Jordan Cove Energy Project L.P.

Resource Report No. 6

Geological Resources

Jordan Cove Energy Project

April 2017

JCEP LNG TERMINAL PROJECT

Resource Report 6 – Geological Resources

To Verify Compliance with this Minimum FERC Filing Requirement:	See the Following Resource Report Section:
1. Identify the location (by milepost) of mineral resources and any planned or active surface mines crossed by the proposed facilities – Title 18 Code of Federal Regulations (CFR) part (§) 380.12 (h)(1 & 2)	Section 6.3
2. Identify any geologic hazards to the proposed facilities – 18 CFR § 380.12 (h)(2)	Section 6.4
3. Discuss the need for and locations where blasting may be necessary in order to construct the proposed facilities – 18 CFR § 380.12 (h)(3)	Section 6.2
4. For liquefied natural gas (LNG) projects in seismic areas, the materials required by "Data Requirements for the Seismic Review of LNG Facilities," National Bureau of Standards Information Report 84-2833 – 18 CFR § 380.12 (h)(5)	Section 6.5 Appendix A.6 Appendix B.6 Appendix C.6
5. 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.	Not Applicable

INFORMATION RECOMMENDED OR OFTEN MISSING	**See the Following Resource Report Section:**
1. Identify any sensitive paleontological resource areas crossed by the proposed facilities. (Usually only if raised in scoping or if the project affects federal lands.)	Section 6.6
2. Briefly summarize the physiography and bedrock geology of the project.	Section 6.1
3. If proposed pipeline crosses active drilling areas, describe plan for coordinating with drillers to ensure early identification of other companies' planned new wells, gathering lines, and above-ground facilities.	N/A
4. If the application is for underground storage facilities:	N/A
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.	

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ACRONYMS

ASCE	American Society of Civil Engineers
CFR	Code of Federal Regulations
CPT	Cone Penetration Test
CSZ	Cascadia Subduction Zone
DOGAMI	Oregon Department of Geology and Mineral Industries
FERC	Federal Energy Regulatory Commission
JCEP	Jordan Cove Energy Project, L.P.
km	kilometer
LNG	liquefied natural gas
MOF	Material Offloading Facility
M_W	moment magnitude
NGVD 29	National Geodetic Vertical Datum
NSHM	National Seismic Hazard Map
PCGP	Pacific Connector Gas Pipeline, LP
PGA	Peak Ground Accelerations
RFP	Roseburg Forest Products Company
SLIDO	Statewide Landslide Information Database for Oregon
SPT	Standard Penetration Test
U.S.	United States
USGS	U.S. Geological Survey

RESOURCE REPORT 6
GEOLOGICAL RESOURCES

6.0 INTRODUCTION

Jordan Cove Energy Project, L.P. ("JCEP") is seeking authorization from the Federal Energy Regulatory Commission ("FERC" or "Commission") under Section 3 of the Natural Gas Act to site, construct, and operate a natural gas liquefaction and liquefied natural gas ("LNG") export facility ("LNG Terminal"), located on the bay side of the North Spit of Coos Bay, Oregon. JCEP will design the LNG Terminal to receive a maximum of 1,200,000 dekatherms per day of natural gas and produce a maximum of 7.8 million tons per annum of LNG for export. The LNG Terminal will turn natural gas into its liquid form via cooling to about -260°F, and in doing so it will reduce in volume to approximately 1/600th of its original volume, making it easier and more efficient to transport.

In order to supply the LNG Terminal with natural gas, Pacific Connector Gas Pipeline, LP ("PCGP") is proposing to contemporaneously construct and operate a new, approximately 235-mile-long, 36-inch-diameter natural gas transmission pipeline from interconnections with the existing Ruby Pipeline LLC and Gas Transmission Northwest LLC systems near Malin, Oregon, to the LNG Terminal ("Pipeline," and collectively with the LNG Terminal, the "Project"). PCGP will submit a contemporaneous application to FERC that will include its own set of resource reports with references to certain materials in the LNG Terminal resource reports.

This resource report is consistent with and meets or exceeds all applicable FERC filing requirements. A checklist showing the status of FERC's filing requirements for Resource Report 6 (18 CFR § 380.12) is included preceding the table of contents.

6.1 GEOLOGIC SETTING

The LNG Terminal site (which includes Ingram Yard, the Access and Utility Corridor, and the South Dunes site) is located within the Pacific Border Physiographic province at the western edge of the coastal headlands of the Central Coast Mountain Range, on the North Spit of Coos Bay. The North Spit of Coos Bay marks the southern edge of the Holocene-age Coos Bay dune sheet (Peterson, et al. 2005). The Kentuck Project site is located east of Coos Bay near the confluence of Kentuck Slough and Mettman Creek.

The LNG Terminal is located near the eastern edge of the Cascadia Subduction Zone ("CSZ"), an active convergent plate boundary between the segmented subducting Explorer, Juan de Fuca, and Gorda Plates and the overriding North America Plate (Wells, et al. 2000). The LNG Terminal site is within Juan de-Fuca Plate segment of the CSZ. The converging tectonic plates have resulted in the accretion of marine deltaic sediments and volcanic seamounts, referred to as the Siletzia terrane, to the western edge of the North American Plate (Heller and Ryberg 1983).

The active converging tectonic plates create a deformation zone along the western edge of the accretionary wedge complex, strike-slip faulting in the North American Plate, and a zone of bedrock folding that extends from the coast eastward. The major tectonic elements associated with the subduction zone include the accretionary wedge complex, a deformed forearc basin (the Coast Range and Willamette Valley), a volcanic arc complex (the Cascade Mountain Range), and a backarc (eastern Oregon and Washington).

The project area lies at the junction of the accretionary wedge complex and the forearc basin. Local bedrock structures reflect east-west compressional deformation resulting from ongoing oblique subduction on the CSZ that has occurred since the late middle Miocene epoch (Wells and Peck 1961), and includes the megathrust itself, north-south-trending folds, north-south-trending reverse and thrust faults, and west-northwest-trending oblique strike-slip faults (Black and Madin 1995; Madin et al. 1995; Goldfinger et al. 1992). The location and extent of local fold and fault structures have been inferred from stratigraphic, geomorphic, and geophysical evidence. Exposed geologic structures south of the site include the South Slough Syncline, the Westport Arc (anticline), and the eastern and western forks of the Westport Arc (Allen and Baldwin 1944).

Sedimentary rocks exposed in the Coos Bay area were deposited during periods of sea level change (regressions and transgressions) in the Coos Basin. Convergent tectonism uplifted these sedimentary rocks and caused the initial faulting and folding now observed in bedrock units south and east of Coos Bay. Bedrock units exposed south of the LNG Terminal site have been folded into a series of north-trending anticlines and synclines primarily due to east-west tectonic compression. The anticlines and synclines plunge slightly to the north and may be present at depth beneath the LNG Terminal site. Faults are generally either north-south-trending reverse faults or thrust faults, bedding plane reverse faults, or west-northwest reverse faults (Madin et al. 1995).

Neogene age bedrock exposed in the Coos Bay region includes Eocene to Pliocene marine interbedded siltstones and sandstones of the Coaledo Formation, the Bastendorff Formation, and the Empire Formation (Baldwin et al. 1973; Beaulieu and Hughes 1975). The upper member of the Coaledo Formation is composed of gray, coarse to fine-grained weakly cemented sandstone, mudstone, and minor amounts of coal. The upper Coaledo Formation also underlies alluvial deposits in the Kentuck Slough. The Bastendorff Formation consists of thinly laminated gray siltstones and mudstones that weather to light brown. The Empire Formation is medium-grained sandstone with minor siltstone, conglomerate, and water laid tuff (Madin et al. 1995). The lower, fossiliferous portion of the Empire Formation has been described informally as the Miocene Beds exposed at Fossil Point southwest of the LNG Terminal (Ehlen 1967).

The LNG Terminal site is located within the Coos Bay dune sheet that features lowland areas generally underlain by Quaternary age unconsolidated wind-blown sediments. Geologic mapping in the area shows stable (vegetated) and unstable sand dunes (Beaulieu and Hughes 1975) underlain by sedimentary rock. Recent dating of dune sand in the Florence and Coos Bay dune sheets indicates that the dunes in the immediate proximity of the project area were deposited during the late Holocene epoch; however, late-Pleistocene dune deposits may also be exposed (Peterson et al. 2005).

Surface soils have been disturbed by the operations of the Roseburg Forest Products Company ("RFP"), the Weyerhaeuser Company, and the former Kentuck Golf Course, and from the placement of fill material. The U.S. Army Corps of Engineers spread materials dredged during maintenance of the Coos Bay navigation channel on the LNG Terminal site. The historical fill materials placed on portions of the LNG Terminal site are predominantly sand with a small percentage of silt.

The site topography varies within Ingram Yard range from approximately elevation 20 feet elevation in the western portion of the site, which is relatively flat, up to approximately elevation 125 feet in the northeastern portion of the site, which is covered by a north-south oriented longitudinal sand dune. Along the Access and Utility Corridor, ground surface elevations are variable, ranging from a low of approximately 20 feet up to 135 feet in the area of a dune. Adjacent to wetlands within the Access and Utility Corridor, the ground surface elevations are approximately 15 feet. At the South Dunes site, the elevation is less variable and is approximately 15 feet. In the western portion of the South Dunes Site, the elevation increases up to approximately 60 feet in the area of a landfill. For all areas of the LNG Terminal adjacent to Coos Bay, the ground surface slopes down to meet the water level.

Geotechnical studies for the LNG Terminal facilities on the North Spit indicate that the LNG Terminal site is typically mantled with relatively clean, fine-grained sand. The geotechnical investigations for all of the sites that will be utilized for construction and operation of the LNG Terminal ("JCEP Project Area") conducted by GRI are provided in Appendix A.6 (GRI 2017). Historical records and aerial photography indicate that the flatter, upper portion of the LNG Terminal site on the North Spit is typically sand fill to depths of about 10 feet. The sand fill ranges from loose to very dense, and is typically underlain by dense to very dense sand with a trace of silt. Organics are present in portions of the site where the site was not stripped prior to fill placement. The very dense sand is underlain by refusal blow count silt and sand at depths of about 120 feet in the vicinity of the proposed tanks. A geotechnical boring completed on Ingram Yard encountered hard clayey silt that was classified as poorly indurated silty shale at a depth of about 252 feet. Another boring drilled about 480 feet north, did not encounter the poorly indurated silty shale when terminated at a depth of about 280 feet; rather, the soil was classified as silt and sand at this depth. Outcrops of weathered sandstone and siltstone of the Coaledo Formation can be observed north and south of the Trans Pacific Parkway/US-101 Intersection. At the South Dunes site, bedrock was not encountered in a boring, which terminated at a depth of approximately 240 feet in clayey silt that was first encountered at a depth of approximately 168 feet.

Two overwater geophysical surveys have been performed between the LNG Terminal and the Southwest Oregon Regional Airport, which is located on the south side of the Federal Navigation Channel (GRI 2017). The overwater surveys indicated that bedrock is present at a depth of about elevation -120 feet near the south edge of the proposed slip.

Sand fill is also present to a depth of about 15 feet at the location of the Trans Pacific Parkway/US-101 Intersection. An approximate 5-foot-thick layer of alluvial silt to clayey silt was encountered beneath the sand fill at this location. Similar to the other locations on the North Spit, this area is underlain by sand until reaching the underlying Coaledo Formation. The sand at the intersection locations is typically loose to a depth of about 30 feet and dense to very dense below 30 feet (GRI 2017). Although the Coaledo Formation was not encountered in the explorations for the intersection, this formation can be seen in roadside cuts along US-101 north and south of the LNG Terminal site.

Geotechnical information at the Kentuck Project site indicates that the lower-lying portions of the site are mantled and underlain by soft alluvial deposits to depths of more than 100 feet in some areas. The alluvium consists of interbedded layers of sand, silt, and clay that can contain a relatively high organic content. Dense sands were encountered beneath the soft alluvial deposits at depths of about 100 feet on the western portion of the site. Sandstone and siltstone of the Coaledo Formation underlie the alluvial deposits, and form the hillsides north and south of the site. The depth of the Coaledo Formation varies with the distance from the hillsides.

Impacts to surface geology will be limited primarily to the construction phase of the LNG Terminal, when the topographic features at specific locations on the site will be altered by clearing, mechanical excavation, dredging, and fill placement. All soil material cut at Ingram Yard, including material dredged for the marine slip, will be used for regrading purposes at LNG

Terminal site, on the RFP property, and at the Kentuck Project site. The majority of the slip dredging/excavation will be completed in an upland environment to minimize in-water work. The in-water dredging work will occur only as the last phase of work during an in-water work window. All open-water marine construction will be completed in accordance with permitted in-water work windows.

Site elevations for the LNG Terminal are provided in Resource Report 1, Table 1.3-1. The elevations of the portion of the RFP property to be filled will be aligned with the elevations of Ingram Yard and the Access and Utility Corridor. Final grading and landscaping consists of gravel surfacing, asphalt surfacing, concrete paved surfaces, and grassed areas.

6.2 BLASTING

Geotechnical investigations completed for the LNG Terminal have not identified hard rock within the development boundary that requires blasting. No blasting would be required during any phase of construction of the LNG Terminal, as geotechnical investigations indicate that the site consists of unconsolidated granular material. Therefore, no impacts from blasting are anticipated.

6.3 MINERAL RESOURCES

The principal mineral production of Oregon in order of value was crushed stone, and construction sand and gravel (USGS 2013). Mineral resources identified in Coos County, Oregon, include gold, platinum, chromium, clay, manganese, sand, gravel, silica, stone, and titanium (Baldwin et al. 1973). There are three permitted sand and gravel mines within 0.25 mile of the LNG Terminal site. All three of these mines are closed and are not producing material (DOGAMI 2017).

Based on studies of coal and natural gas resources in the Coos Bay area (Newton 1980; Mason and Hughes 1975), coal and gas resources may occur at depths within or below sandstone at the LNG Terminal site. Coal deposits are present in the upper and lower members of the Coaledo Formation. However, the depth of burial (paleotemperature) was not sufficient to generate large quantities of hydrocarbons (Newton 1980). The Steva coal seam and the Hardy coal seam have been identified within the vicinity of the Kentuck Project site (Diller 1914). Based on the State of Oregon Mineral Information Layer for Oregon-Release 2, there are no permitted coal mines or oil and gas wells within 0.25 mile of the LNG Terminal site (DOGAMI 2017).

Construction and development of the LNG Terminal site will not affect any known or potential mineral resources or the recovery of any mineral resources and would not preclude future utilization of potential leasable resources in deeper, underlying geologic formations.

6.4 GEOLOGIC AND OTHER NATURAL HAZARDS

Geologic and other natural hazards in the vicinity of the LNG Terminal include seismic hazards, landslides, ground subsidence, and other natural hazards and these are discussed further below.

6.4.1 Seismic Hazards

Seismic hazards include earthquakes, faults, soil liquefaction, and tsunami and are discussed below.

6.4.1.1 Earthquakes

The Cascadia Subduction Zone (CSZ) is the dominant tectonic feature in western Oregon, and various lines of geologic evidence indicate the CSZ has produced megathrust earthquakes (Atwater et al. 1995; Goldfinger et al. 2012). Megathrust earthquakes occur when the fault between the tectonic oceanic plate subducting beneath the continental North American plate suddenly slips (Audet et al. 2010). Offshore, subduction causes a deformation zone along the western edge of the accretionary wedge complex, strike-slip faulting in the North America plate, and a zone of folding that extends from the coast westward. Onshore, the major tectonic elements associated with the subduction zone include the accretionary wedge complex of the Oregon Coast Range, deformed forearc basin (Willamette Valley), a volcanic arc complex (the Cascade Range), and a backarc region east of the Cascade Mountains (Lewis et al. 2003).

The Coos Bay area is located in a zone of low historical seismicity, and records of earthquakes that could be felt in the vicinity of the LNG Terminal site are limited. There is one historical record of an earthquake with a magnitude greater than 3.0 within a 50 kilometer ("km") radius of the site in the Advanced National Seismic System database and the U.S. Geological Survey ("USGS") 2014 National Seismic Hazard Map ("NSHM") earthquake database. This earthquake was a local magnitude 3.3 event located off the coast of Barview, Oregon (22 km away) in 2016. Other notable earthquakes felt in the vicinity of the LNG Terminal site include a moment magnitude ("M_w") earthquake rated 7 off the coast of Crescent City, California (200 km away) in 1991, a M_w 4.9 off the coast of Waldport, Oregon (105 km away) in 2004, a M_w 6 approximately 280 km off the coast of Coos Bay in 2012, and a M_W 5.5 approximately 225 km off the coast of Coos Bay in 2016.

Ground motion results were developed in accordance with 49 CFR Part 193 and the FERC Guidelines. 49 CFR Part 193 specifies the 2006 edition of the National Fire Protection Association 59A Standard as the basis for seismic design of LNG terminals. The FERC Guidelines require application of portions of the American Society of Civil Engineers ("ASCE") 7-05 standard. Because the LNG Terminal will use the 2014 Oregon Structural Specialty Code that references ASCE 7-10, development of the ground motions also considers ASCE 7-10.

The FERC Guidelines categorize LNG facility structures and ancillary components to define which design standard is applicable for each structure. The guidelines provide different seismic recommendations for the following classes of structures: (1) Category I structures, (2) Category II structures, and (3) Category III structures. The FERC Guidelines define waterfront structures as a specific subset of Category II structures with their own definitions. The seismic guidelines for these groups of structures are outlined in the site-specific seismic hazard study (Appendix B.6).

In Table 6.4-1, the peak ground accelerations ("PGA") and the spectral acceleration values at 0.2 and 1.0 second periods from the USGS NSHM are compared to the site-specific values for the same return periods for the Maximum Considered Earthquake ("MCE"), Operating Basis Earthquake, and Safe Shutdown Earthquake ground motions, in accordance with the FERC Guidelines. The comparison in Table 6.4-1 includes values for soft rock site conditions as well as the anticipated site soil conditions after construction.

Table 6.4-1 Ingram Yard Seismic Ground Motion Values

Parameter	Site-Specific Design Values	ASCE 7-05 Design Values	ASCE 7-10 Design Values
S_S – Mapped short period spectral response accelerations (5 percent damped) (g)	1.692#	1.500	1.409
S_1 – Mapped 1 second period spectral response accelerations (5 percent damped) (g)	0.737#	0.718	0.717
Site Class (After mitigation of liquefiable soils)	D	D	D
Site Coefficient F_a	Not Applicable	1.0	1.0
Site Coefficient F_v	Not Applicable	1.5	1.5
S_{DS} - Design spectral response accelerations at short periods (5 percent damped) (g)	1.025	1.000	0.939
S_{D1} - Design spectral response accelerations at 1 second period (5 percent damped) (g)	0.988	0.718	0.717
PGA – Mapped geometric mean peak ground acceleration (5 percent damped) (g)	0.816	Not Applicable	0.614
Site Coefficient F_{PGA}	Not Applicable	Not Applicable	1.000
PGA_M – Design geometric mean peak ground acceleration (5 percent damped) (g)	0.490	0.600 (S_S/2.5)	0.614

Notes:
Geometric mean ground motion

6.4.1.2 Faults

Twelve faults that are considered seismogenic in the USGS NSHM are located within 150 km of the LNG Terminal site. Table 6.4-2 provides information on the faults, and Figure 6.4-1 shows the fault locations. These 12 faults include the CSZ, a megathrust fault, and 11 crustal faults.

The three closest faults are the CSZ (15 km), the South Slough (16 km), and the Coquille Anticline (27 km). There are three additional crustal faults within 67 km of the LNG Terminal site and five additional crustal faults within 132 km of the LNG Terminal site. The CSZ has the greatest potential for earthquakes with a M_w of 8.6 to 9.3 during a rupture of the entire length of the CSZ (Petersen et al. 2014). The maximum M_w of the crustal faults range from 6.1 to 7.3 (Petersen et al. 2014). Additional information on these faults can be found in the site-specific seismic hazard study provided in Appendix B.6.

McInelly and Kelsey (1990) identified possible Holocene fault activity on the Barview fault based on radiocarbon dating of tree stumps hypothesized to have died about 220 years before, when displacement on the fault placed them in contact with more saline or brackish water. However, observations of living and dead trees just above the tide zone by Madin et al. (1995) suggest that normal wave erosion rather than fault movement may have killed the trees. Given the uncertainty in the potential activity of the Barview fault, this fault is added to the 12 other faults in Table 6.4-2 that are considered seismogenic in the USGS NSHM for consideration at the LNG Terminal site. A maximum M_W of 6.3 is used for the Barview fault, because it may be part of the South Slough faults identified in the USGS NSHM.

In addition to the faults discussed and identified in the USGS database and the Barview fault, Briggs (1994) indicated the possibility of a Holocene-active fault located in Pony Slough, immediately southeast of the LNG Terminal site. The potential for a fault was based on vertical displacements measured in stratigraphy of marsh core samples obtained from across Pony Slough. An overwater geophysical seismic reflection survey was conducted to further explore the possible existence of an active fault at this location. The geophysical survey was located across the mouth of Pony Slough and along the east-west aligned portion of Coos Bay, immediately south of the South Dunes site, to identify depth to bedrock, bedrock structure, and the presence of any unmapped faults (GRI 2017). Review of the results of the seismic reflection survey at Pony Slough did not indicate the presence of a fault across Pony Slough or across the bay at the location of the LNG Terminal site.

Table 6.4-2 Fault Sources within 100 miles (161 Kilometers) of the LNG Terminal Site

Fault Name	Fault Type	Maximum Magnitude	Distance form Site Miles (km)
Cascadia Subduction Zone	Megathrust	8.6 - 9.3	9.3 (15)
Barview fault	Thrust	6.3	4.5 (7.3)
South Slough faults	Thrust	6.3	9.9 (16)
Coquille anticline	Reverse	6.8	17 (27)
Battle Rock fault zone	Normal	7.0	39 (63)
Beaver Creek fault zone	Normal	6.5	40 (64)
Cape Blanco anticline	Thrust	7.1	40 (65)
Waldport faults	Reverse	6.4	63.4 (102)
Whaleshead fault zone	Strike Slip	7.0	64.0 (103)
Alvin Canyon fault	Strike Slip	7.2	68.4 (110)
Stonewall anticline	Reverse	6.8	73.9 (119)
Daisy Bank fault	Strike Slip	7.3	80.2 (129)
Yaquina faults	Reverse	6.1	82.0 (132)

6.4.1.3 Soil Liquefaction

Field and laboratory studies have demonstrated that if saturated, loose to medium dense sands and some softer, low plasticity, fine-grained soils, such as sandy silts, are subject to cyclic shear stresses of a sufficient magnitude and duration, an increase in pore water pressure can result. As pore water pressure increases, the effective stress in the soil mass below the groundwater level decreases, which results in a corresponding loss of shear strength in the saturated material. The limiting case is: If the pore water pressure ratio approaches 100 percent, the material will lose most of its shear strength and deform as a viscous fluid (complete liquefaction). Additional information on liquefaction can be found in the Geotechnical Report provided in Appendix C.6.

The majority of the sand soils encountered at Ingram Yard are dense enough to resist liquefaction during design-level earthquakes; however, liquefiable soils are present throughout the Ingram Yard, with depths varying with location. Liquefaction at Ingram Yard and along the Access and Utility Corridor is estimated to be in distinct soil layers from the groundwater table to a maximum of approximately elevation -30 feet (NAVD 88). At the Ingram Yard and Access and Utility Corridor, the liquefiable layers could extend below the dunes. At the South Dunes site, liquefaction is estimated in a soil zone that starts at the groundwater table and extends to variable depths from elevation 0 feet to approximately elevation -25 feet. Ground improvement methods consisting of vibro-compaction and deep soil mixing are being considered to mitigate the risk of liquefaction. The impacts to the site of vibro-compaction will be an increased density of the sand, and there are no anticipated adverse consequences to the geology. The impact of deep soil mixing will be reinforcement of the soils, and there are no anticipated adverse consequences to the geology.

Similar to the other facilities on the North Spit, the risk of liquefaction at the Trans Pacific Parkway/US-101 Intersection is most significant to depths of about 25 feet, and denser materials were encountered below this depth. The proposed improvements at the Trans Pacific Parkway/US-101 Intersection will be constructed to meet the Oregon Department of Transportation seismic design requirements considering liquefaction.

The explorations completed at the Kentuck Project site encountered soft and loose alluvial soils to depths of about 100 feet in some areas. The loose sand and low plasticity silts encountered are susceptible to liquefaction, while higher plasticity silts and clays encountered are not liquefiable. The design for the bridge structure planned at the Kentuck Project site will consider liquefaction effects.

Lateral spreading involves lateral displacement of large, surficial blocks of soil as a result of liquefaction of a saturated surface layer, and can develop in gentle slopes and move toward a free face, such as a river channel. Displacement occurs in response to the combination of gravitational forces and inertial forces generated by an earthquake. Where a free face exists, liquefiable soils may be susceptible to lateral spreading. Where soil susceptible to lateral spreading is present at the LNG Terminal, ground improvement consisting of vibro-compaction and/or deep soil mixing will be completed to mitigate the lateral spreading hazard.

6.4.1.4 Tsunamis

The west coast of the United States has historically been subject to minor inundation from tsunamis generated by distant earthquakes in South America, Alaska, and Japan. Kelsey et al. (2005) note that tsunamis generated from these distant subduction zone earthquakes have minor inundation effects because of the long diagonal approach of tsunami waves to the west coast from these sources. Based on this explanation, observations made around the Indian Ocean following the 2004 megathrust Sumatran earthquake, and recent modeling (DOGAMI 2012) indicate a tsunami generated by a megathrust earthquake on the CSZ will present the greatest tsunami inundation risk at the LNG Terminal site.

The impacts and hazards of tsunamis to an industrialized area were well illustrated during the 2011 Tohoku, Japan earthquake. This tsunami was generated by an offshore subduction zone earthquake; subsidence occurred and increased the tsunami impacts significantly in some areas. Because similar earthquake and subsidence are of concern off the Oregon coast, the lessons learned from the 2011 Tohoku earthquake regarding subsidence, run-up, scour, and foundation performance provide a useful case history for evaluating hazards at the LNG Terminal site.

The Oregon Department of Geology and Mineral Industries (“DOGAMI”) produced tsunami hazard maps for a tsunami generated by a megathrust earthquake on the CSZ, for most of the Oregon coast in 1995 (Priest 1995), 2002 (Priest et al. 2002), and more recently in 2012 (DOGAMI 2012). All studies include run-up scenarios that vary wave height and co-seismic subsidence. It is noted that the 1995 maps are not considered to be accurate in accordance with the most recent research, but are referred to here since they are still officially referred to in Oregon Revised Statutes 455.466 and 455.447, which are referenced in the building code.

A site-specific tsunami hazard study completed by Coast and Harbor Engineering (CHE 2017), and Moffatt & Nichol (M&N 2017) evaluated the tsunami inundation elevation for the postconstruction geometry for the LNG Terminal. The tsunami hazard at the facility has been evaluated for a subduction zone rupture consistent with the latest DOGAMI rupture scenarios, L1 and XL1, which represent the 2,475- and 10,000-year events. Rupture scenario L1 is greater than the 100-, 500-, and 1,000-year events recommended by Volume 2, Section 13.I.2.4 of FERC's Guidance Manual for Environmental Report Preparation (February 2017). The modeled rupture scenario XL1 has an estimated return period longer than the 10,000-year event discussed in Volume 2, Section 13.I.2.4 of FERC's Guidance Manual for Environmental Report Preparation (February 2017). Critical components of The LNG Terminal are located at elevations that exceed the L1 event which is estimated by DOGAMI to be greater than a 2,475 year event. To allow for the most conservative approach to mitigate potential hazards from a tsunami, the LNG storage tanks will be located within an area enclosed by a berm with a peak crest elevation higher than that required to mitigate the L1 event.

The Kentuck Project site is frequently underwater during wet portions of the year, and the DOGAMI mapping (DOGAMI 2012) confirms that it is located within the estimated tsunami inundation zone. Because no permanent LNG Terminal facilities are planned at the Kentuck Project site, there are no appreciable impacts from tsunami inundation at that site.

The existing Trans Pacific Parkway/US-101 Intersection is also located in the tsunami inundation zone. To maintain grades, improvements to the intersection will not remove the intersection from the tsunami inundation zone.

6.4.2 Landslides

The type and occurrence of landslides in the vicinity of the LNG Terminal were evaluated using information gathered though review of geologic maps, literature, aerial photography, Light Detection and Ranging ("LiDAR"), and Statewide Landslide Information Database for Oregon ("SLIDO") (Burns et al. 2014; Burns et al. 2016). Landslides were identified on the hillslopes above the town of Glasgow, Oregon, and on hillslopes above Kentuck Slough. Maps of landslide occurrence and susceptibility are provided on Figures 6.4-2 and 6.4-3 (Burns and Watzig 2014; Burns et al. 2016). No landslide deposits were identified within the LNG Terminal site. On Figure 6.4-3, a moderate to high landslide susceptibility hazard is mapped on the dune ridges at the LNG Terminal site; however, as indicated in Figure 6.4-2, active landslides have not been identified on the sand dunes. The high susceptibility indicated on Figure 6.4-3 at the LNG Terminal site is primarily based on the steep slopes of the dune deposits. JCEP will regrade the steep dunes that will eliminate potential landslide hazards related to dune sand stability.

At Kentuck Slough, as shown in Figure 6.4-2, landslides currently exist in isolated areas on the slopes surrounding the area, and Figure 6.4-3 shows a high susceptibility for landslides on the slopes surrounding Kentuck Slough. Because no LNG Terminal structures are planned for this area, the existence of these landslides is not considered significant to the LNG Terminal.

Constructed slopes planned for the LNG Terminal were evaluated for static and seismic conditions, with results and any required mitigation measures presented in the Geotechnical Report (KBJ 2017).

6.4.3 Ground Subsidence

Ground subsidence can result from co-seismic coastal subsidence, karst terrain, fluid extraction, or underground mining, each of which is described in this section.

6.4.3.1 Co-seismic Coastal Subsidence

Modeling of megathrust earthquake ruptures on the CSZ indicates sequences of interseismic uplift and co-seismic coastal subsidence. The predictions for coastal subsidence are locally constrained by features such as submerged trees and buried intertidal marshes interpreted to be associated with the 1700 CSZ earthquake. This repeated coastal subsidence pattern has been documented along the length of the CSZ (Atwater et al. 1995; Clague 1997; Goldfinger 2003). Leonard et al. (2004) presents profiles of coastal deformations from northern California to southern Canada based on this geologic information. The subsidence information indicates that the largest coastal subsidence, of 3 to 6 feet, occurred in northern Oregon and southern Washington, with subsidence ranging from 0 to 3 feet elsewhere. Leonard et al. (2004) estimated an average of 2 feet of co-seismic subsidence occurred in the Coos Bay area during the 1700 earthquake. Leonard et al. (2004) also estimated that the co-seismic subsidence in the Coos Bay area will range from 0 to about 5 feet during a future magnitude M_w 8 to M_w 9 megathrust earthquake located along this portion of the CSZ.

Subsidence estimates for the area have been updated as part of the recent updated tsunami modeling completed for the southern Oregon Coast (Witter et al. 2011) and site-specific modeling completed for the LNG Terminal (CHE 2017 and M&N 2017). These studies use the DOGAMI fault scenarios L1 and XL1 which to represent the 2,500-year and 10,000-year events. These studies estimate the subsidence at the LNG Terminal site for DOGAMI scenario L1 are in the order of 7.6 feet and for DOGAMI scenario XL1 are in the order of 12 feet.

The subsidence estimates reflect deformations over much of coastal Oregon, and will vary over large areas and distances. The regional subsidence is not anticipated to generate damaging differential settlements beneath the LNG Terminal site.

6.4.3.2 Karst Terrain

Karst terrain describes a distinctive topography that results from the dissolution of soluble carbonate and evaporite rocks by slightly acidic surface water or groundwater. Karst terrain is characterized by the presence of sinkholes, caverns, and disappearing streams.

Karst terrain has not been identified within the LNG Terminal site on the National Karst Map (Weary and Doctor 2014). Carbonate or evaporate rocks have not been identified within the LNG Terminal site (Beaulieu and Hughes 1975). The hazards associated with karst terrain are not anticipated for the LNG Terminal.

6.4.3.3 Fluid Extraction

Ground subsidence due to fluid extraction can occur when large quantities of subsurface fluids (such as oil, gas, or groundwater) have been withdrawn from certain types of rocks and sediments. Rock and sediments compress as fluid pressure in the material is reduced by pumping activities and effective stress on the rock or sediment increases. As a result of the increased stress, the porosity and volume of porous material is reduced. The reduction in volume decreases the thickness of the unit, which results in subsidence at the ground surface.

Petroleum hydrocarbon extraction for oil and gas is not likely commercially viable within the LNG Terminal site.

The LNG Terminal site is located on the North Spit of Coos Bay at the southern end of the Dune-Sand Aquifer. Groundwater extraction wells are present on the Siuslaw National Forest Oregon Dunes Recreation Area north of the LNG Terminal site. Three of the RFP wells are within the footprint of a proposed construction laydown area on the RFP property. The laydown area will revert back to use by RFP following construction.

The Coos Bay-North Bend Water Board will supply the LNG Terminal site with water during construction and operation. Additional water will be supplied during construction using temporary wells installed at Ingram Yard. Additionally, localized dewatering wells may be used to lower groundwater levels to facilitate soil improvement techniques during site preparation. All on-site construction wells will be operated only for the period of construction; therefore, any impacts to groundwater levels from pumping on-site during construction will be temporary, and water levels will recover when the pumping is terminated.

The Coos Bay-North Bend Water Board uses a portion of the Dune-Sand Aquifer for public water supply; the closest well is approximately 3,500 feet north of the LNG Terminal site (Groundwater Solutions 2006). Model simulations for the Dune-Sand Aquifer indicate that a maximum of 10 million gallons per day could be pumped with little risk of inducing seawater to flow into the wells (Jones 1992). With no permanent water supply wells planned for the LNG Terminal, there will be no reduction in the groundwater level from pumping at the LNG Terminal site during plant operations. The low risk of inducing seawater from pumping of the Dune-Sand Aquifer at high rates indicates that the aquifer has a high capacity. Therefore, reduction of the groundwater level at the LNG Terminal site is considered unlikely; therefore, ground subsidence is not anticipated to occur.

6.4.3.4 Underground Mining

Ground subsidence may occur in areas where abandoned underground mines that could collapse are located. Abandoned underground mines have not been identified in the vicinity, and therefore, the LNG Terminal will be unaffected by mine subsidence. The hazards associated with underground mines collapse are not anticipated.

6.4.4 Other Natural Hazards

In addition to the seismic hazards, landslides, and ground subsidence hazards, this section discusses other natural hazards, including biogenic gas, volcanoes, extreme wind and hurricanes, and flooding and scour.

6.4.4.1 Biogenic Gas

The borings, soil and rock samples, and laboratory testing associated with the extensive geotechnical investigation of the LNG Terminal site have not identified additional evidence of potential significant biogenic gas sources or potential hazards with natural soil or rock units. The peat layers identified in borings and test pits completed on the South Dunes site and Ingram Yard are relatively thin, have a high percentage of inorganic sand and silts, and are not considered to be a significant potential source of biogenic gas.

6.4.4.2 Volcanoes

The Cascade Mountain Range is the volcanic arc complex of the CSZ and is located approximately 100 miles east of the LNG Terminal site. Rising molten rock from the subducting Juan de-Fuca tectonic slab that erupts at the surface as a volcano can pose a variety of eruptive hazards in the region. Volcanoes of the Cascade Mountains are found from northern California to British Columbia. The eruptive hazards of Cascade Volcanoes include ash fall, pyroclastic flows, lava flows, debris avalanche, and lahars. The nearest Cascade Volcano is the Crater Lake caldera that was formed during the eruption and collapse of Mount Mazama approximately 7,700 years ago. River valleys 44 miles from the summit were destroyed by pyroclastic flows, and ash was deposited to the northeast of the volcano as far as southern Canada (Bacon 1997).

The LNG Terminal site is over 100 miles west of the nearest volcanic hazard area along the Cascade Mountains. At this distance, the pyroclastic flows, lava flows, debris avalanche, and lahars eruptive hazards would not reach the LNG Terminal site. Volcanic ash (tephra) consists of small pulverized pieces of rock and glass ejected during an eruption that could travel by wind in the atmosphere to the LNG Terminal site. Ash is hard, abrasive, and mildly corrosive. Ash has a low density and small particle size and therefore is able to spread over broad areas by wind. The ash begins to fall when the energy needed to keep the particles in the air diminishes. The size of ash particles that fall to the ground generally decreases exponentially with increasing distance from the volcanic vent in the prevailing wind direction (Wolfe and Pierson 1995). Tephra fragments larger than a few centimeters typically do not fall more than a few miles from the vent and are not likely to impact the project area.

Although a future eruption of the Mount Mazama volcano is possible, a large pyroclastic eruption is not considered likely for many thousands of years in the future, because the magma reservoir that fed the eruption of Mount Mazama has not had sufficient time to regenerate a large volume of gas-rich magma (Bacon et al. 1997).

The LNG Terminal site would not be directly affected by the various types of volcanic eruption hazards due to the distance of the hazard, the upwind location of the LNG Terminal site from the volcanic hazard, and the low likelihood of volcanic eruption during the lifetime of the LNG Terminal.

6.4.4.3 Extreme Wind/Hurricanes

Tropical cyclones (i.e., hurricanes) do not occur near the LNG Terminal site. Tropical and subtropical cyclones are by nature barotropic, warm core systems that require sea surface temperatures of 80°F or higher. Sea surface temperatures off of the Oregon coast near the LNG Terminal site average between 50°F and 55°F year-round (National Oceanographic Data Center), which is far too cool to support tropical cyclone formation and/or sustenance. Additionally, tropical cyclones require low deep-layer wind shear environments characteristic of the weak upper-level flow regimes found in tropical latitudes. Given the location of the LNG Terminal site in the mid-latitudes, moderate to strong upper-level westerly winds generally prevail. These upper-level winds contribute to deep-layer wind shear environments that are not conducive to tropical cyclones.

Strong extratropical cyclones (baroclinic, cold core systems) are a common occurrence along the Oregon coast during the late fall and winter, and even into the early spring. Several times every year, winds can reach hurricane force at different locations along the Oregon coast (WRCC 2017). Strong winds that reach hurricane force can and do occur occasionally at the LNG Terminal site.

ASCE 7-05 dictates inputs for structural analysis and design for locations and territories of the United States, and Section 6.5.4.2 states the following:

> In areas outside hurricane-prone regions, regional climatic data shall only be used in lieu of the basic wind speeds given in Fig. 6-1 when (1) approved extreme-value statistical-analysis procedures have been employed in reducing the data; and (2) the length of record, sampling error, averaging time, anemometer height, data quality, and terrain exposure of the anemometer have

> been taken into account. Reduction in basic wind speed below that of Fig. 6-1 shall be permitted.

This statement remains unchanged in ASCE 7-10, Section 26.5.3.

The LNG Terminal will be designed to maintain structural integrity in the most critical combination of wind velocity and duration having a probability of exceedance in a 50-year period of 0.5 percent (10,000-year mean return interval) per 49 CFR 193.2067 paragraph (b)(2)(ii). This mean return interval exceeds the requirements of ASCE 7. For the LNG Terminal site location, the strength level 10,000-year design wind speed was determined to be 127 miles per hour (3 second gust wind speed, 33 feet, Exposure Category C) (CPP 2016).

6.4.4.4 Flooding and Scour

Flooding is addressed for estuarine flooding, storm surge, and sea level rise in this section.

Rip rap will be used to prevent scour and erosion of those parts of the LNG Terminal Site impacted by the tidal range including the Marine Basin and MOF. The rip-rap elevation is determined as a function of the historic high tide level in Coos Bay and the historic high wave. Above this elevation, a system designed to provide erosion and scour due to less frequent events such as storm surge will be used. An anchored reinforced vegetation system or similar may be used if shown to be suitable. Seed beds will use existing site top soil where possible with American Dune Grass or similar native species in order to stabilize the soil.

For the remainder of the shoreline at the LNG Terminal site, which is not considered to be tidally influenced, erosion protection will consist of an anchored reinforced vegetation system or equivalent. Seed beds will use existing site top soil where possible with American Dune Grass or a similar native species in order to stabilize the soils.

The site elevations of the pipeline and all aboveground facilities (except for the MOF) are higher than the maximum coastal flooding elevation; therefore, they are protected from flooding and scour.

6.4.4.4.1 Estuarine Flooding

Estuarine flooding elevations are established in accordance with the project specific analysis of impacts of fill on flooding and the Federal Emergency Management Agency ("FEMA"). FEMA has developed detailed maps that display the base 100-year flood elevation of each specific site based on historic, meteorological, and hydraulic data, as well as open-space conditions, flood control works, and development. The maps were developed in response to the National Flood Insurance Program (NFIP) that was enacted by the US Congress in 1968. The 100-year flood is a regulatory standard used by Federal agencies and most states to administer floodplain management programs. The 100-year flood is used by the NFIP as a basis for insurance programs nationwide (FEMA FIRM).

The base 100-year flood elevation for the LNG Terminal site established by FEMA is 11 feet and the base 100-year flood elevation at the South Dunes site established by FEMA is 12 feet. (FEMA, FIRM 2014). A recent study has estimated the 500-year flood elevation for the LNG Terminal site to be 12.6 and 12.8 ft for the Terminal and South Dunes sites, respectively (SHN 2017).

Fill to be added for the LNG Terminal site will add ~0.004 feet to these flood elevations (SHN 2017). The added elevation is negligible and is therefore excluded from the final estuarine flooding elevations.

6.4.4.4.2 Storm Surge

Coastal flooding elevations as a hazard due to storm surge have been established. The maximum flooding elevations take into account wave run up plus the tide in a 100-year storm (M&N 2017). A FEMA conversion factor to convert from the National Geodetic Vertical Datum of 1929 (NGVD 29) to the North American Vertical Datum of 1988 (NAVD 88) was used. The conversion factor is +3.62 feet and is added directly to the NGVD 29 value of 21.0 feet, thus a coastal flooding (storm surge) elevation of 24.62 feet at the NAVD 88 was determined for the LNG Terminal site.

6.4.4.4.3 Sea Level Rise

Sea level rise associated with global climate change has been observed in various coastal locations. Climate change induced sea level fluctuations are expected to continue in the future. Sea level rise in Coos Bay, Oregon has been projected at a rate of 1.62 ± 1.02 mm/year (Ruggiero et al. 2010). Therefore, the theoretical maximum annual sea level rise is 2.64 mm/year. Over an assumed 50-year life span of the LNG Terminal this would amount to 132 mm or 0.433 feet of potential sea level rise.

The National Oceanic and Atmospheric Administration (NOAA) maintains a website that tracks the potential sea level rise. Based on sea level data from 1970 to 2015 the trend is for sea level to increase at 0.98 mm/year with a 95 percent confidence interval of ± 0.83 mm/yr for Charleston, Oregon, located in lower Coos Bay. Thus by extrapolating out this analysis, the equivalent sea level raise over the 50-year life span of the LNG Terminal would be 49 mm or 0.16 feet. (NOAA 2015)

These two references indicate that the estimated sea level rise ranges from 0.16 to 0.43 feet at the LNG Terminal site and this has been accounted for in the design of the LNG Terminal.

6.5 FACILITIES IN SEISMIC RISK AREAS

A site-specific seismic hazard study (KBJ 2017) for the LNG Terminal site is provided in Appendix B.6.

6.6 PALEONTOLOGY

Fossils are the preserved remains or traces of organisms from the past that are generally older than Holocene age deposits. Vertebrate fossils have been identified at Fossil Point, located 5 miles southwest of the LNG Terminal site. Fossil types encountered include clams, gastropods, and sand dollars. Pieces of whale and sea lion fossils have also been found in this area. Sedimentary rocks units identified in the vicinity of the LNG Terminal have a potential for paleontological resources. However, the LNG Terminal will be sited on Holocene and Pleistocene unconsolidated sedimentary deposits with little paleontological resources. Shell fragments have been identified in the unconsolidated deposits, but these fragments have little paleontological value. There are no known paleontological resources that will be impacted by the LNG Terminal.

6.7 GEOTECHNICAL INVESTIGATIONS

Numerous geotechnical investigations have been completed to support the design for the LNG Terminal since 2005. These investigations have been conducted at the LNG Terminal site, the Trans Pacific Parkway/US-101 Intersection, and the Kentuck Project site. The investigations were conducted to evaluate subsurface characteristics and conditions, with investigation techniques including the following:

- Mud-rotary borings with Standard Penetration Tests (“SPT”) using hammer energy measurements
- Cone Penetration Test (“CPT”) probes with pore pressure measurements
- Test pits
- Soil electrical resistivity testing
- P-S suspension logging, crosshole testing, downhole testing, seismic reflection surveys, and refraction microtremor to measure shear and compression wave velocities
- Borehole pressuremeter testing
- Pump testing
- Laboratory testing

The borings and shear wave velocity logging on the LNG Terminal site were completed to depths of approximately 300 feet. In all, more than 130 borings, 85 CPTs, and 31 test pits have been completed for the LNG Terminal. A data report providing the data from the geotechnical explorations completed to date for the LNG Terminal is in Appendix A.6 (GRI 2017). Additional subsurface investigation is planned, including borings, CPTs, PMTs, and geophysical testing to support final design. Appendix 13.J of Resource Report 13 provides the proposed investigation to support final design.

The results of the geotechnical investigation to date indicate that subsurface conditions at the site are suitable for the LNG Terminal, provided that adequate site preparation and foundation design and construction methods are implemented.

Liquefaction, subsidence, and tsunami hazards will be addressed. Ground improvement methods including vibro-compaction and deep soil mixing are being considered to mitigate the liquefaction, lateral spreading, and seismic slope stability. Driven pipe piles and drilled shafts are being proposed to support much of the critical equipment and structures. The following discussion summarizes the subsurface conditions and foundation systems planned, with more detailed discussions provided in the Geotechnical Report (KBJ 2017) in Appendix C.6.

6.7.1 Ingram Yard Subsurface Condition Summary

A number of design profiles were developed for the LNG Terminal site. The design profiles were differentiated based on differences in the amount of fill to be placed or sand dune to be excavated and minor differences in the existing subsurface conditions. These conditions are summarized here, and the design profiles and geologic cross sections are presented in detail in the Geotechnical Report (KBJ 2017) in Appendix C.6.

Throughout the LNG Terminal site, the subsurface conditions are relatively consistent below elevation -30 feet. The existing sands above elevation -30 feet consist of either existing sand fill or native dune or estuary sand deposits. Historical records indicate that the upper approximately 10 feet of the sand west of the dunes is likely fill. The existing sand fill and underlying native sand are physically indiscernible; however, in some areas, the transition to the native sand can be identified based on the presence of an organic/peat layer at the interface that occurs between elevation 11 feet and elevation 8 feet. The existing sand fill and organics/peat were only identified west of the existing dune. The existing sand fill generally had N_{60}-values (which are the standard penetration test N-values or the number of blows to drive a standard 2-inch split barrel sampler the last 12 inches of an 18-inch sample interval using a 140-

pound hammer falling 30 inches, normalized to 60 percent hammer energy) that were less than 10 blows per foot with design N_{60}-values of 7 to 8 blows per foot. The native sand typically had N_{60}-values greater than 20 blows per foot. The fines content of the existing sand fill and native sand generally ranged from 5 to 10 percent.

In the area of the dune on the eastern portion of the Ingram Yard site, the sands are native starting at the ground surface.

Below elevation -30 feet, the native sand is predominantly fine-grained, with occasional shells and silt zones. The fines content of the sand is generally less than 10 percent. Below elevation -30 feet, the native sand density is markedly greater than the overlying sand and has N_{60}-values greater than 50 blows per foot.

A sand-silt unit is present beneath the native sand at elevations ranging from -110 feet to -160 feet. The sand-silt unit density is significantly greater than the overlying sand and generally has field N-values of 50 or more in the first 6 inches of the SPT. The sand-silt unit has a fines content ranging from 5 to 60 percent and is non-plastic.

A boring completed for the geotechnical investigation to a depth of about 252 feet on the Ingram Yard site encountered hard clayey silt that was classified as poorly indurated silty shale. Another boring drilled about 480 feet north, did not encounter the poorly indurated silty shale when terminated at a depth of about 280 feet.

6.7.2 Access and Utility Corridor Subsurface Condition Summary

A number design profiles were developed within the Access and Utility Corridor. The design profiles were developed based on differences in the amount of fill or excavation required for site development and minor differences in the existing subsurface conditions identified above elevation -30 feet. A summary of conditions is provided here, and the design profiles and geologic cross sections are presented in the Geotechnical Report in Appendix C.6.

The sands consisted of both fill and native sand. Organics and peat were encountered only in the western end of the Access and Utility Corridor between elevation -11 feet and elevation -10.5 feet. The majority of the existing sand fill had N_{60}-values of less than 10 blows per foot, with design values of 7 to 8 blows per foot. The majority of the native sand N_{60}-values were greater than 15 blows per foot. The fines content for most of the sands ranged from 5 to 10 percent.

Below elevation -30 feet, the conditions for the Access and Utility Corridor are similar to those described for the LNG Terminal site.

6.7.3 South Dunes Site Subsurface Condition Summary

A number of design profiles were developed for the South Dunes site. The design profiles were developed based on minor differences in the existing subsurface conditions identified above elevation -30 feet. The design profiles and geologic cross sections are presented in the Geotechnical Report in Appendix C.6, and a summary of the subsurface conditions are provided here.

As at Ingram Yard and along the Access and Utility Corridor, the subsurface conditions at the South Dunes site are relatively constant below elevation -30 feet. The conditions above elevation -30 feet vary between design profiles mainly due to variation in the sands and the presence or absence of peat/organics. Peat/organics were encountered in several areas of the South Dunes site at elevations ranging from 4 to 9 feet.

The existing sand above elevation -30 feet consists of fill and native dune and estuary sand deposits. The existing sand fill and underlying native sand were basically indistinguishable; however, the transition between the existing sand fill and native sand was inferred based on the presence of peat/organics, where encountered. The existing sand fill generally has lower N_{60}-values than other areas of the LNG Terminal site, with design values of 3 to 14 blows per foot. The native sand typically has N_{60}-values greater than 15 blows per foot. The fines content of the sands typically ranged from 5 to 10 percent.

In the northeast quadrant of the South Dunes site, a layer of clay was encountered between elevation 6 feet and elevation 3.5 feet. The clay thickness varies from 0.3 feet to 2.5 feet, and the material is very soft to soft with a high plasticity.

In the east central portion of the South Dunes site, the subsurface investigation encountered driftwood. The estimated extent of the driftwood is based on observations during subsurface investigations and a historical photo that shows accumulations of driftwood in the east central portion of the South Dunes site. The depth to driftwood and the maximum depth of the driftwood are not precisely known, but it is estimated to extend not more than 10 feet below ground surface.

Below elevation -30 feet, the subsurface conditions are fairly consistent across the South Dunes site. The native sand is predominantly fine-grained sand, with occasional shells and silt zones. A deep boring at the South Dunes site indicates that the native sand extends to elevation -151 feet. The native sand in this interval has a design N_{60}-value greater than 50 blows per foot.

Below elevation -151 feet, clayey silt was encountered that extended to an elevation of at least -221 feet, which was the lowest elevation of material classification. Description of the clayey silt from the boring log indicated weak cementation, with hard to very hard consistency based on N_{60}-values ranging from 12 to 75 blows per foot and with a general increase in stiffness with depth. Geotechnical tests on the clayey silt indicated high plasticity.

6.7.4 Groundwater Characterization Summary

The groundwater elevations for the LNG Terminal were estimated using the measured groundwater levels in piezometers along with data from CPT probes. Groundwater recordings indicate the following:

- The groundwater levels fluctuate seasonally in response to rainfall and have varied by up to approximately 4 feet.
- The groundwater levels are typically higher to the north as the distance from Coos Bay increases.
- The tidal influence to groundwater levels decreases as the distance from Coos Bay increases.
- Based on the historical groundwater monitoring, groundwater flow within the LNG Terminal site is generally to the south toward Coos Bay, with localized flow on the west side of the LNG Terminal site toward the Henderson Property.

Design groundwater elevations vary from 8 feet to 17.5 feet depending on the location.

6.7.5 Foundations Summary

A combination of spread or strip footings, mats, and deep foundations will be used to support the structural loads for the LNG Terminal site. Ground improvements discussed in Section 6.6.1.3 will be implemented below structures to mitigate liquefaction.

Miscellaneous structures will be supported by square and strip footings. All spread and strip footings will be founded a minimum depth of 1 foot below final grade based on the anticipated maximum depth of frost penetration. For square and strip footings less than 20 feet wide, the gross allowable bearing pressure is limited to 3.0 kilopounds per square foot for settlements of less than 1.5 inches. Larger and/or more heavily loaded foundations will be analyzed on an individual basis.

Mat foundations will be used to support the LNG tanks. A base isolation friction pendulum bearing system is planned for the LNG tanks. The base isolators would be located between the concrete slabs for the LNG tanks.

The use of deep foundations will be required for structures and equipment that cannot satisfy the bearing capacity requirements, settlement limitations, lateral and/or uplift load requirement, and/or economics of shallow foundations. Deep foundations are primarily required to resist seismic shear and overturning, or wind loads. The deep foundations to support large compression, tension, and/or lateral loads will be pipe piles or drilled shafts depending on the required vertical or horizontal loading requirements.

The compression and tension axial capacity of pipe piles and drilled shafts are calculated with a safety factor of 2.0; therefore, full-scale compression and tension load tests are required to be performed on-site for pipe piles and drilled shafts. If load testing is not performed, the factor of safety will be increased to 3.0.

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FIGURES

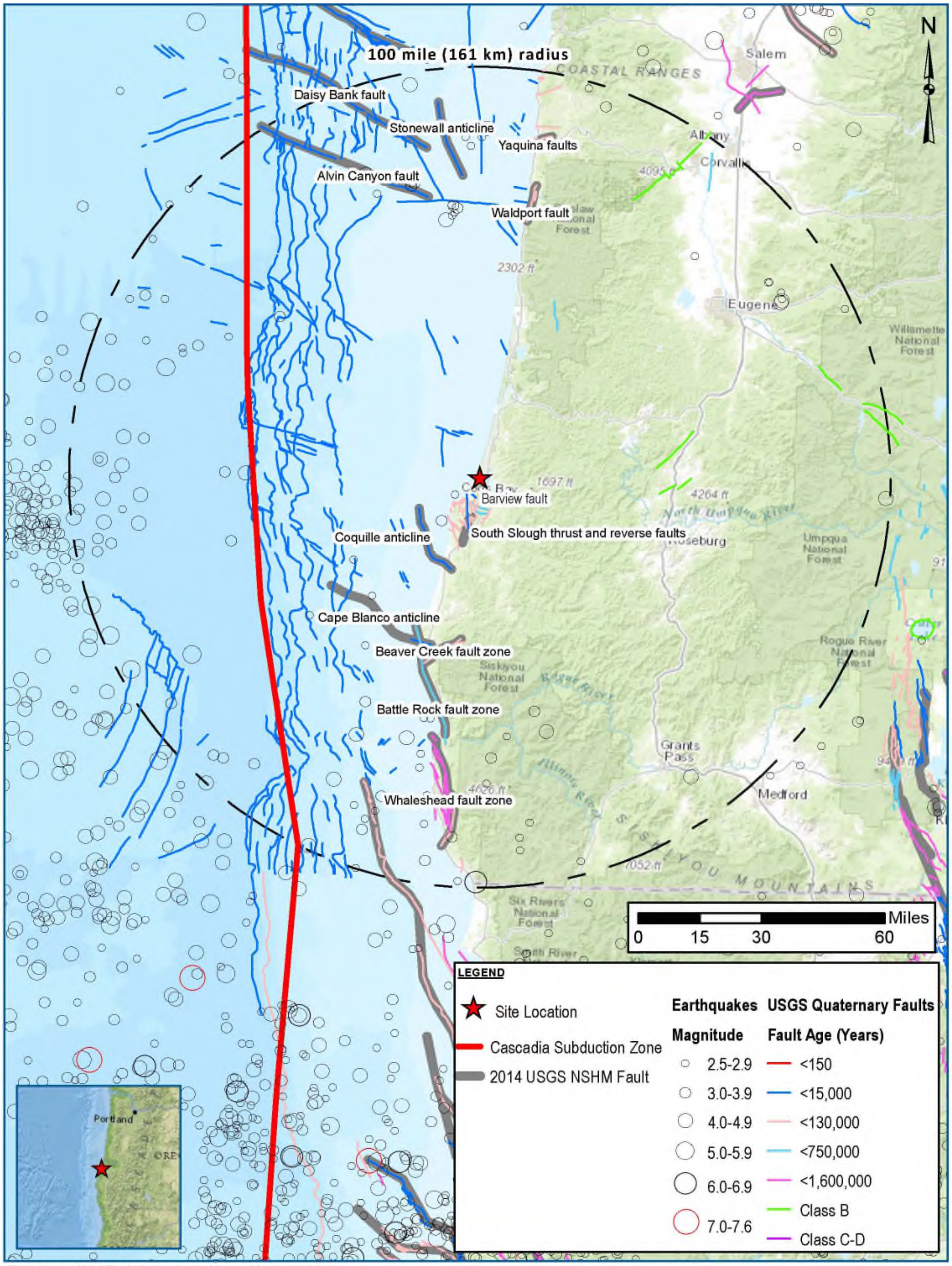

Figure 6.4-1: Potentially Seismogenic Fault Locations within 100 miles of the LNG Terminal Site

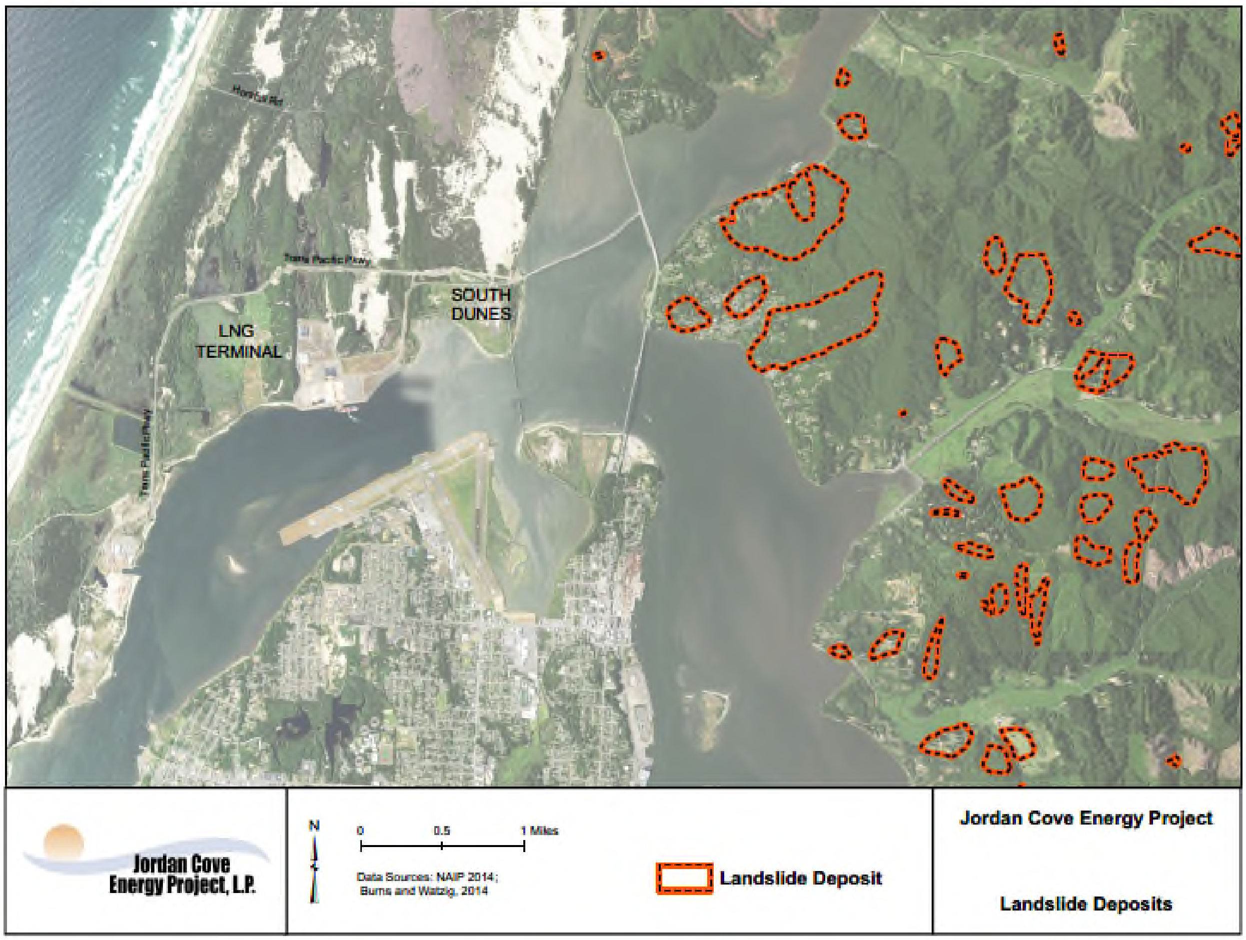

Figure 6.4-2: Mapped Landslide Deposits

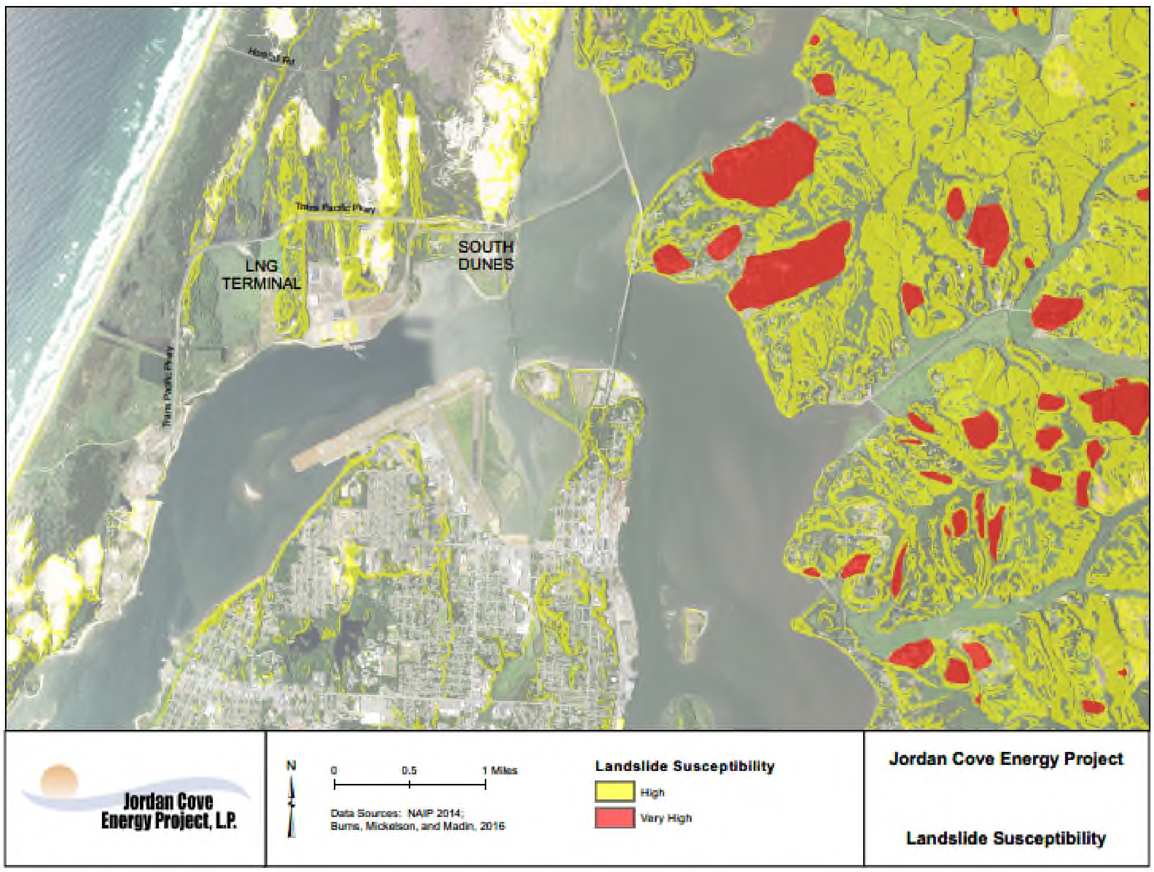

Figure 6.4-3: Landslide Susceptibility in the Vicinity of the LNG Terminal Site

APPENDICES

[PLACEHOLDER]

THE FOLLOWING APPENDICES

TO BE PROVIDED IN A SUBSEQUENT DRAFT

APPENDIX A.6
Geotechnical Data Report

APPENDIX B.6

Site-Specific Seismic Hazard Study

APPENDIX C.6

Geotechnical Report

APPENDIX D.6

Estuary Flood Risk and Hazard Study

APPENDIX E.6
Tsunami Hydrodynamic Modelling

APPENDIX F.6

Tsunami Maximum Run up Modelling

APPENDIX G.6
Tsunami Wave Amplitude Analysis

APPENDIX H.6
Design Wind Speed Assessment