K3.10 HEALTH AND SAFETY

The evaluation of impacts on human health and safety is a required component of the National Environmental Policy Act (NEPA) as it pertains to negative and beneficial consequences of a proposed project on potentially affected communities. This appendix supports Section 3.10, Health and Safety.

K3.10.1 Health

This appendix contains information on the health effects categories (HECs) 1 through 8 supplemental to Section 3.10, Health and Safety. HECs 1 through 4 are the focus of and are detailed in Section 3.10, Health and Safety because they are the most relevant to the project or are a concern to stakeholders and affected communities; therefore, this appendix presents a brief summary of HECs 1 through 4 and provides their baseline data tables, if generated. HECs 5 through 8 are expected to have lower relevance to the project, and are also detailed in this appendix, including baseline data tables, if generated.

K3.10.1.1 HEC 1: Social Determinants of Health

Factors such as income, education, isolation, and early access to healthcare are termed social determinants of health (SDH) because any changes in these factors, positive or negative, can lead to corresponding changes in the physical, mental, and social health of the population. For those SDH not covered in Section 3.3, Needs and Welfare of the People–Socioeconomics, Table K3.10-1 below, summarizes the additional SDH that are relevant and important indicators for this HEC since they may potentially be impacted by the project. Overall, the affected communities whose health may be most impacted by the project in EIS analysis area (or communities that may use the area for residence, subsistence, or recreation) are the remote, rural communities in the Bristol Bay Region (includes the Lake and Peninsula Borough [LPB], Bristol Bay Borough, and Dillingham Census Area) and Kenai Peninsula Region. The remote communities generally have lower levels of employment, income, formal educational attainment, and access to amenities than the urbanized communities. While they are comparable to the larger urban areas in some areas of health, there are other areas such as alcohol consumption where the rural areas may have higher health needs.

Table K3.10-1: Social Determinants of Health

Determinant	Data Period	Iliamna Lake/Lake Clark Commun-ities	Nushagak/ Bristol Bay Commun-ities	Lake and Peninsula Borough	Dilingham Census Area	Bristol Bay Borough	Bristol Bay Region	Kenai Peninsula Region	Anchorage /Mat-Su Region	Alaska	National
Life Expectancy in Years	2009-2013	--	--	--	--	--	71.4 (AN)	71.6 (AN)	71.6 (AN)	70.7 (AN) 78.0 (White)	79.1 (White)
Adequate Prenatal Care in Percent (%)	2009-2013 (unless noted)	63.3 (all races; 2014-2016)	36.1 (all races; 2014-2016)	55.3[a] (all races; 2014-2016)	47.4[b] (all races; 2014-2016)	51.8 (all races; 2014-2016)	35.4 (AN)	64.2 (AN)	63.9 (AN)	50.0 (AN) 54.5 (AN 2013) 68.8 (White 2013) 62 (all races; 2014-2016)	--
Infant Mortality (rate per 1,000 live births)	2009-2013 (unless noted)	--	--	--	--	--	5.9[c] (AN)	--	5.6 (AN)	6.7 (AN) 8.9 (AN 2013) 3.5 (White 2013)	5.1 (White 2013)
Teen Pregnancy (rate per 1,000 births)	2009-2013 (unless noted)	--	70[c] (all races; 2014-2016)	--	44.4[b] (all races; 2014-2016)	--	65.8 (AN)	45.2 (AN)	52.9 (AN)	69.2 (AN) 47.3 (AN 2013) 20.5 (White 2013) 27.5 (all races; 2014-2016)	18.6 (White 2013)
Adult Dental Care (percent with dental visit in past year)	2006-2014 (unless noted)	--	--	--	--	--	66.4 (AN)	56.3 (AN)	63.7 (AN)	58.7 (AN) 56.5 (AN 2014) 65.5 (White 2014)	65.3 (White 2014)

Table K3.10-1: Social Determinants of Health

Determinant	Data Period	Iliamna Lake/Lake Clark Commun-ities	Nushagak/ Bristol Bay Commun-ities	Lake and Peninsula Borough	Dilingham Census Area	Bristol Bay Borough	Bristol Bay Region	Kenai Peninsula Region	Anchorage /Mat-Su Region	Alaska	National
Adult Tooth Loss (percent with 1 or more teeth removed due to tooth decay or gum disease)	2006-2014 (unless noted)	--	--	--	--	--	58.6 (AN)	59.1 (AN)	51.9 (AN)	59.5 (AN) 60.5 (AN 2014) 37.7 (White 2014)	43.4 (all races; 2014)
Adult Mental Health (average days poor mental health per 30 days)	2010-2014 (unless noted)	--	--	2.2 (all races; 2011-2015)	2.8 (all races; 2011-2015)	2.6 (all races; 2011-2015)	3.2 (AN)	4.7 (AN)	4.6 (AN)	3.6 (AN) 3.0 (White) 3.2 (all races; 2011-2015)	3.4 (all races; 2005-2009)
Adult Binge Drinking (percent in past 30 days)	2010-2014 (unless noted)	--	--	16.6 (all races; 2011-2015)	14.1 (all races; 2011-2015)	24.5 (all races; 2011-2015)	14.8 (AN)	27.4 (AN)	19.7 (AN)	19.8 (AN) 19.8 (White) 18.8 (all races; 2011-2015)	17.7 (White)
Adult Alcohol Mortality (rate per 100,000 population)	2012-2015	--	--	--	--	--	49.3[c] (AN)	--	43.0 (AN)	29.8 (AN) 3.9 (non-AN)	3.0 (White)

Notes:
-- = Not Available
AN = Alaska Native
Mat-Su = Matanuska-Susitna
[a] LPB, excluding the eight Iliamna Lake/Lake Clarke Communities.
[b] Dillingham Census Area, excluding the three Nushagak/Bristol Bay Communities.
[c] Rate based on less than 20 cases/counts (may not be statistically reliable)

Iliamna Lake/Lake Clark communities include Port Alsworth, Newhalen, Kokhanok, Nondalton, Iliamna, Levelock, Iguigig, and Pedro Bay.
Nushagak/Bristol Bay communities include New Stuyahok, Koliganek, and Ekwok.
Other surrounding potentially affected communities, such as Dillingham, are represented in the information provided for the larger areas in which they reside (Dillingham Census Area, Bristol Bay Borough, and Kenai Peninsula Borough [KPB]).
The Bristol Bay Region includes the LPB, Dillingham Census Area, Bristol Bay Borough, and surrounding area. Kenai Region includes KPB and the surrounding area.
Sources: ANTHC 2016a, 2016b, 2016c, 2017b, 2017c, 2017d, 2017e, 2017f, 2017g, 2017h; McDowell Group 2018b

K3.10.1.2 HEC 2: Accidents and Injuries

Accidents and injuries include both fatal and non-fatal incidents that are primarily unintentional and affect the mortality and morbidity rates of a community. Intentional incidents include homicide and suicide (note: overlaps with and homicide 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). Table K3.10-2 presents the baseline accident and injury rates for the affected communities. Overall, in comparison to national and state rates, the levels of unintentional deaths and injuries in the potentially affected communities were higher. Suicide mortality rates for the Dillingham Census Area was similar to Anchorage and state rates, while Bristol Bay region rates were higher and the Kenai Peninsula rates were lower in comparison to the Dillingham Census Area, state and national rates.

K3.10.1.3 HEC 3: Exposure to Potentially Hazardous Materials

Environmental exposure to chemicals through the air, land, or water is also considered a health determinant. Baseline data may be qualitative in terms of proximity to known contamination sources, or quantitative through analytical data collection (e.g., water quality data, soil analytical data). Overall, baseline conditions of exposure to potentially hazardous chemicals may include the occurrence of localized poor air quality in some areas from outdoor dust or indoor air pollution, as well as elevated levels of a few naturally occurring metals in soils, surface waters, groundwater, and some food sources. Exposure to these trace elements through direct and dietary exposure pathways represents baseline hazardous exposure potential for the potentially affected communities in the EIS analysis area. Although there are numerous known contaminated sites in the EIS analysis area, these sites are under active oversight by government agencies, and agency directives are expected to control or prevent exposure to the general public. Therefore, the proximity of these sites is not expected to contribute to the baseline exposure to hazardous materials. In the EIS analysis area, background data were obtained for air and are presented and discussed in Section 3.20, Air Quality. Baseline data were collected for soil, surface water, sediment, groundwater, vegetation, and fish tissue, and are provided and discussed in their respective sections: Section 3.14, Soils; Section 3.18, Water and Sediment Quality; Section 3.26, Vegetation; and Section 3.24, Fish Values. In addition, Section 3.23, Wildlife Values, provides a description of the birds, terrestrial mammals, and marine mammals that are known and have a potential to occur in the project area, while Section 3.9, Subsistence, provides information on traditional ecological knowledge, seasonal rounds, and subsistence harvest patterns for each of the potentially affected communities evaluated for subsistence.

Table K3.10-2: Accidents and Injuries

Determinant	Data Period	Iliamna Lake/Lake Clark Commun-ities	Nushagak /Bristol Bay Commun-ities	Lake and Peninsula Borough	Dilingham Census Area	Bristol Bay Borough	Bristol Bay Region	Kenai Peninsula Region	Anchorage / Mat-Su Region	Alaska	National
Unintentional Injury Deaths (rate per 100,000 population)	2012-2015 (unless noted)	160[c] (all races; 2012-2016)	--	--[a]	180[b] (all races; 2012-2016)	140[c] (all races; 2012-2016)	151.8 (AN)	65.0[c] (AN)	101.7 (AN)	99.4 (AN) 38.9 (non-AN)	42.4 (White)
Unintentional Injury (percent of injuries)	2009-2016	--	--	92.4 (all races)	84 (all races)	--	85.5 (all races)	--	--	83.3 (all races)	--
Unintentional Injury Hospitalization (rate per 100,000 population)	2002-2011	--	--	--	--	--	134.4 (AN)	94.9 (AN)	102.4 (AN)	109.2 (AN)	--
Hospitalizations due to Falls, ranking of cause of hospitalization	2009-2016 (unless noted)	--	--	#1 Leading Cause	#1 Leading Cause	#2 Leading Cause	--	--	--	43.9 (AN; 2002-2011) #1 Leading Cause	--

Table K3.10-2: Accidents and Injuries

Determinant	Data Period	Iliamna Lake/Lake Clark Commun-ities	Nushagak /Bristol Bay Commun-ities	Lake and Peninsula Borough	Dilingham Census Area	Bristol Bay Borough	Bristol Bay Region	Kenai Peninsula Region	Anchorage / Mat-Su Region	Alaska	National
Hospitalizations due to Vehicles, ranking of cause of hospitalization	2009-2016 (unless noted)	--	--	#2 Leading Cause is Other Land Transport	#2 & #3 Leading Causes are Other Land Transport & Motor Vehicle Traffic	#1 Leading Cause is Other Land Transport	--	--	--	31.5 (AN; 2002-2011 #2 & #4 Leading Causes are Other Land Transport and Motor Vehicle Traffic	--
Suicide Mortality (age-adjusted rate per 100,000 population)	2012-2015 (unless noted)	--	--	--	40[b,c] (all races; 2012-2016)	--	58.1[c] (AN)	30.1[c] (AN)	37.0 (AN)	40.9 (AN) 17.9 (non-AN)	14.3 (White)

Notes:
-- = Not Available
AN = Alaska Native
Mat-Su = Matanuska-Susitna
[a] LPB, excluding the eight Iliamna Lake/Lake Clark Communities.
[b] Dillingham Census Area, excluding the three Nushagak/Bristol Bay Communities.
[c] Rate based on less than 20 cases/counts (may not be statistically reliable)
Iliamna Lake/Lake Clark communities include Port Alsworth, Newhalen, Kokhanok, Nondalton, Iliamna, Levelock, Iguigig, and Pedro Bay.
Nushagak/Bristol Bay communities include New Stuyahok, Koliganek, and Ekwok.
Other surrounding potentially affected communities, such as Dillingham, are represented in the information provided for the larger areas in which they reside (Dillingham Census Area, Bristol Bay Borough, and KPB)
The Bristol Bay Region includes the LPB, Dillingham Census Area, Bristol Bay Borough, and surrounding area. Kenai Region includes the KPB and surrounding area.
Sources: ANTHC 2015, 2017f, 2017i, 2017j; McDowell et al. 2011a; McDowell Group 2018b

K3.10.1.4 HEC 4: Food, Nutrition, and Subsistence Activity

The role of adequate and high-quality food and nutrition is of paramount importance to health. The cost of living is higher in Alaska than the national average, and the cost of living/food in the EIS analysis area is typically more than two times that of Anchorage (see Section 3.3, Needs and Welfare of the People – Socioeconomics). Table K3.10-3 presents the baseline nutrition, lifestyle, and poverty levels for the affected communities. In Alaska, subsistence activities greatly contribute to community nutrition and food security since they provide dietary items such as fish, game, and berries that are highly nutritious, low in cost, and also support cultural and social cohesion. A large proportion of households in the Environmental Impact Statement (EIS) analysis area participates in subsistence activities and depends on the procured wild food resources (see Section 3.9, Subsistence). Percentages of nutritional intake are typically fairly similar between LPB, Dillingham Census Area, Bristol Bay Borough, and Alaska (see Section 3.10, Health and Safety, HEC 4). Overall, LPB, Dillingham Census Area, and Bristol Bay Borough families have lower rates of those living below the poverty level threshold for Alaska Natives state-wide, and fairly similar to national whites (see Section 3.10, Health and Safety, HEC 4). Subsistence activities are the basis of many local economies and are important for nutrition and food security in the communities in the EIS analysis area as compared to the state.

K3.10.1.5 HEC 5: Infectious Diseases

The role of infectious diseases in the mortality and morbidity rates of a population is well known. Planned project activities include the creation of worker housing and camps during construction and operations, and may bring together various populations of workers under communal conditions that would be managed in accordance with the project's programs for maintenance of clean, hygienic, and sanitary operations. Reportable infectious diseases (influenza and pneumonia) were the tenth leading cause of death to all races in Alaska (ADHSS 2017a). Conditions that may promote the spread of infectious disease include unsafe water, poor personal hygiene, and unsanitary conditions. As discussed under HEC 6, the potentially affected communities in the EIS analysis area have a high rate of water and sanitation service; therefore, baseline sanitary conditions in these communities do not promote the spread of infectious disease. Other infectious diseases impact human health quality and mortality, including sexually transmitted infections, HIV, tuberculosis, septicemia, and viral hepatitis. Immunizations play an important role in decreasing the rates of some infectious diseases.

Table K3.10-4 presents the leading infectious disease rates for Alaska and regions, when available, as well as childhood immunization rates. Regional Alaska Native rates of sexually transmitted infections (as represented by chlamydia and gonorrhea) are comparable to or lower than state Alaska Native rates, while the more urban Anchorage region has rates higher than the state average (ANTHC 2017k, 2017l). However, state and regional Alaska Native sexually transmitted infections rates are two or more times the rates of non-Alaska Native state rates and three or more times the national rates for whites. Childhood immunization rates in Bristol Bay Borough are lower than state and national rates.

Table K3.10-3: Food, Nutrition, and Subsistence

Determinant	Data Period	Lake and Peninsula Borough	Dilingham Census Area	Bristol Bay Borough	Alaska	National
Adults Who Have a Subsistence Lifestyle (percent)	2009-2015	78.5 (all races)	79.5 (all races)	74.1 (all races)	30.5 (all races)	--
Adults Who Eat Less Than Five Daily Servings of Fruit and Vegetables (percent)	2007-2015	81.2 (all races)	81.0 (all races)	90.8 (all races)	78.6 (all races)	--
Adults Who Consume One or More Sugar Sweetened Beverages or Soda (percent)	2011-2015	37.7 (all races)	48.6 (all races)	25.3 (all races)	30.5 (all races)	--
Families Below the Federal Poverty Level Threshold (percent)	2012-2016 (unless otherwise noted)	15.2 (all races)	14.8 (all races)	4.3 (all races)	23.2 (2011-2015; AN)	12.1 (2011-2015; whites)
By Individual Potentially Affected Communities (percent; all races)		Kokhanok - 28.6 Nondalton - 25.0 Newhalen - 23.5 Levelock - 14.3 Iliamna - 9.1 Port Alsworth - 5.6 Igiugig - 0 Pedro Bay - 0	New Stuyahok - 28.1 Ekwok - 16.7 Koliganek - 5.7			

Notes:
-- = Not Available
AN = Alaska Native
Subsistence lifestyle and nutrition determinants are self-reported, and subsistence lifestyle was defined by the respondents.
'Sugar-sweetened beverages or soda' do not include 100% fruit juice, diet drinks, or artificially sweetened drinks.
The federal poverty threshold is updated for inflation, but does not vary geographically, and is based on pre-tax income (ANTHC 2017a).
Sources: McDowell 2018a, 2018b; ANTHC 2017a

Table K3.10-4: Infectious Diseases

Infectious Disease Indicators (Period)	Bristol Bay Region	Kenai Region	Anchorage/ Mat-Su Region	Alaska	National
Influenza and Pneumonia (mortality age-adjusted rate per 100,000 population) (2012-2015)	--	--	--	21.3 (AN) 9.9 (non-AN)	15 (White)
Tuberculosis (rate per 100,000 population) (2016)	--	--	--	37 (AN) 7.7 (all races)	2.9 (all races)
Chlamydia Cases (age-adjusted rate per 100,000 population) (2015)	1,728.3 (AN)	873.8 (AN)	2,504.4 (AN)	1,653.8 (AN) 452.3 (non-AN)	187.2 (White)
Gonorrhea Cases (age-adjusted rate per 100,000 population) (2015)	169.4* (AN)	184.5* (AN)	792.2 (AN)	436.7 (AN) 70.6 (non-AN)	44.2 (White)
Immunization Rate for Alaskan Children (percent) (2015, unless noted)	40.0 Bristol Bay Borough (all races; 2016)	--	--	75.1 (AN) 66.3% (all races)	72.7 (White)

Notes:
-- = Not Available
* = rate based on less than 20 cases/counts (may not be statistically reliable)
AN = Alaska Native
Mat-Su = Matanuska-Susitna
The Bristol Bay Region includes the LPB, the Dillingham Census Area, Bristol Bay Borough, and surrounding area. Kenai Region includes KPB and surrounding area.
Sources: ANTHC 2017a, 2017k, 2017l, 2017m; ADHSS 2017b, 2018; McDowell Group 2018b

Some regional rates (mortality from influenza and pneumonia, and tuberculosis rates, as well as immunization rates in the Kenai and Anchorage regions) are not readily available. However, deaths from infectious disease were not rated among the top three leading causes of deaths reported for the Bristol Bay, Kenai, or Anchorage regions (ADHSS 2017a; McDowell 2018b). Therefore, the lack of regional infectious disease rates might be due to the low state rates (ADHSS 2017a; ANTHC 2017i), privacy concerns, and/or tracking or reporting methodology.

K3.10.1.6 HEC 6: Water and Sanitation

The lack of safe water supply (i.e., running water) and suitable sewage disposal can represent a major public health and community development problem. The project would develop, operate, and maintain its own water supply and water treatment facilities. Lack of in-home water and sewer service may cause severe skin infections and respiratory illnesses. Prior to 2004, a large portion of rural Alaska communities were classified as “unserved Rural Alaska Communities,” which is defined as a community having 45 percent or more homes that are not served by central wells, and have a mix of central sewage plumbing, septic systems, honey buckets, and outhouses.

In 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 (which includes Bristol Bay Borough, Dillingham Census Area, and LPB), 99 percent of households had water and sewer services. In the Kenai Peninsula, service was 100 percent (ANTHC 2017n). However, as discussed in Section 3.3, Needs and Welfare of the People–Socioeconomics, for rural communities that have water and sanitary service systems, operating and maintaining the systems are challenged by the high cost of energy, lower populations to support higher than average maintenance costs, and a shortage of experienced maintenance operators (ASCE 2018). For further details on water, sewer, and solid waste; see Section 3.3, Needs and Welfare of the People–Socioeconomics.

K3.10.1.7 HEC 7: Non-Communicable and Chronic Diseases

Non-communicable and chronic diseases consume a large part of healthcare resources and affect the overall health status of a population. The incidence of such disease is typically associated with multiple contributing factors including genetics, lifestyle and socioeconomic status, and trends, which may be relatively slow to show increases or decreases. In the context of evaluating an individual project, it may be difficult to attribute a single project-related cause to changes in disease incidence. However, community-wide changes, such as increases in employment rates and economic security or access to healthcare, may result in improved health outcomes related to chronic diseases. Therefore, understanding baseline rates of non-communicable and chronic diseases helps to inform a better understanding of overall community health status although the impacts related to a single project may not be easily defined.

Similar to state-wide trends, the three recent leading causes of death due to non-communicable and chronic diseases for the potentially affected communities were cancer and heart disease (at community, borough/census area, and regional levels), as well as chronic obstructive pulmonary disease, including chronic lower respiratory disease, at regional level (ADHSS 2017a; ANTHC 2017a, 2017i; McDowell 2018a, 2018b). Table K3.10-5 presents the recent average age-adjusted non-communicable and chronic disease mortality (i.e., death) rates for the three leading regional causes, as well as percentage of Medicare recipients with Alzheimer's disease/dementia, and several chronic disease contributing factors.

Heart disease rates (per 100,000 individuals) in the Iliamna Lake/Lake Clark communities and Nushagak/Bristol Bay communities are higher than Anchorage and state rates (McDowell 2018b; ADHSS 2017a; ANTHC 2017a, 2017i, 2017p). Cancer death rates (per 100,000 individuals) in the Iliamna Lake/Lake Clark communities are higher than Nushagak/Bristol Bay communities, as well as Anchorage and state rates, which were all fairly similar (McDowell 2018b; ADHSS 2017a; ANTHC 2017a, 2017i, 2017o). While Kenai Peninsula and Anchorage regions have chronic obstructive pulmonary disease rates lower than state levels, the Bristol Bay region has much higher rates than the state (ANTHC 2017a, 2017q).

Table K3.10-5: Non-Communicable and Chronic Diseases

Disease Type and Metric	Date Period	Iliamna Lake/ Lake Clark Commun-ities	Nushagak/ Bristol Bay Commun-ities	Lake and Peninsula Borough	Dilingham Census Area	Bristol Bay Borough	Bristol Bay Region	Kenai Peninsula Region	Anchorage/Mat-Su Region	Alaska	National
Cancer Deaths (age-adjusted rate per 100,000 population)	2012-2015	320 [c,e] (all races; 2012-2016)	230 [c,e] (all races; 2012-2016)	340[a,e] (all races; 2012-2016) 229.3[a] (all races; 2005-2014)	160[b,e] (all races; 2012-2016) 196.4[a] (all races; 2005-2014)	140 [c,e] (all races; 2012-2016) 273.7[a] (all races; 2005-2014)	232.4 (AN)	203.1 (AN)	259.2 (AN)	242.7 (AN) 154.5 (non-AN) 175.7 (all races; 2005-2014)	164 (White)
Heart Disease Deaths (age-adjusted rate per 100,000 population)	2012-2015 (unless noted)	280[c] (all races; 2012-2016)	330[c] (all races; 2012-2016)	410[a] (all races; 2012-2016)	190[b] (all races; 2012-2016)	140 [c] (all races; 2012-2016)	262.6 (AN)	264.3 (AN)	226.1 (AN)	208.2 (AN) 133.3 (non-AN)	167.7 (White)
Chronic Obstructive Pulmonary Disease Deaths (age-adjusted rate per 100,000 population)	2012-2015	--	--	--	--	--	91.3 [c] (AN)	56.3 [c] (AN)	61.2 (AN)	68.0 (AN) 35.2 (non-AN)	44.0 (White)
Alzheimer's Disease/Dementia (percent of Medicare Beneficiaries)	2015	--	--	--	8.2	5.6	--	--	--	7.1	--

Table K3.10-5: Non-Communicable and Chronic Diseases

Disease Type and Metric	Date Period	Iliamna Lake/ Lake Clark Commun-ities	Nushagak/ Bristol Bay Commun-ities	Lake and Peninsula Borough	Dilingham Census Area	Bristol Bay Borough	Bristol Bay Region	Kenai Peninsula Region	Anchorage/Mat-Su Region	Alaska	National
Chronic Disease Contributing Factors											
Adult Overweight (percent with a BMI of 25 to 29.9)	2010-2014 (unless noted)	--	--	70.0 (all races; 2011-2015)	71.3 (all races; 2011-2015)	84.7 (all races; 2011-2015)	38.6 (AN)	37.8 (AN)	35.0 (AN)	34.9 (AN)[d] 38.2 (White)[d]	35.9 (White)
Adult Obesity (percent with a BMI of 30 or more)	2010-2014 (unless noted)	--	--				35.1 (AN)	36.3 (AN)	37.4 (AN)	35.2 (AN)[d] 26.9 (White)[d]	26.4 (White)
Adult Physical Activity (percent who meet recommended weekly activity)	2011-2013	--	--	--	--	--	36.9 (AN)	11.3 (AN)	17.5 (AN)	18.5-18.7 (AN) 24.6-26.4 (White)	20.4-20.9 (all races)
Adults Who Believe Get Enough Physical Activity (percent)	2011-2015	--	--	74.3 (all races)	57.2 (all races)	73.2 (all races)	--	--	--	52.0 (all races)	--
Adult Current Smoking (percent who have had100+ cigarettes and currently smoke)	2010-2014 (unless noted)	--	--	29.1 (all races; 2011-2015)	34.8 (all races; 2011-2015)	27.8 (all races; 2011-2015)	45.3 (AN)	33.9 (AN)	31.1 (AN)	36.4 (AN) 18.3 (White) 20.5 (all races; 2011-2016)	19.0 (White)

Table K3.10-5: Non-Communicable and Chronic Diseases

Disease Type and Metric	Date Period	Iliamna Lake/ Lake Clark Commun-ities	Nushagak/ Bristol Bay Commun-ities	Lake and Peninsula Borough	Dilingham Census Area	Bristol Bay Borough	Bristol Bay Region	Kenai Peninsula Region	Anchorage/Mat-Su Region	Alaska	National
Adult Formerly Smoked (percent who had 100+ cigarettes)	2011-2015	--	--	28.3 (all races)	25.9 (all races)	30.1 (all races)	--	--	--	27.5 (all races)	
Adult Current Smokeless Tobacco Use (percent currently use smokeless tobacco product)	2010-2014	--	--	--	--	--	15.0 (AN)	14.8 (AN)	6.7 (AN)	12.8 (AN) 3.8 (White)	3.4 (2014, all races)
Adult Ever Used Chewing Tobacco (percent)	2011-2015	--	--	29.5 (all races)	30.5 (all races)	35.5 (all races)	--	--	--	21.0 (all races)	--

Notes:
-- = Not Available
AN = Alaska Native
Mat-Su = Matanuska-Susitna
[a] LPB, excluding the eight Iliamna Lake/Lake Clark Communities.
[b] Dillingham Census Area, excluding the three Nushagak/Bristol Bay Communities.
[c] Rate based on less than 20 cases/counts (may not be statistically reliable)
[d] Alaska-wide and all races, 66.1 percent of adults are overweight/obese (2011-2015).
[e] Malignant neoplasms (cancerous tumors).
Iliamna Lake/Lake Clark communities include Port Alsworth, Newhalen, Kokhanok, Nondalton, Iliamna, Levelock, Iguigig, and Pedro Bay.
Nushagak/Bristol Bay communities include New Stuyahok, Koliganek, and Ekwok.
Other surrounding potentially affected communities, such as Dillingham, are represented in the information provided for the larger area in which they reside (Dillingham Census Area, Bristol Bay Borough, and KPB)
The Bristol Bay Region includes the LPB, the Dillingham Census Area, Bristol Bay Borough, and surrounding area. Kenai Region includes Kenai Borough and surrounding area.
Recommended physical activity defined as 150 minutes of moderate-intensity activity or 75 minutes vigorous-intensity activity, or an equivalent combination, each week per Center for Disease Control's 2008 Physical Activity Guidelines for Americans.
Sources: ANTHC 2017o, 2017p, 2017q, 2017r, 2017s, 2017t, 2017u, 2017v; CDC 2016; McDowell 2018a, 2018b

Cancer was one of the top two causes of death in the LPB, while cancer and heart disease were the top two causes of death in the Dillingham Census Area. The three types of cancer with the highest incidence were colon/rectum (17.9 percent), lung (17.2 percent), and breast (15.1 percent) (ANTHC 2017a, 2017o). The highest rate (per 100,000 individuals) of cancer incidence is colorectal cancer in the LPB (107.7) and Dillingham Census Area (107.7), while the highest rate of cancer incidence is breast cancer in Bristol Bay Borough (213.7) (McDowell 2018b). Colorectal cancer and lung and bronchus cancer had the highest cancer mortality rates per 100,000 individuals in the LPB (107.7 and 48.5, respectively), and the Dillingham Census Area (73.9 and 38.2, respectively). Most of these cancer incidence and mortality rates appear higher than those reported for Alaska overall, with a colorectal cancer incidence rate of 43.1, female breast cancer incidence rate of 125.6, and colorectal cancer mortality rate of 43.1; but Alaska's lung and bronchus cancer mortality rate (59.9) is higher (McDowell 2018b; ADHSS 2017a; ANTHC 2017a, 2017i, 2017o).

Chronic disease contributing factors include but are not limited to weight, physical activity, smoking, and tobacco use. In general, the LPB and Dillingham Census Area have fairly similar rates of adults who are overweight and obese (i.e., a Body Mass Index above 25) compared to the state, while Bristol Bay rates were higher in comparison. The LPB and Bristol Bay Borough self-report much higher percentages of believing they get enough physical activity compared to Alaska overall, while the Dillingham Census Area self-reports rates only slightly above Alaska overall (McDowell 2018b). In general, smoking and tobacco use rates of current smokers, and adults who have used chewing tobacco, are higher in LPB, the Dillingham Census Area, and Bristol Bay Borough in comparison to state levels.

K3.10.1.8 HEC 8: Health Services Infrastructure and Capacity

An important measure of the health-related resilience and support structure of a community is the quality and quantity of healthcare that is available to the residents. In the context of evaluating project impacts to health, the capacity of existing healthcare services to accommodate baseline health care needs as well as the healthcare needs of populations that may migrate in or emergency incidents that may occur during project activities may be of concern. For example, if a project is located in an area that is already underserved with regard to healthcare services, the addition of more workers who may need to use the services may further strain an already over-loaded system. In many cases, project proponents may commit to operating their own healthcare facilities to serve their employees, thus avoiding any demands on the local systems.

Health Services. The LPB and Bristol Bay Borough report lower or similar access to health plans, medical care, and a personal doctor compared to Alaska overall, but higher medical costs. The Dillingham Census Area reports lower or similar access to medical care, access to a doctor, and medical cost, but reports higher access to health plans than seen in Alaska overall (McDowell et al. 2011a, 2018b).

These health services findings are summarized on a more regional basis in Section 3.3, Needs and Welfare of the People–Socioeconomics. Healthcare services generally include small local clinics operated by regional providers. Access to the region and most of its communities is limited to small aircraft and boat.

Relatively up-to-date and complete information on baseline health services infrastructure and capacity is available for the eight Iliamna Lake/Lake Clark communities in the LPB and the three Nushagak/Bristol Bay communities in the Dillingham Census Area, for LPB, Dillingham Census Area, and Bristol Bay Borough (McDowell Group 2018b).

Hospitalizations. Hospitals in the area serve a variety of adult and pediatric needs for the surrounding communities. In 2015, the statewide leading causes of diagnosed hospitalizations were pregnancy/childbirth, respiratory diseases, and digestive system diseases (ANTHC 2016d). The following summarizes the leading causes of hospitalizations in 2016 (ADHSS 2017c) and 2017 (McDowell Group 2018b):

- Statewide – Pregnancy/childbirth, newborn/neonate conditions, and musculoskeletal/ connective tissue diseases in 2016. Childbirth, septicemia (except in labor), and osteoarthritis in 2017.
- Southwest Region (includes LPB, the Dillingham Census Area, and Bristol Bay Borough) – Pregnancy/childbirth, newborn/neonate conditions, and respiratory diseases in 2016.
  - LPB – Childbirth and other complications of birth, including postpartum care of mother in 2017.
  - Dillingham Census Area – Childbirth, septicemia (except in labor), pneumonia (except that caused by tuberculosis or sexually transmitted diseases), and alcohol-related disorders in 2017.
  - Bristol Bay Borough – Childbirth and alcohol-related disorders in 2017.
- Gulf Coast Region (includes Kenai Peninsula) – Musculoskeletal/connective tissue diseases/disorders, pregnancy/childbirth, and newborn/neonate conditions in 2016.
- Anchorage – Pregnancy/childbirth, newborn/neonate conditions, and musculoskeletal/ connective tissue diseases/disorders in 2016.

Although there are some variations in the top three leading causes of hospitalizations by year and region, pregnancy/childbirth and newborn/neonate and/or complications of pregnancy and childbirth or newborn/neonate conditions are consistently the leading causes.

Adequacy of Health Services. Areas may be designated as having health impact issues for the adequacy of the health services, designated as Health Professional Shortage Area (HPSA) and/or a Medically Underserved Area/Population (MUA/P). HPSA designation may be due to a shortage of primary medical care, dental, or mental health providers, while MUA/P designation may include groups of persons who face economic, cultural, or linguistic barriers to healthcare (HRSA 2018). The LPB (with the eight communities closest to the project), the Dillingham Census Area (with the three other communities geographically close to the project), Bristol Bay Borough, Kenai Peninsula, and Anchorage are all designated as MUA/P (Dillingham Census Area and Kenai Peninsula Borough are designated MUA/P – governor's exception). Table K3.10-6 presents the HPSA ratings (out of 26) for these regions. The rating is used to establish the communities with the greater needs per shortage area, indicated by those communities with higher HPSA ratings.

It should be noted that these designations are most directly comparable when the populations are similar; otherwise, a relatively low population area such as the LPB may appear to have less "need" than a densely populated area, when the difference may be more due to the population disparity than the actual "need." Furthermore, comparing a community to a larger region or state would not be meaningful since the region or state value represents a sum total that includes the communities.

Table K3.10-6: Health Professional Shortage Area Ratings

Shortage Area	Lake and Peninsula Borough	Bristol Bay Borough	Dillingham Cenus Area	Kenai Peninsula Borough	Anchorage Borough
Primary Care	--	15-17	13-17	8-18	3-21
Dental Care	16	0-16	16-20	6-23	6-20
Mental Health	14	14-16	14-20	15-21	6-20

Notes:
-- = Not listed.
Source: HRSA 2018

K3.13 GEOLOGY

This appendix contains supplemental information on the affected environment for the following topic(s) related to:

- Geology-related field and desktop studies.
- Paleontological resources.

K3.13.1 Geology-Related Field and Desktop Studies

The geology-related findings presented in Section 3.13 and Section 4.13, Geology, were based on the review of field and office studies completed in the project area, including the following:

- Relevant existing literature and studies completed by the Applicant and others, including published geological reports and maps prepared by the US Geological Survey (USGS), Alaska Division of Geological and Geophysical Surveys and others (Knight Piésold 2011a, 2011d; Detterman and Reed 1973, 1980; Hamilton and Klieforth 2010; Nokleberg et al. 1994; Plafker et al. 1994; Wilson et al. 2012).
- Evaluation and interpretation of aerial photographs taken from aircraft, which can provide a good understanding of the surficial geological conditions (Knight Piésold 2011a, 2011d).
- Field reconnaissance studies, including helicopter and on-the-ground geologic mapping to verify the aerial photograph–related findings (Knight Piésold 2011a, 2011d).
- Offshore drill holes and bathymetry (depth of water) surveys to support the ferry transportation corridors and natural gas pipeline alternative–related studies (Knight Piésold 2011a, 2011d; GeoEngineers 2018a).
- In the mine study area:
  - More than 700 drill holes were completed in the mine study area using helicopter-portable drilling equipment (Section 3.13, Geology, Figure 3.15-3). About 500 of the drill holes were completed to understand the mineralogy, and the remaining drill holes supported civil engineering-related studies. Rock and soil samples were collected for detailed evaluation during and after the field work (Knight Piésold 2011a, 2011d, 2018 [borehole Geographical Information System location data and borehole log information received, report in progress by Knight Piésold]).
  - Excavation of more than 300 test pits in the mine study area that ranged in depth between about 1.5 to 3 meters, and were completed by a helicopter-portable excavation apparatus (Knight Piésold 2011a, 2011d).
  - Ground-based (versus from aircraft) geophysical surveys were completed with helicopter- and boat-portable instruments in the mine study and project area to understand the physical characteristics of the mineralized bedrock and near-shore sediments. These studies were non-invasive (did not include drilling or excavations), and relied on electronic sensors to map the geology. The geophysical studies included seismic reflection, infrared imagery, and induced polarization (Knight Piésold 2011a, 2011d).

K3.13.2 Paleontological Resources

K3.13.3 Alternative 1 – Applicant's Proposed Alternative

K3.13.3.1 Mine Site

Cretaceous age Kahiltna flysch sedimentary units are largely derived from eroded volcanic rocks, and are not likely to contain fossils. Other volcanic and intrusive igneous rocks in the mine site area are not suitable lithologies for fossil formation and preservation. Quaternary age glacial sediments at the mine site are unlikely to host fossils, and without measurable permafrost, significant findings of frozen Pleistocene age megafauna are not likely (Blodgett and Zhang 2018; Arctos 2018).

K3.13.3.2 Transportation Corridor

As with the mine site, the intrusive igneous and volcanic bedrock that spans most of the mine access transportation corridor is not an amenable lithology for fossil formation and preservation. Pleistocene age glacial sediments along the transportation corridor are unlikely to host fossils, and without the preserving effects of measurable permafrost, significant findings of Pleistocene age megafauna are not likely (Blodgett and Zhang 2018; Arctos 2018).

There are known paleontological resource sites at the southern terminus of the transportation corridor, where the road meets the port. Quaternary age beach deposits present in the area are locally fossiliferous, originating from erosion of nearby Jurassic age marine sedimentary rock (see Amakdedori port section below); therefore, fossils are likely present in that area (Detterman and Reed 1973). About 20 acres of the transportation corridor footprint is on Quaternary age beach deposits that could contain significant fossil resources. Additionally, the transportation corridor comes within 800 feet of the Talkeetna and Naknek formations, which have produced significant vertebrate paleontological resources (Wilson et al. 2012).

K3.13.3.3 Amakdedori Port

Jurassic age marine sedimentary rocks around the port site are host to numerous diverse marine invertebrate fossils. Fossil ammonites, brachiopods, cephalopods, and pelecypods are abundant in the Naknek and Talkeetna Formation members exposed in the bluff directly northeast of the port facility (Blodgett and Zhang 2018; Detterman and Reed 1973, 1980; Wilson et al. 2012). Cephalopod fossils eroded from nearby Jurassic age sedimentary rock have been found in the same beach deposits in the port facility footprint (Arctos 2018). Although these are common fossils, they are considered significant as sources of new data concerning Jurassic period evolutionary trends, species survival beyond Triassic period extinctions, and the global and regional development of Jurassic age marine biological communities (Sandy and Blodgett 2000). The Naknek Formation at other sites in the region contains vertebrate fossils from the Jurassic marine reptile *Megalneusaurus*, which represents the only find of this species in Alaska, and one of only two occurrences of this genus in North America (Blodgett et al. 1995; Weems and Blodgett 1996). Terrestrial vertebrate trackways have also been discovered in the Naknek Formation at other locales in the region (Blodgett et al. 1995). These findings demonstrate a potential for paleontological resources in the Amakdedori port footprint.

K3.13.4 Natural Gas Pipeline Corridor

The paleontological environment of the natural gas pipeline corridor is the same as that discussed above for the transportation corridor. Quaternary age sediments along both sides of Cook Inlet are unlikely to contain fossils, and without the preserving effect of measurable permafrost, significant findings of Pleistocene age megafauna are not likely (Blodgett and Zhang 2018; Arctos 2018). In the offshore section of corridor, the shallow floor of Cook Inlet is filled with abundant sand, pebbles, cobbles, and boulders flushed into the inlet from young glacial deposits across the region; no fossil resources would be expected.

K3.13.4.1 Alternative 1 – Summer-Only Ferry Operations Variant

The paleontological environment for this variant is the same as for Alternative 1.

K3.13.4.2 Kokhanok East Ferry Terminal Variant

The paleontological environment for Alternative 1 scenarios are considered to be comparable to the proposed alternative based on the presence of similar substrate conditions; however, Jurassic, Triassic, and possibly older complex assemblages of metamorphosed volcanic and sedimentary rock associated with the Kokhanok Complex coincide with the Kokhanok east ferry terminal variant footprint. Based on the reported mix of lithologies of variable metamorphic grade, the presence or preservation of fossils in this discrete lithologic occurrence at the Kokhanok port site is considered low to unlikely.

K3.13.4.3 Alternative 1 – Pile-Supported Dock Variant

The paleontological environment for this variant is the same as for Alternative 1.

K3.13.4.4 Alternative 2 (North Road and Ferry and Downstream Dams and Alternative 3 (North Road Only)

The Diamond Point port footprint would be on volcanic and intrusive igneous bedrock. The north access road and/or pipeline segments of Alternative 2 and Alternative 3 (including the concentrate pipeline variant) is contiguously mapped as volcanic and intrusive igneous bedrock with interspersed segments, including Quaternary age glacial sediments (Wilson et al. 2015). Igneous substrates are not considered amenable for fossil preservation and formation. Similar to all other alternatives, interspersed Quaternary age glacial sediments are considered unlikely to host fossils.

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.

K3.15 GEOHAZARDS

This appendix contains additional technical information on the following topics related to the affected environment for geohazards described in Section 3.15, Geohazards:

- Liquefaction processes and depth
- Baseline geotechnical data coverage at the mine site

K3.15.1 Liquefaction

Liquefaction occurs when a saturated or partially saturated soil substantially loses strength and stiffness in response to an applied stress, such as earthquake shaking, which causes it to behave like a liquid. When a soil is saturated by water, which often exists below the groundwater table, the water fills gaps between soil grains (i.e., pore spaces). In response to the soil compressing, this water increases in pressure and is forced to flow out of the soil to zones of low pressure, usually up to the ground surface. However, if the loading is rapidly applied and large enough, or is repeated many times (e.g., earthquake shaking), the water cannot flow out in time before the next cycle of load is applied, and the water pressure could build up and exceed the forces (contact stresses) between the grains of soil that keep them in contact with one another. These contacts between grains are the means by which weight from structures and overlying soil layers are transferred from the ground to deeper soil or rock. This loss of soil structure causes the soil to lose its strength, and triggers liquefaction.

The depth to which liquefaction can occur has implications for the behavior of saturated tailings in an earthquake (see Section 4.15, Geohazards). Knowledge on the maximum depth of liquefaction has evolved in recent years because of large global earthquakes and resultant liquefaction (Bray 2013; Stewart and Knox 1995; Tchakalova 2018; WSDOT 2013). The Washington State Department of Transportation Geotechnical Design Manual M 46-03.09 limits the depth for considering liquefaction to 80 feet, but suggests that analyses be performed to determine liquefaction probability if loose materials are below 80 feet. Stewart and Knox (1995) conclude it is possible for excessive porewater pressures to exist considerably below 100 feet, that are sufficient to overcome the stiffness created by overburden pressures and exceed the thickness for liquefaction, and that great earthquakes can generate stresses of sufficient intensity and duration to produce liquefaction conditions in unconsolidated sediments below 1,000 feet. Tchakalova (2018) adds that the maximum depth at which liquefaction can occur is probably the same as the maximum depth at which sands and silts can remain unconsolidated, and maintain a sufficient porosity and hydraulic conductivity, and that whatever those depths, earthquakes of M8.0 or greater can produce stresses in the hypocenter and epicenter zones sufficient to overcome overburden pressures below 1,000 feet.

K3.15.2 Baseline Geotechnical Data Coverage

Table K3.15-1 lists the approximate number of geotechnical drillholes, test pits, and seismic lines collected in and near the footprint of different facilities at the mine site. A summary of overburden deposits and bedrock encountered in each area is provided in Section 3.15, Geohazards.

Table K3.15-1: Baseline Geotechnical Data Coverage at Mine Site

Area	Facilities	Number of Drill Holes[1]	Number of Test Pits[1]	Number of Seismic Lines
NFK-West	Bulk TSF main embankment, impoundment, and quarries	39	37	9
NFK-East	Pyritic TSF and associated SCPs	14	38	9
NFK-North	Main WMP, bulk TSF main embankment SCP, emergency dump pond	29	13	0
Pit Area	Open pit and rim	31	30	6
Bulk TSF South	Bulk TSF South embankment, and associated SCP and sediment pond	11	10	2
South of Pit Area	Open pit WMP, pit overburden stockpile, and associated sediment ponds	7	20	3

Notes:
[1] Numbers are approximate as there may be overlap between adjacent areas.
NFK = North Fork Koktuli
SCP = seepage collection pond
TSF = tailings storage facility
WMP = water management pond
Source: Knight Piésold 2011c; PLP 2013a; PLP 2018-RFI 014