SR 519 Intermodal Access Project Phase 2: South Atlantic Corridor

Geology and Soils Discipline Report

Prepared for

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Federal Highway Administration

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Acronyms and Abbreviations

	A
AASHTO	American Association of State Highway and Transportation Officials
	B
bgs	below ground surface
BMPs	best management practices
	E
Ecology	Washington State Department of Ecology
	G
g	percentage of gravity
GIS	geographic information system
	M
M	moment magnitude
	S
SFZ	Seattle Fault Zone
SPTs	standard penetration tests
SR	State Route
	U
USGS	United States Geological Survey
	W
WDNR	Washington State Department of Natural Resources
WSDOT	Washington State Department of Transportation
	Y
yr B.P.	years before present

Glossary of Technical Terms

Aquifer – A layer of permeable rock, sand, or gravel through which groundwater flows. Aquifers often supply water to wells and springs.

Densification – To make soft or loose soils stronger by increasing the density of the soil. Various methods of densification can be used, including compaction, preloading, vibration, and dewatering.

Fault zone – A group of fractures in soil or rock where there has been displacement of the two sides relative to one another. The relative movement can be predominantly horizontal, vertical, or inclined.

Ground shaking – The oscillation or vibration of earth materials resulting from natural causes, such as an earthquake or volcanic activity, or from human activities, such as construction or vehicular traffic. The level of ground shaking can range from being barely perceptible to large enough to damage structures supported on the ground.

In-place soil mixing – Mixing the soil in-place with a substance, such as concrete, that causes the soil to become stronger and less permeable. In-place soil mixing is often used to reduce the liquefaction potential for loose, saturated, granular soils.

Lateral spreading – Lateral movement of level or near level ground associated with liquefaction of soil during an earthquake. The amount of movement can range from a few inches to many feet depending on the size of the earthquake, the liquefaction potential of the soil, and the geometry of the location.

Liquefaction – A loss of strength in saturated, sand-like soils due to earthquake-induced ground shaking. This phenomenon usually occurs in loose sands and non-plastic silts located below the water table; however, in some less common cases loose gravels and sensitive clay-like soils can also liquefy. The loss in strength of liquefied soil can lead to slope instabilities and foundation bearing failures. Liquefaction is usually accompanied by permanent settlement as a result of soil densification from the liquefaction process. The Washington Division of Geology and Earth Resources has developed maps showing potential liquefaction zones in Washington.

Plasticity – The condition of being soft and capable of being molded and retaining its change in shape after being bent, stretched, or squeezed. Geotechnical engineers use the term plasticity as a method of describing the engineering characteristics of the soil.

Pleistocene - Geologic epoch: the epoch of geologic time, about 1.6 million to 10,000 years ago, characterized by the disappearance of continental ice sheets and the appearance of humans.

Sand boil – An accumulation of sand, commonly in the form of a low mound, produced by the liquefaction of loose, saturated sand during a seismic event.

Seiche – The periodic oscillation of water within restricted basins, such as lakes, bays, and reservoirs. The waves generated by these oscillations can attain heights of tens of feet (City of Seattle, 1992), though in most cases the oscillations are a few inches to a few feet.

Subsidence – The sinking of land resulting from natural shifts or human activity, frequently causing structural damage to buildings. Subsidence can result from earthquakes, as well as withdrawal of water or petroleum from the earth.

Subduction zone – The place where two lithospheric plates (the crust and the uppermost mantle of the earth) come together, one riding over the other.

Tsunami – A sea wave of local or distant origin that results from large-scale seafloor displacements associated with large earthquakes, major submarine landslides, or exploding volcanic islands. The sea wave can range in height from a few inches to many tens of feet where it reaches landfall. The consequence of a tsunami can be flooding of a shoreline as the wave travels onshore. In addition to flooding, the sea wave can produce large wave forces on structures located within the path of the wave.

Tsunami inundation zone – An area of land that is predicted to be covered with water if a tsunami were to occur in the area. The Washington Division of Geology and Earth Resources has developed maps showing potential inundation zones in Washington.

Vibratory ground motion – Shaking of the ground. Vibratory ground motion can be caused by earthquakes, operation of construction equipment, or the daily activity of man.

Summary

What is the proposed project and why is it needed?

The Washington State Department of Transportation (WSDOT) proposes to construct improvements to State Route (SR) 519 in Seattle as Phase 2 of the SR 519 Intermodal Access Project. The project would include three components:

- A proposed new Interstate 90 (I-90) off-ramp to South Atlantic Street (I-90 off-ramp)
- A proposed new South Royal Brougham Way railroad overpass (BNSF Railway overpass)
- Roadway widening along the existing South Atlantic Street east of First Avenue South and improvements to the intersection of First Avenue South and South Atlantic Street

SR 519 is an important thoroughfare for cars, trucks, and pedestrians in Seattle's South of Downtown (SODO) district. In 2004, WSDOT opened Phase 1 of the SR 519 project, consisting of the South Atlantic Street overpass (Edgar Martinez Drive) and a new on-ramp from South Atlantic Street to I-5 and I-90. The Proposed Action (SR 519 Intermodal Access Project – Phase 2: South Atlantic Corridor) would complete the SR 519 project by providing a direct westbound connection from the I-5/I-90 freeway system to the Seattle waterfront and Port of Seattle. Currently, westbound traffic from the freeway exits at Fourth Avenue South and follows a circuitous route to South Atlantic Street to cross safely over the BNSF Railway tracks located just east of Safeco Field and Qwest Field. Vehicular and pedestrian traffic on South Royal Brougham Way must use an at-grade railroad crossing. New

roadway structures are needed to allow vehicles and pedestrians to reach their destinations safely, quickly, and directly.

The Proposed Action would connect the existing westbound off-ramp from I-5 and I-90 to the current South Atlantic Street overpass, and it would construct improvements at the intersection of First Avenue South and South Atlantic Street and widen South Atlantic Street to accommodate traffic along this new route. A grade-separated crossing over the railroad tracks at South Royal Brougham Way would also be built.

This project would increase traffic mobility and safety by improving connections between Interstates 5 and 90 and Port of Seattle terminals, the Washington State Ferries terminal at Colman Dock, waterfront commercial interests, and the stadium area. The project would also allow people to walk more safely to and from the stadium area.

What is the affected environment?

The affected environment for geology and soils consists of topography, geology, soil characteristics, groundwater conditions, and existing and potential aggregate sources. Geology is further broken down into regional and site geology.

Some of these elements, such as topography and soil characteristics, could be affected by the Proposed Action. Others, such as seismicity, would not change as a result of the project and therefore would not be affected. However, the potential for seismicity creates a hazard that could potentially affect public safety if adequate planning were not carried out during design.

Geology and soil conditions have an important influence on how the project is constructed and how it performs over the long term. For this reason, this Geology and Soils Discipline Report covers all of the elements listed above to confirm that adverse effects *because* of the project or *on* the project would not occur or, if present, could be mitigated during design and construction.

How were the effects of the project on geology and soils analyzed?

The project team determined the effects of the Proposed Action primarily through a qualitative review of the project features relative to the regional and local geology, soil types and consistency, and groundwater conditions within the study area. They also conducted a visual reconnaissance of the study area.

What geology and soils effects could occur during construction of the project, and what mitigation is proposed?

Construction of the Proposed Action could have both direct and indirect effects related to geology and soils. The distinction between these two types of effect relates to the area being affected and the timing of the effect. Direct effects are those that occur in the same place and at the same time as construction of the Proposed Action. Generally, these are within the project footprint, and they occur as work is being done. Examples of direct effects during construction could include:

- Exposure of surficial soils during construction, leading to sediment transport away from the project footprint during heavy rainfalls and surface-water runoff
- Construction of the approach fill embankment between Third Avenue South and Fourth Avenue South, resulting in additional loads to the subgrade and settlement of the soil below and adjacent to the fill
- Excess soils from excavations for bridge foundations and from removal of unsuitable soils where embankments and roadways are constructed, requiring offsite disposal
- Demolition debris that results when existing bridges and roadways are modified or replaced as part of the new construction, again resulting in offsite transport and disposal

Several other direct effects might also occur during construction of the Proposed Action, such as:

- Settlement of soils resulting from vibrations caused by ground improvement, pile driving, or other similar activities
- Earth spoils and sediment-laden water that is produced if ground improvement is required to mitigate the potential for liquefaction around structure foundations or at structure approaches
- Quantities of contaminated soils that result from excavation of foundations for roadways or structure foundations in areas that have been contaminated by past activities
- Compression of underlying soils due to stockpiles of construction materials or excavated soils
- Excavation slope failures, liquefaction, lateral flow or spreading, and ground settlement if a large earthquake were to occur during construction.

Indirect effects associated with geology and soils are those that would affect areas outside the immediate area of construction or that would occur at some point in time after construction has been completed. An example of an indirect effect would be a reduction of aggregate supplies from sources in the Puget Sound area to meet roadway subgrade and approach fill construction requirements. Another indirect effect might be accumulations of sediment in the storm drainage system as small amounts of sediment leave the site after each rainfall or from occasional spillage from trucks leaving the site.

Direct effects from most construction activities for the Proposed Action would be mitigated by implementing standard design and construction procedures. These mitigation measures range from implementation of best management practices (BMPs) during construction to modifying the design requirements for the project. The indirect effects of the project would require implementation of various design measures that would either control or prevent the occurrence of the indirect effect. For example, if earth loads could result in excessive settlement beneath an approach fill, leading to damage of utilities, the ground could be improved during construction so

that the soil could withstand the new loads without unacceptable settlement.

What geology and soils effects could occur during operation of the project, and what mitigation is proposed?

Operation of the project over the long term could also have direct and indirect effects related to geology and soils. These effects would occur after the completion of construction and during the operational life of the facility.

Direct effects during facility operations could include long-term settlement due to compression of soils supporting the roadways or structures built for the project, eventually requiring repair of the roadway surface or adjacent utilities. Another direct effect might be the vibrations associated with truck traffic on the new roadway, causing settlement of the ground supporting the roadway.

Indirect effects could include increased maintenance to nearby surface streets and utilities from long-term settlement of soil beneath the new approach fills. Another potential indirect effect during operation would be damage to the sports facility or discomfort to sports fans from vibrations caused by trucks traveling on South Royal Brougham Way.

The effects of long-term settlement and seismic hazards associated with geology and soils could be mitigated using current design methods. Effects of traffic-induced vibrations on the new elevated structures can be mitigated by minimizing the source of vibration or by providing special isolation joints. Seismic hazards can be mitigated by such things as improving the characteristics of the ground or by strengthening the bridge structure to resist the earthquake loads.

What cumulative effects related to geology and soils would there be?

The Proposed Action would introduce modifications to local streets and new elevated structures that would connect with existing structures, some of which are also elevated.

Construction and operation of these structures could result in both negative and beneficial cumulative effects related to geology and soils.

The negative cumulative effects could involve seismic hazards, depletion of aggregate resources, and changes in groundwater flow regimes.

- In the event of an earthquake, both new and existing structures could be cumulatively affected by seismic loading. The cumulative effects could include a loss of service of the new elevated structures because of failure of existing structures. Service could also be lost if the Proposed Action does not adequately consider the potential for seismic loading, such as increased seismic loads or liquefaction of the ground, resulting in damage that requires months or even years to repair or replace the structures.
- Other reasonably foreseeable future actions are planned near the SR 519 study area in coming years, including the Alaskan Way Viaduct project, reconstruction of the Colman Dock, the Spokane Street Viaduct project, completion of the BNSF Railway tracks, closure of South Holgate Street rail crossing, and several utility pipeline projects. Along with the Proposed Action, these projects would extract aggregate from local sources, imposing a cumulative effect on the local availability of aggregate. Depending on their relative timing and construction demands, these projects could cumulatively reduce the local availability of aggregate and require longer haul distances, placing an upward pressure on construction costs.
- Construction of drill shaft foundations for structures and, if required, use of ground improvement at approaches to the South Royal Brougham Way structure to mitigate liquefaction potential could alter groundwater flow characteristics for the general area, particularly as other future developments use similar foundations or ground treatment methods to deal with soft ground conditions and

the potential for poor performance of soils during seismic loading.

The Proposed Action could contribute to a beneficial cumulative effect through the removal of contaminated soils that might be encountered during bridge foundation construction. (See the *Hazardous Materials Discipline Report* for more information on contaminated soils.)

Are any of the identified effects considered substantial?

Substantial effects related to soils and geology would be those that might require new locations for the project elements or the use of a different method of supporting the roadway or structures. No substantial effects of the Proposed Action related to geology and soils have been identified. This conclusion is based on the local geology within the project footprint, the nature of the geologic hazards that were identified, and the type of development.

What effects associated with geology and soils would occur if the Proposed Action is not built?

With the No Build Alternative, most of the construction effects of the Proposed Action would be avoided. Seismic hazards and the related indirect effects would still exist regardless of whether the project is built or not.

Chapter 1 Introduction

1 Why are geology and soils considered in this report?

Geology and soils are considered in this discipline report because the types of geology and soils in the study area would affect the type of construction methods used for the project. Hazards associated with geology and soils would also affect the construction and operation of the project, and if not considered appropriately, could result in a risk to public safety.

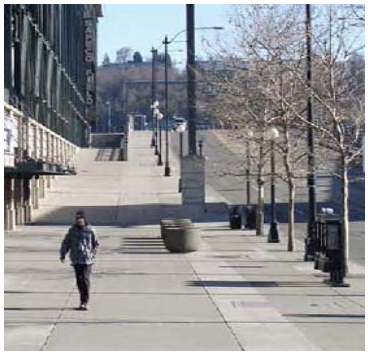
2 What are the key points of this report?

The key points of this report as related to geology and soils are:

- The geology and soil conditions within the project study area are relatively well understood and appear to be suitable for successful design and construction of the project. For this analysis, geology and soil conditions of the study area were evaluated in terms of topography, geology, soil characteristics, groundwater conditions, and existing and potential aggregate sources.
- Although seismic hazards such as seismic-induced ground shaking, ground-surface rupture, liquefaction, and tsunamis exist within the project study area, these hazards could either be mitigated or are too distant or infrequent to pose a substantial risk during the design life of the facility. For example, the effect of seismic-induced ground shaking and liquefaction would be mitigated through implementation of appropriate design and construction procedures. Surface rupture and tsunamis are either too distant or too infrequent to pose a substantial risk.

Chapter 2 Description of Alternatives

SR 519 is an important thoroughfare for cars, trucks, and pedestrians in Seattle's South Downtown (SODO) district (Exhibit 2-1). In 2004, WSDOT opened Phase 1 of the SR 519 project, consisting of the South Atlantic Street railroad overpass (Edgar Martinez Drive South) and a new eastbound on-ramp from South Atlantic Street to I-5 and I-90. The overpass separates road and railway traffic at Third and Fourth Avenues South and improves access to the freeway system from important waterfront facilities such as the Port of Seattle terminals, railroad freight yards, and the Washington State Ferries terminal at Colman Dock.

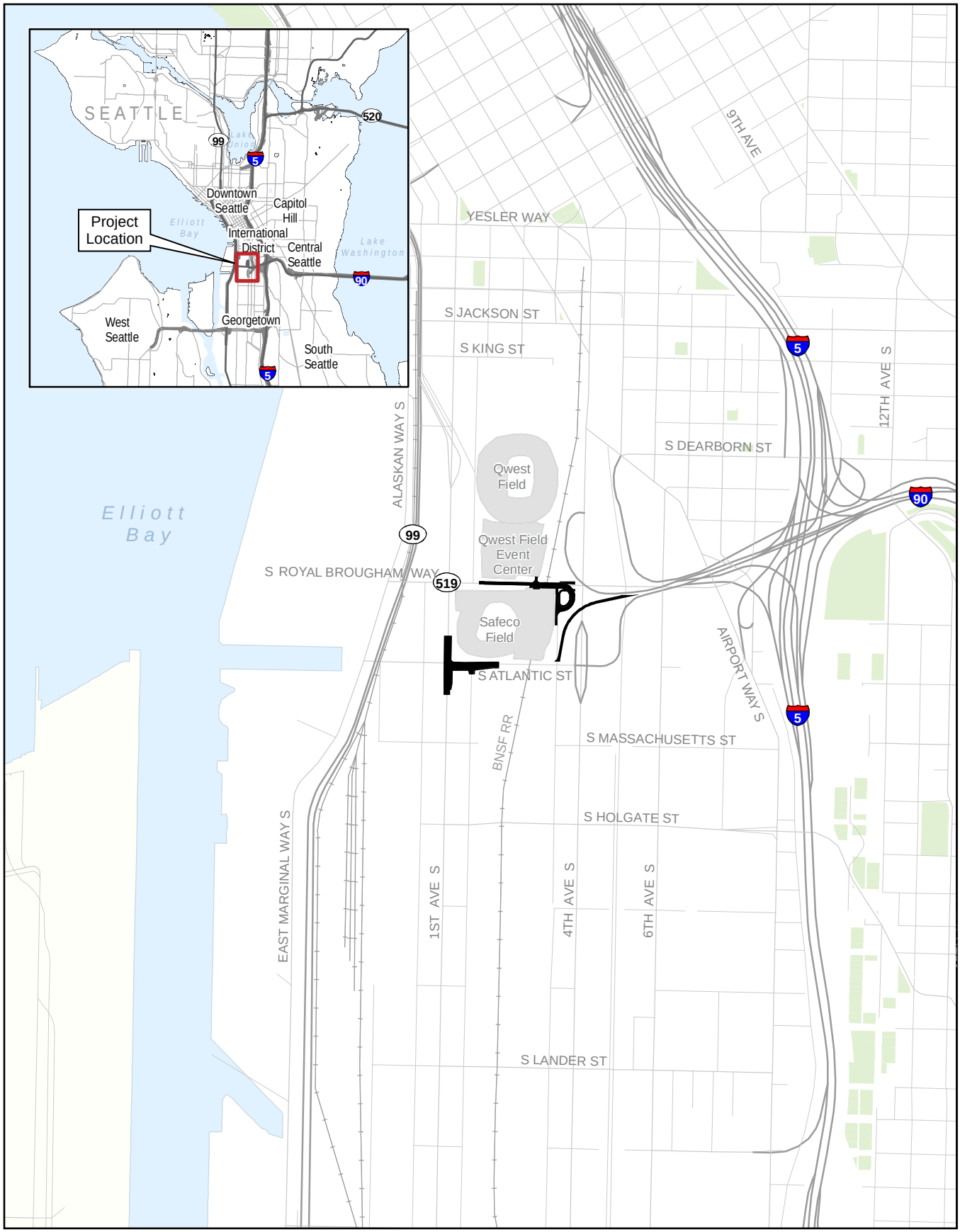


New South Atlantic Street overpass built in SR 519 Phase 1

The Phase 1 project had four main components which:

- Provided the eastbound connection from the waterfront to I-5 and I-90 via South Atlantic Street
- Removed the old eastbound I-90 ramp on Fourth Avenue South
- Made improvements to South Atlantic Street between First Avenue South and the Alaskan Way South/East Marginal Way intersection
- Constructed the South Weller Street Pedestrian Bridge

When Phase 1 opened, eastbound freight, ferry, and event traffic immediately moved more freely, because connections from the Port of Seattle, waterfront, and stadium area to the freeway system were improved.



Source: City of Seattle (2007) and King County (2006)

Stadiums

Project

N

0 1,000 Feet

Exhibit 2-1
Vicinity Map

1 Why is the Phase 2 project needed?

SR 519 provides a vital roadway system for east-west traffic through Seattle, but it currently does not assist in the efficient westbound movement of cars, trucks, trains, and pedestrians through Seattle's SODO district. The route passes through an area that has changed so much in recent years that the roadway arrangement is not well suited to present conditions. A new design and new roadway structures are needed to allow vehicles and pedestrians to reach their destinations safely, quickly, and more directly.

This project would help to resolve several issues:

- Safety concerns from traffic and people crossing surface-level railroad tracks in the stadium area
- The expected increase in rail traffic and pedestrian crossings at South Royal Brougham Way when Sound Transit Central Link light rail service begins in 2009, resulting in safety concerns and travel delays
- Poor westbound access between I-5/I-90 and the Seattle waterfront, especially the Port of Seattle terminals and the Washington State Ferries terminal at Colman Dock
- Delays in moving products between Port of Seattle terminals and local, regional, and national markets

2 What is the purpose of the project?

This project would improve traffic mobility and safety by improving westbound connections between I-5/I-90 and the Port of Seattle terminals, the Washington State Ferries terminal at Colman Dock, waterfront commercial interests, and the stadium area. The project would allow people to walk more safely to and from the stadium area.

The purpose of the project is to:

- Provide a more direct route between I-5/I-90 and the Seattle waterfront, so that westbound freight, commuters, and local traffic can move more safely and efficiently through the stadium area

- Improve safety and reduce railroad and vehicle delays at the surface-level rail crossing on South Royal Brougham Way west of Fourth Avenue South
- Improve safety for people walking to events, work, and neighborhood destinations
- Reduce truck and rail traffic conflicts so that freight operators can move products more efficiently between Port of Seattle terminals and markets

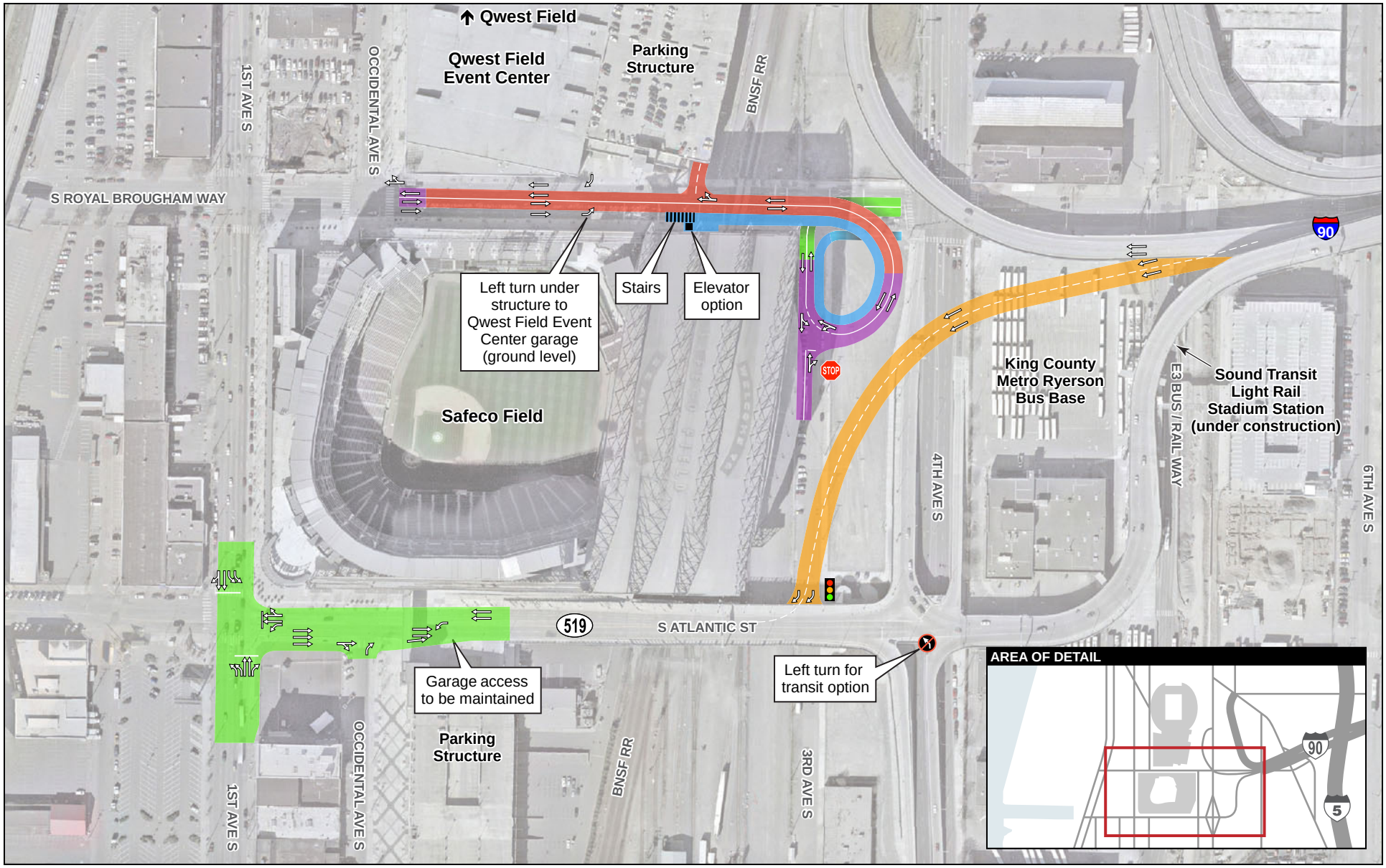
3 What are the project alternatives?

Two alternatives were analyzed for this report: the Proposed Action and the No Build Alternative. The Proposed Action, which has been designed to meet current and projected future traffic conditions, was developed following the completion of an earlier NEPA Environmental Assessment and associated Finding of No Significant Impact (FONSI) (USDOT et al., 1997) and builds on the more recent screening and evaluation of 21 preliminary Phase 2 options by WSDOT in a feasibility study (KPFF et al., 2006).

Proposed Action

The Proposed Action (SR 519 Intermodal Access Project Phase 2: Atlantic Corridor) would connect the existing westbound off-ramp from I-5 and I-90 to the existing South Atlantic Street overpass. It would also provide improvements at the intersection of First Avenue South and South Atlantic Street to accommodate traffic more efficiently along the route. In addition, it would build a grade-separated crossing over the railroad tracks at South Royal Brougham Way. These proposed improvements are described in more detail below and are illustrated on Exhibit 2-2. Traffic flow with the proposed improvements in place is shown in Exhibit 2-3. All proposed improvements would comply with the Americans with Disabilities Act of 1990 (ADA).

I-90 Off-Ramp to South Atlantic Street. A new two-lane elevated ramp connection would be built from westbound I-90 to terminate at a signalized T-intersection on the South Atlantic Street railroad overpass.

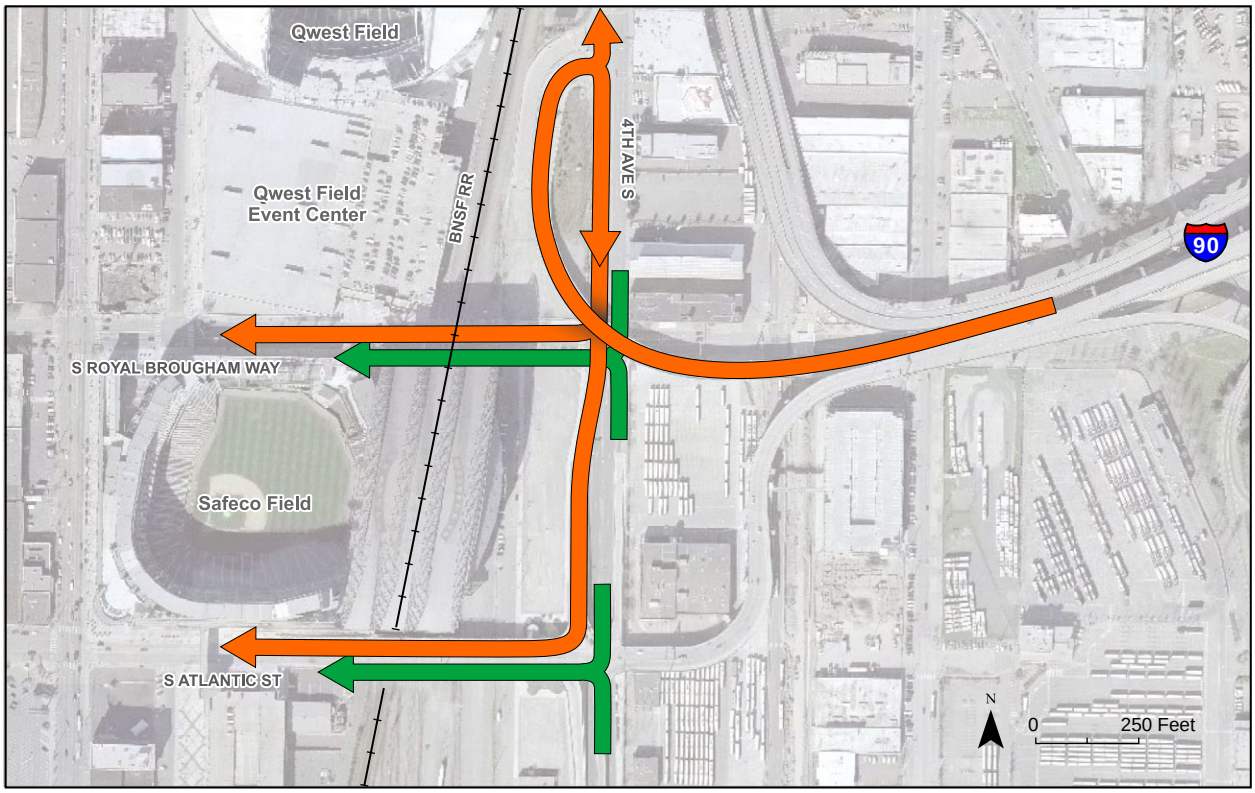


Arterial Bridge
Elevated Ramp
Pedestrian Bridge
Surface Improvements
Fill Embankment

N

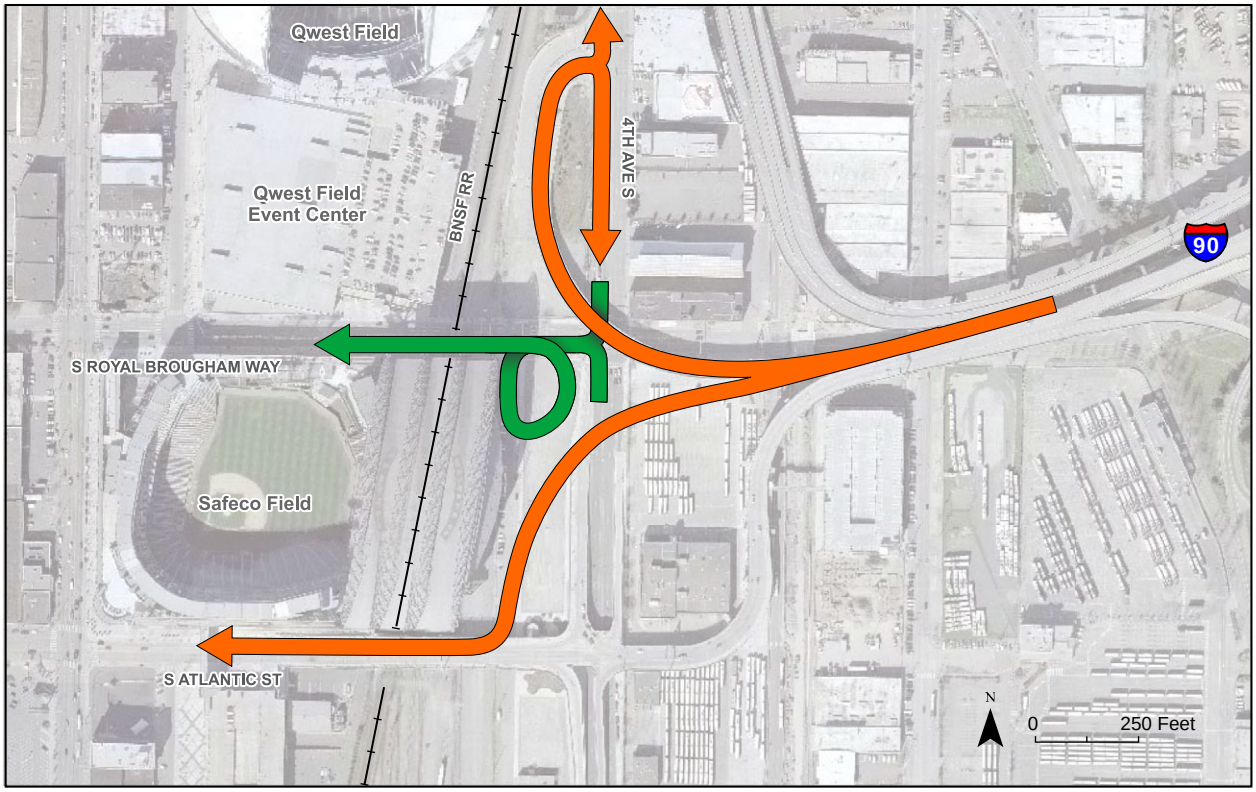
0 250 Feet

Exhibit 2-2
Project Elements



Existing Westbound Regional Routes
Existing Westbound Local Routes

Existing Westbound Travel Routes



Proposed Westbound Regional Routes
Proposed Westbound Local Routes

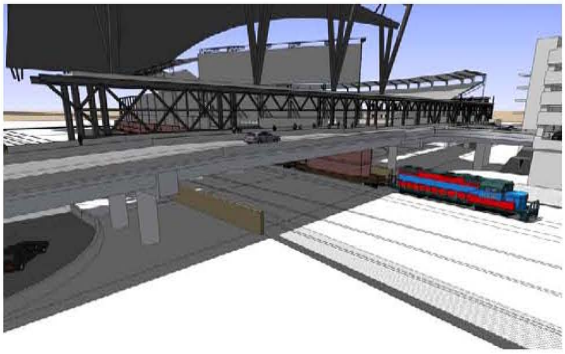
Proposed Westbound Travel Routes

Exhibit 2-3
Existing and Proposed Westbound Travel Routes

The new South Atlantic Street connection would serve westbound freeway traffic exiting I-90 and I-5. The new ramp would be entirely elevated, passing over Fourth Avenue South and Third Avenue South and connecting to the South Atlantic Street overpass southeast of Safeco Field. Exiting northbound I-5 traffic would be routed to South Atlantic Street, while exiting southbound I-5 traffic would have the option of using either the new off-ramp to South Atlantic Street or the existing I-90 off-ramp to Fourth Avenue South.

South Royal Brougham Way Railroad Overpass. The South Royal Brougham Way at-grade railroad crossing would be closed, but it could possibly be opened to public services in the event of a major emergency in the vicinity. A new two-lane elevated structure would be built, connecting Occidental Avenue South to Third Avenue South. The new overpass would transport vehicular, pedestrian, and bicycle traffic over the railroad tracks and provide a new connection and entrance from South Royal Brougham Way to the second level of the Qwest Field Event Center parking garage. The new ramp would accommodate local two-way traffic and provide ADA-compliant access.

Proposed ramp at east end of South Royal Brougham Way railroad overpass



South Royal Brougham Way existing at-grade railroad crossing (left) and proposed overpass (right)

Improvements to the Intersection of First Avenue South and South Atlantic Street. The project would widen the intersection by adding additional turn lanes to each approach. Existing parking lanes along First Avenue South would be converted into travel lanes, with a new eastbound lane added to South Atlantic Street. Sidewalks along the southern edge of

South Atlantic Street east of First Avenue South would be relocated to the south to accommodate the added eastbound lane.

Construction Components

Construction of the SR 519 Phase 2 project could take about 3 years, and WSDOT is exploring ways to accelerate this schedule. Construction would involve three project components:

- Improvements to the intersection of First Avenue South and South Atlantic Street could begin first, with construction starting in 2009 and lasting 6 to 9 months.
- Construction of the new I-90 ramp connection to the South Atlantic Street overpass could last 15 to 18 months and could begin as improvements to the intersection of First Avenue South and South Atlantic Street are underway.
- Construction of the new South Royal Brougham Way railroad overpass, most likely beginning in 2010, could overlap with construction of the new I-90 off-ramp and last 18 to 21 months.

Proposed Construction Schedule

Access for emergency service vehicles would be maintained at all times. A construction management plan (CMP) would be developed to optimize the sequencing of the SR 519 Phase 2 project elements. The CMP would identify approaches that best

coordinate with and minimize unwanted effects on the following:

- Stadiums and Event Center activities
- Port of Seattle container operations
- Washington State Ferries
- BNSF Railway mainline and yard operations, AMTRAK mainline operations, and Sound Transit commuter rail operations
- Sound Transit Link light rail operations, Sounder commuter rail service, and Regional Express bus operations
- King County Metro Ryerson Bus Base operations and Metro bus service throughout the affected area, including through-routes operating within the area, and access to the bases and downtown Seattle transit tunnel
- Greater Duwamish Manufacturing and Industrial Center freight operations

Temporary construction staging areas would be required to store equipment and materials during construction. A gravel lot owned by WSDOT, bounded by South Atlantic Street and South Royal Brougham Way, and Third Avenue South and Fourth Avenue South, would serve as the primary construction staging area for the SR 519 Phase 2 project. This lot is vacant, and no adverse environmental effects are expected from staging at this location. Other temporary staging areas would be determined through consultation with King County and the City of Seattle during project design.

No Build Alternative

Under the No Build Alternative, the three proposed Phase 2 components discussed above would not be built. Westbound traffic exiting from I-5 and I-90 would continue to flow as shown in Exhibit 2-3.

4 What permits would be required to build the project?

The SR 519 Phase 2 project would be built under close regulatory scrutiny. WSDOT would apply to the State of Washington, King County, and the City of Seattle for a number of permits and approvals. They would most likely include, but not necessarily be limited to:

- National Pollutant Discharge Elimination System (NPDES) Construction Stormwater General Permit (Washington State Department of Ecology)
- Wastewater Discharge Approval (King County)
- Street Use Permit (City of Seattle)
- Side Sewer Permit (City of Seattle)
- Noise Variance (City of Seattle)

WSDOT will confirm the requirement for these and other permits as engineering design and construction planning proceed in coordination with the permitting authorities.

Chapter 3 Methodology

1 What is the study area for geology and soils and how was it selected?

The study area for geology and soils consists of two areas: regional and site-specific. The project team reviewed the regional geology and how it relates to the project footprint, and then conducted a site-specific analysis of the geology and soils for the area within or affecting the project footprint.

2 How was the information collected?

Information was collected from publicly available archives, databases, and published reports. Key reference information on subsurface conditions in the study area was obtained using the following sources:

- Geologic maps from the U.S. Geological Survey (USGS), and the Division of Geology and Earth Resources within the Washington State Department of Natural Resources (WDNR)
- City of Seattle Department of Planning and Development Environmentally Critical Areas Update website http://www.seattle.gov/DPD/Planning/Environmentally_Critical_Areas_Update/NewGeologicHazardAreas/default.asp
- USGS on-line publications database http://www.usgs.gov/pubprod/
- USGS Earthquake Hazards Program website http://earthquakes.usgs.gov/research/hazmaps/
- Washington State Department of Ecology (Ecology), Well Logs http://apps.ecy.wa.gov/welllog/

- WDNR on-line geology publications database http://www.dnr.wa.gov/geology/pubs/pubs_ol.htm
- Urban Corridors Office (UCO) at WSDOT

3 What methods were used to evaluate potential effects of the Proposed Action and the No Build Alternative?

The project team evaluated the potential effects of the Proposed Action through a qualitative review of the project features relative to the regional and site geology, characteristics of deeper soils, groundwater conditions, and existing and potential aggregate sources. This qualitative review was based on experience drawn from past projects developed in areas characterized by similar geology, including seismicity, and similar expected features of the Proposed Action. The expected features include the use of drilled shaft foundations to support elevated structures and earth approach fills at the start and ends of elevated structures.

Drilled shaft foundations consist of cylindrical holes that are bored in the ground and filled with steel reinforcement and concrete. The diameter of the shaft could range from 2 feet to 12 feet or more. The length can be 100 feet or more. The shafts for the Proposed Action would likely be 8 to 10 feet in diameter and extend roughly 80 feet below the ground surface.

The past similar projects provide evidence that by appropriately considering the potential direct and indirect effects of development in relation to geologic and soil characteristics, current design, construction, and operation methods can be implemented safely and without damaging those characteristics.

When identifying potential effects related to geology and soils, the project team primarily considered existing soil and geologic conditions and how these conditions could be changed by construction of the project. Some geologic conditions, such as seismicity, would not be affected by construction in the sense that building the project would not increase the potential for seismic activity. However, in this case the potential for seismicity creates a hazard that could potentially affect public safety if adequate planning were not carried out during design.

For this assessment, an attempt was made to consider all types of effects related to geology and soils, regardless of the likelihood of occurrence. In many cases, these effects have a very low likelihood of occurrence and therefore pose little risk.

Other effects are addressed in standards of care or best management practices that are routinely adopted for design and construction.

4 What would be considered a substantial adverse effect on geology and soils?

A substantial adverse effect would be one that has a high likelihood of occurrence and would present a risk to public property, public utility service, or public safety. An example would be an area of steep slopes, where a new roadway would be at risk from landslides. In this example, it might be necessary to change the roadway alignment to reduce risk to an acceptable level.

For the SR 519 study area, the most substantial risk related to geology and soils is the potential for earthquake ground shaking and the effects of this shaking on the stability of soils supporting the project structural components.

Chapter 4 Affected Environment

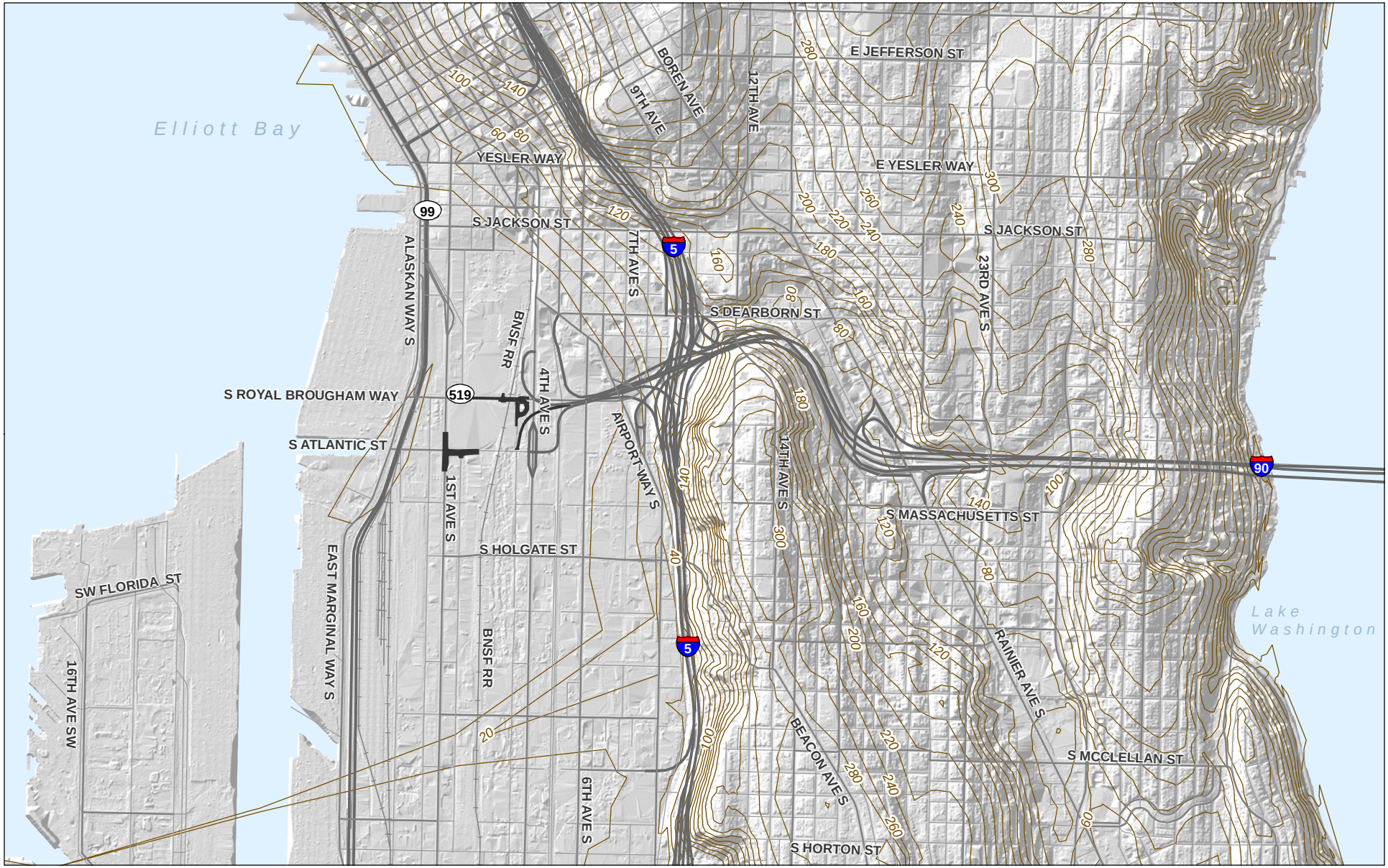
1 What are the general geological conditions in the study area?

The project team collected and reviewed information from the sources listed in Chapter 3 to develop a description of geological conditions within the study area. This description covers topography, geology, soil characteristics, groundwater conditions, and existing and potential aggregate sources. The locations of possibly contaminated soils and contaminated groundwater are discussed in the *Hazardous Materials Discipline Report* prepared for the project. The general geology and soil conditions interpreted from these reviews are described below.

Topography

The regional topography consists of a series of north-south trending ridges separated by deep troughs. The troughs are now occupied by streams, lakes, and the waterways of Puget Sound. This regional topography was shaped first by glaciations that moved back and forth across the region many thousands of years ago, and then more recently by erosion processes and landform changes made by our development of the area. The regional topography is shown in Exhibit 4-1.

The local topography within and adjacent to the study area is flat-lying with a very gentle downward gradient of less than 1 percent to the west, toward Elliott Bay. The study area topography is shown in Exhibit 4-2. As discussed in the next section, much of the present topography is the result of hydraulic mining done in the early 1900s and the subsequent modification of the area for development.



Note:The vertical datum is North American 1983.

Source: City of Seattle (2007) and King County (2006)

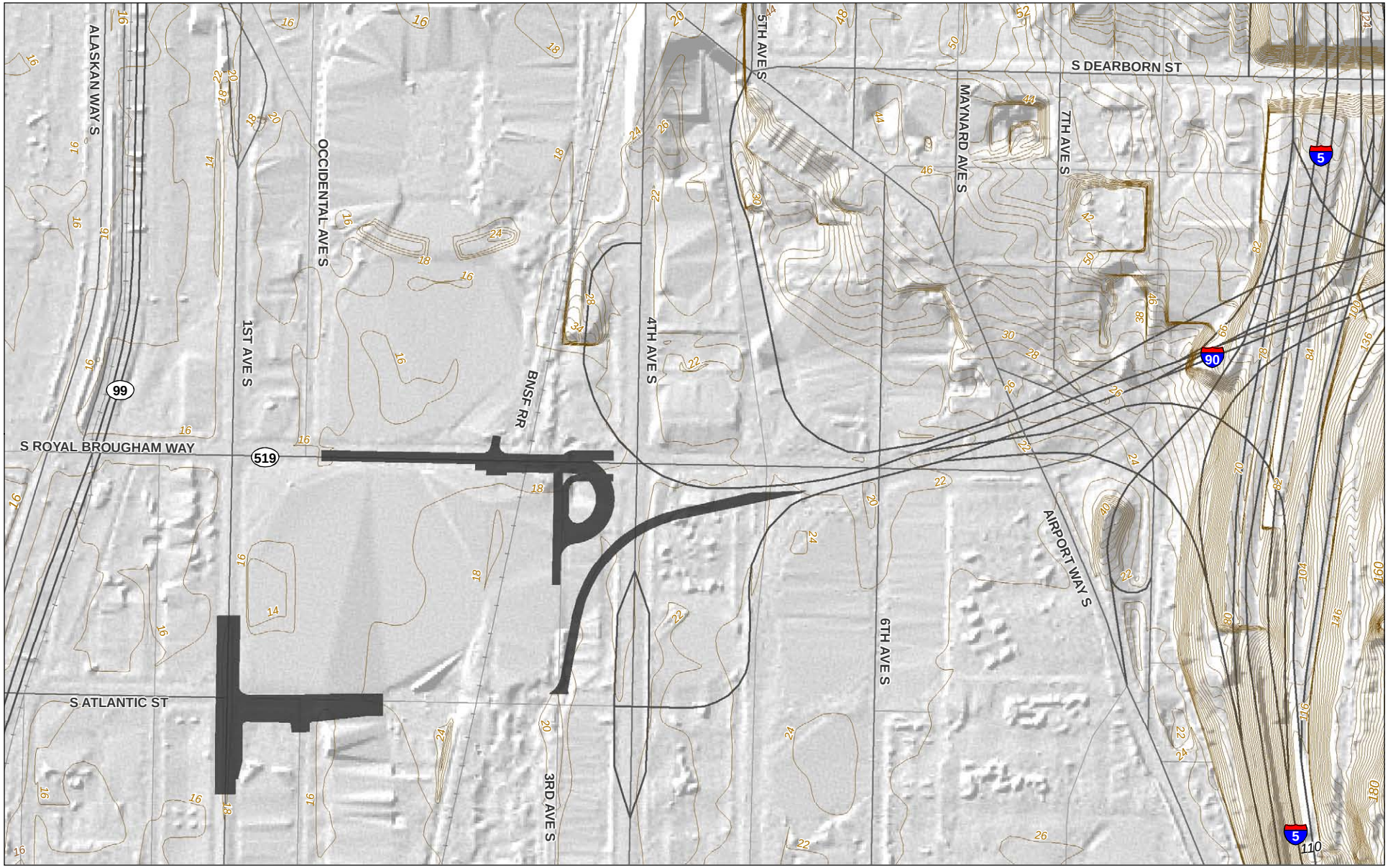
20-ft Contour

Project

N

0 2,000 Feet

Exhibit 4-1
Regional Topography



Note: The vertical datum is North American 1983.

Source: City of Seattle (2007)

2-ft Contour

Project

N

0 500 Feet

Exhibit 4-2
Site Topography

Geology

This section describes how the geology in the region formed. Then it summarizes the geologic information within and near the study area that was used to perform the geology review. Finally, the section discusses the site geology for the study area. The site geology includes geologic units encountered within the study area based on existing information.

Regional Geology

The geomorphology in the Puget Sound region, including the study area, is primarily the result of multiple glaciations that occurred from 2 million to 10,000 years ago, a period referred to by geologists as the Pleistocene Epoch. Each advance and retreat of the glaciers during the Pleistocene resulted in modification of the land from erosion and deposition of soils.

The repeated glaciation left a thick deposit of unconsolidated soil in the region that includes the study area. These glacial deposits overlie bedrock. The depth to bedrock in the project footprint is between 800 and 900 feet below ground surface (bgs) (Yount et al., 1985).

Geologic Information for Study Area

The geologic units and soil characteristics within the study area were defined using geotechnical information available in public archives and websites. The sources of existing geotechnical information included the GeoMapNW archives at the University of Washington, the Washington State Department of Ecology (Ecology) website, WSDOT project files in the Urban Corridors Office (UCO) at WSDOT, and project reports in the CH2M HILL Seattle library. Some reports were for earlier phases of the SR 519 project. References collected from WSDOT and CH2M HILL that were used as a basis for preparing this discipline report are listed in Chapter 7, References.

The available information from these sources consisted of published maps by government agencies, geotechnical reports, driller's well logs, environmental impact statements, and environmental reports, as follows:

- Published maps included topographic maps, geologic maps, and geologic hazard areas maps.
- The collected geotechnical and environmental reports included summaries of existing geological conditions as well as site plans, boring logs, cross sections of subsurface soil profiles, geotechnical recommendations, and soil index testing results.
- Driller's well logs included soil descriptions and groundwater information.

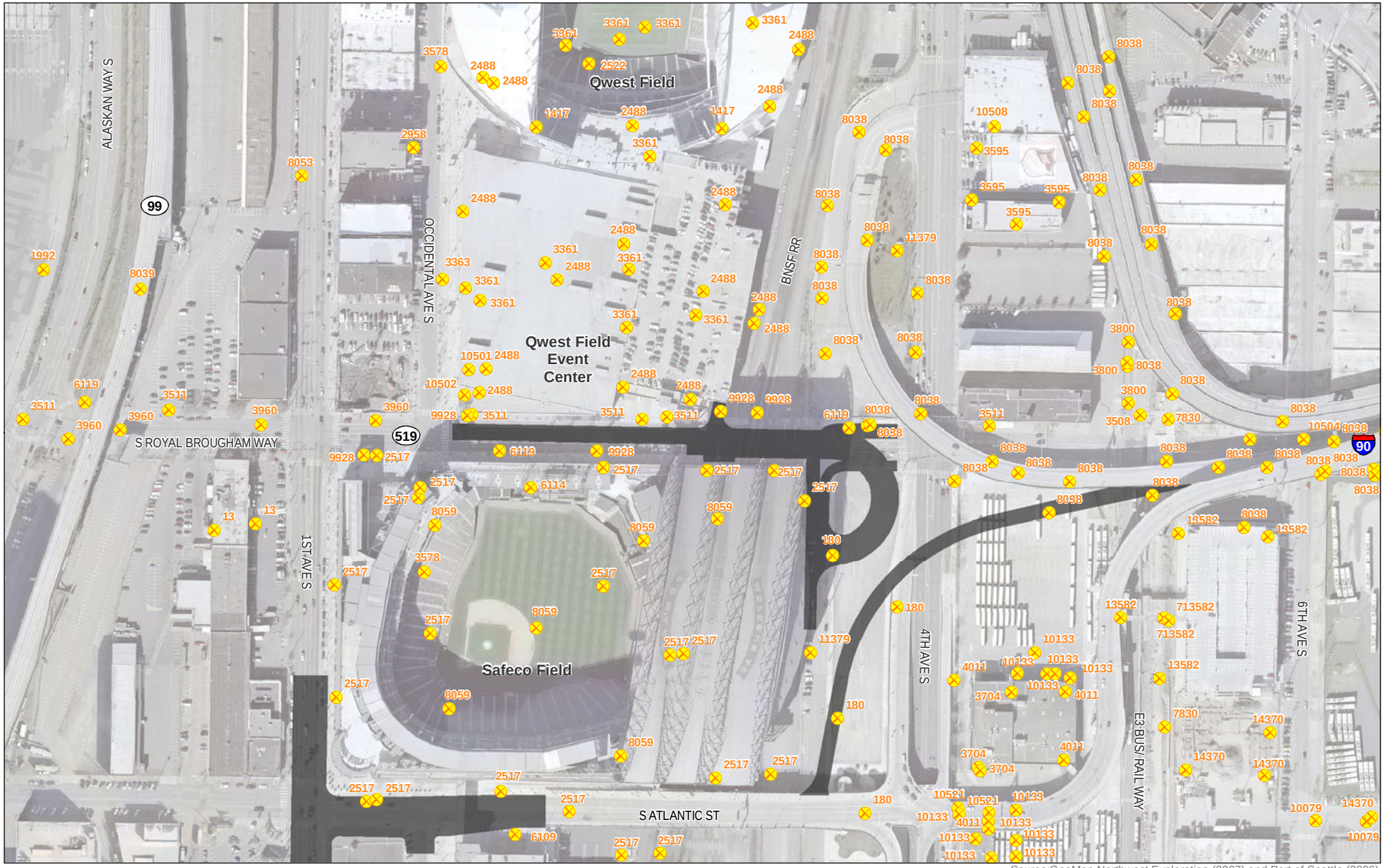
One of the most important sources of information was the GeoMapNW archives at the University of Washington. Information collected from GeoMapNW included data on over 300 test holes that were drilled within or adjacent to the study area. The test holes provided information about soil types and consistency to depths of up to 124 feet bgs. Test hole information included visual descriptions of the soil, results from standard penetration tests (SPTs), and the engineering classifications of the soil. Locations of test-hole information collected from GeoMapNW are shown on Exhibit 4-3, and Appendix A presents a list of the reports from which this information was originally obtained.

The Standard Penetration Test (SPT) is conducted to obtain a measure of the resistance of the soil and to retrieve a disturbed soil sample. Results of the SPT are presented as the SPT blowcount, "N". Values of N provide a means for evaluating the relative density of granular (coarse-grained) soils and the consistency of cohesive (fine-grained) soils. Low N-values indicate soft or loose deposits, while high N-values are evidence of hard or dense materials.

The project team also reviewed 56 Ecology well logs for borings and wells up to 121 feet deep within or near the study area. Some of the well logs provided general visual soil descriptions and depths where groundwater was encountered. Other logs provided only groundwater well construction details or well decommissioning details and did not provide soils information.

Site Geology

A description of the geologic units that underlie the study area was developed from a published geologic map by Troost et al. (2005). This map is generally considered the most recent, authoritative discussion of geology for the Seattle area. More detailed descriptions of the soils underlying the site based on the collected existing geotechnical reports are in the next subsection, "Soil Characteristics".



Note: Number next to location refers to UW Document ID listed in Appendix A.

Source:GeoMap Northwest Exploration (2007) and Port of Seattle (2006)

Exploration Location (approx.)

Project

N

0 200 Feet

Exhibit 4-3

Locations of Geotechnical Explorations Conducted for Other Projects

The surficial geology in the project footprint is mapped as tideflat deposits (Qtf) and artificial fill (the hatching overlay) by Troost et al. (2005), as shown in Exhibit 4-4. Areas shown as artificial fill are locations where fill placement is relatively extensive and is likely to be thick enough to be of engineering significance (greater than about 6.5 feet thick). Within the study area, fill is underlain by loose or soft dredged materials or tideflat deposits.

According to available geotechnical reports, tideflat deposits consist of alluvium, estuarine deposits, and beach deposits. These deposits are underlain by reworked glacial deposits. Reworked glacial deposits are underlain by dense glacial soils, which are typically encountered at about 50 feet bgs within the project footprint. Glacial soils consist of outwash and glaciomarine deposits.

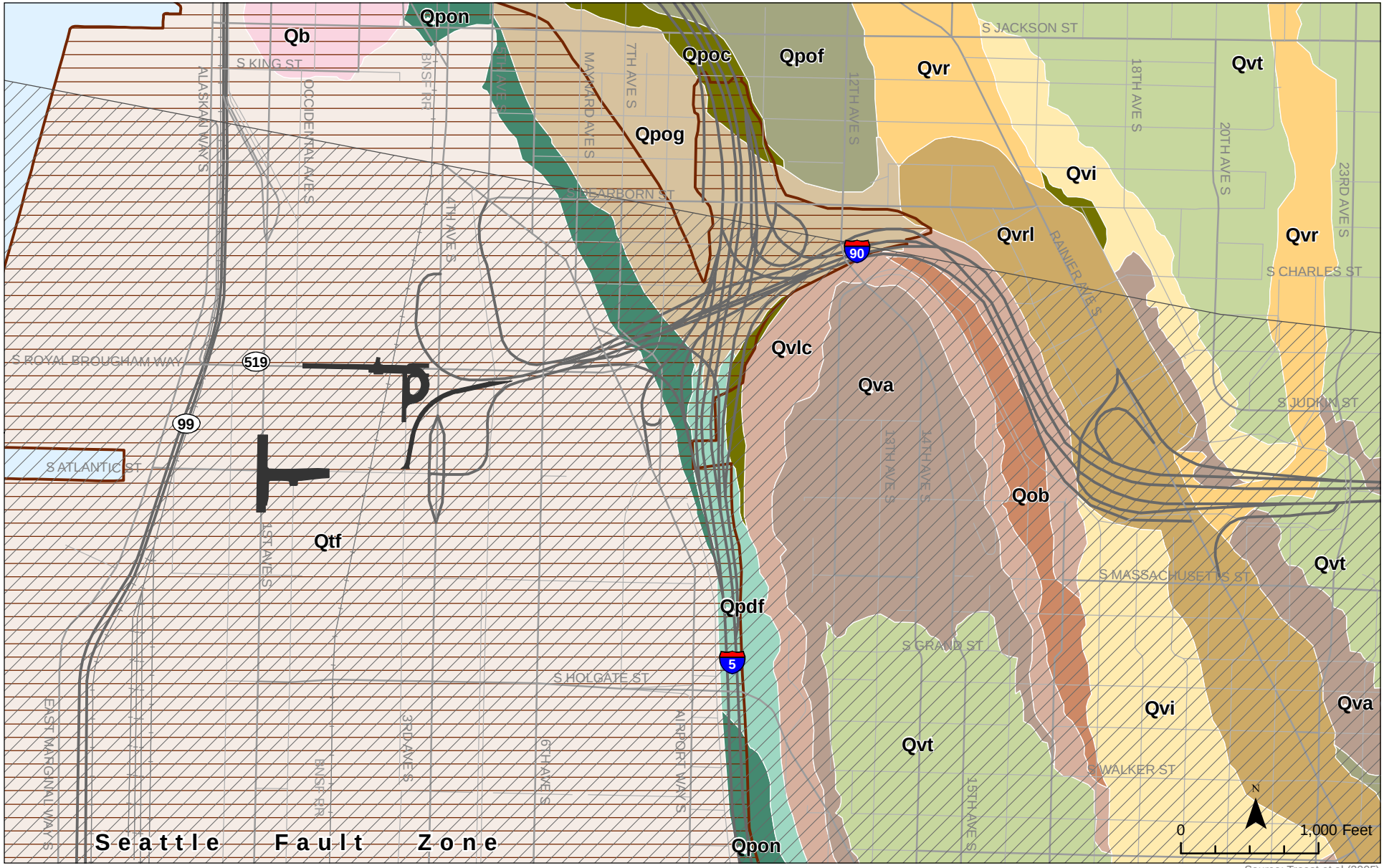
A general description of the above-mentioned geologic units, based on mapping and commentary according to Troost et al. (2005) and Shannon and Wilson (2004, 2005), is provided in Exhibit 4-5. A more detailed description of the soil characteristics, based on specific available geotechnical reports, is provided in the next subsection.

Exhibit 4-6 summarizes typical engineering properties and hazard susceptibilities of the geologic units that are potentially within the project footprint.

Soil Characteristics

The characteristics of soils underlying the study area are important for this environmental review, because they determine to a large extent the methods of design and construction that would be used and the long-term operational issues that must be considered.

The main documents that were reviewed to determine subsurface soils encountered in the study area were by Yount et al. (1990) and Shannon and Wilson (2004, 2005).



Source: Troost et al (2005)

Qb	Beach deposit	Qvi	Ice contact deposit	Qob	Olympia beds	Qpon	Pre-Olympia non-glacial till		Project
Qtf	Tideflat deposit	Qvt	Vashon Till	Qpoc	Pre-Olympia course-grained deposits	Qpdf	Possession glaciolacustine deposits		
Qvr	Recessional Outwash deposit	Qva	Advance outwash deposit	Qpof	Pre-Olympia fine-grained deposits		Artificial Fill		
Qvrl	Recessional Lacustrine deposit	Qvlc	Lawton Clay member of the Vashon Drift	Qpog	Pre-Olympia Glacial deposits		Seattle Fault Zone		

Exhibit 4-4
Surficial Geologic Map

EXHIBIT 4-5. SUMMARY OF GEOLOGIC UNITS

Geologic Unit (Map Symbol)	Description	Density/Hardness
Artificial Fill (af)	Gravel, sand, silt, concrete, garbage, slag, and other materials, placed as a direct result of human activity, of substantial areal extent or thickness. Mapped where boring data provided sufficient information to delineate extent or where topography and overlying development suggests likelihood of fill, and where greater than about 6.5 feet in thickness.	Very soft to stiff or very loose to dense
Tideflat deposits (Qtf)	Silt, sand, organic sediment, and detritus, with some shells, historically exposed in broad coastal benches at low tide and now covered with fill. Aggraded northward in the Duwamish River valley with rising sea level and alluvial filling of the Duwamish valley.	Very loose to dense or very soft to stiff
Alluvium (Ha)	Sand, silt, gravel, and cobbles deposited by streams and running water. Locally contains very soft peat lenses.	Loose to dense or soft to stiff
Estuarine deposits (He)	Silty clay and fine sand deposits of the ancestral Duwamish River.	Very soft to stiff or loose to dense
Beach deposits (Hb)	Sand and gravel deposited or reworked by modern wave action. Commonly overlain by fill.	Loose to dense
Reworked glacial deposits (Hrw)	Heterogeneous mixture of several soil types of glacial deposits that have been reworked by fluvial or wave action. Lies over glacially overridden soils.	Loose to dense
Outwash (Qpgo)	Clean to silty sand, gravelly sand, sandy gravel. Glaciofluvial sediment deposited as glacial ice advanced through the Puget Lowland.	Very dense
Glaciomarine deposits (Qpgm)	Heterogeneous and variable mixture of clay, silt, sand, and gravel; rare shells; cobbles and boulders common. Till-like deposit with clayey matrix deposited in proglacial lake by icebergs, floating ice, and gravity currents.	Very dense or hard

Source: Troost et al. (2005) and Shannon and Wilson (2004, 2005)

EXHIBIT 4-6. SUMMARY OF TYPICAL ENGINEERING PROPERTIES AND HAZARD SUSCEPTIBILITY OF GEOLOGIC UNITS

Geologic Unit (Map Symbol)	Strength	Permeability	Liquefaction Potential[a]
Artificial fill	Potentially low	Variable	Potentially high
Tideflat deposits (Qtf)	Potentially low	Variable	Potentially high
Alluvium (Ha)	Potentially low	Variable	Potentially high
Estuarine deposits (He)	Potentially low	Variable	Potentially high
Beach deposits (Hb)	Potentially low to medium	High	Moderate to low
Reworked glacial deposits (Hrw)	Potentially low to medium	Variable	Low
Outwash (Qpgo)	High[b]	High	Low
Glaciomarine deposits (Qpgm)	High	Low	Low

Note: The terms low, medium, and high were determined based on professional opinion from experience with the soil types. The hazard susceptibility was determined based on criteria in City of Seattle Municipal Codes 25.09.020 and professional opinion.
[a]Liquefaction depends in part on density of the material and the groundwater table elevation. These ratings assume a shallow groundwater condition.
[b]High strength unless cut vertically below the water table, then potentially low to medium strength.

In general, these reports describe the soils underlying the study area as an upper layer of fill underlain by tideflat deposits, which included alluvium, estuarine deposits, and beach deposits; underlain by reworked glacial deposits; underlain by glacially overconsolidated soils that consist of outwash and glaciomarine deposits.

The study area is located within an area of extensive regrading in which millions of cubic yards of hydraulic fill have completely obliterated much of the preexisting topography (Liesch et al., 1963). WSDOT (1997) reports that fill was deposited in the study area between 1900 and 1910 by hydraulic mining of the hillsides in the surrounding area. Fill materials dredged from the Duwamish River and Elliott Bay have also been deposited in the study area.

The fill material within the study area ranges from sands and gravels to soft clays. The fill has widely variable properties, ranges from 20 to 45 feet thick, and is likely contaminated. Refer to the Hazardous Materials Discipline Report for information regarding potential contamination of soils.

According to Shannon and Wilson (2004, 2005), fill occurs in two distinct zones:

- The upper portion of the fill is either engineered or non-engineered and was placed using a variety of methods and materials. The fills are commonly dense or stiff if engineered, but very loose to dense or very soft to stiff if non-engineered. Fills consist of sand to gravelly sand with variable amounts of silt, and layers of very soft to soft, cohesive silts and clay. Refuse such as cinder blocks, brick, glass, concrete, railroad construction debris, and abundant wood debris (timbers, sawdust, and treated timber piles), as well as cobbles and boulders, are encountered in this portion of the fill layer.
- The lower portion of the fill was deposited by sluicing (hydraulically) the nearby hillsides or dumping that occurred between 1895 and 1902. This fill consists of granular or cohesive material that was excavated from higher elevations in the surrounding area to raise the grade above tidal levels. These soils consist of very loose to medium-dense, clean to silty, fine and fine-to-medium sand with minor amounts of clay and abundant organics and organic-rich seams.

Sluicing was performed by using highly pressurized water to move the soils and lower the grade of the hillsides.

Underlying the fill, tideflat deposits are encountered. Tideflat deposits consist of interbedded alluvium, estuarine deposits, and beach deposits:

- Alluvium consists of very loose to very dense, clean sand, slightly silty to silty sand and gravel with varying amounts of clay, gravelly sand or sandy gravel, and contained abundant shell fragments, and varying amounts of fine wood fragments.

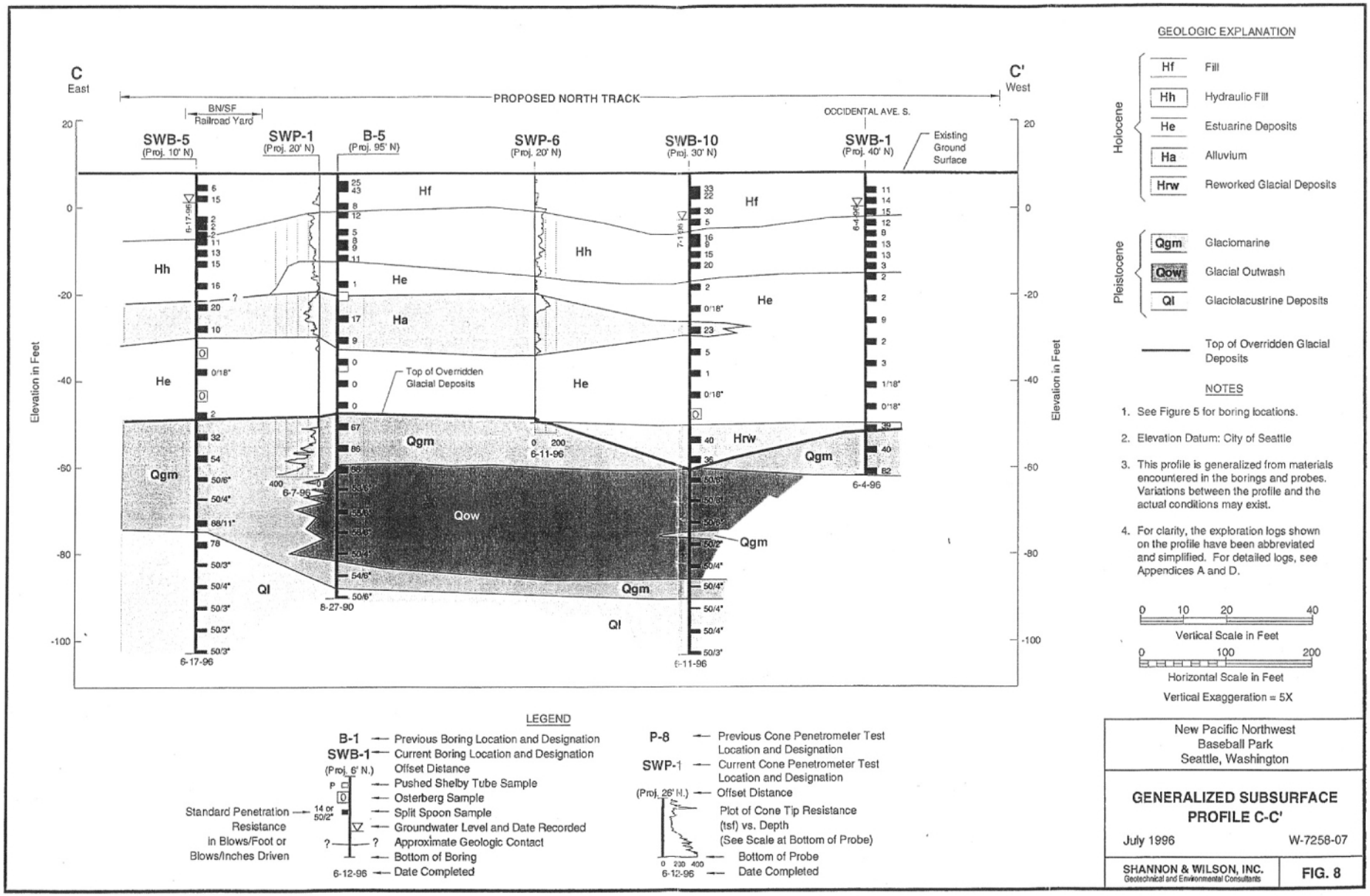
- Estuarine deposits consist of loose to medium dense, silt and sandy silt to very soft to stiff, clayey silt and silty clay with interbeds of organic-rich soils.
- Beach deposits consist of loose to dense sand and gravel and may contain scattered cobbles and locally cohesive fines, and scattered to abundant shell fragments and wood debris.

Alluvium, estuarine deposits, and beach deposits are underlain by reworked glacial deposits. These deposits are loose to dense and may be a mixture of more than one soil type that developed from the reworking of glacial deposits by tidal, alluvial, and wave processes. Scattered cobbles and boulders may be found in the reworked glacial deposits.

Reworked glacial deposits are underlain by dense or hard glacially consolidated soils that are generally encountered at depths ranging from 45 to 70 feet bgs. The glacially consolidated soils consist of Pre-Vashon, glacial and non-glacial, outwash and glaciomarine deposits. In general, these soils consist of a mixture of silt, sand, and gravel with varying amounts of cobbles and boulders. Cobbles and boulders are found commonly in these Pre-Vashon deposits. Abundant, very fine organics and wood fragments exist within the glacially consolidated, non-glacial soils.

The loose sands and gravels in the artificial fill and tideflat deposits are potentially susceptible to liquefaction. The soft cohesive silts and clays are compressible and have relatively low bearing strengths. The underlying, glacially consolidated, very stiff to hard or dense to very dense silt, sand, and gravel are opposite in consistency, with high bearing strength, low compressibility, and low liquefaction potential.

A generalized subsurface profile (C-C’) by the firm Shannon and Wilson (1996) is presented in Exhibit 4-7. This profile was created parallel to Royal Brougham Way, as shown in Exhibit 4-7. The profile shows Shannon and Wilson’s interpretation of subsurface conditions based on borings that were drilled in that area.



SOURCE: Shannon & Wilson, 1996.

Exhibit 4-7
General Profile C-C'
by Shannon & Wilson

Groundwater Conditions

The study area is in the Duwamish River Valley topographic unit (Liesch et al., 1963). The principal aquifers are in unconsolidated Holocene soils and underlying glacially consolidated, coarse-grained layers that are confined by fine-grained soils. Wells tapping these aquifers range in yield from a negligible amount to more than 500 gallons per minute (Liesch et al, 1963).

Holocene is the period of time since the last glaciation. In the Puget Sound area, the Holocene is generally considered to be the last 10,000 to 13,000 years. Soils formed in the Holocene were not consolidated by the weight of glaciers and, therefore, are often softer or less dense in consistency.

In general, the groundwater flow gradient is relatively flat toward Elliott Bay. Results of previous explorations within or near the project study area indicate that the groundwater table is typically 8 to 10 feet bgs but can be as shallow as 2 feet bgs. Zones of perched groundwater may be encountered at shallow depths above low-permeability clay layers. Close to Elliott Bay, groundwater levels may fluctuate by about ½ foot with the tide.

For further information on groundwater in the study area, please refer to the Water Resources Technical Memorandum prepared for this project.

Existing and Potential Aggregate Sources

Imported aggregate would be required for roadway subgrades and for bridge approach fills. The aggregate would have to be brought to the site, as any excess onsite materials appear to contain too much fine-grained soil to serve as adequate roadway subgrade material or as fill for bridge approaches.

Fine-grained soils are not usually suitable for subgrade or approach fills because of the difficulty of compacting these materials, particularly during wet-weather periods, and their tendency to deteriorate under repeated traffic loads.

The location of the project is such that the aggregate could be brought in by truck or barged from other locations in the Puget Sound area. It is also possible that some aggregate need may be met by recycling concrete debris from the demolition of structures for the SR 519 project or other nearby projects.

Aggregate quantity requirements for the project are expected to be less than 10,000 cubic yards. This quantity is small compared to most roadway construction projects, and therefore the project does not have unusual requirements for imported materials.

2 Do the existing geology and soil conditions pose any geologic hazards for the study area?

The potential for geologic hazards within the project study area was identified by reviewing hazard and critical areas maps published by the City of Seattle, USGS, and WDNR, and from interpretations of the available geotechnical information. The City of Seattle Municipal Code (SMC) 25.09.020 defines geologic hazard areas as "liquefaction-prone areas, landslide-prone areas, seismic hazards areas, and volcanic hazard areas".

Two types of geologic hazards were identified on the City of Seattle 2006 GIS maps and WDNR maps for the project study area: liquefaction and seismic hazards. The potential occurrence of these hazards was evaluated on the basis of existing information about soils and geology and results of a visual reconnaissance of the project study area, as discussed below.

Liquefaction-Prone Areas

The study area is mapped as being in a liquefaction-prone area by the City of Seattle, as shown in Exhibit 4-8, and is mapped as having a high potential for liquefaction by Palmer et al. (2004). The SMC defines liquefaction-prone areas as "areas typically underlain by cohesionless soils of low density, usually in association with a shallow groundwater table, that lose substantial strength during earthquakes."

For liquefaction to occur in these loose, saturated, cohesionless soils, a threshold level of ground shaking must occur. This threshold level can be as low as 0.15g, where g is the acceleration of gravity. This level of ground shaking can result from relatively distant earthquakes, such as the 2001 Nisqually earthquake. Although the epicenter of this earthquake was located over 60 miles from downtown Seattle, observations of liquefaction were made in various nearby locations, including the Port of Seattle and at Boeing Field. This type of earthquake occurs roughly every 30 to 40 years in the area.

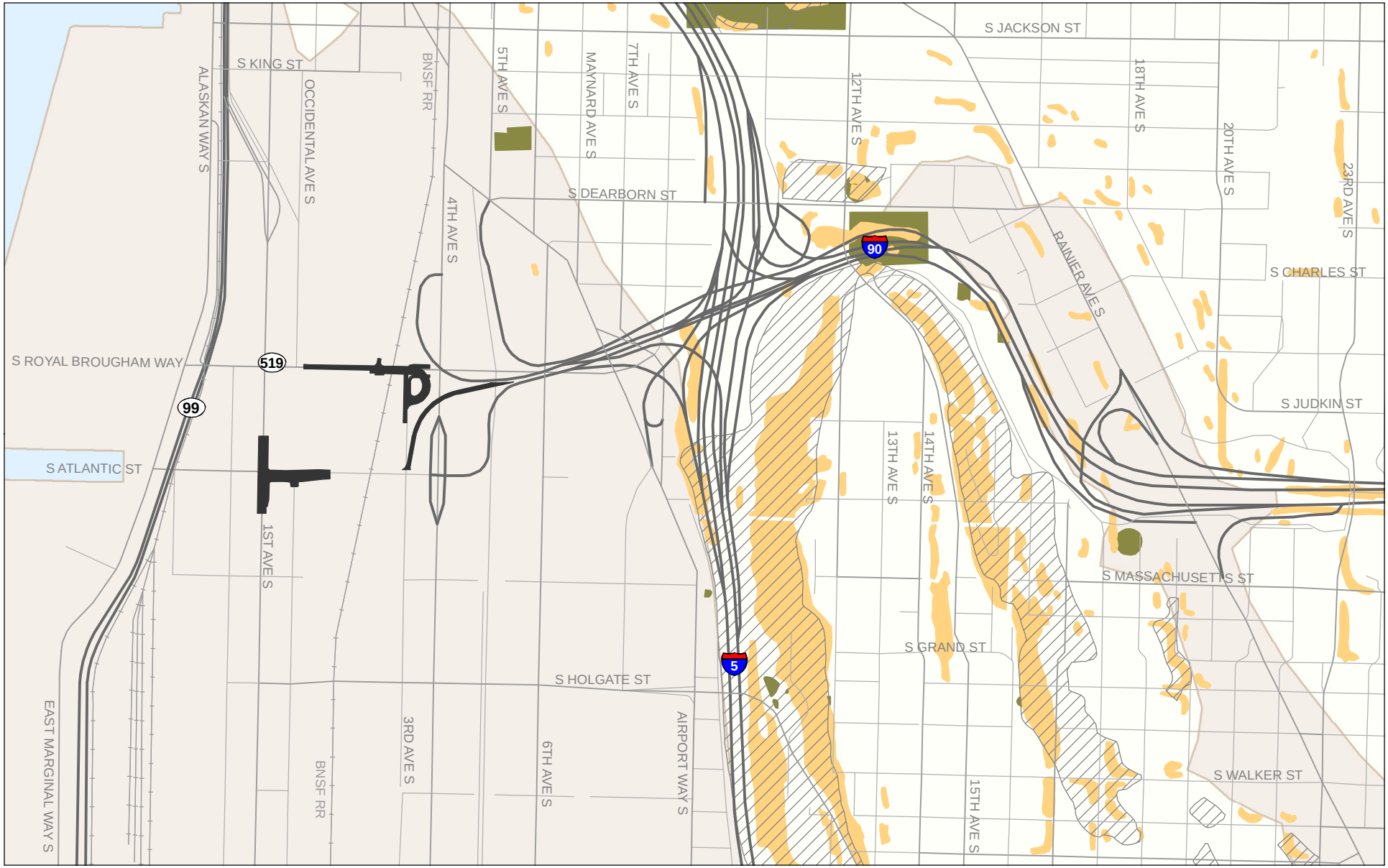


Exhibit 4-8
Geologic Hazards

Fills and some tideflat deposits located in the study area are loose and saturated, and therefore these soils are potentially susceptible to liquefaction during earthquake shaking. Liquefaction would likely develop in random locations within loose sands and low-plasticity silts. Clayey silts and silty clays between the liquefied layers would not liquefy but could undergo some strength loss due to the effects of repeated cycles of shearing stress and the high pore-water pressures in the liquefied layers.

The consequence of liquefaction of the loose cohesionless soils that are below the water table would be permanent lateral and vertical movement of the ground in the areas of liquefaction. Permanent ground movement could occur from:

- Densification of loose granular soils (i.e., sands and low-plasticity silts) during seismic shaking and as excess pore-water pressures dissipate after shaking
- Lateral spreading as the soil moves towards Elliott Bay
- Ground settlement associated with localized sand boils
- Bearing failure of foundations supported on liquefied soil
- Slope failures of embankments supported above liquefied soils.

Photos 4-1 and 4-2 show the conditions that can occur from permanent movement of the ground associated with liquefaction.

A detailed assessment of these secondary effects from liquefaction would be conducted during final project design to quantify these hazards and identify suitable mitigation measures.

Photo 4-1. Liquefaction during the 1965 SeaTac earthquake caused both lateral and vertical movement of the ground in the Port of Seattle. Photo courtesy of the Karl V. Steinbrugge Collection (Palmer et al., 2004)

Seismic Hazard Areas

According to SMC 25.09.020, the study area is located within a Seismic Hazard Area. The SMC identifies the following conditions that could make up a Seismic Hazard Area:

a. Areas of the City subject to ground shaking from seismic hazards that are addressed by the Building Code (SMC Title 22).

b. The Seattle Fault zone as delineated in Troost et al., 2005, …or as the Director determines is more accurately mapped by the U.S. Geological Survey, as set out in a Director's Rule.

c. For tsunamis… and tsunami inundation, the water body and land area as shown in Walsh, et al., 2003…

d. The shoreline and upland areas surrounding Lake Washington are classified as an unknown risk from tsunamis under WAC 365-190-080 (4) (b) (iii).

e. For seiches, the water bodies of Elliott Bay, Lake Union and Lake Washington.

f. The shoreline and upland areas surrounding the waterbodies in subsection (e) are classified as an unknown risk from seiches under WAC 365-190-080 (b) (iii).

Photo 4-2. During the 2001 Nisqually earthquake, liquefied sand was extruded onto the ground surface beneath railroad tracks. Photo by Stephen Palmer (Palmer et al., 2004)

A seiche is a standing wave in an enclosed or partly enclosed body of water that is analogous to the sloshing of water that occurs when an adult suddenly sits down in a bathtub (Noson et al., 1988).

Preliminary evaluations of these seismic hazards were performed for the study area to determine whether each of these hazards represents a potential environmental risk for the project.

Ground Shaking

The project is located in an area that has been subject to past earthquakes and that will undergo shaking again in the future. Seismic events in western Washington result from three source mechanisms: (1) the very large magnitude (**M** 8.5+) Cascadia source off the coast of Washington and Oregon; (2) the intraplate source (**M** 6.5 to **M** 7.5) occurring 20 to 40 miles beneath Puget Sound; and (3) random crustal events (**M** 5 to **M** 7) that could occur in the upper 15 miles virtually anywhere in the region. Exhibit 4-9 shows the location of the three source mechanisms for seismic events in western Washington.

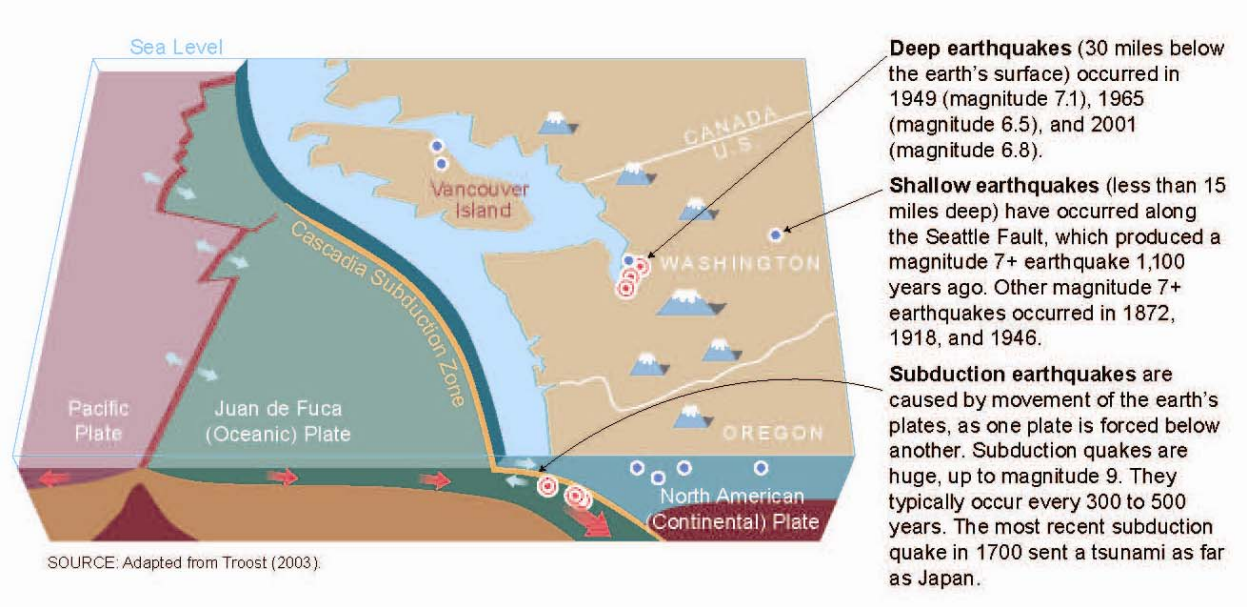


EXHIBIT 4-9. POTENTIAL SEISMIC SOURCE ZONES IN THE PACIFIC NORTHWEST

An earthquake on one of these source mechanisms could result in vibratory ground motions within the study area. These motions travel from the source of rupture. For strong earthquakes, the vibratory ground motions can often be felt more than 100 miles from the source of the earthquake. The severity of the ground shaking at the project site will depend on the specific location of the earthquake and the size of the event, which is defined as the earthquake magnitude (**M**).

Various methods are available for estimating the likely level of ground motion at the site. These methods include a web-based set of maps developed by the USGS, which allows the ground motion to be estimated based on probability methods. The probability method considers the chance that the strong ground motions will occur.

As the ground motions travel to the ground surface at the site, they can be amplified or attenuated depending on the strength of the ground shaking and the consistency and dynamic properties of the soil. Small ground motions caused by distant earthquake or small nearby earthquakes will often be amplified, whereas strong ground motions can diminish. Detailed review of the tendency for amplification or

attenuation is part of the design process that would be performed for the site.

The Nisqually earthquake was the most recent substantial earthquake causing damaging ground motions in the Seattle area. This earthquake occurred deep beneath the ground surface within the subducting Juan de Fuca plate. Levels of ground motion used as a basis for design of the SR 519 project are several times higher than the levels recorded in the project vicinity during the Nisqually earthquake.

Seattle Fault

The study area is mapped within the Seattle Fault Zone (SFZ) according to Troost et al. (2005), City of Seattle (2006a), and USGS (2007a). The SFZ extends from the edge of the Puget Lowland and west across the Puget Lowland, crossing Lake Sammamish, Lake Washington, Puget Sound, Bainbridge Island, and portions of the Kitsap Peninsula. The SFZ is considered an active fault (Johnson et al., 1999; Johnson, 2004; USGS 2007a, b), meaning that it is considered capable of moving again sometime in the future and was included as a potential source in the USGS ground motion hazard map.

The information compiled by Johnson (2004) indicates that the fault zone is about a 2.5- to 4.5-mile-wide, east-trending fault that consists of three or more thrust faults that create a wedge shape. According to Johnson (2004), Holocene (about the last 10,000 years) activity has been well documented for the SFZ, with the most recent known surface-faulting event occurring about 1,050 to 1,020 years before present (yr B.P.). Late Holocene land-level changes, tsunamis, and (or) landslides from many sites around the region are evidence of a large earthquake that can be correlated with this most recent surface-faulting along the SFZ. Johnson (2004) cites in his compilation that this large earthquake (inferred **M**>7) caused uplift south of the Seattle fault and subsidence north of the Seattle basin.

Tsunamis and Seiches

Tsunamis or seiches are a possible secondary seismic effect of earthquake ground shaking. These hazards involve water waves that are created by an earthquake. Tsunamis occur when large

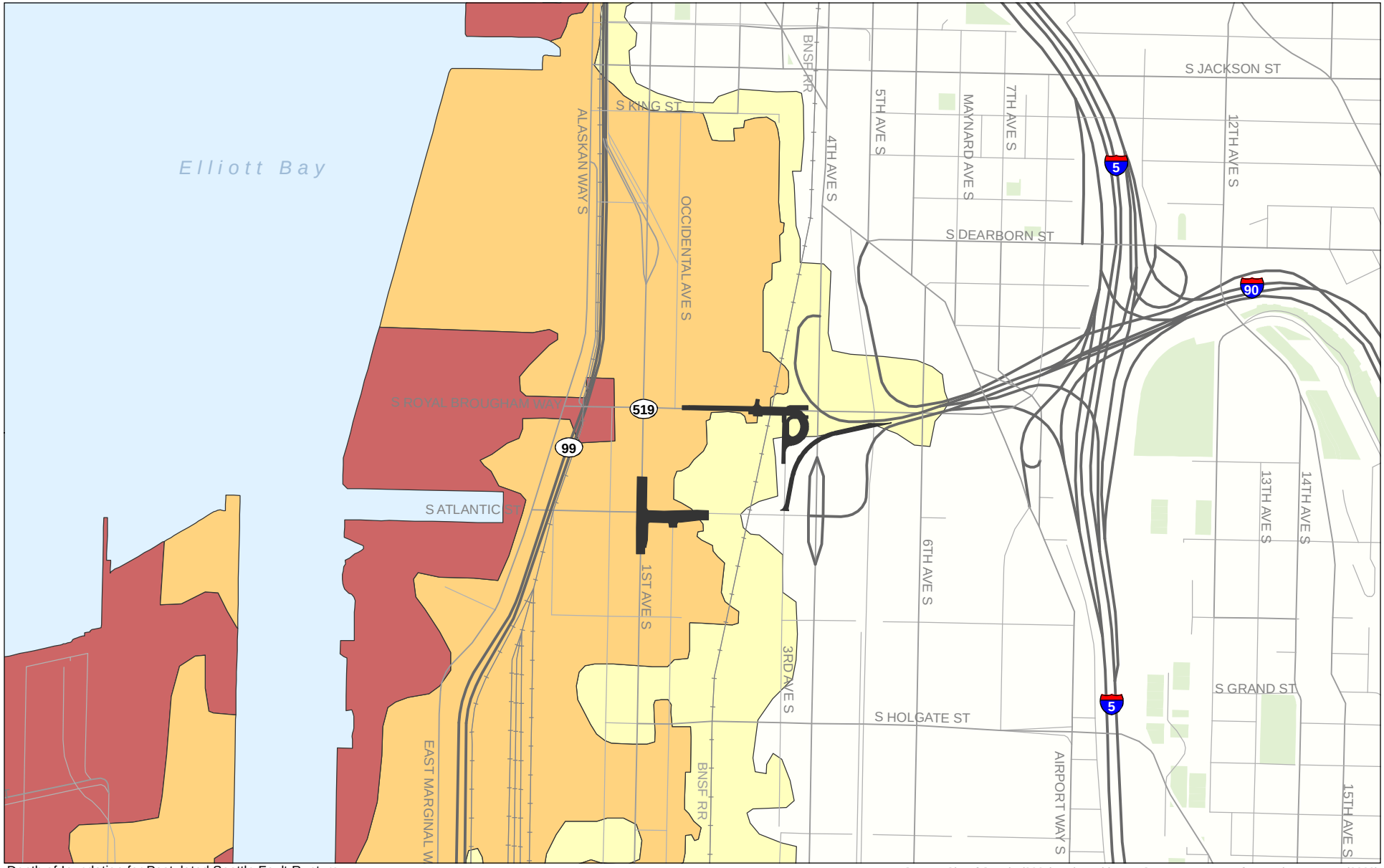
volumes of soil are displaced below the ocean, while seiches involve the oscillation of the water from shaking of the earth. As an example of a small-scale seiche, small waves were observed in the Seattle area immediately after the 2002 Denali earthquake in Alaska.

Earthquakes may induce seiches in lakes, bays, and rivers. While seiches may develop in Elliott Bay, which is the closest body of water to the study area, it is highly unlikely that the size of the seiche would cause flooding of the study area during or after a seismic event because of the size of the water area and the distance of the study area from the water.

The project site is identified as being in a tsunami inundation zone, which is an area of land that is predicted to be covered with water if a tsunami were to occur in the area. A tsunami inundation map, created from the tsunami inundation map by Walsh et al. (2003) for WDNR, is presented in Exhibit 4-10. This map indicates that the project study area has a potential inundation depth of up to 6.5 feet. The map is based on a computer model of waves generated by a magnitude 7.3 earthquake on the Seattle fault.

If a tsunami occurred, the study area could be inundated, depending on tidal conditions at the time of the occurrence and the height of the sea wave. The risk of a tsunami inundation is generally thought to be low, given the low annual frequency of large earthquakes on the Seattle Fault.

Although earthquakes off the west coast of Washington (on the Cascadia fault zone), Japan, or Alaska could also generate tsunamis, the location of Seattle is believed to be far enough from the ocean that only small waves would occur, if any, in Elliott Bay. Also, there would likely be enough warning to evacuate these facilities if a large tsunami from a distant source were forecasted. Nevertheless, a potential for this hazard does exist.



Depth of Inundation for Postulated Seattle Fault Rupture

Source: City of Seattle (2007) and Washington State Department of Natural Resources (2003)

- 6 - 16 Feet
- 2 - 6 feet
- 0 - 2 feet
- Park
- Project

N

0 1,000 Feet

Exhibit 4-10
Tsunami Inundation

Chapter 5 Environmental Consequences and Mitigation Measures

1 How would project construction temporarily affect geology and soils in the study area?

Two types of effects involving geology and soils generally occur during construction of a project: direct and indirect. Direct effects are those that either result from changes in the geology or soil conditions or those that are determined by geology and soil conditions. The simplest example of a direct effect is the need to change surface soil elevations to meet roadway grade requirements. Indirect effects are those that occur later in time or are farther away from the construction. The latter category might include compression of soil beneath new approach fills that would eventually result in settlement of nearby utilities.

Proposed Action

Direct Effects

The planned construction would result in a number of direct effects related to geology and soils, and these effects would have adverse environmental consequences if they are not appropriately identified, evaluated, and mitigated. Examples of potential direct effects for the Proposed Action are summarized below:

- The construction of the SR 519 project will involve various activities that could lead to sediment mixing with stormwater and creating turbid water. Sources of turbidity include uncovered and exposed soils, trucks spilling soil, and the tracking of mud from truck tires onto the roadway. These sources will be controlled during construction

As discussed in section 4.5, past activities in the area have resulted in soil and groundwater contamination. Contaminated soils could be harmful to people, and therefore special regulations have been written to protect the public from these risks.

through the use of normal erosion control and erosion mitigation measures.

- Contaminated soils and groundwater were encountered during construction of Phase 1 of the SR 519 project. As discussed in the *Hazardous Materials Discipline Report*, contaminated soils exist within the proposed construction footprint. Soils would be excavated during the construction of bridge and roadway foundations, and it is likely that some contaminated soils would be encountered. If encountered, these soils will require special handling, transport, and disposal at offsite locations.
- Earth loads would result from construction of new roadway approach fills at South Royal Brougham Way and from soil stockpiles used during construction of the project. If fill is more than a few feet in height, loads from the fill can cause settlement of the soil under and/or adjacent to the fill or stockpile. If adequate precautions are not taken, the settlement could damage nearby utilities or pavement. Lateral movement of soil at the toe of the embankment would also result as the embankment settles. If the lateral movement were large enough, it could also damage adjacent features.
- Drilled shafts foundations are currently planned for supporting elevated structures and possibly portions of the South Royal Brougham Way approaches. During construction of the drilled shafts, loosely compacted sand and clay could be encountered below the groundwater table. In some locations, bricks and old timber pilings from the 1900s could be present. Cobbles and boulders are also known to exist in the glacial deposit under the sand and gravel layer. These conditions have the potential to delay or cause difficulties during construction.
- Numerous utilities are located along South Royal Brougham Way, Third Avenue South, and Fourth Avenue South. If excavations for construction of elevated structure foundations and for relocation of utilities are not adequately supported, then lateral and vertical movements of the

ground supporting the utilities would occur. These movements would result in damage to buried utilities and to structures or roadways located adjacent to the excavations, if the amount of movement is excessive. Design studies would be conducted to evaluate the potential for these movements.

- Existing soils within the study area are both compressible and liquefiable. If these soils need to be improved in some areas to make them suitable for development of the project, then special construction methods would be required. These construction methods could include use of stone columns, jet grouting, or in-place cement-soil mixing. These construction methods would normally generate earth spoils and water with high sediment content. Special containment and disposal procedures would be required to prevent the spoils and water from damaging nearby "clean" areas.
- Ground vibrations would occur during construction as heavy equipment operates within the project footprint. The vibrations could result from a number of sources such as demolition of existing structures, ground improvement activities, bridge foundation construction, compaction equipment operations, and truck traffic. If these vibrations exceed threshold levels in nearby areas, then the vibrations would be annoying to individuals working or living in the area, would possibly cause settlement of loose soils near the source of vibration, or would potentially cause minor damage to structures or utilities due only to the vibrations.

Ground vibrations result when equipment impacts the ground. The level of vibration decreases with distance from the source. People feel the vibration at much lower levels than will damage structures or most equipment.

- The new roadway and structures would require removal of small sections of existing roadway and existing bridge structures in order to build the new facilities. This requirement would result in the generation of small amounts of concrete and asphalt from the demolition of the existing roadway and structures. The total amount of demolition debris would likely be less than a thousand cubic yards. This material would have to be disposed of as construction debris or processed for reuse. The quantities of construction debris appear to be too small to reprocess for

only the SR 519 project, but potentially could be reprocessed as part of other ongoing projects in the area. If the concrete and asphalt cannot be reprocessed, it will be disposed in landfills, reducing the available volume at the landfills.

- Existing soils would be excavated during construction of the drilled shaft foundations for bridge structures, as well as for any ground improvement at the approach ramps. The amount of excess soil from shaft construction could be more than 200 cubic yards per shaft. Depending on the number and size of the shaft foundations, and the amount of excavation at the approaches, the resulting total volume of excavated soil could be several thousand yards or more. This excavated soil would not be suitable for construction (without amendments such as cement or fly ash) because of the amount of fine-grained material. Excavated soil that cannot be used for landscape material would need to be removed and transported offsite. Some of this soil could be contaminated with hazardous materials. Excavated soils would be tested to determine if hazardous materials were present. If hazardous materials were found in the soil, it would require special handling and containment and would need to be disposed at a licensed disposal facility.
- An earthquake could occur during construction, resulting in embankment slope failures, liquefaction, ground settlement, or damage to partially completed structures. If such an event were to occur and there was damage to the work completed, then there would be schedule delays as damaged areas are repaired. The normal approach during design and construction is to assume that this risk is very small.

Indirect Effects

Indirect effects associated with geology and soils would occur later in time or farther from the project footprint. For example:

- Aggregate would be required for concrete, subgrade fills, and possibly for approach fills. The amounts of aggregate for the project are estimated to be small, probably less than

Aggregate refers to gravel and sand that is used as roadbed material or is mixed with cement and water to make concrete. The gravel and sand are mined from gravel pits located in the Puget Sound area.

15,000 cubic yards, because of the type of development. Use of aggregate on the project would reduce supplies of material that might be used elsewhere for other projects. As noted, the quantity required for construction of this project is minimal in comparison with the quantity of aggregate that is used on typical roadway projects and the amount available regionally.

- Soils would be exposed to the weather when roadway surfaces are replaced and the ground at drilled shaft and bridge approaches is exposed. Exposed soils could be carried far enough offsite by rainwater that roads or drainage facilities outside the study area would be affected, if appropriate mitigation measures were not taken. Spillage from trucks and soil on truck tires could also eventually result in similar consequences beyond the study area without adequate mitigation measures.
- Trucks would be required to bring heavy equipment or construction materials to the site and to remove excess soils and construction debris. These trucks would cause deterioration of nearby streets and roadways if the loads exceeded the strength of the roadway base material, leading to cracking or rutting of pavements.

No Build Alternative

Without the Proposed Action the construction-related effects described above would be avoided. For example, with the No Build Alternative, there would be no potential for adverse vibrations from construction, the aggregate supplies needed for the Proposed Action would be used for other purposes, and there would be no potential for erosion of exposed soils located in fills and stockpiles.

2 What long-term effects associated with geology and soils would occur during operation of the project?

Just as with the short-term, construction-related effects discussed above, the long-term consequences of operating the Proposed Action would also include direct and indirect effects

related to geology and soils. Because the expected life of the Proposed Action would be 75 years or longer, effects that would be accommodated or avoided during construction have the potential to persist and possibly increase over time. For example, fill for the new bridge approaches could cause progressive settlement extending beyond the footprint of the structures, eventually leading to cracking of pavements and damage to utilities located adjacent to the fill.

Proposed Action

Direct Effects

Long-term direct effects of the Proposed Action that relate to geology and soils were identified based on the conceptual plans for design. Examples of long-term direct effects based on these conceptual plans include:

- Long-term settlement of the soil beneath the earth fills for the approaches to the new ramp to South Atlantic Street and to the overpass at South Royal Brougham Way. If this settlement is more than an inch or two, added maintenance to the new structures and poor ride quality on the approaches or ramps would result. Periodic re-leveling and repaving of the approach roadway would likely be required.
- Damage to the new elevated structures and approach fills at South Royal Brougham Way from traffic-induced vibrations. If levels of vibration are high and are not corrected, these vibrations would result in either damage to the elevated structures, including fatigue of structural connections, or damage to approach fills such as settlement of loose, cohesionless soil supporting the approach, eventually requiring added maintenance or resulting in poor ride quality.
- Modification of groundwater flow paths in areas where ground improvement methods are used to mitigate potential effects of seismic loading, such as at the South Royal Brougham Way approaches. The volume of earth affected by foundations and ground improvement by itself is very limited relative to groundwater flow regimes in the area;

When fills are added to an area, the soil beneath the fill begins to compress. The zone of compression occurs not only below the fill but extends outside the new load – potentially affecting nearby pavements, sidewalks, and buried utilities such as sewer and water lines, fiber optic cables, and gas lines.

however, as noted later, the cumulative effect of combined projects could be a consideration.

- Ground settlement and increased loads caused by earthquake shaking on new elevated structures. The consequences of earthquake-induced ground shaking would be liquefaction and densification of water-saturated, sand-like soils if soils are not improved. Liquefaction can result in lateral spreading of the soil toward Elliott Bay, ground settlement, bearing failures, and instability of any slopes associated with approach fills. If these mechanisms are not appropriately identified and mitigated, they would lead to either loss of lateral support or additional loads on drilled shafts from liquefaction, soil settlement, or lateral soil movement, potentially resulting in damage to the bridge structure and loss of service.

Seismic loading results from the ground vibrations that occur as a result of an earthquake. The vibrations result in added forces in structures and in the ground. These forces can cause soil to become fluid-like in consistency, referred to as liquefaction, or settle as the soil densifies. As the soil settles, it can cause increased friction on foundations. This is referred to as drag loads.

- Damage to transitions between the South Atlantic Street ramp structure to the existing westbound I-90 off-ramp at the north end and to the existing South Atlantic Street overpass at the south end during seismic loading. If the potential for relative movement between the structures is not adequately considered during design, earthquake-induced ground shaking on the new ramp structure would induce loading on the existing structures, potentially resulting in over-loading and damage to the existing structures. Similarly, the potential for additional loading to existing large-diameter pipes from the seismic response of foundations supporting the new Royal Brougham will be evaluated and mitigated if necessary.

Indirect Effects

Indirect effects related to geology and soils possibly include:

- Increased maintenance of surface streets and utilities from long-term settlement associated with the planned approach fill embankment between Third Avenue South and Fourth Avenue South. If earth loads are large, large vertical and lateral soil movements would occur if the ground is not improved before placement of the earth fills. The zone of influence from the new earth loads would potentially

Royal Brougham Way has numerous utilities, including old brick sewers and high-pressure gas mains, which could be damaged if the ground settles.

extend into the street, causing displacement of adjacent sidewalks, streets, and utilities.

- Damage to adjacent sports facilities from traffic-induced vibrations originating on the new bridge structure at South Royal Brougham Way. If the vibrations on the structure are not isolated from the sports facilities and levels of vibration at the sports facilities are large, damage would potentially occur, resulting in added maintenance to facilities or annoyance to fans using the facilities.

No Build Alternative

If the Proposed Action were not built, some of the long-term operational effects noted above would not occur, such as vibrations related to vehicle loading. However, some would remain. For example, seismic hazards and the related secondary effects will occur whether the project is built or not.

3 What measures are proposed to mitigate identified adverse effects due to the project?

Various procedures can be implemented to avoid or minimize adverse effects of the project related to geology and soils. These mitigation measures would be identified and evaluated during detailed engineering design and construction planning.

Construction Mitigation

Unwanted effects of most construction activities would be mitigated by implementing standard design and construction procedures. These mitigation measures range from applying best management practices (BMPs) to reduce erosion and control sediment during construction to modifying design requirements to minimize effects of settlement. Such measures would be determined during detailed engineering design and construction planning. Typical examples of these measures include:

- Prior to the start of construction, a Temporary Erosion and Sediment Control (TESC) Plan identifying what BMPs would be used, and where they would be used, would be written. During construction, this plan would be implemented and modified. A water quality monitoring

plan would also be implemented during construction. BMPs for erosion control would normally include items such as silt fences, straw bales, and sedimentation ponds. These requirements would be listed in construction documents. Construction documents would also require that stockpiles of imported earth fill and aggregate are either covered or surrounded by silt fences if the period of exposure is long; that the amount of earth exposed for construction is limited, particularly during wet winter months; that sedimentation in water pumped from construction excavations is filtered in Baker tanks or other suitable means before disposal; and that geotextile covers are placed over storm drain entrances to collect sediment in surface water. Construction documents may also require that trucks hauling aggregate or earthfill to the site cover their loads with tarps or limit the amount of earth to avoid spillage. If there is a potential that truck tires will carry sediment from the site to surface streets, truck access routes or wheel washes could be required to use rock surfacing to limit tracking of soil from the site. An inspection plan that addresses signs of erosion, instability, or settlement of stockpiles would be required.

The amount of exposed earth for the proposed action is relatively small, limiting the potential for sediment transport. Nevertheless, strict requirements will be placed on the contractor to limit offsite movement of soil.

- Contaminated soil and groundwater are known to occur within the study area. As these are encountered, they would require special handling, containment, and disposal. Before soil is excavated in any location, the potential for contamination would be evaluated further, possibly with additional field explorations and laboratory analyses, to establish the degree of contamination that must be considered during excavations. If the contamination exceeds certain levels in the area of excavation, workers performing the excavations will be required to wear special protective clothing and additional erosion control protective measures will be required to prevent contaminated stormwater runoff. If the level of contamination exceeds regulatory standards, soils will require transport in water-tight bed liners, trucks will be required to pass through wheel washes before leaving the work area, and

contaminated soils will require disposal at regulated landfills. Additional discussions of hazardous waste issues are provided in the *Hazardous Materials Discipline Report.*

- The potential for vertical and lateral movement of the ground during construction of new approach ramps would be quantified during the design phase of the project. If vertical or lateral movements of the earth from new fills are predicted to be excessive, they would be mitigated through the use of ground improvement methods, lightweight fills, or other methods. Utilities would be relocated or protected in locations where ground settlement cannot be mitigated.
- Unfavorable soil and groundwater conditions (e.g., loose silts and sands below the groundwater table, old timber pilings, and other construction debris from the early 1900s) in areas where deep foundations will be constructed would be mitigated through the use of foundation drilling equipment specifically designed to provide borehole support during drilling and capable of removing debris. Contract documents would be prepared to advise potential contractors of these construction risks. If determined during design to be critical, full-depth casing would be required to maintain hole stability.
- If the potential for vertical or horizontal ground movement next to excavations is determined to be excessive during design, the construction documents would require use of stiff retaining wall systems or lateral support using earth anchors or structural bracing. The location of the wall would also be monitored during excavations using survey methods and geotechnical instrumentation to warn of developing movements.
- In areas requiring ground improvement to mitigate potential effects of liquefaction or settlement, strict controls would be imposed on construction methods to contain spoils and excess water caused by the ground improvement technique. These controls would typically include use of earth dams to confine fluids, continuously re-circulating water, and limiting the amount of onsite stockpiling of

Lightweight fills are construction materials that weigh less than an equivalent amount of soil or concrete. One example is extruded polystyrene, often called geofoam. Large blocks of geofoam can weight just a few pounds but still support the weight of trucks.

Ground improvement techniques are used to improve the strength of the subgrade soils. Typical ground improvement techniques include stone columns, lightweight fills, and vibro compaction.

spoils from excavations. Another alternative would be to select ground improvement methods that would not produce as much spoils and excess water.

- To mitigate the effect of ground vibrations during construction, construction documents would require that equipment be selected and operated to minimize the potential for vibration. For example, in constructing the drilled shaft bridge foundations, the use of special equipment to rotate the steel shaft casings in the ground would be considered in the vicinity of sensitive underground utilities. Similarly, methods of ground improvement that produce limited vibrations, such as deep cement-soil mixing, would be identified in construction specifications, if determined necessary after detailed engineering review.
- The amount of construction debris and excess earth that must be disposed at landfills would be limited by reprocessing concrete into aggregate to the extent possible. This reprocessed aggregate would be re-used in concrete or fills on the SR 519 project or other projects in the Seattle area. Similarly, asphalt can also be reprocessed and mixed with soil for fills, and steel rebar can also be recycled. Uncontaminated soil from excavations would be used as fill either for the proposed development or at other projects in the area requiring earth fill. Although the direct potential for reprocessing demolition debris is limited for the SR 519 project because of the small amount of debris being generated, the potential exists for reprocessing the debris with debris from other nearby projects, such as the Alaska Way Viaduct project, if the construction periods for the other projects coincide with the SR 519 project.
- The likelihood of an earthquake during construction is very low, and little related to soils and geology can be done to mitigate for its occurrence. However, if an earthquake were to occur, mitigation strategies would be developed to revise construction schedules or rebuild damaged facilities.

Operational Mitigation

During preliminary design, WSDOT would conduct geotechnical investigations to understand subsurface conditions prior to final design. Mitigation measures for long-term fill settlement, traffic-induced vibrations, and seismic hazards would be identified following this investigation and methods of mitigating their potential effects would be developed, where determined appropriate. Examples of these mitigation measures include the following:

- To avoid the risk of long-term ground settlement, the proposed structures would be constructed on deep foundations that extend through the compressible soils to denser bearing material. At the bridge approach fill located between Third and Fourth Avenues, either ground improvement or deep foundations would be used to reduce settlement.
- The potential for traffic-induced vibrations from use of the new South Royal Brougham Way structure or new approaches would be mitigated by minimizing the source of vibrations, such as construction joints or rapid changes in roadway grade. If design studies determine the potential for excessive vibrations between the elevated structure and the sports facilities, isolation joints or similar systems would be used to minimize the potential for damage to the existing facilities.
- If groundwater flow in the study area was determined to be adversely affected by the installation of ground improvement methods, ground improvement construction methods that limit the effects to groundwater flow would be identified in construction documents. These alternate methods might involve use of stone columns rather than jet grouting or in-place soil mixing procedures.
- New structures at risk from earthquake-induced liquefaction and ground settlement will be designed according to WSDOT seismic design methods for liquefaction and ground settlement. Where design studies identify substantial risk, deep foundations will be used to

Stone columns are built of gravel and sand, while jet grouting and soil mixing create zones made up of cement and soil. Gravel columns are more porous than soil-cement columns.

carry the seismic loads to suitable bearing materials. If required, soils will also be improved to reduce the risk of liquefaction and related seismic damage.

- All new structures would be designed to meet or exceed earthquake loading requirements in the latest issues of the American Association of State Highway and Transportation Officials (AASHTO) LRFD Bridge Design Specifications (AASHTO, 2004. For seismic hazards on existing structures due to induced loading from the proposed South Atlantic Street ramp structure, the proposed structure will be designed to be structurally isolated from the existing structures, or will be designed with sufficient stiffness to reduce additional seismic load on the existing structure. Similarly, the potential for additional loading to existing large diameter pipes from the seismic response of foundations supporting the new Royal Brougham will be evaluated and mitigated if necessary.

4 Are any of the identified effects considered substantial?

Effects considered to be substantial are those that might require new locations for the project or the use of a different method of supporting a roadway or structures.

This environmental assessment determined that no direct or indirect effects of the Proposed Action related to geology and soils would be substantial. This conclusion is due in part to the general flatness of topography within the project footprint, the minimal need for widening, and the current land use. With these conditions, there is limited need for imported borrow material and limited need for large excavations. The relative flatness within the project footprint would also limit the potential for erosion and the need for erosion control.

The most important issue related to soils and geology appears to be the potential for seismic loading. Appropriate mitigation methods are available to deal with the consequences of seismic loading, including mitigation for liquefaction potential and densification of the soil through use of ground improvement

methods. Designers must also follow WSDOT and American Association of State Highway and Transportation Officials (AASHTO) design requirements for seismic loading as they design all bridges, retaining walls, and related components of the project.

Chapter 6 Cumulative Effects

1 What are cumulative effects, and why are they important?

Cumulative effects are important because they help us to understand the project in terms of a "bigger picture." They can reveal possible unintended consequences of the Proposed Action or No Build Alternative that might not be apparent when we look at the project by itself. Because of this, cumulative effects help us to evaluate how sustainable the project is likely to be in future years, and how it might interact with other projects that are planned but have not been built yet.

What are cumulative effects?

Cumulative effects are impacts on the environment that result "from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions, regardless of what agency or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time. Defined by FHWA and Council on Environmental Quality (CEQ) regulations (40 CFR 1508.7)" (WSDOT, 2006)

2 How did the study team identify expected cumulative effects on geology and soils?

The project team identified expected cumulative effects of the Proposed Action and No Build Alternative by following a process recommended by the President's Council on Environmental Quality (CEQ, 1997) and as identified in Chapter 412 of the WSDOT *Environmental Procedures Manual* (WSDOT, 2007). First, the team considered other past and present projects that have already affected or were affected by the geology and soils in the area. These past and present actions have changed geology and soils in and around the SR 519 study area from their original condition. The most important of these past actions was the filling of the area with tens of feet of fill in the early 1900s. Next, the expected direct and indirect effects of the project on geology and soils, discussed in Chapter 5, were added. Finally, the probable effects of other projects that are planned but not yet built were considered.

The project team combined past and present actions and RFFAs with the expected direct and indirect effects of each of the two alternatives to produce a cumulative picture of how geology and soils might be affected, with and without the Proposed Action, in the future.

Past and Present Actions

Past projects in the study area, during the nineteenth and early twentieth centuries produced cumulative effects related to soils and geology that were largely negative, resulting from what would now be regarded as substandard construction practices.

- Fills were initially placed in the study area with little consideration of location, method of placement, and little regard for existing soils, structures, or debris that was buried in the process. As the area was developed, little was done to protect the filled area from human activities or to plan for future development in the area.
- In most cases, older roadway structures were built according to the then-current design standards, and sometimes without consideration of seismic loading. Often construction materials and techniques were not optimal for resisting earthquake damage. As the understanding of seismic risk improved, requirements for seismic design became more stringent. Nevertheless, structures constructed as recently as the 1980s may not be able to meet some current seismic design requirements.
- Past construction practices paid little attention to gravel depletion, soil erosion, or the disposal of construction debris. Resources for construction, such as gravel, were plentiful and located nearby, and abundant land was available for the disposal of demolition debris.

The cumulative effect of past design and construction practices became evident in terms of deterioration in wildlife habitat from accumulations of sediment in streams and waterways, an increased cost of imported construction materials, and more stringent regulatory requirements for waste disposal sites. As the infrastructure also aged, a greater percentage lacked the ability to meet current earthquake design standards, making the

public more at risk from a large seismic event. However, the cumulative disposal of fill in the tidelands bordering Elliott Bay resulted in the additional buildable land that now includes much of downtown Seattle, including the study area, producing a practical outcome.

As undesirable cumulative effects have become recognized, better construction practices have led to improved conditions. These practices have included BMPs to protect against soil erosion, and recycling of construction debris into usable building materials. Roadway and bridge design codes have also been improved to provide better protection for the public, resulting in facilities that are more capable of resisting seismic events without damage.

Direct and Indirect Effects of the Proposed Action

The direct and indirect effects of the Proposed Action relative to geology and soils (see Chapter 5) would be largely controllable through the use of appropriate design methods and implementation of BMPs and mitigation methods during design and construction.

For direct and indirect effects that would not be avoidable, such as an incremental reduction in aggregate supply from the extraction of gravel needed for approach fills, an opportunity exists for reduction of adverse cumulative effects through efforts to re-use existing demolition debris. Similarly, excavated soils can be used as fill either onsite or at other locations in the project vicinity.

Although the potential risk from seismic loading would be mitigated through the use of current design standards on the Proposed Action, the cumulative risk to other structures or facilities in the area remains unchanged in the short term. However, as part of WSDOT's earthquake mitigation strategy, major access routes are given priority to the seismic upgrade work, eventually leading to reduced risk on the overall transportation network.

A cumulative effect on groundwater flow could eventually result in the study area from the combined effects of deep

foundations and ground improvement used for this and other developments. Foundations and some types of ground improvements are impermeable to water flow, and therefore create a barrier to groundwater flows for the general area. This cumulative effect is expected to be of minor consequence because of the project location near Elliott Bay and the limited hydraulic gradient being affected.

Direct and Indirect Effects of the No Build Alternative

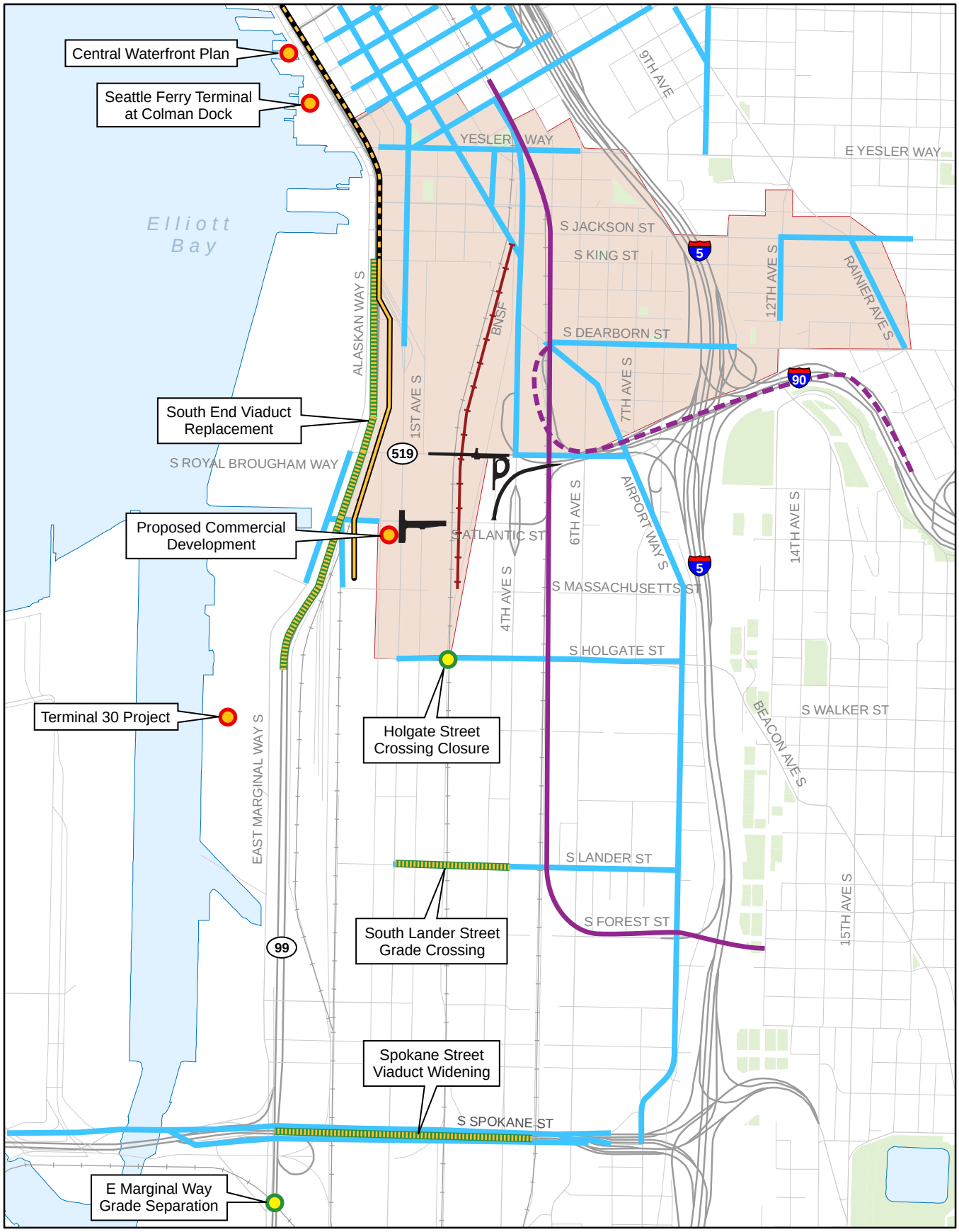
If the No Build Alternative were selected, a few direct and indirect effects related to geology and soils would be positive. These effects would be related primarily to avoiding the need to use aggregate resources and for the disposal of construction demolition debris and unsuitable soils at offsite locations.

There is, however, one beneficial effect of the Proposed Action that would not be realized. It involves the removal of contaminated soil from the site. Under the No Build Alternative, this benefit would not be realized.

Reasonably Foreseeable Future Actions

Exhibit 6-1 shows approximate locations of some of the larger reasonably foreseeable future actions (RFFAs) that could add to or interact with the Proposed Action to contribute to cumulative effects on geology and soils. Exhibit 6-2 briefly summarizes information about these projects. As previously noted, they include:

- The Alaskan Way Viaduct and Seawall Replacement Project from South Holgate Street to South King Street, and the two-phase Electrical Line Relocation Project, which are Moving Forward projects within the Alaskan Way Viaduct and Seawall Replacement Program
- The South Spokane Street Viaduct project
- Completion of BNSF Railway track improvements
- Sound Transit light rail projects
- Closure of the South Holgate Street rail crossing



Source: City of Seattle (2007) and King County (2006)

- Project
- Livable South Downtown Study Area (Approx.)
- BNSF Railway Completion
- Electrical Line Relocation Phase 1 and Phase 2
- Sound Transit Central Link
- Proposed Sound Transit East Link
- Bridging the Gap Paving Project
- Road Project
- Development Project

N

0 1,000 Feet

Exhibit 6-1
Reasonably Foreseeable Future Actions

EXHIBIT 6-2. REASONABLY FORESEEABLE FUTURE ACTIONS IN OR NEAR THE STUDY AREA

Project[a]	Location	Purpose	Proponent	Expected Construction Time Frame[b]
Alaskan Way Viaduct and Seawall Replacement Project from South Holgate Street to South King Street	SR 99 from South Holgate Street to South King Street	Build new SR 99 between South Holgate Street and South King Street. Includes South Atlantic Street and South Royal Brougham Way grade separation, detour routes, and temporary connections	Washington State Department of Transportation	2009-2012
Electrical Line Relocation	Phase 1: South Massachusetts Street to South King Street Phase 2: South King Street to Union Street	Remove network distribution lines and transmission lines that are located under the existing Viaduct before it is demolished	Washington State Department of Transportation	Phase 1: Construction scheduled for 2008-2009. Phase 2: To be determined.
Completion of BNSF Railway Improvements	King Street Station to South Royal Brougham Way	Reduce rail transportation conflicts along the BNSF right-of-way; increase safety at the BNSF crossing of South Royal Brougham Way	BNSF Railway	Improvements at South Royal Brougham Way have been completed; with additional improvements along the BNSF right-of-way currently in progress.
Central Link Light Rail	Downtown Seattle to Sea-Tac Airport	Provide light rail service between downtown Seattle and Sea-Tac Airport	Sound Transit	2008-2009
East Link Light Rail	Downtown Seattle to Redmond	Provide light rail service between downtown Seattle, Mercer Island, Bellevue, and Redmond	Sound Transit	Construction not scheduled. Environmental impact statement scheduled for release in fall 2009.
Proposed Commercial Development	South side of South Atlantic Street between First Avenue South and Utah Avenue South	Provide office and retail uses	Gull Industries	2010-2012
Livable South Downtown Planning Study	The study examines growth and planning issues specific to Pioneer Square, the Chinatown/ International District (including the Little Saigon area east of I-5), and the northernmost edges of the Greater Duwamish Manufacturing and Industrial Center.	Stimulate housing and related development consistent with the Mayor's Center City Seattle strategy	City of Seattle, Department of Planning and Development	Environmental impact statement and legislative proposals in 2008
Closure of South Holgate Street at BNSF Railway Crossing	South Holgate Street at the BNSF Railway crossing	Eliminate conflicts between rail and vehicle traffic.	City of Seattle, Department of Transportation	Construction not scheduled

EXHIBIT 6-2. REASONABLY FORESEEABLE FUTURE ACTIONS IN OR NEAR THE STUDY AREA

Project[a]	Location	Purpose	Proponent	Expected Construction Time Frame[b]
South Lander Street Grade Separation	South Lander Street between First Avenue South and Fourth Avenue South	Improve safety and traffic flow by constructing a roadway bridge for vehicles, bicycles, and pedestrians over the BNSF Railway tracks.	City of Seattle, Department of Transportation	2009-2011
South Spokane Street Viaduct Widening	South Spokane Street from Sixth Avenue South to West Seattle Bridge	Improve traffic safety and upgrade the structural and seismic performance of the viaduct that connects I-5 to the West Seattle High Level Bridge. Construct a new eastbound loop ramp to Fourth Avenue South, to the south of South Spokane Street.	City of Seattle, Department of Transportation	Seismic retrofit, median barrier installation, and street-level utility relocations have been completed. Viaduct widening and ramp construction is scheduled to start in 2008 and would be constructed in phases as funds become available, so exact construction range not known.
Bridging the Gap Paving Projects	Seattle arterial streets	As part of a larger program, the paving projects will resurface, restore, or replace approximately 300 lane-miles of arterial streets; rehabilitate or replace 3-5 bridges and seismically retrofit 5 additional bridges; repair or restore approximately 144 blocks of existing sidewalks; build approximately 117 blocks of new sidewalks; rehabilitate approximately 50 stairways; and restripe about 5,000 crosswalks.	City of Seattle, Department of Transportation	2006-2013
Central Waterfront Plan	South Atlantic Street to West Thomas Street along the shoreline edge of the Center City	Following replacement of the existing Alaskan Way Viaduct, construct new parks and open spaces, shoreline and habitat improvements, improved linkages to the downtown core, *and* transit connections, *and implement* land use and regulatory changes.	City of Seattle	Presently in planning process. Construction will begin with the removal of the viaduct and will be ongoing for several years.

EXHIBIT 6-2. REASONABLY FORESEEABLE FUTURE ACTIONS IN OR NEAR THE STUDY AREA

Project[a]	Location	Purpose	Proponent	Expected Construction Time Frame[b]
Terminal 30 Conversion	East Marginal Way South between approximately South Holgate Street and South Lander Street	Terminal 30 had been used for cruise operations but will be converted back to its original use as a container terminal. This and the adjacent Terminal 25 will provide 70 acres for container use.	Port of Seattle	2007-2009
East Marginal Way Grade Separation Project	East Marginal Way South just south of South Spokane Street	Provide a north- and southbound grade separation on Duwamish Avenue South, relocating East Marginal Way through this corridor to improve access among Port of Seattle terminals, rail yards, and industrial warehouses.	Port of Seattle	2006-2008
Washington State Ferries Terminal Improvements at Colman Dock	Pier 54 at Seattle Waterfront on Alaskan Way South	Upgrade structures and facilities and increase capacity.	Washington State Department of Transportation	Construction not scheduled. For 2008-2009, focus will be on system-wide planning and coordination with nearby projects, including the proposed SR 519 Phase 2.

[a]Only major planned projects are listed. Many other projects that could be implemented in the reasonably foreseeable future are not shown.
[b]Dates are approximate.
Sources: General information from the WSDOT, City of Seattle, Port of Seattle, and Sound Transit websites.

- Conversion of the Port of Seattle's Terminal 30 to a container terminal
- The East Marginal Way Grade Separation Project
- The City of Seattle's Central Waterfront Plan
- The City of Seattle's Bridging the Gap paving projects
- Washington State Ferries Terminal Improvements at Colman Dock

In addition, many other developments not yet planned in detail could result from a decision to move forward with the Livable South Downtown program (City of Seattle, 2006b).

Urban development is increasing in portions of the South Downtown area immediately north of the study area. This area, which includes Seattle's International District/Chinatown/Little Saigon neighborhood, is currently the subject of Livable South Downtown, a major planning effort by the City of Seattle's Department of Planning and Development. In November 2007, the City of Seattle released the *Draft EIS for Livable South Downtown Planning* (City of Seattle 2007a), a SEPA programmatic EIS which evaluates options for a comprehensive neighborhood plan for the South Downtown area.

The study examines growth and planning issues specific to Pioneer Square, the Chinatown/International District (including the Little Saigon area east of I-5), and the northernmost edges of the Greater Duwamish Manufacturing and Industrial Center. Preliminary recommendations were released by the City's Department of Planning and Development in March 2006. Land use and zoning changes considered as part of this process will require conducting an environmental review prior to legislative decision-making.

The project most likely to interact with the Proposed Action in the near future is the Alaskan Way Viaduct and Seawall Replacement Project from South Holgate Street to South King Street, which will replace the south end of the Viaduct (Exhibit 6-1). That project, a Moving Forward project within the

Alaskan Way Viaduct and Seawall Replacement Program, is scheduled for construction from 2009 to 2012, the same time frame as the Proposed Action, and it will be located immediately west of the proposed SR 519 improvements.

The project team examined these RFFAs to see if they might interact with the Proposed Action to produce a cumulative effect on geology and soils.

The primary influences that appeared to contribute to cumulative effects from the RFFAs were related to use of construction materials, quantities of construction debris, and seismic hazards, as summarized below:

- Construction of the Proposed Action would require concrete and reinforcing steel to construct structures and foundations, asphalt to replace pavement, aggregate for roadbase materials, and various other construction materials. These requirements would be similar to other projects being constructed in the area, such as the Alaskan Way Viaduct and the Spokane Street Viaduct. When considered in total, a large demand would be placed on material resources. A potential outcome is that costs for construction of project components would increase, likely at a rate greater than the national rate of inflation.
- Construction debris would result from various sources during work on the project. This would include concrete debris from tie-in to existing structures and buildings, as well as asphalt from roadways that are excavated along South Royal Brougham Way, on Fourth and Third Avenues, and along First Avenue. Similar to the above discussion of construction materials, this debris would be similar to that which would result from other nearby projects. These RFFAs would be both beneficial and negative. The beneficial effects would be that by considering all the projects together, the economics of reprocessing much of the debris becomes more feasible. The negative effect would relate to debris that cannot be recycled and would have to be disposed of in landfills; the

capacity of the landfills would be reached more rapidly because of the combined disposal amounts.

- The seismic hazard also is an RFFA that has both positive and negative effects when considered with other projects. For example, the SR 519 project will be designed to the latest seismic standards, resulting in improved safety to the public. However, the higher safety would be limited to the new structures and not the tie-ins to existing structures. The risk on the existing structures would potentially be higher because of the higher usage that is likely to result for the corridor. It is also possible that some liquefaction-related hazards, such as lateral spreading, might be reduced if work for the Alaskan Way Viaduct or Spokane Street Viaduct resulted in ground improvement along the waterfront.

3 Would the Proposed Action contribute to cumulative effects on geology and soils?

The Proposed Action might contribute to cumulative effects related to geology and soils, as summarized in Exhibit 6-3.

EXHIBIT 6-3. SUMMARY OF EXPECTED CUMULATIVE EFFECTS RELATED TO GEOLOGY AND SOILS

Type of Cumulative Effect	Description of Cumulative Effect
Proposed Action	
Seismic risk	The Proposed Action would introduce elevated structures that would connect to previously built structures, some of which are also elevated. Seismic loading during an earthquake could put these existing structures at risk. The cumulative effect on structures by seismic-induced ground shaking and liquefaction for the Proposed Action would be mitigated through appropriate design, construction, and operational procedures. (See Chapter 5 for further details on seismic risk and mitigation.) Although existing structures would not be retrofitted to meet current seismic standards, an indirect cumulative effect would be that a higher priority would likely be given to retrofitting the existing structures so that the risk to this critical transportation corridor is reduced.
Reduction in the availability of local aggregate	The use of gravel aggregate for roadway construction and approach fills would incrementally reduce the availability of fill material from existing aggregate resources. Although requirements for gravel aggregate would be minimal relative to the regional supply, the Proposed Action, in combination with other reasonably foreseeable construction projects in the Seattle area, would contribute to the gradual reduction of aggregate material

EXHIBIT 6-3. SUMMARY OF EXPECTED CUMULATIVE EFFECTS RELATED TO GEOLOGY AND SOILS	
Type of Cumulative Effect	**Description of Cumulative Effect**
	available from nearby aggregate sources, requiring longer import distances. These longer distances would add to the regional construction costs. The increasing focus on re-using demolition debris would help offset these increased regional costs.
No Build Alternative	
Seismic risk	Seismic hazards and the related secondary effects would occur whether or not the Proposed Action was implemented.
Improved local aggregate supplies	Most of the construction effects would be avoided. For example, with the No Build Alternative, the aggregate supplies would be used for other purposes, and there would be no need for fills and stockpiles.

4 How would cumulative effects on geology and soils be monitored, mitigated, and managed?

As previously noted, seismic hazards to multiple structures would be the most important cumulative effect associated with the Proposed Action. All structural components of the Proposed Action would be designed to withstand a ground motion caused by a seismic event that has a low probability of exceedance during its design life (75 years). The structures would be designed not to collapse under the conditions imposed by this design event through the use of deep foundations that carry seismic loads to suitable bearing materials. If required, soils would be improved to reduce the risk of liquefaction and related seismic damage.

The seismic hazard to existing structures resulting from induced loading from the proposed I-90 off-ramp to South Atlantic Street has been considered. The proposed structure would be designed either to be structurally isolated from the existing structures, or to have sufficient stiffness not to impart additional seismic load on the existing structure.

For more detailed information on seismic hazard and how it would be mitigated, please see Chapters 4 and 5.

Chapter 7 References

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Appendix A
List of Existing Geotechnical Reports from GeoMapNW

Appendix A
Geotechnical Reports Obtained from GeoMapNW
(These reports are the information sources for the geotechnical exploration locations shown on Exhibit 4-3.)

UW Document ID (if applicable)	Consultant	Document Name	Date	Number of Explorations Included in Report (within or near study area)	Type(s) of Explorations	Explorations Depths Range (feet bgs)
180	Roger Lowe Associates, Inc. Earth Sciences	Soils and Foundation Investigation Phase I, Proposed Warehouse Development for Fisher Properties, Inc., Seattle, Washington	November 15, 1979	7	Borings	55 - 85'
2488	Shannon and Wilson, Inc.	Geotechnical Report, Seattle Seahawks Stadium and Exhibition Center, Seattle, Washington	March 1998	17	Boring and CPTs	Borings: 15.0 - 90.3' CPTS: 57.5 - 65.5'
2517	Hunt-Kiewit	New Pacific Northwest Baseball Park, Geotechnical and Environmental Report in Bid Documents, Book 5 Geotechnical Report Volume 2	August 1996	32	Borings and Piezocone Probes	Borings: 14.0 - 138.0' Piezocone Probes: 57.0 - 98.0' Test Pits: 8.0 - 9.0'
3361	Geolabs-Washington, Inc.	Soils and Foundation Investigation, Proposed King	April 1972	51	Borings, CPTs, Test Pits	Borings: 9.0 - 100.0' CPTs: 23.0 - 30.5' Test Pits: 5.0 - 10.0'

Appendix A
Geotechnical Reports Obtained from GeoMapNW
(These reports are the information sources for the geotechnical exploration locations shown on Exhibit 4-3.)

UW Document ID (if applicable)	Consultant	Document Name	Date	Number of Explorations Included in Report (within or near study area)	Type(s) of Explorations	Explorations Depths Range (feet bgs)
		County Multipurpose Stadium, King Street Station Site, Seattle, Washington				
3511	Shannon and Wilson, Inc.	Draft Geotechnical Report, Kingdome Sewer Separation Project, Seattle, Washington	May 1992	12	Borings	31.5 - 108.5'
3578	Metropolitan Engineers	Final Report-Soils Investigation Elliott Bay Interceptor, Section 5, Seattle, Washington	April 19, 1968	29	Borings	28 - 130'
3704	Converse, Ward, Davis, Dixon Geotechnical Consultants	Geotechnical Exploration, Fourth Avenue and Connecticut, Seattle, Washington, Metro Interim Operating Base	September 19, 1979	2	Boring and Test Pit	Boring: 85.5' Test Pit: 3.5'
3960	Metropolitan Engineers	Final Report, Foundation Investigation, Elliott Bay Interceptor Regulators, King Street Regulator, Connecticut Street Regulator, Hanford	July 3, 1969	17	Borings	31 - 81'

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UW Document ID (if applicable)	Consultant	Document Name	Date	Number of Explorations Included in Report (within or near study area)	Type(s) of Explorations	Explorations Depths Range (feet bgs)
		Street Regulator, Hanford Street Regulator, Alaskan Way Interceptor, Sections 4, 5, and 6, Seattle, Washington				
6109	Shannon and Wilson, Inc.	Produce Terminal Building for Northern Pacific Railway Company, Plan of Logs and Borings	October 5, 1992	4	Borings	76.0 - 91.5'
6119	Seattle Engineering Department, Materials Laboratory	Log of Test Borings - Connecticut Street	November 1973	6	Borings	15.0 - 20.0'
8038	Hart Crowser	Subsurface Explorations and Design Phase Geotechnical Engineering Study, SR-90, Seattle Access General Purpose and Transit/HOV Lanes, Seattle, Washington Volume II of III,	August 1986	33	Borings and Probes	Borings: 58.5 - 113.5' Probes: 24.2 - 72.2'

Appendix A
Geotechnical Reports Obtained from GeoMapNW
(These reports are the information sources for the geotechnical exploration locations shown on Exhibit 4-3.)

UW Document ID (if applicable)	Consultant	Document Name	Date	Number of Explorations Included in Report (within or near study area)	Type(s) of Explorations	Explorations Depths Range (feet bgs)
		Appendix A, Field Explorations, Appendix B Laboratory Testing Program				
9928	Seattle Engineering Department, Materials Laboratory	Alaskan Way/Royal Brougham TIA	February 11, 1992	8	Borings	2 - 113.5'
10133	Black & Veatch Waste Science, Inc.	Final Underground Storage Tank, Site Assessment Report, King County Department of Transportation, Ryerson Operating Base	February 1996	12	Borings	9.0 - 19.0'
10501	Department of Ecology	Water Well Report	May 1, 1997	1	Well log	30'
10502	Department of Ecology	Water Well Report	February 25, 1997	1	Well log	20'
11379	Shannon and Wilson, Inc.	Report Addendum No. 095-1, Geotechnical Data Report (GDR), Seattle Monorail	April 1, 2004	1	Boring	106.4'

Appendix A
Geotechnical Reports Obtained from GeoMapNW
(These reports are the information sources for the geotechnical exploration locations shown on Exhibit 4-3.)

UW Document ID (if applicable)	Consultant	Document Name	Date	Number of Explorations Included in Report (within or near study area)	Type(s) of Explorations	Explorations Depths Range (feet bgs)
		Project (SMP), Seattle, Washington				
13582	Shannon and Wilson, Inc.	Geotechnical Report Atlantic/Central Base Employee Parking Garage, Seattle, Washington	June 2002	5	Borings	86.5 - 101.5'
	Department of Ecology	Well Logs	1990 - 2006	55	Well log	55'
	Washington State Department of Transportation	Contract Provisions For Construction, SR-90 MP 1.94 to MP 2.23, SR 519 MP 0.20 to 0.00, Intermodal Access - Phase 1, S. Atlantic Street, Volume 2 of 2	1997	28	Borings	14.0 - 124.0'

Chapter 5 Environmental Consequences and Mitigation Measures

1 How would project construction temporarily affect geology and soils in the study area?

Two types of effects involving geology and soils generally occur during construction of a project: direct and indirect. Direct effects are those that either result from changes in the geology or soil conditions or those that are determined by geology and soil conditions. The simplest example of a direct effect is the need to change surface soil elevations to meet roadway grade requirements. Indirect effects are those that occur later in time or are farther away from the construction. The latter category might include compression of soil beneath new approach fills that would eventually result in settlement of nearby utilities.

Proposed Action

Direct Effects

The planned construction would result in a number of direct effects related to geology and soils, and these effects would have adverse environmental consequences if they are not appropriately identified, evaluated, and mitigated. Examples of potential direct effects for the Proposed Action are summarized below:

- The construction of the SR 519 project will involve various activities that could lead to sediment mixing with stormwater and creating turbid water. Sources of turbidity include uncovered and exposed soils, trucks spilling soil, and the tracking of mud from truck tires onto the roadway. These sources will be controlled during construction

As discussed in section 4.5, past activities in the area have resulted in soil and groundwater contamination. Contaminated soils could be harmful to people, and therefore special regulations have been written to protect the public from these risks.

through the use of normal erosion control and erosion mitigation measures.

- Contaminated soils and groundwater were encountered during construction of Phase 1 of the SR 519 project. As discussed in the *Hazardous Materials Discipline Report*, contaminated soils exist within the proposed construction footprint. Soils would be excavated during the construction of bridge and roadway foundations, and it is likely that some contaminated soils would be encountered. If encountered, these soils will require special handling, transport, and disposal at offsite locations.
- Earth loads would result from construction of new roadway approach fills at South Royal Brougham Way and from soil stockpiles used during construction of the project. If fill is more than a few feet in height, loads from the fill can cause settlement of the soil under and/or adjacent to the fill or stockpile. If adequate precautions are not taken, the settlement could damage nearby utilities or pavement. Lateral movement of soil at the toe of the embankment would also result as the embankment settles. If the lateral movement were large enough, it could also damage adjacent features.
- Drilled shafts foundations are currently planned for supporting elevated structures and possibly portions of the South Royal Brougham Way approaches. During construction of the drilled shafts, loosely compacted sand and clay could be encountered below the groundwater table. In some locations, bricks and old timber pilings from the 1900s could be present. Cobbles and boulders are also known to exist in the glacial deposit under the sand and gravel layer. These conditions have the potential to delay or cause difficulties during construction.
- Numerous utilities are located along South Royal Brougham Way, Third Avenue South, and Fourth Avenue South. If excavations for construction of elevated structure foundations and for relocation of utilities are not adequately supported, then lateral and vertical movements of the

ground supporting the utilities would occur. These movements would result in damage to buried utilities and to structures or roadways located adjacent to the excavations, if the amount of movement is excessive. Design studies would be conducted to evaluate the potential for these movements.

- Existing soils within the study area are both compressible and liquefiable. If these soils need to be improved in some areas to make them suitable for development of the project, then special construction methods would be required. These construction methods could include use of stone columns, jet grouting, or in-place cement-soil mixing. These construction methods would normally generate earth spoils and water with high sediment content. Special containment and disposal procedures would be required to prevent the spoils and water from damaging nearby "clean" areas.
- Ground vibrations would occur during construction as heavy equipment operates within the project footprint. The vibrations could result from a number of sources such as demolition of existing structures, ground improvement activities, bridge foundation construction, compaction equipment operations, and truck traffic. If these vibrations exceed threshold levels in nearby areas, then the vibrations would be annoying to individuals working or living in the area, would possibly cause settlement of loose soils near the source of vibration, or would potentially cause minor damage to structures or utilities due only to the vibrations.

Ground vibrations result when equipment impacts the ground. The level of vibration decreases with distance from the source. People feel the vibration at much lower levels than will damage structures or most equipment.

- The new roadway and structures would require removal of small sections of existing roadway and existing bridge structures in order to build the new facilities. This requirement would result in the generation of small amounts of concrete and asphalt from the demolition of the existing roadway and structures. The total amount of demolition debris would likely be less than a thousand cubic yards. This material would have to be disposed of as construction debris or processed for reuse. The quantities of construction debris appear to be too small to reprocess for

only the SR 519 project, but potentially could be reprocessed as part of other ongoing projects in the area. If the concrete and asphalt cannot be reprocessed, it will be disposed in landfills, reducing the available volume at the landfills.

- Existing soils would be excavated during construction of the drilled shaft foundations for bridge structures, as well as for any ground improvement at the approach ramps. The amount of excess soil from shaft construction could be more than 200 cubic yards per shaft. Depending on the number and size of the shaft foundations, and the amount of excavation at the approaches, the resulting total volume of excavated soil could be several thousand yards or more. This excavated soil would not be suitable for construction (without amendments such as cement or fly ash) because of the amount of fine-grained material. Excavated soil that cannot be used for landscape material would need to be removed and transported offsite. Some of this soil could be contaminated with hazardous materials. Excavated soils would be tested to determine if hazardous materials were present. If hazardous materials were found in the soil, it would require special handling and containment and would need to be disposed at a licensed disposal facility.
- An earthquake could occur during construction, resulting in embankment slope failures, liquefaction, ground settlement, or damage to partially completed structures. If such an event were to occur and there was damage to the work completed, then there would be schedule delays as damaged areas are repaired. The normal approach during design and construction is to assume that this risk is very small.

Indirect Effects

Indirect effects associated with geology and soils would occur later in time or farther from the project footprint. For example:

- Aggregate would be required for concrete, subgrade fills, and possibly for approach fills. The amounts of aggregate for the project are estimated to be small, probably less than

Aggregate refers to gravel and sand that is used as roadbed material or is mixed with cement and water to make concrete. The gravel and sand are mined from gravel pits located in the Puget Sound area.

15,000 cubic yards, because of the type of development. Use of aggregate on the project would reduce supplies of material that might be used elsewhere for other projects. As noted, the quantity required for construction of this project is minimal in comparison with the quantity of aggregate that is used on typical roadway projects and the amount available regionally.

- Soils would be exposed to the weather when roadway surfaces are replaced and the ground at drilled shaft and bridge approaches is exposed. Exposed soils could be carried far enough offsite by rainwater that roads or drainage facilities outside the study area would be affected, if appropriate mitigation measures were not taken. Spillage from trucks and soil on truck tires could also eventually result in similar consequences beyond the study area without adequate mitigation measures.
- Trucks would be required to bring heavy equipment or construction materials to the site and to remove excess soils and construction debris. These trucks would cause deterioration of nearby streets and roadways if the loads exceeded the strength of the roadway base material, leading to cracking or rutting of pavements.

No Build Alternative

Without the Proposed Action the construction-related effects described above would be avoided. For example, with the No Build Alternative, there would be no potential for adverse vibrations from construction, the aggregate supplies needed for the Proposed Action would be used for other purposes, and there would be no potential for erosion of exposed soils located in fills and stockpiles.

2 What long-term effects associated with geology and soils would occur during operation of the project?

Just as with the short-term, construction-related effects discussed above, the long-term consequences of operating the Proposed Action would also include direct and indirect effects

related to geology and soils. Because the expected life of the Proposed Action would be 75 years or longer, effects that would be accommodated or avoided during construction have the potential to persist and possibly increase over time. For example, fill for the new bridge approaches could cause progressive settlement extending beyond the footprint of the structures, eventually leading to cracking of pavements and damage to utilities located adjacent to the fill.

Proposed Action

Direct Effects

Long-term direct effects of the Proposed Action that relate to geology and soils were identified based on the conceptual plans for design. Examples of long-term direct effects based on these conceptual plans include:

- Long-term settlement of the soil beneath the earth fills for the approaches to the new ramp to South Atlantic Street and to the overpass at South Royal Brougham Way. If this settlement is more than an inch or two, added maintenance to the new structures and poor ride quality on the approaches or ramps would result. Periodic re-leveling and repaving of the approach roadway would likely be required.
- Damage to the new elevated structures and approach fills at South Royal Brougham Way from traffic-induced vibrations. If levels of vibration are high and are not corrected, these vibrations would result in either damage to the elevated structures, including fatigue of structural connections, or damage to approach fills such as settlement of loose, cohesionless soil supporting the approach, eventually requiring added maintenance or resulting in poor ride quality.
- Modification of groundwater flow paths in areas where ground improvement methods are used to mitigate potential effects of seismic loading, such as at the South Royal Brougham Way approaches. The volume of earth affected by foundations and ground improvement by itself is very limited relative to groundwater flow regimes in the area;

When fills are added to an area, the soil beneath the fill begins to compress. The zone of compression occurs not only below the fill but extends outside the new load – potentially affecting nearby pavements, sidewalks, and buried utilities such as sewer and water lines, fiber optic cables, and gas lines.

however, as noted later, the cumulative effect of combined projects could be a consideration.

- Ground settlement and increased loads caused by earthquake shaking on new elevated structures. The consequences of earthquake-induced ground shaking would be liquefaction and densification of water-saturated, sand-like soils if soils are not improved. Liquefaction can result in lateral spreading of the soil toward Elliott Bay, ground settlement, bearing failures, and instability of any slopes associated with approach fills. If these mechanisms are not appropriately identified and mitigated, they would lead to either loss of lateral support or additional loads on drilled shafts from liquefaction, soil settlement, or lateral soil movement, potentially resulting in damage to the bridge structure and loss of service.

Seismic loading results from the ground vibrations that occur as a result of an earthquake. The vibrations result in added forces in structures and in the ground. These forces can cause soil to become fluid-like in consistency, referred to as liquefaction, or settle as the soil densifies. As the soil settles, it can cause increased friction on foundations. This is referred to as drag loads.

- Damage to transitions between the South Atlantic Street ramp structure to the existing westbound I-90 off-ramp at the north end and to the existing South Atlantic Street overpass at the south end during seismic loading. If the potential for relative movement between the structures is not adequately considered during design, earthquake-induced ground shaking on the new ramp structure would induce loading on the existing structures, potentially resulting in over-loading and damage to the existing structures. Similarly, the potential for additional loading to existing large-diameter pipes from the seismic response of foundations supporting the new Royal Brougham will be evaluated and mitigated if necessary.

Indirect Effects

Indirect effects related to geology and soils possibly include:

- Increased maintenance of surface streets and utilities from long-term settlement associated with the planned approach fill embankment between Third Avenue South and Fourth Avenue South. If earth loads are large, large vertical and lateral soil movements would occur if the ground is not improved before placement of the earth fills. The zone of influence from the new earth loads would potentially

Royal Brougham Way has numerous utilities, including old brick sewers and high-pressure gas mains, which could be damaged if the ground settles.

extend into the street, causing displacement of adjacent sidewalks, streets, and utilities.

- Damage to adjacent sports facilities from traffic-induced vibrations originating on the new bridge structure at South Royal Brougham Way. If the vibrations on the structure are not isolated from the sports facilities and levels of vibration at the sports facilities are large, damage would potentially occur, resulting in added maintenance to facilities or annoyance to fans using the facilities.

No Build Alternative

If the Proposed Action were not built, some of the long-term operational effects noted above would not occur, such as vibrations related to vehicle loading. However, some would remain. For example, seismic hazards and the related secondary effects will occur whether the project is built or not.

3 What measures are proposed to mitigate identified adverse effects due to the project?

Various procedures can be implemented to avoid or minimize adverse effects of the project related to geology and soils. These mitigation measures would be identified and evaluated during detailed engineering design and construction planning.

Construction Mitigation

Unwanted effects of most construction activities would be mitigated by implementing standard design and construction procedures. These mitigation measures range from applying best management practices (BMPs) to reduce erosion and control sediment during construction to modifying design requirements to minimize effects of settlement. Such measures would be determined during detailed engineering design and construction planning. Typical examples of these measures include:

- Prior to the start of construction, a Temporary Erosion and Sediment Control (TESC) Plan identifying what BMPs would be used, and where they would be used, would be written. During construction, this plan would be implemented and modified. A water quality monitoring

plan would also be implemented during construction. BMPs for erosion control would normally include items such as silt fences, straw bales, and sedimentation ponds. These requirements would be listed in construction documents. Construction documents would also require that stockpiles of imported earth fill and aggregate are either covered or surrounded by silt fences if the period of exposure is long; that the amount of earth exposed for construction is limited, particularly during wet winter months; that sedimentation in water pumped from construction excavations is filtered in Baker tanks or other suitable means before disposal; and that geotextile covers are placed over storm drain entrances to collect sediment in surface water. Construction documents may also require that trucks hauling aggregate or earthfill to the site cover their loads with tarps or limit the amount of earth to avoid spillage. If there is a potential that truck tires will carry sediment from the site to surface streets, truck access routes or wheel washes could be required to use rock surfacing to limit tracking of soil from the site. An inspection plan that addresses signs of erosion, instability, or settlement of stockpiles would be required.

The amount of exposed earth for the proposed action is relatively small, limiting the potential for sediment transport. Nevertheless, strict requirements will be placed on the contractor to limit offsite movement of soil.

- Contaminated soil and groundwater are known to occur within the study area. As these are encountered, they would require special handling, containment, and disposal. Before soil is excavated in any location, the potential for contamination would be evaluated further, possibly with additional field explorations and laboratory analyses, to establish the degree of contamination that must be considered during excavations. If the contamination exceeds certain levels in the area of excavation, workers performing the excavations will be required to wear special protective clothing and additional erosion control protective measures will be required to prevent contaminated stormwater runoff. If the level of contamination exceeds regulatory standards, soils will require transport in water-tight bed liners, trucks will be required to pass through wheel washes before leaving the work area, and

contaminated soils will require disposal at regulated landfills. Additional discussions of hazardous waste issues are provided in the *Hazardous Materials Discipline Report.*

- The potential for vertical and lateral movement of the ground during construction of new approach ramps would be quantified during the design phase of the project. If vertical or lateral movements of the earth from new fills are predicted to be excessive, they would be mitigated through the use of ground improvement methods, lightweight fills, or other methods. Utilities would be relocated or protected in locations where ground settlement cannot be mitigated.
- Unfavorable soil and groundwater conditions (e.g., loose silts and sands below the groundwater table, old timber pilings, and other construction debris from the early 1900s) in areas where deep foundations will be constructed would be mitigated through the use of foundation drilling equipment specifically designed to provide borehole support during drilling and capable of removing debris. Contract documents would be prepared to advise potential contractors of these construction risks. If determined during design to be critical, full-depth casing would be required to maintain hole stability.
- If the potential for vertical or horizontal ground movement next to excavations is determined to be excessive during design, the construction documents would require use of stiff retaining wall systems or lateral support using earth anchors or structural bracing. The location of the wall would also be monitored during excavations using survey methods and geotechnical instrumentation to warn of developing movements.
- In areas requiring ground improvement to mitigate potential effects of liquefaction or settlement, strict controls would be imposed on construction methods to contain spoils and excess water caused by the ground improvement technique. These controls would typically include use of earth dams to confine fluids, continuously re-circulating water, and limiting the amount of onsite stockpiling of

Lightweight fills are construction materials that weigh less than an equivalent amount of soil or concrete. One example is extruded polystyrene, often called geofoam. Large blocks of geofoam can weight just a few pounds but still support the weight of trucks.

Ground improvement techniques are used to improve the strength of the subgrade soils. Typical ground improvement techniques include stone columns, lightweight fills, and vibro compaction.

spoils from excavations. Another alternative would be to select ground improvement methods that would not produce as much spoils and excess water.

- To mitigate the effect of ground vibrations during construction, construction documents would require that equipment be selected and operated to minimize the potential for vibration. For example, in constructing the drilled shaft bridge foundations, the use of special equipment to rotate the steel shaft casings in the ground would be considered in the vicinity of sensitive underground utilities. Similarly, methods of ground improvement that produce limited vibrations, such as deep cement-soil mixing, would be identified in construction specifications, if determined necessary after detailed engineering review.
- The amount of construction debris and excess earth that must be disposed at landfills would be limited by reprocessing concrete into aggregate to the extent possible. This reprocessed aggregate would be re-used in concrete or fills on the SR 519 project or other projects in the Seattle area. Similarly, asphalt can also be reprocessed and mixed with soil for fills, and steel rebar can also be recycled. Uncontaminated soil from excavations would be used as fill either for the proposed development or at other projects in the area requiring earth fill. Although the direct potential for reprocessing demolition debris is limited for the SR 519 project because of the small amount of debris being generated, the potential exists for reprocessing the debris with debris from other nearby projects, such as the Alaska Way Viaduct project, if the construction periods for the other projects coincide with the SR 519 project.
- The likelihood of an earthquake during construction is very low, and little related to soils and geology can be done to mitigate for its occurrence. However, if an earthquake were to occur, mitigation strategies would be developed to revise construction schedules or rebuild damaged facilities.

Operational Mitigation

During preliminary design, WSDOT would conduct geotechnical investigations to understand subsurface conditions prior to final design. Mitigation measures for long-term fill settlement, traffic-induced vibrations, and seismic hazards would be identified following this investigation and methods of mitigating their potential effects would be developed, where determined appropriate. Examples of these mitigation measures include the following:

- To avoid the risk of long-term ground settlement, the proposed structures would be constructed on deep foundations that extend through the compressible soils to denser bearing material. At the bridge approach fill located between Third and Fourth Avenues, either ground improvement or deep foundations would be used to reduce settlement.
- The potential for traffic-induced vibrations from use of the new South Royal Brougham Way structure or new approaches would be mitigated by minimizing the source of vibrations, such as construction joints or rapid changes in roadway grade. If design studies determine the potential for excessive vibrations between the elevated structure and the sports facilities, isolation joints or similar systems would be used to minimize the potential for damage to the existing facilities.
- If groundwater flow in the study area was determined to be adversely affected by the installation of ground improvement methods, ground improvement construction methods that limit the effects to groundwater flow would be identified in construction documents. These alternate methods might involve use of stone columns rather than jet grouting or in-place soil mixing procedures.
- New structures at risk from earthquake-induced liquefaction and ground settlement will be designed according to WSDOT seismic design methods for liquefaction and ground settlement. Where design studies identify substantial risk, deep foundations will be used to

Stone columns are built of gravel and sand, while jet grouting and soil mixing create zones made up of cement and soil. Gravel columns are more porous than soil-cement columns.

carry the seismic loads to suitable bearing materials. If required, soils will also be improved to reduce the risk of liquefaction and related seismic damage.

- All new structures would be designed to meet or exceed earthquake loading requirements in the latest issues of the American Association of State Highway and Transportation Officials (AASHTO) LRFD Bridge Design Specifications (AASHTO, 2004. For seismic hazards on existing structures due to induced loading from the proposed South Atlantic Street ramp structure, the proposed structure will be designed to be structurally isolated from the existing structures, or will be designed with sufficient stiffness to reduce additional seismic load on the existing structure. Similarly, the potential for additional loading to existing large diameter pipes from the seismic response of foundations supporting the new Royal Brougham will be evaluated and mitigated if necessary.

4 Are any of the identified effects considered substantial?

Effects considered to be substantial are those that might require new locations for the project or the use of a different method of supporting a roadway or structures.

This environmental assessment determined that no direct or indirect effects of the Proposed Action related to geology and soils would be substantial. This conclusion is due in part to the general flatness of topography within the project footprint, the minimal need for widening, and the current land use. With these conditions, there is limited need for imported borrow material and limited need for large excavations. The relative flatness within the project footprint would also limit the potential for erosion and the need for erosion control.

The most important issue related to soils and geology appears to be the potential for seismic loading. Appropriate mitigation methods are available to deal with the consequences of seismic loading, including mitigation for liquefaction potential and densification of the soil through use of ground improvement

methods. Designers must also follow WSDOT and American Association of State Highway and Transportation Officials (AASHTO) design requirements for seismic loading as they design all bridges, retaining walls, and related components of the project.

Chapter 6 Cumulative Effects

1 What are cumulative effects, and why are they important?

Cumulative effects are important because they help us to understand the project in terms of a "bigger picture." They can reveal possible unintended consequences of the Proposed Action or No Build Alternative that might not be apparent when we look at the project by itself. Because of this, cumulative effects help us to evaluate how sustainable the project is likely to be in future years, and how it might interact with other projects that are planned but have not been built yet.

What are cumulative effects?

Cumulative effects are impacts on the environment that result "from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions, regardless of what agency or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time. Defined by FHWA and Council on Environmental Quality (CEQ) regulations (40 CFR 1508.7)" (WSDOT, 2006)

2 How did the study team identify expected cumulative effects on geology and soils?

The project team identified expected cumulative effects of the Proposed Action and No Build Alternative by following a process recommended by the President's Council on Environmental Quality (CEQ, 1997) and as identified in Chapter 412 of the WSDOT *Environmental Procedures Manual* (WSDOT, 2007). First, the team considered other past and present projects that have already affected or were affected by the geology and soils in the area. These past and present actions have changed geology and soils in and around the SR 519 study area from their original condition. The most important of these past actions was the filling of the area with tens of feet of fill in the early 1900s. Next, the expected direct and indirect effects of the project on geology and soils, discussed in Chapter 5, were added. Finally, the probable effects of other projects that are planned but not yet built were considered.

The project team combined past and present actions and RFFAs with the expected direct and indirect effects of each of the two alternatives to produce a cumulative picture of how geology and soils might be affected, with and without the Proposed Action, in the future.

Past and Present Actions

Past projects in the study area, during the nineteenth and early twentieth centuries produced cumulative effects related to soils and geology that were largely negative, resulting from what would now be regarded as substandard construction practices.

- Fills were initially placed in the study area with little consideration of location, method of placement, and little regard for existing soils, structures, or debris that was buried in the process. As the area was developed, little was done to protect the filled area from human activities or to plan for future development in the area.
- In most cases, older roadway structures were built according to the then-current design standards, and sometimes without consideration of seismic loading. Often construction materials and techniques were not optimal for resisting earthquake damage. As the understanding of seismic risk improved, requirements for seismic design became more stringent. Nevertheless, structures constructed as recently as the 1980s may not be able to meet some current seismic design requirements.
- Past construction practices paid little attention to gravel depletion, soil erosion, or the disposal of construction debris. Resources for construction, such as gravel, were plentiful and located nearby, and abundant land was available for the disposal of demolition debris.

The cumulative effect of past design and construction practices became evident in terms of deterioration in wildlife habitat from accumulations of sediment in streams and waterways, an increased cost of imported construction materials, and more stringent regulatory requirements for waste disposal sites. As the infrastructure also aged, a greater percentage lacked the ability to meet current earthquake design standards, making the

public more at risk from a large seismic event. However, the cumulative disposal of fill in the tidelands bordering Elliott Bay resulted in the additional buildable land that now includes much of downtown Seattle, including the study area, producing a practical outcome.

As undesirable cumulative effects have become recognized, better construction practices have led to improved conditions. These practices have included BMPs to protect against soil erosion, and recycling of construction debris into usable building materials. Roadway and bridge design codes have also been improved to provide better protection for the public, resulting in facilities that are more capable of resisting seismic events without damage.

Direct and Indirect Effects of the Proposed Action

The direct and indirect effects of the Proposed Action relative to geology and soils (see Chapter 5) would be largely controllable through the use of appropriate design methods and implementation of BMPs and mitigation methods during design and construction.

For direct and indirect effects that would not be avoidable, such as an incremental reduction in aggregate supply from the extraction of gravel needed for approach fills, an opportunity exists for reduction of adverse cumulative effects through efforts to re-use existing demolition debris. Similarly, excavated soils can be used as fill either onsite or at other locations in the project vicinity.

Although the potential risk from seismic loading would be mitigated through the use of current design standards on the Proposed Action, the cumulative risk to other structures or facilities in the area remains unchanged in the short term. However, as part of WSDOT's earthquake mitigation strategy, major access routes are given priority to the seismic upgrade work, eventually leading to reduced risk on the overall transportation network.

A cumulative effect on groundwater flow could eventually result in the study area from the combined effects of deep

foundations and ground improvement used for this and other developments. Foundations and some types of ground improvements are impermeable to water flow, and therefore create a barrier to groundwater flows for the general area. This cumulative effect is expected to be of minor consequence because of the project location near Elliott Bay and the limited hydraulic gradient being affected.

Direct and Indirect Effects of the No Build Alternative

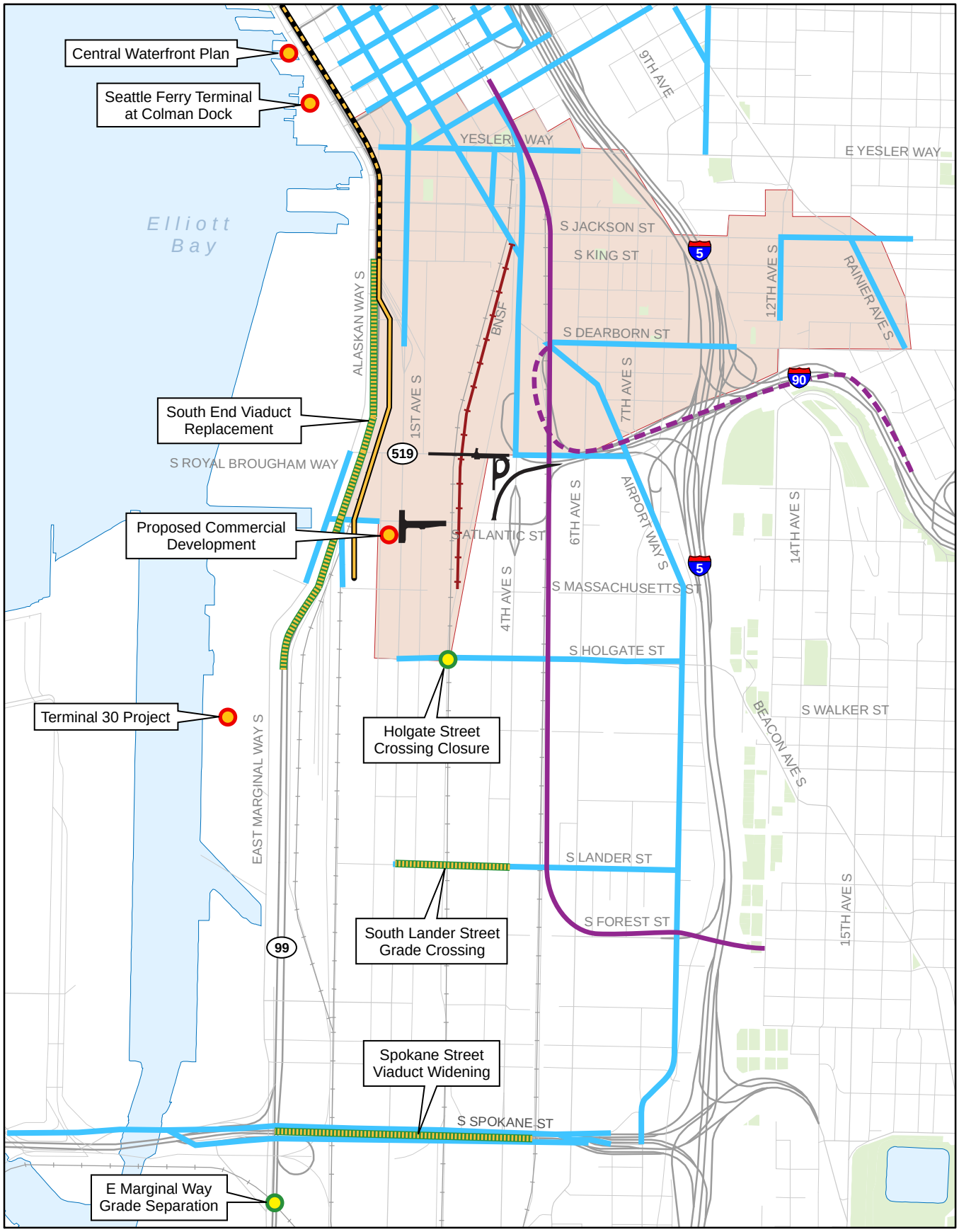
If the No Build Alternative were selected, a few direct and indirect effects related to geology and soils would be positive. These effects would be related primarily to avoiding the need to use aggregate resources and for the disposal of construction demolition debris and unsuitable soils at offsite locations.

There is, however, one beneficial effect of the Proposed Action that would not be realized. It involves the removal of contaminated soil from the site. Under the No Build Alternative, this benefit would not be realized.

Reasonably Foreseeable Future Actions

Exhibit 6-1 shows approximate locations of some of the larger reasonably foreseeable future actions (RFFAs) that could add to or interact with the Proposed Action to contribute to cumulative effects on geology and soils. Exhibit 6-2 briefly summarizes information about these projects. As previously noted, they include:

- The South Holgate Street to South King Street Viaduct Replacement Project, and the two-phase Electrical Line Relocation Project, which are Moving Forward projects within the Alaskan Way Viaduct and Seawall Replacement Program
- The South Spokane Street Viaduct project
- Completion of BNSF Railway track improvements
- Sound Transit light rail projects
- Closure of the South Holgate Street rail crossing



Source: City of Seattle (2007) and King County (2006)

- Project
- Livable South Downtown Study Area (Approx.)
- BNSF Railway Completion
- Electrical Line Relocation Phase 1 and Phase 2
- Sound Transit Central Link
- Proposed Sound Transit East Link
- Bridging the Gap Paving Project
- Road Project
- Development Project

N

0 1,000 Feet

Exhibit 6-1
Reasonably Foreseeable Future Actions

EXHIBIT 6-2. REASONABLY FORESEEABLE FUTURE ACTIONS IN OR NEAR THE STUDY AREA

Project[a]	Location	Purpose	Proponent	Expected Construction Time Frame[b]
South Holgate Street to South King Street Viaduct Replacement Project	SR 99 from South Holgate Street to South King Street	Build new SR 99 between South Holgate Street and South King Street. Includes South Atlantic Street and South Royal Brougham Way grade separation, detour routes, and temporary connections	Washington State Department of Transportation	2009-2012
Electrical Line Relocation	Phase 1: South Massachusetts Street to South King Street Phase 2: South King Street to Union Street	Remove network distribution lines and transmission lines that are located under the existing Viaduct before it is demolished	Washington State Department of Transportation	Phase 1: Construction scheduled for 2008-2009. Phase 2: To be determined.
Completion of BNSF Railway Improvements	King Street Station to South Royal Brougham Way	Reduce rail transportation conflicts along the BNSF right-of-way; increase safety at the BNSF crossing of South Royal Brougham Way	BNSF Railway	Improvements at South Royal Brougham Way have been completed; with additional improvements along the BNSF right-of-way currently in progress.
Central Link Light Rail	Downtown Seattle to Sea-Tac Airport	Provide light rail service between downtown Seattle and Sea-Tac Airport	Sound Transit	2008-2009
East Link Light Rail	Downtown Seattle to Redmond	Provide light rail service between downtown Seattle, Mercer Island, Bellevue, and Redmond	Sound Transit	Construction not scheduled. Environmental impact statement scheduled for release in fall 2009.
Proposed Commercial Development	South side of South Atlantic Street between First Avenue South and Utah Avenue South	Provide office and retail uses	Gull Industries	2010-2012
Livable South Downtown Planning Study	The study examines growth and planning issues specific to Pioneer Square, the Chinatown/ International District (including the Little Saigon area east of I-5), and the northernmost edges of the Greater Duwamish Manufacturing and Industrial Center.	Stimulate housing and related development consistent with the Mayor's Center City Seattle strategy	City of Seattle, Department of Planning and Development	Environmental impact statement and legislative proposals in 2008
Closure of South Holgate Street at BNSF Railway Crossing	South Holgate Street at the BNSF Railway crossing	Eliminate conflicts between rail and vehicle traffic.	City of Seattle, Department of Transportation	Construction not scheduled

EXHIBIT 6-2. REASONABLY FORESEEABLE FUTURE ACTIONS IN OR NEAR THE STUDY AREA

Project[a]	Location	Purpose	Proponent	Expected Construction Time Frame[b]
South Lander Street Grade Separation	South Lander Street between First Avenue South and Fourth Avenue South	Improve safety and traffic flow by constructing a roadway bridge for vehicles, bicycles, and pedestrians over the BNSF Railway tracks.	City of Seattle, Department of Transportation	2009-2011
South Spokane Street Viaduct Widening	South Spokane Street from Sixth Avenue South to West Seattle Bridge	Improve traffic safety and upgrade the structural and seismic performance of the viaduct that connects I-5 to the West Seattle High Level Bridge. Construct a new eastbound loop ramp to Fourth Avenue South, to the south of South Spokane Street.	City of Seattle, Department of Transportation	Seismic retrofit, median barrier installation, and street-level utility relocations have been completed. Viaduct widening and ramp construction is scheduled to start in 2008 and would be constructed in phases as funds become available, so exact construction range not known.
Bridging the Gap Paving Projects	Seattle arterial streets	As part of a larger program, the paving projects will resurface, restore, or replace approximately 300 lane-miles of arterial streets; rehabilitate or replace 3-5 bridges and seismically retrofit 5 additional bridges; repair or restore approximately 144 blocks of existing sidewalks; build approximately 117 blocks of new sidewalks; rehabilitate approximately 50 stairways; and restripe about 5,000 crosswalks.	City of Seattle, Department of Transportation	2006-2013
Central Waterfront Plan	South Atlantic Street to West Thomas Street along the shoreline edge of the Center City	Following replacement of the existing Alaskan Way Viaduct, construct new parks and open spaces, shoreline and habitat improvements, improved linkages to the downtown core, *and* transit connections, *and implement* land use and regulatory changes.	City of Seattle	Presently in planning process. Construction will begin with the removal of the viaduct and will be ongoing for several years.

EXHIBIT 6-2. REASONABLY FORESEEABLE FUTURE ACTIONS IN OR NEAR THE STUDY AREA

Project[a]	Location	Purpose	Proponent	Expected Construction Time Frame[b]
Terminal 30 Conversion	East Marginal Way South between approximately South Holgate Street and South Lander Street	Terminal 30 had been used for cruise operations but will be converted back to its original use as a container terminal. This and the adjacent Terminal 25 will provide 70 acres for container use.	Port of Seattle	2007-2009
East Marginal Way Grade Separation Project	East Marginal Way South just south of South Spokane Street	Provide a north- and southbound grade separation on Duwamish Avenue South, relocating East Marginal Way through this corridor to improve access among Port of Seattle terminals, rail yards, and industrial warehouses.	Port of Seattle	2006-2008
Washington State Ferries Terminal Improvements at Colman Dock	Pier 54 at Seattle Waterfront on Alaskan Way South	Upgrade structures and facilities and increase capacity.	Washington State Department of Transportation	Construction not scheduled. For 2008-2009, focus will be on system-wide planning and coordination with nearby projects, including the proposed SR 519 Phase 2.

[a]Only major planned projects are listed. Many other projects that could be implemented in the reasonably foreseeable future are not shown.
[b]Dates are approximate.
Sources: General information from the WSDOT, City of Seattle, Port of Seattle, and Sound Transit websites.

- Conversion of the Port of Seattle's Terminal 30 to a container terminal
- The East Marginal Way Grade Separation Project
- The City of Seattle's Central Waterfront Plan
- The City of Seattle's Bridging the Gap paving projects
- Washington State Ferries Terminal Improvements at Colman Dock

In addition, many other developments not yet planned in detail could result from a decision to move forward with the Livable South Downtown program (City of Seattle, 2006b).

Urban development is increasing in portions of the South Downtown area immediately north of the study area. This area, which includes Seattle's International District/Chinatown/Little Saigon neighborhood, is currently the subject of Livable South Downtown, a major planning effort by the City of Seattle's Department of Planning and Development. In November 2007, the City of Seattle released the *Draft EIS for Livable South Downtown Planning* (City of Seattle 2007a), a SEPA programmatic EIS which evaluates options for a comprehensive neighborhood plan for the South Downtown area.

The study examines growth and planning issues specific to Pioneer Square, the Chinatown/International District (including the Little Saigon area east of I-5), and the northernmost edges of the Greater Duwamish Manufacturing and Industrial Center. Preliminary recommendations were released by the City's Department of Planning and Development in March 2006. Land use and zoning changes considered as part of this process will require conducting an environmental review prior to legislative decision-making.

The project most likely to interact with the Proposed Action in the near future is the South Holgate Street to South King Street Viaduct Replacement Project, which will replace the south end of the Viaduct (Exhibit 6-1). That project, a Moving Forward project within the Alaskan Way Viaduct and Seawall

Replacement Program, is scheduled for construction from 2009 to 2012, the same time frame as the Proposed Action, and it will be located immediately west of the proposed SR 519 improvements.

The project team examined these RFFAs to see if they might interact with the Proposed Action to produce a cumulative effect on geology and soils.

The primary influences that appeared to contribute to cumulative effects from the RFFAs were related to use of construction materials, quantities of construction debris, and seismic hazards, as summarized below:

- Construction of the Proposed Action would require concrete and reinforcing steel to construct structures and foundations, asphalt to replace pavement, aggregate for roadbase materials, and various other construction materials. These requirements would be similar to other projects being constructed in the area, such as the Alaskan Way Viaduct and the Spokane Street Viaduct. When considered in total, a large demand would be placed on material resources. A potential outcome is that costs for construction of project components would increase, likely at a rate greater than the national rate of inflation.
- Construction debris would result from various sources during work on the project. This would include concrete debris from tie-in to existing structures and buildings, as well as asphalt from roadways that are excavated along South Royal Brougham Way, on Fourth and Third Avenues, and along First Avenue. Similar to the above discussion of construction materials, this debris would be similar to that which would result from other nearby projects. These RFFAs would be both beneficial and negative. The beneficial effects would be that by considering all the projects together, the economics of reprocessing much of the debris becomes more feasible. The negative effect would relate to debris that cannot be recycled and would have to be disposed of in landfills; the

capacity of the landfills would be reached more rapidly because of the combined disposal amounts.

- The seismic hazard also is an RFFA that has both positive and negative effects when considered with other projects. For example, the SR 519 project will be designed to the latest seismic standards, resulting in improved safety to the public. However, the higher safety would be limited to the new structures and not the tie-ins to existing structures. The risk on the existing structures would potentially be higher because of the higher usage that is likely to result for the corridor. It is also possible that some liquefaction-related hazards, such as lateral spreading, might be reduced if work for the Alaskan Way Viaduct or Spokane Street Viaduct resulted in ground improvement along the waterfront.

3 Would the Proposed Action contribute to cumulative effects on geology and soils?

The Proposed Action might contribute to cumulative effects related to geology and soils, as summarized in Exhibit 6-3.

EXHIBIT 6-3. SUMMARY OF EXPECTED CUMULATIVE EFFECTS RELATED TO GEOLOGY AND SOILS

Type of Cumulative Effect	Description of Cumulative Effect
Proposed Action	
Seismic risk	The Proposed Action would introduce elevated structures that would connect to previously built structures, some of which are also elevated. Seismic loading during an earthquake could put these existing structures at risk. The cumulative effect on structures by seismic-induced ground shaking and liquefaction for the Proposed Action would be mitigated through appropriate design, construction, and operational procedures. (See Chapter 5 for further details on seismic risk and mitigation.) Although existing structures would not be retrofitted to meet current seismic standards, an indirect cumulative effect would be that a higher priority would likely be given to retrofitting the existing structures so that the risk to this critical transportation corridor is reduced.
Reduction in the availability of local aggregate	The use of gravel aggregate for roadway construction and approach fills would incrementally reduce the availability of fill material from existing aggregate resources. Although requirements for gravel aggregate would be minimal relative to the regional supply, the Proposed Action, in combination with other reasonably foreseeable construction projects in the Seattle area, would contribute to the gradual reduction of aggregate material

EXHIBIT 6-3. SUMMARY OF EXPECTED CUMULATIVE EFFECTS RELATED TO GEOLOGY AND SOILS	
Type of Cumulative Effect	**Description of Cumulative Effect**
	available from nearby aggregate sources, requiring longer import distances. These longer distances would add to the regional construction costs. The increasing focus on re-using demolition debris would help offset these increased regional costs.
No Build Alternative	
Seismic risk	Seismic hazards and the related secondary effects would occur whether or not the Proposed Action was implemented.
Improved local aggregate supplies	Most of the construction effects would be avoided. For example, with the No Build Alternative, the aggregate supplies would be used for other purposes, and there would be no need for fills and stockpiles.

4 How would cumulative effects on geology and soils be monitored, mitigated, and managed?

As previously noted, seismic hazards to multiple structures would be the most important cumulative effect associated with the Proposed Action. All structural components of the Proposed Action would be designed to withstand a ground motion caused by a seismic event that has a low probability of exceedance during its design life (75 years). The structures would be designed not to collapse under the conditions imposed by this design event through the use of deep foundations that carry seismic loads to suitable bearing materials. If required, soils would be improved to reduce the risk of liquefaction and related seismic damage.

The seismic hazard to existing structures resulting from induced loading from the proposed I-90 off-ramp to South Atlantic Street has been considered. The proposed structure would be designed either to be structurally isolated from the existing structures, or to have sufficient stiffness not to impart additional seismic load on the existing structure.

For more detailed information on seismic hazard and how it would be mitigated, please see Chapters 4 and 5.

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Appendix A
List of Existing Geotechnical Reports from GeoMapNW

Appendix A
Geotechnical Reports Obtained from GeoMapNW
(These reports are the information sources for the geotechnical exploration locations shown on Exhibit 4-3.)

UW Document ID (if applicable)	Consultant	Document Name	Date	Number of Explorations Included in Report (within or near study area)	Type(s) of Explorations	Explorations Depths Range (feet bgs)
180	Roger Lowe Associates, Inc. Earth Sciences	Soils and Foundation Investigation Phase I, Proposed Warehouse Development for Fisher Properties, Inc., Seattle, Washington	November 15, 1979	7	Borings	55 - 85'
2488	Shannon and Wilson, Inc.	Geotechnical Report, Seattle Seahawks Stadium and Exhibition Center, Seattle, Washington	March 1998	17	Boring and CPTs	Borings: 15.0 - 90.3' CPTS: 57.5 - 65.5'
2517	Hunt-Kiewit	New Pacific Northwest Baseball Park, Geotechnical and Environmental Report in Bid Documents, Book 5 Geotechnical Report Volume 2	August 1996	32	Borings and Piezocone Probes	Borings: 14.0 - 138.0' Piezocone Probes: 57.0 - 98.0' Test Pits: 8.0 - 9.0'
3361	Geolabs-Washington, Inc.	Soils and Foundation Investigation, Proposed King	April 1972	51	Borings, CPTs, Test Pits	Borings: 9.0 - 100.0' CPTs: 23.0 - 30.5' Test Pits: 5.0 - 10.0'

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UW Document ID (if applicable)	Consultant	Document Name	Date	Number of Explorations Included in Report (within or near study area)	Type(s) of Explorations	Explorations Depths Range (feet bgs)
		County Multipurpose Stadium, King Street Station Site, Seattle, Washington				
3511	Shannon and Wilson, Inc.	Draft Geotechnical Report, Kingdome Sewer Separation Project, Seattle, Washington	May 1992	12	Borings	31.5 - 108.5'
3578	Metropolitan Engineers	Final Report-Soils Investigation Elliott Bay Interceptor, Section 5, Seattle, Washington	April 19, 1968	29	Borings	28 - 130'
3704	Converse, Ward, Davis, Dixon Geotechnical Consultants	Geotechnical Exploration, Fourth Avenue and Connecticut, Seattle, Washington, Metro Interim Operating Base	September 19, 1979	2	Boring and Test Pit	Boring: 85.5' Test Pit: 3.5'
3960	Metropolitan Engineers	Final Report, Foundation Investigation, Elliott Bay Interceptor Regulators, King Street Regulator, Connecticut Street Regulator, Hanford	July 3, 1969	17	Borings	31 - 81'

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UW Document ID (if applicable)	Consultant	Document Name	Date	Number of Explorations Included in Report (within or near study area)	Type(s) of Explorations	Explorations Depths Range (feet bgs)
		Street Regulator, Hanford Street Regulator, Alaskan Way Interceptor, Sections 4, 5, and 6, Seattle, Washington				
6109	Shannon and Wilson, Inc.	Produce Terminal Building for Northern Pacific Railway Company, Plan of Logs and Borings	October 5, 1992	4	Borings	76.0 - 91.5'
6119	Seattle Engineering Department, Materials Laboratory	Log of Test Borings - Connecticut Street	November 1973	6	Borings	15.0 - 20.0'
8038	Hart Crowser	Subsurface Explorations and Design Phase Geotechnical Engineering Study, SR-90, Seattle Access General Purpose and Transit/HOV Lanes, Seattle, Washington Volume II of III,	August 1986	33	Borings and Probes	Borings: 58.5 - 113.5' Probes: 24.2 - 72.2'

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Geotechnical Reports Obtained from GeoMapNW
(These reports are the information sources for the geotechnical exploration locations shown on Exhibit 4-3.)

UW Document ID (if applicable)	Consultant	Document Name	Date	Number of Explorations Included in Report (within or near study area)	Type(s) of Explorations	Explorations Depths Range (feet bgs)
		Appendix A, Field Explorations, Appendix B Laboratory Testing Program				
9928	Seattle Engineering Department, Materials Laboratory	Alaskan Way/Royal Brougham TIA	February 11, 1992	8	Borings	2 - 113.5'
10133	Black & Veatch Waste Science, Inc.	Final Underground Storage Tank, Site Assessment Report, King County Department of Transportation, Ryerson Operating Base	February 1996	12	Borings	9.0 - 19.0'
10501	Department of Ecology	Water Well Report	May 1, 1997	1	Well log	30'
10502	Department of Ecology	Water Well Report	February 25, 1997	1	Well log	20'
11379	Shannon and Wilson, Inc.	Report Addendum No. 095-1, Geotechnical Data Report (GDR), Seattle Monorail	April 1, 2004	1	Boring	106.4'

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Geotechnical Reports Obtained from GeoMapNW
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UW Document ID (if applicable)	Consultant	Document Name	Date	Number of Explorations Included in Report (within or near study area)	Type(s) of Explorations	Explorations Depths Range (feet bgs)
		Project (SMP), Seattle, Washington				
13582	Shannon and Wilson, Inc.	Geotechnical Report Atlantic/Central Base Employee Parking Garage, Seattle, Washington	June 2002	5	Borings	86.5 - 101.5'
	Department of Ecology	Well Logs	1990 - 2006	55	Well log	55'
	Washington State Department of Transportation	Contract Provisions For Construction, SR-90 MP 1.94 to MP 2.23, SR 519 MP 0.20 to 0.00, Intermodal Access - Phase 1, S. Atlantic Street, Volume 2 of 2	1997	28	Borings	14.0 - 124.0'