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.

Use of the most stringent regulatory criteria for comparison to baseline water and sediment quality data provides a benchmark for analysis of current water and sediment conditions. Although the baseline environment is relatively pristine, some exceedances of the most stringent regulatory criteria may exist. These exceedances are not necessarily abnormal for a mineralized geologic area. Comparison of baseline data to the most stringent regulatory criteria provides context for how existing environmental conditions compare to regulatory standards that may be used to assess potential impacts.

K3.18.1.1 Surface Water Quality Criteria

In Alaska, surface water quality is regulated by the 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.

The US Environmental Protection Agency (EPA) provides oversight of WQS selection under the Clean Water Act (CWA 40 Code of Federal Regulations [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 would 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) would remain the applicable CWA standards.

CWA also requires EPA to promulgate best available technology-based effluent controls on new industrial discharges, which applies to copper and molybdenum mines under 40 CFR Part 440 Subpart J. For certain mine treatment facilities, effluent discharge volume is to the difference between precipitation (including runoff) and evaporation, and the effluent concentrations for certain constituents limited to daily and monthly values in the regulations. Although the discharge volume limitation may apply to the Pebble mine site, the chemical effluent limitations in Subpart J are generally less stringent than those described below.

In instances where 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,j]	
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)[k]	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
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	—	—

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

Water Quality[a]				Sediment Quality[b,c,j]	
Parameter[d]	**Unit**	**Most Stringent Criteria**	**Basis**	**TEL**	**PEL**
Vanadium (Total)	mg/L	0.1	WQBEL-HH	—	—
Zinc (H) (Total)	mg/L	0.02895	WQBEL-ALA	123,000	315,000
Total Dissolved Solids	mg/L	500	WQBEL-HH	—	—
pH	—	6.5 to 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)[g]	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 $CaCO_3$)[i]	mg/L	~=100	-	—	—

Notes:
[a] Water quality limits are based on the lowest 15th percentile hardness of the three proposed discharge locations. Numerical hardness values used for development of hardness-dependent criteria include: Cd – 18.7, Cr III – 16, Cu – 18.3, Pb – 19.4, Ni (total) – 19.1, Ag – 47, and Zn – 18.7
[b] Sediment quality units = micrograms per kilogram
[c] Based on National Oceanic and Atmospheric Administration (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); the criteria in this table are based on the technology-based effluent limitations guideline (ELG) in 40 CFR Part 440 Subpart J.
[g] Ammonia: value is freshwater chronic criterion, which 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 the table
[i] There is no criterion for hardness in the State of Alaska WQS. Hardness value indicates the most stringent condition, although the hardness-dependent criteria (cadmium, copper, chromium III, lead, nickel, silver, zinc) are determined on the basis of site-specific conditions in the receiving streams as indicated above.
[j] Dash mark (—) implies no available data.
[k] There are no anthropogenic sources of hexavalent chromium at the mine site, nor are mineral assemblages considered favorable for hexavalent chromium genesis (e.g., chromite).

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
CaCO3 = calcium carbonate
PEL = Probable Effects Level
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
TEL = Threshold Effects Level

Source: ADEC 2018b; Buchman 2008; Knight Piésold 2018a; Schlumberger et al. 2011a

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 15th percentile of hardness measured at the three discharge locations for the project, which are in tributaries to the North Fork Koktuli (NFK), South Fork Koktuli (SFK), and Upper Talarik Creek (UTC) (see 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) is 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) 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

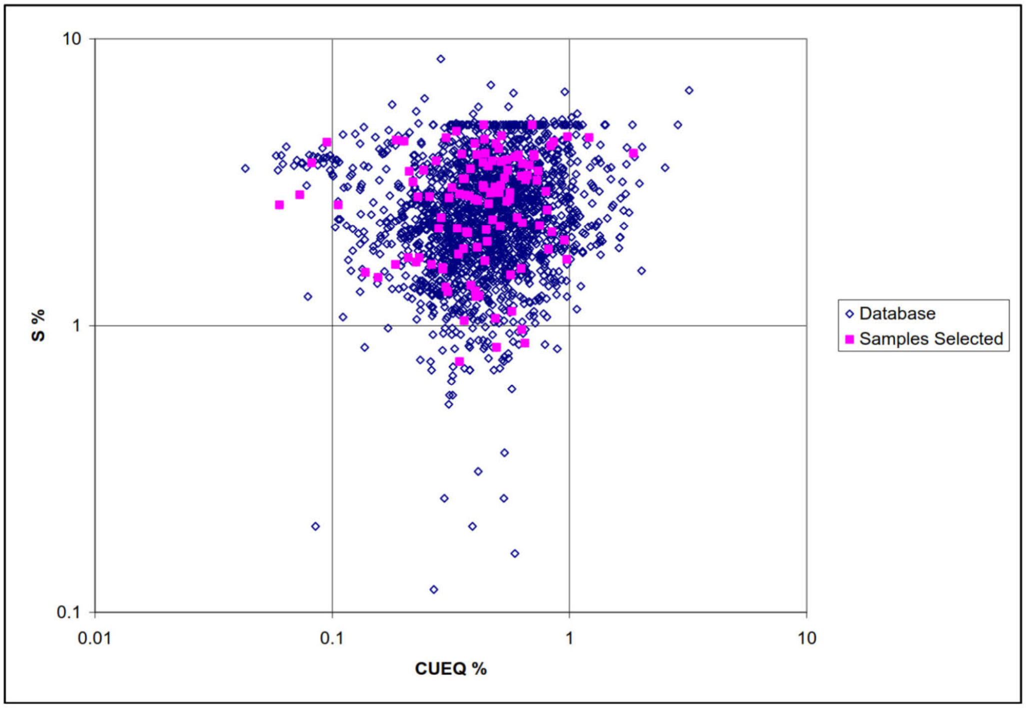
The geochemical evaluation presented in Section 3.18, Water and Sediment Quality, primarily relies on data presented in SRK (2011a, 2018a, c, d). These data were developed using representative overburden, rock cores, and metallurgical waste (tailings) samples from the Pebble east and west zones (PEZ and PWZ), and rock core samples from borings drilled in three 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).

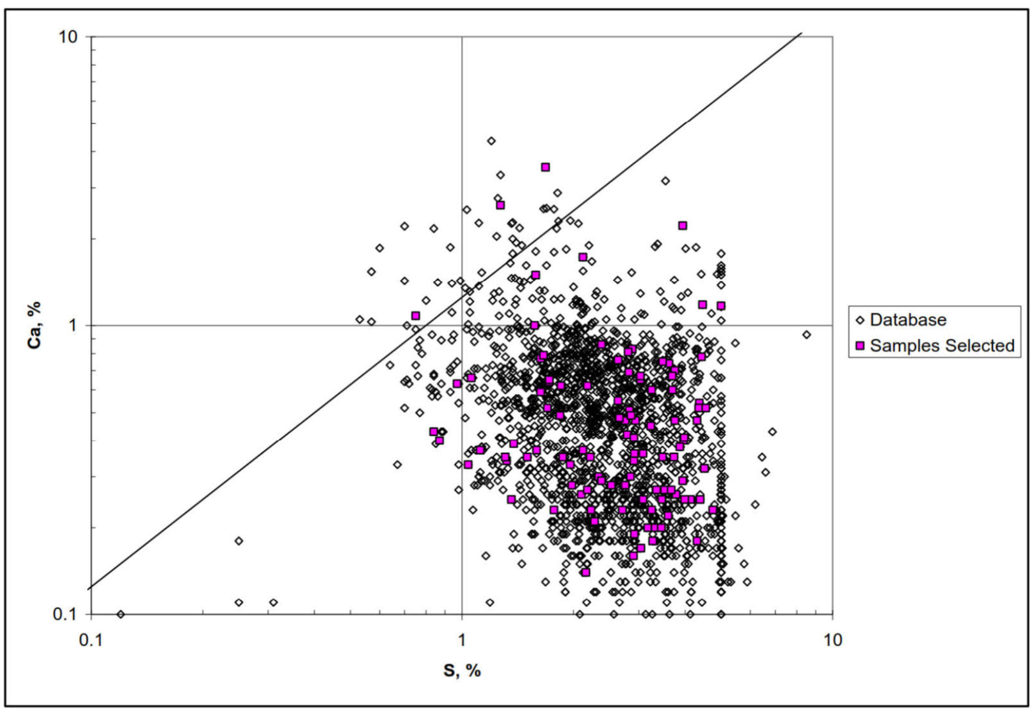
A total of 1,049 overburden and pre-Tertiary and Tertiary rock core samples from various rock and alteration types in the Pebble deposit, 64 tailings samples from metallurgical process test runs, and 138 rock core samples from boreholes drilled at the construction quarries have been tested to date. Of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

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.

US Army Corps of Engineers

GEOCHEMICAL CHARACTERIZATION – REPRESENTATIVE SAMPLE DISTRIBUTION

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]	0

Notes:
[a] One of these tests comprised material from both the Pebble East and Pebble West zones.
[b] Three of these tests comprised material from both the Pebble East and Pebble West zones.
[c] 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

Subsequent work (SRK 2019a) indicates that improved recovery of metals would result in lower sulfide content and finer grain size in the rougher tailings. The lower sulfide content would result in lower acid potential than previously assumed based on previous geochemical data. The finer particle size may inhibit oxidation by resulting in greater moisture retention and lower oxygen diffusion. As a result, the previous non-potentially acid generating (PAG) classification of the rougher tailings would not change.

Furthermore, SRK (2019a) noted that the sulfidic tailings stream would have a finer particle size and a slightly higher sulfide content due to removal from the rougher tailings. However, the management plan for the sulfidic tailings stream is immediate submergence to limit oxidation of the tailings, regardless of its characteristics, and prevent onset of acid generation.

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.

SRK (2019a) provided additional information that the combined PEZ-PWZ data are considered representative of the geochemistry of materials from the PWZ only. SRK (2019a) indicates that the 95th percentile on the mean used to assess site geochemistry for the combined PEZ-PWZ data likely overestimates the constituent release rates, because the PEZ constituent concentrations are generally greater than those of the PWZ. SRK concluded that the combined dataset yields higher release rates for arsenic, copper, selenium, and sulfate for acidic materials, and similar release rates for these constituents for basic materials, compared to the PWZ data only. Therefore, the combined PEZ-PWZ data appears to yield conservative results.

In some mineralized deposits, rock type alone can be a good indicator of whether a rock would potentially produce ARD and/or ML. There are two main geological divisions at the 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, b, 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 mine site are predominantly 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 Pebble deposit.

In contrast, the majority of the Tertiary age and younger rocks that comprise the cover and overburden materials at the 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 non-PAG rocks can be distinguished using a site-specific NP/AP ratio of 1.4 (PLP 2018a), and is applicable to pre-Tertiary, Tertiary, and overburden materials. Inherent uncertainty exists in the deduction of a site-specific NP/AP ratio for the designation of PAG from non-PAG waste rock. A more conservative NP/AP ratio could be used to mitigate the potential of mischaracterizing PAG from non-PAG waste rock, and has been listed as a potential mitigation measure in Appendix M1.0, Mitigation Assessment.

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

Number of Samples	Litho Code	Mean Paste pH	Mean S(T), %	Mean S(SO_4), %	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
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

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

Number of Samples	Litho Code	Mean Paste pH	Mean S(T), %	Mean S(SO$_4$), %	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	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
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

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

Number of Samples	Litho Code	Mean Paste pH	Mean S(T), %	Mean S(SO_4), %	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]
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
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
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

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

Number of Samples	Litho Code	Mean Paste pH	Mean S(T), %	Mean S(SO_4), %	Mean S(S-2), %	Mean AP, kgCaCO₃/t	Mean NP (Sobek), kgCaCO₃/t	Mean Modified NP, kgCaCO₃/t	Mean TIC, kgCaCO₃/t	Mean TIC, %	NP/AP[a]
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
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

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

Number of Samples	Litho Code	Mean Paste pH	Mean S(T), %	Mean S(SO$_4$), %	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]
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
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

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

Number of Samples	Litho Code	Mean Paste pH	Mean S(T), %	Mean S(SO_4), %	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	X.YM-DxN	6.76	2.61	0.03	—	80.63	—	2.13	0.83	0.01	0.03
1	X.YMzN(?)/ X.YM-DxN	6.41	1.64	0.17	—	45.94	—	1.13	0.83	0.01	0.02
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
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

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

Number of Samples	Litho Code	Mean Paste pH	Mean S(T), %	Mean S(SO_4), %	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 (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
Dash mark (—) implies no available data
ABA = acid base accounting
AP = acidification potential
kgCaCO_3/t = kilograms calcium carbonate per ton
NP = neutralization potential
PEZ = Pebble East Zone
PWZ = Pebble West Zone
SO_4 = sulfate
TIC = Total Inorganic Carbon
Source: PLP 2018a

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 ideal, controlled laboratory conditions. Actual conditions in the field, with colder temperatures and long winters, are likely to be less conducive to acid formation, and further delay the onset of ARD. However, SRK (2006) reports that under low temperature conditions, large-scale effects can be significant. For example, trapped heat produced by sulfide mineral oxidation may offset the benefit of low temperatures on the rate of sulfide oxidation, and seasonal climatic effects in cold climates may result in heating of wastes comparable to warmer climates. A more conservative approach would be to use the average summer temperature, rather than the average annual temperature. SRK (2006) also recommends that in the absence of site-specific data, a rate ratio of 0.31 be used for pyrite for low-temperature oxidation rate reduction corrections in the Arrhenius equation.

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. SRK (2019a) clarified that the main basis for calculating the time for the development of acidic conditions was the interpretation of the humidity cell test (HCT) data.

SRK (2019a) further indicated that the current waste management approach assumes that PAG waste rock will be exposed for 1.5 years prior to being submerged by rising water levels in the pyritic tailings facility. Long delays in storage of PAG materials would result in greater accumulation of leachable weathering products than is currently assumed in this analysis, and an increase in the proportion of rock acidifying prior to flooding. This would result in higher solute concentrations in the pyritic tailings facility. However, the current engineering design limits exposure to 1.5 years, and there is no basis to evaluate the effect a delay in flooding would have.

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 circumneutral 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). To be conservative, the source term concentrations were developed at the 95th percentile.

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 represent a range of anticipated mine tails during operations. Although the project as proposed would not produce gold plant tails, these results generally yielded higher or similar sulfur contents to the pyritic tails, and are included in the discussion below to provide a conservative overview of the available data. Most of the tailings samples tested represent rougher tails, which would 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 was analyzed using optical mineralogy and x-ray diffraction methods and humidity cell, subaqueous leach column, and field barrel tests.

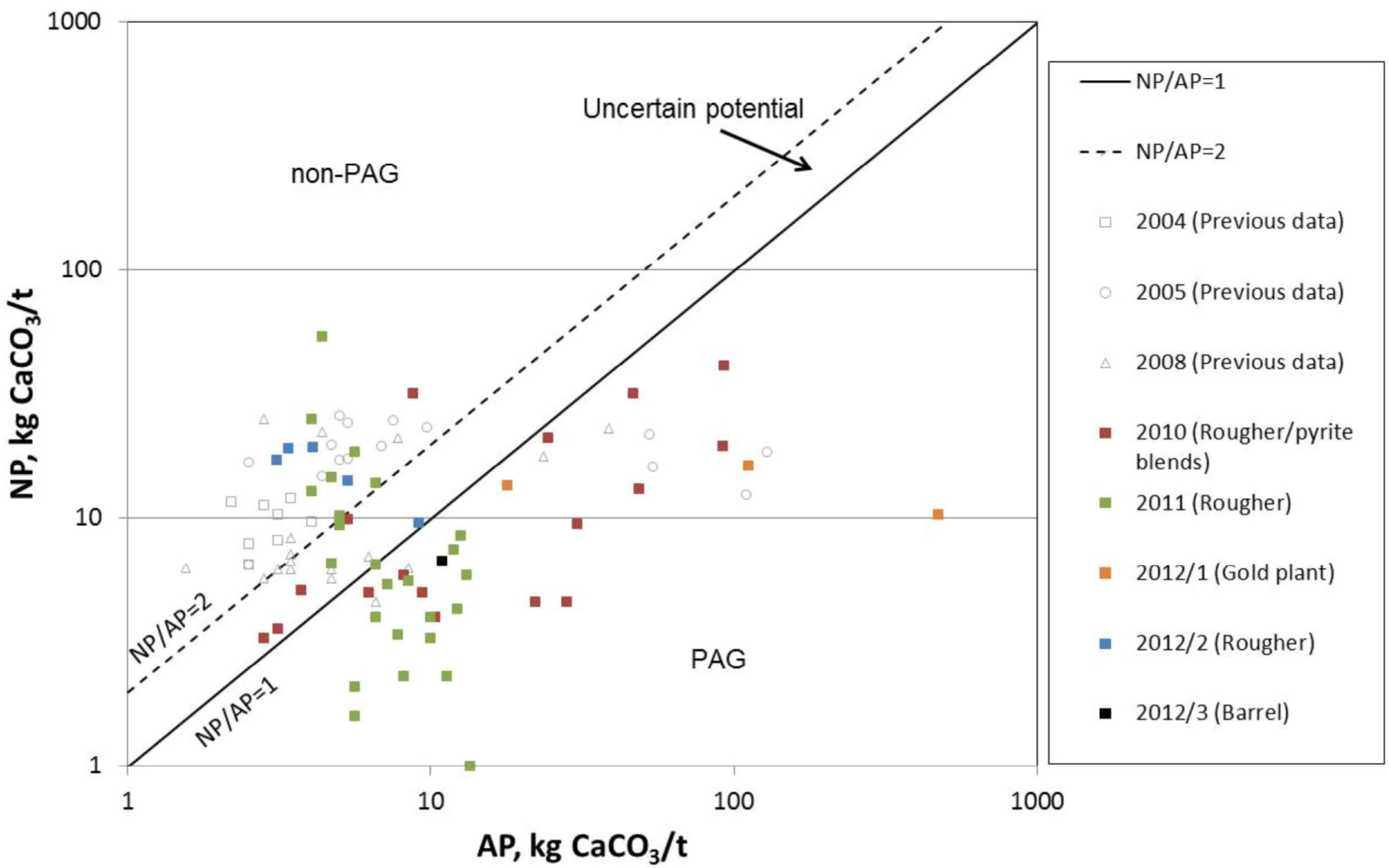
Mineralogy determinations indicate that the rougher tailings are dominated by potassium and plagioclase feldspars (about 67 percent), quartz (about 12 percent), muscovite and biotite (about 13 percent), carbonate minerals (about 4 percent), and trace hematite, pyrite, and rutile. ABA tests indicate that 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. Although 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.

Tailings supernatant analyses are summarized in Table K3.18-4 based on dissolved metals data. 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 (As, Co, Cu, Mn, Mo, Ni, Sb, Se, and Zn). For mercury, most of the supernatant mercury results (69 percent) were not detected at a detection limit of 10 nanograms per liter (ng/L), less than the applicable water quality standard of 12 ng/L. Several higher-concentration samples (14 percent) were diluted for analysis, which resulted in elevated detection limits up to 50 ng/L in the dissolved mercury tests. Mercury was only detected in 18 percent of the supernatant samples analyzed, and ranged in concentration from 12 to 450 ng/L. The 50th 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 above, and shown in Table K4.18-2.

K3.18.2.3 Construction Rockfill Geochemical Characteristics

Construction rockfill would be obtained from quarries in Cretaceous age granodiorite outside of the footprint of the mine. To evaluate the potential needs to manage the rock geochemistry and to estimate contact water quality, PLP tested rock from boreholes in three 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 was 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.



Source: PLP 2018a

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

PEBBLE PROJECT EIS

FIGURE K3.18-2

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)[a]										
Batches Tested During Period 2010 to 2012																
2010 set																
LCT-25	Rougher/pyrite blend	8.0	166	135.1	—[b]	0.020	0.007	0.002	0.00004	-0.0002[c]	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[d]	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[e]																
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 (continued)

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[d]	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[e]											
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] Metals data are based on dissolved metals results.
[b] "—" values in an otherwise empty cell = not measured.
[c] Negative values = concentration of the element was below the method detection limit (MDL). MDLs ranged from 0.00001 to 0.00005 mg/L for Ag and Hg; 0.00005 to 0.005 mg/L for Cd, Co, Cr, Cu, Ni, Pb, Tl, and Zn; and 0.03 mg/L for Fe; all remaining metals were present above MDLs.
[d] Table includes data for various tailings products, such as gold plant tails, that may not be a waste stream during mine operations.
[e] Where concentrations were below the MDL, average values were calculated using half the MDL value.
L = Liter; mgS_2O_3 = milligrams thiosulfate; $mgCaCO_3$ = milligrams calcium carbonate; mg/L = milligrams per liter
Al = aluminum; Sb = antimony; As = arsenic; Ag = silver; Cd = cadmium; Ca = calcium; Cr = chromium; Co = cobalt; Cu = copper; Fe = iron; Pb = lead
Mg = magnesium; Mn = manganese; Hg = mercury; Ni = nickel; K = potassium; Mo = molybdenum; Se = selenium; Na = sodium; Tl = thallium; Zn = zinc
Source: PLP 2018a, Table 11-31 and Appendix 11B

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

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 in 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.

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. Use of samples from both the PEZ and PWZ provides the most representative and conservative assessment of ARD/ML potential because PEZ samples tend to be more acidic and have higher metal contents (SRK 2018f).

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 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 would 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
PEZ = Pebble East Zone PWZ = Pebble West Zone
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 [2018a: Tables 9.1-15 through 9.1-24] and Schlumberger et al. [2011: Tables 9.1-31 through 9.1-36]) and are incorporated here by reference.

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

Analyte	Number of Samples	Percent Detected	Range of Detects (Min-Max) [a]	Mean[a,b]	Median[a,b]	Standard Deviation[b]
Field and Physical parameters (mg/L, except where noted)						
Total Dissolved Solids	327	99%	3.10 - 72.5	36.6	37.5	11.7
pH (Field, Standard Units)	348	100%	**3.31** - 8.36	6.65	6.70	0.68
Dissolved Oxygen	342	100%	**5.75** - 14.6	9.89	9.94	1.87
Water Temperature (^{0}C)	347	100%	-0.30 - **19**	4.17	1.27	4.79
Specific Conductivity (Field, uS/cm)	345	100%	7.0 - 710	47.9	47	38.4
Turbidity (NTU)	319	100%	0.10 - 8.8	1.04	0.74	1.14
Total Suspended Solids	325	81%	0.15 - 10.8	1.19	0.79	1.39
Oxidation Reduction Potential (mV)	343	100%	-248 - 349	137	155	95.1
Major Ions (mg/L)						
Calcium (dissolved)	230	100%	1.82 - 10.1	5.16	5.32	1.63
Calcium (Total)	235	100%	1.79 - 9.88	5.12	5.24	1.62
Magnesium (Dissolved)	231	100%	0.38 - 2.66	1.33	1.36	0.55
Magnesium (Total)	235	100%	0.37 - 2.86	1.32	1.35	0.56
Sodium (Dissolved)	231	100%	0.99 - 3.41	2.41	2.48	0.51
Sodium (Total)	235	100%	1.18 - 3.58	2.39	2.46	0.52
Potassium (Dissolved)	226	100%	0.096 - 1.15	0.41	0.42	0.16
Potassium (Total)	236	100%	0.081 - 1.10	0.40	0.41	0.16
Alkalinity (total)	336	99%	**3.10** - 49.1	21.4	22.3	7.83
Sulfate	234	100%	0.53 - 9.56	2.21	2.09	1.13
Chloride	237	100%	0.20 - 1.38	0.65	0.63	0.17
Fluoride	237	52%	0.031 - 0.14	0.039	0.031	0.018

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

Analyte	Number of Samples	Percent Detected	Range of Detects (Min-Max) [a]	Mean[a,b]	Median[a,b]	Standard Deviation[b]
Hardness as $CaCO_3$	327	100%	5.90 - 36.4	18.1	18.3	6.22
Nutrients, (mg/L)						
Total Ammonia as Nitrogen (N)	291	18%	0.031 - 0.17	0.050	0.031	0.032
Nitrate-Nitrite	229	77%	0.031 - 3.94	0.19	0.10	0.35
Total Phosphorous (P)	233	82%	0.0031 - 0.17	0.023	0.018	0.018
Total Orthophosphate (as P)	40	0%	0.031 - 0.10	0.079	0.10	0.032
Total Metals (mg/L)						
Aluminum	325	96%	0.0036 - **0.42**	0.034	0.022	0.043
Arsenic	236	33%	0.000099 - 0.00079	0.00034	0.00031	0.000098
Barium	287	100%	0.0013 - 0.013	0.0034	0.0033	0.0013
Cadmium	323	9%	0.0000062 - **0.000094**	0.000020	0.000015	0.0000097
Chromium	234	77%	0.000062 - 0.0010	0.00029	0.00025	0.00016
Copper	324	73%	0.00015 - **0.0036**	0.00042	0.00039	0.00025
Iron	326	100%	0.015 - **1.05**	0.22	0.21	0.16
Lead	324	27%	0.000022 - **0.0024**	0.00012	0.000032	0.00028
Manganese	323	100%	0.00088 - **0.096**	0.013	0.011	0.012
Molybdenum	235	88%	0.000015 - 0.00055	0.00018	0.00017	0.000094
Nickel	308	67%	0.000030 - 0.00093	0.00025	0.00020	0.00014
Selenium	154	5%	0.000029 - 0.00031	0.00027	0.00031	0.000082
Silver	232	2%	0.0000029 - 0.000020	0.0000064	6.2E-06	0.0000020
Zinc	324	53%	0.00044 - 0.015	0.0023	0.0020	0.0016
Dissolved Metals (mg/L)						
Aluminum	325	92%	0.002 - 0.063	0.013	0.0089	0.011
Arsenic	233	23%	0.000081 - 0.00067	0.00031	0.00031	0.000071

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

Analyte	Number of Samples	Percent Detected	Range of Detects (Min-Max) [a]	Mean[a,b]	Median[a,b]	Standard Deviation[b]
Barium	254	100%	0.0014 - 0.0072	0.0031	0.0031	0.00084
Cadmium	325	7%	0.0000062 - 0.000078	0.000020	0.000015	0.000010
Chromium	216	69%	0.000062 - 0.00094	0.00028	0.00024	0.00014
Copper	237	69%	0.00016 - 0.0017	0.00041	0.00041	0.00015
Iron	326	97%	0.0062 - 0.44	0.11	0.093	0.071
Lead	285	20%	0.000022 - 0.00037	0.000070	0.000036	0.000055
Manganese	314	100%	0.00048 - **0.054**	0.0082	0.0068	0.0067
Molybdenum	210	87%	0.0000062 - 0.00078	0.00019	0.00018	0.00011
Nickel	184	77%	0.000077 - 0.0012	0.00033	0.00029	0.00016
Selenium	236	6%	0.000029 - 0.00078	0.00028	0.00031	0.000077
Silver	236	3%	0.0000029 - 0.000016	0.0000062	6.2E-06	0.00000097
Zinc	230	61%	0.00068 - 0.0075	0.0025	0.0022	0.0012
Cyanides (mg/L)						
Cyanide (total)	210	7%	0.0015 - 0.0050	0.0020	0.0015	0.00082
Cyanide (WAD)	327	10%	0.0015 - **0.012**	0.0024	0.0015	0.0014
Organic Compounds, (mg/L)						
Dissolved Organic Carbon	201	100%	0.17 - 4.83	1.58	1.39	0.88

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 the reported detection limit (RDL)
ºC = degrees Celsius
$CaCO_3$ = calcium carbonate
uS/cm = Microsiemens per centimeter
mV = millivolts
mg/L = milligrams per liter
NTU = Nephelometric Turbidity Units
WAD = Weak Acid Dissociable
Source: ERM 2018a

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

Analyte	Number of Samples	Percent Detected	Range of Detects (Min-Max) [a]	Mean[a,b]	Median	Standard Deviation
Field and Physical parameters (mg/L, except where noted)						
Total Dissolved Solids	493	99%	3.1 - 96.2	39.4	36.2	17.8
pH (Field, Standard Units)	603	100%	3.54 - **8.85**	6.63	6.65	0.60
Dissolved Oxygen	597	100%	**3.53** - 18.2[c]	9.89	9.88	2.03
Water Temperature (^{0}C)	607	100%	-0.33 - **23.4**	4.33	2.03	4.71
Specific Conductivity (Field, µS/cm)	600	100%	20 - 133	52.3	45	22.2
Turbidity (NTU)	484	100%	0.080 - 23	1.34	0.78	1.98
Total Suspended Solids	492	89%	0.15 - 16	1.69	1.03	1.98
Oxidation Reduction Potential (mV)	587	100%	-259 - 516	128	138	92.5
Major Ions (mg/L)						
Calcium (Dissolved)	330	100%	2.28 - 13.4	6.18	5.44	2.36
Calcium (Total)	333	100%	2.34 - 13.8	6.17	5.38	2.29
Magnesium (Dissolved)	329	100%	0.35 - 3.9	1.4	1.09	0.79
Magnesium (Total)	333	100%	0.28 - 3.9	1.4	1.09	0.78
Sodium (Dissolved)	330	100%	1.09 - 4.67	2.33	2.09	0.76
Sodium (Total)	333	100%	1.1 - 5.23	2.32	2.05	0.75
Potassium (Dissolved)	326	100%	0.12 - 1.07	0.36	0.32	0.14
Potassium (Total)	333	100%	0.11 - 0.96	0.35	0.31	0.14
Alkalinity (Total)	500	99%	**3.1** - 40	**18**	**16**	7.54
Sulfate	333	100%	0.90 - 28.8	8	5.34	6.09
Chloride	333	100%	0.14 - 1.45	0.69	0.70	0.18
Fluoride	334	62%	0.031 - 0.23	0.044	0.036	0.022
Hardness as $CaCO_3$	493	100%	7.91 - 52.9	20.5	17.4	9.03

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

Analyte	Number of Samples	Percent Detected	Range of Detects (Min-Max) [a]			Mean[a,b]	Median	Standard Deviation
Nutrients, (mg/L)								
Total Ammonia as Nitrogen (N)	423	18%	0.031	-	0.16	0.052600	0.031	0.032
Nitrate-Nitrite	322	85%	0.031	-	1.21	0.17	0.13	0.15
Total Phosphorous (P)	330	78%	0.0031	-	0.095	0.019	0.014	0.016
Total Orthophosphate (as P)	68	0%	0.031	-	0.10	0.070	0.10	0.035
Total Metals (mg/L)								
Aluminum	491	98%	0.0019	-	**1.09**	0.039	0.025	0.061
Arsenic	330	25%	0.00016	-	0.0010	0.00033	0.00031	0.000097
Barium	417	100%	0.0013	-	0.016	0.0041	0.0032	0.0023
Cadmium	487	9%	0.0000062	-	0.000073	0.000019	0.000015	0.0000083
Chromium	333	67%	0.000062	-	0.0011	0.00027	0.00023	0.00017
Copper	473	92%	0.00011	-	**0.0090**	0.0014	0.0010	0.0013
Iron	493	96%	0.0062	-	**2.41**	0.29	0.15	0.30
Lead	488	26%	0.000022	-	**0.0030**	0.00011	0.000048	0.00024
Manganese	493	100%	0.00011	-	**0.20**	0.024	0.011	0.028
Molybdenum	331	98%	0.000015	-	0.0017	0.00051	0.00042	0.00028
Nickel	477	68%	0.000062	-	0.0013	0.00033	0.00025	0.00019
Selenium	260	14%	0.000058	-	0.00062	0.00029	0.00031	0.000073
Silver	327	6%	0.000003	-	0.000031	0.0000064	0.0000062	0.0000020
Zinc	491	60%	0.00031	-	0.022	0.0027	0.0028	0.0021
Dissolved Metals (mg/L)								
Aluminum	464	96%	0.0020	-	0.040	0.0098	0.0080	0.0069
Arsenic	329	18%	0.00012	-	0.00091	0.00031	0.00031	0.000064
Barium	388	100%	0.0010	-	0.0096	0.0039	0.0031	0.0021

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

Analyte	Number of Samples	Percent Detected	Range of Detects (Min-Max) [a]			Mean[a,b]	Median	Standard Deviation
Cadmium	485	6%	0.0000062	-	0.000074	0.000019	0.000015	0.0000081
Chromium	306	65%	0.000062	-	0.0010	0.00025	0.00021	0.00015
Copper	418	89%	0.00015	-	**0.0049**	0.0011	0.00088	0.00075
Iron	488	91%	0.0062	-	**1**	0.12	0.062	0.13
Lead	427	19%	0.000022	-	**0.00042**	0.000072	0.000033	0.000062
Manganese	474	100%	0.000056	-	**0.12**	0.019	0.0078	0.024
Molybdenum	313	98%	0.000031	-	0.0017	0.00051	0.00042	0.00028
Nickel	292	72%	0.000090	-	0.0012	0.00042	0.00039	0.00020
Selenium	334	10%	0.000047	-	0.00062	0.00029	0.00031	0.000067
Silver	333	2%	0.000003	-	0.000013	0.0000062	0.0000062	0.0000008
Zinc	366	66%	0.00047	-	0.011	0.0028	0.0031	0.0013
Cyanides (mg/L)								
Cyanide	330	8%	0.0015	-	0.016	0.0024	0.0015	0.0015
Cyanide (WAD)	469	8%	0.0015	-	**0.0078**	0.0022	0.0015	0.0012
Organic Compounds, (mg/L)								
Dissolved Organic Carbon	305	89%	0.15	-	4.76	1.27	1.02	0.88

Notes:
[a] Bold values indicate fields that exceed the most stringent water quality criteria
[b] When calculating the mean, median, and standard deviation, non-detects with "U" or "UJ" qualifiers were included as the reported detection limit (RDL)
[c] Maximum DO concentrations above saturation levels were in overburden for three wells, but were not flagged as confirmed outliers. DO measurements above saturation levels are relatively common and could result due to instrument calibration against factors such as air temperature variations and photosynthetic oxygen (YSI 2019).
ºC = degrees Celsius
$CaCO_3$ = calcium carbonate
DO = dissolved oxygen
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	Percent Detected	Range of Detects (Min-Max) [a]	Mean[a,b]	Median[a,b]	Standard Deviation[b]
Field and Physical parameters (mg/L, except where noted)						
Total Dissolved Solids	590	100%	3.75 - 115	52.8	49	19.1
pH (Field, Standard Units)	764	100%	**4.5** - **9.33**	6.9	6.92	0.54
Dissolved Oxygen[c]	757	100%	**2.69** - 18.6	9.7	9.53	1.83
Water Temperature (^{0}C)	767	100%	-0.93 - **15.7**	3.89	2.96	3.82
Specific Conductivity (Field, uS/cm)	760	100%	10 - 750	77.6	73	38.3
Turbidity (NTU)	570	100%	0.0 - 16.3	1.39	0.87	1.71
Total Suspended Solids	584	81%	0.15 - **25.8**	3.21	1.83	3.62
Oxidation Reduction Potential (mV)	729	100%	-180 - 519	115	112	72.6
Major Ions (mg/L)						
Calcium (Dissolved)	443	100%	2.37 - 17.3	8.92	8.9	2.38
Calcium (Total)	445	100%	2.12 - 16.7	8.95	8.97	2.33
Magnesium (Dissolved)	442	100%	0.64 - 4.73	2.1	1.7	0.98
Magnesium (Total)	444	100%	0.66 - 5	2.1	1.7	0.97
Sodium (Dissolved)	443	100%	1.02 - 6.73	2.77	2.55	0.74
Sodium (Total)	444	100%	0.95 - 6.84	2.77	2.53	0.73
Potassium (Dissolved)	435	100%	0.11 - 1.2	0.45	0.40	0.18
Potassium (Total)	443	100%	0.19 - 1.36	0.45	0.39	0.18
Alkalinity (Total)	601	100%	**3.73** - 74	31.6	31.8	9.4
Sulfate	444	100%	0.90 - 41.6	6.28	3.3	8.14
Chloride	443	100%	0.031 - 1.15	0.70	0.70	0.14
Fluoride	429	82%	0.0060 - 0.16	0.044	0.037	0.021
Hardness as $CaCO_3$	591	100%	7.25 - 62.2	32	30.8	9.49
Nutrients, (mg/L)						

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

Analyte	Number of Samples	Percent Detected	Range of Detects (Min-Max) [a]	Mean[a,b]	Median[a,b]	Standard Deviation[b]
Total Ammonia as Nitrogen (N)	526	19%	0.0050 - **0.25**	0.042	0.031	0.034
Nitrate-Nitrite	435	93%	0.0050 - 1.74	0.21	0.17	0.20
Total Phosphorous (P)	442	82%	0.0031 - 0.11	0.019	0.014	0.016
Total Orthophosphate (as P)	47	0%	0.031 - 0.10	0.068	0.10	0.035
Total Metals (mg/L)						
Aluminum	584	98%	0.0032 - **0.66**	0.073	0.037	0.096
Arsenic	445	70%	0.00012 - 0.0028	0.00095	0.00090	0.00066
Barium	528	100%	0.0012 - 0.018	0.0053	0.0050	0.0024
Cadmium	578	15%	0.0000030 - **0.00010**	0.000017	0.000015	0.000010
Chromium	445	84%	0.000062 - 0.0012	0.00036	0.00030	0.00019
Copper	590	73%	0.000050 - **0.0054**	0.00061	0.00040	0.00076
Iron	588	100%	0.015 - **1.3**	0.24	0.16	0.21
Lead	586	38%	0.0000050 - **0.0028**	0.000089	0.000053	0.00015
Manganese	587	100%	0.00068 - **0.16**	0.026	0.013	0.030
Molybdenum	427	94%	0.000015 - 0.00053	0.00025	0.00027	0.000094
Nickel	575	75%	0.000030 - 0.0040	0.00061	0.00040	0.00063
Selenium	441	3%	0.000030 - 0.00040	0.00030	0.00031	0.000066
Silver	438	11%	0.0000029 - 0.000032	0.0000076	0.0000062	0.0000047
Zinc	588	50%	0.00020 - 0.016	0.0025	0.0023	0.0016
Dissolved Metals (mg/L)						
Aluminum	564	98%	0.0020 - **0.14**	0.013	0.0073	0.016
Arsenic	441	68%	0.000089 - 0.0027	0.00082	0.00069	0.00060
Barium	517	100%	0.0011 - 0.013	0.0049	0.0045	0.0023
Cadmium	573	11%	0.0000030 - 0.000073	0.000017	0.000015	0.000009

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

Analyte	Number of Samples	Percent Detected	Range of Detects (Min-Max) [a]			Mean[a,b]	Median[a,b]	Standard Deviation[b]
Chromium	416	76%	0.000050	-	0.0011	0.00031	0.00026	0.00017
Copper	473	67%	0.000030	-	**0.0026**	0.00047	0.00041	0.00038
Iron	587	93%	0.0034	-	0.43	0.090	0.062	0.081
Lead	524	22%	0.0000030	-	0.00037	0.000057	0.000031	0.000049
Manganese	580	100%	0.00025	-	**0.15**	0.020	0.0084	0.028
Molybdenum	403	93%	0.000015	-	0.00057	0.00025	0.00028	0.000094
Nickel	436	65%	0.000070	-	0.0038	0.00068	0.00050	0.00065
Selenium	445	2%	0.000029	-	0.0010	0.00030	0.00031	0.000088
Silver	441	6%	0.0000029	-	0.000044	0.0000068	0.0000062	0.0000040
Zinc	488	51%	0.00020	-	0.0084	0.0025	0.0023	0.0013
Cyanides (mg/L)								
Cyanide	433	6%	0.00090	-	0.0081	0.0022	0.0020	0.0011
Cyanide (WAD)	573	8%	0.00090	-	**0.021**	0.0022	0.0015	0.0015
Organic Compounds, (mg/L)								
Dissolved Organic Carbon	438	92%	0.15	-	9.38	1.52	1.2	1.23

Notes:
[a] Bold values indicate fields that exceed the most stringent water quality criteria
[b] When calculating the mean, median, and standard deviation, non-detects with "U" or "UJ" qualifiers were included as the reported detection limit (RDL)
[c] Maximum DO concentrations above saturation levels were in overburden for three wells, but were not flagged as confirmed outliers. DO measurements above saturation levels are relatively common and could result due to instrument calibration against factors such as air temperature variations and photosynthetic oxygen (YSI 2019).

ºC = degrees Celsius
DO = dissolved oxygen
mV = millivolts
NTU = Nephelometric Turbidity Units
$CaCO_3$ = calcium carbonate
mg/L = milligrams per liter
uS/cm = Microsiemens per centimeter
WAD = Weak Acid Dissociable

Source: ERM 2018a

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

Analyte	Number of Samples	Percent Detected	Range of Detects (Min-Max)	Mean [a,b]	Median [a,b]	Standard Deviation [b]
Field and Physical Parameters (mg/L, except where noted)						
Total Dissolved Solids	11	100%	20.0 - 68.1	44.3	43.8	11.7
pH (Field, Standard Units)	10	100%	**4.74** - **8.61**	6.32	6.26	1.14
Dissolved Oxygen	10	100%	**5.65** - 8.85	7.37	7.42	1.06
Water Temperature (°C)	10	100%	3.16 - **13.8**	9.09	9.62	3.65
Specific Conductivity (Field, uS/cm)	10	100%	17.0 - 64.0	38.2	0.035	0.017
Turbidity (NTU)	10	100%	0.25 - 7.44	1.98	1.09	2.26
Total Suspended Solids	11	91%	0.40 - 14.8	4.27	1.03	5.95
Oxidation Reduction Potential (mV)	10	100%	-77.8 - 223	128	143	89.9
Major Ions (mg/L)						
Calcium (Dissolved)	11	100%	2.52 - 7.37	4.78	5.17	1.78
Calcium (Total)	11	100%	2.59 - 7.77	5.02	5.12	1.90
Magnesium (Dissolved)	11	100%	0.42 - 1.92	1.05	1.18	0.57
Magnesium (Total)	11	100%	0.43 - 1.96	1.09	1.15	0.61
Sodium (Dissolved)	10	100%	1.74 - 2.98	2.18	2.11	0.41
Sodium (Total)	11	100%	1.67 - 3.17	2.19	2.05	0.47
Potassium (Dissolved)	11	100%	0.073 - 0.46	0.20	0.16	0.12
Potassium (Total)	11	100%	0.079 - 0.48	0.20	0.17	0.12
Alkalinity (Total)	11	100%	**10.0** - 29.9	**19.8**	22.0	6.95
Sulfate	11	100%	0.36 - 11.2	3.56	1.33	3.82
Chloride	11	100%	0.39 - 0.76	0.54	0.49	0.12
Fluoride	11	64%	0.041 - 0.070	0.038	0.042	0.020
Hardness as $CaCO_3$ (Not Filtered)	11	100%	8.23 - 27.5	17.0	17.8	7.23
Cations (mg/L, except where noted)						

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

Analyte	Number of Samples	Percent Detected	Range of Detects (Min-Max)			Mean [a,b]	Median [a,b]	Standard Deviation [b]
Nitrogen (N), Ammonia (as N)	11	64%	0.016	-	0.20	0.071	0.050	0.059
Nitrogen (N), Nitrate-Nitrite	11	82%	0.032	-	1.19	0.28	0.073	0.37
Total Phosphorus (P)	11	100%	0.0070	-	0.059	0.023	0.023	0.014
Total Orthophosphate (as P)	10	0%	NA	-	NA	0.043	0.050	--
Total Metals (mg/L)								
Aluminum	11	100%	0.020	-	0.19	0.053	0.031	0.053
Antimony	5	45%	0.000024	-	0.00015	0.000036	0.000012	0.000046
Barium	11	100%	0.0021	-	0.0073	0.0040	0.0033	0.0018
Iron	11	100%	0.064	-	**1.03**	0.40	0.32	0.27
Copper	11	100%	0.00018	-	**0.0038**	0.0013	0.00039	0.0014
Zinc	11	100%	0.0010	-	0.0057	0.0032	0.0029	0.0016
Lead	11	36%	0.000042	-	**0.00044**	0.00011	0.000050	0.00014
Cadmium[c]	11	0%	0	-	0	0.000018	0.000019	--
Arsenic	11	45%	0.00049	-	0.0013	0.00048	0.00026	0.00041
Nickel	11	45%	0.00024	-	0.00047	0.00022	0.00010	0.00015
Molybdenum	11	73%	0.00020	-	0.00073	0.00035	0.00028	0.00028
Manganese	11	100%	0.0022	-	**0.074**	0.035	0.041	0.026
Dissolved Metals (mg/L)								
Aluminum	11	100%	0.0025	-	0.025	0.015	0.017	0.0074
Antimony	11	45%	0.000019	-	0.00013	0.000032	0.0000075	0.000040
Barium	11	100%	0.0010	-	0.0058	0.0033	0.0031	0.0015
Iron	11	91%	0.029	-	0.44	0.16	0.16	0.14
Copper	10	100%	0.00020	-	0.0021	0.00083	0.00030	0.00082
Zinc	9	100%	0.0013	-	0.0039	0.0027	0.0023	0.0011

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

Analyte	Number of Samples	Percent Detected	Range of Detects (Min-Max)			Mean [a,b]	Median [a,b]	Standard Deviation [b]
Lead	4	100%	0.00010	-	0.00028	0.00016	0.00014	0.000078
Cadmium[c]	11	0%	0	-	0	0.000018	0.000019	--
Arsenic	11	45%	0.00035	-	0.00091	0.00036	0.00016	0.00028
Nickel	2	100%	0.00027	-	0.00046	0.00036	0.00036	0.00013
Molybdenum	11	73%	0.00017	-	0.00070	0.00035	0.00027	0.00028
Manganese	11	100%	0.00029	-	**0.051**	0.017	0.010	0.018
Cyanides (mg/L)								
Cyanide (Total)[c]	11	0%	0	-	0	0.00075	0.00075	--
Cyanide (WAD)	11	27%	0.0016	-	0.0050	0.0013	0.00075	0.0013

Notes:
[a] Bold values indicate fields that exceed the most stringent water quality criteria
[b] When calculating the mean, median, and standard deviation, non-detects with "U" or "UJ" qualifiers were included as 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)
ºC = degrees Celsius
$CaCO_3$ = calcium carbonate
mg/L = milligrams per liter
mV = millivolts
uS/cm = Microsiemens per centimeter
NTU = Nephelometric Turbidity Units
WAD = Weak Acid Dissociable
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	Percent Detected	Range of Detects (Min-Max) [a]	Mean [a,b]	Median[a,b]	Standard Deviation[b]
Total Metals (mg/L)						
Aluminum	82	99%	0.00486 - **0.925**	**0.095**	0.04625	0.1635
Antimony	82	60%	0.0000016 - 0.0019	0.00011	0.00004	0.00023
Arsenic	82	66%	0.00002 - 0.0081	0.00084	0.0004	0.00157
Barium	82	100%	0.00128 - 0.01100	0.00491	0.00332	0.00365
Beryllium	82	7%	0 - NA	0.00001	0.00001	0
Bismuth	65	12%	0 - 0.00075	0.00033	0.00001	0.00037
Boron	81	28%	0.0013 - 0.005	0.00279	0.00155	0.00192
Cadmium	80	12%	0 - **0.0022**	0.00004	0.00002	0.00024
Calcium	82	100%	2.34 - 14	7.13915	7.125	2.47983
Chromium	82	73%	0.00003 - 0.0010	0.00027	0.00023	0.00026
Cobalt	82	87%	0 - 0.0001	0.00006	0.00005	0.00006
Copper	82	100%	0.00011 - 0.0014	0.00063	0.00043	0.00047
Iron	82	94%	0.00310 - **2.110**	0.2081	0.08155	0.33514
Lead	82	35%	0.00002 - **0.0011**	0.00013	0.00005	0.00017
Magnesium	82	100%	0.18000 - 1.27000	0.8786	0.951	0.31163
Manganese	82	99.0%	0.0005 - **0.1560**	0.0128	0.00389	0.02247
Mercury	82	29%	0.00015 - 0.00001	0	0	0
Molybdenum	82	95%	0.00016 - 0.00153	0.00064	0.00054	0.00034
Nickel	82	91%	0.00005 - 0.00063	0.00029	0.00028	0.00014
Potassium	82	100%	0.11300 - 0.8650	0.3142	0.226	0.20499
Selenium	82	17%	0.00001 - 0.00026	0.00011	0.00013	0.00005
Silver	82	4%	0 - 0.00003	0	0	0
Thallium	82	5%	0 - 0.00001	0.00001	0	0

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

Analyte	Number of Samples	Percent Detected	Range of Detects (Min-Max) [a]	Mean [a,b]	Median[a,b]	Standard Deviation[b]
Tin	79	10%	0.00003 - 0.00050	0.00014	0.00009	0.00016
Vanadium	82	68%	0.00010 - 0.0032	0.00042	0.00033	0.00049
Zinc	82	24%	0.00050 - 0.0129	0.0028	0.00191	0.00291
Dissolved Metals (mg/L)						
Aluminum	81	77%	0.00100 - 0.057	0.0151	0.0125	0.01088
Antimony	78	53%	0.0000016 - 0.00028	0.00005	0.00004	0.00005
Arsenic	81	56%	0.00004 - 0.00585	0.00046	0.00016	0.00087
Barium	81	100.0%	0.00126 - 0.0135	0.0042	0.00235	0.0033
Beryllium	81	0%	0 - 0.000040	0.00001	0.00001	0
Bismuth	72	1%	0 - 0.00075	0.00033	0	0.00037
Boron	76	12%	0.00155 - 0.0119	0.0024	0.00155	0.00139
Cadmium	81	15%	0.0000031 - 0.00006	0.00002	0.00002	0.00001
Calcium	79	100%	2.34 - 12.9	6.989	6.9	2.43038
Chromium	71	62%	0.00003 - 0.00143	0.0002	0.00016	0.00019
Cobalt	76	75%	0 - 0.0004	0.00004	0.00003	0.00002
Copper	72	100%	0.00019 - 0.0021	0.00043	0.00035	0.00023
Iron	81	80%	0.00400 - 0.215	0.0554	0.024	0.06144
Lead	62	58%	0.00002 - 0.00035	0.00013	0.00011	0.00007
Magnesium	81	100%	0.1810 - 1.340	0.8590	0.95	0.30271
Manganese	81	96%	0.00025 - 0.0332	0.0052	0.00177	0.00699
Molybdenum	78	96%	0.00016 - 0.00159	0.00065	0.00055	0.00035
Nickel	48	98%	0.00005 - 0.00056	0.00035	0.00035	0.0001
Potassium	72	100%	0.1120 - 0.855	0.3099	0.233	0.19807
Selenium	81	17%	0.00001 - 0.00021	0.00011	0.00008	0.00005

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

Analyte	Number of Samples	Percent Detected	Range of Detects (Min-Max) [a]	Mean [a,b]	Median[a,b]	Standard Deviation[b]
Silicon	81	100%	2.240 - 6.570	4.219	4.15	1.16255
Silver	81	1%	0 - 0.00001	0	0	0
Thallium	80	3%	0 - 0.00001	0.00001	0	0
Tin	81	0%	0.00003 - 0.00085	0.00011	0.00003	0.00012
Vanadium	81	47%	0.00008 - 0.00074	0.00022	0.00013	0.00015
Zinc	69	12%	0.00075 - 0.0143	0.00239	0.00208	0.0017
Anions (mg/L, except where noted)						
Chloride	82	100%	0.42 - 2.33	0.961	0.920	0.340
Fluoride	82	54%	0.016 - 0.12	0.041	0.039	0.023
Cyanide	82	12%	0.0013 - 0.0066	0.002	0.0013	0.0016
Cyanide (WAD)	82	16%	0.0013 - **0.0077**	0.0018	0.0013	0.0013
Nitrogen (N), Nitrate+Nitrite (as Nitrogen)	81	86%	0.016 - 8.09	0.840	0.520	1.22
Phosphorus (P), Total Orthophosphate (as P)	82	71%	0.0017 - 0.445	0.048	0.019	0.064
Sulfate	82	100%	0.91 - 59.1	6.06	3.75	8.05
Cations (mg/L, except where noted)						
Ammonia as Nitrogen (N)	82	15%	0.015 - **0.464**	0.045	0.016	0.073
Sodium (dissolved)	77	100%	1.03 - 3.9	1.952	1.88	0.58475
Sodium (total)	82	100%	0.987 - 4.13	1.968	1.835	0.6175
Miscellaneous Parameters (mg/L, except where noted)						
Acidity (total)	82	2%	0.79 - 9.5	2.6	2.1	1.7
Alkalinity (total)	82	90.0%	**1.60** - 33.0	**19**	21	7
Hardness as $CaCO_3$ (Not Filtered)			-			
pH (Field, Standard Units)			-			

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

Analyte	Number of Samples	Percent Detected	Range of Detects (Min-Max) [a]	Mean [a,b]	Median[a,b]	Standard Deviation[b]
Specific Conductivity (Field, uS/cm)	82	100%	21.00 - 600	70.00	60	66.000
Total Dissolved Solids	82	100%	10 - 126	4.350	44.4	19.400000
Total Suspended Solids	82	89%	0.075 - **56**	4.2	1.5	10.2
Water Temperature (°C)	80	100%	0.08 - **22.7**	7.42	6.94	5.16

Notes:
[a] Bold values indicate fields that exceed the most stringent water quality criteria
[b] When calculating the mean, median, and standard deviation, non-detects with "U" or "UJ" qualifiers were included as the reported detection limit (RDL). Non-detect results of zero without a “U” or “UJ” qualifiers were included as one-half the method detection limit (MDL)
ºC = degrees Celsius
$CaCO_3$ = calcium carbonate
mg/L = milligrams per liter
mV = millivolts
uS/cm = Microsiemens per centimeter
NTU = Nephelometric Turbidity Units
WAD = Weak Acid Dissociable
Source: Schlumberger et al. 2011a

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

Analyte	Number of Samples	Percent Detected	Range of Detects (Min-Max) [a]			Mean [a,b]	Median[a,b]	Standard Deviation[b]
Total Metals (mg/L)								
Aluminum	50	92%	0.00735	-	**1.36**	**0.1530**	0.0130	0.294845687
Antimony	50	38%	0.0000016	-	0.0000630	0.000129	0.000027	0.000557
Arsenic	50	16%	0.000020	-	**0.021100**	0.00067	0.000125	0.00308
Barium	50	0%	0.00062	-	0.02130	0.00814	0.00266	0.00427
Beryllium	50	14%	0.0000015	-	0.0000342	0.0000084	0.0000075	0.0000062
Bismuth	50	4%	0.0000016	-	0.0007500	0.0002730	0.0000016	0.0003617
Boron	50	44%	0.00143	-	0.01400	0.00427	0.00155	0.00341
Cadmium	50	20%	0.0000031	-	0.0000683	0.0000192	0.0000078	0.0000162
Calcium	50	0%	1.030	-	9.210	3.290	1.370	2.017
Chromium	50	44%	0.0000310	-	0.0006920	0.000210	0.000129	0.000223
Cobalt	50	78%	0.0000050	-	0.0005990	0.0001290	0.0000144	0.0001720
Copper	50	98%	0.000114	-	**0.034600**	0.004310	0.002637	0.007166
Iron	50	82%	0.0013	-	0.8260	0.1080	0.0066	0.1604
Lead	50	38%	0.000016	-	**0.0012**	0.000145	0.000033	0.000233
Magnesium	50	0%	0.1000	-	0.6480	0.3010	0.1725	0.1326
Manganese	50	94.0%	0.00025	-	**0.05450**	0.01120	0.00067	0.01396
Mercury	50	18%	0.0000001	-	**0.0000320**	0.00000084	0.00000088	0.00000081
Molybdenum	50	70%	0.000017	-	0.000997	0.000375	0.000352	0.000278
Nickel	50	76%	0.000031	-	0.000678	0.000213	0.000105	0.000154
Potassium	50	0%	0.1030	-	0.5130	0.2510	0.1340	0.1043
Selenium	50	6%	0.0000143	-	0.0001550	0.0000966	0.0000775	0.0000485
Silver	50	6%	0.0000014	-	0.0000205	0.0000036	0.0000031	0.0000033
Thallium	50	2%	0.0000021	-	0.0000210	0.0000067	0.0000031	0.0000051

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

Analyte	Number of Samples	Percent Detected	Range of Detects (Min-Max) [a]			Mean [a,b]	Median[a,b]	Standard Deviation[b]
Tin	50	14%	0.000030	-	0.002290	0.000155	0.000122	0.000327
Vanadium	50	60%	0.000052	-	0.001830	0.000322	0.000170	0.000352
Zinc	50	78%	0.00075	-	0.01850	0.00436	0.00549	0.00401
Dissolved Metals (mg/L)								
Aluminum	49	80%	0.0035	-	0.058	0.0133	0.0060	0.0104
Antimony	45	40%	0.0000016	-	0.0001120	0.000064	0.000009	0.000163
Arsenic	48	17%	0.000006	-	0.007760	0.000406	0.000125	0.001409
Barium	50	0%	0.00060	-	0.01510	0.00662	0.00248	0.00327
Beryllium	50	4%	0.0000015	-	0.0000162	0.0000068	0.0000075	0.0000024
Bismuth	48	2%	0.0000016	-	0.0007500	0.0002720	0.0000016	0.0003623
Boron	46	30%	0.00134	-	0.01300	0.00405	0.00435	0.00294
Cadmium	49	18%	0.0000031	-	0.0000754	0.0000179	0.0000078	0.0000162
Calcium	50	0%	1.020	-	9.760	3.330	1.670	2.199
Chromium	50	42%	0.0000310	-	0.0008890	0.000179	0.000172	0.000205
Cobalt	48	71%	0.0000050	-	0.0005810	0.0000947	0.0000126	0.0001254
Copper	45	0%	0.000198	-	0.026	-	**0.00042[c]**	-
Iron	50	68%	0.0013	-	0.1230	0.0247	0.0066	0.0247
Lead	33	58%	0.000016	-	**0.000414**	0.000131	0.000050	0.000085
Magnesium	50	0%	0.968	-	0.5990	0.2740	0.1669	0.1257
Manganese	50	92%	0.00010	-	0.03150	0.00666	0.00050	0.00889
Molybdenum	42	71%	0.000050	-	0.000881	0.000412	0.000324	0.000276
Nickel	28	86%	0.000083	-	0.000521	0.000286	0.000182	0.000134
Potassium	50	0%	0.1000	-	0.4560	0.2390	0.1295	0.0888
Selenium	50	6%	0.0000143	-	0.0001550	0.0000970	0.0000775	0.0000480

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

Analyte	Number of Samples	Percent Detected	Range of Detects (Min-Max) [a]			Mean [a,b]	Median[a,b]	Standard Deviation[b]
Silicon	50	98%	1.050	-	4.320	2.510	2.240	0.739
Silver	50	8%	0.0000014	-	0.0000158	0.0000035	0.0000031	0.0000023
Thallium	50	2%	0.0000021	-	0.0000304	0.0000067	0.0000031	0.0000057
Tin	50	0%	0.000030	-	0.000155	0.000076	0.000031	0.000060
Vanadium	49	41%	0.000025	-	0.000584	0.000174	0.000264	0.000121
Zinc	41	88%	0.00000	-	0.01700	0.00378	0.00447	0.00320
Anions (mg/L, except where noted)								
Chloride	50	100%	0.31	-	1.7	0.861	0.559	0.426
Fluoride	50	42%	0.016	-	0.088	0.035	0.033	0.020
Cyanide	50	8%	0.0013	-	0.0066	0.0016	0.0013	0.0010
Cyanide (WAD)	50	8%	0.0013	-	0.0037	0.0015	0.0024	0.0007
Nitrogen (N), Nitrate+Nitrite (as N)	49	88%	0.0395	-	**26.4**	1.39	0.188	3.85
Phosphorus (P), Total Orthophosphate (as P)	50	70%	0.0	-	0.60	0.04	0.0264	0.896
Sulfate	49	100%	0.53	-	33.9	5.39	2.08	6.05
Cations (mg/L, except where noted)								
Nitrogen (N), Ammonia (as N)	50	20%	0.020	-	0.03	0.040	0.053	0.043
Sodium (dissolved)	45	0%	0.620	-	2.36	1.220	1.017	0.412
Sodium (total)	50	0%	0.770	-	2.73	1.250	1.010	0.432
Miscellaneous Parameters (mg/L, except where noted)								
Acidity (Total)	50	34%	0.79	-	10.0	1.78	0.79	1.43
Alkalinity (Total)	50	100%	**1.55**	-	20.8	**5.9**	4.4	5.00
Hardness as $CaCO_3$ (Not Filtered)	50	100%	2.98	-	25.5	9.46	7.97	5.463232
pH (Field, Standard Units)	50	100%	**4.69**	-	**8.59**	**6.43**	**6.49**	0.82

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

Analyte	Number of Samples	Percent Detected	Range of Detects (Min-Max) [a]			Mean [a,b]	Median[a,b]	Standard Deviation[b]
Specific Conductivity (Field, uS/cm)	50	100%	10.5	-	270	43	17	48.6
Total Dissolved Solids	50	96%	1.55	-	110	24.5	8.3	18.7
Total Suspended Solids	50	86%	0.08	-	**34.8**	3.50	0.20	7.10
Water Temperature (°C)	50	100%	0.09	-	**22.0**	6.84	6.58	4.88

Notes:
[a] Bold values indicate fields that exceed the most stringent water quality criteria
[b] When calculating the mean, median, and standard deviation, non-detects with "U" or "UJ" qualifiers were included as the reported detection limit (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
ºC = degrees Celsius
$CaCO_3$ = calcium carbonate
mg/L = milligrams per liter
mV = millivolts
uS/cm = Microsiemens per centimeter
NTU = Nephelometric Turbidity Units
WAD = Weak Acid Dissociable
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]	FOD	Min	Max	Mean [a,c]	FOD	Min	Max	Mean [a,c]	FOD	Min	Max	Mean [a,c]	FOD
Total Metals (mg/L)																
Aluminum	0.0022	0.016	0.0061	100%	0.0037	**1.26**	0.040	100%	0.0028	**0.20**	0.015	100%	0.0056	**0.85**	0.066	100%
Antimony	0.000014	0.00005	0.000028	83%	0.000005	0.000061	0.000026	83%	0.000008	0.000033	0.000022	82%	0.000002	0.00015	0.000028	78%
Arsenic	0.00013	0.00051	0.00019	17%	0.00013	0.00092	0.00023	19%	0.00013	0.00040	0.00016	5%	0.00013	0.00059	0.00019	17%
Barium	0.0048	0.0063	0.0055	100%	0.00071	0.022	0.0054	100%	0.0046	0.0093	0.0062	100%	0.0049	0.014	0.0063	100%
Beryllium	0.000008	0.000013	0.00001	0%	0.000008	0.000013	0.000011	0%	0.000008	0.000013	0.000011	0%	0.000008	0.000013	0.00001	0%
Bismuth	0.000002	0.000022	0.000006	13%	0.000002	0.000039	0.000006	9%	0.000002	0.000013	0.000006	3%	0.000002	0.000008	0.000005	6%
Boron	0.0016	0.005	0.0036	50%	0.0013	0.0068	0.0032	58%	0.0013	0.0079	0.0030	61%	0.0016	0.0056	0.0037	64%
Cadmium	0.000008	0.000029	0.000009	7%	0.000008	0.000033	0.000013	16%	0.000008	0.000025	0.000013	0%	0.000008	0.000025	0.00001	6%
Calcium	5.37	6.51	5.95	100%	2.63	7.46	5.69	100%	3.9	6.21	5.30	100%	4.41	6.55	5.50	100%
Chromium	0.00005	0.00045	0.00020	57%	0.000031	0.00066	0.00022	61%	0.000031	0.00067	0.00033	47%	0.000031	0.00064	0.00022	64%
Cobalt	0.000005	0.000031	0.000015	87%	0.000005	0.00038	0.000028	89%	0.000005	0.000064	0.00002	66%	0.000011	0.00039	0.000057	100%
Copper	0.00042	0.0007	0.00050	100%	0.00038	**0.0027**	0.00058	100%	0.00035	0.0016	0.00058	100%	0.00057	**0.0079**	0.002	100%
Iron	0.0031	0.026	0.013	67%	0.0099	**1.06**	0.084	85%	0.0031	**1.56**	0.066	66%	0.0067	0.884	0.068	81%
Lead	0.000016	0.00005	0.000019	0%	0.000016	**0.00065**	0.000077	13%	0.000016	0.00035	0.00012	18%	0.000016	**0.00042**	0.00006	19%
Magnesium	0.72	0.94	0.85	100%	0.60	1.15	0.84	100%	0.56	0.83	0.75	100%	0.58	0.99	0.76	100%
Manganese	0.00067	0.0025	0.0012	100%	0.00069	0.030	0.0032	100%	0.0001	0.0095	0.0039	97%	0.00035	**0.082**	0.0082	100%
Mercury	0	0.000003	0	7%	0	0.000003	0.000001	7%	0	0.000003	0.000001	3%	0	0.000003	0.000001	3%
Molybdenum	0.00063	0.0011	0.00076	100%	0.000089	0.0012	0.00070	100%	0.00053	0.00089	0.00068	100%	0.00050	0.00092	0.00071	100%
Nickel	0.0001	0.00028	0.00020	80%	0.0001	0.0023	0.00024	80%	0.0001	0.00053	0.00019	79%	0.0001	0.0010	0.00025	78%
Potassium	0.47	0.59	0.54	100%	0.24	1.86	0.53	100%	0.34	0.66	0.52	100%	0.43	0.65	0.51	100%
Selenium	0.000078	0.00025	0.00012	0%	0.000078	0.00025	0.00014	0%	0.000078	0.00025	0.00014	0%	0.000078	0.00025	0.00013	0%
Silver	0.000003	0.000007	0.000003	7%	0.000003	0.000035	0.000005	2%	0.000003	0.000012	0.000005	8%	0.000003	0.000007	0.000003	8%
Thallium	0.000003	0.000005	0.000004	0%	0.000003	0.000014	0.000004	1%	0.000003	0.000005	0.000004	0%	0.000003	0.000022	0.000003	6%
Tin	0.000031	0.00005	0.00004	0%	0.000031	0.00005	0.000043	0%	0.000031	0.00005	0.000044	0%	0.000031	0.000071	0.00004	3%
Vanadium	0.0001	0.00025	0.00013	3%	0.0001	0.0027	0.00021	9%	0.0001	0.00025	0.00018	0%	0.0001	0.0014	0.00022	19%
Zinc	0.00023	0.015	0.0024	40%	0.00023	0.016	0.0025	51%	0.00023	0.014	0.0028	68%	0.00023	0.013	0.0031	66%
Dissolved Metals (mg/L)																
Aluminum	0.00031	0.0046	0.0021	64%	0.00031	**0.11**	0.016	93%	0.001	0.0089	0.0044	77%	0.00273	0.018	0.0059	100%
Antimony	0.000007	0.000058	0.00003	87%	0.000002	0.000068	0.000028	81%	0.000005	0.000059	0.000021	82%	0.000005	0.00005	0.000027	83%
Arsenic	0.00012	0.00046	0.00017	10%	0.00013	0.00056	0.00025	11%	0.00013	0.00031	0.00016	5%	0.000125	0.00049	0.00017	11%
Barium	0.0033	0.0069	0.0054	100%	0.0001	0.0076	0.0050	99%	0.0045	0.0076	0.0056	100%	0.00466	0.0063	0.0056	100%
Beryllium	0.000008	0.000013	0.00001	0%	0.000008	0.000034	0.000011	3%	0.000008	0.000013	0.000011	0%	0.000008	0.000013	0.00001	0%

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]	FOD	Min	Max	Mean [a,c]	FOD	Min	Max	Mean [a,c]	FOD	Min	Max	Mean [a,c]	FOD
Bismuth	0.000002	0.000008	0.000005	0%	0.000002	0.000017	0.000006	11%	0.000002	0.000008	0.000006	0%	0.000002	0.000008	0.000005	3%
Boron	0.0016	0.0053	0.0034	53%	0.0013	0.010	0.0031	63%	0.0013	0.0052	0.0023	47%	0.00155	0.0067	0.0035	58%
Cadmium	0.000008	0.00005	0.00001	3%	0.000008	0.000063	0.000011	4%	0.000008	0.000035	0.000014	13%	0.000008	0.000025	0.000009	2%
Calcium	3.92	6.85	5.80	100%	0.0078	7.34	5.59	99%	4.03	6.43	5.23	100%	3.97	6.49	5.47	100%
Chromium	0.000031	0.00063	0.00018	40%	0.000031	0.00051	0.00017	45%	0.000031	0.00052	0.00028	66%	0.000031	0.00055	0.00020	66%
Cobalt	0.000002	0.000026	0.000014	77%	0.000002	0.000029	0.000016	81%	0.000005	0.000025	0.000017	76%	0.000005	0.000094	0.000024	83%
Copper	0.00033	0.00059	0.00043	100%	0.00005	0.00071	0.00049	99%	0.00031	0.00071	0.00052	100%	0.00053	0.0027	0.00094	100%
Iron	0.0031	0.024	0.010	47%	0.0031	0.25	0.041	64%	0.0031	0.064	0.020	55%	0.0031	0.025	0.012	61%
Lead	0.000016	**0.0022**	0.00017	60%	0.000016	0.00015	0.000052	54%	0.000016	0.00013	0.000035	50%	0.000016	0.00013	0.000045	61%
Magnesium	0.55	1.05	0.86	100%	0.00078	1.01	0.83	98%	0.56	0.88	0.75	100%	0.558	0.89	0.76	100%
Manganese	0.0001	0.0013	0.00038	90%	0.000031	0.0033	0.00078	96%	0.000066	0.0028	0.0010	97%	0.000195	0.0062	0.0012	100%
Mercury	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Molybdenum	0.00040	0.00090	0.00072	100%	0.000003	0.0010	0.00068	99%	0.00048	0.000814	0.00067	100%	0.000536	0.00084	0.00071	100%
Nickel	0.00017	0.00042	0.00026	100%	0.000016	0.00043	0.00024	89%	0.0001	0.00044	0.00024	94%	0.0001	0.00073	0.00028	94%
Potassium	0.35	0.61	0.53	100%	0.0078	0.69	0.51	99%	0.34	0.58	0.49	100%	0.432	0.61	0.51	100%
Selenium	0.000078	0.00016	0.00012	0%	0.000078	0.00017	0.00013	1%	0.000078	0.00025	0.00014	0%	0.000078	0.00025	0.00013	0%
Silicon	0.80	1.39	1.04	100%	0.075	2.39	1.16	99%	0.83	11.2	3.17	100%	1.04	1.46	1.21	100%
Silver	0.000003	0.000009	0.000003	3%	0.000003	0.000014	0.000004	1%	0.000003	0.000003	0.000003	0%	0.000003	0.000003	0.000003	0%
Thallium	0.000003	0.000005	0.000004	0%	0.000003	0.000012	0.000004	4%	0.000003	0.000005	0.000004	0%	0.000003	0.000005	0.000004	0%
Tin	0.000031	0.00012	0.000044	3%	0.000031	0.00011	0.000044	3%	0.000031	0.00011	0.000046	3%	0.000031	0.00005	0.00004	0%
Vanadium	0.0001	0.00026	0.00014	3%	0.0001	0.00048	0.00018	7%	0.0001	0.00025	0.00019	5%	0.0001	0.00024	0.00014	6%
Zinc	0.00023	0.014	0.0032	62%	0.00023	0.020	0.0017	66%	0.00023	0.015	0.0025	69%	0.0005	0.016	0.0019	83%
Anions (mg/L, except where noted)																
Chloride	0.54	1.17	1.04	100%	0.41	5.38	1.05	100%	0.82	1.23	1.04	100%	0.87	1.08	0.99	100%
Fluoride	0.034	0.089	0.05	100%	0.032	0.086	0.051	100%	0.033	0.088	0.05	100%	0.016	0.083	0.044	97%
Cyanide (Total)	0.001	0.001	0.001	0%	0.001	0.003	0.001	1%	0.001	0.002	0.001	3%	0.001	0.003	0.001	0%
Cyanide (WAD)	0.001	0.004	0.001	3%	0.001	0.003	0.001	5%	0.001	0.001	0.001	0%	0.001	0.003	0.001	0%
Thiocyanate	0.16	0.5	0.36	0%	0.16	0.5	0.33	1%	0.03	0.5	0.26	0%	0.03	0.5	0.32	0%
Total Nitrate + Nitrite (as Nitrogen)	0.016	0.91	0.11	83%	0.016	1.93	0.219	89%	0.016	0.22	0.086	90%	0.016	0.26	0.13	94%
Nitrite (as Nitrogen)	—	—	—	—	0.016	0.016	0.016	0%	0.016	0.016	0.016	0%	—	—	—	—
Nitrate (as Nitrogen)	—	—	—	—	0.032	1.93	0.981	100%	0.039	0.045	0.042	100%	—	—	—	—
Total Phosphorus (P)	0.001	0.7	0.035	47%	0.001	0.12	0.009	36%	0.001	0.052	0.008	50%	0.001	0.24	0.02	58%
Orthophosphate	—	—	—	—	0.016	0.04	0.028	50%	0.016	0.016	0.016	0%	—	—	—	—

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]	FOD	Min	Max	Mean [a,c]	FOD	Min	Max	Mean [a,c]	FOD	Min	Max	Mean [a,c]	FOD
Sulfate	2.17	5.74	3.92	100%	0.91	5.93	3.69	100%	3.1	4.74	3.77	100%	3.45	4.38	3.89	100%
Cations (mg/L, except where noted)																
Ammonia (as Nitrogen)	0.016	0.05	0.022	3%	0.016	0.16	0.029	12%	0.016	0.13	0.03	29%	0.016	0.15	0.026	8%
Sodium (total)	1,340	2,090	1,707	100%	1,410	4,100	1,974	100%	1,360	1,990	1,710	100%	1,350	1,850	1,573	100%
Sodium	1,130	2,230	1,720	100%	15.5	4,120	1,969	99%	1,350	2,120	1,724	100%	1,300	1,790	1,587	100%
Miscellaneous Parameters (mg/L, except where noted)																
Acidity	0.79	1.57	1.18	0%	0.79	2.63	1.37	11%	0.79	2.5	1.42	11%	0.79	5	1.40	13%
Alkalinity	**14**	**17**	**15.67**	100%	**12**	**29.6**	15.58	100%	**10**	**16**	**13.26**	100.%	**10.5**	**15**	**13.57**	100%
Hardness (as $CaCO_3$)	16.4	20	18.33	100%	9.03	22.6	17.68	100%	12.4	18.9	16.34	100%	13.4	20.1	16.83	100%
pH (field measurement, pH Units)	**6.01**	7.34	6.86	100%	**6.25**	7.8	7.14	100%	**6.11**	8.17	7.31	100%	**4.5**	7.67	6.66	100%
Conductivity (µmhos/cm)	—	—	—		—	—	—		—	—	—		—	—	—	—
Total Dissolved Solids	13.8	52.5	26.4	100%	5	71.3	28.74	99%	13.8	35	27.52	100%	12.5	56	27.47	100%
Total Suspended Solids	0.075	1.09	0.35	63%	0.075	**22.7**	0.96	73%	0.075	8.56	0.94	45%	0.075	**77.6**	4.50	75%
Temperature (Field Measurement, °C)	4	16.28	8.67	100%	4.57	**17.86**	10.74	100%	3.81	**16.78**	10.76	100%	4	**16.31**	8.18	100%
Total Organic Carbon	0.62	1.01	0.84	100%	0.46	0.96	0.74	100%	0.33	0.66	0.52	100%	0.35	0.83	0.61	100%

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
°C = degrees Celsius
$CaCO_3$ = calcium carbonate
FOD = frequency of detection
µmhos/cm = micromhos per centimeter
mg/L = milligrams per liter
WAD = Weak Acid Dissociable
Source: HDR 2011a

Data Quality and Control

Data quality was assessed, and an outlier analysis was performed, as part of the data reduction process described in Schlumberger et al. (2011a). More than 4,000 laboratory water samples were analyzed for data quality and outliers. A small portion of the data (about 2 percent) were rejected due to deficiencies in meeting the quality control criteria. Field parameters collected include specific conductance, dissolved oxygen (DO), temperature, oxidation-reduction potential, turbidity, and TSS. Field measurements were collected in situ following field sampling and Quality Assurance Project Plan (QAPP) procedures as described in Shaw Alaska (2011b). Data were subject to quality assurance and quality control (QA/QC) measures following sample collection, processing, and shipping. Samples were a combination of grab sampling as necessary, and using depth-integrating methods as field and streamflow conditions allowed.

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 in the analysis 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 concentration 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 western and eastern parts of the north access road, respectively, which are pertinent to Alternative 2—North Road and Ferry with Downstream Dams, and Alternative 3—North Road Only. The samples were divided based on the geology: samples west of GS-11A (Figure 3.18-4) are in an area of Quaternary surficial deposits over volcanic and sedimentary rocks, while samples to the east are 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 1a 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 (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.

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**
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
°C = degrees Celsius
$CaCO_3$ = calcium carbonate
mg/L = milligrams per liter
mV = millivolts
NTU = nephelometric turbidity units
uS/cm = Microsiemens per centimeter
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)				
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
°C = degrees Celsius
CaCO3 = calcium carbonate
mg/L = milligrams per liter
mV = millivolts
NTU = Nephelometric Turbidity Units
uS/cm = Microsiemens per centimeter
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**
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
°C = degrees Celsius
CaCO3 = calcium carbonate
mg/L = milligrams per liter
mV = millivolts
NTU = Nephelometric Turbidity Units
uS/cm = Microsiemens per centimeter
Source: ERM 2018a

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 than 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.

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 Alternative 2 and Alternative 3.

Salinity Gradient—Water quality in the Iliamna/Iniskin estuary, about 30 miles north of the Amakdedori port site, was studied from 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 (Buchman 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 TSS, 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 inside 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 in each lithologic group. Results exceeding the most stringent criteria listed in Table K3.18-1 are shown in bold.

Data Quality and Control

Data quality was assessed, and an outlier analysis was performed, as part of the data reduction process as described in Schlumberger et al. (2011a). Samples were collected following field sampling and QAPP procedures described in Shaw Alaska (2011b), which included QA/QC measures for sample collection, processing, and shipping. Ten percent of all groundwater samples were duplicates and triplicates collected for data QA/QC purposes. Additional checks for data QA/QC, including data comparison between field and laboratory samples and data comparison to historical groundwater data, are further described in Schlumberger et al. (2011a).

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 eastern end of the lake (Alternative 2 and Alternative 3).

Data Quality and Control

Data quality was assessed, and an outlier analysis was performed, as part of the data reduction process as described in SLR et al. (2011a). Samples were collected following field sampling and QAPP procedures described in Shaw Alaska (2011b). In total, 197 sediment samples were collected in the mine study area from 71 different locations. Stream sediment samples analyzed were composite samples composed of sediments collected from three locations across the stream channel. All samples were tested for trace elements, and most were analyzed for various anions and cations (183 to 197 samples) (SLR et al. 2011a). Data were subject to QA/QC measures following sample collection, processing, and shipping procedures in the QAPP.

Table K3.18-17: Groundwater Well Completions and Number of Samples

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
		UTC	SRK-2	D (134)	Sand, Silty Sand	19
	Bedrock	SFK	PQ-4	D (133)	Bedrock Contact	17
			SRK-3	D (73)	Bedrock Contact	17
			SRK-5	D (78)	Bedrock Contact	8
	Deep Bedrock	UTC	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

Table K3.18-17: Groundwater Well Completions and Number of Samples

Area	Target Zone	Watershed	Well Nest ID[a]	Well ID (Depth)[b,c]	Lithology[d]	Total Number of Samples Collected
			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
			P-08-84	S (32)	Sand, Silty Sand	12
		UTC	MW-2	D (135)	Gravel with Sand	22

Table K3.18-17: Groundwater Well Completions and Number of Samples

Area	Target Zone	Watershed	Well Nest ID[a]	Well ID (Depth)[b,c]	Lithology[d]	Total Number of Samples Collected
			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

Table K3.18-17: Groundwater Well Completions and Number of Samples

Area	Target Zone	Watershed	Well Nest ID[a]	Well ID (Depth)[b,c]	Lithology[d]	Total Number of Samples Collected
			P-08-54	D (114)	Bedrock Contact	8
			P-08-61	D (88)	Bedrock Contact	9
			P-08-84	D (74)	Bedrock Contact	12
		UTC	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
			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
ID = Identification NFK = North Fork Koktuli
SFK = South Fork Koktuli UTC = Upper Talarik Creek
Source: Schlumberger 2015b

Table K3.18-18: Groundwater Data Summary—Mine Site

Analyte[c]	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[c]	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[c]	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[c]	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**	—

Table K3.18-18: Groundwater Data Summary—Mine Site

Analyte[c]	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]	
Field Water Temperature (°C)	0.12	9.47	3.59	3.63	0.66	8.04	3.28	2.02	—	—
Field Dissolved Oxygen	**-0.37**	20.22	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)
[c] MDLs and FOD presented in Schlumberger 2015b, Table 3
Dash mark (—) implies no available data
°C = degrees Celsius
$CaCO_3$ = calcium carbonate
FOD = frequency of detection
MDLs = Maximum Detection Limits
mg/L = milligrams per liter
mV = millivolts
WAD: Weak Acid Dissociable
µmhos/cm = micromhos per centimeter
Source: Schlumberger 2015b

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

Analyte[a]	Number of Samples	Frequency of Detection	Range of Detects (mg/kg) (Min-Max)[b]	Mean (mg/kg)[b]	Median[b]	Standard Deviation[b]
Trace Elements						
Aluminum	197	100%	1,820 – 25,200	11,218	10,600	4,400
Antimony	197	86%	0.03 – 2.30	0.23	0.17	0.24
Arsenic	197	96%	1.23 **– 270**	**14.2**	**9.57**	**23.0**
Barium	197	100%	12.3 – 239	74.7	66.0	39.4
Beryllium	197	96%	0.079 – 0.97	0.35	0.33	0.16
Bismuth	197	29%	0.063 – 3.10	1.11	0.089	6.39
Boron	196	41%	0.59 – 11.5	6.78	2.25	20.7
Cadmium	197	78%	0.068 – 2.60	0.26	0.19	0.25
Calcium	197	100%	583 – 23,400	3,773	3,260	2,302
Chromium	197	100%	0.43 – 105	15.4	14.4	9.26
Cobalt	197	99%	0.51 – 49.1	7.86	6.62	6.10
Copper	197	100%	1.3 – **200**	27.3	12.9	32.7
Iron	197	100%	2,670 – 83,400	21,617	20,400	11,737
Lead	197	99%	1.46 – **40.3**	6.90	5.28	5.84
Magnesium	197	99%	410 – 7970	3,586	3,680	1,470
Manganese	197	100%	28.7 – 6970	623	414	746
Mercury	197	57%	0.011 – **0.42**	0.040	0.022	0.055
Molybdenum	197	81%	0.28 – 22.0	2.02	0.87	3.13
Nickel	197	100%	0.64 **– 46.9**	8.95	8.31	4.98
Potassium	197	99%	75 – 1770	545	534	220
Selenium	197	68%	0.018 – **13.1**	1.15	0.53	1.77
Silver	197	35%	0.0341 – 2.54	0.12	0.060	0.24
Thallium	197	68%	0.0079 – 0.45	0.11	0.076	0.16
Tin	197	23%	0.16 – 46.2	1.21	0.52	3.42
Vanadium	197	100%	2.2 – 143	44.9	40.5	22.3
Zinc	197	98%	9.9 – **313**	61.8	52.6	45.4
Anions and Cations						
Ammonia (as Nitrogen)	196	97%	3.9 – 1730	235	74.2	316
Chloride	184	79%	0.327 – 223	5.31	1.75	18.4
Cyanide (Total)	194	64%	0.03 – 2.10	0.39	0.078	0.82
Cyanide (WAD)	12	100%	0.13 – 0.96	0.54	0.48	0.29
Fluoride	183	62%	0.11 – 118	2.24	0.51	9.37
Sodium	197	85%	18 – 630	194	186	109
Sulfate	184	97%	0.499 – 2,600	51.8	9.16	204

Notes:
[a] All data are 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] (mg/kg)	Iliamna Village					Pedro Bay					Pile Bay				
	Range of Detects			Mean[b,d]	FOD	Range of Detects			Mean[b,d]	FOD	Range of Detects			Mean[b,d]	FOD
	Min[b,c]	-	Max[b,c]			Min[b,c]	-	Max[b,c]			Min[b,c]	-	Max[b,c]		
Trace Elements															
Aluminum	4,800	-	12,600	8,020	100%	3,380	-	11,200	5940	100%	8,360	-	10,700	9,530	100%
Antimony	0.023	-	0.19	0.091	71%	0.029	-	0.13	0.081	38%	0.0929	-	0.107	0.1	100%
Arsenic	4.47	-	7.28	5.67	100%	0.71	-	**7.71**	2.99	88%	4.22	-	5.48	4.85	100%
Barium	64.3	-	138	94.9	100%	19	-	59.7	35.1	100%	97.8	-	123	110	100%
Beryllium	0.12	-	0.42	0.21	100%	0.091	-	0.26	0.15	75%	0.065	-	0.11	0.088	100%
Bismuth	0.030	-	0.15	0.086	0%	0.03	-	0.25	0.11	0%	0.12	-	0.16	0.14	100%
Boron	1.14	-	6.33	3.09	71%	1.07	-	6.19	3.27	63%	1.54	-	3.23	2.38	50%
Cadmium	0.045	-	**22.3**	**2.94**	71%	0.065	-	0.25	0.15	50%	0.16	-	0.16	0.16	100%
Calcium	2,670	-	5,600	3,930	100%	1,940	-	5,000	3,100	100%	3,630	-	4,670	4,150	100%
Chromium	4.35	-	10.5	6.53	100%	1.23	-	6.34	2.61	88%	7.21	-	9.23	8.22	100%
Cobalt	1.86	-	4.58	3.41	100%	0.51	-	2.68	1.74	88%	4.76	-	6.66	5.71	100%
Copper	4.61	-	23.6	13.5	100%	6.67	-	16.1	11.6	100%	56.9	-	90.6	**73.8**	100%
Iron	8,290	-	15,400	10,900	100%	1,850	-	26,400	10,100	100%	17,000	-	24,100	20,600	100%
Lead	2.09	-	**79.1**	13.2	100%	1.29	-	7.76	3.36	100%	5.75	-	6.01	5.88	100%
Magnesium	1,730	-	4,080	2,800	100%	483	-	2,400	1,070	100%	3,860	-	4,510	4,190	100%
Manganese	150	-	292	227	100%	38.6	-	279	137	100%	307	-	591	449	100%
Mercury	0.0060	-	0.064	0.023	29%	0.0060	-	0.049	0.026	25%	0.012	-	0.019	0.016	50%
Molybdenum	0.23	-	5.02	2.56	71%	0.23	-	8.47	3.58	75%	2.23	-	2.93	2.58	100%
Nickel	2.3	-	6.43	4.62	100%	1.55	-	5.91	2.85	100%	4.02	-	6.07	5.05	100%
Potassium	486	-	1,590	768	100%	106	-	572	338	88%	1,150	-	1,580	1,370	100%
Selenium	0.13	-	6.64	2.12	71%	0.073	-	**12.5**	3.39	50%	0.15	-	0.63	0.39	50%
Silver	0.015	-	0.077	0.043	0%	0.015	-	0.127	0.057	0%	0.015	-	0.081	0.048	50%
Thallium	0.0054	-	0.077	0.033	43%	0.0046	-	0.082	0.037	50%	0.028	-	0.061	0.044	100%
Tin	0.49	-	6.78	1.56	29%	0.484	-	3.42	1.19	0%	0.50	-	0.97	0.73	0%
Vanadium	20.2	-	40.8	30.4	100%	3.21	-	42.3	19.9	88%	37.8	-	48.8	43.3	100%
Zinc	23.2	-	88.2	42	100%	12.6	-	43.7	27.4	100%	45.2	-	58.3	51.8	100%

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

Analyte[a] (mg/kg)	Iliamna Village					Pedro Bay					Pile Bay				
	Range of Detects			Mean[b,d]	FOD	Range of Detects			Mean[b,d]	FOD	Range of Detects			Mean[b,d]	FOD
	Min[b,c]	-	Max[b,c]			Min[b,c]	-	Max[b,c]			Min[b,c]	-	Max[b,c]		
Anions and Cations															
Ammonia (as Nitrogen)	37.2	-	512	222	100%	58.6	-	570	345	100%	40.3	-	86.7	63.5	100%
Chloride	7.32	-	97.6	47.3	100%	2.37	-	18.5	11.9	100%	1.53	-	3.11	2.32	100%
Cyanide (Total)	0.016	-	0.4	0.14	67%	0.014	-	0.43	0.128	75%	0.014	-	0.058	0.036	50%
Fluoride	0.64	-	13	3.29	50%	0.76	-	53.7	12.4	50%	0.98	-	3.99	2.49	50%
Sodium	28	-	971	477	100%	154	-	636	416	100%	428	-	591	510	100%
Sulfate	3.31	-	146	43	100%	2.66	-	426	144	100%	19.7	-	88.8	54.3	100%
Miscellaneous															
Total Solids (%, Wet)	19.2	-	66.8	38.7	100%	12.1	-	65.6	26.8	100%	50.8	-	55.6	53.2	100%
Total Organic Carbon (%)	0.62	-	10.8	4.72	100%	0.684	-	13.9	6.28	100%	0.945	-	1.08	1.01	100%

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 (four sample locations for Iliamna Village Area, three sample locations for Pedro Bay Area, and one sample location for Pile Bay)
[d] Mean values for each area represent the average of mean values at each sample location in the respective area
FOD = frequency of detection
mg/kg = milligrams per kilogram
Source: HDR 2011a

K3.26 VEGETATION

Table K3.26-1 describes the 50 field-verified vegetation types (Three Parameters Plus and HDR 2011a), identifies whether the type occurs predominantly in wetlands or uplands, and shows membership to the vegetation structure types applied in Section 3.26 and Section 4.26, Vegetation.

Table K3.26-1: Summary of Project Vegetation Types in the Mapping Area

Vegetation Structure Type	Project Vegetation Type	Abbreviation	Definition[1]	Predominantly Occurs in Wetland or Upland
Forest (≥10% cover of trees over 10 feet in height)				
Open/Closed Forest	Closed White Spruce Forest	CWSF	Closed forests dominated by white spruce (*Picea glauca*) where tree cover is ≥60%.	Upland
	Open White Spruce Forest	OWSF	Open forests dominated by white spruce (*Picea glauca*) where tree cover ranges from 25 to 59%.	Upland
	White Spruce Woodland	WSW	Woodlands dominated by white spruce (*Picea glauca*) where tree cover ranges from 10 to 24% and most trees are over 10 feet tall. Openings between trees may be dominated by mosses, lichens, herbs, and/or shrubs.	Upland
	Black Spruce Woodland	BSW	Woodlands dominated by black spruce (*Picea mariana*) where tree cover ranges from 10 to 24% and most trees are over 10 feet tall. Openings between trees may be dominated by mosses and lichens, herbs, and/or shrubs.	Wetland
	Closed Broadleaf Forest	CBF	Closed forests dominated by broadleaf tree species (e.g., *Betula papyrifera* var. *kenaica, Populus balsamifera*) where tree cover is ≥60%.	Upland
	Open Broadleaf Forest	OBF	Open forests dominated by broadleaf tree species (e.g., *Betula papyrifera* var. *kenaica, Populus balsamifera*) where tree cover ranges from 25 to 59%.	Upland
	Broadleaf Woodland	BW	Woodlands dominated by broadleaf tree species (e.g., *Betula papyrifera* var. *kenaica, Populus balsamifera*) where tree cover ranges from10 to 24%.	Wetland/Upland
	Closed Mixed Forest	CMF	Closed forests co-dominated by broadleaf (e.g., *Betula papyrifera* var. *kenaica, Populus balsamifera*) and needleleaf (e.g., *Picea glauca, P. mariana*) tree species where tree cover is ≥60%.	Upland
	Open Mixed Forest	OMF	Open forests co-dominated by broadleaf (e.g., *Betula papyrifera* var. *kenaica, Populus balsamifera*) and needleleaf (e.g., *Picea glauca, P. mariana*) tree species where tree cover ranges from 25 to 59%.	Upland
	Mixed Forest Woodland	MFW	Woodlands co-dominated by black and/or white spruce (*Picea mariana, P. glauca*) and broadleaf (e.g., *Betula papyrifera* var. *kenaica, Populus balsamifera*) tree species where tree cover ranges from 10 to 24%. Most of the trees are over 10 feet tall.	Upland
	Dwarf White Spruce Scrub	DWSS	Stands dominated by dwarf white spruce (*Picea glauca)* where trees are under 10 feet tall and cover ranges from 10 to 59%. If trees are over 10 feet tall and	Upland

Table K3.26-1: Summary of Project Vegetation Types in the Mapping Area

Vegetation Structure Type	Project Vegetation Type	Abbreviation	Definition[1]	Predominantly Occurs in Wetland or Upland
			cover is >10%, the scrub class does not apply. May be lichen rich on drier microsites.	
	Dwarf Black Spruce Scrub	DBSS	Stands dominated by dwarf black spruce (*Picea mariana*) where trees are under 10 feet tall and cover ranges from 10 to 59%. If trees are over 10 feet tall and cover is >10%, the scrub class does not apply. May be lichen rich on drier microsites.	Wetland/Upland
Scrub (<10% cover of trees over 10 feet in height, >25% shrub cover)				
Closed Tall Shrub	Closed Willow Tall Shrub	CWTS	Closed stands of tall (≥5 feet) shrub where willow species (e.g., *Salix pulchra, S. barclayi*) dominate. Shrub cover is ≥75% and tree cover is <10%. In some sites, resin and dwarf birch (*Betula glandulosa, B. nana*) may be mixed with the willow.	Upland
	Closed Alder Tall Shrub	CATS	Closed stands of tall (≥ 5 feet) shrub where alder species (e.g., *Alnus viridis* ssp. *sinuata*) dominate. Shrub cover is ≥75% and tree cover is <10%.	Upland
	Closed Alder-Willow Tall Shrub	CAWTS	Closed stands of tall (≥ 5 feet) shrub where alder and willow species (e.g., *Alnus viridis* ssp. *sinuata, Salix pulchra, S. barclayi*) co-dominate. Shrub cover is ≥75% and tree cover is <10%.	Upland/Wetland
Open Tall Shrub	Open Alder Tall Shrub	OATS	Open stands of tall (≥5 feet) shrub where alder species dominate. Shrub cover ranges from 25 to 74% and tree cover is <10%.	Upland
	Open Alder-Willow Tall Shrub	OAWTS	Open stands of tall (≥ 5 feet) shrub where alder and willow species co-dominate. Shrub cover ranges from 25 to 74% and tree cover is >10%.	Upland
	Open Willow Tall Shrub	OWTS	Open stands of tall (≥5 feet) shrub where willow species (e.g., *Salix pulchra, S. barclayi*) dominate. Shrub cover ranges from 25 to 74% and tree cover is <10%. In some sites, resin and dwarf birch (*Betula glandulosa, B. nana*) may be mixed with the willow.	Upland
Closed Low Shrub	Closed Willow Low Shrub	CWLS	Closed stands of low (8 inches to 5 feet) shrub where willow species (e.g., *Salix pulchra, S. barclayi*) dominate. Shrub cover is ≥75% and tree cover is <10%. In some sites, resin and dwarf birch (*Betula glandulosa, B. nana*) may be mixed with the willow.	Wetland
	Closed Alder-Willow Low Shrub	CAWLS	Closed stands of low (8 inches to 5 feet) shrub where alder and willow species (e.g., *Alnus viridis* ssp. *sinuata, Salix pulchra, S. barclayi*) co-dominate. Shrub cover is ≥75% and tree cover <10%.	Wetland/Upland

Table K3.26-1: Summary of Project Vegetation Types in the Mapping Area

Vegetation Structure Type	Project Vegetation Type	Abbreviation	Definition[1]	Predominantly Occurs in Wetland or Upland
	Closed Alder Low Shrub	CALS	Closed stands of low (8 inches to 5 feet) shrub where alder species (e.g., *Alnus viridis* ssp. *sinuata)* dominate. Shrub cover is ≥75% and tree cover <10%.	Upland
Open Low Shrub	Open Sweetgale-Graminoid Bog	OSGB	Bogs and fens characterized by open stands of low (8 inches to 5 feet) shrub. Sweetgale (*Myrica gale)* is the dominant shrub species. Shrub cover ranges from 25 to 74%, graminoid cover is >25%, and tree cover is >10%. These communities occur on peat ≥8 inches thick.	Wetland
	Open Mixed Shrub-Sedge Tussock	OMSST	Tussock tundra co-dominated by low (8 inches to 5 feet) shrubs and sedges. Shrub cover ranges from 25 to 74% cover; sedge cover is >25%. Tussock cottongrass (*Eriophorum vaginatum*) and Bigelow's sedge (*Carex bigelowii*) are the dominant and subdominant tussock-forming sedges, respectively. Trees are absent or scarce.	Wetland
	Open Dwarf Birch-Ericaceous Shrub Bog	ODBESB	Bogs characterized by dwarf birch, ericaceous shrubs, and abundant moss. The cover of shrubs over 8 inches tall ranges from 25 to 74%; the cover of tall (≥ 5 feet) shrubs is <25%; tree cover is <10%. Dominant species include resin and dwarf birch (*Betula glandulosa, B. nana),* blueberry (*Vaccinium uliginosum*), lingonberry (*V. vitis-idaea*), marsh Labrador tea (*Ledum palustre* ssp. *decumbens*)*,* black crowberry (*Empetrum nigrum*), and bog rosemary (*Andromeda polifolia*). The combined cover of resin and dwarf birch is ≥10%. These communities develop on peat ≥8 inches thick. Peatmosses (*Sphagnum* spp.) are abundant at most sites, but may be absent.	Wetland
	Ericaceous Shrub Bog	ESB	Bogs characterized by ericaceous shrubs, abundant moss and sparse dwarf birch (*Betula nana*). Low (8 inches to 5 feet) shrub cover is ≥25%. Dominant shrub species are: black crowberry (*Empetrum nigrum*), blueberry (*Vaccinium uliginosum*), lingonberry (*V. vitis-idaea*), small cranberry (*V. oxycoccos*), bog rosemary (*Andromeda polifolia*), and marsh Labrador tea (*Ledum palustre* ssp. *decumbens*). These communities develop on peat ≥16 inches thick. Peatmosses (*Sphagnum* spp.) are always present and usually dominant. Other mosses, such as feather mosses, may also occur.	Wetland
	Low Ericaceous Shrub Tundra	LEST	Treeless areas dominated by low (8 inches to 5 feet) ericaceous shrubs. Shrub cover is ≥25%. Dominant shrubs include black crowberry (*Empetrum nigrum*), blueberry (*Vaccinium uliginosum),* lingonberry *(V. vitis-idaea*), small cranberry (*V. oxycoccos*), bog rosemary (*Andromeda polifolia*), marsh Labrador tea (*Ledum palustre* ssp. *decumbens*), and bog Labrador tea (*L. groenlandicum*).	Upland

Table K3.26-1: Summary of Project Vegetation Types in the Mapping Area

Vegetation Structure Type	Project Vegetation Type	Abbreviation	Definition[1]	Predominantly Occurs in Wetland or Upland
			These communities develop on mineral soils where the thickness of surface organics is <16 inches.	
	Open Dwarf Birch Scrub	ODBS	Open stands of low (8 inches to 5 feet) shrub dominated by dwarf and resin birch (*Betula nana, B. glandulosa*). Shrub cover ranges from 25 to 74%. While most of these communities are comprised of low shrub, this type should also be used for the occasional stand of tall (≥ 5 feet) resin birch (*B. glandulosa*).	Upland/Wetland
	Shrub Birch-Willow	SBW	Open stands of low (8 inches to 5 feet) shrub co-dominated by birch (*Betula nana*) and willow (*Salix barclayi*) species. Shrub cover is 25 to 74%.	Upland
	Open Willow Low Shrub	OWLS	Open stands of low (8 inches to 5 feet) shrub dominated by willow species (*Salix barclayi, S. pulchra*). Low shrub cover ranges from 25 to 74%; tall (>5 feet) shrub cover is <25% and tree cover is <10%. These communities usually develop on 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 low (8 inches to 5 feet) shrubs where willow species (e.g., *Salix pulchra*) dominate. Low shrub cover ranges from 25 to 74%. These communities develop on peat ≥8 inches thick, and compared to Open Willow Low Shrub types are wetter with a hydrology often maintained by groundwater.	Wetland
	Open Alder-Willow Low Shrub	OAWLS	Open stands of low (8 inches to 5 feet) shrub where alder and willow species (*Alnus viridis* ssp. *sinuata, Salix barclayi*) are co-dominant. Shrub cover ranges from 25 to 74%, tree cover is <10%.	Wetland
	Open Alder Low Shrub	OALS	Open stands of low (8 inches to 5 feet) shrub where alder (e.g., *Alnus viridis* ssp. *sinuata*) is the dominant species. Low shrub cover ranges from 25 to 74%; tall (>5 feet) shrub cover is <25%; tree cover is <10%.	Upland
Dwarf Shrub	Dwarf Ericaceous Shrub Tundra	DEST	Treeless areas dominated by dwarf (<8 inches) ericaceous shrubs. Dominant shrub species include *Arctostaphylos* spp., *Vaccinium* spp., black crowberry (*Empetrum nigrum*), Aleutian mountainheath (*Phyllodoce aleutica*), and mountain heather (*Cassiope* spp.) Lichens are common but cover is <60%. If lichen cover is ≥60% percent, the Dwarf Ericaceous Shrub-Lichen Tundra vegetation type should be used.	Upland

Table K3.26-1: Summary of Project Vegetation Types in the Mapping Area

Vegetation Structure Type	Project Vegetation Type	Abbreviation	Definition[1]	Predominantly Occurs in Wetland or Upland
	Dwarf Ericaceous Shrub Tundra – Hummock	DEST-H	Treeless areas dominated by dwarf (<8 inches) ericaceous shrubs. Dominant shrub species include *Arctostaphylos* spp., *Vaccinium* spp., black crowberry *(Empetrum nigrum*), Aleutian mountainheath (*Phyllodoce aleutica*), and mountain heather (*Cassiope* spp.). The ground surface consists mostly of moderate (5.9 to 17.7 inches relief) and large (> 17.7 inches relief) hummocks. Significant lichen cover may develop on hummocks.	Upland
	Dwarf Ericaceous Shrub Tundra – Equisetum	DEST-EQ	Treeless areas dominated by dwarf (<8 inches) ericaceous shrubs with abundant horsetail (*Equisetum* spp.) Dominant shrubs include *Arctostaphylos* spp., *Vaccinium* spp., black crowberry *(Empetrum nigrum*), Aleutian mountainheath (*Phyllodoce aleutica*), and mountain heather (*Cassiope* spp.); cover of horsetail is >25%.	Upland
	Dwarf Ericaceous Shrub Tundra – Carex	DEST-C	Treeless areas dominated by dwarf (<8 inches) ericaceous shrub with abundant sedge. Dominant shrubs include *Arctostaphylos* spp., *Vaccinium* spp., black crowberry (*Empetrum nigrum*), Aleutian mountainheath (*Phyllodoce aleutica*), and mountain heather (*Cassiope* spp.). Sedge species (*Carex* spp.) cover is >25%. Lichen-rich on drier microsites.	Upland
	Dwarf Ericaceous Shrub-Lichen Tundra	DESLT	Treeless areas dominated by dwarf (<8 inches) shrub and lichen. Dominant shrubs include *Arctostaphylos* spp., *Vaccinium* spp., black crowberry *(Empetrum nigrum*), Aleutian mountainheath (*Phyllodoce aleutica*), and mountain heather (*Cassiope* spp.). Lichen cover is >60%.	Upland
Herbaceous (<10% of tree cover and <25% of shrub cover)				
Dry to Moist Herbaceous	Halophytic Dry Graminoid	HDG	Herbaceous community dominated by American dunegrass (*Leymus mollis).* Coastal in distribution occurring on sand dunes and the upper parts of coastal flats and beaches; grades seaward to halophytic herb communities. Dune communities are typically uplands, coastal flat communities can be wetlands.	Upland
	Bluejoint Tall Grass	BTG	Herbaceous community dominated by bluejoint reedgrass (*Calamagrostis canadensis*); subordinate forbs and graminoids may occur. The herbaceous stratum ranges from 2.5 to 5 feet tall. Woody plants are absent or scarce.; where they occur, trailing shrubs (e.g., *Salix pulchra*) grow in a low layer below the grass stratum.	Upland

Table K3.26-1: Summary of Project Vegetation Types in the Mapping Area

Vegetation Structure Type	Project Vegetation Type	Abbreviation	Definition[1]	Predominantly Occurs in Wetland or Upland
	Bluejoint-Herb	BH	Herbaceous community dominated by bluejoint reedgrass (*Calamagrostis canadensis*); interspersed with other low-growing herbs. The herbaceous stratum ranges from 2.5 to 5 feet tall. Woody plants are absent or scarce.	Upland
	Mesic Herb	MH	Herbaceous communities that do not satisfy the criteria of other project vegetation types. Herbaceous species numerous; shrub cover is <25% but the shrub beauverd spirea (*Spiraea stevenii*) may be dominant. Occurs on mesic subalpine and drier alpine sites.	Upland
Wet Herbaceous	Halophytic Graminoid Wet Meadow	HGWM	Herbaceous community characterized by species adapted to living in saline environments. Coastal distribution. Dominant species include circumpolar reedgrass (*Calamagrostis deschampsioides*), Lyngbye's sedge (*Carex lyngbyei*), largeflower speargrass (*Poa eminens*), Arctic daisy (*Chrysanthemum arcticum*), and Pacific silverweed (*Argentina egedii* ssp. *egedii*).	Wetland
	Subarctic Sedge-Moss Wet Meadow	SSMWM	This type includes numerous wet herbaceous communities that were difficult to separate on aerial photography. Types included are: subarctic lowland sedge-moss bog meadow, subarctic lowland sedge bog meadow, subarctic lowland sedge wet meadow, wet sedge-herb meadow tundra, and subarctic lowland herb bog meadow. Communities are dominated or co-dominated by graminoids; forbs may also co-dominate. Shrub cover is <25%. When present, shrubs form a low, trailing layer below the herbaceous stratum. Moss is abundant on many sites. Soils are saturated or may have shallow surface water. Most sites develop on peat ≥8 inches thick.	Wetland
	Fresh Sedge Marsh	FSM	Herbaceous community dominated by cottongrass species (e.g., *E. angustifolium*); water sedge (*Carex aquatilis*) is often abundant. Other common herbs are purple marshlocks (*Comarum palustre*) and bluejoint reedgrass (*Calamagrostis canadensis*). Plants are emergent in standing water (>6 inches deep) that persists through the growing season in most years. Trees, shrubs, and lichens are absent; aquatic mosses may be present but are not abundant. The community develops at the edge of ponds, lakes, and low-velocity streams.	Wetland
	Fresh Herb Marsh	FHM	Herbaceous community dominated by emergent forbs in standing water (>6 inches deep) that persists through the growing season in most years. Dominant species are water horsetail (*Equisetum fluviatile*), bluejoint reedgrass (*Calamagrostis canadensis*), water sedge (*Carex aquatilis*), pendantgrass (*Arctophila fulva*), and purple marshlocks (*Comarum palustre*).	Wetland

Table K3.26-1: Summary of Project Vegetation Types in the Mapping Area

Vegetation Structure Type	Project Vegetation Type	Abbreviation	Definition[1]	Predominantly Occurs in Wetland or Upland
	Aquatic Herbaceous	AH	Permanently-flooded herbaceous communities dominated by rooted and floating vascular plants. Dominant species are: pendantgrass (*Arctophila fulva*), common mare's-tail (*Hippuris vulgaris*), greater creeping spearwort (*Ranunculus flammula*), threadleaf crowfoot (*Ranunculus trichophyllus*). Standing or flowing water persists through the growing season.	Wetland
Other (<25% vegetation)				
Other	Partially Vegetated	PV	Sparsely vegetated type where vegetation cover ranges from 10 to 25%. This type 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 cover by pioneering annual plants as the growing season progresses. May also be applied to sparsely vegetated rubble and scree fields, mountaintops, and gravel bars.	Upland
	Barren	BARE	Barren areas where the cover of vascular plants is <10%. This type is applied to unvegetated gravel bars, beaches, seasonal pond bottoms, rubble fields, and scree slopes.	Wetland/Upland
	Snow	SNOW	Persistent snowfields.	Upland
Open Water	Open Water	OW	Open water where cover of vascular plants is <25%. Includes streams, rivers, lakes, and ponds.	Waters

Note:

[1]Forest density classes (closed, open, woodland) are differentiated base on tree canopy coverage (>60%, 25-59%, 10-24%, respectively). Shrub density classes (closed, open) are differentiated based on shrub canopy cover (>75%, 25-75%, respectively). Dwarf tree scrub classes are differentiated from forest classes by trees that are <10 feet tall at maturity. 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).

Source: EBD Chapter 13 – Three Parameters Plus and HDR 2011a; EBD Chapter 38 – HDR and Three Parameters Plus 2011a; HDR 2018c

K4.10 HEALTH AND SAFETY

The evaluation of impacts on human health and safety is a 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 and safety evaluation of the potentially affected communities and workforce crossover issues “outside the fence” 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 Section 3.10 and Section 4.10, Health and Safety (ADHSS 2015). Because health is a multi-dimensional concept with physical, mental, and social aspects, the 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 assessing both determinants and outcomes, an evaluation of health status, health needs, health impacts, and mitigation/monitoring recommendations (if warranted) can be developed that are based on a good understanding of the 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 that 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 health and safety evaluation is limited to affected communities “outside of the fence,” (outside the mine site and other mine-related components). Accordingly, the health and safety evaluation 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 evaluation does consider “crossover issues,” such as areas where workers are housed, or where workforce behaviors result in interactions/overlap with the affected communities. Additionally, the USACE cannot commit that Pebble Limited Partnership (PLP) would comply with MSHA, OSHA, and other regulations.

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: 1) be able to adapt to the impact with ease and maintain pre-impact level of health; or 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: 1) be able to adapt to the health impact with some difficulty and would maintain pre-impact level of health with support; or 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: 1) not be able to adapt to the health impact or to maintain pre-impact level of health; or 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 reducing 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 and safety 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 evaluation 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, 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 evaluation, 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 and safety evaluation, 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.

The health and safety evaluation presented herein falls between a "desktop" HIA (qualitative and brief assessment) and a "rapid appraisal" HIA (more in-depth than desktop) as defined in the HIA guidance (ADHSS 2015), using available or accessible health information, limited stakeholder engagement, and key informant input, but without conducting new field surveys. 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 project components (mine, transportation corridor, port, and natural gas pipeline) 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 evaluation, 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.

Best management practices (BMPs) and industry standards applicable to the project are a form of mitigation and are considered when assessing the impacts of the project in the EIS. In addition, PLP's mitigation measures and design features were also factored into the EIS evaluation, when appropriate and possible (e.g., stationary source air emissions). The additional mitigation measures suggested during the EIS process were not assumed in the evaluation, but are provided in Appendix M1.0, Mitigation Assessment.

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 project. The purpose of this health and safety evaluation is to assess the impacts of the 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 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 nearby 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, violent crime, and family stress and 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 and Safety, would continue in the EIS analysis area.

K4.10.2 Alternative 1a

This section presents the environmental consequences to community health for Alternative 1a. This evaluates potential impacts (both positive and negative) to the affected communities from the project during all three phases. 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 per HEC in the subsections below) for all project components would be expected to be more noticeable in smaller, rural communities and less perceptible in the Municipality of Anchorage. The HECs discussed in the subsections below were evaluated for potential negative (adverse) and positive (beneficial) impacts from the project.

This section does not independently evaluate the human health impacts from potential spills or failures because evaluations of potential impacts are provided in Section 4.27, Spill Risk. 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. The following summarizes the health and safety evaluation included 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 BMPs 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.

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	2, beneficial impacts to health for affected population during construction and operation	3, long-term	2, entire small communities and limited households in large communities that benefit from regional economic opportunities	**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	2, able to maintain pre-impact levels of health with support; negative and beneficial impacts to health for affected population during construction and operation	3, long-term	2, entire small communities and limited households in large communities	**9**	33 to 66%	♦♦♦	**3**
	Closure	±	1	1, negative impacts, but would expect and adapt to the change during closure	3, long-term	2, entire small communities and limited households in large communities	**7**	10 to 33%	♦♦	**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	±	1	2, able to maintain pre-impact levels of health with support; beneficial impacts to health for specific population	3, long-term	1, limited number of households	**7**	10 to 33%	♦♦	**2**
	Closure	±	1	2, able to maintain pre-impact levels of health with support; beneficial impacts to health for specific population	3, long-term	1, limited number of households	**7**	1 to 10%	♦♦	**2**

Notes:
The sum of the impact dimensions (Table K4.10-1) are used to determine the severity ranking. The severity ranking and likelihood rating determines the impact rating (1 to 4 diamonds), which indicates the corresponding overall significance impact rating category of 1, 2, 3, or 4 (Table K4.10-2).

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, although employment would substantially decrease. 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 measurable 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. Sensitive sub-groups such as children, the disabled, elderly, and low-income households, and indigenous communities can be disproportionately affected by impacts to socioeconomic changes (e.g., could result in short-term nutritional dislocations for children in households living below the poverty threshold, which has the potential to impact their development [short-term impact] and throughout their lifetime [long-term impact]).

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 (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 possibility of this benefit occurring is considered likely, 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. 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. Sensitive sub-groups such as children, the disabled, elderly, low-income households, and indigenous communities can be disproportionately affected by impacts to psychosocial stressors. An example would be a community's fear that a proposed project could impact their environment and subsistence resources for current generations and the ones to come, leading to decreased mental health. 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, crime, suicide (overlaps with HEC 2), and mental health issues. Community members have expressed that increases in crimes, drug and alcohol use, and violence against women and girls (also see family stress and stability) due to the workforce employed by the project are primary concerns for the potentially affected communities. For other mine projects, some women reported excessive drinking and anger in some spouses when they returned from their mine rotation (UBC 2014). It is difficult to predict the impact of the project on violent crime rates, in part because violent crime rates were not readily available for the potentially affected communities closest to the project, LPB, or Bristol Bay Borough. Compared to the urban Anchorage region, state, and national rates, the Dillingham Census Area and Kenai Peninsula reported higher baseline rape rates and the Dillingham Census Area reported higher aggravated assault rates (see Section 3.10, Health and Safety and Appendix K3.10), while robbery rates in the Dillingham Census Area and Kenai Peninsula appear to be similar to or less than the urban Anchorage, state, and national rates. Increases in psychosocial stress may result in increases of violent crime in the potentially affected communities (e.g., increased anger, substance abuse, and poor mental health could lead to increases in aggravated assault and rape), which could be especially hard on communities with elevated baseline rates. Conversely, decreases in psychosocial stress may do the opposite and result in decreases of violent crime. 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. There is also the potential for decreases in psychosocial stress from improved economic opportunities, increase in jobs available in the region, and increased employment (see Section 3.10, Health and Safety). 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 3 (beneficial and adverse) for construction and operations, and as Category 2 for closure (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 about as likely as not for the construction and operation phases, and unlikely for the closure phase, 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 potentially affected communities. Sensitive sub-groups such as infants, children, the disabled, elderly, low-income households, and indigenous communities can be disproportionately affected by impacts to family stress and stability. For example, emotional stress to the infant or child from family stress and instability can negatively impact infant and child development, and can continue throughout their lifetimes.

Increases in family stress and instability could occur due to long-term work rotations (living at the mine site while working and going home during off periods). As noted previously, community members have expressed that increases in violence against women and girls due to the workforce employed by the project is a primary concern for the potentially affected communities. Approximately 50 percent of adult women in Bristol Bay, Kenai Peninsula, and Anchorage/ Matanuska-Susitna Regions, as well as Alaska overall, report experiencing violence in their lifetime (AVS 2015). Approximately 43 percent of adult women in Bristol Bay, Kenai Peninsula, and Anchorage/Matanuska-Susitna regions, as well as Alaska overall, report experiencing intimate partner violence in their lifetime, while approximately 32 percent experience sexual violence in their lifetime (AVS 2015). 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; Status of Women Council of the NWT 1999). Women reported an increase in spousal assaults as a result of mine employment and long-distance commuting, as well as noticeable strains on marriages and relationships (Status of Women Council of the NWT 1999). The rotation schedules and long absences also led to more disruptive behavior in children and reported difficulties in managing older children when the parent was away (Status of Women Council of the NWT 1999). In several communities, additional stress was noted for extended family members (such as grandparents) who provided child care while a parent was away working at the mines (UBC 2014; Status of Women Council of the NWT 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 (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 is 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 along the transportation corridor. Transportation-related unintentional accidents and injuries are a leading cause of hospitalizations in the state and in the EIS analysis area (see 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. No access would be allowed beyond the mine site safety boundary. The boundary would be reduced during the post-closure phase of the project.

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 use of the ferry to transport the public and all-terrain vehicles (ATVs)/snowmachines. 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 and occasional passenger vehicles. Open water created by the ice-breaking ferry would disrupt some cross-lake snowmachine routes and could 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). Alternatively, 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.

Accidents and injuries (impacting 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), including where the transportation corridor would cross the Gibraltar and Newhalen rivers. 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 a 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 project-related 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 is 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 (see 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 relevant and appropriate safety training by competent and qualified person(s) 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 from 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 unlikely, because of the potential for promotion of safety awareness and culture, and its likely limited scale.

Table K4.10-4: Summary of HEC 2 Impacts: Accidents and Injuries for Alternative 1a

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 along transportation corridor (same rating unless otherwise noted)	Construction	-	3	air = 3, unable to maintain pre-impact level of health surface and water = 2, able to maintain pre-impact level of health with medical intervention	2, medium-term	0, individual cases	8 (air) 7 (water/ surface)	<1 % (air) 10 to 33% (surface) 10 to 33% (water)	♦♦	**2**
	Operations				3, long-term		9 (air) 8 (water/ surface)		♦♦	**2**
	Closure				3, long-term		9 (air) 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**

Notes:
The sum of the impact dimensions (Table K4.10-1) is used to determine the severity ranking. The severity ranking and likelihood rating determines the impact rating (1 through 4 diamonds), which indicates the corresponding overall significance impact rating category of 1, 2, 3, or 4 (Table K4.10-2).

Intentional Injury: Suicide Rate

Across the state, suicide was the fourth leading cause of death among Alaska Native people during the period from 2012 to 2015 (ANTHC 2017f). Baseline suicide mortality rates vary by region, but are generally similar to state rates for Alaska Native people (age-adjusted rate of 40.9 per 100,000 population, which equates to approximately 0.04 percent of the population), as discussed in Section 3.10, Health and Safety. However, regional rates are based on less than 20 cases/counts, and may not be statistically reliable. Suicide, in general, is considered to be an unlikely action 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 unlikely 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 help decision-makers assess whether actions to reduce negative impacts would be helpful for reducing negative impacts.

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, this section does not independently evaluate human health impacts from potential spills or failures, but includes a summary of the health and safety evaluation provided in Section 4.27, Spill 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).

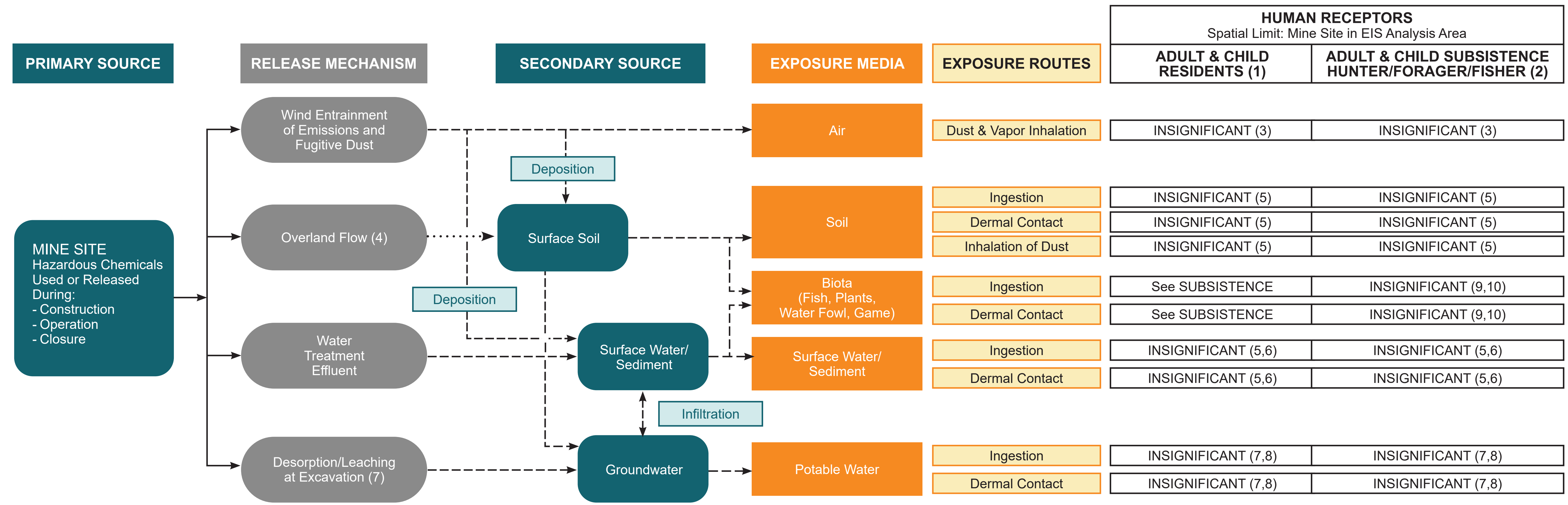
The health effects are grouped as non-cancer (e.g., reproductive, developmental, and metabolic effects) and cancer effects, in the context of the Alaska Department of Environmental Conservation's (ADEC's) and US Environmental Protection Agency's (EPA's) commonly used conceptual frameworks to evaluate 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 evaluation for this HEC 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 evaluation 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.



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 in 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 waterbodies (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 would 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).

LEGEND

The CSM is based on Alternative 1a, 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.

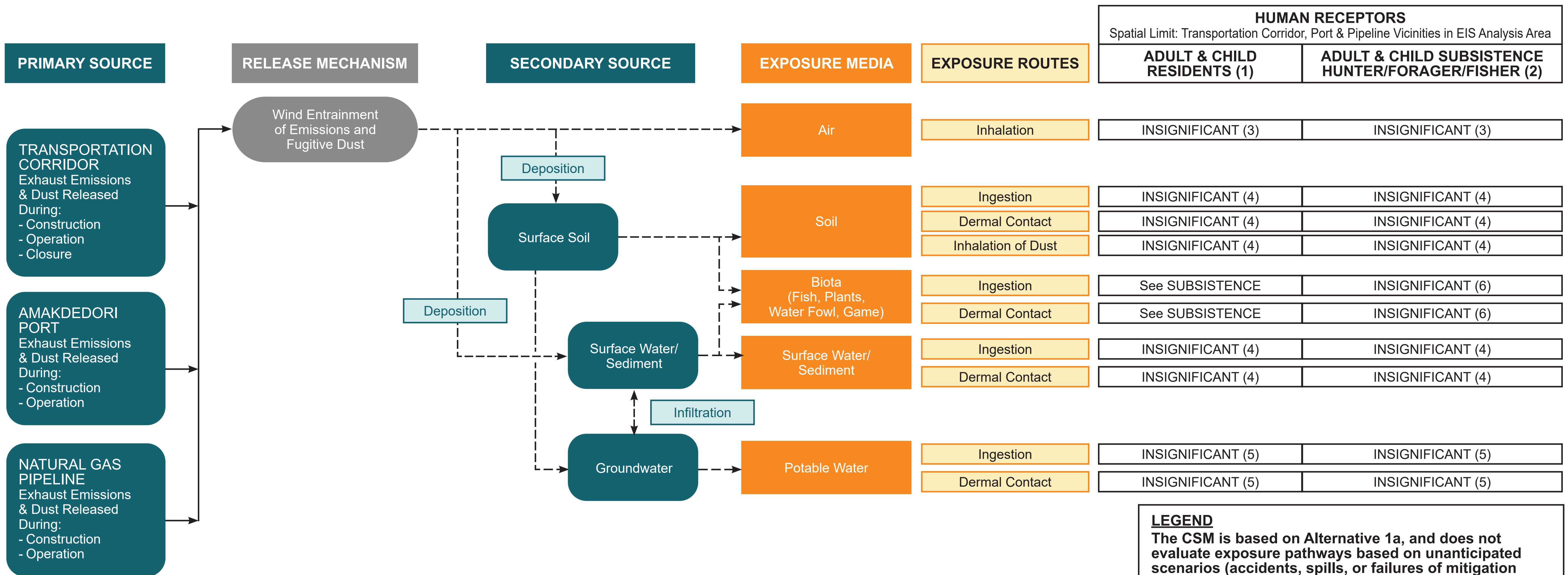
Exposure Pathways:
- **"Complete"** refers to a potential exposure pathway resulting in receptor exposure of project-related hazardous constituents in various media during any of the project phases.
- **"Incomplete"** refers to a potential exposure pathway with a break in the path that prevents receptors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

········▶ Transport Pathway Is Incomplete
– – – –▶ Transport Pathway Is Complete, but Insignificant
———▶ Transport Pathway Is Complete

Mine Site
Conceptual Site Model

Figure K4.10-1

H:\Graphics\Pebble Mine\05-2020 CSModel - Mine Site.INDD - VMG 05/21/2020



NOTES

(1) The same 11 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.

(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) 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 Section 4.20, Air Quality; Section 4.14, Soils; Section 4.18, Water and Sediment Quality; and Section 4.9, Subsistence.

LEGEND

The CSM is based on Alternative 1a, 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

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

Figure K4.10-2

If humans 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, the concentration of any COPCs at the expected exposure points is determined when possible (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.

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-potentially acid generating (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-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 would not be expected to impact the mine drinking water wells north of the core facility, and 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 (see Section 4.17, Groundwater Hydrology; Section 4.18, Water and Sediment Quality; and Chapter 2, Alternatives). Therefore, mine site groundwater is not considered a source "outside the fence" during the operations phase and 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 (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 waterbody. 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.

If people are exposed at high enough doses, many metals may exert adverse short- and long-term 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 presents some of the health effects associated with the metals listed in Table K4.10-5.

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.

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[4]	Fugitive Dust Deposition on Soil and Waterbodies[5]	Bioaccumu-lative 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		
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	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[4]	Fugitive Dust Deposition on Soil and Waterbodies[5]	Bioaccumu-lative and Potential for Subsistence Concern[6]
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]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.
[5]HAP metals (Sb, As, Be, Cd, Cr, Co, Pb, Mn, Hg, Ni, and Se) and Cu from mine site fugitive wet and dry dust deposition (PLP 2018-RFI 009 and PLP 2019-RFI 009b) to soil and waterbodies were evaluated in Section 4.14, Soils; 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).

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
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, 1994b, 1995a, 1995b, 1998a, 1998b, 2004a, 2004b, 2005a, 2005b, 2009; HEAST 2000a, 2000b; NLM 2019a, 2019b.

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 evaluation 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 evaluation, 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 evaluation 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-RFI 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 evaluation did not include HAPs. For this health evaluation, the total HAP annual emissions from all project components, 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:
AAQS = Ambient Air Quality Standards
HAP = hazardous air pollutants
NO_2 = nitrogen dioxide
PSD = Prevention of Significant Deterioration
PM = particulate matter
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 2019b).
[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. Therefore, 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 to 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 under all alternatives, 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 (Wolla and Sullivan 2017), 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 developed a Conceptual Fugitive Dust Control Plan (FDCP) to reduce the potential for airborne dust and control fugitive dust emissions from the activities associated with the construction, operation, and closure of the mine (PLP 2019-RFI 134). The Final FDCP would be developed during feasibility design work to support state permitting, and would be in place prior to construction commencement. Per the Conceptual FDCP, PLP would implement design features and active and passive controls to reduce fugitive dust emissions from the project. The Conceptual FDCP describes the equipment, methodology, training, and performance assessment techniques that would be used to control fugitive dust from the activities of the project. The PLP has committed to updating the Conceptual FDCP, as required, through mine permitting and operations. Specific measures suggested by the public for controlling fugitive dust (that are not already covered by existing design features, the Conceptual FDCP, or measures presented in Chapter 5, Mitigation) have been added to Appendix M1.0, Mitigation Assessment, for a comprehensive list of all measures identified during the NEPA process. All suggested measures have been assessed based on three factors described in Chapter 5, Mitigation, (Effective, Jurisdiction/ Enforcement, Reasonable), with the goal of disclosing the likelihood that the measures would be adopted by the Applicant or implemented as a condition in a state, federal, or local permit by the responsible agencies as part of their permit decisions following completion of the NEPA process. Within the limits of its regulatory authority, ADEC can require an assessment of ambient air quality to verify whether fugitive dust is

causing or significantly contributing to concentrations of particulate matter above ambient air standards.

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 discussion 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 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. Health impacts to potentially affected communities “outside the fence” due to mine site dust deposition is evaluated in the following subsections.

Deposition of HAP metals and Copper 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. In addition, potential increases of copper concentrations in soils at the mine site from fugitive dust deposition were also estimated using AERMOD modeling data, dust deposition rates (PLP 2019-RFI 009b), and baseline soil data. Although copper is not an HAP metal, deposition modeling was performed because comments were received in public hearings regarding the potential for copper in mine site dust to impact fish in downstream watersheds. 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 (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. For copper, the expected concentration increase in the future relative to baseline would be 6.18 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 and copper 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 Notes 11 and 12 of Table B1 (ADEC 2018b). Arsenic naturally occurs throughout Alaska (from volcanic releases and natural weathering of minerals and ores) and represents natural background concentrations as long as there are no known anthropogenic sources (e.g., contamination from commercial and industrial processes and materials) (ADEC 2018j). Because no contaminated site records coincided with or were in proximity to the project footprint (see Section 3.14, Soils), the baseline conditions represent naturally occurring elevated arsenic background. 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. Of these non-HAP metals, copper was evaluated for dust deposition above. For the remaining non-HAP metals, the mean concentrations 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 2018a):

- 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), 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), 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, 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 and copper (all had less than 1 percent increase from baseline, with the exception of antimony [3.04 percent increase] and copper [6.18 percent]). 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—Inadvertent release of hydrocarbons to surface waterbodies would result in a direct impact to surface water quality. As discussed in Section 4.18, Water and Sediment Quality, the likelihood of small hydrocarbon spills (small amounts of vehicle- or ferry-related pollutants) from transportation-related sources would be reduced through the application of BMPs and fuel handling requirements. Should a small spill occur, controls would be implemented, including an in-place spill response plan. In addition, based on the fate and transport of hydrocarbons, it would be expected that lighter-weight hydrocarbons would volatilize from the surface water, while heavier hydrocarbons would partition to sediment. See the discussion below under "Potential Minor Releases to Sediment". Therefore, this potential exposure pathway would be considered potentially complete, but insignificant.

Transportation Corridor Minor Releases to Sediment—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). In addition, should a small spill occur, it would be expected that potential impacts would be minimized or mitigated because control measures would be immediately implemented to reduce impacts to the environment. 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, potential increases of HAP metal and copper 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 PLP 2019-RFI 009b), 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 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 and copper, which would increase by 3.17 percent and 5.84 percent, respectively. See Appendix K4.18 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, 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 increase), 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 and copper concentrations in surface water at the mine site from fugitive dust deposition were evaluated. Baseline mean concentrations of HAP metals and copper were below the Alaska WQS. First, future concentrations were estimated based on a semi-quantitative sediment-to-surface-water partitioning approach to predict the change in surface water quality from dust deposition at the North Fork Koktuli (NFK) watershed, South Fork Koktuli (SFK) watershed, Upper Talarik Creek (UTC), and Frying Pan Lake, as detailed in Appendix K4.18. 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), with the exception of copper, which would increase by 5.84 percent. None of the estimated future concentrations of HAP metals and copper at the end of mine site operations, using the partitioning approach, resulted in exceedances of the most stringent Alaska WQS, which are presumed to be protective of human health. Secondly, future concentrations were estimated for Frying Pan Lake to provide a more conservative analysis of potential impacts of fugitive dust deposition to surface waterbodies; this assumes that 100 percent of fugitive dust deposited over the lake is entrained in and mixed in the water column, and includes WTP discharges (i.e., mixing model), as detailed in Appendix K4.18. Then, the percent change of constituent concentrations in Frying Pan Lake was applied to other mine site waterbodies (NFK watershed, SFK watershed, and UTC) as a conservative estimate of maximum potential increase of surface water concentrations due to fugitive dust deposition. Appendix K4.18 presents the predicted change in surface water quality from the surface water mixing model. The mixing model results indicate no exceedances of the most stringent Alaska WQS. 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 mine site safety boundary and could result in negligible increases of HAP metals and copper 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.

Because the dust deposition modeling used in the future media estimations in Section 4.14, Soils; and Section 4.18, Water and Sediment Quality was based on maximum rates at the boundary of the mine site, this evaluation used estimated future media concentrations (soil, groundwater, surface water, sediment) expected immediately outside the mine, which would be protective of potential project-related dust deposition impacts farther away, including existing drinking water protection areas near the project and the potentially affected communities. 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 uses the baseline and estimated soil concentrations of HAP metals and copper in soil at the end of mine operations from 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. 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 4.9, 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 evaluation also assesses 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 and copper with expected increases of 3.2 percent and 6.18 percent, respectively), 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 Values, 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 (see Section 4.23, Wildlife Values). 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 and copper in abiotic media at the end of project operations. In addition, the other non-HAP metals that are potentially bioaccumulative (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 waterbodies 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 and copper at the end of mine site operations would cause no exceedances of the most stringent Alaska WQS (see Appendix K4.18). Selection of the most stringent Alaska WQS included evaluation of criteria protective of the environment and human health (see Water Exposure Pathways, above), 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). Likewise, human health criteria based on consumption of aquatic organisms were available for copper, which is also bioaccumulative (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 one of the two other potentially bioaccumulative non-HAP metals (zinc at 69,000 micrograms per liter [µg/L]). Given the slight increases estimated for the HAP metals and copper in surface water (less than 1 percent for all HAP bioaccumulative metals and less than 6 percent for copper), and the baseline concentrations for zinc are well below its criteria (see Appendix K3.18), 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. 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 waterbodies 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. Although waterbirds could still potentially use the pit lake as a source of drinking water, this is unlikely 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, and they are likely to favor those locations (see 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 BMPs, 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 be distinguishable from current baseline levels and/or exceed 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 the transportation corridor, Amakdedori port, and the natural gas pipeline 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. Although the exposure pathways for all project components were deemed complete but insignificant, given the potential for potential exposure of water birds to mine site standing water and the potential for activities to impact subsistence foods (e.g., dust deposition onto berries), the health effect was assigned a score of 2 (moderate risks to illness or injury patterns and intervention may be needed). 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. Likewise, the likelihood of impacts for subsistence foods would be very unlikely (1 to 10 percent) for the transportation corridor, Amakdedori port, and the natural gas pipeline, given the limited sources and negligible impacts from these phases compared to the mine site. Although the mine site exposure pathways are either incomplete or complete but insignificant, the likelihood of impacts for subsistence foods would be unlikely (10 to 33 percent) for the mine site given the potential exposure of shorebirds and wildlife to standing waterbodies at the mine, which would be mitigated by PLP's WMP and other BMPs.

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 of 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%	♦	**1**
	Operations				3, long-term		7 (M)		♦♦	**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
							7 (T, Pi, Po)	(T, Pi, Po)		
	Closure				3, long-term		7 (M) 7 (T, Pi, Po)		♦♦	**2**
Increased risk of exposure to bioaccumulated chemicals in Fish, Waterfowl, Wildlife, and Plant Foods	Construction	-	2 (M), 1 (T, Pi, Po)	1	2, medium-term	2, potentially affected community	7 (M) 6 (T, Pi, Po)	10 to 33% (M) 1 to 10% (T, Pi, Po)	♦♦ ♦	**2 (M)** **1 (T, Pi, Po)**
	Operations				3, long-term		8 (M) 7 (T, Pi, Po)		♦♦	**2**
	Closure				3, long-term		8 (M) 7(T, Pi, Po)		♦♦	**2**

Notes:
Project-specific indicators: M = Mine Site; T = Transportation Corridor; Po = Amakdedori Port; Pi = Natural Gas Pipeline
The sum of the impact dimensions (Table K4.10-1) is used to determine the severity ranking. The severity ranking and likelihood rating determine the impact rating (1 through 4 diamonds), which indicates the corresponding overall significance impact rating category of 1, 2, 3, or 4 (Table K4.10-2).

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.

<u>Food, Nutrition, and Food Security</u>

Food security includes both physical and economic access to enough safe and nutritious food to meet healthy dietary requirements, and includes four supporting factors: availability, access, utilization, and stability (FAO 2006). For Native Alaskans, food security may also include the ability to maintain a subsistence lifestyle, including access to quality traditional foods and maintaining cultural values. 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). 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; who may reduce subsistence food consumption due to concerns regarding food contamination; and who may be less able to afford further increases in food prices. Potential food security impacts 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), and to sensitive sub-groups such as children, the disabled, elderly, low-income households, and indigenous communities. For example, decreases in access to safe and nutritious food could result in short-term nutritional dislocations for children in households living below the poverty threshold, which has the potential to impact their development (short-term impact) and throughout their lifetime (long-term impact).

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 result in replacement of subsistence foods with store-bought foods with lower nutritional value and/or 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.

<u>Subsistence Activity</u>

The Bristol Bay Region reports that subsistence activities are one of the most important parts of the community members’ lives (BBRV 2011). In addition to the nutritional benefits of a subsistence lifestyle, a subsistence lifestyle can also maintain cultural values, now and into the future, through teaching children subsistence skills and connection with and stewardship of the environment. Project impacts to subsistence-level food security and nutrition could result in both adverse and beneficial potential impacts (see 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 and values. 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 ATVs and snowmachines. The ferry could also facilitate access to subsistence resources by transporting residents and their vehicles across the lake. PLP would work with local communities to find solutions for ferry transportation use (PLP 2018-RFI 027).

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, and quantity 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).

Monitoring to assess the need to reduce potential negative impacts is recommended for impact ratings of Category 2 and Category 3. 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.

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 and quality of subsistence resources	Construction	±	2 (M) 1 (T, Pi, Po)	1	2, medium-term	2, communities and households that share subsistence resources and harvest	7 (M) 6 (T, Pi, Po)	33 to 66%	♦♦♦ ♦♦	**3 (M)** **2 (T, Pi, Po)**
	Operations	±	2 (M) 1 (T, Pi, Po)	1	3, long-term		8 (M) 7 (T, Pi, Po)		♦♦♦	**3**
	Closure	±	1 (M) 0 (T, Pi, Po)	0	3, long-term	1, limited to households	5 (M) 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
The sum of the impact dimensions (Table K4.10-1) is used to determine the severity ranking. The severity ranking and likelihood rating determine the impact rating (1 through 4 diamonds), which indicates the corresponding overall significance impact rating category of 1, 2, 3, or 4 (Table K4.10-2).

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 K4.10-10 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. Poverty levels and health disparities for indigenous communities and other sensitive subgroups such as children, the disabled, and elderly have the potential to impact other HECs (e.g., socioeconomics under HEC 1 and food security under HEC 4), which in turn have the potential to impact infectious diseases. For example, low-income households that are food insecure may be affected by malnutrition, which can affect a person's immune system and increase susceptibility to infectious diseases. Low-income households may not have access to preventative healthcare (such as getting routine vaccinations, which would reduce communicable disease transmission to individuals and reduce the spread of such diseases in local communities). 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 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, Groundwater Hydrology, 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 from 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 K4.10-10). 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 were 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 (see 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 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 STI 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) 10-33% (M, Po)	♦♦ ♦	**2 (T, Pi)** **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) 10-33% (M, Po)	♦♦ ♦	**2 (T, Pi)** **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
The sum of the impact dimensions (Table K4.10-1) is used to determine the severity ranking. The severity ranking and likelihood rating determine the impact rating (1 through 4 diamonds), which indicates the corresponding overall significance impact rating category of 1, 2, 3, or 4 (Table K4.10-2).

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). Poverty levels and health disparities for indigenous communities and other sensitive subgroups such as children, the disabled, and the elderly have the potential to impact other HECs (e.g., socioeconomics under HEC 1), which then have the potential to impact water and sanitation. For example, low-income households may not be able to afford in-home water and sewer services.

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).

<u>Summary</u>

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**

Note:
The sum of the impact dimensions (Table K4.10-1) is used to determine the severity ranking. The severity ranking and likelihood rating determine the impact rating (1 through 4 diamonds), which indicates the corresponding overall significance impact rating category of 1, 2, 3, or 4 (Table K4.10-2).

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. Poverty levels and health disparities for indigenous communities and other sensitive subgroups such as children, the disabled, and the elderly have the potential to impact other HECs (e.g., socioeconomics under HEC 1 and food security under HEC 4), which in turn have the potential to impact non-communicable and chronic diseases. For example, changes in subsistence habits, diet, and nutrition, and changes in activity patterns could also affect the incidence of chronic diseases among indigenous communities.

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, and quantity and quality of subsistence resources could be both negative and positive (Table K4.10-9). 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 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 or decreased 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 K4.10-12). 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 a 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 or decreased cancer, respiratory, and cardiovascular morbidity and mortality rates due to increased or decreased diet/nutrition and increased or 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 BMPs 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 potentially be 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 or decrease 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	±	1	1	3, long-term	1, limited number of households	6	33 to 66%	♦♦	**2**
	Closure	±	1	1	3, long-term	1, limited number of households	6	33 to 66%	♦♦	**2**
Increase in cancer, respiratory, cardio-vascular, developmental and neurological morbidity and mortality rates due to exposure from hazardous chemicals	Construction	-	1 (M) 0 (T, Pi, Po)	0	2, medium-term	2, potentially affected community	5 (M) 4 (T, Pi, Po)	10 to 33% (M) 1 to 10% (T, Pi, Po)	♦	**1**
	Operations	-	1 (M) 0 (T, Pi, Po)	0	3, long-term	2, potentially affected community	6 (M) 5 (T, Pi, Po)	10 to 33% (M) 1 to 10% (T, Pi, Po)	♦	**1**
	Closure	-	1 (M) 0 (T, Pi, Po)	0	3, long-term	2, potentially affected community	6 (M) 5 (T, Pi, Po)	10 to 33% (M) 1 to 10% (T, Pi, Po)	♦	**1**

Notes:
Project-specific indicators: M = Mine Site, T=Transportation Corridor, Po= Amakdedori port, Pi = Natural Gas Pipeline Corridor
The sum of the impact dimensions (Table K4.10-1) is used to determine the severity ranking. The severity ranking and likelihood rating determine the impact rating (1 through 4 diamonds), which indicates the corresponding overall significance impact rating category of 1, 2, 3, or 4 (Table K4.10-2).

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

Access to health and safety services is important for achieving health and safety 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 level of access to safety services can impact psychosocial and family stress, while response to accidents and injuries can potentially increase accident/injury severity outcomes. Poverty levels and health disparities for indigenous communities and other sensitive subgroups such as children, the disabled, and the elderly have the potential to impact other HECs (e.g., socioeconomics under HEC 1), which then have the potential to impact access to health and safety services. For example, low-income families living just above the poverty line may not be able to afford healthcare or dental insurance and may not qualify for financial assistance.

The following sections present the evaluation of the potential impacts from decreased access to healthcare and safety services under routine conditions and emergency situations that could overwhelm local and regional healthcare and safety service capacities. Table K4.10-13 summarizes the potential impact levels for health and safety 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 and Safety Services

Several entities provide healthcare services in the EIS analysis area (see 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 Ekuk, which had a population of zero in 2009 (McDowell Group et al. 2011a; McDowell Group 2018b).

The potentially affected communities closest to the project have lower access to safety services than larger nearby communities, such as Dillingham, which has a police department and a hospital (McDowell Group 2018a, 2018b) and Anchorage. Although two of the three Nushagak/Bristol Bay communities in the Dillingham Census Area (New Stuyahok and Koliganek) have village public safety officers (VPSO) and/or village police officers (VPO), the eight Iliamna Lake/Lake Clark communities in the LPB (Nondalton, Kokhanok, Newhalen, Iliamna, Levelock, Pedro Bay, Igiugig, Port Alsworth, and Ugashik) and the third Nushagak/Bristol Bay community in the Dillingham Census Area (Ekwok) are not served by a VPSO or VPO, and instead rely on Alaska State Trooper coverage (see Section 3.10, Health and Safety). Although three communities (Newhalen, Nondalton, and Iliamna) were served by an ambulance, fire truck, and emergency medical technicians, the remaining communities were underserved by these other first responders. Two communities (Port Alsworth and Ekwok) are not served by any of these other first responders, while the remaining communities were only served by one or two (Section 3.10, Health and Safety).

The project has the potential to impact access to routine healthcare and safety services. On-site mine rescue and medical emergencies would likely be handled by a mine rescue team. On-site mine and Amakdedori port safety would be handled by project security and on-site medical services. 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. Additionally, some project employees, when outside of the mine site, might require public safety services from nearby communities (e.g., Kokhanok, Iliamna, or Newhalen). For example, if a mine vehicle accident occurred along the transportation corridor near one of these communities, then local public first responders may be the first on scene. This would not be expected to occur often because of project mitigations, including employee training, traffic/speed controls, and mine first responders. It is unclear what impacts the project may have on crime (see HEC 1), but if violent crimes increase due to increased psychosocial and family stress, it is possible that this could put additional strain on the health and safety services of the potentially affected communities.

In addition, positive impacts may also occur related to routine healthcare and safety services. Municipal tax revenues generated by the project and increased revenue stream to the LPB may result in the hiring of VSPO or VPO in one or more of these communities, and expansion or improvements to existing healthcare facilities and other health and safety services. Therefore, these positive impacts may result in net benefits to all members of the community with regard to access and quality of healthcare and safety services (see Section 4.3., Needs and Welfare of the People-Socioeconomics).

Given that the project could have both positive and negative impacts, a noticeable effect on access to routine healthcare and safety services would not be expected for residents living in the EIS analysis area, including the communities near the mine site. The summary impact level for access to routine healthcare and safety services for the potentially affected communities is rated Category 1 for all project components and phases (Table K4.10-13). 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 and on-site safety services.

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

Although many of the project workers would be trained in emergency response and first aid and the mine would have on-site security and medical facilities to support workers, the mine site safety and 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; although 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 in seven of nine communities (McDowell Group et al. 2011a). The three Nushagak/Bristol Bay communities (New Stuyahok, Koliganek, and Ekwok) are each serviced by a healthcare clinic (McDowell Group 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 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 Group 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 large-scale emergency healthcare and safety services 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 and safety services and infrastructure are rated as Category 1 for access to routine healthcare and safety services, and Category 2 for access to healthcare and safety services 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 and Safety 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 and safety services	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 and safety services 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**

Note:
The sum of the impact dimensions (Table K4.10-1) is used to determine the severity ranking. The severity ranking and likelihood rating determine the impact rating (1 through 4 diamonds), which indicates the corresponding overall significance impact rating category of 1, 2, 3, or 4 (Table K4.10-2).

K4.10.3 Alternative 1

Impacts from Alternative 1 would be the same as or similar to Alternative 1a, with few exceptions. The area of Iliamna Lake used for the ferry would be different and the route would be slightly shorter, because the ferry would travel to the north ferry terminal instead of the Eagle Bay ferry terminal. The mine access road alignment would route from the north ferry terminal to the mine site, with a spur road to Iliamna; and the port access road would be the same as Alternative 1a. This alternative's natural gas pipeline alignment would follow the transportation corridor for the entirety and have a slightly shorter route across Iliamna Lake; however, impacts would be the same as Alternative 1a. Impacts from the Amakdedori port would be the same as Alternative 1a. Socioeconomic impacts under this Alternative would be similar to impacts under Alternative 1a.

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 year-round ferry operations.

As discussed in Section 4.23, Wildlife Values, caribou are likely to avoid the mine site facilities and may avoid a 6.8- to 8.7-mile radius around the mine site; moose are anticipated to avoid areas along the roadways, with avoidance areas of approximately 0.6 mile on either side of the roadways. Similar to Alternative 1a, 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 of Alternative 1 (as well as the Summer-Only Ferry Operations Variant of Alternative 2), where vehicle traffic would be doubled during the summer (see Section 4.23, Wildlife Values). Given these considerations, potential for dietary impacts to caribou and moose from mine site dust deposition onto vegetation would be anticipated to be the same as Alternative 1a (i.e., low impact) (Section K4.10.2.3).

Overall, the HEC for which Alternative 1 consequences may be slightly different from Alternative 1a is HEC 2: Accidents and Injuries due to transportation because the mine access road alignment is different, including a slightly shorter ferry route and pipeline crossing of Iliamna Lake. Those impacts would be the same as Alternative 1a along the port access road. Along the mine access road, 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 K4.10-14), including the crossing of the Newhalen and Gibraltar rivers. The health effect, magnitude, duration, and geographic extent would all remain the same as Alternative 1a. Because there would be no difference in the overall number of flights or barge and ferry trips relative to Alternative 1a, the likelihood of accidents and injuries related to air and surface water would be the same as for Alternative 1a. Similar to Alternative 1a, the overall number of truck trips would remain the same, operate year-round, and would have similar use of roads; therefore, the likelihood of accidents and injuries related to surface transportation would remain unlikely (10 to 33 percent).

If the Kokhanok East Ferry Terminal Variant were to be built, differences in impacts would occur relative to the south ferry terminal. The Kokhanok East Ferry Terminal Variant has thicker ice for a longer duration than the 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 ore 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 twice as much ferry traffic.

K4.10.4 Alternative 2—North Road and Ferry with Downstream Dams

Impacts from the project would be the same as or similar to Alternative 1a, with few exceptions. The area of Iliamna Lake used for the ferry would be different, because it would encompass 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 1a. Socioeconomic impacts under this variant would be similar to impacts under Alternative 1a. This alternative's natural gas pipeline alignment would follow the north access road alignment, and not cross Iliamna Lake; therefore, there would be no hazards or impacts at Iliamna Lake during construction of the pipeline, as would occur under Alternative 1a. Impacts from the port at Diamond Point would be the same or similar to those for Amakdedori port.

Overall, the HEC for which Alternative 2 consequences may be slightly different from Alternative 1a 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 K4.10-14), including the crossing of the Newhalen River. The health effect, magnitude, duration, and geographic extent would all remain the same as Alternative 1a. Because there would be no difference in the overall number of flights or barge and ferry trips relative to Alternative 1a, the likelihood of accidents and injuries related to air and surface water would be the same as for Alternative 1a. Similar to Alternative 1a, the likelihood of accidents and injuries related to surface transportation would remain unlikely (10 to 33 percent), because there would be no increase in truck trips under Alternative 2. Under the Alternative 2—Summer-Only Ferry Operations Variant, like Alternative 1 traffic on the Williamsport-Pile Bay Road would include doubled mine-related summer traffic, and continuing or increasing levels of public boat portage. Similar to Alternative 1, the potential for a greater likelihood of accidents during the Summer-Only Ferry Operations Variant would be reduced if the road was built to handle this increased summer capacity. The Newhalen River North Crossing Variant would be the same as Alternative 2.

K4.10.5 Alternative 3—North Road Only

Impacts from the project would be the same as or similar to Alternative 1a with exceptions discussed below. 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 1a 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 1a, 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 slightly different 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 1a. 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 Alternative 1, Alternative 2, and Alternative 3

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

Table K4.10-14: Summary of HEC 2 Impacts: Accidents and Injuries for Alternative 1, Alternative 2, and Alternative 3

Potential Impact	Project Phase	Negative/ Positive	Health Effect	Magnitude	Duration	Geographic Extent	Severity Ranking	Likelihood Rating	Impact Rating	Impact Category
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 surface and water = 2, able to maintain pre-impact level of health with medical intervention	2, medium-term	0, individual cases	8 (air) 7 (water/ surface)	<1 % (air) 10 to 33% (surface) 10 to 33% (water)	♦♦	**2**
	Operations				3, long-term		9 (air) 8 (water/ surface)		♦♦	**2**
	Closure				3, long-term		9 (air) 8 (water/ surface)		♦♦	**2**

Note:
The sum of the impact dimensions (Table K4.10-1) is used to determine the severity ranking. The severity ranking and likelihood rating determine the impact rating (1 through 4 diamonds), which indicates the corresponding overall significance impact rating category of 1, 2, 3, or 4 (Table K4.10-2).