3.4 GEOLOGY AND SOILS

3.4.1 Studies and Coordination

For the geology impacts evaluation, the basis of comparison among the alternatives is the estimated length of various transportation improvements within the geologic hazard areas and consideration of the magnitude of disturbance.

The primary data sources for determining the various geologic hazards included:

- The King County and City of Redmond sensitive areas maps (King County Zoning Code Section 21A; Redmond Community Development Guide, code section 20D)
- Snohomish County Geologic Hazard Areas Maps (GeoEngineers, 1991)
- U.S. Geological Survey (USGS) surficial geology maps (Minard, 1985; Galster and Laprade, 1991; Wong et al., 1999)
- U.S. Department of Agriculture, Soil Conservation Service (SCS) soil maps for King and Snohomish County (Snyder, 1973; Debose and Klungland, 1983).
- King County Code and USGS sponsored papers (Hobblitt et al., 1998; Waitt et al., 1995) for volcanic hazards
- USGS sponsored papers (Blakely, 2000; Brocher, 2000; Blakely et al., 1999; Johnson et al., 1999; Wong et al., 1999) and in-house reports (CH2M HILL, 1998) for fault locations and characteristics

3.4.2 Methodology

A detailed, though subjective, rating system, which was used to compare the geologic impacts of each alternative, is discussed in the *I-405 Corridor Program Draft Geology and Soils Expertise Report* (CH2M HILL, 2001), herein incorporated by reference. This section of the EIS contains only relative ratings among the alternatives and a general assessment of the overall impact of each geologic hazard. The comparison of the alternatives' impacts was based on the approximate length of equivalent lane miles of new construction through each geologic hazard area. A rating of low was given if the impacts of the hazard can probably be mitigated without increasing construction cost by more than one percent. A rating of high was given if mitigation of the hazard might increase construction costs by more than 100 percent. No cost estimates were computed; the projection of approximate mitigation cost was based on experience and professional judgement.

3.4.3 Affected Environment

3.4.3.1 Regional Geology

The soils and land types found within the I-405 corridor are heavily influenced by multiple Pleistocene glaciations that resulted in a series of north-south-trending ridges of glacial drift separated by deep troughs. The troughs are now occupied by lakes and streams and their associated alluvial and lacustrine deposits. Regional geology is discussed in detail in the *I-405 Corridor Program Draft Geology and Soils Expertise Report* (CH2M HILL, 2001).

3.4.3.2 Regional Seismicity

The Uniform Building Code (1997) defines the Puget Sound as Seismic Zone 3, which represents an area susceptible to moderately high seismic activity. For comparison, much of Alaska and California are within Seismic Zone 4 and are susceptible to greater seismic activity.

Probabilistic maps that provide ground accelerations for use in design have been developed by the USGS and adopted by the Federal Emergency Management Agency (Building Seismic Safety Council, 1997). The maps combine the effects of earthquakes from three different sources:

- Shallow, crustal earthquakes, for example, along the Seattle Fault, with a magnitude 6.5 to 7.
- Subduction zone earthquakes from the boundary between the Juan de Fuca Plate and the North American Plate that are roughly 40 to 70 kilometers deep beneath the Puget Sound area, with a magnitude of 7 to 7.5.
- Large, shallow subduction zone earthquakes that would occur along the plate boundaries west of the Washington coast, with a magnitude of 8 or 9.

Firm ground conditions would occur at the ground surface along some portions of the alignments; however, in some areas firm ground would occur 100 feet or more below the ground surface. In locations where firm ground is at depth, amplification of the ground motions could occur as the motions propagate toward the surface. The amount of amplification could be 20 percent or higher at sites where more than 100 feet of very soft soil occurs. These levels of acceleration, whether amplified or not, are sufficient to cause liquefaction in loose saturated soil, failure of slopes, and additional inertial loading to structures located on or in the soil.

In addition to the seismic ground shaking discussed above, tectonic movement can occur at fault lines if the fault zones penetrate to the ground surface. One active (i.e., considered to have experienced movement within the last approximately 10,000 to 15,000 years) fault crosses the I-405 corridor, the Seattle Fault. The northern boundary of potential faulting is approximately SE 25th Street in Bellevue, and the southern boundary is approximately N. 40th Street in Renton and SE May Valley Road in Newcastle. Another active fault, the South Whidbey Fault, touches the northeast corner of the study area. Evidence suggests that the return interval for the Seattle Fault is approximately 5,000 years for a magnitude 7.1 event and 1,100 years for a magnitude 6 event (Blakely et al., 1999). The recurrence interval for the South Whidbey Fault may be similar.

3.4.3.3 Soils

The King and Snohomish county soil surveys (Snyder et al., 1973; Debose and Klungland, 1983) provide detailed soil maps of the study area. These maps are generally representative of average conditions in the upper several feet of soil profile. One way in which surficial soil mapping is useful for this study is for determining erosion hazards, as described under Erosion Hazards later in this section.

A detailed description of the soil types is not included here because many of the soils along the existing state highways and arterials have been modified by construction activities. Adjacent to these areas, the most prevalent soil type across the study area is the Alderwood complex. This is a gravelly, sandy loam that forms on glacial till. The permeability is relatively rapid above a hardpan layer, then very slow through it. Available water capacity is low. On slopes steeper than 25 percent, it has rapid runoff and a high erosion hazard.

3.4.3.4 Geologic and Soil Resources

Geologic or soil resources are considered to be culturally or economically valuable. Sand and gravel deposits suitable for mining and mineral deposits are considered as geologic resources. Topsoil suitable for agricultural or landscaping use is considered a soil resource.

There are no known mineral or commercial sand and gravel pits that would be covered over or made unusable by any of the proposed alternatives. However, imported (i.e., from an offsite WSDOT or commercially developed source) sand and gravel for the pavement and pavement base, structural concrete, and specially engineered fills would use a portion of the limited sand and gravel resources that have been permitted and developed within the region. For a study of this scale, it is impossible to estimate the volume of aggregate needed for concrete structures or specially engineered fill. However, very approximate and relative quantities of aggregate for the improvements can be estimated from conservative approximations of the aggregate needed for the pavement, pavement base, and subgrade drainage. These approximate quantities are shown in Table 3.4-1.

Table 3.4-1: Approximate Quantity of Aggregate Required for Each Alternative

Alternative	Estimated Quantity of Aggregate (million tons) [a]
No Action Alternative	1
1. HCT/TDM	1.5
2. Mixed Mode with HCT/Transit Emphasis	3
3. Mixed Mode	3
4. General Capacity	4
Preferred Alternative	3.5

[a] As computed from estimates of pavement, pavement base, and subsurface drainage for typical arterial, freeway, and rail roadway sections.

The following facts help to put the required aggregate quantity estimates of Table 3.4-1 into perspective:

- Washington State construction projects consume nearly 77 million tons of aggregates a year (Washington Aggregates and Concrete Association, 2000).
- There are approximately 20 sand and gravel companies within the 12-county Puget Sound region; the approximate annual production is 20 million tons (Huckell/Weinman, 1993).
- One of the larger pits in the Puget Sound region processes about 3 to 4 million tons of aggregate per year (Huckell/Weinman, 1993).

Although topsoil is present over some of the undisturbed or landscaped areas through which the alternatives would pass, topsoil is generally considered to be readily available throughout the study area. Because it is undesirable to construct facilities on top of topsoil, it is likely that topsoil would not be "lost" due to construction, but rather, removed and used elsewhere in the region.

3.4.3.5 Geologic Hazard Areas

Geologically hazardous areas are defined as areas that, because of their susceptibility to erosion, sliding, earthquake, or other geologic events are not suited for development consistent with public health and safety concerns. Washington State's Growth Management Act (Chapter 36.70A RCW) requires all cities and counties to identify critical areas within their jurisdictions and to formulate development regulations for their protection.

The geologic hazards discussed in this report are erosion hazards, landslide hazards, seismic hazards, mine hazards, and volcanic hazards. Some jurisdictions (King County, Bothell, and Newcastle) have regulations governing steep slope hazards. Since the hazards associated with steep slopes are related to erosion or landslides, steep slope hazards themselves are not discussed in this report.

Construction over soft soils can involve more disturbance of the ground surface than construction over firm soil, and ground settlement, weak soils, and high groundwater are potential design issues. Seismic hazard areas are typically mapped as areas with potentially soft ground due to geologic origin, as discussed in a subsequent section. Therefore, seismic hazards and soft ground hazards are considered together for the remainder of this report.

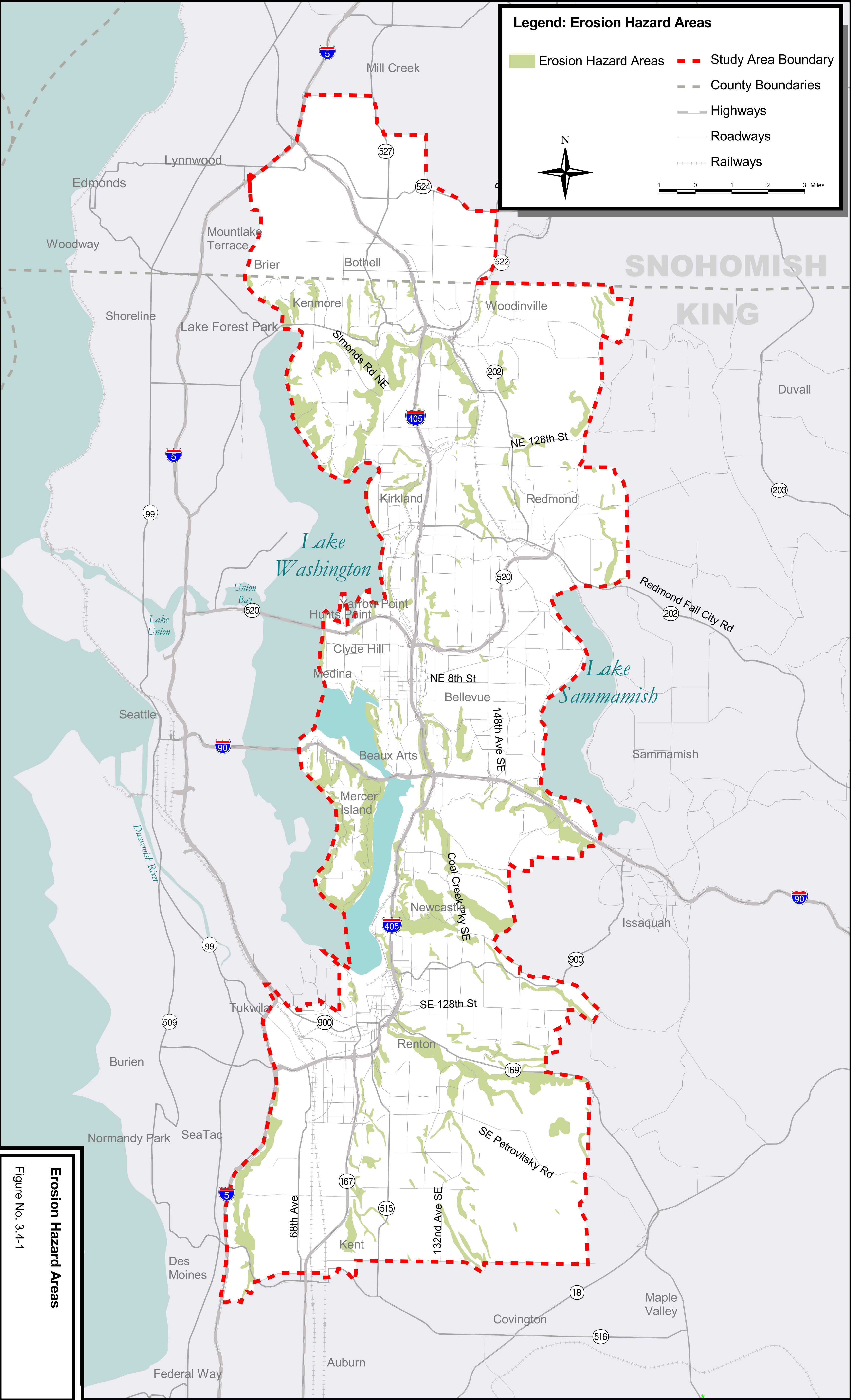
In addition to making construction more difficult and costly or adding risk to the long-term operation of transportation facilities, development activities within these geologic hazard areas are regulated by local and county ordinances. The cities of Bothell, Woodinville, Kirkland, Newcastle, Renton, Redmond, and Tukwila, in addition to Snohomish and King counties, all have their own sensitive areas ordinances. In most cases, development is allowed, but only if approved mitigation measures are designed by competent professionals.

Figures 3.4-1, 3.4-2, and 3.4-3 show the approximate locations of erosion, landslide, seismic, and mine hazard areas, respectively, as mapped by King County (1999), the City of Redmond (2000), and Snohomish County (GeoEngineers, 1991). The definitions of geologic hazards in the ordinances of other cities within the study area have enough similarities to the King County definitions that the King County maps can be used for analysis in cities outside of Redmond. The hazard areas themselves are described in the subsections below.

3.4.3.6 Erosion Hazards

Erosion hazard areas are typically defined as soils that form on fine-grained geologic units or till that are steeper than 15 percent or soils that form on coarse-grained soils that are sloped at 40 percent or more. In addition to regulations to control erosion on slopes as discussed above, King County has recently enacted regulations limiting fall and winter clearing and grading in designated salmon stream watersheds (KCC-16.82.150 d). This is discussed in more detail in the *I-405 Corridor Program Draft Geology and Soils Expertise Report* (CH2M HILL, 2001).

Construction of any transportation facilities that involves clearing the protective vegetation and moving soil within an erosion hazard area involves a relatively high risk of eroding soil particles. Mitigation measures, as discussed in section 3.4.6, can reduce the risk of erosion to medium levels. Alternatively, it may be possible to design the facilities so that vegetation disturbance and the accompanying risk of erosion in erosion hazard areas is minimized, or to locate the facility outside of the erosion hazard area. Many of the proposed alternatives are on the edges of mapped erosion hazard areas, so final siting could place them outside of the hazard area. Erosion



Erosion Hazard Areas

Figure No. 3.4-1

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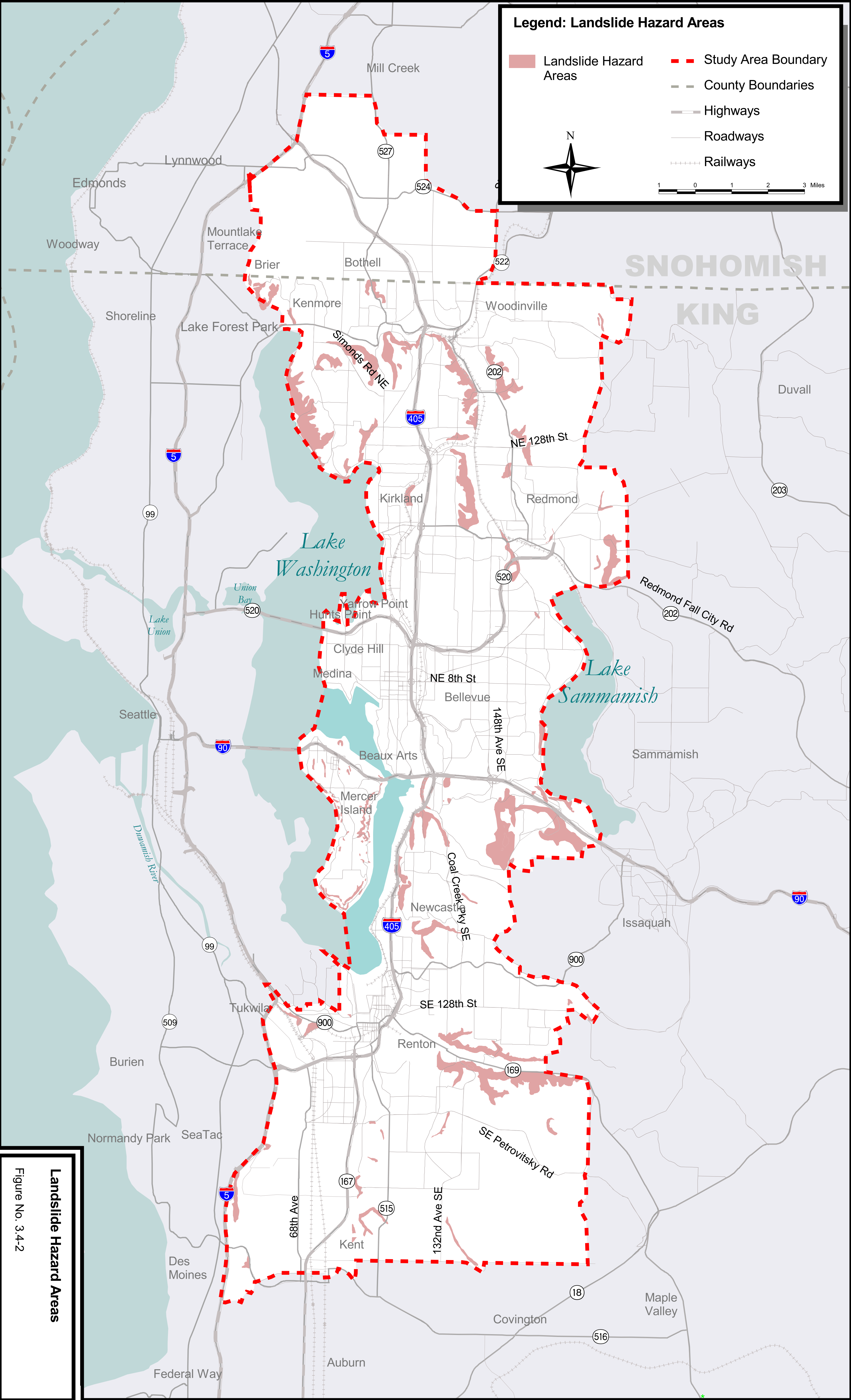

Landslide Hazard Areas

Figure No. 3.4-2

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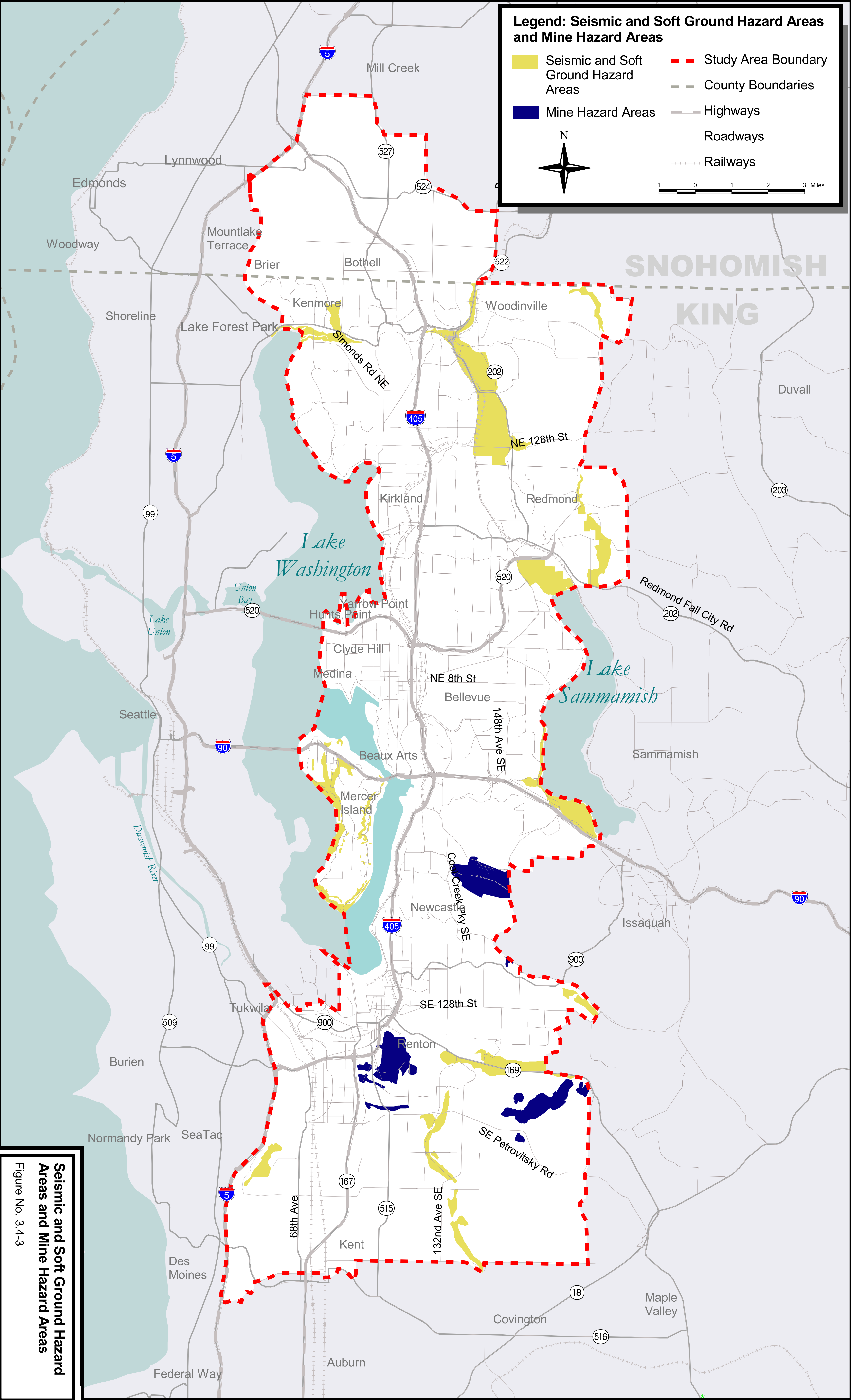

Seismic and Soft Ground Hazard Areas and Mine Hazard Areas

Figure No. 3.4-3

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of soil particles could result in sediment accumulation and reduction in water quality downslope. Mitigation measures can reduce the risks of these offsite impacts to low levels. Therefore, erosion at the construction site does not directly translate to riparian zone or stream habitat degradation. Because of concern about the impact of erosion on critical habitat, as defined by the Endangered Species Act, the location of critical habitat relative to erosion hazard areas was examined. Most of the major erosion hazard areas that could be affected by the proposed alternatives are near chinook salmon habitat.

Mapped erosion hazards within the study area are shown on Figure 3.4-1. They are scattered throughout the study area but concentrations of erosion hazards that impact proposed alternatives are located along the margins of the Sammamish River Valley, on the western slope of the Bear Creek Valley, along I-405 between SE 8^{th} St. in Bellevue and Coal Creek Parkway, along I-405 in the Newcastle area, along I-90 across much of Mercer Island, and along I-90 from approximately West Lake Sammamish Parkway to the eastern study boundary.

3.4.3.7 Landslide Hazards

The jurisdictions within the study area inside of King County generally define landslide hazards as any slopes steeper than 40 percent or slopes of 15 percent or more that also have interbedded sand and silt or clay, springs or seeps, landslide deposits or other indications of past landsliding, or show signs of rapid stream downcutting or wave or bank erosion.

Snohomish County has mapped landslide hazards on a scale of moderate to very high. Moderate landslide hazard areas are defined as sloping between 15 and 40 percent and underlain by soils that consist largely of sand, gravel, bedrock, or glacial till. High landslide hazard areas are defined as sloping between 15 and 40 percent and underlain by silt and clay or sloping more steeply than 40 percent. Very high landslide hazard areas are known, mappable landslide deposits.

There are no very high landslide hazard areas within the study area in Snohomish County. Only moderate landslide hazard areas are located adjacent to any of the proposed roadway improvements. All of the landslide hazard areas have been shown on Figure 3.4-2. Notable areas of these hazards that would impact the alternatives are located along the margins of the Sammamish River Valley, on the western slope of the Bear Creek Valley, along I-405 between SE 8^{th} Street in Bellevue and Coal Creek Parkway, along I-405 in the Newcastle area, and along I-90 from approximately West Lake Sammamish Parkway to the eastern study boundary.

3.4.3.8 Seismic and Soft Ground Hazards

Seismic hazards are generally considered to be areas with a severe risk of ground shaking or deformation during an earthquake. Prediction of amplified ground shaking or liquefaction and associated deformation that could damage civil works, engineered structures, or residences requires detailed knowledge of soil composition, stratigraphy, groundwater, and ground slope. Therefore, the local jurisdictions have taken a conservative approach, generally classifying all post-glacial deposits in low-lying areas as seismic hazards. In effect, the seismic hazard map (Figure 3.4-3) can also be considered a soft ground hazard map. Design and construction of transportation facilities over soft ground must contend with potential settlement, weak soil conditions, and typically high groundwater.

Seismic and soft ground hazards within the study area are shown in Figure 3.4-3. The hazard areas affecting study alternatives are the Sammamish River Valley, Bear Creek Valley, North Creek Valley, and the area between I-90 and the south end of Lake Sammamish.

3.4.3.9 Mine Hazards

Coal mine hazards have been mapped by King County as large expanses surrounding underground mines and their shafts and adits. The risk of encountering a mine opening, sinkhole, or enlarging depression within a mapped hazard area is relatively low.

Figure 3.4-3 shows the coal mine hazards in King County. The only coal mine hazards in the vicinity of proposed improvements are in Renton, in the area of the I-405 S-curves and on the eastern side of SR 167 just south of the I-405 interchange. There are no known coal or other underground mines within the study area in Snohomish County.

3.4.3.10 Volcanic Hazards

Volcanic hazards could arise from several different phenomena. The three phenomena of concern to the study area are tephra accumulation, lahars, and the associated flooding. (Tephra is a general term for all pyroclastic materials produced by a volcano. Lahars are mudflows on the flanks of a volcano.)

The annual probability of a one-centimeter or greater accumulation of tephra from any of the Cascade volcanoes within the study area is between 0.02 and 0.1 percent (Hoblitt, et al., 1998). None of the sensitive areas ordinances addresses the tephra hazard. Although accumulations of more than a centimeter of tephra can result in major economic losses, the risk of permanent damage to facilities is small and the risk is similar for all locations within the study area.

Volcanic hazards from lahars and associated flooding are thought to be a risk within several river valleys with headwaters around Mt. Rainier and Glacier Peak. None of the lahar hazard zones from Glacier Peak extend south of Arlington (Waitt, et al., 1995). There is a "significantly reduced risk" below the 100- to 500-year recurrence interval, of lahars or post-lahar sedimentation within the Green River Valley between Auburn and Elliot Bay (Hoblitt, et al., 1998). The King County Sensitive Areas Ordinance does not consider areas north of the White River (just south of Auburn) to be volcanic hazard areas.

3.4.4 Impacts

In order to construct the proposed facilities, the topography would be altered, soils would be disturbed, and impervious surface would be added. In general, more roadway lanes or equivalent disturbance for HCT facilities can be expected to result in greater potential impact and higher cost for mitigation. <u>As described in Section 3.4.2 (Methodology), an impact rating of low was assigned if the identified impacts of the geologic hazard can probably be mitigated without increasing construction cost by more than one percent. A rating of high was given if mitigation of the hazard might increase construction costs by more than 100 percent.</u>

Impacts on the geology and soils within the I-405 Corridor affected area would be considered substantial if an alternative either (1) permanently removes geologic or soil resources that are not readily available elsewhere, (2) causes a threat to public health and safety, or (3) is anticipated to involve mitigation costs that exceed the anticipated construction costs. If the proposed improvements are constructed using generally accepted local geotechnical engineering practice, no substantial impacts are anticipated for any of the alternatives.

3.4.4.1 No Action Alternative

Construction Impacts

Erosion Hazards

Clearing the protective vegetation and moving soil during construction allows rainfall and runoff to erode soil particles. Thus, there is the potential for loss of soil at the site of disturbance and downslope, sediment accumulation in downstream areas, and reduction in runoff water quality. Overall, the risk that unmitigatable impacts could occur as a result of constructing through erosion hazard areas is rated high for all alternatives; however, the design solutions and best management practices (BMPs) identified in Section 3.4.6 are expected to reduce these to levels that are not substantial.

The No Action Alternative involves HOV facilities in the vicinity of the 44th St interchange in Renton and the Sunset interchange in Renton, as well as widening 140th Way SE to 5 lanes on the slopes of the Cedar River Valley in Fairwood, all in erosion hazard areas. The No Action Alternative has the lowest magnitude of erosion hazards of any I-405 Corridor Program alternative.

Landslide Hazards

Construction of rail lines, freeway lanes, or ramps would involve cuts and fills and/or bridge and retaining wall structures that have the potential to destabilize landslide-prone hillsides. Overall, the risk of unmitigatable impacts due to constructing in landslide hazard areas is rated low for all alternatives.

The No Action Alternative involves HOV facilities in the vicinity of the 44th St interchange in Renton, as well as widening 140th Way SE to five lanes on the slopes of the Cedar River Valley in Fairwood, all in landslide hazard areas. The No Action Alternative has the lowest magnitude of landslide hazard of any I-405 Corridor Program alternative.

Seismic and Soft-Ground Hazards

Seismic and soft-ground hazards may potentially affect all of the alternatives. Overall, the risk of unmitigatable construction impacts in these areas is rated low for all alternatives.

The No Action Alternative includes addition of two to three lanes to several sections of existing roadway in the Sammamish River Valley, widening 140th Avenue to five lanes in the Cedar River Valley, and additional ramps or lanes for the I-5/I-405 interchange at Swamp Creek, all in seismic and soft-ground hazard areas. The No Action Alternative has the lowest magnitude of seismic and soft-ground hazards of any I-405 Corridor Program alternative.

Other Hazards

Mine hazards and volcanic hazards within the study area are anticipated to be low for the No Action Alternative and all action alternatives.

Using heavy equipment during construction will cause ground vibrations. Actual vibrations will depend on the type of heavy equipment, distance from the source, and ability of the soil to transmit vibrations. Vibrational impacts are commonly measured in terms of peak particle velocity. In general, peak particle velocity tends to be reduced logarithmically with distance from the source. For example, Wiss (1974) reported that peak particle velocities for most construction equipment were reduced by a factor of 40 with a tenfold increase in distance from the source (i.e., the velocity at a distance of 10 feet is 40 times less than the velocity 1 foot from the source). The threshold for damage to sensitive historic and residential structures is commonly accepted at a peak particle velocity between 0.1 and 1 inch per second, while the damage threshold for commercial structures is generally between 1 and 10 inches per second (Whyley and Sarsby, 1992; Hart Crowser, 1986; Wiss, 1974). Humans generally cannot perceive vibrations of less than 0.01 inch per second and find vibrations greater than 1 inch per second very disturbing. Typical construction vibrations are noted in Table 3.4-2 below (Wiss, 1974).

Table 3.4-2: Typical Construction Vibrations

Equipment Type	Peak Particle Velocity at a Distance of 10 feet (inch/second)	Peak Particle Velocity at a Distance of 100 feet (inch/second)
Small dozer	0.01	<0.001
Truck	0.3	0.009
Large dozer, shaft drilling	0.4	0.01
Diesel pile driver (36,000 feet per pound)	6.0	0.2

As outlined in Table 3.4-2, most of the construction-related vibrations, with the exception of pile driving, will be imperceptible to people outside of the construction zone. Pile-driving vibrations (and noise) may be felt a few hundred feet from the source and have the potential to cause damage to sensitive structures.

The potential for vibration impacts is lowest for the No Action Alternative because it involves the least amount of total construction and involves the fewest number of foundations in soft ground where pile driving would be a potential method of foundation support.

Operational Impacts

Erosion Hazard

Once construction is complete, vegetation can usually be reestablished or some nonerodable surface installed to limit erosion. It may take several seasons for the vegetation to reach pre-construction protective levels and some accelerated erosion may occur during this time. Some surfaces outside of the shoulders may not be allowed to revert to pre-construction vegetation because of maintenance needs (for example, ditches). Overall, the risk of unmitigatable operational impacts due to locating facilities in erosion hazard areas is rated medium for No Action Alternative and all action alternatives.

Erosion that would be considered unmitigatable is the slight acceleration of naturally occurring erosion processes. For example, the increased runoff due to replacing trees with grass and asphalt, even with detention to slow the velocities, might accelerate erosion that would otherwise occur over a longer period of time. With proper mitigation, the erosion rates would not be anticipated to be high enough to change the character of streambed materials or impact downstream water quality by observable amounts.

Other Hazards

Vibrations due to traffic vary with the type of vehicle, the distance from the traveled lanes, the ability of the soil to transmit vibrations, and the speed of the vehicle. Based on the discussion of potential construction vibration impacts, most traffic vibrations will be imperceptible at distances of 100 feet or more from the traveled lane. The No Action Alternative will have the lowest potential for operational vibration impacts because traffic speeds will be lower and there will be fewer new lanes closer to existing structures.

3.4.4.2 Alternative 1: HCT/TDM Emphasis

Construction Impacts

Erosion Hazards

Alternative 1 would involve earthwork for adding one or more rail lines along the BNSF railroad right-of-way, which passes through erosion hazards in the following locations:

- Between SR 522 and NE 124th Street near Totem Lake
- A short section (about 1 mile) in the vicinity of Yarrow Bay in Kirkland
- A segment (about three-quarter mile) near Forbes Drive in Kirkland
- In Bellevue between SE 8th Street and Coal Creek Parkway
- Between approximately SE 68th Street in Bellevue and NE 44th Street in Renton
- The Renton S-curves

Alternative 1 also would add one lane to Avondale Road, which is located within an erosion hazard area. Overall, Alternative 1 has the lowest magnitude of erosion hazards of any of the action alternatives.

Landslide Hazards

Alternative 1 would involve earthwork for adding one or more rail lines along the BNSF railroad right-of-way, which passes through landslide hazards in the following locations:

- Between SR 522 and NE 124th Street near Totem Lake
- A segment (about 3/4 mile) near Forbes Drive in Kirkland
- Between I-90 and Coal Creek Parkway
- Between approximately SE 68th Street in Bellevue and NE 44th Street in Renton

Alternative 1 also would add one lane to Avondale Road, which is located within a landslide hazard area. Overall, Alternative 1 has the lowest magnitude of landslide hazards of any of the action alternatives.

Seismic and Soft-Ground Hazards

Alternative 1 would add one or more rail lines along the BNSF railroad right-of-way and I-405 between NE 124th Street and approximately NE 195th Street, and add one lane to Avondale Road, both in seismic and soft-ground hazard areas. Overall, Alternative 1 has the lowest magnitude of seismic and soft-ground hazards of any of the action alternatives.

Other Hazards

Mine hazards and volcanic hazards within the study area are anticipated to be low.

The potential for construction-related vibration impacts will be higher than the No Action Alternative, but lower than the other alternatives because Alternative 1 has the least amount of earthwork and the least amount of construction in soft soil areas that might use pile foundations (besides the No Action Alternative).

Operational Impacts

Erosion Hazard

Operational impacts related to erosion hazards are the same as described for the No Action Alternative.

Other Hazards

The potential for operational vibration impacts is low.

3.4.4.3 Alternative 2: Mixed Mode with HCT/Transit Emphasis

Construction Impacts

Erosion Hazards

Alternative 2 would result in the same earthwork for adding one or more rail lines along the BNSF railroad right-of-way as described for Alternative 1, as well as the addition of one lane to Avondale Road. Alternative 2 also would add the equivalent of two lanes to I-405 through erosion hazard areas in the following locations:

- The north-facing slope just south of the SR 522 interchange
- In Bellevue between SE 8th Street and Coal Creek Parkway
- In the vicinity of the Coal Creek interchange
- Between approximately SE 68th Street in Bellevue and NE 30th Street in Renton
- The Renton S-curves

In addition, Alternative 2 would construct four to five new lanes between NE 124th Street and NE 145th Street and widen the existing SR 202 roadway by two to three lanes north of NE 145th Street on the western edge of the Sammamish River Valley. Overall, Alternative 2 has a higher magnitude of erosion hazard than Alternative 1, but is ranked lower than Alternatives 3 and 4 and the Preferred Alternative.

Landslide Hazards

Alternative 2 would result in the same earthwork for adding one or more rail lines along the BNSF railroad right-of-way as described for Alternative 1, as well as the addition of one lane to Avondale Road. Alternative 2 also would add the two lanes to I-405 through landslide hazard areas in the following locations:

- The north-facing slope just south of the SR 522 interchange
- In the vicinity of the Coal Creek interchange
- Between approximately SE 68th Street in Bellevue and NE 44th Street in Renton

In addition, Alternative 2 would construct four to five new lanes between NE 124th Street and NE 145th Street and widen the existing SR 202 roadway by two to three lanes north of NE 145th Street on the western edge of the Sammamish River Valley. Overall, Alternative 2 has a higher magnitude of landslide hazard than Alternative 1, but is ranked lower than Alternatives 3 and 4 and the Preferred Alternative.

Seismic and Soft-Ground Hazards

Alternative 2 would add one or more rail lines along the BNSF railroad right-of-way as described for Alternative 1, as well as add one lane to Avondale Road in seismic and soft-ground hazard areas. Alternative 2 also would add two lanes to I-405 through seismic and soft-ground hazard areas between approximately Woodinville Drive and NE 195th Street in the vicinity of the SR 522 interchange.

In addition, Alternative 2 would construct four to five new lanes between NE 124th Street and NE 145th Street, widen the existing SR 202 roadway by two to three lanes north of NE 145th Street on the western edge of the Sammamish River Valley, and add lanes, bridges, and retaining walls in the southern Sammamish River Valley and Bear Creek Valley. Overall, Alternative 2 ranks third-highest in magnitude of seismic and soft-ground hazards, behind Alternative 4 and the Preferred Alternative.

Other Hazards

Mine hazards and volcanic hazards within the study area are anticipated to be low.

This alternative ranks behind Alternative 4 and the Preferred Alternative for potential construction-related vibration impacts because of the amount of soft-ground construction with associated potential for pile foundations.

Operational Impacts

Erosion Hazard

Operational impacts related to erosion hazards are the same as described for the No Action Alternative.

Other Hazards

The potential for operational vibration impacts is low.

3.4.4.4 Alternative 3: Mixed Mode Emphasis

Construction Impacts

Erosion Hazards

Alternative 3 would add four lanes to I-405 through erosion hazard areas in the following locations:

- The north-facing slope just south of the SR 522 interchange (interchange)
- In Bellevue between SE 8th Street and Coal Creek Parkway
- In the vicinity of the Coal Creek interchange

- Between approximately SE 68th Street in Bellevue and NE 30th Street in Renton
- The Renton S-curves

In addition, Alternative 3 would add four to five new lanes between NE 124th Street and NE 145th Street; widen the existing SR 202 roadway by two to three lanes north of NE 145th Street on the western edge of the Sammamish River Valley; and add one lane to Avondale Road within erosion hazard areas as described for Alternative 2. Overall, Alternative 3 has a higher magnitude of erosion hazard than the other alternatives, except for Alternative 4 and the Preferred Alternative.

Landslide Hazards

Alternative 3 would add four lanes to I-405 through landslide hazard areas in the following locations:

- The north-facing slope just south of the SR 522 interchange
- In the vicinity of the Coal Creek interchange
- Between approximately SE 68th Street in Bellevue and NE 44th Street in Renton

In addition, Alternative 3 would add four to five new lanes between NE 124th Street and NE 145th Street; widen the existing SR 202 roadway by two to three lanes north of NE 145th Street on the western edge of the Sammamish River Valley; and add one lane to Avondale Road within landslide hazard areas as described for Alternative 2. Overall, Alternative 3 has a higher magnitude of landslide hazard than the other alternatives, except for Alternative 4 and the Preferred Alternative.

Seismic and Soft-Ground Hazards

Alternative 3 would add four lanes to I-405 through seismic and soft-ground hazard areas between approximately Woodinville Drive and NE 195th Street in the vicinity of the SR 522 interchange. In addition, Alternative 3 would construct four to five new lanes between NE 124th Street and NE 145th Street; widen the existing SR 202 roadway by two to three lanes north of NE 145th Street on the western edge of the Sammamish River Valley; add lanes, bridges, and retaining walls in the southern Sammamish River Valley and Bear Creek Valley; and add one lane to Avondale Road within seismic and soft-ground hazard areas as described for Alternative 2. Overall, Alternative 3 has the fourth highest magnitude of seismic and soft-ground hazards behind Alternatives 2 and 4 and the Preferred Alternative.

Other Hazards

Mine hazards and volcanic hazards within the study area are anticipated to be low.

This alternative probably has a lower potential for vibration impacts than Alternatives 2 and 4 and the Preferred Alternative because it involves less construction in soft-ground (potential pile foundation) areas. Construction vibration impacts are probably less than Alternative 4 because this alternative has less general earthwork.

Operational Impacts

Erosion Hazard

Operational impacts related to erosion hazards are the same as described for the No Action Alternative.

Other Hazards

The potential for operational vibration impacts is low.

3.4.4.5 Alternative 4: General Capacity Emphasis

Construction Impacts

Erosion Hazards

Alternative 4 would create the equivalent of 10 lanes of new disturbance (two general purpose lanes, plus four expressway lanes, plus two expressway shoulders, plus two expressway ditches) along I-405 through erosion hazard areas in the following locations:

- The north-facing slope just south of the SR 522 interchange
- In Bellevue between SE 8th Street and Coal Creek Parkway
- In the vicinity of the Coal Creek interchange
- Between approximately SE 68th Street in Bellevue and NE 30th Street in Renton
- The Renton S-curves

In addition, Alternative 4 would add four to five new lanes between NE 124th Street and NE 145th Street and widen the existing SR 202 roadway by two to three lanes north of NE 145th Street on the western edge of the Sammamish River Valley as described for Alternative 2. Overall, Alternative 4 has the highest magnitude of erosion hazards of any I-405 Corridor Program alternative.

Landslide Hazards

Alternative 4 would create the equivalent of 10 lanes of new disturbance along I-405 through landslide hazard areas in the following locations:

- The north-facing slope just south of the SR 522 interchange
- In the vicinity of the Coal Creek interchange
- Between approximately SE 68th Street in Bellevue and NE 44th Street in Renton

In addition, Alternative 4 would add four to five new lanes between NE 124th Street and NE 145th Street and widen the existing SR 202 roadway by two to three lanes north of NE 145th Street on the western edge of the Sammamish River Valley as described for Alternative 2. Overall, Alternative 4 has the highest magnitude of landslide hazard of any I-405 Corridor Program alternative.

Seismic and Soft-Ground Hazards

Alternative 4 would create the equivalent of 10 lanes of new disturbance along I-405 through seismic and soft-ground hazard areas between approximately Woodinville Drive and NE 195th Street in the vicinity of the SR 522 interchange. In addition, Alternative 4 would construct four to five new lanes between NE 124th Street and NE 145th Street, widen the existing SR 202 roadway by two to three lanes between NE 90th Street and SR 522 along the Sammamish River Valley, and add lanes, bridges, and retaining walls in the southern Sammamish River Valley and Bear Creek Valley within seismic and soft-ground hazard areas. Overall, Alternative 4 has the highest potential impacts from seismic and soft-ground hazards.

Other Hazards

Mine hazards and volcanic hazards within the study area are anticipated to be low.

This option has one of the highest potentials for construction-related vibration impacts because it involves the most overall construction, largest footprint, and most construction in soft-ground areas.

Operational Impacts

Erosion Hazard

Operational impacts related to erosion hazards are the same as described for the No Action Alternative.

Other Hazards

The potential for operational vibration impacts is low overall, but slightly higher than the other alternatives because it would involve the highest number of vehicles with more new facilities closer to existing structures.

3.4.4.6 Preferred Alternative

Construction Impacts

Erosion Hazards

The Preferred Alternative would add four lanes plus two 4-foot lane buffers to I-405 through erosion hazard areas in the following locations:

- The north-facing slope just south of the SR 522 interchange
- In Bellevue between SE 8th Street and Coal Creek Parkway
- In the vicinity of the Coal Creek interchange
- Between approximately SE 68th Street in Bellevue and NE 30th Street in Renton
- The Renton S-curves

In addition, the Preferred Alternative would add four to five new lanes between NE 124th Street and NE 145th Street; add two new lanes to Willows Road; widen the existing SR 202 roadway to five lanes between NE 90th Street and NE 145th on the eastern edge of the Sammamish River Valley; and add one lane to Avondale Road within erosion hazard areas. Overall, the Preferred Alternative has a higher magnitude of erosion hazard than the other alternatives except for Alternative 4.

Landslide Hazards

The Preferred Alternative would add four lanes and two 4-foot lane buffers to I-405 through landslide hazard areas in the following locations:

- The north-facing slope just south of the SR 522 interchange
- In the vicinity of the Coal Creek interchange
- Between approximately SE 68th Street in Bellevue and NE 44th Street in Renton

In addition, the Preferred Alternative would add four to five new lanes between NE 124th Street and NE 145th Street; add two new lanes to Willows Road; widen the existing SR 202 roadway by two to three lanes north of NE 145th Street on the western edge of the Sammamish River Valley; add one lane to Avondale Road; and add HOV access and arterial improvements at the NE 44th interchange in Newcastle within landslide hazard areas. Overall, the Preferred Alternative has a higher magnitude of landslide hazard than the other alternatives except for Alternative 4.

Seismic and Soft-Ground Hazards

The Preferred Alternative would add four lanes, two 4-foot lane buffers, and a truck-climbing lane to I-405 through seismic and soft-ground hazard areas between approximately Woodinville Drive and NE 195th Street in the vicinity of the SR 522 interchange. Two-acre transit centers would be added at seismic and soft-ground hazard areas near the Swamp Creek and the SR 522 "downtown Woodinville" interchanges. In addition, the Preferred Alternative would construct four to five new lanes between NE 124th Street and NE 145th Street; widen the existing SR 202 roadway to five lanes between NE 90th Street and SR 522 along the Sammamish River Valley; widen Willows Road by two lanes; add lanes, bridges, and retaining walls in the southern Sammamish River Valley and Bear Creek Valley; and add one lane to Avondale Road within seismic and soft-ground hazard areas. Overall, the Preferred Alternative ranks behind Alternative 4 in magnitude of potential seismic and soft-ground hazards.

Other Hazards

Volcanic hazards within the study area are anticipated to be low. A 2-acre transit center is planned in a coal mine hazard area in downtown Newcastle.

The Preferred Alternative probably has a higher potential for vibration impacts than Alternatives 1, 2, or 3 because it involves more construction in soft-ground (potential pile foundation) areas. Construction vibration impacts are probably less than Alternative 4 because Alternative 4 has more general earthwork and more soft-ground areas.

Operational Impacts

Erosion Hazard

Operational impacts related to erosion hazards are the same as described for the No Action Alternative.

Other Hazards

The potential for operational vibration impacts is low.

3.4.5 Mitigation Measures

3.4.5.1 Construction

Erosion Hazards

Design solutions, including realignment and relocation of improvements to avoid, minimize, or mitigate disturbance in areas with high erosion potential will be considered. In addition, there are many best management practices (BMPs) to reduce erosion and sedimentation during construction. BMPs to prevent erosion and preserve runoff water quality include dry-season construction, re-establishing vegetation before the rainy season, mulching or applying erosion control blankets, and careful management of runoff to keep water off bare slopes and limit flow velocities. Silt fences, ditch check dams, and sedimentation ponds are among the BMPs used to remove sediment from runoff. King County and many local jurisdictions require use of these BMPs as part of the permitting process. Additional BMPs, especially related to construction timing, could be instituted since many of the erosion hazard areas are adjacent to or upstream from chinook salmon habitat.

Landslide Hazards

Facilities in landslide hazard areas can usually be designed to be safely constructed and operated. Temporary cuts through landslide-prone materials could be limited in height or avoided, requiring the use of special retaining wall systems for earth retention. Walls could be designed for higher lateral pressures to limit soil movement. Subsurface drainage may be needed to increase slope stability. Light-weight fill, bridging structures, or realignment and relocation of improvements could be used to avoid loading slopes. All of these design solutions are mitigation measures.

Mine Hazards

If a project is planned in a mine hazard area, a detailed records study would be undertaken to more precisely locate all of the recorded mine facilities. If there appears to be a possibility of a collapsed mine opening or underground room near the proposed facilities, methods ranging from field reconnaissance to exploratory drilling to geophysical techniques would be used to identify the location and extent of potential ground subsidence.

If an opening or surface depression is found or develops after construction, it will be filled with soil or grout or bridged. Suspect areas along WSDOT facilities will be monitored by maintenance crews.

Construction Vibration

The impacts of construction vibrations can be mitigated by restricting the hours of construction or operation of certain types of equipment to times least likely to disturb nearby residences or businesses. In some instances, a drilled pile could be substituted for a driven pile to reduce vibrations. There are other impacts associated with drilled piles (e.g., disposal of drilling spoils, potential for groundwater alteration, and cost) that should be considered before specifying drilled rather than driven piles. Potential impacts to structures and people will be evaluated on a site-specific basis during design.

3.4.5.2 Operation

Erosion Hazards

Mitigation measures will include use of temporary or permanent erosion control blankets, mulching, or soil amendment to promote plant growth. Landscaping will be planned to increase infiltration and reduce runoff where practicable and in consideration of other impacts. Best management practices (BMPs) such as detention ponds, ditches, or structures will be constructed to reduce the stormwater erosion potential to the receiving waters.

Seismic and Soft-Ground Hazards

Mitigation measures will include many of the following: staged construction of embankments so the soil has time to gain strength; wick drains to hasten consolidation and strength gain; constructing embankments of light-weight materials to minimize loading; reinforcing embankments with geosynthetics to add strength and minimize the footprint; preloading to cause settlement prior to construction of the facilities; construction on pile supports; and increasing grades to keep pavement bases above groundwater. Soft-ground hazards at bridge locations, such as the I-5/I-405 Swamp Creek interchange, the I-405/SR 522 interchange, or the eastern terminus of SR 520, will be mitigated by founding the structures on deep foundations.

Earthquakes also pose long-term risks to safe siting of the facilities. Once an appropriate level of risk has been accepted, transportation facilities in seismic hazard areas will be designed and constructed to withstand earthquake accelerations over the lifetime of the facility.

Lifeline utility and transportation routing would be considered as part of the planning process for any improvements within the study area, although it is uncertain if lifeline planning would have an influence on the selection of an alternative. King and Snohomish counties' departments of emergency management could be involved with setting design standards along lifeline routes within the corridor. The work could also be coordinated with the Federal Emergency Management Agency's (FEMA) project IMPACT, which looks at transportation lifelines between the Port of Tacoma and Port of Seattle (EQE International, 2000). Consideration of lifeline requirements could change the design criteria for structures and possibly embankments under seismic loading.

Volcanic Hazard

The volcanic hazard impacts within the study area are anticipated to be quite low; therefore, no mitigation is required.

Operational Vibration

The potential for operational ground vibration impacts is relatively low. With the exception of complex and expensive foundation isolation systems, the only potential mitigating measure is to increase the distance between source and receptor. Impacts at specific locations where the proposed transportation improvements are close to existing facilities will be evaluated during design.

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