GEOLOGY, SOILS AND GROUNDWATER TECHNICAL REPORT

SR 167 – 8th Street E Vic. to S 277th Street Vic.

Southbound HOT Lane

July 2008

Prepared for:

Washington State Department of Transportation

Seattle, Washington

Prepared by:

Shannon and Wilson

Seattle, Washington

Washington State
Department of Transportation

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What is the proposed project and why is it needed?

The Washington State Department of Transportation (WSDOT) plans to widen the State Route (SR) 167 roadway to construct a new southbound high-occupancy toll (HOT) lane from the vicinity of 8th Street E (MP 10.2) in Pierce County, Washington to the vicinity of S 277th Street in Kent (MP 18.24), King County, Washington. The construction of the HOT lane will require widening of the southbound bridge at the SR 18 interchange. Ramp meters will be installed at southbound on-ramps at the SR 167 interchanges with 15th Street SW, Ellingson Road, and 8th Street E. In addition, new signals will be installed at the SR 167 southbound ramp terminals with Ellingson Road and 8th Street E. SR 167 is an important thoroughfare for cars, trucks, and transit in the Green River Valley. This additional capacity will relieve congestion and improve safety for commuters traveling southbound on SR 167.

What is the purpose of this Geology, Soils and Groundwater Report?

This report describes the existing conditions and potential range of effects to geology, soils, and groundwater that may be attributed to the construction and operation of a southbound HOT lane on SR 167, between 8th Street E Vicinity and S 277th Street Vicinity.

What areas and resources will be affected?

The project area is located in the Green River Valley and crosses the cities of Auburn, Algona, and Pacific. The geology, soils, and groundwater resources can be potentially affected by the construction and operations of the new HOT lane in the project area.

How were project effects on geology, soils, and groundwater identified and evaluated?

Project geologists evaluated subsurface conditions in the categories of geology, soils, and groundwater in the project area by compiling and reviewing existing subsurface data, published and unpublished geologic maps and documents, and results of field reconnaissance. Available geotechnical records obtained were reviewed for existing subsurface information in the project area.

What effects will the project have on geology, soils, and groundwater resources?

The potential effects of the project on geology, soils, and groundwater are discussed in Chapter 3 of this report. Effects on geology and soils include settlement of underlying soils from the weight of new embankments, vibrations from driving piles for foundations, sloughing of shallow footings, pavement cracking, and erosion.

Groundwater quality and quantity could be impacted during construction. Stormwater can cause erosion of exposed surfaces and carry sediment off the construction site, reducing water quality. Spills or inadvertent discharges could also reduce groundwater quality. Impermeable surfaces, temporary dewatering, or permanent drainage systems could reduce groundwater quantity.

What mitigation measures are proposed to avoid or reduce project effects on geology, soils and groundwater?

A number of construction-related mitigation measures are identified in Chapter 4 of this report. Such measures include having a geotechnical engineer provide recommendations to reduce embankment settlement, increase embankment stability, and reduce the potential effects of liquefaction. Vibrations caused by driving piles could be monitored to gauge the potential effects on nearby structures, and drilled shaft excavations could be drilled inside a casing or excavated with drilling slurry to reduce the potential for collapse. To reduce erosion potential, WSDOT will implement a Temporary

Erosion and Sedimentation Control (TESC) plan that includes Best Management Practices (BMPs) to control surface runoff. Groundwater quality will be maintained by construction BMPs and by preventing certain construction activities in critical areas. Standard design of dewatering and drainage systems and infiltration of some stormwater could reduce impacts to groundwater quantity.

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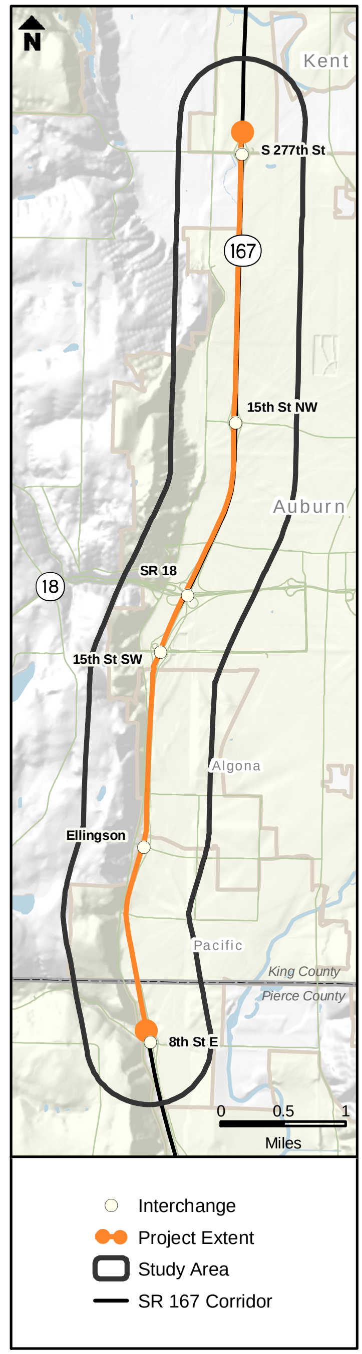
CHAPTER 1 INTRODUCTION

What is the proposed project and why is it needed?

The Washington State Department of Transportation (WSDOT) plans to widen the State Route 167 (SR 167) roadway to construct a new southbound High Occupancy Toll (HOT) lane from the vicinity of 8th Street (MP 10.2) in Pierce County, Washington to the vicinity of S 277th Street in Kent (MP 18.24), King County, Washington (Exhibit 1). This new HOT lane will be a continuation of a southbound HOT lane that was constructed for the HOT Lane Pilot Project, which extends from the I-405 interchange in Renton to S 277th Street in Kent.

> HOT lanes are managed lanes intended to increase mobility by allowing more vehicle use of the lane. HOT lanes maintain free, priority status for transit and carpools, the same as a High Occupancy Vehicle (HOV) lane, but also allow single occupancy vehicles to pay a toll and use the lane. Toll rates will be variable, depending upon the level of congestion.

Exhibit 1
Vicinity Map



The construction of the HOT lane will require widening the roadway to the outside of the existing pavement between 6th Avenue N in Algona and 5th Avenue S in Pacific. In addition, it will require widening the southbound bridge at the SR 18 interchange. Ramp meters will be installed at southbound on-ramps at the SR 167 interchanges with 15th Street SW, Ellingson Road, and 8th Street E. In addition, new signals will be installed at the SR 167 southbound ramp terminals with Ellingson Road and 8th Street E. All of the proposed widening work will occur within the WSDOT right-of-way, with the exception of the stormwater site. The stormwater site will be purchased at the northwest quadrant of the SR 167 / SR 18 interchange area.

SR 167 is an important thoroughfare for cars, trucks, and transit in the Green River Valley. The additional capacity that this project will provide to SR 167 will relieve congestion and improve safety for commuters traveling southbound. This project, combined with other planned SR 167 projects, could make the highway a viable alternative to I-5.

What is the purpose of this report?

This report describes the existing conditions and potential range of effects to geology, soils, and groundwater that may be attributed to the construction and operation of a southbound HOT lane on SR 167, between 8th Street East Vicinity to South 277th Street Vicinity.

This report was prepared as part of a National Environmental Policy Act (NEPA) Documented Categorical Exclusion (DCE), which requires all actions sponsored, funded, permitted, or approved by a federal agency to consider the environmental effects of the proposed project. The Washington State Environmental Policy Act (SEPA) requires a similar evaluation of environmental effects of proposed project of state and local projects. The proposed project is required to comply with both NEPA and SEPA, which includes a review of potential effects and possible mitigation measures. When potential effects to geology, soils or groundwater exist as a result of the proposed project, a review of those potential effects and possible mitigation measures is required by both NEPA and SEPA.

How were effects identified and evaluated for geology, soils, and groundwater resources?

Project geologists evaluated subsurface conditions in the project area by compiling and reviewing existing exploration data, published and unpublished geologic maps and documents, and results of field reconnaissance. They reviewed available geotechnical records to obtain existing subsurface information in the project area. Geotechnical studies, environmental studies, and boring logs were collected from WSDOT and the University of Washington GeoMapNW Project. These reports and studies included:

- Aquifer Recharge Area Map. Pierce County Department of Planning and Land Services
- SR 167, SR 161 to 6th Street, Auburn, Geotechnical Report (WSDOT, 1985)
- SR 167, Sumner to King County Line, Soils Report (WSDOT, 1970)

What are the engineering properties of soils?

To design structures such as roadways and bridge foundations, some of the important physical and engineering properties of soils are:

- Permeability
- Elasticity
- Plasticity
- Strength
- Moisture content
- Density
- Shrink/swell potential
- Compressibility
- Grain size distribution

- SR 167, 15th Street SW to South Grady Way, Bridge Foundation Report (WSDOT by Terra Associates, Inc., 1992)
- Subsurface Investigation, SR 167, King-Pierce County Line to 15th Street SW (Auburn) (WSDOT by Shannon & Wilson, Inc., 1968)
- King Co. Potentiometric surface map

In addition, the project team reviewed other published geologic maps and reports to understand general topographic and geologic conditions along the project area. We provide a complete list of references at the end of this report.

Project team members performed a geologic reconnaissance along the project area by driving along SR 167 and stopping at various points to record features. Features noted included soil exposures; cut and fill slopes; evidence of slope instability; erosion; vegetation that could give clues to underlying geologic conditions; and evidence of ground and structural distress that might indicate poor subsurface conditions.

Based on preliminary plans for the project, geologists evaluated the anticipated soils and geology effects relative to proposed earthwork (cuts and fills), retaining walls, bridge foundations, utilities, and potential landslide areas. Measures to mitigate potential soils and geology effects are presented in Chapter 3 of this report. The range of potential effects will be mitigated by following standard WSDOT practices, implementing project Best Management Practices (BMPs), and following the recommendations of a licensed geotechnical engineer and hydrogeologist.

What are hazardous soil conditions?

Some examples of hazardous soil conditions include landslides from unstable slopes and soils susceptible to fracturing or liquefying during an earthquake.

Soil liquefaction is a phenomenon in which layers of loose sand below the water table behave like a liquid when subjected to intense shaking.

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CHAPTER 2 EXISTING CONDITIONS

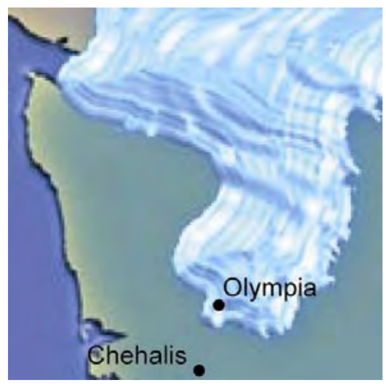
What is the topography of the project area?

The area generally follows the Green and White river valleys. The ground in the valleys is generally level, with some gently rolling areas. Bluffs up to 300 feet high mark the boundaries between the valley and the uplands. The ground surface along the project area ranges from approximately 60 to 100 feet above sea level (these elevations are referenced to the North American Vertical Datum of 1988 [NAVD 88]).

What is the geology in the region and how was it created?

The project lies in the central portion of the Puget Lowland (Lowland), which is an elongated topographic and structural depression filled with a complex sequence of glacial and non-glacial sediments that overlie bedrock. Glaciers covered the area six or more times in the past 2 million years. The ice involved in these glacial episodes originated in the mountains of British Columbia. The maximum southward advance of the ice was about halfway between Olympia and Centralia, as illustrated in Exhibit 2.

Exhibit 2
Maximum Southward Advance of Glacial Ice in the Puget Lowland



The distribution of sediment in the Lowland is complex because each glacial advance partially eroded previous sediments and deposited new sediment. Between glacial episodes, the complete or partial erosion or reworking of deposits, and the deposition of non-glacial sediment, took place. During the last glacial advance, known as the Vashon Stade of the Fraser Glaciation, the ice was about 3,500 feet thick in the project area. The Vashon ice sheet receded from the project area about 13,500 years ago, leaving topography characterized by low-rolling relief about 500 feet above sea level, with some deeply cut ravines and broad valleys. Since then, present-day geologic processes, such as erosion and deposition by streams and landsliding, modified the ground surface and further complicated the geology.

Based on deep wells and seismic surveys in the Puget Basin (Jones, 1996), bedrock lies approximately 1,500 feet below the ground surface along the project area. Bedrock is exposed at the ground surface approximately 15 miles from the proposed highway alignment.

What geologic units are found in the general project area?

Published geologic maps indicate that the last glacial advance, called the Vashon, deposited most of the geologic units in the project area. However, some previous glaciations left deposits in the bluffs at the edge of the valley. Vashon Till mantles the ground surface across the upland plateau, and is occasionally overlain by Recessional Deposits. Below, the Vashon Till consists of advance outwash and Pre-Vashon deposits, which outcrop along the edge of the plateau. Alluvium fills the river valley below the plateau. Deposits of organic peat are also located throughout the valley. Throughout the project area, humans placed fill to modify the ground surface. The geology in the project area is illustrated in Exhibit 3, and described below.

Fill makes up the youngest deposits in the project area. Fill is soil placed by humans and it can have widely variable properties. The properties of the fill depend on the material used and whether people place the fill in an engineered fashion. Most of the fill along the project area consists of silty sand to gravelly sand placed during the original construction of SR 167 and the Union Pacific Railroad. WSDOT originally constructed SR 167 in the 1970s.

Peat is a highly organic, compressible, and fibrous soil. Peat deposits accumulated in parts of rivers, called meanders, that had been cut off from the main river channel. The meanders became small lakes, and eventually wetlands and bogs. The decaying plant material in these wetlands became peat.

Alluvium includes water-deposited sediments that have accumulated in the Green and White river valleys since the Vashon glacier melted. Alluvium may contain clay, silt, peat, sand, and gravel.

Recessional Deposits consist of sand and gravel, or till-like materials that continental glaciers deposited as they melted and receded. As such, recessional deposits have not been overridden and densely compacted by glaciers.

Vashon Till is typically composed of gravelly, silty sand with scattered cobbles and boulders. This unit was deposited at the base of the Vashon glacier and overridden by the glacier. Vashon Till is very dense and relatively impervious.

Advance Outwash consists primarily of sand deposited by streams that issued from the front of the Vashon glacier. The sand was eventually overridden and consolidated by the glacier, and is now very dense.

Pre-Vashon Deposits vary from older glacial deposits to sediments from previous interglacial periods. While the composition of these deposits is variable, all have been glacially overridden and are very hard and dense.

What surficial soils are found in the general project area?

Soil information was obtained from the Soil Survey of Pierce County Area (Soil Conservation Service, 1979) and the Soil Survey of King County Area (Soil Conservation Service, 1973). The Soil Conservation Service (SCS) classifies surficial soils based on characteristics that relate to soil development from the weathering of underlying parent material. Such soil classifications can be used to estimate erosion potential, infiltration capacity, and other agricultural soil properties.

The surficial soils in the project area are illustrated in Exhibit 4. Alluvium was the source material for most soils in the project area. These soils include members of the Puyallup, Briscot, Norma, Oridia, and Renton Series. These soils are typically somewhat-poorly to poorly drained, except the Puyallup Series, which is well-drained. They typically occur on slopes of less than two percent grade, and present a slight erosion hazard.

Alluvium and decaying organic matter in ponds and bogs was the source material for soil in certain location in the project area. These soils include members of the Puget, Snohomish, Semiahmoo, and Seattle Series. These soils are typically poorly to very-poorly drained; occur on slopes of less than two percent grade, and present little to no erosion hazard.

Vashon Till and Pre-Vashon deposits created the soils called Xerochrepts found on the steep upland bluffs along the project corridor. These soils are typically moderately well-drained to excessively drained, occur on slopes between 45 percent and 70 percent grade, and present a severe erosion hazard.

Exhibit 3

The Geology of the Project Area

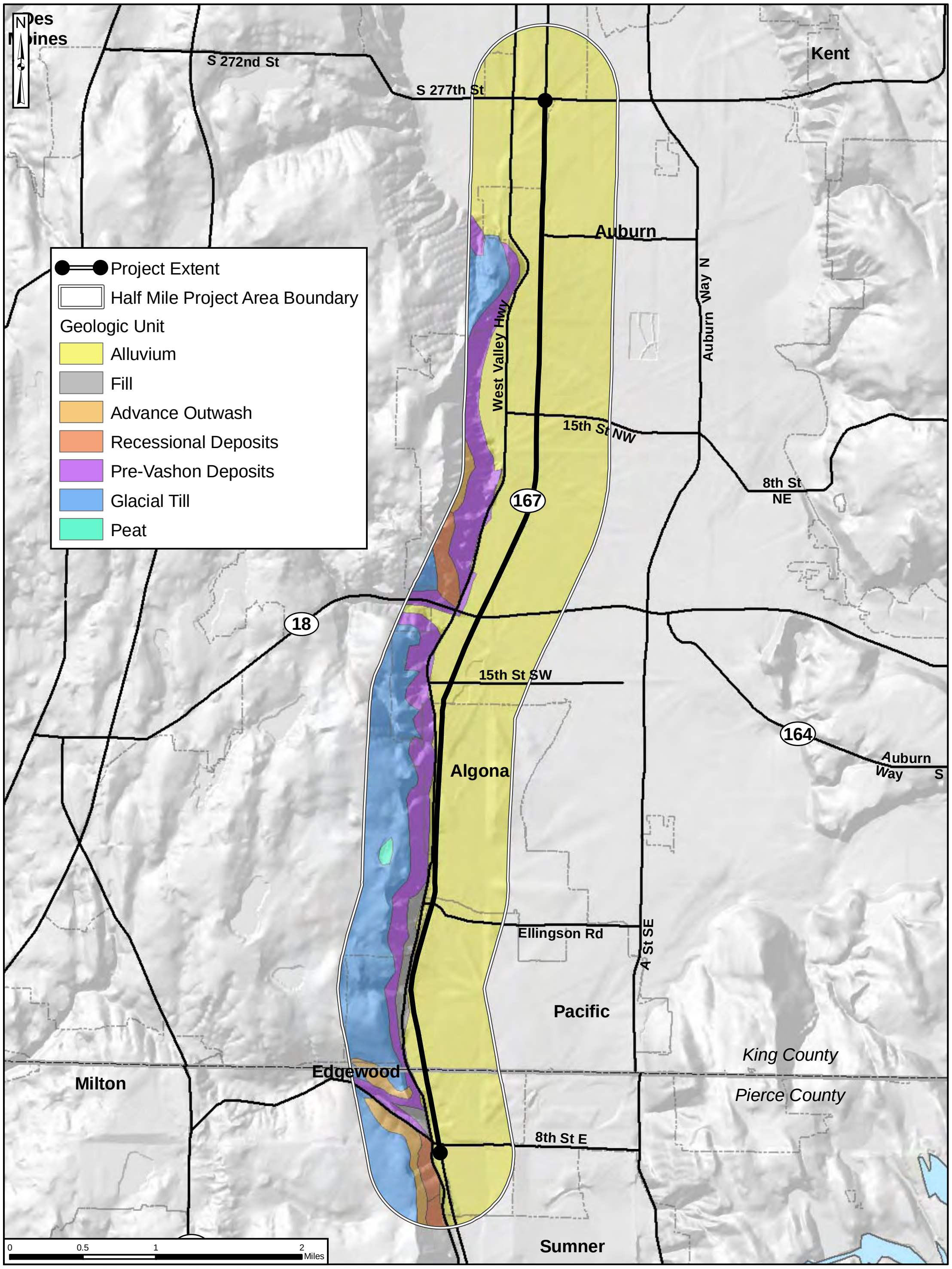
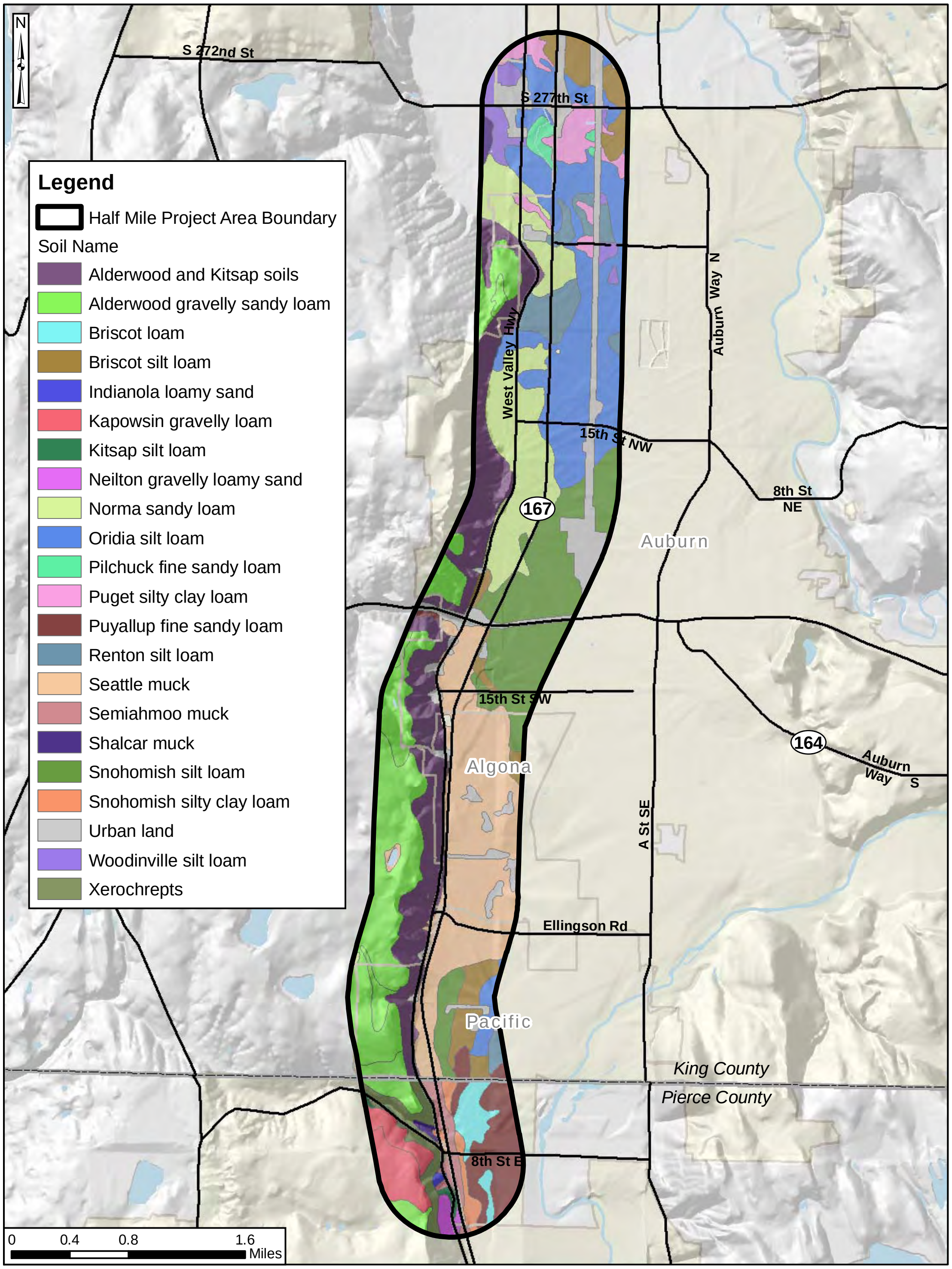


Exhibit 4
Soils Found in the Project Area



What subsurface conditions exist under the proposed project alignment?

The project geologist's understanding of the subsurface conditions under the proposed project alignment is based on published geologic maps, previous subsurface explorations, and field reconnaissance. Most of the project area traverses alluvium deposited by rivers in the valley. The alluvium consists of thick and highly variable deposits of silt, sand, and gravel. Interspersed in the alluvium are layers of compressible peat as thick as 10 feet. In some places, highway construction projects removed peat layers or compressed large mounds of fill material in the process of *preloading*. Most of the highway sits above the surrounding grades on fill embankments that are six to 20 feet high. The following describes the soil conditions in the project area between major intersections:

South of 8th Street E to Ellingson Road/3rd Avenue SW (Pacific)

In this area, the highway is underlain by alluvium, consisting of loose sand and soft, compressible silt and peat. WSDOT did not remove or preload the soft silt and peat in this area during original highway construction.

Ellingson Road/3rd Avenue SW to 15th Street SW (Algona)

The highway continues over alluvial deposits. These deposits consist of loose sand and soft, compressible silt and peat. During original highway construction, WSDOT removed a large amount of silt and peat in the area of the roadway embankments and backfilled the area with compacted fill material.

15th Street SW to South 277th Street (Auburn)

In this section, the highway is underlain by alluvium, consisting of sand and gravel, with occasional areas of soft and compressible silt, clay, or peat. WSDOT did not removed soft substrate material from this area during original highway construction.

What groundwater conditions exist in the project area?

Groundwater is found within saturated geologic units, known as aquifers. The following sections describe the aquifers present in the project area. These descriptions include the approximate depth to the water table and the direction of groundwater flow within the aquifers.

Shallow Water Table Aquifer

A shallow aquifer system completely underlies the proposed project area. The shallow aquifer is in alluvium consisting of sand, gravel, and cobbles that is interbedded with thin layers of silt, clay and peat. In the project area, the alluvium can range between zero and 300-feet thick, depending on the location (Luzier, 1969).

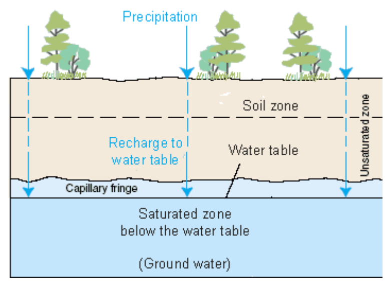
Groundwater levels in the aquifer are shallow and unconfined, with the water table occurring between about three and 25 feet below the ground surface. Seasonal groundwater level fluctuations can range up to about 10 feet (Luzier, 1969).

In the Auburn area of the proposed alignment, groundwater in the shallow aquifer flows northward in the Green River Valley (Luzier, 1969). In the Sumner area of the alignment, the groundwater flows southward into the Puyallup River Valley (Luzier, 1969), and between Auburn and Sumner, the groundwater flow direction is split. Groundwater flow directions near the project alignment are also locally affected by streams, drainages, pumping wells, and other hydraulic features.

The shallow aquifer system occupies the low-lying Green River and Puyallup River valleys. The two rivers form a valley that is elongated in a north-south direction and is bordered to the east and west by highlands. The southern portion of the proposed project alignment runs along the Stuck River in Sumner, as well as the White River. The White River parallels the project alignment south of Sumner and joins the Puyallup River directly south of the proposed project area. Unnamed creeks and drainages also border various sections of SR 167.

What is groundwater?

Groundwater is water contained beneath the surface of the ground that saturates the pores and fractures of sand, gravel, and rock formations.



Graphic Source: USGS

What is an aquifer?

An aquifer is an underground geologic formation of rock, soil or sediment that is naturally saturated with water. An aquifer contains groundwater.

What is the water table?

The water table is a subsurface level where geologic materials begin to become saturated with water.

The groundwater recharge area for the shallow water table aquifer system is inferred based on the regional topography and geologic conditions. Most recharge likely occurs by the infiltration of precipitation through the soil immediately above the aquifer, and by lateral drainage of the uplands to the east and west. To a much lesser degree, some recharge may occur by infiltration from streams, lakes, and wetlands (Woodward, 1992).

What is a groundwater recharge area?

In a groundwater recharge area, there is a substantial inflow of water from the ground surface into an underground aquifer.

Groundwater discharge from the shallow unconfined aquifer system is primarily into the Stuck River, the White River, and other local creeks in the area. Groundwater discharge may also occur in depressions or stormwater drainage features that extend to a depth below the water table.

What is a water right?

A water right is a legal authorization to use a designated amount of groundwater or surface water. The legal authorization comes in the form of a certificate issued by the Washington State Department of Ecology.

What is a water claim?

Water claims are a statement of historically beneficial uses of water. Water claims are valid until the legal use of the water is challenged, usually as a result of reduced water availability.

Upland Aquifer System

Upland aquifer systems exist within the upland around Des Moines/Federal Way to the west of the project area and Covington/Buckley to the east. Groundwater from these upland areas generally flows downward and laterally away from the uplands toward major alluvial valleys like the Green and Puyallup. Groundwater discharges from springs or seeps along the upland bluffs above the river valley, or percolates into deeper geologic units. From a regional perspective, these upland aquifers are generally considered to recharge lower groundwater aquifers.

Deeper Aquifer System

Specific information on deeper aquifer systems in the proposed project vicinity is generally lacking, but the presence of deep aquifer systems may be inferred from area well logs. The deep aquifer systems likely occur in advance outwash sand and gravel.

What is the general groundwater quality in the project area?

The groundwater quality of the shallow unconfined aquifer in the project area is generally considered to be good, with no widespread degradation of water quality, although locally degraded areas may be found (Woodward, 1992). The Washington State Department of Ecology (Ecology) reports that limited fecal coliform and dissolved oxygen problems have occurred in surface waters of streams and rivers adjacent to the project alignment. Due to the permeable nature of the alluvium substrate under most of SR 167, the highway is considered to be within an aquifer susceptibility area. King County classifies the entire area along SR 167 as an area with high susceptibility to groundwater contamination. Contamination susceptibility ratings are based on soil type, depth to aquifer, and geology (Personal communication, 2006). Specific details regarding individual contaminants, their sources, and respective concentrations are provided in the Hazardous Materials Technical Report prepared for this project.

How is groundwater used in the project area?

Groundwater is used as a potable water supply in areas along the project alignment. Particular groundwater uses have been identified from water rights records and water well records.

Groundwater Rights

The project team conducted a water rights search for the area within approximately one mile of the proposed project alignment using Ecology's Water Resource Program.[1] In this area, the groundwater rights filed with Ecology include 29 issued certificates, 135 claims, and two new applications and changed applications. In the same area, the surface water rights filed with Ecology include 78 certificates and 36 claims (Appendix A).

Public Drinking Water Wells

Thirty-four wells are registered with Ecology in Pierce County, within one mile of SR 167 in the project area. Ten of these wells are water supply wells, fifteen are resource protection monitoring wells, and nine are multiple use wells. In King County, within one mile of the project alignment, there are two group A wells (public water systems serving fifteen or more households) and three group B wells (public water systems that do not meet all the use requirements of group A wells). The

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[1] The areas searched in Ecology's Water Resource Program include: (Township 20 North, Range 4 East, sections 1, 2, 11, 12, 13, 14, 23, 24; Township 21 North,

City of Sumner, City of Algona, City of Pacific, and Federal Way Water & Sewer District also have water claims in the area surrounding the proposed project.

What regulatory programs affect groundwater resources along the project alignment?

Many regulatory programs exist to protect groundwater quantity and quality. The following regulatory designations have been assigned to aquifers in the project area and are illustrated in Exhibit 5.

Sole-Source Aquifers

The Environmental Protection Agency (EPA) may officially designate an aquifer as a **sole-source aquifer** if it is needed to supply 50 percent or more of the drinking water for a given aquifer service area, and for which there are no reasonably available alternative sources should the aquifer become contaminated" (EPA, 1995). In Washington State, Ecology administers the sole-source aquifer program. The proposed project alignment does not lie directly over a sole source aquifer. However, the boundary of the Central Pierce County Aquifer, a sole-source aquifer, is located about 0.2 miles south of the project area.

Wellhead Protection Areas

As part of the Safe Drinking Water Act, states are required to implement a wellhead protection program to guard groundwater-fed public water systems. In Washington State, the wellhead protection program is administered by the Washington State Department of Health. Requirements of the program include delineation of a "wellhead protection area for each well, wellfield, or spring" (Washington State Department of Health, 1995). A wellhead protection area is defined as that area around a well in which a contaminant could travel to the wellhead within a given time frame (typically one year, five years, and/or ten years).

Wellhead protection areas in King County include designated areas around two wells in the vicinity of the project alignment, as illustrated in Exhibit 5.

What is wellhead protection?

Wellhead protection includes actions taken to prevent groundwater from becoming contaminated, including: installing wells properly, following wellhead protection plans, assessing water quality, and abandoning wells that are no longer in use or that are damaged.

Critical Aquifer Recharge Areas[2]

The Washington State Growth Management Act requires designation and protection of critical aquifer recharge areas (CARAs) (Ecology 2005). The Washington Administrative Code (WAC) defines CARAs, in Chapter 365-190, as follows: "Areas with a critical recharging effect on aquifers used for potable water are areas where an aquifer that is a source of drinking water is vulnerable to contamination that would affect the potability of the water."

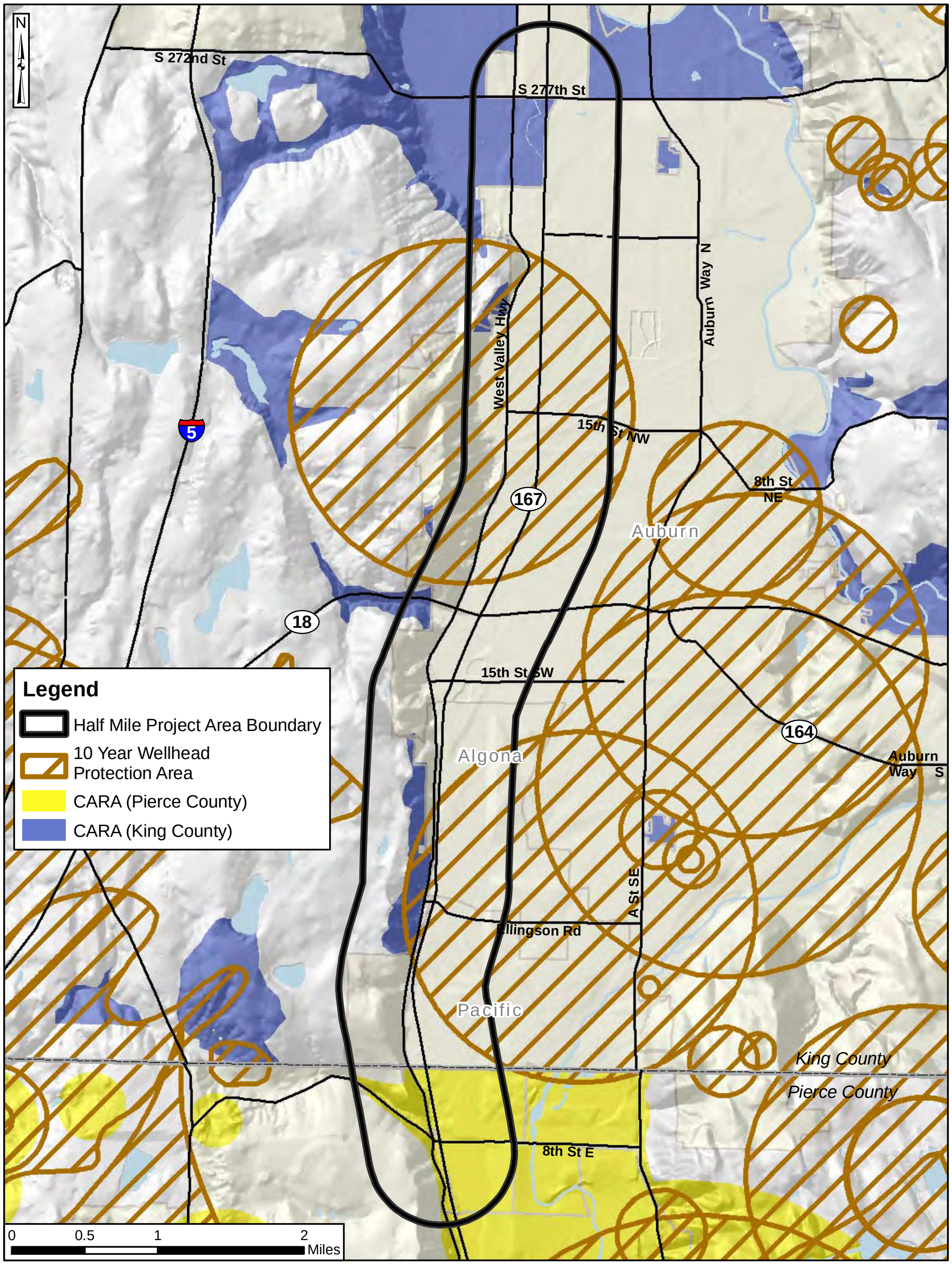
In King County, CARAs include areas above sole-source aquifers and also areas around municipal wells. Their designation is based on soil type, aquifer location, and wellhead protection areas. The proposed project area borders King County CARAs between S 277th Street and extends south for approximately 0.75 miles.

In Pierce County, the entire SR 167 alignment is in an area the County broadly defines as an aquifer recharge area. Pierce County Planning and Land Services require an aquifer recharge and wellhead protection area review for proposed projects, as outlined in Ordinance No. 2004-57s, Chapter 18E.50.

[2] Range 4 East sections 1, 2, 11, 12, 13, 14, 23, 24, 25, 26, 35, 36; and Township 22 North, Range 4 East sections 25, 26, 35, 36).

Exhibit 5

Wellhead and CARA Aquifers in the Project Area



Groundwater Management Areas

To enhance groundwater yield and improve water supply reliability, the State of Washington developed a program to protect and manage groundwater by identifying and designating Groundwater Management Areas. The management program is administered by Ecology. A Groundwater Management Area is defined in the WAC, Chapter 173-100. Generally, Groundwater Management Areas are specific geographic areas where groundwater is managed to protect the health and viability of its residents who use groundwater for drinking. Also, managing groundwater helps to preserve fish and wildlife habitat by ensuring the groundwater and stormwater recharge of streams, lakes, and wetlands for future generations.

The portion of the SR 167 project in King County is within the boundaries of the South King County Groundwater Management Area. The proposed project alignment is within an area that is considered highly susceptible to groundwater contamination. At this time, Pierce County does not have a groundwater management plan for the project area.

What is the tectonic setting and seismic history of the area?

The project area is in a moderately active tectonic province. During the 170-year historical record in the Pacific Northwest, numerous earthquakes of low to moderate strength occurred in the area as well as occasional earthquakes of high strength.

The tectonics and seismicity of the area are the result of ongoing, oblique subduction of the Juan de Fuca Plate beneath the North American Plate. This area is called the Cascadia Subduction Zone. The convergence of these two plates results in three earthquake source zones. These source zones include a shallow crustal zone, the Cascadia Subduction Zone, and a deep subcrustal zone.

Shallow crustal seismicity appears to occur diffusely beneath the Lowland. Until recently, shallow seismicity was not generally correlated with known or inferred faults. However, geologic evidence developed since the 1990s suggests that the geophysical lineament/crustal block boundaries (e.g. the Seattle Fault Zone and Tacoma Fault Zone) beneath the Lowland are capable of producing shallow crustal earthquakes of magnitudes up to 7.5 on the Richter Scale[3] (Johnson et al. 1999). The December 15, 1872, North Cascades earthquake likely had a shallow crustal origin. This earthquake appears to have been the largest recorded historical earthquake in the Pacific Northwest, with an estimated magnitude greater than 7.

Although the area is presently quiet, the Cascadia Subduction Zone is considered a potential earthquake source area. No large earthquakes occurred in this zone according to the written history of the region. However, geologic evidence suggests that coastal estuaries experienced rapid subsidence at various times within the last 2,000 years. It is possible that large earthquakes (magnitude 8 or 9) on the Cascadia Subduction Zone caused this subsidence (Atwater, 1996). Geologic evidence suggests that recurrence intervals for these large earthquakes could range from about 400 to 1,000 years. Geologic evidence and written records appear to show that a magnitude 9 earthquake on the Cascadia Subduction Zone once caused a tsunami in Japan. Japanese records of the tsunami, coupled with data on tsunami travel times, indicate that the earthquake likely occurred on the evening of January 26, 1700 (Satake, 1996).

The deep, subcrustal zone has also been correlated with recent seismic activity. The location of most of these earthquakes were in the subducted Juan de Fuca slab beneath the Lowland, at depths greater than 32 miles, and include the largest historic earthquakes to affect the project area. The magnitude (M_s) 7.1 Olympia earthquake of April 13, 1949, the magnitude (m_b) 6.5 Seattle-Tacoma earthquake of April 29, 1965, and the recent February 28, 2001, magnitude (M_w) 6.8 Nisqually earthquake all originated in the deep, subcrustal zone.

Exhibit 6

Example of Liquefaction

Washington road failure due to liquefaction during the Nisqually Earthquake in 2001

[3] Richter magnitudes are based on a logarithmic scale (base 10). This means that for each whole number up the Richter scale, the amplitude of the ground motion recorded by a seismograph goes up ten times.

What are geologic hazards? Do any exist in the project area?

Geologic hazards are geologic processes that can damage human construction. Geologic hazards in the project area include faulting, liquefaction (see Exhibit 7), soft soil ground motion amplification, landsliding, lahars, soft ground settlement, and erosion.

Faulting

The nearest known potentially active fault is the Tacoma Fault. Recent studies (Brocher et al., 2001) suggest that the fault could be a steep, north dipping reverse fault. This east-southeast-trending fault passes through Commencement Bay and terminates approximately five miles from the project area. The fault locations are largely estimated from overwater seismic reflection profiles within Puget Sound. The locations of the fault on land are extrapolated and not precisely known. Consequently, the Tacoma Fault may extend to the project area. Recent United States Geological Survey (USGS) explorations on suspected Tacoma Fault scarps identified about one foot of displacement in Vashon Till (Sherrod, 2003), indicating that the fault has been active in the last 13,000 years.

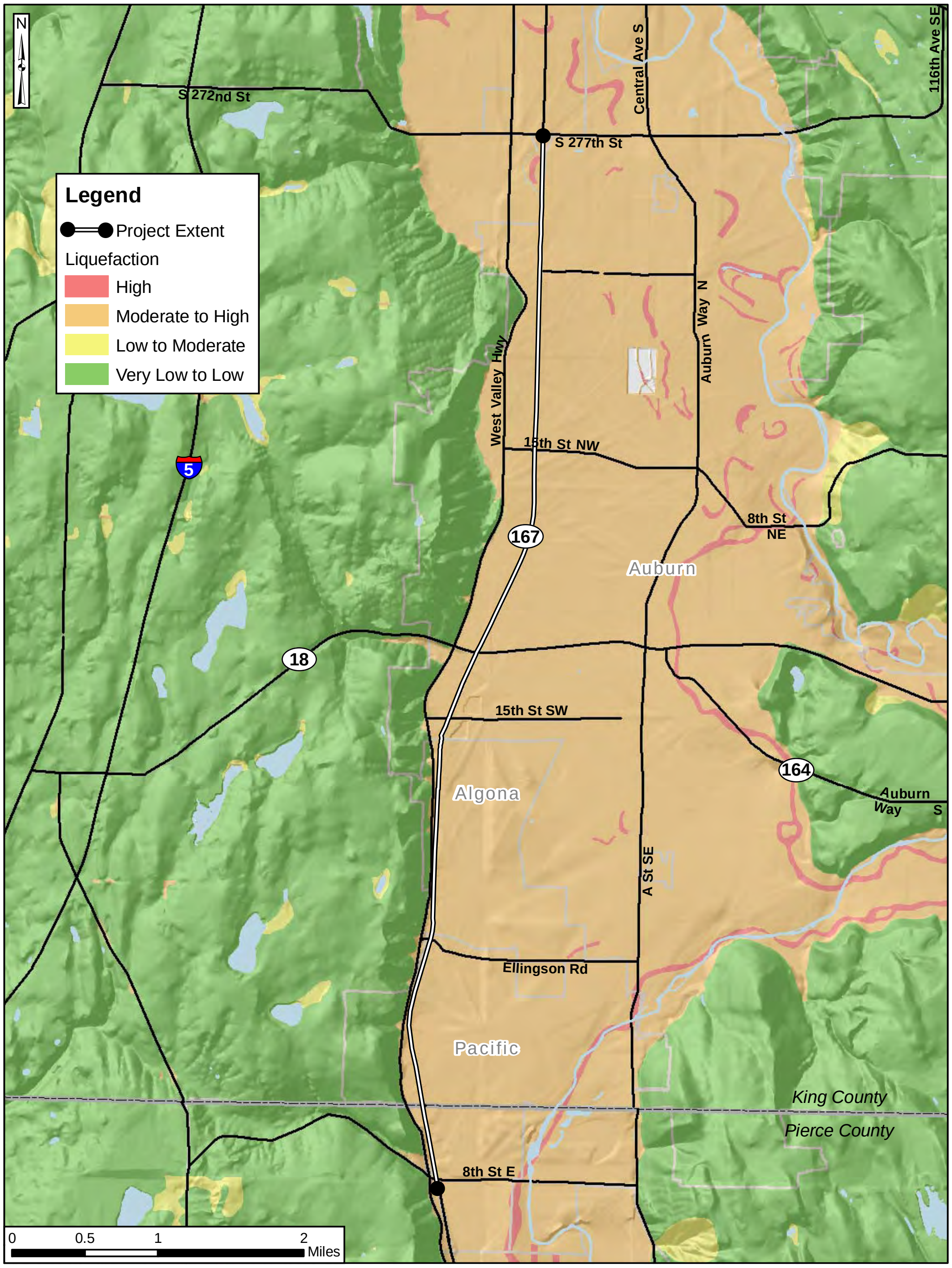
Liquefaction

Soil liquefaction is a phenomenon in which layers of loose sand below the water table behave like a liquid when subjected to intense shaking. As a result of the reduced soil strength during liquefaction, lateral spreading (ground movement on gentle slopes), landsliding, and ground settlement may occur.

Soil units susceptible to liquefaction include loose fill and alluvium, which are present in the Green and White river valleys. According to Palmer et al. (1995), most of the project area is in an area of moderate to high liquefaction risk. The locations of liquefaction hazard areas are illustrated in Exhibit 7.

Exhibit 7

Liquefaction Hazards in the Project Area



Soft Soil Ground Motion Amplification

The type of near-surface soil can significantly affect the localized level of ground shaking experienced during an earthquake. Relatively soft, cohesive soil, like silt, clay, or peat, can increase the intensity of ground shaking. Significant deposits of peat and soft silt have been observed and mapped in the project area; therefore, ground motion amplification may occur during an earthquake in these areas.

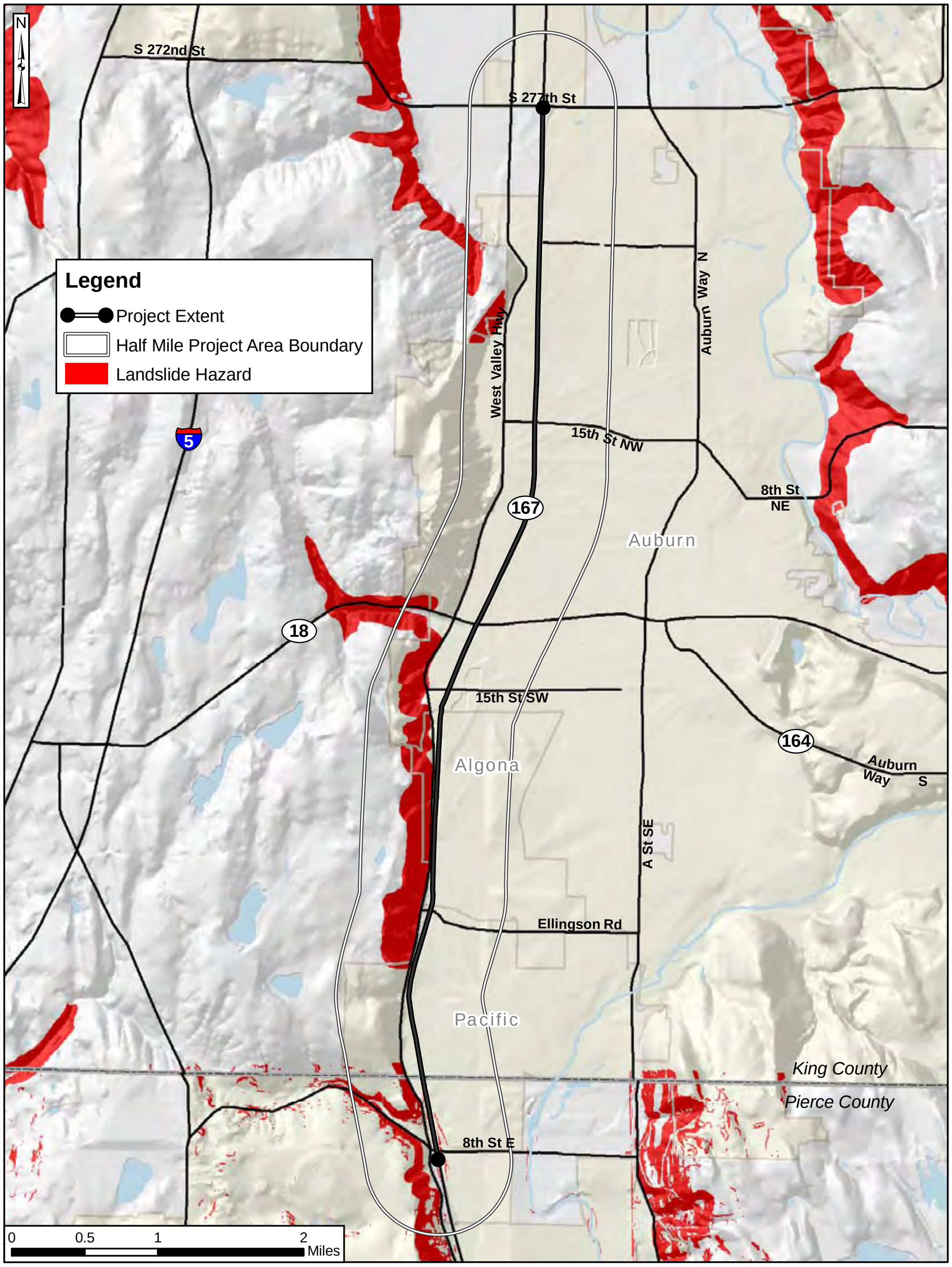
Landslides

Potential landslide hazard areas in the project area include manmade embankments/slopes and the steep bluffs bordering the lower river valley. The SR 167 roadway is built on embankments throughout most of the project area, with maximum embankment heights reaching approximately 20 feet. Exhibit 8 illustrates natural slopes that are potential landslide locations.

In general, most of the manmade and natural slopes in the project area appear stable during normal conditions, but may have a high risk of failure during earthquakes. The direct risk from natural landslide hazards is relatively low in the project area, because SR 167 is primarily located on level or gently sloping ground. An indirect risk from landslide hazards exists in the project area where the highway is closest to the bluffs (e.g., from Ellingson Road to 15th Street SW). In this area, rapidly moving landslides from the bluffs could flow to and potentially onto SR 167.

Exhibit 8

Landslide Hazards in the Project Area



Lahars

A lahar is a gravity-driven mixture of sediment and water that originates from the flanks of a volcano. Such flows are similar to debris flows (i.e., rapidly moving, fluid landslides). Lahars that could affect the project area are very large and would initiate at high elevations on steep slopes, in loose, weak material on volcanoes. Lahars represent a significant hazard for communities downstream of volcanoes because of their ability to travel long distances quickly, transport large debris such as logs and boulders, and bury floodplains under tens of feet of sediment.

Mount Rainier has produced numerous large lahars during the past 10,000 years that flowed down the White River as far as the City of Auburn and the proposed project area. The most well-documented of such lahars is the Osceola Mudflow, which left a deposit up to 40 feet thick at Auburn approximately 5,700 years ago (Dragovich et al., 1994; Vallance and Scott, 1997).

USGS hazard maps generated from field evidence and numerical models suggest that the valley floor along the project area is at risk for future inundation by large lahars from Mount Rainier (Hoblitt et al., 1998; Iverson et al., 1998). If such a lahar were to occur today, it could bury significant areas of the project area and damage structures in its path.

Soft Ground Settlement

Soft soil deposits have the potential to settle when subjected to loads. Relatively soft, cohesive soil, like silt, clay, or peat, is found in the alluvium along the project area. Constructed highway elements, such as embankment fills, paving, or shallow foundations, have the potential to cause up to several feet of settlement if built over these types of soft, compressible soils.

Erosion

In the project area, Soil Conservation Service (SCS) maps show a low overall erosion hazard. The areas more susceptible to erosion are the steep bluffs bordering the valley, small stream and creek ravines, and the manmade highway embankments. During extended-duration or large-volume precipitation events, runoff from the highway or uplands could erode the bluffs or embankments, leading to slope instability and potential highway damage. Creeks and rivers could also overflow their banks, eroding the highway embankments.

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CHAPTER 3 POTENTIAL EFFECTS OF THE PROJECT

The following sections describe possible direct, indirect, and cumulative effects of the project. These effects are related to the construction and/or operation of the facilities associated with the project, which includes bridge widening, fill embankments, and retaining walls.

> *Direct effects* are defined as effects that have a direct, cause-and-effect relationship to the proposed action.
>
> *Indirect effects* are defined as effects that are "caused by an action and are later in time or farther removed in distance but are still reasonably foreseeable" (Federal Regulation on the Protection of the Environment - 40 CFR 1508.8). These effects, which usually result from the initial action, include changes in land use, water quality, social issues, and population density.
>
> *Cumulative effects* are those that "result from incremental consequences of an action when added to other past, present, and reasonably foreseeable future actions." The cumulative effects of a project may be undetectable when viewed in the individual context of direct or indirect effects. However, cumulative effects can add to other disturbances and eventually lead to a measurable environmental change.

Cumulative effects include effects from a proposed project that, when combined with neighboring projects, may lead to a cumulative effect on the environment.

How will construction activities affect the geology, soils, and groundwater?

Direct Effects

The effects of construction activity are short term, and usually occur during construction. Anticipated construction activities for this project include fill placement for retaining walls and embankments, cutting into existing embankments to allow for widening, foundation construction for retaining walls and bridges, and bridge widening. These construction effects, discussed below, will result in short-term geology, soils, and groundwater-related effects to the project area.

Erosion and Sediment Control

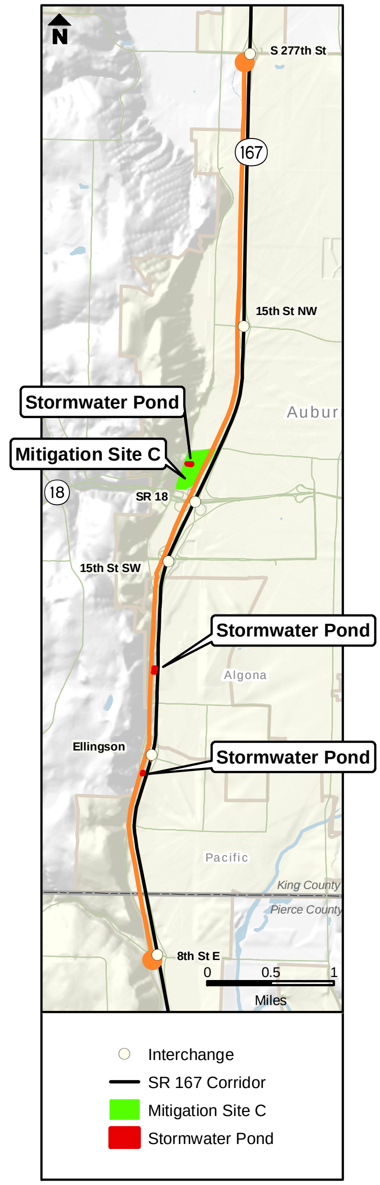
Construction of the HOT lanes will require land clearing, removal of topsoil, and other site preparation work. Because the project area is within the existing SR 167 corridor, construction will create fewer effects to the environment than those that occurred during original grading and construction in the 1970's.

Nearly all of the highway widening will occur on the existing fill WSDOT placed in the 1970's during the original SR 167 construction. Only the stormwater detention ponds and floodplain storage area, Site C in the Mill Creek subbasin, will be outside the historical fill areas. The construction of Site C will require excavation of 38,000 cubic yards of material. Excavation will be isolated from surface waters until complete and the connection to Mill Creek will be the final action once onsite soils are stabilized with erosion control Best Management Practices (BMPs) or established vegetation. The location of the proposed ponds and storage Site C illustrated in Exhibit 9 as Site C.

Areas beneath proposed fill will be cleared of vegetation and debris, and stripped of organic topsoil. The resulting debris will be removed from the project area or stockpiled for later use in landscaped areas.

Areas disturbed during construction will be subject to increased erosion. These areas will have high erosion potential in the presence of surface water, or if exposed during the rainy season. Surface water flow across exposed soil could remove sediment and deposit it in downslope areas. The amount of erosion and sedimentation will depend on the amount of soil exposed and/or disturbed, weather, surface water and groundwater conditions, and erosion control measures implemented. Eroded soil could be carried into stormwater drains, into existing culverts, into adjacent water bodies, and/or onto adjacent properties or streets.

Exhibit 9
Site C Stormwater Detention and Flood Storage



Within construction areas, the tires and tracks of heavy equipment could sink into the soft surface soil if no work pad is present. If a tire wash is not provided, construction vehicle tires could carry soil onto roadways when leaving construction areas.

Groundwater quantity and quality could be impacted by various construction activities. Groundwater quality could be degraded by spills or inadvertent discharges during construction. Stormwater control measures could temporarily reduce recharge to the underlying aquifers. Construction dewatering activities for excavations will temporarily lower the water table, reducing groundwater quantity.

Cuts into Existing Slopes

Construction will require permanent cuts into existing slopes to allow for construction of stormwater treatment ponds. During construction, soil exposed in slope excavations may be susceptible to erosion and possible failure until vegetation is established.

Foundations

Several new structures are proposed for the project, including retaining walls, a noise wall, bridges, and sign structures. The appropriate foundation type to support the new structures depends on many factors, including the subsurface conditions, types of loads that the structure must resist, environmental concerns, surface constraints, etc. For example, shallow foundations may not be practical because of space constraints, and vibration and/or noise concerns may prevent using driven piles. WSDOT will use appropriate techniques given specific circumstances during project construction to reduce effects. Such techniques may include the following:

Shallow Footings

Temporary excavations for shallow footings could slough and affect nearby areas. If the proposed footings are close to existing structures or utilities, lateral movements or settlement of these structures or utilities could occur. Perched groundwater could promote soil caving and erosion.

Drilled Shafts

Drilled shafts will be installed with equipment that causes relatively little vibration. In general, drilled shafts can be installed using the open-hole method, with the excavated hole dry, or filled with water or drilling slurry. Caving or sloughing of soil within the open-hole excavations will affect adjacent structures and buried utilities. Alternatively, a temporary casing could be pushed, vibrated, or driven into the hole to support the shaft soils.

Driven Piles

Pile driving will result in noise and vibration effects to the project area. The vibration caused by driving the pile through the soils will likely affect nearby facilities. These effects could include settlement, slope failures, cracking of pavements, and damage to utilities and/or structures.

Fill Embankments

Fill embankments constructed over fill, peat, or alluvium could settle. The settlement magnitude and extent will depend on the subsurface conditions and the size and height of the fill.

Drainage in Construction Areas

During construction, poor drainage practices could result in surface water flowing onto unstable slopes. This could result in landslides or erosion that affects adjacent properties.

Pavement

Construction vehicles may cause settlement, potholes, cracks, and other roadway distress to portions of the existing roadway. These types of distress could occur if the existing roadway pavement section is not thick enough to support construction vehicles.

What are the likely Indirect Effects of construction activities?

With the implementation of BMPs, the construction activities likely would not lead to indirect effects in the geology or soils. Correctly implemented, the BMPs will reduce indirect effects to the groundwater and related natural resources in the project area. BMPs are described in Chapter 4.

What are the likely Cumulative Effects of construction activities?

There likely would not be cumulative effects on the geology and soils, as these resources are exposed only during construction activity. Water quality elements in the surface water drainage systems will likely prevent any cumulative effects on groundwater quality. Increasing the impermeable ground surface could result in a decrease in groundwater recharge.

How will project operation affect the geology, soils, and groundwater?

Direct Effects

Long-term geology, soils, and groundwater-related effects could occur during normal operations of SR 167, depending on the design. The project will be designed based on the available subsurface information, design procedures and criteria approved by WSDOT, and the existing site conditions. If subsurface conditions at the site are different from those disclosed during the field explorations, or site conditions change during the life of the project, future effects to the site could occur.

Seismic Considerations

An earthquake could trigger landslides on steep slopes and settlement or liquefaction in alluvial deposits. Slopes that could slide or slough during an earthquake include new fill embankments and cut slopes. Alluvial deposits that are potentially susceptible to liquefaction during a seismic event underlie the project area. If liquefaction occurs beneath or alongside foundation structures, loss of bearing capacity, settlement, and lateral displacement may occur. If liquefaction occurs beneath proposed embankments, slope instability and settlement could damage the existing roadway and adjacent facilities.

Cuts into Existing Slopes

Construction activities will require that cuts into existing slopes be made for stormwater treatment ponds. These cuts may experience erosion and surface sloughing over the lifetime of the project. The degree of erosion experienced will depend on near-surface soil types, weather conditions, potential seismic events, vegetation, surface drainage, and other causes.

New Fill

Widening to accommodate the new HOT lane will require placement of structural fill. As discussed previously, even though most fill will occur on top of the fill placed in the 1970's, some fill will be placed toward the existing toe of slope where the existing fill is the shallowest. The new fill will likely have steeper side slopes than the existing fill. Fill, peat, and alluvium deposits could settle because of new fill loads. Granular deposits (fill and alluvium) will settle essentially as the load is applied. Soft or cohesive soil (alluvium and peat) will settle during the first few years after construction, which could cause pavement distress, drainage problems, and other utility problems. In areas where soil deposits containing numerous organics are present (peat and organic alluvium), secondary compression could result in long-term, ongoing settlement. Settlement could damage utilities near or beneath the proposed fills.

Bridge Structures

Widening existing overpasses and underpasses within the project area will involve installing new foundations. Once constructed, no geology, soils, or groundwater-related direct effects are anticipated for the project.

Permanent Drainage

Permanent drainage facilities for slopes, walls, fills, and the like, may result in increased water flow to existing culverts or drainage ditches. Sediment from slope erosion may accumulate in ditches, culverts, swales, and other drainage features. Water that overflows or is incorrectly directed onto slopes or properties could cause erosion, landslides, and other effects. Permanent drainage could decrease groundwater recharge and lower the water table.

What are the likely Indirect Effects of the project operations?

The proposed project includes standalone transportation improvements and will not have indirect geology, soils, and groundwater effects. This project would not create adverse land use effects. Specifically, within the context of the State and local agency Growth Management Act policies, this facility is beneficial in relief of congestion from the local land use growth. An additional benefit is that the project supports the multi-modal goals of regional transit agencies.

What are the likely Cumulative Effects of the project operations?

Anticipated cumulative effects for the proposed project include:

Erosion and Sediment Transport

The cumulative effect of sediment transport from neighboring projects could affect sediment deposits into streams.

Landslides

If construction takes place near the slopes of waterway banks, loads from structures or fills on adjacent properties may lead to slope instability and increased landslide potential.

Ground Settlement

If structures or fills of adjacent projects are placed near the fills of the proposed project, settlement area and magnitude could increase and result in damage to nearby utilities and structures.

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CHAPTER 4 MITIGATION MEASURES

What mitigation measures are proposed to avoid or minimize the effects from project construction?

The proposed project will be constructed in accordance with WSDOT guidelines. The following sections address mitigation for each of the construction effects discussed above.

Erosion and Sediment Control

Construction BMPs will be implemented to protect water resources and reduce erosion from areas with cuts, fills, and excavations. These BMPs will aid in containing sediment onsite. The BMPs implemented could include:

- Construction staging barrier berms, filter fabric fences (silt fences), temporary sediment detention basins, slope covering, and other common methods.
- Erosion control measures suitable to the site conditions will be included as part of the project alternatives design.
- TESC plans will be prepared for approval in accordance with BMPs included in the current WSDOT Highway Runoff Manual.
- Erosion control measures will include vegetative controls, structural controls, and stormwater treatment.
- Other controls that will be implemented include restriction of some work activities to the dry season and limiting access to the site, as appropriate.

Vegetative Controls

Vegetative controls will be implemented to decrease erosion by introducing vegetation that acts to hold soils in place. Specific measures will include:

- Areas disturbed during construction that will not be paved or otherwise permanently covered, will be revegetated to reduce erosion.

- Revegetation methods will include covering cleared or graded areas, and excavation or embankment slopes with netting, mulching, or hydroseeding.

Structural Controls

Structural controls consist of artificial means to prevent sediment from leaving the construction area. Specific mitigation measures may include:

- Parking and staging areas for vehicles and equipment will be covered with a gravel work pad to prevent the disturbance and erosion of the underlying soil.
- Silt fences will be placed around disturbed areas to filter sediment from unconcentrated surface-water runoff.
- Straw bales will be placed in paths of concentrated runoff to filter sediment.
- Temporary ditches, berms, and sedimentation ponds will be constructed to collect runoff so that entrained sediment could settle out of the water prior to being released from the site into drainages, streams, or wetlands.
- Tires and tracks on heavy equipment will be cleaned, as appropriate, before they leave the site to retain sediment on site.
- Truck loads will be covered to mitigate sediment deposit onto roadways.

Stormwater Treatment

Proposed stormwater mitigation measures will comply with temporary stormwater design and treatment procedures based on the current version of the WSDOT Highway Runoff Manual. Specific measures will also include:

- The National Pollutant Discharge Elimination System (NPDES) guidelines will be followed as administered by Ecology.

- A Stormwater Site Plan and a Temporary Erosion and Sedimentation Control (TESC) plan will be approved prior to construction in accordance with the WSDOT guidelines.
- The erosion and sediment control measures will be in place before demolition, clearing, grading or construction.

Groundwater

Impacts to groundwater quality and quantity will be reduced with the use of standard BMPs for construction activities. Specific measures will include:

- In areas of the project that intersect Wellhead Protection Areas (Exhibit 5), WSDOT will be required to take added measured during construction to protect these areas, such as prohibiting refueling operations and fuel and chemical storage.
- Stormwater management in the Wellhead Protection Areas will be coordinated with the local Wellhead Protection agency.

Cuts into Existing Slopes

The potential for slope instability and erosion on cut slopes during construction will be reduced by using BMPs outlined by WSDOT. Specific measures will include:

- Cut slopes and cut walls will be studied and designed by experienced structural and geotechnical engineers.
- Potential landslide activity and erosion may be reduced by intercepting surface water runoff and conveying it through a tightline to the bottom of the slope at a suitable outlet. Additional BMPs may consist of covering the slope with plastic, installing drains, and/or restricting construction to dry weather. As soon as practical during or after construction, vegetative controls should be installed.

Foundations

Pre-construction surveys may be required to monitor and mitigate potential damage to adjacent structures. Instrumentation can be installed in some areas if particularly sensitive structures are present, or if construction may cause vibration or settlement. Additionally, monitoring instruments before and during construction may identify if adverse effects are being experienced by these structures and allow corrective action before damage occurs.

Shallow Footings

During shallow spread footing construction, shoring and adequate drainage will be implemented in areas where unstable soil may be present. Properly designed shoring will mitigate potential settlement and lateral movement of adjacent structures and utilities. Proper design and operation of dewatering systems will reduce the impact of lowering the water table on groundwater quantity.

Drilled Shafts

- During installation of drilled shafts, potential caving or soil erosion in the excavated holes will be mitigated by casing through the upper unstable soils.
- Following drilling and concreting of the drilled shaft, the casing will be removed.
- If needed, areas around the concrete shaft will be grouted to fill potential voids. If the casing cannot be removed, it would be left in place; however, this is not common practice as it reduces the drilled shaft load capacity.
- Adequate drainage will be provided to further mitigate soil instability and erosion.

Driven Piles

To mitigate noise and vibration, low vibration and noise pile-driving equipment will be selected. Specific measures where appropriate will include:

- Predrilling prior to pile driving will take place, if possible, to reduce vibration levels.
- The existing bridge structure that will be widened will be monitored to mitigate potential damage.
- Monitoring instruments before and during construction will identify if vibration and noise levels are approaching or exceeding damage thresholds. If this occurs, pile driving will be stopped until measures are implemented to reduce vibration and noise.

Fill Embankments

- In areas where long-term settlement is anticipated, mechanically stabilized earth (MSE) wall systems may be used to retain the fill because MSE wall systems are more tolerant of settlements than standard fill.
- Lightweight fill material may be used to reduce the load on compressible soil in some areas, thereby reducing settlement. Lightweight fills could include Expanded Polystyrene (EPS) blocks, foamed cement, and other lightweight materials that would be stable over the life of the project.

Drainage in Construction Areas

- Fill and pavement areas will be sloped to prevent ponding of water and softening of subgrade soils.
- Drainage water from construction areas will be directed into suitable drainage features such as culverts and detention ponds.
- Water will be directed away from existing slopes, excavations, or subgrade areas for fill and/or pavement.

Pavement

Portions of existing roadways identified with inadequate pavement to handle construction vehicles will be reinforced. Alternatively, construction vehicles will be routed onto temporary haul roads constructed to handle the vehicle loads, if necessary.

What mitigation measures are proposed to avoid or minimize effects from project operation?

The geology, soils, and groundwater-related features for the proposed project will be evaluated by an experienced geotechnical engineer and hydrogeologist. The engineer will provide design recommendations based on subsurface conditions encountered in field explorations conducted in the project area. These design recommendations will take into account the operation direct effects of the proposed project alternatives and provide for mitigation for these effects.

To define subsurface conditions for the project, geotechnical studies will be completed to support the preliminary design of the project. These studies will include:

- Collecting subsurface information to evaluate the capacity of foundations to support new structures.
- Estimating settlement of the bridge foundations, walls, and embankment fills.
- Designing appropriate measures to mitigate the settlement.
- Evaluating liquefaction potential and its extent, and designing measures as needed to mitigate liquefaction in the project area.
- Evaluating the potential for stormwater infiltration facilities.
- Evaluating the potential for infiltration of stormwater and water from permanent drainage systems to maintain aquifer recharge and water table elevation.

Seismic Considerations

The project features will be designed considering the seismicity of the site and AASHTO and WSDOT criteria for seismic design. Where needed, specific measures to mitigate for potential liquefaction of alluvium deposits will include:

- Designing the foundation elements beneath structures for reduced soil shear strengths and potential vertical and lateral ground displacements.
- Soil improvement techniques would occur beneath embankments that support the traveled way, and may include densification by vibration (e.g., deep dynamic compaction, vibratory probe); densification by displacement and reinforcement (e.g., vibro-replacement stone columns, compaction grouting); grouting and admixtures (e.g., jet grouting, deep mixing); and vibration and drainage (e.g., earthquake drains).
- Appropriate ground improvement techniques will be selected depending on soil type, level of improvement required, area and depth to be improved, proximity of adjacent existing structures, and cost.

Cuts into Existing Slopes

Mitigation for the proposed cuts includes performing proper design, defining the location and extent of unstable soil, and using proper construction procedures. To mitigate slope instability in cut areas, the following measures will be implemented where needed:

- Slope angles will be designed based on the soil characteristics in the cut.
- Vegetation will be nurtured on the slopes until established to mitigate surface erosion and sloughing.

New Fill

To reduce fill effects, retaining walls may be used to widen the roadway for the new HOT lanes. To mitigate specific fill effects, the following measures will be implemented:

- Approach walls may consist of settlement-tolerant MSE walls.
- Undesirable settlement may be reduced by using lightweight fill. (Lightweight fill material will reduce additional vertical stress on underlying compressible soils).
- Undesirable settlement due to secondary compression of peat and organic soils will require that unsuitable soils be removed and replaced and/or by performing ground improvements.
- Existing utilities located beneath or near proposed new fill will be relocated or protected, if the proposed fill load and consequent settlements would cause damage to the utilities.

Permanent Drainage

Permanent drainage facilities for slopes, walls, fills, and the like, will be designed for the anticipated stormwater discharge volumes. Mitigation for stormwater runoff is further discussed in the Draft Type A Hydraulic Report (RW Beck, 2007). Specific measures will include:

- Permanent drainage systems will be installed so that stormwater does not overflow and/or is not directed onto slopes or other areas that may be sensitive to erosion or landsliding.

CHAPTER 5 REFERENCES

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Department of Ecology map of well logs in Pierce County, 1 mile around SR 167

Department of Ecology water rights

Environmental Protection Agency sole-source aquifer map, Pierce County.

King County Potentiometric surface map

King County map of wells, classified as A, B, and C wells

King Co. map of susceptibility to groundwater contamination

King Co. map critical aquifer recharge areas

King Co. map of 6 mo-10 year wellhead protection areas

Pierce Co. Dept of Planning & Land Services Aquifer Recharge Area Map

Pierce Co Health dept. wellhead protection areas

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