

Chapter 14 Geology and Soils

This chapter describes existing geological and soil conditions in the project area, how the project alternatives could affect soil resources, and how geologic hazards, such as landslides, seismicity and volcanic activity, could affect the project. Related information can be found in Chapter 15, Water and Appendix J, Geologic Hazard Assessment.

Words in **bold** and acronyms are defined in Chapter 32, Glossary and Acronyms.

14.1 Affected Environment

14.1.1 Geology

The project area is within three physiographic regions: the Willapa Hills, South Cascades, and Portland Basin. The topography of the Willapa Hills and the South Cascades is mostly gently rolling to steep hills or relatively level terrain in the floodplains of major rivers, such as the Cowlitz River. The portion of the project area within the Portland Basin is mostly flat or nearly flat terrain. Elevation in the project area ranges from 25 feet to 3,311 feet above mean sea level (msl).

The northern portions of the action alternatives and the Casey Road, Baxter Road, and Monahan Creek substation sites are within the Willapa Hills region. Other portions of the Central, East, and Crossover alternatives and options and the West Alternative between the Cowlitz and Lewis rivers are within the South Cascades region. South of the Lewis River, most of the West Alternative and options are within the Portland Basin.

The underlying **bedrock** in the Willapa Hills and South Cascades regions is **igneous** rock, and to a lesser degree, **sedimentary** rock. In most places, the bedrock is covered by clay-rich **residual soils** weathered from the underlying bedrock. The Portland Basin is mostly filled with **sediment** (sand, clay and gravel) deposited by ice age floods (i.e., Missoula Flood deposits). In all three regions, some sediments are derived from volcanic eruptions and **lahars** (volcanic mudflows) from Mt. St. Helens and Mt. Hood. Lahar deposits are near the Cowlitz and Kalama rivers and eastern portions of the Lewis River, and at the Sundial substation site. Other geologic deposits include **glacial till**, glacial outwash, **alluvium** at river crossings, and lake and wetland deposits.

14.1.1.1 Landslide Areas

Landslides are common in hilly and steep areas and along cliffs in southwest Washington. Landslides occur on slopes as gentle as 11 percent (6 degrees) (Wegmann 2006).

The action alternatives cross known landslides and relatively steep slopes that may be susceptible to landslides (see Maps 14-1A through 14-1D and Appendix J) (DGER 2009). In general, mapped landslides and steep slopes are found in the northern (north of the Lewis River) and eastern portions of the project within the Willapa Hills and South Cascades regions. The risk of landslides is low in the relatively flat Portland Basin along the southern portion of the West Alternative.

14.1.1.2 Seismic Risks

The project is in a region where earthquakes occur from the interaction of the Juan de Fuca and North American **tectonic** plates along the offshore Cascadia **subduction** zone. Tectonic plates are pieces of the Earth's crust that move relative to each other. This movement causes earthquakes at the boundaries between the tectonic plates (i.e., at the Cascadia subduction zone), and within the plates. Based on historical and geological records, most earthquakes that generated shaking felt by residents in the project area have occurred along the Cascadia subduction zone, or deep within the subducting Juan de Fuca plate (i.e., Benioff Zone earthquakes). While quiet for centuries, scientists expect this fault could create a 9.0 magnitude or higher earthquake that would be felt by residents across the project area, and the Northwest.

About 476 earthquakes of less than magnitude 3 have occurred within 60 miles of the project area since 1973. Earthquakes measured as magnitude 3 are common in the project area and earthquakes in the 3.2 to 3.4 range are common in the Kelso area. The largest historical earthquakes within 60 miles of any part of the project were (1) a 6.9-magnitude earthquake in 1949, near Olympia, resulting in widespread damage but only minor damage in the Portland-Vancouver area, (2) the 2001 Nisqually quake north of Olympia with a 6.8 magnitude, which was strongly felt in Portland, but caused no damage, (3) the 1993 Scotts Mills Earthquake, better known as the Spring Break Quake, with a magnitude of 5.6 was located about 34 miles south of Portland in Marion County and caused limited damage, and (4) a 5.2-magnitude earthquake in 1962, located within 2 miles of Segment 25, that caused noticeable shaking in the Portland-Vancouver area but only minor damage. The 1949 and 2001 earthquakes were deep earthquakes (e.g., 32 miles deep in 2001) that occurred within the subducting Juan de Fuca plate, but the 1962 and 1993 earthquakes were relatively shallow, at about 10 and 9 miles, respectively, beneath the surface.

All earthquakes occur along **faults**; surfaces between two rock masses where one mass slides past the other. Where a fault is located at the surface, movement of the fault can damage structures built on the fault. Only one fault considered to have been active within the past 1.6 million years is crossed by the action alternatives (USGS 2006). This fault, the Lacamas Lake Fault, is crossed by the southern portion of the West Alternative. The most recent rupture of the Lacamas Lake Fault occurred sometime between 10,000 and 100,000 years ago.

During an earthquake, unconsolidated sediment (typically loose, saturated sand found in river valleys and along lakeshores) can lose strength and behave like a liquid. This is called **liquefaction**. Most of the land crossed by the action alternatives is underlain by bedrock, and would not experience liquefaction during an earthquake. Liquefaction could occur within the Cowlitz, Coweeman, Lewis, East Fork Lewis, and Columbia river valleys. These areas have a moderate to high liquefaction susceptibility (Palmer et al. 2004).

14.1.1.3 Volcanic Activity

The project area is near the volcanically active Cascade Mountains. Both the May 1980 eruption of Mt. St. Helens and previous eruptions of Mt. Hood have triggered lahars that have reached the project area. Volcanic hazards are separated into two zones (Wolfe and Pierson 1995; Scott et al. 1997). The first zone is the area close to the volcano subject to directed blasts, lava flows, **pyroclastic flows**, lahars, ash fall, earthquakes, and ground deformation. The project area does not overlap this zone. The second zone is farther from the volcanoes, and is generally subject only to lahars and ash fall. The action alternatives cross this second zone of potential lahars and

ash flow from Mt. St. Helens along the Kalama and Cowlitz rivers, and from Mt. Hood near the Columbia River and at the Sundial substation site. The entire project area is potentially subject to ash fall from a volcanic eruption.

14.1.2 Soils

Soils in the project area are generally residual, formed from igneous and sedimentary bedrock. Soil thickness varies, with thinner soils on steep slopes, and thicker soils in basins. Alluvial soils are present where the action alternatives cross the Cowlitz, Lewis, and Coweeman rivers. Other soils include glacial deposits (mostly near the Lewis and Cowlitz rivers), volcanic deposits from Mt. St. Helens near the Lewis River, and lahar deposits in Sandy and Cowlitz river floodplains (see Maps 14-2A through 14-2D and Appendix J). Soils in the area generally support agriculture, timber production, urban and rural development, and natural functions such as wetlands and aquifer recharge.

Slope and soil properties such as cohesion, drainage, and organic content are used in determining soil erosion hazard classes (NRCS 2009a). Generally, coarse-grained soils, on level to gentle slopes that are well drained have low erosion-hazard potential. Conversely, fine-grained soils on steep slopes that are poorly drained have the greatest erosion-hazard potential. There are four ratings for erosion hazard: slight, moderate, severe, or very severe (NRCS 2009a). A slight rating indicates that little or no erosion is likely; moderate indicates that some erosion is likely, that roads or trails may require occasional maintenance, and that simple erosion-control measures are needed; and severe and very severe indicate that considerable erosion could be expected from soil disturbance, that the roads or trails require frequent maintenance, and that erosion-control measures or mitigation are needed for unsurfaced roads and trails (NRCS 2009a, 2010a, 2010b). Based on NRCS' soil erosion hazard rating, most soils in the northern (north of the Lewis River) and eastern portions of the project area have a severe soil erosion potential and are susceptible to erosion (see Maps 14-2A and 14-2B and Appendix J). The portion of the West Alternative (including options) from the Lewis River to the Columbia River is on flatter terrain, with most soils rated as having low or moderate soil erosion potential. A few small areas are rated very severe south of Lake Merwin, along the East Fork Lewis River, and south of Rock Creek along the East Alternative.

Compaction susceptibility ratings for soils indicate the amount of force needed to press soil particles together, reduce pore spaces and increase soil density (NRCS 2009a). Most soils in the project area are susceptible to compaction (have low-to-moderate resistance to soil compaction). Soils with a moderate resistance to compaction have features favorable to resisting compaction. A low resistance-to-compaction rating indicates that one or more soil characteristics exist that favor the formation of a compacted layer. Areas with low resistance to compaction occur along the northern portions of the action alternatives, the middle portion of the West Alternative and the southern portions of the Central, East, and Crossover alternatives. Areas with moderate resistance occur along the Cowlitz and Lewis rivers, between Lake Merwin and Yale Dam, and south near Amboy. Less than 1 percent of the soils within the project area have a high resistance to soil compaction.

About 3 percent of the soils along the action alternatives are susceptible to **subsidence**. Subsidence is the gradual or rapid lowering of the ground surface that takes place when the soil surface is depressed or becomes dried out and can occur when the groundwater table is lowered. Soils with a high potential for subsidence are generally peat, silt, or clay and are often found in wetland areas. Within the project area, soils with a high potential for subsidence are

found along about 2 miles of the West Alternative (east end of Segment 25, east of Vancouver) and about ¼ to ½ mile near the west end of West Options 1, 2, and 3 and Crossover Option 1, east of Vancouver where segments 36, 36a, 36b, and 40 come together.

14.2 Environmental Consequences

General impacts that would occur for the action alternatives are discussed below, followed by impacts unique to each alternative.

14.2.1 Impact Levels

Impacts would be **high** where project activities would cause the following:

- Erosion occurs at road, tower, or substation construction and clearing sites on soils with severe or very severe erosion-hazard potential
- Permanent soil compaction occurs under access roads, towers, or substations

Impacts would be **moderate** where project activities would cause the following:

- Erosion occurs at road, tower, or substation construction and clearing sites on soils with a moderate erosion-hazard potential
- Temporary soil compaction occurs near or adjacent to access roads, towers, or substations

Impacts would be **low** where project activities would cause the following:

- Minor erosion occurs at road, tower, or substation construction and clearing sites on soils with a slight erosion-hazard potential
- The only disturbance created by the project would be right-of-way clearing

No impact would occur where project activities would not disturb soils.

14.2.2 Impacts Common to Action Alternatives

14.2.2.1 Construction

Geology

Permanent impacts from access road and tower construction would include some alterations to local topography. Landslides could affect the integrity of towers and road stability and other resources in the area, though towers and roads would generally be sited to avoid unstable locations. Where potentially unstable areas are unavoidable, engineers and geologists would survey locations on foot to select the best tower and road locations, use appropriate design standards for the given soils of the area, and monitor the area as part of routine maintenance. If a landslide did occur, debris could block roads; homes could be damaged or destroyed; water, sewer and power systems could be disrupted; and vegetation, wildlife habitats and other land uses could be damaged or interrupted.

Seismic issues can also affect tower construction (i.e., siting, and type of footing used). All facilities would be built to applicable seismic standards. The current tower design criteria used to account for combined wind and ice loading typically exceeds earthquake-induced loads. For towers located along the Lacamas Lake Fault or other potentially active fault zones that may be identified during the tower siting process, evidence of surface ruptures would be evaluated at the proposed tower locations before construction. Tower locations found near an identified surface rupture would be relocated away from the fault zone.

Much of the project area is underlain by bedrock or has soil with low susceptibility to liquefaction. In the few areas (about 42 to 43 acres for each alternative) where soils are moderately to highly susceptible to liquefaction, the low potential of major seismic activity reduces the likelihood of soil liquefaction. Generally, transmission towers are likely to survive settlement from liquefaction with only minor structural damage. Liquefaction hazard areas would be identified prior to construction based on anticipated soil and groundwater conditions. Several options are available to mitigate for liquefaction, such as avoiding susceptible areas, increasing soil density, and building deep foundations. Mitigation would be considered on a site-by-site basis.

Volcanic hazards such as lahars and ashfall could also affect operation of the transmission line. If possible, towers and roads would be sited to avoid potential lahars along the Kalama and Cowlitz rivers, and near the Columbia River. Because of the large area potentially covered by ashfall and lahars, not all hazards from a volcanic eruption could be avoided or mitigated.

Soils

Construction would temporarily or permanently affect soils by exposing disturbed soils to rain and wind, causing erosion; compacting soils by operating equipment; or by removing soil from use by either taking it off site or covering it with impervious surfaces.

Construction activities would involve excavation (for tower footings, substation ground mat, equipment, and counterpoise), grading and cut-and-fill for roads, tree removal, heavy equipment movement, and materials lay-down. These activities would disturb soils and remove or damage vegetative cover. The exposed soil would be vulnerable to movement off-site through water runoff, wind dispersal, or movement by gravity (soil and rocks rolling downhill). Soil erosion could increase sedimentation in streams and wetlands, which would affect surface and groundwater resources (drinking water) and aquatic habitat. Soil erosion also can create loss or degradation of topsoil, including reducing agricultural productivity. The risk for soil erosion would be greatest during and immediately after construction, when protective vegetation and topsoil have been removed and the soil is being actively disturbed and exposed. Typically, as vegetation becomes reestablished on disturbed surfaces, or the surface is covered (such as by a road, substation, or tower), the potential for erosion decreases.

Construction on steep slopes would occur in soils moderately to severely susceptible to erosion and temporary increases in soil erosion could occur. Limiting site disturbance is the single most effective method for reducing erosion (Ecology 2004). Preserving vegetative cover to the maximum extent feasible helps shield the soil from the elements, slowing runoff velocity and increasing infiltration time, and holding soils in place. Temporary erosion control measures would be maintained until vegetation is reestablished or permanent erosion control measures were in place. Control measures included as part of the project include implementing a SWPPP and designing roads to control runoff and prevent erosion (see Table 3-2). With implementation

of these **Best Management Practices** (BMPs), the impacts would be **low-to-moderate**. Additional measures such as conducting site-specific soil evaluations and performing construction during the dry season could further prevent or reduce erosion (see Section 14.2.8, Recommended Mitigation Measures).

Temporary increases in soil erosion during construction in areas where the erosion-hazard potential is moderate would be a **low-to-moderate** impact and where the erosion-hazard potential is slight, a **low** impact. Erosion would be reduced if construction occurs during the dry season.

Soil compaction would occur if soil particles are pressed together by heavy equipment, by heavy materials storage and staging areas, or repeated vehicle traffic. When soils are compacted, the pore spaces between soil particles are reduced, restricting infiltration and deep rooting, and reducing the amount of water available for plant growth. When infiltration is reduced, runoff may occur and lead to erosion, nutrient loss, and potential water quality problems (NRCS 1996, 2004). Soil water content influences compaction such that the risk is greatest when soils are moist or wet; dry soils are much more resistant to compaction than moist or wet soils (NRCS 1996, 2004). Other factors affecting compaction include the pressure exerted upon the soils (from heavy equipment or vehicles), soil characteristics (organic matter content, clay content and type, and texture), and the number of passes by equipment or vehicle traffic (NRCS 1996).

Soils in the project area generally have low to moderate resistance to soil compaction. This means that the traffic and equipment operating directly on soils would likely compact the soil, especially if the soils are moist or wet. Soil compaction would be expected where equipment operates off access roads, such as during tower and counterpoise construction, and at pulling and tensioning sites. Temporary compaction would be a **moderate** impact during construction. To limit soil compaction, heavy equipment and vehicles would only be operated on access roads and within approved construction footprints; off-road construction would be limited to dry conditions if possible. Compaction could be further prevented or reduced by recommended mitigation such as covering soils with a layer of fabric, gravel, or crushed rock and using mats under machinery during construction; tilling soils after construction; and adding features to block unauthorized use (see Section 14.2.8, Recommended Mitigation Measures). Following these methods to reduce compaction, long-term impacts on soils not under roads, towers, and substations would be **low**.

Permanent effects to soils would occur from placement of towers, access roads, and substations. Though road construction has the potential to cause mass wasting along hillsides, road grades would be varied depending on the erosion potential of the soil, and roads would be rocked where needed to stabilize them, prevent dust, increase their load-bearing capacity, or increase the seasons the roads could be used. Road design would take slopes, soil types, bedrock, and other factors into account based on site-specific information. Soil under towers, access roads, and substations also would be permanently compacted, reducing soil productivity; a long-term **high** impact.

Most soils crossed by the action alternatives are not susceptible to subsidence (NRCS 2010a, 2010b, 2010c); a small portion of the project northwest of Lacamas Lake is potentially susceptible (see Section 14.1.2, Soils). Subsidence caused by lowering groundwater tables during construction of the project, or from compaction by heavy machinery, could damage nearby utilities, roads, and foundations. Low-lying areas could subside and be underwater

permanently or seasonally. However, because the area of subsidence-prone soils is small, intersecting shallow groundwater that would cause subsidence is unlikely, and the overall impact would be **low**.

14.2.2.2 Operation and Maintenance

Operation and maintenance activities could increase erosion potential. Maintenance would involve various sized vehicles and equipment traveling on access roads. However, anticipated erosion rates would remain at or near current levels, once areas are revegetated. Operational mitigation measures, including facility maintenance and monitoring, would limit long-term soil erosion, and long-term impacts would be **low**.

14.2.2.3 Sundial Substation

No mapped landslides are documented within the Sundial site; however, the site is within a lahar deposit originating from Mt. Hood. In the event of a large earthquake, or volcanic event at Mt. Hood, mudflows could reach the site, though the probability of such an event is low. If an earthquake did occur, soils at the site are moderately to highly susceptible to liquefaction.

Substation installation would cause ground disturbance, causing soil erosion (decreasing over time during operations and maintenance, as vegetation becomes reestablished), and soil compaction (both temporary and permanent). Because the soils have a slight erosion-hazard potential (the site is very flat with little chance for sediment to move off-site), impacts to soils from erosion would be **low**.

Soils at the Sundial site have a moderate-to-low resistance to soil compaction (NRCS 2010b). Permanent compaction under the substation would be a **high** impact because soils would no longer be available for agriculture (a use that partially occur around the site), and wetlands present at the site could be filled. Temporary soil compaction in the disturbance area outside the substation footprint would be **moderate** during construction; use of measures such as avoiding work in wet soils, covering susceptible soils and supporting equipment during construction, and tilling soils after construction would reduce compaction; long-term, the project would create **low** compaction impacts.

14.2.3 Castle Rock Substation Sites

14.2.3.1 Casey Road

The Casey Road site is underlain by igneous bedrock so the substation site is unlikely to be affected by liquefaction during an earthquake. No mapped landslides are within the site.

Similar soils impacts as those described for the Sundial site would occur at the Casey Road site. Soils at the Casey Road site have a severe erosion-hazard potential. Erosion during construction would be mitigated, and impacts would be **low-to-moderate**. During operations, impacts from erosion would be reduced to **low**. Additional measures could further reduce or prevent erosion (see Section 14.2.8, Recommended Mitigation Measures).

The Casey Road site soils also have a low resistance to soil compaction. Permanent compaction under the Casey Road Substation would be a **high** permanent impact because soils would no

Impacts common to action alternatives are in Section 14.2.2. The remaining sections discuss impacts unique to each alternative, and recommended mitigation measures.

longer be used for timber production. Similar to the Sundial site, temporary compaction impacts to soils in the disturbance area outside the substation footprint would be **moderate** during construction and **low** long-term after implementation of mitigation measures.

14.2.3.2 Baxter Road

The Baxter Road site is also underlain by igneous bedrock similar to the Casey Road site so the site is unlikely to be affected by liquefaction during an earthquake. No mapped landslides are within the site.

Similar soil impacts as those described for the Sundial and Casey Road sites would occur at the Baxter Road site. Soils at the site have a severe erosion hazard potential. Erosion impacts would be **low-to-moderate** with mitigation. During operations, erosion impacts would be reduced to **low**. Soil compaction under the substation would have a **high** permanent impact because soils would no longer be used for timber production. Similar to the Sundial and Casey Road sites, temporary compaction impacts in the disturbance area outside the substation footprint would be **moderate** during construction and **low** long-term after implementation of mitigation measures.

14.2.3.3 Monahan Creek

The Monahan Creek site is underlain by sedimentary bedrock overlain by alluvial deposits. The substation is unlikely to be affected by liquefaction during an earthquake. No mapped landslides are within the site.

Similar soil impacts to those described for the other substation sites would occur at this site. Soils have a moderate-to-severe erosion-hazard potential. Erosion during construction would be mitigated and impacts would be **low-to-moderate**. During operations, impacts from erosion would be reduced to **low** with implementation of mitigation and as vegetation is reestablished. Additional measures could further reduce or prevent erosion (see Section 14.2.8, Recommended Mitigation Measures).

Soils at the site have a moderate-to-low resistance to soil compaction. Permanent compaction would cause a **high** impact under the substation because soils would no longer be used for livestock grazing. Soil compaction in the adjacent disturbance area would be similar to other substation sites (temporarily **moderate** during construction and **low** in the long-term after implementation of mitigation measures).

14.2.4 West Alternative

The northern portion of the West Alternative (north of the Lewis River) is within potentially landslide-susceptible terrain and crosses mapped landslides (see Maps 14-1A through 14-1D and Appendix J). If a landslide occurred along the West Alternative near roads or urban development, debris flows could reach roads, which could cause damage or block traffic. A landslide along the Coweeman River could affect habitat and sensitive species within WDFW priority habitat, with possible sediment transport to the river or other streams in the area. To mitigate for possible



damage from landslides, towers and roads would be built to appropriate design standards, taking into account soil stability.

Similar to impacts common to action alternatives, construction of the West Alternative would create temporary and permanent soil erosion, compaction, and movement of sediment off site, and permanent effects where impervious surfaces are built. Construction activities requiring excavation would disturb soils and remove or damage vegetative cover. Temporary increases in soil erosion could occur in the northern portion of the West Alternative where soils are severely susceptible to erosion (see Maps 14-2A and 14-2B). About 211 acres of soil with a severe erosion hazard would be disturbed along the West Alternative (see Table 14-1). During construction, implementation of mitigation measures such as minimizing the disturbance area, preserving vegetative cover, limiting the amount of time soil is exposed, and installing appropriate access-road drainage would reduce potentially high impacts to **low-to-moderate** erosion impacts (see Table 3-2). Additional measures such as conducting site-specific evaluations of soil conditions and performing construction during the dry season could further prevent or reduce erosion (see Section 14.2.8, Recommended Mitigation Measures).

Table 14-1 Potential Soil Impacts¹

Alternatives and Options	Soil Erosion-Hazard Potential (acres)			Permanent Soil Compaction (acres) ³	Temporary Soil Compaction (acres) ⁴
	Slight ²	Moderate ²	Severe or Very Severe ²		
West Alternative	131	141	211	238	163
West Option 1	+9	-7	-5	+1	-3
West Option 2	-12	+9	+12	+8	+6
West Option 3	-11	-4	+44	+13	+13
Central Alternative	73	40	596	262	164
Central Option 1	N/C	<-1	+33	+3	-5
Central Option 2	<-1	+38	-38	+31	-11
Central Option 3	+1	+<1	-31	-3	-6
East Alternative	74	70	664	235	157
East Option 1	+5	+37	-47	+28	-9
East Option 2	N/C	-6	-60	-4	+3
East Option 3	N/C	-2	+3	-2	+3
Crossover Alternative	72	85	478	253	157
Crossover Option 1	+7	+25	-3	+14	+12
Crossover Option 2	<-1	-35	+67	-14	+25
Crossover Option 3	<-1	-35	+59	-19	+15

Notes:

N/C – No net change from the action alternative.

The value for each option represents the net change from the action alternative. It was calculated as the total acres of hazard potential or soil compaction added by the option minus the acres of hazard potential or soil compaction in the segments the option replaces.

Acres of new roads, towers (0.065 acre per tower), and substations within each soil erosion hazard class.

3. Compacted area under new roads, towers, and substations.

4. Temporarily compacted area from construction of towers.

Sources: Golder 2010; NRCS 2010a, 2010b, 2010c

Temporary erosion control measures would be maintained until vegetation reestablished or permanent erosion control measures were in place.

Temporary increases in soil erosion during construction in areas where the erosion-hazard potential is moderate would be a **moderate** impact, and south of the Lewis River, where the erosion-hazard potential is slight; a **low** impact. Erosion would be reduced if construction occurs during the dry season.

Erosion impacts during operation and maintenance would be **low** because temporary erosion control measures would be maintained until vegetation reestablished or permanent erosion control measures were in place.

Soils along the West Alternative generally have low-to-moderate resistance to soil compaction. Similar to impacts common to the action alternatives, though temporary soil compaction would be **moderate**, implementation of mitigation measures such as avoiding work in wet soils, covering susceptible soils and supporting equipment during construction, and tilling soils after construction would reduce compaction; **low** long-term impacts would occur on soils not under towers and roads. About 238 acres would be permanently compacted under towers and roads, reducing soil productivity; a long-term **high** impact (see Table 14-1).

A small portion of the West Alternative (about 61 acres), northwest of Lacamas Lake on the east side of Vancouver, is potentially susceptible to ground subsidence. Subsidence resulting from construction and operation of the project could damage nearby utilities, roads, and foundations.

14.2.4.1 West Option 1

West Option 1 would replace a portion of the alternative that follows existing right-of-way just east of Vancouver with an option that is farther west and closer to Vancouver. West Option 1 crosses soils with a slight erosion-hazard potential (see Map 14-2D and Table 14-1) and a low resistance to compaction. West Option 1 also includes about 0.7 acre of construction in areas of potentially subsidence-prone soils.

Impact levels on soils would be the same as the West Alternative.



14.2.4.2 West Option 2

West Option 2 would replace a portion of the alternative in the rural residential areas north of Camas with an option farther to the east in the same area. West Option 2 crosses soils with moderate-to-severe erosion-hazard potential on steeper slopes (see Table 14-1) and low resistance to compaction.

Impact levels on soils would be the same as the West Alternative.



14.2.4.3 West Option 3

West Option 3 would replace a portion of the West Alternative in the rural residential areas north of Camas with a route crossing the rural residential and rural areas farther east. West Option 3 crosses a mapped landslide area near Matney Creek. In this area and in other potential landslide areas (see Maps 14-1A through 14-1D), appropriate engineering designs would lessen the risk of landslide damage.

West Option 3 crosses soils with moderate-to-severe erosion-hazard potential on steeper slopes (see Table 14-1). West Option 3 crosses a higher percentage of soils with a severe erosion-hazard potential as the option moves east into the Cascade foothills. Additional measures could further reduce or prevent erosion (see Section 14.2.8, Recommended Mitigation Measures).

West Option 3 crosses soils with a low resistance to compaction.

Impact levels on soils would be the same as the West Alternative.



14.2.5 Central Alternative

Most of the Central Alternative is within potentially landslide-susceptible terrain and crosses several mapped landslides (see Maps 14-1A through Map 14-1D and Appendix J). To mitigate for possible damage from landslides, towers would be built to appropriate design standards, taking into account soil stability.

Similar to the West Alternative, construction of the Central Alternative would cause temporary and permanent changes to soils from erosion, compaction, or from creation of impervious surfaces. Temporary increases in soil erosion could occur along most of the Central Alternative, where soils are severely susceptible to erosion, similar to the northern portion of the West Alternative. About 596 acres of soil with a severe erosion hazard would be disturbed along the Central Alternative (see Table 14-1). With mitigation, construction would cause **low-to-moderate** erosion impacts. Additional mitigation measures could further prevent or reduce erosion, such as conducting site-specific evaluations of soil conditions, and performing construction during the dry season (see Section 14.2.8, Recommended Mitigation Measures).



Temporary increases in soil erosion during construction in areas where the erosion-hazard potential is moderate would be a **moderate** impact and where the erosion-hazard potential is slight, a **low** impact. Erosion would be reduced if construction occurs during the dry season.

Erosion impacts during operation and maintenance would be **low** because temporary erosion control measures would be maintained until vegetation reestablished or permanent erosion control measures were in place.

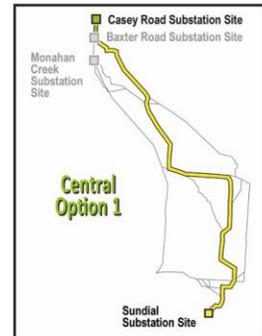
Soils in the northern and southern portions of the Central Alternative generally have low resistance to soil compaction, and soils along the middle portion have moderate resistance. Similar to the other action alternatives, soil compaction would temporarily occur and would be

moderate, but with mitigation measures such as avoiding work in wet soils, covering susceptible soils and supporting equipment during construction, and tilling soils after construction would reduce compaction; long-term impacts on soils not under towers and roads would be **low**. About 262 acres would be permanently compacted under towers and roads, reducing soil productivity; a long-term **high** impact.

14.2.5.1 Central Option 1

Central Option 1 would begin at the Casey Road substation site and the transmission line would cross unpopulated forest production and open space land. Central Option 1 crosses soils with a severe erosion-hazard potential near Castle Rock (see Table 14-1) and soils with a low resistance to compaction.

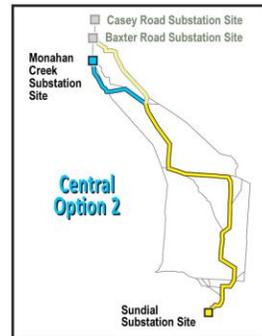
Impact levels on soils would be the same as the Central Alternative.



14.2.5.2 Central Option 2

Central Option 2 would begin at the Monahan Creek substation site and would remove the portion of the Central Alternative crossing the Cowlitz River north of Castle Rock and running farther to the southeast. This option would add a new route running southeast from the Monahan Creek substation site through sparsely populated land, crossing the unincorporated community of West Side Highway next to SR 411, the Cowlitz River and I-5, and running through largely unpopulated land toward the east. Central Option 2 crosses a mapped landslide area near Longview (see Map 14-1A and Appendix J). In this area, and in other potential landslide areas, appropriate engineering designs would lessen the risk of landslide damage. Central Option 2 crosses soils with a severe erosion-hazard potential near Lexington, but crosses less of this soil type overall (see Table 14-1). Central Option 2 crosses soils with a low-to-moderate resistance to compaction.

Impact levels on soils would be the same as the Central Alternative.



14.2.5.3 Central Option 3

Central Option 3 would replace the Lewis River crossing near Ariel and a portion of the Central Alternative between Ariel and Venersborg, with a downstream river crossing and a new route running directly southeast from Ariel through rural residential areas toward Venersborg. Central Option 3 crosses mapped landslide areas near Amboy and the East Fork Lewis River (see Map 14-1C and Appendix J). In this area, and in other potential landslide areas, appropriate engineering designs would lessen the risk of landslide damage. Central Option 3 crosses soils with a moderate-to-severe erosion-hazard potential southeast of Amboy, but crosses less of this soil type overall (see Table 14-1). Most of Central Option 3 crosses soils with a moderate resistance to compaction, with some areas south of the East Fork Lewis River rated with low resistance.

Impact levels on soils would be the same as the Central Alternative.



14.2.6 East Alternative

The East Alternative would be constructed along the most remote and rugged route of the action alternatives.

Most of the East Alternative is within potentially landslide-susceptible terrain and the East Alternative crosses several mapped landslides (see Maps 14-1A through 14-1D and Appendix J). To mitigate for possible damage from landslides, towers would be built to appropriate design standards, taking into account soil stability.

Similar to the West and Central alternatives, construction of the East Alternative would cause temporary and permanent soil erosion. Temporary increases in soil erosion could occur along most of the East Alternative, where soils are severely susceptible to erosion (see Maps 14-2A through map 14-2D). About 664 acres of soil with a severe erosion hazard would be disturbed along the East Alternative (see Table 14-1). With mitigation, construction would result in **low-to-moderate** impacts. Additional measures could further prevent or reduce erosion, such as conducting site-specific evaluations of soil conditions and performing construction during the dry season (see Section 14.2.8, Recommended Mitigation Measures).

Temporary increases in soil erosion during construction in areas where the erosion-hazard potential is moderate would be a **moderate** impact, and where the erosion-hazard potential is slight, a **low** impact. Erosion would be reduced if construction occurs during the dry season.

Erosion impacts during operation and maintenance would be **low** because temporary erosion control measures would be maintained until vegetation reestablished or permanent erosion control measures were in place.

Similar to the Central Alternative, soils in the northern and southern portions of the East Alternative generally have low resistance to soil compaction and soils along the middle portion have moderate resistance. Similar impacts would occur (**moderate** during construction but reduced by mitigation measures and low long-term impacts on soils not under towers and roads). About 235 acres of soil would be permanently compacted under towers and roads, reducing soil productivity; a long-term **high** impact.



14.2.6.1 East Option 1

East Option 1 begins at the Monahan Creek substation site and would remove the portion of the East Alternative crossing the Cowlitz River north of Castle Rock. East Option 1 would use segments southeast of the Monahan Creek substation site that run through sparsely populated land, cross the Cowlitz River and I-5 and run through largely unpopulated land toward the east. East Option 1 crosses mapped landslide areas near the Cowlitz River (see Map 14-1A and Appendix J). In this area, and in other potential landslide areas, appropriate engineering designs would lessen the potential risk of landslide

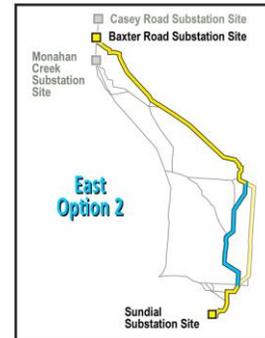


damage. East Option 1 crosses soils with a severe erosion-hazard potential near Lexington, but crosses less of this soil type overall (see Table 14-1). East Option 1 crosses soils with a low resistance to compaction.

Impact levels on soils would be the same as the East Alternative.

14.2.6.2 East Option 2

East Option 2 would replace a portion of the East Alternative between Yale and the rural residential areas north of Camas with a route farther to the west. East Option 2 crosses mapped landslide areas along Salmon Creek (see Map 14-1C and Appendix J). In this area, and in other potential landslide areas, appropriate engineering designs would lessen the risk of landslide damage.

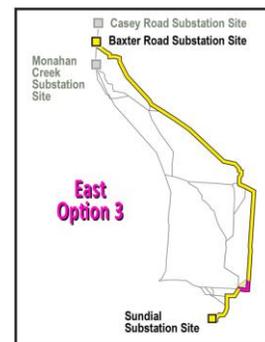


East Option 2 crosses soils with severe erosion-hazard potential south of Yale Dam and east of Amboy, but crosses less of this soil type overall (see Table 14-1). The northern half of East Option 2 crosses soils with a moderate resistance to compaction. Most of the southern half is comprised of soils with low resistance.

Impact levels on soils would be the same as the East Alternative.

14.2.6.3 East Option 3

East Option 3 would replace a short portion of the alternative in unpopulated land with a new route through unpopulated land. East Option 3 crosses soils with severe erosion-hazard potential east of the upper reaches of the Washougal River (see Table 14-1). East Option 3 crosses some soils with low resistance to compaction.



Impact levels on soils would be the same as the East Alternative.

14.2.7 Crossover Alternative

Similar to the Central and East alternatives, most of the Crossover Alternative is within potentially landslide-susceptible terrain. The Crossover Alternative also crosses several mapped landslides (see Maps 14-1A through 14-1D and Appendix J). To mitigate for possible damage from landslides, towers would be built to appropriate design standards, taking into account soil stability.



Similar to the other action alternatives, the Crossover Alternative would cause temporary and permanent changes to soils. Temporary erosion along the middle and lower portions would be similar to the other action alternatives where soils are severely susceptible to erosion. About 478 acres of soil with a severe erosion hazard would be disturbed along the Crossover Alternative (see Table 14-1). Mitigation would be implemented as described for impacts common to the action alternatives, and construction would result in

low-to-moderate erosion impacts. Additional measures could further prevent or reduce erosion (see Section 14.2.8, Recommended Mitigation Measures).

Temporary increases in soil erosion during construction in areas where the erosion-hazard potential is moderate would be a **moderate** impact, and where the erosion-hazard potential is slight, a **low** impact. Erosion would be reduced if construction occurs during the dry season.

Erosion impacts during operation and maintenance would be **low** because temporary erosion control measures would be maintained until vegetation reestablished or permanent erosion control measures were in place.

Soils along the northern and southern portions of the Crossover Alternative generally have low-to-moderate resistance to soil compaction, and soils along the middle portion have moderate resistance. Similar impacts would occur (**moderate** during construction but reduced by mitigation measures and **low long-term impacts on soils not under towers and roads**). About 253 acres of soil would be permanently compacted under towers and roads, reducing soil productivity; a long-term **high** impact.

14.2.7.1 Crossover Option 1

Crossover Option 1 would remove a portion of the alternative crossing north–south through rural residential areas north of Camas between NE Zeek Road and SE 23rd Street, and replace it with a route running west along an existing right-of-way until about NE 232nd Avenue, then southeast through open fields and more rural residential areas. Crossover Option 1 crosses soils with moderate-to-severe erosion-hazard potential (see Table 14-1) and soils with a low resistance to compaction. Crossover Option 1 also crosses about 8 acres of subsidence-prone soils.

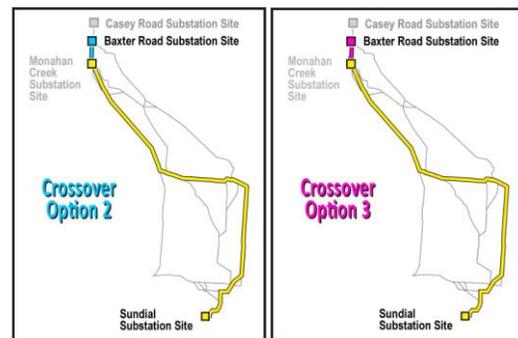


Impact levels on soils would be the same as the Crossover Alternative.

14.2.7.2 Crossover Options 2 and 3

Crossover Options 2 and 3 would begin at the Baxter Road substation site and the new transmission line would cross sparsely populated land. Crossover Option 3 would require some additional new right-of-way. Crossover Options 2 and 3 cross soils with a severe erosion-hazard potential near Castle Rock (see Table 14-1).

Crossover Options 2 and 3 cross soils with a low resistance to compaction, similar to Central Option 1.



Impact levels on soils would be the same as the Crossover Alternative.

14.2.8 Recommended Mitigation Measures

Mitigation measures included as part of the project are identified in Table 3-2. The following additional mitigation measures have been identified to further reduce or eliminate adverse soil impacts by the action alternatives. If implemented, these measures would be completed before, during, or immediately after project construction unless otherwise noted.

- Consider covering soils highly susceptible to compaction with construction matter or a layer of geotextile fabric and gravel or crushed rock on top.
- Till the soils after construction is completed to reduce the degree of compaction if soils are noticeably compacted; this would need to be done carefully to avoid increasing the potential for erosion.
- Place appropriate access controls, such as berms, ditches, gates and fencing, to prevent future unauthorized use of access roads and cleared right-of-way, and to reduce the potential for soil compaction resulting from foot traffic and off-road vehicles.
- Avoid working, dewatering, or clearing areas underlain by organic or soft soil, to the extent possible.
- Use wooden or synthetic construction mats to spread loading from machinery and personnel working on the project, if necessary, for work in areas underlain by organic or soft soil.
- Conduct additional site-specific evaluations in areas of potential landslides to determine degree of recent activity, likelihood of activation or reactivation, potential setbacks, and site-specific stability as appropriate. Site towers in areas not underlain by landslides. If necessary, design site-specific mitigation measures.
- Avoid crossing identified landslide areas with new access roads.
- Conduct location-specific subsurface investigations (i.e., geotechnical drilling) at locations of substations and towers potentially underlain by liquefaction-susceptible soils to evaluate the potential of these soils to liquefy during an earthquake.
- Reduce soil liquefaction through site-specific measures, such as deep foundations (e.g., piles) or soil improvement, if substations or towers are underlain by liquefaction-susceptible soils.

14.2.9 Unavoidable Impacts

Constructing and maintaining the project, regardless of the alternative selected, would cause erosion. The amount of erosion would depend on the route selected, the inherent erodability of the soil, slope, and similar site factors. The effects from such erosion on surface waters would depend on the location of water bodies in relation to project features, such as access roads and the right-of-way. With the implementation of BMPs listed in Table 3-2 and Section 14.2.8, Recommended Mitigation Measures, and modern construction techniques, impacts from erosion would be minor and would not affect nearby water bodies. Following the completion of construction, erosion would decrease and only **low** impacts from erosion would occur from operating and maintaining the project.

Unavoidable soil compaction would result from constructing the project. Access roads and tower and substation foundations would remain compacted for the life of the line. In areas of temporary compaction, such as at construction staging areas, soil compaction would be most severe at the time of construction and would become less severe as the compacted soil is broken up by burrowing animals, plant roots, freeze-thaw, wet and dry cycles, and other natural processes that rework soil. There would be short-term loss of soil productivity in areas underlain by temporarily compacted soil, but productivity would increase with the passage of time.

The project, regardless of the action alternative selected, would have unavoidable exposure to earthquake and volcanic activity since these activities have historically occurred in the area, and are unpredictable. Transmission towers, access roads and substations are not designed to withstand the effects of major landslides, lahars, and ashfall, and impacts could not be avoided.

14.2.10 No Action Alternative

If the project were not built, existing activities within the project area would continue, such as agriculture, urban and suburban development, timber production, road construction and maintenance and recreational use, as well as maintenance activities on existing transmission lines including those owned by BPA. Existing forest roads would continue to be used and maintained. These activities could cause or increase landslides, soil erosion, soil compaction, and soil subsidence (where underlain by soft or organic soils). The degree to which these effects would occur in the future would depend on the practices used; the amount of agricultural, development, and timber production activities that occur; and the topographic, climatic, and geologic conditions where these activities take place. Other impacts described specifically from this project would not occur.

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