3.24 FISH VALUES

Fish values are described in the Environmental Impact Statement (EIS) analysis area in terms of aquatic habitat, fish distribution, and aquatic invertebrates, as applicable, for each project component or variant under each alternative. The results of tissue analyses for trace elements in fish collected at the mine site and Amakdedori port location are included.

3.24.1 EIS Analysis Area

The EIS analysis area includes watersheds and downgradient aquatic habitats that could be affected by project activities, from streams to marine waters.

The analysis area for the mine site under all alternatives and variants includes portions of the North Fork Koktuli (NFK), South Fork Koktuli (SFK), and Upper Talarik Creek (UTC) watersheds. This area includes all aquatic habitats potentially directly or indirectly affected by permitted mine site activities (Figure 3.24-1). The geographic extent of the analysis area is driven by the modeled 2 percent reduction in suitable habitat in the NFK and SFK drainages (see Appendix K4.24 for fish habitat modeling methodology and results).

The analysis area for the port and transportation and natural gas pipeline corridors includes all aquatic habitats within 0.25 mile of project infrastructure, where potential effects would potentially occur from construction and operations under all alternatives and variants.

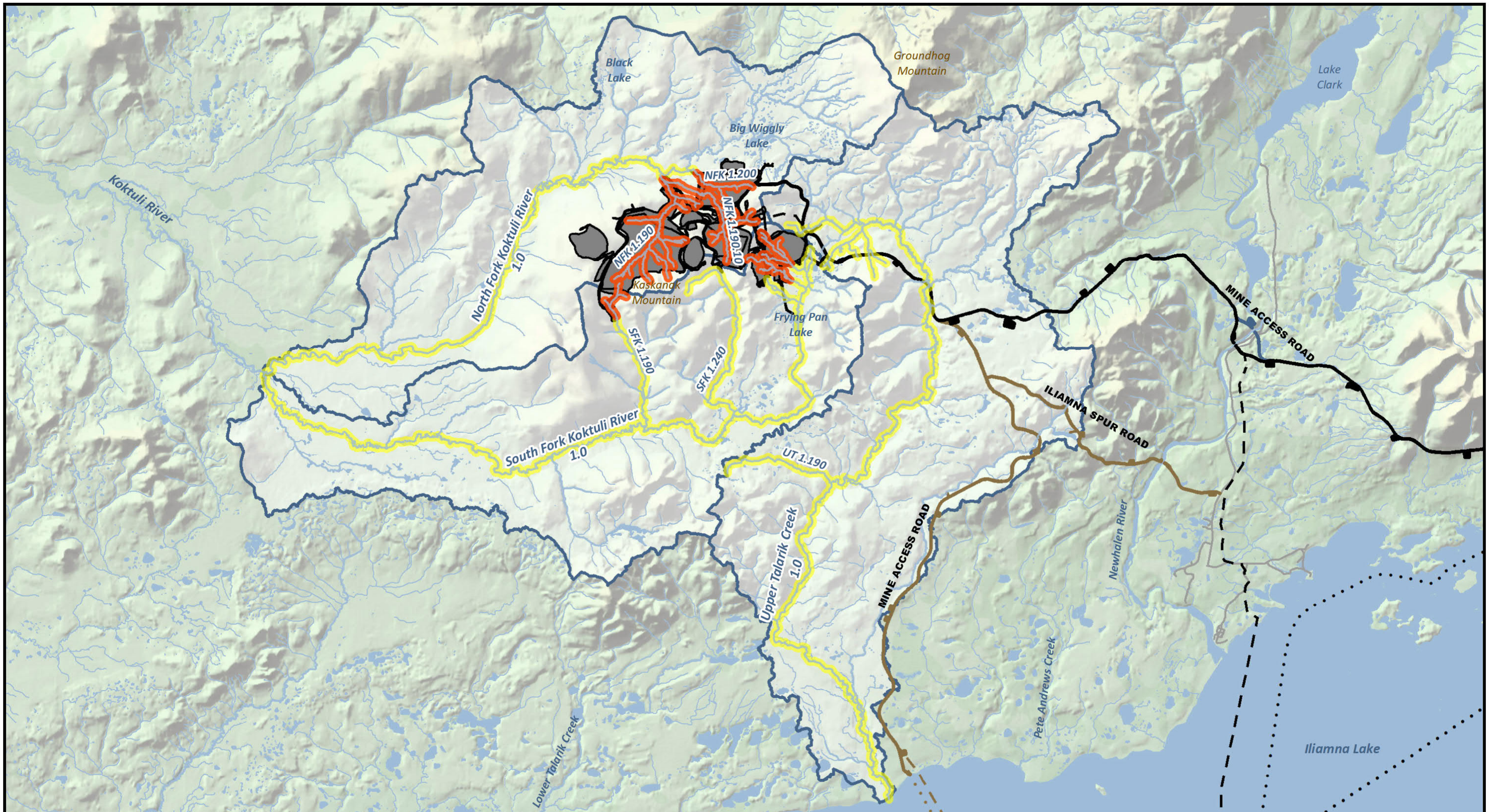
Throughout this section, the reported data on habitat and fish population characteristics are sometimes presented using imperial units, and at other times in metric units, depending on the original source of information.

3.24.2 Habitat Function and Value

Fresh and marine waters in the analysis area provide numerous ecosystem functions and values, including support for a wide array of anadromous and resident fish, aquatic invertebrates, birds, and mammals. Habitat characterizations for aquatic resources are provided in baseline reports (ABR 2011a; R2 et al. 2011a) and include detailed information on the baseline survey methodology, including the identification and characterization of aquatic habitats. Freshwater and marine waterbodies also provide values associated with subsistence, recreation, commercial and sport fishing, hunting, and navigation; and retention or drainage of flood flows. Iliamna Lake is a protected water use area.

3.24.2.1 Stream Habitats

Functions and values of stream and river habitats vary greatly in the analysis area depending on hydrologic regimes, bed and bank structure, floodplain interactions, and other fluvial processes. The watersheds are relatively undisturbed; floodplain processes, sediment and woody debris dynamics, and surface and groundwater exchanges have resulted in a large diversity of aquatic and riparian habitats in the analysis area. This habitat diversity is responsible for the corresponding large population and genetic diversity of salmonids in the wider Bristol Bay basin (Rinella et al. 2009). This large population and genetic diversity has been recognized as contributing to the high productivity and stability of these systems for salmonids (Schindler et al. 2010). Recent genetic analysis has revealed sockeye salmon spawning in the Koktuli River are considered a separate population in the Alaska Department of Fish and Game (ADF&G) genetic baseline, and are one of four genetically similar but distinct populations of river-type Sockeye salmon in the Nushagak River basin (Shedd et al. 2016; Dann et al 2012).



Sources: PLP 2019-RFI153; HDR 2012

US Army Corps of Engineers

2 0 2 4

Miles

Mine Site Analysis Area

- Direct Impacts
- Indirect Impacts
- Water Basin

Action Alternatives

- Ferry Routes
- Natural Gas Pipelines
- Alternative 1a
- Alternative 1
- Alternative 2 Newhalen River North Crossing Variant

MINE SITE ANALYSIS AREA IN THE NORTH FORK KOKTULI, SOUTH FORK KOKTULI, AND UPPER TALARIK BASINS

PEBBLE PROJECT EIS

FIGURE 3.24-1

Streams in the analysis area support five species of anadromous Pacific salmon, at least four species of non-anadromous salmonids, and numerous non-salmonid fishes (R2 et al. 2011a). Streams provide migration, spawning, rearing, and overwintering habitats for fish and invertebrate species. Streams maintain characteristic riparian plant communities and export organic matter to support aquatic food chains. Riparian trees and shrubs provide shade to regulate stream temperatures and contribute large and small woody debris, which are important for channel-forming processes and creation of fish habitat. Aquatic and riparian habitats also have high value for numerous bird and mammal species, including beaver, which create highly used off-channel habitat. Streams also facilitate enrichment of riparian and terrestrial ecosystems with marine-derived nitrogen and other nutrients through the return of spawning salmon. Stream systems in the analysis area also convey and attenuate flood waters, maintain and purify surface waters, moderate groundwater flows, and recharge groundwater systems.

Mine site facilities would occur in the headwaters of the NFK, SFK, and UTC subbasins. Headwater habitats represent one end of a continuum of available stream habitats (Vannote et al. 1980), with large mainstem channels representing the other end. Headwater habitats serve many important functions related to the overall health of each subbasin (EPA 2014). Headwaters can provide spawning and rearing habitats for anadromous and resident fish, and contribute spawning gravels, invertebrate drift, organic nutrients, cool surface flows, groundwater accretion, and woody debris to downstream (mainstem) channels. In many basins, headwaters support high densities of fish, and provide refuge from predators, flood flows, or anthropomorphic impacts. However, many headwater streams in the mine site area have gradients greater than 3 percent, which are generally less productive for anadromous salmonids than lower-gradient reaches (EPA 2014).

3.24.2.2 Lake Habitats

Freshwater lentic habitat in the analysis area ranges from very small ponds to large lakes (approximately 150 acres) and Iliamna Lake (1,000 square miles). The majority of waterbodies of this type in the analysis area are less than 2.5 acres in size (ABR 2011a); however, there is a great variety in depth and hydrologic regime, shoreline complexity, and connectivity to drainages, all of which influence functions and values. Some of the larger lakes provide spawning habitat for sockeye salmon. In addition to fish values, these habitats have been identified as having relatively high species richness for bird and mammal species, including bird species of conservation concern (ABR 2011a), the presence of which is a characteristic of regionally important wetlands (see Section 3.22, Wetlands and Other Waters/Special Aquatic Sites). Water impounded by lakes and ponds is also important for maintaining summer flows and downstream aquatic habitat (R2 Resource Consultants et al. 2011).

3.24.2.3 Marine Habitats

Marine and estuarine waters in Cook Inlet also provide important habitat for fish and benthic invertebrates, as well as numerous birds and marine mammals (see Section 3.23, Wildlife Values; and Section 3.25, Threatened and Endangered Species, for details on birds and marine mammals in the analysis area, respectively). Intertidal waters represent approximately 9 percent of marine waters in the analysis area. Nearshore and estuarine habitats have been investigated in the analysis area, including Amakdedori Beach for Alternative 1a and Alternative 1, and in Iliamna Bay and Cottonwood Bay for Alternative 2 and Alternative 3 (Pentec Environmental/Hart Crowser 2011a, b). Several habitat types, including mudflats, were identified, which provide resources for varying life-stages of numerous fish, including Pacific salmon, nearshore marine species, and several benthic invertebrates. Nearshore habitats are used as rearing areas, migration corridors, spawning areas, and places of refuge from deepwater predators. Essential services of estuaries include provision of food, habitat complexity, buffering from extreme forces of open waters, filtration, sediment trapping, and refuge from predation, which make them prime rearing or “nursery” habitats for numerous species of juvenile fish and invertebrates (Hughes et al. 2014).

3.24.3 Fish Values Baseline Surveys, Habitat Mapping, and Suitability Assessment

3.24.3.1 Fish Values Baseline Surveys

Extensive biological surveying was done in freshwater and marine habitats potentially impacted by project development. Habitat components were assessed throughout the mainstem, tributary, and off-channel habitats surrounding the mine site and at proposed road and pipeline crossings. Surveys focused on characterizing aquatic habitats and verifying the presence, absence, or abundance of fish and aquatic invertebrates. The information presented in this section and in Section 4.24, Fish Values, is largely based on these surveys, along with other biological data available for the region. Sampling in project waters is expected to only identify a proportion of fish that are present; therefore, fish counts, whether from aerial surveys, electrofishing, netting, or snorkeling, would produce an index of abundance. Also, due to the high mobility and migratory nature of several fish species in the analysis area, it is recognized that some habitats surveyed could support fish or specific species even though fish were not observed when biological surveys were conducted. Similarly, stream areas observed to support fish during baseline surveys may be infrequently used by such species; however, given the high intensity of biological sampling in the project area, the survey results are considered representative of fish distribution and habitats in the analysis area.

3.24.3.2 Fish Values Stream Habitat Mapping

Aquatic habitat was mapped in each mainstem reach and in selected tributaries, and included assessment of channel type (Paustian et al. 1992), bankfull width/depth, mesohabitat unit type (Moore et al. 2006; USFS 2001), unit length, width, and depth, presence and amount of instream cover (e.g., woody debris, undercut banks), dominant and subdominant substrate type, riparian species, and locations of seeps and spring outflows (R2 et al. 2011a). Habitat mapping study reaches were selected to represent the continuum of stream characteristics, and resulted in the identification of 1,984 habitat units. Mesohabitat mapping using aerial imagery was also performed to expand the scale of habitat suitability estimates basin-wide (PLP 2018-RFI 048).

Stream habitats shown in figures are based on the National Hydrology Database stream layer and include all fish baseline studies sampling areas and major streams and tributaries. The figures do not depict the fine-scale project mapping of smaller streams and seeps as presented in Section 3.22 and Section 4.22, Wetlands and Other Waters/Special Aquatic Sites. It is recognized that these small-scale watercourses identified in the high-resolution project mapping could support aquatic resources, and are therefore included in the analysis and quantification of impacts.

3.24.3.3 Habitat Suitability Assessments

Construction, operations, and closure of the mine is expected to result in changes to surface flows in streams draining the mine site. Consequently, assessing the effects of modified flows on the quantity and quality of habitat was necessary to evaluate potential impacts and alternatives. Instream flow studies were performed to assess the effects of modified flows in the mainstem NFK, SFK, UTC, and three principal tributaries. The instream flow assessment used the Physical Habitat Simulation (PHABSIM) component in the Instream Flow Incremental Methodology (IFIM) process. Although PHABSIM has uncertainties and limitations like all other models (Reiser and Hilgert 2018), IFIM and PHABSIM represent the most commonly applied and agency-accepted instream flow methodology employed in North American (IFC 2009). PHABSIM combines a highly standardized hydraulic model with a biological model (Habitat Suitability Criteria [HSC]) that describes the relative suitability of water depth, water velocity, and substrate composition for target species and life-stages.

The Pebble PHABSIM model was based on 143 cross-sectional transects throughout the NFK, SFK, UTC, and three principal tributaries; and included more than 1,300 fish habitat use (HSC) observations representing seven anadromous and resident fish species for spawning, juvenile rearing, and adult rearing (for resident species) life-stages. The PHABSIM-developed relationships between streamflow and the suitability of habitat were combined with habitat mapping and simulated daily streamflow time-series data representing wet, normal, and dry water years to estimate the changes in the area (acreage) of suitable habitat in each study reach during pre-project (baseline), project operation, and post-closure time periods. Estimated changes in suitable habitat area were calculated for each species and life-stage based on each species life-stage periodicity (e.g., July and August for Chinook spawning, year-round for coho juvenile rearing), and assuming discharge of treated water into each subbasin. The distribution of treated water into each subbasin was determined by prioritizing species and life-stages (e.g., salmon generally had higher priority than resident species, spawning had higher priority than juvenile rearing) to maximize habitat and minimize impacts to the priority species and life-stages. This instream flow process is more fully described in Appendix K4.24, Fish Values.

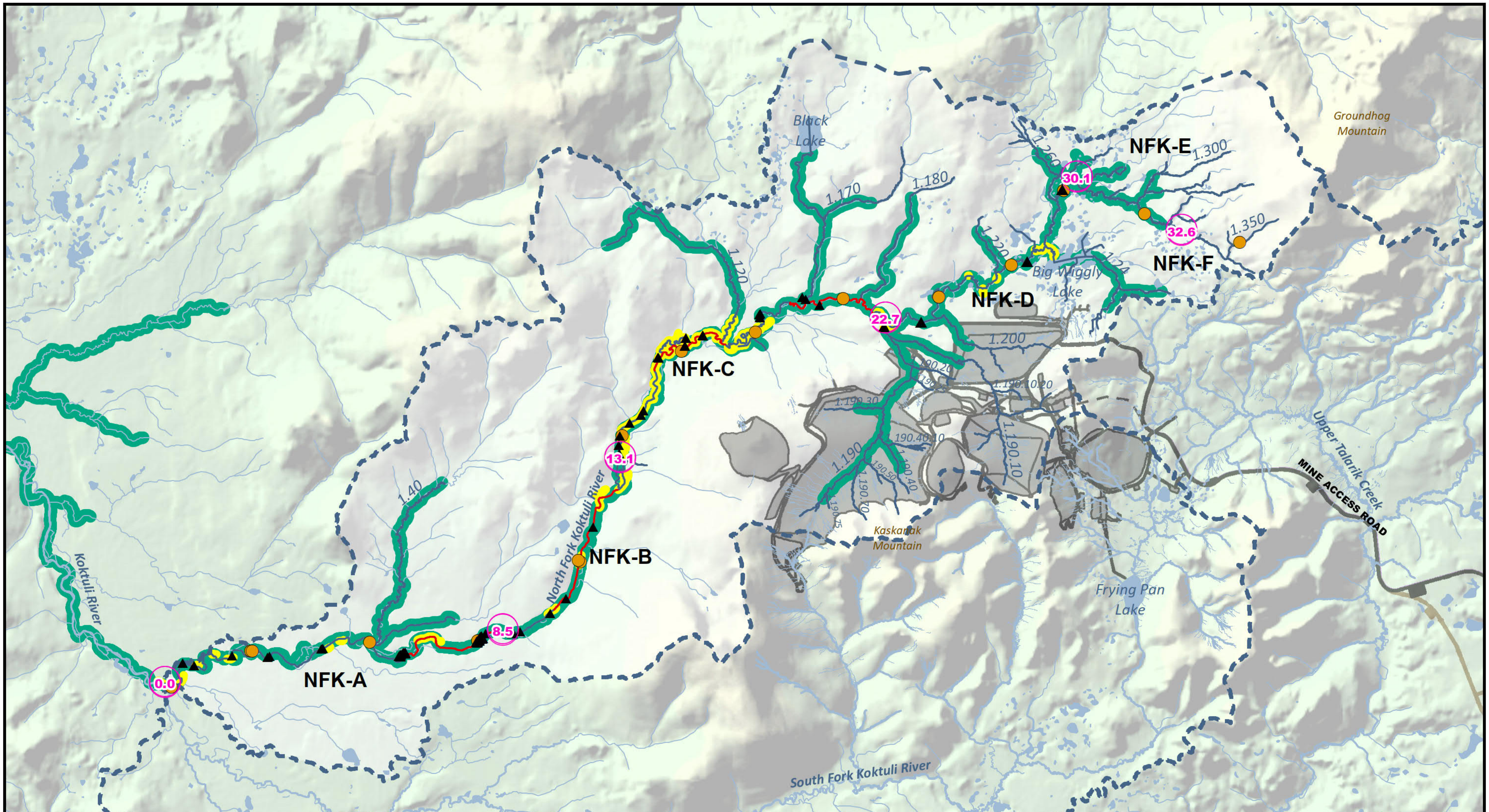
3.24.4 Mine Site

Under all alternatives, the mine site would be situated in the NFK, SFK, and UTC watersheds (Figure 3.24-1; and see Figure 3.16-2). The analysis area for the mine site includes the mainstem NFK and the mainstem SFK from reaches adjacent to the mine site downstream to their confluence; the mainstem UTC from the reach adjacent to the open pit downstream to Iliamna Lake; and tributaries directly draining the mine site facilities or expected to be affected by changes in groundwater accretion (Figure 3.24-2, Figure 3.24-3, and Figure 3.24-4). The 36-mile NFK and 40-mile SFK rivers join to form the Koktuli River, which flows 39 miles downstream into the Mulchatna River. The Mulchatna River continues 44 miles before joining the Nushagak River, which then flows another 109 miles into Bristol Bay. UTC flows for approximately 39 miles into Iliamna Lake, which drains into the Kvichak River and flows 50 miles downstream into Bristol Bay. The NFK, SFK, and UTC subbasins encompass approximately 355 square miles, representing approximately 0.9 percent of the 39,184-square-mile Bristol Bay watershed. The general characteristics and features of the NFK, SFK, and UTC drainage basins are described in Section 3.16, Surface Water Hydrology.

More than 20 fish species are known to inhabit the mine site analysis area, including Pacific salmon species Chinook salmon (*Oncorhynchus tshawytscha*), sockeye salmon (*O. nerka*), coho salmon (*O. kisutch*), chum salmon (*O. keta*), and pink salmon (*O. gorbuscha*). Resident fish species in tributaries draining the mine site include rainbow trout (*O. mykiss*), Dolly Varden (*Salvelinus malma*), Arctic grayling (*Thymallus arcticus*), and sculpins (slimy, *Cottus cognatus*, or *coastrange*, *C. aieuticus*.) (Table 3.24-11).

Impacted Mine Site Streams—Habitat and Fish Use

- Pacific salmon habitat in the direct mine site footprint is considered to have less high-quality spawning and rearing habitat characteristics when compared to downstream habitats.
- Streams directly impacted by the mine site tend to have higher gradients, fewer off-channel and overwintering habitats, lower proportions of spawning gravels, and less woody debris when compared to downstream habitats.
- The majority of adult fish and spawning observations for all Pacific salmon occurred considerably downstream of waters directly affected by mine facilities.
- Observed densities of juvenile salmon in streams around the mine site are substantially lower than in downstream reaches, where more favorable habitat conditions are present.
- Resident fish species documented in the mine site area include: Arctic grayling, slimy sculpin, Dolly Varden, northern pike, and rainbow trout, among other species.



Sources:PLP 2019-RFI153; USGS; ADF&G; PLP (R2 et al. 2011)

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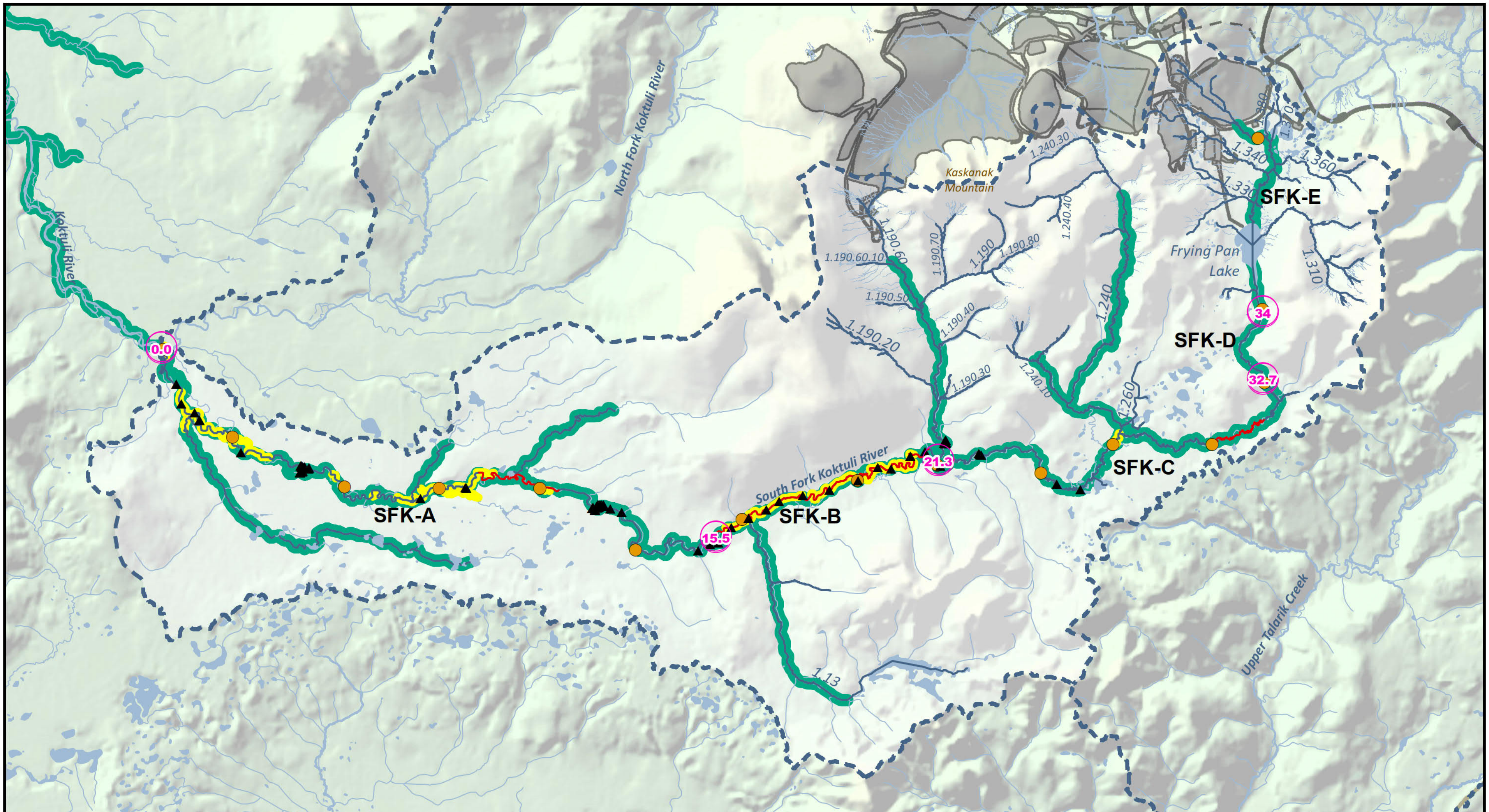
1 0 1 2
Miles

- Mainstem Reaches with River Mile
- Mainstem Index Sites
- PHABSIM Transects
- Open Water (2006 Survey)
- Off-Channel Habitat Study Reach (2005-20018, 2012)
- North Fork Koktuli Principal Tributaries
- Other Perennial/Intermittent Streams
- Anadromous Waters Catalog Channels
- Watershed Boundary
- Alternative 1a

ANADROMOUS WATERS, MAINSTEM REACHES, TRIBUTARIES, FISH SAMPLING INDEX SITES, OFF-CHANNEL HABITAT STUDY SITES, AND WINTER OPEN WATER AREAS IN THE NORTH FORK KOKTULI SUBBASIN

PEBBLE PROJECT EIS

FIGURE 3.24-2



Sources:PLP 2019-RFI153; USGS; ADF&G;
PLP (R2 et al. 2011)

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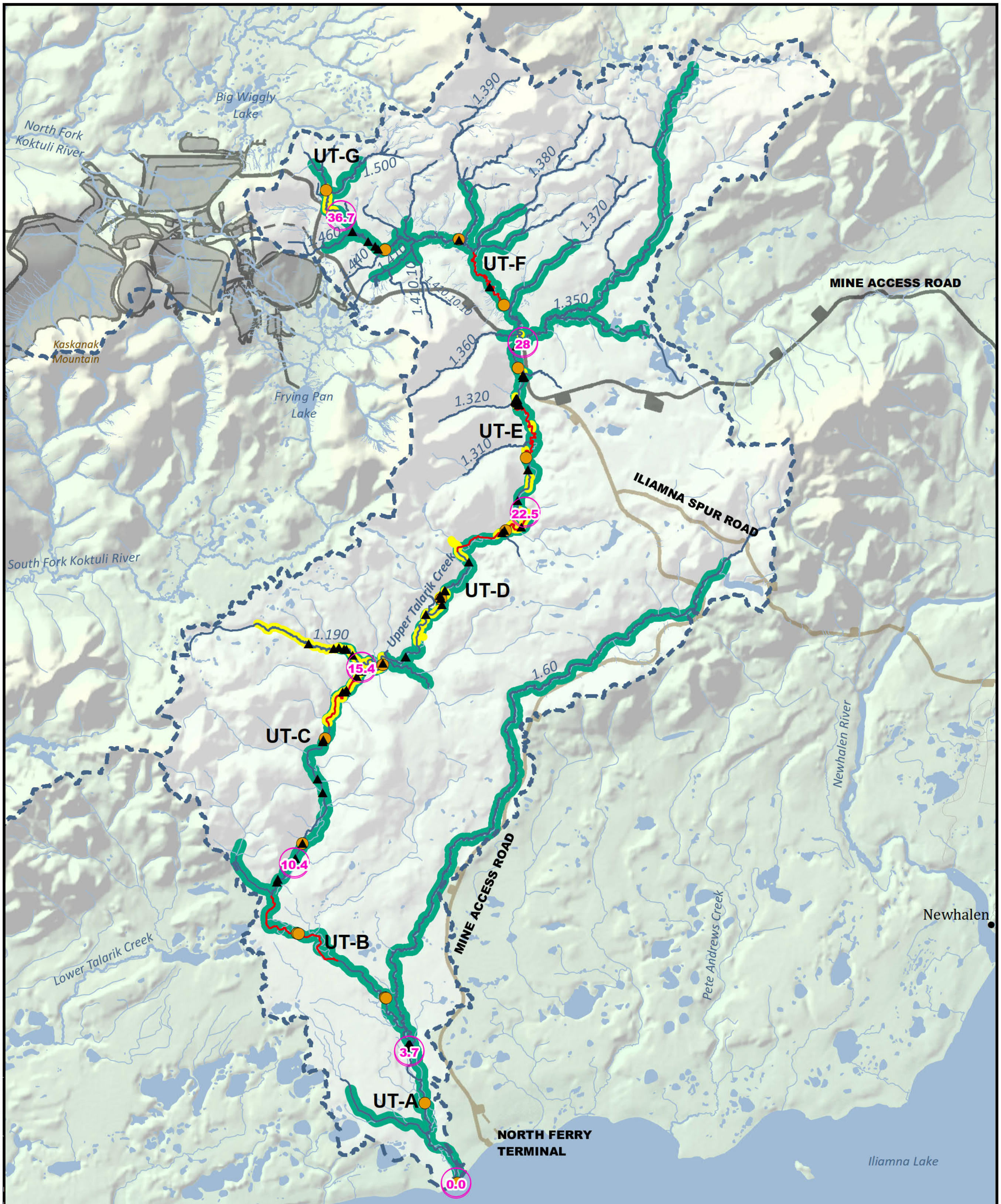
1 0 1 2
Miles

Mainstem Reaches with River Mile
Mainstem Index Sites
PHABSIM Transects
Open Water (2006 Survey)
Off-Channel Habitat Study Reach (2005-20018, 2012)
South Fork Koktuli Principal Tributaries
Other Perennial/Intermittent Streams
Anadromous Waters Catalog Channels
Watershed Boundary
Alternative 1a

ANADROMOUS WATERS, MAINSTEM REACHES, TRIBUTARIES, FISH SAMPLING INDEX SITES, OFF-CHANNEL HABITAT STUDY SITES, AND WINTER OPEN WATER AREAS IN THE SOUTH FORK KOKTULI SUBBASIN

FIGURE 3.24-3



Sources: PLP 2019-RFI153; USGS; ADF&G; PLP (R2 et al. 2011)

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1 0 1 2
Miles

Mainstem Reaches with River Mile
Mainstem Index Sites
PHABSIM Transects
Open Water (2006 Survey)
Off-Channel Habitat Study Reach (2005-20018, 2012)
Upper Talarik Principal Tributaries
Other Perennial/Intermittent Streams
Anadromous Waters Catalog Channels
Watershed Boundary

Action

Alternative 1a
Alternative 1

ANADROMOUS WATERS, MAINSTEM REACHES, TRIBUTARIES, FISH SAMPLING INDEX SITES, OFF-CHANNEL HABITAT STUDY SITES, AND WINTER OPEN WATER AREAS IN THE UPPER TALARIK CREEK SUBBASIN

PEBBLE PROJECT EIS

FIGURE 3.24-4

3.24.4.1 Aquatic Habitat

Mainstem, tributary, and off-channel aquatic habitats potentially directly and indirectly impacted by mine site construction and operation are described for the NFK, SFK, and UTC watersheds (Figure 3.24-2, Figure 3.24-3, and Figure 3.24-4). Aspects of habitat described for each watershed include mileage, streamflows, groundwater influence, water temperature, and available nutrients. Pacific Salmon spawning and rearing habitats in the analysis area are also described. The quantification of streambed habitat was based on the most detailed survey data, whether from PLP, AWC, or Alaska Freshwater Fish Inventory (AFFI) survey data, to delineate the distribution and assessment of impacts to resident and anadromous fish species in the mine site analysis area.

North Fork Koktuli River

The majority of the mine site facilities would be in the NFK watershed (Figure 3.24-2), including most of the bulk tailings storage facility (TSF), pyritic TSF, water management ponds (main and open pit), millsite/camp, and water treatment plant—north discharge location; (see Chapter 2, Alternatives, for details on mine site components). The NFK River watershed extends northeast from the confluence with the SFK River to Groundhog Mountain, approximately 7 miles northeast of the mine site (Figure 3.24-2). The NFK drains 64.7 miles of currently documented anadromous stream channels, with a total basin area of about 113 square miles, which represent 0.3 percent of Bristol Bay's 39,184-square-mile watershed. Approximately 23 percent of the NFK basin area and 8.3 miles of mainstem channel are upstream of Tributaries 1.190 and 1.200 and the mine site footprint (Figure 3.24-2). The ADF&G Anadromous Waters Catalog (AWC) (Johnson and Blossom 2018) lists 12 anadromous fish-bearing tributaries entering the NFK, including Tributaries 1.190 and 1.200, which would contain the majority of the mine site footprint. Overall, there are numerous first-, second-, and third-order streams that would not be impacted from mine site development, as shown in Figure 3.24-2.

Mainstem and Tributary Habitat

Throughout most of its length, the mainstem NFK is a low-gradient (mostly 0.1 to 0.8 percent), unconfined, meandering, single-thread channel bordered by willows (*Salix* spp.), shrub, and dwarf shrub riparian species. Habitat typing conducted on foot and via aerial imagery reveals that the mainstem NFK downstream of the mine site (Reaches A, B and C, Figure 3.24-2) is an alternating series of riffle and run/glide habitats dominated by riffles (56 to 65 percent) with very few (1 to 2 percent) mainstem pools (Table 3.24-1) (R2 et al. 2011a). Upstream of the mine site in NFK Reaches D, E, and F, the NFK contains similar proportions of riffle and run/glide habitats, with increasing frequency of beaver-formed pools in headwater reaches. NFK Reaches A, B, and C have bankfull widths of 67 feet, 68 feet, and 61 feet, respectively, with bankfull depths ranging from 4.3 feet in NFK-A to 2.2 feet in NFK-C (Table 3.24-2). Dominant substrate is gravel in NFK-C, with a riparian wetland composed of willow shrub. The upper 10 miles of the NFK flows through a region with small (less than 3 acres) shallow lakes, dominated by Big Wiggly Lake (Figure 3.24-2). Table 3.24-2 lists physical habitat features for mainstem and tributary reaches of the NFK (and SFK and UTC).

Instream cover for fish rearing is relatively scarce in the NFK mainstem because of the absence of large riparian trees and associated large woody debris (LWD) (Table 3.24-2); but cobble substrates, undercut banks, and overhanging vegetation provide cover for rearing juvenile salmon, as well as juvenile and adult resident species (R2 et al. 2011a). Small woody debris (SWD) and increased depths associated with beaver dams also provide cover for rearing fish in many off-channel locations. Substrate is dominated by gravel, with low amounts of fine sediments (less than 10 percent) in reaches downstream of the mine site. The prevalence of non-embedded gravel substrates and dominance of riffle and run/glide habitats provides spawning habitat for salmonids. In contrast to the lower river, substrate in the mainstem upstream of the mine site contains higher amounts of sand and silt derived from glacial lacustrine and lacustrine deposits underlying the Big Wiggly Lake basin north of the mine site (Schlumberger 2011a).

Table 3.24-1: Frequency (percent) of Habitat Types in the NFK, SFK, and UTC Mainstem Reaches in the Mine Site Analysis Area[1]

Tributary	Mainstem Reach	Riffle	Run/Glide	Pool
NFK	A	64%	35%	1%
	B	65%	34%	1%
	C	56%	42%	2%
	D	46%	45%	9% [2]
SFK	A	65%	32%	3%
	B	44%	54%	2%
	C	27%	64%	5%
	D	55%	24%	3%
UTC	A	54%	45%	1%
	B	53%	44%	3%
	C	24%	74%	2%
	D	16%	77%	7%
	E	19%	69%	12%
	F	20%	51%	22%

Notes:

[1]Includes habitat from mainstem reaches adjacent to and downstream of the mine site (Figure 3.24-1).

[2]Includes pools formed by beaver dams.

NFK = North Fork Koktuli

SFK = South Fork Koktuli

UTC = Upper Talarik Creek

Source: R2 et al. 2011a

Table 3.24-2: Physical Habitat Characteristics in Mainstem and Select Tributary Reaches in the Mine Site Analysis Area

Reach	Tributary	Bankfull Width (feet)	Bankfull Depth (feet)	Slope (%)	Substrate (dominant/ subdominant)	Pool frequency #/100 meters	Dominant Riparian
NFK-A	N/A-mainstem	67	4.3[1]	0.5 to 1.0	Gravel/cobble/sand	0.3	Willow shrub
NFK-B	N/A-mainstem	68	2.6[1]	0.5	Gravel/cobble/sand	0.3	Willow shrub
NFK-C	N/A-mainstem	61	2.2[1]	0.5 to 1.0	Gravel/cobble	0.1	Willow shrub
NFK-C	1.190	6.5 to 30	3.1	2 to 3	Cobble/gravel	0.8	Willow shrub
NFK-C	1.190.10	5.8 to 14	1.6	0.5 to 3.7	Cobble/boulder/gravel	0.4	Willow shrub, fen, other herbaceous
NFK-C	1.190.10.03	6.5	1.3	1.5	Sand/silt	0.8	Willow shrub, tundra
NFK-C	1.190.10.20	14.6	1.3	2.8	Sand/silt	0.6	Willow shrub
NFK-C	1.190.30	4.6	1.3	1.5	Gravel/cobble	1.8	other herbaceous
NFK-C	1.190.40	8.5	1.6	2.2	Cobble/gravel	1.45	Willow shrub, other herbaceous
NFK-C	1.190.40.10	4.5	1.6	3.0	Cobble/boulder	1.8	Willow shrub, other herbaceous
NFK-C	1.190.20	5.5	2.2	1.5	Sand/silt	0.6	Willow shrub, other herbaceous
NFK-C	1.190.20.10	6.5	1.6	6.0	Boulder/cobble	0	other herbaceous
NFK-C	1.190.25	4.8	1.3	3.7	Cobble/boulder	1.0	Willow shrub, other herbaceous
NFK-C	1.190.30	7.0	1.9	3.0	Cobble/boulder/gravel	1.4	Willow shrub, other herbaceous
NFK-C	1.190.40	6.5 to 11	1.9	1.8 to 3.2	Sand/silt/cobble/gravel	1.0	Willow shrub, other herbaceous
NFK-C	1.190.40.10	5.9	1.6	3 to 6.8	Cobble	1.4	other herbaceous
NFK-C	1.190.40.10.10	3.25	1.6	4.5	Sand/silt	1.7	Willow shrub
NFK-C	1.190.50	6.8 to 13.3	1.95	2.7 to 11	Gravel/cobble	0.5	Willow shrub, other herbaceous

Table 3.24-2: Physical Habitat Characteristics in Mainstem and Select Tributary Reaches in the Mine Site Analysis Area

Reach	Tributary	Bankfull Width (feet)	Bankfull Depth (feet)	Slope (%)	Substrate (dominant/ subdominant)	Pool frequency #/100 meters	Dominant Riparian
NFK-C	1.190.50.10	7.5	1.6	2.8	Gravel	0	Willow shrub, other herbaceous
NFK-C	1.190.70	9.75	1.95	3.7 to 11.5	Boulder	0.1	other herbaceous
NFK-C	1.190.75	10.4	1.3	6.3	Cobble	0.5	other herbaceous
NFK-D	N/A-mainstem	29	N/A	1.0 to 1.5	Gravel/sand	N/A	Willow shrub
NFK-D	1.200	47.2	1.5	1.1	Gravel/cobble	0.7	other herbaceous, Willow shrub
NFK-D	1.200.10	7.0	1.7	3.5	Cobble/sand-silt	0.3	other herbaceous, Willow shrub
NFK-E	N/A-mainstem	9	N/A	0.5	Sand/gravel/organics	N/A	Willow shrub
NFK-F	N/A-mainstem	N/A	N/A	N/A	N/A	N/A	Willow shrub
SFK-A	N/A-mainstem	66	2.6[1]	0.5	Gravel/sand	0.1	Willow shrub
SFK-B	N/A-mainstem	60	2.7[1]	0.5	Gravel/cobble	0.1	Willow shrub
SFK-B	1.190	7.45 to 33	1.6 to 2.9	2.5 to 12	Gravel/cobble/boulder	0.42	Willow Shrub/other herbaceous
SFK-B	1.190.20	11.3	2.0	6.8 to 11	Boulder/gravel/sand-silt	0.57	Willow/alder shrub/other herbaceous
SFK-B	1.190.20.10	6.5	1.4	4.5	Sand-silt/boulder	1.3	Alder shrub/willow shrub
SFK-B	1.190.20.20	9.1	1.3	11	Boulder/sand-silt	1.25	Alder shrub/willow shrub
SFK-B	1.190.20.30	7.4	1.0	10	Sand-silt, boulder	0.9	Alder shrub/willow shrub
SFK-B	1.190.20.40	5.2	1.3	8.5	Sand-silt/cobble	0.8	Willow Shrub/other herbaceous
SFK-B	1.190.20.50	7.8	1.3	24.0	Boulder/cobble	0.5	other herbaceous
SFK-B	1.190.20.60	5.5	1.3	2.0	Sand-silt	1.2	other herbaceous
SFK-B	1.190.30	6.1	1.7	1.5 to 5.0	Sand-silt/gravel	0.55	Willow Shrub/other herbaceous

Table 3.24-2: Physical Habitat Characteristics in Mainstem and Select Tributary Reaches in the Mine Site Analysis Area

Reach	Tributary	Bankfull Width (feet)	Bankfull Depth (feet)	Slope (%)	Substrate (dominant/ subdominant)	Pool frequency #/100 meters	Dominant Riparian
SFK-B	1.190.30.10	4.8	1.95	5.0	Sand-silt	0.4	Willow Shrub
SFK-B	1.190.40	8.1	1.95	3.4	Cobble/gravel	0.85	other herbaceous
SFK-B	1.190.50	6.7	1.6	2.3 to 6.3	Cobble/boulder	1.3	Alder shrub
SFK-B	1.190.50.10	3.25	0.97	8.0	Sand-silt	0.6	other herbaceous
SFK-B	1.190.60	8.5 to 19	1.7	3.3 to 5.0	Cobble/boulder/sand-silt	0.2	Alder shrub/other shrub
SFK-B	1.190.60.10	9.4	1.95	7.0 to 13.3	Boulder/cobble	1.05	Alder shrub/willow shrub
SFK-B	1.190.60.20	7.15	1.3	7.5 to 12	Boulder/cobble	1.7	Alder shrub/willow shrub
SFK-B	1.190.60.40	6.17	1.3	11	Gravel/sand-silt	1.45	Willow shrub/other herbaceous
SFK-B	1.190.70	11.3	2.11	12	Boulder/Cobble	1.1	
SFK-B	1.190.80	9.2	1.95	3.3 to 13	Cobble/gravel/boulder	0.05	Other shrub
SFK-B	1.190.80.10	6.8	1.3	7.7	Cobble/gavel	0.3	Other herbaceous
SFK-B	1.190.80.20	4.8	1.6	3.0	Gravel/sand-silt	2	Willow shrub
SFK-C	N/A-mainstem	26	3.6	0.9	Gravel/sand-silt	2.1	Willow shrub
SFK-C	1.240	4.8 to 37	0.5	0.8 to 10.0	Gravel/cobble/boulder	0.08	Willow/alder shrub, other herbaceous
SFK-C	1.240.10	9.6	0.8	1.0	Cobble/sand-silt/gravel	0.5	Willow/alder shrub, other herbaceous
SFK-C	1.240.10.20	13	1.3	3.0	Cobble/boulder	0.4	other herbaceous
SFK-C	1.240.10.25	5.5	1.0	6.0	Boulder/cobble	2.1	other herbaceous
SFK-C	1.240.10.30	7.4	1.6	9.3	Cobble/boulder	0.3	Alder/Willow shrub/other herbaceous
SFK-C	1.240.30	11.3 to 16.5	1.7	3.8 to 5.0	Cobble/boulder/gravel	0.03	Willow/other shrub/other herbaceous
SFK-C	1.240.40	5.2 to 10.4	1.3	4.5 to 5.2	Cobble/boulder/gravel	0.35	other herbaceous

Table 3.24-2: Physical Habitat Characteristics in Mainstem and Select Tributary Reaches in the Mine Site Analysis Area

Reach	Tributary	Bankfull Width (feet)	Bankfull Depth (feet)	Slope (%)	Substrate (dominant/ subdominant)	Pool frequency #/100 meters	Dominant Riparian
SFK-C	1.240.40.10	3.5	0.65	4.8	Gravel/cobble	0.6	other herbaceous
SFK-C	1.240.70	5.5	1.0	3.3	Boulder/cobble	0	other herbaceous
SFK-C	1.260	20 to 28	2.4	1.25	Gravel/sand-silt	2.7	Alder/Willow shrub/other herbaceous
SFK-C	1.260.10	2.2	1.3	1.0	Organics	0	Willow shrub/other herbaceous
SFK-D	N/A-mainstem	39	1.3	0.5	Gravel	0.9	Alder shrub/Willow shrub
SFK-E	N/A-mainstem	15.4	2.3	1.3 to 2.8	Sand-silt/organics	1.0	Willow shrub
SFK-E	1.340	4.55 to 14.95	1.86	0.3 to 2.1	Sand-silt/organics	0.74	Willow shrub, other herbaceous
SFK-E	1.340.40	4.8 to 18.2	2.27	2.1	Organics/sand-silt/gravel	0	Willow shrub, other herbaceous
SFK-E	1.370	9.8	1.64	1.0	gravel	0	Tundra/other herbaceous
UT-A	N/A-mainstem	99	4.6	1.4	Gravel/sand-silt	0.3	Willow shrub
UT-B	N/A-mainstem	89	4.6	1.2	Gravel/sand-silt	0.1	Willow shrub
UT-C	N/A-mainstem	72[1]	2.5[1]	N/A	N/A	0.1	N/A
UT-C	1.190	N/A	N/A	4.6	Cobble/gravel	0.6	N/A
UT-D	N/A-mainstem	60[1]	2.3[1]	N/A	N/A	0.2	N/A
UT-E	N/A-mainstem	56[1]	2.3[1]	N/A	N/A	0.5	N/A
UT-F	N/A-mainstem	25[1]	2.3[1]	1.0 to 2.5	Gravel/sand-silt	1.7	Alder shrub/Willow shrub
UT-F	1.360	6.5 to 14.9	2.1	1.7 to 12.5	Cobble/gravel	0.53	Willow shrub/Alder shrub
UT-F	1.360.50	5.85	1.6	15	Cobble/gravel	0.9	Alder shrub

Table 3.24-2: Physical Habitat Characteristics in Mainstem and Select Tributary Reaches in the Mine Site Analysis Area

Reach	Tributary	Bankfull Width (feet)	Bankfull Depth (feet)	Slope (%)	Substrate (dominant/ subdominant)	Pool frequency #/100 meters	Dominant Riparian
UT-F	1.410	3.5 to 13.65	0.75	1.5 to 4.5	Gravel/sand-silt	0.82 (higher pool densities in lower reach)	Willow shrub/other shrub/other herbaceous
UT-F	1.410.10	4.2 to 12.0	0.53	2.5-38.0	Gravel/boulder/sand-silt	0.1	Alder shrub/Willow shrub/other shrub/ Tundra
UT-F	1.410.10.10	5.5	2.2	1.7	Sand-silt	0.2	Willow shrub
UT-F	1.410.30	8.12	2.43	3.5 to 11.5	Gravel/boulder	1.15	Alder shrub/Willow shrub/other shrub
UT-F	1.410.40	6.18	1.95	1.8 to 2.7	Gravel/sand-silt	1.2	Tundra
UT-F	1.410.40.10	6.8	1.95	1.8	Sand-silt	1.7	Tundra
UT-F	1.440	9.1	4.55	1.0	Sand-silt	2.9	Other herbaceous
UT-F	1.460	9.9	2.43	1.0 to 2.0	Gravel	1.3	Other herbaceous
UT-G	N/A-mainstem	1.7	0.7	1.7	Organics/sand-silt	2.3	Willow shrub

Notes:

[1]bankfull widths and depths are from geomorphology study, remaining data from channel typing study (R2 et al. 2011a)

N/A=data not available

NFK = North Fork Koktuli

SFK = South Fork Koktuli

UTC = Upper Talarik Creek

Source: R2 et al. 2011a

Tributary 1.190 and its sub-tributaries drain approximately 8 square miles, and are incised coarse gravel, cobble, and boulder bed streams flowing through moraine and colluvial deposits, with slopes of 2 percent to greater than 7 percent (Table 3.24-2, Figure 3.24-2). Channel habitat features are dominated by short rapids/riffle reaches and scour pools irregularly spaced at about 1 pool per 100 meters (/100 m). Vegetation types documented in the 1.190 drainage during habitat surveys (R2 et al. 2011a) were dominated by willow shrub and other herbaceous species; alder (*Alnus spp.*) shrub or other larger woody plants were rarely observed in Tributary 1.190. Tributary 1.190.10 is the largest sub-tributary of NFK 1.190, with bankfull width of 6 to 14 feet and depth of approximately 1.5 feet, with a boulder and cobble substrate and a slope of 0.5 to 3.7 percent. Vegetation types documented in the drainage during habitat surveys were dominated by willow shrub and other herbaceous species. Tributary 1.200 enters the NFK in the lower end of reach NFK-D, approximately 1 mile upstream of the Tributary 1.190 confluence. This tributary is 47 feet wide, approximately 1.5 feet deep, with a gravel/cobble substrate and a slope of 1 to 2 percent. Vegetation types documented in the drainage during habitat surveys were dominated by willow shrub and other herbaceous species.

Both headwater Tributaries 1.190 and 1.200 support rearing habitat for Chinook salmon and coho salmon. Coho spawning habitat occurs in Tributary 1.190. Resident fish species include Arctic grayling, Dolly Varden, rainbow trout, and slimy sculpin. Details on fish inhabiting the mine site area are provided below.

Off-Channel Habitat

Off-channel habitat (OCH) provides important rearing habitat for a variety of fish species (Swales and Levings 1989; Nickelson et al. 1992; Pollock et al. 2004), particularly species preferring deeper and slower microhabitats such as that found in beaver complexes (Table 3.24-3). Given the relative rarity of pool habitats or LWD cover in mainstem reaches of the mine site, OCH may be particularly important to overwintering juvenile salmonids, which require slow velocities or dense instream cover during periods of low water temperatures (Allen 2000; Bell 2001; Griffith and Smith 1993; Huusko et al. 2007).

Table 3.24-3: Percentage by Area of Habitat Types in Off-Channel Habitat Intensive Study Sites[1]

Tributary Study Site	Beaver Complex	Pond Outlet Channel	Alcove	Percolation Channel	Isolated Pond	Side Channel
NFK OCH Sites	85%a	3%	2%	4%	1%	5%
SFK OCH Sites	91%	2%	2%	<1%	3%	2%
UTC OCH Sites	93%	1%	1%	1%	1%	3%

Notes:

[1]Total area at intensive study sites is 3,286 acres (NFK), 3,331 acres (SFK), and 3,763 acres (UTC).

NFK = North Fork Koktuli

OCH = Off-channel habitat

SFK = South Fork Koktuli

UTC = Upper Talarik Creek

Source: PLP 2018b, Appendix 15A

The NFK valley downstream of the mine site contains abundant OCH; almost 90 percent of the mainstem channel downstream of the mine site is bordered by some degree of OCH (estimate based on aerial imagery). Four OCH study sites were evaluated in the NFK (Figure 3.24-2) in 2008 and 2012 (PLP 2018b, Appendix 15A). The off channel intensive study site in reach NFK-C was dominated by beaver complexes (85 percent), but also included beaver pond outlet channels, side channels, percolation channels, alcoves, and isolated ponds (Table 3.24-3). In general, OCHs in the NFK, SFK, and UTC contained more fine sediments than adjacent mainstem reaches, and summer sampling typically showed OCHs with warmer water temperatures (mostly less than 1 degree Celsius [°C] difference), and dissolved oxygen levels 1 to 4 milligrams per liter (mg/L) less than the mainstem. Off-channel habitats are hydrologically connected to the NFK via surface flows or groundwater upwelling (Schlumberger 2011a). Hydrologic connections between the mainstem channel and OCHs are abundant, with more than 90 connection points identified in the 2008 intensive study site. Most connections occurred at alcoves, followed by beaver pond outlet channels. Streamflows connecting the mainstem channel with OCHs were hydraulically assessed at multiple locations, and showed connections over a wide variety of flows, ranging from 14 cubic feet per second (cfs) to 490 cfs (R2 et al. 2011a, Appendix 15.1D)]. Approximately 50 percent of OCH area is present with mainstem flows of 20 cfs to 110 cfs, depending on study site. Near-maximum OCH area is estimated to occur in NFK study sites at flows of approximately 100 cfs to 275 cfs. See Section 3.22, Wetlands and Other Waters/Special Aquatic Sites, for a description of riverine wetlands in the analysis area.

Spawning and Rearing Habitat

Spawning site selection by Pacific salmon is influenced by a variety of chemical and physical characteristics such as water depth, substrate particle size and embeddedness, water velocity, hyporheic flow, dissolved gases, and water temperature (Geist et al. 2002; McHugh and Budy 2004; Quinn 2018; Vincent-Lang et al. 1984). The availability of suitable spawning gravel may limit both the amount of salmon habitat and resulting productivity in streams. Most fish spawning and rearing occurs in areas with surface expressions of groundwater (R2 et al. 2011a) that also have suitable depths, water velocities, and gravel size for spawning (Wolman 1993). These areas are more prevalent in the middle and lower reaches of the NFK, SFK, and UTC, as evidenced by the extent of open water during winter surveys (Knight Piésold et al. 2011a) (see Section 4.16, Surface Water Hydrology; and Section 4.17, Groundwater Hydrology).

Chinook salmon spawning habitat occurs throughout the lower 21 miles of the NFK downstream of the mine site (Figure 3.24-2) and extends into the upper NFK adjacent to Big Wiggly Lake (Johnson and Blossom 2018). The majority of spawning habitat occurs in the first 10 miles of the NFK (reach NFK-A), approximately 20 miles downstream from the mine site (R2 et al. 2011a). Juvenile Chinook rearing habitat occurs throughout most of the NFK mainstem (Table 3.24-4), as well as several NFK tributaries, including Tributary 1.400 in the lower reach; Tributary 1.170 downstream of Black Lake; Tributary 1.190 and its primary sub-tributary at the mine site; Tributary 1.200; and Tributary 1.240, which flows through Big Wiggly Lake. Juvenile Chinook were most commonly observed in riffles and other mainstem habitats, but were also found to occupy low-velocity off-channel habitats.

Coho salmon spawning and rearing habitat is widely distributed in the NFK basin (Table 3.24-4). Preferred coho spawning habitat appears to be in the 10 miles of mainstem immediately downstream of the mine site (reach NFK-C), based on field observations (R2 et al. 2011a).Sockeye salmon spawning habitat primarily occurs in the lower 10 miles of the NFK (reach NFK-A), but the run extends upstream to the vicinity of Big Wiggly Lake (R2 et al. 2011a). Although some spawning habitat has been documented in the upper NFK basin, most juvenile rearing habitat occurs downstream of the mine site, based on field observations. Rainbow trout occupy up to 31 miles of habitat in the mainstem NFK and tributaries, including Tributary 1.190. Dolly Varden and sculpin were reported in 40 miles of stream channel, and Arctic grayling are present in at least 28 miles of stream channel.

Table 3.24-4: Estimated Mileage of Spawning and Rearing Habitat for Pacific Salmon, Resident Salmonids, and Resident Non-Salmonids in the Mine Site Analysis Area[1, 2]

Subbasin	Species	Spawning (miles)[3]	Rearing (miles)[3]	Present (miles)[3]
NFK	Chinook salmon	21.4	25.6	0.6
NFK	Coho salmon	26.4	29.3	0.2
NFK	Sockeye salmon	22.5	18.2	0
NFK	Chum salmon	19.5	4.8	0
NFK	Pink salmon	0	0	0
NFK	Rainbow trout[4]	N/A	N/A	31
NFK	Dolly Varden[4]	N/A	N/A	40
NFK	Arctic Grayling[4]	N/A	N/A	28
NFK	Sculpin[4]	N/A	N/A	40
SFK	Chinook salmon	30.0	33.3	1.4
SFK	Coho salmon	31.5	43.5	4.3
SFK	Sockeye salmon	19.4	24.4	9.0
SFK	Chum salmon	19.2	1.9	2.3
SFK	Pink salmon	0	0	0
SFK	Rainbow trout[4]	N/A	N/A	41
SFK	Dolly Varden[4]	N/A	N/A	51
SFK	Arctic Grayling[4]	N/A	N/A	45
SFK	Sculpin[4]	N/A	N/A	54
UTC	Chinook salmon	30.9	24.6	2.7
UTC	Coho salmon	34.7	35.6	0
UTC	Sockeye salmon	32.4	30.8	1.1
UTC	Chum salmon	51.9	0	2.1
UTC	Pink salmon	N/A	N/A	3.9
UTC	Rainbow trout[4]	N/A	N/A	37
UTC	Dolly Varden[4]	N/A	N/A	42
UTC	Arctic Grayling[4]	N/A	N/A	37
UTC	Sculpin[4]	N/A	N/A	38

Notes:

[1]Includes mileage from mainstem and tributary reaches directly or indirectly affected by the project (Figure 3.24-1).

[2]Total anadromous mileages per subbasin are 64.7 miles in NFK, 60.0 miles in SFK, and 76.2 miles in UTC, based on AWC and PLP stream layers.

[3]Includes AWC listing as “spawning” or “rearing”; Frying Pan Lake not included; additional waters listed as species “present” but not specified by life-stage.

[4]Stream mileage based on upstream-most on upstream-most observation for species in AWC, AFFI or PLP sampling data (life-stage not specified but assume both rearing and spawning). Stickleback and northern pike also present in some locations.

N/A = Not Available NFK = North Fork Koktuli

SFK = South Fork Koktuli UTC = Upper Talarik Creek

Source: Johnson and Blossom 2018 (AWC), Alaska Freshwater Fish Inventory, PLP sampling data

Streamflow

Fixed hydrologic station (gage) data and multiple surveys from 2004 to 2008 show that the mainstem NFK remains perennial during base flow levels at all fish-bearing study sites (R2 et al. 2011a). The NFK seasonal hydrograph shows periods of maximum flows during spring snowmelt and late summer/fall rain events, with low flows during mid-summer, and minimum base flows in winter/early spring (Knight Piésold et al. 2011a). Mainstem base flows in the NFK at the mine site (just upstream of the Tributary 1.190 confluence) were typically 15 to 20 cfs in winter, and 40 cfs in summer, with Tributary 1.190 contributing another 4 to 5 cfs and 20 cfs in winter and summer, respectively (Figure 3.24-2). Mean monthly base flows in the lower reach of the NFK averaged 60 to 90 cfs during winter months (January through March), 700 cfs during spring snowmelt (May), 200 cfs during summer base flow (July), and 350 to 450 cfs during fall rains (September through October). All three tributaries (NFK, SFK, and UTC) display sequences of losing and gaining reaches due to groundwater percolation and emergence, respectively (Schlumberger 2011a, 2015a). As noted previously, hydrologic connections between OCHs and mainstem reaches occur at a wide variety of flow levels. Seasonal hydrographs for several reaches of the mainstem NFK are presented in Section 3.16, Surface Water Hydrology.

Flows in headwater Tributary 1.190 and its sub-tributaries are characterized by flashy runoffs during snowmelt and rainstorm events due to higher precipitation, steep catchment in the surrounding uplands, full exposure to incoming storms, and lack of surface flow losses to groundwater in the lower reaches (R2 et al. 2011a). Tributary 1.190.10 exhibits intermittent flow upstream of confluence with Tributary 1.190 for approximately 2 miles during the late summer, which may affect fish production (Figure 3.24-2).

Groundwater Influence

Groundwater inputs are considered important features of salmon habitat, particularly in Alaskan alluvial systems where they play a significant role in determining the extent and volume of ice-free winter habitat (Woody and Higman 2011). Surface flows in headwater and mainstem channels are supported by groundwater accretion, which serves important functions related to water temperature, dissolved nutrients, and other water quality parameters (Douglas 2006). Groundwater inputs factor strongly in the distribution of salmon habitat, particularly for spawning and overwintering life-stages. Chum, Chinook and sockeye salmon have been shown to target areas of groundwater upwelling for spawning, whereas coho prefer downwelling groundwater areas (Woody and Higman 2011; EPA 2014; Woody 2018). Stream areas characterized by emerging groundwater from springs, mainstem upwelling, or headwater tributaries provide circulation, thermal refuge, ice-free habitats, and consistent flows that are attractive to many species of fish and contribute to thermal diversity in downstream waters (Woody and Higman 2011). The mixing of groundwater and surface water creates a unique environment known as the hyporheic zone, an important feature of the stream ecosystem and salmon life history (Douglas 2006; Woody and Higman 2011).

Baseline surveys for assessing fish densities, fish microhabitat use, and developing the flow:habitat relationships via PHABSIM transects were commonly conducted in the regions of rising groundwater. Approximately 32 percent of PHABSIM transects in the NFK subbasin were placed in groundwater areas, and about 60 percent of the salmon spawning HSC observations and 29 percent of fry, juvenile, and adult HSC observations (all species) were also collected in such areas (Figure 3.24-2). Likewise, four of the 13 fish abundance index sites were in groundwater emergence habitat. Environmental baseline adult salmon surveys did reveal a correlation between the locations of adult chum or sockeye salmon and groundwater-influenced reaches of the NFK and SFK.

Groundwater studies indicate that surface waters percolating into the NFK groundwater remain in the NFK subbasin, and do not transfer to either the SFK or UTC subbasins (Schlumberger 2011a). Scattered regions of groundwater influence, based on presence of open water during winter surveys, were apparent in the lowest reach of the mainstem NFK downstream of the mine site, but open water became more common in reach NFK-B and was prevalent throughout most of reach NFK-C and in the lower end of Tributary 1.190 (Figure 3.24-2). In contrast, open water areas were rare in the mainstem NFK upstream of the mine site (Knight Piésold et al. 2011a).

The NFK loses discharge to groundwater where it passes through permeable valley fill of outwash sands and gravels just downstream from the confluence of Tributary 1.190. Gage station data (SEBD 2012) show a small basin upstream of the Tributary 1.190 and NFK confluence contributes a substantial positive flow of 17 to 27 cfs; this trend is reflected in data from a downstream gage. Approximately 2,500 feet downstream, flows were reduced by 5 to 17 cfs, which confirms that reach NFK-C is a losing (surface water to groundwater) reach for approximately 4 river miles downstream of the mine site. Identified losing stream segments are depicted on Figure 3.17-3 in Section 3.17, Groundwater Hydrology (Knight Piésold 2011a, 2015a).

Three years of alluvium groundwater temperatures were recorded at a monitoring well upgradient from the Tributary 1.190/NFK confluence (Schlumberger et al. 2011a). Mean annual groundwater temperatures were 4.0°C; groundwater temperatures from November to May ranged from 2.8°C to 3.6°C, with a 0.8°C variance and an average of 3.2°C.

Surface Water Temperatures

In many stream reaches, ambient surface water temperatures monitored from 2004 to 2009 sometimes exceeded the ADEC 20°C criteria for growth and propagation of fish, shellfish, other aquatic life, and wildlife (ADEC 2018b). The recorded water temperatures in the NFK ranged from a low of 0.3°C to a maximum of 21.9°C (R2 et al. 2011a). Water temperatures in the NFK downstream of the mine site generally remain cool during the summer and cold during winter months, with mean daily temperatures typically between 10°C and 15°C during July and August. In each year of study, the daily maximum water temperature in the NFK immediately upstream of the mine site exceeded the 20°C criteria on about 28 percent of all instantaneous readings during the summer months. The lower temperature thresholds for migration and rearing (15°C) were exceeded on 78 percent of summer readings; and the spawning and egg incubation criteria (13°C) were exceeded on 89 percent of summer readings. Maximum summer (June through August) water temperatures recorded at a gage in Tributary 1.190, which drains the main TSF (Figure 3.24-2), were approximately 5°C colder than the mainstem reach that it flows into (PLP 2011: Table 15.1 through Table 15.4). This difference was more prominent than in the SFK subbasin, where maximum summer water temperatures recorded in SFK Tributary 1.190 downstream of the TSF were approximately 2°C colder than the mainstem reach that it flows into (PLP 2011: Table 15.1 through Table 15.21).

Nutrients and Dissolved Organic Matter

Wipfli and Baxter (2010) describe how the relative importance of energy subsidies from headwaters, terrestrial inputs, benthic production, and marine sources varies in salmon watersheds based on spatial and temporal context. For example, food webs in small headwater streams may be proportionally more dependent on local terrestrial energy subsidies, versus stream communities in downstream waters that may be more dependent on large seasonal fluxes of marine-derived nutrients (MDN). Note that this model was developed from a setting of relatively pristine, old-growth, temperate rainforests in southeastern Alaska, as compared to the open low- and high-scrub riparian vegetation that characterizes Tributary 1.190 and Tributary 1.200.

Because of their narrow width, NFK headwater Tributary 1.190, Tributary 1.200, and the other 15 second- to third-order headwater tributaries outside of the analysis area (USGS Hydro Streams GIS layer) receive proportionally greater inputs of organic material from the surrounding terrestrial vegetation than larger mainstem channels (Vannote et al. 1980). This material is either used locally (Tank et al. 2010) or transported downstream as a subsidy to larger streams in the network (Wipfli et al. 2007). Dissolved organic matter (DOM) in headwater streams is highly variable in quantity and quality, both temporally and spatially (Kiffney et al. 2000; McArthur and Richardson 2002; Meyer et al. 1998). DOM enters streams primarily with groundwater, although some may leach directly from leaf litter that drops directly into streams.

Analysis of nutrient data reveals an influence of nutrients from seeps in the downstream reach of Tributary 1.190 (Schlumberger et al. 2011a). The increased nutrient concentrations recorded at the seeps appear to attenuate approximately 2,500 feet downstream of the confluence of Tributary 1.190 and the NFK mainstem. Nutrient concentrations then remain consistent throughout the mainstem NFK drainage, indicative of either local cycling of nutrient inputs and uptakes in stream reaches, or dilution from combining with mainstem flows. The difference in measured nutrient concentrations from Tributary 1.190 to reach NFK-A 15 miles downstream was 0.018 mg/L.

Data from the SFK and UTC suggest similar attenuation of nutrient inputs from tributaries to mainstem flows. For a more detailed description of surface water and groundwater baseline conditions in the NFK, see Section 3.16, Surface Water Hydrology; Section 3.17, Groundwater Hydrology; and Section 3.18, Water and Sediment Quality.

South Fork Koktuli River

The SFK extends approximately 40 miles upstream from the confluence with the NFK to the headwaters, including 60.0 miles of documented anadromous stream habitat and a 107-square-mile drainage area, representing 0.3 percent of the Bristol Bay watershed (Figure 3.24-1). Overall, there are numerous first-, second-, and third-order streams in the SFK subbasin that would not be impacted from mine site development, as shown in Figure 3.24-3.

Mainstem and Tributary Habitat

The SFK exhibits a repeating sequence of riffle and run/glide habitats, dominated by riffles in reaches SFK-A and SFK-D (Figure 3.24-3), with run/glides dominant in reaches SFK-B and SFK-C (Table 3.24-1). Mainstem pools are rare in the SFK, where they represent 5 percent or less of instream habitat. Like the NFK, the SFK is a low-gradient (0.03 to 0.6 percent), shrub-dominated meandering stream with an abundance of off-channel habitat (R2 et al. 2011a), especially in the lower 20 miles downstream of the mine site where the floodplain broadens (Table 3.24-2). Stream gradient is less than 1 percent in the lower four reaches, but increases to 2.8 percent in the uppermost 1.5 miles of reach SFK-E, just downstream and into the footprint of the open pit. Bankfull width is almost 70 feet in reach SFK-A, but only averages 26 feet in reach SFK-C and 15 feet in reach SFK-E. Bankfull depths range from 2.7 to 3.6 feet in the lower three reaches to 1.3 to 2.3 feet in the upper two reaches. Small, shallow lakes are common adjacent to the mainstem channel in the upper 10 miles of the watershed. The low-gradient and gravel-dominated substrate of the mainstem SFK downstream of the mine site provides spawning and rearing habitat for resident and anadromous salmonids (R2 et al. 2011a). Gravel quality is suitable for spawning and egg incubation, although the proportion of fines in the mainstem substrate is somewhat higher than in the NFK and UTC basins. The lack of large riparian tree species along the SFK mainstem yields little LWD cover; but undercut banks, overhanging vegetation, instream cobbles, and beaver-related SWD are available as cover for rearing by juvenile salmon and juvenile or adult resident fish species.

Instream habitat in the SFK's major northern tributaries (1.190 and 1.240) typically have bankfull widths of 5 to 20 feet and depths from 1 to 2 feet. Channel slopes in Tributary 1.190 were generally greater than 5 percent, with headwater gradients exceeding 10 percent, and most study sites were dominated by cobble and boulder substrates (Table 3.24-2). Tributary 1.240 is similar in character, but with slightly lower gradient with less dominance of boulder substrate. Alder shrub was a more common component of the riparian community in these tributaries compared to the NFK tributaries.

Frying Pan Lake is a 150-acre, shallow, warm lake on the SFK 2.5 miles downstream of the open pit (Figure 3.24-3). Frying Pan Lake provides rearing habitat for juvenile sockeye salmon, Arctic grayling, whitefish, stickleback, sculpin, and a sizable population of northern pike (Johnson and Blossom 2018). Juvenile coho salmon migrating upstream or downstream through the 1.3-mile lake and outlet channel would be subject to predation by the lake's abundant northern pike population.

Off-Channel Habitat

Aerial imagery suggests that up to 70 percent of the mainstem SFK downstream of Frying Pan Lake is bordered by some form of off-channel habitat. Off-channel habitat was assessed at four locations (Figure 3.24-3) in 2005 and 2012 (PLP 2018b, Appendix 15A). Beaver complexes dominated the SFK OCH study sites at 91 percent by surface area, with all other habitat types composing less than 1 to 3 percent of OCH area (Table 3.24-3). More than 100 connection points were identified in three OCH study areas, mostly associated with alcoves and beaver pond outlet channels. Streamflows connecting the mainstem channel with OCHs were hydraulically assessed and showed connections at flows ranging from 5 cfs to 435 cfs. Approximately 50 percent of OCH area was present at flows of 20 cfs to 50 cfs, depending on study site. Near-total OCH area in SFK study sites occurred at lower flows than in the NFK study sites, at approximately 75 cfs to 90 cfs.

Salmon Spawning and Rearing Habitat

Chinook salmon spawning habitat has been documented from the SFK/NFK confluence upstream at least 30 miles to Frying Pan Lake (Table 3.24-4, Figure 3.24-3), although more recent sampling indicated preferred spawning habitat occurs in the lower 20 miles of the SFK (reaches SFK-A and SFK-B) (R2 et al. 2011a). The mainstem SFK between SFK Tributary 1.190 and the Frying Pan Lake outlet routinely dries up during base-flow periods (see Streamflow section for added detail); consequently, even though the substrate consists of a high percentage of gravel, that reach does not provide consistent spawning habitat. Chinook habitat does not extend into the upper SFK basin upstream of Frying Pan Lake or in the footprint of the mine site. However, rearing habitat occurs throughout the mainstem downstream of Frying Pan Lake (although limited in the intermittent reach), and in the lower 4 miles of SFK Tributary 1.190, which drains the southern side of Kaskanak Mountain. Aerial survey data from 2008 showed high concentrations of spawning Chinook salmon in reach SFK-B downstream of the confluence with Tributary 1.190 (Figure 3.24-3). Substrate in the mainstem downstream of this tributary contains from 68 to 96 percent spawning gravels, and groundwater upwelling is abundant in that reach. Rising groundwater and the favorable percentage of gravel provide for good spawning habitat that is reflected in the observations of spawning fish.

Coho spawning habitat in the mainstem SFK extends 31.5 miles almost up to the outlet of Frying Pan Lake, although spawning habitat is limited in the middle intermittent reach. Most spawning habitat was observed via aerial surveys in the lower 20 miles of the mainstem (Table 3.24-4, Figure 3.24-3, reaches SFK-A and SFK-B), and in two tributaries: 1.130 and 1.190 (R2 et al. 2011a). Juvenile coho rearing habitat occurs within at least 43.5 miles of stream channel throughout the SFK basin, including the mainstem, tributaries, and headwaters upstream of Frying Pan Lake. Juvenile coho in the SFK routinely use off-channel habitats, including beaver ponds, side channels, and alcoves. Juvenile coho overwintering habitat has been documented in reaches SFK-A and SFK-B.

Sockeye salmon spawning habitat is limited to the lower 20 miles of mainstem reaches (SFK-A, SFK-B, and SFK-C), but rearing habitat occurs within 24.4 miles of the SFK (Table 3.24-4, Figure 3.24-3). As described for Chinook salmon, aerial surveys also found concentrations of spawning coho and sockeye salmon immediately downstream of the confluence with Tributary 1.190.

Chum spawning habitat is limited to the lower 19 miles of the SFK mainstem, downstream of the seasonally dry channel (Table 3.24-4). Adult chum salmon appear to target areas of rising groundwater during redd site selection; consequently, the highest densities of chum salmon redds occurred in reach SFK-B immediately downstream of the dry channel, where accretion of groundwater is most evident (R2 et al. 2011a).

Rainbow trout habitat occurs in more than 40 miles of mainstem and tributary reaches of the SFK, including upstream of Frying Pan Lake and tributaries. (R2 et al. 2011a). Dolly Varden and Arctic grayling are common in the SFK subbasin, where they occupy from 45 to 51 miles of stream channel (Table 3.24-4). Non-salmonid species, including sculpin, stickleback, and northern pike, inhabit at least 54 miles of mainstem and tributary habitat.

Streamflow

Streamflow patterns in the SFK reflect those in the NFK, with two base-flow periods (summer post-snowmelt and winter) and two high-flow periods (spring snowmelt and fall rain events). Streamflow just upstream of Frying Pan Lake from 2004-2007 averaged 10 to 24 cfs during summer low flow, and 3 to 11 cfs during the winter low flow period (Knight Piésold et al. 2011a). Flows averaged 25 to 30 cfs during the snowmelt and fall high flow periods. In the lowest reach, summer and winter low flows averaged 150 to 300 cfs and 90 to 250 cfs, respectively; with high flows averaging 300 to 600 cfs during snowmelt and 400 to 500 cfs during fall rains. Seasonal hydrographs for several reaches of the mainstem SFK are presented in Section 3.16, Surface Water Hydrology.

Unlike the NFK, the mainstem SFK has a 10-mile reach (SFK-C, Figure 3.24-3), from 2 miles downstream of Frying Pan Lake to SFK Tributary 1.190, which frequently exhibits zero or intermittent flows during winter and summer months (R2 et al. 2011a). Dry or intermittent conditions were observed in this reach during January (2008, 2009), February (2006-2009), March (2005-2008, 2010, 2012), April (2007, 2008) and May (2012), as well as in July (2007), August (2004, 2005, 2007), and September (2004, 2007) (Knight Piésold 2011g). The duration of intermittent flows varied among years, but sometimes persisted for multiple months in winter and early spring, and up to 40 consecutive days in August to early September 2007 (R2 et al. 2011a). Loss of surface flow in this reach is due to thick, permeable glacial deposits and an average transfer of 22 cfs from the SFK basin into the UTC basin via groundwater exchange. The downstream extent of the intermittent reach occurs near SFK Tributary 1.190 at the border of reach SFK-B and reach SFK-C (Figure 3.24-3). In this location, both tributary inflow and groundwater emergence restores surface flow (Knight Piésold et al. 2011a). Figure 3.17-13 in Section 3.17, Groundwater Hydrology, depicts identified losing stream segments.

Groundwater Influence

Winter surveys of open-water habitat revealed abundant groundwater emergence throughout reach SFK-B, as well as extensive portions of reach SFK-A (Figure 3.24-3). As noted previously, emerging groundwater has important effects on local productivity, including the relative distribution and abundance of spawning and rearing fish. In particular, groundwater exerts a significant effect on surface water temperatures. Six of the 11 fish abundance index sites were in mainstem reaches exhibiting groundwater emergence, as well as 35 percent of PHABSIM transects (Figure 3.24-3), 40 percent of salmon spawning (HSC) observations, and almost 80 percent of juvenile and adult rearing HSC observations.

Surface Water Temperature

Water temperature in the SFK ranged from an observed low of 0.7°C to a maximum of 24.4°C. Similar to the NFK, water temperatures tended to be warmer in the upper watershed, where lakes are prevalent; and cooler in the lower reaches, due to emerging groundwater (R2 et al. 2011a). Average daily temperatures during July and August were typically 13°C to 16°C in the upper half of the SFK mainstem, but were only 8°C to 12°C in the area downstream of the intermittent reach. Maximum daily water temperatures exceeded the 20°C criteria for growth and propagation of fish, shellfish, other aquatic life, and wildlife (ADEC 2018b) in 17 percent of measurements at multiple stations in the SFK. The daily maximum temperatures also exceeded the migration and rearing threshold (15°C) on 76 percent of summer readings; and the spawning and egg incubation criteria (13°C) were exceeded on 93 percent of summer readings.

Upper Talarik Creek

UTC flows south approximately 39 miles from its headwaters upstream of the eastern edge of the mine site downstream into Iliamna Lake near the town of Iliamna (Figure 3.24-4). The UTC watershed contains 76.2 miles of documented anadromous habitat in a 135-square-mile watershed, which represents 0.3 percent of the Bristol Bay watershed. Mine site facilities in the UTC basin would be limited to the mine access road and a water treatment discharge pipe. However, the eastern edge of the open pit is at the SFK and UTC watershed boundary; consequently, the open pit (primarily through pit dewatering) and associated roads and facilities, could affect aquatic habitat in the UTC.

Mainstem and Tributary Habitat

The anadromous waters in the UTC basin include almost the entire mainstem channel, as well as habitat within 14 tributaries. There are 23 tributaries of second-order or larger that drain into UTC. Overall, the majority of first-, second-, and third-order tributaries in the UTC subbasin would not be impacted from mine site development (Figure 3.24-4).

Aquatic habitat in the UTC reveals an alternating sequence of riffles and run/glide habitats, with riffles dominating the lower two reaches, and run/glides dominating reaches UTC-C, UTC-D, UTC-E, and UTC-F (Table 3.24-1). Mainstem pools are also rare (1 to 3 percent) in the lower three reaches, but pools become more prevalent in UTC-E and UTC-F at 12 percent and 22 percent, respectively (R2 et al. 2011a). Stream channel gradient is steeper in the lower UTC, compared to the NFK and SFK, with most reaches showing slopes greater than 1 percent, increasing to 2.5 percent in the upper portion of UTC-F (Table 3.24-2). The upper reach and much of the lower reach of the UTC possess relatively wide floodplains, with associated off-channel habitat; but the middle reach is more confined, and largely restricted to a single channel. Bankfull widths exceed 90 feet in reach UTC-A, progressively decreasing to an average width of 25 feet in UTC-F. Similarly, bankfull depths were estimated at 4.6 feet in UTC-A and UTC-B, decreasing to 2.3 feet in the upper reaches. Unlike the NFK and SFK, this middle reach of the UTC is forested, which contributes LWD into the stream channel (R2 et al. 2011a); whereas shrub and dwarf shrub species (including willows [*Salix* spp.]) dominate the upper and lower reaches of UTC. In addition to LWD, undercut banks, overhanging vegetation, and SWD associated with beaver dams also provide instream and overhead cover for juvenile salmon and juvenile or adult resident fish species. The UTC mainstem contains an abundance of gravel that dominates the mainstem reaches and is relatively free of fine sediments, providing quality spawning habitat. Physical habitat in UTC tributaries draining the mine site have bankfull widths of 5 to 15 feet, and depths ranging from 0.5 to 2.5 feet (Table 3.24-2). Channel slopes typically range from 1 percent to 15 percent, with some steeper headwater reaches. Alder shrub and willow shrub are the dominant riparian types in tributary reaches. Pool frequency in UTC tributaries, like the adjacent mainstem reaches, were higher than in the NFK or SFK basins, with one to three pools per 100 meters in most tributary reaches.

Off-Channel Habitat

Off-channel habitats occur along the UTC in roughly similar proportion to the SFK, at about 70 percent of the UTC mainstem channel length, according to aerial imagery. Off-channel habitat was assessed at seven locations (Figure 3.24-4) in 2007 and 2012 (PLP 2018b, Appendix 15A]). As seen in the NFK and SFK, off-channel habitats in the UTC intensive study sites are dominated by beaver complexes (93 percent), with other off-channel habitat types comprising 1 to 3 percent (Table 3.24-3). One hundred forty-five connection points were identified in the UTC OCH study areas, mostly associated with alcoves and beaver pond outlet channels. Hydrologic connections between off-channel habitats and mainstem reaches occur over a wide variety of flow levels, ranging from 39 cfs to 455 cfs. Approximately 50 percent of OCH area in UTC study sites occurred at flows of 10 cfs to 140 cfs, with near-maximum habitat area occurring at flows of approximately 110 cfs to 225 cfs.

Salmon Spawning and Rearing Habitat

Chinook salmon spawning and rearing habitat is interspersed over 30 miles of the 39-mile mainstem UTC (Table 3.24-4); however, Chinook spawning habitat in UTC tributaries is limited to a very short reach of UTC Tributary 1.410, and in UTC Tributary 1.190 (Figure 3.24-4), which receives groundwater flow from the SFK (R2 et al. 2011a). Juvenile Chinook rearing habitat was observed in almost 25 miles of mainstem and tributary habitat features such as run/glide, pool, and riffles in reaches UT-C through UT-E; juvenile Chinook overwintering habitat has been documented in UTC reaches UT-C, UT-D, and UT-E.

Coho salmon spawning habitat extends 34.7 miles, almost the entire length of the mainstem UTC and into several UTC tributaries, including 1.600, 1.350, 1.310, and 1.410 (Figure 3.24-4). The distribution of juvenile coho was similar to that for spawning (35.6 miles), with the addition of several minor tributaries as quantified in Table 3.24-4. Densities of juvenile coho were generally similar in mainstem and off-channel habitat; and maximum densities were observed in UTC Tributary 1.410, which drains the western side of the upper basin immediately proximal to the open pit (R2 et al. 2011a). Coho were observed in November, and again the following April, in reaches UT-D through UT-F, suggesting these reaches may provide overwintering habitat.

Sockeye spawning habitat has been documented in most of the mainstem UTC (32.4 miles) up to the headwaters bordering the mine site, and also encompassed several tributaries, including 1.600, 1.900, 1.350, 1.390, and 1.410 (Table 3.24-4, Figure 3.24-4). Although the spawning habitat is widespread in the UTC, preferred spawning habitat occurs in reach UTC-A (R2 et al. 2011a); and in Tributary 1.600, where up to 43 percent of the UTC sockeye run spawned in 2008. Sockeye rearing habitat is also widespread in the UTC basin, although field observations indicate habitat is somewhat limited in the mainstem and tributaries, likely due to the early emigration of juveniles into Iliamna Lake.

Rainbow trout were more commonly observed in the UTC than in the NFK or SFK, and they occupied at least 37 miles of habitat in UTC (Table 3.24-4). Rainbow trout were found in multiple habitats, including riffle, glides, pools, and beaver ponds throughout all reaches of the UTC (R2 et al. 2011a). Dolly Varden, Arctic grayling, and sculpin are also common in the UTC subbasin, where they occupy 37 to 42 miles of stream habitat. Other non-salmonid species include stickleback, which inhabit much of the mainstem and tributary channels.

Streamflow

The annual hydrograph for the UTC shows the two high-flow and two base-flow periods, similar to the NFK and SFK (Knight Piésold et al. 2011a). Mean high flows in UTC from 2004 to 2008 just downstream of the mine site were 35 to 70 cfs during spring snowmelt and 40 to 50 cfs during fall rains. Winter low flows averaged 10 to 30 cfs, with summer low flows of 20 to 25 cfs. In lower UTC, just downstream of Tributary 1.190, winter and summer low flows averaged 100 to 200 cfs and 150 to 250 cfs, respectively, with spring and fall high flows of 250 to 450 cfs and 300 to 350 cfs, respectively. An exception to the seasonal pattern is UTC Tributary 1.190 (Figure 3.24-4), which receives groundwater accretion from the SFK. Mean monthly streamflow in this tributary was consistently 20 to 30 cfs throughout the year. Seasonal hydrographs for several reaches of the mainstem UTC are presented in Section 3.16, Surface Water Hydrology.

Groundwater Influence

As noted previously, emerging groundwater maintains constant flow in UTC Tributary 1.190, but evidence of emerging groundwater in the mainstem UTC, based on winter open-water surveys, is also seen in many areas of the UTC (Figure 3.24-4). Groundwater inflow is particularly evident in the upper mainstem UTC adjacent to the open pit, and is also apparent in most of Reach UTC-D and in upper Reach UTC-C, just downstream of Tributary 1.190. Fish sampling in the groundwater-influenced area included 5 of the 14 mainstem index sites, 44 percent of the PHABSIM transects (Figure 3.24-4), and 28 percent and 8 percent of salmon spawning and resident fish rearing HSC observations, respectively.

Surface Water Temperatures

Measured water temperatures in the UTC ranged from a low of 2.5°C to a maximum of 18.8°C (R2 et al. 2011a). Summer water temperatures did occasionally exceed the ADEC 15°C criteria for migration and rearing (44 percent of measurements), and 59 percent of the 13°C threshold for spawning and migration (ADEC 2018b), but UTC water temperatures were generally 3°C to 5°C cooler than comparable temperatures in the NFK and SFK, due in part to the abundance of groundwater emergence and the relative lack of inflow from warm, shallow lakes (R2 et al. 2011a). The groundwater inflow from Tributary 1.190 reduced water temperatures in the lower mainstem UTC, which generally remained less than 10°C.

3.24.4.2 Anadromous and Resident Fish Distribution

This section describes fish species (and their densities) that have the potential to occur in the analysis area for the mine site. Expected periodicity for each species and life-stage in the project area is shown in Table 3.24-5. Other fish life history characteristics are available through the ADF&G fish webpages (ADF&G 2018u). For a description of Bristol Bay and Cook Inlet commercial fisheries, refer to Section 3.6, Commercial and Recreational Fisheries. The following information describing the presence, distribution, and abundance of both anadromous and resident fish species and life-stages in the analysis area is based on AWC and AFFI data (Johnson and Blossom 2018), and multiple years (1991, 2004-2009, 2018) of baseline fish sampling, as described in environmental baseline documents (R2 et al. 2011a, PLP 2018b) and the Essential Fish Habitat (EFH) assessment (Appendix I) (Owl Ridge 2019). All five species of Pacific salmon occupy various habitats in the analysis area, as well as sport fish species, including rainbow trout, Arctic grayling, Dolly Varden, northern pike, and many additional non-game species (see Resident Fish Species sections below).

Table 3.24-5: Estimated Life-Stage Periodicities of Select Fish Species in NFK, SFK, and UTC Waterbodies

Species[1]	Life-Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Chinook salmon	Adult Migration							■	■				
	Spawning[3]							■	■				
	Fry Emergence				■	■							
	Juvenile Rearing	■	■	■	■	■	■	■	■	■	■	■	■
	Outmigration				■	■	■						
Coho salmon	Adult Migration								■	■	■		
	Spawning[3]								■	■	■	■	
	Fry Emergence				■	■							
	Juvenile Rearing	■	■	■	■	■	■	■	■	■	■	■	■
	Outmigration				■	■	■						
Sockeye salmon	Adult Migration							■	■	■			
	Spawning[3]							■	■	■	■	■	
	Fry Emergence				■	■							
	Juvenile Rearing	■	■	■	■	■	■	■	■	■	■	■	■
	Outmigration				■	■	■						
Chum salmon	Adult Migration						■	■					
	Spawning[3]							■	■				
	Fry Emergence				■	■							
	Juvenile Rearing				■	■							
	Outmigration				■	■							
Pink salmon	Adult Migration							■	■	■			
	Spawning[3]							■	■	■			
	Fry Emergence				■	■							
	Juvenile Rearing												

Table 3.24-5: Estimated Life-Stage Periodicities of Select Fish Species in NFK, SFK, and UTC Waterbodies

Species[1]	Life-Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Outmigration												
Rainbow trout	Adult Rearing												
	Spawning[3]												
	Fry Emergence												
	Juvenile Rearing												
Dolly Varden	Adult Rearing												
	Spawning[3]												
	Fry Emergence												
	Juvenile Rearing												
Arctic grayling	Adult Rearing												
	Spawning[3]												
	Fry Emergence												
	Juvenile Rearing												
Whitefish[2]	Adult Rearing												
	Spawning[3]												
	Fry Emergence												
	Juvenile Rearing												
Northern[2] pike	Adult Rearing												
	Spawning[3]												
	Fry Hatching												
	Juvenile Rearing												

Notes:

[1]Unless otherwise noted, periodicities taken from project baseline data documents or ADF&G recommendations.

[2]Periodicities estimated from Morrow 1980.

[3]Egg and alevin incubation extends from beginning of spawning to end of fry emergence.

NFK = North Fork Koktuli SFK = South Fork Koktuli UTC = Upper Talarik Creek

North Fork Koktuli River

Figure 3.24-5 shows the relative distribution and composition of anadromous and resident salmonid species in the NFK analysis area. Blue channels represent anadromous waters; yellow channels contained resident salmonids (RS), but anadromous fish were not recorded; green channels only contained resident non-salmonid fish species (NS). Red channels represent sampled stream reaches where no fish were captured or observed. Note that resident salmonids and non-salmonids generally occurred throughout the distribution of anadromous species. Also note that the lack of observations of a particular species is not definitive evidence they do not exist in that location at other times.

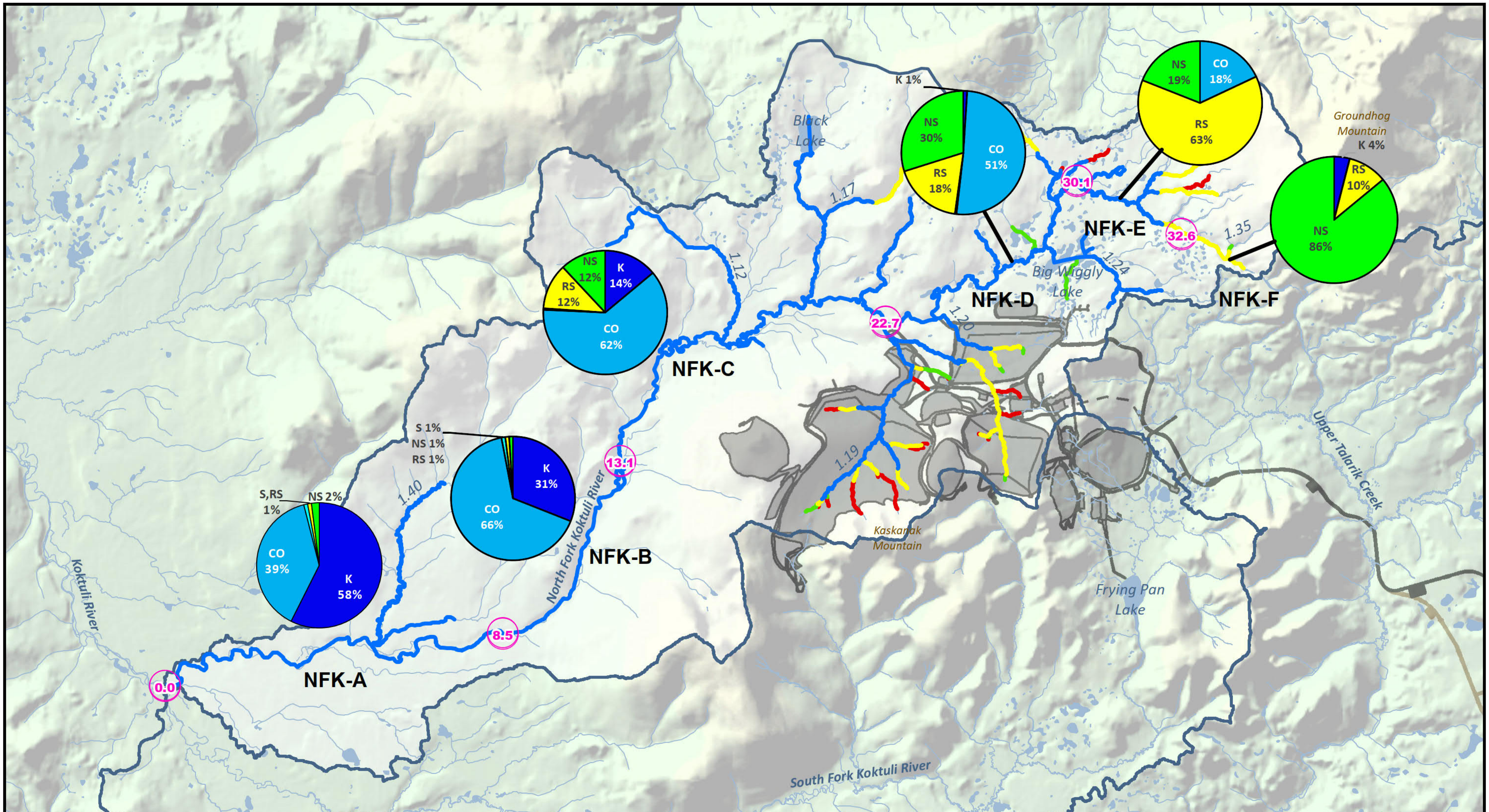
Chinook salmon, coho salmon, sockeye salmon, and chum salmon have been documented in the NFK watershed (Johnson and Blossom 2018). Pink salmon are documented in the mainstem Koktuli River and the UTC, but do not occur in the NFK. Other species found in the NFK watershed include rainbow trout, Dolly Varden, Arctic grayling, threespine stickleback (*Gasterosteus aculeatus*), ninespine stickleback (*Pungitius pungitius*), sculpins (including species such as slimy and coast range sculpin), northern pike (*Esox lucius*), and whitefish (various species, including round whitefish [*Prosopium cylindraceum*], humpback whitefish [*Coregonus pidschian*], and least cisco [*Coregonus sardinella*]). The approximate stream mileage listed in the AWC (Johnson and Blossom 2018) for anadromous species and rainbow trout in the NFK by life-stage is given in Table 3.24-4.

Adult salmon counts in the mine site area were conducted using aerial surveys from July to October during 2004 to 2008. Where possible, large-scale densities were calculated using stream segment lengths and fish counts by stream segment. The total peak daily counts from adult surveys are summarized by river to facilitate run size comparisons across years (Table 3.24-6). Densities of adult salmon by spawning reach and species were determined most comprehensively during 2008 aerial surveys; to illustrate the distribution of adult fish throughout each river and its tributaries, fish observations from the survey demonstrating the most widespread fish distribution for each species are presented in Table 3.24-7. Additionally, cumulative observations of adult salmon and densities by stream reach are presented in Table 3.24-8.

Chinook Salmon

The Nushagak drainage, which includes the NFK and SFK, supports the largest run of Chinook salmon in the Bristol Bay watershed, with annual index averaging about 80,000 fish (ADF&G 2018w). This index represents around 50 percent of the actual king salmon escapement. The NFK generally supports greater numbers of Chinook and chum salmon than the SFK and UTC, and is second only to UTC for coho salmon. Adult Chinook salmon have been documented entering the NFK as early as July 12, with peak documented adult counts occurring between July 23 and August 4. Comparison of fish densities (adult salmon per kilometer [#/km]) across relatively similar stream reaches from 2004 to 2008 show that adult Chinook were most abundant in 2004 and 2005 at 60 to 63 fish/km, with progressively lower densities in the remaining years (Table 3.24-6).

The majority of adult fish and spawning observations for all adult Pacific salmon occurred downstream of waters directly affected by mine facilities. In the NFK, most Chinook spawn in the first 8 miles of the NFK (NFK-A, Table 3.24-7, Table 3.24-8, and Figure 3.24-6), approximately 20 miles downstream from the mine site (R2 et al. 2011a). No adult Chinook were observed in the mainstem NFK upstream of Tributary 1.190 in 2008, although that was the year with the lowest returns to the NFK (Table 3.24-8). Although spawning was relatively abundant in NFK-C, few adults were observed in the upper end of the reach in proximity to the mine site.



Sources:PLP 2019-RFI153; USGS;
ADF&G AWC & AFFI; PLP (R2 et al. 2011)

US Army Corps of Engineers

1 0 1 2

Miles

Fish Distribution and Relative Composition

- Anadromous Salmonids (K=Chinook, CO=Coho, S=Sockeye)
- Resident (non-anadromous) Salmonids (RS)
- Non-Salmonid Fish (NS)
- No Fish Observed

Mainstem Reaches with River Mile

Water Basin

Action Alternative

Alternative 1a

Alternative 1

FISH DISTRIBUTION AND RELATIVE COMPOSITION IN THE NORTH FORK KOKTULI SUBBASIN

PEBBLE PROJECT EIS

FIGURE 3.24-5

Table 3.24-6: Peak Daily Counts and Densities (Fish per Stream Kilometer) of Adult Salmon by Stream and Year Based on Aerial Surveys 2004 to 2008[1,2]

Species	Year	North Fork Koktuli River			South Fork Koktuli River			Upper Talarik Creek		
		Count[3]	Density (#fish/km)[4]	Survey Length (km)	Count[3]	Density (#fish/km)[4]	Survey Length (km)	Count[3]	Density (#fish/km)[4]	Survey Length (km)
Chinook Salmon										
	2004	2,800	62.4	44.9	2,780	82.5	33.7	272	4.5	60.9
	2005	2,889	60.4	47.8	1,660	30.3	54.8	100	1.6	60.9
	2006	740	16.5	44.9	327	9.1	35.8	90	1.5	60.9
	2007	531	9.6	55.6	387	7.1	54.8	152	2.5	60.5
	2008	434	7.8	55.5	590	13.5	43.8	102	1.6	62.5
Chum Salmon										
	2004	435	13.1	33.2	--	--	--	--	--	--
	2005	350	7.8	44.9	361	10.1	35.8	3	0.1	58.2
	2006	753	16.8	44.9	866	24.2	35.8	9	0.1	60.9
	2007	833	18.6	44.9	189	3.4	54.8	10	0.2	60.5
	2008	1,432	31.9	44.9	917	17.9	51.2	44	0.7	62.5
Coho Salmon										
	2004	378	14.6	25.9	270	4.5	60.3	2,621	43.0	60.9
	2005	361	7.6	47.8	565	10.3	54.8	1,041	30.1	34.6
	2006	1,074	23.9	44.9	1,394	38.9	35.8	6,413	110.0	58.3
	2007	114	2.1	55.6	340	5.6	60.3	4,359	72.2	60.4
	2008	1,704	30.7	55.5	1,955	34.4	56.9	5,248	90.3	58.1
Sockeye Salmon										
	2004	563	12.5	44.9	1,730	48.3	35.8	33,070	543.0	60.9
	2005	1,140	25.4	44.9	2,051	40.8	50.3	13,698	224.9	60.9
	2006	1,385	30.8	44.9	2,952	53.9	54.8	11,334	186.1	60.9
	2007	2,188	39.4	55.6	4,112	75.0	54.8	10,557	174.5	60.5
	2008	1,907	34.4	55.5	6,133	140.0	43.8	50,317	805.1	62.5

Notes:
[1]Peak densities for main channel only.
[2]PLP 2018a – SEBD, Appendix 15B2, densities and fish per river kilometer.
[3]Count data reflect the highest number of fish of each species observed on a single survey event.
[4]Density calculated by dividing the number of fish by the survey length.
km = kilometer
Source: Owl Ridge 2019

Table 3.24-7: Adult Salmon Counts from Mainstem and Tributary Surveys and Mainstem Density (fish/km) Estimates Observed During the Survey that Had the Most Widespread Adult Distribution in Each Basin, 2008[1]

River km/ Tributary	Reach	Chinook Salmon			Chum Salmon			Coho Salmon			Sockeye Salmon		
		Count	Density (#fish/km)	%	Count	Density (#fish/km)	%	Count	Density (#fish/km)	%	Count	Density (#fish/km)	%
North Fork Koktuli River		Survey Date: 8/4-5/2008			Survey Date: 7/30-31/2008			Survey Date: 9/28/2008			Survey Date: 7/30-31/2008		
0.0 8.7	NFK/SFK Confluence NFK1.40, NFK-01	189	21.8	43.5	57	6.6	8.9	209	24.1	12.0	1,047	120.6	57.7
14.5	NFK-02	53	9.1	12.2	0	0.0	0.0	174	29.9	10.0	4	0.7	0.2
22.2	NFK-03	96	12.4	22.1	70	9.0	10.9	280	36.2	16.0	7	0.9	0.4
33.2	NFK-04	82	7.5	18.9	516	47.3	80.1	880	80.7	50.4	640	58.7	35.3
36.5	NFK05	13	3.9	3.0	1	0.3	0.2	23	6.8	1.3	0	0.0	0.0
44.9	NFK-06	1	0.1	0.2	0	0.0	0.0	51	6.1	2.9	1	0.1	0.1
48.1	NFK-07	0	0.0	0.0	0	0.0	0.0	11	3.5	0.6	0	0.0	0.0
55.5	NFK-08	0	0.0	0.0	0	0.0	0.0	76	10.2	4.4	0	0.0	0.0
Tributary	NFK 1.190	0	--	0.0	0	--	0.0	27	--	1.5	0	--	0.0
Tributary	NFK 1.240	--	--	--	--	--	--	12	--	0.7	--	--	--
Tributary	NFK 1.240.P1	--	--	--	0	--	0.0	--	--	--	3	--	0.2
Tributary	NFK 1.240.20.P1	0	--	0.0	0	--	0.0	--	--	--	111	--	6.1
Tributary	NFK 1.260	--	--	--	0	--	0.0	1	--	0.1	0	--	0.0
Tributary	NFK 1.270	--	--	--	0	--	0.0	--	--	--	0	--	0.0
Tributary	NFK 1.280	--	--	--	--	--	--	2	--	0.1	--	--	--
	TOTAL	**434**			**644**			**1,746**			**1,813**		
South Fork Koktuli River		Survey Date: 8/4/2008			Survey Date: 7/15-16/2008			Survey Date: 9/29/2008			Survey Date: 7/30/2008		
0.0 2.2	NFK/SFK Confluence SFK-01	42	19	7.1	35	15.8	3.7	49	22.2	3.1	229	103.6	3.7
8.0	SFK-02	114	19.7	19.3	23	4	2.4	274	47.2	17.3	511	88.1	8.3
11.0	SFK-03	139	47.1	23.6	49	16.6	5.2	101	34.2	6.4	308	104.4	5.0
12.8	SFK-04	25	13.9	4.2	29	16.1	3.0	25	13.9	1.6	1,130	627.8	18.4
18.7	SFK-05	77	13	13.1	59	10	6.2	162	27.4	10.3	297	50.3	4.8
21.6	SFK-06	22	7.6	3.7	4	1.4	0.4	39	13.5	2.5	0	--	0.0
24.9	SFK-07	60	17.9	10.2	132	39.4	13.9	59	17.6	3.7	1	0.3	0.0
30.1	SFK-08	93	17.9	15.8	267	51.3	28.1	304	58.5	19.2	600	115.4	9.8
34.3	SFK-09	18	4.3	3.1	312	74.8	32.8	444	106.5	28.1	3,057	733.1	49.8

Table 3.24-7: Adult Salmon Counts from Mainstem and Tributary Surveys and Mainstem Density (fish/km) Estimates Observed During the Survey that Had the Most Widespread Adult Distribution in Each Basin, 2008[1]

River km/ Tributary	Reach	Chinook Salmon			Chum Salmon			Coho Salmon			Sockeye Salmon		
		Count	Density (#fish/km)	%	Count	Density (#fish/km)	%	Count	Density (#fish/km)	%	Count	Density (#fish/km)	%
35.9	SFK-10	0	--	0.0	7	4.4	0.7	5	3.2	0.3	0	--	0.0
43.8	SFK-11	0	--	0.0	0	--	0.0	13	1.6	0.8	0	--	0.0
51.2	SFK-12	--	--	--	0	--	0.0	6	0.8	0.4	--	--	--
56.9	SFK-13	--	--	--	--	--	--	0	--	0.0	--	--	--
Tributary	SFK 1.130	0	--	0.0	6	--	0.6	48	--	3.0	0	--	0.0
Tributary	SFK 1.190	0	--	0.0	28	--	2.9	50	--	3.2	0	--	0.0
Tributary	SFK 1.240	0	--	0.0	0	--	0.0	1	--	0.1	1	--	0.0
	TOTAL	**590**			**951**			**1,580**			**6,134**		
Upper Talarik Creek		Survey Date: 8/8/2008			Survey Date: 8/8/2008			Survey Date: 9/22/2008			Survey Date: 7/29/2008		
0.0 14.5	Confluence of UT & Iliamna Lake UT-01	10	0.7	9.5	0	0.0	0.0	362	25	9.7	21,554	872.6	50.2
24.7	UT-02	40	3.9	38.1	4	0.4	8.5	275	26.9	7.4			
32.3	UT-03	1	0.1	1.0	4	0.5	8.5	804	106.8	21.5	2,137	283.84	5.0
44.9	UT-04	49	3.9	46.7	18	1.4	38.3	716	56.7	19.2	1,435	113.6	3.3
51.0	UT-05	2	0.3	1.9	0	--	0.0	271	44.6	7.3	29	4.8	0.1
54.3	UT-06	0	--	0.0	0	--	0.0	85	25.7	2.3	56	16.9	0.1
58.1	UT-07	0	--	0.0	0	--	0.0	161	42.3	4.3	8	2.1	0.0
60.4	UT-08	0	--	0.0	0	--	0.0	16	6.9	0.4	--	--	--
62.5	UT-09	0	--	0.0	0	--	0.0	1	0.5	0.0	--	--	--
Tributary	UT 1.160 (First Creek)	0	--	0.0	0	--	0.0	420	--	11.3	17,667	--	41.1
Tributary	UT 1.190	1	--	1.0	0	--	0.0	0	--	0.0	--	--	--
Tributary	UT 1.350	0	--	0.0	0	--	0.0	571	--	15.3	0	--	0.0
Tributary	UT 1.390	0		0.0	0	--	0.0	8	--	0.2	53	--	0.1
Tributary	UT 1.410	2	--	1.9	21		44.7	43	--	1.2	30	--	0.1
	TOTAL	**105**			**47**			**3,733**			**42,969**		

Notes:
[1]PLP 2018a – based on aerial surveys reported in SEBD, Tables B2-5, B-10, and B-15, densities and fish per river kilometer.
km = kilometer
Source: Owl Ridge 2019

Table 3.24-8: Aerial Observations of Spawning Salmon by Stream Reach in the North Fork Koktuli River, South Fork Koktuli River and Upper Talarik Creek, 2008[1]

River km	Reach	Chinook Salmon				Chum Salmon				Coho Salmon				Sockeye Salmon			
		# of Surveys	Count	#fish/km	%	# of Surveys	Count	#fish/km	%	# of Surveys	Count	#fish/km	%	# of Surveys	Count	#fish/km	%
North Fork Koktuli River (2008)																	
0.0-13.7	NFK-A	5	567	41.4	57.3	7	344	25.1	12.0	11	1,164	85	22.9	8	4,284	312.7	62.5
13.7-21.1	NFK-B	5	189	25.5	19.1	5	255	34.5	8.9	10	746	100.8	14.7	5	25	3.4	0.4
21.1-36.6	NFK-C	5	234	15.1	23.6	7	2,279	147	79.2	13	2,725	175.8	53.7	9	2,029	130.9	29.6
36.6-48.4	NFK-D	—	0	0	0	—	0	0	0	7	185	15.7	3.6	9	514	43.6	7.5
48.4-52.5	NFK-E	—	0	0	0	—	0	0	0	5	259	63.2	5.1	—	0	0	0
52.5-57.7	NFK-F	—	0	0	0	—	0	0	0	—	0	0	0	—	0	0	0
	TOTAL		**990**				**2,878**				**5,079**				**6,852**		
South Fork Koktuli River (2008)																	
0.0-24.9	SFK-A	7	1,300	52.2	81.8	7	605	24.3	35.4	12	2,352	94.5	41.3	9	7,333	294.5	37.5
24.9-34.3	SFK-B	5	289	30.7	18.2	7	1,103	117.3	64.6	14	3,295	350.5	57.8	8	12,237	1,301.8	62.5
34.3-51.7	SFK-C	—	0	0	0	—	0	0	0	6	49	2.8	0.9	1	1	0.1	0
51.7-54.7	SFK-D	—	0	0	0	—	0	0	0	—	0	0	0	—	0	0	0
54.7-64.2	SFK-E	—	0	0	0	—	0	0	0	—	0	0	0	—	0	0	0
	TOTAL		**1,589**				**1,708**				**5,696**				**19,571**		
Upper Talarik Creek (2008)																	
0.0-5.9	UT-A	3	11	1.9	7.4	1	7	1.2	9.6	11	1,090	184.7	11.3	10	103,233	17,497.1	58.1
5.9-16.8	UT-B	5	26	2.4	17.4	3	5	0.5	6.8	8	438	40.2	4.6	9	41,475	3,805.0	23.3
16.8-24.8	UT-C	3	38	4.8	25.5	2	5	0.6	6.8	10	453	56.6	4.7	6	16,937	2,117.1	9.5
24.8-36.3	UT-D	5	14	1.2	9.4	4	25	2.2	34.2	14	2,632	228.9	27.4	5	13,358	1,161.6	7.5
36.3-45.1	UT-E	4	55	6.3	36.9	4	13	1.5	17.8	12	3,514	399.3	36.6	6	2,355	267.6	1.3
45.1-59.1	UT-F	2	5	0.4	3.4	2	18	1.3	24.7	8	1,477	105.5	15.4	6	284	20.3	0.2
59.1-62.4	UT-G	—	0	0	0	—	0	0	0	2	6	1.8	0.1	—	0	0	0
	TOTAL		**149**				**73**				**9,610**				**177,642**		

Notes:

[1]PLP 2018a—based on aerial surveys reported in EBD Tables 15.1-16,15.1-29, and 15.1-42, stream reaches and fish per river kilometer

km = kilometer

Source: Owl Ridge 2019

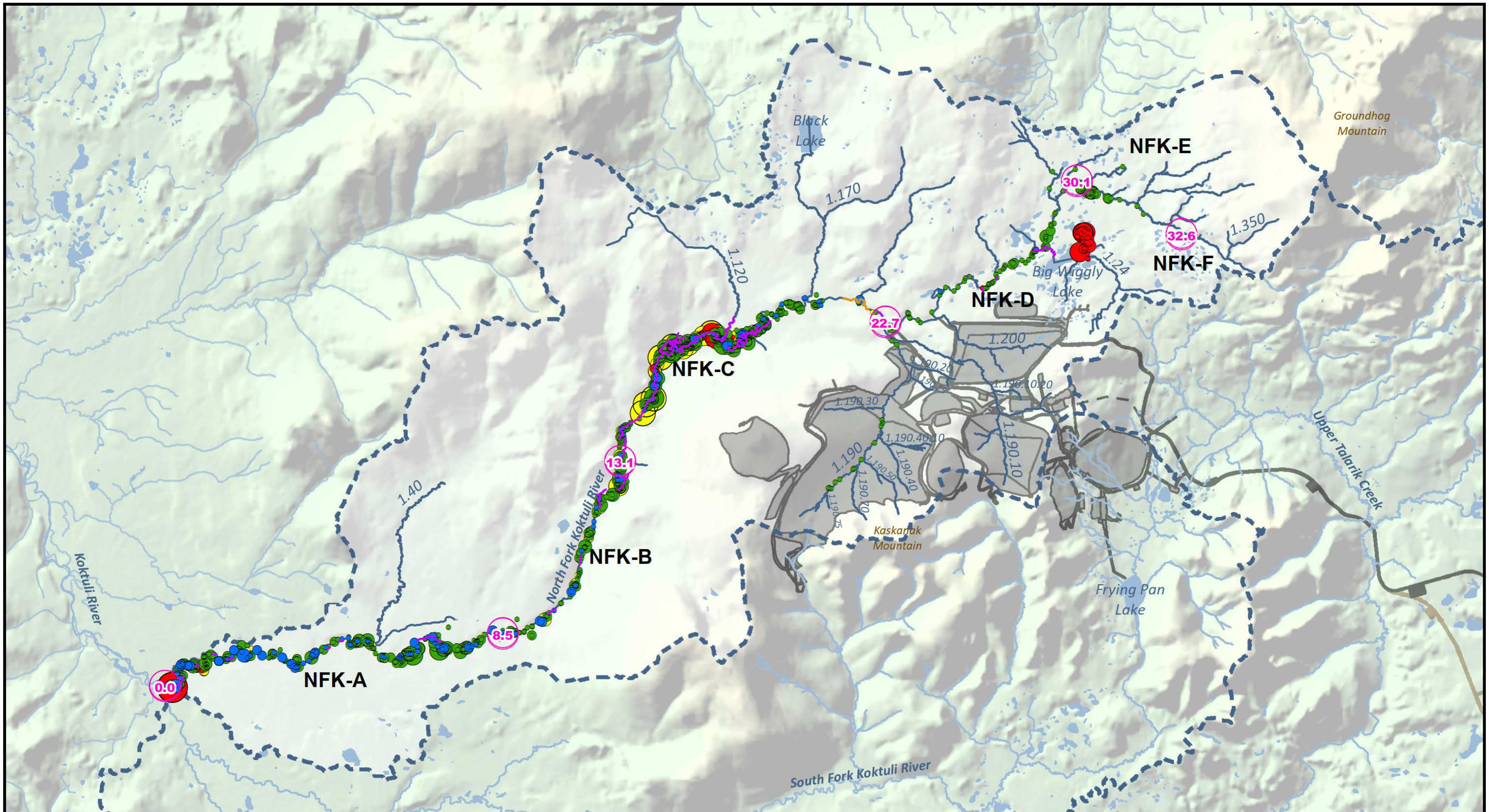
Data from geomorphology studies conducted in NFK-C just downstream of Tributary 1.190 indicate that this reach is influenced by groundwater input from Tributary 1.190 for a length of approximately 2,500 feet, but then transitions to a losing reach of surface flow to groundwater. Pebble count data from that location indicate that substrates consist of 58 percent cobble and 42 percent spawning gravels (R2 el al. 2011a, Appendix 15.1F). Consequently, upper NFK-C is a losing reach with a relatively low percentage of spawning gravel. Accordingly, Figure 3.24-6 shows very few adults in either the gaining reach immediately downstream of Tributary 1.190 or the loosing reach immediately downstream, despite the latter having a high proportion (75 percent) of spawning gravels. Substrate composition 2.5 miles farther downstream has similar substrate composition with 79 percent spawning gravels, and is also in a gaining reach with groundwater expressions. This area immediately downstream of Tributary 1.120 supported the highest densities of adult fish for most salmon species (sockeye, coho, and chum) in the NFK (Figure 3.24-6).

The relative lack of spawning activity in Tributary 1.190 for Chinook and most other salmon species may be due to a combination of limiting habitat characteristics. Visual estimates of spawning gravel concentrations gathered during habitat surveys in Tributary 1.190 indicate that substrate consists of cobbles with 20 percent or less gravels along most of its length, with concentrations increasing to 40 to 60 percent gravels in the lowest reaches just upstream of the confluence with the NFK (R2 el al. 2011a, Appendix 15.1F).

Juvenile Chinook salmon are present year-round in the project area (Table 3.24-5), consisting of three age classes, young-of-the-year (0+), yearlings (1+), and 2+. Surveys have shown highest abundance of rearing juvenile Chinook in the NFK-A mainstem, 15 miles downstream of the NFK Tributary 1.190 and the mine site (Figure 3.24-5). Juvenile Chinook were typically the most common salmon in NFK-A; and the second-most common salmon, after juvenile coho, in NFK-B and NFK-C (R2 et al. 2011a). Mean reach-wide density in 2004-2007 (data combined) was highest in NFK-B at about 31 fish/100 square meters (m^2) (Table 3.24-9). Similarly, in 2008, juvenile Chinook densities were highest in NFK-B (8.8 fish/100 m^2), whereas maximum reach-wide densities in 2009 occurred in NFK-A at more than 18 fish/100 m^2. Note that the mainstem Koktuli River downstream of the NFK/SFK confluence was also sampled over the 2004-2007 time period, when it showed a mean density of 71 fish/100 m^2.

Thirteen index sites were sampled in the NFK mainstem in 2008 and 2009 (Figure 3.24-2). Annual variation in juvenile densities was evident at index sites sampled in 2008 and 2009, which showed higher densities in 2009, with the highest index site density of 73 fish/100 m^2 (Figure 3.24-7). Low numbers (less than 10 fish/100 m^2) of juvenile Chinook were observed in most index sites in 2009, and densities in the mainstem NFK just downstream of the Tributary 1.190 confluence and in the upper mainstem upstream of the mine site were consistently less than 1 fish/100 m^2 in 2008 and 2009. Juvenile Chinook were not observed in Tributary 1.190 proper, but they were identified in two sub-tributaries to 1.190, with an average density of 0.19 fish/100 m^2 in 2008, well below densities observed in lower mainstem index sites. The density of juveniles was estimated in Tributary 1.200 in 2018 at 0.08 fish/100 m^2 (Table 3.24-10, Figure 3.24-2).

Densities of juvenile Chinook in 2008 samples relative to mainstem habitat type in NFK-C were estimated to be highest in run/glide habitats (approximately 8 fish/100 m^2) and lowest in riffles (approximately 1.9 fish/100 m^2), with intermediate densities (approximately 3.5 fish/100 m^2) in pool habitats (R2 et al. 2011a). Likewise, in tributaries Chinook densities were higher in pools (0.5 fish/100 m^2) than in riffles or run/glides (0.28 to 0.06 fish/100 m^2). Overall, juvenile Chinook were more abundant in mainstem habitats (approximately 4.9 fish/100 m^2) than in off-channel or side channel habitats (0.01 to 0.32 fish/100 m^2, respectively).



Sources: PLP 2019-RFI153; USGS; ADF&G; PLP (R2 2008)

US Army Corps of Engineers

1 0 1 2
Miles

Observed Species, Spawning Count

CH; 1 - 5
CH; 6 - 20
CH; 21 - 50
CH; 51 - 100
CH; 101 - 150
CS; 1 - 5
CS; 6 - 20
CS; 21 - 50
CS; 51 - 100
KS; 1 - 5
KS; 6 - 20
KS; 21 - 50
SS; 1 - 5
SS; 6 - 20
SS; 21 - 50
SS; 51 - 100
SS; 151 - 500

Mainstem Reaches with River Mile
Open Water (2006 Survey)
Losing Stream Segment
North Fork Koktuli Studied Streams
Watershed Boundary

Action Alternatives
Alternative 1a
Alternative 1

PACIFIC SALMON SPAWNING DISTRIBUTION, WITH GAINING (OPEN WATER) AND LOSING STREAM REACHES IN THE NORTH FORK KOKTULI SUBBASIN

Figure 3.24-7: Densities (#/100 m²) of juvenile salmon in mainstem NFK index sites by species and year (mainstem Koktuli River data also shown)

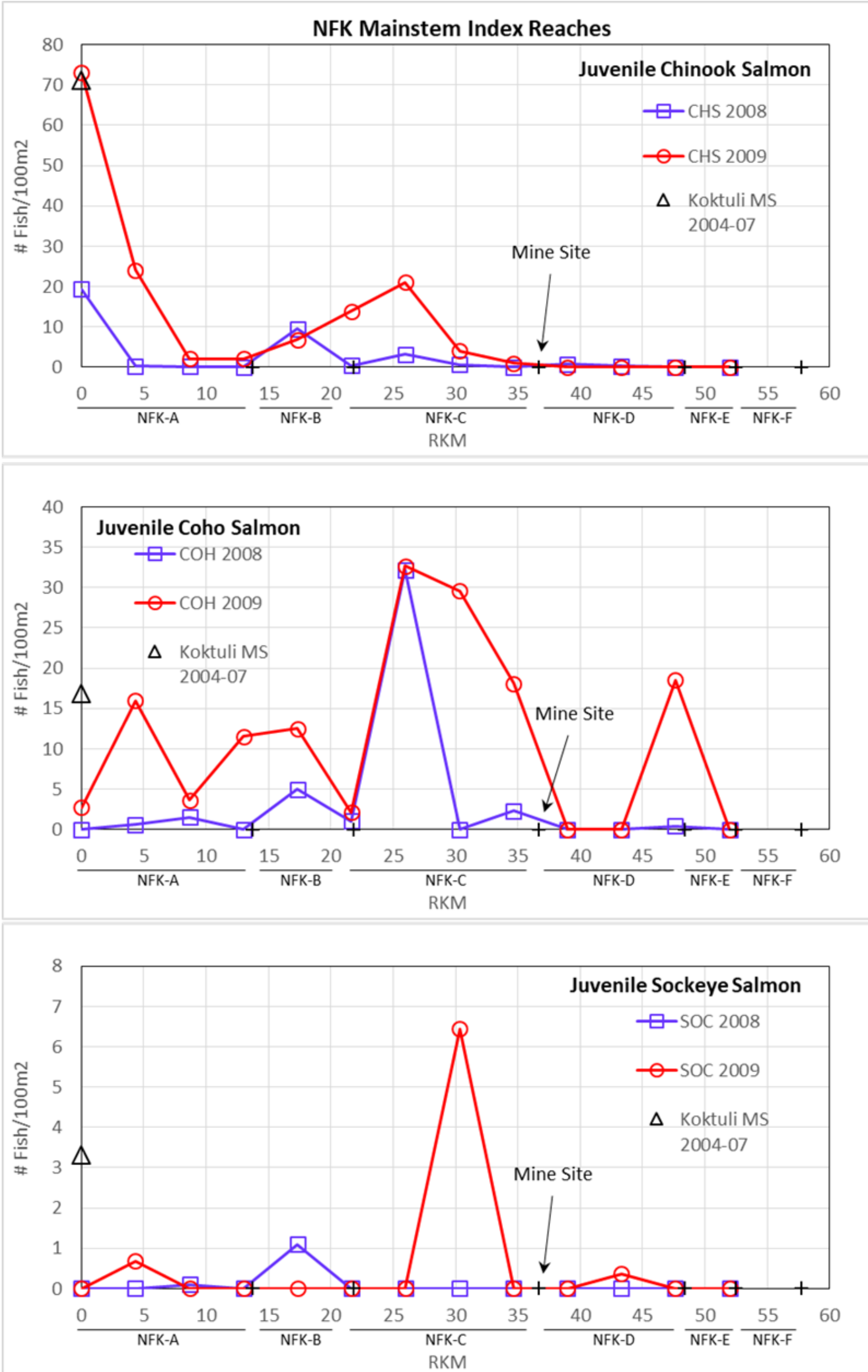


Table 3.24-9: Estimated Densities of Juvenile Pacific Salmon and Juvenile/Adult Resident Fish Species in Mainstem Habitats According to Reach, Year, and Species. Estimated Densities were Less than 1 fish/100 m^2 for all Other Species

Stream Reach	Juvenile Chinook #/100 m^2			Juvenile Coho #/100 m^2			Juvenile Sockeye #/100 m^2		
	2004-2007	2008	2009	2004-2007	2008	2009	2004-2007	2008	2009
Koktuli[1]	71.22	ns	ns	16.85	ns	ns	3.32	ns	ns
NFK-A	1.84	3.77	18.84	17.67	0.52	8.89	0.14	0.03	0.15
NFK-B	30.68	8.77	5.78	34.52	4.60	11.31	0.27	1.18	0.00
NFK-C	2.01	0.88	8.24	28.07	7.19	21.17	0.84	0.00	1.89
NFK-D	ns	0.38	0.00	ns	0.10	2.73	ns	0.00	0.12
NFK-E[1]	ns	0.00	0.00	ns	0.00	0.00	ns	0.00	0.00
SFK-A	24.86	10.62	22.48	37.40	17.02	10.95	1.77	0.28	0.51
SFK-B	0.19	0.16	0.21	6.88	13.75	20.21	0.32	0.48	0.57
SFK-C	0.00	0.00	0.12	0.64	19.77	7.16	0.00	0.35	0.00
SFK-D	0.00	1.39	0.00	2.52	1.85	0.00	0.00	0.00	0.00
SFK-E	0.00	0.00	0.00	1.18	0.19	0.15	0.00	0.00	0.00
UTC-A	ns	0.00	0.38	ns	0.00	1.25	ns	0.00	0.00
UTC-B	ns	17.62	2.65	ns	36.04	46.24	ns	0.14	0.00
UTC-C	11.31	2.26	5.84	67.24	17.10	18.16	2.28	0.00	0.06
UTC-D	3.61	4.64	0.30	48.99	13.72	34.13	0.29	0.00	0.00
UTC-E	4.77	0.15	0.58	42.09	13.24	115.42	1.43	4.12	0.58
UTC-F	1.53	0.00	0.00	123.78	76.30	123.10	0.67	0.00	0.22
UTC-G[1]	0.00	0.00	0.00	0.00	21.53	10.22	0.00	0.00	0.00
Stream Reach	**Rainbow Trout #/100 m^2**			**Dolly Varden #/100 m^2**			**Arctic Grayling #/100 m^2**		
	2004-2007	**2008**	**2009**	**2004-2007**	**2008**	**2009**	**2004-2007**	**2008**	**2009**
Koktuli[1]	0.07	ns	ns	0.20	ns	ns	0.38	ns	ns
NFK-A	0.00	0.00	0.23	0.00	0.74	0.20	0.00	0.52	2.44
NFK-B	0.00	0.00	0.00	0.00	0.14	0.24	0.00	0.21	0.00
NFK-C	0.00	0.00	0.00	0.00	0.10	1.76	6.68	0.26	0.32
NFK-D	ns	0.00	0.00	ns	1.05	0.00	ns	6.01	3.68
NFK-E[1]	ns	0.00	0.00	ns	0.00	0.00	ns	0.00	0.00
SFK-A	0.00	0.03	0.02	3.44	0.03	0.45	0.19	0.08	0.67
SFK-B	0.03	0.00	0.29	0.62	0.64	0.29	2.47	1.53	1.21
SFK-C	0.00	0.00	0.00	0.21	0.82	0.00	6.19	35.31	11.17
SFK-D	0.00	0.00	0.00	0.00	5.55	0.00	45.02	7.86	24.27
SFK-E	0.00	0.00	0.00	0.00	0.00	0.00	7.85	0.75	15.90
UTC-A	ns	0.06	0.11	ns	0.00	0.00	ns	0.00	0.04
UTC-B	ns	10.64	0.21	ns	0.20	0.00	ns	0.61	0.00
UTC-C	0.80	0.00	11.03	0.47	0.00	0.24	32.10	0.06	0.06
UTC-D	0.30	0.45	0.24	0.15	1.22	0.06	1.19	0.39	0.00
UTC-E	0.32	0.15	0.23	0.44	0.15	0.00	0.18	0.29	0.70
UTC-F	0.87	0.00	0.87	0.37	3.35	0.87	0.25	0.16	0.43
UTC-G[1]	0.00	0.00	0.00	7.46	0.00	0.00	0.00	0.00	0.00

Table 3.24-9: Estimated Densities of Juvenile Pacific Salmon and Juvenile/Adult Resident Fish Species in Mainstem Habitats According to Reach, Year, and Species. Estimated Densities were Less than 1 fish/100 m² for all Other Species

Stream Reach	Sculpin #/100 m²			Stickleback sp #/100 m²			Northern Pike #/100 m²		
	2004-2007	2008	2009	2004-2007	2008	2009	2004-2007	2008	2009
Koktuli[1]	0.02	ns	ns	0.07	ns	ns	0.00	ns	ns
NFK-A	0.00	1.31	1.52	0.00	0.00	0.00	0.00	0.00	0.00
NFK-B	0.00	1.25	2.01	0.00	0.00	0.00	0.00	0.00	0.00
NFK-C	0.00	1.35	1.76	0.00	0.00	0.00	0.00	0.00	0.00
NFK-D	ns	6.77	4.15	ns	0.19	0.00	ns	0.10	0.00
NFK-E[1]	ns	0.00	10.00	ns	0.00	0.00	ns	0.00	0.00
SFK-A	0.00	1.13	2.52	0.00	0.00	0.00	0.00	0.00	0.00
SFK-B	0.00	1.05	1.29	0.00	0.00	0.00	0.00	0.00	0.00
SFK-C	4.94	0.94	0.24	0.21	0.00	0.00	0.39	0.47	0.00
SFK-D	19.78	0.92	3.41	0.00	0.00	0.00	1.26	0.46	0.00
SFK-E	9.29	0.38	0.92	0.00	0.00	0.15	2.36	0.57	0.00
UTC-A	ns	0.66	0.15	ns	14.55	7.71	ns	0.00	0.00
UTC-B	ns	1.90	1.96	ns	0.00	0.00	ns	0.00	0.00
UTC-C	13.31	0.26	2.24	0.54	0.00	0.00	0.00	0.00	0.00
UTC-D	3.46	0.97	3.70	0.44	0.00	0.00	0.00	0.00	0.00
UTC-E	7.53	2.06	1.99	0.04	0.00	0.00	0.00	0.00	0.00
UTC-F	28.65	2.55	4.12	0.17	0.00	0.00	0.00	0.00	0.00
UTC-G[1]	16.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Notes:
[1]Reaches outside of analysis area
M² = square miles
NFK = North Fork Koktuli
ns = not sampled
SFK = South Fork Koktuli
UTC = Upper Talarik Creek
Source: PLP 2019–RFI 151

Table 3.24-10: Estimated densities (#/100 m^2) of juvenile salmon and juvenile/adult resident species in tributary habitats in 2008 [1]

Reach	Tributary	Survey Area (m^2)[2]	Juv Chinook	Juv Chum	Juv Coho	Juv Sockeye	Rainbow Trout	Dolly Varden	Arctic Grayling	Sculpin spp.	Stickle-back spp.	Northern Pike
North Fork Koktuli River												
NFK-C	1.190 & Tribs	27,318	0.19	0.00	1.35	0.00	0.30	6.30	0.11	4.12	0.00	0.00
NFK-D	1.200 & Tribs[3]	15,361	0.08	0.00	2.24	0.00	0.00	0.93	0.23	1.72	1.50	0.00
South Fork Koktuli River												
SFK-B	1.190 & Tribs	16,794	0.05	0.00	2.30	0.00	0.18	6.76	2.20	4.65	0.05	0.00
SFK-C	1.240 & Trib	21,502	0.11	0.00	10.11	0.27	0.00	1.35	0.17	2.21	0.42	0.03
SFK-E	1.340	837	0.00	0.00	0.00	0.00	0.00	0.00	0.72	0.60	11.35	0.36
SFK-E	1.370	279	0.00	0.00	0.00	0.00	0.00	0.00	1.43	9.67	0.00	2.51
Upper Talarik Creek												
UT-C	1.190	1,134	0.00	0.00	0.88	0.00	0.00	3.44	0.09	0.00	0.00	0.00
UT-F	1.410 & Tribs	2,574	0.00	0.00	40.71	0.00	0.00	8.62	0.00	1.01	0.31	0.00
UT-F	1.440	60	0.00	0.00	0.00	0.00	0.00	3.35	0.00	0.00	0.00	0.00
UT-F	1.460	816	0.00	0.00	15.68	0.00	0.00	0.00	0.00	4.41	0.00	0.00

Notes:

[1] Densities of burbot, lamprey, and whitefish zero in all listed tributaries

[2] Includes density estimate for highest species-specific count per habitat sampled by electrofishing and snorkeling only

[3] NFK tributary 1.200 densities from 2018 sampling

Juv = juvenile

M^2 = square miles

Trib(s) = tributary(ies)

Source: RFI 151

Sockeye Salmon

Adult sockeye have been documented entering the NFK as early as July 5, with peak documented adult counts occurring in a 1-week window between July 27 and August 4 (R2 et al. 2011a). Annual counts of sockeye in index reaches were relatively consistent between years, with densities of 25 to 40 fish/km in 2005-2008, with 12.5 fish/km in 2004 (Table 3.24-6). Adult sockeye were most abundant in the mainstem NFK downstream of the mine site, with maximum densities in 2008 of 313 fish/km in NFK-A and 131 fish/km in NFK-C (Table 3.24-8). Sockeye also showed local high densities in the lower half of NFK-C, where both emerging groundwater and an abundance of spawning gravel are present. Substantial numbers (>100) of adult sockeye were observed upstream of the mine site in 2008; these fish were all associated with Tributary 1.240 and the Big Wiggly Lake complex (Table 3.24-7, Figure 3.24-6).

Juvenile sockeye salmon were observed in April, July, and August (R2 et al. 2011a). Based on length frequency distributions, these juveniles were young-of-the-year fish. Relative abundance of juvenile sockeye was low (±1 percent) throughout the NFK (Figure 3.24-5). Although some juveniles may rear in-river all year (Table 3.24-5), the low densities suggest many juveniles migrate downstream soon after emergence (Morrow 1980; Quinn 2018). Observed mean densities of juvenile sockeye in mainstem NFK reaches were highest in NFK-C in 2004-2007 and in 2009, and highest in NFK-B in 2008, although all densities were less than 2 fish/100 m^2 (Table 3.24-9). In comparison, the mainstem Koktuli River showed a higher mean density of 3.3 juvenile sockeye/ 100 m^2 in 2004-2007. Densities remained less than 1 fish/100 m^2 at index sites (Figure 3.24-2) from 2008 to 2009, except at one site in NFK-C in 2009, where 6 juveniles/100 m^2 were observed (Figure 3.24-7). Juvenile sockeye were not reported in sampled tributaries to the NFK in 2008 (Table 3.24-10). The low densities of juvenile sockeye in mainstem and tributary reaches prevents assessment of detailed habitat type relationships, although in 2008 sampling in NFK-C, juvenile densities in mainstem habitats were about twice the density of juveniles in off-channel or side-channel habitats (approximately 0.37 versus 0.16 to 0.18 fish/100 m^2) (R2 et al. 2011a).

Coho Salmon

Adult coho salmon have been documented entering the NFK as early as August 15, with peak documented adult counts occurring between September 5 and September 28 (R2 et al. 2011a). Adult coho densities in NFK index sites were highest in 2006 (24 fish/km) and in 2008 (31 fish/km), with minimum densities less than 10 fish/km in 2005 and 2007 (Table 3.24-6). In contrast to Chinook and sockeye salmon, adult coho densities in 2008 were higher in NFK-C (176 fish/km) than in NFK-B (101 fish/km) or NFK-A (85 fish/km). Although adult densities were highest in NFK-C, very few adults were observed in the upper 2 miles closest to the mine site, likely due to lower availability of gravel substrates and/or loss of surface water to groundwater. Also in contrast to the other Pacific salmon species, coho were regularly observed in mainstem reaches NFK-D and NFK-E upstream of the mine site (Table 3.24-8, Figure 3.24-6), and were also observed in several tributaries to the NFK, including Tributary 1.190 (Table 3.24-7).

Juvenile coho salmon are present year-round in the project area, consisting of four age classes: young-of-the-year (0+), yearlings (1+), 2+, and 3+ age; with the preponderance of young–of-the-year overwintering and outmigrating as 1+ fish. Juvenile coho were the most common Pacific salmon inhabiting each of the mainstem reaches of the NFK basin, except NFK-A (Figure 3.24-5). Estimated mean densities of juvenile coho in mainstem reaches were highest in the 2004-2007 period, with densities of 28 to 34 fish/100 m^2 in NFK-B and C, but were less than 10 fish/100 m^2 in all reaches in 2008 (Table 3.24-9). In 2009, juvenile coho were relatively abundant in NFK-C at 21 fish/100 m^2, but densities were low (less than 3 fish/100 m^2) in mainstem reaches upstream of the mine site in all years. Comparison of densities at index sites between 2008 and 2009 showed consistently higher densities in 2009, with a maximum of approximately 30 fish/100 m^2 in the lower and middle sections of NFK-C (Figure 3.24-7), where emerging groundwater is abundant (Figure 3.24-2). Juvenile coho density in the mainstem Koktuli River in 2004-2007 was 17 fish/ 100 m^2, which was generally similar to densities observed in NFK reaches in most years.

Juvenile coho were consistently more abundant in tributary habitats than were other Pacific salmon, but densities were much lower in tributaries than in mainstem index reaches (Table 3.24-10). In Tributary 1.190 and its sub-tributaries, juvenile coho averaged 1.35 fish/ 100 m^2 in 2008, with slightly higher densities (2.24 fish/100 m^2) observed in Tributary 1.200 in 2018. Comparison of juvenile coho densities by mainstem habitat type in NFK-C showed highest densities in pools (up to approximately 93 fish/100 m^2) and lowest in riffles (approximately 14 fish/ 100 m^2), with intermediate densities (approximately 35 fish/100 m^2) in run/glide habitats (R2 et al. 2011a). Juvenile coho were observed at higher densities in side-channel habitats (approximately 50 fish/100 m^2) than in mainstem habitats (25 fish/100 m^2) or off-channel habitats (9 fish/100 m^2) (R2 et al. 2011a). In tributaries, juvenile coho densities were primarily less than 5 fish/100 m^2, and were higher in pools and run/glides than in riffles.

Chum Salmon

Adult chum salmon have been documented entering the NFK as early as July 5, with peak documented fish counts occurring between July 12 and July 20. Adult counts in index sites showed highest spawner densities of 32 fish/km in 2008, with all counts from 2004-2007 less than 20 fish/km (Table 3.24-6). Aerial surveys in 2008 showed that chum salmon, like coho salmon, were most abundant in NFK-C (147 fish/km), with densities of 25 to 35 fish/km in downstream Reaches NFK-A and NFK-B (Table 3.24-8). Also like coho salmon, chum salmon appeared to avoid the upper portion of NFK-C near the mine site; instead, their distribution was highly restricted to the lower half of that reach where groundwater emergence was most evident (Figure 3.24-6). Chum salmon adults were not observed in any tributaries to the NFK during extensive aerial surveys in 2008, although they were observed to use limited tributary habitat in the SFK and UTC.

Juvenile chum salmon were not commonly encountered in any of the three main tributaries, likely due to their life-history pattern of limited stream rearing and early downstream emigration after emergence (Quinn 2018). Observed densities of juvenile chum salmon in the NFK-C mainstem in 2008 were less than 0.1 fish/100 m^2 in all habitat types, and juveniles were not observed in off-channel or side-channel habitats (R2 et al. 2011a). Juvenile chum were observed in the two lower reaches during 2004-2007 sampling, at densities less than 1 fish/100 m^2.

Resident Fish Species

As noted previously, a variety of resident fish species occupy the NFK and its tributaries (Figure 3.24-5, Table 3.24-10). Based on environmental baseline studies, Dolly Varden were the most widely distributed resident salmonid species, although average mainstem densities were less than 2 fish/100 m^2 in all study sites in each year of study, with somewhat higher densities (up to 4 fish/100 m^2) in individual index sites (Table 3.24-9, Figure 3.24-8). Dolly Varden were also distributed farther upstream in headwater tributaries than any other salmonid species, with observed densities in Tributary 1.190 and Tributary 1.200 averaging 6.3 and 0.9 fish/100 m^2, respectively, with maximum densities up to more than 27 fish/100 m^2 (R2 et al. 2011a). Arctic grayling densities were typically low; however, some sample sites contained numerous fish and mean reach densities exceeded 6 fish/100 m^2 in NFK-C in 2004-2007 and in NFK-D in 2008, with a maximum index site density of 14 fish/100 m^2 in NFK-D just upstream of the mine site. Arctic grayling were observed in low densities in Tributary 1.190 (0.11 fish/100 m^2) and its sub-tributaries in 2008, with slightly higher grayling densities (0.23 fish/100 m^2) in Tributary 1.200 in 2018. Rainbow trout were observed at several locations in the mainstem NFK downstream of the mine site, as well as in NFK Tributary 1.190 (but not in Tributary 1.200); however, their relative abundance was low (less than 0.3 fish/100 m^2) compared to other salmonids. In general, estimated densities of rainbow trout and Dolly Varden were higher in NFK tributaries than in mainstem reaches, whereas grayling were more abundant in the mainstem. Of all fish species, sculpin were the most widespread; and in most cases, were likely the most abundant fish, although most sampling methods would underestimate sculpin abundance. Sticklebacks were also observed at many mainstem and tributary study sites, and northern pike were observed in the NFK-D mainstem; likely fish that emigrated from Big Wiggly Lake.

Table 3.24-11 lists all resident fish species known to occur in the analysis area for all project components.

South Fork Koktuli River

The relative distribution and composition of anadromous and resident species, based on AWC (Johnson and Blossom 2018) and EBD data (R2 et al. 2011a), are shown on Figure 3.24-9. Chinook, coho, sockeye, and chum salmon have been documented in the SFK watershed (Johnson and Blossom 2018); however, pink salmon have not been reported in the SFK. Resident fish species documented in the SFK watershed include rainbow trout, Dolly Varden, Arctic grayling, lamprey (Arctic, *Lethenteron camtschaticum*, or Alaskan brook, *L. alaskense* [species not specified]), threespine and ninespine stickleback, sculpin (may include slimy and/or coastrange sculpin), northern pike, whitefish (round whitefish, humpback whitefish, and/or least cisco), and burbot (*Lota lota*) (R2 et al. 2011a). Of these, Dolly Varden, Arctic grayling, and sculpin are the most widely distributed. Arctic char have also been documented in the SFK; however, recent fish surveys did not encounter this species (R2 et al. 2011a). Overall, the SFK supports more fish species than either the NFK or UTC. The approximate stream mileage listed in the AWC (Johnson and Blossom 2018) for anadromous species and rainbow trout in the SFK analysis area by life-stage is given in Table 3.24-4. Periodicity of salmon and resident fish life-history stages (Table 3.24-5) in the SFK are similar to that described for the NFK.

Chinook Salmon

Annual differences in adult Chinook counts in SFK index reaches reflected results from the NFK, with highest densities in 2004 (82.5 fish/km) and 2005 (30.3 fish/km) and lower densities (7.1 to 13.5 fish/km) in 2006 and 2007(Table 3.24-6). Comparison of 2008 counts between reaches showed that adults were most abundant at 52 fish/km in the lowest reach (SFK-A) just upstream of the confluence with the NFK (Figure 3.24-10), with 31 fish/km in SFK-B (Table 3.24-8). No adult Chinook were observed in upstream reaches or in any surveyed tributaries during the 2008 surveys (Table 3.24-7).

Juvenile Chinook salmon were commonly observed in mainstem habitats in SFK-A (Figure 3.24-9), with densities ranging from 10.6 fish/100 m^2 in 2008 to more than 20 fish/100 m^2 in 2004-2007 and 2009 (Table 3.24-9); however, these densities were much lower than those observed in the mainstem Koktuli River (71 fish/100 m^2). In contrast, densities were mostly less than 1 fish/100 m^2 in the remaining mainstem reaches in all years, and juvenile Chinook were not observed in SFK-E closest to the mine site. Fifteen index sites were sampled in the SFK mainstem in 2008 and 2009 (Figure 3.24-3). Comparison of juvenile densities from those index sites showed the same trend (Figure 3.24-11), with mostly higher densities in 2009 and almost 100 fish/100 m^2 in the index site just 5 kilometers upstream from the NFK confluence (Figure 3.24-3). Juvenile Chinook were observed in two SFK tributaries draining the mine site in 2008 (1.190 and 1.240), but at densities of only 0.05 to 0.11 fish/100 m^2 (Table 3.24-10), well below densities observed in the lower SFK or the mainstem Koktuli River (Table 3.24-9). In general, Chinook abundance was generally higher in pool and run/glide habitats than in riffle habitat, and likewise were more abundant in mainstem habitats than in off-channel habitats (R2 et al. 2011a).

Figure 3.24-8: Densities (#/100 m^2) of Juvenile Plus Adult Resident Salmonids in Mainstem NFK, SFK, and UTC Index Sites by Species and Year

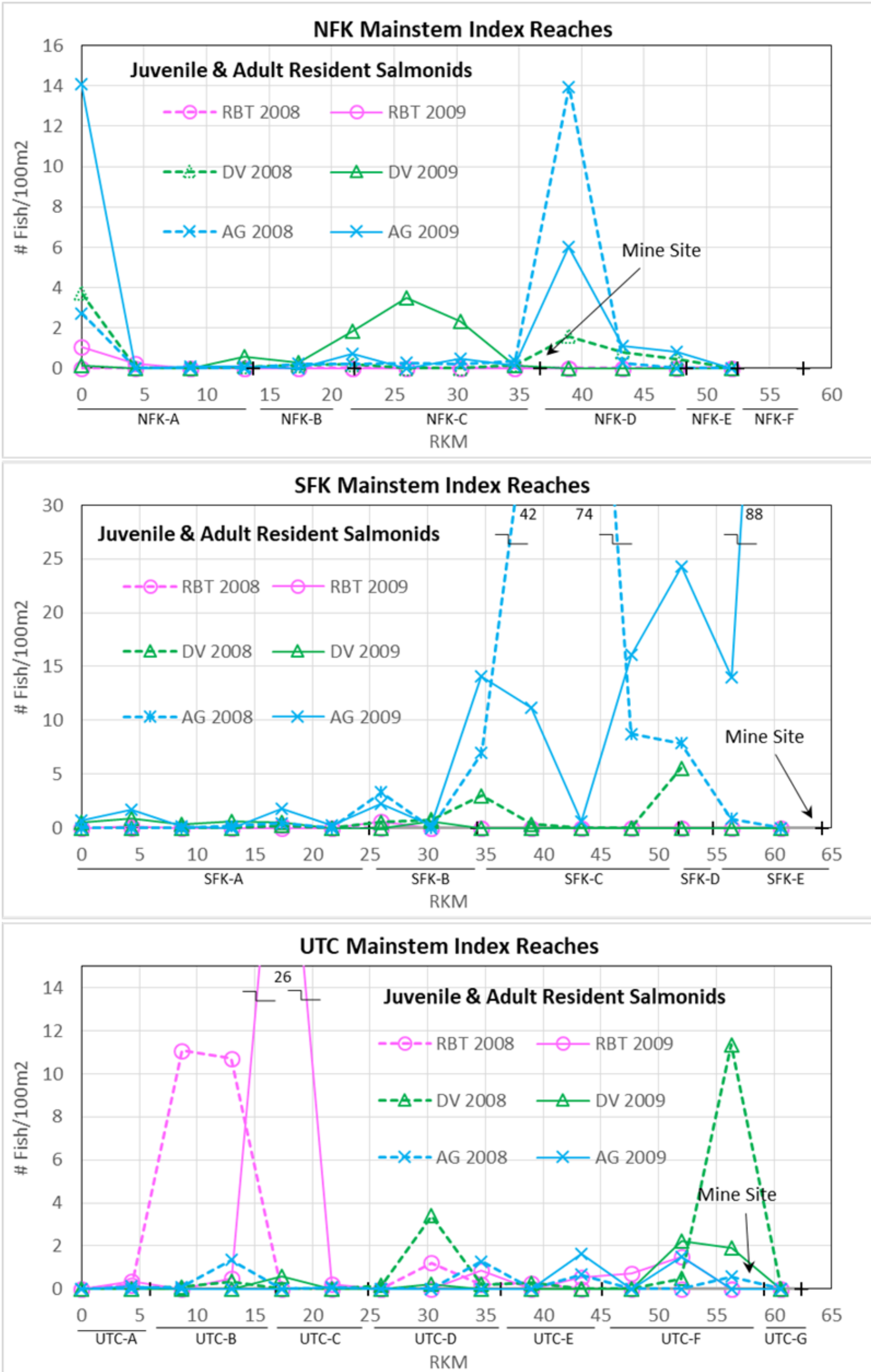
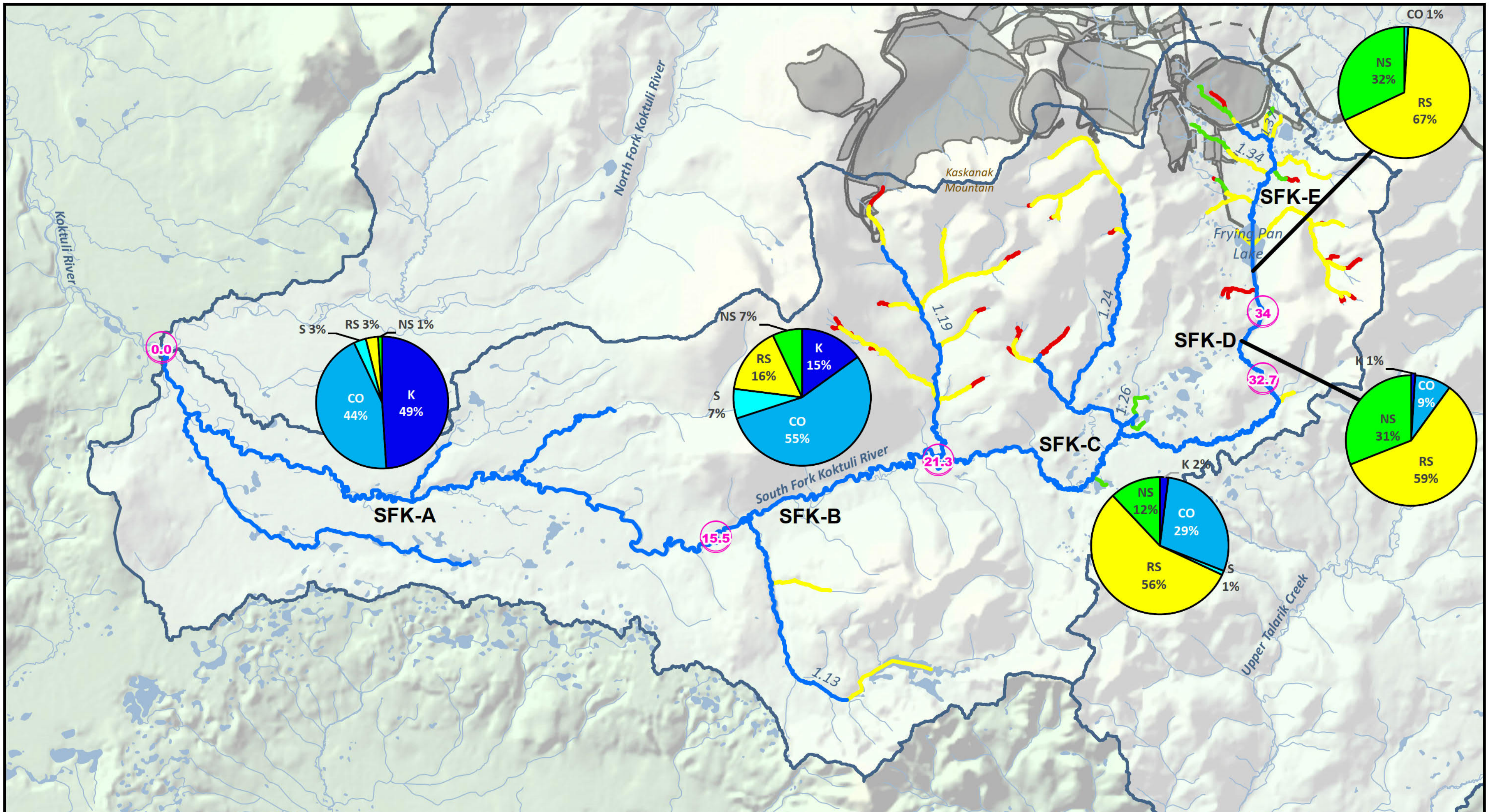


Table 3.24-11: Freshwater Resident Fish and Pacific Salmon Species Known to Occur in the Fish Values Analysis Area

Scientific Family/ Common Family Name	Common Name	Scientific Name	Principal Migratory Patterns	Documented in Project Environmental Baseline Studies
Petromysontidae/ lampreys	Arctic Lamprey	*Lethenteron camtschaticum*	Anadromous	Not identified to species in the field
	Alaskan Brook Lamprey	*Lethenteron alaskense*	Non-anadromous	Not identified to species in the field
Catostomidae/suckers	Long Nose Sucker	*Catostomus catostomus*	Non-anadromous	Y
Esocidae/pikes	Northern Pike	*Esox Lucius*	Non-anadromous	Y
Umbridae/ mudminnows	Alaska Blackfish	*Dallia pectoralis*	Non-anadromous	Y
Osmeridae/smelts	Rainbow smelt	*Osmerus mordax*	Anadromous	N
	Pond smelt	*Hypomesus olidus*	Non-anadromous	Y
Salmonidae/salmonids	Humpback whitefish	*Coregonus pidschian*	Non-anadromous and potentially anadromous	Y
	Least cisco	*Coregonus sardinelia*	Non- anadromous and anadromous	Y
	Pygmy whitefish	*Prosopium coulterii*	Non- anadromous	Y
	Round whitefish	*Prosopium cylindraceum*	Non- anadromous	Y
	Rainbow trout	*Oncorhynchus mykiss*	Non- anadromous in Bristol Bay	Y
	Arctic Char	*Salvelinus alpinus*	Non- anadromous	Y
	Dolly Varden	*Salvelinus malma*	Non- anadromous and anadromous	Y
	Lake trout	*Salvelinus namaycush*	Non-anadromous	Y
	Arctic grayling	*Thymallus arcticus*	Non-anadromous	Y
	Chinook salmon	*Oncorhynchus tshawytscha*	Anadromous	Y
	Coho salmon	*Oncorhynchus kisutch*	Anadromous	Y
	Chum salmon	*Oncorhynchus keta*	Anadromous	Y
	Pink salmon	*Oncorhynchus gorbuscha*	Anadromous	Y
	Sockeye salmon	*Oncorhynchus nerka*	Anadromous	Y
Gadidae/cods	Burbot	*Lota lota*	Non-anadromous	Y
Gasterosteidae/ sticklebacks	Threespine Stickleback	*Gasterosteus aculeatus*	Non- anadromous and anadromous	Y
	Ninespine Stickleback	*Pungitius pungitius*	Non-anadromous	Y
Cottidae/sculpins	Coastrange sculpin	*Cottus aieuticus*	Non-anadromous	Y
	Slimy sculpin	*Cottus cognatus*	Non-anadromous	Y

Note:
Y = Yes
Source: Woody 2018



Sources:PLP 2019-RFI153; USGS;
ADF&G AWC & AFFI; PLP (R2 et al. 2011)

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1 0 1 2
Miles

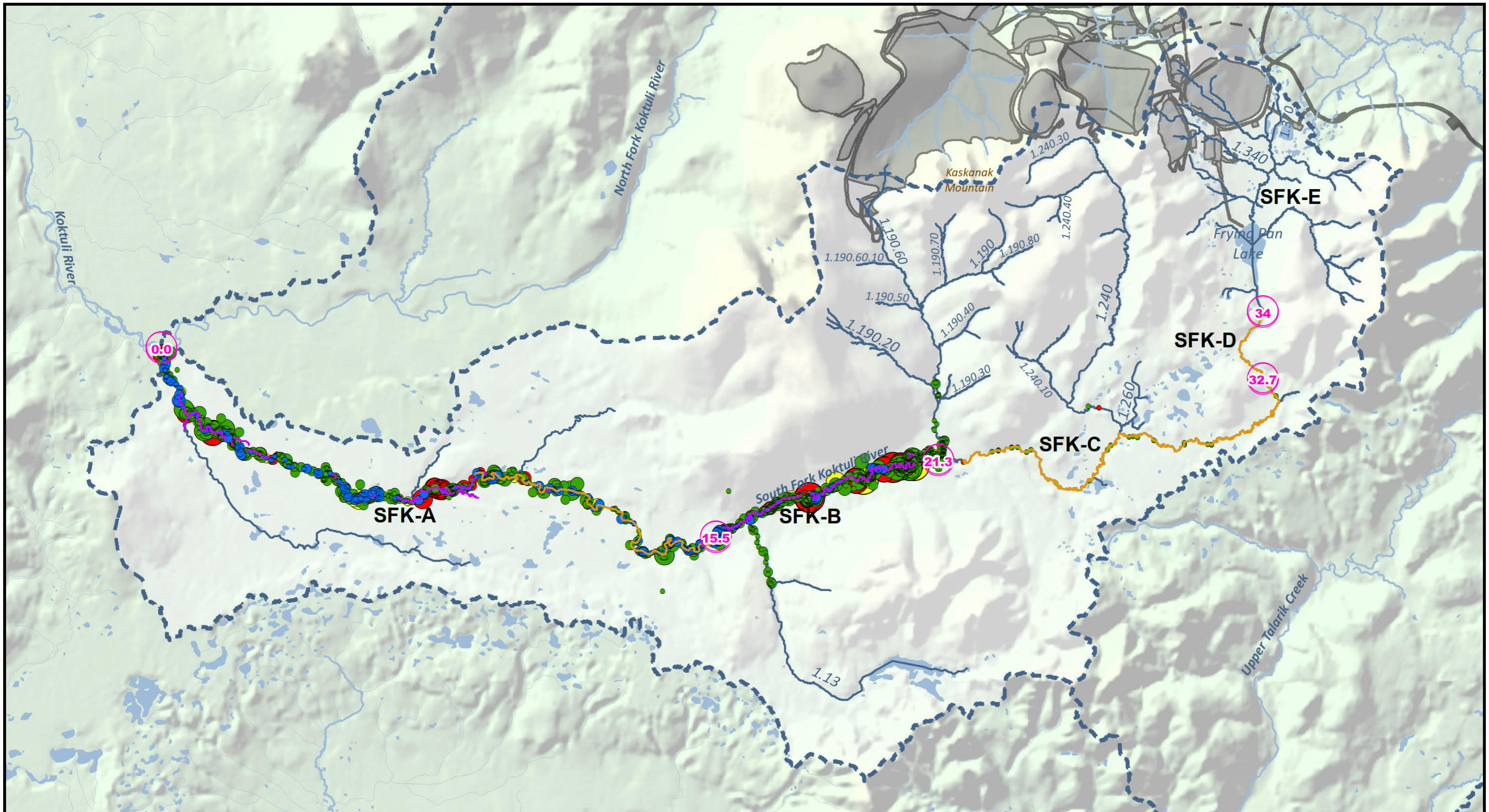
Fish Distribution and Relative Composition

- Anadromous Salmonids (K=Chinook, CO=Coho, S=Sockeye)
- Resident (non-anadromous) Salmonids (RS)
- Non-Salmonid Fish (NS)
- No Fish Observed
- Mainstem Reaches with River Mile
- Water Basin
- Alternative 1a

FISH DISTRIBUTION AND RELATIVE COMPOSITION IN THE SOUTH FORK KOKTULI SUBBASIN

PEBBLE PROJECT EIS

FIGURE 3.24-9



Sources: PLP 2019-RFI153; USGS; ADF&G; PLP (R2 2008)

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N

1 0 1 2

Miles

Observed Species, Spawning Count

- CH; 1 - 5
- CH; 6 - 20
- CH; 21 - 50
- CH; 51 - 100
- CH; 151+
- CS; 1 - 5
- CS; 6 - 20
- CS; 21 - 50
- CS; 51 - 100
- CS; 101 - 150
- KS; 1 - 5
- KS; 6 - 20
- KS; 21 - 50
- SS; 1 - 5
- SS; 6 - 20
- SS; 21 - 50
- SS; 51 - 100
- SS; 101 - 150
- SS; 151 - 500

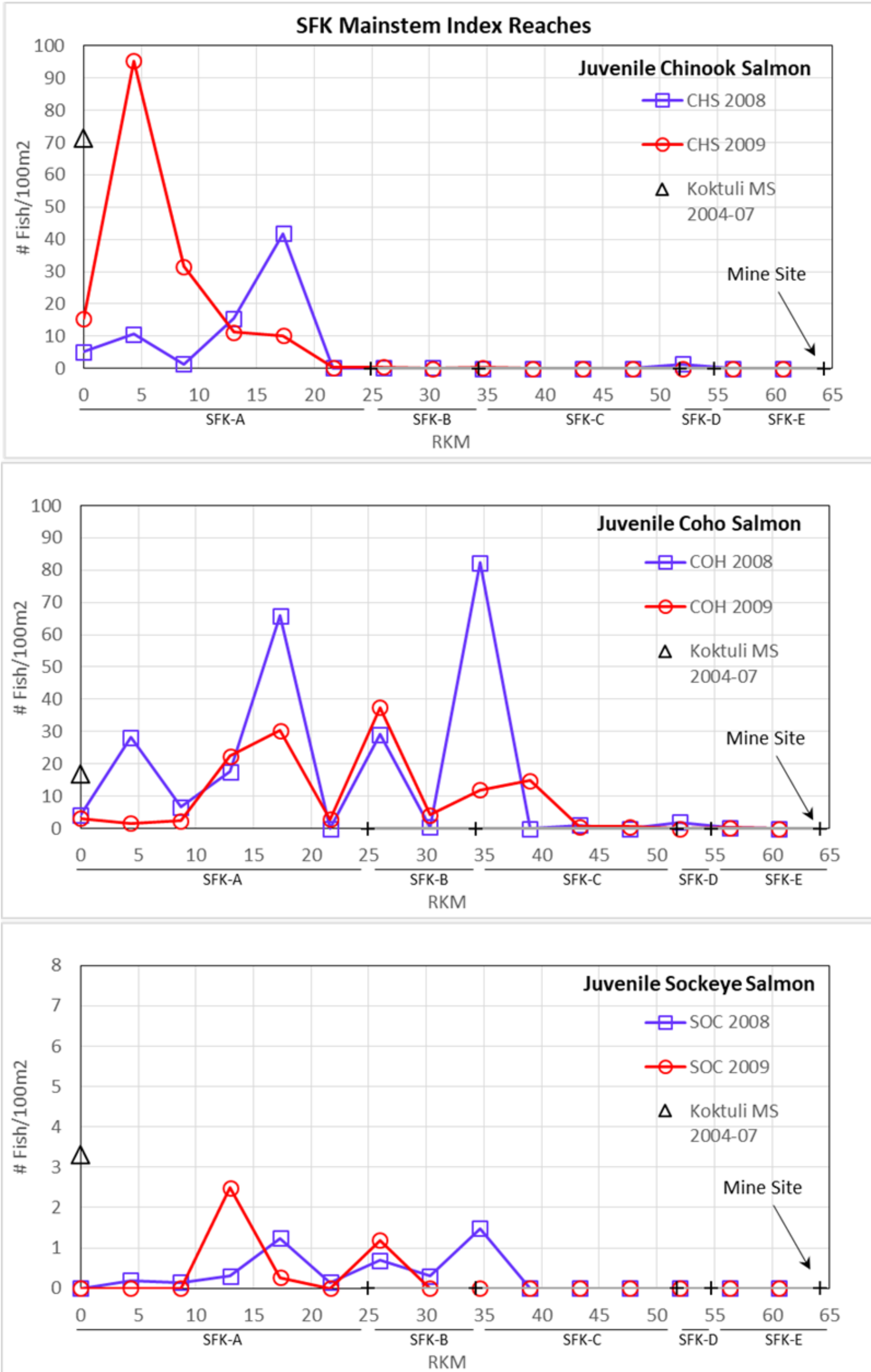
- Mainstem Reaches with River Mile
- Open Water (2006 Survey)
- Losing Stream Segment
- South Fork Koktuli Studied Streams
- Watershed Boundary
- Alternative 1a

PACIFIC SALMON SPAWNING DISTRIBUTION, WITH GAINING (OPEN WATER) AND LOSING STREAM REACHES IN THE SOUTH FORK KOKTULI SUBBASIN

PEBBLE PROJECT EIS

FIGURE 3.24-10

Figure 3.24-11: Densities (#/100 m^2) of Juvenile Salmon in Mainstem SFK Index Sites by Species and Year



Sockeye Salmon

Adult sockeye salmon were commonly observed in the lower two reaches of the SFK, with densities in index sites progressively increasing from 41 to 48 fish/km in 2004 and 2005 to 140 fish/km in 2008 (Table 3.24-6). Adult sockeyes in 2008 were most heavily concentrated in the upper portion of SFK-B in the region of rising groundwater (Figure 3.24-10), where adult densities exceeded 1,300 fish/km (Table 3.24-8). Adult sockeye in SFK-A occurred at lower densities (295 fish/km), but also appeared to be distributed in regions of groundwater influence. In 2008, a single adult sockeye was observed in a tributary to the SFK (Table 3.24-7).

Juvenile sockeye were observed in mainstem habitats in SFK-A and SFK-B in each year of study, and in SFK-C in 2008 (Figure 3.24-9) but were rarely observed in mainstem or tributary reaches farther upstream (Table 3.24-9 and Table 3.24-10). Juvenile densities were mostly less than 2 fish/100 m^2 in mainstem index reaches in both 2008 and 2009 (Figure 3.24-11) and appeared to be similarly distributed among pool, run/glide, and riffle habitats (R2 et al. 2011a). Likewise, juvenile sockeye abundance in 2004-2007 was similar between mainstem, off-channel, and side-channel habitats (R2 et al. 2011a). Sampling in 2004-2007 showed higher densities (3 fish/100 m^2) in the mainstem Koktuli River. Although juvenile sockeye have been captured in Frying Pan Lake (Figure 3.24-3), densities were very low, likely due in part to the robust population of large northern pike inhabiting the lake (R2 et al. 2011a; Johnson and Blossom 2018).

Coho Salmon

Coho salmon are the most widely distributed of the Pacific salmon species in the project area and were observed as adults or juveniles in all five reaches of the mainstem SFK, as well as in numerous tributaries (Figure 3.24-9). The relative abundance of adult coho in mainstem index sites between years closely mirrored the results in the NFK, with highest abundance in 2006 and 2008 at 34 to 39 fish/km (Table 3.24-6), and lowest abundance in 2004 and 2007 (less than 6 fish/km). As for sockeye (and chum) salmon, coho adults were most abundant in the upper portion of SFK-B in the region of rising groundwater, although adult coho were also common in groundwater-influenced portions of SFK-A (Figure 3.24-10). Adult densities in 2008 in the two lower reaches were 95 fish/km in SFK-A and 350 fish/km in SFK-B (Table 3.24-8). Approximately 50 adults were also observed that year in SFK Tributaries 1.130 and 1.190, with a single adult in Tributary 1.240 (Table 3.24-7).

No anadromous fish were documented in channels in the open pit area and associated sediment pond area during sampling in 1991, 2004, or 2008, although coho juveniles were observed in mainstem SFK-E immediately downstream of the southern edge of the open pit and associated service road in a 2008 survey (R2 et al. 2011a). Densities of juvenile coho in mainstem SFK habitats varied between years, with highest densities in SFK-A in 2004-2007 (37 fish/100 m^2), and lowest densities (mostly less than 2 fish/100 m^2) in SFK-D and SFK-E (Table 3.24-9). Index sites generally showed higher densities in 2008 than in 2009, with one site in SFK-A and another site in SFK-B showing densities from about 60 fish to 80 fish/100 m^2 (Figure 3.24-11). Estimated densities in the mainstem Koktuli River in 2004-2007 were similar to or lower than most densities recorded in the lower reaches of the SFK. Coho densities in SFK tributaries draining the mine site averaged 2.3 fish/100 m^2 in Tributary 1.190 and 10.11 fish/100 m^2 in Tributary 1.240 (Table 3.24-10). Coho densities in upper SFK tributaries were zero or near zero, suggesting either lack of proximal spawning activities or spawning habitat, or marginally suitable juvenile rearing habitat. Reach SFK-E is upstream of Frying Pan Lake, which supports a population of piscivorous northern pike. Although juvenile coho are known to occupy beaver-formed and other off-channel habitats (Nickelson et al. 1992; Pollock et al. 2004; Swales and Levings 1989), summer sampling in SFK-B showed higher densities of juveniles in mainstem habitats compared to off-channel and side-channel habitats (R2 et al. 2011a). Juveniles were also widely distributed between pool, riffle, and run/glide habitats in both mainstem and tributary sample sites.

Chum Salmon

Chum salmon were generally less common in the SFK than were other species of Pacific salmon (Figure 3.24-9), with annual densities of adult chum in index reaches ranging from 3 fish/km in 2007 to 24 fish/km the previous year (Table 3.24-6). As noted for chum salmon in the NFK, adults in the SFK were heavily concentrated in one location where rising groundwater is abundant (near the top of SFK-B), which is where coho and sockeye also spawned (Figure 3.24-10). Chum salmon adults also targeted areas of emerging groundwater in the lower reaches of SFK-A. Estimated densities in 2008 were highest in SFK-B at 117 fish/km, with 24 fish/km in SFK-A (Table 3.24-8). A few chum salmon adults were observed in SFK-C just upstream of Tributary 1.190, as well as in the tributary itself (Table 3.24-7).

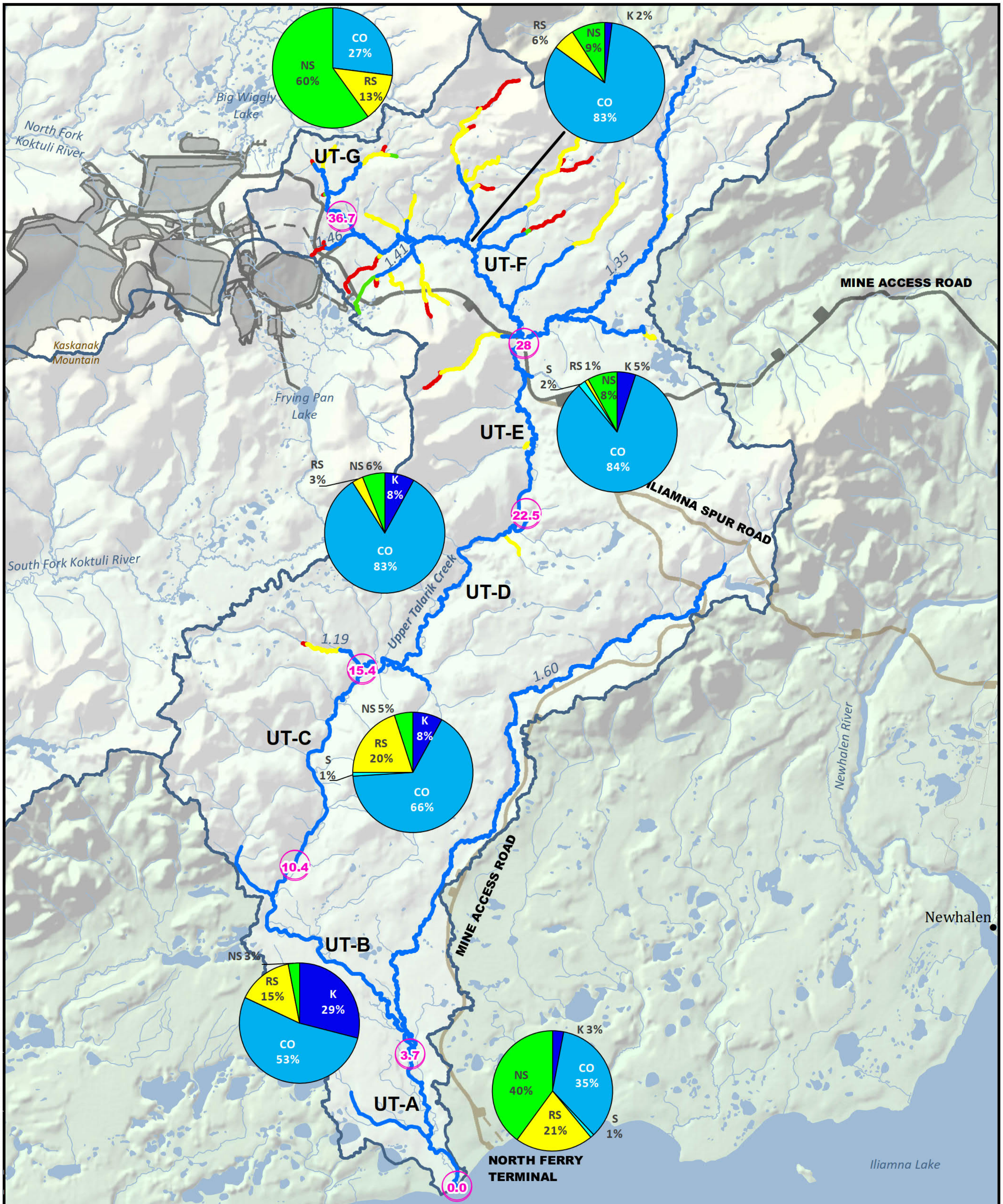
Juvenile chum salmon typically outmigrate at a very early age, and consequently, few juveniles were observed in the SFK mainstem or its tributaries (Table 3.24-9 and Table 3.24-10). Observed abundance of chum salmon juveniles were too low to assess relationships between fish densities and years, habitat types, or channel locations.

Resident Fish Species

Resident fish species were common throughout the SFK basin, with Dolly Varden, Arctic grayling, and sculpin occupying mainstem reaches up to the highest headwater habitats (Figure 3.24-9). Estimated densities of Dolly Varden at mainstem index sites were consistently less than 5 fish/100 m^2, whereas Arctic grayling in upper SFK mainstem reaches sometimes exceeded 40 fish/100 m^2 and were generally more abundant in the SFK than in the NFK and UTC basins (Table 3.24-9, Figure 3.24-8). Although grayling outnumbered Dolly Varden in mainstem reaches, Dolly Varden were generally more abundant and widespread in the lower tributary reaches (Table 3.24-10), with mean densities of 1.35 fish/100 m^2 in Tributary 1.240 and 6.76 fish/100 m^2 in Tributary 1.190 (R2 et al. 2011a). Grayling tended to outnumber Dolly Varden in tributaries higher in the SFK basin, but at densities less than 2 fish/100 m^2). Both species appeared more common in main-channel habitats than in off-channel or side-channel habitats (R2 et al. 2011a). Rainbow trout were observed in only one tributary to the lower SFK (Tributary 1.190), and were occasionally observed in SFK-A and SFK-B, but at densities less than 1 fish/100 m^2. Northern pike were commonly observed, although at low densities (less than 5 fish/100 m^2), in SFK-D and SFK-E, which bracket Frying Pan Lake, and in tributaries above the lake (R2 et al. 2011a).

Upper Talarik Creek

The relative distribution and composition of anadromous and resident fish species, based on AWC data (Johnson and Blossom 2018) and EBD surveys (R2 et al. 2011a), are shown on Figure 3.24-12. In addition to the four species of Pacific salmon found in the NFK and SFK, the UTC also contains an intermittent run of pink salmon in the lower reaches. The UTC is also known as important habitat for large, adfluvial rainbow trout. Other resident species found in the UTC include Dolly Varden, Arctic grayling, whitefish (may include round whitefish, humpback whitefish, and/or least cisco), sculpin (may include slimy and/or coastrange sculpin) and two species of stickleback (i.e., threespine and ninespine). Arctic char have been documented in the UTC; however, no Arctic char were observed in EBD surveys (R2 et al. 2011a). The approximate stream mileage listed in the AWC (Johnson and Blossom 2018) for anadromous species and rainbow trout in the UTC by life-stage is listed in Table 3.24-4.



Sources:PLP 2019-RFI153; USGS; ADF&G AWC & AFFI; PLP (R2 et al. 2011)

US Army Corps of Engineers®

1 0 1 2

Miles

Fish Distribution and Relative Composition

- Anadromous Salmonids (K=Chinook, CO=Coho, S=Sockeye)
- Resident (non-anadromous) Salmonids (RS)
- Non-Salmonid Fish (NS)
- No Fish Observed

Mainstem Reaches with River Mile

Water Basin

Action Alternatives

- Alternative 1a
- Alternative 1

FIGURE 3.24-12

FISH DISTRIBUTION AND RELATIVE COMPOSITION IN THE UPPER TALARIK SUBBASIN

PEBBLE PROJECT EIS

Chinook Salmon

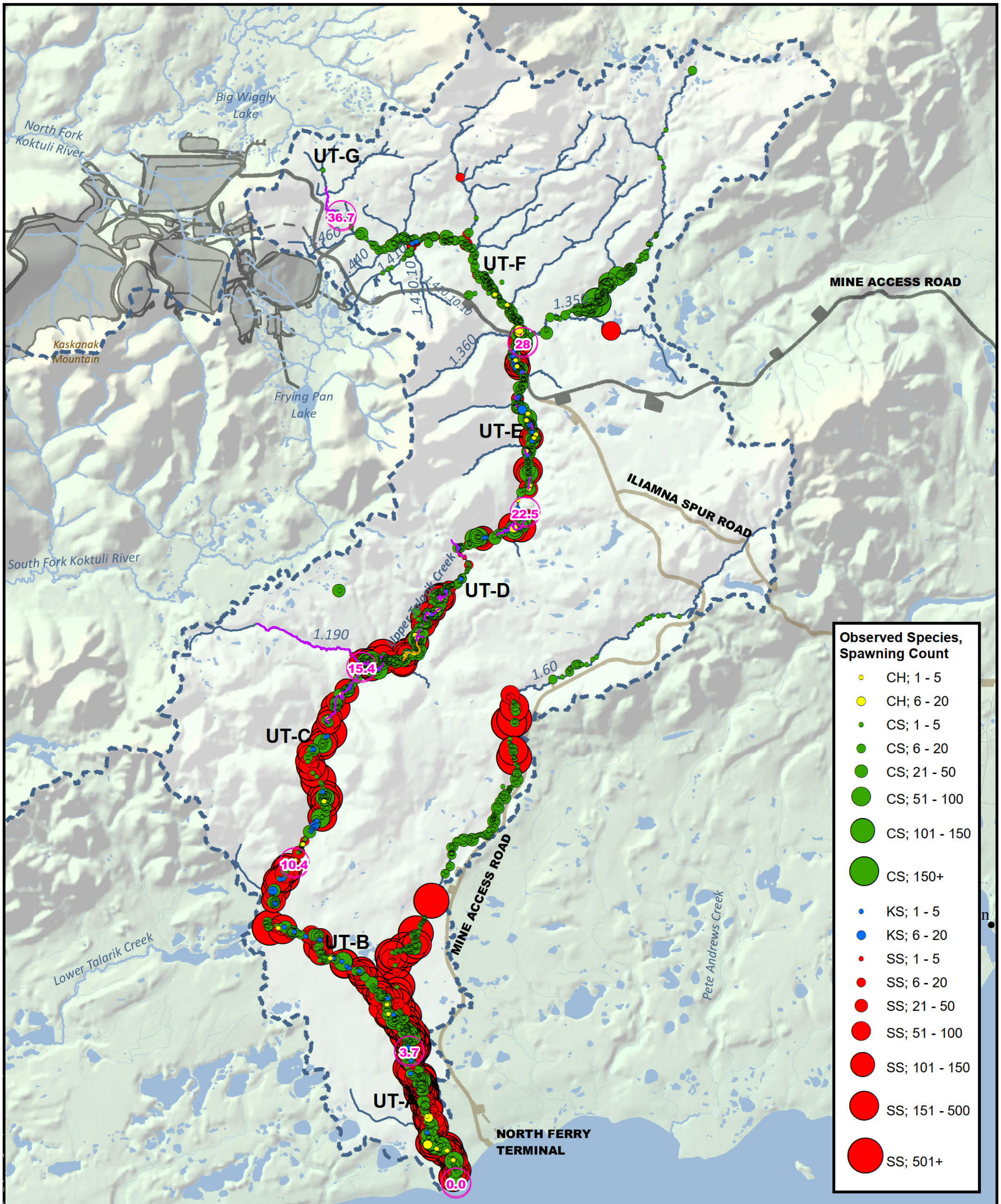
Adult Chinook salmon have been documented entering the UTC as early as July 6, with peak documented fish counts occurring between July 31 and August 8 (R2 et al. 2011a). Aerial adult Chinook surveys in UTC index reaches showed low densities (less than 5 fish/km) in each year of study (2004-2008, Table 3.24-6), with higher densities in UTC-E and UTC-C than in other reaches in 2008 (Table 3.24-8, Figure 3.24-13). In 2008, three Chinook adults were observed in tributaries to UTC: one fish in Tributary 1.190 (which receives groundwater input from the SFK), and two fish in Tributary 1.410 (Table 3.24-7).

Juvenile Chinook salmon are present year-round in the project area, consisting of three age classes: young-of-the-year, (0+), yearlings (1+), and 2+. The distribution of juvenile Chinook in the UTC is similar to the distribution of spawning, although juveniles have been observed higher in the headwater reaches (Figure 3.24-12), and also are known to inhabit additional tributaries, including UTC 1.350 and 1.380 (east-side tributaries outside of the analysis area)(R2 et al. 2011a). Chinook are also presumed to use the lower reaches of the UTC's largest tributary—First Creek or UTC Tributary 1.60—which flows into UTC 4 miles upstream of Iliamna Lake. Comparison of juvenile Chinook densities in mainstem index sites between years showed highest reach-wide densities in the 2004-2007 sampling (0.00 to 11.3 fish/100 m^2), and lowest densities (0.00 to 5.8 fish/100 m^2) in 2009 (Table 3.24-9). Fifteen index sites were sampled in the UTC mainstem in 2008 and 2009 (Figure 3.24-4); comparisons across index sites also showed higher abundance in 2008 than in 2009, with estimates exceeding 20 fish/100 m^2 in UTC-B and UTC-C index sites, but low densities (less than 1 fish/100 m^2) just downstream of, adjacent to, and upstream of the mine site (Figure 3.24-14). Sampling in 2008 showed mean densities of zero juvenile Chinook in all tributaries draining the mine site (Table 3.24-10). In general, juvenile Chinook appeared to be more abundant in slow-water habitats (pools and glides) than in riffles; likewise, more fish were observed in main-channel habitats than in off-channel or side-channel habitats (R2 et al. 2011a).

Sockeye Salmon

Adult sockeye salmon were the most abundant salmonid in the UTC basin, which drains directly into Iliamna Lake, a major spawning and rearing area for sockeye. Abundance of sockeye salmon in the UTC exceeded abundance in both the SFK and the NFK basins combined (R2 et al. 2011a). Adult sockeye have been documented entering the UTC as early as July 5, with peak documented adult counts occurring between July 17 and August 3. Annual adult counts from 2004 to 2008 in index reaches showed high densities of 805 fish/km in 2008 and 543 fish/km in 2004, with densities of approximately 200 fish/km in the remaining years (Table 3.24-6). Sockeye adults were also widely distributed throughout the UTC, with adults observed in all but the highest Reach (UTC-G) in 2008 (Figure 3.24-13). Adult densities in 2008 were more than 17,000 fish/km in UTC-A, almost 4,000 fish/km in UTC-B, and 1,000 to 2,000 fish/km in UTC-C and UTC-D (Table 3.24-8). The 2008 survey also revealed heavy use of UTC Tributary 1.160 (First Creek), with more than 17,000 fish counted (Table 3.24-7). Adult sockeye were also observed in Tributaries 1.390 and 1.410.

Juvenile sockeye salmon were observed in April, July, and August; and based on length frequency; distributions indicate two age classes: young-of-the-year, and 1+ age fish. Despite heavy spawning by sockeyes, juvenile densities were low throughout the UTC (Figure 3.24-12), suggesting typical downstream migration to lake-rearing habitat at an early age (Quinn 2018). Reach-wide densities of juvenile sockeyes were somewhat higher in 2004-2007 than in 2008 or 2009 (Table 3.24-9), with most densities in all reaches and years less than 1 fish/100 m^2. Likewise, densities at index sites in 2008 and 2009 were less than 1 fish/100 m^2, except at one site in UTC-E in 2008, where about 8 juveniles/100 m^2 were observed (Figure 3.24-14). In most index sites juvenile sockeye were generally more abundant in main-channel habitat than in off-channel or side-channel habitats (R2 et al. 2011a). Juvenile sockeye were not observed in tributaries draining the mine site (Table 3.24-10), but were observed in two east-side tributaries in 2008 at densities less than 1 fish/100 m^2(R2 et al. 2011a).



Sources: PLP 2019-RFI153; USGS; ADF&G; PLP (R2 2008)

US Army Corps of Engineers

1 0 1 2

Miles

Mainstem Reaches with River Mile

Upper Talarik Studied Streams

Open Water (2006 Survey)

Losing Stream Segment

Watershed Boundary

Action Alternatives

Alternative 1a

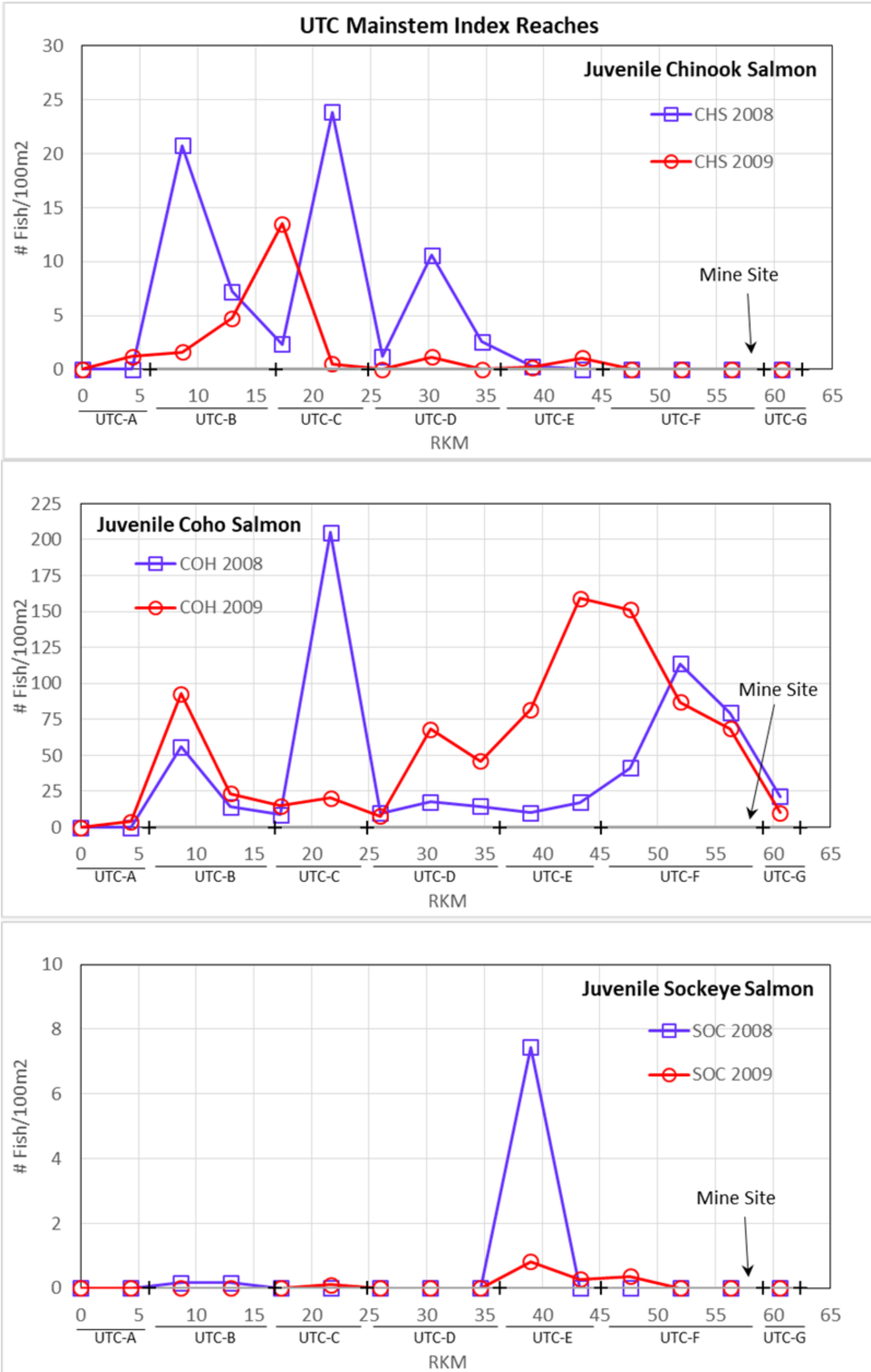
Alternative 1

PACIFIC SALMON SPAWNING DISTRIBUTION, WITH GAINING (OPEN WATER) AND LOSING STREAM REACHES IN THE UPPER TALARIK SUBBASIN

PEBBLE PROJECT EIS

FIGURE 3.24-13

Figure 3.24-14: Densities (#/100 m²) of Juvenile Salmon in Mainstem UTC Index Sites by Species and Year



Coho Salmon

Adult coho salmon have been documented entering the UTC as early as August 8, with peak documented counts occurring between September 2 and September 5. Annual index counts from 2004 to 2008 showed highest densities of adults (90 to 110 fish/km) in 2006 and 2008, with lowest densities of 30 to 43 fish/km in 2004 and 2005 (Table 3.24-6). Coho showed the widest spawning distribution of all Pacific salmon in 2008, with adults observed in all seven mainstem reaches (Figure 3.24-13), although at densities generally far less than those of sockeye salmon. Adult densities of 100 to 400 fish/km occurred in UTC-A, UTC-D, UTC-E, and UTC-F, but only 2 fish/km were observed in UTC-G (Table 3.24-8). As noted for coho in the NFK and SFK in 2008, coho adults in the UTC were more abundant in tributaries than were other salmon species, with more than 400 adults observed in Tributaries 1.160 and 1.350, and lower counts (less than 50 fish/km) in Tributaries 1.390 and 1.410 (Table 3.24-7).

Juvenile coho salmon are present year-round in the project area, consisting of four age classes: young-of-the-year (0+), yearlings (1+), 2+, and 3+ age; with the preponderance young–of-the-year overwintering and outmigrating as 1+ fish (R2 et al. 2011a). Juvenile coho were observed throughout the UTC basin during summer surveys where they were the most abundant salmonid (Figure 3.24-12) and were also found in the upper reaches during overwintering surveys. Reach-wide densities of juvenile coho ranged from 34 fish/100 m^2 to more than 100 fish/100 m^2 in most reaches in 2004-2007 and in 2009, with densities of 13 to 76 fish/100 m^2 in 2008 (Table 3.24-9). Index counts conducted in 2008 and 2009 also showed higher abundance of juvenile coho in 2009 (Figure 3.24-14), with densities exceeding 115 fish/100 m^2 at sites in UTC-D and UTC-E, with a maximum density of 123 fish/100 m^2 at one site in 2008 (Table 3.24-9).

Unlike most other Pacific salmon in the project area, juvenile coho frequently use tributary habitat, whether due to local spawning or immigration from mainstem spawning areas. In 2008, juvenile coho were observed in most sampled tributaries, including three tributaries draining the mine site, with mean densities up to 41 fish/100 m^2 (Table 3.24-10). In general, however, juvenile coho occurred at higher densities in mainstem index sites (Table 3.24-9) than in tributaries. Juvenile densities vary widely between habitat or channel types, with very high densities reported in some backwater habitats; but in other locations, juveniles had similar or higher densities in mainstem habitats than in off-channel or side-channel habitats, and were often found at similar densities in pools, run/glides, and riffles (R2 et al. 2011a).

Chum Salmon

Chum salmon occur in the mainstem UTC up to Tributary 1.350, about 25 miles upstream of the UTC confluence (Figure 3.24-12). Other than pink salmon, which were only observed in 2 years of study, chum salmon were the least abundant salmonid species in the UTC basin (R2 et al. 2011a). Abundance of adult chum salmon in UTC index sites remained less than 1 fish/km in 2005-2008 (Table 3.24-6); however, the few adults that were observed in 2008 occupied mainstem reaches from UTC-A up to UTC-F, adjacent to the mine site (Figure 3.24-13). The 2008 aerial survey only identified adult chum salmon in Tributary 1.410, which drains the eastern slope downstream of the open pit.

Juvenile chum salmon were not observed in UTC tributaries draining the mine site in 2008 (Table 3.24-10), and occurred at densities less than 1 fish/100 m^2 in UTC mainstem reaches (Table 3.24-10). Low densities of stream-rearing chum juveniles is consistent with the species life history of abbreviated river residence time after emergence (Quinn 2018). Juvenile chum densities were insufficient to evaluate habitat type or channel type relationships.

Pink Salmon

Pink salmon follow a strict 2-year lifecycle and are not common in the project area; however, more than 300 adult pink salmon were documented in the lower 4 miles of the UTC in 2006. Because only three pink salmon were observed in 2007, and zero in 2004, 2005, 2008, and 2009 (PLP 2018b), it is uncertain if the migrants represented a native run, or if they were strays from other watersheds. No juvenile pink salmon were observed during fish sampling surveys, which is not unexpected, given that particular species' rapid seaward emigration as newly emerged fry (Quinn 2018).

Resident Fish Species

Rainbow trout, Dolly Varden, slimy sculpin, and Arctic grayling are the resident fishes documented in the headwater reaches near the mine site during baseline field surveys (R2 et al. 2011a). Dolly Varden were widely distributed throughout the UTC basin in both mainstem and tributary habitats (Figure 3.24-12), at densities generally less than 5 fish/100 m^2 in mainstem habitats (Table 3.24-9, Figure 3.24-8). In tributary habitats, Dolly Varden were often observed at densities >10 fish/100 m^2, with mean densities ranging from 0.00 to 8.6 fish/100 m^2 in tributaries draining the mine site (Table 3.24-10). Dolly Varden were generally more abundant than in UTC tributaries in the NFK and SFK basins (R2 et al. 2011a). Arctic grayling densities also largely remained under 1 fish/100 m^2 in all UTC reaches and index sites in both 2008 and 2009. (Table 3.24-9), and were likewise at low densities in tributaries. Sculpin were also found at almost all sampling sites, as was observed in the NFK and SFK basins.

Unlike the NFK and the SFK, rainbow trout were relatively common and widely distributed in the UTC basin. Overall, reach-wide densities of rainbow trout in mainstem reaches were primarily less than 1 fish/100 m^2, with highest densities (10.6 to 11.0 fish/100 m^2) at mainstem index sites in UTC-B in 2008 and UTC-C in 2009 (Table 3.24-9, Figure 3.24-8), but were not observed in sampled tributaries in 2008 (Table 3.24-10). Resident rainbow trout are thought to occur in all three subbasins, but UTC also supports an adfluvial population of large trout that migrate between UTC, Iliamna Lake, and other lake tributaries. This species was targeted in a radio telemetry study in 2007 and 2008, where 97 adult trout were captured and tagged in UTC; 70 fish were subsequently tracked throughout the western half of Iliamna Lake and many of the lake's western tributaries through spring of 2009 (PLP 2018b). UTC-tagged trout visited 10 tributaries to western Iliamna Lake, with most detections in UTC, lower Talarik Creek, Pete Andrews Creek, the Newhalen River, and the Kvichak River. Migration patterns included spring immigration into tributaries (presumably for spawning), and summer foraging throughout the western half of Iliamna Lake or in several tributaries; followed by fall immigration and overwintering in the lower mainstem reaches or outlet lagoon habitats of the five tributaries listed previously (Minard et al. 1992). Twelve to 13 percent of tagged trout returned to UTC for spring spawning or summer foraging, suggesting that some of the tagged fish were transients from other natal tributaries. Relatively few tag detections in Iliamna Lake occurred east of the line between Gibraltar Creek and the Newhalen River; however, a large proportion of detections occurred in offshore areas of western Iliamna Lake, suggesting a pelagic migratory pattern.

Off-Channel Habitat Fish Distribution and Abundance

OCH provides important rearing habitat for a variety of fish species (Swales and Levings 1989; Nickelson et al. 1992; Pollock et al. 2004), particularly species preferring deeper and slower microhabitats such as that found in beaver complexes (Table 3.24-3). Given the relative rarity of pool habitats or LWD cover in mainstem reaches of the mine site, OCH may be particularly important to overwintering juvenile salmonids, which require slow velocities or dense instream cover during periods of low water temperatures (Griffith and Smith 1993; Allen 2000; Bell 2001;

Huusko et al. 2007). More than 10,000 m^2 of OCH were sampled for fish distribution and abundance in three of the intensive OCH study sites (Figure 3.24-2, Figure 3.24-3, and Figure 3.24-4). In each study site, juvenile coho salmon were the most widespread and abundant species and were found in all but two of the 121 sampled units (PLP 2018b, Appendix 15A). Densities of coho were typically lowest in isolated pools (less than 5 fish/100 m^2) and highest in alcoves (7 to 234 fish/100 m^2), percolation channels (18 to 59 fish/100 m^2) and side channels (15 to 133 fish/100 m^2). Densities of coho in beaver ponds, which was the most common OCH type, were intermediate at 5 to 53 fish/100 m^2). Sockeye salmon, sculpin, and sticklebacks were the next most widely distributed species in OCHs, where they were most often observed in alcoves, beaver ponds, percolation channels, and side channels at densities less than 5 fish/ 100 m^2. Chinook salmon were absent in many OCH sampling units, with a maximum observed density of 7.7 fish/100 m^2 in SFK side channels. Chum salmon, rainbow trout, northern pike, and burbot were rarely observed in any OCH sampling units.

Winter Distribution and Abundance

All of the resident fish species and many of the Pacific salmon species reside in the project area over the winter months, a period of harsh environmental conditions that may limit growth and survival. Assessment of winter distribution and abundance of juvenile and adult fish was conducted from 2004 to 2007 at 157 locations spread throughout most reaches of the NFK, SFK, and UTC (R2 et al. 2011a). Multiple sampling methodologies conducted in winter, including deployment of minnow traps, electrofishing, snorkeling, and above-water visual methods, resulted in the capture or observation of 3,321 fish (PLP 2019-RFI 151). Coho salmon and sockeye salmon made up 53 percent of observations, with Chinook salmon and sculpin each adding 11 percent of observations (Table 3.24-12). Most winter sites were in the UTC (39 percent) and SFK (42 percent) subbasins, with 18 percent of sites in the NFK. Although winter sampling was spotty in some reaches (due in part to hazardous conditions), and habitat area data were not always collected to allow estimation of fish densities, the data suggest that overwintering by juvenile salmon is concentrated well downstream of the mine site in Reaches NFK-B, NFK-C, and SFK-A, SFK-B, whereas overwintering fish were more widely distributed in the middle and upper reaches of Reaches UTC-D, UTC-E, and UTC-F.

3.24.4.3 Aquatic Invertebrates

Macroinvertebrates and periphyton (freshwater organisms attached to or clinging to plants and other objects projecting above the bottom sediments) community assemblages are an important component of the aquatic food web for salmonids, and effective indicators of habitat and water quality (Barbour et al. 1999). Due to their mobility, long lifecycle, and sensitivity to environmental conditions, macroinvertebrates have been frequently used for long-term monitoring, and have demonstrated their sensitivity to changes in ecological conditions (EPA 2002). Macroinvertebrate biological assessment indices have been developed for Cook Inlet Basin Ecoregion streams (Rinella and Bogan 2007) and demonstrated important macroinvertebrate community response to disturbance intensity in the region. Metrics such as number of taxa, percentage Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) (together referred to as "EPT taxa"), and Shannon's Diversity Index (SDI) were found to decrease at sites with increased disturbance intensity, while other metrics such as percentage of dominant taxa increased with disturbance intensity (Rinella and Bogan 2007).

In the mine site analysis area, the Koktuli River watershed supports a rich and diverse macroinvertebrate community (Bogan et al. 2012). Sampling of wadeable streams of the Kvichak and Nushagak watersheds in the Bristol Bay region, including the Koktuli and UTC watersheds, found mean site richness to be similar across four subwatersheds (ranging between 23 and 30 taxa), with Chironomidae (midge) family members the most common across all sites (Bogan et al. 2012).

Table 3.24-12: Number of Fish Observed in Winter Sample Sites According to Reach and Species

Reach	No. Sites	Chinook Salmon	Chum Salmon	Coho Salmon	Sockeye Salmon	Arctic Grayling	Dolly Varden	Rainbow Trout	Salmonid sp.	Sculpin sp.	9-Spine STB	3-Spine STB	Un-ID sp.	Totals
KR	1	--	--	--	--	--	1	--	1	--	--	8	--	**10**
NFK-A	1	--	--	--	--	--	--	--	--	1	--	--	--	**1**
NFK-B	6	10	--	21	--	--	23	--	--	4	1	--	--	**59**
NFK-C	18	50	15	27	93	--	39	--	--	9	--	--	--	**234**
NFK-D	3	--	--	--	--	--	--	--	--	--	9	--	--	**9**
SFK-A	12	226	5	64	141	--	24	1	--	36	34	3	--	**539**
SFK-B	49	43	14	303	565	118	135	--	163	208	19	1	33	**1,612**
SFK-D	3	--	--	--	--	1	--	--	--	--	--	--	--	**1**
SFK-E	2	--	--	--	--	2	7	--	--	--	--	--	--	**9**
UT-C	13	7	--	29	2	--	9	2	--	--	1	3	--	**53**
UT-D	20	9	--	253	11	--	2	31	12	79	36	17	19	**473**
UT-E	10	8	--	119	--	--	5	12	--	8	3	--	--	**156**
UT-F	17	--	--	132	--	--	2	--	--	28	1	--	--	**163**
UT-G	2	--	--	--	--	--	2	--	--	--	--	--	--	**2**
Totals	**157**	**353**	**34**	**948**	**812**	**121**	**249**	**46**	**176**	**373**	**104**	**32**	**52**	**3,321**
% of Total		**10.6%**	**1.0%**	**28.5%**	**24.5%**	**3.6%**	**7.5%**	**1.4%**	**5.3%**	**11.2%**	**3.1%**	**1.0%**	**1.6%**	

Notes:
KR = Koktuli River
NFK = North Fork Koktuli
SFK = South Fork Koktuli
sp. = species
STB=stickleback
Un-ID=unidentified species
UTC = Upper Talarik Creek
Species Representing less than 1 percent not shown.
Source: PLP 2019-RFI 151

Freshwater macroinvertebrate and periphyton surveys were conducted in the mine site drainages between 2004 and 2008 in the analysis area to characterize species diversity, abundance, density, and community structure. Study locations included the NFK River, SFK River, Kaskanak Creek, UTC, Chulitna River, Frying Pan Lake, and Big Wiggly Lake (Figure 3.24-15). Study locations correspond to monitoring sites for water quality, hydrology, and fisheries.

The methodological details for the 2004 to 2008 study period are in Chapter 15, Chapter 40, and Appendix F of the Pebble Project EBDs (R2 et al. 2011a). The resulting inventories serve as a basis for assessing potential project impacts.

Macroinvertebrates

A total of 132 primary macroinvertebrate samples and duplicates at a minimum frequency of 10 percent were collected from the monitoring sites established in the analysis area. Macroinvertebrate metrics, as described in the Alaska Stream Condition Index (ASCI) protocol (Major et al. 2001) were calculated from macroinvertebrate data collected using the ASCI method and the Surber method (R2 et al. 2011a). These metrics are indicators of habitat change (Major et al. 2001), and include taxa richness, percentage EPT taxa; percentage Chironomidae family taxa (Chironomidae is within order Diptera, or true flies); percentage other Diptera order taxa; percentage dominant taxon; and Community Tolerance Index (CTI).

The overall results for both the Surber method and the ASCI method indicate that Diptera, including Chironomidae, is the predominant macroinvertebrate order in the mine site area; and Ephemeroptera is the predominate order of EPT. Macroinvertebrate populations with a high proportion of Chironomidae members in the population can indicate a more stressful aquatic habitat in general (Barbour et al. 1999). The aquatic conditions at the mine site include high numbers of Chironomidae, which is considered typical for this area (Oswood et al. 1995).

These observations are consistent with aquatic-habitat surveys, which indicate that the analysis locations in the mine site area are composed mainly of riffle/cobble stream habitats with few to no human-caused effects. Measurements of habitat parameters at each location were within ranges considered good to optimal for aquatic habitat (Major et al. 2001). Analysis of water quality results indicated good to optimal parameter levels for diverse macroinvertebrate communities, as is generally the case.

CTI reflects aquatic habitat quality and is based on the relative tolerance of macroinvertebrate taxa to stressful conditions. CTI scores in 2004, 2005, and 2007 ranged from 3.9 through 6.1, 4.9 through 6.0, and 4.5 through 6.6, respectively (possible range of values 0 to 10).

Periphyton

A total of 115 periphyton samples were collected, and additional duplicate samples were collected at a frequency of approximately 10 percent. The 2004 data indicated relatively uniform taxa richness across all seasons. Periphyton metrics were based on the taxa identifications. Taxa richness at all sample locations ranged from 12 to 19. The percentage dominant taxon at all sample locations ranged from 21 to 72 percent. The percentage dominant taxon in periphyton samples at times totaled more than 50 percent. This result is generally considered a negative indicator for stream health (Wehr and Sheath 2003). However, the stream reaches sampled are considered representative of unimpaired conditions and occur in a region of minimal human effect. Measurements of water-quality parameters consistently fell within ranges considered good to optimal for aquatic habitat health. These results exhibit the natural variability in these environments.

In 2005 and 2007, periphyton samples were analyzed for chlorophyll-a to quantify productivity. In 2005, average chlorophyll-a concentrations ranged from 2.1 milligrams per square meter (mg/m^2) to 17.0 mg/m^2, with variability among the samples. In 2007, average chlorophyll-a concentrations ranged from 2.3 mg/m^2 to 30.2 mg/m^2. No consistent temporal trends were observed in the chlorophyll data between 2005 and 2007, nor was there a trend found between macroinvertebrate taxa richness or percentage EPT and chlorophyll-a concentrations. However, Chironomidae often made up a high percentage of the taxa composition; and in many cases, was the numerically predominant macroinvertebrate family, encompassing more than 50 percent of the sample. Some Chironomidae genera feed on periphyton, or prey on taxa that consume periphyton. In 2005, percentage Chironomidae was found to be highly correlated with chlorophyll-a concentrations ($R^2 = 0.7908$), but this trend was not as evident in 2007 ($R^2 = 0.1157$).

The survey results show that sample locations were composed largely of riffle/cobble habitat. Riffle/cobble is the preferred habitat of EPT taxa. The sampling results for the mine site indicate low-percentage EPT, high-percentage Chironomidae, and high-percentage dominant taxon, conditions which have been associated with poor stream health in other Alaska-based studies (Ott and Morris 2008). No statistically significant relationship was found between most water quality results and the macroinvertebrate metrics data. However, taxa richness in ASCI samples was negatively correlated with temperature.

3.24.4.4 Tissue Trace Element Analysis

Data collected during the period between 2004-2008 at the mine site indicate that the concentrations of trace elements in fish tissue are generally low, and reflective of the natural conditions of the mine site area drainages (see Section 10.3 in SLR Alaska et al. 2011). Some trace elements were detected at elevated concentrations. However, these concentrations are attributed to natural conditions, and are documented as existing or baseline conditions.

Fish samples collected between 2004 and 2008 included 345 whole body, 236 muscle, and 87 liver samples (see Section 10.3.7 in SLR Alaska et al. 2011). These samples were collected from the waterbodies (NFK, SFK, and UTC) and several lakes in the mine site area, and represented several species of fish, including northern pike, Dolly Varden, Arctic grayling, coho and Chinook salmon, and whitefish. Most of the 14 target trace elements were detected in the samples, including methylmercury. Copper and zinc were present at the highest concentrations across different waterbodies. A wide variability of elemental concentrations was apparent over time and among waterbodies, fish species, and tissue types (SLR Alaska et al. 2011: Tables 10.3-1 through 10.3-17).

Differences in tissue copper concentrations appeared to reflect the differences in the underlying geology of the drainages. For example, whole-body copper concentrations in coho and Chinook salmon were higher in SFK than the NFK and UTC. Copper-rich bedrock in the headwaters of SFK may explain this observation, because the bedrock geology contributes significantly to the elemental concentration in the surface water and sediment substrates; and aquatic organisms and the fish uptake of trace elements occur via these environmental media and the food chain. Elemental concentrations were typically higher in liver than in muscle; substantially, for some elements, such as zinc (SLR Alaska et al. 2011: Table 10.3-11 and Table 10.3-17).

The existing baseline data on fish tissue elemental concentrations represent the baseline or existing conditions that are reflective of the natural variabilities in the mine site area that arise due to various factors, such as biogeochemical differences among the major drainages, species- and element-specific differences in uptake, and accumulation of different trace elements by different fish species.

Appendix K4.24 provides additional information on predicted metals discharge concentrations (fugitive dust and water discharges) and the potential impacts from these concentrations on fish and wildlife resources.

3.24.5 Transportation Corridor and Natural Gas Pipeline Corridor

Under all alternatives, components of the transportation and natural gas pipeline corridors include the mine and port access roads (with different alignments for different alternatives), Iliamna Lake, and a portion of Cook Inlet. The analysis area for the transportation and natural gas pipeline corridors and port location includes all aquatic habitats within 0.25 mile of infrastructure, and all habitats within 1,000 feet of blasting areas. This area is where potential effects would be likely to occur from construction and operations under all alternatives and variants. The corridor, including mine access and port access roads, would cross numerous waterbodies that have been documented to support fish.

3.24.5.1 Mine Access Roads

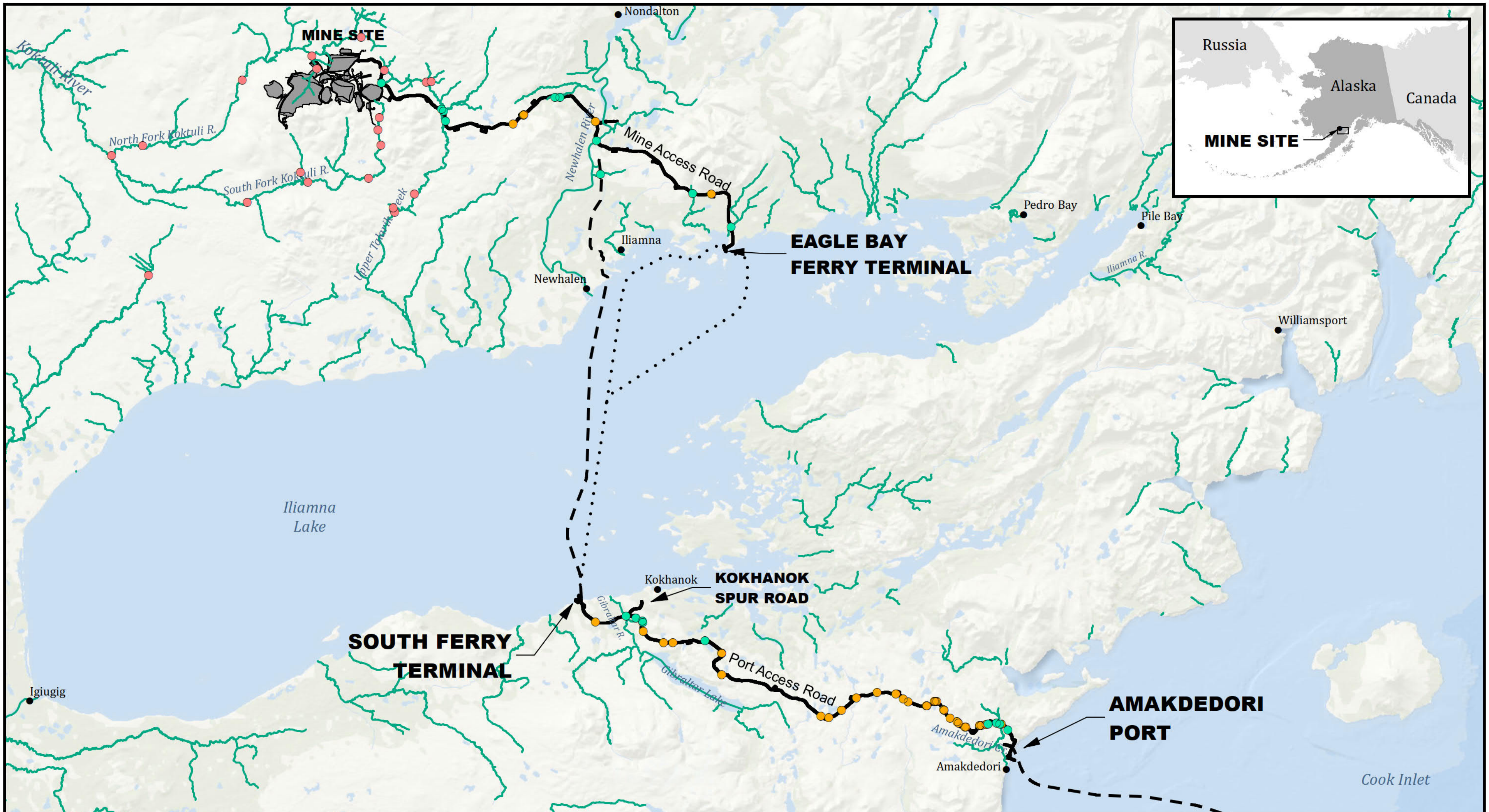
Mine access road corridors differ by alternative but are all north of Iliamna Lake, and connect the mine site to three potential ferry terminal locations depending on alternative (Figure 3.24-15, Figure 3.24-16, and Figure 3.24-17). The following subsections describe the aquatic habitat, anadromous and resident fish populations, and aquatic invertebrates potentially impacted by the mine access roads associated with the alternatives.

Aquatic Habitat

Depending on alternative, the mine access roads would cross waterbodies documented to support fish, many of which are classified as anadromous fish habitat (Figure 3.24-15, Figure 3.24-16, Figure 3.24-17, and Figure 3.24-18; Table 3.24-13 and Table 3.24-14). In addition to the channel crossings listed in Table 3.24-13 and Table 3.24-14, two anadromous tributaries to UTC occur within 0.25 mile of the mine access road corridor or project facilities and could be affected by the project (UTC tributaries 1.46 and 1.35, Figure 3.24-4).

All alternative road alignments would cross major drainages of the UTC and the Newhalen River (Table 3.24-13, Table 3.24-14; Figure 3.24-15 through Figure 3.24-18). The UTC and tributaries support spawning, rearing, and migratory habitat for all five species of Pacific salmon and resident fish species. The Newhalen River provides important migratory fish habitat for large numbers of adult and juvenile sockeye, coho, and Chinook salmon migrating between Iliamna Lake and Lake Clark. Chinook salmon spawning habitat has been documented 0.75 mile downstream from the Newhalen River crossing for Alternative 1. Tributaries of the Newhalen River upstream of the crossing locations provide spawning and rearing habitat for both resident and anadromous species. Arctic char (*Salvelinus alpinus*) are also known to inhabit the Newhalen River between Six Mile Lake and Iliamna Lake. The species and life-stages known to occur at each crossing location were identified from AWC listings or recent field sampling by Pebble Limited Partnership (PLP) (PLP 2018b).

Anadromous streams that would be crossed by the mine access road between the mine site and Eagle Bay under Alternative 1a and Alternative 2 (Figure 3.24-15 and Figure 3.24-17) have been documented to contain Chinook, coho, sockeye salmon, and Arctic char. Resident species include slimy sculpin, rainbow trout, Dolly Varden, longnose suckers, and ninespine stickleback.



Sources: PLP 2019-RFI153; ADF&G

US Army Corps of Engineers

5 0 5 10
Miles

Macroinvertebrate and Periphyton Sampling Site

Stream Crossings

Anadromous Fish

Resident Fish

Anadromous Stream

Alternative 1a

Ferry Route

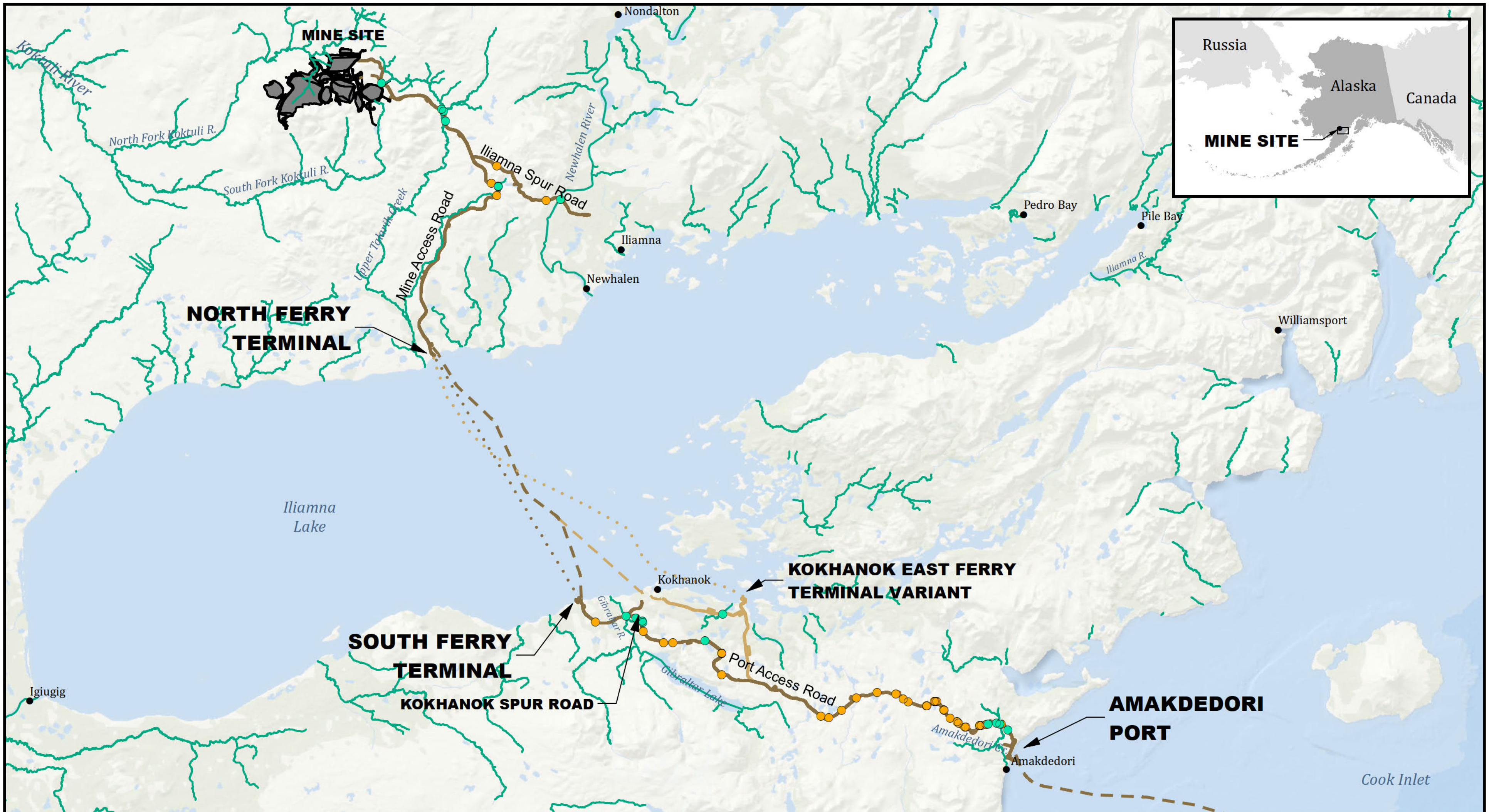
Natural Gas Pipeline

Transportation Corridor

Mine Site

ALTERNATIVE 1A TRANSPORTATION CORRIDOR
FISH STREAM CROSSINGS AND INVERTEBRATE SAMPLING SITES

FIGURE 3.24-15



Sources: PLP 2019-RFI153; ADF&G

US Army Corps of Engineers

5 0 5 10

Miles

Stream Crossings

- Anadromous Fish
- Resident Fish
- Anadromous Stream

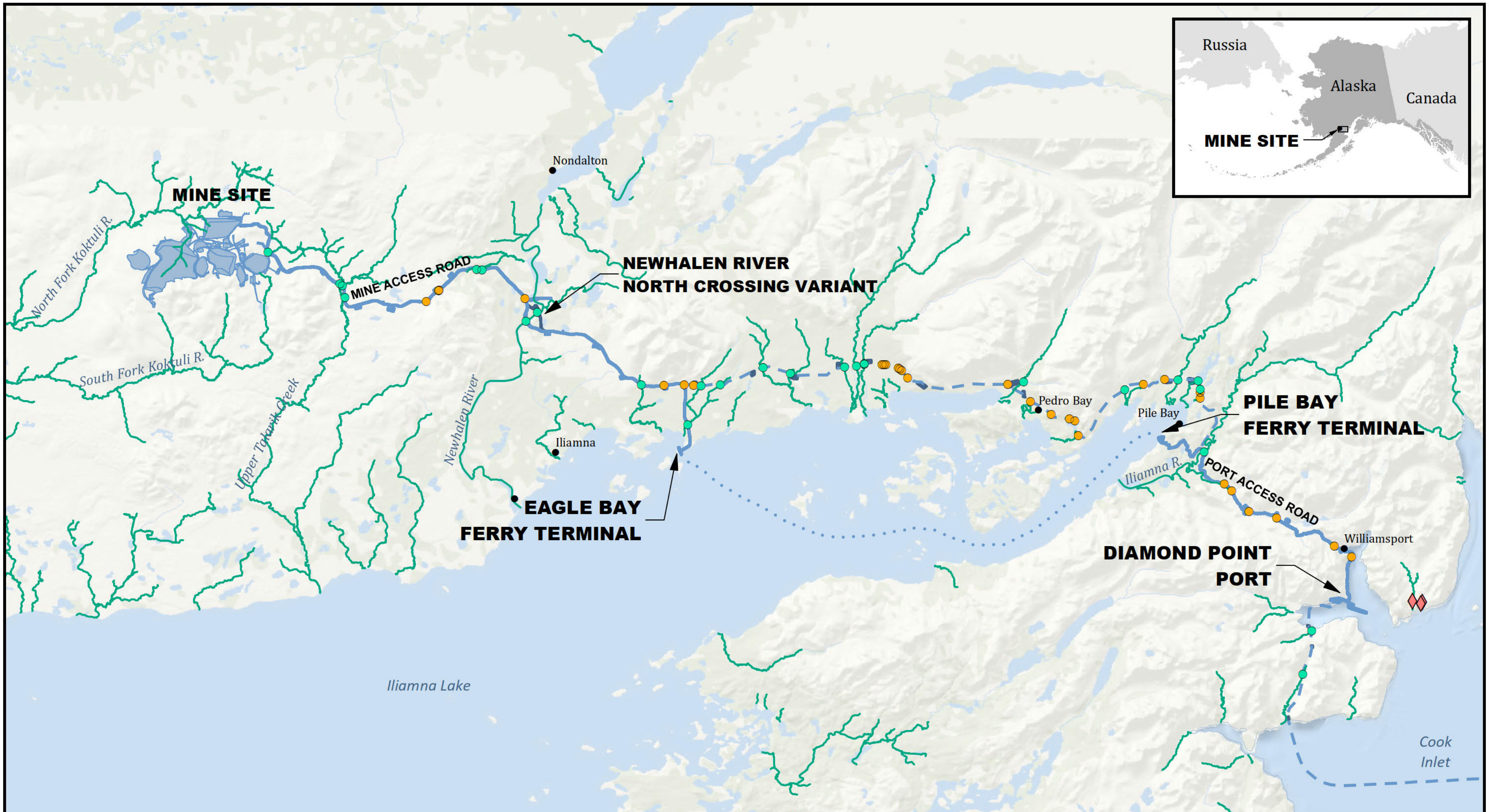
Action Alternatives

- Ferry Routes
- Natural Gas Pipelines
- Alternative 1a
- Alternative 1
- Alternative 1 Kokhanok East Ferry Terminal Variant

ALTERNATIVE 1 TRANSPORTATION CORRIDOR AND FISH STREAM CROSSINGS

PEBBLE PROJECT EIS

FIGURE 3.24-16



Sources: PLP 2019-RFI153; ADF&G

US Army Corps of Engineers

3 0 3 6
Miles

Invertebrate Sampling Site

Stream Crossings

Anadromous Fish

Resident Fish

Anadromous Stream

Alternative 2

Ferry Route

Natural Gas Pipeline

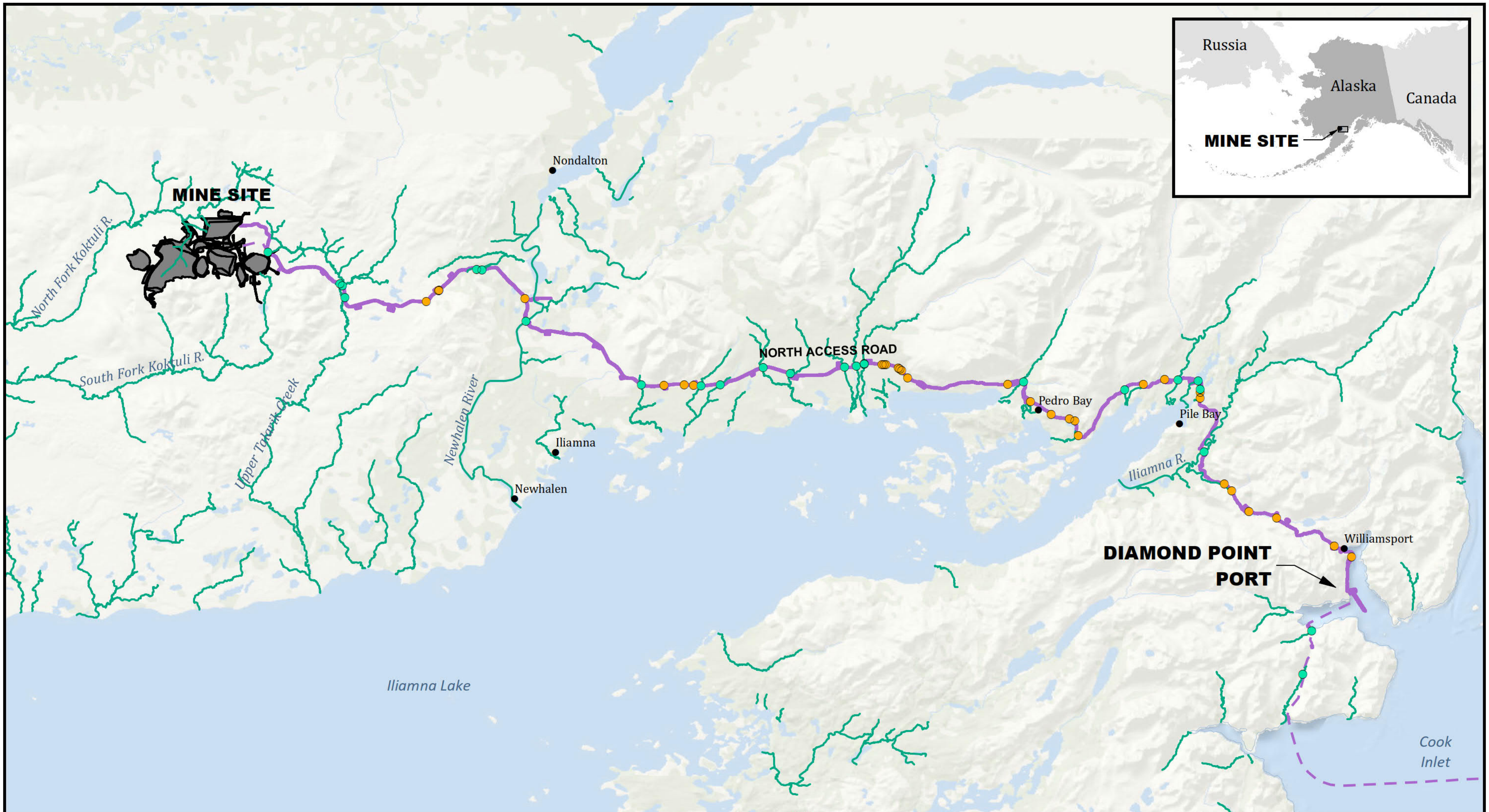
Transportation Corridor

Mine Site

Alternative 2 Variant

Newhalen River North Crossing

ALTERNATIVE 2 TRANSPORTATION CORRIDOR FISH STREAM CROSSINGS AND FRESHWATER INVERTEBRATE SAMPLING SITES NEAR COOK INLET



Sources: PLP 2020-RFI168; PLP 2019-RFI153; ADF&G

US Army Corps of Engineers

3 0 3 6

Miles

Stream Crossings

- Anadromous Fish
- Resident Fish
- Anadromous Stream

Alternative 3

- Natural Gas Pipeline
- Transportation Corridor

Alternative 1a

- Mine Site

ALTERNATIVE 3 TRANSPORTATION CORRIDOR AND FISH STREAM CROSSINGS

PEBBLE PROJECT EIS

FIGURE 3.24-18

Table 3.24-13: Anadromous Waters Crossed by the Mine Access Road under Alternative 1

Tributary[1]	AWC Code	RM[2]	Feature	Species/Life-stage[3]
UTC 1.46[4]	324-10-10150-2183-3307	0.4	culvert	COr, Kr, RBp, SCp
UTC 1.36[4]	324-10-10150-2183-3057	0.4	culvert	COr, DVp, SCp
UTC mainstem[4]	324-10-10150-2183	17	bridge	Ks, Kr, Ss, Sr, COs, COr, CHs, Pp, RBp, DVp, AGp, SCp, SBp, Wp
UTC 1.34[4]	324-10-10150-2183-3050	0.1	culvert	COr
UTC 1.60 (2 crossings)	324-10-10150-2183-3010	14	bridge + culvert	COs, COr, SCp, SBp, DVp
Newhalen River[5]	324-10-10150-2207	9	bridge	Kp, Ss, COp [6]

Notes:

[1]Tributary name from R2 et al. 2011a, if listed.

[2]RM = river miles at crossing upstream of mouth or confluence of tributary (approximate); N/A = distance unknown, channel not defined on map.

[3]Species/Life-stage near crossing from AWC or AFFI.

Species: K=Chinook, S=sockeye, CO=coho, CH=chum, P=pink, AC=Arctic char, DV=Dolly Varden, AG=Arctic grayling, RB=rainbow trout, SC=sculpin, SB=stickleback, W=whitefish; Life-stage: s=spawning, r=rearing, p=present (life-stage not specified).

[4]All alternatives cross these waterbodies.

[5]The Iliamna spur road under Alternative 1 crosses the Newhalen River.

[6]See text for list of resident species

AWC = Anadromous Waters Catalog AFFI = Alaska Freshwater Fish Inventory

Table 3.24-14: Anadromous Waters Crossed by Access Roads and Pipeline Along Alternative 1a, Alternative 2, and Alternative 3 Transportation Corridor and Natural Gas Pipeline Corridor[1]

Tributary[2]	AWC Code	RM[3]	Feature	Species/Life-stage[4]
UTC 1.46, 1.36, 1.34, and mainstem[5]	See Table 3.24-13 for details			
N/A (tributary to Newhalen River)	324-10-10150-2207-3027-4011	1.9	culvert	COp, SCp
N/A (tributary to Newhalen River)	324-10-10150-2207-3027-4011-5005	0.6	culvert	COr, SCp
Newhalen River	324-10-10150-2207	15.5	bridge	Kp, Ss, COp[9]
Bear Creek [10]	324-10-10150-2207-3016	0.7	culvert	COr, Kr, Ss, RBp, SCp
N/A (tributary to Eagle Bay)	324-10-10150-2235	5.8	culvert	Ss, ACp, DVp
Eagle Bay Creek[6]	324-10-10150-2239	0.8	N/A	COr, Ss, ACp, RBp, SCp, SBp
N/A (tributary to Eagle Bay Creek)[7]	324-10-10150-2239-3005	2.4	bridge	Ss, Sr, ACp, DVp, SBp
N/A (tributary to Chekok Bay)[7]	324-10-10150-2261	5.6	bridge	COr, Ss, ACp, RBp, DVp, SCp, SBp
N/A (tributary to Chekok Bay)[7]	324-10-10150-2261-3006	1.0	bridge	COr, COs, Ss, ACp, RBp, DVp, SCp
N/A (tributary to Chekok Creek)[7]	324-10-10150-2267-3001	2.7	culvert	COp, Ss, ACp
Chekok Creek[7]	324-10-10150-2267	3.3	bridge	COp, Ss, ACp, RBp, SCp
Canyon Creek	324-10-10150-2273	3.7	culvert	Ss, Sr, ACp, DVp, SCp
Knutson Creek[7]	324-10-10150-2301	1.6	bridge	Ss, ACp, DVp, SCp
N/A (tributary to Lonesome Bay)[7]	324-10-10150-2333	0.9	bridge	Ss, DVp, SCp
Pile River[7]	324-10-10150-2341	1.6	bridge	Ss, ACp, SCp, SBp
Long Lake outlet[7]	324-10-10150-2343	1.8	bridge	Kp, Sp, RBp
Iliamna River	324-10-10150-2402	4.1	bridge	CHp, COp, Kp, Pp, Ss, DVp, SCp
Browns Peak Creek[8]	248-10-10040	3.8	N/A[7]	COr
Un-named[8]	248-20-10030	0.2	--[7]	CHp

Notes:

[1]Listing represents stream crossings for Alternative 1a and Alternative 2 mine access roads where co-located to Eagle Bay, the Alternative 2 mine access and port access roads, Alternative 2 pipeline, and Alternative 3 north access road and pipeline.

[2] Tributary name from R2 et al. 2011a, if listed.

[3] RM = river miles at crossing upstream of mouth or confluence of tributary (approximate).

[4]Species/Life-stage near crossing from AWC or AFFI. Species: K=Chinook, S=sockeye, CO=coho, CH=chum, P=pink, AC=Arctic char, DV=Dolly Varden, AG=Arctic grayling, RB=rainbow trout, SC=sculpin, SB=stickleback; Life-stage: s=spawning, r=rearing, p=present (life-stage not specified).

[5] All three alternatives.

[6]Eagle Bay Creek crossed by mine access road at RM 0.8 (Applicant's Preferred Alternative and Alternative 2 only) and pipeline at RM 4.0

[7] Streams crossed by pipeline only for Alternative 2, by both pipeline and north access road for Alternative 3.

[8] Streams crossed only by pipeline for Alternative 2 and Alternative 3; crossing feature not specified.

[9] See text for list of resident species

[10]Stream crossed by pipeline only for Preferred Alternative

AWC = Anadromous Waters Catalog
AFFI = Alaska Freshwater Fish Inventory
N/A = Not Applicable
UTC = Upper Talarik Creek

To characterize the north access road corridor, habitat assessments and fish sampling were conducted and summarized according to six watershed groupings (R2 et al. 2011a; R2 and HDR 2011). The Isolated Watershed Group includes two watersheds that drain the southwestern flanks of Roadhouse Mountain; however, these isolated watersheds did not appear to have any surface connection to the Newhalen River or Iliamna Lake. The Roadhouse/Northeast Bay/Eagle Bay Watershed Group includes three watersheds that drain into Iliamna Lake: Roadhouse Creek, an unnamed tributary to Eagle Bay, and Eagle Bay Creek. The Youngs/Chekok/Canyon Watershed Group includes three watersheds that drain into the northern edge of Iliamna Lake: Youngs Creek, Chekok Creek, and Canyon Creek. The Knutson Bay/Pedro Bay Watershed Group consists of Knutson Creek and 11 unnamed tributaries that drain the western and southern sides of Knutson Mountain into Pedro Bay. The Pile Bay/Lonesome Bay Watershed Group includes the Pile River and two unnamed tributaries that flow into Lonesome Bay. The Iliamna River Watershed Group originates on the western side of the Chigmit Mountains and flows southwest into Pile Bay. Williams Creek is the only stream associated with the northern access corridor that drains into Cook Inlet.

Anadromous and Resident Fish Distribution

Anadromous fish distributed in the UTC basin include Chinook, coho, sockeye, and pink salmon. Resident salmonid species found in the UTC include Dolly Varden, Arctic grayling, rainbow trout, and whitefish (may include round whitefish, humpback whitefish, and/or least cisco). Resident non-salmonid fishes observed during sampling in the 1990s and 2004-2008 were sculpin (may include slimy and/or coastrange sculpin), two species of stickleback (threespine and ninespine), and unidentified lamprey (either Arctic or Alaskan brook). The AWC (Johnson and Blossom 2018) also lists Arctic char in the UTC; however, sampling conducted in the 1990s and in 2004-2008 did not report this species (R2 et al. 2011a).

The mine access road under all alternatives would cross channels and tributaries to the UTC that support rearing and/or spawning by coho salmon (Table 3.24-13, Table 3.24-14; Figure 3.24-15, Figure 3.24-16, Figure 3.24-17, and Figure 3.24-18). The mainstem UTC is listed for spawning and rearing habitat for Chinook, coho, and sockeye salmon, as well as chum and pink salmon spawning habitat at or near the bridge location for Alternative 1a and Alternative 1. Alternative 1a would cross eight anadromous streams (Figure 3.24-15). The Alternative 1 crossing at First Creek (UTC 1.60) is in close proximity to coho and sockeye spawning habitat.

Newhalen River

Under all alternatives, the mine access road corridors cross the Newhalen River (Alternative 1 Iliamna spur road would cross the Newhalen River), which is an important link between Lake Clark and Iliamna Lake. These lakes support large populations of sockeye salmon (Woody 2004, Young and Woody 2007). Sockeye spawning is specified by the AWC to occur throughout the Newhalen River, as is the presence of coho and Arctic char (Johnson and Blossom 2018). Chinook spawning habitat is listed for the lower 9 miles of the Newhalen, ending about 0.7 mile downstream of the Alternative 1 spur road crossing, or 15.5 miles downstream of Alternative 1a bridge crossing. The AWC lists Chinook as present in the reaches upstream of the spawning reach. The sockeye run in the Newhalen River peaks from early to late September, with 1955-2002 aerial index counts ranging from a low of 97 to a high of 730,900 fish and a 32-year mean of 85,000 fish, not including tributaries (Morstad 2003). Aerial surveys are known to only account for a proportion of total abundance (averaging 18 percent; ADF&G personal communication 2019); comparative counts from bankside towers on the upper Newhalen River from 1979 to 1984 ranged from 147,000 to almost 3.1 million fish (Poe and Rogers 1984). More recent escapement estimates of sockeye salmon into Lake Clark from 2000-2003 ranged from

172,902 to 264,690 (Woody 2004). Besides salmon, rainbow trout and Arctic grayling are popular sport fish in the Newhalen River. Other resident fish identified at that location include humpback and round whitefish, longnose sucker (*Catostomus catostomus*), and slimy sculpin (Frissel 2014).

Other Waterbodies

Fish sampling in the watershed groupings revealed no fish in the Isolated Watershed survey sites during the October 2007 sampling. Four fish species were documented at the primary survey sites in the Roadhouse/Northeast Bay/Eagle Bay Watershed Group: slimy sculpin, Dolly Varden, rainbow trout, and ninespine stickleback. Coho salmon, sockeye salmon, and Arctic char are also known to occur in this watershed group. Sockeye salmon, rainbow trout, Dolly Varden, and slimy sculpin were found at sites in the Youngs/Chekok/Canyon Watershed Group. Other fish known in this group include coho salmon and Arctic char. In the Knutson Bay/Pedro Bay Watershed Group, sockeye salmon, Dolly Varden, and slimy sculpin were documented at several sites, and Arctic char are also known to be present in this watershed. Slimy sculpin and threespine stickleback were documented in primary and support survey sites in the Pile Bay/Lonesome Bay Watershed Group. Although no salmon were observed during the fish surveys, sockeye salmon and Arctic char are known to be present. Sockeye salmon, Dolly Varden, and slimy sculpin were observed in the Iliamna River Watershed Group. Approximately 3,000 adult sockeye salmon were observed at two support survey sites in August 2004. Williams Creek, which drains into Cook Inlet at Williamsport, contained Dolly Varden when sampled in 2004.

Aquatic Invertebrates

Locations for macroinvertebrate and periphyton sampling were selected to characterize diversity, abundance, and density in freshwater habitats in the transportation and natural gas pipeline corridor study area (Figure 3.24-15). The sampling locations are representative of streams in the Bristol Bay drainage. The transportation corridor study area extends eastward beyond the Bristol Bay drainages into the Cook Inlet drainages. Details on the macroinvertebrate and periphyton studies in the Bristol Bay drainages study area conducted in 2004, 2005, and 2007 are provided in R2 et al. 2011a, Section 15.4.

Sampling to characterize the invertebrates in streams potentially affected by the port access roads was conducted at two sites: Y Valley Creek, and an unnamed creek site (Figure 3.24-17). Because a relatively small portion of the transportation corridor would be in Cook Inlet drainages, two locations were established for macroinvertebrate and periphyton sampling. Sample locations in the analysis area were selected based on undisturbed habitat with few to no human-caused effects. The methodological details for the 2004 to 2008 study period are provided in R2 et al. (2011a) and R2 Resource Consultants and HDR Alaska (2011).

Macroinvertebrate taxa richness was higher in the ASCI samples than in the Surber and the drift samples; and community assemblages were largely driven by Diptera taxa; and in most cases, Chironomidae. Of the Diptera taxa, the Orthocladiinae subfamily (in the Chironomidae family) tended to make up a large percentage of the samples. Of the EPT taxa, the Heptageniidae and Baetidae (both mayfly families), Chloroperlidae (stoneflies), and Brachycentridae (Trichoptera) were well represented in the Surber samples. The presence of these sensitive species is indicative of the comparatively optimal conditions at the site for macroinvertebrate colonization (Merritt and Cummins 1996).

A range of macroinvertebrate habitats was sampled using the ASCI method, while riffle/cobble habitat was sampled using Surber samplers. Taxa richness was greater in ASCI samples (15 to 16 taxa) than compared with Surber and drift samples (five and seven taxa, respectively). The difference in taxa richness indicates that greater taxa diversity is in habitats other than riffle/cobble habitat. Macroinvertebrate studies in other regions have documented variability in taxa richness among samples (DePauw et al. 2006). However, there are insufficient data from this study area to statistically define trends or relationships with respect to particular sampling method variability, or timing of sampling.

An assessment of parameters related to habitat quality indicates optimal conditions at the unnamed creek and Y Valley Creek locations during all sampling events. Standard water quality parameter results were in the optimum range for aquatic life (Hem 1985). Dissolved oxygen levels at the unnamed creek were slightly supersaturated, indicative of cool stream temperatures and swift water conditions at the location. The locations sampled in this study were in an undisturbed area with few to no human-caused effects.

Periphyton metrics for the 2004 data were based on the taxa identifications. Taxa richness was greater for Y Valley Creek than for the unnamed creek (17 and 8 taxa, respectively). The percentage dominant taxon was much higher for the unnamed creek than for Y Valley Creek (79 percent and 35 percent, respectively). The percentage dominant taxon in periphyton samples at times totaled more than 50 percent. This result is generally considered a negative indicator for stream health (Wehr and Sheath 2003). However, the stream reaches sampled are considered representative of unimpaired conditions, pristine, and in a region of minimal human effect. Measurements of water-quality parameters consistently were in ranges considered good to optimal for aquatic habitat health. These results exhibit the natural variability in these environments.

In 2004, one periphyton sample was collected from each of the two sampling locations, and then analyzed for diatom (photosynthesizing algae) taxa composition. Results of this analysis indicate 19 diatom genera were present in the analysis area. In 2005, 10 periphyton samples were collected at one location (Y Valley Creek) and analyzed for chlorophyll-a to quantify productivity. In 2005, average chlorophyll concentrations were 2.4 mg/m^2. Diatom analysis revealed a diverse set of taxa present. Average chlorophyll-a concentrations for Y Valley Creek were in the normal range, compared to other studies in Alaska.

3.24.5.2 Port Access Roads

The following subsections describe the aquatic habitat, anadromous, and resident fish populations potentially impacted by the port access roads associated with the alternatives (see Chapter 2, Alternatives). Aquatic invertebrates are the same as those described previously for the mine access road.

<u>Aquatic Habitat</u>

Under both Alternative 1a (Figure 3.24-15) and Alternative 1 (Figure 3.24-16), the port access road includes eight material sites (Figure 3.14-15 and Figure 3.24-16). The port access road would cross 39 fish-bearing streams, 11 of which are anadromous fish habitat (Table 3.24-15). The multi-span bridge over the Gibraltar River would be approximately 1.2 miles upstream of where it flows into Iliamna Lake. The Gibraltar drainage and tributaries provides important spawning and rearing habitat for sockeye, coho, chum, Arctic char, whitefish, and several resident species (Johnson and Blossom 2018). Pink salmon adults were also observed in the Gibraltar River in July 2018. No stream crossings would occur on the 1.4-mile spur road that connects the port access road to the town of Kokhanok. In addition to the streams crossed by the port access road and pipeline, the lower mainstem Amakdedori Creek passes within 0.25 mile of the location of port facilities.

Stream crossings and aquatic habitat for the Alternative 2 (Figure 3.24-17) and Alternative 3 (Figure 3.24-18) port access road are listed in Table 3.24-14.

Table 3.24-15: Anadromous Waters Crossed by the Port Access Road and Natural Gas Pipeline Under Alternative 1a and Alternative 1

Tributary[1]	AWC Code	RM[2]	Feature	Species/Life-stage[3]
Gibraltar River	324-10-10150-2196	2.3	bridge	CHs, COp, Ss, ACp, Wp,
trib to Gibraltar River	N/A[4]	N/A	culvert	COr
trib to Gibraltar River	N/A[4]	N/A	culvert	COr
trib to Gibraltar River	N/A[4]	N/A	bridge	COr
trib to 324-10-10150-2206	N/A[4]	N/A	bridge	COr
N/A	N/A[4]	N/A	culvert	COr
N/A	N/A[4]	N/A	culvert	COr
trib to Amakdedori Creek	243-40-10010-2008	2.2	bridge	Ss, COs, COr, CHs, DVp, SCp
trib to 243-40-10010-2008	N/A[4]	<0.1	culvert	COr
trib to 243-40-10010-2008	N/A[4]	0.6	culvert	COr
trib to Kokhanok Bay[5]	324-10-10150-2206	1.0	bridge	Ss, ACp

Notes:

[1]Tributary name from R2 et al. 2011a, if listed.

[2]RM = river miles at crossing upstream of mouth or confluence of tributary (approximate); N/A = distance unknown, channel not defined on map.

[3]Species/Life-stage near crossing from AWC or AFFI. Species: K=Chinook, S=sockeye, CO=coho, CH=chum, P=pink, AC=Arctic char, DV=Dolly Varden, AG=Arctic grayling, RB=rainbow trout, SC=sculpin, SB=stickleback, W=whitefish; Life-stage: s=spawning, r=rearing, p=present (life-stage not specified)

[4]New observation not listed in AWC at time of writing; life-stage based on species observation.

[5]Kokhanok East Ferry Variant section only.

AWC = Anadromous Waters Catalog, AFFI = Alaska Freshwater Fish Inventory
N/A = Not Applicable
trib = tributary

Anadromous and Resident Fish Distribution

Gibraltar River

The Gibraltar River would be crossed by the port access road under both Alternative 1a and Alternative 1. Four anadromous species/life-stages are listed in the AWC (Johnson and Blossom 2018) for the lower Gibraltar River (Table 3.24-14): coho presence, chum spawning, sockeye spawning, and Arctic char and whitefish presence. Adult pink salmon were observed by PLP snorkelers in the Gibraltar River in July 2018. Whitefish are also distributed throughout the lower Gibraltar River. The highly productive sockeye spawning run in the Gibraltar River peaks from mid-August to mid-September, with index counts from 1955-2002 averaging about 61,000 adults (Morstad 2003). Index counts are based on aerial surveys and represent approximately 18 percent of actual sockeye abundance. Up to 73,000 sockeye have also been counted spawning along lake beaches, with tens of thousands more using tributaries upstream of Gibraltar Lake, which presumably provides lake rearing habitat for juveniles prior to migrating downstream to Iliamna Lake and Bristol Bay. In 2010, the aerial survey estimate was 292,000 fish in the Gibraltar River and 462,800 in the overall Gibraltar River System. The Gibraltar drainage also provides habitat for Dolly Varden and lake trout (*S. namaycush*), and the river downstream of Gibraltar Lake maintains a productive sport fishery for rainbow trout.

Other Waterbodies

The Amakdedori Creek tributary is an anadromous stream listed for coho spawning and sockeye spawning life-stages at the crossing location, and chum spawning is listed downstream of the location. Juvenile coho were the only salmon observed in the other eight streams with anadromous fish. Resident fish species observed in the 44 fish-bearing streams during 2018 sampling included chars (Dolly Varden or Arctic char), rainbow trout, Arctic grayling, stickleback (threespine and ninespine), northern pike, longnose sucker, burbot, and sculpin (not identified to species).

Under Alternative 2, a port access road would connect the Pile Bay ferry terminal to the existing Williamsport-Pile Bay Road via a 2-mile spur road. Realignments and improvements would be made to the existing road to Williamsport. Under Alternative 3, this same port access road would connect to Williamsport from the western end of the north access road. From Williamsport, a new 3-mile spur road would extend south to Diamond Point port. The port access road to the Pile Bay ferry terminal under Alternative 2 would cross the Iliamna River approximately 4 miles upstream of its mouth (Table 3.24-14). The Iliamna River supports all five species of Pacific salmon, including important spawning habitat for sockeye salmon. The Iliamna River and Chinkelyes Creek are important habitat spawning habitat for sockeye salmon. Aerial survey estimates indicate that hundreds of thousands of spawning sockeye salmon use the system in some years (Morstad 2003). Chinkelyes Creek is listed for sockeye spawning and presence of coho, with rainbow trout, Dolly Varden, and slimy sculpin also known to be present. The spur road from Williamsport to Diamond Point crosses a channel supporting resident fish species. All other streams crossed contain only resident fish species or would be expected to be fishless.

No stream crossings would be associated with the Pile Bay spur road to the ferry terminal, and a single crossing of a channel with resident fish species is associated with the Diamond Point spur road (Figure 3.24-17 and Figure 3.24-18). The existing Williamsport-Pile Bay Road between the two spur roads crosses numerous streams, including a bridge over the anadromous Iliamna River (Table 3.24-14). Additional bridges and culverts are planned to cross resident fish and fishless streams. Although the existing Williamsport-Pile Bay Road or natural gas pipeline would not cross Chinkelyes Creek, it would parallel anadromous waters for approximately 2 miles.

3.24.5.3 Natural Gas Pipeline Corridor

Along the Alternative 2 pipeline route, the road and pipeline would cross numerous stream channels, some of which are listed in the AWC as anadromous waters (Table 3.24-14), and others are inhabited by resident fish species. The Newhalen River provides a migratory connection between Iliamna Lake and Lake Clark for large numbers of adult and juvenile sockeye salmon. Beyond the Newhalen River, the road and pipeline would skirt the western and southern flanks of Roadhouse Mountain, where the mine access road turns south to Eagle Bay, and the pipeline continues east towards Williamsport. Under Alternative 1a, the natural gas pipeline route remains the same, with the exception of the Iliamna Lake pipeline crossing route and an overland route from Newhalen to the mine access road. From the south ferry terminal, the pipeline route is the same for Alternative 1a and Alternative 1 (Figure 3.24-15 and Figure 3.24-16).

Under Alternative 3, the pipeline-only overland portions of the natural gas pipeline corridor are north of Iliamna Lake between Eagle Bay and Pile Bay ferry terminals (see Chapter 2, Alternatives). The pipeline would cross waters supporting anadromous and resident fish habitat, and numerous small channels designated as fishless (Table 3.24-14). In addition to the anadromous channels crossed by the pipeline, the transportation corridor passes within 0.25 mile upslope of several other anadromous waters, including a tributary to Pedro Bay (AWC 324-10-10150-2317-3035), Russian Creek (AWC 324-10-10150-2323), and a tributary to Lonesome Bay (AWC 324-10-10150-2335); each is designated as sockeye spawning habitat. The pipeline under this alternative would be buried adjacent to the road to Diamond Point, then would cross Cook Inlet to the Kenai Peninsula.

The affected environment associated with the natural gas pipeline under Alternative 2 is applicable to the transportation and pipeline corridors under Alternative 3. The number of road and pipeline water crossings for Alternative 3 is very similar to Alternative 2 (Table 3.24-14), with one less crossing of an anadromous channel: Alternative 2 crosses Eagle Bay Creek at two locations (one for the road, one for the pipeline); the Alternative 3 road and adjacent pipeline crosses Eagle Bay Creek in a single location.

3.24.5.4 Iliamna Lake

The following subsections describe general attributes of Iliamna Lake, including aquatic habitat, anadromous and resident fish, lake productivity and MDNs, aquatic invertebrates, and trace metal analyses.

Aquatic Habitat

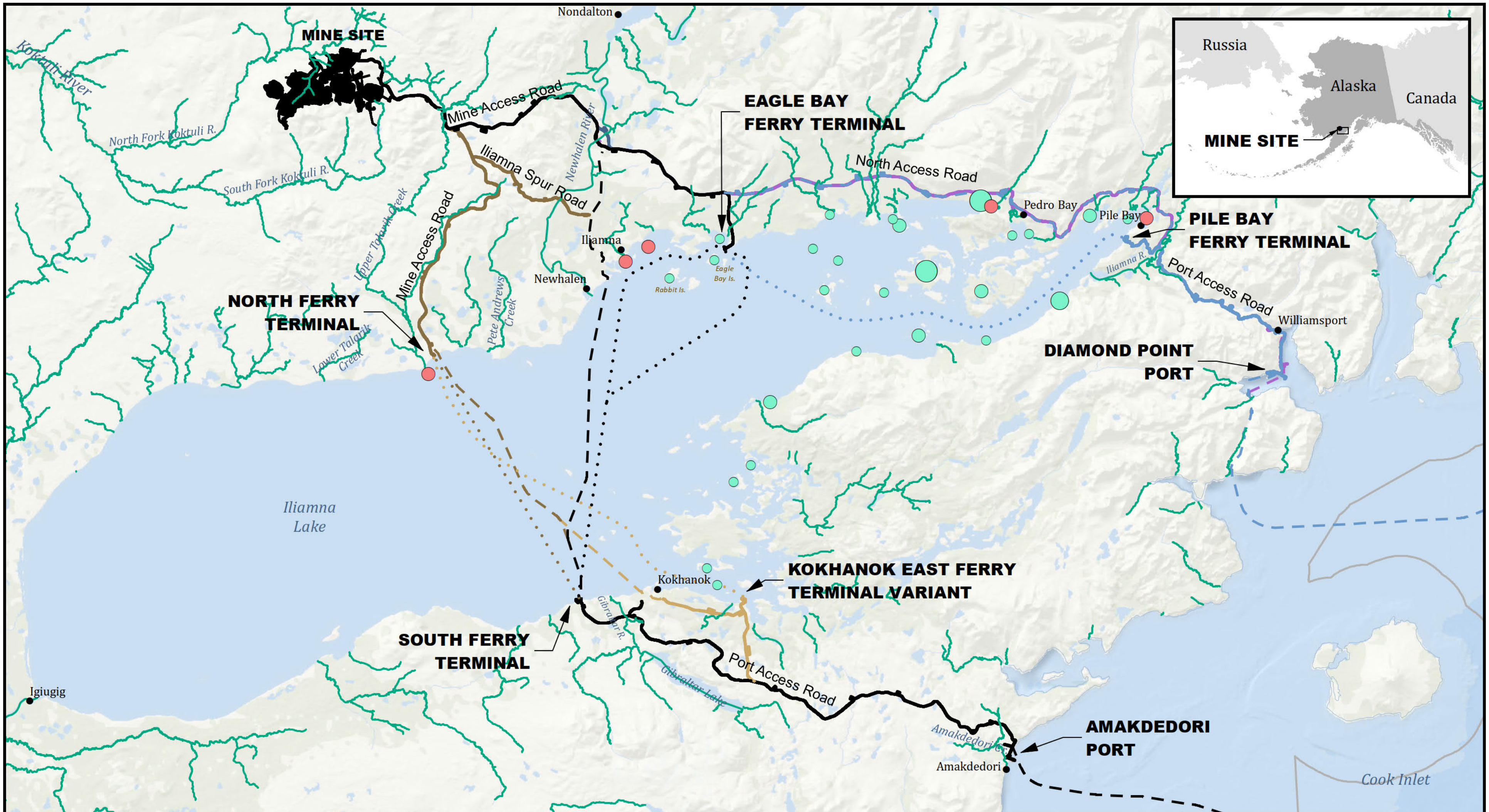
Iliamna Lake is a large lake with a surface area of 1,012 square miles. Iliamna Lake and its numerous tributaries provide spawning and rearing habitat for all five species of Pacific salmon and resident salmonid species, including Dolly Varden and rainbow trout. Major tributaries associated with the analysis area include the Newhalen River, UTC, and the Gibraltar River. The western half of Iliamna Lake is wide, with linear margins and few islands; whereas the eastern half (particularly the far northeastern end) has a contorted shoreline with an abundance of bays, islands, and rocky shoals. The majority of tributaries, including those supporting anadromous species, enter Iliamna Lake on the northern shoreline and surrounding the eastern basin, including Kokhanok Bay; tributaries are less common on the western shoreline.

The difference in physical characteristics of eastern, central, and western basins is also reflected in other notable parameters. Summer water temperatures in the eastern portion of Iliamna Lake can be slightly cooler than the western basin, which is shallower and warmer and supports higher densities of zooplankton than the eastern basin (Rich 2006). Although cooler in the summer, ice breakup in the spring tends to occur at an earlier date in the eastern basin. Additional physical characteristics of Iliamna Lake are described in Section 3.16, Surface Water Hydrology.

Of the anadromous salmonids, sockeye is the most common species in Iliamna Lake, where they are known to use shoreline habitat for spawning (EPA 2014), particularly in the northeastern portion of the lake (Figure 3.24-19). Juveniles also immigrate into the lake from spawning tributaries to use lacustrine rearing habitats. Iliamna Lake is also heavily used by adfluvial rainbow trout, which use a variety of lake habitats for summer foraging (PLP 2018b; Minard et al. 1992).

Anadromous and Resident Fish Distribution

More than 20 fish species have been reported from Iliamna Lake and the Kvichak system (Hauser et al. 2008; Johnson and Blossom 2018; Metsker 1967), including all five anadromous Pacific salmon (Chinook salmon, coho salmon, chum salmon, pink salmon, and sockeye salmon), Arctic char, and lamprey species. Eight non-anadromous salmonids (adfluvial populations of rainbow trout, Dolly Varden, lake trout, Arctic grayling, humpback whitefish, round whitefish, pygmy whitefish (*P. coulterii*), and least cisco) occur in Iliamna Lake, along with numerous non-salmonid species, including northern pike, slimy sculpin, threespine and ninespine stickleback, burbot, Alaska blackfish (*Dallia pectoralis*), longnose sucker, and pond smelt (*Hypomesus olidus*). The most common subsistence fishery is for sockeye salmon; but targeted fisheries also include Arctic grayling and whitefish (Holen and Lemons 2012). See Section 3.9, Subsistence, for more information on subsistence use. Many of these fish species, whether as juveniles or adults, rely on Iliamna Lake's plankton resources for food and growth.



Sources: PLP 2020-RFI168; PLP 2019-RFI153; Morstad 2003; ADF&G; ADNR

US Army Corps of Engineers

5 0 5 10

Miles

Zooplankton Sample Sites

Sockeye Salmon Adult Counts Median Count

- < 2,000
- 2,000 - 5,000
- 5,000 - 10,000
- 10,000 - 20,000

Anadromous Stream

Action Alternatives

- Ferry Routes
- Natural Gas Pipelines
- Alternative 1a
- Alternative 1
- Alternative 1 Kokhanok East Ferry Terminal Variant
- Alternative 2
- Alternative 2 Newhalen River North Crossing Variant
- Alternative 3

FERRY ROUTES, SOCKEYE SALMON BEACH SPAWNING AREAS, AND ZOOPLANKTON SAMPLING SITES IN ILIAMNA LAKE

PEBBLE PROJECT EIS

FIGURE 3.24-19

Bristol Bay is renowned for producing the world's largest runs of sockeye salmon, up to 50 percent of which may return to the Kvichak Basin (Dann et al. 2009). Escapement of adult sockeye salmon to the Kvichak Basin from 2012 to 2018 ranged from 2.1 million to 7.3 million fish (ADF&G escapement data). Most of these fish migrate into Iliamna Lake from July through September on the way to spawning grounds in numerous Iliamna Lake tributaries (including UTC), to beach spawning areas along Iliamna Lake shorelines and islands, or to tributaries of Lake Clark upstream of Iliamna Lake. A radio telemetry study of upstream migrating sockeye salmon in Lake Clark indicated that most sockeye swam directly to spawning locations (Young 2004) and noted that >90 percent migrated during the day (Poe and Rogers 1984, cited by Young 2004). In Iliamna Lake, Blair and Quinn (1991) noted that sockeye salmon tended to migrate along the shoreline and were more likely to move into tributary habitats than beach habitat, a finding similar to that of Young (2004).

Iliamna Lake is particularly noted for supporting still-water spawning by large numbers of sockeye salmon. With some exceptions, annual ground-, boat-, and aerial surveys of spawning salmon areas have been conducted in the basin by ADF&G and the University of Washington since 1920. Widespread aerial surveys have detected shoreline spawning in many areas of Iliamna Lake, with heaviest spawning along island and bay shoreline habitats in the eastern lake basin (Figure 3.24-19). Aerial counts over a 43-year period (1955-2002; some years not sampled) have shown wide annual and spatial variability, with index estimates for Woody Island (for example) ranging from 500 adults in 1963 to more than 607,500 in 1965 (Morstad 2003). Index counts along Knutson Bay's shoreline have ranged from 1,000 fish in 1990 to 1,000,000 in 1960. Although survey sites varied somewhat from year-to-year, overall index counts of adults along Iliamna Lake's shoreline or island beaches from 1965 to 2002 have typically represented between 1 percent and 7 percent of sockeye counted in Kvichak Basin index sites (Morstad 2003). Of the 93 documented spawning locations in Iliamna Lake, 46 are east of Eagle Bay (Rich 2006). The majority of Iliamna Lake's freshwater seal population also resides in the eastern basin, where adult sockeye are the principal prey item during the summer months (Hauser et al. 2008).

Aerial surveys have revealed that most beach spawning occurs in the eastern end of the lake (Figure 3.24-19), where adult densities are highest on exposed points of land at narrows between islands and on reefs (Kerns and Donaldson 1968). Upwelling was not noted at these locations, but eggs were exposed to wind-driven lake currents and seiches, which have been shown to influence subgravel flow in known spawning locations (Leonetti 1997). Kerns and Donaldson (1968) identified four types of spawning bottom: 1) coarse gravel mixture of rocks with little or no sand; 2) irregular small broken rock; 3) large broken rock and irregular rocks; and 4) round boulders; irregular rocks with compact fine material in between. Ninety percent of observed spawning locations were at depths from 6 to 20 feet, with slopes of 15 to 25 degrees.

Studies have demonstrated site fidelity of returning adults in Iliamna Lake, whether to specific tributaries or to beach habitats (Quinn et al. 1999; Quinn et al. 2009). Differences in body morphology and life-history characteristics have been detected between sockeye spawning in tributaries to Iliamna Lake versus fish spawning in the lake's beaches (Blair and Quinn 1991; Habicht et al. 2007). A variety of life history types and multiple distinct, locally adapted populations has been reported by Dann et al. (2013). They noted hierarchical distribution between ecotypes, among drainages in ecotypes, and among populations in drainages. Genetic studies have also shown differentiation between sockeye entering the Kvichak Basin and those spawning in the Nushagak Basin, with at least eight distinct populations identified in the Nushagak and 14 in the Kvichak (Dann et al. 2013). Habicht et al. (2007), using the microsatellite data, examined the population genetic diversity and structure of sockeye salmon spawning in tributaries of Bristol Bay. They found: 1) significant variation over all lakes and in all drainages except Ugashik, Egegik, Wood, and Igushik rivers; 2) genetic structure among sockeye stocks from the large, southeastern

Bristol Bay lakes was shallow, whereas structure among stocks upstream of obstacles to migration and among stocks from northwestern Bristol Bay was more typical of the species; 3) similarity among populations rearing in the four largest lake systems on the southeastern side of the bay (upper and lower Ugasik, Becharof, Naknek-Grosvenor-Coville, and Iliamna lakes); and 4) the Iliamna Lake site collections clustered most closely with site collections from Naknek River (excluding Brooks Lake). Eight genetically discrete reporting groups were identified.

Juvenile sockeye in Iliamna Lake originate from shoreline or island spawning, from tributaries to Iliamna Lake, and from Lake Clark. After spawning, a protracted period of embryonic development follows, and fry emerge from the gravel in streams and lake beaches around the time when ice breaks up in May and June. Juveniles rear in a lake for 1 or 2 years prior to seaward migration, but a number of populations over the range of the species migrate to sea in their first year. In Bristol Bay, those migrating to sea in their first year are uncommon and are almost exclusively in the Nushagak River itself (Quinn et al. 2009). While in the nearshore areas, sockeye fry feed primarily on zooplankton and aquatic insects, shifting to zooplankton as they move to offshore areas later in the summer. The date of emigration of juveniles may depend on the prevailing environmental conditions. In general, warming temperatures in spring may initiate early emigration.

Monitoring studies of juvenile sockeye salmon have been undertaken to assess abundance, distribution, growth, and vertical migration (Nemeth et al. 2014; Schuerell and Schindler 2003). In Iliamna Lake proper, the University of Washington has been sampling juvenile sockeye salmon in June through July since the 1960s using tow nets and beach seines. Both the number and size of juveniles captured varied between years. Rich (2006) found that sockeye fry were the dominant fish species in the eastern portion of Iliamna Lake, with reduced abundance in the western basin. In contrast, yearling sockeye (fish with a fork length of more than 80 millimeters) were more prevalent in the central and western basins, where zooplankton densities also tend to be higher (Rich 2006). Rich (2006) also assessed historical growth data and found that mean size of juveniles averaged almost 10 millimeters longer in the western lake basin (86.2 millimeters) than in the eastern basin (76.8 millimeters). A similar east-to-west trend was observed for fry where fish in the western and central regions averaged 53.4 to 55.2 millimeters, while fry in the eastern basin averaged 51.0 millimeters. Both temperature and fish density were factors affecting fish length, with spring air temperatures exerting the most influence on fry length at the conclusion of the growing season.

Juvenile sockeye are known to exhibit diel vertical migration in oligotrophic lakes. This migration involves juvenile sockeye moving up in the water column during night and moving down the water column during daylight hours. Schuerell and Schindler (2003) studied three lakes on the Wood River system and found a strong positive relationship between the amount of incident light at the lake surface and the depth of the juvenile salmon during the crepuscular periods and night. As the light level increased, the mean depth of the juvenile sockeye salmon also increased. In their study, juvenile sockeye began their upward migration around 2200 hours from their daytime depth near 75 meters They then reached their average nighttime depth of 15 meters around 0230 hours, where they remained for 1 hour before migrating back down again. Relatively few juveniles were observed at depths less than 10 meters during summer or fall sampling. Their results tended to support Clark and Levy’s (1988) antipredation window hypothesis, whereby juveniles balance feeding opportunities with predation risk by using shallower water during periods of reduced light intensity, such as early morning hours in midsummer at northern latitudes, or at dawn and dusk in spring or fall, or at lower latitudes.

Less research is available on the vertical or horizontal distributions of juvenile salmonids in large lakes under winter conditions, particularly in comparison to ice-covered or open-water areas. Long-winter conditions can result in depletion of energy stores among juvenile salmon, due in part to a reduction in zooplankton abundance. Juvenile kokanee in three Idaho lakes continued to feed over the winter months despite complete ice coverage, which blocked 99 percent of light penetration (Steinhart and Wurtsbaugh 2003). Positive growth did occur in one year of study when zooplankton abundance was high going into the winter, but salmon did not grow over the previous winter when plankton densities were lower. However, Ruggerone (1992) found very little feeding during winter, ice-covered conditions in two Alaska lakes.

Evidence of diel vertical migrations during winter months also showed variable results. In one of the three Idaho lakes (Stanley Lake) studied by Steinhart and Wurtsbaugh (1999), juvenile kokanee used deep water (>20 meters) during the day, and migrated into shallower water (less than 8 meters) at night, similar to that seen in summer in the Wood River study (Schuerell and Schindler 2003); however, juveniles in nearby Redfish Lake remained at relatively shallow depths (2 to 5 meters) throughout the day and night. Juvenile kokanee in Alturas Lake did show vertical migration, but only within a relatively narrow range of depths (less than 14 meters). The authors suspected that differences in density and composition of predator species between the three lakes may have been a factor, with a higher predator index in Stanley Lake, which also showed the most prominent vertical migrations.

The Alaska study by Ruggerone (1992) revealed a strong relationship between under-ice depth choice by juvenile salmon and water quality parameters. Black Lake and Chignik Lake are small lakes in comparison to Iliamna Lake, but both support populations of sockeye and coho salmon. Black Lake is very shallow (average under-ice depth 1.1 meters), whereas Chignik Lake has depths exceeding 45 meters. In Chignik Lake, sockeye were more abundant in the lake outlet, followed by offshore and inshore sampling areas. Near the outlet of Chignik Lake, traps set near the surface caught significantly more sockeye than bottom traps; however, sockeye in the offshore sampling area were six times more abundant at 20 meters than at 10 meters, and three times more abundant than at the surface. No juvenile sockeye were captured in baited traps in Black Lake; however, catches of juvenile coho showed a response to water quality trade-offs. Catches of juvenile coho were significantly higher in traps set near the lake bottom compared to traps set near the surface. Water quality data showed that coho preferred warmer (2°C) bottom habitat, despite low levels of dissolved oxygen (3 mg/L), rather than surface waters that had high dissolved oxygen (8 mg/L) but were colder (0.6°C).

Although not directly applicable to Iliamna Lake, numerous studies have consistently demonstrated that stream-dwelling juvenile salmonids in periods of low water temperatures exhibit a strong negative phototaxis response, where they hide in dense, light-blocking cover during the day and emerge into the open water column at night (Contor and Griffith 1995; Griffith and Smith 1993).

In the Kvichak River, sockeye smolts were sampled during their seaward migration in mid-May through mid-June in 2008 to 2013 at two sites after ice had stopped flowing from Iliamna Lake, mostly in May (Nemeth et al. 2014). Variability in abundance estimates was observed both between sites and years. At one site, abundance estimates of smolts ranged from 30.8 million to 57.3 million, and at the other site estimates ranged from 26.9 million to 47.0 million. This monitoring established the run timing between May 22 and June 9 (midpoint of May 27). Most smolts migrated down the left side of the channel over relatively deep water, although smolts were also detected across the entire river. Most smolts in the Kvichak River migrated within the upper 1.0 meter of the water column, and approximately half the run migrated during the daylight hours.

Limited information is available describing the distribution, abundance, or general ecology of resident fish species in Iliamna Lake; however, stickleback are frequently the most abundant fish species observed in trawl surveys, particularly in shallow, nearshore environments in the eastern lake basin (Rich 2006). Stickleback and juvenile salmon are likely the predominant prey species for larger piscivorous fish species, such as northern pike, rainbow trout, lake trout, Arctic char, Dolly Varden, and burbot. Sticklebacks, juvenile salmon, whitefish, sculpin, and lamprey are known or suspected prey species for the lake-resident seal population, particularly during periods when adult sockeye are absent (Hauser et al. 2008). Sculpin are a common inhabitant of the benthic zone and are known to be significant predators of sockeye salmon eggs and newly emerged fry (Kline et al. 1993). Sculpin in Iliamna Lake, as well as stickleback, rainbow trout, and char (species not identified), have all shown enhanced levels of marine-derived nitrogen, and benefit from the abundance of post-spawn sockeye carcasses in Iliamna Lake (Mathisen et al. 1988).

Of the non-anadromous species present in Iliamna Lake, rainbow trout provide an important sport fishery in the lake and associated tributaries, including UTC, the Newhalen River, and the Gibraltar River. The adfluvial form of rainbow trout are widely distributed in the Iliamna Lake basin. Seventy fish of 97 radio-tagged adult trout were tracked throughout the western half of Iliamna Lake and many of the lake's western tributaries through spring of 2009 (PLP 2018b). UTC-tagged trout migrated from 10 tributaries to western Iliamna Lake, with most detections in UTC, lower Talarik Creek, Pete Andrews Creek, the Newhalen River, and the Kvichak River. Migration patterns included spring immigration into tributaries (presumably for spawning), and summer foraging throughout the western half of Iliamna Lake or in several tributaries, followed by fall immigration and overwintering in the lower mainstem reaches or outlet lagoon habitats of the five tributaries listed previously (Minard et al. 1992). Relatively few tag detections in Iliamna Lake occurred east of the line between Gibraltar Creek and the Newhalen River; however, a large proportion of detections occurred in offshore areas of western Iliamna Lake, suggesting a pelagic migratory pattern.

Lake Productivity and Marine-Derived Nutrients

Input of MDN from carcasses of spawned-out salmon (particularly sockeye) is an important factor in the productivity of Iliamna Lake and its primary spawning tributaries (EPA 2014; Mathisen et al. 1988). Nutrients support productivity of phytoplankton, which in turn supports zooplankton, the primary diet of juvenile sockeye in Iliamna Lake. A simulation of the effects of MDN on the productivity of an Idaho lake concluded that adult sockeye carcasses would have been responsible for 3 percent of the annual phosphorus load, and positive effects would be transitory (Gross et al. 1998). This result was due in part to the relatively high flushing rate of Redfish Lake, as well as low smolt-to-adult survival and conservative estimates of pre-dam escapement of sockeye salmon. Given a more liberal escapement estimate that would be comparable to a comparable Alaska lake (Karluk Lake), MDN could contribute up to 17 percent of total phosphorus and 11 percent of total nitrogen. Comparison of MDN effects in Iliamna Lake with several nearby lakes without anadromous fish demonstrated that sampled fish in Iliamna Lake contained higher levels of a marine-origin nitrogen isotope than did fish in the control lakes (Klein et al. 1993).

Aquatic Invertebrates

Zooplankton are a primary source of food for plankton-eating juvenile fishes, including sockeye salmon (Quinn 2018). Hoag (1972) found that sockeye fry most often fed on Bosmina (a genus of copepod), whereas yearling prey mostly consisted of the cladoceran Cyclops. Given the importance of zooplankton to the growth and survival of juvenile salmon rearing in Iliamna Lake, the primary and secondary productivity of Iliamna Lake has been intensively studied, including recent data collected for this project (R2 et al. 2011a). Project baseline studies were conducted in the northeastern portion of Iliamna Lake, which extended from the mouth of UTC to just beyond Northeast Bay just west of Eagle Bay (Figure 3.24-19). Monthly samples taken in Iliamna Lake in May through October 2005 and 2007 at five sites in proximity to the Alternative 2 and Alternative 3 transportation corridor showed six groups of zooplankton: Copepoda (copepod crustaceans), Cladocera (water fleas), Ostracoda (seed shrimp), Rotifera (rotifers or wheel animals), Laevicaudata (clam shrimp), and Anostraca (fairy shrimp). These groups are similar to those documented in previous studies of Iliamna Lake and other lakes in the region (Biesinger 1984; Hoag 1972; Lenarz 1966 [in R2 et al. 2011a]). Seasonal variations in relative abundance of these groups were observed in both years and between sites. Although variations occurred, copepods were most common. Ostracoda, Anostraca, and Laevicaudata were seldom found and comprised less than 1 percent of the overall population of zooplankton. Rich (2006) found that zooplankton densities increased from spring to summer and noted a declining trend from the western basin to the eastern basin.

As part of the Iliamna Lake Study (HDR 2011a, Appendix B), freshwater mussels were collected at Bucket Lake, Finn Bay, Flat Island, and Whistlewing Bay on Iliamna Lake from 2005-2007 (HDR Alaska 2011a, Appendix B). Samples were analyzed for contaminants, and no distribution or abundance data were collected. The closest site to project infrastructure was at Bucket Lake, approximately 2.5 miles east of Alternative 1a natural gas pipeline corridor (Figure 3.24-15). No other mussels were documented in the analysis area.

3.24.5.5 Ferry Terminal Locations and Ferry Crossing Routes

Five potential ferry terminal locations have been identified on the shores of Iliamna Lake for the alternatives and variants (Figure 3.24-19). Figure 3.24-19 also depicts the potential ferry and pipeline crossing routes associated with the alternatives.

In general, the ferry terminal locations and crossing routes are not heavily used by spawning sockeye salmon (Figure 3.24-19). Aerial and snorkel surveys were conducted in July and August near potential ferry terminal sites (Paradox 2018c, d). Aerial surveys indicated that adult sockeye salmon were consistently found at or near the ferry terminal locations and were often swimming in an easterly direction along shore toward spawning locations in an eastern portion of Iliamna Lake or its tributaries. However, with the exception of test redd excavations (incomplete redds without egg deposition) at Eagle Bay North in August, no other signs of spawning or pre-spawning behavior were observed during the aerial or snorkel surveys. There was evidence of concurrent spawning activity at Knutson Bay east of Eagle Bay. As shown on the figure, the largest sockeye salmon spawning aggregations are in the eastern areas of Iliamna Lake. None of the ferry terminal sites appear to be consistently used for spawning by sockeye salmon. The following subsections provide additional information on the affected environment related to fish values at each of the ferry terminal locations.

Eagle Bay

Eagle Bay would be the site of a ferry terminal under Alternative 1a and Alternative 2 (Figure 3.24-19). Index sites were sampled intermittently in Eagle Bay, where counts of adult salmon ranged from 15 fish to about 5,000 fish. Counts were highly variable among the Eagle Bay Islands, just offshore from Eagle Bay, averaging more than 6,000 fish across 21 annual surveys. Adult sockeye were observed swimming along the northern and southern shorelines of the Eagle Bay terminal site in July and August, with greater abundance of fish along the northern margin, and reduced numbers of fish in August (Paradox 2018c, d). Although small areas of cleaned substrate were observed by snorkelers along the margin near the terminal site, none were subsequently developed into redds. A repeat survey in September revealed few adult sockeye along the northern margin, and no further evidence of spawning or spawning behaviors was observed, although heavy spawning activities had already commenced in Knutson Bay during August. Additional information on fish resources in Iliamna Lake is described above.

Two anadromous tributaries flow into Eagle Bay, including Eagle Bay Creek (AWC 324-10-10150-2239), which is listed for coho rearing, sockeye spawning, and the presence of

Arctic char. The AWC tributary 324-10-10150-2235 is on the opposite shore of Eagle Bay from the port site and is listed for sockeye spawning and presence of Arctic char. Historical adult counts in Eagle Bay Creek have ranged from zero in 1963 to more than 30,000 fish in 1975 (Morstad 2003).

Geomorphic studies conducted in 2018 describe beaches and nearshore lake habitats at potential ferry terminal locations, including Eagle Bay North and Eagle Bay South (Paradox 2018b). Two habitat transects were measured at the Eagle Bay North location, which revealed an average slope of 13 percent, and substrates dominated by clean rounded gravel with few fines. The two Eagle Bay South transects had average gradients of 10 and 11 percent, with substrates ranging from well-rounded gravel on the beach and nearshore areas to sub-angular cobbles and boulders at depths greater than 5 feet.

As depicted in Figure 3.24-19, spawning surveys have shown heavy use of the northeastern arm of Iliamna Lake, with highest densities associated with the main island archipelagos, Pedro Bay, and the Newhalen shoreline. Lower densities of spawning have been observed near Eagle Bay.

The ferry route for Alternative 2 traverses the eastern portion of Iliamna Lake, including Eagle Bay and the islands important to spawning sockeye salmon (Porcupine Island, Flat Island, Ross Island, Triangle Island, and Eagle Island), as well as the full length of Pile Bay (Figure 3.24-19). Lower densities of spawning have been observed near Eagle Bay or along the southern beaches of Pile Bay (Southeast Beaches and Finger Beaches), which possesses minimal littoral habitat, than in other bays and islands in the eastern basin (Morstad 2003). Although the islands contain extensive littoral shoal habitat, the ferry route would remain well offshore, where depths range from 200 to more than 900 feet.

North and South Ferry Terminal Sites

Alternative 1 would include a north ferry terminal 0.9 mile east of the UTC mainstem outlet to the lake. Both Alternative 1a and Alternative 1 include the south ferry terminal west of Kokhanok and the Gibraltar River.

Geomorphic studies conducted in 2018 describe beaches and nearshore lake habitats of the terminal locations (Paradox 2018b). The north ferry terminal site is characterized by a wide, gently sloping sand/gravel beach. Beach slopes averaged 13 to 18 percent at three measured transects; substrate consists of sand and rounded gravel with some cobbles at depth. The south terminal site consists of a gravel beach backed by a 20- to 30-foot bluff that transitions to a boulder beach at the bedrock point to the east. Average gradients at the three transects range from 11 to 17 percent. A small stream to the west of the terminal infiltrates the gravelly beach and provides a potential source of upwelling groundwater in the lake.

Fish and habitat surveys were conducted in 2018 near the ferry terminal locations in Iliamna Lake (Figure 3.24-19). Nearshore fish were surveyed May through August near the ferry terminal locations using seine nets, snorkel surveys, and aerial visual surveys from a helicopter (Paradox 2018b, c, d). The two most abundant species captured or observed in the seine and snorkel surveys were threespine stickleback and sockeye salmon. Other species captured or observed near the ferry terminal sites were chum salmon, coho salmon, pink salmon, Dolly Varden, longnose sucker, ninespine stickleback, pond smelt, and sculpin. No salmon spawning or pre-spawning behaviors were observed at the north or south ferry terminal locations, although adult sockeye salmon were observed from aerial surveys at every location in July and August.

The natural gas pipeline segment under Alternative 1a would cross the lake from Newhalen to the south ferry terminal, as compared to the route across the lake from the north to south ferry terminals under Alternative 1 (Figure 3.24-19). Neither the ferry crossing from the Eagle Bay terminal to the south terminal under Alternative 1a, nor the crossing from the north terminal to the south terminal under Alternative 1 would intersect known sockeye spawning habitat. However, the ferry route under Alternative 1a would pass within 0.35 to 0.5 mile of the Eagle Bay Island and Rabbit Island groups, each of which have supported beach spawning of up to 20,000 to 40,000 sockeye in some years (Morstad 2003).

Kokhanok East

The Alternative 1 Kokhanok East Ferry Terminal Variant would place the ferry terminal in the more protected waters of Kokhanok Bay, approximately 10 miles east of the south terminal location (Figure 3.24-19). The ferry route would pass within 0.2 to 1.5 miles of several islands and Lookout Peninsula, over depths mostly between 60 and 150 feet. The shoreline here is generally rocky and deepens rapidly, suggesting that it is unlikely to be preferred spawning habitat (PLP 2018-RFI 078). The pipeline corridor in Iliamna Lake would mostly follow the same path as Alternative 1, but would come ashore east of Kokhanok, joining a road corridor extending east 5.4 miles to the ferry terminal variant, then south 6 miles to join the Alternative 1 route to Amakdedori port, 21 miles to the east.

Specific fish sampling data are not currently available on fish resources for the Kokhanok East Ferry Terminal Variant or the seven channels that would be crossed via culverts along the Kokhanok East section of the transportation and natural gas pipeline corridor; however, a single bridge crossing would occur over AWC stream 324-10-10150-2206, which is listed as supporting sockeye spawning and the presence of Arctic char.

Pile Bay

Under Alternative 2, the ferry would cross from the Eagle Bay terminal to a ferry terminal at Pile Bay (Figure 3.24-19). As described for Eagle Bay, the midwater route of the alternative ferry crossing would not intersect known sockeye spawning habitat, except at the ferry terminal site in Eagle Bay. Lower densities of spawning salmon have been observed along most of the southern shore of Pile Bay, which possesses minimal littoral habitat. However, Pile Bay serves as a migration route for upstream migrant salmon (and trout) to the Iliamna River, Pile River, and several other anadromous tributaries, as well as an outmigration pathway for ocean-bound juvenile salmon.

3.24.5.6 Cook Inlet Portion of the Natural Gas Pipeline Corridor

The affected environment of the Cook Inlet portion of the natural gas pipeline is the same for all alternatives into the middle of Cook Inlet, at which point Alternative 1a and Alternative 1 continue south of Augustine Island and then to landfall at Amakdedori Beach (Figure 3.24-16). The western half of the pipeline route for Alternative 2 and Alternative 3 pass north of Augustine Island to landfall on the north shore of Ursus Cove, then enters and crosses Cottonwood Bay to Diamond Point.

Aquatic Habitat

Cook Inlet is a semi-enclosed estuary in southcentral Alaska that extends northeast approximately 180 miles from the Gulf of Alaska to Anchorage. Cook Inlet is fed by a wide variety of rivers, the largest being the Susitna River at the northern end of the inlet, and the Kenai River draining into the middle reach of the inlet. The substrate composition of Cook Inlet is mostly mudflats along the margins, with sand, clay, pebbles, and cobbles farther offshore. Rocky outcrops and shoals occur in many areas, especially in association with bays and islands. An assessment of nearshore substrate composition between Cook Inlet and Shelikof Strait showed extensive boulder armoring, with approximately 49 percent exposed rocky shore, 31 percent mixed sand and gravel, 12 percent gravel beaches, 3 percent exposed tidal flats, and 2 percent coarse-grained sand

(BOEM 2016b). General flow patterns include a net inflow along the eastern side of the inlet, including the Alaska Coastal Current, with net outflow along the western side (Burbank 1977). Inflow of turbid glacial streams generally produces low visibility, particularly in proximity to river mouths and along the western outflow. Cook Inlet is subject to large tidal fluctuations (up to 40 feet), which results in strong rips and currents in many locations. Winter temperatures result in extensive ice formation in the upper inlet and in isolated bays, with maximum ice coverage in January; breakup typically occurs between March and May.

The natural areas of Cook Inlet most likely to be affected by the pipeline are the lower Cook Inlet central zone and Kamishak Bay (Science Applications, Inc. 1977). The lower central zone is defined as the region north of the Barren Islands between Kamishak and Kachemak bays, and south of a line from Anchor Point to Chinitna Bay. This zone is an area dominated by tidal circulation, with mostly poorly sorted sands as bottom sediments (Science Applications, Inc. 1977). Approximately half of the pipeline route would traverse depths of 200 feet or more, with a substrate largely composed of sand, shells, and pebbles.

Anadromous and Marine Fish Distribution

In addition to all five species of Pacific salmon, marine forage fish, groundfish, and shellfish compose prominent fisheries resources in the region, many of which are monitored by ADF&G's Kamishak Bay bottom trawl survey, which provides abundance, biomass, and density estimates for commercially important shellfish and groundfish. The Cook Inlet area also supports several important groundfish species, with highest estimated biomass from Pacific halibut (*Hippoglossus stenolepis*), Pacific cod (*Gadus macrocephalus*), and walleye pollock (*Gadus chalcogramma*). Other important groundfish species include sablefish (Anoplopoma fimbria), dusky rockfish (*Sebastes ciliatus*), Pacific Ocean perch (*S. alutus*), redbanded rockfish (*S. babcocki*), redstripe rockfish (*S. proriger*), and lingcod (*Ophiodon elongatus*).

Commercially harvested flatfish include arrowtooth flounder (*Reinhardtius stomias*), butter sole (*Isopsetta isolepis*), flathead sole (*Hippoglossoides elassodon*), rock sole (*Lepidopsetta bilineata*), dover sole (*Microstomus pacificus*), rex sole (*Glyptocephalus zachirus*), English sole (*Parophrys vetulus*), starry flounder (*Platichthys stellatus*), Alaska plaice (*Pleuronectes quadrituberculatus*), and yellowfin sole (*Limanda aspera*). Other demersal fish species include sculpins, longnose and big skates (*Rajidae*), spiny dogfish (*Squalus acanthias*) and other sharks (various orders and genera), commander squid (*Berryteuthis magister*), giant Pacific octopus (*Enteroctopus dofleini*), shortspine thornyhead (*Sebastolobus alascanus*), and numerous other marine species (Rumble et al. 2016).

Among forage species, Pacific herring (*Clupea pallasii*) and pond smelt are both found in the Cook Inlet management area (Hammarstrom and Ford 2009), and capelin (*Mallotus villosus*), Pacific sand lance (*Ammodytes hexapterus*), eulachon (*Thaleichthys pacificus*), gunnels (Pholidae), Pacific sandfish (*Trichodon trichodon*), pricklebacks (Stichaeidae), and lanternfish (Myctophidae) may occur proximal to the Cook Inlet pipeline route and/or the Amakdedori port. The EFH (Appendix I) provides habitat and life-history information on marine species in lower Cook Inlet; see Section 3.6, Commercial and Recreational Fisheries, for current and past management activities, as well as catch statistics for many of these species.

Robards et al. (1999) conducted beach seines and mid-water trawls in nearshore habitats of lower Cook Inlet and found a diverse near-shore fish community of at least 52 species. Spatial differences in species diversity and abundance were observed in Cook Inlet, likely due to local oceanographic conditions and sediment inflow. The study also found significant changes in fish community abundance and diversity between 1976 and 1996, apparently related to large-scale climate changes in the North Pacific.

Aquatic Invertebrates

Coastal assessment studies in lower Cook Inlet have shown the area supports a healthy benthic community with balanced populations of species. Species abundance, richness, and diversity indexes are similar to undisturbed habitats and estuaries (Saupe et al. 2005). Investigations of the entire Cook Inlet area have found the lower Cook Inlet to be exposed to fewer contaminants than other locations in Alaska (Saupe et al 2005). Overall, Shannon-Weaver Diversity (H') for benthic communities (Saupe et al. 2005) ranged from 0.91 to 5.64. Polychaete worms (bristle worms) have been found to be the most dominant taxonomic group in benthic communities.

Intertidal environments experience increased wave action, large temperature and salinity shifts, and seasonal ice-gouging, which exert more stressful influences not experienced in subtidal habitats. Despite the physical stresses, some areas of the intertidal environment exhibited substantial biomass of large infauna that far exceeded the subtidal biomass. In addition, the infauna at subtidal stations exhibited a higher degree of in-station similarity than did the infauna at intertidal stations, which is a reflection of the greater diversity of intertidal substrates; likely a consequence of the harsher nature of the intertidal environment.

Subtidal studies found that coarse substrates dominated the area, and the biota therefore reflected this habitat type. Attached and burrowing animals, rather than burrowing infauna, dominated the diverse transects. The average abundance of all taxa observed ranged from 2,210 to 5,150 per square meter. Biomass ranged from 25.9 to 298 grams per square meter. The number of taxa observed ranged from 26 to 40 among sites sampled.

Macroinvertebrates

Clams are abundant along many Cook Inlet beaches. Stocks of razor clams (*Siliqua patula*) are concentrated in the Polly Creek area on the western side of Cook Inlet, and along the eastern side from Anchor Point to Kasilof River. Other clam species include littleneck (*Protothaca staminea*) and butter clams (*Saxidomus giganteus*) (Szarzi et al. 2007). Several species of crab are found in the Cook Inlet area, including tanner (*Chionoecetes bairdi* and *C. opilio*), red and golden king crab (*Paralithodes camtschaticus* and *Lithodes aequispina*), and Dungeness crabs (*Metacarcinus magister* or *Cancer magister*) (ADF&G 2002b, Rumble et al. 2020).

Several species of shrimp are also found in Cook Inlet, including pink (*Pandalus borealis*), sidestripes (*P. dispar*), humpy shrimp (*P. goniurus*), coonstripe shrimp (*P. hypsinotus*), and spot shrimp (*P. platyceros*) (ADF&G 2002b). Other invertebrate species include octopi (various species), green urchin (*Strongylocentrotus droebachiensis*), sea cucumber (*Echinozoa* sp.), and scallops (superfamily Pectinoidea). The predominant octopus species in Cook Inlet is the giant Pacific octopus (*Enteroctopus dofleini*).

Crabs, butter clams, little neck clams, and shrimp in Cook Inlet are no longer commercially harvested. However, scallops are commercially harvested in lower Cook Inlet. Cook Inlet supports large numbers of razor clams and a popular sport fishery on the western side of Cook Inlet. The eastern side of Cook Inlet has been closed to clamming since 2015, due to low population levels. This area does include sessile invertebrates such as coral, sponges (phylum Porifera), sea whips (*Protoptilum* spp.), and sea pens (order Pennatulacea), which are known to be import habitat for groundfish and crab and shrimp species. There are extensive sea whip and sea pen colonies in lower Cook Inlet, and these are known to increase survival of early settled weathervane scallops (*Patinopecten caurinus*) and tanner crab. Pacific halibut and Pacific cod, two of the most important groundfish species in the area, consume a diverse diet of marine invertebrates, many of which are not commercially fished.

Epibiota

Epibiota surveys were conducted in intertidal zones representing a wide range of habitats (Figure 3.24-20). Diverse intertidal habitat types provide feeding areas for numerous pelagic fish (which live in the open ocean) and demersal fish (which live close to the ocean floor), and invertebrates in lower Cook Inlet. In the rocky intertidal habitats, the distribution of vegetation and invertebrates is determined by elevation, substrate, season, and exposure to physical stressors, such as waves, sun, and ice scour. Diversity of both plants and animals among the rocky stations tend to increase with declining wave exposure and salinity and increasing sediment load. Ice is another major stressor of the biologic communities, because winter ice can severely reduce or completely remove sessile epibiota (immobile organisms that live on the surface of other organisms) each winter.

Baseline sampling results indicated several trends in the data. Fewer species of algae less tolerant of saline and variable light (i.e., more estuarine) conditions were present; and areas with high wave exposure had the greatest potential for high macroalgal diversity due to the high levels of disturbance, and greatest exposure to a larger recruiting stock, particularly at Cook Inlet waters.

Subtidal sampling for epifauna had limited visibility and detected relatively sparse epifaunal abundance. Kelp (order Laminarales) was prevalent closest to shore. Rocky substrate dominated most diver transects; therefore, invertebrate fauna was dominated by mobile organisms. Common attached invertebrates included sponges, hydroids (phylum Cnidaria), sea anemones (order Actiniaria), rock jingle (*Pododesmus machrochisma*), and bryozoans. Common mobile invertebrates included snails (class Gastropoda), chitons (class Polyplacophora), nudibranchs (class Gastropoda), crabs (order Decapoda), and sea stars (class Asteroidea). Few demersal fish species were observed, with the exception of whitespotted greenling (*Hexagrammos stelleri*), starry flounder (*Platichthys stellatus*), and other flatfishes (order Pleuronectiformes), which were common.

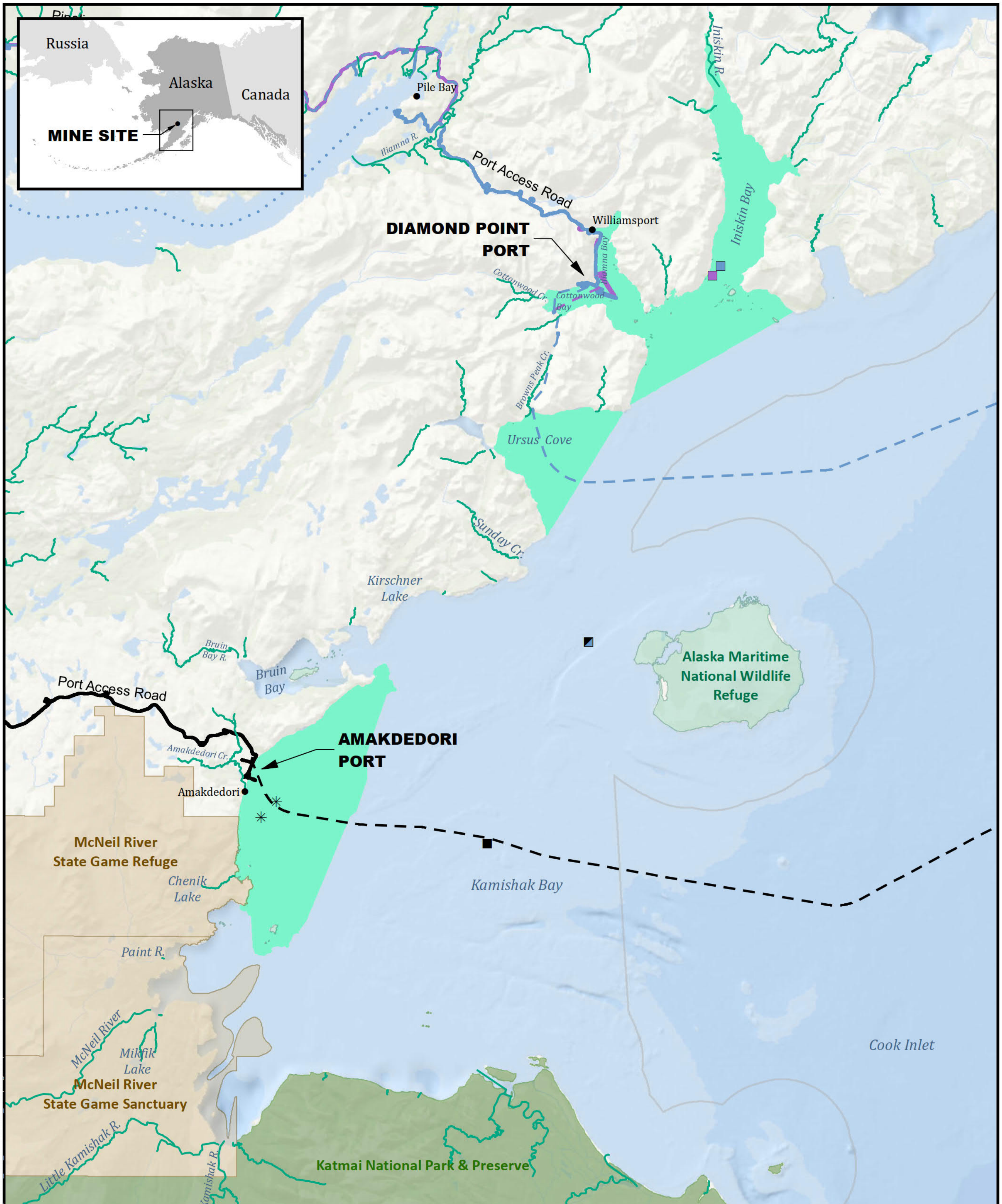
Infauna

Intertidal infauna (animals that live in ocean floor sediments) studies were conducted at multiple intertidal stations between 2004 and 2008 (Figure 3.24-20). Intertidal infauna study results indicate that all animals identified at the genus level are abundant in marine assemblages elsewhere in Alaska (Blanchard et al. 2003). Between 2004 and 2008, differences in abundance, biomass, and diversity were found in the infauna sampling results. These differences reflect small-scale spatial and temporal occurrences and illustrate the constantly shifting baseline conditions in the intertidal infauna assemblage. Intertidal studies found that the average number of infaunal taxa observed per square meter ranged from 1.6 to 8.0 in 2004, and from 1.6 to 14.2 in 2008.

Subtidal study results indicate stability in subtidal ecology over time. The variability of the results of subtidal faunal measures was considerable, but is comparable to the results of studies of similar marine assemblages elsewhere (Feder et al. 2005). Communities are dominated by a few taxa with high abundance, and there is a moderately diverse assemblage of taxa in sites. Subtidal infauna was, overall, more abundant and more diverse than intertidal infauna. Greater stability and lower stress in subtidal environments resulted in greater abundance and diversity.

3.24.6 Amakdedori Port

The following sections describe the affected environment related to fish values at Amakdedori port (Figure 3.24-20).



Sources: PLP 2020-RFI168;
PLP 2019-RFI153; ADF&G; ADNR

US Army Corps of Engineers

2 0 2 4
Miles

- Marine Habitat/Fish Sampling Site
- Anadromous Stream

Action Alternatives

- Lighted Navigation Buoys
- Lightering Locations
- Ferry Routes
- Natural Gas Pipelines
- Alternative 1a
- Alternative 2
- Alternative 3

Other Features

- State Game Refuge/Sanctuary
- National Park
- National Wildlife Refuge

MARINE SAMPLING SITES IN COOK INLET

PEBBLE PROJECT EIS

FIGURE 3.24-20

3.24.6.1 Aquatic Habitat

Amakdedori port would be in the central portion of Kamishak Bay (Figure 3.24-20), which is a relatively shallow, rocky bay with low-energy tidal circulation (Science Applications, Inc. 1977). The southward net transport of water from upper Cook Inlet along the western shore carries heavy loads of suspended matter into Kamishak Bay. This transportation of water also results in the movement of drift ice, which forms in the shallow tidal flats of upper Cook Inlet, into Kamishak Bay. The drift ice thoroughly scours extensive stretches of the intertidal zone, resulting in relatively poor development of eelgrass (*Zostera* marina) beds (Science Applications, Inc. 1977). Rocky substrates (intertidal reefs and subtidal rocky substrate) occur along a substantial portion of the shorelines of Kamishak Bay, and on many offshore reefs and islets (GeoEngineers 2018b, c). Rock is the dominant substrate into the intertidal zone. Mud or other unconsolidated sediments composing beaches extend from the toe of the rocky habitat down into the subtidal zone.

Amakdedori beach has a number of distinct reef complexes that occur in the vicinity of the port site, with varying proximity to the mainland nearshore environment. These range from rock reefs immediately adjacent to land (North Reef), to detached, but near the mainland (Thumb and Thumbnail), to offshore (Palmaria Plains and No Name). Habitat in the immediate vicinity of the port site is a moderate-gradient sand-gravel beach extending for approximately 5 miles (GeoEngineers 2018b, c). The environmental sensitivity index is defined as mixed sand and gravel beaches; and the coastal class is sand and gravel flat fan and/or narrow sand and gravel beach (NOAA 2018h).

The backshore is composed of a storm berm formed by LWD, with a broad flat riparian upland composed primarily of dune grass transitioning to low/dwarf shrub vegetation (GeoEngineers 2018b, c). A substantial sandy-silt flat is present immediately south of the mouth of Amakdedori Creek. Along the periphery of the beach (north, south, and offshore) lie extensive intertidal and subtidal reefs that extend as much as 8 miles offshore, with gaps of deeper subtidal habitat mostly less than 30 feet between them. These reef habitats support dense marine macrovegetation dominated by rockweed (*Fucus* spp.), red algae (phylum Rhodophyta), and kelps (order Laminariales). The nearest documented eelgrass bed to Amakdedori port is in a small cove about 4.4 miles south (NOAA 2018h).

Subtidal habitats are composed primarily of sand, cobbles, boulders, and bedrock. South of Amakdedori is an extensive reef complex dominated by Nordyke Island and Chenik Head Reefs (GeoEngineers 2018b, 2018c). The rocky shores of Nordyke Island and the large reef systems to the north, east, and south of the islands include a complex of conglomerate rock with lower-elevation intrusions of sandstone, providing a variety of elevations and exposures. Broad reefs are also found south of Chenik Head into Amakdedulia Cove. Between Chenik Head and Nordyke Island, the subtidal habitat consists of mixed fines. North Reef is an extended reef system that starts at the northern end of Amakdedori beach and continues to Contact Point. The area of reef most proximal to the project is the southern periphery of the reef adjacent to the broad cobble-gravel habitat of Amakdedori beach.

3.24.6.2 Anadromous and Marine Fish Distribution

Sockeye are abundant in several waterbodies tributary to Kamishak Bay, including the Kamishak River and Mikfik, and Chenik lakes (Figure 3.24-20). Amakdedori Creek currently enters Kamishak Bay 0.7 mile south of the port site and had average annual sockeye salmon runs of 1,200 fish between 1970 and 1980, which increased to an average of 2,364 fish over the past 10 years (Hollowell et al. 2017). The recent 10-year average escapement of pink salmon to Amakdedori Creek was 7,500 fish (Hollowell et al. 2017). Other basins supporting strong runs of pink salmon in Kamishak Bay include the Big and Little Kamishak rivers, Bruin Bay River, Sunday

Creek, and Browns Peak Creek. Principal chum salmon streams entering Kamishak Bay include the McNeil, Bruin, Douglas, Iniskin, Kamishak, and Little Kamishak rivers, Cottonwood Creek, and Ursus Lagoon creeks. See Section 3.6, Commercial and Recreational Fisheries, for more details on salmon runs and commercial fisheries proximal to the port site.

The existing fishery data were expanded by fish community sampling (March through July 2018) conducted by GeoEngineers (2018d) at several locations, including Amakdedori beach (Figure 3.24-20). In total, 27 beach seine samples were collected from the transportation and natural gas pipeline locations. More than 20 fish species (greater than 1,400 specimens) were collected, with juvenile salmonids as the dominant group in all three areas. The number and density of species differed between areas. At Amakdedori beach, 23 species were collected with juvenile salmonids (mostly pink and chum salmon), larval and adult surf smelt (*H. pretiosus*), juvenile whitespotted greenling, and starry flounder, making up 95 percent of the catch. Other species collected in low numbers included walleye pollock, flatfish (no ID), several sculpin species (Cottidae), Pacific sandlance, tomcod (*Microgadus proximus*), threespine stickleback, tubesnout (*Aulorhynchus flavidus*), and tubenose poacher (*Pallasina barbata*). Catch of larval surf smelt suggested drift of these larvae from other locations. Focused spawning surveys (eight sediment samples) at suitable spawning substrate at Amakdedori beach yielded no forage fish eggs. These findings are similar to those from the earlier sampling. Trawl sampling at several locations in 2013 and 2018 produced relatively low catch rates (2 to 3 fish/set) near Amakdedori, in comparison to sets in the Iliamna and Iniskin Estuaries (IIE) and Ursus Cove areas.

Pacific herring spawning surveys in 2018 (GeoEngineers 2018d) were undertaken at low tides to search for eggs on eelgrass and marine algae along Amakdedori beach. Pacific herring spawn survey data suggested that the Amakdedori port facility is isolated from known spawning areas. Seine hauls along Amakdedori beach caught an average of 0.75 herring/set in 2018, compared to catches in the hundreds per set in surveys in the IIE. Due to low stock size, the commercial fishery for herring roe in Kamishak Bay has been closed since 1999 (Hollowell et al. 2017). Herring spawn primarily on eelgrass and rockweed, which is found predominantly south of the port facility around reefs associated with Nordyke Island and Chenik Head, and also north of the port near Contact Point. The reefs associated with areas closer to the Amakdedori port facility (North Reef, Palmaria Plains, and Thumb/Thumbnail) were dominated by Palmaria spp., kelp, and other species that are little used by spawning herring. Pacific herring have been documented to spawn on marine macrovegetation, particularly in May, along the northern and southern edge of the Amakdedori beach sampling area. However, in 2018, no spawning activity was observed in or near the project footprint at Amakdedori beach (GeoEngineers 2018d). The only observed spawning activities were more than 5 miles to the south of the port site near Nordyke Island in late April and mid-May; with heaviest spawning activities associated with a large contiguous bed of eelgrass. Spawning was also observed on other species, including rockweed (*Fucus distichus*).

3.24.6.3 Aquatic Invertebrates

Assessment studies of the marine habitat area of Kamishak Bay have shown that the area largely consists of unconsolidated sediment habitats. These habitats vary widely and support many species of marine invertebrates. The habitats vary from high-energy, relatively steep, cobble/gravel beaches to very fine silt/clay flats. The cliff bases and mountainsides largely have “mixed-fine” beach types that are often relatively productive due to the rock component, allowing development of epibiota (i.e., organisms that live on the surface of other living plants or animals) and sediment that provide microhabitats for infauna (i.e., animals that live in the substrate of a body of water) (GeoEngineers 2018c).

Intertidal unconsolidated habitats were assessed as part of the baseline studies. The beach at Amakdedori is largely devoid of macrobiota (i.e., living organisms that are large enough to be seen with the naked eye), except where barnacles (infraclass Cirripedia) and ephemeral algae attach to larger boulders. This is due to substantial wave energy generated by wind waves and swells. Studies indicated that the lower beach face remains damp at low tides, and harbored epilithic (i.e., growing on a stone or stone-like material) bacterial and diatom films that potentially support smaller grazing crustaceans, which are known to provide prey for smaller fish that feed during high tides. Storm berms at the beach top were dominated by large amounts of LWD interspersed with marine debris. Lower on the beach, accumulations of detached macroalgae were present, deposited by currents and waves that form wrack lines that harbor amphipods and insects feeding both terrestrial birds and shorebirds.

Off the mouth of Amakdedori Creek, a finer-grained delta flat extended out into the subtidal zone. This area supported a population of razor clams. The infauna of the lower beach included a limited variety of polychaetes (bristle worms) and bivalves (e.g., oysters, clams, mussels, and scallops). This finer sand/silt beach supported a number of crustaceans, especially crangonid shrimp (family Crangonidae) that are prey for fish and diving birds.

The area north of Amakdedori beach includes a sharply rising upland that forms an eroding bluff. The upper beach face was a moderately high-energy boulder-cobble beach with occasional outcrops of bedrock. Elevation and wave energy combine to limit biological activity, except for beach hoppers (gammarid amphipods) associated with the wrack line and decaying algal fragments under boulders. Lower tidal elevations included beach hoppers (family Talitridae), barnacles, two barnacle predators (6-rayed seastars (*Leptasterias hexactis*), and drills [*Nucella* sp.]) and scavenger hermit crabs (superfamily Paguroidea). Grazing and ice scour likely prevented establishment of multi-year barnacles in this habitat. Boulder tops in some areas were coated with green (phylum Chlorophyta) and red algae.

A mix of soft habitat types occupied areas in North Reef, where sediment has accumulated in channels or over underlying bedrock to a depth that allowed the settlement and persistence of infauna, including a variety of bivalves, polychaetes, tube-building taxa, and cockles (superfamily Cardioidea). The spoonworm (subclass Echiura) was abundant in deeper, harder clay sediments adjacent to the southern portion of North Reef. Cobbles and gravel set in a hard clay matrix in this area limited the numbers of bivalves and polychaetes. Common algal species were present, including sugar kelp (*Laminaria saccharina*), acid kelp (*Desmarestia viridis*) and several red algae. Subtidal unconsolidated habitats were assessed as part of the baseline studies. The unconsolidated habitats in subtidal areas of Amakdedori Bay vary. Study samples collected in the area yielded little actual sediment, indicating coarse gravel dominates. Shell fragments from sampling indicate a number of bivalves and several gastropods in this study area. The presence of these gastropods suggested substrate has a substantial hard substrate component (i.e., gravel and or cobble dominance). Samples collected in soft sediments yielded abundant gammarid amphipods, sand dollars (order Clypeasteroida) and polychaetes, dominated by relatively large species of sand worm (*Nephtys caeca*). Gravel and rock surfaces exposed above the sediment often support encrusting coralline algae (order Corallinales), along with encrusting bryozoans (Ectoprocta) and hydroids (Hydrozoa). Larger cobbles and boulders often were encrusted with barnacles, tube worms (Polychaetea), and colonial tunicates (*Synoecia* sp.).

3.24.6.4 Fish Tissue Trace Element Analysis

Most inorganic chemicals analyzed were detected in the fish (whitespotted greenling and starry flounder) collected near Amakdedori Beach; except antimony, beryllium, and thallium, which were not detected. Mercury slightly exceeded the tissue screening level in starry flounder. Starry flounder mostly forage on benthic communities found in soft or mixed-soft habitats, which suggests that the source of mercury in this system may be associated with fine-grained sediment habitats. Sediment data supports this idea, as mercury was detected in samples at both sampling sites with concentrations near screening levels. The presence of mercury at these tissue concentrations is likely related to existing sediment mercury concentrations (GeoEngineers 2018a).

Selenium exceeded its screening level in whitespotted greenling. No clear source is identified for selenium, based on sediment/water results for the same analyte. The magnitude of the exceedance is likely due to the higher trophic level at which greenling feed; generally, one level higher than starry flounder. Tin exceeded the screening level in the tissue from both marine fishes collected. No other inorganic chemicals were detected greater than the screening levels in marine fishes analyzed. Concentrations in tissue are representative of existing or background conditions and are unlikely to represent a risk to the fishes sampled. Mercury may be a possible exception in that regional and global sources have contributed to elevated fish tissue concentrations; however, the exceedances of the screening level were low (for a detailed report on fish tissue trace metals analysis, see Appendix K4.24 and SLR et al. 2011a: Section 10.3).

3.24.7 Diamond Point Port

The following sections describe the aquatic habitat and fish distribution at the Diamond Point port site.

3.24.7.1 Aquatic Habitat

Diamond Point port would be at the intersection of Iliamna and Cottonwood bays (Figure 3.24-20). Habitat mapping in both bays, as well as Iniskin Bay and Ursus Cove, showed a wide diversity of nearshore habitat types. The majority of mapped habitat in Cottonwood Bay and Iliamna Bay was composed of intertidal habitat (60 percent), followed by subtidal (36 percent) and beach complex habitat (4 percent). Iniskin Bay had similar habitat proportions, but Ursus Cove had more beach complex (22 percent) and subtidal habitat (41 percent) and less intertidal habitat (37 percent). Ursus Cove also had a significant proportion of rocky reef habitat (55 percent), whereas the other three bays were largely composed of mixed fine and sand/fine substrate types, with 13 percent of marsh habitat in Iniskin Bay (GeoEngineers 2018c). Rocky substrates provide important habitat for rockweeds and other macroalgae, as well as associated invertebrate and fish species. Habitats composed of fine substrate types support diatoms, filamentous algae, and patches of eelgrass, with associated benthic invertebrates.

An extensive rock buttress projects into the intertidal zone from the base of a high cliff at the face of Diamond Point. At the lower edge of this rock habitat, a sand/mud flat extends to the west into Cottonwood Bay, and to the north into Iliamna Bay. The lower elevations at Diamond Point are composed in part of bedrock similar to that at higher elevations. However, boulder/cobble habitat is found at the base of the bedrock and forms the upper edge of the lower mudflat. Scattered eelgrass is present along the shoreline between Diamond Point and Williamsport, as well as west of the point in Cottonwood Bay. More extensive reefs and eelgrass beds are found in the larger Iniskin Bay to the north of Iliamna Bay. Compared to IIE (Pentec Environmental/Hart Crowser 2011a), minimal rock habitat exists on the northern shore of Ursus Cove in the vicinity of the natural gas pipeline route. Occasional ribs of bedrock and a few large boulders break up the generally uniform gravel and cobble beach.

3.24.7.2 Anadromous and Marine Fish Distribution

Pacific salmon return to numerous rivers in Kamishak Bay in proximity to the Diamond Point port site, including rivers entering Bruin Bay, Ursus Cove, Cottonwood Bay, and Iniskin Bay (Figure 3.24-20). Additional information on salmon runs in Kamishak Bay is provided above.

Marine fish and invertebrates were sampled in the IIE by beach seining, otter trawling, and gill or trammel netting in two different time periods (2004 to 2008, and 2010-2012) to establish baseline conditions and temporal variations in species composition and abundance in the marine habitat (Pentec Environmental/Hart Crowser 2011b). Additional sampling occurred in 2012 outside of the IIE, in the adjacent Cottonwood Bay, and immediately south in Rocky and Ursus coves for preliminary characterizations of the fish community (Hart Crowser 2015b). The use of multiple sampling gears provided a better coverage of several habitat types, potential spawning area, nursery areas, species distribution, and use in and outside of embayment in marine and estuarine environments.

Beach seine capture data from the IIE indicate that in the nearshore sandy/cobble habitats, 41 fish species were collected; however, not all species were captured at all stations and months. Overall, Pacific herring, juvenile pink salmon, juvenile chum salmon, Dolly Varden, surf smelt, and Pacific sand lance were the most common species captured in beach seines. The fishes captured in otter trawl represented fauna of open water and deeper waters than represented by seine (Pentec Environmental/Hart Crowser 2011b). Some 28 species were captured, dominated by snake prickleback (*Lumpenus sagitta*), yellowfin sole, starry flounder, Pacific herring, and walleye pollock. In gill nets, Pacific herring (multiple-year classes) dominated the catch, followed by Dolly Varden in both sampling periods. Trammel nets mostly captured spiny dogfish, starry flounder, Pacific halibut, and whitespotted greenling (Pentec Environmental/Hart Crowser 2011b).

The capture of young Pacific herring and salmonids suggests that these species use these areas for rearing. The Pacific herring supported a strong commercial fishery for roe until 1998; it was closed for fishing in 1999 due to low abundance. However, biomass of Pacific herring has not improved to historical levels (ADF&G 2009). Pacific herring spawning surveys in 2018 (GeoEngineers 2018a) were undertaken at low tides searching for eggs on eelgrass and marine algae in the IIE. Surveys conducted in both 2013 and 2018 indicate that herring spawn primarily on eelgrass and rockweed in May. In the IIE, a light density of herring eggs was documented on eelgrass in a small area containing depressions in the mudflat habitat. No other spawning events were documented in the IIE. Past and present surveys suggest that the IIE represents a minor contribution to Pacific herring spawning in Cook Inlet (Owl Ridge et al. 2019). However, the capture of young Pacific herring and salmonids suggests that these species use these areas for rearing.

Studies conducted in 2018 involved 27 beach seine samples, from which more than 20 fish species (greater than 1,400 specimens) were collected, with juvenile salmonids as the dominant group in all three areas. The number and density of species differed between areas. Focused spawning surveys in IIE yielded no forage fish eggs. These findings are similar to those from the earlier sampling (GeoEngineers 2018d). The presence of both juvenile and larger salmonids indicated that species use the nearshore locations as migration corridors between marine and freshwater environments. Catch of larval surf smelt suggested drift of these larvae from other locations.

3.24.7.3 Aquatic Invertebrates

Rocky habitats in the IIE and Ursus Cove environments support a variety of benthic invertebrate species, including sponges, barnacles (mostly *Semibalanus balanoides*), snails such as periwinkles (*Littorina sitkana*), drills (*Nucella* spp.), and limpets (*Lottidae*), sea stars, and crabs (e.g., hermit crab [*Pagurus hirsutiusculus*]), which in turn are prey for fish, bird, and mammal species. The unconsolidated substrate types common in beach, intertidal, and subtidal habitats were occupied by burrowing polychaetes such as *Nephtys* spp. and spoon worm (*Echiurus echiurus*), bivalves (mostly *Mya* and *Macoma* spp.), and crustaceans, including crangonid and mysid shrimp and crabs (GeoEngineers 2018c; Hart Crowser 2015).