4.16 SURFACE WATER HYDROLOGY

This section addresses effects of the project on surface water hydrology (recharge, reduction, movement, and distribution of surface water) (e.g., streams, lakes, marine waters), floodplain values, and shoreline erosion/accretion (i.e., deposition). Potential direct and indirect effects on surface water hydrology from the project may include:

- Stream channels being eliminated or reduced by construction and fill placement associated with the development and operation of the mine
- Streamflow changes resulting from mine operation (e.g., pit dewatering, collection of surface drainage in the mine site, water treatment plant (WTP) discharges, and closure and post-closure water management practices)
- Increased stream bank and channel erosion due to removal of the natural vegetation, construction in streams, or the construction of earthen structures (e.g., dams, road embankments, pads) before they become fully vegetated

The Environmental Impact Statement (EIS) analysis area includes watersheds (i.e., drainage basins) with numerous streams, lakes (including Iliamna Lake), and marine water (Cook Inlet), that have the potential to be impacted by the project.

The impacts analysis for surface water hydrology was based on evaluation of baseline conditions described in Section 3.16, Surface Water Hydrology, and considers operations and closure water management plans and mine site water balance modeling results for all phases of the project (Knight Piésold 2018a, d, r, s; Knight Piésold 2019q, r). Related discussion of impacts to water and sediment quality are addressed in Section 4.18, Water and Sediment Quality. In particular, Section 4.18 includes discussion of impacts related to construction in waterbodies (e.g., suspended sediment during in-water construction of project components and dredging). Impacts to groundwater and surface water/groundwater interaction are addressed in Section 4.17, Groundwater Hydrology. Impacts to wetlands are addressed in Section 4.22, Wetlands and Other Waters/Special Aquatic Sites, and impacts to fish and fish habitat are described in Section 4.24, Fish Values.

Scoping comments requested that a thorough understanding of the groundwater and surface water hydrology and how they relate to each other be demonstrated. Comments also expressed concerns about changes in water volume in the stream areas impacted, as well as changes in the downstream reaches of the watershed resulting from losses of upstream contributions of water. Commenters requested that flow changes in the impacted stream reaches, both from pit dewatering and from any in-stream discharge points, be evaluated; and suggested that areas of stream incision as a result of flow changes should be identified, as well as losses of connectivity to floodplains and riparian wetlands. Additional comments requested that a detailed water balance model be developed.

4.16.1 Summary of Key Issues

Table 4.16-1: Summary of Key Issues for Surface Water Hydrology

Impact Causing Project Component or Activity	Alternative 1a	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variant
Mine Site				
Mine Site—Streamflow During Operations, Maximum Footprint	**Magnitude** **NFK Watershed (Bulk and Pyritic TSFs, Main WMP, Process Facility):** 100 percent of NFK tributary NK1.190 flow diverted or stored due to bulk TSF. NFK River—Annual mean monthly streamflow change from pre-mining conditions of +9.2 percent reach NFK-C, and -0.2 percent reach NFK-A (with treated water discharge). **SFK Watershed (Mine Pit and Groundwater Dewatering Wells, Overburden Stockpile)**: SFK River—Annual mean monthly streamflow change from pre-mining conditions of -42.8 percent reach SFK-E, and -2.2 percent reach SFK-A (with treated water discharge). **UTC Watershed (Mine Access Road):** Upper UTC—Annual mean monthly streamflow change from pre-mining conditions of +2 percent reach UTC-F, and +0.2 percent reach UTC-A (with treated water discharge). **Duration/Extent** The duration of impacts to surface water hydrology would vary from temporary to permanent. The geographic extent of the impact on the NFK and the SFK rivers may extend just below the confluence of the two rivers. After the flows combine at the confluence of the NFK and SFK rivers, discernable changes in flow would be unlikely and are expected to be within historic and seasonal variation in the Koktuli River.	**NFK Watershed:** Same as Alternative 1a. **SFK Watershed:** Same as Alternative 1a. **UTC Watershed:** Same as Alternative 1a.	**NFK Watershed:** Same as Alternative 1a. **SFK Watershed:** Same as Alternative 1a. **UTC Watershed:** Same as Alternative 1a.	**NFK Watershed:** Same as Alternative 1a. **SFK Watershed:** Same as Alternative 1a. **UTC Watershed:** Same as Alternative 1a.

Table 4.16-1: Summary of Key Issues for Surface Water Hydrology

Impact Causing Project Component or Activity	Alternative 1a	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variant
Mine Site – Streamflow Post-Closure (Phase 4)	**Magnitude** **NFK Watershed:** 100 percent of tributary NK1.190 flow diverted or stored due to bulk TSF. NFK River—Annual mean monthly streamflow change from pre-mining conditions of +3.4 percent reach NFK-C, and 0.0 percent reach NFK-A (with treated water discharge). **SFK Watershed:** SFK River—Annual mean monthly streamflow change from pre-mining conditions of -32.8 percent reach SFK-E, and +1.7 percent reach SFK-A (with treated water discharge). **UTC Watershed:** UTC—Annual mean monthly streamflow change from pre-mining conditions of +0.9 percent reach UTC-F, and +0.2 percent reach UTC-A (with treated water discharge). **Duration/Extent** The duration of impacts to surface water hydrology would be the same as those described under operations.	**NFK Watershed:** Same as Alternative 1a. **SFK Watershed:** Same as Alternative 1a. **UTC Watershed:** Same as Alternative 1a.	**NFK Watershed:** Same as Alternative 1a. **SFK Watershed:** Same as Alternative 1a. **UTC Watershed:** Same as Alternative 1a.	**NFK Watershed:** Same as Alternative 1a. **SFK Watershed:** Same as Alternative 1a. **UTC Watershed:** Same as Alternative 1a.
Transportation Corridor				
Road Corridor Construction and Operations	**Surface Water**: **Magnitude/Duration/Extent** Potential for local impacts to surface water hydrology at stream crossings and other waterbodies. Impacts are expected to be short-term, and would result in maintained surface flow system changes in water quantity that are likely within historical seasonal variation. The magnitude of the impacts to surface water resources from water extraction would result in changes in water quantity that are likely within the limits of historic and seasonal variation. The duration of the impacts would be short-term, and the extent would be limited to the waterbody source.	**Surface Water**: Potential impacts similar to Alternative 1a.	**Surface Water**: Potential impacts similar to Alternative 1a.	**Surface Water**: Potential impacts similar to Alternative 1a, with increase in waterbody crossings as compared to Alternative 1a. **Concentrate Pipeline Variant**—increased project footprint because the road corridor would be widened for inclusion of concentrate pipeline.

Table 4.16-1: Summary of Key Issues for Surface Water Hydrology

Impact Causing Project Component or Activity	Alternative 1a	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variant
Ferry Terminal Construction and Operations	**Surface Water**: **Magnitude/Duration/Extent** Potential local impacts to surface water hydrology at the ferry terminal sites are expected to be short-term, and would result in maintained surface flow system changes in water quantity that are likely within historical seasonal variation. **Iliamna Lake:** *Ferry terminals:* Potential local and short-term impacts from disturbance of the shoreline and lakebed during construction. *Ferry operations:* Potential for direct, minimal, local impacts to occur in the form of shoreline and lakebed erosion from vessel wakes and propeller wash year-round. Note: Erosion impacts would be less in winter than summer because of frozen shoreline conditions that are more resistant to erosion.	**Surface Water:** Potential impacts similar to Alternative 1a. **Iliamna Lake:** Potential impacts similar to Alternative 1a. **Summer-Only Ferry Operation Variant** may slightly reduce impact from shoreline erosion. See note under ferry operations under Alternative 1a. **Kokhanok East Ferry Terminal Variant** Potential impacts similar to Alternative 1a ferry terminal location.	**Surface Water:** Potential impacts similar to Alternative 1a at Diamond Point port site. **Iliamna Lake (Eagle Bay/Pile Bay ferry terminals):** Potential impacts similar to Alternative 1a. **Summer-Only Ferry Variant** Potential impacts similar to Alternative 1a. **Newhalen River North Crossing Variant** Potential impacts similar to Alternative 1a.	No ferry under Alternative 3. **Surface Water:** No impacts. **Iliamna Lake:** No Impacts. **Newhalen River North Crossing Variant:** Potential impacts similar to Alternative 1a.
Port Site				
Port Site and Causeway fill/ construction	**Surface Water:** **Magnitude/Duration/Extent** Potential for local impacts at the port site. Impacts are expected to be short-term, and would result in maintained surface flow system changes in water quantity that are likely within historical seasonal variation. **Marine Water:** Potential impacts from the caisson dock and causeway would be minimal, long-term, and local. The causeway is not expected to cause changes in alongshore currents or natural gradients in either water temperature or salinity.	**Surface Water:** Potential impacts similar to Alternative 1a. **Marine Water:** Potential impacts similar to Alternative 1a. **Pile-Supported Dock Variant**. No impacts are expected on marine water currents from the pile-supported causeway.	**Surface Water:** Potential impacts similar to Alternative 1a. **Marine Water:** Diamond Point port: Potential impacts similar to Alternative 1a. **Pile-Supported Dock Variant:** Potential impacts similar to Alternative 1a.	**Surface Water:** Potential impacts similar to Alternative 1a. **Marine Water:** Potential impacts similar to Alternative 1a. **Concentrate Pipeline Variant**: Potential impacts similar to Alternative 1a.

Table 4.16-1: Summary of Key Issues for Surface Water Hydrology

Impact Causing Project Component or Activity	Alternative 1a	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variant
Ship Operations and Mooring	Potential direct, local, short-term impacts can include shoreline and seabed erosion from propeller wash in quiescent water. However, considering the hydrology of the bay(s), impacts from propeller wash would be expected to be short-term and localized during the time the vessel is in the vicinity. caused by ship wakes and propeller wash. **Lightering Locations Primary (A) and Alternate (B):** No effects to surface water hydrology are expected to result from installation of anchors or mooring buoys.	Potential impacts similar to the Alternative 1a. **Lightering Locations Iniskin Bay and Alternate (B):** Potential impacts similar to Alternative 1a.	Potential impacts similar to the Alternative 1a. **Lightering Locations Iniskin Bay and Alternate (B):** Potential impacts similar to Alternative 1a.	Potential impacts similar to the Alternative. 1a **Lightering Location Iniskin Bay:** Potential impacts similar to Alternative 1a.
Natural Gas Pipeline				
Construction and Installation of Pipeline	**Surface Water**: Similar to the impacts for the transportation corridor for the onshore portion of the pipeline. No impacts to hydrology in the marine portion of the pipeline corridor.	**Surface Water**: Similar to the impacts under Alternative 1a.	**Surface Water**: Potential impacts would be similar to the transportation corridor under Alternative 1a. Impacts include an increase in number of waterbody crossings along the pipeline corridor from the mine site to Diamond Point port and from Cottonwood Bay to Ursus Cover as compared to Alternative 1a. Additional acreage and additional stream crossings along segment between Ursus Cove and Cottonwood Bay.	**Surface Water**: Likely the same as for the transportation corridor under Alternative 1a.

Notes:
NFK = North Fork Koktuli
SFK = South Fork Koktuli
UTC = Upper Talarik Creek
WMP = Water Management Pond

4.16.2 Methodology for the Analysis of Surface Water Hydrology Impacts

4.16.2.1 Impacts

Impacts to surface water hydrology were evaluated based on baseline data, water management plans, and surface water modeling. The methodology applied to analyze and predict direct and indirect impacts is based on the range of effects for the following factors:

- Magnitude—Effects on surface water hydrology are estimated by predicting changes in surface water flow systems, including water quantity, flow direction, discharge, and recharge. Effects could be maintained within historic seasonal variation; could exceed baseline variation, but nearby uses and environment would be maintained; or there could be surface water hydrology changes that affect nearby uses or environment.
- Duration—The duration of effects depends on project phase (e.g., length of time required for construction). Surface water hydrology effects could last during a project phase but return to baseline conditions on completion of the phase; conditions could remain throughout the life of the mine (operations) and decades afterwards; or there could be surface water hydrology changes that would not return to baseline for more than 100 years.
- Extent—Effects depend on geographic area. Effects could be limited to portions of the project footprint or component area and not connected to waters outside the component area; could occur beyond the project component areas, potentially throughout the EIS analysis area; or effects could be hydraulically connected to areas beyond the EIS analysis area.
- Potential—Most effects on surface water hydrology in the mine site are considered likely to occur. The likelihood of occurrence of surface water hydrology impacts for other project components would depend on whether surface waterbodies would be intersected or diverted during project activities.

4.16.2.2 Streamflow Analysis for the Mine Site

A mine site water management plan (Knight Piésold 2018a) was developed to: 1) quantify fresh water and mine process water requirements; 2) estimate pit dewatering requirements; 3) support design of water management and treatment systems; 4) minimize the potential for an uncontrolled discharge of untreated contact or tailings water; and 5) predict the impact of mining on streamflow in nearby streams.

This narrative provides a summary of methods and approach used for streamflow analysis to determine streamflow changes that would result from the project during end of mine (i.e., operations) (Knight Piésold 2019r) and post-closure (Knight Piésold 2019q). Modeling and inputs to the model are described in greater detail in both Appendix K3.16 and Appendix K4.16. Appendix K4.16 is frequently cross-referenced in this section. Streamflow analysis was not performed for the construction phase; however, based on analysis for end of mine and post-closure, it is anticipated that the magnitude of the impact during construction would be no greater than the magnitude of the impact at the end of mine.

The streamflow analysis involved streamflow and streamflow change computations:

- For the end of mine and post-closure phases
- With and without WTP discharge to streams
- For several reaches in the North Fork Koktuli (NFK) River, South Fork Koktuli (SFK) River, and Upper Talarik Creek (UTC) (Appendix K4.16, Figure K4.16-6 through Figure K4.16-8)

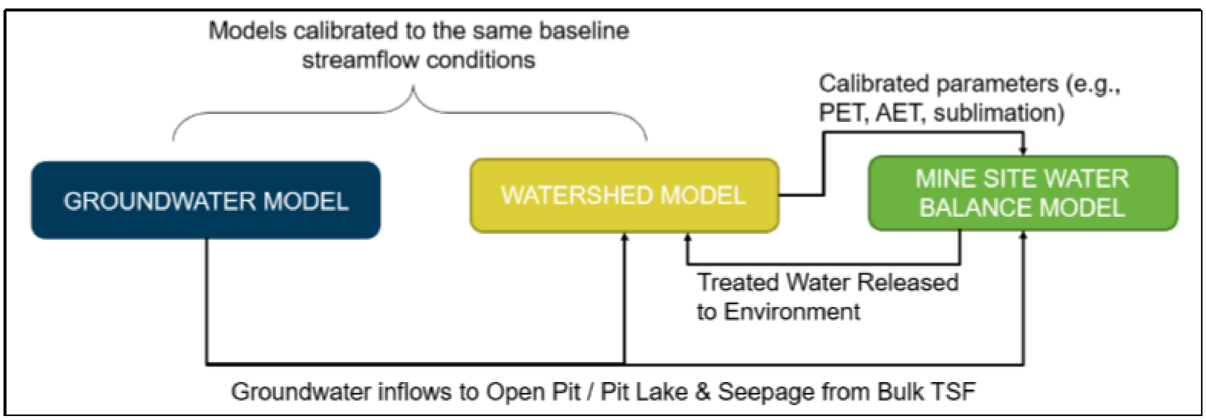
- Using three scenarios (base case, high conductivity [K] and low K)
- For three exceedance probabilities (10 percent, 50 percent, and 90 percent)

Appendix K4.16 provides discussion of the analyses, including additional considerations and explanation of the uncertainty associated with the streamflow and streamflow change estimates.

Comprehensive Water Modeling System

Development of the water management plan for the mine was facilitated by creating a comprehensive water modeling system composed of three models: the baseline watershed model (BWM); the mine site water balance model; and the groundwater model (Knight Piésold 2019g, f, n; PLP 2019-RFI 109g). The models collectively provide the means for quantifying water flows in streams, groundwater, and in the various pipes, ponds, and mine structures associated with all phases of the project—from baseline (pre-development) to post-closure.The BWM results are summarized in Section 3.16, and development of the BWM is described in Appendix K3.16. Additional details related to the BWM are described in Knight Piésold 2019g; additional details related to the mine site water balance are described in Knight Piésold (2019f, n, s). Figure 4.16-1 provides an illustration of the relationships between the three models composing the comprehensive modeling system: groundwater model, watershed model, and the mine site water balance model. The following discussion addresses the mine site water balance model and groundwater model as they relate to water management and streamflow changes analyzed for the project.

Figure 4.16-1: Comprehensive Water Modeling System



PET = potential evapotranspiration
AET = actual evapotranspiration
TSF = bulk storage facility
Source: Knight Piésold 2019f, Figure 3.1

Groundwater Flow Model

The groundwater flow model (BGC 2019a) was used to predict groundwater and seepage flow rates and directions that would result from mine-related activities at the end of mine (operations) and post-closure phase (see Section 4.17, Groundwater Hydrology). Predicted groundwater flows used in the mine site water balance model (water balance model) and water quality model (Knight Piésold 2019s) include pit dewatering (perimeter wells and in-pit wells, and flow directly to the open pit). Seepage flow rates and directions from the bulk tailings storage facility (TSF) were also estimated for end of mine and post-closure using the groundwater flow model. The calibration process and resulting hydrologic parameters for baseline conditions, end of mine, and post-closure are discussed in Section 3.17 and Section 4.17, Groundwater Hydrology. Estimates of groundwater flows in the vicinity of the major mine facilities, particularly groundwater inflows to the open pit, as well as seepage and groundwater inflows to underdrains beneath the bulk TSF, were generated using the groundwater flow model. These groundwater inflow estimates, for the base case and select sensitivity scenarios, were incorporated into the baseline watershed model and mine site water balance model as part of the evaluation of potential streamflow changes (Knight Piésold 2019f, n).

Mine Site Water Balance Model

A mine site water balance model was developed by Knight Piésold (2019s) that has been used to:

- Develop water management strategies
- Estimate the operating capacities required for water storage and conveyance structures, and WTPs
- Estimate changes in average monthly streamflow on the NFK, SFK, UTC, and selected tributaries of those streams affected by the project

The mine site water balance model is used to analyze the movement of water in the mine site using inputs from the baseline watershed model and the groundwater flow model (Knight Piésold 2019f, n). The mine site water balance model provides the volume of surplus water to that which could be distributed between the drainages, after water treatment. For base case and select sensitivity scenarios, the volume of surplus water and the groundwater model inflow estimates were incorporated into the baseline watershed model to evaluate potential streamflow change. (Knight Piésold 2019r, q). Results of the baseline watershed model were used to define the hydrologic parameters at the mine site, and determine groundwater recharge and surface water runoff. Results of the groundwater flow model were used to define the groundwater and seepage flow rates and directions in the project area (BGC 2019a; Knight Piésold 2019s).

The mine site water balance model was also the base model for the water quality model (Knight Piésold 2019s) (see Section 4.18, Water and Sediment Quality), and provides the estimated amount of surplus water available for treatment and release to the surrounding environment.

The mine site water balance model was developed using the GoldSim® modeling platform and uses a monthly timestep. The monthly timestep, which uses mean monthly temperature and total monthly precipitation inputs, allows for water management strategies to be assessed on a long-term scale such as WTP capacity and water management pond (WMP) operating storage requirements. Short-term extreme precipitation events, such as hourly or daily storm events, are not addressed in the mine site water balance model. It is conventional engineering practice for these events to be accounted for in the design of each facility with the allowance of storm storage and freeboard requirements. The mine site water balance model does address the possible range of wet and dry conditions at the mine by incorporating climate variability, which is used to define the operating storage requirements for the water management facilities. Storm storage and freeboard requirements are considered, in addition to the maximum WMP storage requirements determined with the mine site water balance model (Knight Piésold 2019s).

The mine site water balance model simulates the water flow through for the following facilities: process plant, open pit, open pit WMP, pit lake, bulk TSF, pyritic TSF, main WMP, the seepage collection and recycle ponds (SCRPs), and the seepage collection ponds (SCPs), and is used to determine the maximum influent flow to each WTP.

The mine site water balance model treats all the water available for runoff and groundwater recharge as surface water runoff. The mine site water balance model does not explicitly simulate recharge to the groundwater system, but accounts for this volume of water as surface water runoff. This eliminates the need to simulate separate flow paths for groundwater and surface water that report to the water management facilities. However, groundwater flows to the open pit and pumping wells are an addition of water to the mine site water balance model (Knight Piésold 2019s).

Seepage pathways of contact water are explicitly modeled to account for the water quality loading associated with them. The migration of seepage from the TSFs and the main WMP is modeled as specific flow paths in the mine site water balance model for water quality modeling purposes (see Section 4.18, Water and Sediment Quality). These seepage flows are modeled as a loss to the WMPs and as a gain to the SCPs.

Climate variability was incorporated into the mine site water balance model using the 76-year monthly average synthetic temperature and precipitation record (see Section 3.16 and Appendix K3.16, Surface Water Hydrology). Each run of the model uses 20 consecutive years of data. Seventy-six 20-year runs were made, each starting with a different year in the 76-year synthetic record and running for 20 years. This method of analysis was used to preserve the inherent cyclical nature of the climate record, and resulted in 76 evaluations of possible water flow and storage over the life of the mine.

The volume of water managed in the mine site is a function of the climate. More water would be collected and managed during wet climate conditions than in dry climate conditions. Unique model runs (realizations) were used in the mine site water balance model runs to incorporate climate variability. Realizations were selected from the entire set of 76 model realizations to represent relatively dry, average, and relatively wet conditions. The year-to-year variation in annual precipitation differs for each of the realizations, but the realizations were selected based on the representation of dry, average, or wet conditions. The final year of the operations (end of mine) was selected as the representative year for the water balance model. The realizations are described in detail in Knight Piésold 2019s and summarized below.

- Relatively dry climate condition—Realization #7: The annual precipitation in the final year of operations (end of mine) is 31 inches, which is the lowest annual precipitation in the synthetic climate time-series for Pebble 1, and is slightly drier than the 25-year dry year (25-year dry year is estimated to have an annual precipitation of 34 inches). The 20-year average annual precipitation for Realization #7 is 54 inches.
- Average climate condition—Realization #8: Annual precipitation for the final year of operations is 55 inches, which represents the long-term average annual precipitation of the synthetic climate time series for Pebble 1. The 20-year average annual precipitation for Realization #8 is 55 inches.
- Relatively wet climate condition—Realization #10: The annual precipitation for the final year of operations is 89 inches, which is the highest annual precipitation in the synthetic climate time-series for Pebble 1, and is slightly drier than the 200-year wet year (200-year wet year is estimated to have an annual precipitation of 91 inches). The 20-year average annual precipitation for Realization #10 is 54 inches.

The relatively wet condition corresponds to more runoff and direct precipitation being collected in the water management facilities than during the relatively dry condition. The amount of process water managed during all realizations is the same because this is a function of the processing throughput rate and the tailings properties, independent of the climate conditions.

Water that is not available (water losses) for process, or for treatment and discharge to surface water flow includes:

- Evaporation from the surfaces of the WTPs and the cooling towers of the power plant
- Water lost or trapped in the bulk tailings voids stored in the bulk TSF and the pyritic tailings voids and waste rock voids stored in the pyritic TSF
- A small amount of water that is entrained in the concentrate and removed from the mine site with the concentrate
- Water losses due to the process are a function of the throughput rate, the tailings and waste rock properties, and the power plant design; these losses are independent of the climate conditions and therefore similar under all climatic conditions

4.16.3 No Action Alternative

Under the No Action Alternative, federal agencies with decision-making authorities on the project would not issue permits under their respective authorities. The Applicant's Preferred Alternative would not be undertaken, and no construction, operations, or closure activities specific to the Applicant’s Preferred Alternative would occur. Although no resource development would occur under the Applicant's Preferred Alternative, Pebble Limited Partnership (PLP) would retain the ability to apply for continued mineral exploration activities under the State's authorization process (ADNR 2018-RFI 073) or for any activity not requiring federal authorization. In addition, there are many valid mining claims in the area, and these lands would remain open to mineral entry and exploration by other individuals or companies.

It would be expected that current State-authorized activities associated with mineral exploration and reclamation, as well as scientific studies, would continue at levels similar to recent post-exploration activity. The State requires that sites be reclaimed at the conclusion of their State-authorized exploration program. If reclamation approval is not granted immediately after the cessation of activities, the State may require continued authorization for ongoing monitoring and reclamation work as it deems necessary.

As permitted, the activities would not be expected to cause any new effects on surface water hydrology.

PLP would be required to reclaim any remaining sites at the conclusion of their exploration program. If reclamation approval is not granted immediately after the cessation of reclamation activities, the State of Alaska may require continued authorization for ongoing monitoring and reclamation work as deemed necessary. Although these activities would also cause disturbance, reclamation would benefit the mine setting.

4.16.4 Alternative 1a

This section describes potential impacts of the project on surface water hydrology for each project component for all phases of the project. The duration of the impact to streamflow would be long-term, lasting beyond the construction phase in some streams and reaches, but would generally be less during post-closure than during construction or operation. The one exception is NFK Tributary 1.19, which is in the mine site footprint. NFK Tributary 1.19 would be removed during construction and would not be replaced.

4.16.4.1 Mine Site

This section describes the water management methods and structures and estimated impacts to surface water hydrology in the mine site area, including material sites by project phase for construction, end of mine (i.e., operations), and post-closure.

The project would be designed for zero-discharge of untreated contact water during construction, operations, and closure. Water management strategies have been developed to achieve this design and maintain sufficient fresh water for ore processing and other mine site uses (Knight Piésold 2019s).

Construction

Water Management

The primary goal of water management during construction is to manage runoff and minimize surface water contact with disturbed surfaces. Among the first facilities to be constructed would be the water management structures. Where water cannot be diverted, it would be collected, treated, and discharged. Critical water management facilities developed during the construction phase are described in PLP 2020d and include the following:

- Water diversion channels, berms, and collection ditches would be constructed using erosion-control features (e.g., geotextile, riprap), and sized for the 100-year, 24-hour rainfall event. Energy dissipation structures, such as spill basins or similar control measures, would be used, where required, to reduce erosion at the outlets of the diversion channels and collection ditches.
- Sediment control ponds would be sized to attenuate and treat up to the 10-year, 24-hour rainfall-runoff volume, and to safely manage the 100-year, 24-hour rainfall event.
- A temporary cofferdam would be constructed upstream of the bulk TSF main embankment to manage water during the initial construction phase. Runoff from the undisturbed upstream catchment would be collected behind the cofferdam; would be pumped to a location downstream of all construction activities; and would be released in the same watershed.
- Prior to the completion of the TSF embankments and water management structures, all water that does not meet water quality standards would be treated and released.
- Stormwater and sediment control best management practices (BMPs) would be used, including temporary settling basins and silt fencing.[1]

All mine site embankments, except for the bulk TSF and pyritic TSF embankments, would be fully constructed prior to the operations phase (PLP 2018-RFI 019a).

Streamflow

Surface water quantity and distribution in the NFK River, SFK River, and possibly UTC watersheds would be affected during construction through diversion and collection of surface water, initial drawdown of groundwater at the open pit area in preparation for mining activities, and WTP discharge.

The magnitude of the impact on average monthly streamflow in the NFK, SFK, and UTC has not been estimated for the construction phase. However, estimates of the impact on streamflow were determined at end of mine and post-closure, and methods are described in detail in Appendix K4.16 under Streamflow Changes, and Knight Piésold (2019r, q). It is anticipated that the magnitude of the impact during construction would be no greater than the magnitude of the impact at the end of mine. The duration would be expected to be temporary to long-term, and the

[1] These aspects of construction water management would be further developed in a Stormwater Pollution Prevention Plan (SWPPP) (See Chapter 5, Mitigation).

geographic extent of the impact on the NFK and the SFK during construction may extend just below the confluence of the two rivers. After the flows combine at the confluence of the NFK and SFK rivers, discernable changes in flow would be unlikely and are expected to be within historic and seasonal variation in the Koktuli River.

Erosion and Deposition

There would be potential for increased upland and stream channel erosion due to removal of natural vegetation, construction in streams, or the construction of earthen structures. Although the magnitude of the erosion would be larger than natural historic variation, the water management practices would prevent or minimize the magnitude of the impact of the eroded sediment and subsequent deposition (see Chapter 5, Mitigation). The duration of the impact from erosion and deposition could extend into the closure phase. The geographic extent of the erosional disturbance and the deposition of the majority of the sediment would be limited to the mine site, but increased stream sediment load might extend to the Koktuli River (see Section 4.18, Water and Sediment Quality).

The potential for increased channel erosion downstream from road culverts in the mine site would be expected during construction. Based on the typical culvert drawings (see Figure 2-22 and Figure 2-23), if a suitable flood-peak discharge is used for design, the magnitude of the impact is estimated to be small. An additional factor contributing to an estimate of a small magnitude is that the mine is in the headwaters, where stream channels and runoff are smaller than lower in the watersheds. The duration of the impact would be from construction through operations and into closure. The geographic extent of the impact would be within a few hundred feet of the downstream side of the culverts.

The potential for increased erosion downstream from road culverts due to a culvert washout is considered unlikely, based on the typical culvert drawings provided (see Figure 2-22 and Figure 2-23), and if a suitable flood-peak discharge is used for design. However, if it were to occur, the duration of the impact would be long-term, lasting from construction through operations and into closure. The geographic extent of the impact would be within hundreds of feet of the culvert.

Construction of culverts and bridges that are not properly installed, become clogged, or are under-designed could potentially cause backwater. Under these conditions, upstream velocities decrease and deposition potential increases. Additional erosion and deposition detail with regard to bridges and culverts is provided below.

Water Ponding

There is a potential for increased water ponding adjacent to the upstream side of access roads, where drainage could be disrupted by the lack of a drainage structure. If such a situation occurs, it would be in an area with a relatively large volume of traffic, and would be noticed and remedied quickly. Therefore, the duration of the impact would be on the order of weeks. The geographic extent of the area flooded would be on the upstream side of the road, and would be no greater than the area encompassed by the ground, with an elevation equal to the top elevation of the road.

There is a potential for water depth to increase immediately upstream from a culvert during the construction phase. However, culverts are generally designed to pass flood-peak discharges by increasing the depth of water at the inlet. The maximum increase in water depth would occur upstream from the culvert at a location equal to the width of the culvert, and would be less than the difference in the unrestricted water surface elevation and the top of road elevation. The upstream extent of the impact would depend on the magnitude of the increase in water surface elevation and the slope of the stream. The duration of the impact would be about the same as the flood event.

Operations

Water Management

During operations, the main water management objectives are to:

- Minimize the generation of contact water[2]
- Manage fresh water (non-contact water)
- Manage stormwater (runoff from facilities, non-contact water)
- Manage mine drainage (contact groundwater or surface water)
- Manage process water (contact wastewater generated from operations)
- Manage inflow to and discharge from the WTPs

Water not diverted before becoming contact water would be collected and used as process water, or treated and discharged to the environment. No additional water sources outside the mine site would be needed for operations, except potable water for camp personnel that would be obtained from groundwater wells about 0.5 mile northeast of the main WMP (see Section 4.17, Groundwater Hydrology).

The main mine site water management structures during operations include those listed on Table 4.16-2 and depicted on Figure 4.16-2. A brief description of the design criteria for the water management structures is provided in Table 4.16-2. Without an emergency spillway (see Chapter 2, Alternatives), sufficient freeboard must be provided below the crest of embankments to contain the volume of the inflow design flood (IDF), with additional freeboard (2 feet minimum) necessary to contain wind and wave action above the maximum flood pool elevation at the IDF (ADNR 2017a) (see Section 4.15, Geohazards and Seismic Conditions, for information about stability of the embankments).

The volume of water requiring treatment during operations is expected to vary based on the climatic conditions and management of water volume in WMPs to plan for sufficient water supply for mill operations during extended dry periods. The average annual flows calculated for the relatively dry, average, and relatively wet conditions in the mine site water balance model are summarized in Table K4.16-1, Appendix K4.16 for the End of Mine—Base Case scenario (Scenario S0), and the corresponding water balance flow schematic diagram are presented in Figure K4.16-1. Flow path numbers and descriptions shown in the schematic are described in Table K4.16-4. Sensitivity analyses for End of Mine—Base Case scenarios (high bedrock K, scenario S7; low bedrock K, scenario S8) are presented in Table K4.16-2 and Table K4.16-3.

The average total water that would be available for release from the WTPs is listed on a monthly basis in Table K4.16-17 for End of Mine—Base Case scenario. The percentiles are based on the results from the 76 different climate realizations evaluated with the water balance model. The total flow releases from the WTPs, after accounting for clean water requirements at the process, and losses to WTP rejects, at the end of mine—base case, could vary between a high of 53 cubic feet per second (cfs) (90th and 99th percentile results) to a low of 3 cfs (1st percentile results).

[2] **Contact water** = Surface water or groundwater that has contacted mining infrastructure, which includes "mine drainage" defined in Title 40, Code of Federal Regulations (CFR) at 40 CFR Part 440.132(h) as any water drained, pumped, or siphoned from a mine, as well as stormwater runoff and seepage from mining infrastructure; examples include seepage from waste rock piles, seepage from stockpiles (except ore), and water from horizontal drains that accumulates in the pit.

Table 4.16-2: Design Criteria for Water Management Structures—Operations

Water Management Sructure	Design Criteria
Fresh Water Diversion Channels	Convey surface water runoff from undisturbed areas around the mine site to the downstream environment. Extreme precipitation event to be used for design: 100-year, 24-hour rainfall (PLP 2018d).
Open Pit WMP	Maximum operating pond volume of 40 Mft^3 (920 ac-ft) to manage dewatering from the open pit. Water in excess of this capacity would be pumped to the main WMP for management. Storm storage freeboard allowance for the required IDF and a spillway to safely pass larger events with additional freeboard.[1] Extreme precipitation event to be used for design: 100-year, 24-hour precipitation (PLP 2018-RFI 028a).
Main WMP	Minimum operating pond volume of 300 Mft^3 (6,900 ac-ft) to ensure that there is sufficient water available for the process during dry climate conditions. Maximum operating pond volume of 2,450 Mft^3 (56,250 ac-ft) to manage surplus water from the project mine site during wet climate conditions. Stormwater storage freeboard allowance for the required IDF with additional freeboard.[1] Extreme precipitation event to be used for design: PMF from the 24-hour PMP plus the snowmelt from a 100-year snowpack (PLP 2018-RFI 028a). The main WMP would include an emergency spillway designed to safely convey the peak discharge from the IDF, and would direct flows to the NFK.
Bulk TSF	Maximum operating pond volume varies by embankment stage and mine development, but is constrained by the need to maintain a minimum 2,000-foot beach[2] length. Storm storage freeboard allowance for the required IDF without release from the facility with additional freeboard.[1] Extreme precipitation event to be used for design: PMF from the 24-hour PMP plus the snowmelt from a 100-year snowpack (PLP 2018-RFI 028a).
Bulk TSF Main SCP	Maximum operating pond volume of 130 Mft^3 (3,000 ac-ft) to manage seepage and runoff from the main embankment of the bulk TSF. Storm storage freeboard allowance for the IDF and a spillway to safely pass larger events with additional freeboard.[1] Extreme precipitation event to be used for design: 100-year, 24-hour precipitation (PLP 2018-RFI 028a).
Pyritic TSF	Minimum operation pond volume varies by embankment state and mine development, but is constrained by the requirement to maintain a water cover to promote geochemical stability of the pyritic tailings and PAG waste rock. Storm [stormwater] storage freeboard allowance for the required IDF and a spillway to safely pass larger events with additional freeboard.[1] Extreme precipitation event to be used for design: PMF from the 24-hour PMP plus the snowmelt from a 100-year snowpack (PLP 2018-RFI 028a).
Seepage Collection and Recycle Ponds	Ponds are to be operated with the minimum pond volume required by the pump systems. Storm storage freeboard allowance for the required IDF and a spillway to safely pass larger events with additional freeboard.[1] Extreme precipitation event to be used for design: 100-year, 24-hour precipitation (PLP 2018-RFI 028a).
Sediment Ponds	Treat sediment for all inflows resulting from the 1 in 10-year, 24-hour rainfall event, with no flow passing over the spillway (PLP 2018d). Spillway to safely pass the peak outflows resulting from the 1 in 200-year, 24-hour rainfall event, with the starting pond level at the spillway invert (PLP 2018d). Additional freeboard provided.[1]

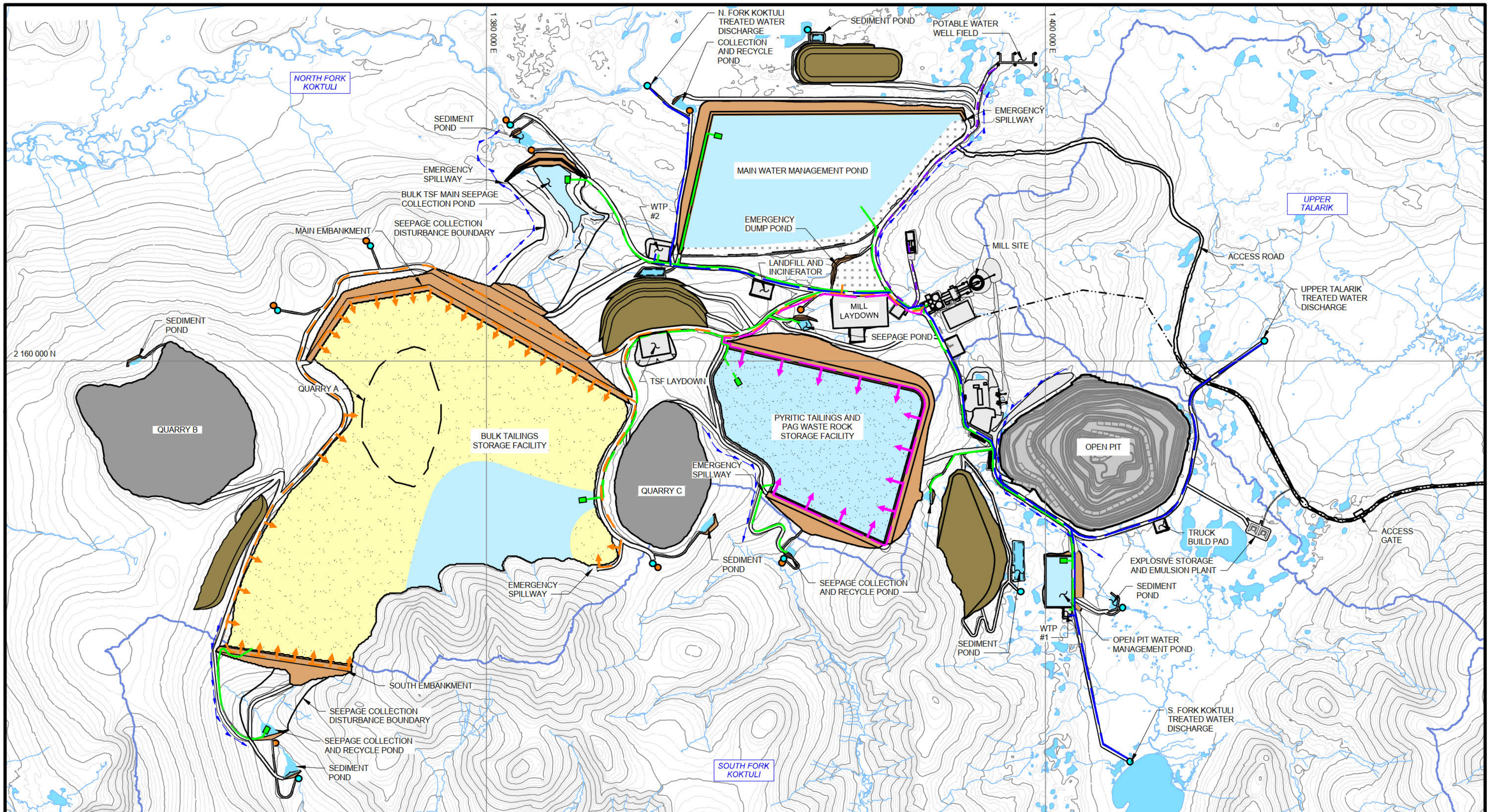
Notes:

[1] Each water management pond would include an additional freeboard allowance for wind-generated wave height and potential seismic deformation. Freeboard is the water level, usually expressed in feet, that is determined by the factor of safety used in engineering design.

[2] Bulk TSF beach = Tailings higher than the level of the supernatant pond are considered the tailings "beach."

ac-ft = acre feet
Mft^3 = millions of cubic feet
PMF = probable maximum flood
IDF = inflow design flood
PAG = potentially acid generating
PMP = probable maximum precipitation

Source: Knight Piésold 2018a, Table 3.1; PLP 2020d; PLP 2018-RFI 028a



Sources: Knight Piesold 2019s

US Army Corps
of Engineers®

0.5 0 0.5 1
Miles

LEGEND

- OPEN PIT
- BULK TAILINGS
- PYRITIC TAILINGS AND PAG WASTE ROCK
- EMBANKMENT FILL
- POND
- LINER
- QUARRY
- OVERBURDEN AND GROWTH MEDIUM STOCKPILE
- ROAD (NOTE 2)
- NATURAL GAS PIPELINE
- RECLAIM PIPELINE
- RECLAIM WATER PUMPING BARGE
- BULK TAILINGS PIPELINE
- BULK TAILINGS DISCHARGE
- PYRITIC TAILINGS PIPELINE
- PYRITIC TAILINGS DISCHARGE
- WTP POTABLE WATER PIPELINE
- WTP DISCHARGE PIPELINE
- WATER QUALITY MONITORING POINT
- GROUNDWATER QUALITY MONITORING AND POTENTIAL PUMP BACK AREA
- DIVERSION CHANNEL
- MAJOR DRAINAGE DIVIDE

NOTES:

1. CONTOUR INTERVAL IS 25 FEET.
2. CONCEPTUAL HAUL, SERVICE, AND ACCESS ROAD CUT AND FILL EXTENTS SHOWN INCLUDE ALLOWANCE FOR BERMS, COLLECTION DITCHES, AND POWER POLES, AS REQUIRED.
3. STOCKPILE AND EMBANKMENT FOOTPRINTS INCLUDE ALLOWANCE FOR COLLECTION DITCHES.
4. GROUNDWATER QUALITY MONITORING LOCATIONS WILL BE ESTABLISHED WITHIN THE ZONE OF INTEREST ALONG THE TOE OF THE EMBANKMENTS AS REQUIRED. ALLOWANCE FOR THE INSTALLATION OF THE MONITORING AND/OR PUMPBACK WELLS INCLUDED WITHIN THE ROAD FOOTPRINTS.

PEBBLE PROJECT EIS

GENERAL ARRANGEMENT AT END OF MINING

FIGURE 4.16-2

Streamflow

Streamflow in the NFK, SFK, and UTC watersheds would be affected by the project during operations. The following provides a summary of results of streamflow analysis provided in Appendix K4.16 under "Stream Changes."

The predicted change in streamflow results presented below are based on the predicted impact at the End of Mine—Base Case Scenario with 50 percent exceedance probability WTP discharge. The base case scenario assumes in-pit and perimeter dewatering wells resulting in a total withdrawal rate of 1,540 gallons per minute (gpm). WTP discharges were assumed to vary between watersheds and by month (Table K4.16-38), with a total average annual discharge of 28.4 cfs (base case scenario). WTP discharges would be released into NFK Reach D, SFK Reach E, and UTC Reach F (Figure K4.16-6 through Figure K4.16-8). The downstream boundary of the analysis is the confluence of the NFK and SFK rivers and Iliamna Lake at the mouth of the UTC. The reach designations (e.g., A, B, C) are in lettered order in the upstream direction, with Reach A always being the most downstream reach considered.

Table 4.16-3 presents the computation results using the base case scenario with 50 percent exceedance probability WTP discharge. The results of the analyses indicate that the impacts to streamflow on the NFK and SFK would be greater during operations than on the UTC, and that reaches closest to the mine site would experience greater impacts to streamflow than reaches farther from the mine site.

Under the 50 percent exceedance probability (Table 4.16-3) average monthly streamflow at NFK, Reach C would vary from 110.2 percent more to 20.4 percent less than the baseline average monthly streamflow, and the annual average monthly streamflow would be 9.2 percent more than the baseline annual average monthly streamflow. At SFK Reach E, average monthly streamflow would vary from 32.1 percent less to 53.0 percent less than the baseline average monthly streamflow, and the annual average monthly streamflow would be 42.8 percent less than the baseline annual average monthly streamflow. At UTC Reach F, average monthly streamflow would vary from 8.6 percent more to 1.3 percent less than the baseline average monthly streamflow, and the annual average monthly streamflow would be 2.0 percent more than the baseline annual average monthly streamflow.

Predicted streamflow changes at the End of Mine—Base Case scenario with 50 percent exceedance probability and WTP discharge indicate that the main stem reaches furthest from the mine activities during operation (Reach A) would have smaller changes in average monthly streamflow than reaches closer to the mine.

NFK Reach A—Near the confluence of the NFK and SFK. The average monthly streamflow with a 50 percent exceedance probability is estimated to vary from 23.5 percent more to 12.1 percent less than the baseline streamflow (Table K4.16-56). The annual average monthly streamflow with a 50 percent exceedance probability is estimated to be 0.2 percent less than the baseline streamflow.

SFK Reach A—Near the confluence of the NFK and SFK. The average monthly streamflow with a 50 percent exceedance probability is estimated to vary from 0.8 percent less to 2.8 percent less than the baseline streamflow (Table K4.16-58). The annual average monthly streamflow with a 50 percent exceedance probability is estimated to be 2.2 percent less than the baseline streamflow.

UTC Reach A—Near the mouth of the UTC. The average monthly streamflow with a 50 percent exceedance probability is estimated to vary from 0.8 percent more to 0.2 percent less than the baseline (i.e., pre-mine) streamflow (Table K4.16-60). The annual average monthly streamflow with a 50 percent exceedance probability is estimated to be 0.2 percent more than the baseline streamflow.

Table 4.16-3: Change in the Average Monthly Streamflow between Baseline and End of Mine with Water Treatment Plant Discharge (Scenario S0, 50 Percent Exceedance Probability Streamflow)

Location	Change in Average Monthly Streamflow from Baseline to End of Mine in Percent (50th Percentile Probability)												Annual Mean Monthly Change
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	
NFK, Reach A	+2.2	+10.6	+19.1	+23.5	-6.2	-12.1	-8.7	-9.2	-8.0	-7.2	-3.5	-3.3	-0.2
NFK, Reach B	+2.9	+11.6	+21.5	+29.0	-9.0	-13.5	-9.5	-10.2	-9.1	-8.1	-3.2	-3.4	-0.1
NFK, Reach C	+8.2	+29.0	+68.1	+110.2	-13.3	-20.4	-15.6	-16.4	-13.9	-13.4	-6.3	-5.4	+9.2
NFK, Reach D	+101.2	+127.9	+157.6	+170.0	+26.9	+23.1	+44.2	+46.1	+36.1	+34.3	+44.4	+73.2	+73.7
NFK, Trib 1.19	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0
SFK, Reach A	-2.7	-2.7	-2.1	-0.8	-1.4	-1.6	-2.8	-2.4	-2.3	-2.5	-2.3	-2.7	-2.2
SFK, Reach B	-2.2	-1.7	-0.5	+1.3	-2.4	-2.6	-3.3	-3.0	-3.2	-2.7	-2.5	-2.4	-2.1
SFK, Reach C	+3.8	0.0	0.0	0.0	-2.5	-2.8	-4.5	-3.9	-4.6	-3.1	-1.5	-1.2	-1.7
SFK, Reach D	+14.6	+27.5	+50.9	+109.0	-13.5	-15.0	-12.9	-11.9	-12.5	-10.2	+3.7	+9.3	+11.6
SFK, Reach E	-50.7	-51.5	-53.0	-52.2	-32.1	-33.1	-34.6	-37.4	-35.6	-38.8	-44.9	-49.4	-42.8
SFK, Trib 1.19	-13.4	-15.2	-17.1	-19.0	-3.7	-4.8	-7.2	-6.6	-5.3	-8.1	-10.6	-12.6	-10.3
SFK, Trib 1.24	+18.4	+97.9	0.0	+2.2	+2.7	+7.7	+11.0	+5.8	+4.8	+4.0	+7.0	+7.3	+14.1
UTC, Reach A	+0.4	+0.5	+0.7	+0.8	0.0	-0.1	-0.2	0.0	0.0	-0.1	0.0	+0.2	+0.2
UTC, Reach B	+0.4	+0.5	+0.6	+0.7	0.0	-0.1	-0.2	0.0	0.0	-0.1	0.0	+0.2	+0.2
UTC, Reach C	+0.5	+0.7	+0.8	+0.9	+0.1	-0.1	-0.2	0.0	0.0	-0.1	0.0	+0.3	+0.2
UTC, Reach D	+0.8	+1.1	+1.3	+1.7	+0.1	-0.2	-0.3	0.0	0.0	-0.2	+0.1	+0.4	+0.4
UTC, Reach E	+1.2	+1.9	+2.5	+3.2	+0.1	-0.2	-0.4	-0.1	-0.1	-0.2	+0.1	+0.6	+0.7
UTC, Reach F	+3.8	+5.5	+6.8	+8.6	+0.4	-0.8	-1.3	-0.2	-0.2	-0.7	+0.3	+1.9	+2.0
UTC, Trib 1.19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Notes:

Reaches are depicted in K4.16, Figure K4.16-6 through Figure K4.16-8

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

Table K4.16-20 through Table K4.16-37 provide estimates of streamflow for all conditions evaluated, and present change in streamflow in both cfs and percent. NFK Tributary 1.19 would be removed during construction and would not be replaced. In the SFK watershed, the headwaters are adjacent to the mine site, and would experience impacts to streamflow. In SFK Tributary 1.19, average monthly streamflow would vary from 3.7 percent less to 19.0 percent less than the baseline average monthly streamflow, and the annual average monthly streamflow would be 10.3 percent less than the baseline annual average monthly streamflow. In SFK Tributary 1.24, the average monthly streamflow would vary from 97.9 percent more to 0.0 percent less than the baseline average monthly streamflow, and the annual average monthly streamflow would be 14.1 percent more than the baseline annual average monthly streamflow. In UTC Tributary 1.19, there would be essentially no change in the magnitude of the average monthly and annual average monthly streamflow.

Average monthly and annual average monthly streamflow on the NFK, SFK, and UTC are likely to change as a result of mining; although the magnitude of the change is likely to be much less on the UTC. The duration of the impact on streamflow would last from sometime during construction to sometime during post-closure. The exception is NFK Tributary 1.19, which would be removed during mining and not replaced during reclamation; thereby permanently removing this stream. The geographic extent of the impact to average monthly streamflows on the NFK and SFK may extend just below the confluence of the two rivers. After the flows combine at the confluence of the NFK and SFK rivers, discernable changes in flow would be unlikely and are expected to be within historic and seasonal variation in the Koktuli River. The geographic extent of the measurable impact on the average monthly streamflows to the UTC is likely to be confined to the upper reaches of the stream.

The potential impacts of streamflow changes on aquatic habitat are discussed in Section 4.22, Wetlands and Other Waters/Special Aquatic Sites; and Section 4.24, Fish Values.

Flood Magnitude and Frequency

Flood magnitude and frequency on the NFK and SFK rivers could potentially change as a result of mine development. Flood magnitude and frequency on the UTC would not likely be affected. The extent of change to flood magnitude would depend on the precipitation event, the storage capacity of the impoundments at the time of the event, and the design storage capacity for each impoundment. Sediment ponds are the only impoundments designed to collect non-contact water, releasing outflow when design storage capacity is exceeded. All other impoundments collect runoff that is considered to be contact water, and are designed to store larger events, and no contact water would be released prior to treatment. Smaller events (10-year event or smaller) would likely be contained in the sediment ponds until storage capacity is reached, which could attenuate flood magnitude downstream of the mine site. Sediment pond storage capacity would be exceeded at a faster rate during larger events, likely reducing effects of attenuation on flood magnitude downstream of the mine site. The geographic extent of potential changes to flood magnitude on the NFK and SFK could extend just below the confluence of the two rivers. After the flows combine at the confluence, discernable change in flow would be unlikely and is expected to be within historic and seasonal variation in the Koktuli River.

Flood Hazards

For the purpose of this document, a flood hazard exists when existing infrastructure is subject to inundation during a 100-year flood (i.e., probability of inundation in any given year is 1 percent). Design events for water management structures are listed in Table 4.16.2. Downstream of the mine site, the NFK, SFK, and UTC watersheds would remain undeveloped; therefore, no flood hazard would exist during operations downstream from the mine site.

Floodplain Functions and Values

Impacts from mine development to wetlands, other waters, special aquatic sites, and regionally important wetlands represent less than 1 percent of the greater watershed area (see Section 4.22, Wetlands and Other Waters/Special Aquatic Sites). Potential impacts to floodplain function and values in the mine site footprint include fragmentation of wetlands and other hydrologic surface connections. Impacts to floodplains where fragmentation occurs would be considered permanent. Outside the mine site footprint, floodplain function and values in each watershed would be permanently affected to some degree, but these changes are not expected to have a measurable impact based on the modeled flow changes and extent of impact.

Erosion and Deposition

The types of the erosional and depositional impacts, and the magnitude, duration, geographic extent, and potential to occur, are the same as described for the construction phase.

Water Ponding

The types of water ponding impacts, and the magnitude, duration, extent, and potential to occur, are the same as described for the construction phase of the project.

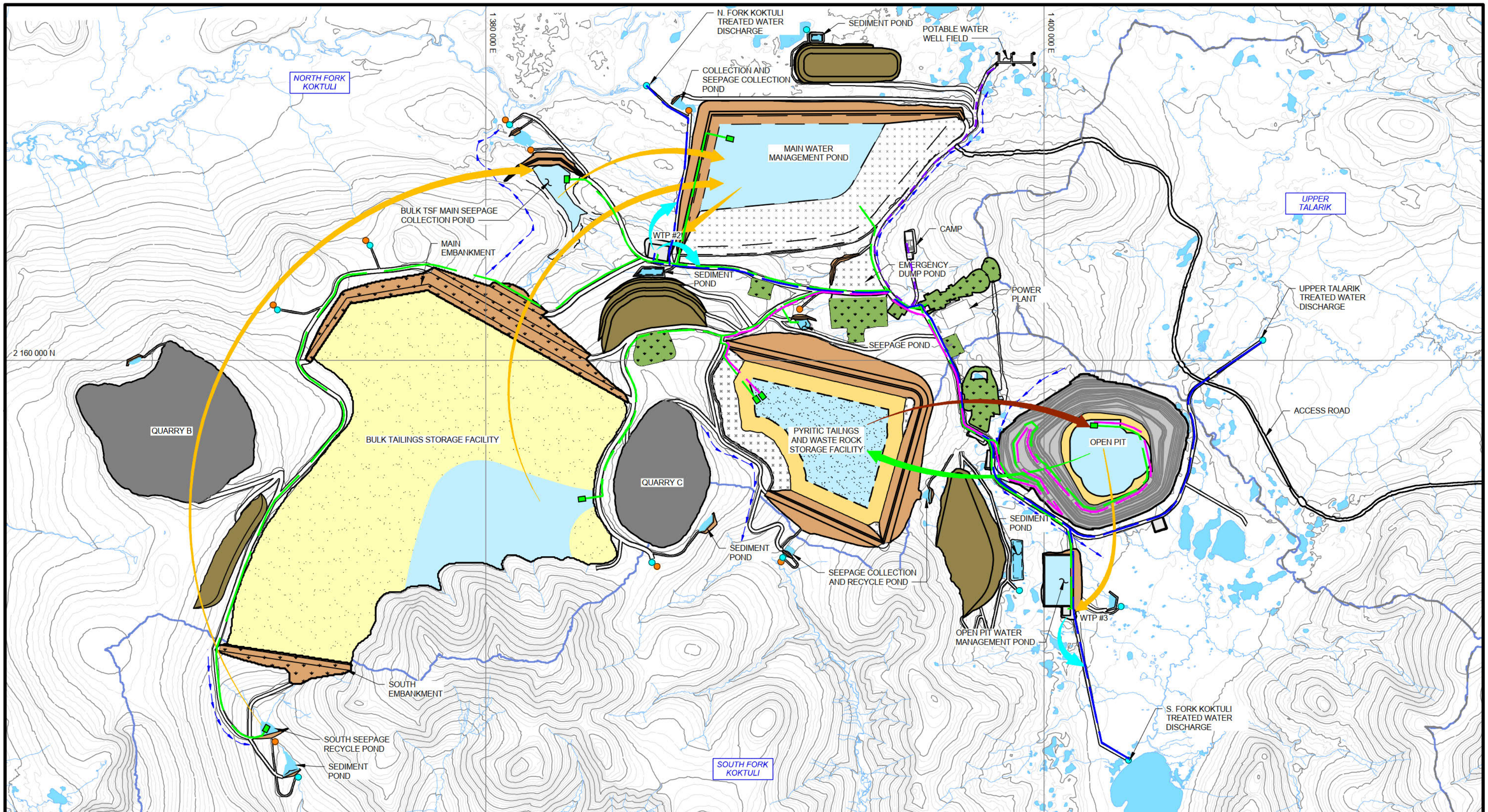
Closure and Post-Closure

Water Management

The project closure has been divided into four main phases.

- Phase 1—Extends from Year 1 to Year 15 after operations. Major reclamation activities include reclamation of quarries and bulk TSF, and placement of pyritic tailings and potentially acid-generating (PAG) waste rock in the open pit. Major surface water management activities include (Knight Piésold 2018d, 2019s):
  - Replacement of WTP #1 with WTP #3
  - Removal of sediment pond north of quarry B
  - Pumping surplus water from the bulk TSF to the main WMP
  - Pumping water from the bulk TSF south and east seepage collection and recycle ponds to the bulk TSF main SCP
  - Pumping water from the bulk TSF main SCP to the main WMP
  - Pumping surface runoff from the bulk TSF embankment and water collected in the seepage collection ponds to the main WMP
  - Treating surplus water from the main WMP at WTP #2 and releasing it to the downstream environment
  - Pumping surplus water from the open pit to WTP #3 and releasing it to the downstream environment
  - Decommissioning and reclaiming the open pit WMP, and direction of surface runoff to the downstream environment
  - Reclamation of quarries.

Figure 4.16-3 shows the arrangement of features at Year 9 of Closure Phase 1, and Figure 4.16-4 shows features that would be present at the end of Closure Phase 1.



Sources: Knight Piesold 2019s

LEGEND

OPEN PIT
BULK TAILINGS
OVERBURDEN AND GROWTH MEDIUM STOCKPILE
REVEGETATED - EMBANKMENT FACE
REVEGETATED - OTHER
EMBANKMENT FILL
SEASONAL POND AREA
POND
PYRITIC TAILINGS
WASTE ROCK
LINER
ROAD
RECLAIM PIPELINE
RECLAIM WATER PUMPING BARGE
PYRITIC TAILINGS PIPELINE
WTP POTABLE WATER PIPELINE
WTP DISCHARGE PIPELINE
WATER QUALITY MONITORING POINT
GROUNDWATER QUALITY MONITORING AND POTENTIAL PUMP BACK AREA
DIVERSION CHANNEL
MAJOR DRAINAGE DIVIDE
TAILINGS WATER
RECLAIM WATER
CONTACT WATER
TREATED WATER

NOTES:

1. COORDINATE GRID IS UTM NAD83, ALASKA STATE PLANES; ZONE 5.
2. CONTOUR INTERVAL IS 25 FEET.
3. DIMENSIONS AND ELEVATIONS ARE IN FEET, UNLESS NOTED OTHERWISE.
4. OPEN PIT OUTLINE PROVIDED BY TETRA TECH, JUNE 2019.

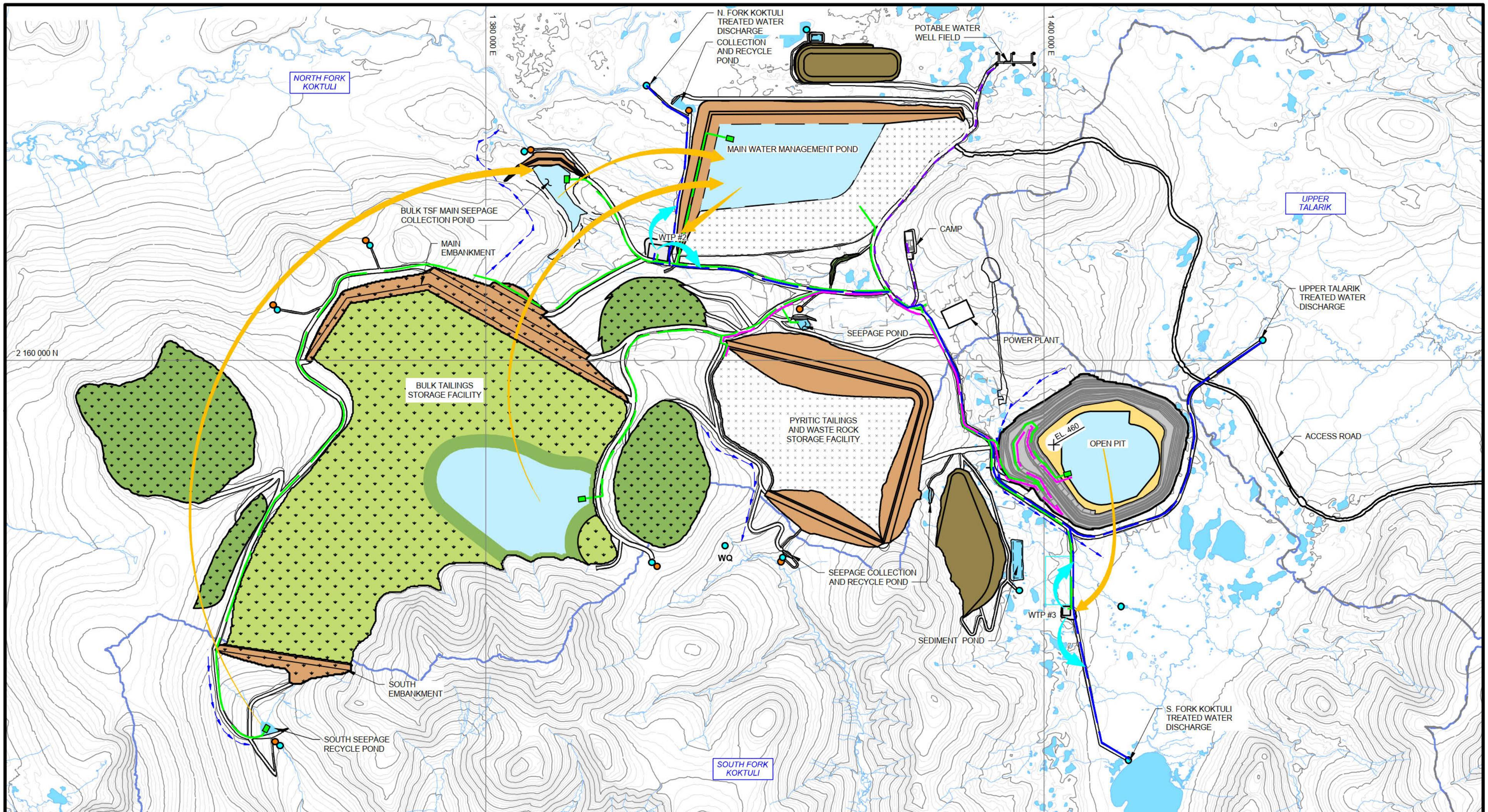
US Army Corps of Engineers®

0.5 0 0.5 1
Miles

PEBBLE PROJECT EIS

GENERAL ARRANGEMENT CLOSURE PHASE 1 - YEAR 9

FIGURE 4.16-3



Sources: Knight Piesold 2019s

US Army Corps of Engineers®

0.5 0 0.5 1

Miles

LEGEND

- OPEN PIT
- REVEGETATED - EMBANKMENT FACE
- REVEGETATED - BEACH
- SEASONAL WETLAND
- REVEGETATED - OTHER
- POND
- WASTE ROCK
- LINER
- OVERBURDEN AND GROWTH MEDIUM STOCKPILE
- RECLAIM PIPELINE
- RECLAIM WATER PUMPING BARGE
- WTP POTABLE WATER PIPELINE
- WTP DISCHARGE PIPELINE
- WATER QUALITY MONITORING POINT
- GROUNDWATER QUALITY MONITORING AND POTENTIAL PUMP BACK AREA
- CLEAN (NON-CONTACT) WATER DIVERSION
- RECLAIMED FACILITY OUTLINE
- MAJOR DRAINAGE DIVIDE
- CONTACT WATER
- TREATED WATER

NOTES:

1. COORDINATE GRID IS UTM NAD83, ALASKA STATE PLANES; ZONE 5.
2. CONTOUR INTERVAL IS 25 FEET.
3. DIMENSIONS AND ELEVATIONS ARE IN FEET, UNLESS NOTED OTHERWISE.
4. OPEN PIT OUTLINE PROVIDED BY TETRA TECH, JUNE 2019.

PEBBLE PROJECT EIS

GENERAL ARRANGEMENT CLOSURE END OF PHASE 1

FIGURE 4.16-4

- Phase 2—Extends from Year 16 to approximately Year 23 after end of mine (when the pit is full). Major reclamation activities include reclamation of the bulk TSF, the pyritic TSF, and main WMP. Major surface water management activities include (Knight Piésold 2018d, 2019s):
  - Decommissioning the open pit clean water diversion channel
  - Reclamation of the pyritic TSF and associated seepage collection ponds and directing surface water discharge to the downstream environment
  - Reclaiming the main WMP and directing surface water runoff to the downstream environment
  - Reclaiming the bulk TSF to the extent possible; tailing consolidation ongoing
  - Pumping surplus water in the bulk TSF to the open pit
  - Pumping water in the bulk TSF south and east seepage collection and recycle ponds to the bulk TSF main SCP
  - Pumping water from the TSF Main SCP to the open pit
  - Decommissioning and reclaiming WTP #2
  - Allowing the open pit to fill to the maximum management (MM) water level (see Section 4.17, Groundwater Hydrology, for more about the MM water level)

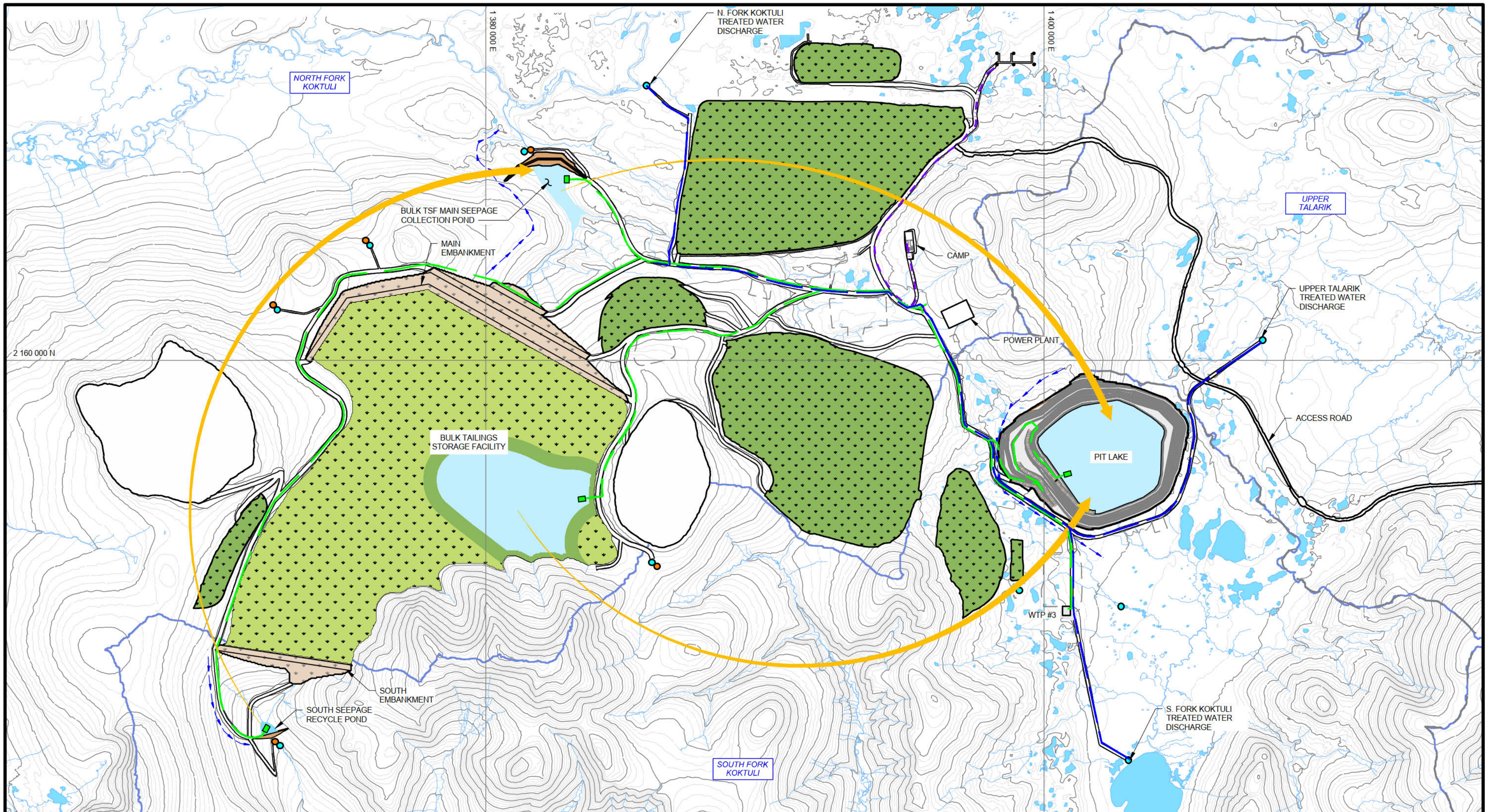
No water is planned to be treated during Phase 2. However, if needed to maintain streamflows, water would be directed to WTP #3 for treatment and release. Figure 4.16-5 shows the general arrangement of features that would be present during closure at the end of Phase 2.

- Phase 3—Extends from Year 23 to Year 50 after operations. Major surface water activities include (Knight Piésold 2018d, 2019s):
  - Pumping surplus water from the bulk TSF to the open pit
  - Pumping water from the bulk TSF south and east seepage collection and recycle ponds to the bulk TSF main SCP
  - Pumping water from the bulk TSF main SCP to the open pit
  - Maintaining water levels in the open pit below the MM level by treating surplus water from the open pit at WTP #3
  - Releasing treated water from WTP #3 to the downstream environment.

Figure 4.16-6 shows the general arrangement of features that would be present at Closure Phase 3.

- Phase 4 Post-Closure (long-term conditions)—Extends from Year 51 to Year 51+ after end of mine. Major surface water activities include (Knight Piésold 2018d, 2019s):
  - Direct discharge of surface water runoff from the reclaimed bulk TSF to the NFK watershed
  - Maintaining water levels in the open pit below the MM water level by treating surplus water from the open pit at WTP #3
  - Pumping water from the bulk TSF south and east seepage collection and recycle ponds to the bulk TSF main SCP
  - Pumping bulk TSF main SCP flows to WTP #3
  - Decommissioning and reclaiming all freshwater diversions, except for the bulk TSF main SCP diversion
  - Releasing treated water from WTP #3 to the downstream environment.

Figure 4.16-7 shows general arrangement of features that would be present at Post-Closure Phase 4.



Sources: Knight Piesold 2019s

LEGEND

OPEN PIT
REVEGETATED - EMBANKMENT FACE
REVEGETATED - BEACH
SEASONAL WETLAND
REVEGETATED - OTHER
POND
RECLAIM PIPELINE
RECLAIM WATER PUMPING BARGE
WTP POTABLE WATER PIPELINE
WTP DISCHARGE PIPELINE
WATER QUALITY MONITORING POINT
GROUNDWATER QUALITY MONITORING AND POTENTIAL PUMP BACK AREA
CLEAN (NON-CONTACT) WATER DIVERSION
RECLAIMED FACILITY OUTLINE
MAJOR DRAINAGE DIVIDE
CONTACT WATER

NOTES:

1. COORDINATE GRID IS UTM NAD83, ALASKA STATE PLANES; ZONE 5.
2. CONTOUR INTERVAL IS 25 FEET.
3. DIMENSIONS AND ELEVATIONS ARE IN FEET, UNLESS NOTED OTHERWISE.
4. OPEN PIT OUTLINE PROVIDED BY TETRA TECH, JUNE 2019.

US Army Corps of Engineers®

0.5 0 0.5 1

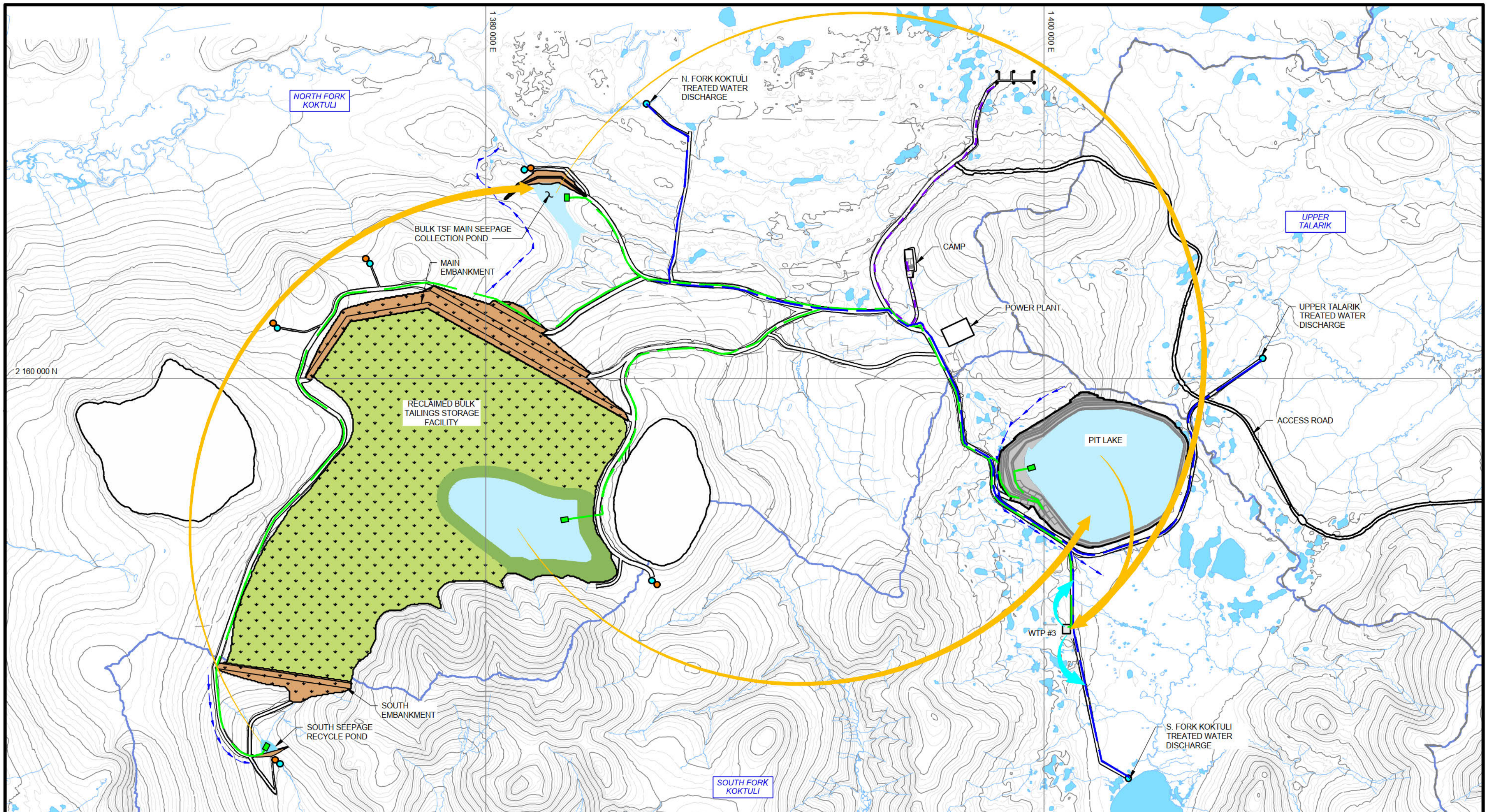
Miles

PEBBLE PROJECT EIS

GENERAL ARRANGEMENT CLOSURE END OF PHASE 2

FIGURE 4.16-5

LEGEND



Sources: Knight Piesold 2019s

LEGEND

- OPEN PIT
- REVEGETATED - EMBANKMENT FACE
- REVEGETATED - BEACH
- SEASONAL WETLAND
- POND
- RECLAIM PIPELINE
- RECLAIM WATER PUMPING BARGE
- WTP POTABLE WATER PIPELINE
- WTP DISCHARGE PIPELINE
- WATER QUALITY MONITORING POINT
- GROUNDWATER QUALITY MONITORING AND POTENTIAL PUMP BACK AREA
- CLEAN (NON-CONTACT) WATER DIVERSION
- RECLAIMED FACILITY OUTLINE
- MAJOR DRAINAGE DIVIDE
- CONTACT WATER
- TREATED WATER

NOTES:

1. COORDINATE GRID IS UTM NAD83, ALASKA STATE PLANES; ZONE 5.
2. CONTOUR INTERVAL IS 25 FEET.
3. DIMENSIONS AND ELEVATIONS ARE IN FEET, UNLESS NOTED OTHERWISE.
4. OPEN PIT OUTLINE PROVIDED BY TETRA TECH, JUNE 2019.

US Army Corps of Engineers®

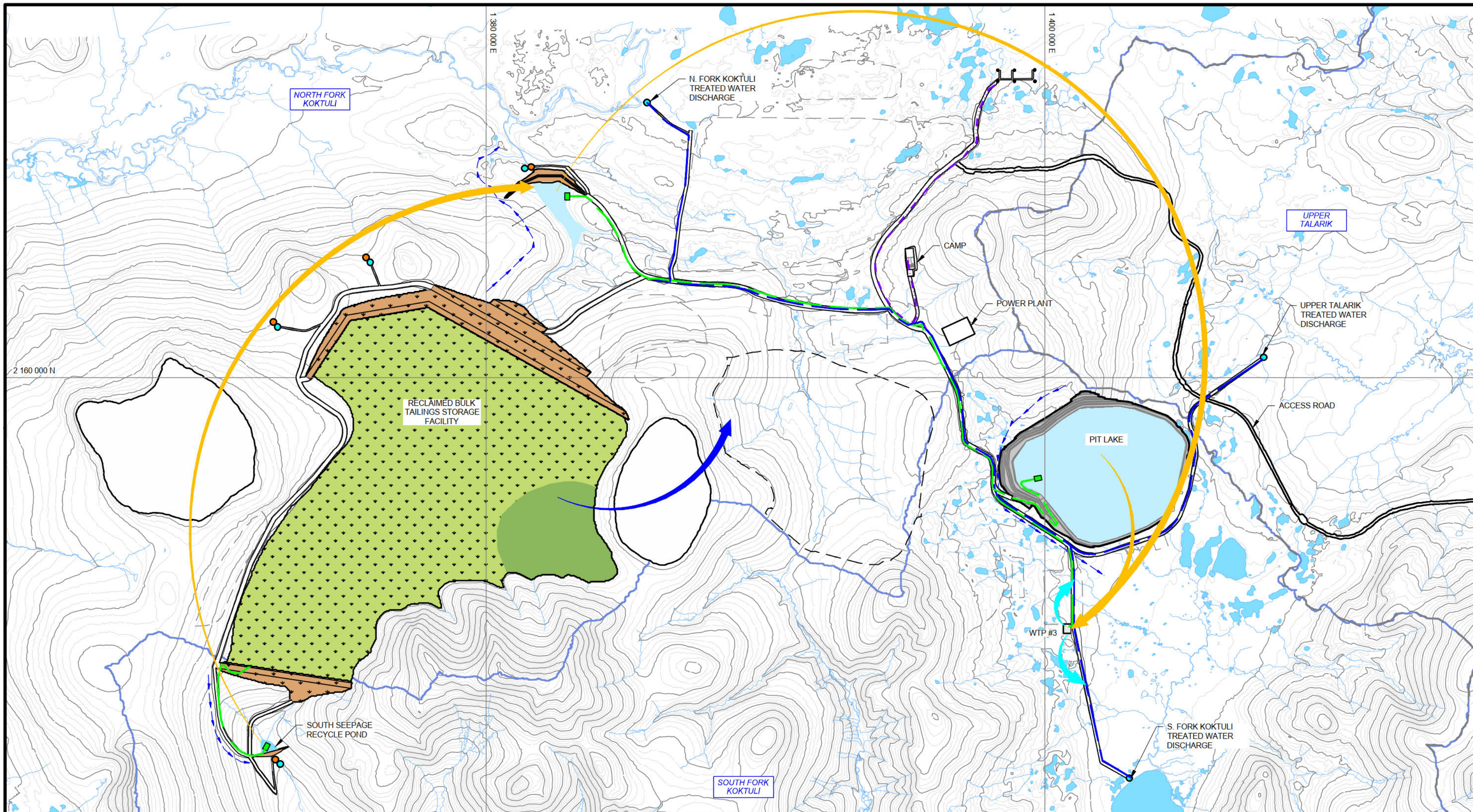
0.5 0 0.5 1

Miles

PEBBLE PROJECT EIS

GENERAL ARRANGEMENT POST-CLOSURE PHASE 3

FIGURE 4.16-6



Sources: Knight Piesold 2019s

LEGEND

- OPEN PIT
- REVEGETATED - EMBANKMENT FACE
- REVEGETATED - BEACH
- SEASONAL WETLAND
- POND
- RECLAIM PIPELINE
- RECLAIM WATER PUMPING BARGE
- WTP POTABLE WATER PIPELINE
- WTP DISCHARGE PIPELINE
- WATER QUALITY MONITORING POINT
- GROUNDWATER QUALITY MONITORING AND POTENTIAL PUMP BACK AREA
- CLEAN (NON-CONTACT) WATER DIVERSION
- RECLAIMED FACILITY OUTLINE
- MAJOR DRAINAGE DIVIDE
- CONTACT WATER
- TREATED WATER
- CLEAN WATER

NOTES:

1. COORDINATE GRID IS UTM NAD83, ALASKA STATE PLANES; ZONE 5.
2. CONTOUR INTERVAL IS 25 FEET.
3. DIMENSIONS AND ELEVATIONS ARE IN FEET, UNLESS NOTED OTHERWISE.
4. OPEN PIT OUTLINE PROVIDED BY TETRA TECH, JUNE 2019.

US Army Corps of Engineers®

0.5 0 0.5 1

Miles

PEBBLE PROJECT EIS

GENERAL ARRANGEMENT POST-CLOSURE PHASE 4

FIGURE 4.16-7

A mine site water balance model for the closure and post-closure periods of the mine site was developed by Knight Piésold (2019s) to assess water entering and leaving the mine site, and to aid in developing WMPs. The closure and post-closure mine plan model was developed similar to the operations mine plan module (discussed above), and used the 76-year synthetic temperature and precipitation record to evaluate the probability of various temperature and precipitation conditions that have probably been experienced at the site over the last 76 years. Each of the four closure phases was evaluated.

Appendix K4.16 provides tables of the mine site average annual water balance results for each of the four phases during each of three precipitation conditions (realizations): dry, average, and wet (2019s). The numbers on the figures correspond with flow path number designations on the tables. Used together, the information describes the flow in and out of each of the mine site features during each of the four closure phases for a dry, an average, and a wet scenario (realization).

Discharge from the WTPs is an important element in maintaining streamflow in the NFK and SFK rivers and UTC. To better understand the probable discharge from the WTPs during each of the closure phases, and to address more than just the average conditions during each phase, Knight Piésold (2019s) estimated the 1st, 10th, 50th, 90th, and 99th percentile values for total water released from the WTPs. This information is provided in Table K4.16-17 through Table K4.16-19, by closure phase.

Information presented in Table K4.16-17 through Table K4.16-19 is the expected total WTP discharge with each of the stated probabilities of occurrence. The variation in the total WTP discharge represented by the various probabilities is due to the variation in monthly and annual temperature and precipitation. Based on the expected variability, total WTP discharges could vary from a high of 68 cfs during Phase 1 Base Case (99th percentile or 99 percent chance the actual flow would be less than this) to a low of 0 cfs during Phase 4 (1st percentile or a 1 percent chance that the actual flow would be less than this). It is expected that on average (Table K4.16-17, Phase 1 Base Case, 50th percentile), the total amount of water to be treated and discharged would be greatest in Phase 1, less in Phase 3, and least in Phase 4; with the possible exception of Phase 2. It is anticipated that there would be no WTP discharge in the 8 years of Phase 2, while the water level raises in the open pit. During Phase 2, the total captured surface runoff, direct pond precipitation, and groundwater inflow is anticipated to be approximately 40 cfs under average climate conditions (Knight Piésold 2019s). During Phase 2, if it becomes necessary to discharge water to maintain streamflows, water would be directed to WTP #3 for treatment and release.

Streamflow

Appendix K4.16 presents predicted streamflow during the closure and post-closure phases. Predicted impacts during post-closure Phase 4 Base Case with 50 percent exceedance probability WTP discharge includes bulk TSF seepage rates and groundwater inflows to the pit lake. WTP discharges are assumed to vary between watersheds and by month (Table K4.16-41). Under the base case scenario, the total average annual WTP discharge is 13.9 cfs, and would be released into NFK Reach D, SFK Reach E, and UTC Reach F. The downstream boundary of the evaluation is the confluence of the NFK and SFK rivers, and Iliamna Lake at the mouth of the UTC. The locations of the reaches evaluated on the NFK, SFK, and UTC are depicted in Figure K4.16-6 through Figure K4.16-8.

Table 4.16-4 provides a summary of stream change computation results using the base case scenario with 50 percent exceedance probability WTP discharge. The results indicate that impacts to streamflow on the NFK and SFK would be greater than on the UTC, and stream reaches closest to the mine site would experience greater impacts to streamflow than reaches farther from the mine site.

Table 4.16-4: Change in Average Monthly Streamflow between Baseline and Post-Closure (Phase 4) with Water Treatment Plant Discharge (S0, 50th Percentile Exceedance Probability Streamflow)

Location	Change in Average Monthly Streamflow from Baseline to Post-Closure in Percent (50th Percentile Probability)												Annual Mean Monthly Change
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	
NFK, Reach A	-0.7	+3.0	+6.9	+10.0	-1.1	-1.8	-0.5	-3.0	-2.4	-5.6	-2.9	-2.2	0.0
NFK, Reach B	-0.7	+3.4	+8.2	+13.0	-1.4	-1.8	-0.1	-3.3	-2.7	-6.1	-2.7	-2.8	+0.3
NFK, Reach C	-1.0	+7.8	+26.8	+45.7	-2.3	-4.8	-1.7	-5.9	-5.7	-7.7	-4.2	-5.7	+3.4
NFK, Reach D	+43.3	+55.6	+66.8	+86.8	0.0	0.0	+17.5	0.0	0.0	0.0	+18.3	+30.6	+26.6
NFK, Trib 1.19	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0
SFK, Reach A	+2.3	+0.6	+3.5	+5.8	+0.9	+0.9	-0.3	+1.2	+1.3	+1.7	+1.1	+1.4	+1.7
SFK, Reach B	+2.4	-0.2	+3.7	+6.1	+1.2	+0.8	-0.6	+2.3	+2.3	+2.8	+1.4	+2.0	+2.0
SFK, Reach C	+125.0	+2.7	0.0	0.0	+4.1	+6.9	+5.2	+13.0	+9.3	+12.7	+9.7	+19.5	+17.3
SFK, Reach D	+24.0	+35.9	+58.8	+65.4	+12.4	+13.8	+0.6	+28.1	+19.3	+21.5	+10.0	+17.8	+25.6
SFK, Reach E	-38.8	-39.2	-40.3	-39.5	-24.4	-25.5	-26.8	-28.6	-27.3	-30.2	-35.1	-38.1	-32.8
SFK, Trib 1.19	-13.4	-15.3	-17.1	-19.0	-5.9	-8.4	-9.1	-8.4	-7.7	-9.2	-10.8	-12.7	-11.4
SFK, Trib 1.24	+2.0	+8.2	0.0	0.0	+0.6	+2.0	+1.7	+1.3	+1.1	+0.4	+0.9	+1.2	+1.6
UTC, Reach A	+0.4	+0.5	+0.6	+0.1	0.0	0.0	0.0	+0.2	0.0	0.0	+0.1	+0.3	+0.2
UTC, Reach B	+0.4	+0.4	+0.6	+0.1	0.0	0.0	0.0	+0.2	0.0	0.0	+0.1	+0.2	+0.2
UTC, Reach C	+0.5	+0.6	+0.8	+0.2	0.0	0.0	0.0	+0.2	+0.1	0.0	+0.1	+0.4	+0.2
UTC, Reach D	+0.6	+0.7	+0.9	-0.1	-0.1	-0.1	-0.1	+0.2	0.0	-0.1	0.0	+0.3	+0.2
UTC, Reach E	+0.9	+1.2	+1.7	-0.3	-0.1	-0.1	-0.1	+0.2	0.0	-0.1	0.0	+0.4	+0.3
UTC, Reach F	+2.7	+3.5	+4.5	-0.7	-0.3	-0.4	-0.3	+0.8	0.0	-0.5	-0.1	+1.5	+0.9
UTC, Trib 1.19	+0.7	+0.8	+0.8	+0.8	+0.6	+0.6	+0.6	+0.7	+0.7	+0.7	+0.7	+0.8	+0.7

Notes:
Reaches are depicted in K4.16, Figure K4.16-6 through Figure K4.16-8
Values for streamflow change are a percentage of the baseline streamflow
A negative streamflow change means that streamflow during operations would be less than the baseline streamflow; a positive streamflow change means that the streamflow during operations would be greater than the baseline streamflow
NFK = North Fork Koktuli
SFK = South Fork Koktuli
UTC = Upper Talarik Creek
Trib = Tributary
Source: Table K4.16-50, Change in the 50 Percent Probability of Exceedance Streamflow between Baseline and Post-Closure with Water Treatment Plant Discharge based on Scenario 0 (Base Case K)

During closure and post-closure, main stem stream reaches closest to the mining operation would experience changes in average monthly and annual average monthly streamflow. Under the 50 percent exceedance probability (Table 4.16-4), average monthly streamflow in NFK Reach C would vary from 45.7 percent more to 7.7 percent less than the baseline average monthly streamflow, and the annual average monthly streamflow would be 3.4 percent more than the baseline annual average monthly streamflow. In SFK Reach E, average monthly streamflow would vary from 24.4 percent less to 40.3 percent less than the baseline average monthly streamflow, and annual average monthly streamflow would be 32.8 percent less than the baseline annual average monthly streamflow. Average monthly streamflow at UTC Reach F would vary from 4.5 percent more to 0.7 percent less than the baseline average monthly streamflow, and the annual average monthly streamflow would be 0.9 percent more than the baseline annual average monthly streamflow.

Main stem stream reaches farthest from the mining operations would experience changes in average monthly and annual average monthly streamflow. Under the 50 percent exceedance probability (Table 4.16-4), average monthly streamflow in NFK Reach A would vary from 10 percent more to 5.6 percent less than the baseline average monthly streamflow, and the annual average monthly streamflow would be 0.0 percent less than the baseline annual average monthly streamflow. In SFK Reach A, average monthly streamflow would vary from 5.8 percent more to 0.3 percent less than the baseline average monthly streamflow, and the annual average monthly streamflow would be 1.7 percent more than the baseline annual average monthly streamflow. In UTC Reach A, average monthly streamflow would vary from 0.6 percent more to 0.0 percent less than the baseline average monthly streamflow, and the annual average monthly streamflow would be 0.2 percent more than the baseline annual average monthly streamflow.

NFK Tributary 1.19 would be removed during construction and would not be replaced. In SFK Tributary 1.19, average monthly streamflow would vary from 5.9 percent less to 19.0 percent less than the baseline average monthly streamflow, and the annual average monthly streamflow would be 11.4 percent less than the baseline average annual monthly streamflow. At SFK Tributary 1.24, the average monthly streamflow would vary from 8.2 percent more to 0.0 percent less than the baseline average monthly streamflow, and the annual average monthly streamflow would be 1.6 percent more than the baseline annual average monthly streamflow. In UTC Tributary 1.19, the average monthly streamflow would vary from 0.8 percent more to 0.6 percent more than the baseline average monthly streamflow, and the annual average monthly streamflow would be 0.7 percent more than the baseline annual average monthly streamflow.

Table K4.16-20 through Table K4.16-37 provide estimates of streamflow for all conditions evaluated, as well as estimates of the change in streamflow in both cfs and percent. The results of the stream change computations indicate that average monthly and annual average monthly streamflow on the NFK, SFK, and UTC watersheds are likely to change as a result of mining; although the magnitude of the change is likely to be much less on the UTC. The duration of the impact on streamflow would last from some time during construction to sometime post-closure (long-term to permanent). The exceptions include NFK Tributary 1.19, SFK Reach E, and SFK Tributary 1.19. NFK Tributary 1.19 would be removed during mining, and not replaced during reclamation, thereby permanently removing this stream. Streamflow reduction in SFK Reach E would be a function of mine pit lake storage, and the reach is upstream from the WTP discharge point. Reduced streamflow in SFK Tributary 1.19 would result from water captured in the south seepage recycle pond, which is returned to the bulk TSF main seepage pond. The geographic extent of the impact to average monthly streamflows on the NFK and the SFK rivers may extend just below the confluence of the two rivers. After the flows combine at the confluence of the NFK and SFK rivers, discernable changes in flow would be unlikely and are expected to be within historic and seasonal variation in the Koktuli River. The geographic extent of a measurable impact on the average monthly streamflows in the UTC is likely to be confined to the upper reaches of the stream.

Flood Magnitude and Frequency

Potential changes to flood magnitude and frequency during closure and post-closure phases on the NFK, SFK, and UTC would be expected to be similar to those described under operations. The extent of change to flood magnitude would depend on the precipitation event, the storage capacity of the impoundments at the time of the event, and the stage of reclamation. The geographic extent of potential changes to flood magnitude on the NFK and SFK could extend to just below the confluence of the two rivers. After the flows combine at the confluence, discernable changes in flow would be unlikely and are expected to be within historic and seasonal variation in the Koktuli River.

Flood Hazards

Flood hazards in the NFK, SFK, and UTC watersheds during closure and post-closure phases are expected to be the same as those described under operations.

Floodplain Functions and Values

Floodplain functions and values in the NFK, SFK, and UTC watersheds during closure and post-closure phases are expected to be the same as those described under operations.

Erosion and Deposition

There is a potential for increased upland and stream channel erosion and subsequent deposition due to removing structures and rehabilitating the mine site during closure phases 1 through 3. Generally, these activities would reduce the potential for erosion. However, if an unexpected storm occurred at a time of significant surface disturbance, it might increase erosion for a limited time. The geographic extent of the erosional scars would probably be limited to the mine site, but sediment deposition could occur outside the mine site, and an increased stream sediment load could possibly extend into the Koktuli River.

During post-closure (Phase 4), the potential for increased upland and stream channel erosion above background conditions is possible. However, the potential would decrease as rehabilitation of vegetation takes effect in the reclaimed areas. The geographic extent of an impact would also continue to lessen with time, and would probably be confined to the upper reaches of the NFK and SFK rivers and UTC by Phase 4.

The potential for increased erosion and subsequent deposition downstream from road culverts would decrease as the culverts are removed and the channels restored. Where culverts remain, the magnitude, duration, and extent of the impact would be much the same as during operations.

Water Ponding

During closure (closure phases 1 through 4), the potential for increased water ponding adjacent to the upstream side of roads, where drainage is disrupted by the lack of a drainage structure, is considered very small. This is because the roads would have been in place for a long period of time, and such areas are expected to have been remedied. Additionally, it is anticipated that many of the roads would be removed and rehabilitated; thereby removing the potential impact. If such a situation was to occur, the magnitude, duration, and extent of the impact would be similar to or less than that during construction.

For the culverts that remain, the potential for increased water depth and potential for deposition of sediment immediately upstream from a culvert is considered the same as during operations. The potential magnitude, duration, and extent of the impact would also be similar to or less than that during construction.

Long-Term Climate Change

Based on the climate change discussion in Section 3.16 and Appendix K3.16, Surface Water Hydrology, although there seems to be general agreement that average annual temperature has been increasing, there does not seem to be agreement on the cause of the change. Most likely, it is related to a combination of long-term climate change and a shift in the Pacific Decadal Oscillation (PDO). Regarding precipitation changes, there seems to be no apparent trend in the annual average total precipitation associated with long-term monitoring sites in the immediate vicinity of the Pebble Project (Knight Piésold 2009), although larger-scale studies suggest there might be (SNAP 2018). Regarding extreme precipitation near the project area, one analysis (Knight Piésold 2018g) indicated that extreme precipitation may be increasing, while another (National Weather Service 2012) concluded that it was not. An analysis of the streamflow records at three long-term monitoring stations in the region (Knight Piésold 2009, 2018g) indicated there was no common trend between the three stations. Another analysis of flood-peak records at 387 stream gage stations throughout Alaska (Curran et al. 2016) found no trend at a large majority of sites, and a 50/50 split in increasing and decreasing trends among the sites exhibiting a trend. Therefore, there is considerable uncertainty about whether long-term climatic change is influencing the hydrology of the area; and if so, what the magnitude of the change might be.

Uncertainty is an everyday reality in hydrologic and hydraulic design. Often, when historic data are used to prepare hydrologic designs, both a mean and a standard deviation are computed. The standard deviation is then used to compute confidence intervals about the mean estimate. The National Weather Service (NWS 2012) study discussed previously provides an example of this. In addition to computing the mean associated with the maximum duration-frequency precipitations (e.g., 1-day, 100-year maximum precipitation), NWS computed and provided the values associated with the 90 percent confidence intervals (e.g., 90 percent confidence intervals about the 1-day, 100-year maximum precipitation). The US Geological Survey (USGS) study (Curran et al. 2016) discussed previously also provides a means of estimating confidence limits associated with the flood-peak magnitudes predicted by the equations.

The values associated with the confidence intervals can then be used to establish reasonable factors of safety (FoS) (e.g., in some cases called "freeboard"). The magnitude of the FoS can change from one project to another, or from one structure to another, to address the severity of the impact resulting from an event that is either larger or smaller than anticipated by the mean estimate. Use of a Monte Carlo analysis is another means of quantifying the risk of a larger or smaller event than the mean or "most likely" event. Due to a lack of a common trend in precipitation and discharge, the use of historic data collected in the vicinity of the Pebble site, without a specific adjustment to account for possible long-term climatic change, seems reasonable, as long as the risk of an event that is larger or smaller than anticipated (based on the historic data) is addressed.

In developing the design precipitation values that would be used for critical aspects of the mine design, a couple of things have been done that would provide a margin of safety against the uncertainties inherent in hydrologic design.

The probable maximum precipitation (PMP) is the precipitation that results from the most severe meteorological conditions possible at the site. The PMP would be used to compute the probable maximum flood (PMF), which would then be used to design the larger dams associated with the mine. Knight Piésold (2018g) evaluated the magnitude of the PMP at meteorological monitoring station Pebble 1, based on both the full synthetic record (1942-2017) and the post-1976 synthetic record (1977-2017). For each of these periods, Knight Piésold computed a PMP value applicable to the April-June period (i.e., spring freshet) and the April-October period (i.e., non-winter months). They found that the values based on the post-1976 record yielded substantially higher estimates of the PMP: 26 percent higher for the 24-hour freshet PMP; and 65 percent higher for the 24-hour non-winter PMP (Knight Piésold 2018g). Despite the fact that the apparent change in extreme precipitation might not continue with another change in the PDO, and the fact that the PDO would probably shift back to a cold regime at some point in the not-too-distant future, PLP has stated that they would use the higher estimates (i.e., the estimates based on the post-1976 record) for design (PLP 2018-RFI 028b).

Similarly, precipitation depth-duration-frequency estimates are required for the design of other structures, such as flow conveyance structures and smaller water-retention structures at the mine site. Knight Piésold (2018g) evaluated the 24-hour precipitation depths likely to occur at Pebble 1 for average frequency of occurrences ranging from 2 to 1,000 years, based on each of two conditions: the full synthetic record (1942-2017), and the post-1976 synthetic record (1977-2017). For every frequency of occurrence evaluated, the 24-hour precipitation depth associated with the post-1976 record was greater: 1 percent greater for the 2-year event, 14 percent greater for the 50-year event, 17 percent greater for the 100-year event, and 20 percent greater for the 200-year event. Again, even though the PDO may change back to a cold regime in the not-too-distant future, PLP has stated that they would use the higher estimates (i.e., the estimates based on the post-1976 record) for design (PLP 2018-RFI 028b).

Although the mine site water balance model does not specifically include a factor to account for a long-term temperature or precipitation change, the model used 76 years of synthetic record based on actual temperature and precipitation measurements made in the vicinity of the mine to estimate the water balance at the mine (Knight Piésold 2018g). The method of synthesizing the record seems reasonable. The record was run through the model in 20-year increments to preserve the cyclic nature of the wet and dry years, while at the same time evaluating all possible starting conditions in the record (Knight Piésold 2018g). Given that no common trends were found in the total annual precipitation record and the average annual discharge record of nearby long-term monitoring stations, and the fact that safety factors (i.e., freeboard) would be incorporated into the water conveyance and water-retaining structures in the mine, this approach would provide sufficient information on the variability of possible flows for which the water balance model would be used.

As plans for the mine continue and permitting efforts advance, more data would be available and the estimates of the magnitude and probability of future events can be re-evaluated, and the design adapted to the “best estimate” of future conditions at that time.

4.16.4.2 Transportation Corridor

The mine access road, explosives storage spur road, port access road, Kokhanok spur road, and a natural gas pipeline along the port and mine access roads would include numerous crossings of waterbodies. The road system would include water crossings with 10 bridges and 84 culverts (see Section 4.24, Fish Values, for discussion of fish-bearing water crossings). The pipeline-only segment from Newhalen to the mine access road under Alternative 1a would include nine water crossings. The exact number and design of waterbody crossings would be determined during final design and permitting. Inlet/outlet protection may be installed at some streams, as necessary, to protect the soil surface from erosive forces, which would expand beyond the toe of the fill. Figure 2-17 provides an overview of the transportation facilities, and Figure 2-18 and Figure 2-19 show the locations of bridges planned to be constructed along the road segments. See Figure 2-21 through Figure 2-23 for typical drawings of waterbody crossing structures.

If not properly designed, constructed, and maintained, culverts and bridges could constrict natural streamflow enough to significantly increase the water velocity at the downstream end of the structure and cause backwater upstream of the structure (backwater is described in detail in the Transportation Corridor subsection under “Bridges”). This could lead to stream bank and/or streambed erosion, and/or excessive erosion at the structure and possibly increased deposition upstream of the structure. Erosion of the streambed and/or banks could result in downstream sedimentation (i.e., deposition), a change in the morphology of the stream, and/or a change to the aquatic habitat (see Section 4.24, Fish Values). If a structure does not allow for adequate flow, water could pool excessively on the upstream side. In extreme cases, improper design or construction could lead to the collapse of a structure.

Stream crossings associated with the roads and pipelines would be designed to minimize potential impacts on surface water hydrology, water quality, and fish passage. Road and pad maintenance BMPs, including application of dust suppressants during dry periods, routine grading, and routine maintenance of drainage ditches and stream crossings, would be implemented and maintained during mine operations (see Chapter 5, Mitigation).

The evaluation of impacts from construction of roads, bridges, culverts, and pipelines on surface water hydrology is based on an understanding of planned mitigation in the form of engineering design, and the planned maintenance that can also significantly reduce impacts. The evaluation also considers the probability of occurrence, magnitude, duration, and extent associated with specific impacts.

See Section 4.24, Fish Values, for information on fish and aquatic resource impacts, and permits that would be required prior to construction of stream crossings.

Roads

Although a final design has not been completed, a typical road section is presented in Figure 2-20. Potential impacts of the road embankments (culverts and bridges addressed separately below) on surface water hydrology during mine construction and operations could include:

- Increased stormwater runoff from road and pad surfaces
- Ponding adjacent to road embankments where drainage is disrupted by the lack of a drainage structure
- Increased sediment deposition due to a road wash-out

The potential for erosion and sediment deposition from disturbed areas would be reduced as vegetation is reestablished after construction activities end; therefore, the duration of this impact would be short-term. The road surface would potentially yield additional runoff compared to native terrain, but because the roads would generally run perpendicular to the drainages crossed, the road would generally only minimally increase the quantity of runoff and sediment to any single receiving drainage.

There is potential for increased stormwater runoff to reach drainages crossed by the roads. Based on typical BMPs for this type of work and the typical designs for the project, the magnitude of the impact would be small to medium, and would decrease as vegetation reestablishes itself on disturbed and freshly constructed surfaces. The duration of the increased stormwater runoff would be on the order of hours following a given rain event. If an erosional surface develops, the duration of the scar would be equal to the time for vegetation to reestablish, and would be minimized with implementation of erosion control BMPs (such as armoring or straw waddles) that would serve to protect the soil surface from erosive forces until vegetation re-establishes (see Chapter 5, Mitigation, and PLP 2019-RFI 135). The geographic extent of the impact from the sediment eroded from the embankment, or ditches along the embankment, would likely be on the order of feet to thousands of feet, depending on many site- and event-specific factors. If an erosional scar developed, the geographic extent would be on the order of feet to hundreds of feet.

Increased ponding would be possible adjacent to the road embankment, where drainage is disrupted by the lack of a drainage structure. If the situation occurs, it is expected that it would be remedied relatively quickly; therefore, the duration of the impact would be on the order of weeks. The geographic extent of the area flooded would be on the upstream side of the road and would be no greater than the area encompassed by the ground, with an elevation equal to the top elevation of the road. If the road washes out, the magnitude of the impact could be medium, and the geographic extent could include an area hundreds of feet downstream of the road.

Temporary Stream and River Crossings

During construction of port access and mine access roads, temporary bridges would be installed in the area of the permanent footprint. Temporary bridges at smaller stream crossings would be required for construction access (PLP 2019-RFI 143). At larger crossings, such as the Newhalen and Gibraltar rivers, temporary work trestles would be installed parallel to the access road bridges to facilitate construction of the permanent bridges by providing temporary access for workers, materials, and equipment (PLP 2019-RFI 157). If an unexpected storm occurred at a time of significant surface disturbance, it might increase erosion, or accretion upstream of the crossing, for a limited time. Although the magnitude of the erosion would be larger than natural historic variation, water management practices would minimize the magnitude of the impact of eroded sediment (see Chapter 5, Mitigation). The geographic extent of erosional disturbance and deposition of sediment would be limited to the temporary crossing area during construction (see Section 4.18, Water and Sediment Quality).

Bridge Crossings

A total of 10 bridges would be constructed for the project under Alternative 1a (see Figure 2-18 and Figure 2-19). Although specific bridge design details would vary with stream size and hydrologic properties, a typical bridge schematic is presented on Figure 2-21. Instream channel work, including installation of bridge footings and embankments, would occur year-round during the first 2 years of construction, as permitted. Under Alternative 1a, the Newhalen River crossing would be the southern crossing location. (A variant under Alternative 1 below addresses the north crossing location). Additional information regarding bridge design and site-specific construction is provided in Chapter 2, Alternatives.

During bridge construction, the potential exists for increased runoff, erosion, and sedimentation as a result of vegetation removal and excavation of soil, rock, and sediment. Erosion and sediment (deposition) control BMPs, including routine maintenance of drainage ditches and stream crossings, would be implemented and maintained during the mine operation period. It is possible that there would be increased runoff, erosion, and sedimentation as a result of vegetation removal and excavation. Based on the use of BMPs and proper maintenance, the magnitude of the impact would likely be small to medium. The duration of the impact would likely to be about as long as it takes the vegetation to reestablish. The geographic extent of the impact resulting from sediment transported by streams would be on the order of thousands of feet to miles, depending on many site- and event-specific factors.

During the life of the bridge (after construction), possible impacts to the stream include:

- Increased backwater on the upstream side of the bridge
- Increased riverbed erosion in the bridge opening
- Increased riverbed and bank erosion downstream from the bridge
- Increased sediment deposition downstream from the bridge
- Increased sediment transport in and downstream from the bridge
- Change in channel morphology downstream from the bridge

The magnitude of impact of a bridge on the stream being crossed is directly related to the criteria used to design the bridge, and the extent to which the bridge was constructed according to the design. Figure 2-21 indicates that the bridge would have armored abutments and be designed so that the 100-year flood water-surface elevation would be 12± inches below the bottom of the low chord of the bridge (a dimension referred to as freeboard). No specific information is provided regarding the design of the scour protection measures. Because the typical bridge drawing references the 100-year flood, it would be assumed that the bridge would be intended to perform adequately during the 100-year event. The probability of experiencing a flood equal to or greater than the 100-year flood one or more times during the 20-year life of the bridge is 18 percent. If the bridge stays in place through mine closure (assuming 70 years), the probability of experiencing a flood equal to or greater than the 100-year flood one or more times during the 70 years is 51 percent.

During floods in which the cross-sectional area of the flow is restricted by the bridge, water would back up behind the bridge. The difference between the unrestricted water surface elevation (WSE) and the restricted WSE on the upstream side of the bridge is called backwater. The magnitude of the backwater would depend on the amount of constriction presented by the bridge and would become larger with larger flood events. The probability that backwater would occur would be possible to probable, depending on the specific bridge design and hydraulic conditions at each stream. The extent of the backwater would be a function of the magnitude of the constriction of the flow through the bridged crossing and the slope of the stream. The duration of the backwater would be somewhat less than the duration of the flood. Backwater is generally a concern if it causes a structure or another resource to be damaged by the inundation created as a result of the backwater.

The more a bridge restricts the streamflow (i.e., the greater the backwater), the higher the velocity through the bridge. The higher the velocity through the bridge, the greater the probability that excessive riverbed erosion[3] (scour) would occur both in and downstream of the bridge, and the greater the probability of excessive river bank erosion downstream of the bridge. With increased erosion comes increased sediment transport and increased sediment deposition. An increase in erosion and deposition can lead to a change in channel morphology. Because there is no information on how much the bridges would restrict streamflow, the magnitude, duration, and extent of the impacts cannot be accurately predicted. However, for a well-developed design based on the 100-year flood and a limited backwater, the magnitude of the impacts due to erosion, sediment deposition, and sediment transport discussed above would likely be relatively small. The duration of the impacts would probably last the life of the bridge, and most of the impacts would probably be within 4 to 6 bridge-lengths downstream.

[3] For the purpose of this discussion, excessive erosion is defined as the additional erosion that occurs at a structure beyond that which would have occurred during the same flood, but without the structure.

Two potential conditions could cause the impacts to be more severe. First, if the bridge abutments or piers are undermined by scour, the bridge could collapse. If the scour protection measures are properly designed and constructed for the 100-year flood, the probability of this is possible (calculated at 18 to 51 percent as stated above). If it occurred, the magnitude of the impact on erosion, sediment deposition, and sediment transport would be large. The duration would be long-term, and the extent of the impact could be miles.

A second concern is the impact of debris on the instream piers, bridge deck, and or bridge opening. Ice and debris can build up on the bridge piers during a flood and restrict the water-way opening. Similarly, ice and debris can build up on the upstream side of the bridge if the freeboard is too small to pass all of the ice and debris. A freeboard of 12 inches, as shown on the typical drawing (see Figure 2-21), provides little room for ice and vegetative debris to clear the bridge during the design flood. The result could be an increased probability of and magnitude of excessive backwater, erosion, sediment deposition, and sediment transport, and could lead to a bridge collapse.

Culverts

A total of 84 culverts would be installed at streams along the transportation corridor. Culverts at streams without fish would be designed and sized for drainage only, in accordance with Alaska Department of Transportation and Public Facilities (ADOT&PF) standards. Culverts at streams with fish would be designed and sized for fish passage in accordance with ADOT&PF and Alaska Department of Fish and Game (ADF&G) standards (see Section 4.24, Fish Values). Specific culvert design details would vary with stream size, hydrologic properties, and permit requirements. Figure 2-22 presents a schematic of a typical culvert where fish passage is not an issue, and Figure 2-23 presents a schematic of a fish passage culvert. No other information regarding the design and construction of the culverts at stream crossings is currently available.

During culvert construction, the potential exists for increased runoff, erosion, and sedimentation as a result of vegetation removal and excavation of soil, rock, and sediment. Erosion and sediment control BMPs, including routine maintenance of drainage ditches and stream crossings, would be implemented and maintained during the mine operation phase. At stream crossings, one of the biggest concerns during construction would be how to manage the water in the stream. Often, this is addressed by timing to coincide with low streamflow, such as in the latter part of winter. If there is streamflow present, it must be addressed prior to culvert installation. Based on the use of BMPs and good maintenance, the magnitude of the impact would be small. The duration of the impact would be about as long as it takes for the vegetation to re-establish. The extent of the impact resulting from sediment transported by streams would be on the order of hundreds of feet to miles, depending on many site- and event-specific factors.

During the life of the culvert (after construction), possible impacts to the stream include:

- Increased backwater on the upstream side of the culvert
- Increased riverbed and bank erosion downstream from the culvert
- Increased sediment deposition downstream from the culvert
- Increased sediment transport downstream from the culvert
- Change in channel morphology downstream from the culvert

The magnitude of the impact of the culvert on the stream being crossed would be directly related to the criteria used to design the culvert, and the extent to which the culvert is constructed according to the design. Figure 2-22 indicates that culverts on non-fish-bearing streams would be installed with a slope that matches the stream slope to the maximum extent practical; inlet and outlet protection constructed per the ADOT&PF Highway Drainage Manual; and inlet and outlet protection extending 16 feet upstream and downstream from the culvert. Figure 2-23 indicates that fish passage culverts would be installed with a buried invert; a constructed channel inside the culvert that matched the dimensions of the natural channel adjacent to the culvert; a streambed slope through the culvert that matches the channel slope to the maximum extent practical, but no more than 1 percent greater; a substrate in the culvert designed per Memorandum of Agreement Stream Simulation Design Requirements; inlet and outlet protection constructed per the ADOT&PF Highway Drainage Manual; and inlet and outlet erosion protection that extends 16 feet upstream and downstream from the culvert. Both drawings indicated that the road surface would be a minimum of 3 feet above the top of the culvert. No information is provided as to the magnitude and recurrence interval of the flood used to design the culverts, or the maximum allowable headwater[4]-to-diameter ratio.

If the culverts are designed for the 25-year flood-peak discharge, the probability of experiencing a flood equal to or greater than the design flood one or more times in 20 years is 56 percent. The probability of experiencing the design flood one or more times in 70 years is 94 percent. If the culverts are designed for the 50-year flood-peak discharge, the probability of experiencing a flood equal to or greater than the design flood one or more times in 20 and 70 years is 33 and 76 percent, respectively. If the culverts are design for the 100-year flood, the probability would be as described above for the bridges.

During floods in which the cross-sectional area of the flow would be restricted by the culvert, water would back up behind the culvert. The magnitude of the backwater would depend on the amount of constriction presented by the culvert, and would become larger with larger flood events. It is probable that backwater would occur. The extent of the backwater would be a function of the magnitude of the constriction of the flow through the culvert and the slope of the stream. The duration of the backwater would be somewhat less than the duration of the flood. Backwater is generally a concern if it causes a structure or another resource to be damaged by the inundation created as a result of the backwater.

The more the culvert restricts streamflow (i.e., the greater the backwater), the higher the velocity through the culvert. The higher the velocity through the culvert, the greater the probability that excessive riverbed erosion (scour) would occur downstream of the culvert; and the greater the probability of excessive river bank erosion downstream of the culvert. With increased erosion comes increased magnitude of sediment transport, and increased magnitude of sediment deposition. An increase in erosion and deposition can lead to a change in channel morphology. Because there is no information available on the extent to which the culverts would restrict streamflow, the magnitude, duration, and extent of the impacts cannot be accurately predicted. However, for a well-developed design based on a 50-year flood and a headwater-to-diameter ratio of no more than 1, the probability, magnitude, duration, and extent of the impacts would be similar to a culvert design by ADOT&PF.

Note that the erosion control aprons for the inlet and outlet of the culverts would help to prevent extensive erosion of the streambed, but may not be long enough to completely prevent it. Additionally, there is usually turbulence at the ends of the apron that causes erosion until the end of the apron comes into equilibrium.

A potential condition that could impact the performance of the culverts is ice and debris buildup on the upstream end of the culvert. Either could cause the headwater elevation to be much greater than anticipated. A greater headwater elevation could lead to a greater magnitude and extent of erosion, sediment deposition, and sediment transport; and could lead to a culvert wash-out.

[4] Headwater is the water surface elevation on the upstream side of the culvert.

Flood Magnitude and Frequency

Changes to flood magnitude and frequency are not expected on streams and rivers along the transportation corridor.

Flood Hazards

Potential flood hazards in the transportation corridor could exist if a flood event occurs that exceeds the design event used to size culverts along the port and mine access roads. If culverts are unable to effectively convey flow during a given flood event, the road could be inundated at stream crossings, and could cause erosion of the road surface and road bed. Additionally, restricted flow could cause backwater and increased potential for deposition upstream of the culvert.

Floodplain Functions and Values

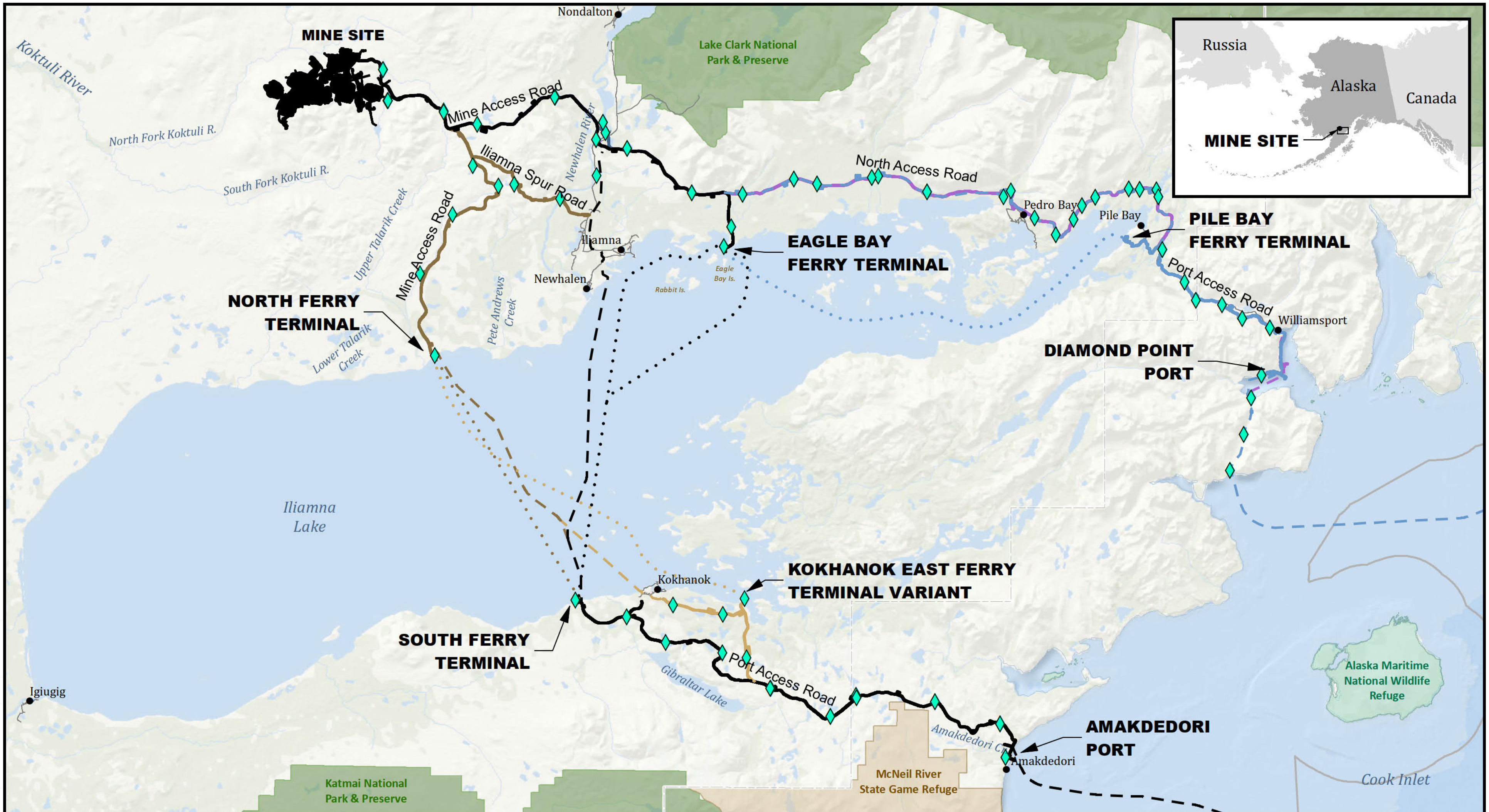
Impacts to floodplain functions and values in watersheds along the transportation corridor are not expected because hydrologic connectivity of wetlands and other waters would be maintained by bridges and culverts. In the event culverts are unable to effectively convey flow during a given flood event, and the road could become inundated, causing erosion of the road surface or road bed, deposition of sediment on floodplain wetlands (if present) downstream of the road crossing could impact floodplain function and value if sediment deposition causes fragmentation of hydrologically connected wetlands and other waters. The distance downstream from the road where sediment deposition could occur would be related to flood magnitude; the downslope gradient of the floodplain; and the extent of road material erosion. Mitigation measures that would be implemented in the design and construction of culverts and bridges to maintain floodplain functions include installing floodplain culverts, permeable roadbeds, or oversized culverts. To avoid constricting the channel and allow connectivity of the floodplain stream crossings, culvert design would meet the US Fish and Wildlife Service culvert design guidelines for ecological function (USFWS 2020) (see Chapter 5, Mitigation).

Surface Water Extraction

Water to be used during construction and operation would be extracted from 21 designated sites along the transportation corridor (Figure 4.16-8, and Appendix K2, Table K2-7). Water extraction sites may be used at any time of the year; although during the winter months, low-flow conditions may limit water availability. Appendix K2 provides information for each water extraction site, including the waterbody type, use, years, and season of use, and estimated extraction rate and volume. Figures in Appendix K2 also show locations of water extraction sites.

ADF&G Fish Habitat Permit requirements (if issued) regulate the minimum streamflow required in anadromous streams, as well as the locations of extraction and the amount permitted for withdrawal. Before the extraction of water from anadromous streams along the road and pipeline corridors, sufficient streamflow would need to be demonstrated to permit summer/winter extraction. Permit compliance (ADF&G Habitat permits) would avoid or minimize the potential for impacts from water withdrawal at streams.

The magnitude and duration of the maximum projected surface water use along the transportation corridor during the 4-year construction phase would be a total of 63 million gallons. Estimated average extraction rates would range from 500 to 1,000 gpm, depending on the streamflow/ volume of the waterbody (PLP 2018-RFI 022). Final estimated quantities for specific uses would be determined during final design and permitting (PLP 2018-RFI 022). All surface water extraction would require compliance with approved state permits (if issued), stipulations, and reporting requirements to protect stream flow, fish, and fish habitat (see Section 4.24, Fish Values).



Sources: PLP 2020-RFI168;
PLP 2019-RFI153; ADNR

US Army Corps of Engineers

5 0 5 10
Miles

Action Alternatives
- Water Extraction Sites
- 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

Other Features
- Local Roads
- Borough Boundary
- National Park
- National Wildlife Refuge
- State Game Refuge/Sanctuary

SURFACE WATER EXTRACTION SITES ALONG TRANSPORTATION CORRIDORS

PEBBLE PROJECT EIS

FIGURE 4.16-8

Potential impacts to surface water resources along the transportation corridor from lake and stream water withdrawal would include reduced water levels and streamflow. Water withdrawal for all uses would be controlled by applicable permits, which would establish limits on the amount of water withdrawn from each source and provide requirements for fish protection. Water withdrawals would require authorization from the State of Alaska; therefore, impacts are analyzed with the expectation that water withdrawals would comply with permit requirements specific to each water source, if a water withdrawal permit is issued. It is reasonable to assume that the rate and volume of water withdrawals would be monitored at each source to ensure permit requirements are met. Therefore, the magnitude of the impacts to surface water resources is generally expected to result in changes in water quantity, likely within the limits of historic and seasonal variation. The duration of the impacts would be short-term, and the extent would be limited to the waterbody source.

4.16.4.3 Amakdedori Port—Runoff, Erosion, and Deposition

The port terminal building would be constructed on an engineered fill patio, designed to be at an elevation high enough to avoid overtopping from tsunami runup and storm surge (see Section 4.15, Geohazards and Seismic Conditions). Stormwater drainage infrastructure such as ditches and culverts would be maintained during operations so that they convey flow as designed, per applicable BMPs (see Chapter 5, Mitigation).

During construction, the potential impacts of the Amakdedori port facility on surface water runoff and erosion and subsequent deposition would be minimized by implementing BMPs for erosion and sediment control and construction at the port (see Section 4.14, Soils; Section 4.18, Water and Sediment Quality; and Chapter 5, Mitigation). Therefore, any direct and indirect impacts on water quantity and velocity would result in maintained surface water flow systems and changes in water quantity that are likely to be within the limits of historic seasonal variation. There is potential for increased erosion during construction of the port; however, the magnitude of the impact would be small to medium, and would decrease as vegetation reestablishes itself on disturbed and freshly constructed surfaces. The duration of the increased erosion would be on the order of hours following a given rain event. If an erosional surface develops, the duration would be equal to the time for vegetation to re-establish, and would also be minimized by erosion and sediment control BMPs that would serve to protect the soil surface from erosive forces until vegetation establishes (Chapter 5, Mitigation). The geographic extent of the impact from surface erosion and subsequent deposition would likely be limited to the port site.

4.16.4.4 Amakdedori Port—Marine Water

Three locations for a port in lower Cook Inlet to support mine operations were considered: Amakdedori in Kamishak Bay; Diamond Point in Iliamna Bay; and a port site north of Diamond Point in Iliamna Bay. To reduce redundancy in the EIS narrative, this section collectively describes all port and dock design alternatives. Three dock designs are addressed, depending on alternative and variant: caisson dock; earthfill sheet pile; and pile-supported dock (as a variant) (Chapter 2, Alternatives). Table 4.16-5 provides the fundamental information for each type of dock construction to support the subsequent narrative. See “Marine Water” subsections for Alternative 2 and Alternative 3 for additional specific information for port locations associated with these alternatives.

During initial “capture” of the port site, there would be no expected impacts to marine hydrology. Impacts would be related to activity such as vessel operations (e.g., anchoring, propeller wash). Impacts would not affect the hydrology of Kamishak Bay; would be short-term (during temporary vessel operations prior to construction); and localized in the vicinity of the immediate shoreline.

Table 4.16-5: Port Alternatives and Lightering Locations

Location/Type	Alternative 1a	Alternative 1	Alternative 2	Alternative 3
Cook Inlet Port	Amakdedori	Amakdedori	Diamond Point (Iliamna Bay)	North of Diamond Point (Iliamna Bay)
Dock type construction	Caisson	Earthfill and Sheet Pile	Earthfill and Sheet Pile	Caisson
Dock variants	No variants	Pile-supported; total 253 piles	Pile-supported; total 518 piles	No dock variant
Lightering—Primary Location	Location A: 12 miles east-southeast	Location A: 12 miles east-southeast	Iniskin Bay	Iniskin Bay
Lightering—Alternate Location	Location B: 18 miles east-northeast (lee of Augustine Island)	Location B: 18 miles east-northeast (lee of Augustine Island)	Location B: 20 miles south-southwest (lee of Augustine Island)	No alternate lightering location

Effects of structures on coastal waters can be classified as "hydrodynamic" or "hydrographic." "Hydrodynamic" refers to changes in the dynamic (or circulatory) aspects of flow; "hydrographic" refers to changes in the water density structure, resulting in vertical and/or horizontal variations in density (called stratification), due to differences in temperature and/or salinity. Both hydrodynamic and hydrographic effects can occur simultaneously.

Linear structures such as causeways, docks, and jetties, or natural coastal features such as capes, headlands, and promontories, which are oriented perpendicularly (or nearly so) to the shoreline, can have pronounced hydrodynamic effects on coastal waters, because they can deflect alongshore currents seaward and thereby affect overall circulation in the adjacent waterbody. If the length of the structure or feature is large relative to the affected waterbody, its effects can be profound; to the extent of altering overall circulation. However, if the structure or feature is relatively short, compared to the waterbody's major dimensions, its effects are a minor perturbation to the overall circulation, and are limited to its immediate vicinity (Colonell et al. 1990).

The areal extent of a structure's effect on the adjacent waterbody depends on the speed and volume of the alongshore flow, as well as the length of the structure and whether it permits throughflow via gaps or breaches. The Alternative 1a and Alternative 3 caisson dock design, with 60-foot spacing between caissons, would be somewhat porous to an alongshore current (allowing natural erosion and deposition), thereby furthering the structure's already small potential effect on overall circulation, as well as allowing easy passage for fish and marine mammals (see Section 4.24, Fish Values; Section 4.25, Threatened and Endangered Species).

Under Alternative 1 and Alternative 2, the dock would be a solid structure (earthfill sheet pile design) that could divert flow of an alongshore current to its distal end; however, the causeway's approximately 2,000-foot length is small relative to dimensions of either Kamishak or Iliamna Bay, and the causeway could therefore exert only minimal effect on the bay's circulation. The dock variant under Alternative 1 and Alternative 2, a pile-supported dock, would be essentially transparent to any alongshore currents; would have no perceptible effect on circulation; and would not pose a barrier to passage of marine life.

Historical and current photos of the coastline at Amakdedori show no evidence of littoral (i.e., coastal) sediment transport (no definitive alongshore current), which would appear as accumulations of sediment (deposition) in the form of spits or fillets at shoreline obstacles.

Therefore, there is no indication that alongshore currents at the Amakdedori port site are either strong or have any predominant direction (Geoengineers 2018c). Even the dock design with the largest footprint, the earthfill sheet pile structure, would be a minor coastal feature in either Kamishak Bay or Iliamna Bay.

A remaining possible concern could be a secondary (hydrographic) effect that has been observed near the two causeways in Prudhoe Bay, Alaska (Colonell et al. 1992). Namely, when the water column near the causeway is vertically stratified, as would occur when warmer, fresher water overlies colder, saltier water, a "pool" of cooler, saltier water tends to form in the causeway's wake on its lee, or "downcurrent" side. This hydrographic condition (i.e., fresh water overlying salt water) could occur only in the immediate vicinity of the mouth of Amakdedori Creek, which is about 4,200 feet from the causeway. Natural mixing of the water column would dissipate any density stratification before it could be carried to the causeway. It is concluded that neither large-scale circulation patterns in either Kamishak Bay or Iliamna Bay, nor small-scale hydrographic conditions, would be affected by any of the dock designs (see Section 4.22, Wetlands and Other Waters/ Special Aquatic Sites, for description of impacts in the immediate vicinity of the dock structure).

The main construction impacts for all dock designs are listed in Table 4.16-6 (see "Vessel Operations" subsection below for impacts that may be specifically caused by vessels during "capture" of the site, construction, and operation at the port). The footprint of the earthfill sheet pile design is five times that of the caisson design under Alternative 1a, although the substantially larger footprint for the sheet pile structure in itself does not imply greater impact on hydrology. The construction impact of the earthfill sheet pile design would be the larger, due to increased suspended sediment over two summers during fill placement. This contrasts with the construction impact of the caisson dock, which could be constructed in a single season, with only limited disturbance of the seabed. Therefore, during construction of the earthfill sheet pile dock, there is greater potential for sediment deposition than during construction of the caisson (or pile-supported) docks.

Construction of an earthfill causeway (Alternative 1 and Alternative 2) would cause elevated concentrations of suspended sediments that would be expected to persist for a few weeks after completion (See Section 4.18, Water and Sediment Quality). If required by State of Alaska permit stipulation, removal of an earthen-fill causeway at the end of the project would cause increases in suspended sediment in Kamishak Bay (or Iniskin Bay for the Diamond Point port site under Alternative 2) that would persist for a few weeks after decommissioning is completed, but not substantially greater than levels routinely observed (see Section 4.18, Water and Sediment Quality).

For Alternative 1a, the caisson dock structure footprint would be the smallest among the action alternatives at 2.1 acres. Alternative 1 and Alternative 2 dock structures (sheet pile design) would be 11.0 acres and 14.1 acres, respectively. The Alternative 3 (caisson) footprint would be 3.2 acres. Under Alternative 1a, the caissons closer to the shore would be 60 square feet, spaced approximately 60 feet apart; under Alternative 3, the caissons closer to shore would also be spaced 60 feet apart, but the footprint would be 120 feet by 60 feet. Effects of the caissons on marine water movements and sediment transport would be significantly reduced, due to its porosity, compared to those for the earthen-fill causeway design. Grooming of seabed for placement of caissons would temporarily re-suspend bottom sediments, which would quickly settle to the seabed due to their coarse nature (Geoengineers 2018c).

The Pile-Supported Dock Variant (Alternative 1, Alternative 2) would have the smallest areal footprint of the dock designs, and because of its being essentially transparent to alongshore flow, the pile-supported structure would also have the smallest hydrodynamic effect on the host waterbody. However, the Pile-Supported Dock Variant would likely be considered to have the greatest noise impact on marine mammals (see Section 4.25, Threatened and Endangered Species).

Table 4.16-6 Construction Impacts for Each Dock Design

Construction Impacts	Caisson		Earthfill/Sheet Pile (base case for Alternative 1 and Alternative 2)	Pile-Supported (Variant of Alternative 1 and Alternative 2)
	Alternative 1a	Alternative 3		
Direct impact to wetlands and other waters (acres below mean high water)	2.1 acres	3.2 acres	11 acres (Alt 1) 14.1 acres (Alt 2)	0.1 acre
Suspended sediments during construction	Limited, associated with seabed preparation for caisson footprints	Limited, associated with seabed preparation for caisson footprints	Significant due to placement of fill	Limited, associated with any drilling required to socket piles
Time to construct	1 summer	One season late summer/fall	2 summers	2 summers
Shallow bedrock	N/A	N/A	May require limited impact pile-driving for final seating of sheet pile.	Would require significant drilling and/or impact pile-driving to socket round piles into bedrock
Susceptibility to ice impacts	N/A	N/A	May require some replacement of slope protection (riprap)	High likelihood of pile replacement
Long-term durability	Should meet project life-cycle requirements	Should meet project life cycle requirements	Minor maintenance and repairs expected	Major maintenance and repairs expected

Notes:
Impacts to marine mammals that would be caused by construction noise are addressed in Section 4.25, Threatened and Endangered Species
N/A = not applicable
Source: PLP 2019b and PLP 2020d

For all alternatives, ore concentrate would be transported via barge in enclosed and locked containers (see Section 4.18, Water and Sediment Quality; and Section 4.27, Spill Risk) from the port terminal to Handysize ships[5]. Weather permitting, the Handysize ships would be moored offshore at Primary Lightering Location A (Alternative 1a and Alternative 1) or Iniskin Bay (Alternative 2 and Alternative 3). If wind and sea conditions do not permit safe anchoring, the ships would be moored at Lightering Location B for all alternatives (leeward side of Augustine Island) except Alternative 3 (see Figure 2-56 and Figure 2-71).

Kamishak Bay (Amakdedori port) already has a dynamic wave climate to which the shoreline has achieved a stable equilibrium (see Section 3.16, Surface Water Hydrology); therefore, the bay's aquatic environment is not likely to be affected by incrementally increased wave activity as a result of the lightering vessels' wakes. See "Marine Water" under Alternative 2 for a similar description of features of Iniskin Bay, Diamond Point, and Alternative 3 port site north of Diamond Point in Iliamna Bay.

Flow emanating from ship propellers produces an incremental increase in current velocity in the water column surrounding the propeller called "propwash." Although propwash effects dissipate

[5]**Handysize ships** are medium bulk carriers with a capacity of 24,000 to 35,000 deadweight tonnage and 130 to 150 meters in length with 10 meters of draft.

rapidly with distance from the propeller, both radially and axially, there is a possibility that the propwash could disturb sediments on the seabed. The magnitude of the incremental increase in current speed due to propwash is a function of several variables that characterize the hydrodynamics of the propeller, including its dimensions (e.g., diameter, number and pitch of blades) rotational speed, and input power (Hong et al. 2012).

Tugs for moving barges would have 12-foot draft, and therefore would have at least 3-foot underkeel clearance at Amakdedori port (barge berths at -15 feet mean lower low water [MLLW]) that are probably sufficient to avoid disturbance of the seabed. A detailed propwash analysis is recommended to be included in the comprehensive coastal engineering analysis during project design (see Appendix M1.0, Mitigation Assessment).

Whether the seabed at or near the dock would be erodible by propeller wash would depend on the composition of the seabed materials (e.g., sand, silt, and rock), and on the management of lightering vessel operations. Establishment of suitable BMPs for vessel operations should be sufficient to minimize adverse impacts. BMPs would include specifications for managing ship speeds (minimizing wakes) and engine power settings (minimizing bottom erosive stress) during approach and departure from the causeway berths. Although ship wakes and propeller wash can contribute substantially to shoreline erosion in relatively quiescent waters, neither is expected to be an issue at Amakdedori, Diamond Point, or the port location north of Diamond Point.

The Handysize ships would not drop anchor, but would be moored at a lightering location, depending on wind and wave conditions. The primary location would be used unless high winds, waves, sea ice, or other factors preclude their use; if so, the alternate lightering location (B) would be used (Alternative 1a, Alternative 1, and Alternative 2).

PLP 2018-RFI 081 describes the mooring systems that would be installed at the primary and alternate lightering locations (see Figure 2-35). Mooring systems would consist of six floating buoys to which the Handysize bulk carrier would be secured during loading. Each buoy would be attached to two permanent anchors on the sea floor. The layout for the permanent anchors (10 to 12) set on the seabed would be finalized in the detailed design, but each would consist of a large weight, such as a rock/concrete-filled 40-foot by 8-foot by 8-foot shipping container that is lowered to the seafloor. Because the mooring system does not require repeated anchoring at the same locations, there would be less temporary disturbance to the seafloor, which reduces the potential for temporary suspended sediment in the vicinity of the vessels.

The mooring spread measures approximately 2,300 feet by 1,700 feet, but the impact footprint on the seabed is limited to the 10 to 12 anchor locations and possible drag of anchor chains on the bottom. To prevent excessive drag and swinging of the anchor chains, a concrete positioning (sinker) block (approximately 3 feet by 3 feet by 3 feet) would be set on the sea floor with enough slack in the chain to allow the buoy to move closer to the main anchor, and thereby reduce the amount of main anchor chain sag to the seabed without excessive movement of the sinker block. Exact chain lengths would be determined during detailed design. Water depth at all three lightering locations is approximately 80 feet.

Vessel Operations

Autumn storms and winter ice would likely present the most significant challenges to vessel operations in/near Kamishak Bay. All vessel support structures would be designed to resist forces due to wind, waves, and ice to provide safe and reliable access to vessels while docked or operating nearby. As is typical, design criteria would be enumerated during the detailed design phase of the project.

During scoping meetings in April 2018, the following remarks were recorded from Mr. Chester Passic, Commander in the US Coast Guard (Peninsula Reporting 2018):

> I'm a commander in the United States Coast Guard. I'm the captain of the Coast Guard vessel Hickory stationed here in Homer. I do all of the aids to navigation in the Cook Inlet, the buoys and the lights…. We do not keep buoys in Cook Inlet for six months a year because of the weather and ice, and we can't keep buoys in Cook Inlet at that time. Kamishak Bay where the deepwater port is proposed is one of the worst places in the world to operate in terms of combination of tide, current, winds, weather. And I don't know if -- I think the Corps needs to investigate the deepwater port there. My concern would be that we can't keep aids to navigation for the vessels going in and out of there.

Regarding trans-shipment operations (lightering), the analysis and modeling of Cook Inlet metocean data by Ausenco (2019b), as well as data collected at port locations (Ausenco 2019a), indicate that all three lightering locations are suitable "under typical conditions." Dickins' analysis (2018) of Cook Inlet sea ice data showed that "significant" ice remains in Iniskin Bay for an average of 1 to 2 months each year; while at lightering location A (Alternative 1a and Alternative 1), significant ice coverage lasts for 1 week each year, with some years being totally ice free. Ice conditions at lightering location B are expected to be similar to lightering location A.

Usability criteria for the primary and alternate lightering locations are provided in Table 4.16-7 (PLP 2018-RFI 081).

Table 4.16-7: Lightering Site Usability Criteria

Condition	Normal Conditions	High Wind/ Wave	Early Ice	Peak Ice	Late Ice
Location A (primary)	Suitable	Use Alternate	Suitable	Likely Suitable	Suitable
Iniskin Bay (primary)	Suitable	Suitable	May Use Alternate	Use Alternate	May Use Alternate
Location B (alternate)	Suitable	Likely Suitable	Suitable	Likely Suitable	Suitable

Note: Location A: Alternative 1a and Alternative 1; Iniskin Bay: primary lightering location for Alternative 2 and Alternative 3; Location B: the alternate lightering location for Alternative 1a, Alternative 1, and Alternative 2.

Source: PLP 2018-RFI 081 and PLP 2020d

It is typical engineering practice that during the detailed project design phase, a discrete event simulation model would be developed to fully assess the potential operational downtime due to weather delays and port throughput. The analysis would incorporate wind, wave, and ice operating thresholds derived from modeling the dynamic behavior of vessels during the loading and trans-shipment processes, which would provide additional insight into those processes and the associated equipment design requirements.

4.16.4.5 Iliamna Lake

Ferry Terminals

Except for Alternative 3, ferry terminals would be built on the northern and southern shores of Iliamna Lake (Table 2-1). During initial "capture" of ferry terminal sites, impacts would be similar to those during construction and related to activity such as temporary anchoring or propeller wash. Impacts would not affect lake hydrology; would be short-term (during temporary vessel operations prior to construction); and localized in the vicinity of the immediate shoreline.

Construction of the ferry terminals would involve placement of rock and aggregate. In terms of extent, some shoreline and lakebed disturbance would be expected at any of the three terminal locations, resulting in temporary increases in suspended sediment concentrations during construction and decommissioning. The extent of such disturbances would be limited to the immediate vicinities of the ferry terminals, and impacts would be prevented or reduced by BMPs (Chapter 5, Mitigation). Transport of suspended sediment concentrations by wind-driven currents alongshore would not be expected to be long-term, or to cover a large geographic area.

Ferry Operations

Estimated wave conditions for winds typical of Iliamna Lake (Section 3.16, Surface Water Hydrology) suggest that the lake already has a dynamic wave climate with which the shoreline has achieved a stable equilibrium; therefore, the lake is not likely susceptible to incrementally increased wave activity that could be caused by the ferry's wake at any of the terminal locations. Whether the lake bottom at or near the ferry terminals would be susceptible (i.e., erodible) to propeller wash would depend on the lake bottom materials (e.g., silt, sand, gravel, rock), and on the management of ferry operations.

All vessel support structures would be designed to resist forces due to wind, waves, and ice to provide for safe and reliable access to ferries while docked or operating nearby. As is typical engineering practice, design criteria would be enumerated during the detailed design phase of the project.

Available information regarding the Iliamna Lake ferry design is provided in PLP 2018-RFI 013, PLP 2018-RFI 029, and PLP 2018-RFI 052, and is also described in Section 4.27, Spill Risk. BMPs would include specifications for management of ferry speed (minimizing wakes) and engine power settings (minimizing bottom erosive stress due to propeller wash) during approach and departure from the terminals. Although vessel wakes and propeller wash could contribute to shoreline erosion in relatively quiescent waters, neither wake nor propeller wash would be expected to affect the shoreline of Iliamna Lake under proper vessel operation BMPs. During winter, the shoreline would be frozen, and therefore not susceptible to any potentially erosive effects of icebreaking operations.

Ice cover on Iliamna Lake is highly variable, so that predictions of probable conditions at the lake crossing routes is not possible with any accuracy. The ferry would be designed to operate year-round, in all ice conditions. There are anecdotal reports of ice thickness in excess of 4 feet on Iliamna Lake.

Based on PLP 2018-RFI 052, the best analog for the Iliamna Lake ferry is the M/V *Williston Transporter*, which has been operating as a log/equipment carrier on Williston Lake (British Columbia) since 1995. Of similar size and capacity to the Iliamna ferry, the *Williston Transporter* reportedly routinely cuts through 4 feet of ice on Williston Lake. A combination of a well-designed ferry, BMPs, and routine surveillance of wind, wave, and ice conditions is expected to be sufficient to ensure safe and reliable operations of the Iliamna ferry.

4.16.4.6 Natural Gas Pipeline Corridor

Marine Water—Kenai Peninsula to Kamishak Bay

Excavation activities associated with construction of the natural gas pipeline from Anchor Point to Amakdedori would result in short-term re-suspension of seabed sediments and subsequent deposition. During horizontal directional drilling (HDD) and construction of the pipeline terminus at Anchor Point, elevated concentrations of suspended sediment would likely not be greater than concentrations that routinely occur in Cook Inlet under natural processes, nor would they persist for more than a single tidal cycle because of the vigorous currents that occur there. For the portion of the pipeline in deeper waters of lower Cook Inlet (greater than 30 feet [10 meters]), these increases would not be noticeable due to the robust current regime and ambient high levels of suspended sediment. In Kamishak Bay, any increases in suspended sediment during trenching would be larger and longer-term than for HDD. However, due to the coarse nature of the bay substrate (Geoengineers 2018c), such re-suspended sediments would deposit on the seabed within a tidal cycle.

Iliamna Lake

Construction of the pipeline by trenching (PLP 2020d) at the north ferry terminal, Eagle Bay ferry terminal, or south ferry terminal would cause short-term increase of suspended sediment concentration in the water column. Extent of the impact would be limited to the immediate vicinity of the construction, and might persist for a few days before being cleared away by wind-driven currents and mixing.

Surface Water Extraction

The magnitude, duration, extent, and likelihood of potential impacts to surface water resources along the pipeline corridor from water withdrawal from streams, lakes, and ponds would be the same as those described under the transportation corridor. Water withdrawal for all uses would be controlled by applicable permits (if issued), which would establish limits on the amount of water withdrawn from each source and provide requirements for fish protection. It is reasonable to assume that the rate and volume of water withdrawals would be monitored at each source to ensure permit requirements are met. Therefore, the magnitude of the impacts to surface water resources is generally expected to result in changes in water quantity, likely within the limits of historic and seasonal variation. The duration of the impacts would be short-term, and the extent would be limited to the waterbody source.

Pipeline

Where the natural gas pipeline alignment follows the port access and mine access roads, it would be in a trench adjacent to the driving surface of the road (see Figure 2-20). Although final design of the pipeline has not been completed, it is anticipated that stream crossings would be constructed by a combination of placing the pipeline in a trench dug across the stream (open cut), boring the pipeline under the stream (HDD), or hanging the pipeline on a bridge structure. Typical schematics for the pipeline stream crossings without bridge structure are provided on Figure 2-44. Currently, no other information regarding the design or construction of the natural gas pipeline stream crossings is available.

During pipeline construction, the potential exists for increased runoff, erosion, and sedimentation as a result of vegetation removal and excavation of soil, rock, and sediment. Erosion and sediment control BMPs would be implemented and maintained during construction and operation of the mine. The potential for these impacts would greatly reduce as vegetation is re-established after the construction activities end. The magnitude, duration, extent, and potential for these impacts would be the same as for vegetation removal and excavation associated with road construction.

At HDD pipeline crossings, there is a potential for the drilling mud used to bore the pipeline below the streambed to be released to the stream through fractures, a process called frac-out. The probability of this occurring is considered possible. If frac-out occurs, sediment load would increase. The magnitude of the impact would depend on how fast the frac-out is recognized and drilling is halted, and the characteristics of the flow in the stream at the time of frac-out. The duration of the impact would be dependent on how fast the frac-out is recognized, but would continue for some time after the pressure on the drilling mud is reduced; therefore, the duration could be hours to days. The extent of the impact would be dependent on how much drilling mud is released, and the magnitude of the flow in the stream at the time of frac-out, but could be hundreds of feet to miles (see Section 4.18, Water and Sediment Quality). Typically, geotechnical investigations would be conducted at HDD stream crossings to evaluate the risk of frac-out during drilling at each crossing (see Table M-1).

At stream crossings constructed by open cut (see Figure 2-44), one of the biggest concerns during construction would be how to manage the water in the stream. Often, this is addressed by timing the cut to coincide with low streamflow, such as in the latter part of winter. If there is streamflow, it must be passed across the open cut. During construction of the open cut, it can be pooled behind a temporary dam and pumped across the open cut, or a flume can be used to pass the water over the open cut. However, at the time the pipeline is placed, water must be contained behind the temporary dam or passed through the cut. The methods used depend on how much water must be passed.

Passing water over the open cut in a flume or by pumping can usually be done with little to no disturbance to the stream beyond the construction zone. If, during the placement of the pipeline, the streamflow must be passed through the cut, there is the potential for increased erosion of the streambed, increased sediment deposition in the channel, and increased sediment transport downstream from the pipeline crossing. If the streamflow must be passed through the open cut, these impacts would be probable. The magnitude of the impacts would depend on site-specific conditions and the procedures used by the contractor. The duration of the impacts would likely be on the order of months. The extent of the impacts would be on the order of hundreds of feet to miles.

During the life of the pipeline, exposure of the pipeline could result in increased erosion, sediment deposition, and sediment transport. The probability that the pipeline would be exposed is directly related to the design criteria. The pipeline should be designed to remain covered during natural streambed erosion and floods up to and equal to a design flood. The design flood should have an acceptable probability of occurrence based on the possible costs and impacts of exposure. Additionally, the pipeline should be situated so that it would not become exposed by the lateral migration of the stream during the life of the pipeline. If the pipeline is exposed, the increased turbulence created by the flow of water around the exposed pipeline would cause increased erosion near the pipeline, and sediment deposition and transport downstream from the pipeline. Because additional design details are not available at this time, the probability of the events discussed above would be small to probable. If the pipeline became exposed, the magnitude of the impact would probably be medium to large. The duration of the impact would be months to years. The extent of the impact would likely be thousands of feet to miles.

Flood Magnitude and Frequency

Changes to flood magnitude and frequency are not expected on streams and rivers along the pipeline route.

Flood Hazards

Potential flood hazards are not expected along the pipeline route, because stream crossings would be constructed by either an open-cut trench, HDD boring under the stream, or hanging the pipeline on a bridge structure.

Floodplain Functions and Values

Potential impacts to floodplain functions and values during pipeline construction could result from excavation and placement of fill; removal of vegetation; compaction, rutting, and mixing of wetland soils where present; and the alteration of stream channels. Pipeline construction would occur over a period of 2 years; therefore, the duration of impacts to floodplain wetlands are anticipated to be temporary, because disturbed areas are expected to return to natural conditions soon after pipeline construction. Sections of the pipeline that require overland (buried) installation would also result in temporary impacts to wetlands and other waters.

4.16.5 Alternative 1

4.16.5.1 Mine Site

The magnitude, duration, extent, and likelihood of impacts to surface water hydrology at the mine site under Alternative 1 are expected to be the same as those described under Alternative 1a.

4.16.5.2 Transportation Corridor

Roads

The port access road alignment under Alternative 1 is the same as described under Alternative 1a. The mine access road would extend from the mine site south to the north ferry terminal on Iliamna Lake. Under Alternative 1, spur roads would include those described under Alternative 1a, and would also include the Iliamna spur road. The Iliamna spur road would be an unpaved road, approximately 9 miles long, connecting the mine access road to the existing road system supporting the communities of Iliamna and Newhalen (see Figure 2-51). The magnitude, duration, extent, and likelihood of impacts to surface water hydrology under Alternative 1 are expected to be the same as those described under Alternative 1a.

Bridge Crossings

A total of 10 bridges would be constructed for the project under Alternative 1. The mine access road would have two bridges, Iliamna spur road would have one bridge, and the port access road would have seven bridges (see Figure 2-51 and Figure 2-52). The magnitude, duration, extent, and likelihood of impacts to surface water hydrology under Alternative 1 are expected to be the same as those described under Alternative 1a.

Culverts

A total of 81 culverts would be installed at streams along the transportation corridor. The magnitude, duration, extent, and likelihood of impacts to surface water hydrology under Alternative 1 are expected to be the same as those described under Alternative 1a.

Flood Magnitude and Frequency

Changes to flood magnitude and frequency under Alternative 1 would be same as those described under Alternative 1a.

Flood Hazards

Flood hazards under Alternative 1 would be same as those described under Alternative 1a.

Floodplain Functions and Values

Potential impacts to floodplain function and values under Alternative 1 would be same as those described under Alternative 1a.

Surface Water Extraction

Twenty potential water extraction sites have been identified to support project construction and operations of Alternative 1. Appendix K2 provides information for each water extraction site, including the location, waterbody type, use, years and season of use, and estimated extraction rate and volumes. The annual volume of water that would be extracted under Alternative 1 for all water extraction sites is 49 million gallons, including 6 million gallons along the Iliamna spur road. Final estimated quantities for specific uses would be determined during final design (PLP 2018-RFI 022). The magnitude, duration, extent, and likelihood of impacts to surface water hydrology under Alternative 1 are expected to be the same as those described under Alternative 1a.

4.16.5.3 Amakdedori Port

The magnitude, duration, extent, and likelihood of impacts to surface water hydrology at the Amakdedori port under Alternative 1 are expected to be the same as those described under Alternative 1a.

4.16.5.4 Natural Gas Pipeline Corridor

The natural gas pipeline corridor under Alternative 1 would follow the port access road, as described under Alternative 1a. The pipeline would cross Iliamna Lake between the south ferry terminal and north ferry terminal, and then follow the mine access road between the north ferry terminal and the mine site (see Figure 2-49). The magnitude, duration, extent, and likelihood of impacts to surface water hydrology under Alternative 1 are expected to be the same as those described under Alternative 1a.

4.16.5.5 Alternative 1—Summer-Only Ferry Operation Variant

The Summer-Only Ferry Operations Variant would preclude the need for ice-breaking operations. Impacts to Iliamna Lake under the Summer-Only Ferry Operations Variant would be the same as described for Alternative 1, during the summer (open water) season.

4.16.5.6 Alternative 1—Kokhanok East Ferry Terminal Variant

Under this variant, 55 million gallons of water could be extracted annually from surface water sources, as compared to 49 million gallons under Alternative 1.

Under this variant, there would be eight rivers crossed by bridges, and 73 streams requiring culverts. The magnitude, duration, extent, and likelihood of impacts to surface water hydrology under this variant would be similar to those for stream crossings and the terminal location in Alternative 1.

4.16.5.7 Alternative 1—Pile-Supported Dock Variant

Construction of a pile-supported dock at Amakdedori would not impact onshore surface water or marine hydrology. During construction of the solid-fill portion of this dock in marine water, the magnitude, duration, and extent of impacts would be a short-term increase in suspended solids in the immediate vicinity of the filled area. If required, removal of a pile-supported dock would result in short-term increases of suspended solids in the water column.

4.16.6 Alternative 2—North Road and Ferry with Downstream Dams

4.16.6.1 Mine Site

The magnitude, duration, extent, and likelihood of impacts to surface water hydrology at the mine site under Alternative 2 are expected to be the same as those described under Alternative 1a, except that some of the impacts would be located about 40 feet upstream due to the upstream shift (compared to the centerline construction in Alternative 1a) of the main TSF embankment (Tributary NK 1.19, gaging station NK 119A).

4.16.6.2 Transportation Corridor

Roads

The mine access road under Alternative 2 is the same as for Alternative 1a—mine site to Eagle Bay ferry terminal. The port access road would connect the Pile Bay ferry terminal with Diamond Point port. The Alternative 2 mine access and port access roads would have 46 stream crossings, with seven bridges and approximately 39 culvert crossings. The magnitude, duration, extent, and likelihood of surface water hydrology impacts associated with the road segments from the mine site to Eagle Bay, and Pile Bay to Diamond Point port (see Figure 2-49 and Figure 2-50) would be similar to the types of impacts described for Alternative 1a, except the road length under Alternative 2 is less than Alternative 1a, there would be fewer stream crossings than Alternative 1a, and the road segment from Williamsport to Diamond Point would require fill in marine waters, whereas Alternative 1a would not fill marine waters.

Surface Water Extraction

Seventeen water extraction sites have been identified for the transportation corridor (port access road and mine access road). Appendix K2 provides information for each water extraction site, including the waterbody type, use, years and season of use, and estimated extraction rate and volumes. Figures in Appendix K2 show the location of water extraction sites identified for Alternative 3.

Flood Magnitude and Frequency

Changes to flood magnitude and frequency under Alternative 2 for the road corridor from the mine site to Eagle Bay would be the same as those described under Alternative 1a and include implementation of the mitigation measures described under this topic in Alternative 1a. The road segment from Pile Bay to Diamond Point port is in steeper, more mountainous terrain with less wetlands, and the same mitigation measures would be implemented as under Alternative 1a.

Flood Hazards

Flood hazards under Alternative 2 for the road corridor from the mine site to Eagle Bay would be the same as those described under Alternative 1a. Flood hazards are not anticipated to occur because the same mitigation measures would be applied for waterbody crossings from Pile Bay to Diamond Point port.

Floodplain Functions and Values

Potential impacts to floodplain function and values under Alternative 2 for the road corridor from the mine site to Eagle Bay would be the same as those described under Alternative 1a. Floodplain function and values are not expected to be impacted along the road segment from Pile Bay to

Diamond Point port. This area has even less wetlands than the segment from the mine site to Eagle Bay and is steep, mountainous terrain.

<u>Ferry</u>

Impacts from ferry operations from Eagle Bay to Pile Bay would have a magnitude, duration, extent, and likelihood of impacts to surface water hydrology similar to those of the ferry operations under Alternative 1a.

4.16.6.3 Diamond Point Port—Runoff, Erosion, and Deposition

Impacts to surface water hydrology at Diamond Point port would be similar to those described under Alternative 1a for Amakdedori port.

4.16.6.4 Diamond Point Port—Marine Water

The Diamond Point port would be constructed at Diamond Point on the northern side of the entrance to Cottonwood Bay, a small (i.e., approximately 9 miles long by 3 miles wide) and shallow (i.e., less than 6 feet deep) westerly extension of Iliamna Bay (PLP 2018-RFI 099). The port structure would consist of an L-shaped solid-fill causeway and wharf, extending approximately 2,000 feet southeast of Diamond Point. The causeway would include a breach approximately 600 feet from the Diamond Point shoreline.

Linear structures or land features, such as causeways, jetties, or natural promontories that are oriented perpendicularly (or nearly so) to the shoreline, can affect nearshore water movements (Colonell et al. 1992). The primary effect of such structures or features is to deflect seaward any alongshore (i.e., parallel to shore) currents, thereby potentially altering circulation in the adjacent waterbody. The areal extent of this effect depends on the strength (speed and volume) of the alongshore flow, as well as the length of the structure or feature. Observations reported in Pentec Environmental/Hart Crowser and SLR (2011) suggest that currents in the Iliamna-Iniskin estuary (IIE) are generally weak and variable, so it is not expected that the port structure would impact large-scale estuarine circulation in its vicinity.

Examination of historic and current photos of the coastline adjacent to the Diamond Point port site suggests that it is a very stable coastline, and that it is rocky and primarily composed of gravel and cobbles. There are no indications of a predominant littoral sediment transport direction, which implies that waves and beach processes, both cross-shore and alongshore, are in a long-established equilibrium, with waves arriving essentially perpendicular to the beach, and having no long-term variation from that direction. Although a coastal structure such as a causeway could interrupt alongshore sediment transport, the present condition of the shoreline suggests that equilibrium would soon be established, and that effects of the structure would be limited to its immediate vicinity.

Earthen-fill causeways can have potential to interrupt littoral (alongshore) water movements, and therefore interrupt littoral sediment transport. Historical and current photos of the coastline at Diamond Point show no evidence of littoral sediment transport, which would appear as accumulations of sediment in the form of spits or fillets at the shoreline obstacles, and also as indication of dominant directions of sediment transport. Although some sediment accumulation at the base at the causeway is inevitable, there are no signs that such accumulation would be large or persistent.

Tugs to be used for moving barges would have 12-foot draft, and therefore would have adequate underkeel clearances of 3 feet at Diamond Point port (barge berths at -20 feet MLLW). None of the variables related to hydrodynamics of the propellers, which would be required for propwash analysis, are available at this time.

The causeway-wharf structure may cause effects to small-scale hydrographic conditions. Localized effects may result if the water column density in its vicinity is stratified, as might occur when warmer, fresher water overlies colder, saltier water. According to Pentec/Hart Crowser and SLR (2011), freshwater inflows to the IIE are generally small, except possibly when due to snowmelt during spring break-up, and would not be considered a point source of freshwater. Consequently, the potential for this effect is virtually non-existent. Therefore, it is concluded that neither large-scale circulation patterns in IIE, nor small-scale hydrographic conditions would be affected by the Diamond Point port structure. Impacts to water quality and substrate from causeway and jetty construction are described in Section 4.18, Water and Sediment Quality. See Section 4.22, Wetlands and Other Waters/Special Aquatic Sites, for description of impacts in the immediate vicinity of the dock structure.

Based on PLP 2018-RFI 099, 643,098 cubic yards of the seabed would be dredged to provide for a barge approach channel and turning basin on the southern side of the causeway (see Chapter 2, Alternatives, for more detail about dredging the shallow channel at Diamond Point). Berms around these stockpiles would contain the sediments, as needed, and collect seepage and stormwater runoff for treatment in settling ponds prior to discharge.

The main moored lightering location would be in Iniskin Bay offshore from the Diamond Point port site. An alternate lightering location would be in Kamishak Bay in the lee of Augustine Island, based on weather conditions during operations (the same as for Alternative 1a).

Dredge Disposal Area

Chapter 2, Alternatives, describes maintenance dredging in the shallow approach to Diamond Point port. There would likely be a short-term increase in suspended sediment load in the dredging operations area during and after (possibly days) dredging activity.

Dredged material would be placed in bermed facilities on uplands east and west of the dock site. The water placed in the bermed containments would seep into underlying soils, and would mix with any shallow groundwater present in the containment area. Therefore, runoff from the disposal site would remain contained in the bermed area and would not affect surface water hydrology. Drainage from the stockpiles would likely be discharged to marine waters after treatment as needed (see Section 4.18, Water and Sediment Quality, for impacts to water quality).

4.16.6.5 Natural Gas Pipeline Corridor

Based on available information about seabed sediments from BOEM (2016) and Intecsea (2019) for the Alternative 2 pipeline corridor segment north of Augustine Island to Ursus Cove, the impacts to surface water hydrology would be the same type and scale as described under Alternative 1a for the portion of the pipeline beginning on the Kenai Peninsula, and crossing Cook Inlet to Kamishak Bay. Construction methods for buried pipeline would be the same as for Alternative 1a (PLP 2020-RFI BSEE 1a) (see Section 4.18, Water and Sediment Quality). Construction-related impacts would be a short-term increase in suspended sediments in the immediate vicinity of construction. The pipeline under Alternative 2 would initially come ashore at Ursus Cove, crossing roughly 28 streams to Cottonwood Bay, then cross in a constructed trench in the bottom of Cottonwood Bay to Diamond Point. The pipeline corridor under Alternative 2 would require crossing approximately 156 waterbodies, compared to 94 under Alternative 1a, including additional trenching required for installation of the Cottonwood Bay pipeline segment.

Impacts would be similar (magnitude, duration, extent, and likelihood) as described under Alternative 1a for the pipeline portion from Diamond Point to the mine. The pipeline-only portion, as compared to a pipeline co-located with a road corridor, is described in Chapter 2, Alternatives.

Surface Water Extraction

Twenty water extraction sites are identified for the pipeline corridor. Appendix K2 provides information for each water extraction site, including the waterbody type, use, years and season of use, and estimated extraction rate and volumes. Figures in Appendix K2 show the location of water extraction sites identified for Alternative 2.

4.16.6.6 Alternative 2—Summer-Only Ferry Operations Variant

The Summer-Only Ferry Operations Variant would preclude the need for ice-breaking operations. Ferry operations for the Summer-Only Ferry Operations Variant would have similar magnitude, duration, extent, and likelihood of impacts to surface water hydrology as summer ferry operations in Alternative 1a.

4.16.6.7 Alternative 2—Pile-Supported Dock Variant

Construction of a pile-supported dock at Diamond Point would not impact onshore surface water or marine hydrology. During construction of the solid-fill portion of this dock in marine water, the magnitude, duration, and extent of impacts would be a short-term increase in suspended solids in the immediate vicinity of filled area. If required, removal of a pile-supported dock would result in short-term increases of suspended solids in the water column. Depending on equipment used to install or remove piles, there would be short-term noise levels well above ambient.

4.16.7 Alternative 3—North Road Only

4.16.7.1 Mine Site

The magnitude, duration, extent, and likelihood of impacts to surface water hydrology at the mine site under Alternative 3 are expected to be the same as those described under Alternative 1a.

4.16.7.2 Transportation Corridor

The road corridor in Alternative 3 would increase the project footprint, because the north road route would have a longer road corridor (see Figure 2-79). Under Alternative 3, waterbody crossings would include 17 bridges and 112 culverts (see Chapter 2, Alternatives). The magnitude, duration, extent, and likelihood of impacts associated with stream crossings would be the same as those for crossings described under Alternative 1a, but there would be more waterbody crossings under Alternative 3.

Flood Magnitude and Frequency

Changes to flood magnitude and frequency under Alternative 3 would be similar to those described under Alternative 2.

Flood Hazards

Flood hazards under Alternative 3 would be similar to those described under Alternative 2.

Floodplain Functions and Values

Potential impacts to floodplain function and values under Alternative 3 would be similar to those described under Alternative 2.

Surface Water Extraction

Thirty-five water extraction sites are associated with the transportation corridor (north access road). Appendix K2 provides information for each water extraction site, including the waterbody type, use, years and season of use, and estimated extraction rate and volumes. Figures in Appendix K2 show the location of water extraction sites identified for Alternative 3.

Water extraction sites associate with the pipeline corridor are listed in Appendix K2, Table K2-17, and depicted on Figure K2-3.

4.16.7.3 Diamond Point Port—Marine Water

The location of the port under Alternative 3 is north of Diamond Point (see Chapter 2, Alternatives, Figure 2-80). The marine component includes a concrete caisson-supported access causeway, marine jetty, and barge loader with a 20-foot-deep dredged access channel. The magnitude, duration, extent, and likelihood of impacts to surface water hydrology at the Diamond Point port under Alternative 3 are expected to be similar to those described under Alternative 2. See Section 4.22, Wetlands and Other Waters/Special Aquatic Sites, for information on potential impacts in the immediate vicinity of the dock.

Dredge Disposal Area

Chapter 2, Alternatives, describes maintenance dredging in the shallow approach to the location for Diamond Point port under Alternative 3. There would likely be a short-term (i.e., possibly days) increase in suspended sediment load in the dredging operations area during and after dredging activity (See Section 4.18, Water and Sediment Quality, for impacts to water quality).

Dredged material would be placed into two bermed stockpiles in uplands north of the port facility (see Figure 2-80). Consolidation and runoff water would be channeled into a sediment pond and suspended sediments would be allowed to settle before discharge to Iliamna Bay (PLP 2020d) (see Section 4.18, Water and Sediment Quality, for impacts to water quality).

4.16.7.4 Natural Gas Pipeline Corridor

The magnitude, duration, extent, and likelihood of impacts to surface water hydrology would be the same as described under Alternative 1a for the portion of the pipeline beginning on the Kenai Peninsula, and crossing Cook Inlet to Kamishak Bay. The natural gas pipeline corridor under Alternative 3 would follow the same corridor described under Alternative 2. Impacts would be the same as described under Alternative 2 for the portion from Diamond Point to the mine site. The onshore pipeline-only segments are longer under Alternative 3 than under Alternative 1a (see Chapter 2, Alternatives, for comparison of pipeline onshore segments between alternatives).

4.16.7.5 Alternative 3—Concentrate Pipeline Variant

The concentrate pipeline (and option for return water pipeline) would be co-located with the road corridor between Diamond Point port and the mine site in a single trench with the natural gas pipeline. Methods of waterbody crossings would be the same as described for Alternative 1a. Reduced discharge water from WTPs could result in a greater reduction in streamflows than those described under Alternative 1a.

The magnitude, duration, extent, and likelihood of impacts to surface water hydrology under this variant would be the same as for Alternative 1a, except with longer road and pipeline corridors under Alternative 3, and a slightly increased footprint in the construction corridor (see Chapter 2, Alternatives, for a description of footprint differences).

The Concentrate Pipeline Variant would reduce the amount of water available for release to surrounding drainages at the mine site by approximately 1 to 2 percent (PLP 2020-RFI 066). The port facility footprint would not increase as compared to Alternative 3—only the types of features present and arrangement would be different that the Alternative 2 facility because of the requirement for dewatering the concentrate, storing water and concentrate, and treating and discharging filtrate water and water used to flush the concentrate line for maintenance (PLP 2020d). The Concentrate Pipeline Variant would result in reduction of water available for discharge to drainages at the mine site by 1 to 2 percent. With the option of the return water pipeline, water extracted from the concentrate slurry and flushing water would be piped back to the mine site.

A concentrate pipeline from the mine site to the port would require two electric pump stations (one at the mine site; and one booster station at an intermediate location between the mine site and the port) resulting in an increased footprint of approximately 0.7 acre (PLP 2018-RFI 066).

Concentrate Storage and Bulk Handling

Concentrate would be dewatered and stored at the port site, and the dewatered concentrate would be stored in a large storage building until the lightering system would be used to load the concentrate onto bulk carriers for transport. The lightering system would use bulk handling of the concentrate to load the bulk carriers, with controls to reduce dust emissions (e.g., covered conveyors) (PLP 2018-RFI 066). Because the material would be stored inside, impacts to surface water hydrology are not expected (see Section 4.18, Water and Sediment Quality, for further analysis of the potential for impacts to water quality [if any] regarding concentrate dust).

4.16.8 Cumulative Effects

Effects of the project on surface water hydrology would include changes to recharge, reduction, movement, and distribution of surface water (e.g., streams, lakes, marine waters), floodplain values, and shoreline erosion/accretion. The analysis area for cumulative effects on surface water hydrology includes all watersheds in which project-related activity would occur, where direct and indirect effects on surface water hydrological systems, including surface and groundwater quantity and flow, could reasonably be expected to occur. This area encompasses the footprint of the project, including alternatives and variants, where a nexus may exist between the project and other past or present activities, as well as reasonably foreseeable future actions (RFFAs) that could contribute to a cumulative effect on surface water.

Section 4.1, Introduction to Environmental Consequences, details the comprehensive set of past, present, and RFFAs considered for evaluation as applicable. A number of the actions identified are considered to have no potential of contributing to cumulative effects on surface water hydrology in the analysis area. These include offshore-based developments; activities that may occur in the analysis area, but are unlikely to result in any appreciable impact on surface water flow; or actions outside of the cumulative effects analysis area.

4.16.8.1 Past and Present Actions

Past and present actions affecting surface water conditions in the analysis area are minimal. Current development consists of a small number of towns, villages, and roads with existing stream-crossing structures such as culverts and bridges. Additional activities include mining exploration, and non-mining-related projects such as transportation, and oil and gas exploration have included site-specific exploratory drilling and temporary support camps, which are typically seasonal, involve a small footprint, and are subject to inspection and reclamation requirements. Past road construction outside of communities include the Williamsport-Pile Bay Road, and roads in the vicinity of Iliamna, Newhalen, and Nondalton. Community development activities have centered around individual communities, and involve housing, utility, and transportation improvements. These actions have resulted in little to no regional changes to surface water, including streamflow, lakes, and surface water/groundwater interaction.

Reasonably Foreseeable Future Actions

RFFAs that could contribute cumulatively to effects on surface water hydrology in the analysis area are limited to those activities that would occur in the Nushagak River or Kvichak River watersheds, or in other waterbodies intersected by the transportation and pipeline corridors in both Bristol Bay and Cook Inlet watersheds. RFFAs that could contribute cumulatively to effects on surface water hydrology, and are therefore considered in this analysis include: Pebble Project expansion scenario buildout; mining exploration activities for Pebble South, Big Chunk South, Big Chunk North, Fog Lake, and Groundhog mineral prospects; onshore oil and gas development; road improvements and the continued development of the Diamond Point Rock Quarry.

The No Action Alternative would not contribute to cumulative effects on surface water hydrology.

The RFFA contribution to increased geohazards are summarized by alternative in Table 4.16-8.

Table 4.16-8 Contribution to Cumulative Effects on Surface Water and Hydrology

Reasonably Foreseeable Future Actions	Alternative 1a	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variant
Pebble Project Expansion Scenario	**Mine Site:** The mine site footprint would have a larger open pit and new facilities to store tailings and waste rock, and WRF water collection ponds, which would contribute to cumulative effects on surface water hydrology through increased capture of surface water flow, increased groundwater pumping to facilitate required pit dewatering, and an extended duration of these effects during operations. Additional design features to capture and treat unused contact water and waste streams would be necessary to manage mine site impacts associated with streamflow reductions in the NFK, SFK, and UTC watersheds. More water would be diverted around mine facilities and/or captured and treated with Pebble Project expansion. Although specific locations of discharge of treated water have not been identified, similar to the Alternative 1a, discharge locations would be close to the perimeter of the Pebble Project expansion facilities; discharged water would comply with state water quality standards; and the volume of discharge would be managed to maintain flow downstream of the discharge points in watersheds affected. **Other Facilities:** Concentrate pipeline/ transportation corridor would extend 54 miles from the Alternative 1a mine access road, along the northern side of Iliamna Lake to Iniskin Bay, and extended to a new deepwater port site at Iniskin Bay. The Amakdedori port facility, transportation corridor (including the Iliamna Lake ferry and associated terminals), and the natural gas pipeline would continue to be used for shipment and transportation of supplies to the mine site. Additional facilities associated with Pebble Project expansion include a compressor station at Amakdedori port, and development of a deepwater port in Iniskin Bay. These facility expansions would cross drainages along the north road route (as described in	**Mine Site:** Identical to Alternative 1a. **Other Facilities:** Similar to Alternative 1a. The portion of the access road from the North Ferry Terminal to the existing Iliamna area road system would already be constructed. The concentrate pipeline/ transportation corridor would extend approximately 76 miles from the Alternative 1 mine access road, along the northern side of Iliamna Lake to Iniskin Bay. **Magnitude:** The magnitude of cumulative impacts to surface water and hydrology would be similar to that under Alternative 1a. The Pebble Project expansion scenario footprint under Alternative 1 would impact approximately 32,418 acres, compared to 9,601 acres under Alternative 1. **Duration/Extent:** The duration and extent of cumulative impacts to surface water and hydrology would be	**Mine Site:** Identical to Alternative 1a. **Other Facilities:** The north access road would be extended east from the Eagle Bay Ferry Terminal to Iniskin Bay. Concentrate and diesel pipelines would be constructed along the Alternative 3 road alignment and extended to a new deepwater port site at Iniskin Bay, both having potentially limited impacts on surface water hydrology at and downstream of stream crossing points due to trenching activities, and potentially increased stream bank and channel erosion. Cumulative effects on surface water hydrology would be less than those discussed under Alternative 1a, because Alternative 2 and Alternative 3 would include some of the same or similar transportation corridor and project port features as the Pebble Project expansion scenario (shared footprints); and the Amakdedori port and	**Mine Site:** Identical to Alternative 1a. **Other Facilities:** Overall, expansion would use the existing north access road; concentrate and diesel pipelines would be constructed along the existing road alignment and extended to a new deepwater port site at Iniskin Bay. **Magnitude:** Overall, expansion would affect less acreage than Alternative 1a (31,892 acres compared to 31,541 acres) or Alternative 1 (32,418 acres compared to 31,541 acres), given that the north access road and gas pipeline would already be constructed. Impacts to surface water and hydrology from Pebble Project expansion would be less than Alternative 1a, Alternative 1, or Alternative 2 along the north access road route. **Duration/Extent:** The duration and extent of cumulative impacts to surface water and hydrology would be

Table 4.16-8 Contribution to Cumulative Effects on Surface Water and Hydrology

Reasonably Foreseeable Future Actions	Alternative 1a	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variant
	Alternative 3), and contribute to the potential cumulative effects on surface water hydrology at and downstream of stream crossing points due to trenching activities and potentially increased stream bank and channel erosion. Impacts would be expected to be limited in extent and low in magnitude, as long as they are properly designed, constructed, and maintained, based on BMPs and permit requirements. **Duration/Extent:** The estimated area of disturbance would be nearly four times greater than under the project, based on infrastructure buildout at the mine site, and the duration would be 58 additional years of mining and 20 years of milling; contributing cumulatively to reduced surface water flow and distribution. Additional design features to capture and treat unused contact water and waste streams would be necessary to manage mine site impacts associated with streamflow reductions in the NFK, SFK, and UTC watersheds. The duration of cumulative impacts to surface water hydrology would vary from temporary to permanent. Potential streamflow reductions in the SFK, NFK, and UTC watersheds, beyond those described under direct/indirect impacts, would likely be similar to the extent that water would be either diverted or captured, treated, and discharged at locations close to the perimeter of the Pebble Project expansion facilities, and discharged water would be in compliance with state instream flow requirements. **Magnitude:** The Pebble Project expansion scenario footprint would impact approximately 31,892 acres, compared to 9,612 acres under Alternative 1a. **Contribution:** This contributes to cumulative effects on surface water and hydrology through reductions and interruptions in streamflow. However, the area in the Kvichak and Nushagak River watersheds is	similar to duration and extent of Alternative 1a. **Contribution:** The contribution to cumulative effects would be slightly more than Alternative 1a, but more than Alternative 2 and Alternative 3.	transportation corridor would not be built. **Magnitude:** Overall, expansion would affect less acreage than Alternative 1a (31,892 acres compared to 31,528 acres) given that a portion of the north road and all of the gas pipeline would already be constructed. Impacts to surface water and hydrology from Pebble Project expansion would be less than Alternative 1a. **Duration/Extent:** The duration and extent of cumulative impacts to surface water and hydrology would be similar to duration and extent of Alternative 1a, although affecting a smaller amount of acreage along the north access road route. **Contribution:** The contribution to cumulative impacts would be similar to Alternative 1a, although affecting a smaller amount of acreage along the north access road route.	similar to duration and extent of Alternative 1a, Alternative 1, and Alternative 2, although affecting a smaller amount of acreage along the north access road route. **Contribution**: The contribution to cumulative impacts would be similar to Alternative 1a, and Alternative 1, and Alternative 2, although affecting a smaller amount of acreage along the north access road route.

Table 4.16-8 Contribution to Cumulative Effects on Surface Water and Hydrology

Reasonably Foreseeable Future Actions	Alternative 1a	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variant
	relatively undeveloped, and effects would be limited to the project footprint, which is a relatively small area in the watersheds. Additionally, water that is diverted around mine facilities and/or captured and treated with Pebble Project expansion would be discharged in a manner similar to Alternative 1a. Discharged treated water would comply with state water quality standards, and the volume of discharge would be managed to maintain flow downstream of the discharge points in watersheds affected.			
Other Mineral Exploration Projects	**Magnitude:** Mineral exploration activities (e.g., Pebble South, Big Chunk North, Big Chunk South, Fog Lake, and Groundhog) could have limited impacts on surface water hydrology in watersheds common to the Pebble Project (e.g., drill pads, camps); however, they would be seasonally sporadic, temporary, and localized based on their remoteness, and would not be expected to have high-magnitude or lasting effects on surface water hydrology. Mining exploration activities, including additional borehole drilling, road and pad construction, and development of temporary camp facilities, would contribute a small amount of surface water and hydrology disturbance at discrete locations, depending on landowner permitting and restoration requirements. For example, the 2018 drilling program proposed by PLP consisted of 61 geotechnical boreholes and 19 diamond-drilled core boreholes with diameters ranging from 2 to 8 inches. **Duration/Extent:** Exploration activities typically occur at a discrete location for one season, although a multi-year program could expand the geographic area affected in a specific mineral prospect. Table 4.1-1 in Section 4.1, Introduction to Environmental Consequences, identifies seven mineral prospects in the analysis area where	Similar to Alternative 1a.	Similar to Alternative 1a.	Similar to Alternative 1a.

Table 4.16-8 Contribution to Cumulative Effects on Surface Water and Hydrology

Reasonably Foreseeable Future Actions	Alternative 1a	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variant
	exploratory drilling is anticipated (four of which are in relatively close proximity of the Pebble Project). **Contribution:** This contributes to cumulative effects of disturbance to surface water and hydrology, although the areal extent of disturbance is a relatively small portion of the Kvichak/Nushagak watersheds. Assuming compliance with permit requirements, contributions to disturbances to surface water and hydrology would be expected to be limited in extent and low in magnitude.			
Oil and Gas Exploration and Development	**Magnitude:** Onshore oil and gas exploration activities would involve temporary overland activities, and in limited cases, exploratory drilling with permit conditions that avoid or minimize ground disturbance. Should it occur, exploratory drilling would involve the construction of temporary pads and support facilities, with permit conditions to minimize ground disturbance, impacts to surface waters, and restoration of drill sites after exploration activities have ceased. **Duration/Extent:** Seismic exploration and exploratory drilling are typically single-season temporary activities. The 2013 Bristol Bay Plan Amendment shows 13 oil and gas wells drilled on the western Alaska Peninsula, and a cluster of three wells near Iniskin Bay. It is possible that additional seismic testing and exploratory drilling could occur in the analysis area, but based on historic activity, is not expected to be intensive. **Contribution:** Onshore oil and gas exploration activities would be required to minimize surface disturbance, and would occur in the analysis area, but distant from the project. The project would have minimal contribution to cumulative effects.	Similar to Alternative 1a.	Similar to Alternative 1a.	Similar to Alternative 1a.

Table 4.16-8 Contribution to Cumulative Effects on Surface Water and Hydrology

Reasonably Foreseeable Future Actions	Alternative 1a	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variant
Road Improvement and Community Development Projects	**Magnitude:** Road improvement projects would take place in the vicinity of communities and have impacts on surface water hydrology, primarily through diversion of surface flow and increased stream bank/channel erosion, that could contribute to cumulative effects in the analysis area. Communities in the immediate vicinity of project facilities, such as Iliamna, Newhalen, and Kokhanok, would have the greatest contribution to cumulative effects. Some improvements and maintenance along the Williamsport-Pile Bay Road are also anticipated. Limited road upgrades could also occur in the vicinity of the natural gas pipeline starting point near Stariski Creek, or in support of mineral exploration previously discussed. Expansion of the Diamond Point Rock Quarry potential to include the excavation of rock, which would require removal of soil overburden materials, and result in a direct and cumulative effect on surface water flow in the footprint of that project. Upland soil disturbances and erosion impacts to coarse soils occurring in rocky mountainous terrain, although limited, could result in contributions of sediment to streams, although over a small area. The estimated area that would be affected by the Diamond Point Rock Quarry is approximately 140 acres (ADNR 2014a). Additional development projects include the Igiugig project, which is an in-river hydrokinetic generator and is not expected to have any effect on surface water hydrology. Knutson creek is a small run of river project with a 7,000-foot penstock that includes a diversion in the creek; however, it is not expected that there would be impacts to streamflow downstream of the penstock powerhouse and drainage into Iliamna Lake.	Similar to Alternative 1a and Alternative 2; greater than Alternative 3.	The footprint of the Diamond Point rock quarry in Alternative 1 coincides with the Diamond Point port footprint in Alternative 2 and Alternative 3. Cumulative impacts would likely be less under Alternative 2 due to project footprints commonly shared with the quarry site.	Similar to Alternative 2; less than Alternative 1a and Alternative 1.

Table 4.16-8 Contribution to Cumulative Effects on Surface Water and Hydrology

Reasonably Foreseeable Future Actions	Alternative 1a	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variant
	Duration/Extent: Disturbance from road construction would typically occur over a single construction season. The quarry could operate year-round, although activities could be sporadic depending on demand for material. Geographic extent would be limited to the vicinity of communities and Diamond Point. **Contribution:** None of the anticipated transportation development in the analysis area would contribute greatly to cumulative effects on surface water hydrology. Road construction would be required to minimize surface disturbance, and would occur in the analysis area, but removed from the project. The project would have minimal contribution to cumulative effects. The operation/expansion of the Diamond Point quarry could contribute to sedimentation and disruption of surface flow, but would be subject to permit conditions and BMPs to minimize these impacts.			
Summary of Project Contribution to Cumulative Effects	Overall, the contribution of Alternative 1a to cumulative effects to surface water and hydrology, when taking other past, present, and reasonably foreseeable future actions into account, would be minor in terms of magnitude, duration, and extent, given the limited acreage affected, and permit requirements limiting changes to surface water and hydrology.	Similar to Alternative 1a, although slightly more acreage would be affected with construction of the north access road route by the Pebble Project expansion.	Similar to Alternative 1a, although slightly less acreage would be affected along the north access road route by Pebble Project expansion.	Similar to Alternative 1a, although less acreage would be affected along the north access road route by the Pebble Project expansion.

Notes:

BMPs = Best Management Practices
NFK = North Fork Koktuli
SFK = South Fork Koktuli
UTC = Upper Talarik Creek
WRF = waste rock facility