
3.17 Geology and Soils

The Pacific Northwest is a geologically active region that experiences occasional earthquakes both large and small. Bridges are vital links in the transportation system and are often especially vulnerable during seismic events. Within the project area, specific geologic and groundwater conditions exist that affect the design, location, and construction techniques employed in developing the CRC project. Understanding relevant geologic and groundwater conditions is critical to ensuring the safety of those who will build and use the CRC project, reducing or eliminating impacts to natural resources, and minimizing potential project schedule delays and cost increases.

This section identifies, describes, and evaluates the long-term and temporary effects from geologic hazards to the CRC project, specifically to the construction and operation of the LPA. This section also identifies potential effects to mineral and groundwater resources from construction and operation of the LPA. While casting and staging areas and Ruby Junction are specifically addressed in this section, the Steel Bridge is not discussed. Geologic hazards will not affect the proposed modifications to the Steel Bridge and the bridge modifications will not result in effects to mineral and groundwater resources. See Chapter 2 for a map of these areas. A comparison of the impacts from the LPA and the DEIS alternatives are summarized in Exhibit 3.17-1. A more detailed description of the impacts of the DEIS alternatives on geology and soils is in the DEIS starting on page 3-395.

The information presented in this section is based on the CRC Geology and Groundwater Technical Report, included as an electronic appendix to this FEIS.

3.17.1 New Information Developed Since the Draft EIS

The following project information has been developed since the publication of the DEIS and has been included in the evaluation for this FEIS:

- Site-specific information regarding potential ground response to earthquakes.
- More specific information on CRC project construction methods and impact locations.

In addition to new information developed since the DEIS, the FEIS includes refinements in design, impacts and mitigation measures. Where new information or design changes could potentially create new significant environmental impacts not previously evaluated in the DEIS, or could be meaningful to the decision-making process, this information and these changes were applied to all alternatives, as appropriate. However, most of the new information did not warrant updating analysis of the non-preferred alternatives because it would not meaningfully change the impacts, would not result in new significant impacts, and would not change other factors

that led to the choice of the LPA. Therefore, most of the refinements were applied only to the LPA. As allowed under Section 6002 of SAFETEA-LU [23 USC 139(f)(4)(D)], to facilitate development of mitigation measures and compliance with other environmental laws, the project has developed the LPA to a higher level of detail than the other alternatives. This detail has allowed the project to develop more specific mitigation measures and to facilitate compliance with other environmental laws and regulations, such as Section 4(f) of the DOT Act, Section 106 of the National Historic Preservation Act, Section 7 of the Endangered Species Act, and Section 404 of the Clean Water Act. FTA and FHWA prepared NEPA re-evaluations and a documented categorical exclusion (DCE) to analyze changes in the project and project impacts that have occurred since the DEIS. Both agencies concluded from these evaluations that these changes and new information would not result in any new significant environmental impacts that were not previously considered in the DEIS. These changes in impacts are described in the re-evaluations and DCE included in Appendix O of this FEIS. Relevant refinements in information, design, impacts and mitigation are described in the following text.

What is moment magnitude, M_w ?

What is moment magnitude, M_w ? The moment magnitude scale, developed in the 1970s, is a method of measuring the strength of an earthquake. It has replaced the more familiar Richter scale because it can accurately measure a wider range of earthquake strengths. Like the Richter scale, the moment magnitude scale is logarithmic; an earthquake with M_w 6.0, for example, is about 32 times as strong as one with M_w 5.0. Moment magnitude scale measurements are similar to but not precisely equal to Richter scale measurements.

What is a lahar?

A lahar is a flow of volcanic material (such as rock debris and gases) and water that travels quickly and can cover great distances. Lahars typically flow downstream of a volcano within a river valley.

3.17.2 Existing Conditions

The CRC's main project area has relatively flat topography, although there are areas with steep slopes, particularly near Burnt Bridge Creek. The project area and surrounding areas are underlain by unconsolidated deposits of sand, gravel, cobbles, and boulders. These deposits provide a valuable aggregate mineral resource in the region. Potential sources of aggregate are within the project area; however, the area is presently highly developed, and extraction of the resource through mining operations is not likely.

Several types of earthquakes could occur in the project area. In particular, there is a large, offshore fault located approximately 120 miles west of the I-5 crossing. A shift in this fault could generate an earthquake with a moment magnitude as high as M_w 9.0 (Atwater and Hemphill-Haley 1997; Gregor et al. 2002). Effects from earthquakes result from ground motion, soil liquefaction, lateral spreading, seismic-generated water waves, and earthquake-induced landslides. Although moment magnitude is only one factor contributing to earthquake damage, earthquakes with high moment magnitudes can cause significant destruction. For example, in 2003, an M_w 8.3 earthquake offshore of Hokkaido, Japan, destroyed many of that island's roads and homes and injured hundreds of people (USGS 2003).

The CRC project is not located within an area where volcanic eruptions are generally predicted. However, there is potential for ash to fall in the project area from a major Mt. St. Helens eruption and for a large increase in sediment load in the Columbia River from an eruption of Mt. Hood (Wolfe and Pierson 1995). In the case of a Mt. Hood eruption, the sediment would enter the Columbia River from lahars coming down the Sandy River.

Groundwater resources in the project area are contained in the Troutdale Aquifer System, a system that is relatively accessible and has a large groundwater capacity. Groundwater from the aquifer system in Oregon and Washington is used for industry, irrigation, heat exchange, and drinking water. Under Section 1424(e) of the Safe Drinking Water Act, projects that seek

federal funding and have the potential to contaminate sole source aquifers “so as to create a significant hazard to public health” are subject to EPA review and approval to ensure that the extent of contamination does not exceed safe drinking water standards. The EPA has designated the Troutdale Aquifer System in Clark County, Washington, as a sole source aquifer, and the City of Vancouver has designated the entire area within the city boundaries as a Critical Aquifer Recharge Area.

Troutdale Sole Source Aquifer

The Troutdale Aquifer System consists of multiple aquifers that are present in various sedimentary deposits found in the Portland Basin where the project area is located. Delineation of aquifers found in the Troutdale Aquifer System has been based on geologic units and boundary conditions that serve to define the extent of the aquifer. The Troutdale Aquifer System has been divided into an upper and lower system. Aquifers present in the lower system are confined and isolated from aquifers present in the upper system. Aquifers present in the upper system are considered to be generally unconfined and consist of three aquifers found in sedimentary deposits associated with and in order of shallowest to deepest; alluvium deposits, catastrophic flood deposits, and the upper Troutdale Formation. With the exception of the Troutdale Formation, these deposits are unconsolidated and generally loose material. The Troutdale Formation, in particular its upper section, is a consolidated conglomerate with a matrix consisting of sand and silt with weak to moderate cementation. Groundwater present in the alluvium and catastrophic flood deposits is associated with the unconsolidated sedimentary aquifer (USA). The USA is an unconfined aquifer with its water table typically extending up into the finer Quaternary alluvium. Depth to the water table typically ranges from 25 to 65 feet below ground surface. Based on its lower permeability compared with catastrophic flood deposits, separate aquifer designations have been applied for groundwater present in the alluvial deposits. Groundwater present in the Troutdale Formation encountered beneath the USA is associated with the Troutdale gravel aquifer (TGA). As described in the Troutdale Sole Source Aquifer Technical Report (Appendix E of the Hazardous Materials Technical Report), water supply wells located in the Vancouver portion of the project area produce from the highly productive catastrophic flood deposit portion of the USA. Due to its lower permeability, location beneath the highly transmissive USA, and greater depth below ground surface, the TGA is generally not used as a water supply source in the project area.

The City of Vancouver relies entirely on groundwater extracted from the Troutdale Aquifer System for its drinking water supply; and two water stations, Water Stations 1 and 3, are located in the vicinity of the main project area. These two water stations produce from the unconfined USA. Aquifer recharge for the USA and the TGA is derived primarily from local precipitation. High production pumping in the City of Vancouver area influences groundwater flow in the USA in the south Clark County area. In response to this pumping, the Columbia River also serves as a recharge source. Discharge is from wells, springs, streams, and the Columbia River. Both recharge and discharge zones occur throughout the project area. This is significant because should contaminants enter the groundwater in a recharge zone, they could travel to a discharge zone such as a city well field. Susceptibility assessments completed by the City of Vancouver found that the

What is a sole source aquifer?

EPA defines a sole source aquifer as an aquifer or aquifer system which supplies at least 50 percent of the drinking water consumed in the area overlying the aquifer and as one for which there is no alternative source or combination of drinking water sources which could physically, legally and economically act to supply those dependent upon the aquifer.

aquifer is most susceptible to contamination from road runoff, spills, and illegal disposal of waste. While similar susceptibility conditions exist in the project area south of Vancouver, the vulnerability of the USA is considered to be lower due to an overall lower use of groundwater and lack of high production pumping in the vicinity of the project area. Consequently, groundwater flow in the USA in the Oregon portion of the project area is understood to naturally flow from areas of recharge to areas of discharge.

Additional details on the existing geologic, soil, and groundwater conditions in the project area are described in the CRC Geology and Groundwater Technical Report (included as an electronic appendix to this FEIS) and the Troutdale Sole Source Aquifer Report (Appendix E of the Hazardous Materials Technical Report).

3.17.3 Long-term Effects

Long-term effects include both future impacts from geologic processes to the completed project and future impacts the completed project may have on geologic and groundwater resources. Exhibit 3.17-1 compares these effects for the LPA to the other build and No-Build alternatives. As shown in the exhibit, the LPA and Alternatives 2 and 3 most improve seismic and volcanic safety by replacing the existing I-5 bridge structures, and have the highest potential demand on local mining and quarry operations. Alternatives 4 and 5 have more modest safety improvements and result in smaller increases in mining and quarry activity, as these alternatives rely on seismic upgrades to the existing bridges and use fewer natural resources. All build alternatives are anticipated to reduce existing slope and landslide issues through soil stabilization and to provide groundwater improvements through improved stormwater management. Although the highway phasing options of both LPA Option A and Option B defer some improvements, on the whole, their impacts are similar to those resulting from the full LPA options, with the exception of slope and seismic impacts, as discussed below.

Exhibit 3.17-1

Comparison of Long-term Effects on and from Geologic and Groundwater Hazards and Resources

Environmental Metric	Locally Preferred Alternative		No-Build	Alt 2: Repl Crossing with BRT ^a	Alt 3: Repl Crossing with LRT ^a	Alt 4: Suppl Crossing with BRT ^a	Alt 5: Suppl Crossing with LRT ^a
	LPA Option A ^b	LPA Option B ^b					
Earthquakes	More extensive seismic improvement (Some seismic improvements deferred).	Same as Option A	No improvement to existing seismic vulnerability.	Same as LPA	Same as LPA	Less extensive seismic improvement.	Less extensive seismic improvement.

Environmental Metric	Locally Preferred Alternative		No-Build	Alt 2: Repl Crossing with BRT ^a	Alt 3: Repl Crossing with LRT ^a	Alt 4: Suppl Crossing with BRT ^a	Alt 5: Suppl Crossing with LRT ^a
	LPA Option A ^b	LPA Option B ^b					
Volcanoes	Most able to withstand lahars.	Same as Option A	Moderate to high potential impact from lahars.	Same as LPA	Same as LPA	Moderate potential impact from lahars.	Moderate potential impact from lahars.
Steep Slopes, Soil Erosion, and Landslides	Potential improvement to slope stability near Burnt Bridge Creek (Existing slope stability issues remain).	Same as Option A	Existing slope stability issues remain.	Same as LPA	Same as LPA	Same as LPA	Same as LPA
Mineral Resources	Higher demand for mineral resources. Potential positive economic benefit to local resource companies.	Same as Option A	No beneficial impact to local resource companies.	Same as LPA	Same as LPA	Slightly less demand for mineral resources than LPA. Some potential positive economic benefit to local resource companies.	Slightly less demand for mineral resources than LPA. Some potential positive economic benefit to local resource companies.
Groundwater Resources	Positive impacts to groundwater quality through improved stormwater management.	Same as Option A	No disturbance or improvements to existing groundwater resources.	Similar to LPA	Similar to LPA	Similar to LPA	Similar to LPA

Source: CRC Geology and Groundwater Technical Report.

a Assumptions are based on information presented in the DEIS assuming the "Clark College MOS".

b Information in parentheses indicates impacts if the LPA Option A or B is constructed with highway phasing.

Geologic Hazards

Geologic hazards are natural geologic conditions that can endanger human lives or wildlife habitat and can threaten property. Geologic hazards include earthquakes, volcanoes, steep slopes, soil erosion, and landslides.

EARTHQUAKES

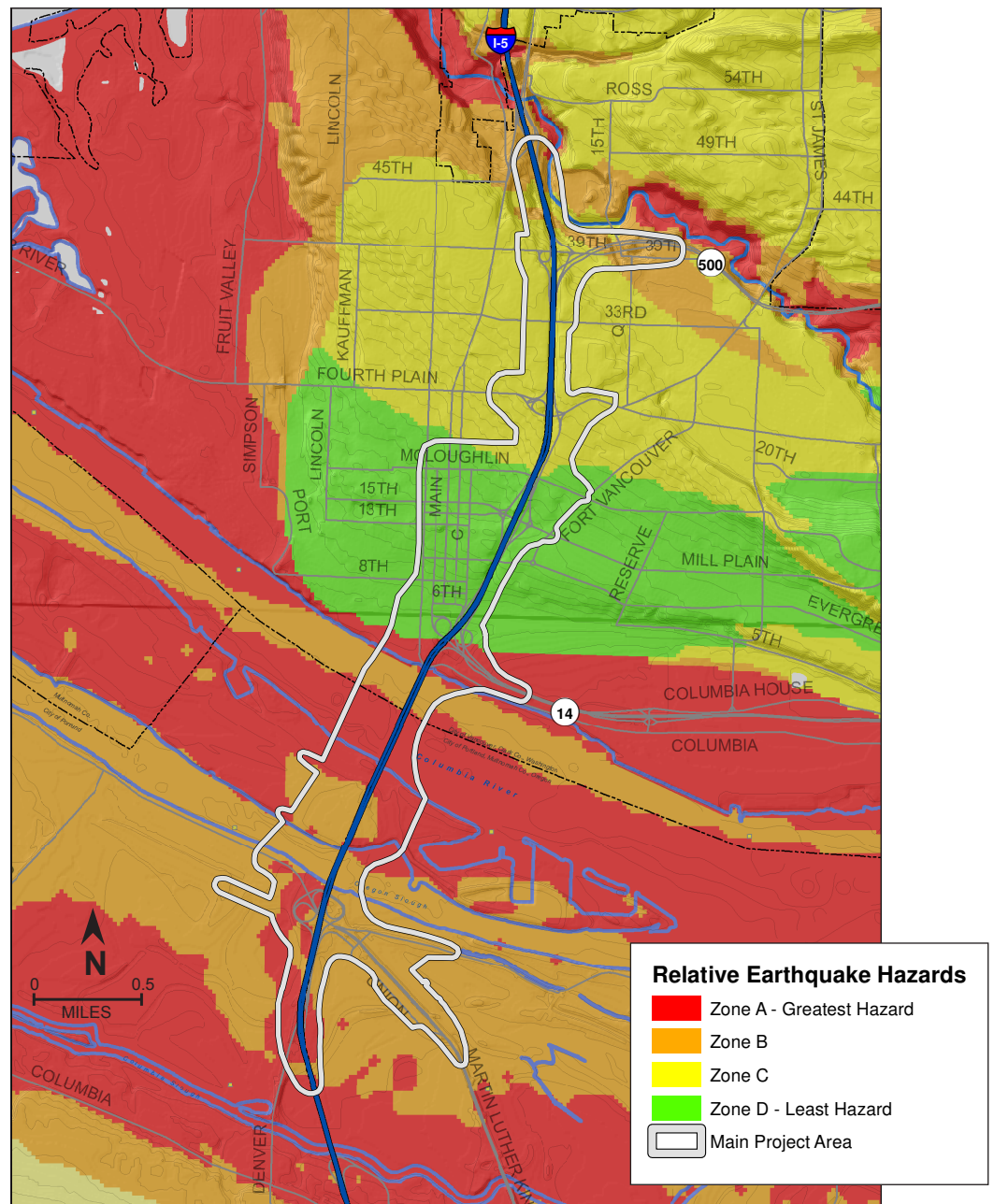
Exhibit 3.17-2 shows a map of the relative earthquake hazard ratings in the main project area. These ratings take into account a variety of potential earthquake effects, with A being the most hazardous areas and D being the least. Earthquake effects include ground motion amplification, slope instability, and soil liquefaction, all of which have a high potential to impact public safety and cause structural damage and economic disruption. The LPA would replace the existing I-5 bridges with new and retrofitted structures built to

Soil liquefaction

A phenomenon associated with earthquakes in which sandy to silty, water-saturated soils behave like fluids. As seismic waves pass through saturated soil, the structure of the soil distorts, and spaces between soil particles collapse, causing ground failure. In general, young, loose sediment and areas with high water tables are the most vulnerable to liquefaction.

modern seismic safety standards. It would also apply modern seismic safety standards to the other interchange and highway improvements constructed as a part of the CRC project, and would stabilize weak soils along the Columbia River on Hayden Island and around Marine Drive. This would improve public safety and structure stability during earthquake seismic events. The CRC project would utilize advancements in engineering and more up-to-date conceptual understandings of earthquake science than were available during construction of the existing facilities, which would be retained under the No-Build Alternative. The project with highway phasing will address almost all of the I-5 related seismic safety issues within the main project area. However, these options defer some improvements at the Victory Boulevard and SR 500 interchanges, and would therefore provide fewer overall seismic improvements than the full LPA.

Exhibit 3.17-2
Relative Earthquake Hazards



Source: Mabey et al. 1994, 1997.

VOLCANOES

Volcanic hazards from regional volcanoes include lahars and ash fall. Deposits of lahars from Mount Hood have been mapped on the Oregon and Washington sides of the Columbia River near the mouth of the Sandy River (Scott et al. 1997). Lahars from Mount Hood could inject a significant amount of sediment-rich flood water containing large rocks and woody debris into the Columbia River upstream of the project area (Wolfe and Pierson 1995). Lahars can cause severe bank erosion and scour around bridge piers. The new bridge piers included with the LPA decrease the chance of bridge failure in the event of lahar activity.

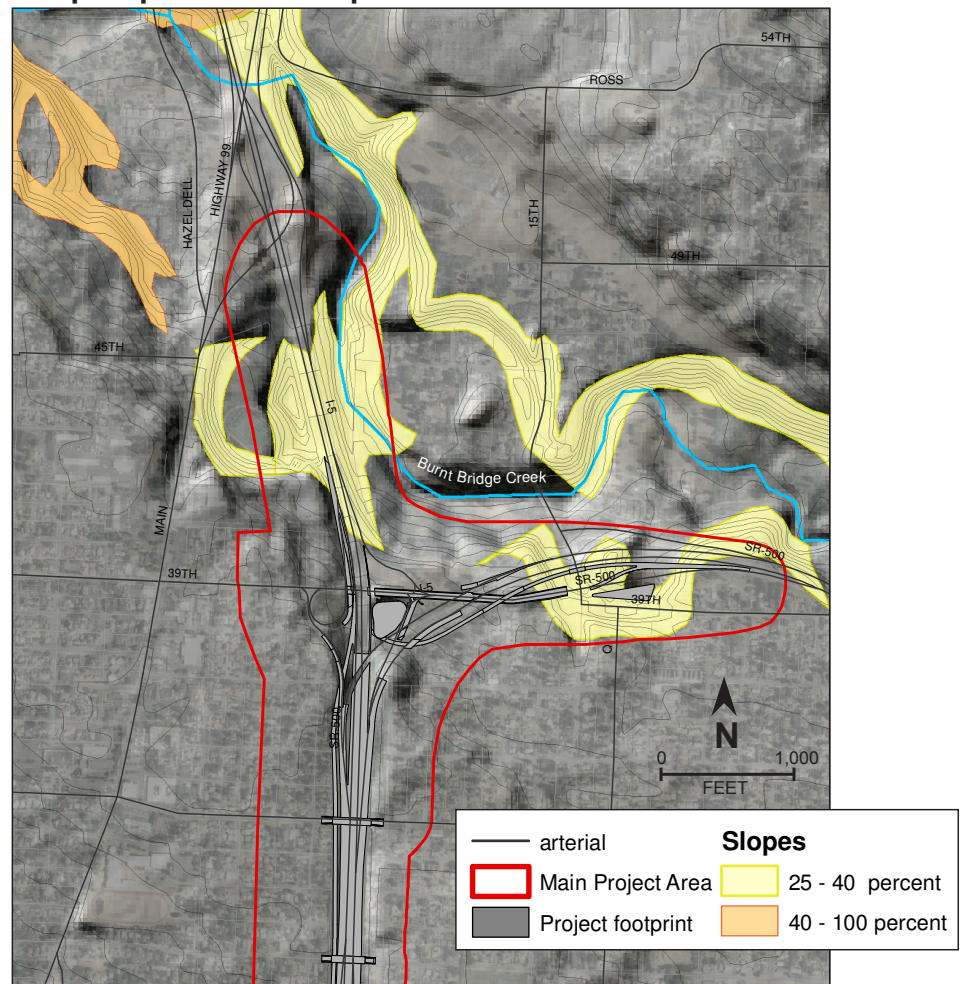
Ash fall from a Mount St. Helens eruption is generally carried northeast with the dominant wind direction. However, in the event of a Mount St. Helens eruption, there is a 1 to 2 percent chance of ash fall accumulation of 4 inches or more within the project area. The added weight from ash accumulation is not anticipated to pose risks to the existing or proposed bridges under any of the project alternatives.

STEEP SLOPES, SOIL EROSION, AND LANDSLIDES

Steep slope hazard areas are areas with slopes equal to or greater than 25 percent. These areas have the potential to experience slope instability, soil erosion, and uncontrolled stormwater runoff. Although no active or historical landslides have been mapped in the project area, the steep slopes found within the Burnt Bridge Creek area have landslide potential, particularly during a significant earthquake event (Exhibit 3.17-3). In addition, soils with moderate to very severe erosion potential have been identified along the steep slopes located along Burnt Bridge Creek.

Steep slopes would mostly be avoided by the project, including in the Burnt Bridge Creek area. However, where steep slopes are adversely impacted, the LPA would include retaining walls or other stabilization techniques, reducing soil erosion and lowering the potential for slope failure. In addition to the use of retaining

Exhibit 3.17-3
Steep Slope Location Map



Source: Merrick and Company 2002.

walls and cut/fill grading, the LPA would install a stormwater management and conveyance system. This would result in a reduced rate of soil erosion and lower potential for soil slump or slide from steep slopes in the project area. By deferring construction of the northern half of the I-5/SR 500 Interchange, the highway phasing options would defer long-term improvements in slope stability in the Burnt Bridge Creek area.

Geologic and Groundwater Resource Effects

Construction of the LPA has the potential to impact both geologic and groundwater resources. The geologic resources impacted would be mining and quarry operations, which exist outside the main project area. As groundwater flows through the project area, groundwater impacts within the project area can also extend beyond the project boundaries.

GEOLOGIC RESOURCES

The LPA would use top soil, fill, aggregate, quarry rock, concrete, and asphalt resources. Some of these materials would be generated by recovering and recycling materials from the demolition of existing roads and bridges within the main project area, while some would consist of new mined or quarried materials. Construction contractors would determine the sources of the materials they use for project construction, although WSDOT and/or ODOT may make specific state-owned sources available as part of the construction contract bidding process. Potential sources of new material include a wide variety of existing mining and quarry operations in the region, as well as potential expansions of existing mining or quarry facilities or construction of new facilities. To the extent practicable, aggregate, quarry rock, asphalt, and concrete materials generated by project-related demolition and construction activities would be recycled or reused.

If existing mining or quarry operations are expanded or new facilities are opened, there would be environmental impacts associated with those actions. However, there appears to be substantial capacity within the already permitted operations to address the demands of the CRC project (Mineral Land Regulation and Reclamation Program 2009; Washington Division of Geology and Earth Resources 2008). In addition, any recyclable aggregate or concrete that is generated by demolition of existing roads and bridges, but that cannot be used by CRC project construction, would be available to other projects in the area, thereby reducing the need to expand or open new mining or quarry facilities. If project contractors use materials from operations that do not exist today, that would likely be based on the contractors' choice rather than a lack of existing operations that could fill the project's needs. The expansion of any existing mines or opening of new mining operations would be subject to relevant federal, state, and local environmental reviews, regulations, and permitting requirements. As the LPA highway phasing options defer a relatively small amount of the overall construction activity, these options would result in slightly less mining and quarry operation.

As stated in the CRC Sustainability Strategy (Appendix C) in order to build a sustainable project, construction materials must be recycled, reduced, and reused to the greatest extent possible. This includes writing specifications to allow waste products to be productively reused or recycled into the project where feasible and minimizing the quantity of materials hauled to landfill.

Please refer to Section 3.10 of Appendix C for more information regarding the project's commitment to reusing and recycling materials during design, contracting, and construction, as well as innovative WSDOT and ODOT programs and strategies that focus on construction materials and sustainable practices.

GROUNDWATER RESOURCES

The LPA would include new subsurface structures such as shafts or piles, retaining walls, and soil stabilization structures. These subsurface structures may result in minor changes in localized groundwater movement. As the LPA highway phasing options defer some interchange improvements, their construction presents less risk of impacts to groundwater movement. The effects of the project on groundwater movement will be evaluated as the design process moves forward, in order to minimize or eliminate any adverse groundwater effects on the project and environment.

The LPA includes significant below-grade construction activities associated with bridge areas, including the installation of shafts and piles to support piers. A potential adverse effect on the Troutdale Aquifer System, specifically the unconsolidated sedimentary aquifer, is the drag down of existing contaminants during pile and shaft installations. An identified mitigation measure is to evaluate existing subsurface soil and groundwater environmental conditions at pile and drill shaft locations to determine the presence of contaminants, if any. As presented in the Troutdale Sole Source Aquifer Technical Report (Appendix E of the Hazardous Materials Technical Report), a search of federal and state regulatory environmental databases did not identify recognized sources of contamination in the project bridge areas. Conducting focused environmental assessments in areas of significant pile-driving and shaft drilling will enable the project to limit the potential for contaminants to enter groundwater.

The aquifer system currently receives local recharge from untreated stormwater generated from portions of the I-5 highway system. The LPA would provide long-term management and treatment of stormwater generated from new and rebuilt impervious surfaces, such as roads and bridges, and stormwater generated from some existing surfaces that will drain to project stormwater management facilities. Stormwater treatment facilities would be located away from City of Vancouver wellhead protection zones for Water Stations 1 and 3.

This would result in improved local groundwater quality, including the groundwater in the sole source aquifer in Clark County. Under the supplemental bridge alternatives (Alternatives 4 and 5), some of the runoff from the existing I-5 bridges would remain untreated, primarily discharging directly to the Columbia River. Because much of this untreated area discharges directly to surface waters and represents only a small percentage of the total treated area, Alternatives 4 and 5 would have groundwater quality benefits similar to the other build alternatives (the LPA and Alternatives 2 and 3). Overall, the LPA highway phasing options have similar groundwater effects as the full build options. For additional information on the sole source aquifer, see Section 3.18, Hazardous Materials, of the FEIS and the supporting CRC Hazardous Materials Technical Report, included as an electronic appendix to this FEIS.

Ruby Junction Maintenance Facility

The expansion of the TriMet Ruby Junction Maintenance Facility is not expected to adversely affect any geologic or groundwater resources. Although the Ruby Junction expansion area is underlain by gravel and is adjacent to an existing gravel operation, the expansion area includes existing residential, commercial, and light industrial uses that make it less attractive for use as a gravel quarry. The stormwater runoff from all impervious areas in the expansion area would be infiltrated to groundwater. The infiltration techniques will comply with the City of Gresham stormwater management requirements and will protect and/or improve the quality and quantity of existing groundwater flows.

The Ruby Junction facility is not in the likely path of a lahar or ashfall from a volcanic eruption of either Mount St. Helens or Mt. Hood, and therefore no long-term effects from volcanic hazards are anticipated. The neighboring gravel operation has created a significant slope adjacent to the Ruby Junction expansion area that could pose potential landslide concerns, particularly in the event of an earthquake. However, the Ruby Junction site is located in earthquake Zone D, the lowest relative earthquake hazard. As is true of the project in general, a further assessment of existing geologic hazards such as, but not limited to, faults, ancestral landslides, steep cut slopes, and soil liquefaction would occur during the final engineering stage of the project.

Indirect Effects

Compared to the No-Build Alternative, the LPA may have the indirect effect of facilitating and accelerating development in Vancouver and on Hayden Island, particularly near the LPA's light rail stations, and to a lesser degree, closer to the Columbia River. Two indirect effects have been identified related to geologic hazards and resources: increased development in earthquake hazard areas and a potential improvement to groundwater quality.

Land use changes around light rail station areas are likely to result in an improvement in stormwater treatment, as new development would be subject to current regulations and treatment requirements. Such changes would likely result in reduced risks to local groundwater quality, including the Troutdale Sole Source Aquifer. The greatest risk from earthquakes in the main project area occurs on Hayden Island near the Columbia River and North Portland Harbor. Although earthquake risk is higher in this area than in most of the project area, new and retrofitted buildings and structures would need to be built to current seismic safety standards, potentially increasing overall public safety and decreasing the likelihood of structural damage and economic disruption.

3.17.4 Temporary Effects

Temporary effects are short-term effects to resources that could occur during construction of the LPA, whether these effects are experienced on site (within the main project area and/or at the Ruby Junction Maintenance Facility) or off site (at the major project casting and staging areas).

Resources

As discussed further in Sections 3.14 and 3.18 (Water Quality and Hydrology and Hazardous Materials, respectively), the LPA Options A and B would

conduct excavation, fill, drilling, and grading activities during construction. Without mitigation, these activities would result in temporary soil erosion, sedimentation, and impacts to stormwater, surface water, and groundwater quality within the main project area. Without mitigation, impacts to stormwater, surface water, and groundwater may also occur at off-site staging and casting facilities.

Geologic Hazards

No temporary effects from potential geologic hazards are expected to occur on site or off site as a result of the No-Build Alternative or the LPA.

3.17.5 Mitigation or Compensation

To prevent or minimize adverse effects from geologic hazards, the following mitigation and minimization measures are included in the LPA. Other adverse effects would be avoided or minimized through project elements and measures discussed above in 3.17.3 and 3.17.4.

Geologic Hazards

- Further assess existing geologic hazards such as, but not limited to, faults, ancestral landslides, steep cut slopes, and soil liquefaction during the final engineering stage of the project. Site-specific assessments would include additional geotechnical testing and monitoring.
- Consistent with WSDOT and ODOT policy, design all new LPA bridges to withstand the most significant earthquake event anticipated within a 1,000-year period without collapse. In addition, and consistent with ODOT policy, design new Oregon bridges to experience minimal damage from the most significant earthquake anticipated to occur within a 500-year period. WSDOT and ODOT may also elect to design bridges of increased importance (such as those crossing the mainstem of the Columbia River) to a higher standard.
- Minimize the extent of construction activities on steep slopes identified in the Burnt Bridge Creek drainage area.
- Adequately assess the use of soil stabilization techniques used to minimize liquefaction of soils during the preliminary engineering stage of the project. Stabilization techniques include the use of compaction grouting, stone columns, and other techniques.
- Implement erosion control and stormwater pollution prevention plans during construction.

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