K3.14 SOILS

This appendix contains additional technical information on the following topics related to baseline soil conditions provided in Section 3.14, Soils:

- Technical classification of soils in the project footprint
- Permafrost occurrence in the project footprint
- Baseline soil chemistry

K3.14.1 Project Footprint Soil Classification

Some soils information provided in the Exploratory Soil Survey of Alaska (ESS) does not translate directly to current 2006 classification system standards, *Keys to Soil Taxonomy, 10th edition* (USDA 2006), but comparative equivalent soil-type estimates can be made. Two additional soil orders that occur in the project area (i.e., Andisols and Gelisols) have been added to the ESS since 1979. Where applicable, soil descriptions from the ESS have been translated to current 2006 classification system equivalents (3PPI 2011a). Corresponding equivalents are based on available ESS descriptions and extrapolations from other nearby studies for the village of Nondalton and Chisik Island (Table K3.14-1).

Table K3.14-1: Corresponding ESS and 2006 Classifications for Applicable Soils

ESS Map Units	1979 Classification	2006 Classification
HY4, SO11, IA7	Pergelic cryofibrists	Typic fibristels
SO11	Humic cryothods	Typic humicryods
IA7, IA9	Typic crandepts	Typic haplocryands Typic vitricryands

Notes:
ESS = Exploratory Soil Survey of Alaska
Source: 3PPI 2011a, Table 5-2

All the soil types in the project footprint are not likely addressed in the ESS, because the ESS is limited to a general soils map and does not provide site-specific interpretations. Although not a direct comparison to Natural Resource Conservation Service soil descriptions, available project soil classification information acquired from shallow sampling activities (18-inch depth) have been incorporated (where available) into a surficial geologic map (Section 3.13, Geology, Figure 3.13-2). A more detailed surficial geologic map of the mine site is provided in Section 3.13, Geology.

K3.14.1.1 Mine Site Soil Types

Soil types (i.e., principal component) and acreages associated with the mine site based on information provided in the ESS are listed below.

- IA9 Typic Cryandepts – 5,798 acres (approximately 71 percent): Very gravelly, hilly to steep association. Soils are well-drained, strongly acidic, and formed in volcanic material with a thin surface cover of decomposed plant matter mixed with volcanic ash. Common vegetation includes alder, grasses, or low shrubs.
- IA7 Typic Cryandepts – 2,331 acres (approximately 29 percent): Very gravelly, nearly level to rolling Peregelic Cryofibrists, nearly level association. Soils are also associated with rolling plains bordering Iliamna Lake and rolling ground moraines, terminal moraines, outwash plains, and paleo-beach ridges, small lakes, and

muskegs. Typic Cryandepts are well-drained, acidic, and formed in shallow volcanic material over gravelly glacial material dominated by low-tundra vegetative species. Shallow permafrost can reportedly be associated with a Pergelic Cryofibrists component (where present) consisting of sedge peat muskegs and coarse acid moss.

K3.14.1.2 Transportation Corridor Soil Types

The ESS recognizes four soil map units in the transportation corridor study area, which are described below with corresponding acreages.

- IA7 Typic Cryandepts – 344 acres (approximately 39 percent)
- IA9 Typic Cryandepts – 203 acres (approximately 23 percent)
- IA17 Dystric Lithic Cryandepts – 328 acres (approximately 37 percent): Hilly to steep association. Soils are associated with low hills and ridges bordering mountainous areas. Well-drained loamy soils are formed in volcanic ash over shallow (20 inches) metamorphic bedrock or gravelly till, and overlain with a thin layer of organic material.
- HY4 Pergelic Cryofibrists – 13.5 acres (approximately 1 percent): Nearly level association. Soils are associated with nearly level, broad, wet lowlands near lakes and coastal margins. Organic-rich sedge and moss (e.g., muskeg) soils underlain by silt and sand mixtures are poorly drained, and can reportedly be associated with the presence of shallow permafrost. Vegetation includes water-tolerant sedges, low shrubs, and black spruce.

K3.14.1.3 Pipeline Corridor Soil Types

Soil types along the shared route for the transportation corridor are the same as those described above. Two detailed soil map units are associated with the approximately 6 acres of pipeline infrastructure ground disturbance on the eastern side of Cook Inlet:

- 640 – Qutal silt loam, 0 to 4 percent slopes, 5.5 acres: Medial over loamy, amorphic over mixed, superactive Aquandic Haplocryods. Soils are associated with moraines on till plains and depressions on till plains dominated by a spruce-birch forest spruce-willow community. Soils consist of very gravelly sand overlain with silt loam and a thin interval of decomposed plant material. Soils are somewhat poorly drained with no flooding or ponding, with a slight hazard of erosion for water, but severe by wind.
- 568 – Island silt loam, 0 to 4 percent slopes, 0.25 acres: Medial over loamy, amorphic over mixed, superactive Pachic Fulvicryands. Soils are associated with till plains dominated by shallow kettles. Soils consist of gravelly sandy loam overlain with silt loam and a thin interval of decomposed plant material. Soils are well-drained with no flooding or ponding, with a slight hazard of erosion by water, but severe hazard of erosion by wind.

K3.14.1.4 Soil Types Unique to Alternatives

ESS soil types (i.e., principal component) that coincide with footprints associated with alternatives are described below.

- RM1 Rough Mountainous Land: Steep rocky slopes.
- SO1 Typic Cryorthods: Nearly level association. Soils are associated with low-rolling glacial moraines, broad terraces, and lake- and muskeg-filled depressions. Well-

drained to very poorly drained soils formed in silty loess (20 to 40 inches) over gravelly glacial till to fibrous organic soils in depressions between moraines.

- SO11 Humic Cryorthods: Hilly to steep association. Soils are associated with foot slopes and moraines. Well-drained soils formed in silty volcanic ash (10 to 24 inches) over very gravelly glacial till, and overlain by partially decomposed organic matter.

K3.14.2 Permafrost Occurrence

Recent permafrost distribution estimates that coincide with project components on the western side of Cook Inlet are considered to be isolated occurrences (Jorgenson et al. 2008). Isolated permafrost varies from 0 to 10 percent of the landscape subsurface. No permafrost occurrence is anticipated to coincide with project infrastructure on the eastern side of Cook Inlet. Thermokarst landform features, which are the result of permafrost freeze and thaw processes, can be indicative of permafrost, or residual expressions of where permafrost no longer exists. Existing thermokarst landscape features and future areas susceptible to thermokarst processes in the project footprint are generally not present (Olefeldt et al. 2016). Frozen ground conditions have been observed in near-surface soils in a few test pits and soil borings, but conditions were indiscernible from active layer processes that annually freeze and thaw at depths of up to 10 feet. Ground temperature measurements at depth in the mine site study area reported a mean temperature of 39.1 degrees Fahrenheit (°F). Groundwater temperature measurements from the deposit area were also above freezing throughout the year. Although such conditions do not preclude the occasional occurrences of permafrost, current conditions do not support increased permafrost development, and any remaining permafrost is considered to be a relic. Where present, relict permafrost is likely limited to shaded areas and north-facing slopes; poorly drained shallow surface soils overlain with insulative organics; and deep, coarse-grained soils (3PPI 2011a). Based on information provided in the ESS, principal components associated with Pergelic Cryofibrists (HY4) and Typic Cryandepts (IA7) soil types in the project footprint may coincide with relict permafrost occurrence in areas of very poorly drained organic soils (e.g., fibrous sedge and muskeg) of nearly level association that include depressions and valley bottoms.

K3.14.3 Baseline Soil Chemistry

Baseline shallow surface soil samples (less than 0.5 foot deep) were collected to determine the variability in naturally occurring constituents at the mine site. A total of 237 surface soil samples was collected from 117 locations in the mine site study area. Theses samples were analyzed for trace elements, cyanide, and sodium at 237 surface soil locations; anions and cations at 235 surface sample locations; petroleum hydrocarbons as diesel-range organics (DRO) and residual range organics (RRO), respectively at 23 surface soil locations; and total organic carbon (TOC) at 53 surface sample locations. The sample locations were considered representative of undisturbed baseline conditions. A list of naturally occurring compounds (NOCs) (i.e., analytes) evaluated as part of the surface soil studies is presented in Table K3.14-2 and Table K3.14-3.

Table K3.14-2: Mine Site Study Area Surface Soil Trace Elements and Cations

Analyte	Frequency of Detection[a]	Percent Detected	Range of Detects (mg/kg) (Min-Max)	Range of Method Detection Limits (mg/kg) (Min-Max)	Range of Method Reporting Limits (mg/kg) (Min-Max)	Mean[b] (mg/kg)	Median[b] (mg/kg)	Standard Deviation[b]	Coefficient of Variation	Comparative Action Levels[c] (mg/kg)
Trace Elements										
Aluminum	237/237	100%	932-109000	.67 – 100	2.14 – 500	17,644	16,400	12,175	0.69	N/A
Antimony	211/237	89%	0.040 – 2.14	0.033 – 2.13	0.11 – 6.86	0.24	0.20	0.22	0.93	33
Arsenic	227/237	96%	1.03 – 73.8	0.30 – 21.3	0.50 – 68.6	10.2	8.07	10.1	0.99	7.2 (inorganic)
Barium	237/237	100%	14.8 - 576	0.050 – 10.0	0.30 – 50.0	84.9	65.5	67.1	0.79	17,000
Beryllium	224/237	95%	0.051 – 5.89	0.033 – 2.13	0.11 – 6.86	0.41	0.34	0.45	1.09	170
Bismuth	105/237	44%	0.073 – 1.05	0.066 – 20.0	0.21 – 100	1.30	0.13	4.26	3.27	N/A
Boron	65/237	27%	0.54 – 9.34	0.36 – 50.0	1.16 – 117	4.82	3.45	4.62	0.96	N/A
Cadmium	146/237	62%	0.072 – 3.06	0.050 – 4.26	0.21 – 13.7	0.24	0.16	0.32	1.33	76 (Diet)
Calcium	237/237	100%	222 – 31,100	10.0 – 645	31.9 – 2,060	2,577	1,700	2,993	1.16	N/A
Chromium	233/237	98%	1.15 – 113	0.050 – 8.24	0.30 – 27.5	17.7	14.7	14.5	0.82	1.0×10^5 (Cr^3) 3.9 (Cr^6)
Cobalt	232/237	98%	0.45 – 24.2	0.030 – 10.3	0.10 – 34.3	6.55	5.63	4.60	0.70	N/A
Copper	236/237	100%	2.65 – 197	0.19 – 12.4	0.64 – 41.2	27.4	16.3	35.2	1.28	3,300
Iron	237/237	100%	588 – 103,000	2.00 – 452	4.00 – 1,460	20,694	19,300	13,532	0.65	N/A
Lead	236/237	100%	0.66 – 78.4	0.050 – 4.26	0.21 – 13.7	8.74	7.54	8.85	1.01	400
Magnesium	237/237	100%	74.1 – 9,930	10.0 – 795	31.9 – 2,540	3,076	2,930	2,022	0.66	N/A
Manganese	237/237	100%	5.43 – 6,560	0.066 – 50.0	0.21 – 300	388	279	559	1.44	N/A
Mercury	224/237	95%	0.014 – 0.72	0.013 – 0.30	0.042 – 2.00	0.12	0.072	0.12	0.98	3.1 (elemental)
Molybdenum	179/237	76%	0.40 – 68.1	0.30 – 21.3	1.00 – 68.6	1.82	0.92	4.71	2.59	N/A
Nickel	235/237	99%	0.59 – 53.8	0.066 – 4.26	0.21 – 13.7	9.16	7.42	7.10	0.77	1,700 (soluble salts)

Table K3.14-2: Mine Site Study Area Surface Soil Trace Elements and Cations

Analyte	Frequency of Detection[a]	Percent Detected	Range of Detects (mg/kg) (Min-Max)	Range of Method Detection Limits (mg/kg) (Min-Max)	Range of Method Reporting Limits (mg/kg) (Min-Max)	Mean[b] (mg/kg)	Median[b] (mg/kg)	Standard Deviation[b]	Coefficient of Variation	Comparative Action Levels[c] (mg/kg)
Potassium	224/237	95%	100 – 5,510	30.0 – 2,130	106 – 6,860	621	511	523	0.84	N/A
Selenium	219/237	92%	0.18 – 79.3	0.050 – 10.3	0.30 – 34.3	2.76	1.10	7.34	2.66	410
Silver	117/237	49%	0.030 – 1.45	0.030 – 2.13	0.10 – 6.86	0.11	0.059	0.20	1.80	410
Thallium	179/237	76%	0.0099 – 5.00	0.0066 – 5.00	0.021 – 30.0	0.24	0.088	0.61	2.53	0.83 (soluble salts)
Tin	27/237	11%	1.06 – 2.90	0.33 – 21.3	1.06 – 100	1.94	0.96	2.99	1.54	N/A
Vanadium	210/237	89%	4.67 – 227	0.10 – 64.5	0.50 – 206	46.4	47.0	31.1	0.67	420
Zinc	235/237	99%	2.77 – 228	0.33 – 21.3	1.06 – 68.6	43.9	40.0	33.2	0.76	25,000
Anions and Cations[d]										
Ammonia (as nitrogen)	214/235	91%	0.50 – 2,200	0.50 – 120	3.00 – 382	363	179	440	1.21	N/A
Chloride	158/237	67%	0.40 – 28.3	0.30 – 30.0	0.98 – 100	2.74	1.50	3.73	1.36	N/A
Cyanide	199/237	84%	0.028 – 0.75	0.024 – 4.00	0.049 – 20.0	0.19	0.15	0.18	0.92	26 (CN^-)
Fluoride	54/235	23%	0.33 – 39.3	0.30 – 18.4	0.98 – 59.5	0.88	0.36	2.67	3.04	N/A
Sodium	215/237	91%	56.2 – 1,860	30.0 – 2,130	106 – 6,860	208	153	181	0.87	N/A
Sulfate	211/237	90%	0.41 – 1,820	0.30 – 30.0	0.98 – 100	19.8	4.26	122	6.19	N/A

Notes:
[a] Number of samples with detectable concentrations / total number of samples analyzed.
[b] When calculating the mean, median, and standard deviation, non-detect results were included as one-half the method detection limit. Non-detect results assigned a "U" or "UJ" qualifier were included as one-half the reporting limit.
[c] Where provided, comparative action level is based on ADEC 18 AAC 75, Oil and Other Hazardous Substances Pollution Control, September 29, 2018, Table B1. Method Two – Soil Cleanup Levels, Human Health, Over 40 Inch Zone (ADEC 2017a).
[d] All data presented on a dry-weight basis.
mg/kg = milligram per kilogram
Min = minimum
Max = maximum
N/A = none available
Source: SLR et al. 2011a, Table 10.1-3

Table K3.14-3: Mine Site Study Area Surface Soil Diesel Range Organics and Residual Range Organics, and Total Organic Carbon

Analyte	Frequency of Detection[a]	Percent Detected	Range of Detects (mg/kg) (Min-Max)	Range of Method Detection Limits (mg/kg) (Min-Max)	Range of Method Reporting Limits (mg/kg) (Min-Max)	Mean[b] (mg/kg)	Median[b] (mg/kg)	Standard Deviation[b]	Coefficient of Variation	Comparative Action Levels[c]
DRO[d]	13/23	57%	11.7 – 1300	2.01 – 127	20.1 – 1,270	209	72.5	299	1.43	8,250
RRO[d]	23/23	100%	32.7 – 12,300	2.01 – 127	20.1 – 1,270	2,028	1,150	2,895	1.43	8,300
TOC[d,e]	53/53	100%	0.3% – 65.1%	0.00026% – 2.08%	0.0061% – 4.16%	6.51%	2.20%	12.6%	1.93	N/A

Notes:
DRO = diesel range organics
mg/kg = milligram per kilogram
Min = minimum
Max = maximum
N/A = none available
RRO = residual range organics
TOC = total organic carbon
[a] Number of samples with detectable concentrations / total number of samples analyzed.
[b] When calculating the mean, median, and standard deviation, non-detect results were included as one-half the method detection limit. Non-detect results assigned a "U" or"UJ" qualifier were included as one-half the method reporting limit.
[c] Where provided, comparative action level is based on ADEC 18 AAC 75, Oil and Other Hazardous Substances Pollution Control, September 29, 2018, Table B2. Method Two – Petroleum Hydrocarbon Soil Cleanup Levels, Ingestion, Over 40 Inch Zone (ADEC 2017a).
[d] All data presented on a dry-weight basis.
[e] For TOC, unit of measure is percentage rather than milligrams per kilogram (mg/kg).
Source : SLR et al. 2011a, Table 10.1-5.

Anions and cations evaluated in surface soil samples included chloride, cyanide, fluoride, sulfate, ammonia (as nitrogen), and sodium. The highest mean concentration among evaluated ions was ammonia, followed by sodium. The lowest mean concentration among evaluated ions was cyanide. Depth-based variations in ion concentrations were apparent, based on comparison to co-located shallow subsurface soil sample results. Mean concentrations of cyanide and ammonia were greater in surface samples, while mean sulfate concentrations were greater in shallow subsurface samples (SLR et al. 2011a).

RRO hydrocarbons were detected at all 23 surface sample locations, and DRO was detected at 13 surface sample locations. Mean concentrations of 209 milligrams per kilogram (mg/kg) and 2,028 mg/kg were reported for DRO and RRO, respectively (Section 3.14, Soils, Table K3.14-3). The elevated presence and wide range of reported hydrocarbon concentrations are attributed to naturally occurring biogenic sources, based on absence of prior disturbances, analytical fingerprint methods, and presence of TOC (SLR et al. 2011a).

Similar to hydrocarbons, reported TOC concentrations varied significantly. TOC concentrations varied from 0.36 percent to 65.1 percent among surface soil locations. The wide range is attributed to variable quantities of organic material retained in sampled matrices during collection.