4.13 GEOLOGY

This section describes project-related impacts on the geologic resources and materials discussed in Section 3.13, Geology, for all project alternatives and variants. Geologic resources addressed herein are defined as bedrock (including ore), overburden (e.g., glacially derived gravels and sands, alluvium along the transportation corridors), and material site resources (e.g., rock, gravel). The impacts to geologic resources described in this section include removal and relocation of these materials for onshore areas.

Impacts to offshore lake and marine sediments, including dredged sediments and the Iliamna Lake pipeline berm, are described in detail in Section 4.18, Water and Sediment Quality; and Section 4.22, Wetlands and Other Waters/Special Aquatic Sites. Impacts to lake and marine sediments are briefly addressed in this section as pertains to the footprint disturbance from pipeline construction.

Appendix K4.13 presents an analysis of potential impacts on paleontological resources. The impacts of the project on other aspects of the geologic environment are described in the following sections: Section 4.14, Soils; Section 4.15, Geohazards and Seismic Conditions; Section 4.17, Groundwater Hydrogeology; Section 4.18, Water and Sediment Quality; and Section 4.22, Wetlands and Other Waters/Special Aquatic Sites, which also describes the affected footprint of project features, and facilities of the components, for all phases of the project.

The Environmental Impact Statement (EIS) analysis area for geology includes the mine (including quarry material sites), port and ferry terminals, and transportation and pipeline corridors.

The impact analysis considered the following factors: magnitude, duration, geographic extent, and potential:

- Magnitude—impacts are assessed based on the magnitude of the impact as indicated by the quantified amount of geologic resources or area expected to be affected.
- Duration—impacts are assessed based on the duration of effects on geologic resources (e.g., short-term, long-term, or permanent). Short-term effects are considered to be those impacts occurring only during the construction and operations phases; long-term effects are considered to be those impacts extending into closure; and permanent effects are considered to be those impacts extending indefinitely into post-closure, with no restorative actions planned.
- Geographic extent—impacts are assessed on the location and distribution of occurrence of the expected effects on geologic resources (e.g., mine site footprint).
- Potential—impacts are assessed based on the potential likelihood of an effect to geologic resources occurring as a result of actions.

Geotechnical investigations and studies have been completed to support engineering design (see Appendix K4.15, Geohazards and Seismic Conditions). Additional investigations and studies are ongoing and would continue as needed to support detailed design and project compliance with all relevant regulations that are protective of the environment. Mitigation measures that could reduce project impacts to geologic resources are discussed in Chapter 5, Mitigation, and Appendix M1.0, Mitigation Assessment.

4.13.1 Summary of Key Issues

All action alternatives would result in a similar magnitude and potential for impacts related to geology. The primary difference between the alternatives would be the areas and volumes of geologic resources that would be affected. Appendix K2 includes detailed tables with the

permanent and temporary construction footprints for each alternative and their respective variants, summarized by project component (mine site, transportation corridor, port, and natural gas pipeline). Table 4.13-1 summarizes the key issues, primarily by permanent direct footprints for geologic resources (bedrock, overburden, and material site resources) across all alternatives, components, and variants.

Table 4.13-1: Summary of Key Issues for Geology

Impact-Causing Project Component	Alternative 1a	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variant
Mine Site				
Mine Site Construction and Operations	Construction and operation of the mine site would result in removal and/or placement of geologic resources in conjunction with all facilities. Impacts would also occur from blasting of bedrock in construction areas.	Impacts would be the same as those for Alternative 1a. ***Summer Only Ferry Operations Variant Project Footprint:*** Increases the mine site footprint by 33 acres, and resulting permanent direct impacts on geologic resources.	Impacts would be similar to those of Alternative 1a, except the bulk TSF main embankment would be a downstream design, which would result in a small (about 1.5 percent) increase in the total mine site footprint, and resulting direct impacts on geologic resources. ***Summer Only Ferry Operations Variant Project Footprint:*** Increases the mine site footprint by 33 acres, and resulting permanent direct impacts on geologic resources.	Impacts would be similar to those for Alternative 1a. ***Concentrate Pipeline Variant***: Increases the mine site footprint by less than 1 acre, and resulting permanent direct impacts on geologic resources.
Mine Site Closure	All embankments other than those at the bulk TSF would be removed, and the areas reclaimed at closure, resulting in direct long-term impacts. Pyritic TSF: Material would be placed in the open pit. The pyritic TSF would be closed and reclaimed in place, resulting in direct long-term impacts. Open Pit: Would be partially backfilled, resulting in direct permanent impacts. Bulk TSF: Would be closed and reclaimed in place, resulting in permanent direct impacts.	Impacts would be the same as those for Alternative 1a. No change in impacts for variants.	Impacts would be the same as those for Alternative 1a, except with a larger bulk TSF footprint. No change in impacts for variants.	Impacts would be the same as those for Alternative 1a. No change in impacts for variants.

Table 4.13-1: Summary of Key Issues for Geology

Impact-Causing Project Component	Alternative 1a	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variant
Transportation Corridor				
Transportation Corridor Construction and Operations	Access Roads: Total 74 miles. Mine Access Road: 35 miles from the mine site to Eagle Bay, mostly surficial glacial deposits. Bedrock ~2 miles, blasting impacts likely. Port Access Road: 37 miles, mostly bedrock; blasting impacts likely. Geologic MSs: 19 total; 380 acres. Mine Access Road MSs: 11 total; 2 would require blasting. Port Access Road MSs: 8 total; all would require blasting. Ferry Terminals: 30 acres of permanent direct impacts for the north and south ferry terminals combined; requiring excavation of surficial glacial deposits and possibly bedrock.	Access Roads: Total 77 miles. Mine Access Road: 28 miles from the mine site to the north ferry terminal, mostly surficial glacial deposits. Bedrock ~2 miles; blasting impacts likely. Iliamna Spur Road: 9 miles, mostly surficial glacial deposits. Port Access Road: same as Alternative 1a. Geologic MSs: 19 total; 251 acres. Mine Access Road MSs: 8 total; 2 would require blasting. Iliamna Spur Road MSs: 3 total; no blasting required. Port Access Road MSs: same as Alternative 1a. Ferry Terminals: 27 acres of permanent direct impacts for the Eagle Bay and south ferry terminals combined; requiring excavation of surficial glacial deposits and possibly bedrock. ***Kokhanok East Ferry Terminal Variant:*** 19 acres of permanent direct impacts Kokhanok East and north ferry terminals combined; requiring excavation of surficial glacial deposits and possibly bedrock. Geologic MSs: 19 total, 358 acres. ***Summer-Only Ferry Variant*:** No changes to geological impacts.	Access Roads: Total 54 miles Mine Access Road: same as Alternative 1a. Port Access Road: 18 miles (~5 miles using existing road). Blasting would likely be required. Geologic MSs: 17 total; 321 acres. Mine Access Road MSs: 11 total; 2 would require blasting. Port Access Road MSs: 6 total; 3 would require blasting. Ferry Terminals: 25 acres of permanent direct impacts for the Eagle Bay and Pile Bay terminals combined; requiring excavation of surficial glacial deposits and possibly bedrock ***Newhalen River North Crossing Variant:*** Impacts would be the same at either crossing location. Slight increase (0.3 mile) in mine access road length than Alternative 2. Geologic MSs: 17, 338 acres. ***Summer-Only Ferry Variant*:** Same road length, but increased footprint from Alternative 2 by 22 acres, and resulting impacts on geologic resources, due to the container yard.	Access Roads: Total 82 miles. Mine Access to Port Road: Mostly surficial glacial deposits from mine site to Knutson Bay, then a combination of glacial deposits and bedrock to the port. Blasting likely for northwestern Knutson Bay, Pedro Bay to Williamsport-Pile Bay Road intersection, and Williamsport to the port. Geologic MSs: 27 total; 604 acres. Mine Access Road to Port MSs: 27 total; 6 would require blasting. Port Access Road MSs: none. Ferry Terminals: none. ***Concentrate Pipeline Variant*:** Same impacts as those for Alternative 2 for the gas pipeline corridor.

Table 4.13-1: Summary of Key Issues for Geology

Impact-Causing Project Component	Alternative 1a	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variant
Transportation Corridor Closure	Geologic MSs: Progressively reclaimed but not backfilled; permanent impacts. Ferry Terminals: Decommission and reclamation at mine closure; long-term impacts.	Same as Alternative 1a.	Same as Alternative 1a.	Same as Alternative 1a. ***Concentrate Pipeline Variant:*** Same impacts as those for the Alternative 2 natural gas pipeline.
Ports				
Port Construction and Operation	Amakdedori Port: Construction of the onshore port terminal and airport (22 acres total) would impact surficial glacial deposits and possibly alluvium.	Amakdedori Port: Construction of the onshore port terminal and airport (22 acres total) would impact the same types of materials as Alternative 1a. ***Pile-Supported Dock Variant:*** Onshore impact same as Alternative 1. ***Summer-Only Ferry Variant:*** Increases the onshore port footprint by 27 acres, and resulting permanent direct impacts on geologic resources, due to the container yard.	Diamond Point Port: Construction of the onshore port terminal (25 acres) would impact the same types of surficial materials as Alternative 1a with possibly some impacts to bedrock in addition. ***Pile-Supported Dock Variant:*** Onshore impacts same as Alternative 2.	Diamond Point Port: Construction of the onshore port terminal (16 acres) would predominantly affect bedrock. **Concentrate Pipeline Variant:** Same as Alternative 3.
Port Closure	Amakdedori Port: Structures and caissons removed after mine closure; impacts would be long-term.	Amakdedori Port: Same as Alternative 1a. ***Pile-Supported Dock Variant****:* Similar to the above, but the impact would be less because of smaller piling footprint and no causeway and wharf earthfill. Long-term impacts. ***Summer-Only Ferry Variant:*** Same as for Alternative 1a, but larger area due to container yard; long-term impacts.	Diamond Point Port: Same as Alternative 1. ***Pile-Supported Dock Variant****:* Less area of impact than Alternative 2; long-term impacts.	Impacts would be similar to those for Alternative 2. ***Concentrate Pipeline Variant****:* Minimal impact difference; long-term impacts.

Table 4.13-1: Summary of Key Issues for Geology

Impact-Causing Project Component	Alternative 1a	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variant
Natural Gas Pipeline Corridor				
Gas Pipeline Construction and Operations	Impacts from onshore segments of the pipeline that are co-located with a road are addressed under the Transportation Corridor (for all action alternatives and variants). Onshore pipeline-only segments (about 15 miles) would directly affect geologic resources during construction; primarily surficial deposits. Geologic MSs: none. The Cook Inlet crossing (buried for most of the route, except for 11.2 miles which would be on the seafloor) and the Iliamna Lake crossing would have temporary impacts on lake and marine sediments (addressed in Section 4.18, Water and Sediment Quality).	Impacts would be the same as Alternative 1a, except the onshore pipeline-only segments (about 5 miles) are shorter and would affect fewer geologic resources. Kenai Peninsula: Same as Alternative 1a. Geologic MSs: none.	Onshore pipeline-only segments (about 45 miles) would directly affect geologic resources during construction; primarily surficial deposits and some bedrock which would likely require blasting. All of the pipeline segments across Cook Inlet would be buried in the seafloor. Impacts to marine sediments are addressed in Section 4.18, Water and Sediment Quality. There would be no pipeline crossing of Iliamna Lake. Geologic MSs: 13 total, 298 acres; 3 require blasting.	Because the pipeline would follow the north access road from the Diamond Point port to the mine site, impacts are addressed under the Transportation Corridor. Onshore pipeline-only segments are limited (less than 10 miles) and would primarily affect surficial deposits and bedrock. Geologic MSs: 3 total, 11 acres; 2 require blasting.
Gas Pipeline Closure	Required through post-closure, resulting in permanent impacts.	Same as for Alternative 1a.	Same as for Alternative 1a.	Same as for Alternative 1a.

Notes:

~ = approximately
HDD = horizontal directional drilling
MS(s) = material site(s)
N/A = Not Applicable
ROW = right-of-way
TSF = tailings storage facility

4.13.2 No Action Alternative

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

many valid mining claims in the area, and these lands would remain open to mineral entry and exploration by other individuals or companies.

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

Geology along the transportation corridor, natural gas pipeline corridor, and at the port sites would remain in its current state. There would be no direct or indirect impacts on baseline geology conditions in the EIS analysis area from implementation of the No Action Alternative.

4.13.3 Alternative 1a

This section addresses the analysis of impacts from Alternative 1a on geologic resources and materials. Scoping comments related to geology requested that impacts to bedrock, surface geology, material resources, and paleontology be analyzed. Paleontological impacts analysis is described in Appendix K4.13.

4.13.3.1 Mine Site

Potential impacts to geology at the mine site include removal and relocation of geologic materials due to construction of the open pit, tailings storage facilities, quarries, and other mine site facilities. These impacts are discussed in the following subsections.

Under Alternative 1a, the magnitude and extent of impacts on geologic resources from construction and operations at the mine site would be the removal and relocation of rock and overburden within 8,390 acres of land (see Figure 2-4, and Section 4.14, Soils) (PLP 2020d). These impacts would be permanent and would be certain to occur if the project is permitted and constructed. Closure of some facilities and regrading of facility footprints during site closure would minimize some of these impacts (see Figure 4.16-3 through Figure 4.16-7).

Open Pit

Removing and relocating overburden and rock from the open pit area would result in direct impacts on geologic resources, which would be permanent, unavoidable consequences of the project.

The magnitude and extent of impacts from excavating the open pit during construction and operation would be the removal and relocation of approximately 1.44 billion tons (approximately 2.9 trillion pounds) of material including overburden, mineralized process material, and waste rock. The open pit would be approximately 8 percent of the total mine site surface area (see Chapter 2, Alternatives).

The majority of rock removed from the open pit would remain at the mine site in the form of tailings. Bulk tailings would remain in the bulk tailings storage facility (TSF). Pyritic tailings (including potentially acid generating [PAG] rock and finer pyritic tailings) would be stored in the pyritic TSF during operations and relocated to the open pit during closure.

A relatively small fraction of the excavated rock from the open pit would make up the economic minerals that would be processed (concentrated) at the mine site then exported off site. This economic mineral portion would include 7.4 billion pounds of copper, 12.1 million ounces of gold, and 398 million pounds of molybdenum (PLP 2020d).

Approximately 89.5 million tons of overburden would be removed from the open pit. Suitable rocky overburden materials would be used for embankment fill, regrading purposes, and other rockfill for the project. Appendix K4.15, Geohazards and Seismic Conditions, addresses the volumes and geotechnical characteristics of the rockfill generated from the open pit and the quarries. Topsoil would be used as a growth medium during reclamation, some overburden material would be used for regrading purposes, and the remainder would be placed in the overburden stockpile.

At the close of mining, the open pit would be partially backfilled with pyritic tailings and PAG waste rock. The partial backfilling would reduce the volume of the open pit, but a permanent void in the landscape would remain. The extent of impacts would be limited to the footprint of the excavated pit and the locations where the materials would be relocated in the mine site. These impacts would be certain to occur if the mine were permitted and built.

Tailings Storage Facilities

A bulk TSF and pyritic TSF would store tailings and waste rock generated from the mined and processed open pit rock (see Figure 2-4). Approximately 88 percent would be bulk tailings, and approximately 12 percent would be pyritic tailings (PLP 2020d).

The bulk TSF would have the largest footprint of the mine site facilities: about 30 percent of the mine site area. The pyritic TSF would compose about 5 percent of the mine site area.

The magnitude and extent of direct impacts on geologic material resources would be from the removal and relocation of rock and overburden required for construction of the two TSFs. The impacts would be limited to the footprints of the facilities. During closure, the pyritic tailings (including PAG waste rock) would be backfilled into the open pit, and the footprint of the pyritic TSF would be regraded to near preexisting topography, so that its impact would be long-term. The bulk TSF would be closed, recontoured, and vegetated at closure, and would remain as a new landform. The impact of the bulk TSF on the landscape would be permanent and would be certain to occur if the mine is permitted and the bulk TSF is constructed.

Quarries

Surficial overburden and bedrock would be removed from three quarries in the western portion of the mine site to provide rockfill for the construction of embankments, roads, and other mining-related facilities (see Figure 2-4). The quarries would be developed primarily in granodiorite bedrock (competent igneous rock), and blasting would be required to remove the rock. The combined areas of the three rock quarries would be an estimated 16 percent of the total mine site area. The magnitude and area of impacts from quarry excavation would be the removal of the following estimated volumes of material and respective dimensions (PLP 2020d; PLP 2018-RFI 015):

- 1.7 billion cubic feet (ft^3) from Quarry A (approximately 5,000 feet by 2,900 feet)
- 3.2 billion ft^3 from Quarry B (approximately 5,800 feet by 7,000 feet)
- 1.4 billion ft^3 from Quarry C (approximately 5,200 feet by 3,300 feet)

The area of Quarry A would be covered during construction of the bulk TSF; Quarries B and C (west and east of the bulk TSF, respectively) would be backfilled and reclaimed during mine closure (see Section 4.16, Surface Water Hydrology, Figure 4.16-4). Excavation of the quarries would result in direct, long-term to permanent impacts on geologic resources. These impacts would be certain to occur if the mine were permitted and built.

Other Mine Site Facilities

Geologic materials would be removed from and/or relocated to various other facility footprints in the mine site, including water management facilities; milling and processing facilities; the power plant; water treatment plants; camp facilities; storage facilities, including laydown areas; and access roads (see Figure 2-4).

The magnitude and extent of the direct impacts on geologic resources at the mine site would be the removal and relocation of geologic materials at these sites, limited to the footprints of the respective facilities. Regrading of some of these facilities at mine closure would minimize impacts on geologic materials (see Section 4.16, Surface Water Hydrology, Figure 4.16-4 through Figure 4.16-7).

Power generation facilities, some camp and storage facilities, access roads, and the open pit water treatment plant would remain to support post-closure water treatment and site monitoring, which would likely continue beyond post-closure. Therefore, the duration of impacts of these facilities on geologic resources would be permanent. The impacts would be certain to occur if the project is permitted and built.

4.13.3.2 Transportation Corridor

The transportation corridor for Alternative 1a includes access roads, material sites, and two ferry terminals on Iliamna Lake. The impacts due to the removal and relocation of geologic materials at these sites are discussed in the following subsections.

Access Roads

Alternative 1a includes the mine access road between the mine site and Eagle Bay ferry terminal; the port access road between the south ferry terminal to Amakdedori port; and the Kokhanok spur road (see Figure 2-18 and Figure 2-19).

The mine access road to the Eagle Bay ferry terminal would be approximately 35 miles long and underlain by surficial glacial deposits, with the potential for bedrock along approximately 2 miles of the corridor, which may require blasting. The port access road from the south ferry terminal to Amakdedori port would be approximately 37 miles long and underlain mostly by bedrock (see Figure 3.13-4).

The construction of access roads would require removing and relocating surficial glacial deposits and bedrock (PLP 2018-RFI 032a). The width of the construction right-of-way (ROW) would vary based on the terrain and underlying geology. The estimated range of disturbed geologic resources to construct the road prism may be roughly 60 to 80 feet (PLP 2020d) (see Figure 2-20). This would include the 30-foot-wide road, embankment slopes, drainage ditches, natural gas pipeline, and cut slopes in surficial glacial deposits and bedrock. Portions of the roadbed underlain by bedrock would likely require blasting (see Figure 3.13-4).

The exact number and design of waterbody crossings would be determined during final design and permitting. Under Alternative 1a, the roads would cross 233 waterbodies, which would require 10 bridges, including crossings of the Newhalen and Gibraltar rivers and Sid Larsen Creek. The remaining crossing structures would consist of various sizes and designs of culverts, depending on fish passage requirements. Impacts at crossings designated as fish passage culverts are addressed in Section 4.24, Fish Values. Bridges and culverts would require rock and riprap consisting of blasted bedrock from the geologic material sites discussed below (PLP 2020d).

The magnitude and extent of direct impacts on geologic resources would be the disturbance of these resources in the access road ROW, at stream crossings footprints, and at the material sites

discussed in the next subsection. The mine access road to Eagle Bay and port access road would be required for site maintenance and monitoring through post-closure. Therefore, impacts on geologic resources would be permanent, and would be expected to occur if the mine access road is permitted and constructed.

Material Sites

The access roads would require rockfill and aggregate for embankments and road surfacing during mine construction, operation, and closure. The rockfill and aggregate would be provided by 19 material sites adjacent to the transportation corridor (Appendix K2, Figure K2-1 and Figure K2-2). There would be 11 material sites along the mine access road and eight along the port access road.

Footprints of the material sites under Alternative 1a would vary from 8 to 45 acres, for a total of approximately 380 acres (see Appendix K2, Alternatives, Table K2-6). The total volume is estimated to be 7.6 million cubic yards (yd^3).

Of the 11 material sites along the mine access road to Eagle Bay, two would be situated in bedrock and would likely require blasting (see Figure 3.13-4 and Table K2-6). The other material sites along the mine access road would be in surficial glacial deposits generally consisting of silt- to gravel-sized materials that would not require blasting.

The eight material sites along the port access road would be situated in bedrock and would likely require blasting.

The magnitude of direct impacts of the project at materials sites would be the removal of rock and gravel from these sites. The impact would be permanent in terms of geologic resources, but the extent would be limited to the material site footprints. The material sites would eventually be stabilized and progressively reclaimed, but generally would not be backfilled during mine closure and post-closure. These impacts to material sites would occur if the project is permitted and built.

Ferry Terminals

Under Alternative 1a, ferry terminals would be constructed on Iliamna Lake at Eagle Bay and the south ferry terminal site west of Kokhanok. Constructing the south ferry and Eagle Bay terminals would require excavation of surficial glacial deposits and possibly bedrock on the combined 30 acres of the terminal footprints (see Figure 2-27 and Figure 2-29).

The magnitude of impacts due to ferry terminal construction on geologic features would be the removal and relocation of geologic materials. The extent of direct impacts would be limited to the footprints of the facilities. The ferry terminals would be closed and the sites would be reclaimed during closure. Impacts related to geology would be permanent, and certain to occur if the project is permitted and the terminals are constructed.

4.13.3.3 Amakdedori Port

Under Alternative 1a, the port would be at Amakdedori on the western shore of Cook Inlet (see Figure 2-32).

Construction of the Amakdedori port would affect an onshore footprint of approximately 22 acres, which includes the port terminal and the airstrip north of the port (see Figure 2-32 and Figure 2-33), directly affecting surficial glacial deposits and possibly alluvium (mostly sand and gravel).

The magnitude of impacts on geologic features due to Amakdedori port construction would be the removal and relocation of surficial geologic deposits. The extent of direct impacts to the geology

would be limited to the onshore footprints of the port. Impacts to marine sediments at the port are described in Section 4.16, Surface Water Hydrology; Section 4.18, Water and Sediment Quality; and Section 4.22 Wetlands and Other Waters/Special Aquatic Sites. The port would be closed and undergo reclamation after completion of the off-site transport of concentrate. Therefore, the duration of impacts would be long-term, and certain to occur if the project is permitted and the Amakdedori port is constructed.

4.13.3.4 Natural Gas Pipeline Corridor

Construction of the shoreline component of the pipeline west of the compressor station at Anchor Point would use horizontal directional drilling (see Section 4.15, Geohazards and Seismic Conditions). From the eastern shore, trenching would be used to install the pipeline beneath the seafloor for pipeline stability, to mitigate geohazards, to address pipeline free spinning and to provide protection against third-party risks. Approximately 11.2 miles of the natural gas pipeline at an average water depth of 197 feet (60 meters) would not require trenching, and the pipe would be laid on the seafloor (NanaWP and Intecsea 2019b). The construction of the pipeline across Cook Inlet would not affect the geologic resources addressed in this section. Impacts to marine sediments from buried pipeline segments in Cook Inlet are described in Section 4.16, Surface Water Hydrology; Section 4.18, Water and Sediment Quality; and Section 4.22 Wetlands and Other Waters/Special Aquatic Sites.

From the western landfall near Amakdedori port, the magnitude of impacts from pipeline construction on upland geologic features would be the removal of both surficial glacial deposits and bedrock (depending on the location along the corridor) to bury the pipeline. Much of this material would be used to backfill the excavation. Upland pipeline construction would be integrated with access road construction in the ROW where practicable, and the extent of impacts would generally be limited to the immediate vicinity of the construction ROW and in established areas used for material laydown and staging of equipment.

Installing the pipeline would likely require drilling and blasting for those segments mapped as underlain by bedrock (see Figure 3.13-4). Where the pipeline installation is coincident with access road construction, the extent of pipeline-related impacts on geologic resources would be considered part of the impact of the access road ROW.

Impacts associated with sections of the natural gas pipeline that are co-located with the transportation corridor are included under the transportation corridor component. Where the overland pipeline installation is not coincident with access road construction (i.e., pipeline-only segments), the magnitude and extent of impacts from pipeline installation on geologic resources in the 150-foot ROW would primarily be limited to the pipeline trench (see Figure 2-48). Alternative 1a includes approximately 15 miles of onshore pipeline-only construction (see Table 2-2). Geologic resources primarily affected would include glacial overburden and potentially bedrock. The disturbed area would be reclaimed after installation of the pipeline, but the impacts of the excavation on geologic resources would be permanent. These impacts would be certain to occur if the project is permitted, and the pipeline is constructed.

For the crossing of Iliamna Lake to the landfall just east of Newhalen, the pipeline would be buried nearshore in sediments to prevent damage but would then be placed on the floor of the lake for most of the crossing (PLP 2020d). The pipeline segment placed on the lake floor (including the span remediation berm approximately 0.6 mile long in Iliamna Lake) (see Chapter 2, Alternatives and PLP 2020-RFI 164) would not affect the geologic resources addressed herein. Impacts to Iliamna Lake sediments are addressed in Section 4.16, Surface Water Hydrology; Section 4.18, Water and Sediment Quality; and Section 4.22 Wetlands and Other Waters/Special Aquatic Sites.

The natural gas pipeline would be required to support mine site maintenance and monitoring through post-closure. The impact on geologic resources would be permanent, because of the displacement of materials required to accommodate the pipeline.

4.13.4 Alternative 1

This section addresses the analysis of impacts on geologic resources and materials from Alternative 1 and variants.

4.13.4.1 Mine Site

The magnitude, duration, extent, and likelihood of impacts to geology in the mine site would be the same as those described for Alternative 1a.

4.13.4.2 Transportation Corridor

The Alternative 1 access roads include the mine access road from the mine site to the north ferry terminal; Iliamna spur road; and the same port access road and Kokhanok spur road as described for Alternative 1a (see Figure 2-51 and Figure 2-52). Impacts would be similar to those described for Alternative 1a, with the exception of the mine access road and Iliamna spur road.

Access Roads

The 28-mile-long mine access road from the mine site to the north ferry terminal on Iliamna Lake would be constructed in mostly surficial glacial deposits, with the potential for bedrock along approximately 2 miles of the corridor. The Iliamna spur road would be approximately 9 miles long and underlain by mostly surficial glacial deposits. The associated disturbance to geologic resources would be similar to that of the mine access road. Geology along the port access road from the south ferry terminal to the Amakdedori port and Kokhanok spur road would be the same as that described for Alternative 1a.

The exact number and design of waterbody crossings would be determined during final design and permitting. Under Alternative 1, roads would cross 224 waterbodies. These crossing structures would consist of 10 bridges, and the remainder would be culverts. The use of culverts to allow fish passage at stream crossings is addressed in Section 4.24, Fish Values. Crossing structures would require rock and riprap consisting of blasted bedrock from the geologic material sites discussed below (PLP 2020d).

The magnitude and extent of direct impacts on geologic resources would be the disturbance of these resources in the mine site access road and port access road ROW, at stream crossings footprints, and at the material sites discussed in the next subsection. The mine access road and port access road would be required for site maintenance and monitoring through post-closure. Therefore, impacts on geologic resources would be permanent, and would be expected to occur if the access roads are permitted and constructed as described for Alternative 1a. Aside from the Iliamna spur road and a different route for the mine access road, impacts would be similar to those described for Alternative 1a.

Material Sites

The access roads would require rockfill and aggregate for embankments and road surfacing during mine construction, operation, and closure. The rockfill and aggregate would be provided by 19 material sites adjacent to the transportation corridor (Appendix K2, Figure K2-3 and Figure K2-4). There would be eight material sites along the port access road; eight along the mine access road; and three along the Iliamna spur road.

Footprints of the material sites would vary from 8 to 22 acres, for a total of approximately 251 acres (Appendix K2, Alternatives, Table K2-13). The total volume is estimated to be 7.5 million yd^3.

The eight material sites along the port access road would be situated in bedrock, and may require blasting (see Figure 3.13-4 and Table K2-13).Two of the eight material sites along the mine access road would likely require blasting, while the remaining six material sites would be in surficial glacial deposits generally consisting of silt- to gravel-sized materials that would not require blasting. All three of the sites along the Iliamna spur road would be in surficial glacial deposits that would not require blasting (PLP 2018-RFI 035) (see Table K2-13).

The magnitude of direct impacts of the project at materials sites would be the removal of rock and gravel from these sites. The impact would be permanent in terms of geologic resources, but the extent would be limited to the material site footprints. The material sites would eventually be stabilized and progressively reclaimed, but generally would not be backfilled during mine closure and post-closure. These impacts to material sites would occur if the project is permitted and built.

Ferry Terminals

Constructing the north and south ferry terminals on Iliamna Lake would require excavation of surficial glacial deposits, and possibly bedrock, on the combined 27 acres of the terminal footprints (see Figure 2-29 and Figure 2-53).

The magnitude of impacts due to ferry terminal construction on geologic features would be the removal and relocation of geologic materials. The extent of direct impacts would be limited to the footprints of the facilities. The ferry terminals would be closed and the sites would be reclaimed during closure. Impacts related to geology would be permanent, and certain to occur if the project is permitted and the terminals are constructed.

4.13.4.3 Amakdedori Port

The onshore facilities at Amakdedori port would be the same as those of Alternative 1a; affecting approximately 22 acres of surficial deposits and possible alluvium (mostly sand and gravel) (see Figure 2-56 and Figure 2-57).

The marine port facilities include a truck route and causeway constructed of an earthfill embankment and a barge berth constructed using an enclosed steel sheet-pile wall wharf structure filled with earthfill (see Figure 2-56). The source of the earthfill would likely be the nearest geologic materials site, MS-A08, and possibly the footprint of the port terminal.

The rockfill access causeway would be constructed in nearshore sediment deposits on the bottom of the bay. Dredging would not be required. Impacts to marine sediments are described in Section 4.16, Surface Water Hydrology; Section 4.18, Water and Sediment Quality; and Section 4.22 Wetlands and Other Waters/Special Aquatic Sites.

The magnitude of impacts on geologic resources due to Amakdedori port construction would be the removal and relocation of geologic materials. The extent of direct impacts to onshore geologic resources would be limited to the onshore footprints of the port. The port would be closed and undergo reclamation after completion of the off-site transport of concentrate. Therefore, the duration of impacts would be long-term, and certain to occur if the project is permitted and the Amakdedori port is constructed.

4.13.4.4 Natural Gas Pipeline Corridor

The segment of natural gas pipeline corridor from the compressor station near Anchor Point on the Kenai Peninsula to the south ferry terminal on Iliamna Lake would be the same as that described for Alternative 1a; the types of impacts along these segments would be the same as described for the Alternative 1a.

From the south ferry terminal, the pipeline would cross Iliamna Lake to the north ferry terminal and then continue along the mine access road to the mine site. Impacts associated with sections of the natural gas pipeline that are co-located with the transportation corridor are included under the transportation corridor component.

Alternative 1 includes approximately 5 miles of onshore pipeline-only construction (see Table 2-2). Installing the pipeline would likely require drilling and blasting for those segments mapped as underlain by bedrock (see Figure 3.13-4). Geologic resources primarily affected would include glacial overburden and potentially bedrock. The magnitude and extent of impacts from pipeline installation on geologic resources would primarily be limited to the pipeline trench within the 150-foot ROW (see Figure 2-48). The disturbed area would be reclaimed after installation of the pipeline, but the impacts of the excavation on geologic resources would be permanent. These impacts would be certain to occur if the project is permitted, and the pipeline is constructed.

For the crossing of Iliamna Lake under Alternative 1, the pipeline would be buried nearshore in sediments to prevent damage, but would then be placed on the floor of the lake for most of the crossing, as described for Alternative 1a. The pipeline segment placed on the lake floor (including the permanent berm on the lakebed along two sections of the Iliamna Lake segment to place the pipeline on; approximately 2 miles combined) (see Chapter 2, Alternatives) would not affect the geologic resources addressed herein. Impacts to Iliamna Lake sediments are addressed in Section 4.16, Surface Water Hydrology; Section 4.18, Water and Sediment Quality; and Section 4.22 Wetlands and Other Waters/Special Aquatic Sites.

The natural gas pipeline would be required to support mine site maintenance and monitoring through post-closure. The impact on geologic resources would be permanent, because of the displacement of materials required to accommodate the pipeline.

4.13.4.5 Alternative 1—Summer-Only Ferry Operations Variant

Mine Site Concentrate Storage

During the winter, concentrate would be stored in a shipping storage container laydown area constructed of rock and gravel fill northeast of the pyritic TSF (see Figure 2-59). Changes at the mine site related to the additional concentrate storage would result in a 33 acre increase in footprint at the mine site. The magnitude and extent of impacts due to construction of the concentrate storage site on geologic features would be the removal and relocation of geologic materials from these 33 acres. The facility would be removed, and the sites would be reclaimed during closure. Therefore, impacts related to geology would be long-term, and certain to occur if the Summer-Only Ferry Operations Variant is chosen, the project is permitted, and the storage area is constructed.

Amakdedori Port

The Summer-Only Ferry Operations Variant would require the Amakdedori port to include an expanded storage yard (27 acres) (see Figure 2-60). The extent of impacts on geologic resources would be limited to the construction footprint. The port would be closed and undergo reclamation after completion of the off-site transport of concentrate for the project. Impacts would therefore be

long-term, and certain to occur if the Summer-Only Ferry Operations Variant is chosen, and the project is permitted and built.

4.13.4.6 Alternative 1—Kokhanok East Ferry Terminal Variant

The mine access road and Iliamna spur road would be the same as described for the Alternative 1 base case, constructed in mostly surficial glacial deposits, with the potential for bedrock along approximately 2 miles of the corridor. The port access road extends approximately 27 miles from the Amakdedori port to a ferry terminal on the southern shore of Iliamna Lake east of the village of Kokhanok (Kokhanok east ferry terminal) and the Kokhanok spur road extends 5 miles from the port access road to the community of Kokhanok (see Figure 2-61 and Figure K2-4). The port access road to the Kokhanok east ferry terminal site would not require a crossing of the Gibraltar River, and would also have fewer overall stream crossings. Although the port access road alignment differs from the Alternative 1 base case, the geology along the port access road from the south ferry terminal to the Amakdedori port and Kokhanok spur road would be similar to that described for the Alternative 1 base case.

The Kokhanok East Ferry Terminal Variant would be constructed east of Kokhanok (see Figure 2-61 and Figure 2-62). Construction of the ferry terminal under this variant would encounter similar geology as construction of the Kokhanok (south) ferry terminal described for Alternative 1a and Alternative 1. The combined footprint for the north ferry terminal and Kokhanok east ferry terminal would be 19 acres.

The Kokhanok East Ferry Terminal Variant would require approximately 64 percent more rockfill material than the Kokhanok ferry terminal under the Alternative 1 base case (PLP 2020d). A total of 19 material sites (up to 358 acres) have been identified for this variant (Appendix K2, Alternatives, Table K2-14). Three of the material sites for the Kokhanok East Ferry Terminal Variant would change from MS-A01 through MS-A03 (totaling approximately 39 acres) to MS-K01 through MS-K03 (totaling approximately 146 acres). This would result in an approximately 70 percent increase in the area of material sites needed to construct the Kokhanok East Ferry Terminal Variant. The total volume is estimated to be 7.6 million yd^3.

The natural gas pipeline alignment from the Amakdedori port would follow the port access road towards the Kokhanok east ferry terminal and the spur road into Kokhanok. From Kokhanok, it would follow an existing road alignment to the point where it departs the shoreline to tie into the proposed route from the Kokhanok west ferry terminal site (Figure 2-61). All other segments of the pipeline would be the same as described for the Alternative 1 base case. Impacts associated with sections of the natural gas pipeline that are co-located with the transportation corridor are included under the transportation corridor component.

The magnitude of impacts on geological features due to construction of the Kokhanok East Ferry Terminal Variant site would be the removal and relocation of geologic materials in the construction footprints of the ferry terminal site, the natural gas pipeline alignment, and the access road to the ferry terminal. The extent of impacts due to the removal of geologic material would be greater than those estimated for the Kokhanok ferry terminal (Alternative 1 base case) because more fill would be required to construct the terminal at the east location.

The closure-related impacts of the Kokhanok East Ferry Terminal Variant would be similar to those for the Kokhanok (south) ferry terminal site. Both ferry terminal sites would be closed and reclaimed in closure, so that the duration of impacts would be long-term. These impacts on geologic resources would be certain to occur if the Kokhanok East Ferry Terminal Variant were chosen, permitted, and built.

4.13.4.7 Alternative 1—Pile-Supported Dock Variant

The onshore facilities and associated impacts to geologic resources at Amakdedori port with incorporation of this variant would be the same as Alternative 1. The pile-supported dock design would reduce impacts to marine sediments compared to the earthen fill dock described for Alternative 1 above. Impacts to marine sediments are described in detail in Section 4.16, Surface Water Hydrology; Section 4.18, Water and Sediment Quality; and Section 4.22 Wetlands and Other Waters/Special Aquatic Sites.

4.13.5 Alternative 2—North Road and Ferry with Downstream Dams

The analysis of impacts from Alternative 2—North Road and Ferry with Downstream Dams on geologic resources is presented below.

4.13.5.1 Mine Site

The magnitude, duration, extent, and likelihood of impacts to geology in the mine site would be essentially the same as those previously described for Alternative 1a, with the exception of an increased bulk TSF footprint.

The Alternative 2 bulk TSF main embankment would be constructed using the downstream method compared to centerline construction with downstream buttresses under Alternative 1a (see Figure 2-65 and Figure 2-66). The footprint for the bulk TSF main embankment constructed with the downstream method would increase by approximately 110 acres, requiring additional embankment fill. The magnitude and extent of impacts to geologic resources would increase from about 78 million yd^3 for Alternative 1a to about 124 million yd^3 for Alternative 2 (PLP 2018-RFI 075a). This would be an increase in direct impacts on geologic resources under Alternative 2 of approximately 5 percent for the bulk TSF main embankment, and approximately 1 percent for the overall mine site (PLP 2018-RFI 075a) as compared to Alternative 1a. The impacts would be permanent because the bulk TSF would be closed and reclaimed in place. The impacts would be expected to occur if Alternative 2 is chosen and the project is permitted and built.

4.13.5.2 Transportation Corridor

Access Roads

Alternative 2 would involve constructing and operating mine and port access roads that would total approximately 54 miles (see Figure 2-64). An estimated 5 miles of the Alternative 2 access road would use an existing road; and the remainder would require new road construction or widening of the existing road.

The mine access road to the ferry terminal at Eagle Bay is the same as that described for Alternative 1a, including possible blasting for approximately 2 miles of the corridor (see Figure 3.13-4, Figure 2-51, and Figure 2-64).

The port access road from the Pile Bay ferry terminal to Williamsport would generally follow the existing road (see Figure 2-69). However, the road would need to be expanded and possibly bypassed in places to make it suitable for use by haul trucks. This would have the potential to result in fewer impacts on geologic resources than constructing a new road. However, material sites would still be needed for both construction and maintenance of the road surface (under Material Sites, below). Portions of the port access road corridor are underlain by surficial glacial deposits where there may be less need for blasting. However, if the existing road were to be bypassed or widened to accommodate the requirements for a haul road, it is possible and in

places likely, that bedrock would be encountered outside the ROW of the existing road. For example, several material sites are likely in bedrock.

Part of the port access road would require construction of a new, approximately 3-mile-long section of road from Williamsport to Diamond Point. Constructing this section of road would require removing and relocating primarily bedrock (competent igneous intrusive rock), and blasting would likely be required (see Figure 3.13-4 and Figure 2-69).

Under Alternative 2, 220 waterbody crossings would be required including three bridges along the mine access road and four bridges along the port access road. The remaining crossing structures would consist of various sizes and designs of culverts, depending on fish passage requirements. Impacts at crossings designated as fish passage culverts are addressed in Section 4.24, Fish Values.The magnitude of direct impacts on geologic resources from constructing the access road would be the removal of geologic materials. The extent of impacts would be limited to the access road ROW. Because the port access road from Pile Bay to Williamsport would be shorter than the port access road from the south ferry terminal to Amakdedori, the total road distance for Alternative 2 (54 miles) would be approximately 27 percent less than under Alternative 1a (74 miles). If the 5 miles of existing road are considered, the net impact on geologic resources under Alternative 2 would be approximately 34 percent less than the impact under Alternative 1a.

As described for Alternative 1a, the Alternative 2 roads would require site maintenance and monitoring through post-closure. Therefore, the impact on geologic resources would be permanent. The impacts would occur if Alternative 2 is chosen and the transportation system associated with it is permitted and built.

Material Sites

Road construction and operational maintenance under Alternative 2 would require material sites to provide required aggregate for road surfacing during mine construction, operation, and closure (see Figure 2-67 through Figure 2-69; and Table K2-22).

For Alternative 2, 17 material sites would be required for construction and maintenance of the transportation corridor versus 19 sites under Alternative 1a. The footprints of the Alternative 2 material sites would vary from approximately 6 acres to 45 acres, for a total of approximately 321 acres for the transportation component (see Table K2-22). This would be approximately 16 percent less area than needed under Alternative 1a. The amount of material estimated to be required for construction and maintenance of the transportation corridor is approximately 4.6 million yd^3. Material sites used for construction of pipeline-only segments of the natural gas pipeline are discussed below under the natural gas pipeline component.

Blasting would likely be required to remove bedrock from five of the 17 Alternative 2 material sites (see Figure 3.13-4). No blasting is anticipated for the 11 material sites associated with the mine access road to the Eagle Bay ferry terminal. Three of the six material sites between Pile Bay, and the port would likely require blasting. This would result in approximately half of the blasting required under Alternative 1a.

As under Alternative 1a, the magnitude of direct impacts on geologic resources at material sites under Alternative 2 would be the removal and relocation of geologic materials for road surfacing. The extent of direct impacts would be limited to the footprints of the material sites. The material sites would eventually be stabilized and progressively reclaimed, but generally would not be backfilled during mine closure and post-closure. Therefore, impacts would be permanent. They would be certain to occur as described if Alternative 2 was chosen, permitted, and built.

Ferry Terminals

The transportation corridor under Alternative 2 would require ferry terminals at Eagle Bay and Pile Bay (combined total of 25 acres). Impacts of the terminal at Eagle Bay are described under Alternative 1a. The terminal at Pile Bay would be approximately the same size as the ferry terminals described for Alternative 1a. The geology at the Pile Bay ferry terminal under Alternative 2 would be similar to the geology at the ferry terminals under Alternative 1a.

The magnitude, duration, extent, and likelihood of impacts of construction of the Alternative 2 ferry terminals on geologic resources would be similar to the impacts of the ferry terminals under Alternative 1a.

4.13.5.3 Diamond Point Port

Alternative 2 includes construction of Diamond Point port at Iliamna Bay (see Figure 2-71). The Diamond Point port facility would use a similar design concept as the Amakdedori port under Alternative 1, with an earthen access causeway and sheet-pile wharf structure. The total footprint of the Diamond Point port would be larger than that of the Amakdedori port. The Diamond Point port onshore portions would encompass an estimated 25 acres of permanently affected geologic resources (mostly bedrock) compared to the roughly 22 acres of permanent impact to onshore areas (mostly surficial deposits) at the Amakdedori port under Alternative 1a and Alternative 1.

The magnitude of direct impacts on geologic resources would be the removal and relocation of geologic materials to construct the onshore portion of the Diamond Point port. Because the Diamond Point port site is larger than the Amakdedori port site, the geographic extent of the onshore impacts of Alternative 2 would be greater than that described under Alternative 1a. Due to the presence of bedrock, the Diamond Point port would also require blasting that may not be required at Amakdedori port.

Dredging would be required at the Diamond Point port to deepen the channel adjacent to and near the port wharf structure, and would remove approximately 650,000 yd^3 of marine sediments. The dredging area would include an estimated 58 acres offshore. Most dredged material (615,000 yd^3) would be used as earthfill behind the sheet pile wall. Remaining material would be placed in the 16 acre dredged materials storage area west of the port terminal. These impacts are described in Section 4.16, Surface Water Hydrology; Section 4.18, Water and Sediment Quality; and Section 4.22 Wetlands and Other Waters/Special Aquatic Sites.

The Diamond Point port would be closed and undergo reclamation after the completion of off-site transport of concentrate, as described for Alternative 1a. Therefore, the duration of impacts would be long-term, and would be certain to occur if this alternative was chosen and the port was permitted and built.

4.13.5.4 Natural Gas Pipeline Corridor

Construction of the natural gas pipeline under Alternative 2 would require disturbing both surficial glacial overburden and bedrock for all upland portions of the pipeline (see Figure 2-73). The corridor route, length, and respective geologic resources would differ from those of Alternative 1a. Under Alternative 2, the natural gas pipeline from the Kenai Peninsula to the mine site would have three main segments: 1) Cook Inlet crossing coming ashore at Ursus Cove; 2) northward to Diamond Point port; and 3) overland to the mine site, along the port and mine access roads with a pipeline-only segment between Pile Bay and the mine access road to Eagle Bay. Under Alternative 2, the natural gas pipeline would not cross Iliamna Lake. All Cook Inlet segments of the pipeline would be buried for Alternative 2 (PLP 2020-RFI BSSE 1a). The construction of the pipeline across Cook Inlet would not affect the geologic resources addressed in this section.

Impacts to marine sediments during construction and operation of the buried pipeline segments in Cook Inlet are described in Section 4.16, Surface Water Hydrology; Section 4.18, Water and Sediment Quality; and Section 4.22 Wetlands and Other Waters/Special Aquatic Sites.

Installing the pipeline would likely require drilling and blasting for those segments mapped as underlain by bedrock. Where the pipeline installation is coincident with access road construction, the extent of pipeline-related impacts on geologic resources would be considered part of the impact of the access road ROW.

Pipeline construction materials and methods for Alternative 2 would be similar to those for Alternative 1a. However, the pipeline segment between the Williamsport Pile Bay Road intersection and the mine access road would require an installation corridor independent of the transportation system (i.e., not co-located with an access road). Alternative 2 includes about 45 miles of onshore pipeline-only construction (see Table 2-2). The magnitude and extent of impacts from pipeline installation on geologic resources would primarily be limited to the pipeline trench within the 150-foot ROW (see Figure 2-48). Geologic resources primarily affected would include glacial overburden and bedrock. The disturbed area would be reclaimed after installation of the pipeline, but the impacts of the excavation on geologic resources would be permanent. These impacts would be certain to occur if the project is permitted, and the pipeline is constructed.

For the pipeline segment between the Williamsport-Pile Bay Road intersection and near Pedro Bay, the corridor is underlain by bedrock with relatively steep topography for portions of the alignment. From Pedro Bay to the western portion of Knutson Bay, the geology would consist mostly of surficial glacial deposits, and then bedrock similar to that found near Pedro Bay. From Knutson Bay to the mine site, the geology would generally consist of surficial glacial deposits, similar to the geology of the Alternative 2 transportation corridor to the Eagle Bay ferry terminal.

Thirteen material sites (up to 298 acres) would be required for construction of pipeline-only segments for Alternative 2 (see Appendix K2, Table K2-22). The amount of material estimated to be required from these material sites is approximately 2.8 million yd^3.

The magnitude of direct impacts on geologic resources from installation of the natural gas pipeline would be the removal and placement of geologic materials for construction. The extent of impacts would be limited to within the construction ROW for pipeline installation. As described for Alternative 1a, the natural gas pipeline would be required for site maintenance and monitoring through post-closure. The duration of the impact on geologic resources would be permanent, and certain to occur if the pipeline as described for Alternative 2 were permitted and built.

4.13.5.5 Alternative 2—Summer-Only Ferry Operations Variant

Impacts would be the same as those described above for Alternative 1 during summer-only ferry operations.

4.13.5.6 Alternative 2—Pile-Supported Dock Variant

The onshore facilities and associated impacts to geologic resources at Diamond Point port with incorporation of this variant would be the same as Alternative 2. The pile-supported dock design would reduce impacts to marine sediments compared to the earthen fill dock described for Alternative 2 above, as described in Section 4.18, Water and Sediment Quality; and Section 4.22, Wetlands and Other Waters/Special Aquatic Sites.

4.13.5.7 Alternative 2—North Crossing of the Newhalen River Variant

This variant considers a north crossing location of the Newhalen River as an alternative to the south crossing location that is evaluated in Alternative 1a. The impacts to geological resources would be the same at either crossing location.

4.13.6 Alternative 3—North Road Only

The analysis of impacts from Alternative 3—North Road Only on geologic resources is presented below.

4.13.6.1 Mine Site

Impacts of Alternative 3 on geologic resources at the mine site would be the same as those described for Alternative 1a.

4.13.6.2 Transportation Corridor

Access Road

The north access road would connect the mine site with the port site north of Diamond Point and would be 82 miles long (see Figure 2-78 and Figure 2-79). The north access road would be about 28 miles longer than the port and mine access roads under Alternative 2.

From the mine site to near Knutson Bay, the geology would consist of surficial glacial deposits, similar to the geology of the Alternative 2 transportation corridor to the Eagle Bay ferry terminal described above, so that blasting may not be required. From the western portion of Knutson Bay to Pedro Bay, the geology would consist mostly of bedrock and surficial glacial deposits, and blasting would be required. From Pedro Bay to the Williamsport-Pile Bay Road intersection, the corridor is mapped as underlain by bedrock and relatively steep topography for portions of the alignment.

The access road from the Williamsport-Pile Bay Road intersection to Williamsport would generally follow the existing road (see Chapter 2, Alternatives), which is underlain by a combination of bedrock requiring blasting and surficial glacial deposits. The last segment of new road from Williamsport to the port site north of Diamond Point would be underlain by bedrock.

Under Alternative 3, 205 waterbody crossings would be required, including 17 bridges. The remaining crossing structures would consist of various sizes and designs of culverts, depending on fish passage requirements. Impacts at crossings designated as fish passage culverts are addressed in Section 4.24, Fish Values.

The magnitude of direct impacts on geologic resources from constructing the access road would be the removal and placement of geologic materials, and the extent of impacts would be limited to the access road ROW. Based on road lengths, Alternative 3 (82 miles) would require removing and relocating approximately 10 percent more geologic material for the access road than under Alternative 1a (74 miles); 6 percent more under Alternative 1 (77 miles); and 34 percent more than under Alternative 2 (54 miles). As with all action alternatives, the road would require maintenance and monitoring through post-closure. Therefore, the duration of the impacts on geologic resources would be permanent. These impacts would be certain to occur if Alternative 3 is chosen and the project is permitted and built.

Material Sites

As with all action alternatives, access road construction and operational maintenance under Alternative 3 would require material sites to provide required aggregate for road surfacing during mine construction, operations, and closure (see Figure K2-7 and Table K2-28).

Twenty-seven material sites would be required for the Alternative 3 north access road, versus 19 material sites under Alternative 1a, 19 sites under Alternative 1, and 17 sites under Alternative 2. The footprints of the Alternative 3 material sites would vary from 6 acres to 45 acres, for a total of an estimated 604 acres (see Table K2-28).

Blasting would likely be required to remove bedrock from six of the Alternative 3 material sites (see Figure 3.13-5 and Table K2-28). All other material sites would be in surficial glacial deposits of sand and gravel and would not require blasting.

The magnitude and extent of direct impacts to material sites under Alternative 3 would be the removal of rock and gravel. The extent of the impact would be limited to the footprints of the material sites; the sites would be eventually stabilized and progressively reclaimed, but not backfilled, during mine closure and post-closure. Therefore, the duration of impacts to the sites would be permanent. These impacts would be expected to occur if Alternative 3 is chosen, permitted, and built.

Ferry Terminals

No ferry terminals would be needed under Alternative 3. Therefore, no associated impacts on geologic resources would occur.

4.13.6.3 Diamond Point Port

The port site under Alternative 3 would be north of Diamond Point (see Figure 2-80 and Figure 2-81).

The Diamond Point port onshore footprint would encompass an estimated 16 acres of permanently affected geologic resources, compared to the roughly 22 acres of permanent impact to onshore areas at the Amakdedori port under Alternative 1a and Alternative 1, and 25 acres under Alternative 2. The onshore port location under Alterative 3 is mostly underlain by bedrock. Local topography is steep, dropping to narrow rocky beaches (PLP 2020d, Figure 1-5) and construction would require blasting of bedrock. The magnitude of direct impacts on geologic resources would consist of the removal and relocation of geologic materials to construct the onshore portions of the Diamond Point port.

Under Alternative 3, the port facility would use a similar marine facility design concept as described under Alternative 1a. The caisson dock for Alternative 3 would be constructed in shallower water than the Diamond Point dock under Alternative 2. As a result, additional dredging would be required for dock construction. The Alternative 3 dredge basin would be 76 acres with approximately 1,100,000 yd^3 of material anticipated to be initially removed for construction of the channel and turning basin, and an additional 700,000 yd^3 of material would be removed during maintenance dredging over the 20-year life of the mine. The dredged material would be placed into two bermed stockpiles (16 acres combined) located in uplands north of the port facility and adjacent to the transportation corridor. Impacts related to dredging of marine sediments are described in Section 4.16, Surface Water Hydrology; Section 4.18, Water and Sediment Quality; and Section 4.22 Wetlands and Other Waters/Special Aquatic Sites.

The Diamond Point port would be closed and would undergo reclamation after the completion of off-site transport of concentrate, as described for the Alternative 1a. Therefore, the duration of impacts would be long-term, and would be certain to occur if this alternative was chosen and the port was permitted and built.

4.13.6.4 Natural Gas Pipeline Corridor

As described for Alternative 1a, construction of the natural gas pipeline under Alternative 3 would require removing and relocating geologic resources to bury the pipeline in an excavated trench for all upland portions of the pipeline.

From the port to the mine site, the Alternative 3 pipeline would follow the same route as the north access road previously described. Material sites used for construction of the co-located north access road and pipeline are described under the transportation corridor above. Three additional material sites (approximately 11 acres) would be required for construction of the pipeline-only segment from Ursus Cove to Diamond Point port location. Two of the three material sites along this segment would require blasting (see Table K-28 and Figure K2-7). The amount of material estimated to be required from these material sites is approximately 200,000 yd^3.

Alternative 3 includes less than 10 miles of onshore pipeline-only construction (see Table 2-2). Installing the pipeline would likely require drilling and blasting for those segments mapped as underlain by bedrock. The magnitude and extent of impacts from pipeline installation on geologic resources would primarily be limited to the pipeline trench within the 150-foot ROW (see Figure 2-48). Geologic resources primarily affected would include overburden and bedrock. The disturbed area would be reclaimed after installation of the pipeline, but the impacts of the excavation on geologic resources would be permanent. These impacts would be certain to occur if the project is permitted, and the pipeline is constructed.

As described for Alternative 2, all Cook Inlet segments of the pipeline would be buried for Alternative 3 (PLP 2020-RFI BSSE 1a). The construction of the pipeline across Cook Inlet would not affect the geologic resources addressed in this section. Impacts to marine sediments for buried pipeline segments in Cook Inlet are described in Section 4.16, Surface Water Hydrology; Section 4.18, Water and Sediment Quality; and Section 4.22 Wetlands and Other Waters/Special Aquatic Sites.

4.13.6.5 Concentrate Pipeline Variant

The Alternative 3 Concentrate Pipeline Variant would involve installing and operating a pipeline to transport concentrate slurry from the mine site to the port location north of Diamond Point. The concentrate pipeline would follow the Alternative 3 north access road route and would be co-located in a single trench with the natural gas pipeline and fiber-optic cable at the toe of the road embankment (see Figure 2-84 and Figure 2-85). Therefore, the impacts to geologic resources would be similar to those under the Alternative 3 transportation corridor.

The Diamond Point port terminal would be modified to accommodate a concentrate pipeline filter plant and bulk storage building (see Figure 2-86). Port operations would change due to the requirements of dewatering the concentrate, storing water and concentrate, and treating and discharging the filtrate water. The overall footprint of the port terminal would not increase; therefore, the impact on geologic materials would be similar to that of the port terminal without concentrate pipeline-related facilities. In addition to the marine facilities described for Alternative 3, the marine facility with the Concentrate Pipeline Variant would include a series of three caissons (60 feet by 60 feet) placed within the dredge basin to provide mooring and loading for concentrate lightering barges; expanding the marine facility footprint by less than 1 acre (approximately 0.2 acre) (see Figure 2-86). Impacts to marine sediments are described in Section 4.16, Surface Water Hydrology; Section 4.18, Water and Sediment Quality; and Section 4.22 Wetlands and Other Waters/Special Aquatic Sites.

The Concentrate Pipeline Variant would also require two electric pump stations; one at the mine site, and one at an intermediate point along the transportation corridor (see Figure 2-83 and

Figure 2-84). The magnitude and extent of impacts on geologic resources at the mine site would be limited to a footprint of about 1 acre. The intermediate pump station would be sited in the footprint of a proposed material site (Figure 2-84) and would not increase the overall footprint. The concentrate pipeline would be decommissioned in place at mine closure; however, to avoid further ground disturbance, the pipeline would not be removed. Therefore, the duration of impact on geologic materials would be permanent. Impacts would be certain to occur at this magnitude if the Alternative 3 Concentrate Pipeline Variant was chosen, and the pipeline is permitted and built.

This variant includes an option to construct an additional 8-inch-diameter return-water pipeline to pump the water extracted from the concentrate back to the mine site. The water return line would be co-located in a single trench with the natural gas pipeline (see Chapter 2, Alternatives). There would be no increase in impacts to geologic resources compared to the main variant.

4.13.7 Cumulative Effects

Impacts to onshore geologic resources would include the removal and relocation of bedrock (including ore), overburden, and material site resources. The cumulative effects analysis area for geologic resources encompasses the onshore footprint of the project, including alternatives and variants, the expanded mine footprint (including road, pipeline and port facilities), and any other reasonably foreseeable future actions (RFFAs) in the vicinity of the project that would result in potential synergistic and interactive effects. In this area, a nexus may exist between the project and other past, present, and RFFAs that could contribute to cumulative effects on geologic resources. Section 4.1, Introduction to Environmental Consequences, details the comprehensive set of past, present, and RFFAs considered applicable for evaluation. A number of actions were considered and determined to have no potential for contributing to cumulative effects on geologic resources in the analysis area. These include offshore-based developments; activities that may occur in the analysis area but are unlikely to result in any appreciable impact on geologic resources (such as tourism, recreation, fishing, and hunting); and actions outside of the cumulative effects analysis area.

4.13.7.1 Past and Present Actions

Past and present actions that have impacted geologic resources in the analysis area include transportation development where existing roads intersect the project footprint, and mineral exploration in locations where past or current activities have impacted geologic resources (e.g., drill sites). Although these actions affect localized areas, they are additive to other actions that may occur, slightly increasing the total cumulative effect on geologic resources. Past exploration at the Pebble deposit has included drilling of over 1,600 boreholes. Similarly, there have been boreholes drilled associated with exploration at other deposits in the analysis area. However, for approved exploration activities on state lands, there are requirements with regard to stabilizing boreholes and site remediation. Overall, the cumulative effects on geologic resources from past and present actions are minimal in extent and minor in magnitude for all alternatives.

4.13.7.2 Reasonably Foreseeable Future

RRFAs that could contribute cumulatively to geology impacts, and are therefore considered in the analysis of cumulative effects to geology include Pebble Project expansion scenario project period; mining exploration activities for Pebble South/PEB, Big Chunk South, Big Chunk North, Fog Lake, and Groundhog mineral prospects; onshore oil and gas development; road improvements and the continued development of the Diamond Point Rock Quarry.

The RFFFA contribution to cumulative effects on geology are summarized by alternative in Table 4.13-2.

The No Action Alternative would not contribute to cumulative effects on geologic resources.

Table 4.13-2 Contribution to Cumulative Effects on Geology

Reasonably Foreseeable Future Actions	Alternative 1a	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variant
Pebble Project Expansion Scenario	**Mine Site:** The mine site footprint would have a larger open pit and new facilities to store tailings and waste rock, which would contribute to cumulative effects on geologic resources through removal of overburden, waste rock, and ore. **Other Facilities:** A north access road, concentrate pipeline, and diesel pipeline would be constructed along the Alternative 3 road alignment, and extended to a new deepwater port site at Iniskin Bay. The mine site access road would be extended east from the Eagle Bay ferry terminal to the Pile Bay terminus of the Williamsport-Pile Bay Road. The existing port access road and ferry system connecting the Amakdedori port would remain in operation. Pipeline construction would have potentially limited impacts on geology from trenching activities **Magnitude:** The Pebble Project expansion scenario project footprint would impact approximately 31,892 acres, compared to 9,612 acres under Alternative 1a. **Duration/Extent:** The duration and extent of cumulative impacts to geology would vary from temporary disturbance during construction to permanent overburden, and ore removal within the footprint of mine and other project facilities over the expanded operations life. The extent of impacts would encompass the expanded mine site, the south access road corridor and the north access road corridor. **Contribution:** This contributes to cumulative effects on geology through removal of overburden, waste rock, and ore. However, the area in the Kvichak and Nushagak River watersheds is relatively undeveloped, and effects would be limited to the project footprint, which is a relatively small area in the watersheds.	**Mine Site:** Same as Alternative 1a. **Other Facilities:** Similar to Alternative 1a. **Magnitude:** Would impact 32,418 acres, similar to Alternative 1a. **Duration/Extent:** The duration and extent of cumulative impacts to geology would be similar to duration and extent of Alternative 1a. **Contribution:** The contribution to cumulative effects from Alternative 1 would be slightly more than from other alternatives.	**Mine Site:** Same as Alternative 1a. **Other Facilities:** The north access road would be extended east from the Eagle Bay ferry terminal to Iniskin Bay. Concentrate and diesel pipelines would be constructed along the Alternative 3 road alignment and extended to a new deepwater port site at Iniskin Bay. **Magnitude:** Overall expansion of Alternative 2 (31,528 acres) would affect slightly less acreage than Alternative 1a (31,892 acres), given that a portion of the north access road and all of the gas pipeline would already be constructed. Impacts to geology from mine expansion would be slightly less than Alternative 1a. **Duration/Extent:** The duration and extent of cumulative impacts to geology would be similar to duration and extent of Alternative 1a, although affecting a slightly smaller amount of acreage. **Contribution:** The contribution to cumulative impacts would be similar to Alternative 1a, although affecting a smaller amount of acreage.	**Mine Site:** Same as Alternative 1a. **Other Facilities:** Overall expansion would use the existing north access road; concentrate and diesel pipelines would be constructed along the existing road alignment and extended to a new deepwater port site at Iniskin Bay. **Magnitude:** Overall expansion of Alternative 3 (31,541 acres) would affect slightly less acreage than Alternative 1a (31,892 acres), given that the north access road and gas pipeline would already be constructed. Impacts to geology from mine expansion would be slightly less than Alternative 1a. **Duration/Extent:** The duration and extent of cumulative impacts to geology would be similar to duration and extent of the other alternatives. **Contribution:** The contribution to cumulative impacts would be similar to the other alternatives.

Table 4.13-2 Contribution to Cumulative Effects on Geology

Reasonably Foreseeable Future Actions	Alternative 1a	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variant
Other Mineral Exploration Projects	**Magnitude:** Mining exploration activities, including additional borehole drilling, road and pad construction, and development of temporary camp facilities would contribute a small amount of disturbance at discrete locations, depending on landowner permitting and restoration requirements. For example, the 2018 drilling program proposed by PLP consisted of 61 geotechnical boreholes and 19 diamond-drilled core boreholes with diameters ranging from 2 to 8 inches. **Duration/Extent:** Exploration activities typically occur at a discrete location for one season, although a multi-year program could expand the geographic area affected in a specific mineral prospect. Table 4.1-1 in Section 4.1, Introduction to Environmental Consequences, identifies seven mineral prospects in the analysis area where exploratory drilling is anticipated (four of which are in relatively close proximity of the Pebble Project). **Contribution:** This contributes to cumulative effects of geologic resource disturbance, although the areal extent of disturbance is a relatively small portion of the Kvichak/ Nushagak watersheds. Assuming compliance with permit requirements, contributions to geology would be minimal.	Similar to Alternative 1a.	Similar to Alternative 1a.	Similar to Alternative 1a.
Oil and Gas Exploration and Development	**Magnitude:** Onshore oil and gas exploration activities could involve seismic and other forms of geophysical exploration, and in limited cases, exploratory drilling. Seismic exploration would involve temporary overland activities, with permit conditions that avoid or minimize surface disturbance,	Similar to Alternative 1a.	Similar to Alternative 1a.	Similar to Alternative 1a.

Table 4.13-2 Contribution to Cumulative Effects on Geology

Reasonably Foreseeable Future Actions	Alternative 1a	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variant
	and therefore impacts to geology. Should it occur, exploratory drilling would involve the construction of temporary pads and support facilities, with permit conditions to minimize surface disturbance and restore drill sites after exploration activities have ceased. **Duration/Extent:** Seismic exploration and exploratory drilling are typically single-season temporary activities. The 2013 Bristol Bay Area Plan Amendment shows 13 oil and gas wells drilled on the western Alaska Peninsula, and a cluster of three wells near Iniskin Bay. It is possible that additional seismic testing and exploratory drilling could occur in the analysis area, but based on historic activity, is not expected to be intensive. **Contribution:** Onshore oil and gas exploration activities would be required to minimize surface disturbance, and would occur in the analysis area, but removed from the project. The project would have minimal contribution to cumulative effects.			
Road Improvement and Community Development Projects	**Magnitude:** Road improvements projects would take place in the vicinity of communities, and have impacts through grading, filling, and potential increased erosion. Only Iliamna and Newhalen are being considered in the analysis area for geologic resource cumulative effects. Some limited road upgrades could also occur in the vicinity of the natural gas pipeline eastern terminus near Stariski Creek. None of the anticipated transportation development in the geologic resources analysis area would	Similar to Alternative 1a and Alternative 2; greater than Alternative 3.	The footprint of the Diamond Point Rock Quarry under Alternative 1a coincides with the Diamond Point port footprint in Alternative 2 and Alternative 3. Cumulative impacts would likely be less under Alternative 2 due to commonly shared project footprints with the quarry site.	Similar to Alternative 2; less than Alternative 1a.

Table 4.13-2 Contribution to Cumulative Effects on Geology

Reasonably Foreseeable Future Actions	Alternative 1a	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variant
	contribute greatly to cumulative effects on those resources. The Diamond Point Rock Quarry would include the excavation of geologic resources, which would represent a direct and cumulative effect. The estimated total rock reserve of the quarry source is approximately 10 to 15 million cubic yards (USFWS 2012g). **Duration/Extent:** Disturbance from road construction would typically occur over a single construction season. Activity at Diamond Point would likely be seasonal, but continue to occur over multiple years. Geographic extent would be limited to the vicinity of communities and Diamond Point. **Contribution:** Road construction would be required to minimize surface disturbance, and would occur in the analysis area, but removed from the project. The project would have minimal contribution to cumulative effects.			
Summary of Project contribution to Cumulative Effects	Overall, the contribution of Alternative 1a on cumulative effects to geologic resources, when taking other past, present, and reasonably foreseeable future actions into account, would be minor in terms of magnitude and extent, given the limited acreage affected and permit requirements. Duration would be permanent.	Similar to Alternative 1a, although slightly more acreage would be affected by expansion.	Similar to Alternative 1a, although slightly less acreage would be affected by expansion.	Similar to Alternative 1a, although slightly less acreage would be affected by expansion.

Note:
PLP = Pebble Limited Partnership