# 4. Environmental Impacts and Mitigation

As discussed in Section 3.3.3, this SEIS identifies alternatives and analyzes their impacts at a level of detail consistent with and appropriate for the broad, plan-level issues being addressed in the Long-Range Plan update and other planning activities and decisions. While more detail may be available for certain corridors or areas where planning analyses are underway, this Final SEIS generally identifies alternatives and their possible impacts at a regional level. For example, this non-project SEIS identifies potential HCT improvements in broad corridors, as opposed to specific alignments, and identifies representative facility and operating characteristics, as opposed to providing project-level details such as specific routes, locations, facilities, or operating characteristics. Additional project or site-specific details, and analysis of their impacts and recommended mitigation measures, will be completed later during project-level environmental review after the updated Long-Range Plan is adopted.

## 4.1 EARTH

This analysis updates the 1993 Final EIS using current Geographic Information System (GIS) data and information from project-level environmental documents for Sound Transit light rail, commuter rail, and regional express bus projects. Existing geologic conditions, potential geologic impacts associated with the No Action Alternative and the Plan Alternative and Options, and potential mitigation measures are discussed. A more detailed evaluation, including project-specific impacts and mitigation measures, will be provided in future project-level planning and environmental review for individual projects developed under the Long-Range Plan.

### 4.1.1 Affected Environment

#### *4.1.1.1 General Geology*

The Central Puget Sound region lies in a glacially scoured basin between mountains to the east and the west. The landscape is a series of north-south trending ridges separated by deep troughs occupied by marine waters, freshwater lakes, and streams.

Most surface and shallow subsurface soils were deposited during the most recent glaciation. These deposits generally include, from the oldest to the youngest:

- Lakebed sediments (silts and clays).
- Deposits from glacial runoff (sands and gravels).
- Glacial till (very dense mixture of gravel, sand, silt, and clay).

Relatively recent (less than 10,000 years old) stream deposits and artificial fill are also present in many places.

There are landslide, liquefaction, and other geologic hazard areas in the Sound Transit District. Figures 4.1-1 and 4.1-2 depict geologic hazard areas in the Sound Transit District based on recent GIS data from Pierce, King, and Snohomish Counties. Geologic hazard areas are often designated Sensitive Areas and may be subject to additional restrictions and permitting. Steep slopes in the area are conducive to landslides. Unconsolidated lakebed deposits and peats are prone to settlement. Strong lateral stresses in hard silt and clay adversely affect construction of retaining walls and underground facilities. Underground facilities could also be adversely affected by the water-bearing sand and gravel.

#### *4.1.1.2 Slide Hazard Areas*

Slide hazards in the project area are associated with steep slopes or loose soils made unstable by geologic or man-made conditions. Factors that can contribute to slope instability include over-steepening of natural slopes; man-made fills consisting of loose, wet, or saturated fill soils; and the presence of groundwater in soils. These conditions can also decrease soil stability by decreasing friction between soil particles in coarse-grained deposits and by creating excess pressure in fine-grained deposits that are poorly drained. Slope stability is also influenced by seismic activity, which is discussed in further detail below.

Geologic hazard areas, including areas categorized by Pierce, King, and Snohomish Counties as steep slope/slide hazard areas, seismic/liquefaction areas, and fault lines, are depicted in Figures 4.1-1 and 4.1-2. Relatively small steep slope/slide hazard areas are found throughout the Sound Transit District. Larger areas are found along the Puget Sound shoreline; in the cities of Seattle, Shoreline, Newcastle, Renton, Auburn, and Sumner; and along the shores of Lake Washington and Lake Sammamish.

Erosion is greater on slopes and can occur through either wind or water action. The rate of erosion also depends on soil type, vegetative cover, and topographic position.

#### *4.1.1.3 Seismic Hazard Areas*

Seismic hazard areas are areas that are subject to severe risk of earthquake damage as a result of seismically induced settlement, soil liquefaction, or landslides. These conditions often occur in valleys and areas of man-made fill. Areas categorized by Pierce, King, and Snohomish Counties as seismic/liquefaction hazard areas are depicted in Figures 4.1-1 and 4.1-2. Relatively small seismic/liquefaction areas are found throughout the Sound Transit District. Notable seismic/liquefaction areas occur along the Puget Sound shoreline in Snohomish County; in the city of Seattle; between Woodinville and Redmond; at the north and south ends of Lake Sammamish; along the Cedar River near Renton; between Kent, Auburn, and Federal Way; and in the large area in Pierce County between Mount Rainier and Commencement Bay.

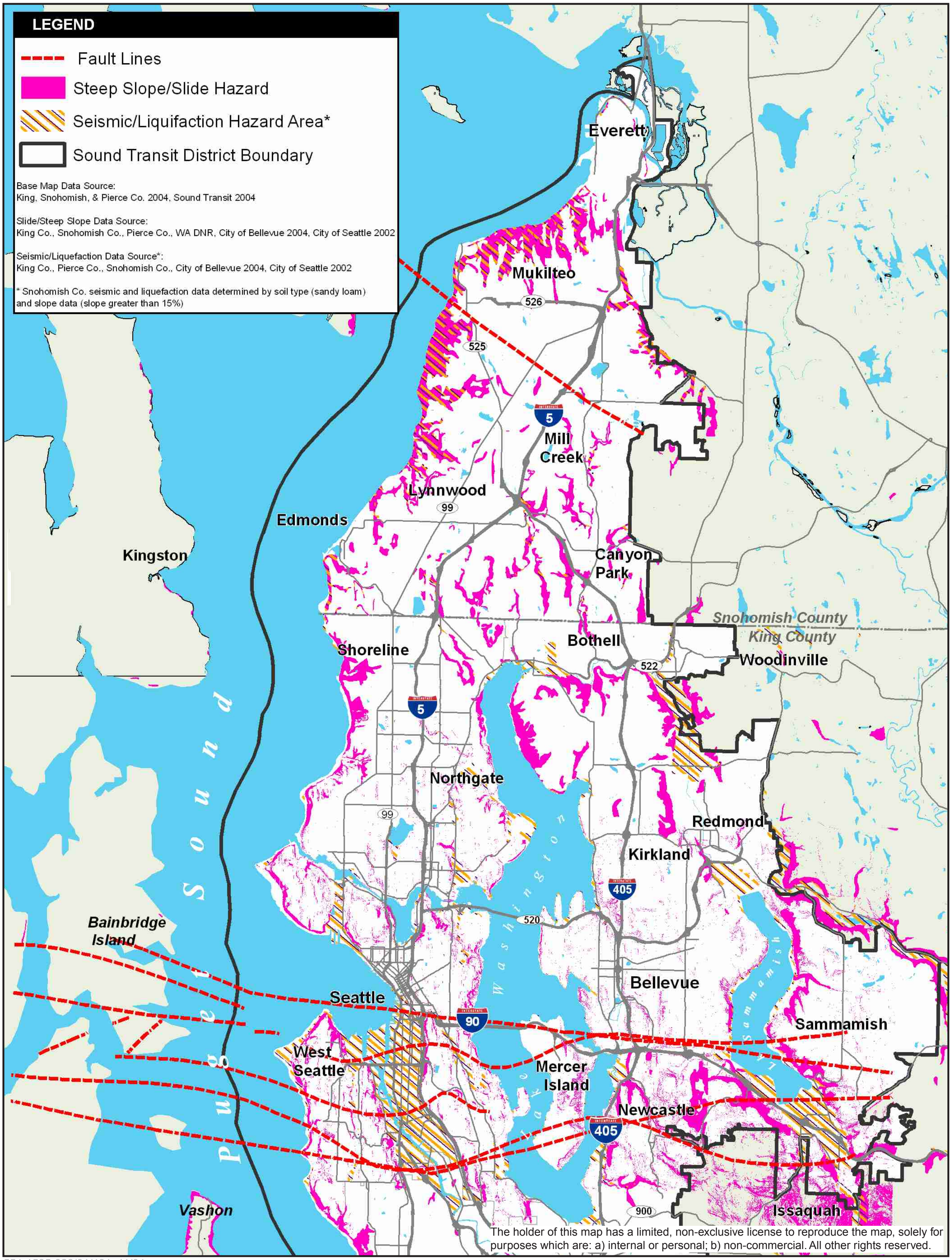
Researchers warn that earthquakes pose a serious threat to life and property in the Puget Sound region. Washington State has the second highest risk of economic loss caused by earthquakes in the nation, behind only California, according to a 2001 study by the Federal Emergency Management Agency (Seattle Fault Earthquake Scenario Project 2005). Since the 1850s, over 25 earthquakes of magnitude 5.0 or greater have occurred in the Puget Sound region (Sound Transit 1999a). The greatest damage is usually near the earthquake's origin, although damage to structures depends on many factors, such as the type of construction, distance from the epicenter, and type of soil beneath the structure (UW 2002).

In the Pacific Northwest, there are multiple sources for earthquakes, including the Cascadia Subduction Zone (a convergence zone between the Juan de Fuca and North American plates [the Juan de Fuca plate is sliding below the North American plate] located about 50 miles off the coasts of British Columbia, Washington, Oregon, and northern California) and shallow crustal fault zones (areas where sections or layers of rock are moving past each other). Subduction zone earthquakes tend to be large and can exceed magnitude 9.0. The geologic record suggests that five or six subduction zone events may have occurred over the last 3,500 years; the most recent was about 300 years ago (UW 2002).

The most notable local earthquake in recent years, the magnitude 6.8 Nisqually earthquake of 2001, was a shallow crustal earthquake. The Nisqually earthquake was located about 18 kilometers northeast of Olympia at a depth of 52.40 meters. The Seattle Fault zone, which runs east-west from Issaquah to Bremerton, is a shallow crustal fault zone. Evidence suggests that a major earthquake occurred about 1,100 years ago on the Seattle Fault. Researchers speculate that the Seattle Fault could produce earthquakes on the order of magnitude 7; however, the recurrence interval of such earthquakes is anticipated to be infrequent (thousands of years) (Sound Transit 1999b). The Seattle Fault is depicted in Figure 4.1-1. Other faults occur in Snohomish County between Lynnwood and Everett and near the southern part of the Sound Transit District near Mount Rainier.

### 4.1.2 Long-Term Impacts

The following section discusses the types of geologic impacts that are expected to occur under the No Action Alternative and Plan Alternative and Options.






554-1585-028/01/431 11/04

SOUNDTRANSIT

0 4
SCALE IN MILES

**Figure 4.1-1**
**Geologic Hazard Areas**

*(This page intentionally left blank)*

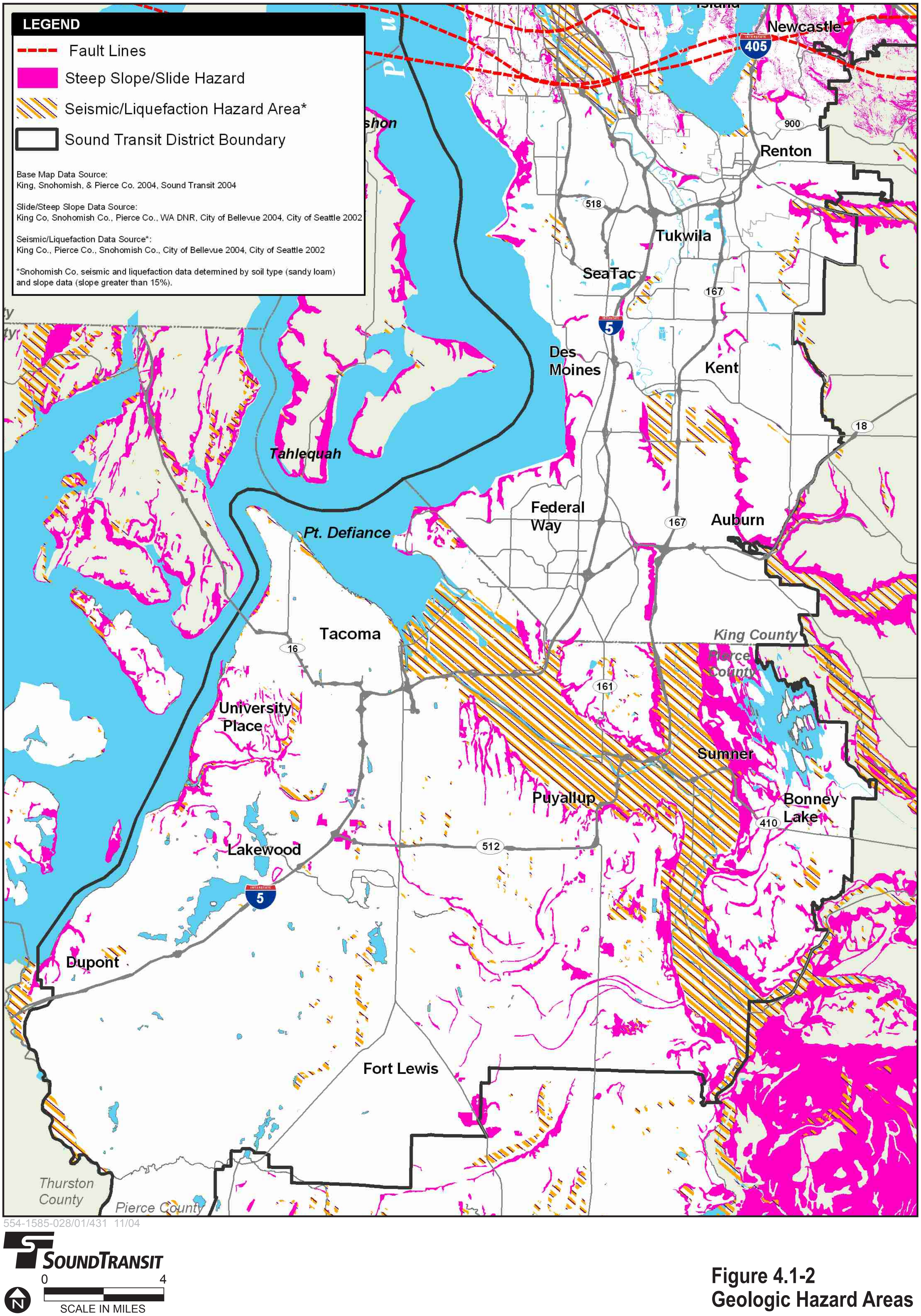



**Figure 4.1-2**
**Geologic Hazard Areas**

*(This page intentionally left blank)*

### 4.1.2.1 *Regional Transit Long-Range Plan Alternative*

The entire Regional Transit Long-Range Plan area may be subjected to earthquake shaking and is considered to have a moderate to high seismic risk. North-south transit corridors would cross the Seattle Fault. Each corridor in the plan area includes soils prone to liquefaction, particularly fill soils, tidal flats, and other unconsolidated deposits. Earthquake-induced soil liquefaction could result in a loss of soil strength, settlement, lateral spreading, and landslides. The magnitude of soil movement and loss of strength is a function of many factors, including soil thickness, soil quality, groundwater level, and the magnitude and location of the seismic event.

Existing steep slopes are conducive to landslides. Landslides can be triggered by a seismic event, the natural stabilization process whereby a steep slope evolves to a flatter profile, an increase in pore water pressure from excessive rainfall that could destabilize the slope, or project construction that traverses or cuts into a steep slope. Runoff from permanent facilities would be managed so as not to result in long-term erosion impacts.

The design of new transit facilities (or renovation and upgrading of existing facilities to accommodate regional transit operation) would comply with all applicable building codes and current or updated seismic code requirements. New transit facilities would be more likely to survive earthquake impacts than older existing transportation infrastructure that was built to less stringent seismic standards.

**Light Rail**

The potential long-term geologic impacts discussed above are relevant to light rail operation. Ground-borne vibrations from light rail trains are not likely to increase the potential for landslides.

Light rail could have at-grade, elevated (including bridges), or belowground profiles. At-grade light rail operation would likely experience the same types of damage that would occur to highways during a substantial earthquake, such as structural weakening, warping, and full destruction. At-grade segments would be more susceptible to liquefaction-induced damage than elevated and belowground profiles because elevated trackway is typically supported on piles that are founded below the liquefaction-prone soils. Belowground tunnels are typically deep and tend to be lower in elevation than the liquefaction-prone soils.

Impacts of regional express bus/bus rapid transit (BRT) as an interim technology in light rail corridors are discussed below under the Regional Express Bus/Bus Rapid Transit section.

**Commuter Rail**

The potential long-term geologic impacts discussed above are relevant to commuter rail train and facility operation. Similar to light rail, ground-borne vibrations from commuter rail trains are not likely to increase the potential for landslides. Commuter rail would be mainly at-grade, although elevated, belowground, and bridge segments sometimes occur. The seismic risks associated with at-grade segments discussed above are most applicable to commuter rail systems.

**Regional Express Bus/Bus Rapid Transit**

The potential long-term geologic impacts discussed above are relevant to regional express bus vehicle and facility operations. Regional express bus operation is not expected to create ground-borne vibrations. Regional express bus improvements would be mainly at-grade, although elevated, belowground, and bridge segments may occur. The seismic risks associated with at-grade segments discussed above are most applicable to regional express bus/BRT. Depending on the extent of seismic damage, buses could be detoured around damaged areas, and temporary repairs to at-grade pavement could be accomplished quickly.

Regional express bus/BRT could operate as an interim service on all or portions of the light rail corridors. Therefore, the at-grade segments listed in the light rail section could also be impacted by interim regional express bus/BRT improvements.

### 4.1.2.2 *Plan Alternative Options*

The Options would have the same types of geologic impacts as those described above for the Plan Alternative. Depending on the corridor options selected for addition to the Plan Alternative, geologic impacts could increase in magnitude.

**New Light Rail Corridors**

The light rail options are additional corridors that have not been included in the Plan Alternative; therefore, geologic impacts would increase in magnitude compared to the Plan Alternative due to the added number of transit improvements. The types of impacts that could occur would be similar to those discussed for light rail under the Plan Alternative. If regional express bus/BRT were operated as an interim service in all or portions of the light rail options corridors, the impacts would be as discussed below.

**Streetcar**

Geologic impacts would increase in magnitude compared to the Plan Alternative due to the added number of transit improvements. The types of impacts that could occur would be similar to those discussed for at-grade light rail corridors under the Plan Alternative.

**Monorail**

Monorail options are a change in technology for the same light rail corridors under the Plan Alternative and Options. Geologic impacts associated with monorail corridors would be similar in type and magnitude to elevated light rail corridors discussed under the Plan Alternative.

**Commuter Rail**

Geologic impacts would increase in magnitude compared to the Plan Alternative due to the added number of project actions. The types of impacts that could occur would be similar to the commuter rail alignments discussed under the Plan Alternative.

**Regional Express Bus/Bus Rapid Transit**

Geologic impacts would increase in magnitude compared to the Plan Alternative due to the added number of transit improvements. The types of impacts that could occur would be similar to those discussed for regional express bus/BRT under the Plan Alternative.

### *4.1.2.3 No Action Alternative*

The No Action Alternative assumes completion and implementation of projects identified in *Sound Move*. As such, geologic impacts with the No Action Alternative would be similar to but less than the Plan Alternative, since the scale and intensity of development would be less.

## 4.1.3 Construction Impacts

### *4.1.3.1 Regional Transit Long-Range Plan Alternative*

Potential geologic impacts that could occur during construction include landslides, vibration, dewatering, spoils stockpiling and erosion, and water quality impacts from construction over or near water. Construction could cause erosion impacts associated with vegetation removal, fill placement, cutting into the toe of slopes, and removal or stockpiling of spoils. Earthwork could cause silt-laden runoff to be transported off-site, potentially degrading water quality in local surface waters. The severity of potential erosion would be a function of the quantity of vegetation removed, site topography, and the volume of soils stockpiled. Soils disturbed during construction would be revegetated and would not experience long-term erosion impacts.

**Light Rail**

Construction of at-grade and elevated alignments could have the impacts discussed above, especially if cut-and-fill techniques are required. Belowground construction of tunnels and underground facilities would have greater geologic impacts than at-grade or elevated construction. Excavation may require blasting, which could have noise, vibration, and safety impacts. Construction vibration may affect structures, depending on construction and soil types, method of excavation, and distance to structures. Excavations that encounter bedrock and involve installation of driven piles are more likely to have vibration impacts. Settlement may occur due to vibrations, dewatering, or ground loss and would be of particular concern near large structures and in sand and gravel, fill, and lake and stream deposits. Tunneling would create large volumes of spoils that can have high erosion potential when stockpiled. Substantial dewatering may be required during tunneling, depending upon the method of tunneling, the depth to groundwater, and the permeability of soils. Excavation for the installation of elevated light rail column foundations has similar impacts, but would be much less in extent because column foundations are only needed every 60 to 100 feet.

Cut-and-cover tunnel construction creates more spoils per linear feet of track than tunneling by mining, and a greater potential for erosion and contamination of spoils exists. Soils may settle during dewatering and movement of structures near the excavation. A small portion may be contaminated and would need to be properly treated and/or disposed (see Section 4.7, Environmental Health). Most spoils would be generated from deep tunneling, where the likelihood of encountering contamination is very low.

**Commuter Rail**

Commuter rail improvements are not expected to involve substantial amounts of excavation to the extent that they would be in existing rail corridors. However, new or expanded track section, station, and park-and-ride lot construction would require some excavation and earth impacts.

**Regional Express Bus/Bus Rapid Transit**

Similar to commuter rail, regional express bus facilities are not expected to involve substantial amounts of excavation, although station and park-and-ride lot construction would require some excavation and earth impacts. If new roadways were required, the same types of profile-specific impacts as discussed for light rail could potentially occur.

#### *4.1.3.2 Plan Alternative Options*

The Options would have the same types of construction impacts as those described above for the Plan Alternative. Geologic impacts of monorail construction would be similar to the impacts of constructing elevated light rail discussed above. Depending on the corridor options selected for the Plan Alternative, construction impacts would increase as new corridors are developed or as more intensive construction occurs. Otherwise, impacts remain as characterized for the Plan Alternative.

#### *4.1.3.3 No Action Alternative*

The types of construction impacts to earth that would occur with the No Action Alternative would be similar to those of the Plan Alternative. However, the magnitude of impact would be lower largely because the No Action Alternative would require less belowground construction.

### 4.1.4 Potential Mitigation Measures

Geologic conditions would be studied further in project-level planning and environmental review, and impacts could be avoided by adjusting alignments. Where alignments cannot be changed, potential problem areas could be identified and mitigated in design and construction. Facilities will meet applicable local, state, and federal codes for earthquake safety.

#### *4.1.4.1 Long-Term*

The potential impacts of surface settlement, subsurface settlement, and other ground movements could be minimized by ground modification (grouting, freezing, removal of unsuitable materials, etc.) and structural modification (deep foundations, underpinning, spanning deposits, etc.). In addition, facilities could be designed to avoid worsening potential seismic effects and to counteract potential liquefaction through various means of support. Where facilities are located next to unstable slopes, a slide warning system could be used to detect landslides.

#### 4.1.4.2 Construction

**Landslides**

Potential ground movements could be monitored during construction, and adequate support to adjacent structures could be provided. For landslides and steep slopes, mitigation is required only if construction of an alternative traverses or cuts into existing steep slope/landslide hazard areas, removes vegetation from existing steep slopes, or is in such close proximity to an existing steep slope/landslide hazard that the construction could impact the slope or vice versa. Potential mitigation measures include locating new facilities away from unstable slopes, limiting clearing and grading, using an engineered structure (retaining wall), regrading the slope to an allowable inclination, installing drainage improvements, and revegetating to protect soils from erosion. Permanent slopes would be designed and constructed with adequate safety factors.

**Vibration**

Mitigation for vibration and settlement impacts to shallow foundations could include a pre-condition survey and a construction monitoring program. The possibility of construction vibration-triggered sliding could be reduced by driving piles during the drier summer months when slopes are typically more stable, by pre-drilling or jetting to reduce the energy needed to facilitate pile penetration, or by using auger-drilled piles that do not require driving. Additional mitigation could include underpinning structures, installing recharge wells (for dewatering), modifying construction techniques, displacement grouting (during tunneling), or releveling and repair.

**Dewatering**

For dewatering mitigation, detailed analysis is during project design could estimate potential dewatering effluent volumes and the potential presence of contaminants. Construction techniques could be used to reduce the sediment and contaminants in the effluent, if necessary, prior to disposal. The project would coordinate with local jurisdictions to dispose large volumes of dewatering effluent to storm or sanitary sewers as appropriate.

**Spoils Stockpiling and Erosion**

Underground construction would generate large volumes of spoils. Potential impacts include erosion at stockpile and disposal sites. Disposal of the spoils would depend upon whether the spoils are clean or contaminated, the type of soil (coarse-grained or fine-grained), soil moisture content, regional demand for fill soils at the time the project is undertaken, availability of disposal sites, and several other factors. Site-specific analysis, construction planning and sequencing, and economic evaluation could be conducted to determine the characteristics and proper management of the spoils.

To control erosion during construction, contractors would employ standard mitigation measures within the construction limits. These mitigation measures would be approved by the local jurisdictions and could reduce the amount of silt-laden runoff leaving the construction site, minimize dust, and reduce erosion. Use of clean fill soils containing little or no silt and clay could also help reduce the erosion potential.

**Over-water Construction**

In areas with over-water construction, compressible soils could be pre-loaded to reduce settlement under the approach fills, and turbidity could be controlled with appropriate erosion control methods.

### 4.1.5 Significant Unavoidable Adverse Impacts

Some significant unavoidable adverse impacts, such as landslides and erosion, from the No Action Alternative or Plan Alternative and Options are possible. Facility design for future project-specific actions would meet current design standards and consider geologic and seismic hazards that affect the project.