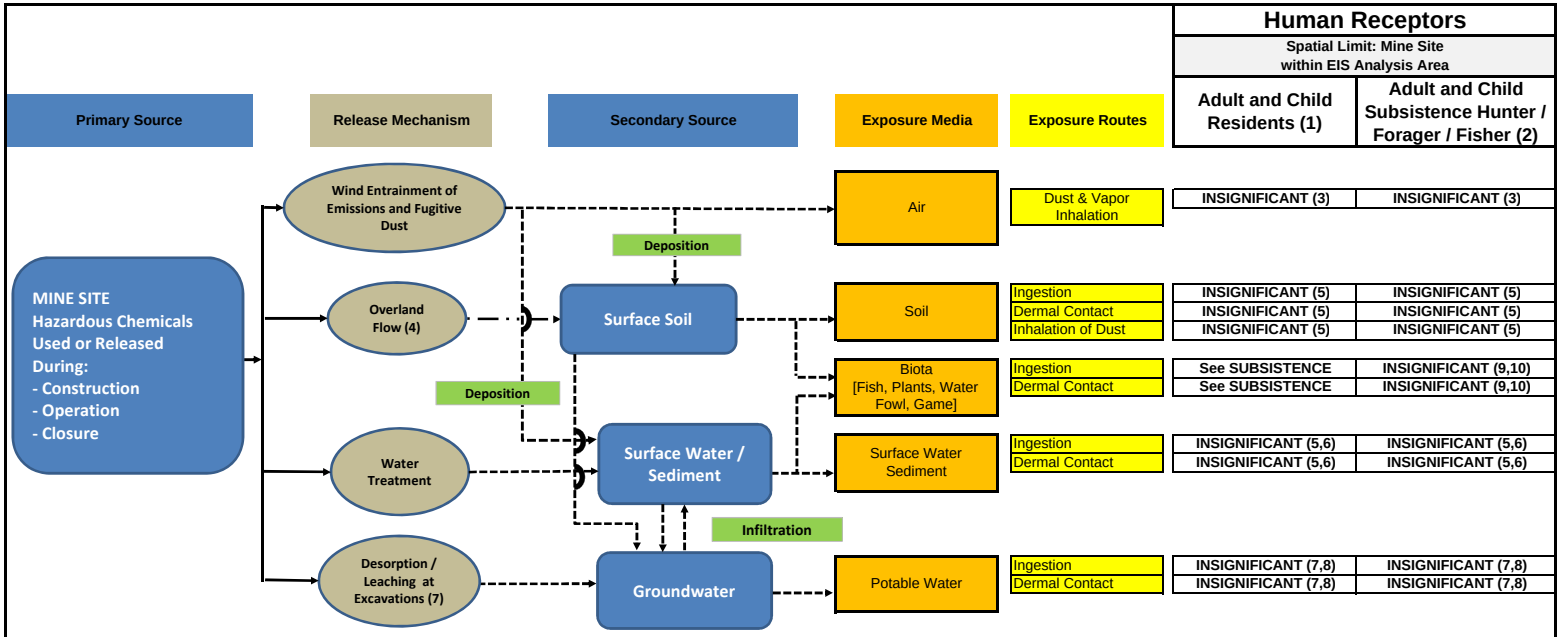
One way to show the exposure pathway analysis is through the use of a conceptual site model (CSM) that illustrates the potential project COPC source(s), release mechanism(s), secondary source(s), exposure media, exposure routes, and types of human receptors, as well as the likelihood of exposure. Likelihood of exposure may be deemed insignificant based on multiple factors; including, but not limited to, expected project mitigation measures or geographical distance from the source. Two Pebble Project CSMs were developed and are presented in

Figure K4.10-1 (mine site) and Figure K4.10-2 (transportation corridor, Amakdedori port, and natural gas pipeline).

The two types of receptors most likely to be exposed to project-related chemicals are identified as residents (adults and children), and area users, including people engaged in recreational or subsistence activities such as fishing, hunting, and gathering. Many of the residents and subsistence users may be the same people. The residential communities closest to the mine site are Iliamna, Newhalen, and Nondalton, each of which is approximately 17 miles away from the mine site. Similarly, the community closest to the transportation corridor and pipeline route is Kokhanok, which would have a spur road to the community. Therefore, everyday exposure by residents to project-related chemicals may be limited; it is more likely that recreational and subsistence activity users may be the most frequent visitors to the areas impacted by project-related chemicals. These users may be residents drawn from the potentially affected communities identified in the EIS analysis area or visitors from other areas.

If people could be exposed to project-related chemicals, then it is important to know what those chemicals are and how high or low that level of exposure might be. For those pathways that are deemed potentially complete and significant, the concentration of any COPCs at the expected exposure points is determined when possible (i.e., the geographical locations where an individual comes in contact with the source material, such as air, soil, groundwater, sediment, surface water, or subsistence foods). Future media-specific exposure point concentrations are estimated, when possible, by modeling expected project-related increases from baseline concentrations. Then, baseline conditions and estimated future concentrations (when available) can be compared to health-protective criteria (also known as screening levels) to determine if health impacts from exposure to hazardous chemicals is unlikely to or could potentially result in human health concerns. In the absence of available estimated future exposure point concentrations, a more qualitative evaluation may be performed to assess potential future exposure and effects. These quantitative and qualitative evaluations are then used to inform risk-management decisions (e.g., impact avoidance, monitoring, and mitigation measures).

The following subsections present the anticipated project sources and COPCs, and the media-specific exposure pathway analysis and exposure concentrations evaluation when relevant.




## LEGEND

**The CSM is based on Alternative 1, and does not evaluate exposure pathways based on unanticipated scenarios (accidents, spills, or failures of mitigation measures) or health impacts to the project-related workforce at the mine site.**

**Exposure Pathways:** "Complete" refers to a potential exposure pathway resulting in receptor exposure of project-related hazardous constituents in various media during any of the project phases.
"Incomplete" refers to a potential exposure pathway with a break in the path that prevents receptors from exposure to project-related hazardous constituents.

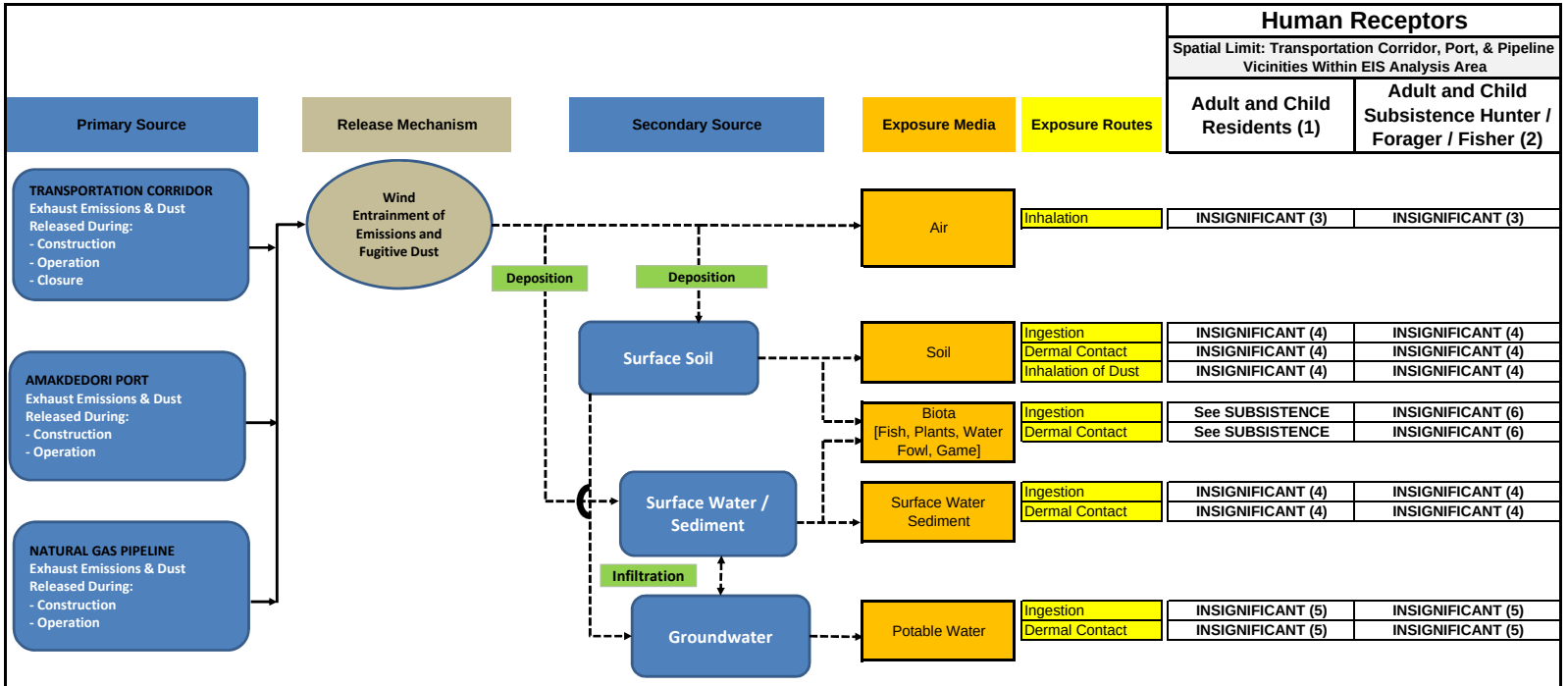
Transport Pathway is incomplete
Transport pathway is complete, but insignificant
Transport pathway is complete

**Notes:**

(1) The closest communities to the mine site are Iliamna, Newhalen, and Nondalton (within the Lake and Peninsula Borough), each of which are approximately 17 miles from the deposit. An additional five Lake and Peninsula Borough communities are within the EIS analysis area, but are further from the mine site (Kokhanok, Port Alsworth, Pedro Bay, Levelock, and Igiugig). In addition, three Nushagak/Bristol Bay communities in the Dillingham Census Area were also identified as near the EIS analysis area (New Stuyahok, Koliganek, and Ekwok). Residential exposure to harvested biota shared by subsistence users is captured and evaluated under subsistence receptors. Likewise, residential direct exposure during recreational activities is captured and evaluated under direct media exposure for subsistence receptors.
(2) Nineteen communities, including the eight in Lake and Peninsula Borough and two in Nushagak/Bristol Bay (Ekwok data insufficient), are known to use the EIS analysis area for subsistence (see Section 3.10, Health and Safety; and Section 3.9, Subsistence).
(3) Mine site construction and operations near-field impact assessments show criteria pollutant annual emissions would be below air quality standards and PSD Class II increments. Mine site closure emissions and impacts are expected to be similar to construction. Mine site HAP annual emissions for all phases are below Title V permit thresholds (see Section 4.20, Air Quality).
(4) Mine site overland flow would not occur; non-contact and contact water would be captured and sent to the water treatment plant (i.e., incomplete).
(5) Mine site dust deposition modeling and estimated media (soil, sediment, surface water) impacts indicate that increases would be negligible, with increases of less than 3.2 percent for antimony, and less than 1 percent for all other metals. Therefore, risks/hazards would be expected to be indistinguishable from baseline (i.e., incremental increase insignificant). See the soil exposure pathway discussions in Section K4.10.2.3, as well as Soils, Section 4.14.
(6) Mine site non-contact and contact water would be treated, and effluent would meet permitting requirements prior to discharge (i.e., insignificant).
(7) During the life of the mine, mine site operations and tailings impacts to groundwater would remain within the mine site boundaries (i.e., incomplete). During post-closure, once groundwater monitoring indicates water quality criteria are met, then direct discharge would occur (i.e., insignificant).
(8) Mine site dust deposition modeling and estimated soil concentrations at the boundary are less than migration to groundwater criteria (i.e., insignificant).
(9) Because soil, sediment, and surface water impacts from mine site dust deposition would be negligible relative to baseline (see Note 5), impacts to wild foods would similarly be expected to be negligible to slight, relative to baseline. Therefore, risk/hazards from ingesting impacted wild foods would be expected to be indistinguishable from baseline (i.e., insignificant). In addition, caribou and moose are likely to avoid areas impacted by dust deposition, and subsistence users may avoid harvesting resources near the mine site and transportation corridor due to air/dust deposition concerns. Therefore, potential dietary exposure to terrestrial wild foods impacted by dust deposition would be anticipated to be low for subsistence users.
(10) There could be a potential for waterfowl to be exposed to mine site standing water bodies (e.g., pit lake, freshwater impoundments, tailings pond); be impacted by contamination; and then harvested "outside the fence" and ingested by the affected communities. However, the pit lake is not anticipated to provide suitable foraging habitat for waterbirds, and therefore, the most likely potential route of exposure is from drinking water from the pit lake. Because waterbirds will have multiple other nearby water sources to drink from that provide higher-quality habitat, they are likely to favor those locations (Section 4.23, Wildlife Values). In addition, impacts to wildlife from all aspects of the project, including around the pit lake, would be minimized or mitigated through PLP's development and implementation of a Wildlife Management Plan (see Chapter 5, Mitigation). Therefore, substantive exposure of wildlife, including waterfowl, is not anticipated (i.e., insignificant).

**Mine Site Conceptual Site Model**

**Figure K4.10-1**




## LEGEND

**The CSM is based on Alternative 1, and does not evaluate exposure pathways based on unanticipated scenarios (accidents, spills, or failures of mitigation measures) or health impacts to the project-related workforce at the mine site.**

**Exposure Pathways:** "Complete" refers to a potential exposure pathway resulting in receptor exposure of project-related hazardous constituents in various media during any of the project phases. "Incomplete" refers to a potential exposure pathway with a break in the path that prevents receptors from exposure to project related hazardous constituents.

- Transport Pathway is incomplete
- Transport pathway is complete, but insignificant
- Transport pathway is complete

**Notes:**

(1) The same eleven affected communities evaluated for the mine site were evaluated for these components, given geographic proximity to the EIS analysis area (see Figure K4.10-1). The eight Lake and Peninsula Borough communities are closest to the transportation corridor, while Kokhanok is the closest community to Amakdedori port (25 miles away). Residential exposure to harvested biota shared by subsistence users is captured and evaluated under subsistence receptors. Likewise, residential direct exposure during recreational activities is captured and evaluated under direct media exposure for subsistence receptors.

Nineteen communities, including the eight in Lake and Peninsula Borough and two in Nushagak/Bristol Bay (Ekwok data insufficient), are known to use the EIS analysis area for subsistence (see Section 3.10, Health and Safety; and Section 3.9, Subsistence).

(3) The Amakdedori port, ferry terminals, and natural gas pipeline compressor station operations near-field impact assessments show $NO_2$ annual emissions would be below air quality standards. Because of lower activity level and criteria pollutant annual emissions for all these project components and phases relative to the mine site operations, it is anticipated that they would have lower near-field impacts than those estimated for the mine site operations, which were found to have near-field modeling less than air quality standards and PSD Class II increments. Total HAP annual emissions for all components and phases are expected to be below Title V permit thresholds (see Section 4.20, Air Quality).

(4) Transportation corridor, Amakdedori port, and the natural gas pipeline activities could result in dust deposition onto soil, surface water, sediment, and vegetation. Because baseline soils would be disturbed during construction, and local rock sources would be used for construction of the roadways, dust deposition would not be expected to increase metal concentrations above baseline conditions. Therefore, any potential impacts would be expected to be indistinguishable from baseline (i.e., insignificant).

(5) Because dust deposition would not be expected to increase metals concentrations above baseline (see Note 4), any subsequent leaching to groundwater would not be expected to result in concentrations above baseline (i.e., insignificant).

(6) Because air emissions would be expected to be below air quality standards and PSD Class II increments (Note 3), and dust deposition would not be expected to increase metals concentrations above baseline (see Note 4), impacts to wild foods above baseline would not be expected (i.e., insignificant). See the air, soil, water, and subsistence exposure pathway discussions in Section K4.10.2.3. Also see Air Quality, Section 4.20; Soils, Section 4.14; Water and Sediment Quality, Section 4.18; and Subsistence, Section 4.9.

**Transportation Corridor, Amakdedori Port, Natural Gas Pipeline Conceptual Site Model**

**Figure K4.10-2**

## Anticipated Project Sources and Chemicals of Potential Concern

The primary anticipated project sources of potential contamination are from hazardous chemicals used, released, or present during construction, operations, and closure. Based on the information presented in Chapter 2, Alternatives, as well as the sections discussing chemical impacts to individual media such as air, soils, water, and others, specific project sources and general categories of COPCs and the media in which they might occur are summarized below:

- Criteria air pollutants and hazardous air pollutants emitted to air: Mine site, transportation corridor, Amakdedori port, and the natural gas compressor station on the Kenai Peninsula air emissions during construction, operations, and closure from stationary sources (e.g., turbines, generators, boilers), mobile sources (e.g., vehicle and mobile equipment exhaust), and fugitive sources (e.g., air particulates from blasting, drilling, vehicle road dust, and wind erosion). The air emission–associated COPCs include criteria air pollutants and hazardous air pollutants (HAPs).
- Metals from materials and handling deposited onto surfaces: Mine site fugitive dust emissions from material and handling activities (mined ore, quarry rock, overburden, and waste rock) could result in wet and dry dust deposition onto soils, waterbodies, and vegetation (e.g., berries). This could result in increased concentrations of metals COPCs above baseline in and outside of the mine site due to the concentration of heavy metals found in orebody materials. The transportation corridor, Amakdedori port, and natural gas pipeline fugitive emissions also have the potential to result in dust deposition. However, because only existing soils with baseline levels of naturally occurring metal concentrations would be disturbed during construction, and local non-PAG rock sources would be used for construction of the roadway, dust deposition would not be expected to increase metals concentrations above baseline conditions (see Section 4.14, Soils).
- Metals from non-potentially acid generating (PAG) waste rock in mine site: Mine site use of non-PAG waste rock for infrastructure construction at the mine (e.g., tailings storage facility [TSF] embankments, water management pond embankments, and roads) could result in negligible metals releases compared to other mine sources, such as material and handling fugitive dust emissions (see Section 4.14, Soils). Non-PAG waste rock is considered to have a low susceptibility to hydraulic and wind erosion. Therefore, the use of non-PAG waste rock for infrastructure construction in the mine site is considered an insignificant source of COPCs (e.g., metals) “inside the fence” at the mine site, and an incomplete source-receptor pathway “outside the fence.”
- Metals in runoff and contact water: Mine site surplus water (e.g., non-contact stormwater runoff and contact water) would be collected separately on site and discharged to downstream drainages during operations and closure after treatment under permits. Contact water influent COPCs would include metals and general water quality parameters (see Section 4.18, Water and Sediment Quality).
- Metals in groundwater: Mine site operations and facilities (e.g., tailings, waste rock, and contact water storage) would directly impact groundwater quality at the mine site. During the life of the mine, groundwater impacts would be expected to be captured by the seepage collection systems or contained in the open pit cone of depression, remaining within the mine site boundaries, and would not be expected to impact the mine drinking water wells north of the core facility (see Section 4.18, Water and Sediment Quality, and Chapter 2, Alternatives). Therefore, mine site groundwater is considered a source “outside the fence” during the operations phase that would not contribute to any complete exposure pathways. Post-closure, once

groundwater seepage collection system monitoring indicates that the water quality meets the approved criteria for discharge without treatment, direct discharge would occur. Similar to mine site effluent, post-closure groundwater COPCs would include metals and other water quality parameters. As discussed in Appendix K.4.17, groundwater levels would be monitored during mine operations to maintain hydraulic containment. Monitoring and contingencies would be further developed as design progresses.

- Metals in dust: Mine site dust deposition could result in increased concentrations of metal COPCs in soil (see discussion above) that could subsequently leach to groundwater.
- Metals in ponds and impoundments: Mine site activities would create new areas of standing water (e.g., freshwater storage impoundments, tailings pond, and pit lake). A variety of birds could potentially be affected by environmental contamination by contact with water and foraging in these locations (see Section 4.23, Wildlife Values). These birds may then be harvested "outside the fence" and ingested by human subsistence receptors (see Section 4.9, Subsistence). COPCs would include metals and other water quality parameters.
- Petroleum-related chemicals in soils and waterways: Transportation corridor operations would include the use of fuel, oil, and lubricants during the normal course of roadway and ferry operations, and these materials could be inadvertently released onto roadbeds or into a water body. These materials are petroleum hydrocarbon COPCs.

Table K4.10-5 presents a list of the project-related COPCs for the health evaluation, individually listing metals, because they are COPCs in multiple media.

**Table K4.10-5: Pebble Project COPCs**

| Chemicals and Compounds | Mine Site, Materials Reagents and Concentrates[1] | Air Pollutants[2] | Mine Site Storage Ponds and WTP[3] | Groundwater[5] | Fugitive Dust Deposition on Soil and Waterbodies[4] | Bioaccumulative and Potential for Subsistence Concern[6] |
|---|---|---|---|---|---|---|
| Mine Site Materials and Reagents | X | | | | | |
| Mine Site Concentrates | X | | | | | |
| Criteria Air Pollutants | | X | | | | |
| Hazardous Air Pollutants (HAPs) | | X | | | | |
| Aluminum (Al) | | | X | X | | |
| Antimony (Sb) | | | X | X | X | |
| Arsenic (As) | | | X | X | X | X |
| Barium (Ba) | | | X | X | | |

**Table K4.10-5: Pebble Project COPCs**

| Chemicals and Compounds | Mine Site, Materials Reagents and Concentrates[1] | Air Pollutants[2] | Mine Site Storage Ponds and WTP[3] | Groundwater[5] | Fugitive Dust Deposition on Soil and Waterbodies[4] | Bioaccumulative and Potential for Subsistence Concern[6] |
|---|---|---|---|---|---|---|
| Beryllium (Be) | | | X | X | X | |
| Bismuth (Bi) | | | X | X | | |
| Boron (B) | | | X | X | | |
| Cadmium (Cd) | | | X | X | X | X |
| Chromium, total (Cr) | | | X | X | X | X[7] |
| Cobalt (Co) | | | X | X | X | |
| Copper (Cu) | X[1] | | X | X | | X |
| Lead (Pb) | | Negligible (less than 0.001 ton per year) | X | X | X | X |
| Manganese (Mn) | | | | X | X | |
| Mercury (Hg) | | | X | X | X | X[7] |
| Molybdenum (Mo) | X[1] | | X | X | | |
| Nickel (Ni) | | | X | X | X | X |
| Selenium (Se) | | | X | X | X | X |
| Silver (Ag) | | | X | X | | X |
| Thallium (Tl) | | | X | X | | |
| Silicon (Si) | | | X | X | | |
| Tin (Sn) | | | X | X | | |
| Vanadium (V) | | | X | X | | |
| Zinc (Zn) | | | X | X | | X |
| Other Water Quality Parameters[6] | | | X | X | | |

Notes:
[1]Individual mine site materials and reagents are presented and discussed in Chapter 2, Alternatives, and Appendix K2. Mine site concentrates include copper-gold concentrate and molybdenum concentrate, which both contain sulfide minerals and other metals present in ore material. Potential mine site reagent, compound, and concentrate releases to the environment are not anticipated, but are evaluated in Section 4.27, Spill Risk.
[2]Criteria pollutants include carbon monoxide (CO), nitrogen oxides (NOx), particulate matter (PM), sulfur dioxide, volatile organic compounds, and lead. Among the 189 chemicals that are regulated as HAPs, the project-related metals HAPs are Sb, As, Be, Cd, Cr, Co, Pb, Mn, Hg, Ni, and Se. The project-related organic HAPs with the largest emissions would be: acetaldehyde, benzene, formaldehyde, hexane, hydrochloric acid, and toluene. For further details, see Air Quality, Section 4.20, and Appendix K4.20.
[3]The chemicals/compounds listed for mine site storage ponds and water treatment plant (WTP) inflows and effluent do not include essential nutrients (e.g., calcium, iron, magnesium, potassium, sodium) or other water quality parameters (e.g., pH, total dissolved solids, hardness, chloride, sulfate). For further details, see Section 4.18, Water and Sediment Quality, and Appendix K4.18.
[4]HAP metals from mine site fugitive wet and dry dust deposition (PLP 2018-RFI 009) to soil and water bodies were evaluated in Section 4.14, Soils; Section 4.18, Water and Sediment Quality; and Appendix K4.18.

[5]Groundwater has the potential to be impacted by the mine site storage pond and WTP compounds and from fugitive dust compounds. Therefore, the potential compounds in groundwater are the same as those potential sources. For further details, see Section 4.18, Water and Sediment Quality, and Appendix K4.18.
[6]Bioaccumulative compounds as identified by ADEC 2017b, Appendix C, Bioaccumulative Compounds of Potential Concern.
[7]Only specific forms of chromium and mercury are bioaccumulative: hexavalent chromium and methyl mercury. As noted in Section 4.14, Soils, there are no anthropogenic sources of hexavalent chromium, nor are mineral assemblages considered favorable for hexavalent chromium genesis (e.g., chromite).

If people are exposed at high enough doses, many metals may exert adverse non-cancer effects (e.g., reproductive, developmental, and metabolic effects) on humans, but only a few are considered to be known or probable carcinogens. Table K4.10-6, below, presents some of the health effects associated with the metals listed in Table K4.10-5.

**Table K4.10-6: Potential Health Effects for Metal COPCs**

| Inorganic Chemicals | Carcinogenic | Non-Carcinogenic |
|---|---|---|
| Aluminum (Al) | Not listed | Neurotoxicity and developmental effects |
| Antimony (Sb) | Not listed | Hematologic effects |
| Arsenic (As) | Lung, liver, kidney, bladder, skin | Hyperpigmentation, keratosis, and possible vascular complications |
| Barium (Ba) | Not listed | Nephropathy |
| Beryllium (Be) | Lung | Small-intestine lesions |
| Bismuth (Bi) | Not listed | Low toxicity |
| Boron (B) | Not listed | Developmental effects (decreased fetal weight) |
| Cadmium (Cd) | Lung | Significant proteinuria (renal toxicity) |
| Chromium (Cr)[1] | Not listed | Reduction in absolute weight of liver and spleen |
| Cobalt (Co) | Lung | Hematopoietic, thyroid, pulmonary, and developmental effects |
| Copper (Cu) | Not listed | Gastrointestinal system irritation |
| Lead (Pb) | Kidney | Neurotoxicity, developmental delays, hypertension, impaired hearing acuity, impaired hemoglobin synthesis, and male reproductive impairment |
| Manganese (Mn) | Not listed | Central nervous system effects |
| Inorganic Mercury (Hg) | Not listed | Hand tremor, increases in memory disturbances, slight subjective and objective evidence of autonomic dysfunction |
| Molybdenum (Mo) | Not listed | Increase in uric acid levels |
| Nickel (Ni) | Lung | Decreased body and organ weights |
| Selenium (Se) | Not listed | Clinical selenosis (degenerative and fibrotic changes, especially of the liver and of the skin and its derivatives) |
| Silver (Ag) | Not listed | Argyria (permanent dark discoloration of skin) |
| Thallium (Tl) | Not listed | Hair follicle atrophy |
| Silicon (Si) | Not listed | Low toxicity |

**Table K4.10-6: Potential Health Effects for Metal COPCs**

| Inorganic Chemicals | Carcinogenic | Non-Carcinogenic |
|---|---|---|
| Tin (Sn) | Not listed | Renal and hepatic lesions |
| Vanadium (V) | Not listed | Decreased hair cystine |
| Zinc (Zn) | Not listed | Decrease in erythrocyte Cu, Zn-superoxide dismutase activity |

Notes:
Not Listed = Not Listed as a carcinogen by EPA
[1] Information for trivalent chromium ($Cr^{3}$+) is presented because there are no anthropogenic sources of hexavalent chromium ($Cr^{6}$+), nor are mineral assemblages considered favorable for $Cr^{6}$+ genesis (e.g., chromite) (see Section 4.14, Soils).
Sources: EPA 2006, 2008; IRIS 1987, 1988a, 1988b, 1989, 1991a, 1991b, 1992, 1994, 1995a, 1995b, 1998a, 1998b, 2004a, 2004b, 2005a, 2005b, 2009; HEAST 2000a, 2000b; NLM 2019a, 2019b.

An evaluation of the potentially complete media-specific exposure pathways are presented below for those project sources identified above that could be sources of COPCs to the affected communities. Those project components that were identified as being an incomplete source of COPCs are not evaluated further below.

## Air Exposure Pathways

Project air emissions could potentially be inhaled by the affected communities, including adult and child residents, subsistence, and recreational users in the vicinity of these project components and phases (e.g., inhalation of particulate matter [PM] from vehicle traffic along the transportation corridor). As noted in ADHSS (2015), air emissions that are in compliance with permits are presumed to be protective of human health; however, unregulated emissions (e.g., particulate deposition from fugitive dust that may contain heavy metals or other potentially toxic substances) may impact wild foods (e.g., berries and other wild plants consumed) and may require evaluation prior to human consumption.

This section describes air quality impacts to health in the context of three types of sources:

- Stationary point sources (air permits required)
- Mobile sources (permits not required)
- Fugitive sources (permits not required)

As detailed in Section 4.20, Air Quality, air emissions were modeled for all project components and phases, except closure phases for the transportation corridor, Amakdedori port, and the natural gas pipeline. Near-field impact assessment was performed for mine site closure and operations (stationary and fugitive sources), Amakdedori port ferry terminal operations (stationary sources), and the natural gas pipeline compressor station operations (stationary source). For the mine site, dispersion modeling was based on the ambient air boundary at the safety zone boundary established around the mine site, from which the public would be precluded to ensure the public would not be exposed to potential work-site safety risks. The predominant wind directions are from the southeast and northwest (PLP 2018 RFI-009). For the near-field impact assessment, dispersion modeling was used to calculate maximum predicted ambient air concentrations (project plus background) for relevant criteria pollutants at the end of each project component and phase (see Section 4.20, Air Quality).

The results of the near-field impact assessment show that mine site closure and operations, Amakdedori port operations, and the natural gas compressor station operations would result in localized impacts, but that criteria pollutant concentrations would be below Prevention of Significant Deterioration (PSD) Class II increments, and below applicable ambient air quality

standards (AAQS), which are protective of human health and the environment. Impacts would dissipate when the activities ceased (PLP 2018-RRFI 009). In the future, the mine, port, and pipeline would undergo a complete permitting analysis, and would be expected to operate in compliance with these permits (Section 4.20, Air Quality). Table K4.10-7 summarizes the near-field modeling performed by component and phase, as well as the results.

The highest emissions are expected to be generated during mine site operations, and emissions from all other project phases and components are expected to be lower in comparison. Therefore, if emissions from mine site operations are considered to be acceptable for human health, it is unlikely that other components or phases would be of concern. Mine site closure, transportation corridor construction and operations, Amakdedori port construction and operations, and the natural gas pipeline compressor station construction and operations total annual emissions from all sources (stationary, fugitive, and mobile) are all estimated to be less than mine site operations total annual emissions (see Section 4.20, Air Quality). Because of lower activity level and emissions during these components and phases relative to the mine site operations, it is anticipated that they would have lower near-field impacts than those estimated for the mine site operations, which were found to have near-field modeling less than AAQS. The transportation corridor, Amakdedori port, and the natural gas pipeline closure/post-closure activities and emissions, which were not estimated, are expected to be similar to construction phases for their respective components within a given year (see construction evaluations/discussions above). In summary, criteria air pollutant emissions for all project components and phases are expected to result in localized impacts during project activities; are anticipated to have near-field impacts below AAQS; and air quality impacts would dissipate when the activities cease.

The near-field impact assessment did not include HAPs. For this health evaluation, the total HAP annual emissions from all project components and phases and sources (stationary, mobile, and fugitive) were compared to the stationary source Title V HAP permit thresholds, which are set at limits protective of human health and the environment. Although this threshold is designed for stationary source permitting evaluations, it is sufficient for the purposes of the EIS to identify if HAP emissions are likely to be a potential health concern (e.g., if total HAP annual emissions are greater than the thresholds). As shown in Table K4.10-7, total HAP annual emissions for all project components and phases are below the individual HAP and total HAP Title V permit thresholds, which are set at limits protective of human health.

**Table K4.10-7: Annual HAP and PM Comparison**

| Project Component | Phase | Hazardous Air Pollutants | | Criteria Pollutants[1] | | |
|---|---|---|---|---|---|---|
| | | Annual Total HAPs[1] (tpy) | Annual HAP Threshold[3] (tpy) | Criteria Pollutants Annual Emissions Estimated? | Near-field Modeled? | Near-field Model Result or Comparison to Operations Phase |
| Mine Site | Construction | 5.5 | 10 / 25 | Yes; All Criteria Pollutants | Yes; All Criteria Pollutants from Stationary and Fugitive Sources | All Criteria Pollutants Below AAQS and PSD Class II increments |
| | Operations | 9.1 | | Yes; All Criteria Pollutants | Yes; All Criteria Pollutants from Stationary and Fugitive Sources | All Criteria Pollutants Below AAQS and PSD Class II increments |
| | Closure | 4.7 | | Yes; All Criteria Pollutants | No; Not Required | Would be less than Mine Site Operations Emissions[4] |
| Transportation Corridor | Construction | 7.35 | | Yes; All Criteria Pollutants | No; Not Required | Would be less than Mine Site Operations Emissions[4] |
| | Operations | 2.6 | | Yes; All Criteria Pollutants | No; Not Required | Would be less than Mine Site Operations Emissions[4] |
| | Closure | No[2] | | No[2] | No; Not Required | Would be less than Mine Site Operations Emissions[4] |
| Amakdedori Port | Construction | 3.6 | | Yes; All Criteria Pollutants | No; Not Required | Would be less than Mine Site Operations Emissions[4] |
| | Operations | 8.9 | | Yes; All Criteria Pollutants | Yes; Only $NO_2$ from Stationary Sources | Below AAQS for $NO_2$; All would be less than Mine Site Operations Emissions[4] |
| | Closure | No[2] | | No[2] | No; Not Required | Would be less than Mine Site Operations Emissions[4] |
| Natural Gas Pipeline Compressor Station | Construction | 0.02 | | Yes; All Criteria Pollutants | No; Not Required | Would be less than Mine Site Operations Emissions[4] |
| | Operations | 0.22 | | Yes; All Criteria Pollutants | Yes; Only $NO_2$ from Stationary Source | Below AAQS for $NO_2$; All would be less than Mine Site Operations Emissions[4] |
| | Closure | No[2] | | No[2] | No; Not Required | Would be less than Mine Site Operations Emissions[4] |

Notes:
tpy = tons per year
[1] For further details on criteria pollutant and HAP annual emissions for each project component and phase, see Section 4.20, Air Quality.
[2] Closure/post-closure emissions were not estimated because they are expected to be similar to construction emissions within a given year (Section 4.20, Air Quality).
[3] Title V Major Source (Permit) Thresholds for individual (10 tpy) and combined (25 tpy) HAPs (EPA 2019).
[4] Because of lower activity level and emissions during these components and phases relative to the mine site operations, it is anticipated that they would have lower near-field impacts than those estimated for the mine site operations

### *Fugitive Air Emission Project Design and Mitigation Measures*

The fugitive air annual emission estimates evaluated above did not account for project design and mitigation measures. The following summarizes the measures that PLP would implement to reduce localized and near-field air quality fugitive dust emissions and impacts:

- Coarse ore would be stockpiled in a covered steel-frame building to minimize dust emissions. Baghouse-type dust collectors would be present where appropriate. Water would be added during operations suppress dust. Specialized bulk cargo containers equipped with removable locking lids would contain thickened concentrates for transport to Amakdedori port. The pyritic tailings and PAG waste would be stored subaqueously during operations, removing the potential for wind erosion and dust dispersion. During closure, the bulk TSF would be reclaimed for revegetation and surface stabilization, eliminating the beaches as a dust source (see Section 4.14, Soils).
- Fugitive emission project sources would not be in close proximity to the potentially affected communities. Potentially affected communities are at distances of at least 17 miles from the Pebble deposit, and greater than 1 mile from the port access road, with the exception of Pedro Bay under Alternative 3. Fugitive dust deposition, snow plow deposition, and other gravel spray impacts would be expected to be fairly localized in the vicinity of the mine project activity, and linearly along either side of the port and access roads. The heaviest dust deposition along the roads would be anticipated to occur within 35 feet (Walker and Everett 1987), but could occur at distances of 330 feet (see Section 4.26, Vegetation). Subsistence and recreational users would likely adjust the resource use areas to target resources that would be less affected by dust deposition (see Section 4.9, Subsistence).
- Mitigation measures would be used to control dust generation at the mine site and along the transportation corridor during operations activities, as well as during construction and closure activities for all components (see Section 4.20, Air Quality). PLP has committed to development of a fugitive dust control plan (FDCP) for mitigation and control of project activity-related fugitive dust and wind erosion. The anticipated FDCP would use best management practices and best available control technology (PLP 2018-RFI 071a). The plan would describe the equipment, methodology, training, and performance assessment techniques that would be used to control fugitive dust from site activities and wind erosion. Potential mitigation and minimization measures, including the fugitive dust control plan, are further addressed in Chapter 5, Mitigation.

### *Summary of Air Exposure Pathway*

In summary, the air inhalation exposure pathway from all project components would not be expected to impact the health of the affected communities, including residents, subsistence receptors, and recreational users, based on the air emission quantitative evaluations above (near-field impact assessments and comparisons to HAP thresholds), and qualitative evaluations (annual emission comparisons and project design features). With implementation of dust mitigation measures, the potential fugitive dust impacts from the project would be further reduced. Therefore, the air inhalation exposure pathway “outside the fence” would be considered a complete but insignificant exposure pathway. Potential impacts from mine site dust deposition onto soil, waterbodies, and wild foods “outside the fence” are discussed below.

## Soil Exposure Pathways

People may come in contact with chemicals in soil by the oral (incidental ingestion), dermal, and dust inhalation routes. Mine site material and handling activities (mined ore, quarry rock, overburden, and waste rock) and wind erosion of exposure bulk tailings could result in fugitive emissions and wet and dry fugitive dust deposition in the mine site and "outside the fence," resulting in increased metals in soil. The metals present in dust may include those already evaluated in the air quality evaluation under the category of HAPs, as well as metals that may be present, but are not listed as HAPs.

The predominant wind directions are from the southeast and northwest (PLP 2018 RFI-009).

At the mine site, the employee camp would be situated northeast of the core mine facility, away from the predominant wind directions. In addition, the mine camps would implement dust deposition mitigation measures, and follow PLP's health and safety plans, which would be protective of the health of mine employees while on-duty, and while off-duty at the on-site camp. Mine site fugitive emissions would not be expected to be a substantial source of metals from dust deposition to off-duty employees at the mine site camp. Therefore, the soil exposure pathway to resident employees "inside the fence" would be considered a potentially complete but insignificant exposure pathway.

### *Deposition of HAP metals onto Soil*

Outside the mine site, members of the affected communities, such as human subsistence receptors and recreational users, could come into direct contact with soil potentially impacted from mine site dust deposition "outside the fence." As discussed in Section 4.14, Soils, potential increases of HAP metal concentrations in soils at the mine site from fugitive dust deposition were estimated using the AERMOD modeling data, dust deposition rates (PLP 2018-RFI 009), and baseline soil data. Dust deposition rates were estimated at the maximum point along the ambient air boundary of the mine site ("at the fence"). Section 4.14, Soils, presents the predicted change in soil quality from mine site dust deposition. These results indicate a small expected increase in metals concentration in soil due to dust deposition "at the fence." Expected concentration increases in the future relative to baseline for all HAP metals (see Table K4.10-5) ranged from 0.11 percent (inorganic mercury) to 0.72 percent (cadmium), with the exception of antimony, which would be expected to increase by 3.04 percent. See Section 4.14, Soils, for further details on selection of fugitive dust COPCs and dust deposition calculations for soils.

At the end of 20 years of mine operations, the concentrations of all evaluated metals in soils would be barely distinguishable from baseline concentrations, and would remain below human health-protective thresholds, with a minor exception for arsenic, cobalt, and manganese. In Section 4.14, Soils, the concentrations of the HAP metals at the end of mine site operations (baseline plus 20 years of dust deposition) were compared to human health comparative action levels (CALs) based on ADEC Method Two – Soil Cleanup Levels. Only arsenic would be expected to have estimated concentrations in the future above the human health CALs. However, given that arsenic baseline concentrations also exceed the CAL, and the negligible increase estimated at end of mine site operations (0.57 percent increase), estimated concentrations in the future would be expected to have negligible increased cancer risk and hazard compared to baseline conditions (increased concentration in the future would be indistinguishable from the cancer and noncancer risks associated with baseline concentration). The natural occurrence of elevated arsenic concentrations in soil is acknowledged in ADEC Technical Memorandum, Arsenic in Soil, dated March 2009; and Notes 11 and 12 of Table B1 (ADEC 2018b). In the remaining metals, the increases from dust deposition would not cause exceedances of the human health CALs, based on available ADEC levels.

For cobalt and manganese, which lack human health CALs based on ADEC levels, the baseline and estimated concentrations at the end of mine operations were compared to the EPA residential soil Regional Screening Levels (RSLs) of 2.3 milligrams per kilogram (mg/kg) and 180 mg/kg, respectively (EPA 2018a; at target hazard quotients of 0.1). Both baseline and estimated concentrations at the end of mine site operations of cobalt and manganese were above the EPA residential RSLs; however, the estimated future hazards would be indistinguishable from baseline hazards, given the negligible increases estimated for concentrations in the future for cobalt (0.30 percent increase) and manganese (0.18 percent increase).

### *Deposition of non-HAP Metals onto Soil*

In addition to the HAP metals evaluated for dust deposition above, non-HAP metals may be present in mine site fugitive dust (e.g., present in soils/ore at mine site). These include aluminum, barium, bismuth, boron, copper, molybdenum, silicon, silver, thallium, tin, vanadium, and zinc. The mean concentration of these metals in the mine site EIS analysis area surface soil (see Appendix K3.14) were compared to ADEC levels (over 40-inch zone), if available; or to EPA residential RSLs at a target hazard quotient of 0.1 (EPA 2018):

- The baseline mean mine site soil concentrations of the majority of metals were less than ADEC levels, or EPA RSLs for soil. Baseline mean mine site soil concentrations of barium (84.9 mg/kg), copper (27.4 mg/kg), silver (0.11 mg/kg), tin (1.94 mg/kg), vanadium (46.4 mg/kg), and zinc (43.9 mg/kg) were much lower than their ADEC levels: barium (1,700 mg/kg), copper (3,300 mg/kg), silver (410 mg/kg), vanadium (420 mg/kg) and zinc (25,000 mg/kg). In addition, the thallium baseline mean concentration (0.24 mg/kg) was lower than the ADEC soil cleanup level (0.83 mg/kg). Boron and molybdenum, which lack ADEC levels, had baseline mean concentrations (4.82 mg/k boron and 1.82 mg/kg molybdenum) much lower than the EPA residential RSLs for soil (1,600 mg/kg boron and 39 mg/kg molybdenum).
- Aluminum, which lacks an ADEC level, had a baseline mean concentration (17,644 mg/kg) that exceeded the EPA residential RSLs for soil (7,700 mg/kg at a target hazard quotient of 0.1). At the more realistic target hazard quotient of 1, the aluminum mean concentration would not exceed the EPA RSLs. Bismuth and silicon did not have ADEC or EPA soil criteria, but are typically considered to be of low human health toxicity.

Many of these metals, particularly barium, boron, copper, molybdenum, silver, tin, vanadium, and zinc, are considered to have low human health toxicity, as indicated by the higher magnitude of their soil screening criteria. In addition, bismuth and silicon are typically considered to be of low human health toxicity. For all of these non-HAP metals, the potential increase from dust deposition over the 20-year mine site operations would be expected to be negligible, similar to HAP metals (most had less than 1 percent increase from baseline, and all had less than 3.2 percent increase). Therefore, any increased non-HAP metal concentrations at the end of mine site operations would be expected to have cancer risks or noncancer hazards indistinguishable from baseline risks/hazards.

Overall, after the operations phase is concluded, it is expected that concentrations of HAP and non-HAP metals in soils would be almost indistinguishable from current baseline concentrations, and would not result in any new exceedances of health-based criteria. Based on the evaluations and discussions presented above, dust deposition impacts to soil would not be expected to impact the health of the affected communities, including subsistence receptors and recreational users, through direct exposure, relative to baseline conditions. Therefore, the soil exposure

pathway from dust deposition "outside the fence" would be considered a complete but insignificant exposure pathway.

## Water Exposure Pathways

**Mine Site Discharges to Surface Waterbodies** – Water discharges from the mine site would be controlled and managed. As discussed in Section 4.18, Water and Sediment Quality, and Appendix K4.18, the stormwater runoff from mine site facilities that does not come in direct contact with mining infrastructure would be treated for sediment prior to discharge (Knight Piésold 2018a). Mine site contact water would be treated before being discharged to the environment to ensure compliance with the most stringent applicable Alaska water quality standards (WQS), which were selected as the lowest of human health, drinking water, water supply, irrigation water, effluent limits, and ecological criteria for each chemical (see Appendix K3.18).

During operations, the mine site would have two WTPs, and both would be constructed with multiple, independent treatment trains, which would enable ongoing water treatment during mechanical interruption of any one train. Both WTPs would use treatment plant processes commonly used in the mining and other industries around the world. Non-contact and contact water discharges would be regulated by ADEC through various permits, and would be treated to meet permit requirements prior to discharge (Section 4.18, Water and Sediment Quality, and Appendix K4.18). As with air, water discharges that are in compliance with permits would be presumed to be protective of human health (ADHSS 2015). Because mine site effluent would be treated to meet permitting requirements prior to discharge, the mine site effluent would not be expected to result in impacts to surface water quality, and would be presumed to be protective of human health, even for the most intensive uses, such as potable use and household water supply. Therefore, the treated mine site effluents (non-contact stormwater and WTP discharges) would not be considered a significant source of COPCs to human receptors "outside the fence." This potential exposure pathway would be complete, but insignificant.

Once groundwater seepage collection systems post-closure monitoring indicates that water quality meets the approved criteria for discharge without treatment, direct discharge would occur. This would occur at approximately year 50 post-closure (Section 4.18, Water and Sediment Quality). Similar to mine site treated effluents, direct discharge of post-closure mine site groundwater would only occur once water quality criteria are met; therefore, it would be considered a complete but insignificant exposure pathway.

**Transportation Corridor Minor Releases to Surface Waterbodies** – Transportation corridor operations could result in the inadvertent release of vehicle- or ferry-related materials (fuel, oil, and lubricants) during the normal course of operations. These inadvertent releases could occur onto the roadbed and runoff into stream or pond substrates, or be released into Iliamna Lake and incorporated into lakebed substrate. As discussed in Section 4.18, Water and Sediment Quality, these potential impacts on freshwater sediment contamination would extend throughout the life of the mine and into post-closure. Similarly, marine vessel operations could result in inadvertent releases of materials (fuel, oil, and lubricants) during normal operations to Kamishak Bay and Cook Inlet waters, and become incorporated into seafloor sediment. However, any marine sediment contamination would be expected to contribute a negligible amount of contamination to baseline levels, given the dilution and flushing at Amakdedori port, and the ongoing flushing of seawater at Cook Inlet (see Section 4.18, Water and Sediment Quality). Therefore, this potential exposure pathway would be considered potentially complete, but insignificant.

**Mine Site Fugitive Dust Deposition to Surface Waterbodies** – Mine site material and handling activities (mined ore, quarry rock, overburden, and waste rock) would result in fugitive emissions that could result in wet and dry dust deposition "outside the fence," and could result in increased HAP metals in waterbodies. As discussed in Section 4.18, Water and Sediment Quality, and Appendix K4.18, Water and Sediment Quality potential increases of HAP metal concentrations in sediments at the mine site from fugitive dust deposition were estimated using the AERMOD modeling data, dust deposition rates (PLP 2018-RFI 009), and baseline sediment data. Dust deposition rates were estimated at the maximum point along the ambient air boundary of the mine site (i.e., "at the fence"). Appendix K4.18, Water and Sediment Quality presents the predicted change in sediment quality from mine site dust deposition. These results indicate a small expected increase in metals concentration in sediment due to dust deposition. Expected concentration increases in the future relative to sediment baseline for all metals ranged from 0.11 percent (manganese) to 0.66 percent (cadmium), with the exception of antimony, which would increase by 3.17 percent. See Appendix K4.18, Water and Sediment Quality for further details on these calculations.

Similar to soils, the estimated sediment HAP metal concentrations at the end of mine site operations were compared to soil-based human health CALs, under the assumption that people may come in direct contact with sediments during fishing or other recreational activities. As presented in Appendix K4.18, Water and Sediment Quality arsenic is the only metal with estimated concentrations in the future above the human health CALs based on ADEC levels, but baseline concentrations also exceed the CAL. For cobalt and manganese, which lack human health CALs based on ADEC levels, the baseline and estimated concentrations in the future were compared to the EPA residential soil RSLs (at target hazard quotients of 0.1) of 2.3 mg/kg and 180 mg/kg, respectively (EPA 2018a). Both baseline and estimated concentrations of cobalt and manganese at the end of mine operations were above the EPA residential RSLs. The estimated future risk/hazards for arsenic, cobalt, and manganese would be indistinguishable from baseline risk/hazards, given the negligible increases estimated for sediment concentrations in the future for arsenic (0.41 percent), cobalt (0.25 percent increase), and manganese (0.11 percent increase). Therefore, mine site dust deposition impacts to sediment would not be expected to impact the health of the affected communities, including subsistence receptors and recreational users, through direct exposure, relative to baseline conditions. Therefore, the sediment exposure pathway from dust deposition "outside the fence" would be considered a complete but insignificant exposure pathway.

Next, the potential increases of HAP metal concentrations in surface water at the mine site from fugitive dust deposition were estimated as detailed in Appendix K4.18, Water and Sediment Quality, which presents the predicted change in surface water quality from dust deposition at the NFK watershed, SFK watershed, UTC, and Frying Pan Lake. These results indicate a small expected increase in metals concentration in surface water at each of these watersheds/waterbodies due to dust deposition. Expected concentration increases at the end of mine operations relative to baseline ranged from 0.11 percent (manganese) to 0.66 percent (cadmium), and caused no exceedances of the most stringent Alaska WQS, which are presumed to be protective of human health. Therefore, the surface water exposure pathway from dust deposition "outside the fence" would be considered a complete but insignificant exposure pathway.

**Mine Site Fugitive Dust Deposition to Groundwater** – As discussed above under the soil exposure pathways, mine site wet and dry dust deposition impacts were estimated at the boundary of the mine site (i.e., "at the fence"), and could result in negligible increases of HAP metals concentrations in soil. Metals in soil may subsequently leach to groundwater, representing a potential source of increased metals to groundwater in the EIS analysis area.

The closest potentially affected communities to the mine site are Iliamna, Newhalen, and Nondalton, each of which is approximately 17 miles away. All three have community drinking water wells. The dust deposition impacts would be less in proximity to these communities, and other potentially affected communities farther away, than those modeled at the mine site boundary. However, any dust deposition onto soils near the communities may subsequently leach to groundwater, which could be used as drinking water by the affected communities.

Appendix K4.18, Water and Sediment Quality uses the baseline and estimated soil concentrations of HAP metals in soil at the end of mine operations due to dust deposition, and compares them to CALs, based on ADEC levels. The migration to groundwater CAL represents the soil concentration level at which there would be potential for substances to leach to groundwater and pose a human health risk or hazard (ADEC 2017b). With the exception of arsenic, baseline and predicted concentrations of metals in soil at the end of mine operations would be below the migration to groundwater CALs based on ADEC levels, below which human health is presumed to be protected, as shown in Appendix K4.18, Water and Sediment Quality. Although estimated future arsenic concentrations in soil exceed the migration to groundwater CAL, this is primarily due to the baseline soil conditions that also exceed the migration to groundwater CAL. Given the low magnitude of increase of arsenic in soil at the end of mine operations relative to baseline (0.57 percent), the migration of arsenic in soils to groundwater at the end of mine operations would be expected to be indistinguishable from baseline soil-to-groundwater migration, and could result in potential negligible increases of arsenic in groundwater in the future, relative to baseline.

For cobalt, lead, and manganese, which lack migration to groundwater CALs based on ADEC levels, the baseline and estimated concentrations at the end of mine operations were compared to the EPA residential soil to groundwater RSLs of 0.027 mg/kg, 14 mg/kg, and 2.8 mg/kg, respectively (EPA 2018a; at target hazard quotients of 0.1). Lead baseline and future estimated concentrations were below the EPA residential RSL. Both baseline and estimated future concentrations of cobalt and manganese were above the EPA residential RSLs; however, the estimated future hazards would be indistinguishable from baseline hazards, given the negligible increases estimated for concentrations at the end of mine operations. Therefore, the incremental cobalt and manganese risk/hazard from exposure to future groundwater would be expected to be indistinguishable from baseline risk/hazard in groundwater.

Based on the evaluations and discussions presented above, dust deposition impacts to soil and subsequent potential migration to groundwater would not be expected to impact the health of the affected communities relative to baseline groundwater conditions. Therefore, the groundwater exposure pathway from dust deposition “outside the fence” would be considered a potentially complete but insignificant exposure pathway.

## Subsistence Foods Exposure Pathways

Exposure to project-related chemicals through food may occur in two ways: first, people may consume food resources on which dust containing chemicals has been deposited directly, such as berries and other plant produce. Second, people may consume food that has taken up project-related chemicals from the surrounding environmental media by a process of bioaccumulation (e.g., uptake of metals by edible fish from water or invertebrate prey items, or uptake by plants from soils). The potential for bioaccumulation varies greatly among metals, and this evaluation considers only those metals identified by ADEC or EPA as bioaccumulative. ADEC considers several metals to be potentially bioaccumulative (e.g., arsenic, cadmium, hexavalent chromium, copper, lead, methyl mercury, nickel, selenium, and zinc; ADEC 2017b). As noted in Section 4.14, Soils, there are no anthropogenic sources of hexavalent chromium, nor are mineral assemblages considered favorable for hexavalent chromium genesis

(e.g., chromite); therefore, chromium is not evaluated for the bioaccumulative food exposure pathways.

Affected communities, particularly rural residents, consuming a subsistence diet may be exposed to higher levels of bioaccumulative compounds because subsistence foods may compose a very large portion of their daily dietary intake. Section 4.21, Subsistence, notes that subsistence users may avoid harvesting resources near the mine site and transportation corridor due to air/dust deposition concerns; and may avoid harvesting waterfowl because of concerns about birds becoming contaminated from landing on and using open water at mine site facilities. However, this health assessment also evaluates the potential exposure of project-related chemicals that may be released to primary media (e.g., soil, surface water, sediment) and may be bioaccumulated in biota (e.g., subsistence foods), which in turn could be ingested by subsistence receptors. The subsistence receptor evaluation is protective of residential exposure to harvested biota shared by subsistence receptors, and of residential recreational exposure. Because the subsistence receptor evaluation captures and is protective of these potential exposure pathways (i.e., residential exposure to subsistence foods and residential recreational exposure), they are not evaluated separately.

**Consumption of Terrestrial Plant Foods Impacted by Mine Site Dust Deposition** – As previously discussed, mine site fugitive emissions would result in direct dust deposition to soil and vegetation (e.g., berries) in the EIS analysis area. In addition, vegetation may uptake metals in soil impacted by dust deposition. As discussed in Section 4.26, Vegetation, the duration of the effects from fugitive dust on vegetation may be seasonal, because dust is washed off the vegetation/berries surrounding the project during winter months, or can occur throughout the duration of project activities. The geographic extent of effects to vegetation from fugitive dust is areas adjacent to the construction activities, active mine site, and roads with vehicle traffic or in unpaved surface areas, with the highest concentrations of dust closest to the source (see Section 4.26, Vegetation). The heaviest dust deposition along the roadways would be anticipated to occur within 35 feet of the roadways (Walker and Everett 1987), but could occur at distances of 330 feet (Walker et al. 1987a; Section 4.26, Vegetation). In addition, because mine site dust deposition from fugitive emissions is expected to result in only slight increases in metal concentrations in soil at the mine site boundary (all less than 1 percent increase, except antimony at 3.2 percent increase), potential uptake of metals into plants from dust-impacted soil would be expected to be indistinguishable from baseline. Therefore, potential dietary exposure to plant foods impacted by dust deposition would be anticipated to be low for subsistence users. Given these considerations, this exposure pathway (consumption of plant foods potentially impacted by mine site dust deposition) is considered potentially complete, but insignificant.

**Consumption of Terrestrial Wildlife Resources with Bioaccumulative Chemicals** – As noted above, mine site fugitive dust emissions have the potential to directly deposit onto vegetation, or may result in plant uptake of metals in soil impacted by dust. In turn, this vegetation has the potential to be ingested by herbivorous and omnivorous wildlife, which may subsequently be harvested and consumed by subsistence users. As noted earlier, the potential for bioaccumulation varies greatly among metals, and this evaluation considers only those metals identified as bioaccumulative.

As discussed in Section 4.23, Wildlife, caribou are likely to avoid the mine site facilities and may avoid a 6.8- to 8.7-mile radius around the mine site. The Mulchatna caribou herd currently does not typically range in the area of the transportation and natural gas pipeline corridors. They are not anticipated to occur in large numbers in the area of the project, and may only be encountered on rare occasions. Moose densities are low in the vicinity of the mine site due to a lack of suitable habitat. Moose are known to occur more commonly in the transportation corridor

(due to higher-quality habitat); however, moose are anticipated to avoid areas along the roadways, with avoidance areas of approximately 0.6 mile on either side of the roadways. The level of avoidance would vary depending on time of day and actual vehicular traffic, and is likely to increase under the Summer-Only Ferry Operations Variant, where vehicle traffic would be doubled during the summer (see Section 4.23, Wildlife). Given these considerations, potential for dietary impacts to caribou and moose from mine site dust deposition onto vegetation would be anticipated to be low.

Increases of terrestrial wildlife (upland game) at the end of project operations would be expected to be negligible to slight, given the predicted negligible increases of HAP metals in abiotic media at the end of project operations. In addition, the other non-HAP metals that are potentially bioaccumulative (copper, silver, and zinc) would also be expected to have negligible increases from baseline, and are considered to have low human health toxicity, as indicated by their higher ADEC levels (see Soil Exposure Pathway, above). Therefore, risks and hazards to the affected communities from harvesting and ingesting terrestrial wildlife would be expected to be indistinguishable from baseline. In addition, caribou and moose are likely to avoid areas impacted by dust deposition, and subsistence users may avoid harvesting resources near the mine site and transportation corridor due to air/dust deposition concerns. Therefore, potential dietary exposure to terrestrial wildlife impacted by dust deposition would be anticipated to be low for subsistence users. Given these considerations, this exposure pathway (consumption of wildlife with bioaccumulative metals potentially impacted from mine site dust deposition) is considered potentially complete, but insignificant.

**Consumption of Fish and Waterbirds with Bioaccumulative Metals** – As previously discussed, mine site fugitive emissions would result in direct dust deposition to surface water bodies in the EIS analysis area. In addition, mine site activities would create new areas of standing water in the mine site that may attract waterbirds, including various freshwater storage impoundments, the tailings pond, and the pit lake. Edible fish have the potential to uptake bioaccumulative metals from water, sediments, or invertebrate prey items; and waterbirds have the potential to uptake bioaccumulative metals in water and aquatic prey items. The edible fish and waterbirds may then be harvested "outside the fence," and consumed by subsistence users.

***Fish*** – Estimated concentrations of HAP metals at the end of mine site operations would cause no exceedances of the most stringent Alaska WQS (see Appendix K3.18, Water and Sediment Quality). Selection of the most stringent Alaska WQS included evaluation of criteria protective of the environment and human health (see Water Exposure Pathways), including evaluation of available ADEC human health criteria based on consumption for aquatic organisms. Of the bioaccumulative HAP metals, human health criteria based on consumption for aquatic organisms were available for mercury, nickel, and selenium (although other criteria were ultimately selected as the most stringent Alaska WQS).

ADEC human health criteria based on consumption of aquatic organisms were available for two of the potentially bioaccumulative non-HAP metals (copper at 1,300 micrograms per liter [µg/L], and zinc at 69,000 µg/L). Given the slight increases estimated for the HAP metals in surface water (less than 1 percent for all HAP bioaccumulative metals), and the baseline concentrations for copper and zinc are well below these criteria (see Appendix K3.18, Water and Sediment Quality), any potential increases at the end of mine life would be expected be below the criteria protective of consumption of aquatic organisms.

Although ADEC human health criteria based on consumption of aquatic organisms were not available for the remaining bioaccumulative HAP metals (arsenic, cadmium, and lead), or for the remaining non-HAP bioaccumulative metal (silver), ADEC drinking water criteria were available

for arsenic and cadmium, and were considered in the selection of the most stringent Alaska WQS, for which predicted surface water concentrations at the end of mine site operations did not exceed. Another criterion for cadmium was selected because it was more stringent (see Appendix K3.18, Water and Sediment Quality). In addition, surface water concentrations at end of mine operations for lead and silver (see Appendix K3.18, Water and Sediment Quality) were below EPA RSLs for tapwater (EPA 2018a): 15 µg/L for lead, and 9.4 µg/L for silver.

In summary, surface water concentrations are expected to be below water quality criteria protective of the environment and human health (although based on drinking water in some instances). Increases of all bioaccumulative metals in fish at the end of the project operations phase would be expected to be negligible to slight, given the predicted negligible increases of HAP metals in surface water at the end of project operations. Given these considerations, this exposure pathway (consumption of fish with bioaccumulative metals potentially impacted from mine site dust deposition) is considered potentially complete, but insignificant.

***Waterbirds*** – A variety of birds could potentially use the new areas of standing water at the mine site, especially the pit lake, during migration; and be affected by environmental contamination through contact with water and foraging in these locations (see Section 4.23, Wildlife Values). These birds may then be harvested "outside the fence," and ingested by human subsistence and recreational receptors (see Section 4.9, Subsistence).

Appendix K4.18 presents the predicted concentrations of metals and water quality parameters in mine site standing water bodies during operations and post-closure (extending from 20 years to 125 years post-closure). Multiple bioaccumulative metals (arsenic, cadmium, copper, lead, mercury, nickel, selenium, silver, and zinc) would be predicted to exceed their water quality criteria in one or more of the standing water features. The concentrations of these metals would vary throughout the decades post-closure; however, even at 125 years post-closure, these metals would still be elevated above water quality standards (see Section 4.23, Wildlife Values).

Waterbirds can ingest metals from a variety of sources, including directly from drinking water, food, substrate, and vegetation. The pit lake is not anticipated to provide suitable foraging habitat for waterbirds, because it is anticipated to be deep; contain no shallow water habitats (due the steep sides); and not support freshwater vegetation that is attractive to many species of waterfowl and shorebirds. Therefore, the most likely potential route of exposure is from drinking water from the pit lake. Because waterbirds would have multiple other water sources to drink from (such as nearby Frying Pan Lake to the south, and Long and Nikabuna lakes to the north) that provide higher-quality habitat, they are likely to favor those locations (Section 4.23, Wildlife Values).

Overall, bioaccumulation potential is expected to be low for migratory waterfowl, because they would not be expected to have sufficient exposure to the mine site water storage features, including the pit lake. Impacts to wildlife from all aspects of the project, including around the pit lake, would be minimized or mitigated through PLP's development and implementation of a Wildlife Management Plan (WMP). The WMP would be developed for the project prior to commencement of construction. The WMP would detail the best management practices, including describing the equipment, methodology, training, and assessment techniques that would be used to minimize the potential for wildlife interaction and minimize impact to species (see Section 4.23, Wildlife Values; and Chapter 5, Mitigation). Based on the discussions presented above, this potential exposure pathway (consumption of waterbirds with bioaccumulative metals potentially exposed to mine site standing water areas) is considered potentially complete, but insignificant.

## Evaluation of Mercury

The potential impacts of all the metals considered to be COPCs have been evaluated under HEC 3, and are not expected to be a concern. Mercury is often mentioned as a particular concern by stakeholders and the communities, and its evaluation is briefly summarized here. For this project, mercury occurs only as a naturally occurring metal in soils and ores, and is not used as a processing chemical or reagent during any part of the mining, extraction, processing, or transportation processes. Therefore, the only source of mercury in this project would be release of naturally occurring mercury from handling of soils and ores.

Although mercury is present in many chemical states, it is most often characterized as the less-toxic inorganic mercury than the more-toxic organic form called methylmercury. Inorganic mercury also has the potential to be moderately volatile in the environment. Methylmercury is typically formed through biological activity only in reducing environments such as sediments with low oxygen content and available sulfides. It then accumulates in aquatic tissues, particularly fish, and can thereby be consumed by humans.

Mercury can be toxic to adults and children, including infants and developing fetuses (ATSDR 1999). Exposure to high levels of metallic, inorganic, or organic mercury can permanently damage the brain, kidneys, and developing fetus. Very young children are more sensitive to mercury than adults. Mercury in the mother's body passes to the fetus and may accumulate there, possibly causing damage to the developing nervous system. It can also pass to a nursing infant through breast milk. Mercury's harmful effects that may affect the fetus include brain damage, mental retardation, incoordination, blindness, seizures, and inability to speak. Children poisoned by mercury may develop problems of their nervous and digestive systems, and kidney damage.

In this evaluation, the status of naturally occurring mercury in the environmental media has been demonstrated to be as follows: in air, mercury is included in "total HAPs," which are below AAQS and Class II PSD increments for the modeled components and phases, including mine site operations. Other components and phases have lower activity level and emissions relative to the mine operations; therefore, it is anticipated that they would have lower impacts than those estimated for the mine operations. In soil, the projected increase in mercury concentrations at the end of mine operations is a 0.11 percent increase in inorganic mercury, which would be indistinguishable from current baseline levels. Mercury discharges to surface water from mine operations are not expected to be a concern, because anticipated total mercury would be less than the lowest of criteria that are protective of human health and aquatic life. Mercury deposition to surface water and sediment is also expected to be lower than the most stringent health-protective surface water and soil criteria. Because the increases of mercury in soil, surface water, and sediment are expected to be almost indistinguishable from current baseline levels, no measurable increases are expected in plant life, terrestrial wildlife, or aquatic biota, including fish. The levels in fish would be lower than Alaska water quality standards for human fish consumption. Although waterfowl in standing-water ponds may be exposed to mercury in water and subsequently consumed by people, the WMP would be used to minimize/mitigate exposure, and waterbirds are likely to favor other waterbodies outside the mine site because they would provide higher-quality habitat.

Overall, although the toxicity of mercury is an understandable concern for stakeholders, it is not expected to be a health concern for this project, because it is not used in processing; future concentrations are not expected to exceed current baseline levels and/or health-protective screening levels; and exposure reduction plans would be in place for waterfowl.

**Summary of HEC 3 Impacts**

The mine site CSM (Figure K4.10-1) and transportation corridor, Amakdedori port, and natural gas pipeline CSM (Figure K4.10-2) present an illustrated summary of the exposure pathway analysis. All potential exposure pathways were either incomplete; potentially complete but insignificant; or complete but insignificant.

Table K4.10-8 summarizes the potential impact levels for the potentially complete hazardous chemical exposure pathways, including the potential health effect consequence, magnitude, duration, and geographic extent of the impact, and likelihood of the impact occurring based on the evaluations presented above.

The summary impact to human health is rated Category 2 for potential increased risk of exposure to potentially hazardous chemicals in air, soil, surface water, sediment, groundwater, and wild foods. For all project components during all phases, the health effect was assigned a score of 1 (minor risks to illness or injury patterns), because most environmental changes would be similar to or only slightly above baseline. The magnitude of these impacts is expected to be minor, and is assigned a score of 1, because those impacted are expected to adapt, such as though avoidance of dust-deposited foods. The geographic extents of these impacts are assigned a score of 2, because the affected communities could be impacted at a community level. The likelihood of these impacts occurring is very unlikely (1 to 10 percent) for the transportation corridor, Amakdedori port, and the natural gas pipeline, because impacts above baseline would not be expected. The likelihood of impacts from the mine site would be unlikely (10 to 33 percent), because the potential incremental cancer risk and non-cancer hazards would be expected to be indistinguishable from baseline risks and hazards. The likelihood of impacts for subsistence foods would be as likely as not (33 to 66 percent), because it depends partially on behavioral factors such as avoidance of dust-deposited or impacted areas by fish, wildlife, and waterfowl.

The overall rating of Category 2 means that measures for the avoidance of negative impacts may be considered. There is some inherent uncertainty in the estimates of concentrations of chemicals in environmental media and subsistence organisms for a period 24 years in the future. This uncertainty is minimized by using conservative assumptions that may tend to overestimate future concentrations, but could also benefit by field validation in the form of monitoring programs to track COPC concentrations in environmental media in the areas where people may come in contact with soil, water, and other resources. In addition, dependence on behavioral factors by people and wildlife, such as avoidance of dust-deposited plant materials and metal-contaminated pit lakes and impoundments, may also benefit by surveys and monitoring programs to confirm that such avoidance is occurring to help reduce exposure.

**Table K4.10-8: Summary of HEC 3 Impacts: Exposure to Potentially Hazardous Materials**

| Potential Impact | Project Phase | Negative/ Positive | Health Effect | Magnitude | Duration | Geographic Extent | Severity Ranking | Likelihood Rating | Impact Rating | Impact Category |
|---|---|---|---|---|---|---|---|---|---|---|
| Increased risk of exposure to potentially hazardous chemicals in air | Construction | - | 1 (M), 1 (T, Pi, Po) | 1 | 2, medium-term | 2, potentially affected community | 6 (M) 6 (T, Pi, Po) | 10 to 33% (M) 1 to 10% (T, Pi, Po) | ♦ | **1** |
| | Operations | | | | 3, long-term | | 7 (M) 7 (T, Pi, Po) | | ♦♦ | **2** |
| | Closure | | | | 3, long-term | | 7 (M) 7 (T, Pi, Po) | | ♦♦ | **2** |
| Increased risk exposure to potentially hazardous chemicals in surface water and sediment | Construction | - | 1 (M), 1 (T, Pi, Po) | 1 | 2, medium-term | 2, potentially affected community | 6 (M) 6 (T, Pi, Po) | 10 to 33% (M) 1 to 10% (T, Pi, Po) | ♦ | **1** |
| | Operations | | | | 3, long-term | | 7 (M) 7 (T, Pi, Po) | | ♦♦ | **2** |
| | Closure | | | | 3, long-term | | 7 (M) 7 (T, Pi, Po) | | ♦♦ | **2** |
| Increased risk of exposure to potentially hazardous chemicals in groundwater | Construction | - | 1 (M), 1 (T, Pi, Po) | 1 | 2, medium-term | 2, potentially affected community | 6 (M) 6 (T, Pi, Po) | 1 to 10% (M, T, Pi, Po) | ♦ | **1** |
| | Operations | | | | 3, long-term | | 7 (M) 7 (T, Pi, Po) | | ♦♦ | **2** |
| | Closure | | | | 3, long-term | | 7 (M) 7 (T, Pi, Po) | | ♦♦ | **2** |
| Increased risk of exposure to potentially hazardous chemicals in soil | Construction | - | 1 (M), 1 (T, Pi, Po) | 1 | 2, medium-term | 2, potentially affected community | 6 (M) 6 (T, Pi, Po) | 10 to 33% (M) 1 to 10% (T, Pi, Po) | ♦1 | **1** |
| | Operations | | | | 3, long-term | | 7 (M) 7 (T, Pi, | | ♦♦ | **2** |

**Table K4.10-8: Summary of HEC 3 Impacts: Exposure to Potentially Hazardous Materials**

| Potential Impact | Project Phase | Negative/ Positive | Health Effect | Magnitude | Duration | Geographic Extent | Severity Ranking | Likelihood Rating | Impact Rating | Impact Category |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Po) | | | |
| | Closure | | | | 3, long-term | | 7 (M)<br>7 (T, Pi, Po) | | ♦♦ | **2** |
| Increased risk of exposure to bioaccumulated chemicals in Fish, Waterfowl, Wildlife, and Plant Foods | Construction | - | 2 (M),<br>1 (T, Pi, Po) | 1 | 2, medium-term | 2, potentially affected community | 7 (M)<br>6 (T, Pi, Po) | 33 to 66% (M)<br>10 to 33% (T, Pi, Po) | ♦ | **1** |
| | Operations | | | | 3, long-term | | 8 (M)<br>7 (T, Pi, Po) | | ♦♦ | **2** |
| | Closure | | | | 3, long-term | | 8 (M)<br>7(T, Pi, Po) | | ♦♦ | **2** |

Notes: Project-specific indicators: M = Mine Site; T = Transportation Corridor; Po = Amakdedori Port; Pi = Natural Gas Pipeline

### K4.10.2.4 HEC 4: Food, Nutrition, and Subsistence Activity

Most of rural Alaska sustains a "mixed, subsistence-market" economy, wherein families invest money into small-scale, efficient technologies to harvest wild foods (ADHSS 2015). In the non-urban areas of the state, many households depend on a mix of cash, subsistence (hunting, fishing, and gathering), sharing, and non-cash trading; and many of the communities in the vicinity of project components have a high participation in subsistence harvest activities and consumption. Potential impacts, either positive or negative, on food security and subsistence resources, could have large and persistent impacts on community health. The potential environmental consequences to socioeconomics from the project, including impacts to cost of living and price of food, which subsequently can impact community nutrition and food security, are evaluated in Section 4.3, Needs and Welfare of the People—Socioeconomics. The potential consequences to subsistence activity and associated community nutrition and food security are evaluated in Section 4.9, Subsistence. This section summarizes those findings, and incorporates them in the generation of this HEC ranking.

#### Food, Nutrition, and Food Security

Food security includes both physical and economic access to nutritious food, and includes four supporting factors: availability, access, utilization, and stability (FAO 2006). The socioeconomic evaluation concluded that the project could result in increases in economic opportunities, which in turn could result in steady income throughout the year, and help reduce seasonal fluctuations prevalent in the region (Section 4.3, Needs and Welfare of the People–Socioeconomics). By raising incomes, the project also has the potential to lower the cost of living for nearby communities, and increase the affordability and access aspects of food security. However, increased incomes and higher public revenues could also lead to overall price increases in market foods. Food security might decrease for those members of a community who do not derive economic benefits from the project, and who may be less able to afford further increases in food prices. This would particularly apply to the 5 to 28 percent of the community populations who currently live below the poverty threshold (e.g., Kokhanok, Nondalton, Newhalen, Levelock, Iliamna, Port Alsworth, New Stuyahok, Ekwok, and Koliganek; see Appendix K3.10).

The potential for impacts from the standpoint of nutrition and utilization was also considered. If community members reduce their level of subsistence food consumption, the impacts could also result in replacement of subsistence foods with store-bought foods at greater expense. More than 75 percent of the populations of the potentially affected communities self-reported a subsistence lifestyle, with consumption of fish, mammals, and plant foods (see Section 3.10, Health and Safety). Reductions in the diversity or quantity of access, availability, or consumption of these foods, and replacement by processed, store-bought foods, could result in a less-nutritious diet and associated health effects such as weight gain and chronic conditions. The potential for dietary changes to consumption of subsistence resources was evaluated as low, although more effort to access these resources might be necessary. This is described in further detail below.

#### Subsistence Activity

For subsistence-level nutrition, there could be both adverse and beneficial potential impacts (Section 4.9, Subsistence). Potential negative impacts could come from actual or perceived decreases in access to, availability/quantity of, and/or quality of subsistence recourses, which could also adversely impact community health/well-being and cultural identity. This may happen if community members need to travel farther for subsistence resources, and/or adapt to different species of subsistence resources. Availability of resources would not be heavily impacted,

because no population-level impacts to fish are anticipated; and while individual mammals could face individual mortality from collisions with vehicles, it would not affect the availability of wildlife for subsistence.

Subsistence users would likely adjust the seasonal round, resource use areas, and species composition of harvest resources to target resources that would be less affected by project activities. Although these adaptive approaches would likely sustain harvest levels for affected communities, they may increase expenses and time needed to harvest subsistence resources, and add to psychosocial stress and anxiety. However, benefits may also occur, because increased incomes and employment can positively affect subsistence harvest levels and participation in a myriad of ways, including making procurement of hunting and fishing equipment more affordable. Once constructed, the transportation corridor roads and the natural gas pipeline right-of-way are expected to restrict access to the public, but could have a positive effect on access to subsistence resources (depending on the level of access agreed to between the State, PLP, and the LPB); because these cleared routes could facilitate overland travel by all-terrain vehicles and snowmachines. The ferry could also facilitate access to subsistence resources by transporting local residents and their vehicles across the lake. PLP would work with local communities to find solutions for ferry transportation use (PLP 2018-RFI 027). Under the Summer-Only Ferry Operations Variant, the ferry would not impact cross-lake local transport.

In addition, the HEC 3 evaluation on potential exposure to hazardous chemicals through subsistence wild foods, including plants, fish and wildlife, was taken into consideration. The HEC 3 evaluation concluded that project-related hazardous chemical increases to the environment from the mine site would be expected to be negligible compared to baseline concentrations, while the other project components would be insignificant. Anticipated avoidance behavior by people, wildlife, and other biota that may be exposed to bioaccumulative metals would also assist in reducing exposure to project-related chemicals in subsistence foods. Therefore, adverse impacts to high-quality, high-volume salmon resources are not likely to occur, nor to any other kind of subsistence food. Any increased risks or hazards to human health from the project would be expected to be indistinguishable from baseline.

## Summary

The potential impact levels for food, nutrition, and subsistence activity are summarized in Table K4.10-9. This includes the potential health effect consequence, magnitude, duration, and geographic extent of the impact, and likelihood of impact occurrence, based on the evaluations presented in Section 4.3, Needs and Welfare of the People—Socioeconomics, Section 4.9, Subsistence, and HEC 3. The summary impact to human health is rated Category 2 for potential health benefits due to the potential for decreased food cost relative to income, because economic benefits are likely to make food purchases more affordable. The summary impact to human health relative to access to, quantity of, and quality of subsistence resources is rated Category 3 for mine site construction and operations. It is rated Category 2 for construction of the other project components, and Category 3 for operations and closure for other project components and all closure phases for both negative (adverse) and positive impacts (potential for decreased access to and/or quantity of subsistence resources, and increased income for subsistence equipment).

**Table K4.10-9: Summary of HEC 4 Impacts: Food, Nutrition, and Subsistence**

| Potential Impact | Project Phase | Negative/ Positive | Health Effect | Magnitude | Duration | Geographic Extent | Severity Ranking | Likelihood Rating | Impact Rating | Impact Category |
|---|---|---|---|---|---|---|---|---|---|---|
| Decrease in food cost relative to income | Construction | + | 1 | 1, noticeable, but limited and localized | 2, medium-term | 1, limited to households that benefit from economic opportunities | 5 | 66 to 90% | ♦♦ | **2** |
| | Operations | + | 1 | 1, noticeable, but limited and localized | 3, long-term | | 6 | | ♦♦ | **2** |
| | Closure | + | 0 | 0 | 3, long-term | | 4 | | ♦♦ | **2** |
| Access to, quantity of, and quality of subsistence resources | Construction | +/- | 2 (M)<br>1 (T, Pi, Po) | 1 | 2, medium-term | 2, communities and households that share subsistence resources and harvests | 7 (M)<br>6 (T, Pi, Po) | 33 to 66% | ♦♦♦<br>♦♦ | **3 (M)**<br>**2 (T, Pi, Po)** |
| | Operations | +/- | 2 (M)<br>1 (T, Pi, Po) | 1 | 3, long-term | | 8 (M)<br>7 (T, Pi, Po) | | ♦♦♦ | **3** |
| | Closure | +/- | 1 (M)<br>0 (T, Pi, Po) | 0 | 3, long-term | 1, limited to households | 5 (M)<br>4 (T, Pi, Po) | | ♦♦ | **2** |
| Decrease or increase in food security, relative to impacts to cost of living/food and subsistence resources | Construction | +/- | 1 | 1, noticeable, but limited and localized, offset by increased income | 2, medium-term | 1, limited to households | 5 | 33 to 66% | ♦♦ | **2** |
| | Operations | +/- | 1 | 1, noticeable, but limited and localized, offset by increased income | 3, long-term | | 6 | | ♦♦ | **2** |
| | Closure | +/- | 0 | 0 | 3, long-term | | 4 | | ♦♦ | **2** |

Notes: Project-specific indicators: M = mine site; T = transportation corridor; Po = Amakdedori port; Pi = natural gas pipeline

For the impact ratings of Category 2 and Category 3, monitoring to assess the need to reduce potential negative impacts is recommended. This may include monitoring access to, availability of, and quality of (as represented by tissue analyses for chemicals) subsistence resources as recommended, particularly for edible fish species and waterfowl. Monitoring of food security, in terms of trends in market food prices and affordability for community members living near or below the poverty threshold is also recommended.

### K4.10.2.5 HEC 5: Infectious Diseases

The following sections present the evaluation of the potential impacts on rates of infectious diseases, including sexually transmitted infections (STIs) (e.g., gonorrhea, chlamydia, Hepatitis C, and HIV); respiratory diseases (e.g., influenza and pneumonia); foodborne illness (e.g., salmonella and E. Coli); and zoonotic diseases (disease that is passed between animals and humans). Table K4.10-9 summarizes the potential impact levels for infectious diseases, including the potential health effect consequence, magnitude, duration, and geographic extent of the impact, and likelihood of the impact occurring.

The mine site personnel camp facilities would include a main construction camp to accommodate 1,700 workers. The total number of direct-hire project employees is expected to be around 2,000 workers during the construction phase and 850 during operations. During construction and operation, the camp facilities would include a potable water supply from a series of groundwater wells north of the mine site, outside of the estimated cone of depression around the proposed open pit. The camp facilities would likely include common wash modules containing toilets, showers, and personnel laundry facilities. Temporary camps would be used during construction that would be moved as construction progresses. The Amakdedori port shore-based complex would include employee accommodations and common washrooms during operations.

A groundwater well would be installed at the port to supply potable water for use by personnel. The well would be situated upland from the shoreline to avoid potential saltwater intrusion. PLP would likely conduct worker code of conduct training, and implement a closed work camp and workforce health education programs that would promote awareness of infectious diseases and preventive measures. The project would likely provide a place where workers who have infectious diseases (of any kind) could be diagnosed and treated, and measures would be taken to avoid transmittal of diseases to others. See Chapter 2, Alternatives, and Section 4.17, Hydrogeology, for more project details. During project construction, operations, and closure, public access to or through the mine site would be restricted for safety, which would include the mine site worker camp, further reducing the potential for transmission of infectious disease into or out of the worker camps. This would also be true of the worker camps planned for the transportation, pipeline, and port facilities.

The following sections describe the potential project impacts on affected communities due to potential increases or decreases in rates of infectious disease.

#### Increases in Sexually Transmitted Infection Rates

Increases in STI rates could occur due to employment of workers from outside the region, and/or the rotation of the workforce during the various project phases; particularly construction. Residents living in the vicinity of the project workforce camps are the most vulnerable receptors to increases in STIs due to their proximity. Because the mine site and Amakdedori port would be in remote areas, the probability of worker interactions with the residents living in local communities would be lower, relative to the construction workforce camps for the transportation corridor and natural gas pipeline.

Chlamydia and gonorrhea are reported as higher than national prevalence rates for the state, but particularly among Alaska Native populations (Section 3.10, Health and Safety). Chlamydia trachomatis was reported as 4 times more common than gonorrhea. In the Bristol Bay Region, rates of chlamydia are higher than state-wide Alaska Native populations, while chlamydia rates in the Kenai Peninsula Region are lower than state-wide Alaska Native populations, but still much higher than non-white Alaska Native state populations and nationally. Although the Bristol Bay and Kenai Peninsula regions appear to have gonorrhea rates less than the state-wide Alaska Native rates, both had fewer than 20 cases of gonorrhea during the reporting period, and the rate may not be statistically reliable.

The potential impact of increases in STI rates for the potentially affected communities is rated Category 1 for all phases and components, except for during construction of the transportation corridor and natural gas pipeline, which are rated Category 2 (Table K4.10-9). For all components and phases, the health effect is considered to pose a minor risk of health injury. Because the project would use individuals primarily from the region for the workforce (i.e., there would not be a major influx of workers from outside the region), and statewide STI rates are lower than the local regional rates, it is expected that STI rates would not show a discernable change. Therefore, the likelihood of increased STI rates is considered as likely as not (33 to 66 percent) for the construction of the transportation corridor and pipeline, due to the larger workforce (including those that already have STIs and may transmit to others) that would be housed in temporary camps near local communities; but unlikely (10 to 33 percent) for all phases at the mine site and Amakdedori port due to geographic remoteness.

## Increases in Infectious Diseases

Increases in infectious disease rates could occur from employment of workers from outside the region and/or the rotation of the workforce during the project phases. Influenza and pneumonia was the tenth top cause of death statewide (ANTHC 2017i). Influenza and pneumonia rates of death are higher for Alaska Natives than those experienced by non-Alaska Natives and nationally. In addition, Alaska continues to have some of the highest tuberculosis rates in the nation (ADHSS 2017b), with Alaska Natives experiencing the greatest rates (Section 3.10, Health and Safety).

Impacts to human health from increases in infectious disease rates would be the same as discussed for sexually transmitted diseases. The potential impact of increases in infectious (respiratory) diseases rates for the potentially affected communities is rated Category 1 for all phases and components, except for during construction for the transportation corridor and natural gas pipeline, which are rated Category 2.

## Increases in Rates of Foodborne Illnesses and Zoonotic Diseases

Increases in rates of foodborne illnesses and zoonotic diseases could occur due to improper food handling/catering services and food disposal at the project workforce camps during the project phases. Food-borne illnesses or zoonotic diseases from improper food disposal practices, such as harboring and feeding of wildlife near project camps, could occur at the project workforce camps, and be transmitted to the local communities via rotating staff. The potential for increased rates of foodborne illnesses and zoonotic diseases would be expected to impact primarily the local communities near the project components. This scenario is considered unlikely if the project adheres to and enforces regulations related to food services (such as 18 Alaska Administrative Code [AAC] 31) and wildlife interactions at the base camps or workforce housing.

The potential for increases in rates of foodborne illnesses and zoonotic diseases would be greatest in project workforce camps or workforce housing, with camps at all project components during construction, and at the mine site and Amakdedori port during operations and closure. The potential impact of increases in rates of foodborne illnesses and zoonotic diseases is rated Category 1 for all project phases (Table K4.10-10). For all project phases, the health effect is considered a minor risk of health injury. The magnitude of this impact is assigned a score of 1, because those affected would be expected to easily adapt to this impact with some intervention. The geographic extent of this impact is assigned a score of 0, because this impact would be limited to individual cases. The likelihood of this impact occurring would be very unlikely (1 to 10 percent), because the base camps would have safe food handling and disposal protocols in place to manage the food handling and catering services that would be provided for the project workforce.

**Summary**

Impacts related to infectious diseases are rated as Category 1 for the operations and closure phases for all project components for the operations and closure phases. Therefore, actions to reduce negative impacts would not be needed, as long as the planned project policies and procedures are implemented. Two exceptions were ranked as Category 2: the potential for occurrence and transmission of STIs and infectious respiratory diseases during the construction phase, in the context of construction workforce camps and their possible interactions with their own families and local communities. Development and implementation of health education and training programs to avoid and minimize the spread of infectious diseases is recommended as a best practice. On-site healthcare facilities and clinics to detect, treat, and monitor the occurrence of infectious diseases are recommended as mitigation measures.

**Table K4.10-10: Summary of HEC 5 Impacts: Infectious Diseases**

| Potential Impact | Project Phase | Negative/ Positive | Health Effect | Magnitude | Duration | Geographic Extent | Severity Ranking | Likelihood Rating | Impact Rating | Impact Category |
|---|---|---|---|---|---|---|---|---|---|---|
| Increase in sexually transmitted infection rates (including gonorrhea, chlamydia, Hepatitis C, and HIV) | Construction | - | 1 | 1, noticeable, but limited and localized | 2, medium-term | 1, limited to infected individuals and their households | 5 | 33 to 66% (T, Pi)<br>10-33% (M, Po) | ♦♦<br>♦ | **2 (T, Pi)**<br>**1 (M, Po)** |
| | Operations | | 1 | 1, noticeable, but limited and localized | 3, long-term | | 6 | 10 to 33% | ♦ | **1** |
| | Closure | | 1 | 1, noticeable, but limited and localized | 3, long-term | | 6 | 10 to 33% | ♦ | **1** |
| Increase in infectious (respiratory) disease morbidity and mortality rates (e.g., influenza and pneumonia) | Construction | - | 1 | 1, noticeable, but limited and localized | 2, medium-term | 1, limited to infected individuals and their households | 5 | 33 to 66% (T, Pi)<br>10-33% (M, Po) | ♦♦<br>♦ | **2 (T, Pi)**<br>**1 (M, Po)** |
| | Operations | | 1 | 1, noticeable, but limited and localized | 3, long-term | | 6 | 10 to 33% | ♦ | **1** |
| | Closure | | 1 | 1, noticeable, but limited and localized | 3, long-term | | 6 | 10 to 33% | ♦ | **1** |
| Increase in rates of foodborne illness and zoonotic diseases | Construction | - | 1 | 1, noticeable, but limited and localized | 2, medium-term | 0, limited to individual cases | 4 | 1 to 10% | ♦ | **1** |
| | Operations | | 1 | 1, noticeable, but limited and localized | 3, long-term | | 5 | 1 to 10% | ♦ | **1** |
| | Closure | | 1 | 1, noticeable, but limited and localized | 3, long-term | | 5 | 1 to 10% | ♦ | **1** |

Notes:
Project-specific indicators: M = Mine Site, T=Transportation Corridor, Po= Amakdedori port, Pi = Natural Gas Pipeline Corridor

### K4.10.2.6 HEC 6: Water and Sanitation

This section presents the evaluation of the potential impacts of increases in morbidity and mortality rates due to the availability and quality of water and sanitation services. Lack of in-home water and sewer service in some locations of rural Alaska causes severe skin infections and respiratory illnesses; residents of Southwest Alaska suffer rates of invasive pneumococcal disease that are among the highest in the world (ADEC 2018d). As discussed in Section 3.10, Health and Safety, as of 2016, 83.5 percent of rural Alaska Native communities were served by water and sewer services (a significant increase since 2004). In the Bristol Bay region, 99 percent of households had water and sewer services; and in the Kenai Peninsula region, service was 100 percent (ANTHC 2017n). It is unlikely that the project would directly affect access to water and sanitation services in the local communities.

The potential impact of increases in mortality and morbidity rates due to change in the availability, and quality of water and sanitation services, is rated Category 1 for the potentially affected communities for all project phases (Table K4.10-11). Because the majority of potentially affected communities have high baseline rates of water and sanitation service, it would be unlikely that there would be any perceptible changes from baseline to the affected communities due to the project. Therefore, the health effect and magnitude of impact are both assigned scores of 0 for all phases. The geographic extent of this impact is assigned a score of 0, because this impact would be limited to individual cases and households, if it does occur. The likelihood of increasing mortality and morbidity rates due to change in the availability and quality of water and sanitation services of communities near the project would be considered extremely unlikely (<1 percent).

#### Summary

The potential for project-related impacts on health effects in the context of water and sanitation facilities is ranked as a Category 1 impact. No actions to reduce negative impacts would be necessary.

**Table K4.10-11: Summary of HEC 6 Impacts: Water and Sanitation**

| Potential Impact | Project Phase | Negative/ Positive | Health Effect | Magnitude | Duration | Geographic Extent | Severity Ranking | Likelihood Rating | Impact Rating | Impact Category |
|---|---|---|---|---|---|---|---|---|---|---|
| Increase in morbidity and mortality rates due to the availability and quality of water and sanitation facilities | Construction | - | 0 | 0 | 2, medium-term | 0, individual cases | 2 | <1% | ♦ | **1** |
| | Operations | | | | 3, long-term | | 3 | | ♦ | **1** |
| | Closure | | | | 3, long-term | | 3 | | ♦ | **1** |

### K4.10.2.7 HEC 7: Non-Communicable and Chronic Diseases

This section presents the evaluation of the potential impacts of increases in non-communicable and chronic morbidity and mortality rates in the potentially affected communities (such as cancer, cardiovascular, and respiratory). Although several factors (such as excess weight, physical activity, diet and nutrition, diabetes, and tobacco use) can contribute to increases in non-communicable and chronic morbidity and mortality rates, the evaluation of potential impacts focused on factors that could be directly attributed to the project. Potential exposure to project-related hazardous chemicals could result in increases in non-communicable and chronic (such as cancer, respiratory, and cardiovascular) morbidity and mortality rates in the potentially affected communities. For example, increased cancer rates in affected communities could occur from hazardous chemical exposure through ingestion of bioaccumulative and carcinogenic chemicals in subsistence foods. Changes in subsistence habits, diet, and nutrition, and changes in activity patterns could also affect the incidence of chronic diseases.

#### Chronic Disease Impacts from Diet, Nutrition, and Exercise

As discussed for HEC 4, the project would be expected to decrease food costs and increase food security, related to increased income levels for those who benefit economically from the project; while impacts to access to, quantity of, and quality of subsistence resources could be both negative and positive (see Table K4.10-8). Subsistence activities are a central feature of Alaska Native history and society, and support healthy diet and nutrition, physical activity needs, and are an important aspect of preserving cultural heritage and mental health (see Section 3.10, Health and Safety).

All of the affected communities report higher baseline subsistence lifestyle (75 percent or higher) compared to Alaska overall (31 percent), while LPB and Bristol Bay Borough report higher percentages of adults who believe they get enough physical activity. With increased food security and decreased food costs (relative to income), it is possible that subsistence activities could be reduced in some community households and lead to lower rates of physical activity; but it is also possible that increased income would be used to supplement the subsistence lifestyle. In addition, subsistence users would likely adjust the resource use areas to target resources that would be less affected by actual or perceived impacts from the project (see Section 4.9, Subsistence) For community members employed by PLP, the project could increase rates of physical activity for some, while reducing physical activity rates for those in less physically active positions (i.e., vehicle drivers and equipment operators). In addition, individuals who may obtain full-time employment on the project may have reduced availability to engage in subsistence activities, thereby simultaneously experiencing increased incomes and reduced levels of fitness and subsistence activities, as reported in several other studies for Alaskan populations (Nobmann et al. 2005; Redwood et al. 2008).

The summary impact level for increased morbidity and mortality rates for cancer, respiratory, and cardiovascular diseases from changes in diet, nutrition, and physical activity for the potentially affected communities is rated Category 2 (Table K4.10-11). For all three components and project phases, the health effect was assigned a score of 1 (minor), given both the positive and negative potential impacts to diet, subsistence, and physical activity. The magnitude of impact was also assigned a score of 1, given the possible noticeable but limited/localized positive or negative project impacts to diet and nutrition, and that those potentially negatively impacted are expected to be able to adapt and maintain pre-impact level of health. The geographic extent of this impact is assigned a score of 1, because impacts would be limited to a number of households. The likelihood of increased cancer, respiratory, and cardiovascular

morbidity and mortality rates due to decreased diet/nutrition and decreased physical activity is considered as likely as not (33 to 66 percent).

## Chronic Disease Impacts from Exposure to Hazardous Chemicals

Based on the findings of the evaluation on potential exposure to hazardous chemicals, as presented for HEC 3, the project-related hazardous chemical increases to the environment from the mine site would be expected to be negligible compared to baseline concentrations, while the other components would be insignificant. Any increased risks or hazards to human health would be expected to be indistinguishable from baseline. In addition, mitigation measures and best management practices would be implemented to further minimize potential exposures of hazardous chemicals to receptors in the potentially affected communities.

The summary impact level for increased morbidity and mortality rates for cancer, respiratory, and cardiovascular diseases for the potentially affected communities is rated Category 1 (Table K4.10-12). For the mine site during all phases, the health effect and magnitude of impact are assigned scores of 1 and 0, respectively (minor increases compared to baseline). For the other components during all project phases, the health effect and magnitude of impact are both assigned a score of 0 (not perceptible and minor, respectively). The geographic extent of this impact is assigned a score of 2, because the communities in the vicinity of the EIS analysis area could be potentially affected. Based on the HEC 3 findings, the likelihood of increased cancer, respiratory, and cardiovascular morbidity and mortality rates due to increased exposure to potentially hazardous chemicals is considered unlikely (10 to 33 percent) for the mine site, and very unlikely (1 to 10 percent) for the other three components.

## Summary

Overall, positive or negative impacts related to changes in chronic, non-infectious diseases is rated as Category 2 with respect to food, nutrition, and physical activity determinants (including bioaccumulation concerns for subsistence foods). Impacts on chronic diseases due to exposure to hazardous chemicals is rated as Category 1. Consideration of monitoring of key metrics related to food availability and affordability is recommended to avoid negative impacts on chronic disease and long-term health status. Monitoring of exposure to project-related hazardous chemicals in dietary media may be considered to address uncertainties in exposure and use assumptions.

**Table K4.10-12: Summary of HEC 7 Impacts: Non-communicable and Chronic Diseases**

| Potential Impact | Project Phase | Negative/ Positive | Health Effect | Magnitude | Duration | Geographic Extent | Severity Ranking | Likelihood Rating | Impact Rating | Impact Category |
|---|---|---|---|---|---|---|---|---|---|---|
| Increase in cancer, respiratory, cardio-vascular, developmental, and neurological morbidity and mortality rates due to change in diet, nutrition, and physical activity | Construction | +/- | 1 | 1 | 2, medium-term | 1, limited number of households | 5 | 33 to 66% | ♦♦ | **2** |
| | Operations | | | | 3, long-term | | 6 | | ♦♦ | **2** |
| | Closure | | | | 3, long-term | | 6 | | ♦♦ | **2** |
| Increase in cancer, respiratory, cardio-vascular, developmental and neurological morbidity and mortality rates due to exposure from hazardous chemicals | Construction | - | 1 (M)<br>0 (T, Pi, Po) | 0 | 2, medium-term | 2, potentially affected community | 5 (M)<br>4 (T, Pi, Po) | 10 to 33% (M)<br>1 to 10% (T, Pi, Po) | ♦ | **1** |
| | Operations | | | | 3, long-term | | 6 (M)<br>5 (T, Pi, Po) | | ♦ | **1** |
| | Closure | | | | 3, long-term | | 6 (M)<br>5 (T, Pi, Po) | | ♦ | **1** |

Notes:
Project-specific indicators: M = Mine Site, T=Transportation Corridor, Po= Amakdedori port, Pi = Natural Gas Pipeline Corridor

### K4.10.2.8 HEC 8: Health Services Infrastructure and Capacity

Access to health services is important for achieving health equity and increasing the quality of life for all individuals. The level of access to health services can impact life expectancy, mortality, and morbidity rates; early detection and treatment of health conditions; and control of infectious diseases through increased access to vaccines. The following sections present the evaluation of the potential impacts from decreased access to healthcare under routine conditions and emergency situations that could overwhelm local and regional healthcare capacities. Table K4.10-12 summarizes the potential impact levels for health services infrastructure and capacity, including the potential health effect consequence, magnitude, duration, and geographic extent of the impact, and likelihood of the impact occurring.

#### Access to Routine Healthcare

Several entities provide healthcare services in the EIS analysis area (Section 3.3, Needs and Welfare of the People—Socioeconomics). Every LPB community has a health clinic (Nondalton, Kokhanok, Newhalen, Iliamna, Levelock, Pedro Bay, and Igiugig), with the exception of two communities (Port Alsworth and Ugashik). The three Nushagak/Bristol Bay communities in the Dillingham Census Area in close proximity to the EIS analysis area (New Stuyahok, Koliganek, and Ekwok) each have a health clinic. In addition, health clinics are in every community in the Dillingham Census Area, except Portage Creek and Ekek, which had a population of zero in 2009 (McDowell et al. 2011a; McDowell et al. 2018b).

The project has the potential to impact access to routine healthcare. On-site mine rescue and medical emergencies would likely be handled by a mine rescue team. Medical evacuation would be available by fixed-wing aircraft or helicopter to fly injured workers to medical facilities—likely in Anchorage. All project workforce camps would include first-aid provisions. Some project employees might obtain healthcare from healthcare facilities in nearby communities (e.g., Kokhanok, Iliamna, or Newhalen), although that would not be expected to occur often, because the mine site would have on-site medical facilities to support workers. Therefore, a noticeable effect on access to routine healthcare services would not be expected for residents living in the EIS analysis area, including the communities near the mine site.

In addition, positive impacts may also occur related to routine healthcare. Municipal tax revenues generated by the project and increased revenue stream to the LPB may result in expansion or improvements to existing healthcare facilities and services, and therefore result in net benefits to all members of the community with regard to healthcare access and the quality of available services, as noted in Section 4.3., Socioeconomics.

The summary impact level for access to routine healthcare for the potentially affected communities is rated Category 1 for all project components and phases (Table K4.10-12). For all project phases, the health effect is assigned a score of 1 (minor). The likelihood of this impact occurring would be unlikely, because mine site workers would be expected to typically use on-site medical facilities.

#### Access to Healthcare due to Large-Scale Emergency Situations and Overwhelming Local and Regional Healthcare Capacities

Although many of the workers would be trained in emergency response and first aid, the mine site medical resources may not be adequate to handle life-threating health conditions or multiple injured personnel in an emergency, depending on the situation. Due to the remote region and terrain, air travel is the primary mode of long-distance transportation, especially for major

medical or medical emergency issues. However, while this scenario is possible, the probability of occurrence of emergency scenarios would be rare.

As discussed in Section 3.10, Health and Safety, much of the region is classified as medically underserved, or has a shortage of health care professionals; however, the LPB is not listed as having a shortage of primary care health professionals. The LPB is serviced by a network of healthcare clinics, which are located in seven of nine communities (McDowell et al. 2011a). The three Nushagak/Bristol Bay communities (New Stuyahok, Koliganek, and Ekwok) are each serviced by a healthcare clinic (McDowell et al. 2018b). These clinics are staffed by medical and dental professionals with internet connections to specialists in Anchorage and around the country. However, the closest hospital is in Dillingham, approximately 125 miles southwest of the mine site, and is only a 16-bed facility. Because air/water transportation service to Anchorage (200 miles northeast of the mine site) is better equipped than to Dillingham, the affected communities in the LPB and the Kenai Peninsula Borough typically receive hospital care and other major medical services at the Alaska Native Medical Center in Anchorage (McDowell et al. 2011a). Mine site workers in need of medical emergency care that surpasses the capabilities of the on-site medical facility would be evacuated (via air, as described above) to appropriate medical facilities, likely in Anchorage.

The summary impact level for access to routine healthcare for the potentially affected communities is rated Category 2 for all project components and phases (Table K4.10-13). For all project phases, the health effect is assigned a score of 2 (moderate injury that may require intervention). Although possible, the probability of occurrence of emergency scenarios would be expected to be rare due to project safety protocols that would be employed. Therefore, this impact would be considered very unlikely (1 to 10 percent) to occur.

## Summary

The overall project-related impacts to health services and infrastructure are rated as Category 1 for access to routine healthcare, and Category 2 for access to healthcare during emergencies for all project components during all phases. No action is warranted to reduce negative health impacts under routine conditions. Adequate planning and periodic monitoring of the adequacy of emergency preparedness services and infrastructure may be recommended to avoid negative health impacts to the community during emergency situations.

**Table K4.10-13: Summary of HEC 8 Impacts: Health Services Infrastructure and Capacity**

| Potential Impact | Project Phase | Negative/ Positive | Health Effect | Magnitude | Duration | Geographic Extent | Severity Ranking | Likelihood Rating | Impact Rating | Impact Category |
|---|---|---|---|---|---|---|---|---|---|---|
| Access to routine healthcare | Construction | -/+ | 1 | 1, adaptable and able to maintain pre-impact levels of health | 2, medium-term | 1, limited number of households | 5 | 10 to 33% | ♦ | **1** |
| | Operations | | | | 3, long-term | | 6 | | ♦ | **1** |
| | Closure | | | | 3, long-term | | 6 | | ♦ | **1** |
| Access to healthcare due to emergency situations and overwhelming local and regional healthcare capacities | Construction | - | 2 | 2, able to maintain pre-impact levels of health with support | 2, medium-term | 2, potentially affected community | 8 | 1 to 10% | ♦♦ | **2** |
| | Operations | | | | 3, long-term | | 9 | | ♦♦ | **2** |
| | Closure | | | | 3, long-term | | 9 | | ♦♦ | **2** |

### K4.10.3 Alternative 2 – North Road and Ferry with Downstream Dams

Impacts from the project would be the same as or similar to Alternative 1, with few exceptions. The area of Iliamna Lake used for the ferry would be different, because it encompasses the areas at the northern end of the lake around Pedro Bay (as opposed to Kokhanok). Under the Summer-Only Ferry Operations Variant, transportation impacts on the lake would be eliminated during the winter, but double during the summer; and the air quality impacts from ferry and truck traffic would be the same as those for Alternative 1. Socioeconomic impacts under this variant would be similar to impacts under Alternative 1. This alternative's natural gas pipeline alignment would follow the north access road alignment, and not go across Iliamna Lake; there would be no hazards or impacts at Iliamna Lake during construction of the pipeline, as would occur under Alternative 1. Impacts from the port at Diamond Point would be the same or similar to those as Amakdedori port.

Overall, the HEC for which Alternative 2 consequences may be most noticeably different from Alternative 1 is HEC 2: Accidents and Injuries due to transportation. However, even given the differences noted above, the transportation-related accidents and injury summary impact to human health would remain the same, and would remain at a Category 2 for all phases and transportation types (Table K4.10-13). The health effect, magnitude, duration, and geographic extent would all remain the same as Alternative 1. Because there would be no difference in the overall number of flights or barge and ferry trips relative to Alternative 1, the likelihood of accidents and injuries related to air and surface water would be the same as for Alternative 1. Similar to Alternative 1, the likelihood of accidents and injuries related to surface transportation would remain very unlikely (1 to 10 percent), because there would be no increase in truck trips. However, the likelihood of accidents and injuries for surface transportation may increase to unlikely (10 to 33 percent) under the Summer-Only Ferry Operations Variant, because traffic on Williamsport-Pile Bay Road would include doubled mine-related summer traffic, and continuing or increasing levels of public boat portage. The potential for a greater likelihood of accidents would be reduced if the road was built to handle this increased summer capacity.

### K4.10.4 Alternative 3 – North Road Only

Impacts from the project would be the same as or similar to Alternatives 1 and 2, with a few exceptions. The use of Iliamna Lake for a ferry would be eliminated, shifting project-related transportation impacts to the area around Pedro Bay, rather than around Kokhanok. Impacts from the port at Diamond Point would be the same or similar to those as Amakdedori port. The Concentrate Pipeline Variant would build a slurry pipeline from the mine to the port, and include a dewatering and treatment plant at Diamond Point so that the slurry water could be discharged at the port, or returned to the mine site for reuse, by constructing a second pipeline. Potential hazardous materials impacts would remain the same as under Alternative 1, because the effluent would be treated to meet the Alaska water quality criteria prior to discharge. This variant would likely decrease employment of truck operators, but increase employment at the water treatment plant (WTP)/dewatering facility, but with lower overall employment. For the region as a whole, the impacts on the cost of living for Alternative 3 would be largely the same as the impacts of Alternative 1, and would likely lower the high cost of living for the communities near the transportation corridor, similar to Alternative 2. However, because of the different alignments of the transportation corridor and natural gas pipeline, Kokhanok would likely experience less of a benefit, while Pedro Bay would likely experience more of a benefit over the long term.

Similar to Alternative 2, the HEC for which Alternative 3 consequences may be most noticeable from other alternatives is HEC 2: Accidents and Injuries due to transportation. However, even given the differences noted above, the transportation-related accidents and injury summary

impact to human health would remain the same—at a Category 2 for all phases and transportation types (Table K4.10-14). There would be no change in the number of air transportation flights or truck transportation trips. The health effect, magnitude, duration, and geographic extent would all remain the same as Alternative 1. Therefore, the likelihood for air transport–related accidents and injuries would remain the same, as would surface transportation–related accidents and injuries, because the Williamsport-Pile Bay Road would be expected to handle year-round capacity needs. Even though the ferry operation on Iliamna Lake would be eliminated, the project would continue to use Cook Inlet; therefore, the probability of accidents and injuries related to water transportation would be extremely unlikely for Iliamna Lake, and unlikely for Cook Inlet. Under the Concentrate Pipeline Variant, the potential for surface transportation related to truck transport would decrease even further due to reduced trucks from the mine site to the port.

**Table K4.10-14: Summary of HEC 2 Impacts: Accidents and Injuries for Alternatives 2 and 3**

| Potential Impact | Project Phase | Negative/ Positive | Health Effect | Magnitude | Duration | Geographic Extent | Severity Ranking | Likelihood Rating | Impact Rating | Impact Category |
|---|---|---|---|---|---|---|---|---|---|---|
| **Alternative 2 – North Road and Ferry with Downstream Dams** | | | | | | | | | | |
| Increase in unintentional accidents and injuries morbidity and mortality rates due to air, surface, and water transportation (same rating unless otherwise noted) | Construction | - | 3 | air = 3, unable to maintain pre-impact level of health<br>surface and water = 2, able to maintain pre-impact level of health with medical intervention | 2, medium-term | 0, individual cases | 8 (air)<br>7 (water/ surface) | <1 % (air)<br>1 to 10% to 10 to 33% (surface)<br>10 to 33% (water) | ♦♦ | **2** |
| | Operations | | | | 3, long-term | | 9 (air)<br>8 (water/ surface) | | ♦♦ | **2** |
| | Closure | | | | 3, long-term | | 9 (air)<br>8 (water/ surface) | | ♦♦ | **2** |
| **Alternative 3 – North Road Only** | | | | | | | | | | |
| Increase in unintentional accidents and injuries morbidity and mortality rates due to air, surface, and water transportation (same rating unless otherwise noted) | Construction | - | 3 | air = 3, unable to maintain pre-impact level of health<br>surface and water = 2, able to maintain pre-impact level of health with medical intervention | 2, medium-term | 0, individual cases | 8 (air)<br>7 (water/ surface) | <1 % (air)<br>1 to 10% (surface)<br>10 to 33% (water) | ♦♦ | **2** |
| | Operations | | | | 3, long-term | | 9 (air)<br>8 (water/ surface) | | ♦♦ | **2** |
| | Closure | | | | 3, long-term | | 9 (air)<br>8 (water/ surface) | | ♦♦ | **2** |

## K4.10.5 Summary of Key Impacts

See Table K4.10-15 for a summary of key issues.

**Table K4.10-15: Summary of Key Issues for Health and Safety**

| Impact-causing Project Component | Alternative 1 and variants | Alternative 2 and variants | Alternative 3 and variants |
|---|---|---|---|
| All Project Components | Increase in household incomes, employment, and education attainment. The Summer-Only Ferry Operations Variant would lower the cost of living and increase employment opportunities, but not by as much as the proposed alternative because of seasonal versus year-round employment (+ Category 3 during construction and operations).<br>Decrease in food cost relative to income (+ Category 2). | Same as Alternative 1, including Summer-Only Ferry Operations Variant, although impacts would shift more toward Pedro Bay instead of Kokhanok. | Same as Alternative 1.<br>The concentrate pipeline variant would have similar impacts to the Summer-Only Ferry Operations Variant under Alternative1. |
| | Increase and decrease in psychosocial stress (+/- Category 3 during construction and operations; +/- Category 2 during closure).<br>Increase and decrease in family stress and stability (+/- Category 2 during operations and closure).<br>Increase and decrease in unintentional injury (e.g., falls, cuts, poisoning) (+/- Category 2).<br>Increase and decrease in access to, quantity of, and quality of subsistence resources (+/- Category 2 to 3 depending on component and phase).<br>Decrease or increase in food security (+/- Category 2).<br>Increase in cancer, respiratory, and cardio-vascular morbidity and mortality rates due to change in diet, nutrition, and physical activity (+/- Category 2). | | |
| | Decrease in household incomes, employment, and education attainment (- Category 2 during closure).<br>Increase in intentional injury (suicide) (- Category 2).<br>Increased risk of exposure to hazardous chemicals in abiotic media and to bioaccumulated chemicals in subsistence foods (-Category 2 during operations and closure).<br>Decreased access to healthcare due to emergency situations and overwhelming local and regional healthcare capacities (- Category 2). | | |
| Transportation Corridor | Increase in unintentional accidents and injuries morbidity and mortality rates due to air, surface, and water transportation, particularly regarding winter access across Iliamna Lake from the ice-breaking ferry. PLP would put some measures in place to minimize impacts, such as trail marking and crossings.<br>The Kokhanok East Ferry Terminal Variant would include access to Sid Larson Bay without crossing the ferry route.<br>The Summer-Only Ferry Operations Variant would eliminate the potential hazards to snowmachine winter lake | Impacts would be similar to Alternative 1, except that the routes and closest communities affected would be around Pedro Bay instead of Kokhanok.<br>The Summer-Only Ferry Operations Variant could increase the likelihood of surface transportation accidents and injuries along Williamsport-Pile Bay Road from an increase in truck traffic if mitigation measures are not taken to build to meet the increased | Impacts would be similar to Alternatives 1 and 2, except that the elimination of the ferry on Iliamna Lake would r shift project-related transportation impacts to the area around Pedro Bay, rather than around Kokhanok. Impacts from the port at Diamond Point would be the same or similar to those as Amakdedori port.<br>The concentrate pipeline variant impacts would |

**Table K4.10-15: Summary of Key Issues for Health and Safety**

| Impact-causing Project Component | Alternative 1 and variants | Alternative 2 and variants | Alternative 3 and variants |
|---|---|---|---|
| | crossings, but increase summer lake and road traffic (- Category 2). | mine-related and public summer capacity (- Category 2). | remain the same as under Alternative 1 because the effluent would be treated to meet Alaska water quality criteria prior to discharge. (- Category 2) |
| Transportation Corridor and Natural Gas Pipeline | Increase in sexually transmitted infection rates (- Category 2 during construction) and in infectious (respiratory) disease morbidity and mortality rates (- Category 2 during construction). | Same as Alternative 1. | Same as Alternative 1. |