4.11 Geologic and Soil Resources

Geology and soils are evaluated as part of an environmental document because conditions in the project area can influence the type and size of a project's structure, the noise level, the amount of ground disturbance created during construction, and the volume of soils needed to be excavated. In addition, geology and soils are related to the presence of geologic hazards such as earthquake vulnerability (see definitions in right inset box). Geology and soil considerations affect project construction methods and, if not adequately considered during project design, could affect the long-term operations and safety of the project.

This section provides a general overview of regional and local geological conditions, existing soil data, and geological hazard information, including a general evaluation of seismic hazards and liquefaction or inundation from tsunami or seiche that could occur in the study area. The study area is defined as the area within public right-of-way where the new project tracks, turnback tracks, access tracks, and stations are proposed, as described in Section 3.4.2 of this EA. The study area also includes the proposed OMF expansion sites.

Geologic Hazard Areas

Steep slopes are slopes steeper than 40 percent with a vertical elevation change of at least 10 feet.

Landslide hazards may occur where the slope is steeper than 40 percent, in areas with indications of past landslide activity, and in areas that have shown significant movement during the last 10,000 years.

Seismic hazard areas are subject to potential risk from earthquake-induced ground shaking and fault displacement. Ground shaking can result in slope failure, settlement, liquefaction, a tsunami, or a seiche.

Liquefaction refers to soils with little or no cohesion that lose strength during earthquakes. Liquefaction typically occurs in areas where there is a shallow groundwater table.

A **tsunami** is a sea wave resulting from an underwater landslide or seafloor movement during an earthquake.

Seiches are periodic oscillations in an enclosed body of water during an earthquake.

Peat settlement-prone areas are areas where the soils are highly compressible and prone to settlement.

Volcanic hazard areas are those areas in the project vicinity subject to inundation by lahars or related flooding from volcanic activity on Mount Rainer.

4.11.1 Topography, Regional Geology, and Seismicity

Regional topography in the Seattle area has been influenced by repeated glaciations during the past million years, and it is dominated by north-south trending ridges and troughs formed through glacial erosion and sediment deposition (Troost et al., 2005). In the project vicinity, approximately 1,500 feet of glacial and nonglacial sediments overlie bedrock (Troost et al., 2005). The City of Seattle is generally composed of hilly terrain. Elevation in Seattle varies between sea level and up to approximately 450 feet above sea level. Topography generally slopes from northeast to southwest, toward Elliott Bay. The streets parallel to Elliot Bay, such as First Avenue, are relatively flat.

In addition, the project vicinity has undergone extensive modification over the past 150 years, including moving the shoreline waterward with construction of the Elliott Bay seawall. Historic photographs indicate that the shoreline was originally located close to the current-day First Avenue. Building the seawall led to raising the ground level in the historic Pioneer Square area approximately one story higher. Basements for most buildings were originally the ground floor. Also, in the late 1800s, an enormous regrading project, known as the Denny Regrade, resulted in leveling a large hill to lower the topography from Denny Way to Jackson Street and between First Avenue and Fifth Avenue, making way for the entire downtown Seattle as it stands today.

The King County interactive database includes the results of numerous soil boring data along the LPA alignment. A sampling of boring data suggests a range of soil conditions along the alignment, generally limited to silts, sands, and clay of varying density and consistency (Washington State Department of Natural Resources, 2014). The borings reveal fill material and manmade debris within surficial layers from early development and earthwork. Fill material was observed in the vicinity of the Newslane Tower (First and Pike), MC-1 Site Development (First and Union), Carma Center (First and University), the 1000 First Street Project (First and Madison), and the Buttnick Building (First and Washington). The uppermost native material commonly consists of loose to medium-dense fine sand and silty sand within the upper 10 to 15 feet. Below 15 feet, the material density and consistency generally increase substantially, becoming very dense or hard and consisting of interbedded sand, sandy silt, sandy clay, and variations of silt, sand, and clay.

The City of Seattle is a seismically active area. The closest fault is in the 6-kilometer-wide Seattle fault zone, which runs west to east across the south part of the city, according to the Geologic Map of Seattle (Troost and Booth, 2008). The upper boundary of the Seattle fault zone lies just south of the study area in Pioneer Square. Although activity within the Seattle fault zone could be a major contributor to potential ground shaking, a fault rupture from the Seattle fault zone is unlikely in the study area.

4.11.2 Hydrogeological Conditions

Hydrogeological conditions in the project vicinity are greatly influenced by the steep topography of the region and Elliott Bay to the west. Groundwater flow is primarily from the east-northeast to west-southwest, toward Elliott Bay. Depth to groundwater along the new track alignment on First Avenue is as shallow as 12 feet in the south portions of the study area and becomes deeper moving northward (Washington State Department of Natural Resources, 2014). Depth to groundwater at the South Lake Union OMF expansion site is between 75 to 80 feet below ground surface (Touchstone SLU LLC, 2014). Depth to groundwater in the area around the Chinatown-International District OMF expansion site is between 20 and 30 feet below ground surface (Washington State Department of Natural Resources, 2014).

4.11.3 Geologic Hazards

Based upon information in Section 25.09 of the Seattle Municipal Code, geologic hazards include the following: liquefaction, landslide, peat settlement, volcanic hazards, and seismic hazards, which include tsunamis and seiches. These situations could result in soil settlement, thereby undermining the infrastructure integrity. The study area does not include steep slopes nor is it considered a landslide hazard area. The southern one-third of the study area is located in the

Pioneer Square District, which is characterized as having high liquefaction susceptibility.[1] In addition to liquefaction, the Pioneer Square-Skid Road Historic District could be inundated by a seiche from a seismic event, and there are areas where peat settlement is a concern. Other areas of the study area are less susceptible because they are at higher elevation.

The Seattle Police Department is responsible for the Disaster Readiness and Response Plan and, among other responsibilities, coordinates the emergency broadcast system to provide advanced warnings to vacate the area in the event of tsunami and seiche events. The Disaster Readiness and Response Plan was develop in response to the Seattle Hazard Identification and Vulnerability Analysis (both available at http: //www.seattle.gov/emergency-management/what-if/plans).

4.11.4 Impacts

4.11.4.1 No Build Alternative

Under the No Build Alternative, the existing geology and soils environment would essentially remain the same and there would be no change in existing risks from seismic hazards.

4.11.4.2 Locally Preferred Alternative

Operational Impacts

Geologic risks consist of seismic hazards, seiches, and potential soil settlement, each of which could affect the condition of the trackway.

Strong ground shaking could cause movement for the streetcar and possible derailment or damage to the rail alignment from ground movement and liquefaction. The trackway nearest the Pioneer Square District has high liquefaction susceptibility, whereas the Pike Street and Stewart Street areas of the study area are designated as very low susceptibility, but these roadways are still adjacent to areas of high liquefaction susceptibility. The streetcar track design would meet seismic standards including replacement of soft soils.

Following a seismic event, a tsunami could inundate the Pioneer Square District. No other portion of the LPA would be within the zone of inundation; the existing and renovated seawall raised the ground level. There are no further design solutions to prevent hazards of inundation.

Although original geologic or existing geotechnical conditions show a presence of soft or loose soils in the southern portion of the project alignment, the overall risk of settlement is low because the LPA would be entirely within existing roadway right-of-way where settlement has not occurred over multiple years of use. Historically, streetcars have operated in the same corridor. Engineering design and current seismic standards will be used to avoid impacts during

[1] Approximately the southern one-third (Pioneer Square District) of the study area is in an area determined to be Site Class E (Soft Soil) according to the King County Soil Site Classes map (Map 11-5), based on the National Earthquake Hazard Reduction Program. The northern section of the study area is an area determined to be Site Class D (Stiff Soil); however, the alignment would run adjacent to and near the area mapped as being Site Class D (King County, 2010).

operation. Neither of the OMFs is located on soft or loose soils; therefore, settlement is not anticipated in those areas.

Construction Impacts

Impacts during construction would be associated with the equipment used to perform the construction, as well as the direct and indirect impacts of the construction activities. Construction activities have the potential to cause a number of geology- and soils-related short-term impacts on the environment. Construction activities would include disturbances of up to 8 feet to relocate utilities and augering of up to 15 feet to install the OCS poles. The South Lake Union OMF would include a retaining wall behind the sidewalk along Fairview Avenue that would support the site excavation of up to 5 feet lower than the sidewalk, because the storage tracks require a relatively flat grade. There are no other deep foundations required for structures or the construction of retaining walls. Impacts during construction would be associated with the equipment used to perform the construction, as well as the direct and indirect impacts of the construction activities.

Soil erosion may occur during excavation of roadbed and stockpiling spoils during construction, where rain could erode soil piles. Construction BMPs consistent with the stormwater pollution protection plan to be prepared for the project would reduce the effects of erosion. Refer to Section 4.8, Stormwater/Water Quality, for information.

Heavy equipment used during construction could cause ground vibration that may be of concern for historic properties and annoyance to people working and living in the area. The major sources of construction vibration could include vibratory ground improvement, earth excavation in hard ground using jackhammers, and vibratory rollers for subgrade compaction. As described in Section 4.4, Noise and Vibration, based on the existing geology and the building materials near the construction areas, no vibration impacts during construction are anticipated.

Construction is not anticipated to reach groundwater depth in most of the study area, even in the Pioneer Square Historic District, where groundwater is most shallow (about 12 feet). The OCS suspension poles need to be placed as deep as 15 feet, but the OCS poles are not proposed in areas with shallow groundwater because the streetcars would be wireless in Pioneer Square Historic District.

During construction, seismic hazards could occur without adequate warning, resulting in failures of excavation or ground settlement anywhere in the study area. Work schedules would likely be delayed as efforts are made to repair damaged components of the work. Some disruption could also occur to utilities or nearby structures from the damage to exposed cuts or fills. This impact is not specific to the Center City Connector. During such a rare event, Seattle would follow the Seattle’s Disaster Readiness and Response Plan.

During final design, SDOT will complete an additional geotechnical investigation to determine subsurface conditions and to identify the presence or absence of near-surface obstructions (e.g., manmade debris) to refine track and OMF design requirements and construction techniques, in accordance with current seismic standards. The project-specific subsurface investigation may include (1) test borings, (2) test pits, (3) geophysical surveys and testing, (4) laboratory testing, (5) geotechnical engineering analyses, and (6) evaluations such as bearing capacity, liquefaction and settlement, lateral spreading, and ground improvement, and (7) determination of which seismic resistance design standards apply. The additional testing would also address soil settlement probability to identify where soils need to be improved or removed to substantially reduce settlement risk.

Engineering design and current seismic standards will be used to minimize potential impacts during construction. While seismic events can vary in degree of intensity, current seismic design standards can prevent most human health risks associated with unanticipated seismic events.

Although a seismic event and resulting liquefaction cannot be entirely avoided, current building codes require projects to meet seismic design standards to reduce the effects of an event on the project and reduce risk to human life.

4.11.5 Mitigation Measures

Due to standard engineering and design practices, no adverse geologic impacts have been identified; therefore, no mitigation is proposed.