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. 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 within the mine site, water treatment plant discharges, and closure and post-closure water management practices).
- Increased stream bank and channel erosion due to removal of the natural vegetation, construction within 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 were based on evaluation of baseline conditions in Section 3.16, Surface Water Hydrology, and considers operational and closure water management plans and water balance modeling results for all phases of the project (Knight Piésold 2018a, 2018d, 2018i, 2018j). Related discussion of impacts to water and sediment quality are addressed in Section 4.18, Water and Sediment Quality. 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. Mitigation measures are described in Chapter 5, Mitigation.

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, as well as any proposed 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 earthquake impacts on hydrology characteristics be analyzed, and that a detailed water balance model be developed.

4.16.1 Methodology for the Analysis of Surface Water Hydrology 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.
- Geographic 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 to Occur – Most effects on surface water hydrology within 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 No Action Alternative

Under the No Action Alternative, the Pebble Project would not be undertaken. No construction, operations, or closure activities would occur. Therefore, no additional future direct or indirect effects on surface water hydrology would be expected. Although no resource development would occur under the No Action Alternative, permitted resource exploration activities currently associated with the project may continue (ADNR 2018-RFI 073). Pebble Limited Partnership (PLP) would have the same options for exploration activities that currently exist. In addition, there are many valid mining claims in the area, and these lands would remain open to mineral entry and exploration. 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.

4.16.3 Alternative 1 – Applicant's Proposed Alternative

This section describes potential impacts of the project on surface water hydrology for each project component for all phases of the project.

4.16.3.1 Mine Site

This section describes the potential impacts to surface water hydrology within the mine site area, including material sites by project phase.

<u>Construction</u>

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 permanent 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 elements during construction are described in PLP 2018d and include:

- 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 tailings storage facility (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 within 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 North Fork Koktuli (NFK) River, South Fork Koktuli (SFK) River, and possibly Upper Talarik Creek (UTC) watersheds would be affected during construction through diversion and collection of surface water, initial drawdown of groundwater in preparation for mining activities, and water treatment plant discharge.

The magnitude of the impact on average monthly flow in the NFK, SFK, and UTC has not been estimated for the construction period. However, estimates of the impact during operations and post-closure are discussed in the “Operations” and “Closure and Post-Closure” sections that follow. It is anticipated that the magnitude of the impact during construction would be no greater than the magnitude of the impact during operations. Within a river, the reaches of the river closest to the mine site are generally anticipated to experience greater impact to the magnitude of the streamflow than reaches farther from the mine site.

The main stem reaches furthest from the mining operation are anticipated to experience smaller magnitude changes in average monthly streamflow (AECOM 2019b). During construction, in UTC Reach A (AECOM 2019b, Figure 21) (near the mouth of the UTC), the magnitude of average monthly streamflow with a 50th percentile probability is expected to vary from 0.1 percent less to 0.6 percent more than the baseline streamflow. The average annual streamflow with a 50th percentile probability is estimated to be 0.1 percent more than the baseline streamflow. In NFK Reach A, (near the confluence of the NFK and SFK) the average monthly streamflow with a 50th percentile probability is expected to vary from 10 percent less to 14 percent more than the baseline streamflow. The average annual streamflow with a 50th percentile probability is estimated to be 9 percent less than the baseline streamflow. In SFK Reach A (near the confluence of the NFK and SFK), the magnitude of average monthly streamflow with a 50th percentile probability is expected to vary from 4 percent less to 1 percent

[1] These aspects of construction water management would be further developed in a Stormwater Pollution Prevention Plan (SWPPP) required for mine permitting.

less than the baseline streamflow. The average annual streamflow with a 50th percentile probability is estimated to be 3 percent less than the baseline streamflow.

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 operations. The one exception is NFK Tributary 1.19. NFK Tributary 1.19 is within the mine site footprint; would be removed during construction; and would not be replaced.

The geographic extent of the impact on the NFK and the SFK during construction would extend below the confluence of the two rivers, but not past the Koktuli River.

Erosion

There would be potential for increased upland and stream channel erosion due to removal of natural vegetation, construction within streams, or the construction of earthen structures. Although the magnitude of the erosion would be larger than natural historic variation, the proposed water management practices would keep the magnitude of the impact of the eroded sediment small (see Chapter 5, Mitigation). The duration of the impact 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 within the mine site would be expected during construction. Based on the typical culvert drawings provided on Chapter 2, Alternatives, Figure 2-18 and Figure 2-19, 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 Chapter 2, Alternatives, Figure 2-18 and Figure 2-19), 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.

Water Ponding

There is a potential for increased water ponding adjacent to the upstream side of access roads, where drainage is disrupted by the lack of a drainage structure. If such a situation occurs, it would be within 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 water treatment plants (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 4.16-1 and depicted on Figure 4.16-1. A brief description of the design criteria for the water management structures is provided in Table 4.16-1.

The mine 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 2018a, 2018d).

A water balance model was developed by Knight Piésold (2018a) that has been used to:

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

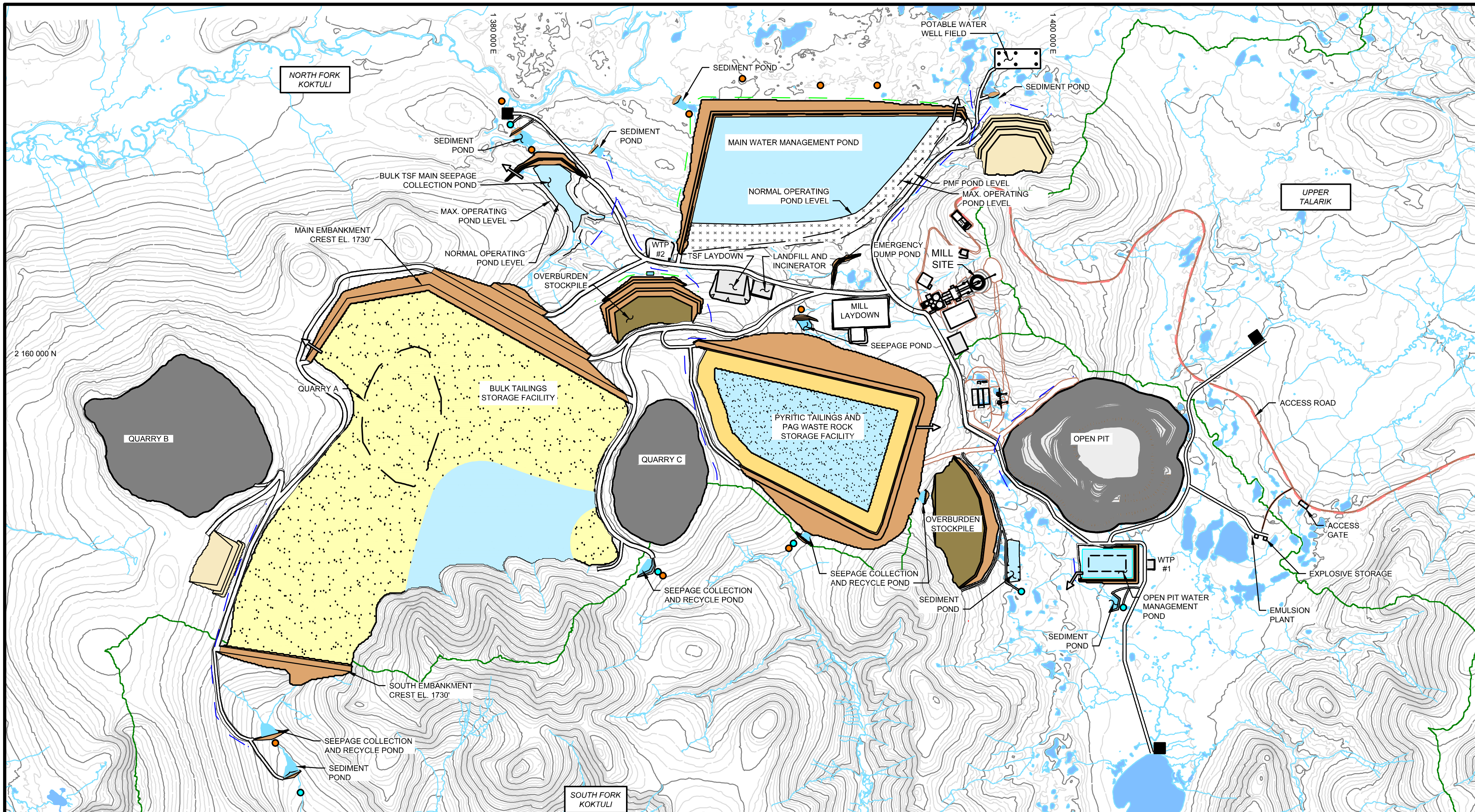
The water balance model consists of three separate modules: the watershed module, the groundwater module, and the mine plan module. The mine plan module models the movement of water within the mine system, using inputs from the watershed module and the groundwater module. Additional details regarding the water balance model are provided in Sections 3.16 and Appendix K3.16, and Knight Piésold (2018a).

[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 4.16-1: 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).
OP 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).
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 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
IDF = inflow design flood
Mft^3 = millions of cubic feet
PMF = probable maximum flood
PMP = probable maximum precipitation
Source: Knight Piésold 2018a, Table 3.1; PLP 2018d; PLP 2018 – RFI 028a



Sources: Knight Piesold 2018d

LEGEND

- OPEN PIT
- BULK TAILINGS
- OVERBURDEN STOCKPILE
- GROWTH MEDIUM STOCKPILE
- EMBANKMENT FILL
- POND
- PYRITIC TAILINGS
- PAG WASTE ROCK
- LINER
- 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
- NATURAL GAS PIPELINE (10 inch DIAMETER)
- ROAD
- WTP DISCHARGE POINT
- WATER QUALITY MONITORING POINT
- GROUNDWATER QUALITY MONITORING AND POTENTIAL PUMP BACK AREA
- DIVERSION CHANNEL
- DRAINAGE DIVIDE
- COLLECTION DITCH
- EMERGENCY SPILLWAY

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 PLP, JULY 04, 2018.
5. ACCESS ROAD PROVIDED BY RECON LLC. ROAD CONNECTION TO MINE SITE COMPLETED BY AUSENCO LTD.
6. CONCEPTUAL HAUL, SERVICE, AND ACCESS ROAD CUT AND FILL EXTENTS SHOWN INCLUDE ALLOWANCE FOR BERMS, DITCHES, AND POWER POLES, AS REQUIRED.
7. ORIGINAL DRAINAGE DIVIDES PROVIDED BY HDR, JUNE 15, 2018. DRAINAGE DIVIDES HAVE BEEN REVISED AROUND MINE FACILITIES AS REQUIRED.

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MINE SITE FEATURES AT END OF OPERATIONS

FIGURE 4.16-1

The output of the mine plan module is average monthly flow. Climate variability was incorporated into the model using the 76-year average monthly synthetic temperature and precipitation record (see Section 3.16, Surface Water Hydrology, and Appendix K3.16). The model was run with 20 years of consecutive data at a time. 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.

Based on the results from the mine plan module, the magnitude of impacts would be a surplus of process water during operations under average and above-average precipitation scenarios (Knight Piésold 2018a). Water available for discharge to the environment after treatment would be less than the baseline flows because of water lost in tailings voids, evaporation, and other minor uses; possibly on the order of 22 to 28 cubic feet per second (cfs) annually (Knight Piésold 2018r). In terms of magnitude, the average annual process water surplus during maximum operations is estimated to be 29 cfs, which would be treated and discharged throughout the year in a manner to optimize downstream fish and aquatic habitat (Knight Piésold 2018i).

Appendix K4.16 provides a table of the mine site water balance results for operations under relatively dry, average, and wet precipitation conditions (called "realizations"), and the corresponding water balance flow schematic diagram (Knight Piésold 2018a, Table A.1 and Figure A.1). The numbers on the schematic figure correspond with flow path number designations on the table. Used together, the information describes the flow in and out of mine site features during operations when the final year is relatively dry, average, and wet (called relatively dry, average and wet realizations) (Knight Piésold 2019a). Each realization considered a 20-year period taken from the 76-year synthetic record. The relatively dry realization (Realization #36; Appendix K4.16) has a 20-year average annual precipitation of 56 inches, with a Year 20 (of operations) annual precipitation of 33 inches. The probability of the precipitation being less than 33 inches in the final year of operations is approximately 4 percent (Knight Piésold 2019a). The relatively average realization (Realization #5; Appendix K4.16) has a 20-year average annual precipitation of 57 inches, with a Year 20 (of operations) annual precipitation of 58 inches. The relatively wet realization (Realization #10) has a 20-year average annual precipitation of 57 inches, with a Year 20 (of operations) annual precipitation of 93 inches. The probability of the precipitation being greater than 93 inches in the final year of operations is approximately 0.2 percent (Knight Piésold 2019a).

In reviewing the water balance estimates, it should be noted that the predictions may be subject to significant uncertainty, due in part to uncertainty associated with the input from the groundwater module (see Section 4.17, Groundwater Hydrology and Appendix K4.17). At this time, it is believed that the predictions of groundwater flow to the pit would be more likely to be low than high. If this is true, it would mean that the WTPs would need to process and discharge more water than currently anticipated.

Adaptive water management strategies during operations would include the ability to provide additional water storage capacity in the bulk TSF; provide surplus storage capacity in the WMPs; and provide for expansion of the WTP rate by building excess capacity (Knight Piésold 2018a). Additional water storage capacity would be made available under above-average precipitation conditions by directing excess water to the open pit; then pumping, treating, and discharging water to restore the pit water to the design level (Knight Piésold 2018a).

Streamflow

Most of the mine site features would be in the NFK watershed. However, the open pit, open pit WMP, WTP#1, and WTP#1 discharge-south would be in the SFK watershed. Only the WTP#1 discharge-north and a segment of the mine access road would be in the UTC watershed.

The annual average monthly streamflow and average monthly streamflow during baseline, and operations on the NFK, SFK, and UTC, were evaluated by Knight Piésold (2018f, 2018i, 2018k). The conditions used in the watershed module to represent operations assumed the maximum mine footprint and an average groundwater pit inflow of about 2,700 gallons per minute (gpm). The WTP releases were assumed to vary between watersheds and between months, with a total average annual discharge of 29 cfs (Knight Piésold 2018i). Additional details concerning the watershed module are presented in Section 3.16, Surface Water Hydrology.

Estimates of the change in average monthly streamflow and annual average monthly streamflow, from baseline conditions to operations, at selected reaches within the NFK, SFK, and UTC, are presented in AECOM (2019b) based on information presented in Knight Piésold (2018k). Average monthly streamflows with various probabilities of occurrence were evaluated. The downstream boundary of the evaluation is the confluence of the NFK and SFK rivers and Iliamna Lake at the mouth of UTC. A brief summary of the results for the average monthly streamflow with a 50th percentile probability of occurrence is presented in Table 4.16-2. Figures showing the locations of the reaches are presented in AECOM 2019b. Figures showing the estimated changes in average monthly and annual average monthly streamflow with the following probabilities of occurrence are also presented in AECOM 2019b: 10-year low-flow, 5-year low-flow, 50th percentile streamflow, mean average monthly streamflow, 5-year high-flow, and 10-year high-flow.

The results of the analyses (AECOM 2019b; Knight Piésold 2018k) indicate that the magnitude of the streamflow on UTC is much less likely to be impacted by operations than the streamflow on the NFK and SFK. As would be expected, within a stream, the reaches of the stream closest to the mine site are generally anticipated to experience greater impacts to streamflow than reaches farther from the mine site.

For instance, the main stem reaches of the streams closest to the mining operation are anticipated to experience the following changes in the average monthly and annual average monthly streamflow with a 50th percentile probability of occurrence during operations. In UTC Reach F (AECOM 2019b, Figure 21), the magnitude of both the average monthly and annual average monthly streamflow with a 50th percentile probability are anticipated to be within 1 percent (plus or minus) of baseline streamflow3. In NFK Reach C (AECOM 2019b, Figure 19), the average monthly streamflow with a 50th percentile probability is expected to vary from 20 percent less to 23 percent more than the baseline streamflow, depending on the month. The annual average monthly 50th percentile streamflow is estimated to be 16 percent less than the baseline annual average monthly 50th percentile streamflow. In SFK Reach E (AECOM 2019b, Figure 20), average monthly streamflow with a 50th percentile probability is expected to vary from 97 percent less to 37 percent less than the baseline streamflow, depending on the month. The annual average monthly 50th percentile streamflow is estimated to be 54 percent less than the baseline annual average monthly 50th percentile streamflow.

[3] The computations presented in Table 4.16-2 indicate 0.0 percent change at Reach F, but a change larger than 0 at Reaches B and C. Because the largest impact is anticipated to be in the reaches closest to the mine site, the difference is probably due to rounding errors in the model. Additionally, considering the uncertainties inherent in such a model, it is probably reasonable to simply state that the change would be less than 1 percent.

Table 4.16-2: Change in the Average Monthly Streamflow from Baseline to Operations

Location	Change in Average Monthly Streamflow from Baseline to Operations in Percent (50th Percentile Probability)												Annual Mean Monthly Change
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	
NFK, Reach A	-0.6	4.7	11.1	14.3	-8.3	-10.0	-4.8	-7.3	-9.1	-7.3	-6.0	-6.4	-8.5
NFK, Reach B	-2.5	3.1	11.0	17.0	-9.6	-15.1	-7.5	-7.2	-12.1	-10.2	-7.9	-7.5	-10.2
NFK, Reach C	-6.4	0.5	12.7	23.4	-17.9	-19.7	-11.4	-16.0	-19.1	-15.3	-12.8	-11.0	-15.6
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	-4.1	-3.3	-3.5	-2.0	-1.3	-2.8	-3.1	-2.7	-2.4	-2.9	-2.9	-3.6	-2.5
SFK, Reach B	-3.6	-2.8	-2.5	-1.6	-2.0	-4.9	-4.4	-4.2	-3.9	-4.3	-3.4	-4.2	-3.5
SFK, Reach C	-35.8	-1.0	0.0	0.0	-1.6	-5.6	-5.8	-5.3	-4.6	-5.1	-3.6	-7.8	-4.0
SFK, Reach D	-3.2	7.1	36.0	118.9	-5.7	-14.6	-5.2	-4.0	-5.7	-6.6	0.2	-7.4	-4.3
SFK, Reach E	-87.0	-89.3	-96.9	-93.3	-37.0	-37.0	-50.5	-57.2	-50.7	-57.6	-69.0	-81.6	-53.9
SFK, Trib 1.19	-9.8	-10.6	-11.6	-12.0	-6.6	-6.5	-7.6	-7.4	-7.3	-7.9	-9.2	-9.3	-6.9
SFK, Trib 1.24	-10.3	-15.6	-46.7	0.0	-2.7	-4.9	-4.8	-4.3	-3.9	-3.7	-4.6	-6.2	-3.5
UTC, Reach A	0.3	0.4	0.6	0.6	0.1	-0.1	0.0	0.0	0.0	-0.1	0.0	0.2	0.1
UTC, Reach B	0.3	0.4	0.6	0.6	0.1	-0.1	0.0	0.0	0.0	-0.1	0.0	0.2	0.1
UTC, Reach C	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
UTC, Reach D	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
UTC, Reach E	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
UTC, Reach F	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
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:
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.

Of the reaches evaluated within the main stems of the streams, those farthest from the mining operation are anticipated to experience the following changes in the average monthly and annual average monthly streamflow with a 50th percentile probability of occurrence during operations. In UTC Reach A, the magnitude of both the average monthly and annual average monthly streamflow with a 50th percentile probability are anticipated to be within 1 percent (plus or minus) of baseline streamflow. The annual average monthly 50th percentile streamflow is estimated to be less than 1 percent less than the baseline annual average monthly 50th percentile streamflow. In NFK Reach A, the average monthly streamflow with a 50th percentile probability is expected to vary from 10 percent less to 14 percent more than the baseline streamflow, depending on the month. The annual average monthly 50th percentile streamflow is estimated to be 9 percent less than the baseline annual average monthly 50th percentile streamflow. In SFK Reach A, the average monthly streamflow with a 50th percentile probability is expected to vary from 4 percent less to 1 percent less than the baseline streamflow, depending on the month. The annual average monthly 50th percentile streamflow is estimated to be 3 percent less than the baseline average annual monthly 50th percentile streamflow.

With regard to the tributaries, UTC Tributary 1.19 is anticipated to experience changes in the magnitude of the streamflow of similar order of magnitude to the changes anticipated to occur on the main stem. NFK Tributary 1.19 would be removed during construction, and would not be replaced. Two tributaries on the SFK, whose headwaters are adjacent to the mine site, would experience impacts to streamflow magnitude similar to that anticipated to occur on the main stem of the SFK, at locations between the farthest upstream and downstream reaches evaluated.

Although this discussion addresses the change in flow in terms of percent change from the baseline condition, it is often important to consider the change in flow in terms of cfs. The figures in AECOM 2019b, Figure 1A through Figure 18D, present the change in average monthly and annual average monthly streamflow in both percent change and in cfs.

On NFK and SFK rivers, there would be a potential for a change in the average monthly and annual average monthly streamflow. The duration of the impact to streamflow on the NFK River and the SFK River would last through operations and to some point post-closure. The impact to NFK Tributary 1.19 would be permanent. The geographic extent of the impact on the NFK River and the SFK River would extend below the confluence of the two rivers, but would not extend past the Koktuli River.

On the UTC, the potential for a change in the average monthly and annual average monthly streamflow would be less likely. The duration of the impact may extend through construction and into post-closure, but the magnitude of the change in streamflow would be less than 1 percent. The geographic extent of the impact on UTC would be expected to occur in 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.

In reviewing these estimates, it should be noted that the predictions presented above may be subject to significant uncertainty, due in part to uncertainties associated with the input from the groundwater module (see Section 4.17, Groundwater Hydrology). If groundwater flow into the pit is greater than anticipated, the pumping rate to dewater the pit would be greater than anticipated. This would cause more water to be treated and released to the streams, but would also potentially cause an increase in the loss of streamflow to the dewatering effort. This could cause the magnitude of changes in streamflow to be greater or less than predicted above; and could cause reaches to be impacted that at present are thought to be un-impacted.

Erosion

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

Water Ponding

The types of water ponding impacts, and the magnitude, duration, geographic 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 activities include (Knight Piésold 2018d):
  - Reconfiguration of WTP #1 as WTP #3
  - Removal of sediment pond north of Quarry B
  - Pumping surplus water from the 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 within 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.

Figure 4.16-2 shows the arrangement of features at Year 9 of Closure, and Figure 4.16-3 shows features that would be present at the end of Closure Phase 1 (Year 15).

- Phase 2 – Extends from Year 16 to Year 20 after operations. Major reclamation activities include reclamation of the bulk TSF and quarries, and reclamation of the pyritic TSF and main WMP. Major surface water activities include (Knight Piésold 2018d):
  - Decommissioning of the open pit clean water diversion channel
  - Reclamation of the bulk TSF and associated seepage collection ponds and directing surface water discharge to the downstream environment
  - Reclamation of the main WMP and directing surface water runoff to the downstream environment
  - 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.

The plan is that no water would be treated during Phase 2. However, if necessary to maintain streamflows, water would be directed to WTP #3 for treatment and release. Figure 4.16-4 shows the general arrangement of features that would be present during closure at the end of Phase 2.

- Phase 3 – Extends from Year 21 to Year 50 after operations. Major reclamation activities include reclamation of TSF and main WMP. Major surface water activities include (Knight Piésold 2018d):
  - 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 within 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.

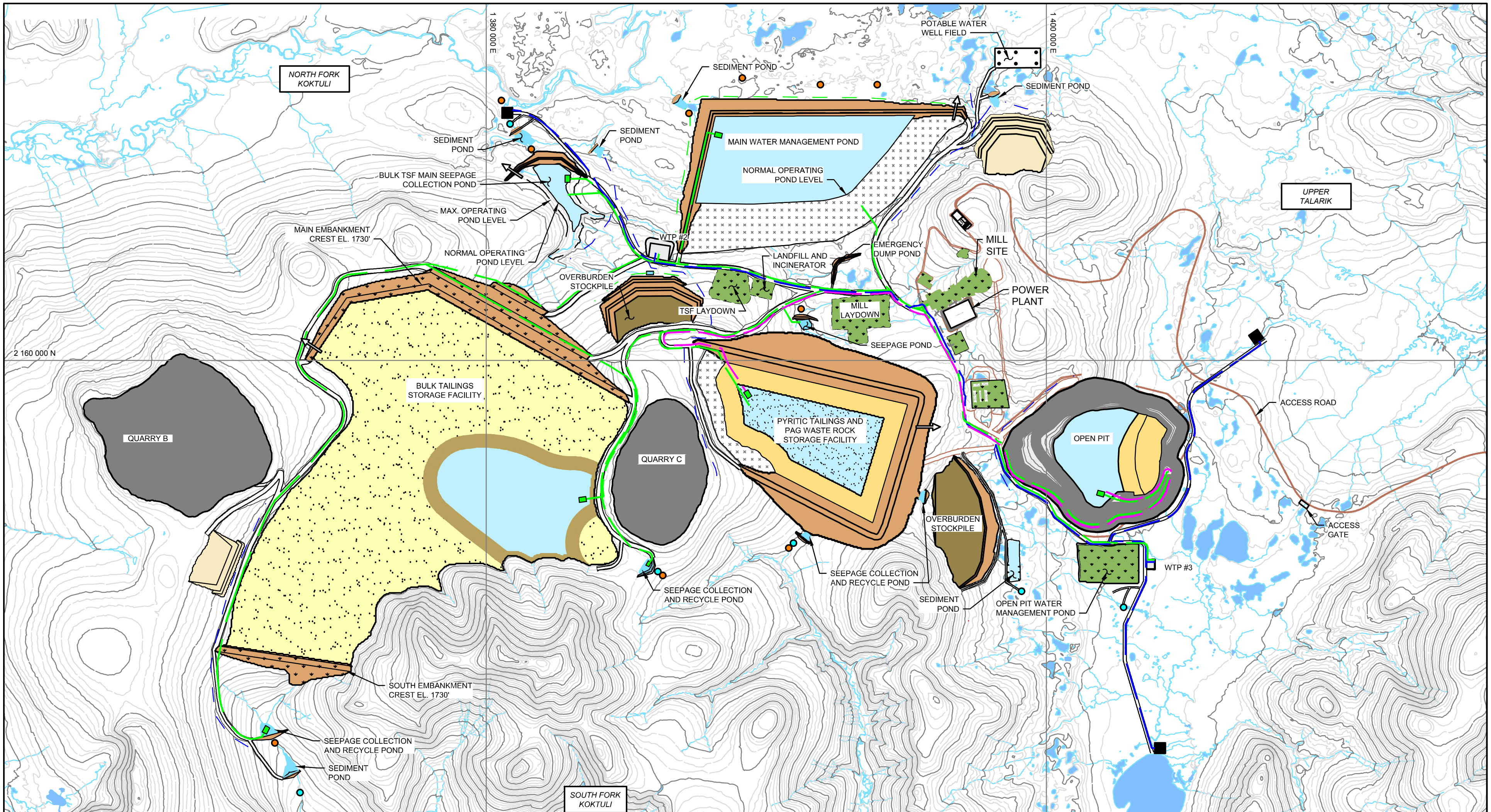
Figure 4.16-5 shows the general arrangement of features that would be present at Closure Phase 3.

- Phase 4 (Post-Closure) – Extends from Year 51 to Year 51+ after operations. Major surface water activities include (Knight Piésold 2018d):
  - Direct discharge of surface water runoff from the reclaimed bulk TSF to the NFK watershed
  - Maintaining water levels within 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 or the bulk TSF main SCP diversion
  - Releasing treated water from WTP #3 to the downstream environment.

Figure 4.16-6 shows general arrangement of features that would be present at Post-Closure Phase 4.

A water balance model for the closure and post-closure periods of the mine site was developed by Knight Piésold (2018d) to assess water entering and leaving the mine site, and to aid in developing water management plans. The closure and post-closure mine plan module 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 (Knight Piésold 2018d). 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).



Sources: Knight Piesold 2018d

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0.5 0 0.5 1

Miles

LEGEND

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

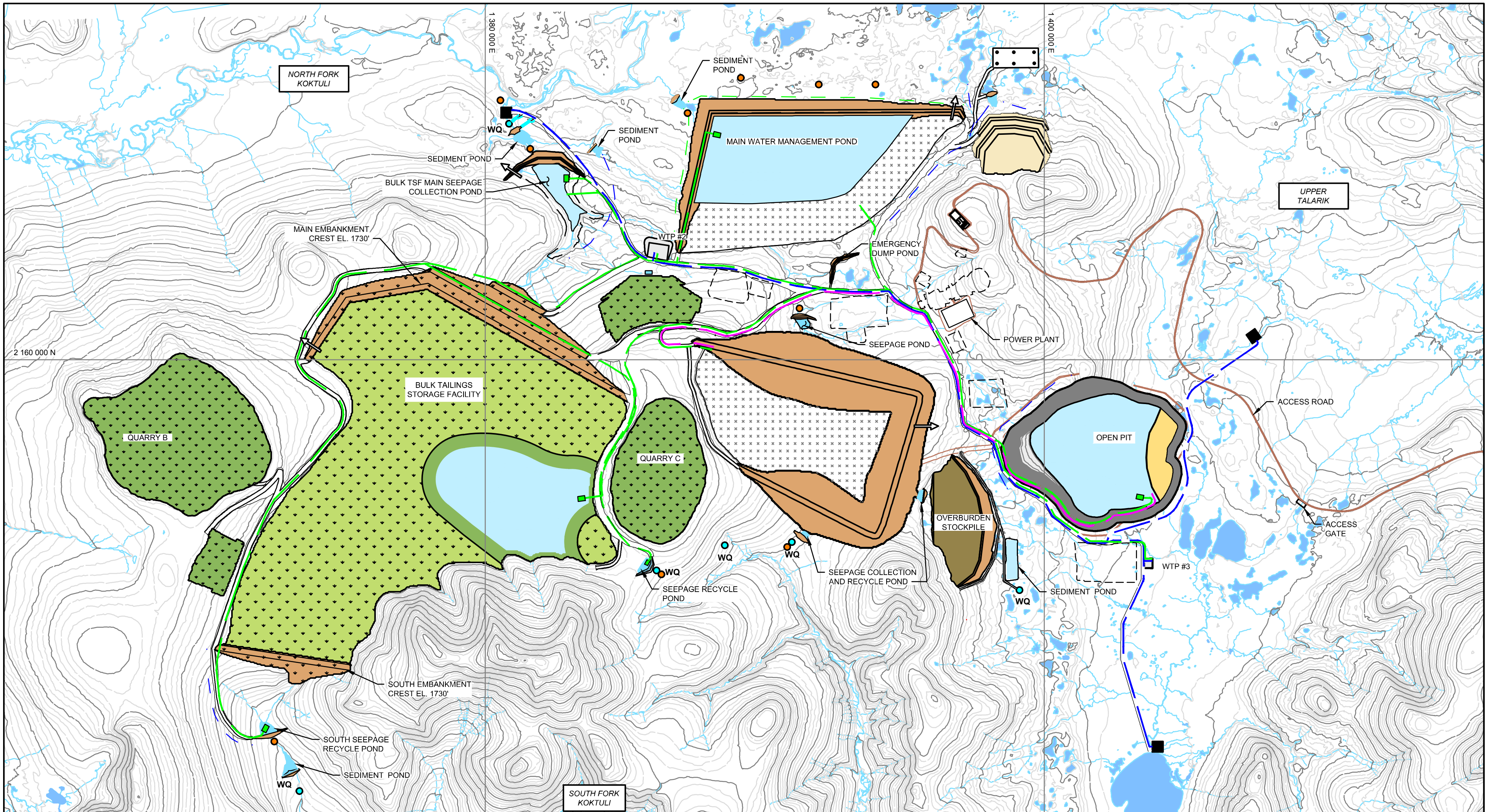
NOTES:

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 PLP, JULY 04, 2018.
5. ACCESS ROAD PROVIDED BY RECON LLC. ROAD CONNECTION TO MILL SITE COMPLETED BY AUSENCO LTD.

CLOSURE PHASE 1 - YEAR 9

PEBBLE PROJECT EIS

FIGURE 4.16-2



Sources: Knight Piesold 2018d

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
- PAG WASTE ROCK
- LINER
- RECLAIM PIPELINE
- RECLAIM WATER PUMPING BARGE
- WTP DISCHARGE PIPELINE
- WTP DISCHARGE POINT
- WATER QUALITY MONITORING POINT
- GROUNDWATER QUALITY MONITORING AND POTENTIAL PUMP BACK AREA
- CLEAN (NON-CONTACT) WATER DIVERSION
- CONTACT WATER DIVERSION
- EMERGENCY SPILLWAY
- PYRITIC TAILINGS PIPELINE
- RECLAIMED FACILITY OUTLINE
- CONTACT WATER
- TREATED WATER

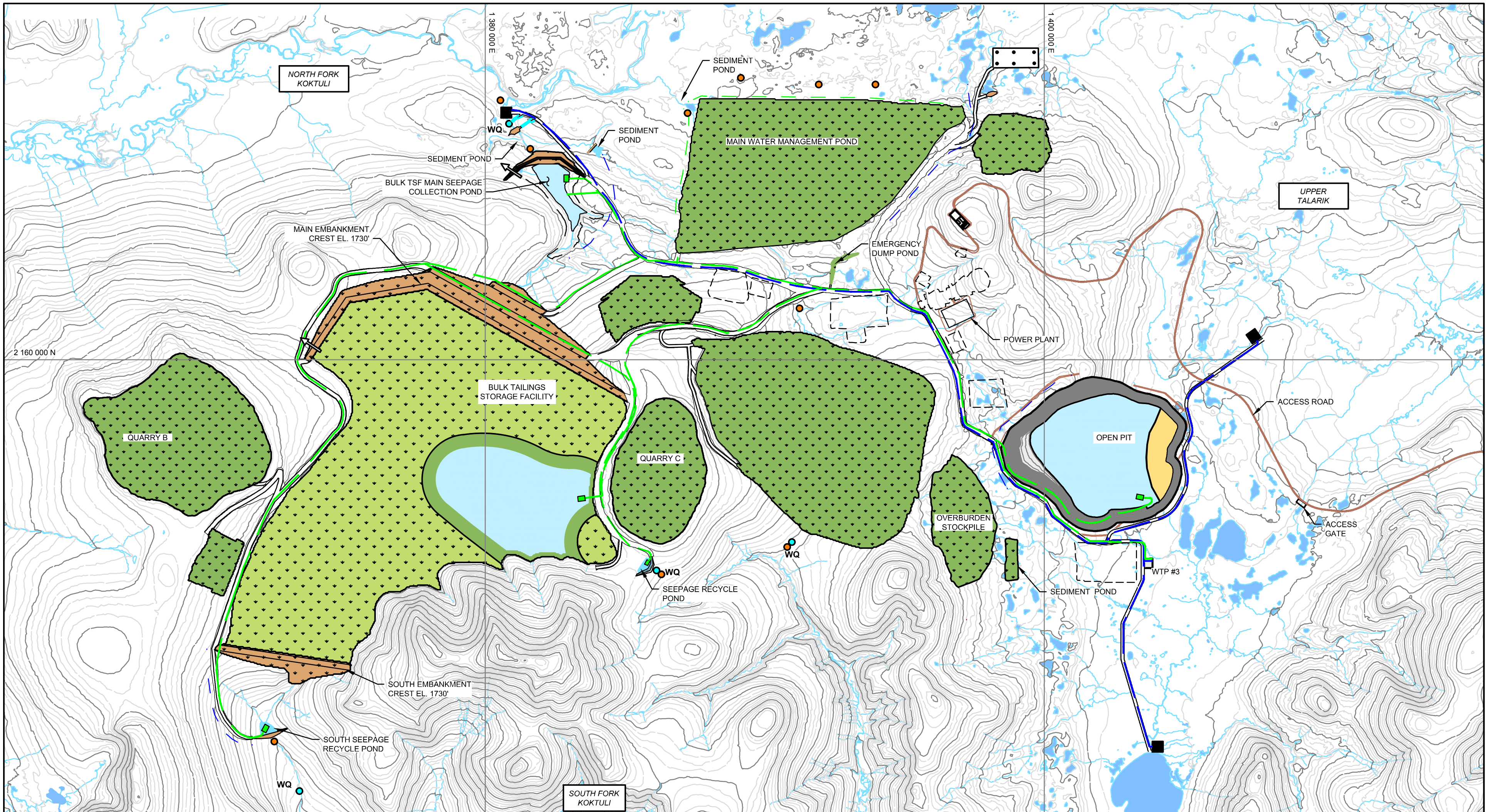
NOTES:

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 PLP, JULY 04, 2018.
5. ACCESS ROAD PROVIDED BY RECON LLC. ROAD CONNECTION TO MILL SITE COMPLETED BY AUSENCO LTD.

CLOSURE END OF PHASE 1

PEBBLE PROJECT EIS

FIGURE 4.16-3



Sources: Knight Piesold 2018d

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
- PAG WASTE ROCK
- RECLAIM PIPELINE
- RECLAIM WATER PUMPING BARGE
- WTP DISCHARGE PIPELINE
- WTP DISCHARGE POINT
- WQ WATER QUALITY MONITORING POINT
- GROUNDWATER QUALITY MONITORING AND POTENTIAL PUMP BACK AREA
- CLEAN (NON-CONTACT) WATER DIVERSION
- CONTACT WATER DIVERSION
- EMERGENCY SPILLWAY
- RECLAIMED FACILITY OUTLINE
- CONTACT WATER

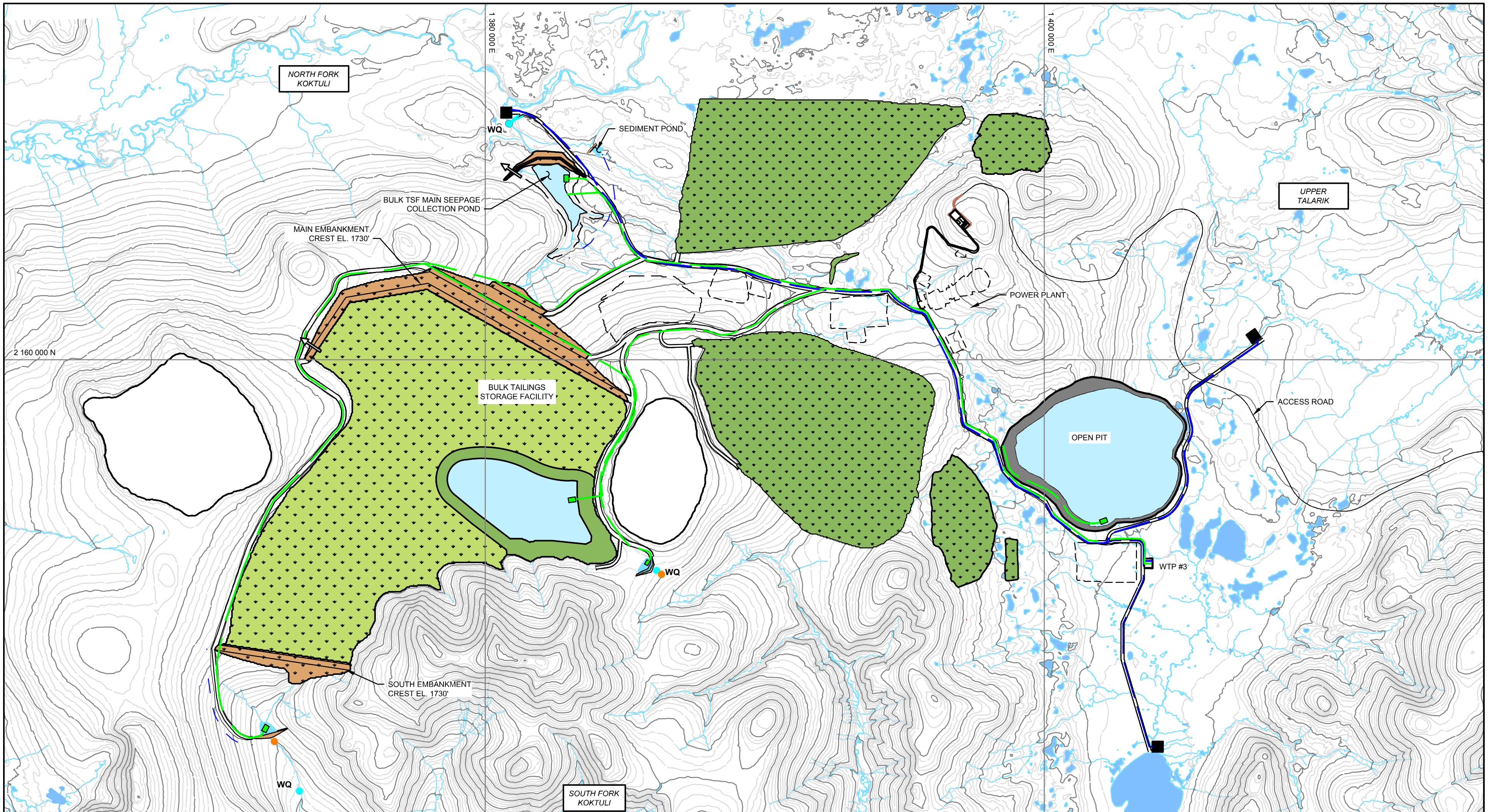
NOTES:

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 PLP, JULY 04, 2018.
5. ACCESS ROAD PROVIDED BY RECON LLC. ROAD CONNECTION TO MILL SITE COMPLETED BY AUSENCO LTD.

CLOSURE END OF PHASE 2

PEBBLE PROJECT EIS

FIGURE 4.16-4



Sources: Knight Piesold 2018d

LEGEND

- OPEN PIT
- REVEGETATED - EMBANKMENT FACE
- REVEGETATED - BEACH
- SEASONAL WETLAND
- REVEGETATED - OTHER
- POND
- RECLAIM PIPELINE
- RECLAIM WATER PUMPING BARGE
- WTP DISCHARGE PIPELINE
- WTP DISCHARGE POINT
- WATER QUALITY MONITORING POINT
- GROUNDWATER QUALITY MONITORING AND POTENTIAL PUMP BACK AREA
- CLEAN (NON-CONTACT) WATER DIVERSION
- EMERGENCY SPILLWAY
- RECLAIMED FACILITY OUTLINE
- 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 PLP, JULY 04, 2018.

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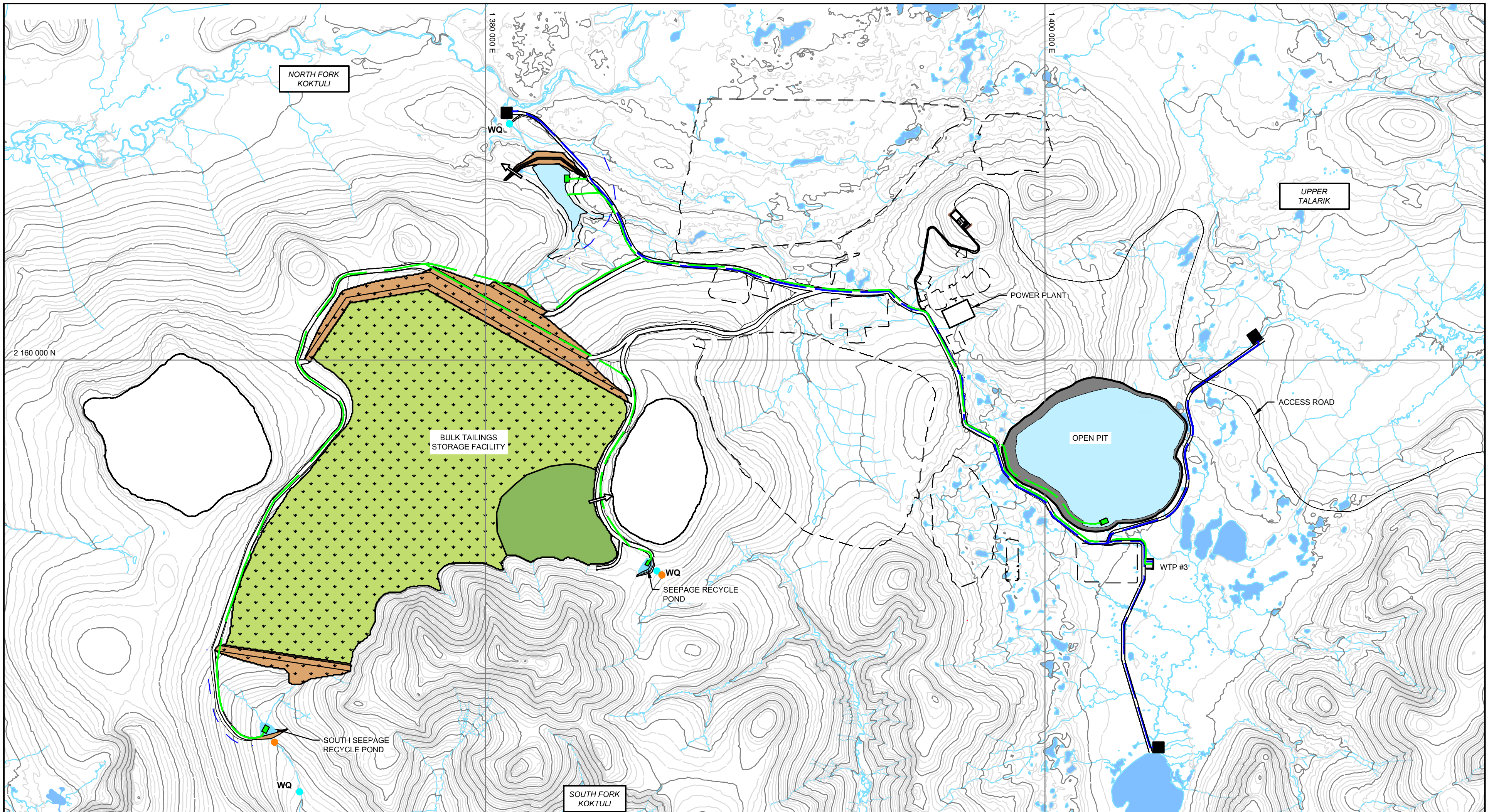
Miles

PEBBLE PROJECT EIS

CLOSURE PHASE 3

FIGURE 4.16-5



Sources: Knight Piesold 2018d

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
- RECLAIM PIPELINE
- RECLAIM WATER PUMPING BARGE
- WTP DISCHARGE PIPELINE
- WTP DISCHARGE POINT
- WQ WATER QUALITY MONITORING POINT
- GROUNDWATER QUALITY MONITORING AND POTENTIAL PUMP BACK AREA
- CLEAN (NON-CONTACT) WATER DIVERSION
- EMERGENCY SPILLWAY
- RECLAIMED FACILITY OUTLINE
- 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 PLP, JULY 04, 2018.

POST CLOSURE PHASE 4

PEBBLE PROJECT EIS

FIGURE 4.16-6

Discharge from the WTPs is an important element in maintaining streamflow within the NFK and SFK rivers and UTC. To better understand the probable discharge from the WTPs during each of the four closure phases, and to address more than just the average conditions during each phase, Knight Piésold (2018d) estimated the 1st, 10th, 50th, 90th and 99th percentile values for total water released from the WTPs. This information is summarized in Table 4.16-3 by closure phase.

The information presented in Table 4.16-3 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 58 cfs during Phase 1 (99th percentile or 99 percent chance the actual flow would be less than this) to a low of 3 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 4.16-3, 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 5 years of Phase 2, while the open pit is filling. 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. During Phase 2, if it becomes necessary to discharge water to maintain streamflows, water would be directed to WTP #3 for treatment and release.

In reviewing the anticipated WTP discharge (Table 4.16-3), it should be noted that the predictions may be subject to significant uncertainty, due in part to uncertainty associated with the input from the groundwater module (see Section 4.17, Groundwater Hydrology). At this time, it is thought that the predictions of groundwater flow to the pit are more likely to be low than high. If this is true, it would mean that the WTPs would need to process and discharge more water than currently anticipated.

Streamflow

Estimates of the change in average monthly streamflow and annual average monthly streamflow, from baseline conditions to post-closure (Phase 4), at selected reaches within the NFK and SFK rivers and UTC, are presented in AECOM (2019b), based on information presented in Knight Piésold (2018k). Average monthly streamflows with various probabilities of occurrence were evaluated. A brief summary of the results for the average monthly streamflow with a 50th percentile probability of occurrence is presented in Table 4.16-4. Figures showing the locations of the reaches are presented in AECOM (2019b). Figures showing the estimated changes in average monthly and annual average monthly streamflow with the following probabilities of occurrence are also presented in AECOM (2019b): 10-year low-flow, 5-year low-flow, 50th percentile streamflow, mean average monthly streamflow, 5-year high-flow, and 10-year high-flow.

The results of the analyses (AECOM 2019b) indicate that the magnitude of the streamflow on UTC would be less likely to be impacted after closure is complete than the streamflow on the NFK and SFK rivers. As would be expected, within a stream, the reaches of the stream closest to the mine site are generally anticipated to experience greater impacts to streamflow than reaches farther from the mine site.

Table 4.16-3: Total Water Treatment Plant Discharge by Closure Phase and Probability of Occurrence

Closure Phase 1					
Month	Total Release from WTPs (cfs)				
	1st Percentile	10th Percentile	50th Percentile	90th Percentile	99th Percentile
Jan	16	23	46	53	55
Feb	15	21	45	51	55
Mar	15	21	37	49	55
Apr	15	22	40	51	56
May	33	51	55	57	57
Jun	24	54	57	57	58
Jul	17	51	56	57	57
Aug	32	52	56	57	57
Sep	34	53	56	57	58
Oct	15	49	55	56	57
Nov	15	44	53	56	57
Dec	15	25	47	55	56
Annual Average	21	39	50	55	57

Closure Phase 2					
Month	Total Release from WTPs (cfs)				
	1st Percentile	10th Percentile	50th Percentile	90th Percentile	99th Percentile
Jan	0	0	0	0	0
Feb	0	0	0	0	0
Mar	0	0	0	0	0
Apr	0	0	0	0	0
May	0	0	0	0	0
Jun	0	0	0	0	0
Jul	0	0	0	0	0
Aug	0	0	0	0	0
Sep	0	0	0	0	0
Oct	0	0	0	0	0
Nov	0	0	0	0	0
Dec	0	0	0	0	0
Annual Average	0	0	0	0	0

Closure Phase 3					
Month	Total Release from WTPs (cfs)				
	1st Percentile	10th Percentile	50th Percentile	90th Percentile	99th Percentile
Jan	19	19	23	29	48
Feb	20	20	20	29	48
Mar	19	19	19	29	48
Apr	21	22	26	29	48
May	29	29	30	41	48
Jun	26	29	40	48	48
Jul	22	29	34	48	48
Aug	29	29	36	48	48
Sep	27	29	39	48	48
Oct	24	29	34	48	48
Nov	20	27	29	48	48
Dec	19	19	29	45	48
Annual Average	23	25	30	41	48

Closure Phase 4					
Month	Total Release from WTPs (cfs)				
	1st Percentile	10th Percentile	50th Percentile	90th Percentile	99th Percentile
Jan	3	4	7	10	19
Feb	3	4	7	9	19
Mar	4	4	7	9	18
Apr	5	7	11	16	19
May	13	17	18	19	20
Jun	6	14	18	19	20
Jul	6	14	18	20	20
Aug	11	15	18	20	20
Sep	10	14	18	20	20
Oct	6	10	17	20	20
Nov	5	8	9	20	20
Dec	4	5	8	16	17
Annual Average	6	10	13	16	19

Notes:
Total release from WTP is the sum of the flows available for release from WTP#2 and WTP#3 during closure phases.
cfs = cubic feet per second WTPs = water treatment plants
Source: Knight Piésold 2018d, Table 5.1

Table 4.16-4 Change in the Average Monthly Streamflow from Baseline to Post-Closure (Phase 4)

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	-1.1	1.7	4.2	5.9	-6.0	-5.6	-3.8	-6.4	-6.7	-5.6	-7.4	-4.5	-5.0
NFK, Reach B	-2.8	0.2	4.7	7.0	-7.7	-8.6	-5.8	-5.1	-6.3	-6.0	-7.4	-4.0	-6.5
NFK, Reach C	-4.7	-1.6	5.5	8.9	-15.5	-10.6	-8.0	-13.8	-12.3	-8.7	-6.9	-4.5	-10.3
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	-3.8	-2.2	-3.8	-4.2	-1.0	-2.3	-2.5	-2.1	-1.9	-2.3	-2.9	-2.9	-2.5
SFK, Reach B	-2.8	-1.5	-2.2	-2.3	-1.5	-3.4	-4.0	-3.8	-3.3	-3.5	-4.1	-3.7	-3.2
SFK, Reach C	-61.6	-1.0	0.0	0.0	-2.2	-5.0	-8.5	-8.2	-6.3	-7.2	-9.3	-12.8	-5.7
SFK, Reach D	-11.4	-6.6	12.0	20.2	-9.9	-11.7	-6.5	-8.4	-8.2	-10.1	-9.8	-12.4	-8.9
SFK, Reach E	-99.9	-100.0	-100.0	-84.3	53.8	-3.6	-11.4	16.8	16.4	-18.0	-94.6	-99.2	-21.5
SFK, Trib 1.19	-2.1	-2.2	-2.4	-2.2	-1.7	-3.0	-2.0	-1.8	-1.7	-1.8	-1.7	-1.9	-1.8
SFK, Trib 1.24	-7.1	-11.7	-30.9	0.0	-1.8	-3.6	-3.3	-3.0	-2.7	-2.5	-3.2	-4.3	-2.8
UTC, Reach A	0.1	0.2	0.3	0.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	-0.2
UTC, Reach B	0.1	0.2	0.3	0.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	-0.2
UTC, Reach C	0.1	0.2	0.3	0.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	-0.3
UTC, Reach D	0.3	0.4	0.6	0.1	0.0	-0.1	-0.1	0.0	-0.1	-0.1	-0.1	0.1	0.0
UTC, Reach E	0.5	0.6	1.0	0.3	0.1	-0.1	-0.1	0.0	-0.1	-0.1	-0.1	0.1	0.0
UTC, Reach F	1.7	2.1	3.2	0.8	0.2	-0.5	-0.3	-0.1	-0.4	-0.4	-0.3	0.5	-0.3
UTC, Trib 1.19	-0.5	-0.5	-0.5	-0.5	-0.5	-0.4	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.7

Notes:
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.

For instance, the main stem reaches of the streams closest to the mining operation are anticipated to experience the following changes in the average monthly and annual average monthly streamflow with a 50th percentile probability of occurrence during post-closure (Phase 4). Stream reaches are depicted in AECOM 2019b, Figure 19 through Figure 21). In UTC Reach F, the magnitude of the average monthly streamflow with a 50th percentile probability is expected to vary from 1 percent less to 3 percent more than the baseline streamflow, depending on the month. The annual average monthly 50th percentile streamflow is estimated to be less than 1 percent less than the baseline annual average monthly 50th percentile streamflow. In NFK Reach C, the average monthly streamflow with a 50th percentile probability is expected to vary from 16 percent less to 9 percent more than the baseline streamflow, depending on the month. The annual average monthly 50th percentile streamflow is estimated to be 10 percent less than the baseline annual average monthly 50th percentile streamflow. In SFK Reach E, average monthly streamflow with a 50th percentile probability is expected to vary from 100 percent less to 54 percent more than the baseline streamflow, depending on the month. The annual average monthly 50th percentile streamflow is estimated to be 22 percent less than the baseline annual average monthly 50th percentile streamflow.

Of the reaches evaluated within the main stems of the streams, those farthest from the mining operation are anticipated to experience the following changes in the average monthly and annual average monthly streamflow with a 50th percentile probability of occurrence during operations. In UTC Reach A, the average monthly streamflow with a 50th percentile probability is expected to vary from less than 1 percent less to less than 1 percent more than the baseline streamflow, depending on the month. The annual average monthly 50th percentile streamflow is estimated to be less than 1 percent less than the baseline annual average monthly 50th percentile streamflow. In NFK Reach A, the average monthly streamflow with a 50th percentile probability is expected to vary from 7 percent less to 6 percent more than the baseline streamflow, depending on the month. The annual average monthly 50th percentile streamflow is estimated to be 5 percent less than the baseline annual average monthly 50th percentile streamflow. In SFK Reach A, the average monthly streamflow with a 50th percentile probability is expected to vary from 4 percent less to 1 percent less than the baseline streamflow, depending on the month. The annual average monthly 50th percentile streamflow is estimated to be 3 percent less than the baseline annual average monthly 50th percentile streamflow.

With regard to the tributaries, the following magnitude and extent of impacts are anticipated. At UTC Tributary 1.19, the average monthly streamflow and annual average monthly streamflow with a 50th percentile probability is expected to be less than 1 percent less than the baseline 50th percentile average monthly streamflow. NFK Tributary 1.19 would be removed during construction and would not be replaced. At SFK Tributary 1.19, the average monthly streamflow with a 50th percentile probability is expected to vary from 3 percent less to 2 percent less than the baseline streamflow, depending on month. The annual average monthly 50th percentile streamflow is estimated to be 2 percent less than the baseline average annual monthly 50th percentile streamflow. At SFK Tributary 1.24, the average monthly streamflow with a 50th percentile probability is expected to vary from 31 percent less to 0 percent more (same as baseline streamflow) than the baseline streamflow, depending on month. The annual average monthly 50th percentile streamflow is estimated to be 3 percent less than the baseline annual average monthly 50th percentile streamflow.

Although this discussion addresses the change in flow in terms of percent change from the baseline condition, it is often important to consider the change in flow in terms of cfs. The figures in AECOM (2019b) present the change in average monthly and annual average monthly streamflow in both percent change and in cfs.

On NFK and SFK rivers, the potential for a change in the average monthly and annual average monthly streamflow would be likely. The duration of the impact to streamflow on the NFK and the SFK rivers would last essentially forever. The impact to NFK Tributary 1.19 would create change in streamflow in the NFK River, and would be permanent. The geographic extent of the impact on the NFK and the SFK rivers may extend below the confluence of the two rivers, but not past the Koktuli River.

On the UTC, the potential for a change in the average monthly and annual average monthly streamflow would be much less likely. If impacted, the duration of the impact would essentially last forever. The geographic extent of the impact on UTC is most likely to be in the upper reaches of the stream.

In reviewing these estimates, it should be noted that the predictions presented above may be subject to significant uncertainty, due in part to uncertainties associated with the input from the groundwater module (see Section 4.17, Groundwater Hydrology).

Erosion

There is a potential for increased upland and stream channel erosion 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, with time, the potential should decrease. The geographic extent of an impact would also continue to shrink 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 downstream from road culverts would decrease as the culverts are removed and the channels restored. Where culverts remain, the magnitude, duration, and geographic extent of the impact would be much the same as during operations.

Water Ponding

During the closure phase (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 would 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 geographic 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 immediately upstream from a culvert is considered the same as during operations. The potential magnitude, duration, and geographic 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, Surface Water Hydrology, and Appendix K3.16, 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). With regard to 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 site (Knight Piésold 2009), although larger-scale studies suggest there might be (SNAP 2018). With regard to extreme precipitation near the Pebble site, 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 located throughout Alaska (Curran et al. 2016) found no trend at the vast majority of sites, and a 50/50 split in increasing and decreasing trends among the sites exhibiting a trend. Therefore, there is considerable uncertainty as to whether or not long-term climatic change is influencing the hydrology of the area, and 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 above 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), they 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 above 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 (e.g., in some cases called "freeboard"). The magnitude of the factor of safety 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 at this time, 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 (2018b) 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, they computed a probable maximum precipitation 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 (PLP 2018d). 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 on the mine site. Knight Piésold (2018b) 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, despite the fact that the PDO may change back to a cold regime in the not-too-distant future, the 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).

The water balance model, although it does not specifically include a factor to account for a long-term temperature or precipitation change, used 76 years of synthetic record, based on actual temperature and precipitation measurements made in the vicinity of the mine, to estimate what the water balance at the mine might be (Knight Piésold 2018a). 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 2018a). 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 within the mine, this approach would provide sufficient information on the variability of possible flows for which the water balance model would be used.

Finally, as plans for the mine continue to evolve and as the mine continues to apply for permits, 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.

4.16.3.2 Transportation Corridor

The mine access road, port access road, and a natural gas pipeline along those roads would include numerous crossings of waterbodies. The road system would include water crossings with nine bridges and 86 culverts (see Section 4.24, Fish Values, for discussion of fish-bearing 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. Chapter 2, Alternatives, Figure 2-13 provides an overview of the transportation facilities, and Figure 2-14 and Figure 2-15 show the locations of major drainage structures (culverts and bridges) planned to be constructed along the road segments. See Chapter 2, Alternatives, Figure 2-17, Figure 2-18, and Figure 2-19 for typical water body 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. This could lead to stream bank and/or streambed erosion, and/or excessive erosion at the structure. Erosion of the streambed and/or banks could result in downstream sedimentation, a change in the morphology of the stream, and/or a change to the aquatic habitat (see Section 3.24, 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 geographical 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.

Roads

Although a final design has not been completed, a typical road section is presented in Figure 2-16. 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 sedimentation due to a road wash-out.

The potential for erosion and sedimentation 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 proposed 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. If an erosional surface develops, the duration of the scar would be equal to the time for vegetation to reestablish. 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 adjacent to the road embankment, where drainage is disrupted by the lack of a drainage structure, would be possible. If the situation occurs, it is anticipated 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.

Bridge Crossings

A total of nine bridges would be constructed for the project under Alternative 1, as described in Chapter 2, under Alternative 1, Transportation Corridor (see Chapter 2, Alternatives, Figure 2-14 and Figure 2-15). Although specific bridge design details would vary with stream size and hydrologic properties, a typical bridge schematic is presented on Figure 2-17. Instream channel work, including installation of bridge footings and embankments, would occur year-round during the first 2 years of construction, as permitted. No other information regarding the bridge design and site-specific construction beyond that provided in Chapter 2, Alternatives, is available at this time.

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 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 to 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.
- Increase riverbed erosion within the bridge opening.
- Increased riverbed and bank erosion downstream from the bridge.
- Increased sediment deposition downstream from the bridge.
- Increased sediment transport within 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. Chapter 2, Alternatives, Figure 2-17 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 as to 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 (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[4] (scour) would occur both within 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 geographical 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.

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 geographic 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 2-17) 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 86 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

[4] 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.

requirements. Chapter 2, Alternatives, Figure 2-18 presents a schematic of a typical culvert where fish passage is not an issue, and Figure 2-19 presents a schematic of a fish passage culvert. No other information regarding the design and construction of the culverts at stream crossings is available at this time.

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 period. 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 reestablish. The geographic 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. Chapter 2, Alternatives, Figure 2-18 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. Chapter 2, Alternatives, Figure 2-19 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 within 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 to the flood used to design the culverts, or the maximum allowable headwater[5]-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 of 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

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

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 geographical 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 geographic extent of the impacts would be similar to a culvert design by ADOT&PF.

Note that the erosion control aprons proposed 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 cause 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.

Surface Water Extraction

Water to be used during construction and operation would be extracted from 20 designated sites along the transportation corridor (Figure 4.16-7, and Appendix K2, Table K2-8). 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 would avoid the potential for impacts from water withdrawal at streams.

Sources: PLP 2018; ADNR

US Army Corps of Engineers

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Miles

All Action Alternatives
- Water Extraction Sites

Alternative 1
- Mine Site
- Transportation Corridor
- Natural Gas Pipeline

Kokhanok East Ferry Terminal Variant
- Transportation Corridor
- Natural Gas Pipeline

Alternative 2
- Transportation Corridor
- Ferry Route

Alt 2 Pipeline
- Natural Gas Pipeline

Alternative 3
- Transportation Corridor

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

SURFACE WATER EXTRACTION SITES ALONG TRANSPORTATION CORRIDOR

PEBBLE PROJECT EIS

FIGURE 4.16-7

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 49 million gallons: 19 million gallons along the mine access road, 6 million gallons along the Iliamna spur road, and 24 million gallons along the port access road. 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).

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 withdrawal would be permitted, and would therefore meet the requirements of ADF&G and Alaska Department of Natural Resources (ADNR) for a water withdrawal permit (if 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 intensity 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.

4.16.3.3 Amakdedori Port, Kamishak Bay

Runoff, Erosion, and Sedimentation

The port terminal building would be constructed on an engineered fill patio, designed to be at an elevation high enough to avoid tidal surge from major storms (see Section 4.15, Geohazards). 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 would be minimized by implementing BMPs for erosion 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.

Marine Water in the Port Vicinity

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 natural features is to deflect seaward any alongshore (i.e., parallel to shore) currents, thereby potentially altering circulation in the adjacent water body. 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. Suspended sediment, if any, tends to accumulate as fillets on either or both sides of the base of the structure (i.e., where it is attached to the existing shoreline).

Examination of historic and current photos of the coastline adjacent to the Amakdedori port site suggests that it is a very stable coastline, and that is composed primarily 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 that arrive essentially perpendicular to the beach, and have no long-term or persistent variation from that direction. This is indicated by the absence of accumulations of sediment in the form of spits or fillets at the shoreline obstacles, and also as lack of indication of a predominant sediment transport direction.

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 Amakdedori 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 of the causeway is inevitable, there are no signs that such accumulation would be large or persistent.

There is no indication that alongshore currents at the Amakdedori port site are strong, or have any predominant direction. The combined lengths of the proposed structures (solid-fill causeway and wharf) are about 2,000 feet, which is relatively short compared to the dimensions of Kamishak Bay. Consequently, it is not expected that structures being considered would affect large-scale circulation features in Kamishak Bay, or that any effects that might occur would be permanent, but limited to the immediate vicinity of the structures.

Of possible concern might be a secondary effect of the causeway-wharf structure, which could result if the water column density in its vicinity is stratified, as might occur when warmer, fresher water overlies colder, saltier water. This hydrographic condition would 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 obliterate any density stratification before it would be carried to the causeway. It is concluded that neither large-scale circulation patterns in Kamishak Bay, nor small-scale hydrographic conditions, would be affected by the proposed causeway and wharf structure.

The causeway would support servicing of the lightering vessels that would transport ore concentrate to the Handysize ships moored offshore. Wave forecasts for wind conditions typical of Kamishak Bay (Section 3.16, Surface Water Hydrology) suggest that the bay already has a dynamic wave climate to which the shoreline has achieved a stable equilibrium; consequently, the bay is not susceptible to incrementally increased wave activity as a result of the lightering vessels' wakes.

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 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 proposed to be used for moving barges would have 12-foot draft, and therefore would have adequate underkeel clearances of 3 feet at Amakdedori port (barge berths at -15 feet mean lower low water [MLLW]). None of the variables related to hydrodynamics of the propellers, which would be required for propwash analysis, are available at this time.

Whether the seabed at or near the causeway would be susceptible (i.e., erodible) to 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; namely, BMPs would include specifications for managing ferry speed (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 in Kamishak Bay.

During winter, sea ice could become an operational issue. The causeway may provide shelter from ice on its leeward side, but this would be variable throughout the winter because of shifts in prevailing winds.

Construction of the earthen-fill causeway would cause elevated concentrations of suspended sediments that would be expected to persist for a few weeks after completion, but would not be substantially greater than the maximum levels routinely observed in lower Cook Inlet. If required by permit stipulation, removal of the earthen-fill causeway at the end of the project would cause increases in suspended sediment in Kamishak Bay 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).

4.16.3.4 Iliamna Lake

Ferry Terminals

Ferry terminals would be built on the northern and southern shores of Iliamna Lake. The project description (PLP 2018d) notes that planned construction of causeways consists of rock and aggregate. In terms of extent, some shoreline and lakebed disturbance would be expected to occur on both sides of the lake, 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 controlled by the incorporation of BMPs. Transport of suspended sediment concentrations by wind-driven currents along shore would not be expected to be of long duration or to cover a large geographic area.

Vessel Operations

Wave forecasts for wind conditions typical of Iliamna Lake (Section 3.16, Surface Water Hydrology) suggest that the lake already has a dynamic wave climate to 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. 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. BMPs would include specifications for management of ferry speed (minimizing wakes) and engine power settings (minimizing bottom erosive stress) 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.

4.16.3.5 Natural Gas Pipeline Corridor

Marine Water – Kenai Peninsula to Kamishak Bay

During construction of pipeline in Kamishak Bay short-term increases in suspended sediment concentration in the water column would occur. Increases for trenching would be larger and longer-term than those for horizontal directional drilling (HDD); however, neither would persist for more than several days, nor would either be larger than maximum concentrations that would prevail in the bay under severe storm conditions. During HDD construction of the pipeline terminus on the Kenai Peninsula, short-term increases in suspended sediment concentration would occur, but would not be greater than concentrations routinely occurring in Cook Inlet, nor would they persist for more than a day or two due to the vigorous currents that occur there.

Iliamna Lake

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

Surface Water Extraction

The magnitude, extent, duration, 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 impacts to surface water resources would be expected to result in changes in water quantity, likely within the limits of historic and seasonal variation.

Pipeline

Where the natural gas pipeline alignment follows the port access and mine access roads, it would be located in a trench adjacent to the driving surface of the road (see Chapter 2, Alternatives, Figure 2-16). 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 bridge structure. Typical schematics for the pipeline stream crossings without bridge structure are provided in Chapter 2, Alternatives, Figure 2-37 and Figure 2-38. No other information regarding the design or construction of the natural gas pipeline stream crossings is available at this time.

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 reestablished after the construction activities end. The potential, magnitude, duration, and geographic extent of these impacts would be the same as for vegetation removal and excavation associated with road construction.

At HDD pipeline crossings, there is a potential that the drilling mud used to bore the pipeline below the streambed would 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 geographic 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.

At stream crossings constructed by open cut (see Chapter 2, Alternatives, Figure 2-37), one of the biggest concerns during construction is how to handle the water in the stream. Often, this is addressed by timing the cut to coincide with low streamflow, such as in the later part of the 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 within 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 all 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 located 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.

4.16.3.6 Alternative 1 – Summer-Only Ferry Operations 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.

4.16.3.7 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.

The magnitude, extent, duration, and likelihood of impacts to surface water hydrology under this variant would be similar to those for the terminal location in Alternative 1.

4.16.3.8 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, extent, and duration 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.

4.16.4 Alternative 2 – North Road and Ferry with Downstream Dams

4.16.4.1 Mine Site

The magnitude, extent, duration, and likelihood of impacts to surface water hydrology under Alternative 2 are expected to be the same as those described under Alternative 1, except for the upstream shift (compared to the centerline construction in Alternative 1) of the main TSF embankment by about 40 feet upstream (tributary NK 1.19, gaging station NK 119A) (see Chapter 2, Alternatives).

4.16.4.2 Transportation Corridor

Roads: Mine Site to Eagle Bay and Pile Bay to Diamond Point Roads

The magnitude, extent, duration 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 Chapter 2, Alternatives, Figure 2-49 and Figure 2-50), would be similar to the types of impacts described for Alternative 1, except the road corridor length is less in Alternative 2. The road segments for Alternative 2 would result in fewer stream crossings than Alternative 1. Alternative 2 would have seven bridges and approximately 39 culvert crossings.

Water Extraction Sites

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 water body 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.

Ferry: Eagle Bay to Pile Bay Ferry

Ferry operations from Eagle Bay to Pile Bay would have similar magnitude, extent, duration, and likelihood of impacts to surface water hydrology as ferry operations in Alternative 1.

4.16.4.3 Diamond Point Port

Runoff, Erosion, and Sedimentation

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

Marine Water in the Port Vicinity

The Diamond Point port would be constructed at Diamond Point on the northern side of the entrance to Cottonwood Bay, a small (approximately 9-mile-long by 3-mile-wide) and shallow (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 to the 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 magnitude of 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 water body. 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 within 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 proposed to be used for moving barges would have 12-foot draft, and therefore, would have adequate underkeel clearances of 3 feet at Diamond 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.

Of possible concern might be a secondary effect of the causeway-wharf structure, which could 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 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.

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 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 1).

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. Section 4.18, Water and Sediment Quality, describes the potential for impacts to water quality (if any) regarding concentrate dust.

Dredge Disposal Area

Chapter 2 describes proposed 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 an onshore bermed facility west and upland of the dock site. The water placed in the bermed containment would seep into underlying soils, and would mix with any shallow groundwater present. Therefore, runoff from the disposal site would remain contained in the bermed area, and would not affect surface water hydrology.

4.16.4.4 Natural Gas Pipeline Corridor

The magnitude, extent, duration, and likelihood of impacts to surface water hydrology would be the same as described under Alternative 1 for the portion of the pipeline beginning on the Kenai Peninsula, and crossing Cook Inlet to Kamishak Bay. 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, cross overland to Cottonwood Bay, then cross in a constructed trench in the bottom of Cottonwood Bay to Diamond Point. The bulk of the pipeline corridor under Alternative 2 would have more waterbody crossings than Alternative 1, requiring 17 bridges and 105 culvert crossings, and the additional trenching required for installation of the Cottonwood Bay pipeline segment.

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

Water Extraction Sites

Twenty water extraction sites are identified for the pipeline corridor. Appendix K2 provides information for each water extraction site, including the water body 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.

4.16.4.5 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, extent, duration, and likelihood of impacts to surface water hydrology as summer ferry operations in Alternative 1.

4.16.4.6 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, extent, and duration 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.

4.16.5 Alternative 3 – North Road Only

4.16.5.1 Mine Site

Under Alternative 3, the magnitude, extent, duration, and likelihood of impacts to the project mine site would be the same as under Alternative 1.

4.16.5.2 Transportation Corridor

The road corridor in Alternative 3 would increase the project footprint, because the north road route would have a longer road corridor (Chapter 2 provides details regarding the differences in footprint between alternatives, Figure 2-59 through Figure 2-61). Under Alternative 3, waterbody crossings would include 17 bridges and 105 culverts (see Chapter 2, Alternatives). The magnitude, extent, duration, and likelihood of impacts associated with stream crossings would be the same as those for crossings described under Alternative 1, but there would be more waterbody crossings under Alternative 3.

<u>Water Extraction Sites</u>

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 water body 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.

4.16.5.3 Pipeline Corridor

The magnitude, extent, duration, and likelihood of impacts to surface water hydrology would be the same as described under Alternative 1 for the portion of the pipeline beginning on the Kenai Peninsula, and crossing Cook Inlet to Kamishak Bay. Alternative 3 would also include an onshore stand-alone pipeline segment from Ursus Cove to Cottonwood Bay with two water crossings. Impacts would be the same as described under Alternative 2 for the portion from Diamond Point to the mine site. The stand-alone onshore pipeline segments are longer under Alternative 3 than under Alternative 1 (see Chapter 2 for comparison of pipeline onshore segments between alternatives).

<u>Water Extraction Sites</u>

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

4.16.5.4 Diamond Point Port

Impacts would be the same in magnitude, duration, extent, and likelihood as described for Alternative 2.

4.16.5.5 Alternative 3 – Concentrate Pipeline Variant

There are two options considered under this variant: one for the concentrate pipeline only, and another for a return water pipeline with the concentrate pipeline concept. The concentrate pipeline (and optional water return pipeline) would be co-located with the road corridor in a single trench with the natural gas pipeline. Methods of waterbody crossings would be the same as described for Alternative 1.

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

The Concentrate Pipeline Variant would include a water-return pipeline to move water back to the mine site. This variant would result in no additional project footprint at Diamond Point, and preclude the need for the discharge of treated water into Cook Inlet (see Section 4.18, Water and Sediment Quality). The Concentrate Pipeline Variant would eliminate the need for a WTP at the port; and instead, would require a return water pump station of appropriate capacity (PLP 2018-RFI 066). This option would result in negligible change in footprint at the port site as compared to Alternative 1, and there would be no additional impact to surface water hydrology as a result of the pump station footprint.

A concentrate pipeline from the mine site to the port location 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). This alternative would reduce the amount of WTP water released at discharge locations at the mine site by approximately 1 to 2 percent (PLP 2018-RFI 066). The reduction in WTP-released discharge would be a result of the need for water to create the concentrate slurry, and to flush the concentrate pipeline during maintenance. Reduced discharge water from WTPs could result in a greater reduction in streamflows than those described under Alternative 1.

4.16.6 Summary of Key Issues

Table 4.16-5 provides a summary of impacts on surface water hydrology, marine water, and lake water (Iliamna Lake).

Table 4.16-5: Key Issues Summary – Surface Water Hydrology

Impact Causing Project Component or Activity	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variant
Mine Site			
Mine Site – Streamflow During Operations, Maximum Footprint	**NFK Watershed (Bulk and Pyritic TSFs, Main WMP, Process Facility):** 100% of NKF tributary NK1.190 flow diverted or stored due to Bulk TSF. NFK River – Mean annual	**NFK Watershed:** Same and Alternative 1. **SFK Watershed:** Same and Alternative 1. **UTC Watershed:** Same and Alternative 1.	**NFK Watershed:** Same and Alternative 1. **SFK Watershed:** Same and Alternative 1. **UTC Watershed:** Same and Alternative 1.

Table 4.16-5: Key Issues Summary – Surface Water Hydrology

Impact Causing Project Component or Activity	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variant
	streamflow reduction from pre-mining conditions of 7% at both NK100C and NK100A (with treated water discharge). **SFK Watershed (Mine Pit and Groundwater Dewatering Wells, Overburden Stockpile)**: SFK River – Mean annual streamflow reduction from pre-mining conditions of 4% at SK100F and 2% at SK100A (with treated water discharge). **UTC Watershed (Mine Access Road):** Upper UTC – Mean annual streamflow reduction from pre-mining conditions of 1% at UT100D (with treated water discharge).		
Mine Site – Streamflow Post-Closure (Phase 4)	**NFK Watershed:** 100% of NKF tributary NK1.190 flow diverted or stored due to Bulk TSF. NFK River – Mean annual streamflow reduction from pre-mining conditions of 4% at NK100A (with treated water discharge). **SFK Watershed:** SFK River – Mean annual streamflow reduction from pre-mining conditions of 9% at SK100F and 1% at SK100A (with treated water discharge). **UTC Watershed:** UTC – No mean annual streamflow reduction from pre-mining conditions (with treated water discharge).	**NFK Watershed:** Same and Alternative 1. **SFK Watershed:** Same and Alternative 1. **UTC Watershed:** Same and Alternative 1.	**NFK Watershed:** Same and Alternative 1. **SFK Watershed:** Same and Alternative 1. **UTC Watershed:** Same and Alternative 1.
Transportation Corridor			
Road Corridor Construction and Operations	**Surface Water**: Potential for local impacts to surface water hydrology at stream crossings. Impacts are expected to be short term, and would result in maintained	**Surface Water**: Impacts similar to Alternative 1.	**Surface Water**: Impacts similar to Alternative 1, with increase in waterbody crossings as compared to Alternative 1. Concentrate Pipeline Variant – increased project

Table 4.16-5: Key Issues Summary – Surface Water Hydrology

Impact Causing Project Component or Activity	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variant
	surface flow system changes in water quantity that are likely within historical seasonal variation.		footprint as the road corridor would be widened for pipeline inclusion.
Ferry Terminal Construction and Operations	**Surface Water**: 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 could 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. **Variants:** Summer-Only Ferry Operation Variant may slightly reduce impact from shoreline erosion. See Note under Ferry operations above. Kokhanok East Ferry Terminal Variant: Impact would be similar to Alternative 1 ferry terminal location.	**Surface Water:** Impacts similar to Alternative 1 at Diamond Point port site. **Iliamna Lake (Eagle Bay/Pile Bay ferry terminals):** Potential impacts would be similar to those for Alternative 1. **Variants:** Potential impacts would be similar to those for Alternative 1.	**Surface Water:** None **Iliamna Lake:** None **Variants:** None

Table 4.16-5: Key Issues Summary – Surface Water Hydrology

Impact Causing Project Component or Activity	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variant
Port Site			
Port Site and Causeway fill/construction	**Surface Water**: 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 causeway may be deflection of alongshore currents. Impacts would be minimal, long-term, and local. The causeway is not expected to cause changes in natural gradients in either water temperature or salinity. *Variants:* Pile-Supported Dock Variant. No impacts are expected on marine water currents from the pile-supported causeway.	**Surface Water**: Impacts similar to alternative 1. **Marine Water:** Diamond Point marine port: Impacts similar to Alternative 1. **Variants:** Pile-supported dock. Impacts similar to Alternative 1.	**Surface Water**: Impacts similar to alternative 1. **Marine Water:** Impacts similar to Alternative 1. **Variants:** Concentrate pipeline, Impacts similar to Alternative 1.
Ship Operations and Mooring	Potential direct, local, short-term impacts may include shoreline and seabed erosion (and elevated suspended sediment in water column; see Section 4.18, Water and Sediment Quality) caused by ship wakes and propeller wash. **Lightering Locations Primary (A) & Alternate (B):** During construction, direct, local and short-term impacts to surface water quality would occur as anchors and mooring buoys are installed. Impacts would include elevated suspended sediment in water column, seabed disturbance (see Section 4.18, Water and Sediment Quality).	Similar to Alternative 1. **Lightering Locations Iniskin Bay and Alternate (B):** Similar to Alternative 1.	Similar To Alterative 1. **Lightering Locations Iniskin Bay and Alternate (B):** Similar to Alternative 1.

Table 4.16-5: Key Issues Summary – Surface Water Hydrology

Impact Causing Project Component or Activity	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variant
Natural Gas Pipeline			
Construction and Installation of Pipeline	**Surface Water**: Likely the same as for the transportation corridor Alternative 1.	**Surface Water**: Impacts similar to transportation corridor Alternative 2. Additional acreage and an additional 3 stream crossings to segment crossing Ursus Cove.	**Surface Water**: Likely the same as for the transportation corridor Alternative 1.

4.16.7 Cumulative Effects

The EIS 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 proposed 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 hydrology.

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 EIS analysis area. These include offshore-based developments, activities that may occur within 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 (e.g., Donlin Gold, Alaska Liquefied Natural Gas [LNG]).

RFFAs that could contribute cumulatively to effects on surface water hydrology in the cumulative effects analysis area are limited to those activities that would occur within 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. Past, present, and RFFAs that could contribute cumulatively to effects on surface water hydrology, and are therefore considered in this analysis include:

- Pebble Project buildout – develop 55 percent of the resource over 78-year period
- Pebble South*
- Big Chunk South*
- Big Chunk North*
- Fog Lake*
- Groundhog*
- Diamond Point Rock Quarry

**Indicates exploration activities only.*

4.16.7.1 Past and Present Actions

Past and present actions affecting surface water conditions in the EIS 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, oil and gas exploration, or community development actions. Mining and oil/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 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 impacts to surface water, including streamflow, lakes, and surface water/groundwater interaction.

4.16.7.2 Reasonably Foreseeable Future Actions

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

Alternative 1 – Applicant's Proposed Alternative

Pebble Mine Expanded Development Scenario – An expanded development scenario for this project, as detailed in Section 4.1, Introduction to Environmental Consequences, Table 4.1-2, would include an additional 58 years of mining (for a total of 78 years) over a substantially larger mine site footprint, and would include increases in port and transportation corridor infrastructure. The mine site footprint would have a larger open pit and new facilities to store tailings and waste rock (Section 4.1, Introduction to Environmental Consequences, Figure 4.1.1), 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.

The Pebble mine expanded development scenario project footprint would impact approximately 34,790 acres, compared to 12,371 acres under Alternative 1. The magnitude of cumulative impacts to surface water hydrology would vary from temporary to permanent, increasing potential streamflow reductions in the SFK, NFK, and UTC watersheds beyond those described under Alternative 1.

The Pebble mine expanded development scenario would result in additional development not included under Alternative 1:

- Increased pit footprint
- Increased TSF and waste rock storage capacity
- Additional processing infrastructure
- Construction of a new port site with diesel fuel and concentrate pipeline(s) extending to the mine site

The estimated area of disturbance would be greater than under the proposed 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 effects on 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 Amakdedori port facility, proposed 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 mine expansion include a compressor station at Amakdedori port, and development of a deep-water port in Iniskin Bay. An access road as well as concentrate and diesel pipelines would be constructed from the mine site to Iniskin Bay. These facility expansions would cross drainages along the north road route from 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.

Other Mineral Exploration Projects – Mineral exploration would continue in the analysis area for the mining projects listed previously in this section. Exploration activities, including additional borehole drilling, road and pad construction, and development of temporary camps and other support facilities, would contribute to the potential cumulative effects on surface water hydrology, although impacts would be expected to be limited in extent and low in magnitude.

Some limited RFFAs associated with 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.

Road Improvement and Community Development Projects – Road improvement projects could have impacts on surface water hydrology, primarily through increased stream bank and channel erosion, and could contribute to cumulative effects in the EIS analysis area. Most of the likely road improvements in the area would be within the development footprint of existing communities, with only Iliamna and Newhalen being considered to be within the cumulative effects analysis area for surface water hydrology. Some improvements and maintenance along the Williamsport-Pile Bay Road are also anticipated. Some limited road upgrades could occur in the vicinity of the natural gas pipeline starting point near Stariski Creek, or in support of mineral exploration activities previously discussed. None of the anticipated transportation development within the EIS analysis area would contribute greatly to cumulative effects on surface water hydrology.

Additional RFFAs that have the potential to affect surface water hydrology in the EIS analysis area are limited to the Diamond Point rock quarry. That RFFA would 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 within 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, albeit over a small area. The estimated area that would be affected by the Diamond Point rock quarry is approximately 140 acres (ADNR 2014a).

Alternatives 2 – North Road and Ferry with Downstream Dams and Alternative 3 – North Road Only

Pebble Mine Expanded Development Scenario – Expanded mine site development and associated contributions to cumulative effects on surface water hydrology would be similar for all alternatives. Under Alternatives 2 and 3, project expansion would use the existing Diamond Point port facility; would use the same natural gas pipeline; and would use the constructed portion of the north access road. A concentrate pipeline and a diesel pipeline from the mine site to Iniskin Bay would be constructed along the road corridor, 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 1, because Alternatives 2 and 3 would include some of the same or similar transportation corridor and project port features as the mine expanded development scenario (shared footprints); and the Amakdedori port and transportation corridor would not be built.

Other Mineral Exploration Projects, Road Improvement, and Community Development Projects – Cumulative effects of these activities on surface water hydrology would be similar to those discussed under Alternative 1. As discussed under Alternative 2, the proposed Diamond Point rock quarry has the potential to affect surface water hydrology over a limited area. The footprint of the Diamond Point rock quarry coincides to a large degree with the Diamond Point port footprint under Alternatives 2 and 3. The increase in soil disturbance and erosion impacts could result in cumulative effects on surface water hydrology; those effects would be the same as identified under Alternative 1. Cumulative impacts from the Diamond Point rock quarry would likely be less under Alternative 2, due to commonly shared project footprints between the Pebble port facilities and the proposed quarry site.