Alaska LNG

DOCKET NO. PF14-21-000
DRAFT RESOURCE REPORT NO. 6
GEOLOGICAL RESOURCES
PUBLIC VERSION

Document Number: USAKE-PT-SRREG-00-0006

RESOURCE REPORT No. 6 SUMMARY OF FILING INFORMATION [1]	
Filing Requirement	**Found in Section**
Identify the location (by milepost) of mineral resources and any planned or active surface mines crossed by the proposed facilities. (§ 380.12(h)(1&2)) • Describe hazards to the facilities from mining activities, including subsidence, blasting, slumping or land sliding or other ground failure.	6.3
Identify any geologic hazards to the proposed facilities. (§ 380.12(h)(2)) • For the offshore this information is needed on a mile-by-mile basis and will require completion of geophysical and other surveys before filing.	6.4
Discuss the need for and locations where blasting may be necessary in order to construct the proposed facilities. (§ 380.12(h)(3))	6.5
For LNG projects in seismic areas, the materials required by "Data Requirements for the Seismic Review of LNG Facilities," NBSIR84-2833. (§ 380.12(h)(5))	6.4.1
For underground storage facilities, how drilling activity by others within or adjacent to the facilities would be monitored, and how old wells would be located and monitored within the facility boundaries. (§ 380.12(h)(6))	NA
Additional Information Often Missing and Resulting in Data Requests	
Identify any sensitive paleontological resource areas crossed by the proposed facilities. (Usually only if raised in scoping or required by land-managing agency.)	6.7
Briefly summarize the physiography and bedrock geology of the project area.	6.2.3
If the application is for underground storage facilities: Describe monitoring of potential effects of the operation of adjacent storage or production facilities on the proposed facility, and vice versa; Describe measures taken to locate and determine the condition of old wells within the field and buffer zone and how the applicant would reduce risk from failure of known and undiscovered wells; and Identify and discuss safety and environmental safeguards required by state and Federal drilling regulations.	NA

[1] Guidance Manual for Environmental Report Preparation (FERC, August 2002). Available online at http://www.ferc.gov/industries/gas/enviro/erpman.pdf.

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ACRONYMS AND ABBREVIATIONS

ABBREVIATION	DEFINITION
Abbreviations for Units of Measurement	
°C	degrees Celsius
°F	degrees Fahrenheit
BSCF/D	billion standard cubic feet per day
cfs	cubic feet per second
cm	centimeters
dB	decibels
dBA	A-weighted decibels
ft	feet
g	grams
gpm	gallons per minute
ha	hectare
hp	horsepower
Hz	hertz
in	inches
kg	kilogram
kHz	kilohertz
kW	kilowatts
L_{dn}	day-night sound level
L_{eq}	equivalent sound level
L_{max}	maximum sound level
m^3	cubic meters
Ma	mega-annum (millions of years)
mg	milligrams
mg/L	milligrams per liter
mg/m^3	milligrams per cubic meter
MGD	million gallons per day
mm	millimeters
MMBtu/hr	million British thermal units per hour
MMSCF/D	million standard cubic feet per day
MPH	miles per hour
MMTA	million metric tons per annum
ng	nanograms
ppb	parts per billion
ppbv	parts per billion by volume
ppm	parts per million
ppmv	parts per million by volume
Psig	pounds per square inch gauge
rms	root mean square
SPL	sound pressure level

ABBREVIATION	DEFINITION
tpy	tons per year
µg	microgram
µg/kg	micrograms per kilogram
µPa	micropascals
Other Abbreviations	
§	section or paragraph
AAAQS	Alaska Ambient Air Quality Standards
AAC	Alaska Administrative Code
ACC	Alaska Conservation Corps
ACEC	Areas of Critical Environmental Concern
ACP	Arctic Coastal Plain
ACRC	Alaska Climate Research Center
ACS	U.S. Census, American Community Survey
AD	aggregate dock
ADCCED	Alaska Department of Commerce, Community, and Economic Development
ADEC	Alaska Department of Environmental Conservation
ADF&G	Alaska Department of Fish and Game
ADGGS	Alaska Division of Geological and Geophysical Surveys
ADM	average daily membership
ADNR	Alaska Department of Natural Resources
ADOLWD	Alaska Department of Labor and Workforce Development
ADOT&PF	Alaska Department of Transportation and Public Facilities
AEIC	Alaska Earthquake Information Center
AES	Arctic Slope Regional Corporation Energy Service
AGDC	Alaska Gasline Development Corporation
AGPPT	Alaska Gas Producers Pipeline Team
AHPA	Alaska Historic Preservation Act
AHRS	Alaska Heritage Resources Survey
AIDEA	Alaska Industrial Development and Export Authority
AKNHP	Alaska Natural Heritage Program
AMP	approximate mile post
ANCSA	Alaska Native Claims Settlement Act
ANGPA	Alaska Natural Gas Pipeline Act
ANGTS	Alaska Natural Gas Transportation System
ANILCA	Alaska National Interest Lands Conservation Act
ANIMIDA	Arctic Nearshore Impact Monitoring in the Development Area
ANS Task Force	Aquatic Nuisance Species Task Force
ANVSA	Alaska Native Village Statistical Area
AOGCC	Alaska Oil and Gas Conservation Commission
AOI	Area of Interest
APCI	Air Products and Chemicals Inc.
APDES	Alaska Pollutant Discharge Elimination System
APE	Area of Potential Effect

ABBREVIATION	DEFINITION
API	American Petroleum Institute
APP	Alaska Pipeline Project
Applicants	ExxonMobil Alaska LNG LLC, ConocoPhillips Alaska LNG Company, BP Alaska LNG LLC, TransCanada Alaska Midstream LP, and Alaska Gasline Development Corporation
APSC	Alyeska Pipeline Service Company
AQRV	Air Quality Related Value
Arctic NWR	Arctic National Wildlife Refuge
ARD	acid rock drainage
ARDF	Alaska Resource Data File
ARPA	Archaeological Resources Protection Act of 1979
ARRC	Alaska Railroad Corporation
AS	Alaska Statute
ASAP	Alaska Stand Alone Pipeline
ASME	American Society of Mechanical Engineers
ASOS	Automated Surface Observation System
ASRC	Arctic Slope Regional Corporation
ATC	Allakaket Tribal Council
ATWS	additional temporary workspace
AWOS	Automated Weather Observing System
B.C.	British Columbia
BACT	Best Available Control Technology
BGEPA	Bald and Golden Eagle Protection Act
BIA	U.S. Department of the Interior, Bureau of Indian Affairs
BLM	U.S. Department of the Interior, Bureau of Land Management
BMP	best management practices
BOD_5	biochemical oxygen demand
BOEM	U.S. Department of the Interior, Bureau of Ocean Energy Management
BOG	boil-off gas
BP	Before Present
C.F.R.	Code of Federal Regulations
CAA	Clean Air Act
CAMA	Central Arctic Management Area
CCP	Comprehensive Conservation Plans
CDP	Census Designated Place
CEA	Chugach Electric Association
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CGF	Central Gas Facility
CGP	Construction General Permit
CH_4	methane
CHA	Critical Habitat Area
CIRCAC	Cook Inlet Regional Citizens Advisory Council

ABBREVIATION	DEFINITION
CIRI	Cook Inlet Region Inc.
CLG	Certified Local Government
CO	carbon monoxide
CO_2	carbon dioxide
CO_2e	total greenhouse gas emissions, in CO_2-equivalent global warming potential
COC	Certificate of Compliance
CONUS	Continental U.S.
COOP	National Weather Service, Cooperative Observer Program
CPCN	Certificate of Public Convenience and Necessity
CRA	Certificate of Reasonable Assurance
CSD	Contaminated Sites Database
CSP	Contaminated Sites Program
CSU	conservation system units
CV	coefficient of variation
CWA	Clean Water Act
DB	Denali Borough
DEM	Digital Elevation Model
DGGS	ADNR Division of Geological and Geophysical Surveys
DH	dock head
DHSS	Alaska Department of Health and Social Services
DMLW	Alaska Department of Natural Resources, Division of Mining, Land, and Water
DPS	Distinct Population Segment
DWPP	Drinking Water Protection Program
EDA	U.S. Department of Commerce, Economic Development Administration
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
EO	Executive Order
EPA	U.S. Environmental Protection Agency
EPRP	Emergency Preparedness and Response Plan
ERL	Environmental, Regulatory and Lands
ERMA	Extended Recreation Management Areas
ESA	Endangered Species Act
ESD	Emergency Shut Down
ESU	Evolutionary Significant Unit
FAA	U.S. Department of Transportation, Federal Aviation Administration
FCC	Federal Communications Commission
FE	U.S. Department of Energy, Office of Fossil Energy
FEED	front-end engineering design
FEIS	Final Environmental Impact Statement
FEMA	U.S. Department of Homeland Security, Federal Emergency Management Agency
FERC	U.S. Department of Energy, Federal Energy Regulatory Commission

ABBREVIATION	DEFINITION
FERC Plan	FERC Erosion Control, Revegetation, and Maintenance Plan
FERC Procedures	FERC Wetland and Waterbody Construction and Mitigation Procedures
FLPMA	Federal Land Policy and Management Act (of 1976) BLM
FMP	Fisheries Management Plan
FNSB	Fairbanks North Star Borough
FR	Federal Regulation
GDP	Gross Domestic Product
GHG	greenhouse gases
GIS	geographic information system
GMU	Game Management Units
GP	General Permit
GRI	Gas Research Institute
GTP	gas treatment plant
GWP	Global Warming Potential
H_2S	hydrogen sulfide
HABS	Historic American Building Survey
HAER	Historic American Engineering Record
HAP	Hazardous Air Pollutant
HAPC	Habitat Areas of Particular Concern
HCA	High Consequence Area
HDD	horizontal directional drill
HDMS	Hazard Detection and Mitigation System
HGM	hydrogeomorphic
HLV	heavy lift vessel
HMR	Hazardous Materials Regulations
HRS	Hazard Ranking System
IBA	Important Bird Areas
ICS	Incident Command System
IHA	Incidental Harassment Authorization
IHLC	Inupiat History, Language, and Culture
ILI	In-line Inspection
IMP	Integrity Management Plan
IP	Individual Permit
ISO	International Organization for Standardization
JPO	State and Federal Joint Pipeline Office
kbpd	thousand barrels per day
KCC	Kuparuk Construction Camp
KOP	key observation points
KPB	Kenai Peninsula Borough
KTC	Kuparuk Transportation Company
LiDAR	light detection and ranging
Liquefaction Facility	natural gas liquefaction

ABBREVIATION	DEFINITION
LLC	Limited Liability Company
LNG	liquefied natural gas
LNGC	liquefied natural gas carrier
LOA	Letter of Authorization
LOD	Limits of Distribution
LP	Limited Partnership
LPG	liquefied petroleum gas
LUP	Land Use Permit
LUST	Leaking Underground Storage Tanks
MACT	maximum achievable control technology
Mainline	An approximately 800-mile-long, large-diameter gas pipeline
MAOP	maximum allowable operating pressure
MARPOL	Marine Pollution Protocol
MBTA	Migratory Bird Treaty Act
MCD	marine construction dock
MHHW	mean higher high water
MHW	mean high water
ML&P	Anchorage Municipal Light and Power
MLA	Mineral Leasing Act
MLBV	Mainline block valve
MLLW	mean lower low water
MLW	mean low water
MMPA	Marine Mammal Protection Act
MMS	Mainline Meter Station
MOE	margin of error
MOF	material offloading facility
MP	Mainline milepost
MPRSA	Marine Protection Research and Sanctuaries Act of 1972
MSB	Matanuska-Susitna Borough
MSCFD	Thousand standard cubic feet per day
N_2O	nitrous oxide
NAAQS	National Ambient Air Quality Standards
NAS	nonindigenous aquatic species
NCC	national certification corporation
NCDC	National Climatic Data Center
NDE	non-destructive examination
NEP	non-essential experimental population
NEPA	National Environmental Policy Act
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NFIP	National Flood Insurance Program
NGA	Natural Gas Act
NHPA	National Historic Preservation Act of 1996, as amended

ABBREVIATION	DEFINITION
NID	Negligible Impact Determination
NLURA	Northern Land Use Research Alaska, LLC
NMFS	National Oceanic and Atmospheric Administration, National Marine Fisheries Service
NO_2	nitrogen dioxide
NO_X	nitrogen oxides
NOAA	National Oceanographic and Atmospheric Administration
NOI	Notice of Intent
North Slope	Alaska North Slope
NPDES	National Pollutant Discharge Elimination Systems
NPL	National Priority List
NPP	National Park and Preserve
NPR-A	National Petroleum Reserve – Alaska
NPS	National Park Service
NRCS	Natural Resources Conservation Service
NRHP	National Register of Historic Places
NSA	Noise-Sensitive Areas
NSB	North Slope Borough
NSPS	New Source Performance Standards
NTC	national training center
NTP	Notice to Proceed
NVIC	Navigation and Vessel Inspection Circular
NWA	Northwest Alaska Pipeline
NWI	National Wetland Inventory
NWR	National Wildlife Refuge
O_3	Ozone
OC	open-cut
OCS	Outer Continental Shelf
OD	outside diameter
OEP	FERC, Office of Energy Projects
OHA	ADNR Division of Parks and Outdoor Recreation, Office of History and Archaeology
ONA	Outstanding Natural Area
OPMP	ADNR, Office of Project Management and Permitting
OU	Operating unit
PAC	potentially affected community
Pb	the element lead
PBTL	Prudhoe Bay Gas Transmission Line
PBU	Prudhoe Bay Unit
PCB	polychlorinated biphenyl
PHMSA	Pipeline and Hazardous Materials Safety Administration
$PM_{2.5}$	particulate matter having an aerodynamic diameter of 2.5 microns or less
PM_{10}	particulate matter having an aerodynamic diameter of 10 microns or less
PMP	Point Thomson Gas Transmission Line milepost

ABBREVIATION	DEFINITION
POC	Plan of Cooperation
POD	Plan of Development
Project	Alaska LNG Project
PRPA	Paleontological Resources Preservation Act
PSD	Prevention of Significant Deterioration
PTTL	Point Thomson Gas Transmission Line
PTU	Point Thomson Unit
PWS	public water supply
Q&A	question and answer
RCA	Regulatory Commission of Alaska
RCRA	Resource Conservation and Recovery Act
RNA	Research Natural Area
ROD	Record of Decision
ROE	right-of-entry
ROW	right-of-way
RR	Resource Report
SCC	Deadhorse Airport
SDWA	Safe Drinking Water Act
SEIS	Supplemental Environmental Impact Statement
SGR	State Game Refuge
SHPO	State Historic Preservation Office(r)
SIP	State Implementation Plan
SMA	Special Management Areas
SRMA	Special Recreation Management Areas
SO_2	sulfur dioxide
SPCC	Spill Prevention, Control, and Countermeasure Plan
SPCO	State Pipeline Coordinator's Office
SPLASH	Structure of Populations, Levels of Abundance, and Status of Humpbacks
SPMT	self-propelled module transporters
SRA	State Recreation Area
SRR	State Recreation River
STATSGO	State Soil Geographic
STATSGO2	State Soil Geographic2 – General Soils Map of Alaska & Soils Data (2011)
SWAPA	Southwest Alaska Pilots Association
SWPPP	Stormwater Pollution Prevention Plan
TAHC	total aliphatic hydrocarbons
TAPS	Trans-Alaska Pipeline System
TBD	To be determined
TCC	Tanana Chiefs Conference
The Applicants' Plan	Applicants' Upland Erosion Control, Revegetation, and Maintenance Plan
The Applicants' Procedures	Applicants' Wetland and Waterbody Construction, and Mitigation Procedures
TPAH	total polycyclic aromatic hydrocarbons

ABBREVIATION	DEFINITION
TSA	Transportation Security Administration
TSCA	Toxic Substances Control Act
TSD	tug support dock
TSS	total suspended solids
UCIDA	United Cook Inlet Drift Association
UIC	Underground Injection Control
U.S.	United States
U.S.C.	U.S. Code
USACE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard
USDA	U.S. Department of Agriculture
USDHHS	U.S. Department of Health and Human Services
USDOE	U.S. Department of Energy
USDOI	U.S. Department of the Interior
USDOT	U.S. Department of Transportation
USDW	underground sources of drinking water
USFS	U.S. Department of Agriculture, Forest Service
USFWS	U.S. Department of the Interior, Fish and Wildlife Service
USGS	U.S. Geological Survey
VOC	volatile organic compound
VPSO	Village Public Safety Officer
VRM	Visual Resource Management Methodology
VSM	Vertical Support Members
WELTS	Well Log Tracking System
WRCC	Western Regional Climate Center
WSA	Waterway Suitability Assessment
WSR	Wild and Scenic Rivers

Information in this draft Resource Report, including maps, is preliminary and may change during Project pre-filing. Updated information will be provided in the subsequent draft and final versions of the Resource Reports.

6.0 RESOURCE REPORT NO. 6 – GEOLOGICAL RESOURCES

6.1 PROJECT DESCRIPTION

The Alaska Gasline Development Corporation, BP Alaska LNG LLC, ConocoPhillips Alaska LNG Company, ExxonMobil Alaska LNG LLC, and TransCanada Alaska Midstream LP (Applicants) plan to construct one integrated LNG Project (Project) with interdependent facilities for the purpose of liquefying supplies of natural gas from Alaska, in particular the Point Thomson Unit (PTU) and Prudhoe Bay Unit (PBU) production fields on the Alaska North Slope (North Slope), for export in foreign commerce and opportunity for in-state deliveries of natural gas.

The Natural Gas Act (NGA), 15 U.S.C. § 717a(11) (2006), and FERC regulations, 18 C.F.R. § 153.2(d) (2014), define "LNG terminal" to include "all natural gas facilities located onshore or in State waters that are used to receive, unload, load, store, transport, gasify, liquefy, or process natural gas that is ... exported to a foreign country from the United States." With respect to this Project, the "LNG terminal" includes the following: a liquefaction facility (Liquefaction Facility) in Southcentral Alaska; an approximately 800-mile, large diameter gas pipeline (Mainline); a gas treatment plant (GTP) on the North Slope; a gas transmission line connecting the GTP to the PTU gas production facility (PTU Gas Transmission Line or PTTL); and a gas transmission line connecting the GTP to the PBU gas production facility (PBU Gas Transmission Line or PBTL). All of these facilities are essential to export natural gas in foreign commerce.

These components are shown in Resource Report No. 1, Figure 1.1-1, and their current basis for design is described below.

The new Liquefaction Facility will be constructed on the eastern shore of Cook Inlet in the Nikiski area of the Kenai Peninsula. The Liquefaction Facility will include the structures, equipment, underlying access rights and all other associated systems for pre-processing (other than that performed by the GTP) and liquefaction of natural gas, as well as storage and loading of LNG, including terminal facilities (dock) and auxiliary marine vessels used to support marine terminal operations (excluding LNG carriers). The Liquefaction Facility will include three liquefaction trains combining to process up to approximately 20 million metric tons per annum (MMTPA) of LNG. Three 160,000 cubic meter (m^3) tanks will be constructed to store the LNG. The Liquefaction Facility will be capable of accommodating two LNG carriers. The size range of LNG carriers that the Liquefaction Facility will accommodate will be determined through further engineering study and consultation with the United States Coast Guard (USCG) as part of the Waterway Suitability Assessment (WSA) process.

In addition to the Liquefaction Facility, the LNG Terminal will include the following interdependent facilities:

- Mainline: A new large-diameter natural gas pipeline approximately 800 miles in length will extend from the Liquefaction Facility to the GTP on the North Slope, including the structures, equipment, and all other associated systems. The diameter of the pipeline has not been finalized but for the purpose of these Resource Reports a 42-inch diameter pipeline is assumed. The Mainline will include compressor stations, heater stations, meter stations, and various mainline block valves; pig launcher and receiver facilities; and associated ancillary and auxiliary facilities. Ancillary and auxiliary facilities will include additional temporary work spaces, access roads, helipads, construction camps, pipe storage areas, contractor yards, material extraction sites, and material disposal sites. Along the Mainline route, there will be at least five off-take interconnection points to allow for the opportunity for future in-state deliveries of natural gas. The size and location of such interconnection points are unknown at this time. None of the potential third-party facilities used to condition, if required, or move natural gas away from these off-take points will be part of the Project.

- GTP: A new GTP and associated facilities in the Prudhoe Bay area will receive natural gas from the PBU Gas Transmission Line and the PTU Gas Transmission Line. The GTP will treat/process the natural gas for delivery into the Mainline. The Project also includes a new pipeline that will deliver natural gas processing byproducts from the GTP to the PBU.

- PBU Gas Transmission Line: A new natural gas transmission line will extend approximately one mile from the inlet flange of the GTP to the outlet flange of the PBU gas production facility.

- PTU Gas Transmission Line: A new natural gas transmission line will extend approximately 60 miles from the inlet flange of the GTP to the outlet flange of the PTU gas production facility.

- Ancillary Facilities: Existing State of Alaska transportation infrastructure will be used during the construction of these new facilities including ports, airports, roads, and airstrips (potentially including previously abandoned airstrips). The potential need for new infrastructure and modifications or additions to these existing in-state facilities is under evaluation. The Liquefaction Facility, Mainline, and GTP will require the construction of material offloading facilities.

Draft Resource Report No. 1, Appendices A and B contain general maps of the Project footprint. Detailed plot plans will be developed during the pre-front-end engineering and design (Pre-FEED) process and will be provided to the Commission in a subsequent draft of Resource Report No. 1. An update to the current list of affected landowners is being filed under separate cover as privileged and confidential information.

Outside the scope of the Project, but in support of, or related to, the Project, additional facilities or expansion/modification of existing facilities will be needed or may be constructed. These other projects may include:

- Modifications/new facilities at the PTU;

- Modifications/new facilities at the PBU;

- Relocation of the Kenai Spur Highway; and

- Third-party pipelines and associated infrastructure to transport natural gas from the off-take interconnection points to markets in Alaska.

6.1.1 Purpose of Resource Report

As required by 18 C.F.R. § 380.12, Alaska LNG Applicants have prepared this draft Resource Report in support of their application under Section 3 of the NGA to construct and operate the Project facilities. The purpose of this draft Resource Report is as follows:

- Describe the existing geologic setting, mineral resources, geologic hazards, and paleontological resources in the vicinity of the Project;
- Summarize potential effects to these resources resulting from the construction and operation of the Project; and
- Identify potential general mitigation measures to avoid or minimize potential adverse effects to geological and paleontological resources in the vicinity of the Project area.

The data for this Resource Report were compiled based on a review of the following:

- Engineering design and proposed construction plans;
- USGS topographic maps;
- Recent aerial photography;
- Field survey data;
- Scientific literature; and
- Geographic Information System (GIS) data from federal and state agencies.

Upon completion of a review of the Project footprint and available information, including studies by private oil and natural gas companies, geotechnical investigations (subsurface exploration and laboratory testing program) for support of engineering design and execution planning will be conducted to reduce effects of geotechnical hazards. This will include offshore hazard surveys.

6.1.2 Agency and Organization Consultations

This section describes consultations that have been conducted with agencies and other parties interested in the Project. As Project details are refined in the Pre-FEED process currently underway, consultations will be conducted. A subsequent draft of this Resource Report will describe these consultations.

6.1.2.1 Federal Agencies

A summary of all Public, Agency, and Stakeholder Engagement is provided in Resource Report No. 1, Appendix C. Subsequent versions of this report will provide summaries of any meetings related to geological resources.

6.1.2.2 State Agencies

A summary of Public, Agency, and Stakeholder Engagement is provided in Resource Report No. 1, Appendix C. Subsequent versions of this report will provide summaries of any meetings with state agencies concerning geological resources.

6.2 PHYSIOGRAPHIC AND GEOLOGIC SETTING

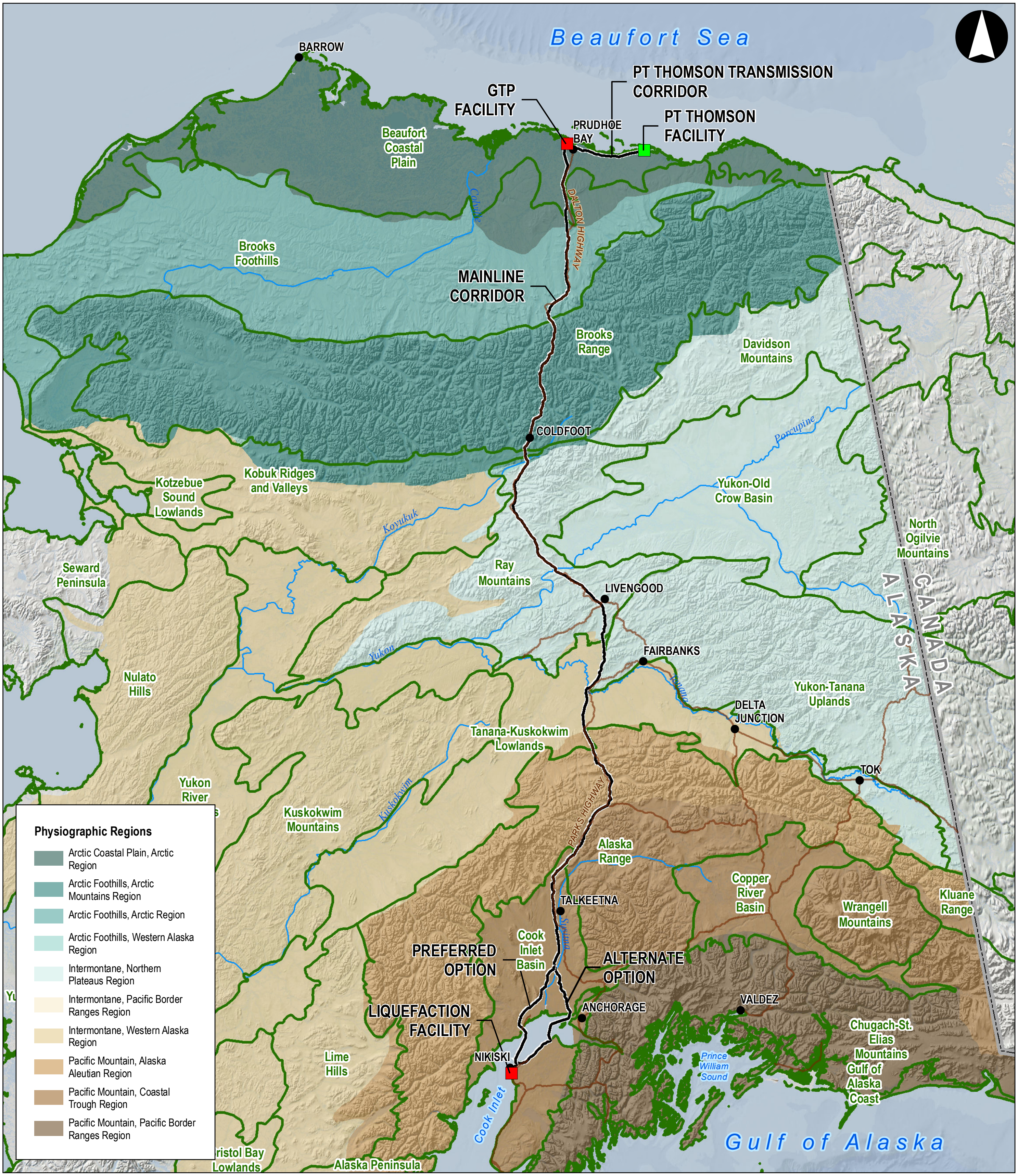
6.2.1 Physiographic Regions and Ecoregions

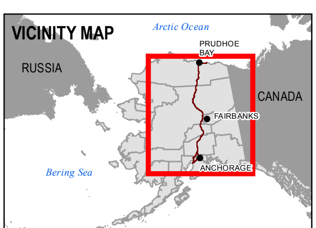
Alaska comprises the far northwestern portion of the North American continent. The state is bordered by the Arctic Ocean to the north, the Bering and Chukchi Seas to the west, the Pacific Ocean to the south and Canada to the east. The southern border of the state lies on the edge of the tectonic boundary between the Pacific Plate, which underlies the Pacific Ocean, and the North American Plate, upon which Alaska resides. The Pacific Plate is being thrust (subducted) beneath Alaska within a subduction zone, or a megathrust. This convergence of the two tectonic plates is responsible for making Alaska a geologically active landscape, most notably producing the Aleutian chain of volcanoes and earthquake activities in the state.

Alaska contains two massive east-west trending mountain ranges, the Brooks and Alaska Range. The Brooks Range is the oldest mountain range in Alaska, and is an extension of the Canadian Rockies. The Alaska Range is a young, actively uplifting mountain range forming as a result of the convergence of the Pacific and North American plates. Between the mountain ranges are extensive stretches of lowlands that are traversed by major rivers.

Throughout the last ice age and up through today, glaciers and massive ice sheets have shaped the terrain, carving out valleys and depositing thick blankets of glacial sediments in low-lying regions. Freeze and thaw cycles, erosion by water and wind, and mass wasting continue to shape the geomorphology of the landscape.

The vast terrain of Alaska has been divided into general physiographic regions based on variation in topography and large-scale geomorphic processes (Wahrhaftig, 1965). Additionally, the state has been divided into ecoregions that are more specific to the discipline of geology, based on lithology, soil type, surficial geology, and land cover (Nowacki et al., 2002). The following sections provide a description of the ecoregions and physiographic regions crossed by the Project area. The ecoregions and physiographic regions along the Project corridor are mapped in Figure 6.2.1-1 and described in Table 6.2.1-1.





LEGEND

- Project Facility
- Existing Facility
- Alaska Place Names
- Project Corridor
- Major Highways
- Major Rivers
- Ecoregions

0 25 50 100 150 Miles

DISCLAIMER

The information contained herein is for informational or planning purposes only, It does not nor should it be deemed to be an offer, request or proposals for rights or occupation of any kind. The Alaska LNG Project Participants and their respective officers, employees and agents, make no warranty, implied or otherwise, nor accept any liability, as to the accuracy or completeness of the information contained in these documents, drawings or electronic files. Do not remove or delete this note from document, drawing or electronic file.

PREPARED BY:	EXP ENERGY SERVICES INC.
SCALE:	1:6,000,000
DATE: 2015-01-12	SHEET: 1 of 1

ALASKA PHYSIOGRAPHIC REGIONS & ECOREGIONS

FIGURE 6.2.1-1

Alaska LNG

X:\Projects\ExxonMobil\SCLNG\Mapping\20150106_ResourceReportFigures_Rev3\RR6\Figure 6_2_1-1 Physiographic Regions and Ecoregions.mxd

TABLE 6.2.1-1

Physiographic Provinces and Ecoregions Crossed by the Alaska LNG Project

<table>
<tr><th>Physiographic Region[a]</th><th>Ecosystem[b]</th><th>Ecoregion[c]</th><th>Borough/Census Area</th><th>Alaska LNG Facility</th></tr>
<tr><td>Arctic Coastal Plain</td><td rowspan="5">Polar-Arctic Tundra</td><td>Beaufort Coastal Plain</td><td rowspan="4">North Slope Borough</td><td>Mainline
PTTL
PBTL
GTP</td></tr>
<tr><td rowspan="4">Arctic Mountains</td><td>Brooks Range Foothills</td><td>Mainline</td></tr>
<tr><td rowspan="3">Brooks Range</td><td>Mainline</td></tr>
<tr><td>Mainline</td></tr>
<tr><td rowspan="4">Yukon-Koyukuk Census Area</td><td>Mainline</td></tr>
<tr><td rowspan="2">Interior Lowlands and Uplands</td><td rowspan="8">Boreal- Intermontane Boreal</td><td>Kobuk Ridges and Valleys</td><td>Mainline</td></tr>
<tr><td>Ray Mountains Yukon Tanana Uplands</td><td>Mainline</td></tr>
<tr><td rowspan="2">Yukon-Tanana Uplands</td><td rowspan="3">Ray Mountains</td><td>Mainline</td></tr>
<tr><td>Fairbanks North Star Borough</td><td>Mainline</td></tr>
<tr><td rowspan="3">Tanana-Kuskokwim Lowlands</td><td rowspan="3">Yukon-Koyukuk Census Area</td><td>Mainline</td></tr>
<tr><td rowspan="3">Tanana Kuskokwim Lowlands</td><td>Mainline</td></tr>
<tr><td>Mainline</td></tr>
<tr><td rowspan="4">Alaska Range</td><td rowspan="2">Denali Borough</td><td>Mainline</td></tr>
<tr><td rowspan="5">Boreal-Alaska Range Transition</td><td rowspan="3">Alaska Range</td><td>Mainline</td></tr>
<tr><td rowspan="3">Matanuska-Susitna Borough</td><td>Mainline</td></tr>
<tr><td>Mainline</td></tr>
<tr><td rowspan="2">Cook Inlet-Susitna Lowlands</td><td rowspan="2">Cook Inlet Basin</td><td>Mainline</td></tr>
<tr><td>Kenai Peninsula Borough</td><td>Liquefaction Facility</td></tr>
</table>

a Major Land Resource Regions as provided in NRCS Staff (2004).
b Physiographic regions generalized from Nowacki, G., Spencer, P., Fleming, M., Brock, T. and Jorgenson, T. 2001. Unified Ecoregions of Alaska, U.S. Geological Survey Open-File Report 02-297. 1 sheet, scale 1:4,000,000.
c Unified Ecoregions of Alaska (Nowacki et al. 2001).

6.2.1.1 Liquefaction Facility

The Liquefaction Facility will be located in the Cook Inlet Basin Ecoregion. A description of the terrain, bedrock, surficial geology, and current geomorphic processes within this ecoregion is provided below.

Cook Inlet Basin Ecoregion

The Liquefaction Facility will be sited on the northeastern shore of the Cook Inlet Basin, amid Holocene through Upper Pleistocene glaciolacustrine deposits (Wilson, 2012). Underlying bedrock is oil and gas-bearing Upper Tertiary continental deposits, including sandstone, siltstone, claystone, conglomerate, and coal beds (Beikman, 1980).

6.2.1.2 Interdependent Facilities

For the purpose of this section, the Interdependent Facilities include the Mainline, GTP, PBTL, and PTTL. The physiographic provinces and ecoregions crossed by the Interdependent Facilities are provided in Table 6.2.1-1. An overview of the terrain, bedrock, surficial geology, and current geomorphic processes within each ecoregion crossed by the Interdependent Facilities is provided below.

Beaufort Coastal Plain Ecoregion

The northern-most portion of the Project occurs in the Beaufort Coastal Plain Ecoregion, which runs north of the intersection between Ivishak and Sagavanirktok Rivers just north of the Brooks Range Foothills Ecoregion. The Beaufort Coastal Plain includes the area around the North Slope’s Prudhoe Bay, and extends eastward towards Point Thompson. The region includes both onshore and offshore areas along the continental shelf, which gently slopes seaward at an average gradient of four feet per mile. The area is drained by the Sagavanirktok River, which meanders in its upper reaches and is braided in its lower reaches. The river has a wide, coarse-grained floodplain (Harrison and Osterkamp, 1976).

The bedrock in the Beaufort Coastal Plain Ecoregion comprises thick sequences of Paleozoic to Cenozoic sedimentary rocks, including sandstone, siltstone, and shale. Strata dip gently to the north. These sedimentary rocks contain valuable deposits of oil and natural gas, and have been the target of petroleum exploration in the North Slope region. Depth to bedrock varies from just a few feet to hundreds of feet beneath young overlying sediments.

Overlying the bedrock are varied deposits of both marine and terrestrial sediments that reflect the rise and fall of sea level since the last ice age. Sediments up to hundreds of feet thick underlie the coastal North Slope area and extend approximately 50 miles offshore. The deposits include glaciofluvial deposits, braided stream alluvium, peat, deltaic sediments, shallow marine fine sand, silt, clay, and ice-rafted boulders. In local areas where sediments are coarse-grained and more resistant to erosion, constructional shoals, sandbars, and barrier islands have formed. An example is Reindeer Island, about 8 miles offshore of Prudhoe Bay.

Permafrost is extensive throughout the Beaufort Coastal Plain Ecoregion. As a result, soils in the area are very poorly drained. Downward percolation of groundwater is very restricted and permafrost and freeze/thaw features dominate the landscape. Polygonal shaped ground caused by expansion of ice wedges is common throughout the region, as are pingos, small ice-cored hills resulting from growing ground-ice masses.

Brooks Range Foothills Ecoregion

Immediately north of Galbraith Lake and Atigun River, the Mainline corridor transects an 80-mile stretch of the Brooks Range Foothills Ecoregion that generally parallels the Sagavanirktok River north of the Brooks Range. The Brooks Range Foothills comprise of broad uplands rising towards the south. Devonian and Cretaceous sandstone and shale strata form east- to west-trending ridges and mesas along the northern foothills, and irregular buttes, mesas, and ridges farther south. This bedrock is overlain in the lower areas by Quaternary sediments, including alluvium, colluvium, glacial deposits, and loess.

Brooks Range Ecoregion

The Mainline corridor follows the Middle Fork Koyukuk, Dietrich and Atigun river valleys for just over 100 miles in the Brooks Range Ecoregion, north of the Kobuk Ridges and Valleys Ecoregion. Relief rises abruptly from several hundred feet in the northern foothills up to 8,000 feet above sea level in the higher peaks of the Brooks Range to the south. The range trends east and west, and forms the continental divide. Streams drain the range towards the north into the Arctic Ocean and south into the Bering Sea, following valleys that have been periodically glaciated. Small valley glaciers flank the higher peaks, but are not extensive. No active glaciers are present along the Mainline corridor where it passes through the Brooks Range.

Bedrock in the northern and central Brooks Range are predominantly folded and faulted Paleozoic to Mesozoic sedimentary rock, including limestone, sandstone, and shale. The geologic section includes tightly folded Paleozoic metamorphic rocks that are interspersed within the sedimentary rock sequence. Farther south in the range, Proterozoic to Paleozoic metamorphic rocks dominate, with minor granitic intrusions.

In the Brooks Range Ecoregion, valley bottoms are buried with deep colluvium and coarse-grained floodplain deposits. The actively eroding mountain valleys are lined with talus slopes, alluvial fans, outwash terraces, and colluvial and alluvial fans. Glacial moraines also line valleys where glaciers have retreated in the past. High elevation valleys in the range also contain snow avalanche and slushflow deposits.

Mass wasting is prevalent throughout the Brooks Range. Rock glaciers, landslides, flow slides, and solifluction lobes move down slopes and valleys at variable rates. The Dietrich River Valley in particular is host to abundant solifluction lobes and flow slides. Solifluction lobes are particularly abundant where bedrock is shale, phyllite, or siltstone. The Dietrich River Valley is narrow and steep in its upper reaches, with abundant fans of alluvium and colluvium along tributaries. Glacial carving is apparent in the wide U-shape of cross profiles in the southern valley, where the floodplain widens and the drainage becomes more braided (Brown and Kreig, 1983).

Kobuk Ridges and Valleys Ecoregion

The Mainline corridor briefly passes through the Kobuk Ridges and Valleys Ecoregion before continuing south into the Ray Mountains. South of the Brooks Range, the Kobuk Ridges and Valleys Ecoregion has largely been shaped by glacial activity throughout the last Ice Age. Glaciers repeatedly scoured down the valleys, leaving behind wide, U-shaped valleys. Bedrock outcrops are minimal throughout the Ecoregion, as the area is draped with thick glacial deposits. Where bedrock does outcrop along high ridges, it is composed of Cretaceous sandstones, shale, siltstone and conglomerate (Beikman, 1980). Thick accumulations of glacial sediment have been deposited throughout lowlands and deltaic regions, and geomorphic features exhibit erosion by streams and wind.

Ray Mountains Ecoregion

The south-trending ridgeline that the Mainline corridor will follow south of Livengood for almost 30 miles in the Ray Mountains is composed of early Cretaceous flysch of the Wilber Creek unit (graywacke, conglomerate, siltstone, and shale). The Ray Mountains Ecoregion consists of low mountains and hills rising to elevations generally ranging from 2,000 to 4,000 feet. The southern portion of the Ray Mountains Ecoregion is predominantly composed of late Paleozoic to middle Mesozoic fine-grained, massive volcanics and thin interbeds of chert (Foster and Keith, 1994).

The Ray Mountains were locally glaciated during the Pleistocene, and are now mostly unglaciated and covered with colluvial and eolian deposits. Retransported eolian deposits are abundant in lower elevations.

Yukon-Tanana Uplands Ecoregion

The Mainline corridor parallels a 20-mile stretch of south-trending ridges of the Yukon-Tanana Uplands Ecoregion, surrounded by the Tanana River Valley. These uplands consist of rounded hills rising 500 – 1500 feet above adjacent valleys (up to 3000 feet total elevation) with gentle side slopes. Similar to the Ray Mountains, the Yukon-Tanana Uplands were subject to local alpine glaciation during the Pleistocene. Bedrock is composed felsic schist, micaceous quartzite, chloritic or actinolitic greenschist, greenstone, and marble of the Fairbanks Schist unit (360-540 Ma), as well as, allochthonous garnet-bearing quartz-biotite-muscovite schist and quartzite (250-540 Ma) (Wilson et al., 1998).

Tanana-Kuskokwim Lowlands

The Mainline corridor drops into the Tanana River Valley (Tanana-Kuskokwim Lowlands) for nearly 50 miles, surrounded by the Alaska Range to the south and the Ray Mountains to the north. The Tanana-Kuskokwim Lowlands Ecoregion consists of a flat area with an accumulation of Quaternary colluvial and eolian deposits, reworked by various meandering rivers and creeks. Bedrock is buried by a thick layer of Quaternary soils, but would likely consist of metasedimentary conglomerate-mudstone, arenite, chert, and quartzite of the Wickersham unit (480-1000 Ma), as well as, Fossil Creek Volcanics (440-480 Ma) that extend into the lowlands from the Ray Mountains Ecoregion to the northwest (alkali basalt, agglomerate, and volcanoclastic conglomerate) (Wilson et al., 1998). Additionally, bedrock may include Tertiary conglomerate, mudstone, claystone, lignite, and sandstone of the Nenana unit (1.8-23 Ma) in the southern portions of the lowlands, mixed with abundant Phanerozoic metavolcanic and metavolcaniclastic rocks (318-416 Ma) and locally younger, possibly coal-bearing sedimentary rocks (5-55 Ma). Outcrops of this bedrock occur in the southern portion of the Mainline corridor near the Yukon-Tanana Uplands.

Alaska Range Ecoregion

The Alaska Range Ecosystem is composed of several accreted terranes, creating a highly diverse belt of rocks trending generally southwest-northeast along the Project corridor (Wilson et al., 1998). The rugged mountains and hills are separated by lowlands of moraines and outwash from Pleistocene glaciation. In the northern portion of the Alaska Range Ecoregion, the Mainline corridor will likely intersect abundant conglomerate, mudstone, claystone, lignite, and sandstone of the Tertiary Nenana unit (1.8-23 Ma), with some intermittent metavolcanic and metavolcaniclastic rocks (318-416 Ma). Younger, possibly coal-bearing sedimentary rocks have been mapped across the Nenana River and also crop out through colluvium in the valleys or along shallow ridges in the corridor, especially along the Healy fault near Dry Creek and Otto Lake.

The Park Road fault, at the intersection of the Denali Park Road and George Parks highway, separates pelitic and quartzose schist and phyllite of the Alaska Range unit to the north (360-543 Ma) from the Cantwell Formation to the south (65-83 Ma). The upper Cantwell Formation consists of upper volcanic rocks (rhyolite, dacite, andesite, and felsic volcanics), which are expected to crop out along the western edge of Mount Fellows in the Mainline corridor, as well as, lower sedimentary conglomerate, shale, sandstone, coal, arkose, siltstone, and argillite. Cantwell rocks are also mixed with early Cretaceous and late Jurassic marine metasedimentary flysch as part of the Gravina-Nuzotin belt (99-161 Ma). Additionally, intermittent outcrops of Triassic (200-251 Ma) schist, quartzite, and amphibolite are mapped throughout the area, along with traces of the late Devonian Yanert Fork sequence (360-385 Ma), a thick marine sequence of metasedimentary and metavolcanic rocks in the Yanert River valley.

Farther south is the Denali Fault zone, where the bedrock in this area likely consists of a continuation of the Cantwell Formation from the north, as well as some late Triassic (199-228 Ma) subaerial basalt flows of the Nikolai Greenstone, mixed with mélange and limestone blocks north of the Denali fault. Immediately south, and along the western flanks of the Reindeer Hills, the Mainline corridor will intersect flysch (99-161 Ma), as well as, Paleocene to Miocene hypabyssal felsic and intermediate intrusions (1.8-65 Ma). The Reindeer Hills are predominantly composed of Nikolai flood basalts, which outcrop along the western edge of the George Parks Highway and the Project corridor, terminating at the mouth of Eldridge Glacier.

Cook Inlet Basin Ecoregion

The preferred Mainline corridor (western corridor) will cross Cook Inlet northward from Nikiski and land on the northwestern shores of the Cook Inlet Basin amid the diverse glacial deposits that span the region. Holocene to Upper Pleistocene glacial deposits here include alluvium, moraines, glacioestuarine, and modified glacial deposits (Wilson, 2012). Underlying bedrock is oil and gas-bearing Upper tertiary sandstone, siltstone, claystone, conglomerate, and coal beds (Beikman, 1980). The Mainline corridor will likely intersect outcrops of intermediate to felsic intrusive bedrock near the base of Mount Susitna (e.g., tonalite, monzonite, and grandiorite).

The preferred Mainline corridor (western corridor) will then continue north along the Susitna River drainage, where surface deposits are predominately Upper Pleistocene glacial, glacioestuarine deposits, outwash and stream alluvium, tidal-flat sediments, and estuarine deposits (Reger et al., 2007).

An eastern alternative Project corridor (see Figure 6.2-1) would pass north from the Nikiski area, through Upper Pleistocene moraine and modified glacial deposits (Wilson, 2012). Bedrock in this area is the same oil and gas-bearing Upper Tertiary continental deposits that underlie glacial deposits in the Nikiski area (Beikman, 1980). The eastern alternative Project corridor would cross Cook Inlet to the north, and make landfall among predominately Upper Pleistocene glacial, glacioestuarine deposits, outwash and stream alluvium, tidal-flat sediments, and estuarine deposits. The corridor would continue northward along the Susitna drainage, through these mixed glacial deposits (Reger et al., 2007).

6.2.2 Topography

Topography in the Project area varies widely, from sea level at the North Slope up through the high mountain peaks of the Brooks Range and the Alaska Range, and dips below sea level at the Cook Inlet crossing. Figure 6.2.2-1 shows the topography throughout the Project area. Table 6.2.2-1 summarizes elevations across the Project area and will be completed in subsequent versions of this report.

6.2.2.1 Liquefaction Facility

Cook Inlet Basin Ecoregion

The Liquefaction Facility is located in the northwestern Kenai Peninsula. Wide, gently sloping plains of glacial outwash dominate this area, and relief is low. Elevations range from 100 – 200 feet above sea level.

6.2.2.2 Interdependent Facilities

Topography crossed by the Interdependent Facilities varies from low coastal plains to high mountain passes. A review of the topography is discussed below from north to south along the Mainline and associated Project facilities.

Beaufort Coastal Plain Ecoregion

In the Beaufort Coastal Plain Ecoregion along the North Slope, topographic relief is very minimal. Elevations range from sea level at the coast to approximately 500 feet above sea level, where the land begins to rise up towards the Brooks Range. The land slopes upward to the south at a very low gradient of about 10 feet per mile, making the land appear nearly flat across its wide expanse. Pingos, small ice-cored hills that result from permafrost action, serve as occasional topographic highs, rising up from the flat plains to elevations of tens of feet. Streambanks carved into the lowlands represent the only other notable topography.

Brooks Range Foothills Ecoregion

The Mainline corridor enters the Brooks Range Foothills Ecoregion northwest of the confluence of the Ivishak and Sagavanirktok rivers. The northern plains gently slope upward along the Sagavanirktok River Valley southward towards the Brooks Range Foothills. The corridor runs southward along the west bank of the Sagavanirktok River at approximately 1,500 feet. From there, the corridor steadily rises to an elevation of 2,700 feet above sea level on the north end of Galbraith Lake.

Brooks Range Ecoregion

The Mainline corridor enters the Brooks Range Ecoregion at the north end of Galbraith Lake and shortly crosses the Atigun River at an elevation of 2,700 feet above sea level. The corridor continues southward along the eastern banks of the meandering Atigun River, maintaining an average elevation of 2,700 feet. The elevation gradually rises to the south as the corridor approaches the Continental Divide. The Project corridor crosses the Continental Divide through Atigun Pass, at an elevation of approximately 4,700 feet above sea level. On the south side of the Brooks Range, the corridor gradually descends southwestward across the Chandalar Shelf, reaching an elevation of approximately 2,400 feet in the upper reaches of the

Dietrich River Valley. The corridor continues south along the Dietrich, quickly dropping in elevation. The corridor begins to trend south/southwest starting at the upper reaches of the Middle Fork Koyukuk River Valley, at an elevation of 1,400 feet. The corridor maintains that approximate elevation as it trends southwest along the east bank of the Middle Fork Koyukuk River, dropping elevation slightly south of the town of Wiseman. Finally, the corridor passes the Cathedral Mountains to the east, and diverges from the Koyukuk as it drops to a lower elevation, exiting the Brooks Range Ecoregion at an elevation of some 600 feet above sea level.

Kobuk Ridges and Valleys Ecoregion

After descending along the Brooks Range river valleys, the Project corridor briefly passes through the Kobuk Ridges and Valleys Ecoregion for some five miles, trending southward. The terrain in this ecoregion gently undulates at between 600 and 1,000 feet. Approaching the Ray Mountains to the south, the topography rises to approximately 1,500 feet as the corridor exits the ecoregion.

Ray Mountains Ecoregion

Entering the Ray Mountains Ecoregion, elevations along the Mainline corridor slowly rise to the south. The corridor passes through a series of small valleys between 1,000 and 1,500 feet in elevation. The corridor then drops to approximately 800 feet above sea level to cross the South Fork of the Koyukuk River. From there, the corridor trends southwestward, roughly paralleling the Jim River at approximately 1,200 feet, and passing east of the Kanuti Flats. The Mainline corridor turns south at Prospect Creek, passing through undulating ridges and valleys between 1,000 and 2,000 feet. Near the Fish Creek crossing, the corridor begins to trend southeastward through undulating hills between 1,500 and 2,000 feet in elevation, then crosses the Kanuti River at approximately 1,000 feet. The terrain continues to undulate gently towards the southeast, with elevations ranging between 1,500 and 2,000 feet. Approaching the Yukon, the corridor elevation gradually drops below 1,000 feet, finally crossing the Yukon River at approximately 300 feet. South of the Yukon River, the Project corridor rises rapidly up to approximately 1,000 feet elevation, and extends southeastward through undulating hills and valleys between 1,400 to 1,800 feet elevation to the Cascaden Ridge. The corridor drops to 400 feet to cross the Tolovana River, then continues to the southeast. The corridor trends south across undulating ridges between 1,200 and 1,700 feet in elevation, and then gently drops in elevation to the south as it approaches the Tanana-Kuskokwin Lowlands Ecoregion.

Tanana-Kuskokwim Lowlands Ecoregion (Northern Transect)

The Mainline corridor transects the Tanana-Kuskokwim Lowlands in two locations. The first, more northerly, crossing of the Yukon-Tanana Uplands Ecoregion is a short 10 mile stretch along the Tatalina River Valley at an average of 300 feet elevation. The second crossing is described below.

Yukon-Tanana Uplands Ecoregion

The Mainline corridor meanders southward along the border between the Tanana-Kuskowim Lowlands and the Yukon-Tanana Uplands Ecoregions for some 20 miles. The corridor elevations here range from 300 feet to just over 700 feet on the western flanks of the uplands.

Tanana-Kuskokwim Lowlands Ecoregion (Southern Transect)

After passing through the Yukon-Tanana Uplands, the Mainline corridor once again enters the Tanana-Kuksokwim Lowlands. The first northerly crossing is described above. The second, more southerly, crossing of the ecoregion trends southward above the banks of the Nenana River, at approximately 300 feet. Continuing southward, elevations gradually rise to ~1,200 feet approaching the Alaska Range.

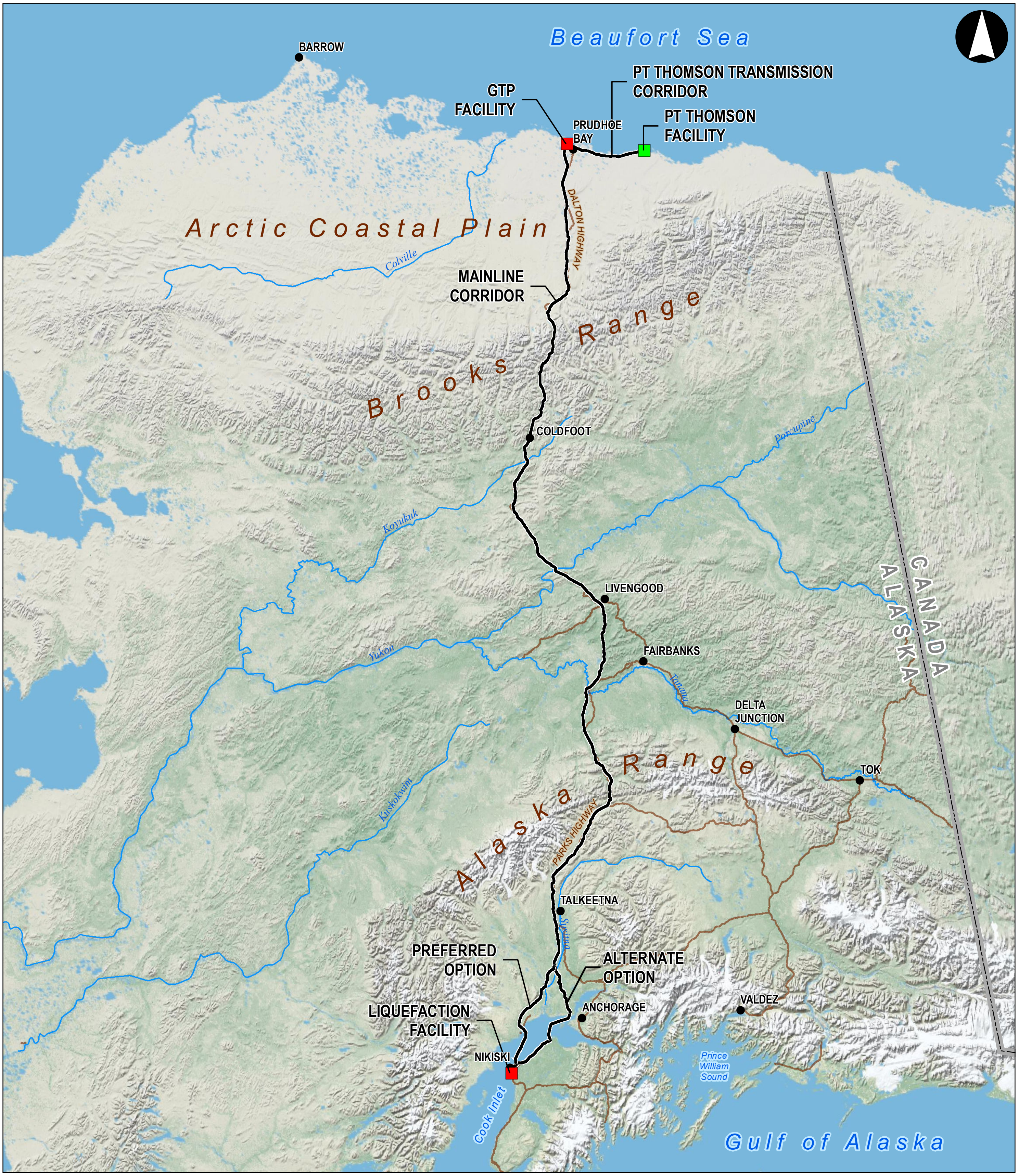
Alaska Range Ecoregion

The Project corridor enters the Alaska Range Ecoregion along the western banks of the Nenana River at approximately 1,100 feet. The corridor follows the Nenana River Valley southward through the north central Alaska Range between 1,000 and 2,000 feet in elevation. The elevations rise up to approximately 3,200 feet as the corridor skirts the western flank of Reindeer Hills. From the base of Reindeer Hills at 2,200 feet, the elevations average 2,200-2,400 feet as the Mainline corridor passes southwestward along the eastern flanks of Broad Pass. The corridor then drops down to the eastern banks of the Chulitna River, and exits the Alaska Range Ecoregion at 1,100 feet elevation.

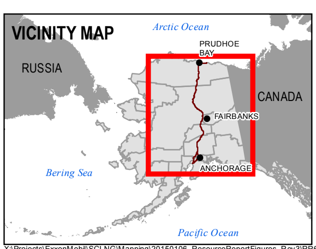
Cook Inlet Basin Ecoregion

At the boundary between the Alaska Range and Cook Inlet Basin Ecoregions, the Project corridor descends from an elevation of approximately 1,100 feet near Little Coal Creek along the Chulitna River southwestward. As the corridor continues along the eastern banks of the Chulitna, the elevation drops to approximately 900 feet near Byers Lake. From here, the corridor turns south and crosses the Chulitna River. The corridor passes west of the confluence of the Chulitna and Susitna Rivers, trending southward at elevations between 400 and 500 feet. The corridor continues south/southwestward along the western banks of the Susitna River, with elevations between 100-200 feet above sea level. Approaching Cook Inlet, the corridor crosses the Yentna River at some 100 feet elevation, then gently rises across the southern and eastern flanks of Mount Susitna between 200 and 300 feet. The Project corridor then trends south-southeast and crosses the Beluga River at some 100 feet in elevation. The corridor then trends southward, turns southeast along Threemile Creek, maintaining an approximate 100-150 elevation, and continues to the shores of Cook Inlet, north of Viapan Lake. The Project corridor then heads southeast into Cook Inlet, where it passes approximately 100 feet below sea level, and trends south-southwest, and making landfall at Boulder Point in Nikishka Bay. The Project corridor then follows the eastern shore of Nikishka Bay at an elevation of 100-200 feet to the south of Bernice Lake and the LNG Facilities.

The eastern alternative Mainline corridor diverges from the westerly route some 12 miles northeast of the confluence of the Yentna and the Susistna Rivers on the north side of Cook Inlet. From there, the eastern route crosses the Susitna River and trends south-southeast to Point Mackenzie, maintaining around 100-200 feet elevation across various wetlands and the Little Susitna River. The corridor then projects nearly one mile into Knik Arm and trends southwest along the boundary between the Matanuska-Susitna and Greater Anchorage Area boroughs. The Mainline curves south into the Kenai Peninsula Borough, dropping to 80 feet below sea level, and heads south towards the mouth of Miller Creek. From there, the corridor follows the eastern shore of Cook Inlet south-southwest at 100 to 200 feet in elevation to reconnect with the western corridor above the shores of Nikishka Bay near Boulder Point.



VICINITY MAP



LEGEND

- Project Facility
- Existing Facility
- Alaska Place Names
- Project Corridor
- Major Highways
- Major Rivers

0 25 50 100 150 Miles

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SCALE:	1:6,000,000
DATE: 2015-01-09	SHEET: 1 of 1

TOPOGRAPHIC MAP

FIGURE 6.2.2-1

Alaska LNG

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TABLE 6.2.2-1

Topography in the Alaska LNG Project Area (By Ecoregion)

Alaska LNG Facility	Approximate MP	Ecoregion	Average Elevation Range (ft)	Topography	Special Features
Liquefaction Facility	Not Applicable	Cook Inlet Basin	100-200	Low relief	Susitna River valley and inlet
Mainline	TBD	Beaufort Coastal Plain	200-500	Low relief	Thermokarst formations; pingos, thaw lakes
	TBD	Brooks Range Foothills	500-2,700	Hills / Low Mtns	Ridges, valleys
	TBD	Brooks Range	600-4,700	Mountains	Rugged mountains
	TBD	Kobuk Ridges and Valleys	600-1,500	Undulating	Ridges, valleys
	TBD	Ray Mountains	600-2,000	Valley	Tolovana River valley and eastern ridgeline
	TBD	Tanana-Kuskokwim Lowlands	300-1,100	Valley	Tanana River valley
	TBD	Yukon-Tanana Uplands	300-700	Undulating Lowlands	Border between two ecoregions
	TBD	Alaska Range	Up to 2,700	Mountain Pass	George Parks Hwy and Nenana River valley - eastern boundary of Denali National Park
	TBD	Alaska Range	Up to 3,800	Ridgeline	Reindeer Hills
	TBD	Alaska Range	1,300-3,800	Valley	Chulitna River valley
	TBD	Cook Inlet Basin	300-1,100	Valley/Foothills	Chulitna River valley
GTP, PBTL PTTL	TBD	Beaufort Coastal Plain	200-500	Low relief	Thermokarst formations; pingos, thaw lakes

6.2.3 Surface and Bedrock Geology

Surficial and bedrock geology of the Project area is summarized in Table 6.2.3-1 using preliminary assessments of the Project corridor. Subsequent versions of this report will provide additional information.

TABLE 6.2.3-1

Surficial Geology and Shallow Bedrock in the Alaska LNG Project Area

Facility Name	Ecoregion	Anticipated Surficial Geology	Bedrock Likely Less than 8 feet Below the Surface	Trenching or Foundation Recommendations
LIQUEFACTION FACILITY				
LNG Plant	Cook Inlet Basin	Glaciofluvial	Not likely	TBD
Marine Terminal	Cook Inlet Basin	Glaciofluvial	Not likely	TBD
PIPELINES				
Mainline	Beaufort Coastal Plain	Glaciofluvial, alluvium	Possible	TBD
	Brooks Range Foothills	Metasedimentary rock, loess	Likely	TBD
	Brooks Range	Metasedimentary rock, colluvium	Likely	TBD
	Kobuk Ridges and Valleys	Metasedimentary rock	Possible	TBD
	Ray Mountains	Metasedimentary, volcanics, colluvium	Possible	TBD
	Tanana-Kuskokwim Lowlands	Colluvium	Not likely	TBD
	Yukon-Tanana Uplands	Metamorphic rocks, colluvium	Possible	TBD
	Tanana-Kuskokwim Lowlands	Colluvium	Not likely	TBD
	Alaska Range	Intrusive rocks, metamorphic rocks, volcanic rocks, glacial, glaciofluvial	Likely	TBD
	Cook Inlet Basin	Glacial deposits and outwash	Possible	TBD
PBTL	Beaufort Coastal Plain	Glaciofluvial, alluvium	Possible	TBD
PTTL	Beaufort Coastal Plain	Glaciofluvial, alluvium	Possible	TBD
PIPELINE ABOVEGROUND FACILITIES				
Liquefaction Facility Meter Station	Cook Inlet Basin	Glaciofluvial	Not likely	TBD
Mainline Meter Station	TBD	TBD	TBD	TBD
PBU Meter Station	Beaufort Coastal Plain	Glaciofluvial, alluvium	Possible	TBD
PTU Meter Station	Beaufort Coastal Plain	Glaciofluvial, alluvium	Possible	TBD

TABLE 6.2.3-1

Surficial Geology and Shallow Bedrock in the Alaska LNG Project Area

Facility Name	Ecoregion	Anticipated Surficial Geology	Bedrock Likely Less than 8 feet Below the Surface	Trenching or Foundation Recommendations
Compressor Stations, Heater Stations, MLBVs (not on Compressor sites)	TBD	TBD	TBD	TBD
PIPELINE ASSOCIATED INFRASTRUCTURE				
Access Roads	TBD	TBD	TBD	TBD
Surficial Geology and Shallow Bedrock in the Alaska LNG Project Area	TBD	TBD	TBD	TBD
Contractor Yards	TBD	TBD	TBD	TBD
Pipe Yards	TBD	TBD	TBD	TBD
Construction Camps	TBD	TBD	TBD	TBD
Disposal Sites	TBD	TBD	TBD	TBD
Material Sites	TBD	TBD	TBD	TBD
GTP				
GTP	Beaufort Coastal Plain	Glaciofluvial, alluvium	Possible	TBD
ASSOCIATED GTP INFRASTRUCTURE				
Module Staging Area	Beaufort Coastal Plain	Glaciofluvial, alluvium	Possible	TBD
Access Roads	Beaufort Coastal Plain	Glaciofluvial, alluvium	Possible	TBD
Construction Camp	Beaufort Coastal Plain	Glaciofluvial, alluvium	Possible	TBD
Material Sites	TBD	TBD	TBD	TBD
Offshore West Dock	TBD	TBD	TBD	TBD
Water Reservoir, Pump Facilities, Transfer Line	TBD	TBD	TBD	TBD

Source: Alaska resource Data File (ARDF), 2014 - http://mrdata.usgs.gov/ardf/

6.2.3.1 Liquefaction Facility

Cook Inlet Basin Ecoregion

The Liquefaction Facility is sited on the northeastern shore of the Cook Inlet Basin, amid Holocene through Upper Pleistocene glaciolacustrine deposits (Wilson, 2012). Underlying bedrock is oil and gas-bearing Upper Tertiary continental deposits, including sandstone, siltstone, claystone, conglomerate, and coal beds (Beikman, 1980).

6.2.3.2 Interdependent Facilities

A diverse geologic environment will be crossed by the Interdependent Facilities. The surface and bedrock geology are discussed below.

Beaufort Coastal Plain Ecoregion

Bedrock geology in the Beaufort Coastal Plain Ecoregion is composed of thick sequences of Paleozoic to Cenozoic sedimentary rocks, including sandstone, siltstone, and shale. Depth to bedrock varies from just a few feet to several hundred feet beneath young overlying sediments. Sediments include glaciofluvial deposits, braided stream alluvium, peat, deltaic sediments, shallow marine fine sand, silt, clay, and ice-rafted boulders (Osterkamp and Harrison, 1976).

Brooks Range Foothills Ecoregion

Bedrock in the Brooks Range Foothills Ecoregion is predominantly Devonian and Cretaceous sandstone and shale. Bedrock outcrops at the surface in many moderate to high elevation areas, and shallow bedrock is present in much of the area. Sedimentary cover varies in thickness, and includes alluvium, colluvium, glacial drift, and loess.

Brooks Range Ecoregion

Bedrock in the Brooks Range Ecoregion is predominantly tightly deformed metasedimentary rocks, with minor felsic intrusions. Bedrock is exposed at the surface in much of the moderate to high elevation areas of the Brooks Range. Valley bottoms are buried by thick colluvium and coarse floodplain deposits. High elevation valleys in the range also contain avalanche and slushflow deposits.

Kobuk Ridges and Valleys Ecoregion

Bedrock in the Kobuk Ridges and Valleys Ecoregion outcrops at and near the surface along the high ridges and moderate peaks. Bedrock includes Upper to Lower Cretaceous rocks, including continental deposits of shale and siltstone in the northern reaches, and sandstones, shale, siltstone and conglomerate farther south (Beikman, 1980). Thick accumulations of glacial sediment have been deposited throughout lowland and deltaic regions.

Ray Mountains Ecoregion

Bedrock in the Ray Mountains Ecoregion includes late Paleozoic to middle Mesozoic fine-grained, massive volcanics, and early Cretaceous flysch (including greywacke, conglomerate, siltstone, and shale) (Foster et al., 1994). The Ray Mountains were locally glaciated during the Pleistocene, and are now mostly unglaciated and covered with colluvial and eolian deposits. Retransported eolian deposits are abundant in lower elevations.

Tanana-Kuskokwim Lowlands Ecoregion (Northern Transect)

The Mainline corridor passes through two main sections of the Tanana-Kuskokwim Lowlands Ecoregion, to the north and south of the Yukon-Tanana Uplands Ecoregion (see Figure 6.2.1-1). The northern section of the Ecoregion is described here.

Bedrock in the northern section of the Tanana-Kuskokwim Lowlands Ecoregion is buried by a thick layer of Quaternary soils and is not well understood. Bedrock likely consists of metasedimentary conglomerate-mudstone, arenite, chert, and quartzite of the Wickersham unit (480-1000 Ma). Fossil Creek Volcanics (440-480 Ma) present in the Ray Mountains Ecoregion to the northwest (alkali basalt, agglomerate, and volcanoclastic conglomerate) are also likely present at depth (Wilson et al., 1998).

Yukon-Tanana Uplands Ecoregion

Bedrock in the Yukon-Tanana Uplands Ecoregion is composed of felsic schist, micaceous quartzite, chloritic or actinolitic greenschist, greenstone, and marble of the Fairbanks Schist unit (360-540 Ma), as well as allochthonous garnet-bearing quartz-biotite-muscovite schist and quartzite (250-540 Ma) (Wilson et al., 1998). Bedrock outcrops at the surface in moderate to high elevations.

Tanana-Kuskokwim Lowlands Ecoregion (Southern Transect)

The Mainline corridor passes through two main sections of the Tanana-Kuskokwim Lowlands Ecoregion, to the north and south of the Yukon-Tanana Uplands Ecoregion (see Figure 6.2.1-1). The southern section of the Ecoregion is described here.

Bedrock outcrops in the southern section of the Tanana-Kuskokwim Lowlands Ecoregion include Tertiary conglomerate, mudstone, claystone, lignite, and sandstone of the Nenana unit (1.8-23 Ma), mixed with abundant Phanerozoic metavolcanic and metavolcaniclastic rocks (318-416 Ma) and locally younger, possible coal-bearing sedimentary rocks (5-55 Ma).

Alaska Range Ecoregion

Bedrock outcrops at, or near, the surface through much of the Alaska Range (Wilson et al., 1998; Wilson et al., 2009). Bedrock in the Alaska Range Ecoregion is extremely diverse, being comprised of multiple accreted terranes that generally trend southwest-northeast along the proposed pipeline corridor. Rugged mountains and hills are separated by lowlands of moraines and outwash from Pleistocene glaciation.

In the northern portion of the Alaska Range Ecoregion, the Project corridor intersects abundant conglomerate, mudstone, claystone, lignite and sandstone of the Tertiary Nenana unit (1.8-23 Ma), with some intermittent metavolcanic and metavolcaniclastic rocks (318-416 Ma). Younger, possible coal-bearing sedimentary rocks have been mapped across the Nenana River that may also outcrop through colluvium in the valleys or along shallow ridges in the corridor, especially along the Healy fault near Dry Creek and Otto Lake.

The Park Road fault (at the intersection of the Denali Park Road and George Parks Highway) separates pelitic and quartzose schist and phyllite of the Alaska Range unit to the north (360-543 Ma) from the Cantwell Formation to the south (65-83 Ma). The Cantwell Formation outcrops along Mt. Fellows and consists of upper volcanic rocks (rhyolite, dacite, andesite and felsic volcanics) as well as lower sedimentary units (conglomerate, shale, sandstone, coal, arkose, siltstone, and argillite). Cantwell rocks are also mixed with early Cretaceous and late Jurassic marine metasedimentary flysch as part of the Gravina-Nuzotin belt (99-161 Ma). Additionally intermittent outcrops of Triassic (200-251 Ma) schist, quartzite, and amphibolite are mapped throughout the area, along with traces of the late Devonian Yanert Fork sequence (360-385 Ma), which is a thick marine sequence of metasedimentary and metavolcanic rocks in the Yanert River valley.

The Project corridor crosses the Denali fault, where the Nenana River jogs east and the corridor climbs along the western edge of the Reindeer Hills. In these hills, the Mainline intersects more of the Cantwell Formation (continued from the north), as well as some late Triassic (199-228 Ma) subaerial basalt flows of the Nikolai Greenstone, mixed with mélange and limestone blocks north of the Denali fault. Immediately south and along the western flanks of the Reindeer Hills, the Project intersects flysch (99-161 Ma) as well as Paleocene to Miocene hypabyssal felsic and intermediate intrusions (1.8-65 Ma). The Reindeer Hills are dominantly composed of Nikolai flood basalts, which outcrop along the western edge of the George Parks Highway and the Project corridor, terminating at the mouth of Eldridge Glacier.

The corridor runs along the eastern edge of Broad Pass and the Chulitna River (just outside the eastern Boundary of Denali National Park) in abundant Quaternary colluviums. However, the Mainline may intersect some intensely deformed and local patches of highly metamorphosed flysch-like turbiditic rocks in northern portions of the pass. Additionally, peralkaline granite intrusions (55-65 Ma) or younger granite and granodiorite (33-55 Ma) are also mapped sporadically in this area.

Cook Inlet Basin Ecoregion

The Mainline corridor will then continue south along the Susitna River drainage, where surface deposits are predominantly Upper Pleistocene glacial, glacioestuarine deposits, outwash and stream alluvium, tidal-flat sediments, and estuarine deposits (Reger et al., 2007). The Mainline corridor may intersect outcrops of intermediate to felsic intrusive bedrock near the base of Mount Susitna (e.g. tonalite, monzonite, and granodiorite). The preferred Mainline corridor (western corridor) then passes along the northwestern shores of the Cook Inlet Basin, amid diverse glacial deposits. The corridor crosses beneath the shallow waters of Cook Inlet to the southeast, and makes landfall on the northwestern shores of the Kenai Peninsula north of Nikiski. Holocene to Upper Pleistocene glacial deposits here include alluvium, moraines, glacioestuarine, and modified glacial deposits (Wilson, 2012). Underlying bedrock in the Nikiski area is oil and gas-bearing Upper Tertiary sandstone, siltstone, claystone, conglomerate and coal beds (Beikman, 1980).

An eastern alternative Project corridor would continue southward along the Susitna drainage through mixed glacial deposits (Reger et al., 2007). This route passes through predominantly Upper Pleistocene glacial, glacioestuarine deposits, outwash and stream alluvium, tidal-flat sediments, and estuarine deposits along the northern shores of Cook Inlet. The alternative corridor would cross Cook Inlet to the south, making landfall on the northwestern corner of the Kenai Peninsula, and pass south through Upper Pleistocene moraine and modified glacial deposits towards the Nikiski area (Wilson, 2012). Bedrock in this area is the same oil and gas-bearing Upper Tertiary continental deposits that underlie glacial deposits in the Nikiski area (Beikman, 1980).

6.3 MINERAL RESOURCES

The Project area will either transect or border a variety of exploitable or potentially exploitable resources. Resources addressed in this Resource Report include metals, (e.g. gold, copper), oil and natural gas, coal, and industrial resources (e.g. sand, gravel, and rock). Resource information was collected from the Alaska Department of Natural Resources (ADNR) online access to Alaska Resource Data Files (ARDF, 2014) and interactive map of active and inactive projects around the state (ADNR, 2014). Additionally, potential industrial resource locations were identified using a combination of Google Earth imagery, USGS topographic maps, and video footage shot along the Project corridor in 2014.

6.3.1 Mining Operations

Alaska's vast land, active tectonics, and diverse geology have resulted in an abundance of mineral resources (AKRDC, 2014). The Project corridor passes through, or is adjacent to, several areas of known or potential mineral deposits (ADNR, 2014) including:

- Antimony;
- Chalcopyrite;
- Diatomaceous earth;
- Gold;
- Limestone;
- Manganese;
- Molybdenite;
- Silver;
- Sulfides (copper, nickel); and
- Titanium.

Table 6.3.1-1 is a preliminary location summary for mineral resources within 0.5 mile of the Project corridor. Information in these tables will be updated subsequent drafts of this Resource Report.

TABLE 6.3.1-1

Mineral Claims/Leases/Occurrences Within 0.5 Miles of the Project Area

Alaska LNG Facility	Ecoregion	Borough / Recording District	Milepost (Temporary Description)	Site Description			Approx. Dist. From Centerline (feet)	Direction from Centerline
				Site Name	Claim / Lease	State/ Fed		
LIQUEFACTION FACILITY								
LNG Plant	Cook Inlet Basin	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Marine Terminal	Cook Inlet Basin	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PIPELINES								
Mainline	Brooks Range	Fairbanks	N Gold Creek	1 Below Discovery	Gold Placer Claim?	Federal	TBD	east
	Brooks Range	Fairbanks	N Gold Creek	2 Below Discovery	Gold Placer Claim?	Federal	TBD	east
	Brooks Range	Fairbanks	N Gold Creek	3 Below Discovery	Gold Placer Claim?	Federal	TBD	west
	Brooks Range	Fairbanks	W Cathedral Mt.	23 Below Discovery	Gold Placer Claim?	Federal	TBD	west
	Brooks Range	Fairbanks	W Cathedral Mt.	24 Below Discovery	Gold Placer Claim?	Federal	TBD	west
	Brooks Range	Fairbanks	W Cathedral Mt.	25 Below Discovery	Gold Placer Claim?	Federal	TBD	west
	TBD	Yukon-Koyukuk Census area	TBD	1 Below Discovery	Gold Placer Claim	Federal	TBD	TBD
	TBD	Yukon-Koyukuk Census area	TBD	3 Below Discovery	Gold Placer Claim	Federal	TBD	TBD
	TBD	Yukon-Koyukuk Census area	TBD	2 Below Discovery	Gold Placer Claim	Federal	TBD	TBD
	TBD	Yukon-Koyukuk Census area	TBD	24 Below Discovery	Gold Placer Claim	Federal	TBD	TBD
	TBD	Yukon-Koyukuk Census area	TBD	25 Below Discovery	Gold Placer Claim	Federal	TBD	TBD
	Ray Mountains	Fairbanks	S of Winter Creek	GKSX 30	Gold Mining Claim	State	TBD	east
	Ray Mountains	Fairbanks	S of Winter Creek	GKSX 32	Gold Mining Claim	State	TBD	east
	Ray Mountains	Fairbanks	S of Winter Creek	GKSX 34	Gold Mining Claim	State	TBD	east
	Ray Mountains	Fairbanks	N of Eagle Creek	GKSX 36	Gold Mining Claim	State	TBD	east
	Ray Mountains	Fairbanks	Eagle Creek	GKSX 1	Gold Mining Claim	State	TBD	east

TABLE 6.3.1-1

Mineral Claims/Leases/Occurrences Within 0.5 Miles of the Project Area

Alaska LNG Facility	Ecoregion	Borough / Recording District	Milepost (Temporary Description)	Site Description			Approx. Dist. From Centerline (feet)	Direction from Centerline
				Site Name	Claim / Lease	State/ Fed		
	Ray Mountains	Fairbanks	S of Eagle Creek	GKSX 3	Gold Mining Claim	State	TBD	east
	Ray Mountains	Fairbanks	S of Eagle Creek	GKSX 5	Gold Mining Claim	State	TBD	east
	Alaska Range	Nenana	Denali Fault & Nenana River	CASKI # 5	Limestone? Claim	State	TBD	east
	Alaska Range	Nenana	Denali Fault & Nenana River	CASKI # 6	Limestone? Claim	State	TBD	east
	Alaska Range	Nenana	Denali Fault & Nenana River	CASKI # 4	Limestone? Claim	State	TBD	east
	Alaska Range	Nenana	Denali Fault & Nenana River	CASKI # 2	Limestone? Claim	State	TBD	east
	Alaska Range	Nenana	Denali Fault & Nenana River	CASKI # 10	Limestone? Claim	State	TBD	east
	Alaska Range	Nenana	Denali Fault & Nenana River	CASKI # 11	Limestone? Claim	State	TBD	east
	Alaska Range	Nenana	Denali Fault & Nenana River	CASKI # 12	Limestone? Claim	State	TBD	east
	Alaska Range	Talkeetna	Squaw Creek	Corrie Sue 2	Placer Gold Claim	State	TBD	west
	Alaska Range	Talkeetna	Squaw Creek	Suzie Q	Placer Gold Claim	State	TBD	west
	Alaska Range	Talkeetna	Squaw Creek	Suzie Q II	Placer Gold Claim	State	TBD	west
	Alaska Range	Talkeetna	Squaw Creek	Jessie Ron I	Placer Gold Claim	State	TBD	west
	Alaska Range	Talkeetna	Chulitna River & Blair Lake	Mule # 1	Lease	State	TBD	east
	Alaska Range	Talkeetna	Chulitna River & Blair Lake	Mountain Horse # 10	Lease	State	TBD	east
	Alaska Range	Talkeetna	Chulitna River & Blair Lake	Lazy Mule # 2	Lease	State	TBD	east
	Alaska Range	Talkeetna	Chulitna River & Blair Lake	Stubborn Mule # 5	Lease	State	TBD	east
	Alaska Range	Talkeetna	Chulitna River & Blair Lake	Running Horse # 3	Lease	State	TBD	east
	Alaska Range	Talkeetna	Chulitna River & Blair Lake	Pack Mule # 4	Lease	State	TBD	east
	Cook Inlet Basin	Anchorage	Theodore River	Last Chance 8	Lease	State	TBD	under
	Cook Inlet Basin	Anchorage	Threemile Creek	Threemile 264	Lease	State	TBD	west
	Cook Inlet Basin	Anchorage	N of Fire Island	Unnamed	Offshore Fe/Ti Lease	State	TBD	north

TABLE 6.3.1-1

Mineral Claims/Leases/Occurrences Within 0.5 Miles of the Project Area

Alaska LNG Facility	Ecoregion	Borough / Recording District	Milepost (Temporary Description)	Site Description			Approx. Dist. From Centerline (feet)	Direction from Centerline
				Site Name	Claim / Lease	State/ Fed		
PBTL	Beaufort Coastal Plain	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PTTL	Beaufort Coastal Plain	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PIPELINE ABOVEGROUND FACILITIES								
Liquefaction Facility Meter Station	Cook Inlet Basin	Cook Inlet Basin	TBD	TBD	TBD	TBD	TBD	TBD
PBU Meter Station	Beaufort Coastal Plain	Beaufort Coastal Plain	TBD	TBD	TBD	TBD	TBD	TBD
Mainline Meter Station	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
PTU Meter Station	Beaufort Coastal Plain	Beaufort Coastal Plain	TBD	TBD	TBD	TBD	TBD	TBD
Compressor Stations, Heater Stations, MLBVs (not on Compressor sites)	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
PIPELINE ASSOCIATED INFRASTRUCTURE								
Access roads	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
ATWS	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Contractor yards	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Pipe yards	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Construction camps	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Disposal sites	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Material sites	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Disposal sites	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
GTP								
GTP	Beaufort Coastal Plain	Beaufort Coastal Plain	TBD	TBD	TBD	TBD	TBD	TBD
ASSOCIATED GTP INFRASTRUCTURE								
Module Staging Area	Beaufort Coastal Plain	Beaufort Coastal Plain	TBD	TBD	TBD	TBD	TBD	TBD
Access Roads	Beaufort Coastal Plain	Beaufort Coastal Plain	TBD	TBD	TBD	TBD	TBD	TBD

TABLE 6.3.1-1

Mineral Claims/Leases/Occurrences Within 0.5 Miles of the Project Area

Alaska LNG Facility	Ecoregion	Borough / Recording District	Milepost (Temporary Description)	Site Description			Approx. Dist. From Centerline (feet)	Direction from Centerline
				Site Name	Claim / Lease	State/ Fed		
Construction Camp	Beaufort Coastal Plain	Beaufort Coastal Plain	TBD	TBD	TBD	TBD	TBD	TBD
Material Sites	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Offshore of West Dock	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Water Reservoir, Pump Facilities, Transfer Line	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD

Source: Alaska resource Data File (ARDF), 2014 - http://mrdata.usgs.gov/ardf/

6.3.2 Oil and Natural Gas Well Production

The Alaska Department of Natural Resources, Division of Oil and Gas, conducts a competitive oil and gas lease sale on state lands to enable and manage oil and gas development (DNR-DOG, 2014). DNR has designated five areas of the state with moderate to high potential for oil and gas development and has designated these areas for competitive bid sales. Four of the five lease sale tracts will be crossed by the Project (DNR-DOG, 2014):

- Beaufort Sea;
- North Slope;
- North Slope Foothills; and
- Cook Inlet.

A summary of the lease sale statistics is provided in Table 6.3.2-1 (DNR, 2014). Figure 6.3.2-1 depicts the oil and gas exploration and license areas along the Project corridor. A preliminary list of identified active, or potentially active, oil and gas leases within 2,000 feet of the Project area is provided in Table 6.3.2-2. These tables will be updated in subsequent drafts of this Resource Report.

TABLE 6.3.2-1

Area-Wide Lease Sale Statistics for the Four Areas Crossed by the Project (DNR, 2014).

Area-wide Sales	Size (acres)	Number of Tracts	Tract Size (acres per tract)
Beaufort Sea	2 million	573	640-5760
North Slope	5.1 million	1225	640-5760
North Slope Foothills	7.6 million	1347	1280-5760
Cook Inlet	4.2 million	815	640-5760

The PBU production field is within the North Slope lease sale area. PBU is the largest oil field in North America (AOGCC, 2013). During its peak in 1987, PBU oil production totaled 1,627,036 barrels per day. Field production has since declined to approximately a quarter of the peak production rates. Total field production as of February 2011, amounts to approximately 11.3 billion barrels of oil since the pool was discovered in 1968.

A list of identified active, or potentially active, oil and gas leases within 2,000 feet of the Project area is provided in Table 6.3.2-2. The Project would not impact any underlying state oil and gas leases located on the subsurface estate.

TABLE 6.3.2-2

Oil & Gas Leases and Wells Within 2,000 Feet of the Project Area

Alaska LNG Facility	Site Description		Approx. Milepost	LST Number [a]	Apprx. Distance (feet) and Direction	Status
	Area-wide Lease Sale	Claim / Lease				
LIQUEFACTION FACILITY						
LNG Plant	Cook Inlet Basin	TBD	TBD	TBD	TBD	TBD
Marine Terminal	Cook Inlet Basin	TBD	TBD	TBD	TBD	TBD
PIPELINES						
Mainline	North Slope	Lease	TBD	NS1118	TBD	TBD
	North Slope	Lease	TBD	NS1120	TBD	TBD
	North Slope	Well	TBD	N/A	TBD	TBD
	North Slope	Exploration	TBD	N/A	TBD	TBD
	North Slope	Exploration	TBD	N/A	TBD	TBD
	North Slope	Lease	TBD	NS1121	TBD	TBD
	North Slope	Lease	TBD	NS1123	TBD	TBD
	North Slope	Lease	TBD	NS1124	TBD	TBD
	North Slope	Lease	TBD	NS1002	TBD	TBD
	North Slope	Well	TBD	N/A	TBD	TBD
	North Slope	Well	TBD	N/A	TBD	TBD
	North Slope	Lease	TBD	NS1005	TBD	TBD
	North Slope	Lease	TBD	NS1008	TBD	TBD
	North Slope	Lease	TBD	NS0833	TBD	TBD
	North Slope	Lease	TBD	NS0832	TBD	TBD
	North Slope	Lease	TBD	NS0836	TBD	TBD
	North Slope	Lease	TBD	NS0835	TBD	TBD
	North Slope	Lease	TBD	NS0838	TBD	TBD
	North Slope	Lease	TBD	NS0654	TBD	TBD
	North Slope	Lease	TBD	NS0653	TBD	TBD

TABLE 6.3.2-2

Oil & Gas Leases and Wells Within 2,000 Feet of the Project Area

Alaska LNG Facility	Site Description		Approx. Milepost	LST Number [a]	Apprx. Distance (feet) and Direction	Status
	Area-wide Lease Sale	Claim / Lease				
	North Slope	Lease	TBD	NS0657	TBD	TBD
	North Slope	Lease	TBD	NS0660	TBD	TBD
	North Slope	Lease	TBD	NS0661	TBD	TBD
	North Slope	Lease	TBD	NS0567	TBD	TBD
	North Slope	Lease	TBD	NS0568	TBD	TBD
	North Slope	Lease	TBD	NS0565	TBD	TBD
	North Slope	Lease	TBD	NS0478	TBD	TBD
	North Slope	Lease	TBD	NS0481	TBD	TBD
	North Slope	Lease	TBD	NS0484	TBD	TBD
	North Slope	Lease	TBD	NS0393	TBD	TBD
	North Slope	Lease	TBD	NS0398	TBD	TBD
	North Slope	Lease	TBD	NS0399	TBD	TBD
	North Slope	Lease	TBD	NS0396	TBD	TBD
	North Slope	Lease	TBD	NS0310	TBD	TBD
	North Slope	Lease	TBD	NS0311	TBD	TBD
	North Slope	Lease	TBD	NS0223	TBD	TBD
	North Slope	Lease	TBD	NS0224	TBD	TBD
	North Slope	Lease	TBD	NS0137	TBD	TBD
	North Slope	Well	TBD	N/A	TBD	TBD
	North Slope	Lease	TBD	NS0138	TBD	TBD
	North Slope	Lease	TBD	NS0050	TBD	TBD
	North Slope	Lease	TBD	FH0051	TBD	TBD
	North Slope Foothills	Lease	TBD	FH0054	TBD	TBD
	North Slope Foothills	Lease	TBD	FH0053	TBD	TBD
	North Slope Foothills	lease	TBD	FH0055	TBD	TBD
	North Slope Foothills	Lease	TBD	FH0056	TBD	TBD
	North Slope Foothills	Lease	TBD	FH0151	TBD	TBD
	North Slope Foothills	Lease	TBD	FH0152	TBD	TBD
	North Slope Foothills	Lease	TBD	FH0153	TBD	TBD
	North Slope Foothills	Lease	TBD	FH0228	TBD	TBD

TABLE 6.3.2-2

Oil & Gas Leases and Wells Within 2,000 Feet of the Project Area

Alaska LNG Facility	Site Description		Approx. Milepost	LST Number [a]	Apprx. Distance (feet) and Direction	Status
	Area-wide Lease Sale	Claim / Lease				
	North Slope Foothills	Lease	TBD	FH0229	TBD	TBD
	North Slope Foothills	Lease	TBD	FH0300	TBD	TBD
	North Slope Foothills	Lease	TBD	FH0295	TBD	TBD
	North Slope Foothills	Lease	TBD	FH0301	TBD	TBD
	North Slope Foothills	Lease	TBD	FH0298	TBD	TBD
	North Slope Foothills	Lease	TBD	FH0370	TBD	TBD
	North Slope Foothills	Lease	TBD	FH0371	TBD	TBD
	North Slope Foothills	Lease	TBD	FH0368	TBD	TBD
	North Slope Foothills	Lease	TBD	FH0430	TBD	TBD
	North Slope Foothills	Lease	TBD	FH0425	TBD	TBD
	North Slope Foothills	Lease	TBD	FH0431	TBD	TBD
	North Slope Foothills	Lease	TBD	FH0428	TBD	TBD
	North Slope Foothills	Lease	TBD	FH0490	TBD	TBD
	North Slope Foothills	Lease	TBD	FH0491	TBD	TBD
	North Slope Foothills	Lease	TBD	FH0550	TBD	TBD
	North Slope Foothills	Lease	TBD	FH0545	TBD	TBD
	North Slope Foothills	Lease	TBD	FH0548	TBD	TBD
	North Slope Foothills	Lease	TBD	FH0547	TBD	TBD
	North Slope Foothills	Lease	TBD	FH0604	TBD	TBD
	North Slope Foothills	Lease	TBD	FH0605	TBD	TBD
	North Slope Foothills	Lease	TBD	FH0600	TBD	TBD
	North Slope Foothills	Lease	TBD	FH0603	TBD	TBD
	North Slope Foothills	Lease	TBD	FH0601	TBD	TBD
	North Slope Foothills	Lease	TBD	FH0602	TBD	TBD

TABLE 6.3.2-2

Oil & Gas Leases and Wells Within 2,000 Feet of the Project Area

Alaska LNG Facility	**Site Description**		**Approx. Milepost**	**LST Number** [a]	**Apprx. Distance (feet) and Direction**	**Status**
	Area-wide Lease Sale	**Claim / Lease**				
	North Slope Foothills	Lease	TBD	FH0599	TBD	TBD
	North Slope Foothills	Lease	TBD	FH0657	TBD	TBD
	North Slope Foothills	Lease	TBD	FH0652	TBD	TBD
	North Slope Foothills	Lease	TBD	FH0655	TBD	TBD
	North Slope Foothills	Lease	TBD	FH0708	TBD	TBD
	North Slope Foothills	Lease	TBD	FH0711	TBD	TBD
	North Slope Foothills	Lease	TBD	FH0714	TBD	TBD
	North Slope Foothills	Lease	TBD	FH0760	TBD	TBD
	North Slope Foothills	Lease	TBD	FH0759	TBD	TBD
	North Slope Foothills	Lease	TBD	FH0761	TBD	TBD
	North Slope Foothills	Lease	TBD	FH0762	TBD	TBD
	North Slope Foothills	Lease	TBD	#392405	TBD	TBD
	North Slope Foothills	Lease	TBD	#392406	TBD	TBD
	North Slope Foothills	Lease - Exploration	TBD	#390606	TBD	TBD
	Cook Inlet	Lease	TBD	CI0707	TBD	TBD
	Cook Inlet	Lease	TBD	CI0708	TBD	TBD
	Cook Inlet	Lease	TBD	CI0710	TBD	TBD
	Cook Inlet	Lease	TBD	CI0709	TBD	TBD
	Cook Inlet	Lease	TBD	CI0714	TBD	TBD
	Cook Inlet	Lease	TBD	CI0679	TBD	TBD
	Cook Inlet	Lease	TBD	CI0682	TBD	TBD
	Cook Inlet	Lease	TBD	CI0640	TBD	TBD
	Cook Inlet	Lease	TBD	CI0641	TBD	TBD
	Cook Inlet	Lease	TBD	CI0647	TBD	TBD
	Cook Inlet	Lease	TBD	CI0650	TBD	TBD
	Cook Inlet	Lease	TBD	CI0648	TBD	TBD
	Cook Inlet	Lease	TBD	CI0651	TBD	TBD
	Cook Inlet	Lease	TBD	CI0652	TBD	TBD

TABLE 6.3.2-2

Oil & Gas Leases and Wells Within 2,000 Feet of the Project Area

Alaska LNG Facility	Site Description		Approx. Milepost	LST Number [a]	Apprx. Distance (feet) and Direction	Status
	Area-wide Lease Sale	Claim / Lease				
	Cook Inlet	Lease	TBD	CI0600	TBD	TBD
	Cook Inlet	Lease	TBD	CI0601	TBD	TBD
	Cook Inlet	Lease	TBD	CI0608	TBD	TBD
	Cook Inlet	Lease	TBD	CI0609	TBD	TBD
	Cook Inlet	Lease	TBD	CI0555	TBD	TBD
	Cook Inlet	Lease	TBD	CI0558	TBD	TBD
	Cook Inlet	Well	TBD	N/A	TBD	TBD
	Cook Inlet	Lease	TBD	CI0561	TBD	TBD
	Cook Inlet	Lease	TBD	CI0565	TBD	TBD
	Cook Inlet	Lease	TBD	CI0502	TBD	TBD
	Cook Inlet	Lease	TBD	CI0495	TBD	TBD
	Cook Inlet	Lease	TBD	CI0498	TBD	TBD
	Cook Inlet	Lease	TBD	CI0497	TBD	TBD
	Cook Inlet	Lease	TBD	CI0500	TBD	TBD
	Cook Inlet	Lease	TBD	CI0499	TBD	TBD
	Cook Inlet	Lease	TBD	CI0422	TBD	TBD
	Cook Inlet	Lease	TBD	CI0423	TBD	TBD
	Cook Inlet	Well	TBD	N/A	TBD	TBD
	Cook Inlet	Lease	TBD	CI0426	TBD	TBD
	Cook Inlet	Lease	TBD	CI0425	TBD	TBD
	Cook Inlet	Lease	TBD	CI0429	TBD	TBD
	Cook Inlet	Lease	TBD	CI0347	TBD	TBD
	Cook Inlet	Lease	TBD	CI0350	TBD	TBD
	Cook Inlet	Lease	TBD	CI0353	TBD	TBD
	Cook Inlet	Lease	TBD	CI0357	TBD	TBD
	Cook Inlet	Lease	TBD	CI0360	TBD	TBD
	Cook Inlet	Lease	TBD	CI0279	TBD	TBD
	Cook Inlet	Well	TBD	N/A	TBD	TBD
	Cook Inlet	Well	TBD	N/A	TBD	TBD
	Cook Inlet	Lease	TBD	CI0282	TBD	TBD
	Cook Inlet	Lease	TBD	CI0280	TBD	TBD
	Cook Inlet	Lease	TBD	CI0281	TBD	TBD
	Cook Inlet	Lease	TBD	CI0229	TBD	TBD

TABLE 6.3.2-2

Oil & Gas Leases and Wells Within 2,000 Feet of the Project Area

Alaska LNG Facility	Site Description		Approx. Milepost	LST Number [a]	Apprx. Distance (feet) and Direction	Status
	Area-wide Lease Sale	Claim / Lease				
	Cook Inlet	Lease	TBD	CI0230	TBD	TBD
	Cook Inlet	Lease	TBD	CI0235	TBD	TBD
	Cook Inlet	Lease	TBD	CI0189	TBD	TBD
	Cook Inlet	Lease	TBD	CI0190	TBD	TBD
	Cook Inlet	Lease	TBD	CI0191	TBD	TBD
	Cook Inlet	Lease	TBD	CI0192	TBD	TBD
PBTL	Beaufort Coastal Plain	TBD	TBD	TBD	TBD	TBD
PTTL	Beaufort Sea	Lease	TBD	BS083	TBD	TBD
		L				
	North Slope	Lease	TBD	NS0907	TBD	TBD
	North Slope	Lease	TBD	NS0898	TBD	TBD
					TBD	
	North Slope	Lease	TBD	NS0899	TBD	TBD
	North Slope	Lease	TBD	NS0900	TBD	TBD
	North Slope	Lease	TBD	NS0890	TBD	TBD
	North Slope	Lease	TBD	NS0891	TBD	TBD
	Beaufort Sea	Lease	TBD	BS0116	TBD	TBD
	North Slope	Lease	TBD	NS0984	TBD	TBD
	North Slope	Lease	TBD	NS0884	TBD	TBD
	North Slope	Lease	TBD	NS0885	TBD	TBD
	North Slope	Lease	TBD	NS0886	TBD	TBD
	Beaufort Sea	Lease	TBD	BS0134	TBD	TBD
	Beaufort Sea	Lease	TBD	BS0156	TBD	TBD
	North Slope	Lease	TBD	NS0876	TBD	TBD
	North Slope	Lease	TBD	NS0877	TBD	TBD
	North Slope	Lease	TBD	NS0867	TBD	TBD
	North Slope	Lease	TBD	NS0868	TBD	TBD
	Beaufort Sea	Lease	TBD	BS0189	TBD	TBD
	North Slope	Lease	TBD	NS0869	TBD	TBD
	Beaufort Sea	Lease	TBD	BS0190	TBD	TBD

TABLE 6.3.2-2

Oil & Gas Leases and Wells Within 2,000 Feet of the Project Area

Alaska LNG Facility	Site Description		Approx. Milepost	LST Number [a]	Apprx. Distance (feet) and Direction	Status
	Area-wide Lease Sale	Claim / Lease				
	Beaufort Sea	Lease	TBD	BS0211	TBD	TBD
	North Slope	Lease	TBD	NS1029	TBD	TBD
	Beaufort Sea	Lease	TBD	BS0210	TBD	TBD
	North Slope	Lease	TBD	NS1028	TBD	TBD
	North Slope	Lease	TBD	NS1021	TBD	TBD
	North Slope	Lease	TBD	NS1018	TBD	TBD
	North Slope	Lease	TBD	NS1019	TBD	TBD
	North Slope	Lease	TBD	NS1022	TBD	TBD
	North Slope	Lease	TBD	NS1020	TBD	TBD
	North Slope	Lease	TBD	NS1009	TBD	TBD
	North Slope	Lease	TBD	NS1126	TBD	TBD
	North Slope	Lease	TBD	NS1127	TBD	TBD
	North Slope	Lease	TBD	NS1128	TBD	TBD
	North Slope	Lease	TBD	NS1122	TBD	TBD
	Beaufort Sea	Lease	TBD	BS0280	TBD	TBD
	North Slope	Exploration	TBD	N/A	TBD	TBD
	North Slope	Lease	TBD	NS1120	TBD	TBD
	North Slope	Lease	TBD	NS1118	TBD	TBD
PIPELINE ABOVEGROUND FACILITIES						
Liquefaction Facility Meter Station	Cook Inlet Basin	TBD	TBD	TBD	TBD	TBD
Mainline Meter Station	TBD	TBD	TBD	TBD	TBD	TBD
PBU Meter Station	Beaufort Coastal Plain	TBD	TBD	TBD	TBD	TBD
PTU Meter Station	Beaufort Coastal Plain	TBD	TBD	TBD	TBD	TBD
Compressor Stations, Heater Stations, MLBVs (not on Compressor sites)	TBD	TBD	TBD	TBD	TBD	TBD
PIPELINE ASSOCIATED INFRASTRUCTURE						
Access Roads	TBD	TBD	TBD	TBD	TBD	TBD
ATWS	TBD	TBD	TBD	TBD	TBD	TBD

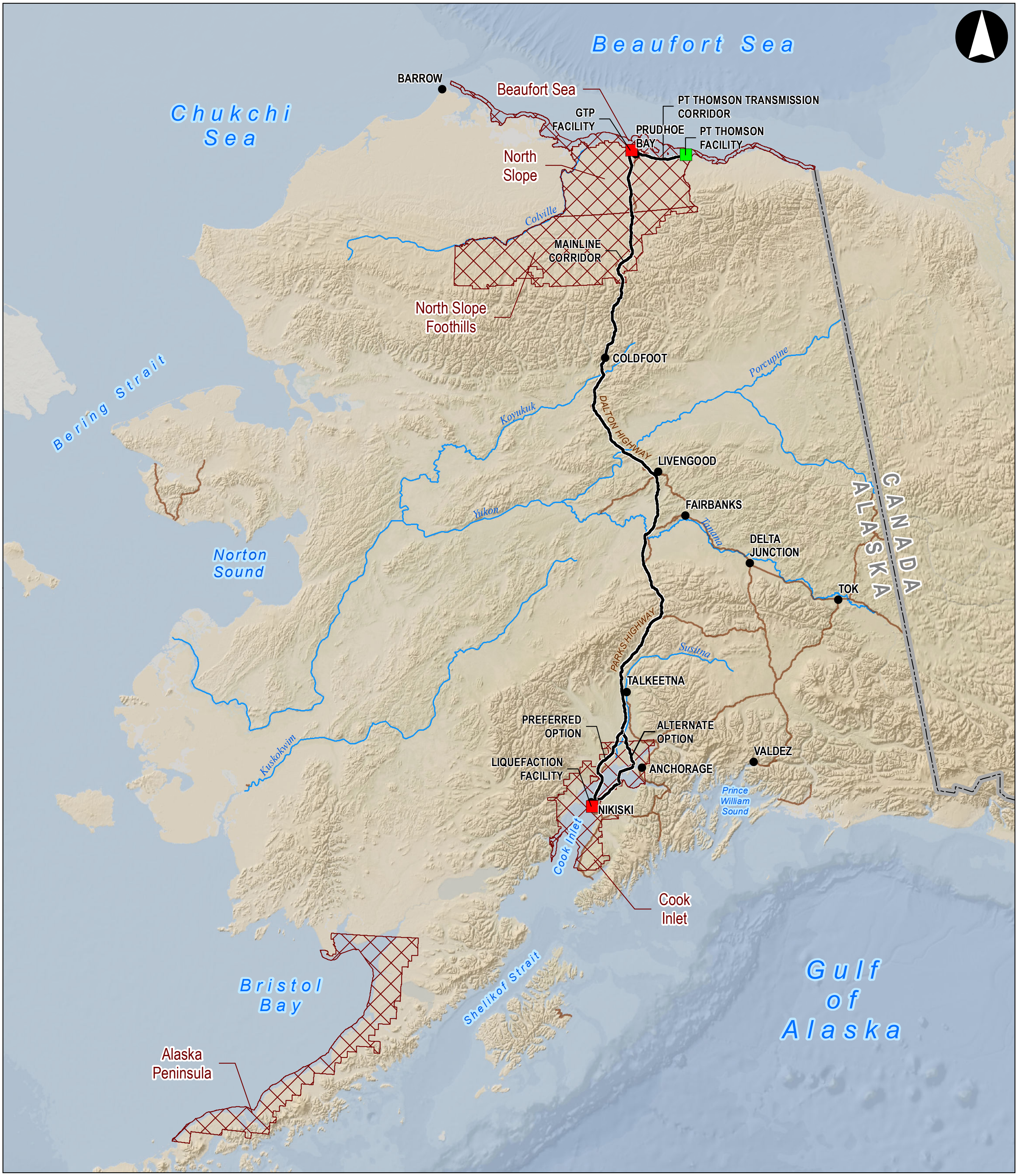
TABLE 6.3.2-2

Oil & Gas Leases and Wells Within 2,000 Feet of the Project Area

Alaska LNG Facility	Site Description		Approx. Milepost	LST Number [a]	Apprx. Distance (feet) and Direction	Status
	Area-wide Lease Sale	Claim / Lease				
Contractor Yards	TBD	TBD	TBD	TBD	TBD	TBD
Pipe Yards	TBD	TBD	TBD	TBD	TBD	TBD
Construction Camps	TBD	TBD	TBD	TBD	TBD	TBD
Disposal Sites	TBD	TBD	TBD	TBD	TBD	TBD
Material Sites	TBD	TBD	TBD	TBD	TBD	TBD
GTP						
GTP	Beaufort Coastal Plain	Lease	TBD	NS1118	TBD	TBD
		Lease	TBD	NS1120	TBD	TBD
ASSOCIATED GTP INFRASTRUCTURE						
Module Staging Area	Beaufort Coastal Plain	TBD	TBD	TBD	TBD	TBD
Access Roads	Beaufort Coastal Plain	TBD	TBD	TBD	TBD	TBD
Construction Camp	Beaufort Coastal Plain	TBD	TBD	TBD	TBD	TBD
Material Sites	TBD	TBD	TBD	TBD	TBD	TBD
Offshore of West Dock	TBD	TBD	TBD	TBD	TBD	TBD
Water Reservoir, Pump Facilities, Transfer Line	TBD	TBD	TBD	TBD	TBD	TBD

Notes:
[a] LST refers to Lease Sale Tract, designated by the ADNR, Division of Oil and Gas.

Source: ADNR, Division of Oil and Gas, 2014.



VICINITY MAP

LEGEND

- Project Facility
- Existing Facility
- Alaska Place Names
- Project Corridor
- Major Highways
- Major Rivers
- Areawide Sale Boundary

0 50 100 200 Miles

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PREPARED BY:	EXP ENERGY SERVICES INC.		
SCALE:	1:8,500,000		
DATE:	2015-01-06	SHEET:	1 of 1

OIL & GAS EXPLORATION & LICENSE AREAS

FIGURE 6.3.2-1

Alaska LNG

X:\Projects\ExxonMobil\SCLNG\Mapping\20150106_ResourceReportFigures_Rev3\RR6\Figure 6_3_2-1 Oil and Gas Exploration and License Areas.mxd

6.3.3 Coal Resources

A preliminary list of coal resources crossed by the Project is provided in Table 6.3.3-1. This table will be updated in subsequent drafts of this Resource Report.

TABLE 6.3.3-1

Coal Resources Within 0.5 Miles of the Project Area

Alaska LNG Facility	Ecoregion	Site Description*			Milepost (from)	Milepost (to)
		Coal Type	Name	Rock Unit*		
LIQUEFACTION FACILITY						
LNG Plant	Cook Inlet Basin	None	N/A	N/A	TBD	TBD
Marine Terminal	Cook Inlet Basin	None	N/A	N/A	TBD	TBD
PIPELINES						
Mainline	Beaufort Coastal Plain	Lignite	(None)	Kco – Colville Group	27.5	35
	Beaufort Coastal Plain	Lignite underlain by subbituminous coal	(None)	Tsl – Sagavanirktok Formation	35	57.5
	Brooks Range Foothills	Lignite underlain by subbituminous coal	(None)	Tsl – Sagavanirktok Formation	57.5	69.8
	Brooks Range Foothills	30-inch (minimum) thick subbituminous coal beds	(None)	Kco – Colville Group	69.8	74.8
	Brooks Range Foothills	14-inch (minimum) thick subbituminous coal beds	NORTHERN	Kc- Mainly Corwin Fm of Nanushuk Group	122.5	128
	Kobuk Ridges and Valleys	Coal field	TRAMWAY BAR	Kcb - Continental rocks, includes upper member Bergman Group and Kaltag and Nulato Fms	251	256.5
	Ray Mountains	Bituminous coal	UPPER KOYUKUK	Kcc - Continental rocks	256.5	274
	Ray Mountains	Subbituminous coal	RAMPART	Tccb - Continental Rocks	367.6	374
	Tanana-Kuskokwim Lowlands	Coal basin	Middle Tanana	Varies	436.6	442.8

TABLE 6.3.3-1

Coal Resources Within 0.5 Miles of the Project Area

Alaska LNG Facility	Ecoregion	Site Description*			Milepost (from)	Milepost (to)
		Coal Type	Name	Rock Unit*		
	Tanana-Kuskokwim Lowlands	Coal basin	Middle Tanana	Varies	466	502
	Tanana-Kuskokwim Lowlands	Coal basin with subbituminous coal	Nenana	QTu,Varies - Nenana Gravel and surficial deposits, undivided	502	518
	Tanana-Kuskokwim Lowlands	Coal basin with subbituminous coal	Nenana	QTu,Varies - Nenana Gravel and surficial deposits, undivided	518	527.6
	Alaska Range	30-inch (minimum) thick subbituminous coal beds	HEALY CREEK	Tuu - Usibelli Group (includes Grubstake, Lignite Creek, Suntrana, Sanctuary, and Healy Creek Fms)	527.6	529.3
	Alaska Range	Coal basin with subbituminous coal	Nenana	Varies	529.3	536.8
	Alaska Range	Coal district	BROAD PASS	Varies	577	581
	Alaska Range	30-inch (minimum) thick lignite beds	BROAD PASS	Tls - Continental Rocks	581	592
	Alaska Range	Coal district	BROAD PASS	Varies	592	598
	Alaska Range	Coal district	BROAD PASS	Varies	613.2	616.8
	Alaska Range	Lignite	BROAD PASS	Tls - Continental Rocks	616.8	618.7
	Cook Inlet Basin	Lignite	BROAD PASS	Tls - Continental Rocks	618.7	622.7
	Cook Inlet Basin	Coal district	BROAD PASS	Varies	622.7	625
	Cook Inlet Basin	Coal Basin	Susitna	Varies	636.1	641.3
	Cook Inlet Basin	Subbituminous coal	Susitna	Tu - Kenai Group, undivided	641.3	642.2
	Cook Inlet Basin	Coal Basin	Susitna	Varies	642.2	644.6

TABLE 6.3.3-1

Coal Resources Within 0.5 Miles of the Project Area

Alaska LNG Facility	Ecoregion	Site Description*			Milepost (from)	Milepost (to)
		Coal Type	Name	Rock Unit*		
	Cook Inlet Basin	Subbituminous coal	Susitna	Tu - Kenai Group, undivided	644.6	646.3
	Cook Inlet Basin	Coal Basin	Susitna	Varies	646.3	657
	Cook Inlet Basin	Subbituminous coal	Susitna	Tu - Kenai Group, undivided	657	704.5
	Cook Inlet Basin	Coal Field	Susitna	Varies	704.5	715
	Cook Inlet Basin	Subbituminous coal	Susitna	Tu - Kenai Group, undivided	715	720.7
	Cook Inlet Basin	Coal Field	Susitna	Varies	720.7	725.3
	Cook Inlet Basin	Coal Basin	Susitna	Varies	725.3	734.1
	Cook Inlet Basin	30-inch (minimum) thick subbituminous coal beds	Cook Inlet	Tu - Kenai Group, undivided	734.1	736.2
	Cook Inlet Basin	Subbituminous coal	Cook Inlet	Tku - Sedimentary rocks, undivided	736.2	742.2
	Cook Inlet Basin	30-inch (minimum) thick subbituminous coal beds	BELUGA	Tt - Tyonek Formation	742.2	767.3
	Cook Inlet Basin	Coal basin	Cook Inlet	Varies	767.3	794.6
	Cook Inlet Basin	Subbituminous coal	KENAI	Varies	794.6	806
	EASTERN PRE-FEED ROUTE					
	Cook Inlet Basin	30-inch (minimum) thick subbituminous coal beds	Susitna	Tu - Kenai Group, undivided	709.5	723.4
	Cook Inlet Basin	30-inch (minimum) thick subbituminous coal beds	Susitna	Tu - Kenai Group, undivided	723.4	738.8
	Cook Inlet Basin	Subbituminous coal	Cook Inlet	Tku - Sedimentary rocks, undivided	738.8	749.6
	Cook Inlet Basin	Coal basin	Cook Inlet	Varies	749.6	776.7
	Cook Inlet Basin	Subbituminous coal	KENAI	Varies	776.7	820

TABLE 6.3.3-1

Coal Resources Within 0.5 Miles of the Project Area

Alaska LNG Facility	**Ecoregion**	**Site Description***			**Milepost (from)**	**Milepost (to)**
		Coal Type	**Name**	**Rock Unit***		
PBTL	Beaufort Coastal Plain	None	N/A	N/A	N/A	N/A
PTTL	Beaufort Coastal Plain	None	N/A	N/A	N/A	N/A
PIPELINE ABOVEGROUND FACILITIES						
Liquefaction Facility Meter Station	Cook Inlet Basin	TBD	TBD	TBD	TBD	TBD
Mainline Meter Station	TBD	TBD	TBD	TBD	TBD	TBD
PBU Meter Station	Beaufort Coastal Plain	TBD	TBD	TBD	TBD	TBD
PTU Meter Station	Beaufort Coastal Plain	TBD	TBD	TBD	TBD	TBD
Compressor Stations, Heater Stations, MLBVs (not on Compressor sites)	TBD	TBD	TBD	TBD	TBD	TBD
PIPELINE ASSOCIATED INFRASTRUCTURE						
Access Roads	TBD	TBD	TBD	TBD	TBD	TBD
ATWS	TBD	TBD	TBD	TBD	TBD	TBD
Contractor Yards	TBD	TBD	TBD	TBD	TBD	TBD
Pipe Yards	TBD	TBD	TBD	TBD	TBD	TBD
Construction Camps	TBD	TBD	TBD	TBD	TBD	TBD
Disposal Sites	TBD	TBD	TBD	TBD	TBD	TBD
Material Sites	TBD	TBD	TBD	TBD	TBD	TBD
GTP						
GTP	Beaufort Coastal Plain	None	N/A	N/A	N/A	N/A
ASSOCIATED GTP INFRASTRUCTURE						
Module Staging Area	Beaufort Coastal Plain	None	N/A	N/A	N/A	N/A
Access Roads	Beaufort Coastal Plain	None	N/A	N/A	N/A	N/A
Construction Camp	Beaufort Coastal Plain	None	N/A	N/A	N/A	N/A
Material Sites	TBD	TBD	TBD	TBD	TBD	TBD

TABLE 6.3.3-1

Coal Resources Within 0.5 Miles of the Project Area

Alaska LNG Facility	Ecoregion	Site Description*			Milepost (from)	Milepost (to)
		Coal Type	**Name**	**Rock Unit***		
Offshore of West Dock	TBD	TBD	TBD	TBD	TBD	TBD
Water Reservoir, Pump Facilities, Transfer Line	TBD	TBD	TBD	TBD	TBD	TBD

*Source: Merritt, R.D., and Hawley, C.C., 1986, Map of Alaska's coal resources: Special Report SR 37, State of Alaska, Department of Natural Resources, Division of Geological & Geophysical Surveys, Fairbanks, AK. Web Source Link: http://www.dggs.alaska.gov/metadata/SR37.faq.html#what.2

6.3.4 Industrial Resources

The Project area contains many potential industrial resources, or material "borrow" resources (e.g. gravel, sand, limestone, etc.). Table 6.3.4-1 provides a preliminary list of potential borrow areas within 0.5 mile of the Project corridor. These sites were identified using a combination of Google Earth imagery, USGS topographic maps, and video footage shot along the Project corridor in 2014. Industrial resource locations presented here are preliminary until they can be confirmed during future field investigations. This table will be updated in subsequent drafts of this Resource Report. In addition, details will be provided concerning the borrow areas which will be used for the Project.

TABLE 6.3.4-1

Potential Industrial Resources Within 0.5 Mile of the Project Area

Alaska LNG Facility	Borough / District	Approx. Milepost	Site Description		Distance (feet) and Direction	Status
			Location	**Potential Resource Type**		
LIQUEFACTION FACILITY						
LNG Plant	Cook Inlet Basin	N/A	N/A	None	N/A	N/A
Marine Terminal	Cook Inlet Basin	TBD	TBD	TBD	TBD	TBD
PIPELINES						
Mainline	Brooks Foothills	85.5	Happy Valley	Gravel	east	Active
	Brooks Foothills	114	Sagavanirktok River	Gravel	east	Active
	Brooks Foothills	140.5	Galbraith Airport	Gravel	west	Active
	Brooks Range	162	Large Gravel Pit, N of Atigun Pass	Gravel	east	Active

TABLE 6.3.4-1

Potential Industrial Resources Within 0.5 Mile of the Project Area

Alaska LNG Facility	Borough / District	Approx. Milepost	Site Description		Distance (feet) and Direction	Status
			Location	Potential Resource Type		
	Brooks Range	165	Flat pad / storage area	Gravel / Storage	west	Unknown
	Brooks Range	168	River cuts	Gravel	west/east	Unknown
	Brooks Range	171	Small River bank - buried pipeline?	Gravel	east	Unknown
	Brooks Range	191	N of Jim Creek	Gravel	east	Active
	Brooks Range	193.4	N of Jim Creek	Limestone / Gravel	east	Active
	Brooks Range	195	Jim Creek	Gravel	west	Unknown
	Brooks Range	205.5	Dietrich Camp	Gravel	west	Abandoned
	Brooks Range	219	Gold Creek	Gravel	east	Unknown
	Brooks Range	229.2	Minnie Creek	Gravel	east	Unknown
	Brooks Range	230.4	S of Minnie Creek	Gravel	east	Unknown
	Brooks Range	238.5	N of Coldfoot	Gravel	west	Active
	Brooks Range	251.2	S of Cathedral Mtn	Gravel	east	Unknown
	Kobuk Ridges and Valleys	255.5	E of Middle Creek	Gravel	west	Unknown
	Ray Mountains	271	Jim River	Gravel	west	Unknown
	Ray Mountains	278	Prospect Creek	Gravel	west	Unknown
	Ray Mountains	283.5	S of Prospect Creek	Gravel	west	Unknown
	Ray Mountains	285.3	S of Prospect Creek	Gravel	west	Unknown
	Ray Mountains	296	N of Fish Creek	Gravel	west	Unknown
	Ray Mountains	307.8	Caribou Mtn	Gravel	west	Abandoned
	Ray Mountains	324.3	S of West Fork Dall River	Gravel	east	Active
	Ray Mountains	326.4	S of West Fork Dall River	Gravel	west	Active
	Ray Mountains	332.3	N Fort Hamlin Hills	Gravel	east	Multiple Active / Abandoned
	Ray Mountains	336.4	N Fort Hamlin Hills	Gravel	east	Unknown
	Ray Mountains	348	Ray River	Gravel	east	Unknown
	Ray Mountains	350.5	Ray River - buildings	Gravel / Storage	east	Unknown
	Ray Mountains	352	Hot Spot Café lot	Gravel	east	Unknown
	Ray Mountains	353	S of Hot Spot Café	Gravel	east	Unknown
	Ray Mountains	358.5	Pump Station 6	Gravel / Storage	west	Unknown

TABLE 6.3.4-1

Potential Industrial Resources Within 0.5 Mile of the Project Area

Alaska LNG Facility	**Borough / District**	**Approx. Milepost**	**Site Description**		**Distance (feet) and Direction**	**Status**
			Location	**Potential Resource Type**		
	Ray Mountains	364.5	N of Isom Creek	Gravel	west/east	Unknown
	Ray Mountains	370.5	S of Isom Creek	Gravel	east	Unknown
	Ray Mountains	372	N of Hess Creek	Gravel	west	Unknown
	Ray Mountains	378	N of Hess Creek	Gravel	south	Unknown
	Ray Mountains	379.6	N of Hess Creek	Gravel	south	Unknown
	Ray Mountains	394	Lost Creek	Gravel	west	Unknown
	Alaska Range	522.2	Panguingue Creek	Gravel	west	Unknown
	Alaska Range	523	Panguingue Creek	Gravel	west	Unknown
	Alaska Range	524	Panguingue Creek	Gravel	northwest	Active
	Alaska Range	525	Healy	Gravel around coal mines	east	Active
	Alaska Range	531	McKinely RV Park and Campground	Gravel	northwest	Unknown
	Alaska Range	547	Yanert Rd connection to McKinley Park	Gravel	west	Active
	Alaska Range	550	Deneki Lakes	Gravel	west	Unknown
	Alaska Range	553.5	Carlo Creek - N of Denali Creekside Cabins	Gravel	west	Active
	Alaska Range	560.8	Panorama Mountain	Gravel / Rock Quarry	east	Active
	Alaska Range	561.3	Panorama Mountain	Gravel / Rock Quarry	east	Active
		568.5	Cantwell	Gravel	west	Active
	Cook Inlet Basin	640.1	N of Troublesome Creek	Gravel	west	Unknown
	Cook Inlet Basin	653	S of Blaire Lake	Gravel	east	Active
	Cook Inlet Basin	653.5	S of Blaire Lake	Gravel	east	Active
PBTL	Beaufort Coastal Plain	TBD	TBD	TBD	TBD	TBD
PTTL	Beaufort Coastal Plain	57	Large gravel pit	Gravel	southwest	Active

TABLE 6.3.4-1

Potential Industrial Resources Within 0.5 Mile of the Project Area

Alaska LNG Facility	Borough / District	Approx. Milepost	Site Description		Distance (feet) and Direction	Status
			Location	Potential Resource Type		
PIPELINE ABOVEGROUND FACILITIES						
Liquefaction Facility Meter Station	Cook Inlet Basin	Glaciofluvial	Not likely	TBD	TBD	TBD
PBU Meter Station	Beaufort Coastal Plain	Glaciofluvial, alluvium	Possible	TBD	TBD	TBD
Mainline Meter Station	TBD	TBD	TBD	TBD	TBD	TBD
PTU Meter Station	Beaufort Coastal Plain	Glaciofluvial, alluvium	Possible	TBD	TBD	TBD
Compressor Stations, Heater Stations, MLBVs (not on Compressor sites)	TBD	TBD	TBD	TBD	TBD	TBD
PIPELINE ASSOCIATED INFRASTRUCTURE						
Access Roads	TBD	TBD	TBD	TBD	TBD	TBD
ATWS	TBD	TBD	TBD	TBD	TBD	TBD
Contractor Yards	TBD	TBD	TBD	TBD	TBD	TBD
Pipe Yards	TBD	TBD	TBD	TBD	TBD	TBD
Construction Camps	TBD	TBD	TBD	TBD	TBD	TBD
Disposal Sites	TBD	TBD	TBD	TBD	TBD	TBD
Material Sites	TBD	TBD	TBD	TBD	TBD	TBD
GTP						
GTP	Beaufort Coastal Plain	N/A	N/A	None	N/A	N/A
ASSOCIATED GTP INFRASTRUCTURE						
Module Staging Area	Beaufort Coastal Plain	TBD	TBD	TBD	TBD	TBD
Access Roads	Beaufort Coastal Plain	TBD	TBD	TBD	TBD	TBD
Construction Camp	Beaufort Coastal Plain	TBD	TBD	TBD	TBD	TBD
Material Sites	TBD	TBD	TBD	TBD	TBD	TBD
Offshore of West Dock	TBD	TBD	TBD	TBD	TBD	TBD

TABLE 6.3.4-1

Potential Industrial Resources Within 0.5 Mile of the Project Area

Alaska LNG Facility	Borough / District	Approx. Milepost	Site Description		Distance (feet) and Direction	Status
			Location	Potential Resource Type		
Water Reservoir, Pump Facilities, Transfer Line	TBD	TBD	TBD	TBD	TBD	TBD

Notes:

[a] 'Active' indicates obvious signs of recent use (estimated within the last two years). 'Abandoned' sites have new growth cover (secondary succession). 'Unknown' indicates one of the following: unclear aggregate type, no obvious signs of recent activity, or no new growth to indicate abandonment.

Source: GoogleEarth Imagery (2011-2014); USGS Topographic maps; exp. Alaska LNG Immersive Video

6.3.5 Summary of Mineral Resources in the Project Area

6.3.5.1 Liquefaction Facility

The actual footprint of the Liquefaction Facility, including ancillary facilities, will be identified during the Pre-FEED process. Information concerning potentially affected mines, oil and natural gas wells/well fields, and borrow areas from construction and operation of the Liquefaction Facility will be presented in a subsequent draft of this Resource Report, once further details are known.

6.3.5.2 Interdependent Facilities

Pipelines

The actual footprint of the Mainline will be identified during the Pre-FEED process. Information concerning potentially affected mines, oil and natural gas wells/well fields, and borrow areas from construction and operation of the Mainline will be presented in a subsequent draft of this Resource Report once further details are known.

GTP

The actual footprint of the GTP, including ancillary facilities, will be identified during the Pre-FEED process. Information concerning potentially affected mines, oil and natural gas wells/well fields, and borrow areas from construction and operation of the GTP will be presented in a subsequent draft of this Resource Report once further details are known.

PBTL

The actual footprint of the PBTL will be identified during the Pre-FEED process. As facility sites are refined in the Pre-FEED process, details concerning potentially affected mines, oil and natural gas wells/well fields, and borrow areas from construction and operation will be presented in a subsequent draft of this Resource Report once further details are known.

PTTL

The actual footprint of the PTTL will be identified during the Pre-FEED process. As facility sites are refined in the Pre-FEED process, details concerning potentially affected mines, oil and natural gas wells/well fields, and borrow areas from construction and operation will be presented in a subsequent draft of this Resource Report once further details are known.

Aboveground and Ancillary Facilities

The locations of the aboveground (e.g., compressor stations, heater stations) and ancillary facilities (e.g., construction camps) are not known at this time. As facility sites are refined in the Pre-FEED process, details concerning potentially affected mines, oil and natural gas wells/well fields, and borrow areas from construction and operation will be presented in a subsequent draft of this Resource Report once further details are known.

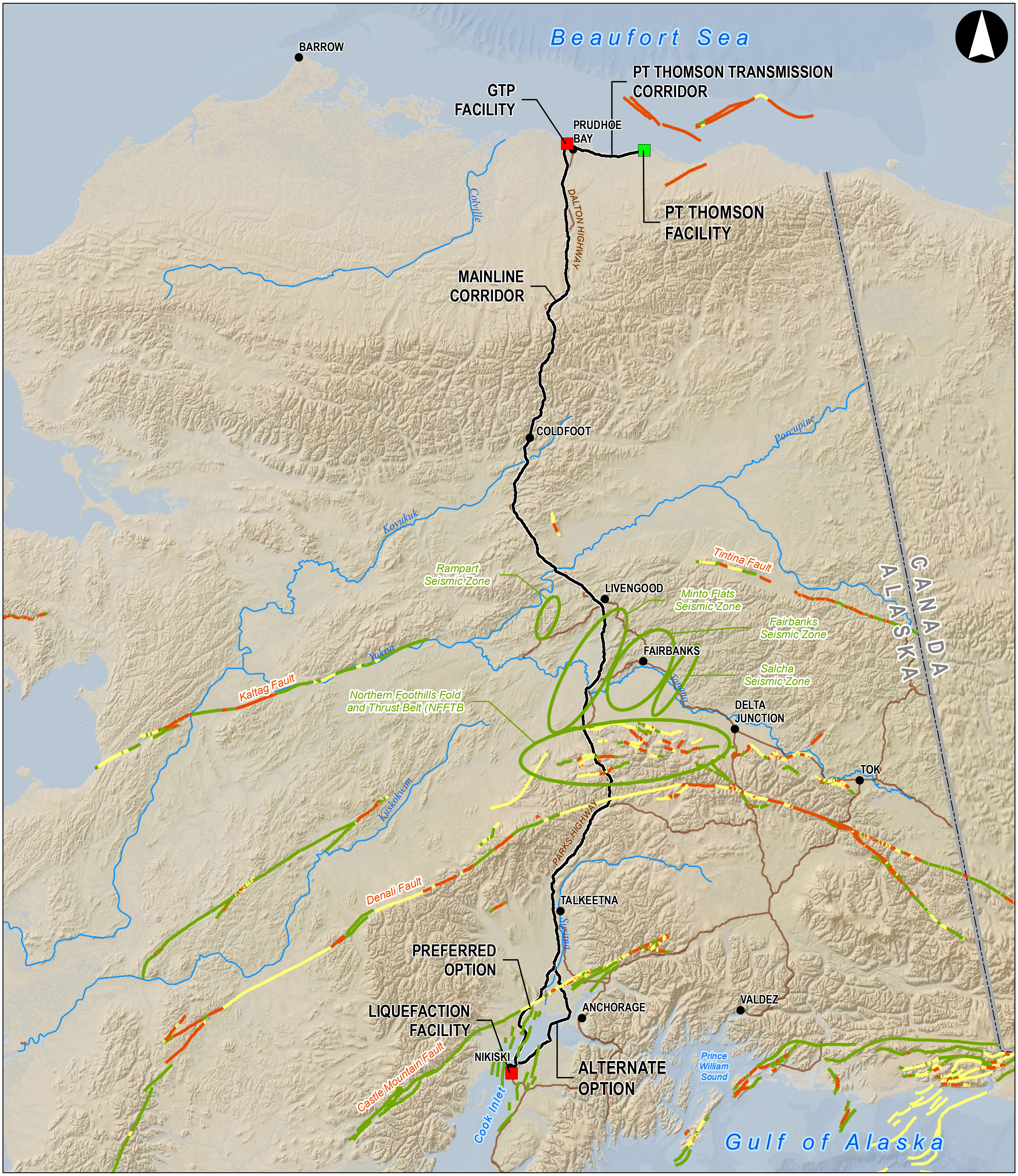
6.4 GEOLOGIC HAZARDS

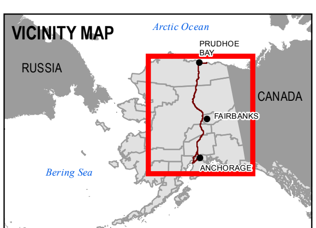
Geologic hazards are naturally occurring events or conditions arising from the geology or active geological processes which can lead to damage of landscapes, property, and/or injury to people. Geologic hazards addressed in this Resource Report include fault and seismic hazards, volcanic hazards, mass wasting, subsidence, acid rock drainage, naturally occurring asbestos, erosion, and scour.

The State of Alaska is located along the plate boundary between the North American and Pacific tectonic plates. This makes the area an active geologic region, including volcanic and seismic activity. Seismicity is a primary concern in the southern portion of the state, where motion along the tectonic plate boundary and a variety of active faults produces abundant earthquakes. Earthquakes can be, in turn, the cause of other hazards, such as landslides. An overview of potential geologic hazards encountered in the Project area is provided in the sections below.

6.4.1 Fault and Seismicity Hazards

Although the entire state of Alaska can be considered seismically active, most earthquakes occur in southern Alaska close to the tectonic plate boundary. The majority of the large, active fault systems such as the Denali fault system are concentrated within the Alaska Range (Figure 6.4.1-1). Twelve (12) smaller scale fault systems are active in other sections of Alaska. The Liquefaction Facility and southern portion of the Mainline will be located within the zone of elevated seismic risk. Seismic activity in the northern part of the state, north of the Alaska Range, is less frequent and less severe than in the south.





LEGEND

- Project Facility
- Existing Facility
- Alaska Place Names
- Project Corridor
- Major Highways
- Major Rivers

Quaternary Faults

- Inferred
- Moderately Constrained
- Well Constrained

0 25 50 100 150 Miles

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MAJOR FAULTS AND SEISMIC ZONES

FIGURE 6.4.1-1

Alaska LNG

X:\Projects\ExxonMobil\SCLNG\Mapping\20150106_ResourceReportFigures_Rev3\RR6\Figure 6_4_1-1 Major Faults and Seismic Zones.mxd

The size of an earthquake is measured using seismometers, and reported as an earthquake magnitude. The most commonly used magnitude scale is the M_w, which is a logarithmic scale with no upper limit. The effects of an earthquake in relation to its magnitude are described in Table 6.4.1-1. The impact that an earthquake has on humans is subjectively/qualitatively ranked as the intensity of the earthquake. The Modified Mercalli Intensity scale assigns ranks of intensity on a scale of I to XII. Human perceptions or structural response to earthquakes of various levels of intensity are described in Table 6.4.1-2. The subsection of the Modified Mercalli Intensity scale pertinent to the Project's region is detailed in this table.

TABLE 6.4.1-1

Earthquake Effects in Relation to Magnitude

Earthquake Magnitude (MW)	Perception or Effect
Less than 2.0	Micro earthquakes, not felt.
2.0–2.9	Generally not felt, but recorded.
3.0–3.9	Often felt, but rarely causes damage.
4.0–4.9	Noticeable shaking of indoor items, rattling noises. Significant damage unlikely.
5.0–5.9	Can cause major damage to poorly constructed buildings over small regions. At most slight damage to well-designed buildings.
6.0–6.9	Can be destructive in areas up to about 100 miles across in populated areas.
7.0–7.9	Can cause serious damage over larger areas.
8.0–8.9	Can cause serious damage in areas several hundred miles across.
9.0–9.9	Devastating in areas many hundreds to several thousand miles across.
10.0+	Never recorded, widespread devastation across very large areas

TABLE 6.4.1-2

Human Perceptions or Structural Responses to Maximum Modified Mercalli Intensities

Maximum Modified Mercalli Intensity	Human Perception or Structural Response
IV	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
VIII	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
IX	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.
XI	Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.
XII	Damage total. Lines of sight and level are distorted. Objects thrown into the air.

Source: USGS, 2015a

Seismicity in Alaska is concentrated in three regions:

- Tectonic plate boundaries;
- Crustal faults; and
- The Aleutian Alaskan Wadati-Benioff zone.

Most of Alaska's earthquakes originate along the southwestern edge of the state, where the Pacific plate sinks beneath the North American plate. These tectonic boundaries produce the state's largest magnitude earthquakes. Although most of these earthquakes originate offshore, the large scale nature of the ground motion means that they can cause damage inland. The Aleutian megathrust fault was the source of an earthquake with a magnitude of 9.2 magnitude in 1964. The Fairweather-Queen Charlotte transform faults were also the source of an earthquake with a magnitude of 8.0 in 1899 (Fairweather) and magnitude of 8.1 in 1949 (Queen Charlotte) (Figure 6.4.1-2).

A second source of frequent and large shallow earthquakes is along crustal faults throughout state. Most of these faults are concentrated within the Alaska Range (Figure 6.4.1-2). These crustal faults were the source of an earthquake with a magnitude of 7.9 in 2002 (Denali fault earthquake). An overview of Alaska seismicity is depicted in Figure 6.4.1-3. Table 6.4.1-3 shows how historic earthquakes greater than intensity IV will be portrayed in a subsequent draft in this Resource Report.

TABLE 6.4.1-3

Historic Earthquakes Greater Than Intensity IV Within 100 Miles of the Alaska LNG Project Area

Approximate Nearest Milepost	Epicenter Direction and Distance from Right-of-Way	Event Month/Day /Year	West Longitude	North Latitude	Body Wave Magnitude	Surface Wave Magnitude	Maximum Modified Mercali Intensity

6.4.1.1 Soil Liquefaction

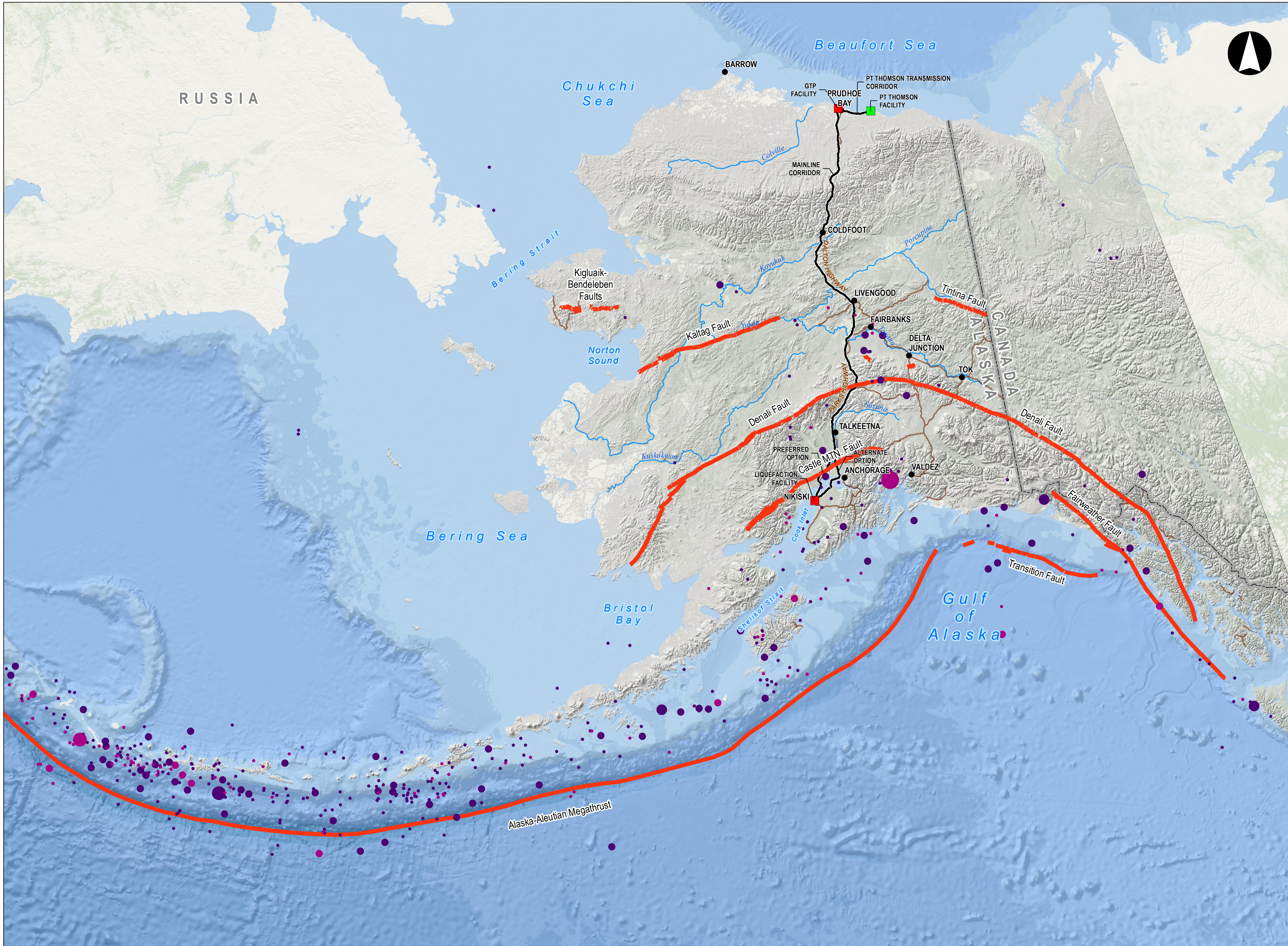
Soils and sediments that are saturated and lack cohesion may be susceptible to soil liquefaction. Soil liquefaction is the temporary change of a solid soil into a soil with liquid properties that may last for hours to days. Areas that generally contain soils and sediments in such conditions are often found along rivers, streams, lakes, and ocean shorelines. Where groundwater is shallow, a soil is more likely to be susceptible to liquefaction. Younger sediments that have not yet experienced significant compaction are the most susceptible. If a soil is frozen, it cannot experience liquefaction.

Seismic waves passing through a saturated soil is a common cause of soil liquefaction. The energy of the seismic waves causes the soil particles to lose strength and act like a viscous fluid. Liquefaction can lead to ground displacement or ground failure, which can result in damage to overlying structures.

EARTHQUAKES LARGER THAN M 6.0 IN ALASKA

FIGURE 6.4.1-2

Alaska LNG



LEGEND

- Project Facility
- Existing Facility
- Alaska Place Names
- Active or Potentially Active Faults
- Project Corridor
- Major Highways
- Major Rivers

Pre 1964

- 6.1 - 6.9
- 7.0 - 7.9
- 8.0 - 8.4
- 8.5 - 8.9
- 9.0 or Larger

Post 1964

- 6.1 - 6.9
- 7.0 - 7.9
- 8.0 - 8.4
- 8.5 - 8.9
- 9.0 or Larger

0 45 90 180 Miles

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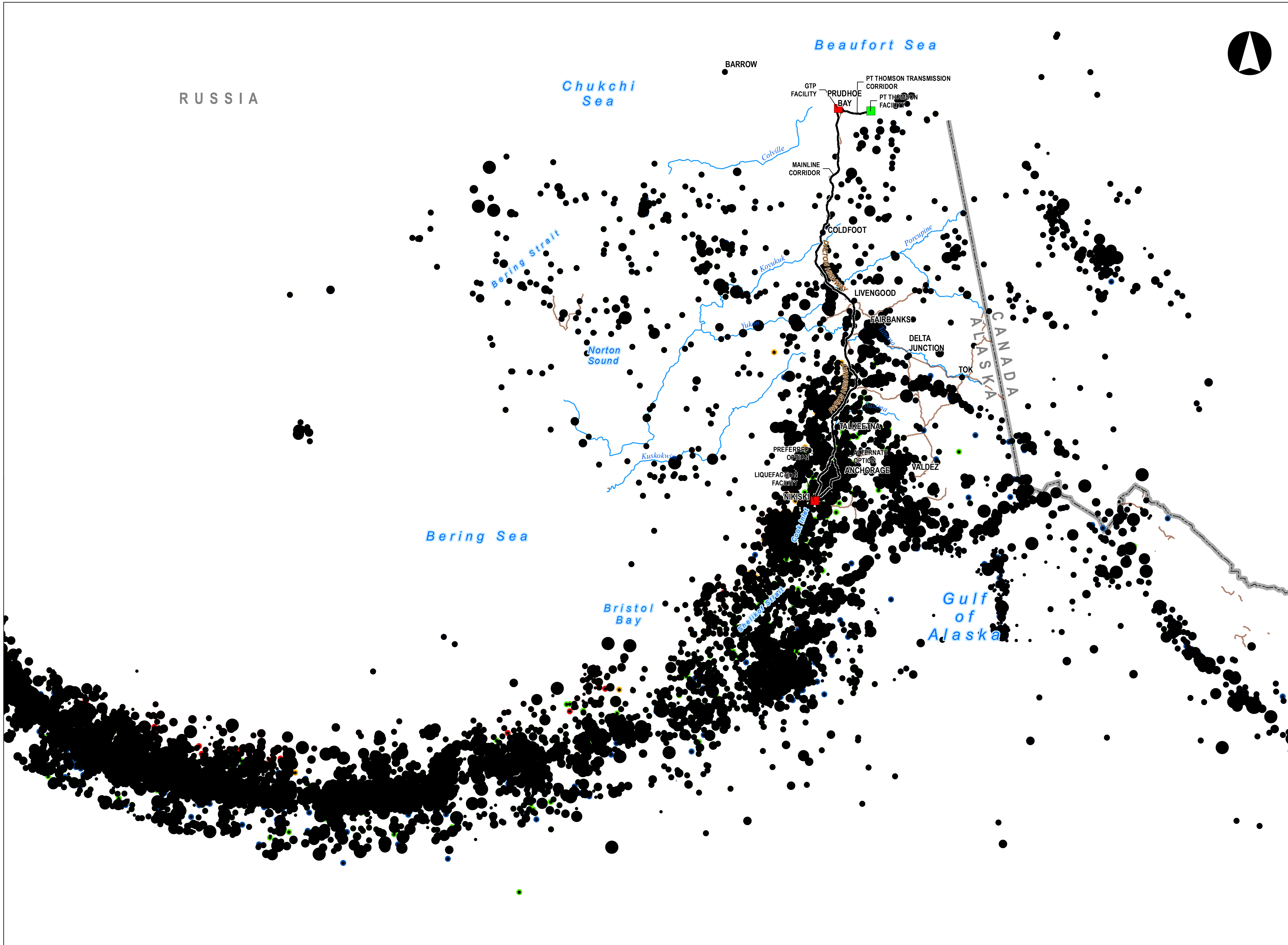
VICINITY MAP

X:\Projects\ExxonMobil\SCLNG\Mapping\20150106_ResourceReportFigures_Rev3\RR6\Figure 6_4_1-2 Earthquakes Larger than M 6_0 in Alaska.mxd

ALASKA SEISMICITY (1898-2012)

FIGURE 6.4.1-3

Alaska LNG



LEGEND

- Project Facility
- Existing Facility
- Alaska Place Names
- Project Corridor
- Major Highways
- Major Rivers

Earthquake Depth

- 0-30 km
- 31-100 km
- 101-150 km
- >150

Earthquake Magnitude

- M = 1.0-3.9
- M = 4.0-4.9
- M = 5.0-5.9
- M = 6.0-6.9
- M = 7.0-7.9
- M > 8.0

0 45 90 180 Miles

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VICINITY MAP

6.4.1.2 Tsunamis and Seiches

With the extensive coastlines and high seismicity throughout the southern portion of the state, Alaska has the highest potential for tsunami and seiche hazards in the nation. Tsunamis are massive water waves that propagate through any depth of water, and become hazardous when passing through shallow water and onto shorelines. Seiches are oscillating standing waves that can occur within any enclosed or partially enclosed water body, and are hazardous when their extreme vertical oscillations intersect shorelines. Tsunamis are usually generated by earthquakes or large landslides, while seiches can be caused by earthquakes or extreme wind and weather events (USGS, 2015b).

Large magnitude earthquakes in southern Alaska, particularly those that originate along the tectonic plate boundary, can generate both tsunami and seiche waves. Such waves can inundate coastal areas, endangering lives and infrastructure in low-lying areas for several miles inland. Coastal areas in southern Alaska are also susceptible to tsunami waves generated from earthquakes in distant locales around the North Pacific.

Ground displacement during the Great Alaskan Earthquake of 1964 generated tsunami waves of up to 70 meters in height, the largest ever recorded in North America. Secondary local tsunami waves were also generated by underwater landslides during the earthquake. The run-up of these waves destroyed coastal infrastructure in the port towns of Valdez, Seward, Chenega, and Kodiak (Alaska Earthquake Information Center, 2014). Seiches also resulted from the ground motion during the 1964 earthquake, causing local damage along shorelines. Seiches generated from the Great Alaska Earthquake were recorded at hundreds of locales around the world following the earthquake (USGS, 2015b).

The Project area's location along the Cook Inlet provides some protection from large-scale megathrust-generated tsunamis, as Cook Inlet is separated from the main body of the Pacific Ocean. The southernmost Project area is less susceptible to tsunami hazards than are the coastal areas along the south and east portions of the Kenai Peninsula.

6.4.1.3 Potential Seismic Hazards in the Project Area

The Project will cross several faults and fault zones that are known or suspected to be active. Faults are considered active if there is evidence of displacement along the fault in the last 10,000 years, and/or if the seismic history suggests a high potential for future rupture along the fault. Fault rupture displacement occurs when the ground surface moves due to slip at the surface along a fault. Ground cracking related to fault rupture can occur directly along the fault, and ground failure can result from ground shaking at significant distances from the fault (Alaska Division of Geological & Geophysical Surveys [DGGS], 2011). Potentially active faults are a significant consideration in the design engineering of an LNG facility and natural gas pipeline. The pipeline must be designed to deform both longitudinally and in flexure in order to avoid brittle failure during surface displacement.

The location of major faults and seismic zones within the Project area is depicted in Figure 6.4.1-1 and Table 6.4.1-4 lists the major faults that will be crossed by the Project area.

TABLE 6.4.1-4

Active and Potentially Active Faults in the Vicinity of the Alaska LNG Project Area

Nearest Facility	Segment/Borough or Census Area	Fault Name/No.	Proximate to Approximate MP Beginning	Proximate to Approximate MP End	Closest Point (feet) and Direction
Liquefaction Facility	Kenai Peninsula B.	Castle Mountain Fault	TBD	TBD	TBD
Mainline	North Slope Borough	None	TBD	TBD	TBD
	Yukon-Koyukuk Census Area	Dall City Seismic Zone	TBD	TBD	TBD
		Rampart Seismic Zone			
		Minto Flats Seismic Zone			
	Fairbanks North Star Borough	Fairbanks Seismic Zone	TBD	TBD	TBD
	Denali Borough	Denali Fault	TBD	TBD	TBD
		Hines Creek Fault			
		Parks Road Fault			
		Healy Creek Fault			
		Stampede Fault			
		Little Panguigue Creek Fault			
		Buzzard Creek Fault			
		Northern Foothills Thrust			
	Kenai Peninsula B	Castle Mountain Fault	TBD	TBD	TBD
GTP, PBTL, PTTL	North Slope Borough	None	TBD	TBD	TBD

Liquefaction Facility

The most significant earthquake to have impacted the southernmost portion of the Project area was Alaska's Great Earthquake of 1964, which was due to large-scale motion along the megathrust between the North American plate and the Pacific plate. The Pacific plate is estimated to have advanced approximately 9 meters along the plate boundary as a result of the stress on the plates being released. Significant damage occurred throughout southern Alaska, including ground displacement, shaking, landslides, soil liquefaction, and ensuing tsunamis. Other significant historical earthquakes have occurred along the megathrust as well, including earthquakes with a magnitude of 7.5 in 1979, a magnitude of 7.8 in 1988, and a magnitude of 7.9 in 1987 (Alaska Earthquake Information Center, 2011). Although these megathrust earthquakes do not originate within the Project area, their massive scale can generate strong ground motions for hundreds of miles in all directions.

Interdependent Facilities

As noted above, within the southern portion of the Project area, earthquakes are quite common. Earthquakes are much less frequent in northern Alaska, and seismicity is low throughout the northern Project area (Plafker et al., 1994). Within 50 miles of the Project area in the northernmost ecoregions (Beaufort Coastal Plain, Brooks Range Foothills, and Brooks Range Ecoregions), there have only been three earthquakes in the last 50 years that had a magnitude greater than 5.0 (Alaska Earthquake Information Center, 2011).

Within the Kobuk Ridges and Valleys, Ray Mountains, Tanana-Kuskokwim Lowlands, and Yukon-Tanana Uplands Ecoregions, there have been 23 earthquakes in the last 50 years that were of a magnitude greater than 5.0 within 50 miles of the Project area (Alaska Earthquake Information Center, 2011).

Within the Ray Mountains Ecoregion, the Mainline corridor passes through several different seismic zones, including the Dall City and Rampart seismic zones. The Dall City seismic zone is not well defined, but is known to have had a series of large earthquakes from the late 1960s through the 1980s, including a magnitude 5.2 earthquake in 1969 and five earthquakes with a magnitude greater than 5.0 in 1985. The Rampart seismic zone is northwest of Fairbanks, between the Kaltag fault and Tintina fault system. Historic earthquakes in this area include one with a magnitude of 6.8 in 1968 and another with a magnitude of 5.0 near the Village of Rampart in 2003 (Alaska Earthquake Information Center, 2011).

Extending south from the Ray Mountains Ecoregion into the Yukon-Tanana Uplands Ecoregion, two seismic zones occur with significant historical earthquake activity: the Fairbanks and Minto Flats seismic zones. The Fairbanks seismic zone is a large zone of northeast-trending high angle faults that extends from the Yukon-Tanana Uplands Ecoregion to north of Fairbanks (Kolker et al., 2007). There have been occasional large magnitude earthquakes throughout this seismic zone, including a magnitude 7.3 earthquake in 1904, a magnitude 6.1 earthquake in 1967, a magnitude 5.2 earthquake in 1981, and a magnitude 7.2 earthquake in 1947 (Alaska Earthquake Information Center, 2011). The Minto Flats seismic zone is an area of elevated earthquake activity that extends from the Denali Fault in the south to the Tintina Fault in the north. In 1995, there was a magnitude 6.0 earthquake in the northern end of the Minto Flats seismic zone (Freymueller et al., 2008).

The Cook Inlet Basin and Alaska Range Ecoregions have had significant historical earthquake activity. Since 1960, there have been over 90 earthquakes with a magnitude greater than 5.0 within these two Ecoregions (Alaska Earthquake Information Center, 2011).

In the Alaska Range, the Mainline corridor will pass through the Northern Foothills Fold and Thrust Belt (NFFTB), a zone of active and potentially active faults that have experienced seismic activity for at least 3 million years (Freymueller et al., 2008), and cross the active Denali Fault. The NFFTB includes the Parks Road, Healy, Healy Creek, Stampede, Little Panguigue Creek, and Buzzard Creek faults and the Northern

Foothills Thrust. The Denali Fault is a major fault that extends for several hundred miles, roughly east-west through the Alaska Range. Historical movement has been recorded along several locations within this fault system (Alyeska Pipeline Services Company, 2007; Berg and Plafker, 1994). There was a historically significant earthquake with a magnitude of 7.2 along the Denali Fault in 1912 and an earthquake with a 7.9 magnitude in 2002, which impacted the Trans-Alaska Pipeline System (TAPS). TAPS was designed to resist damage from earthquakes up to magnitude 8 by sliding along lubricated slider beams. This allows the pipeline to gently give way to ground deformation, rather than experiencing brittle failure. The TAPS engineering design proved successful, and the pipeline did not suffer significant damage from the 7.9 magnitude quake.

Within the Cook Inlet Basin Ecoregion, the Mainline corridor will cross the active Castle Mountain Fault. This fault is a large-scale northeast-trending right lateral strike-slip fault that runs along the southern edge of the Talkeetna Mountains and across the Susitna River delta. The Castle Mountain Fault produced earthquakes with a magnitude of 5.7 in 1983 and a magnitude of 4.6 in 1996, both along the eastern portions of the fault. The western portion of the fault has not seen significant earthquake activity for approximately 650 years (Hauessler et al., 2002). However, approximately 40 miles to the north of the central Castle Mountain Fault, there was a magnitude 6.3 earthquake in late 2014. This earthquake struck approximately 60 miles west of the Mainline corridor, 20 miles west of the town of Skwentna (Alaska Earthquake Information Center, 2014).

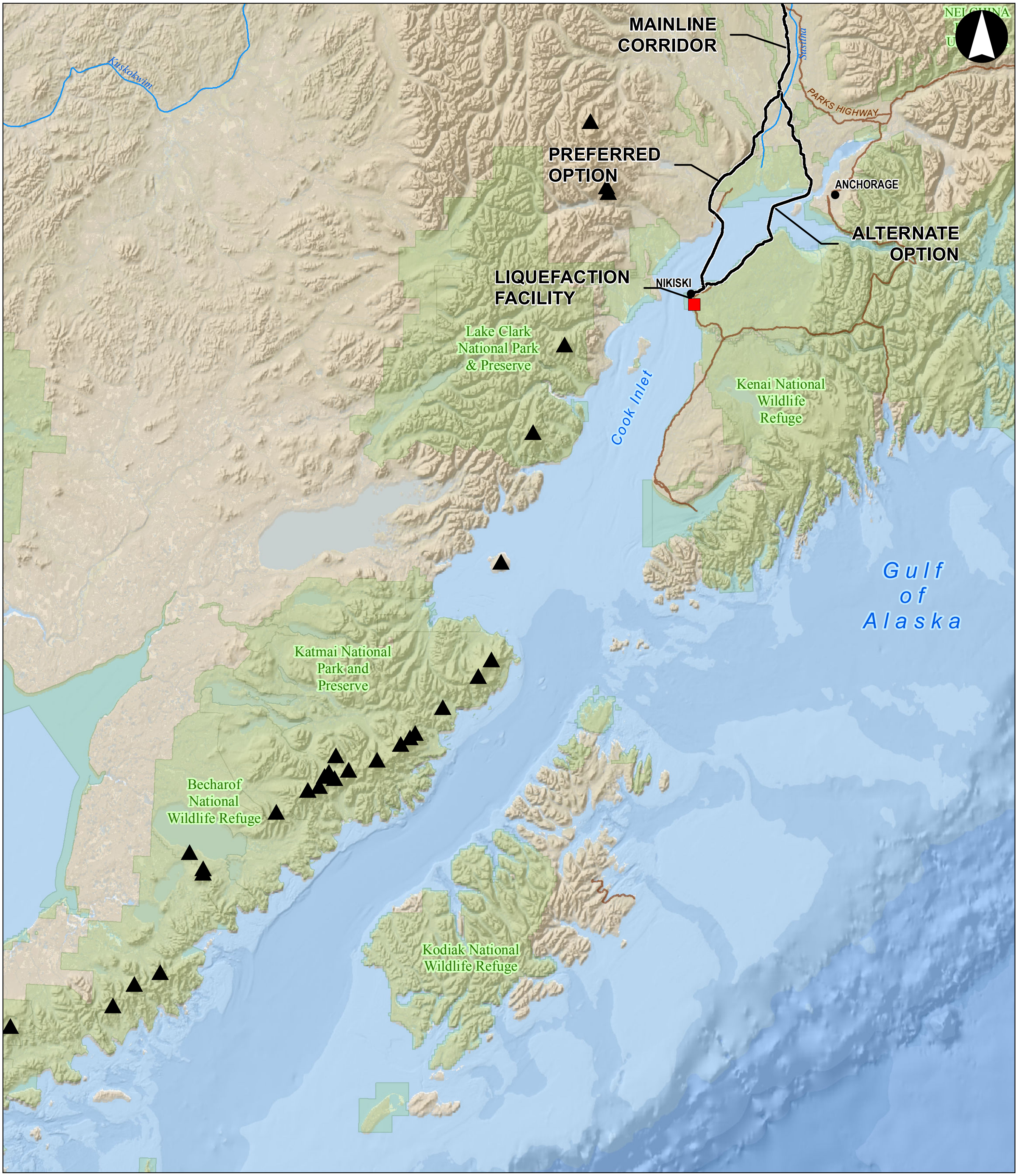
6.4.2 Volcanic Hazards

Southern Alaska is a volcanically active region with most of the volcanoes lying along the Aleutian Chain, which runs the length of the Alaska Peninsula and the Aleutian Islands. The Aleutian Chain is approximately 2,000 miles long and contains approximately 100 volcanoes, half of which have been historically active (Alaska Volcano Observatory, 2014). The northern portion of the Aleutian Chain includes Cook Inlet, with active volcanoes located along the west side of the inlet (Figure 6.4.2-1).

Volcanoes in the vicinity of the Project area are listed in Table 6.4.2-1 (Alaska Volcano Observatory, 2014). The closest active volcanoes to the Project area include the following:

- Redoubt Volcano, located approximately 50 miles southwest of the LNG facility;
- Iliamna Volcano, located approximately 75 miles southwest of the LNG facility;
- Augustine Volcano, located approximately 115 miles south-southwest of the LNG facility; and
- Mount Spurr, located approximately 40 miles west of the Mainline corridor.

All four of these volcanoes are active stratovolcanoes, having been built up through explosive eruptions of ash and pyroclastics, and thick, viscous lava flows.



VICINITY MAP

LEGEND

- Project Facility
- Existing Facility
- Alaska Place Names
- Volcanoes
- Project Corridor
- Major Highways
- Major Rivers
- State and Federal Conservation Lands

0 15 30 60 Miles

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COOK INLET VOLCANOES

FIGURE 6.4.2-1

Alaska LNG

X:\Projects\ExxonMobil\SCLNG\Mapping\20150106_ResourceReportFigures_Rev3\RR6\Figure 6_4_2-1 Cook Inlet Volcanoes.mxd

Cook Inlet separates the volcanoes from the Kenai Peninsula, where the Liquefaction Facility will be located. The most significant potential hazard that these volcanoes could pose to the Project is ashfall. Many of the other volcanic hazards, such as lahars, lava flows, or pyroclastic flows, are not a significant concern in the Project area due to (1) the distance from the volcanoes and (2) the separation provided by Cook Inlet.

TABLE 6.4.2-1

Volcanoes in the Vicinity of the Alaska LNG Project Area

Nearest Facility	Segment/Borough or Census Area	Volcanic Feature	Approximate MP	Approximate location of Closest Point (miles) and Direction	Most Recent Activity
Liquefaction Facility	Kenai Peninsula Borough	Redoubt	TBD	TBD	2009
		Iliamna	TBD	TBD	1953
		Augustine	TBD	TBD	2005
Mainline	Kenai Peninsula Borough	Mount Spurr	TBD	TBD	1992
GTP	North Slope Borough	None	N/A	TBD	N/A
PBTL	North Slope Borough	None	NA	TBD	NA
PTTL	North Slope Borough	None	N/A	TBD	N/A

Source: Alaska Volcano Observatory, 2014

6.4.2.1 Ashfall

Explosive volcanic activity produces tephra, which includes any airborne volcanic ejecta, from tiny particles of ash up through moderate sizes cinders and large volcanic bombs. Volcanic ash becomes suspended in the air and can travel great distances, including circling the earth in the upper atmosphere. Volcanic ash and the associated volcanic gases can be highly corrosive to metallic machinery. Volcanic ash is also composed of sharp shards that can abrade hard surfaces.

Larger volcanic tephra from the Cook Inlet volcanoes, including cinders and bombs, will fall close to the volcanic vent, and is not capable of reaching the Project area. However, the predominantly eastern direction of winds in southern Alaska could blow ash from erupting volcanoes towards the Project area. Volcanic ashfall from Cook Inlet volcanoes typically reaches the southern Project area during moderate to large-scale eruptions (Alaska Volcano Observatory, 2014). Ash entering machinery through air intake valves or other openings can damage or destroy machines. In high concentrations, ashfall can also create respiratory distress for people, especially those who suffer from asthma.

6.4.2.2 Lahars

Lahars are volcanic mud flows, made up of fresh volcanic ash and other rock debris, and mobilized by rain water or melted snow and ice. Lahars are a typical volcanic hazard close to stratovolcanoes, particularly along drainages. For example, eruptions in 1989-90 and again in 2009 from Mt. Redoubt, some 50 miles southwest of the Liquefaction Facility, sent lahars downstream of the volcano, nearly to the shores of the

Cook Inlet (Alaska Volcano Observatory, 2014). Potential lahars from Mt. Spurr are capable of traveling to the shores of Cook Inlet, but would likely follow drainages well south of the western proposed Project area.

Lahars are unlikely to be a significant hazard to the Project area. Although lahars can travel for tens of miles from a volcanic vent, Cook Inlet lies between the volcanoes and the Project area. Any massive scale lahars from the west side of Cook Inlet would flow into the inlet and disperse, posing no threat to the Project area.

6.4.2.3 Pyroclastic Flows

Pyroclastic flows are high-speed, extremely hot flows of volcanic ash, gas, and other debris. Pyroclastic flows will destroy anything in their path without warning, and are typical of Cook Inlet volcanoes. Pyroclastic flows, however, are unlikely to be a significant hazard to the Project area. These flows would typically travel only a few miles from the volcanic vent, although they are capable of traveling tens of miles from a vent during a catastrophic eruption (USGS Volcano Hazards Program, 2014). Cook Inlet lies between the volcanoes and the Project area. Any massive catastrophic eruption, pyroclastic flows on the west side of Cook Inlet would flow into the inlet and disperse. There is no evidence to suggest that a pyroclastic flow would reach the Project area.

6.4.2.4 Lava Flows

Lava flows from Cook Inlet volcanoes tend to be slow-moving, high viscosity flows, typically only advancing several meters per day. Lava flows from Cook Inlet volcanoes rarely travel beyond the flanks of the erupting volcano (Alaska Volcano Observatory, 2014). In the unlikely event that a highly mobile lava flow were to erupt, the lava flow would intersect Cook Inlet before reaching the Project area and would immediately be quenched and cooled, posing no threat to the Project area.

6.4.2.5 Flank Collapse

During a massive, catastrophic eruption, portions of a volcano’s flank can collapse into a landslide, similar to what occurred at Mount Saint Helens in 1980. If a similar event were to occur at Cook Inlet, landslide debris, lahars, and/or pyroclastic flows could reach the Inlet. Depending on their proximity, nearshore sections of the Mainline could be buried, damaged, or obliterated. If such a catastrophic eruption were to occur, landslide and pyroclastic material could also reach Cook Inlet with sufficient force to cause a tsunami.

Flank collapse would only occur in a very extreme, catastrophic eruption. This scale of eruption is possible among the Cook Inlet volcanoes. Within the last 10,000 years, Mt. Spurr experienced a flank collapse that spread debris for tens of miles from the volcano (Alaska Volcano Observatory, 2014). It is unknown if this eruption impacted the Cook Inlet. Significant damaging impacts to land on the east side of Cook Inlet would be unlikely, however heavy ash fall within the southern project area would be likely.

6.4.2.6 Volcanic Gases

Carbon dioxide, hydrogen sulfide, and sulfur dioxide are all dangerous and potentially lethal volcanic gases that can be released in massive quantities during an eruption. If the gases were erupted in sufficient quantity, and the winds blew to the east/northeast, concentrated gases could create hazardous conditions for people in the Project area. This would only occur in the event of a rare, massively catastrophic eruption.

6.4.3 Mass Wasting

Mass wasting (landslides) is the large-scale, downward movement of geological materials, including rocks, sediments, soils, water, ice, and snow. Gravity is the dominant force behind mass wasting events, but they can also be triggered by the motion of water or wind, or large-scale disturbances such as earthquakes. Water and ice present in the material can exacerbate activity. Events are classified into categories depending on:

- The type of materials involved;
- The speed at which the materials are mobilized; and
- The way the material moves downslope.

These types of mass wasting events include:

- Falls;
- Slides and slumps;
- Flows;
- Avalanches;
- Creep;
- Rock glaciers; and
- Subsidence.

Mass wasting events identified in the vicinity of the Project area will be listed in a table similar to Table 6.4.3-1.

TABLE 6.4.3-1

Mass Wasting (Landslides) in the Vicinity of the Alaska LNG Project Area

Nearest Facility	Segment/Borough or Census Area	Active Landslide	Probable Mass Movement Type	Closest Point (miles) and Direction	Most Recent Activity

6.4.3.1 Falls

Falls are mass wasting events in which the material involved "freefalls" down slope, and the material is not in contact with the slope. Falls occur on steep slopes or cliffs faces and are generally dry mass movements, not requiring water or wet sediments for mobilization. Most falls are rock falls, composed of competent rock; however, coarse, dry sediments can also produce falls.

6.4.3.2 Slides and Slumps

Slides are catastrophic mass wasting events in which material is suddenly mobilized downward along a failure surface, such as a fault plane or a bedding plane. Mobilized materials move as a cohesive unit, unlike those involved in a flow. Deep-seated landslides are typical types of slides.

Slumps involve material moving downslope along a curved failure surface, with a rotational movement of the slumping materials. Slumps occur on a smaller scale than slides and may mobilize more gradually, they are typically not catastrophic. Slumps most often occur in highly fractured rock, sediments, or soil.

6.4.3.3 Flows

Flows are mass movements of unconsolidated materials that move downslope in a chaotic fashion (e.g., debris flows and mudflows). During a flow, soil, sediments, gravel, boulders, or vegetation debris, often mixed with water, mobilize at relatively high speeds and have long run-out distances. The ratio of mass thickness to run-out distance (e.g., length of flow) is generally small.

6.4.3.4 Avalanches

Avalanches are mass wasting events involving mostly snow and ice, which may also entrain other debris such as rocks, soil, and vegetation. Most severe avalanches originate on slopes between 30 and 45 degrees, as slopes steeper than 45 degrees, or shallower than 25 degrees, rarely experience avalanches (USDA, 2004). Snow avalanches are capable of moving at extremely high speeds, and can be a significant threat to infrastructure and people.

When snow absorbs significant meltwater during the annual spring thaw season in the Arctic and Subarctic the saturated snow is susceptible to a mass wasting failure called a "slushflow." These wet snow avalanches are common on slopes in the arctic and subarctic during the spring and early summer. Slushflows are generally slower than dry snow avalanches, and do not have the ability to override high topography, but they have the potential to be very destructive. The high water and debris content of the slushflows allows them to generate considerable momentum, with potential for long run-out distances, even along very gentle slopes (Onesti, 1985).

6.4.3.5 Creep and Solifluction

Creep, or slope creep, is the slowest form of mass wasting, and can occur over a period of decades. Unconsolidated sediments are the most susceptible to creep and a rapid increase in sediment moisture may convert a slow creep into a rapid slide.

During the summer thaw season in the Arctic and Subarctic, thawing ice-rich soils on slopes may be susceptible to a type of slow flow called solifluction. When a thin layer of thawed permafrost detaches from the material below and mobilizes, it is considered a “skin flow.” Solifluction is addressed in more detail in Resource Report No. 7.

6.4.3.6 Rock Glaciers

Rock glaciers are common in northern Alaska, particularly within the valleys of the Brooks Range. Rock glaciers are mass movements involving immature, coarse talus with a high proportion of interstitial ice. Seasonal thaw allows for creep in the interstitial ice and the rock glaciers slowly advance downslope. Such movements can form lobate flows. Seasonally, rock glaciers advance downslope on top of bedrock or sediments, or alternatively may be located on top of a deeper valley glacier. In areas of retreating glaciers, rock glaciers may be left behind when the ice beneath them melts.

6.4.3.7 Subsidence

Subsidence is the lowering of surface elevation caused by a reduction in subsurface support. This can happen on any scale, from small, localized collapses, to a widespread, regional loss of elevation. Subsidence can be caused by a wide variety of natural and human-induced changes to the subsurface. The most common natural cause of subsidence is dissolution of carbonate rock, resulting in extensive cave systems and collapse features (such as sinkholes), typical of karst topography. Other causes of subsidence include underground mines which experience local collapses; groundwater which is pumped out of an area rapidly; and seasonal or human-induced thawing of interstitial ice in permafrost areas (e.g., thermokarst).

A portion of the Project area will overlie limestone (carbonate) bedrock that could be susceptible to dissolution by groundwater. In areas where the water table is within the limestone strata and surface sediments are thin (less than 30 feet), the potential exists for the development of karst topography. However, in arctic and subarctic environments, dissolution of carbonate rock is not a vigorous process, and tends to modify the landscape on a timescale of hundreds to thousands of years.

Where the Project corridor will pass through Atigun Pass, the bedrock includes moderately to steeply dipping limestone beds, likely associated with the Baird Group (Mull and Adams, 1989). In this area, bedrock is overlain by thin glacial deposits and immature soils. Mapping by Davies et al. (1984) suggests there is the potential for subsurface karst features, including fissures, tubes, and caves. Thick limestone in the vicinity of Galbraith Lake and in the Dietrich River valley contains numerous karst caves and openings.

6.4.4 Acid Rock Drainage

Acid rock drainage and metal leaching are naturally occurring processes that may be generated when excavating and/or exposing areas with rocks pyrite-bearing or permissive for the presence of sulfide minerals. Where the bedrock is exposed to weathering conditions (e.g., water and oxygen), sulfide minerals present in the rocks may be oxidized releasing acidic, sulfate and metals-laden drainages commonly known as acid rock drainage. This acidic drainage, or runoff, can impact aquatic organisms, wildlife, and human populations. Pyrite is the main mineral of concern for acid rock drainage and is ubiquitous in nature.

Naturally occurring carbonate minerals such as calcite are effective in neutralizing acid rock drainage. Where these minerals are present in sufficient amount in the exposed rock, they can dissolve quickly and buffer the acidity generated from sulfide oxidation, which in turn results in the precipitation of metals out of the drainage.

Overburden and sediments that have been reworked by water and/or wind over thousands of years generally do not contain sulphide minerals, and therefore do not tend to pose a risk of acid rock drainage. Major sections of the Project area are covered with thick deposits of glacial sediments. In most of these areas, bedrock is buried deeply beneath the sediments and construction would not be deep enough to reach the buried bedrock. These regions with thick overburden cover are expected to have a very low to no potential for acid rock drainage and metal leaching.

In areas where construction activities are expected to excavate, disturb or expose the bedrock, there could be a potential for acid rock drainage and metal leaching. The rock types encountered in the Project area capable of hosting sulfide minerals include:

- Merozoic and Cenozoic-aged shale;
- Mudstone;
- Schist;
- Claystone;
- Coal shale; and
- Igneous rocks.

A preliminary desktop screening was carried out in 2014 to identify and rank the Mainline corridor according to the potential for acid rock drainage and metal leaching using publically available geological, mineralogical and geochemical data as well as qualitative data collected during previous acid rock drainage field investigation. Samples were collected during a field investigation in the summer of 2014, and sent to the laboratory for static tests recommended for the assessment of acid rock drainage and metal leaching. The results of these tests, and additional investigation that will be conducted during the Pre-FEED phase, will be used to rank the Project area based on the risk for acid rock drainage and metal leaching. The number of areas where these rock types are encountered is expected to be limited. Table 6.4.4-1 outlines the information that will be provided in subsequent versions of this report.

TABLE 6.4.4-1

Areas Susceptible to Potential Acid Rock Drainage in the Alaska LNG Project Area

Nearest Facility	Segment/Borough or Census Area	Geologic Description	Acid Rock Drainage Hazard Rating	Comments on Hazard Rating

6.4.5 Naturally Occurring Asbestos

Naturally occurring asbestos (NOA) has recently become a concern in Alaska, as it has impacted state projects over the past several years. The term 'asbestos' refers to a variety of magnesium silicate minerals that naturally occur in fibrous form or 'asbestiform.' Accidental inhalation or ingestion of asbestos particles is known to cause or contribute to fibrosis and malignancies of the lung and other organs (Perkins et al., 2009). Asbestos minerals are most often associated with ultramafic rocks, which are known to occur in some locales throughout Alaska. A subsequent draft of this Resource Report will identify any areas of known or potential NOA occurrence within the Project area.

6.4.6 Erosion and Scour

As described in Resource Report No. 2, multiple stream channel crossings occur along the Project corridor (Mainline and PTTL). Bank/channel erosion and scour are naturally occurring processes that pose a hazard to pipeline infrastructure. Scour may also occur within ocean bodies. Channel migration is another natural process that may be exacerbated by the burial of a pipeline, which can promote the mobilization of loosened sediments. The erosion of sediments around a buried pipeline, or underlying pipe bridge supports, can lead to the undercutting the pipeline, leaving the pipeline unsupported (spanning).

Typically, pipelines are buried at sufficient depth to avoid most concerns about erosion. However, seasonal or flash flooding (e.g., catastrophic increase in stream discharge) can lead to extensive erosion, exposing buried pipe, or undercutting pipe bridge supports. Flooding hazards are particularly high during the spring thaw, when melting snow and ice combines with increased precipitation, leading to high stream discharges and increased stream loads. Ice dams are also not uncommon during spring thaw, which can breach, leading to flash flooding. Mobilized stream ice from the breakup of an ice dam or aufeis (ice overflow) poses an additional threat due to potential ice scour.

Subsea scour may be a particular hazard in Cook Inlet due to extreme tidal fluctuations, strong currents, and high levels of sediment (Thurston and Choromanski, unknown date). Seafloor features in Cook Inlet undergo geomorphic processes that are highly influenced by strong currents, including:

- Lag gravel: Sediments deposited by glaciers with subsequent removal of fine and medium-grained particles.
- Sand ribbons: Strips of sand oriented parallel to prevailing tidal currents.
- Sand waves: Occurring in approximately 130-400 feet of water, and reaching amplitudes of 50-2000 feet.
- Comet marks: Erosional tail of lag gravel behind a seafloor obstruction.

Locations within the Project area where the potential for erosion and scour is anticipated to be high will be listed in a subsequent draft of this Resource Report, in a table similar to Table 6.4.5-1.

TABLE 6.4.5-1

Areas Susceptible to Erosion and Scour in the Alaska LNG Project Area

Facility	Segment/Borough or Census Area	Description	Approximate MP	Recommendations

6.5 POTENTIAL CONSTRUCTION IMPACTS AND MITIGATION MEASURES

Some general geological resource impacts that may occur during construction of projects similar to this one are:

- Blasting for the installation of some facilities, and for the extraction of gravel resources required for construction;
- Building in areas of potential geologic hazards;
- Northern areas of the Project corridor are more likely to be prone to permafrost-specific impacts, such as solifluction; and
- Southern areas of the Project corridor are more susceptible to seismic hazards.

A general summary of potential impacts to geological resources from construction of projects similar to this Project is provided in Appendix A. This Appendix also includes a summary of the types of plans, as examples, that can be developed to address potential impacts. As additional Project details become available, a subsequent draft of this Resource Report will identify site-specific impacts to geology and mineral resources crossed or in the vicinity of the (1) Liquefaction Facilities and (2) the Interdependent Facilities. Included will be a discussion of potential plans and/or BMPs, including site-specific measures (e.g., special installation techniques) for identified geologic hazards (e.g., erosion, subsidence).

6.6 POTENTIAL OPERATIONAL IMPACTS AND MITIGATION MEASURES

Geological resource considerations for Project operation are generally related to potential geologic hazards. Mitigation of potential geologic hazards generally involves preventative action through continued monitoring and best engineering practices.

A general summary of potential impacts to geological resources from operation of projects similar to this Project is provided in Appendix A. This Appendix also includes a summary of the types of plans, as examples, that can be developed to address potential impacts. As additional Project details become available, a subsequent draft of this Resource Report will identify site-specific impacts to geology and mineral resources crossed or in the vicinity of the (1) Liquefaction Facilities and (2) the Interdependent Facilities. Included will be a discussion of proposed studies and plans, including site-specific measures (e.g., foundation systems, etc.) for identified geologic hazards (e.g., tsunamis, earthquakes).

6.7 PALEONTOLOGICAL RESOURCES

Paleontological resources are the remains of former life preserved in rocks or sediments. These include fossils, imprints, moulds, casts, or traces. Fossils of plants and animals, both marine and terrestrial, are a valuable scientific resource which document the history of life on the planet. Fossils are protected under the following laws:

- Antiquities Act (any fossil which is considered of scientific value);

- The Omnibus Public Land Management Act of 2009, Public Law 111-011. Title VI Subtitle D Paleontological Resources Preservation (PRPA);
- Alaska Historic Preservation Act;
- Federal Land Policy and Management Act;
- Federal Cave Resources Protection Act; and
- Archaeological Resources Protection Act.

Some of the rock formations present in the Project area are either known to contain paleontological resources or have the potential to contain them. Most sedimentary rocks will contain some microfossils, including bacteria, algae, planktonic plants, and invertebrates (e.g., insects, worms). These microfossils are common and widespread around the world and are not necessarily considered scientifically significant. Larger fossils that are potentially present in the Project area include dinosaurs of the Mesozoic age and mammoths of the Pleistocene age. These larger vertebrate fossils are rare, not commonly found intact, and more scientifically significant. Therefore, rock formations which are most likely to contain large vertebrate fossils are of the greatest concern.

Sedimentary rocks are sediments which have been deposited by water or wind, and later lithified into solid rock, such as sandstone, limestone, and shale. These rocks are the most likely formations in which to find vertebrate fossils. Sediments which have been deposited and not yet lithified into solid rock are considered unconsolidated sediments, such as alluvial, fluvial, glaciofluvial, and eolian deposits. These sediments may also contain vertebrate remains, particularly more recent remains, such as Pleistocene animals. The unconsolidated sediments are most likely to contain vertebrate remains when they contain layers of permafrost. Paleontological resources in the vicinity of the Project area will be listed in a table similar to Table 6.7-1.

TABLE 6.7-1

Known or Potential Areas of Paleontological Resources in Proximity to the Alaska LNG Project Area

Nearest Facility	Segment/Borough or Census Area	Approximate MP		Closest Point (feet) and Direction	Known or Potential Occurrence	Details
		Beginning	Ending			

6.7.1 Liquefaction Facility

Bedrock beneath the Liquefaction Facility is composed of upper Tertiary continental deposits (sandstone, siltstone, claystone, conglomerate, and coal) of the Kenai Group (Beikman, 1980). Due to lack of bedrock outcrops in this area, little is known about the abundance of Tertiary age fossils in the area. The same rocks of the Kenai Group, however, outcrop on the west side of Cook Inlet, and are known to contain abundant Tertiary plant fossils (Wolfe et al., 1966).

Cook Inlet Basin Ecoregion

The Cook Inlet Basin Ecoregion is well known for its fossiliferous sedimentary rocks. This Cook Inlet Basin Ecoregion is located near the convergence of the Pacific and North American Plates. Terrane accretion throughout the Tertiary has introduced diverse crustal blocks, adding varied outcrops of Mesozoic, Tertiary, Late Miocene, and Early Pliocene age rocks. Much of the Cook Inlet area is overlain by young glacial sediments, but where bedrock outcrops, some areas yield abundant marine invertebrate and terrestrial plant fossils of Mesozoic and Tertiary age.

6.7.2 Interdependent Facilities

An overview of potential paleontological resources within the ecoregions crossed by the Project's Interdependent Facilities is provided below.

Beaufort Coastal Plain Ecoregion

Potentially fossil-bearing rocks in the Beaufort Coastal Plain Ecoregion include marine sandstone, limestone, shale, and siltstone. In some places along the North Slope, these fossil-bearing marine sedimentary rocks are up to 20,000 feet thick. The sedimentary rocks of the Middle Devonian age (~380-390 Ma) contain the oldest known fossils in the area. The Devonian and post-Devonian fossils include mostly small invertebrate marine animals: brachiopods, cephalopods, gastropods, pelecypods, sponges, bryozoans, corals, and crinoids (Lindsey, 1986).

Dinosaur fossils of twelve different types have been recovered from Late Cretaceous strata (~65-100 Ma) in the Beaufort Coastal Plain Ecoregion. Approximately 50 miles west of Prudhoe Bay, dinosaur fossils from adult and young hadrosaur, tyrannosaur, and troodons have been found along the Colville River (BLM, 2014). No dinosaur fossils have been discovered within the Project area, although the Late Cretaceous sandstone present there could possibly contain them. Middle Jurassic through Cretaceous rocks on the North Slope also contains terrestrial plant fossils.

Quaternary age strata west of the Project area contain abundant remains of both marine and terrestrial mammals, including otter, seal, whale, mammoth, moose, caribou, musk ox, bison, antelope, camel, horse, and mountain lion, as well as birds. "Lowland loess" is an eolian deposit of glacial silt which is very common along the northern portions of the Project area. Where permafrost is present within silt, it is possible to find remains of Quaternary age vertebrates.

Brooks Range Foothills and Brooks Range Ecoregions

Potentially fossil-bearing bedrock in the Brooks Range includes marine sedimentary rock and metamorphosed marine rocks. Overlying sediments include glacial deposits, colluvium, alluvium, lacustrine deposits, and eolian deposits, some of which may also be fossil-bearing. In various locales throughout the Brooks Range, faulting has exposed fossil-bearing strata at the surface. In the northeastern Brooks Range, metamorphic marine sedimentary rocks have yielded fossils of marine invertebrates, coral, gastropods, and bivalves (Reifenstuhl, 1991). Similar rock types occur within the Mainline corridor, and thus, fossils are potentially present where the Project area traverses the Brooks Range.

Kobuk Ridges and Valleys Ecoregion

The Mainline corridor passes very briefly through the Kobuk Ridges and Valleys Ecoregion. Bedrock in the area is composed of late Cretaceous continental deposits, overlain by deep deposits of Quaternary glacial, glaciofluvial, outwash, and lacustrine, alluvial, and eolian sediments. Within similar sediments throughout the region, Pleistocene-age fossils have been found, such as mammoth and mastodon, especially where permafrost is present. Fossils from prior to the Quaternary are either lacking or very uncommon in this area.

Ray Mountains Ecoregion

Sedimentary rocks in and around the Ray Mountains Ecoregion contain abundant Paleozoic marine fossils. The oldest fossils in the area are Early Cambrian trace fossils. Abundant Ordovician fossils from the Fossil Creek volcanics and Tolovana limestone include gastropods, trilobites, bryozoans, brachiopods, and corals. Silurian and Devonian fossils of the Tolovana, Cascaden, and Skajit limestones include brachiopods, corals, gastropods, and other bivalves. Mississippian age bryozoan, crinoid, coral, gastropod, and brachiopod fossils are present in marine sedimentary rocks within the Ray Mountains Ecoregion. Additionally, there is a wide assortment of well-preserved Cretaceous plant fossils which outcrop along the Yukon River (Lindsey, 1986).

Abundant remains of Pleistocene vertebrates have also been found in the region, including mammoth, mastodon, bison, saiga antelope, horse, musk oxen, and birds (Lindsey, 1986). Pleistocene remains are most commonly found in permafrost areas throughout the region.

Tanana-Kuskokwim Lowlands and Yukon Tanana Uplands Ecoregions

South of Livengood, fossils of freshwater mollusks, insects, and vertebrates are abundant. In addition, fossils of extinct Pleistocene vertebrates have also been found in the area, including mammoth, mastodon, bison, saiga antelope, horse, musk oxen, and birds.

Alaska Range Ecoregion

The Alaska Range is composed of several different accreted terranes, and thus rock types in the area are extremely diverse. There are many known and potential fossil-bearing strata within the Alaska Range Ecoregion. Rocks of the Chulitna Terrane in particular, contain abundant fossil species, including Triassic-age bivalves, gastropods, ammonites and conodonts, and Paleozoic-age radiolarian, bivalves, and crinoids. Strata of the West Fork Terrane contain Upper Jurassic radiolarians, and rocks of the Kahiltna Flysch Terrane bear Lower Cretaceous-age bivalve and belemnite fossils (Blodgett and Clautice, 2000).

Cook Inlet Basin Ecoregion

Bedrock beneath the southernmost Mainline corridor is composed of upper Tertiary continental deposits (sandstone, siltstone, claystone, conglomerate, and coal) of the Kenai Group (Beikman, 1980). Due to lack of bedrock outcrops in this area, little is known about the abundance of Tertiary age fossils in the area. The same rocks of the Kenai Group, however, outcrop on the west side of Cook Inlet, and are known to contain abundant Tertiary plant fossils (Wolfe et al., 1966). A description of fossil potential in the Cook Inlet Basin Ecoregion is provided in Section 6.7.1.1.

6.7.3 Potential Construction Impacts and Mitigation Measures

In general, sensitive paleontological resources could be damaged or destroyed when a project is constructed through areas that may contain paleontological resources. Such activities can include:

- Excavation and earthmoving activities;
- Erosion of the fossil-bearing strata from slope grading, vegetation clearing, etc.; and/or
- Increased public access to the area leading to a higher risk for being removed or damaged.

A general summary of potential impacts to paleontological resources from construction of projects similar to this Project is provided in Appendix A. This Appendix also includes a summary of the types of plans, as examples, that can be developed to address potential impacts. If the Project will cross any known significant paleontological resources or construction of the Project is anticipated to inhibit any future exploration of these resources, a subsequent draft of this Resource Report will identify potential plans or measures for construction of the (1) Liquefaction Facilities, and (2) the Interdependent Facilities. Also included in a subsequent draft of this Resource Report will be a discussion of a Significant Paleontological Resources Unanticipated Discoveries Plan.

6.7.4 Potential Operational Impacts and Mitigation Measures

In general, sensitive paleontological resources could be impacted during maintenance operations of a project such as clearing and excavation where no prior surveys or studies had been undertaken. Since the likelihood of this kind of occurrence is low, and because the Project will be documenting resources within the Project footprint for assessment, no new areas will be impacted.

6.8 REFERENCES

Alaska Department of Natural Resources (ADNR), Division of Oil and Gas. 2014. State of Alaska: Five-Year Program of Proposed Oil and Gas Lease Sales. Published January 2014. Web Source Link: http://dog.dnr.alaska.gov/Leasing/Documents/5YearReports/2014/2014-Five-Year-Program.pdf.

Alaska Division of Geological & Geophysical Surveys (DGGS). 2011. Guidebook to Geologic Hazards in Alaska. Available online at: http://www.dggs.alaska.gov/sections/engineering/geohazards/glossary.php. Accessed October 2014.

Alaska Earthquake Information Center (AEIC). 2014. Available online at: http://www.aeic.alaska.edu. Accessed October 2014.

Alaska Oil and Gas Conservation Commission (AOGCC). 2013. Prudhoe Bay Unit, Prudhoe Oil Pool: AOGCC Pool Statistics. Available online at: http://doa.alaska.gov/ogc/annual/current/18_Oil_Pools/Prudhoe%20Bay%20-%20Oil/Prudhoe%20Bay,%20Prudhoe%20Bay/1_Oil_1.htmh. Accessed October 2014.

Alaska Resource Data File (ARDF). 2014. Descriptions of mines, prospects, and mineral occurrences in Alaska. Compiled from published literature and from unpublished reports and data from industry, the U.S. Bureau of Mines, the U.S. Geological Survey and other sources. Available online at: http://mrdata.usgs.gov/ardf/. Accessed October 2014.

Alaska Volcano Observatory (AVO). 2014. Volcano Information. Available online at: http://www.avo.alaska.edu/volcanoes/index.php. Accessed October 2014.

Alyeska Pipeline Services Company (APSC). 2007. TAPS Final Renewal EIS. Anchorage, Alaska.

Beikman, H.M. 1980. Geologic Map of Alaska: U.S. Geological Survey.

Berg, H.C and Plafker, G, Eds. 1994. Neotectonic Map of Alaska pp 49-140 in Vol. G-1, The Geology of Alaska, in The Geology of North America, G. Plafker and H.C. Berg (editors), Geologic Society of America, Boulder, Colorado.

Blodgett, R.B., and Clautice, K.H., 2000, Fossil locality map of the Healy A-6 Quadrangle, south-central Alaska: Alaska Division of Geological & Geophysical Surveys Report of Investigation 2000-5, 42 p., 1 sheet, scale 1:63,360. doi: 10.14509/2680.

Bradley, D.C., Bundtzen, T. K., Dover, J. H.; Haeussler, P. J.; Weber, F.R., and Wilson, F.H. 1998. Geologic Map of Central (Interior) Alaska. U.S. Geological Survey Open-File Report OF 98-133-A, Version 1.2.

Brown, J. and R.A. Kreig. 1983. Guidebook to Permafrost and Related Features, Elliot and Dalton Highways, Fox to Prudhoe Bay, Alaska. Alaska Division of Geological & and Geophysical Surveys. Guidebook no. 4. 230 p.

Davies, W. E., J.H. Simpson, G.C. Ohlmacher, W.S. Kirk and E.G. Newton. 1984. Engineering Aspects of Karst. U.S. Geological Survey. National Atlas of the United States of America, scale 1:7,500,000. GIS Version, U.S. Geological Survey Open-File Report 2004-1352 at http://pubs.usgs.gov/of/2004/1352/

Department of Natural Resources. 2014. Alaska Resource Data Files (ARDF) and Interactive Map. Available online: http://mrdata.usgs.gov/ardf/. Accessed October 2014.

Ekström, G.; Freymueller, J.T.; Haeussler, P.J.; and Wesson, R. 2008. Active Tectonics and Seismic Potential of Alaska, American Geophysical Union Geophysical Monograph Series 179, American Geophysical Union, Washington, D.C.

Foster, H.L. and Keith, T.E.C. 1994. Geology of the Yukon-Tanana area of east-central Alaska, in Plafker, George, and Berg, H.C., ed., The Geology of Alaska: Geological Society of America.

Freymueller, J.T., P.J. Haeussler, R. Wesson, and G. Ekström, Eds. 2008. Active Tectonics and Seismic Potential of Alaska, American Geophysical Union Geophysical Monograph Series 179, American Geophysical Union, Washington, D.C.

Haeussler, Peter J.; Hults, Chad P; Labay, Keith A; Schmidt, Jeanine M.; Schmoll, Henry R.; Wilson, F. H.; and Yehle, Lynn A. 2009. Preliminary Geologic Map of the Cook Inlet Region, Alaska — Including parts of the Talkeetna, Talkeetna Mountains, Tyonek, Anchorage, Lake Clark, Kenai, Seward, Iliamna, Seldovia, Mount Katmai, and Afognak 1:250,000-scale Quadrangles. U.S. Geological Survey. Open-File Report 2009-1108, version 1.0.

Haeussler, Peter J.; Hults, Chad P; Labay, Keith A; Schmidt, Jeanine M.; Schmoll, Henry R.; Wilson, F. H. ; and Yehle, Lynn A. 2012. Preliminary Geologic Map of the Cook Inlet Region, Alaska — Including parts of the Talkeetna, Talkeetna Mountains, Tyonek, Anchorage, Lake Clark, Kenai, Seward, Iliamna, Seldovia, Mount Katmai, and Afognak: U.S. Geological Survey Scientific Investigations Map 3153.

Harrison, W.D. and Osterkamp, T.E. 1976. Subsea Permafrost at Prudhoe Bay, Alaska: Drilling Report and Data Analysis. Geophysical Institute Report Number UAG R-245; Sea Grant Report Number 76-5. University of Alaska, Fairbanks.

Kolker, A.; Larsen, J.; Layer, P; Newberry, R.; and Stepp, P. 2007. Geologic Setting of the Chena Hot Springs Geothermal System, Alaska Thirty-Second Workshop on Geothermal Reservoir Engineering. Stanford University, Stanford, California. January 22-24. Available online at: http://pangea.stanford.edu/ERE/pdf/IGAstandard/SGW/2007/kolker.pdf. Accessed October 2014.

Lindsey, K.D. 1986. Paleontological Inventory and Assessment of Public Lands Administered by Bureau of Land Management, State of Alaska, Bureau of Land Management, Anchorage, Alaska, pp 35-44, 89-103, 121-251.

Mull, C.J., and K.E. Adams.1989. Dalton Highway, Yukon River to Prudhoe Bay, Alaska. Generalized Geologic Map of the Brooks Range and Arctic Slope, Northern Alaska. Alaska Department Division of Geological and & Geophysical Surveys. Guidebook 7, v. 1. Sheet 1, scale 1:2,851,200. 155 p.

Nowacki, G. M. Spencer, T. Fleming, T. Brock and T. Jorgenson. 2002. Unified Ecoregions of Alaska: 2001: U.S. Geological Survey, Open-File Report 02-297. 1 sheet, scale 1:4,000,000.

Onesti, L.J, 1985. Meteorological conditions that initiate slushflows in the central brooks range, Alaska. Annals of glaciology, 6, 23-25.

Osterkamp, T.E. and W.D. Harrison. 1976. Subsea Permafrost at Prudhoe Bay, Alaska: Drilling Report and Data Analysis. Geophysical Institute Report Number UAG R-245; Sea Grant Report Number 76-5. University of Alaska, Fairbanks. 67 pp. plus app.

Perkins, Robert A.; Hargesheimer, John; Winterfield, Aaron. December 2009. Naturally Occurring Asbestos in Alaska and Experiences and Policy of Other States Regarding its Use. Alaska Department of Transportation and Public Facilities, DOT # FHWA-AK-RD-10-01; Alaska University Transportation Center, INE/AUTC 09.09. Institute of Northern Engineering Publications.

Plafker, G. and H.C. Berg, Eds. 1994. Neotectonic Map of Alaska pp 49-140 in Vol. G-1, The Geology of Alaska, in The Geology of North America, G. Plafker and H.C. Berg (editors), Geologic Society of America, Boulder, Colorado.

Reger, R.D., A.G. Sturmann, E.E. Berg, and P.A.C. Burns, 2007, A guide to the late Quaternary history of northern and western Kenai Peninsula, Alaska: Alaska Division of Geological & Geophysical Surveys Guidebook 8, 112 p. 6 sheet, scale 1:63,360.

Reifenstuhl, R.R. 1991. Paleontological Data from 29 Outcrop Sample of Late Cretaceous to Jurassic Age, Sagavanirktok Quadrangle, Northeastern Brooks Range, Alaska. Alaska Division of Geological and Geophysical Surveys.

Resource Development Council for Alaska, Inc. (AKRDC). Alaska's Mining Industry – Background. Available online at: http://www.akrdc.org/issues/mining/overview.html. Accessed October 2014.

Thurston, D.K.; Choromanski, D.R. [Unknown Date]. Quaternary Geology of Lower Cook Inlet, Alaska. ICAM-94 Proceedings: Regional terrane.

U.S. Department of Agriculture. 2002. Snow Avalanche – Their Characteristics, Forecasting and Control. Available online at: http://people.uwec.edu/jolhm/EH3/Group4/references/snow%20avalanche.htm. Accessed December, 2014.

U.S. Bureau of Land Management (BLM). 2014. Dinosaurs on Alaska's North Slope, Alaska State Office. Available online at: http://www.blm.gov/pgdata/etc/medialib/blm/ak/aktest/culture_res/culture_pdfs.Par.48740.File.dat/alaska_dinosaurs.pdf.

U.S. Geological Survey (USGS). 1997. Geologic Map of Alaska: Geologic Units: U.S. Geological Survey, Anchorage, AK. Available online at: http://agdc.usgs.gov/data/usgs/geology/. Accessed October 2014.

USGS, 2014. Alaska Geologic Map Data. Available online at: http://mrdata.usgs.gov/geology/state/state.php?state=AK. Accessed October 2014.

USGS. 2015a. Earthquake Hazards Program - Magnitude / Intensity. Available online at: Comparisonhttp://earthquake.usgs.gov/learn/topics/mag_vs_int.php. Accessed January 2015.

USGS Earthquake Hazards Program. 2015b. Seismic Seiches. Available online at: http://earthquake.usgs.gov/learn/topics/seiche.php. Accessed January 2015.

USGS Volcano Hazards Program. 2014. Volcano Hazards. Available online at: http://volcanoes.usgs.gov/hazards/index.php. Accessed October 2014.

Wahrhaftig, C. 1965. Physiographic Divisions of Alaska, U.S. Geological Survey Professional Paper 482, Washington, D.C.

Wilson, F.H., Dover, J.H., Bradley, D.C., Weber, F.R., Bundtzen, T.K., and Haeussler, P.J. 1998. Geologic map of central (interior) Alaska: U.S. Geological Survey Open-File Report 98-133, 76 p., 3 sheets, scale 1:500,000.

Wilson, Frederic H.; Dover, James H.; Bradley, Dwight C.; Weber, Florence R.; Bundtzen, Thomas K.; and Haeussler, Peter J. 1998. Geologic Map of Central (Interior) Alaska. U.S. Geological Survey Open-File Report OF 98-133-A, Version 1.2.

Wilson, F. H.; Hults, Chad P.; Schmoll, Henry R.; Haeussler, Peter J.; Schmidt, Jeanine M.; Yehle, Lynn A.; and Labay, Keith A. 2009. Preliminary Geologic Map of the Cook Inlet Region, Alaska—Including parts of the Talkeetna, Talkeetna Mountains, Tyonek, Anchorage, Lake Clark, Kenai, Seward, Iliamna, Seldovia, Mount Katmai, and Afognak 1:250,000-scale Quadrangles. U.S. Geological Survey. Open-File Report 2009-1108, version 1.0.

Wolfe, J.A., Hopkins, D.M., and Leopold, E.B. 1966. Tertiary Stratigraphy and Paleobotany of the Cook Inlet Region, Alaska. U.S. Geological Survey Professional Paper.

APPENDIX A GENERAL IMPACTS FROM SIMILAR PROJECTS IN ALASKA

Potential Impact	Project Activity												*Potential Plans to Address Impacts
	Grading, Clearing, Excavating (incl. Blasting), Trench, Pipelay, Backfill, Reclamation	Water Crossings (Pipelines & Bridges)	Ice Roads & Pads	Erosion Control & Drainage Control	Water Withdrawal & Usage	Water Discharge	Solid Waste Storage & Disposal	General Infrastructure Activities	Facility Construction	Facility Operations	Offshore Construction	Resource Report No.	
Air Emissions (including dust) from Construction	X	X	X	X	X	X	X	X	X		X	1, 9	C, J, O, T, W
Air Emissions from Operations										X		9	J, W, LL
Surface Water Quality Impacts (Increased Turbidity [TSS] / Sedimentation in Surface Water)	X	X	X	X	X	X	X	X	X	X	X	2, 3, 7	G, H, J, T, V, Y, II, KK
Contamination Migration	X	X				X	X	X		X		1, 2, 3, 7	G, I, GG
Disruption / Loss of Wildlife, Fish or Marine Mammal Habitat	X	X	X	X	X	X		X	X	X	X	2, 3	A, B, C, G, H, K, N, R, V, DD, EE, JJ
Disturbance & Vessel Strikes from Vessel Traffic								X		X	X	3	B, N
Disturbance of Known Historic Archaeological or Architectural) and Paleontological Resources	X	X	X					X	X		X	1, 4, 6, 7	C, D, E, Z, AA
Erosion	X	X		X		X			X		X	1, 2, 6, 7, 8	G, H, II, KK
Groundwater Impacts (Withdrawal, Drawdown, Vertical & Horizontal Hydraulic connectivity, Wells)	X	X	X		X				X	X		1, 2	Y, MM
Hazards to Aviation								X	X	X		1, 11	M
Hazards to Marine Navigation		X						X			X	1, 11	B, M
Inadvertent HDD Mud Release		X										1, 2, 3, 7	I
Incidental Take of Wildlife, Birds, & Marine Mammals	X	X	X		X	X	X	X	X		X	3	A, B, C. F, G, H, N, R
Increased Surface Water Runoff	X			X		X			X	X		2, 3, 7	Y, II
Introduction of Non-native Species	X	X	X			X		X	X	X	X	2, 3	G, K, KK
Impact to Public Use or Public Land	X	X						X	X	X	X	1, 2, 3, 8	B, F, H, L, BB, CC, FF
Impacts to existing infrastructure	X							X	X	X	X	1, 2, 3, 7, 8	M, S, U
Construction Noise Impacts	X	X						X	X			3, 9	C, F, P, N, FF, JJ
Operational Noise Impacts										X		9	F, P, FF
Potential Impacts to Vegetation, Wildlife, Fish, Birds, & Threatened Species	X	X	X	X	X	X	X	X	X	X	X	1, 2, 3, 6, 7, 8, 9	A, C. G, H, K, Q, R, T, DD,EE, JJ
Fish passage impacts		X										3	H, DD, JJ
Reduced Surface Water Recharge Rates	X		X		X	X						2, 3, 6	V, Y, MM
Watercourse Realignment and Scouring		X		X		X		X	X			2	G, H, V
Seismic Hazards / Mass Wasting, Soil Liquefaction	X	X						X	X	X	X	1, 6, 11	X
Tundra Degradation, Thermokarst	X	X	X	X	X				X	X		2, 3, 6, 7	G, X, KK
Unanticipated Discovery of Cultural Resources	X	X	X					X	X		X	1, 4	D, E
Unanticipated Discovery of Paleontological Resources	X	X						X	X		`	1, 4, 6	C, Z, AA
Unplanned spills/releases		X							X	X	X	2	G, I, HH, II
Vegetation & Topsoil Degradation or Loss	X		X	X				X				3, 7	G, II, KK

Potential Impact	Project Activity												*Potential Plans to Address Impacts
	Grading, Clearing, Excavating (incl. Blasting), Trench, Pipelay, Backfill, Reclamation	Water Crossings (Pipelines & Bridges)	Ice Roads & Pads	Erosion Control & Drainage Control	Water Withdrawal & Usage	Water Discharge	Solid Waste Storage & Disposal	General Infrastructure Activities	Facility Construction	Facility Operations	Offshore Construction	Resource Report No.	
Vertical and Horizontal Hydraulic Connectivity of Ground Water and Surface Water (Groundwater Discharge to Surface Water)	X	X	X		X	X			X		X	2, 3	C, G, X, Y, MM
Visual Impacts	X	X					X	X	X	X	X	1, 8	L, V, CC
Waste from Construction and Operations - Liquid and Solid, Hazardous and Non-Hazardous									X	X		2, 8	T
Impacts to Wetlands – footprint and functionality									X			2	DD, EE
***Potential Plans to Address Activity**	A, C, D, E, G, K, L, O, P, R, Z, GG, II, KK	D, E, G, H, I, K, L, O, V, Y, DD, EE, II, JJ	G, L, O, R	G, L, O, V, II, KK	G, L, O, MM	G, K, L, O Y, MM	G, O, T, Y, GG, HH	D, G, M, O, R, S, HH, II	D, E, F, G, K, M, P, R, S, T, W, X, Z, FF, GG, HH, JJ, II, MM	F, HH, J, K, O, P, R, T, W, FF, MM	D, E, G, M, N, O, P, Q, R, W	All	

List of Potential Plans*

A. Avian Protection Plan

B. Marine Logistics Shipping Plan

C. Blasting Plan

D. Unanticipated Cultural Resource Discovery Plan

E. Cultural Resources Data Recovery Plans and/or Treatment Plans

F. Ambient Noise Level Studies

G. FERC 2013 Wetland and Waterbody Construction and Mitigation Procedures with Requested Project-Specific Variances (the Applicants' Procedures) AKLNG Procedures

H. Site-specific Waterbody Crossing Plans

I. HDD Inadvertent Release Plan (Project Specific HDD Contingency Plan)

J. Health Impact Assessment

K. Invasive Species Mitigation Plan

L. Public Land Construction Plan

M. Project Logistics Plans

N. Marine Mammal Mitigation and Monitoring Plan

O. Mobile Emissions Control Plan

P. Noise Control and Mitigation Plan

Q. Plan of Cooperation (POC)

R. Polar Bear and Wildlife Interaction Plan

S. Project Transportation Plan

T. Project Waste Management Plan

U. Project-specific Railroad crossing Plans

V. Riparian Buffer Planting Plan

W. Modeling Site-specific Impacts to Air Quality Emissions

X. Site-specific Geohazards Plan

Y. Water Monitoring Plan

Z. Unanticipated Paleontological Discovery Plan

AA. Paleontological Resources Management Plans

BB. Site-specific Public Land Use and Recreational Use Coordination Plans

CC. Visual Aesthetics Study

DD. Site-specific Wetland Resources Crossing Plans (as required)

EE. Wetland Mitigation Plans

FF. Site-specific Noise Mitigation Plans (as required)

GG. Unanticipated Contamination Discovery Plan

HH. Spill Prevention, Control, and Countermeasure Plan (SPCC)

II. Storm Water Pollution Prevention Plan (SWPPP) – general and spread specific

JJ. Species-specific Wildlife Protection Plan

KK. FERC 2013 Upland Erosion Control, Revegetation, and Maintenance Plan with Requested Project-Specific Variances (the Applicants' Procedures) AKLNG Plan

LL Design/Operations Emissions Management Plan

MM Groundwater Management Plan

* In addition to the potential plans listed above, FERC requires implementation plans that outline how the Project will meet all required environmental permits and stipulations. The applicants will also prepare overarching Construction Environmental Management Plans and Operations Environmental Management Plans for the Project.