APPENDIX O: SOILS AND GEOLOGY TECHNICAL MEMORANDUM

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I-405, Bellevue to Lynnwood Improvement Project

INTERSTATE 405 Corridor Program

Congestion Relief & Bus Rapid Transit Projects

SOILS AND GEOLOGY TECHNICAL MEMORANDUM

April 2011

Washington State Department of Transportation

U.S. Department of Transportation
Federal Highway Administration

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SUMMARY

Why are we considering soils/geology as part of this project?

Soils and geologic conditions can affect and be influenced by the proposed project. Considering these elements during the planning stages allows WSDOT to develop mitigation measures specific to these conditions. Possible mitigation measures include changing the project alignment (avoidance), designing project structures or components to accommodate the soil and geologic conditions, and implementing protective measures and techniques that reduce effects to environmental conditions.

Underlying geologic and soils conditions are used to identify risks associated with the physical environment within the project area. The risks identified for this project include the potential for landsliding, slope instability, liquefaction, and erosion. Other identified geologic hazards include soft ground conditions.

What is the purpose of this study?

The purpose of this technical memorandum is to present an assessment of the soils and geologic conditions in the I-405, Bellevue to Lynnwood Improvement Project area. Underlying geologic conditions can be a major factor affecting project design (e.g., foundations, pavement sections, retaining walls, bridges, etc.). The soils and geology of the area, together with topographic conditions, present several hazard areas along the corridor including those associated with erosion, landsliding, soft ground, susceptibility to seismic events, and steep slopes.

The project will be constructed in a highly variable geologic environment. Potential project effects on the soils and geology during construction include disturbance of moisture-sensitive soils[1], increased erosion potential, and vibration effects from construction equipment. The presence of erosion hazard areas, soft ground areas, and liquefaction-prone areas may affect the project and will be prominent design and construction considerations. The Washington State Department of Transportation (WSDOT) has managed these types of conditions on several other projects, including the original construction of I-405. Once construction is complete and the highway is in use, the built project will have no adverse effects on the soils and geology.

The majority of potential adverse effects associated with the construction and operation of the project will be avoided or minimized through the use of best management practices (BMPs) and by following the procedures outlined in the WSDOT Geotechnical Design Manual and the WSDOT Bridge Design Manual.

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[1] Moisture-sensitive soils may become muddy and unstable with a small increase in moisture content and operation of equipment on these soils can be difficult.

While WSDOT will avoid the majority of potential effects on soils and geology by using standard WSDOT procedures and implementing BMPs, WSDOT will likely face a few unavoidable adverse effects, such as the disturbance of moisture-sensitive soils, cuts in landslide-prone areas, increased erosion potential, and vibration effects from construction equipment, that will require additional, site specific mitigation.

PROJECT DESCRIPTION

What is the intent of the Bellevue to Lynnwood project and what are the improvements?

The Bellevue to Lynnwood Improvement Project is intended to improve safety and reduce congestion along I-405 between NE 6th Street in Bellevue and I-5 in Lynnwood. To accomplish this, WSDOT proposes the following improvements:

- Northbound lane from NE 124th Street to SR 522;
- Braided ramps between the I-405 northbound on-ramp from NE 160th Street and the northbound I-405 off-ramp to SR 522;
- Southbound transit shoulders between SR 522 and NE 160th Street and between SR 527 and NE 195th Street;
- New northbound and southbound structures over NE 132nd Street and a new northbound structure over the railroad for the I-405 northbound off-ramp to NE 124th Street;
- Small amounts of additional widening, between four and eight feet, at several locations for buffers, wider shoulders, tolling equipment, enforcement areas and maintenance pull-outs; and
- Minor upgrades to pedestrian facilities in some areas.

Exhibit 1 shows the Bellevue to Lynnwood project vicinity. Exhibit 2, sheets 1 through 17, shows more detail of the project improvements in the 17-mile long corridor.

Exhibit 1: Project vicinity

Are there related projects?

The Bellevue to Lynnwood Improvement Project is designed to compliment other projects along I-405 including:

- Kirkland Nickel Stage 1 Project, which added one lane in each direction between NE 85th Street and NE 124th Street and opened to traffic in November 2007;
- NE 195th Street to SR 527 Auxiliary Lane Project, which added one northbound lane between NE 195th Street and SR 527 and opened to traffic in June 2010; and
- NE 8th Street to SR 520 Braided Ramps Project, which creates new multi-level "braided" ramps to separate vehicles entering and exiting northbound I-405 between NE 8th Street and SR 520 and is anticipated to be open to traffic during the summer of 2012.

The Kirkland Nickel Stage 2 Project will reconfigure the NE 116th Street interchange, and northbound and southbound lanes between NE 70th Street and NE 85th Street, and a southbound lane between SR 522 and NE 124th Street, and between NE 70th Street and SR 520. The Kirkland Nickel Stage 2 project has been environmentally cleared and permitted, and, along with the other projects mentioned in this section, is considered part of the baseline conditions for this analysis. The Bellevue to Lynnwood Improvement Project will be constructed at the same time.

What will the completed project provide?

The Bellevue to Lynnwood Improvement Project fills in the remaining gaps and allows WSDOT to provide an improved system on I-405 between NE 6th Street and I-5. WSDOT has designed this project to maximize the use of existing pavement and minimize the need for new pavement. In some areas, small amounts of widening of less than a lane width, together with narrower shoulders and lanes, will allow an additional lane. In other areas, narrowing the shoulders and lanes will allow an additional lane without any pavement widening.

Exhibit 3 shows the configuration in each of the project segments when this project and the related projects described above are complete.

How will this portion of I-405 be operated after the project is completed?

In this environmental document, WSDOT and FHWA are considering two operational alternatives: 1) Express Toll and General Purpose Lanes (ETL); and 2) High Occupancy Vehicle and General Purpose Lanes (HOV). Under both scenarios, the project footprint is the same. The occupancy requirement for HOVs in this portion of the I-405 corridor is the same. It is assumed the occupancy requirement, to maintain HOV performance standards under WSDOT's HOV policy, will be three or more people (HOV 3+). The difference is in how the roadway lanes would be managed.

Alternative 1: Express Toll and General Purpose Lanes (ETL)

This operational alternative will provide two express toll lanes in each direction between NE 6th Street in Bellevue and SR 522 in Bothell, and one express toll lane in each direction between SR 522 and I-5 in Lynnwood. The express toll lane system will be open toll free to all HOV traffic with three or more occupants and all transit operations. The express toll lane system will also be open to single occupant vehicles (SOVs) and HOVs with two occupants through tolling.

The southern end of the express toll lane system will be at the existing direct access ramps at NE 6th Street in Bellevue where one of the two northbound express toll lanes will begin and one of the two southbound express toll lanes will end. South of the NE 6th Street, the other express toll lanes will connect with the existing single northbound and southbound HOV lanes. The northern end of the system would be much like it is today with I-405 becoming SR 525. Access points will be at various locations along the mainline as shown in Exhibit 4. The express toll lanes will be separated from the general purpose (GP) lanes by a two- to four-foot wide buffer. At an access point, the buffer will open and a section of transition lane may be provided between the express toll and general purpose lanes to ease ingress and egress to the system.

Alternative 2: High Occupancy Vehicle and General Purpose Lanes (HOV)

This operational alternative will allow HOV users with three or more occupants and transit vehicles to use the single HOV lane, similar to today's operation. Access between the HOV lane and GP lanes will be allowed throughout the project, except northbound between NE 6th Street and SR 520 where access is not allowed under today's operation. The new northbound lane between NE 124th Street and SR 522 will be operated as a GP lane.

What will conditions be like if the project is not built?

No Build Alternative

A No Build Alternative has been evaluated as the basis for comparing effects associated with the Build Alternatives. No new improvements would be made beyond those constructed as a part of the Kirkland Nickel Project Stage 2 and the NE 8th Street to SR 520 Braided Ramps Project. The No Build Alternative does not include additional stormwater treatment or any roadway improvements that would increase roadway capacity, reduce congestion, or improve safety on I-405. Only routine activities such as road maintenance, repair, and minor safety improvements would occur. As with the two build alternatives, we assume that the occupancy requirement for HOVs in this portion of the I-405 corridor will be three or more people (HOV 3+).

Exhibit 2: Project improvements – sheet 1 of 17

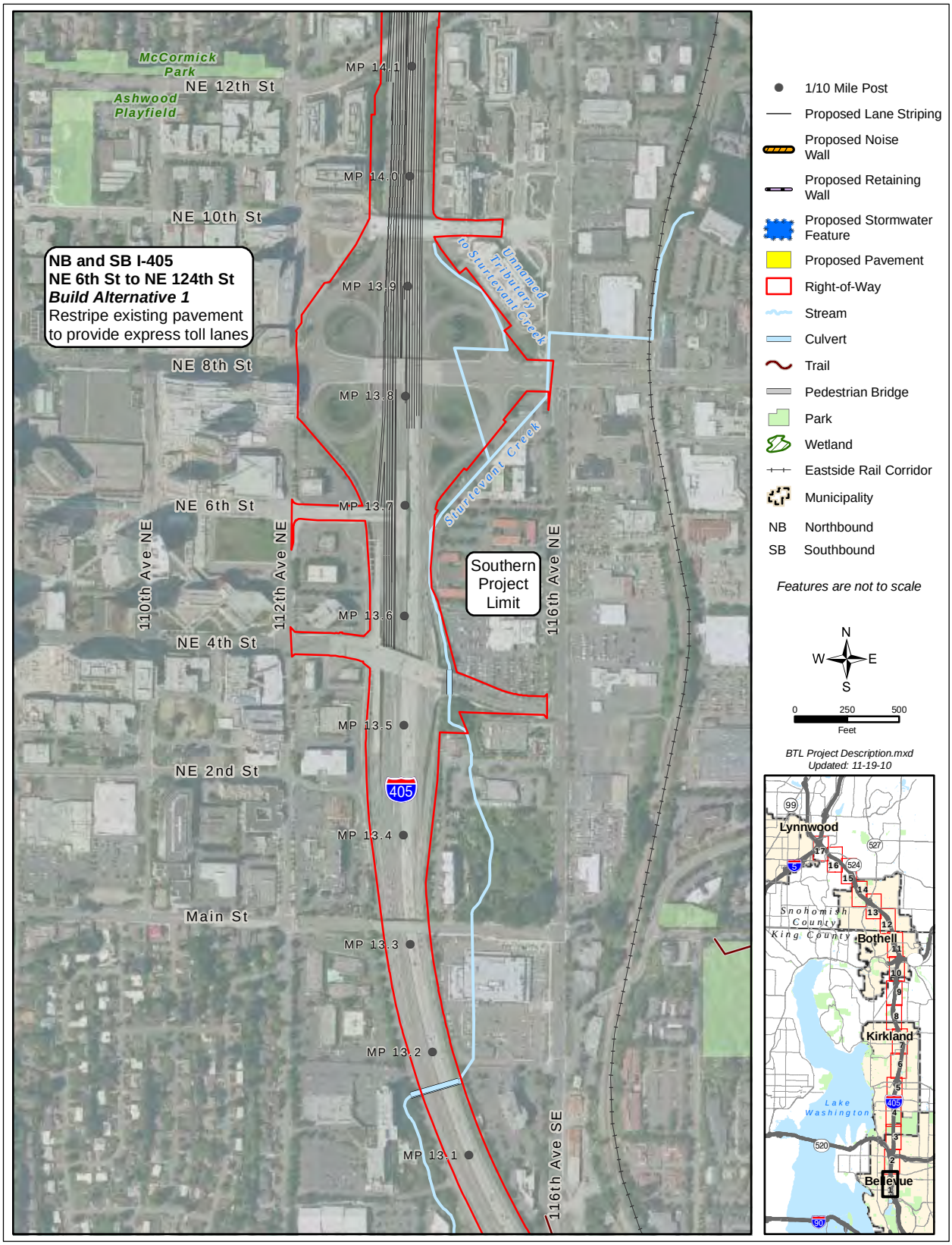


Exhibit 2: Project improvements – sheet 2 of 17

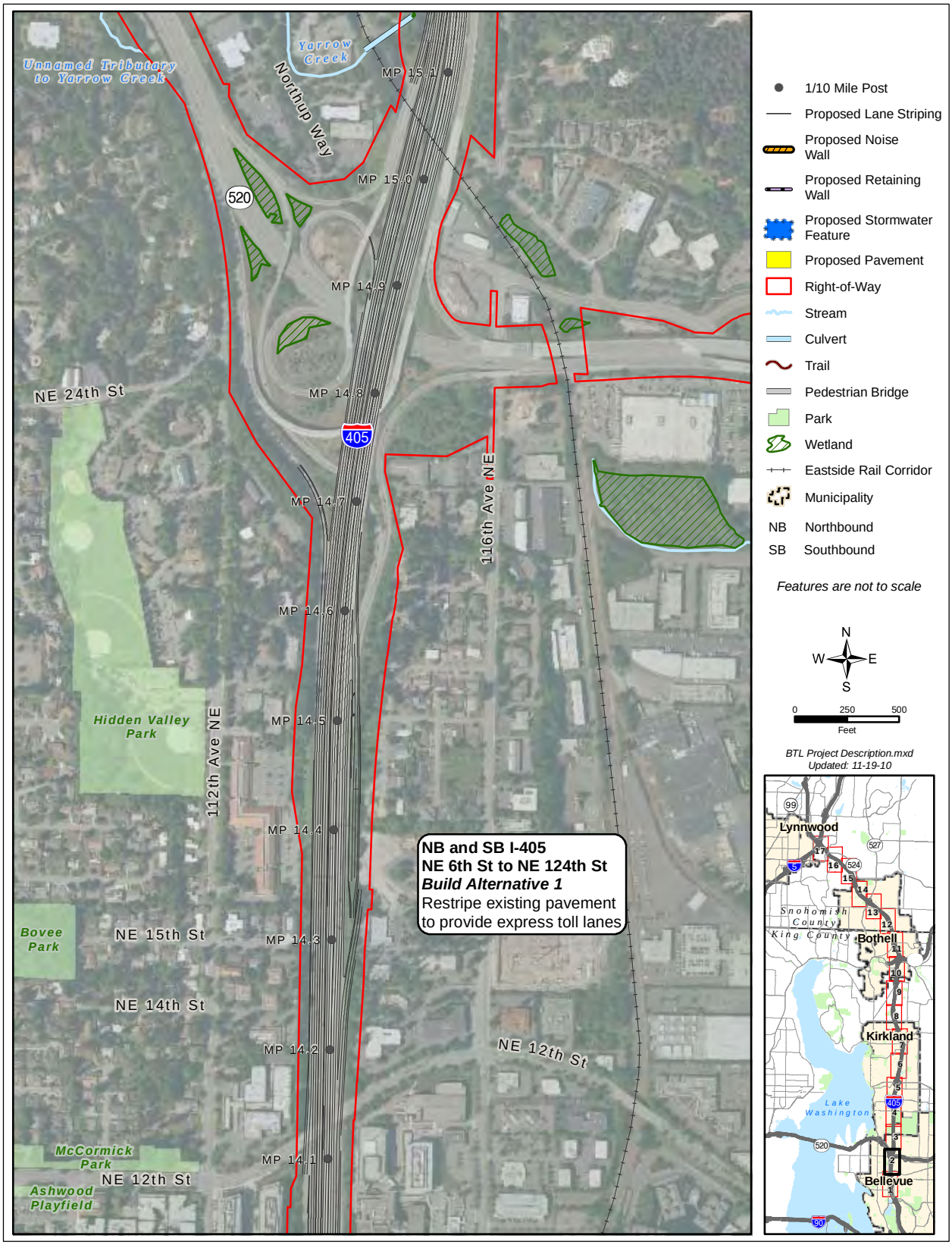
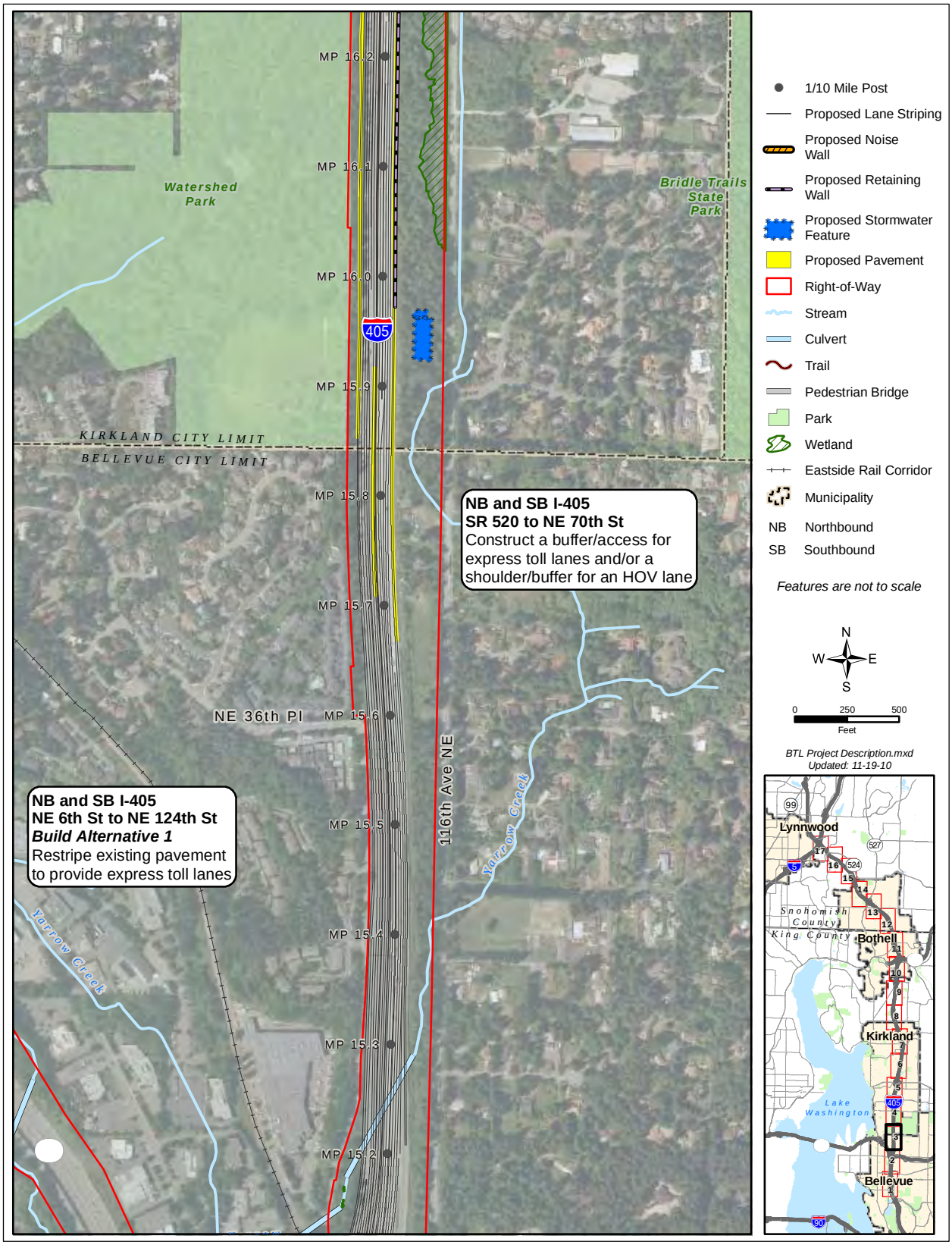


Exhibit 2: Project improvements – sheet 3 of 17



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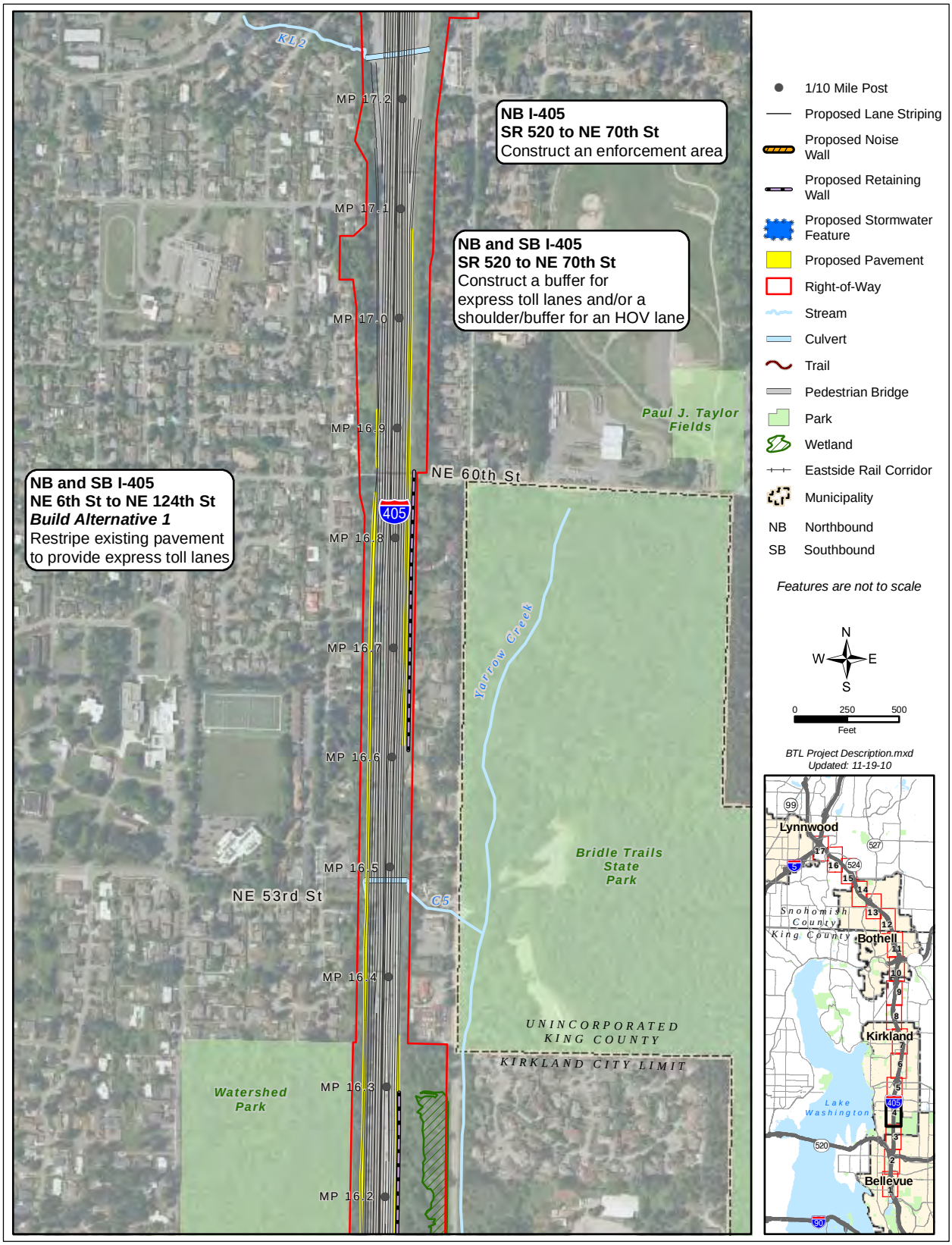

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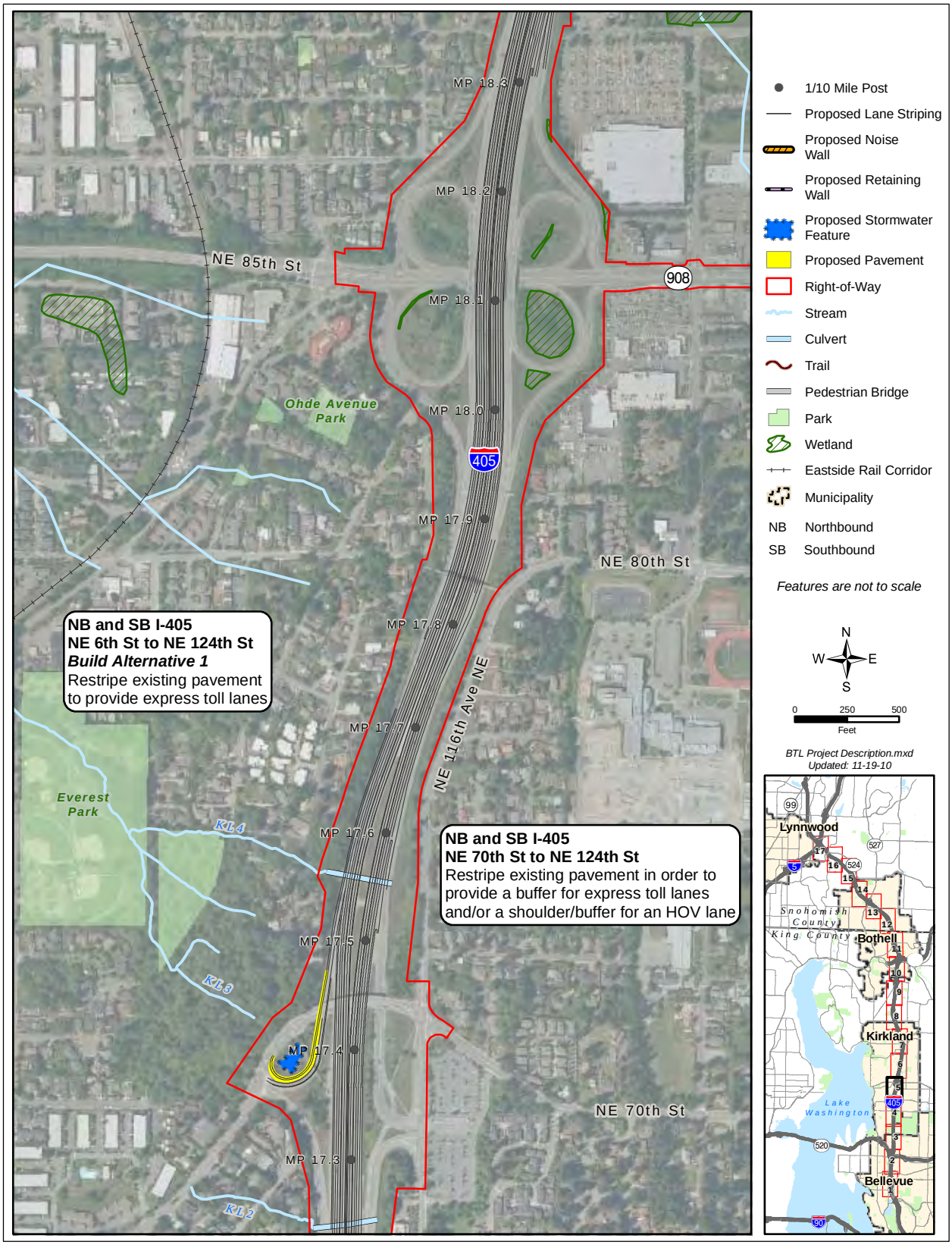

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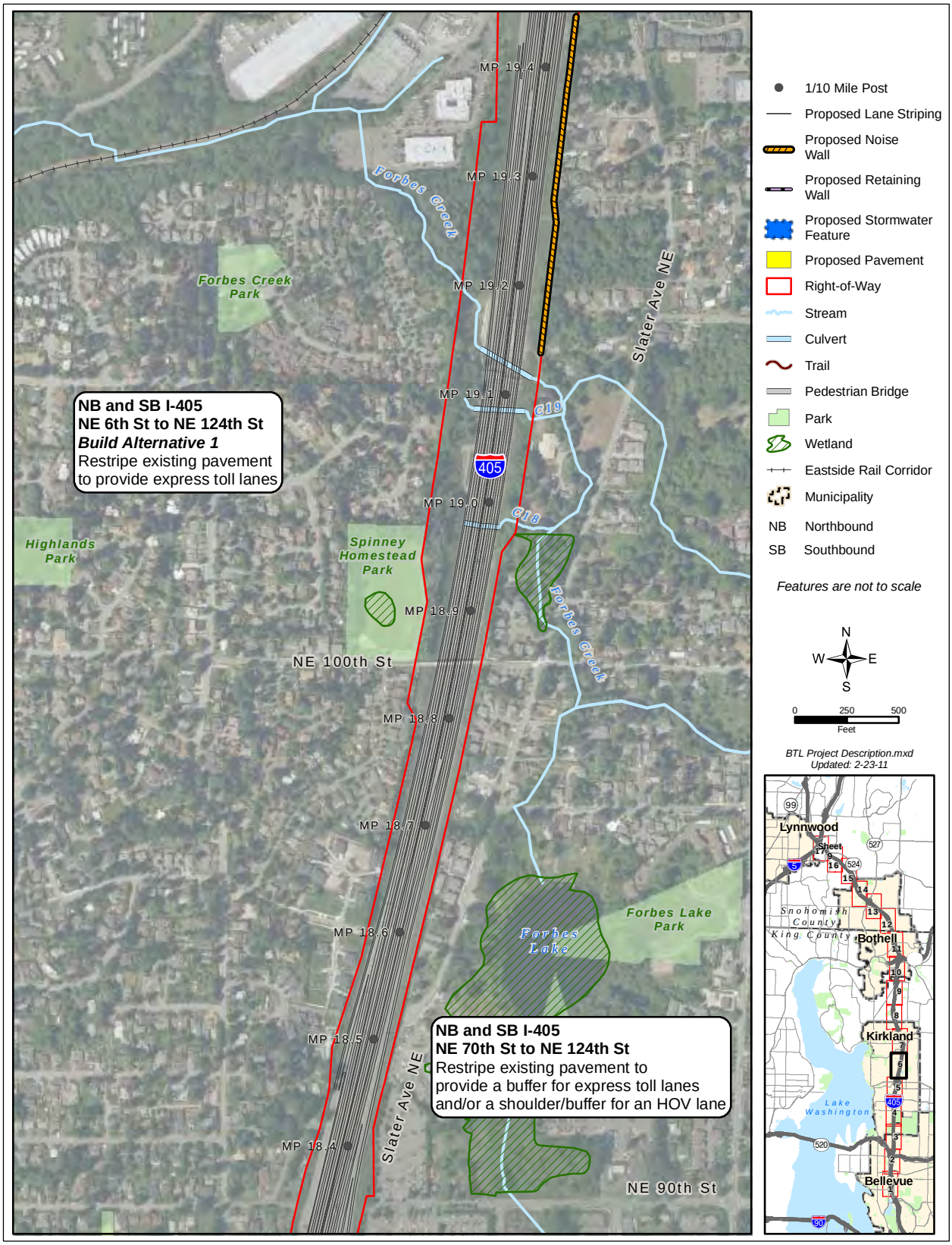

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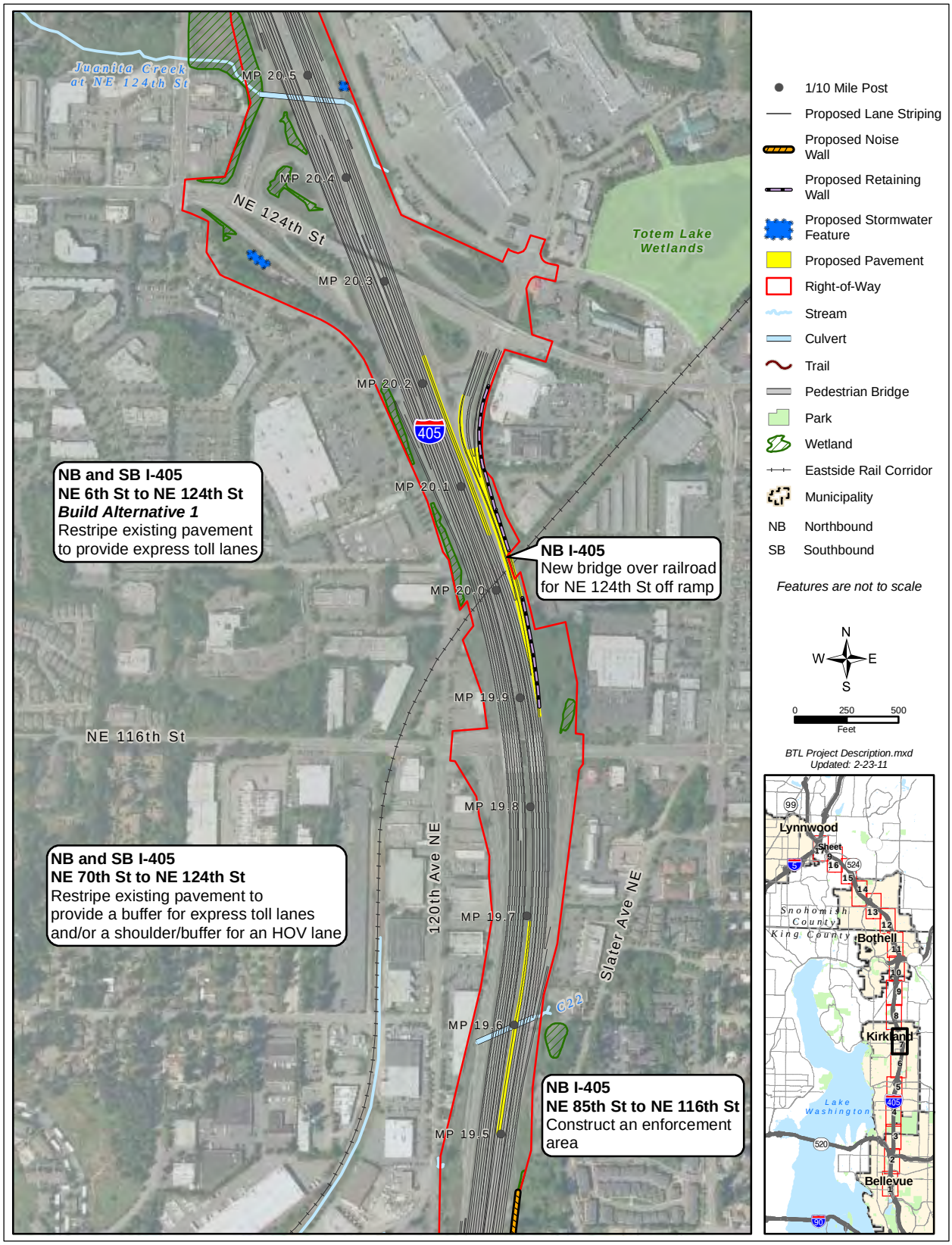

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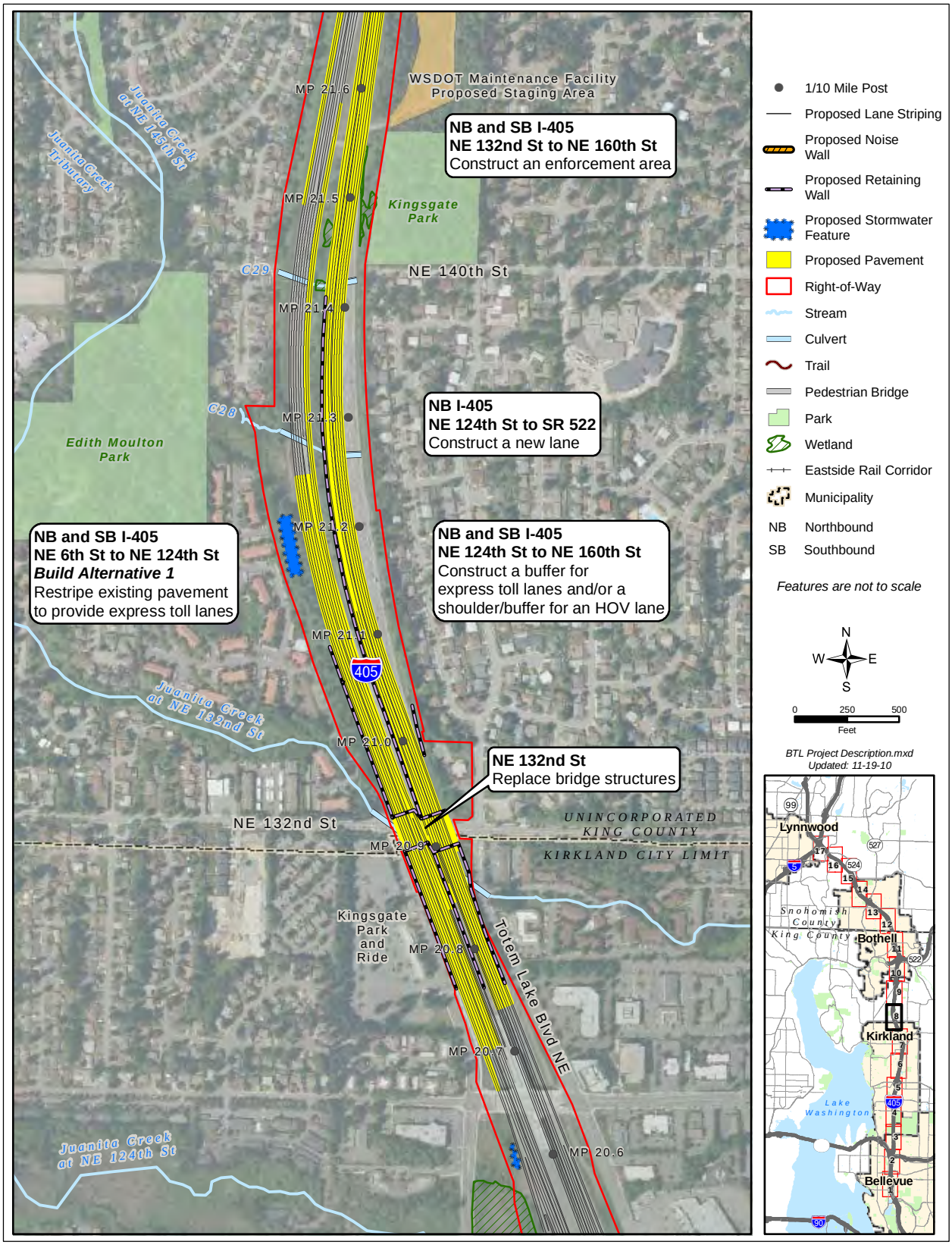

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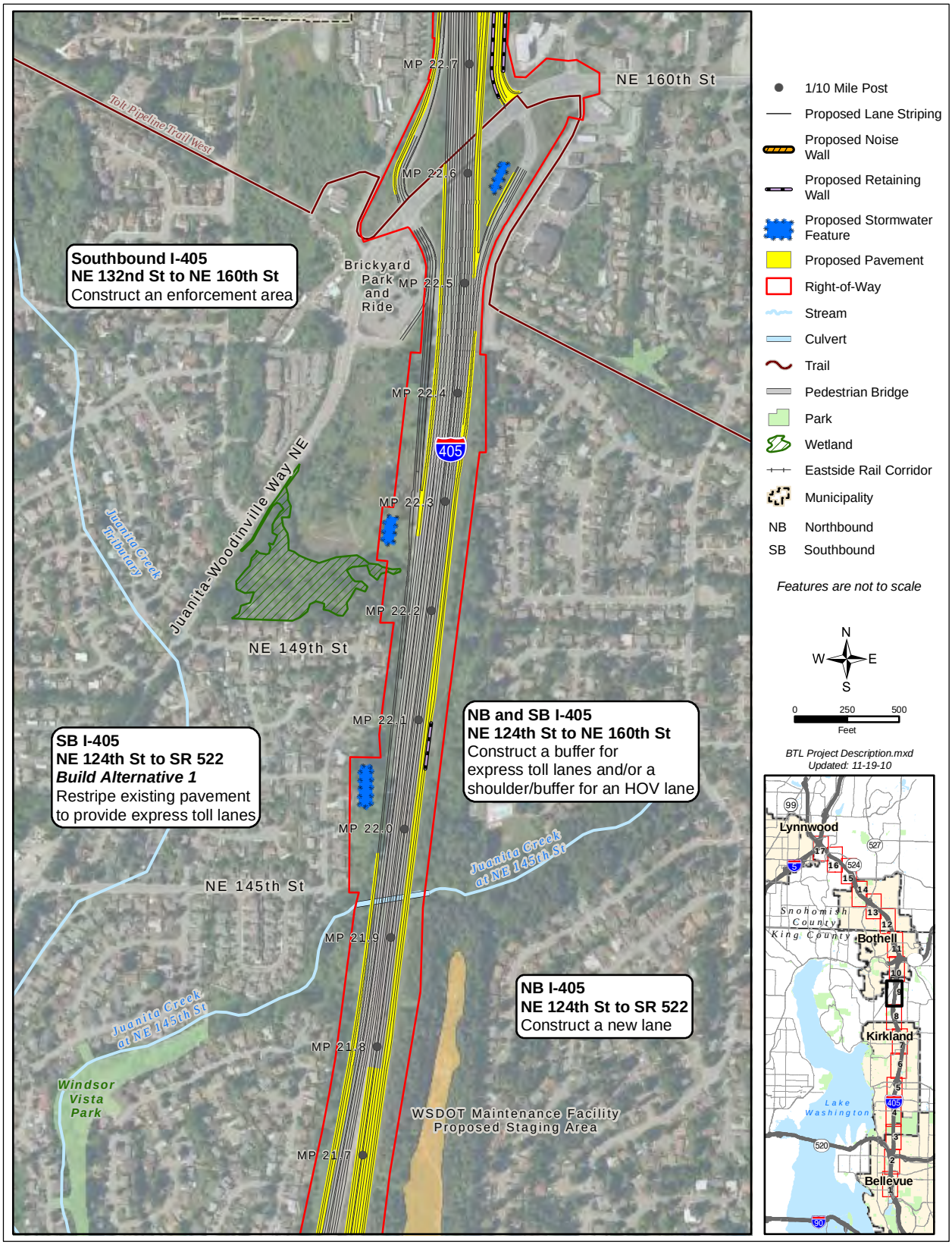

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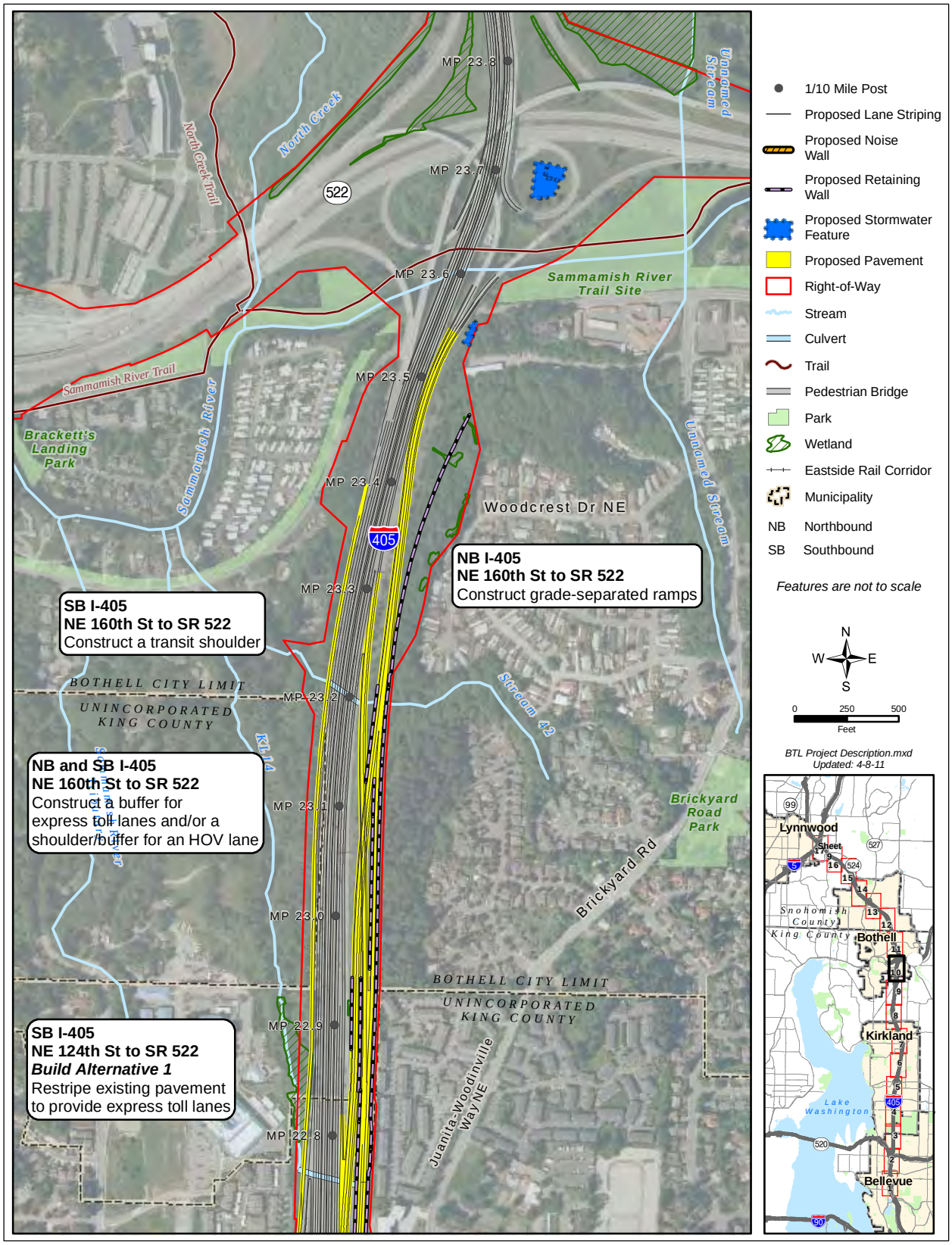

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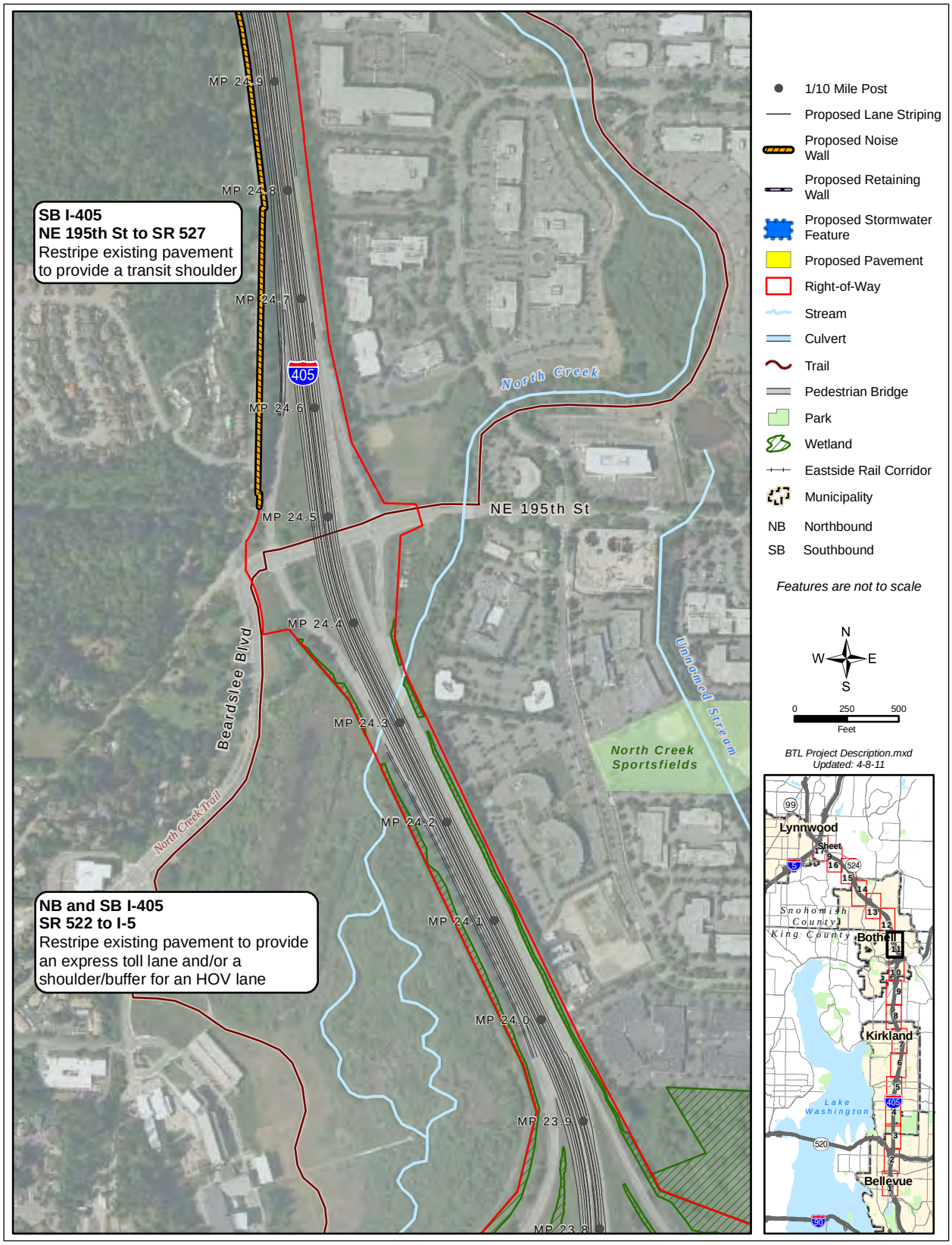

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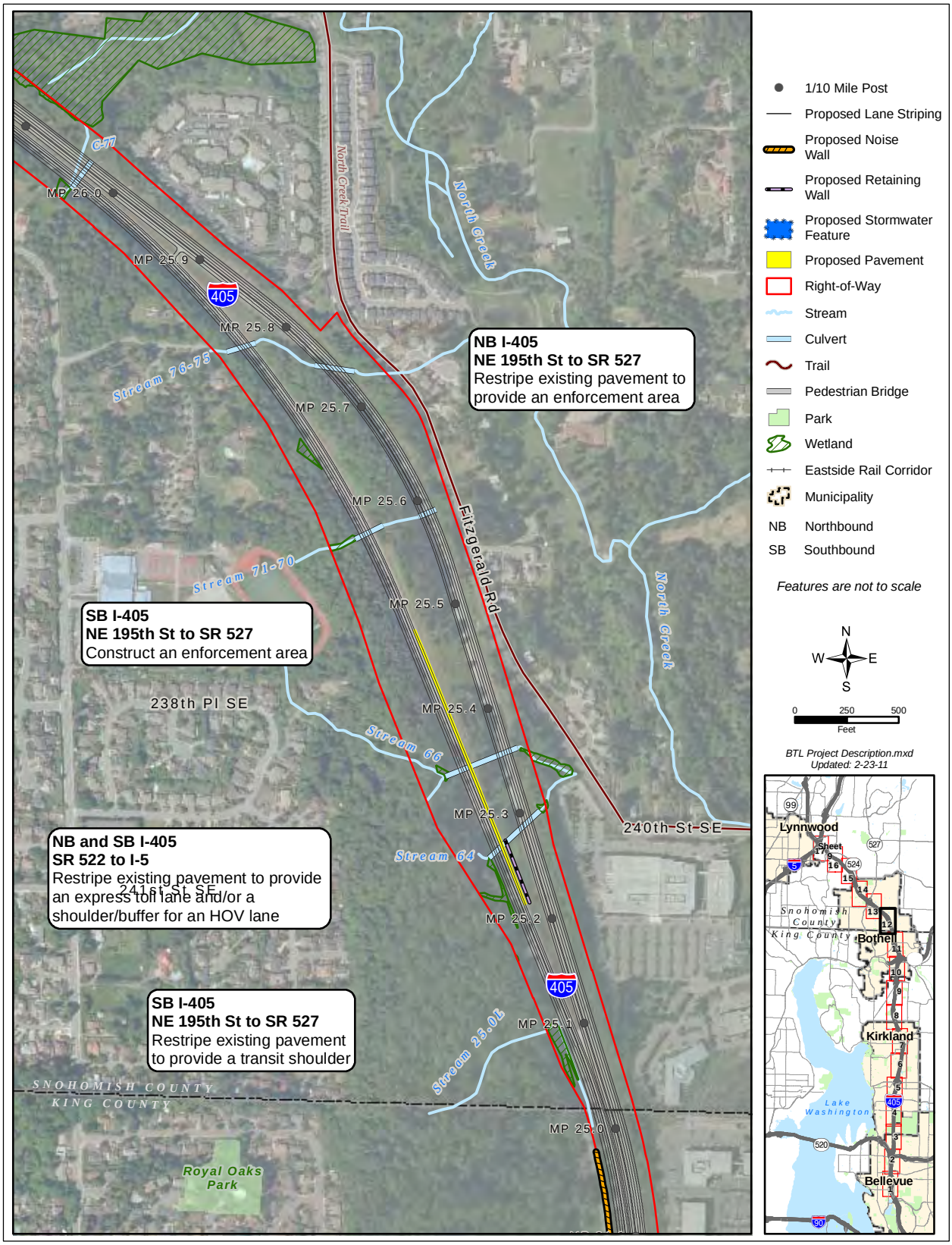

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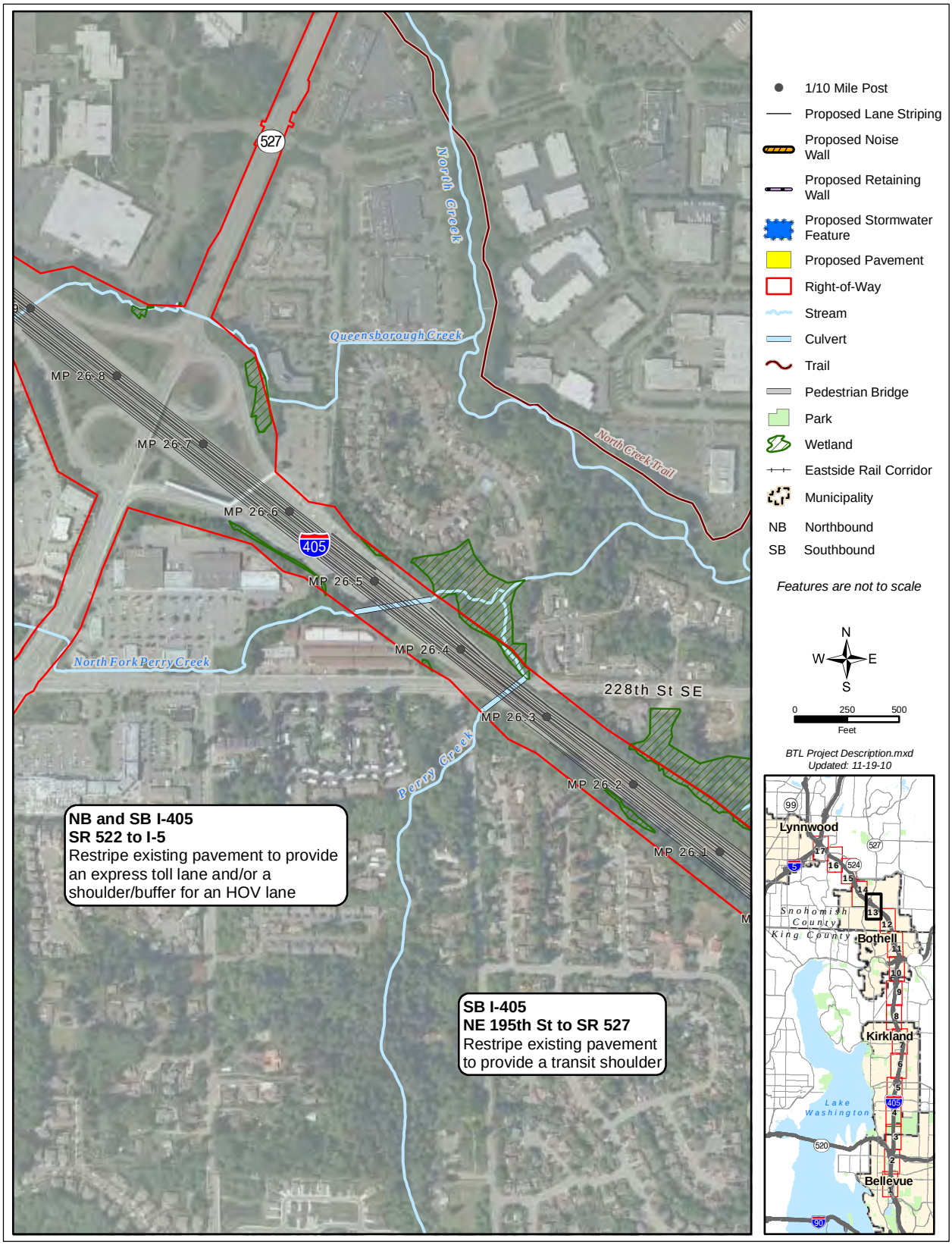


Exhibit 2: Project improvements – sheet 14 of 17

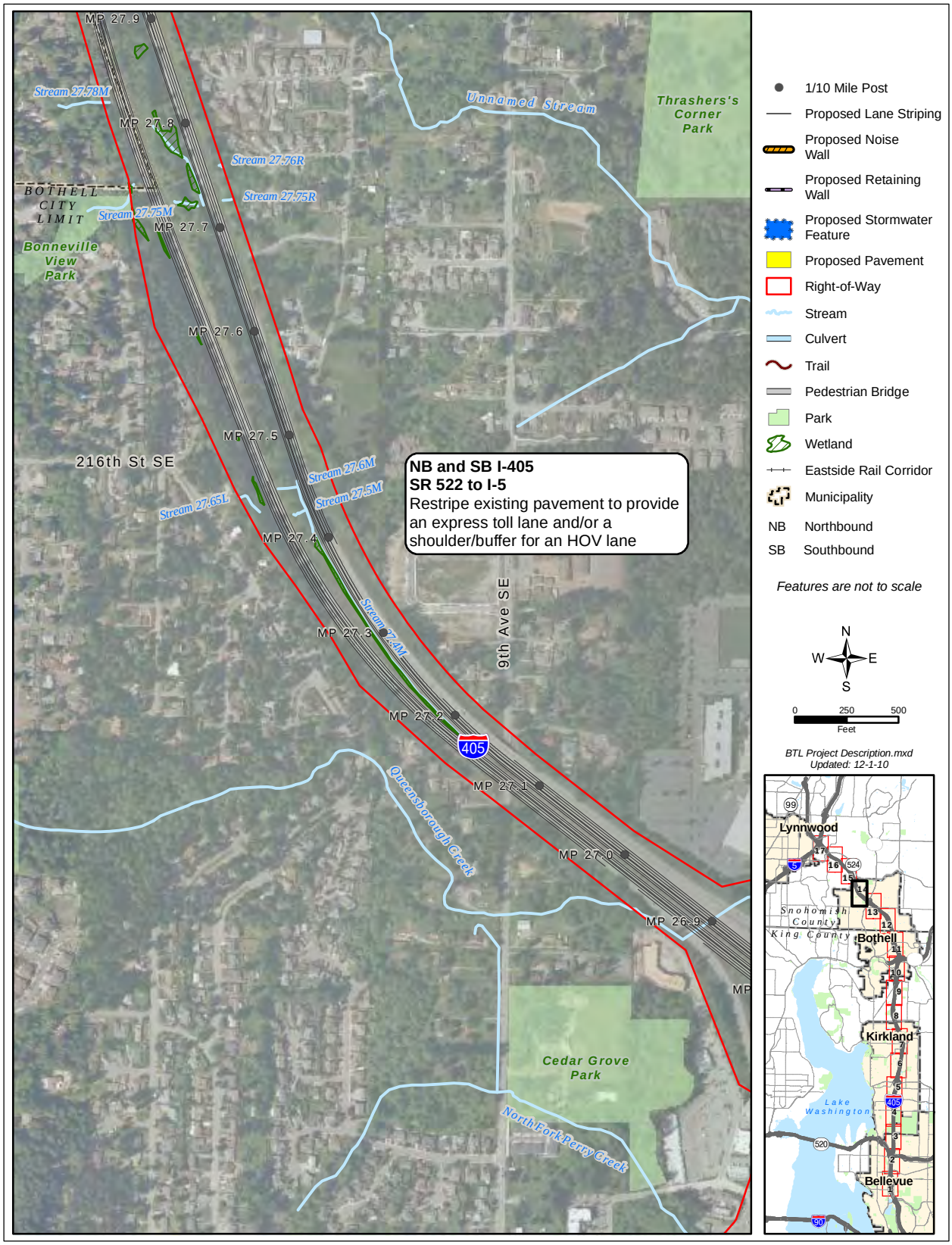


Exhibit 2: Project improvements – sheet 15 of 17

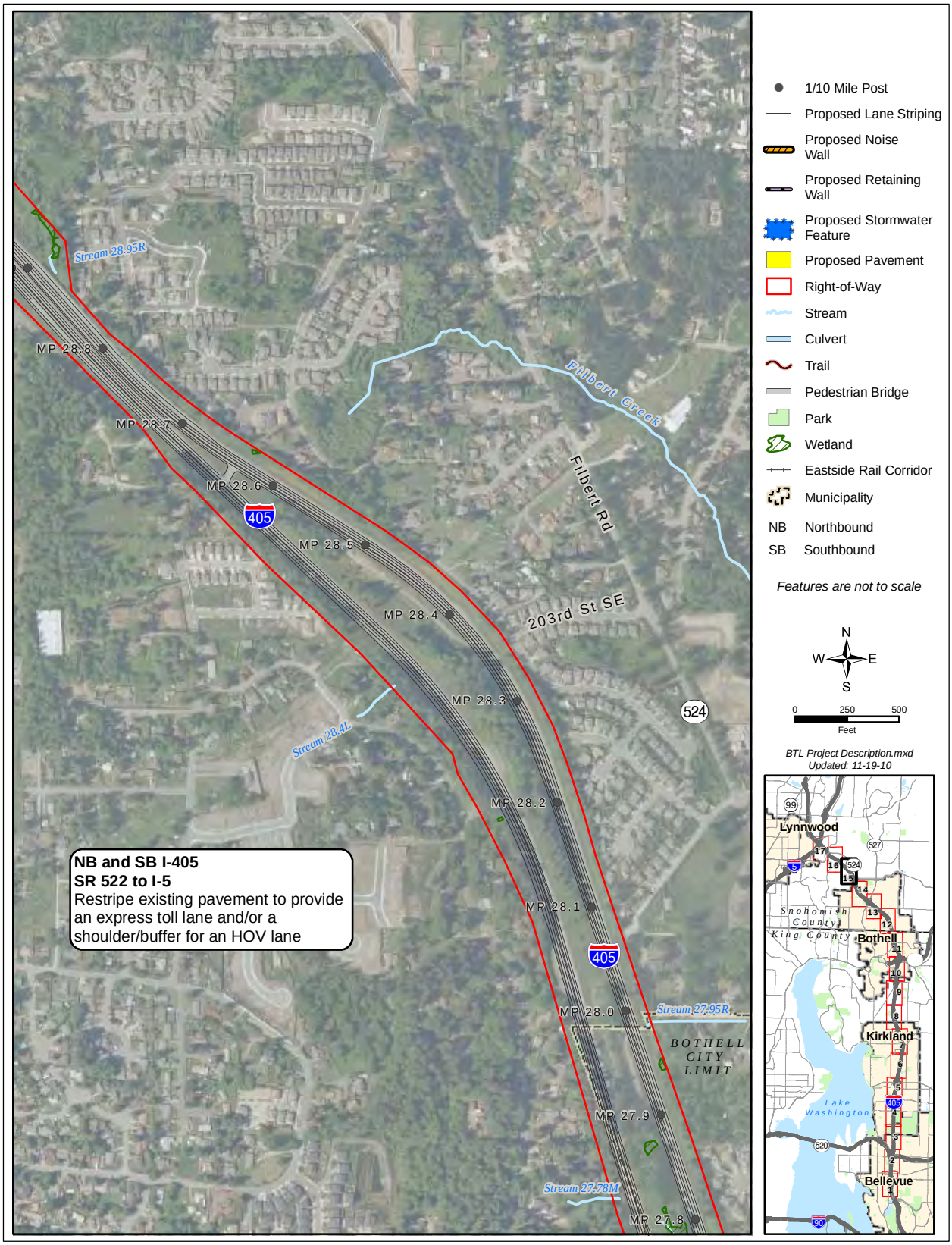


Exhibit 2: Project improvements – sheet 16 of 17

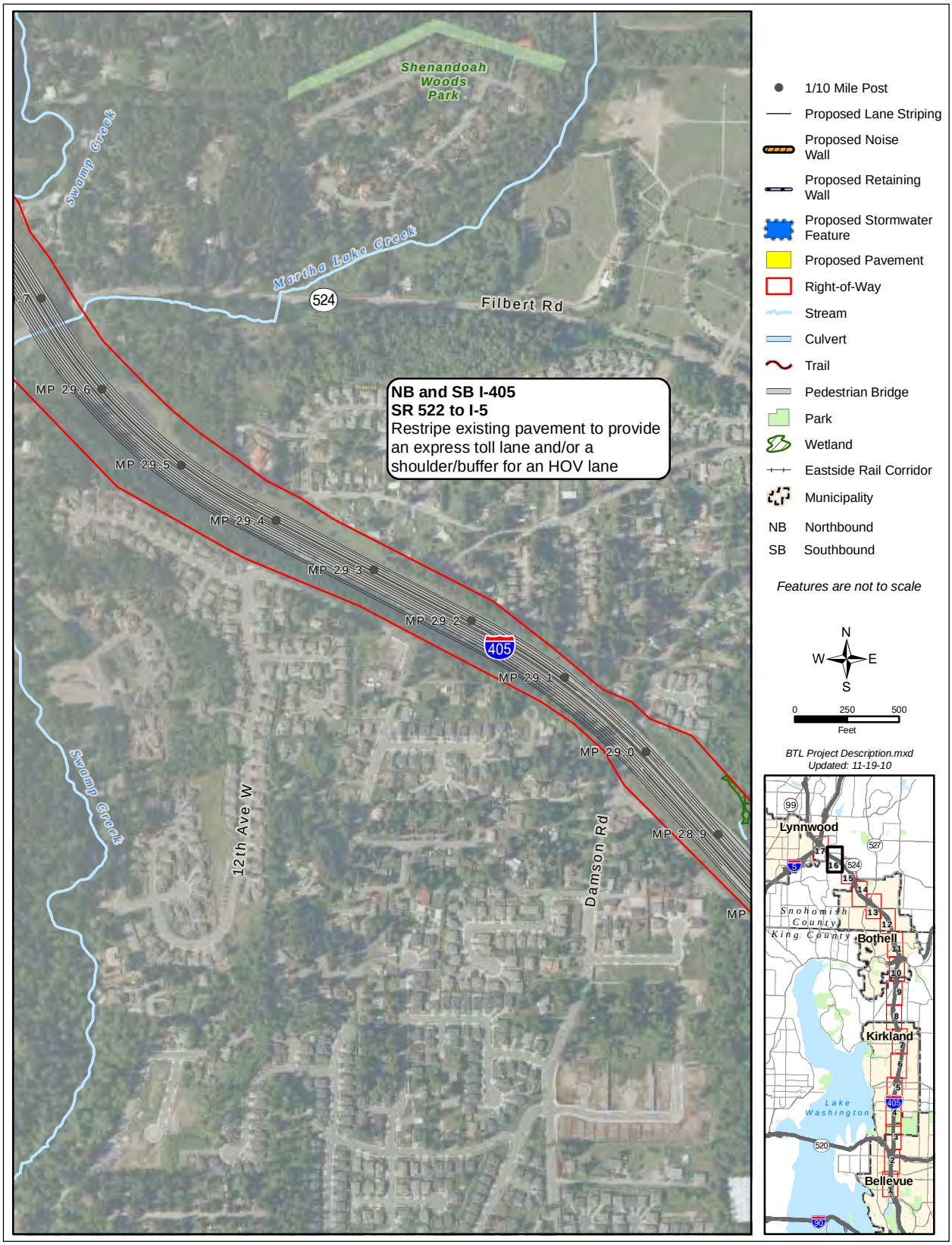


Exhibit 2: Project improvements – sheet 17 of 17

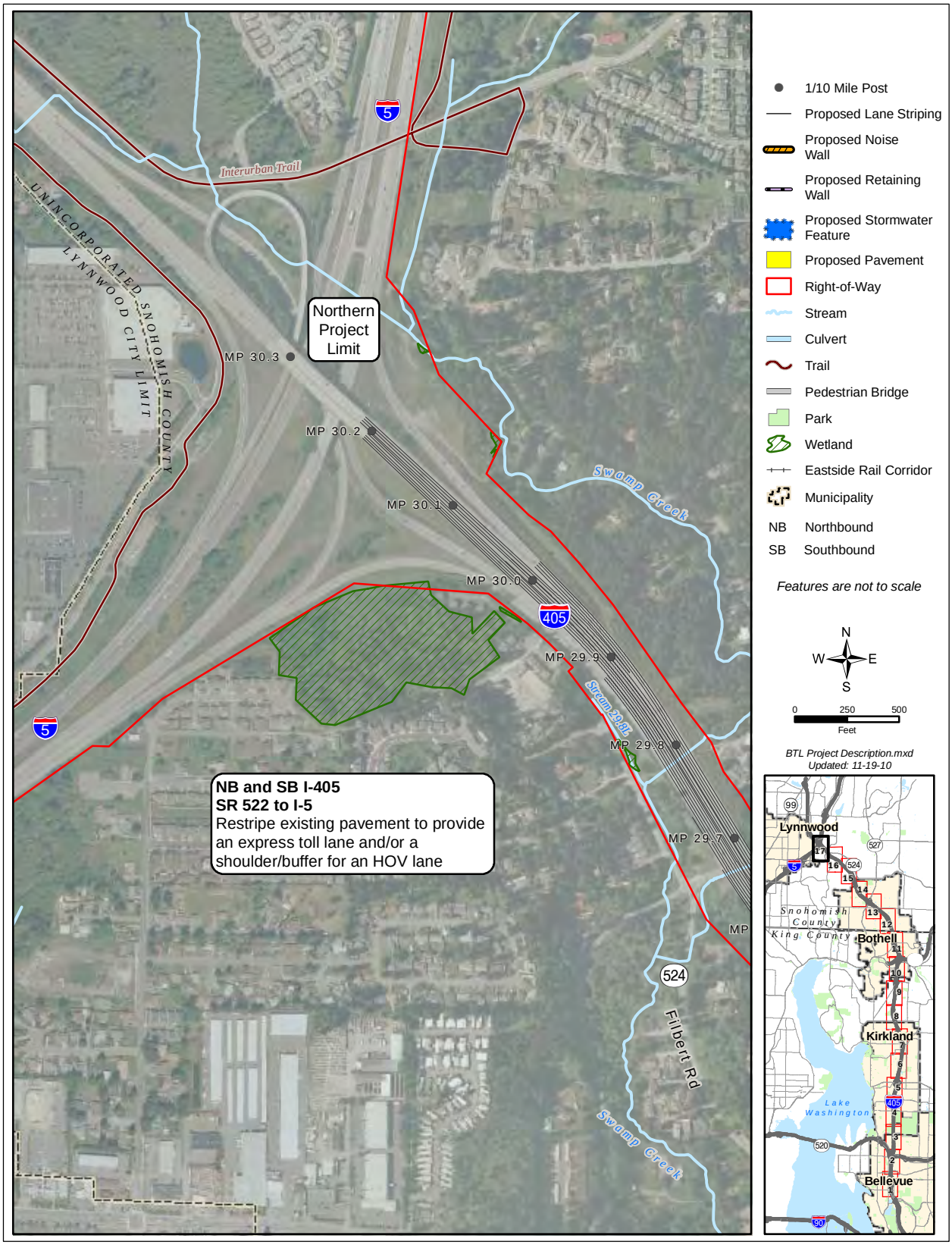


Exhibit 3: Project alternatives – sheet 1 of 2

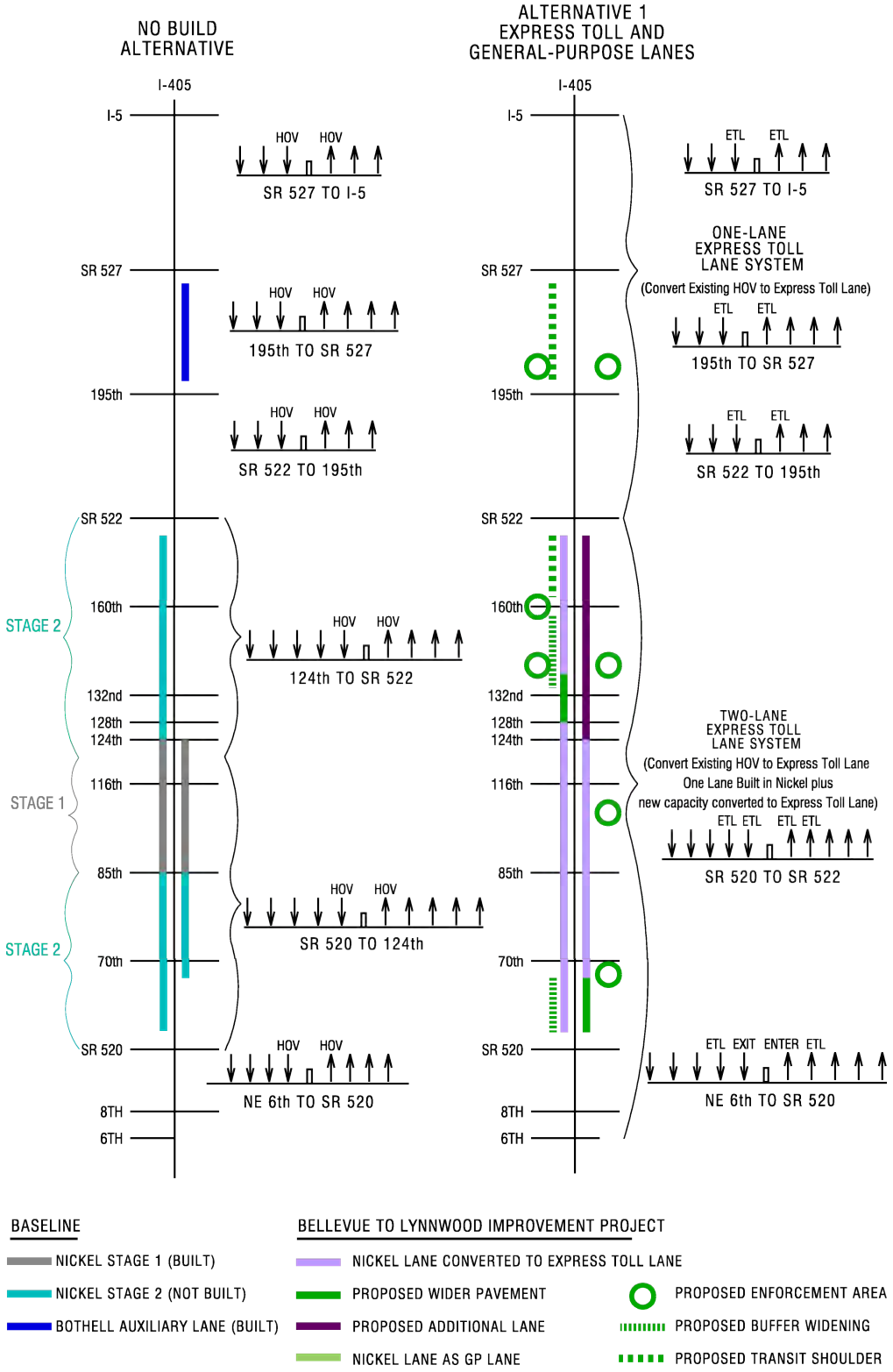


Exhibit 3: Project alternatives – sheet 2 of 2

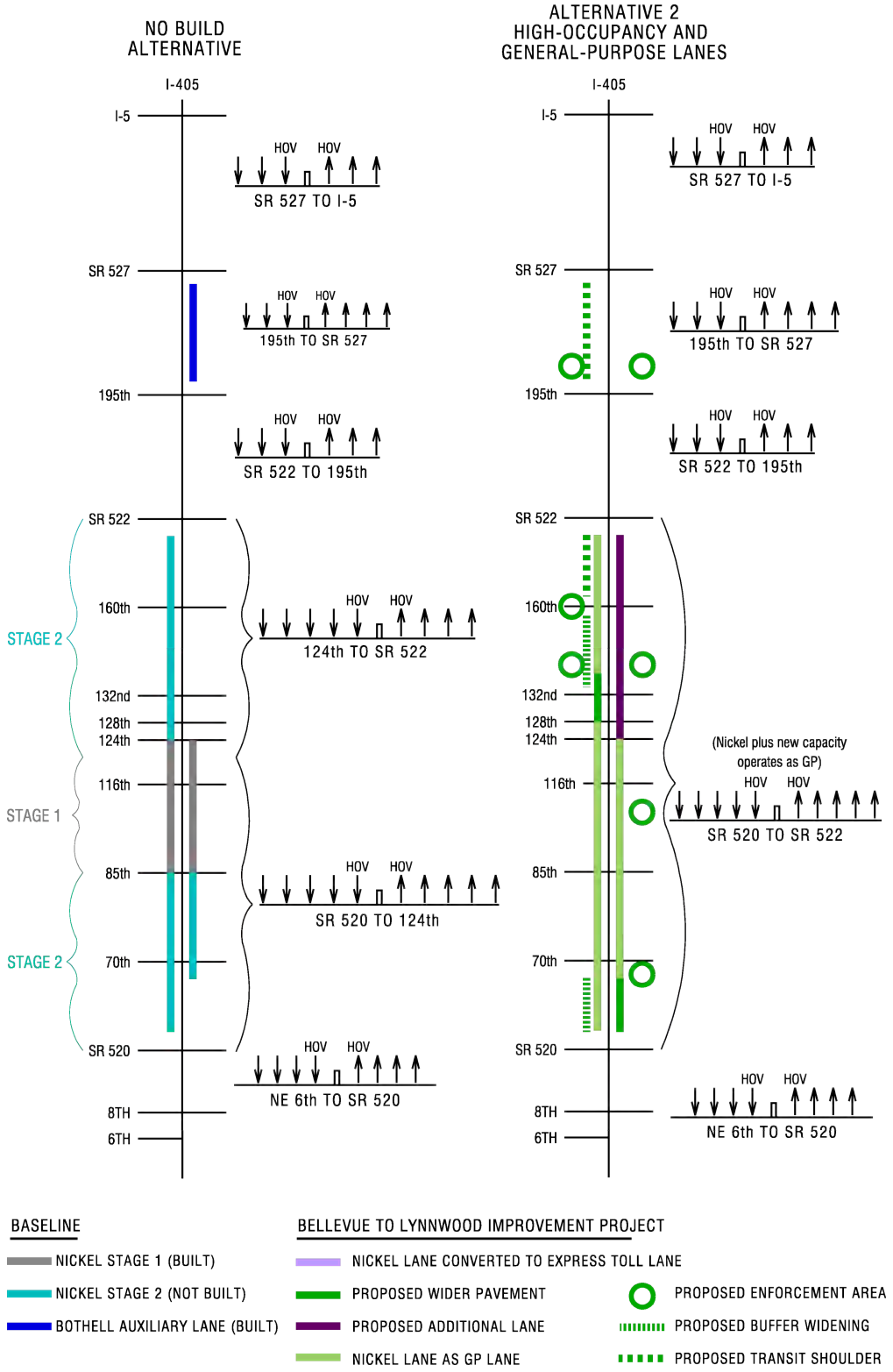
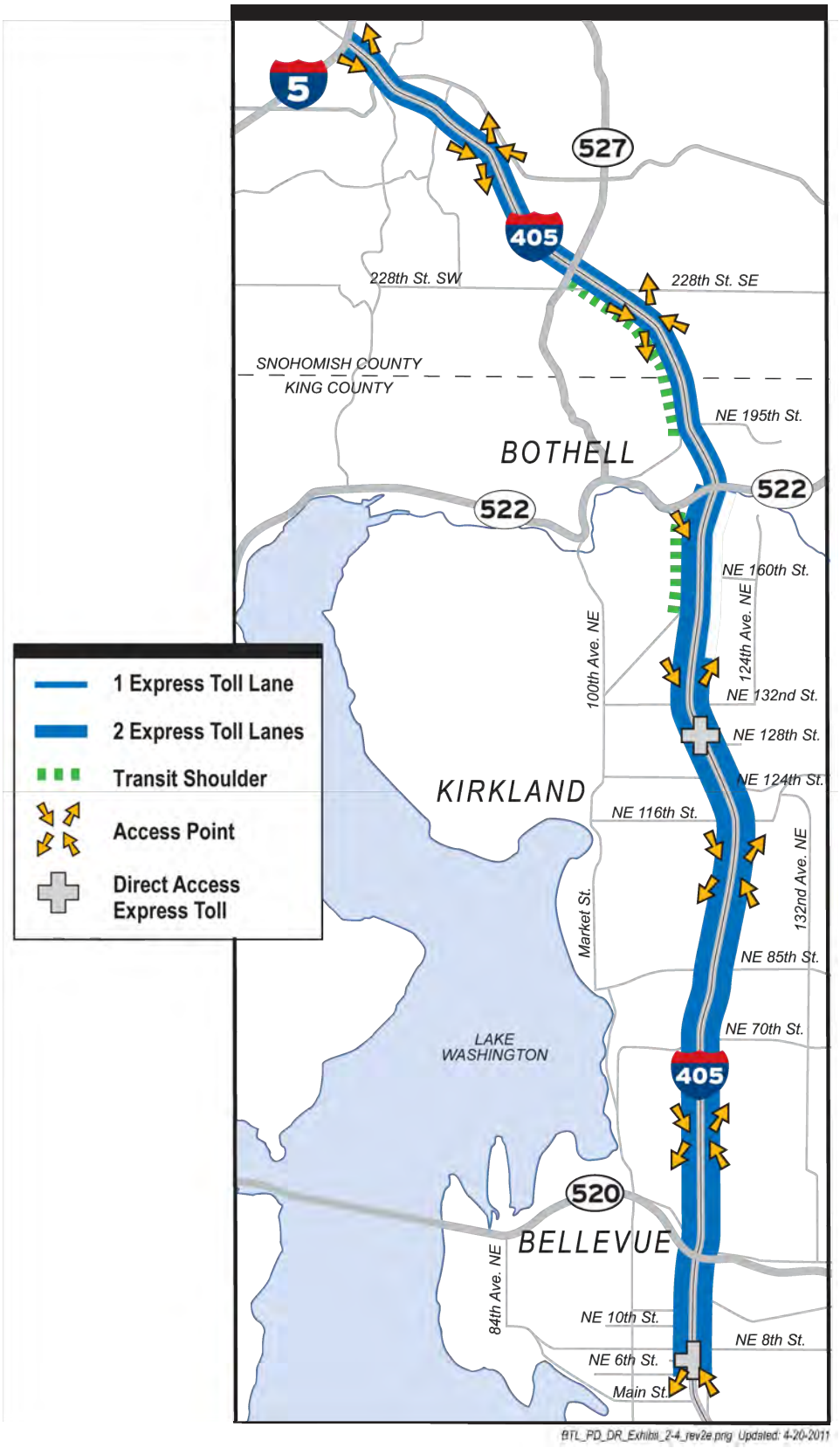


Exhibit 4: Express Toll Lanes access locations



BASELINE CONDITIONS

What are the soil and geologic conditions of the study area?

The I-405, Bellevue to Lynnwood Improvement Project lies in a moderately populated area located along an upland separating the Lake Washington and Lake Sammamish troughs. The area is primarily underlain by dense geologic materials of glacial origin, with a relatively shallow groundwater table. Detailed descriptions of the mapped soil and geologic units are shown on Exhibits 5 and 6, respectively, with the corresponding maps shown on Exhibit B-1, sheets 1 through 8 (soil units), and Exhibit B-2, sheets 1 through 8 (surface geologic units). The soils and geology in the project area, together with the topographic conditions, produce several hazard areas along the corridor. Five types of geologic hazard areas were identified in the baseline right-of-way during the assessment, as described in the Methodology section of this document. These hazard areas include those associated with: erosion, seismic events, landslides, soft ground, and steep slopes. These geologic hazard areas are shown on Exhibit B-3, sheets 1 through 8.

The baseline conditions discussed in this section were interpreted from a review of available documents including the Kirkland Nickel Project Geology, Soils, and Groundwater Discipline Report, the I-405 Corridor Final Environmental Impact Statement, and the Geotechnical Baseline Reports for the Kirkland Nickel Phase 1 and Phase 2 segments, as specified in Appendix A. The draft Geotechnical Data Report (November 2010) and Geotechnical Baseline Report (November 2010) for the Bellevue to Lynnwood Improvement Project were also reviewed.

The southern area of the Bellevue to Lynwood Improvement Project, between NE 6th Street and SR 520, is within the study area of the I-405, NE 8th Street to SR 520 Braided Ramps project Geology and Soils Technical Memorandum (WSDOT 2008). Soils units, geologic units and geologic hazard area exhibits from that report are provided in Appendix C.

Soils

The majority of the near-surface soils in the project area along the I-405 corridor are naturally- occurring, undisturbed soils of glacial origin. These soils are generally moderately well-drained to well-drained, and range from gravelly sandy loam to fine sandy loam. Soils in the vicinity of the Sammamish River and other streams are poorly-drained silty clay loam to muck of a modern alluvial origin. Peat and other organic soils occur in numerous depressional areas at the surface. In the northern part of the project area, most of the near surface soils have been replaced with artificial fill materials imported for the construction of I-405. A description of these soil units is provided in Exhibit 5.

Geology

The project corridor is located within the central Puget lowland bordered by the Cascade Mountain Range to the east and the Olympic Mountains to the west. The Puget lowland is a north-south trending trough whose near-surface geology is dominated by deposits from a series of glaciations over the past two million years.

In the project vicinity, deposits associated with the Vashon Stade of the Fraser Glaciation dominate the landscape. The advance and retreat of the Vashon age Puget lobe of the Cordilleran ice sheet, between roughly 13,000 to 18,000 years ago, deposited most of the near-surface materials and sculpted most of the present landforms within the Puget lowland. The deposits of this glacial episode reflect a wide range of glacial depositional environments that overlie earlier glacial and non-glacial deposits, and Tertiary age bedrock. The Vashon Stade deposits include proglacial lacustrine deposits, advance outwash, till, and recessional outwash.

As the glacier advanced southward, streams deposited sediment that formed a broad plain in front of the advancing glacier. The advance deposits grade from coarse to fine with increasing depth, with silts and clays (lake deposits) at the base, and coarse-grained sand and gravel nearer the top.

Till, consisting of heterogeneous, non-stratified deposits with particle sizes ranging from clay to large boulders, was deposited directly from the glacier itself. The maximum ice thickness in the project vicinity was roughly 3,000 feet.

As the glacier retreated, the depositional sequence was repeated in the reverse order. Depositional sequences generally consist of coarse-grained gravel and sand overlain by fine-grained silts and clays. The retreat was rapid relative to the advance of the glacier, and the recessional deposits are generally not as thick as the advance deposits. As the glacier retreated to the north, a series of elongated valleys, including the Lake Washington and Lake Sammamish troughs, remained. The I-405 corridor in the project area is situated on an upland area separating these troughs.

Following the Fraser Glaciation, Holocene sediments were deposited over the glacial materials in the project area. These deposits typically consist of alluvial soils in river and stream valleys, and colluvial deposits (landslide materials) along slopes.

The majority of the alignment in the project area is underlain by glacial till and glacial outwash, as shown on Exhibit B-2, sheets 1 through 8. Descriptions of these geologic units are provided in Exhibit 6. Glacial till generally underlies the southern and northern limits of the project corridor, while the majority of the project corridor is underlain by glacial outwash. The majority of the alluvial deposits are in the vicinity of the Sammamish River and its tributaries.

Geologic hazard areas

Geologic hazard areas in the vicinity of the project area include: erosion hazard areas, landslide hazard areas, soft ground areas, seismic hazard areas, and steep slope hazard areas. The locations of these hazard areas are shown on Exhibit B-3, sheets 1 through 8 and are described below:

- **Erosion hazard** – An erosion hazard is a measure of the susceptibility of an area of land to prevailing agents of erosion (Houghton and Charman, 1986). It is determined by climate, topography, soil erodibility, and land use. The majority of the soils in the study area are classified as possessing a slight to moderate erosion potential. Soils with high erosion potential include glacially derived soils on slopes greater than 15 percent. The mapped, erosion-prone areas are located on the western portion of the alignment between milepost (MP) 17.3 and MP 17.4; on the eastern portion of the alignment between MP 21.5 and MP 21.6; and on both sides of the alignment between MP 22.85 and MP 23.45, as shown on Exhibit B-3, sheets 2 through 5 (King County Erosion Hazard GIS Data, 1997).
- **Landslide hazard** – As with most slopes in western Washington, shallow surficial landsliding is common, particularly during periods of ground saturation. Surficial landslides typically occur in the upper 2 to 5 feet of soil or weathered bedrock; their movement occurs episodically, generally in response to heavy rainfall. Earthquake related shaking tends to increase the size of surficial landslide areas, as well as the frequency of movement.
- **Active landslide activity**. An active landslide is present adjacent to the southbound lanes of I-405 in the vicinity of MP 23.03 to MP 23.04[2], approximately 30 feet west of the pavement edge. The landslide appears to be the result of shallow groundwater seepage and may be a new landslide within older landslide debris. The seepage causes erosion of the sandy soils, resulting in undercutting, shallow sliding, and block failures[3] in the overlying soils. The soils observed are relatively dense; however, there is an exposed slope with an inclined sedimentary layer, which is indicative of past block movement.

  The landslide feature consists of a 15- to 20-foot high, near-vertical scarp that is roughly 60 to 80 feet wide. The scarp is at the top of a ravine that is regressing towards I-405. The height of the near vertical scarp decreases at the north and south edges of the ravine, creating an arc or bowl-shaped feature. This arc feature is represented as a steep slope area on Exhibit B-3, sheet 4 at MP 23.0.

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[2] This feature is not shown on publicly available maps but was identified during field reconnaissance conducted by GeoEngineers in 2005.

[3] A block failure is a block of soil translating along a planar failure surface as opposed to rotational failure surface.

- **Historic landslide activity**. An ancient landslide area has been identified from approximately MP 22.7 to MP 25.55[4]. There is no evidence of recent instability with the exception of an unstable area associated with cuts made to construct the current northbound lanes. Soils in the landslide area have been analyzed and logged by others in previous studies[5]. These soils consist of over 60 feet of a compact to dense, fine sand overlying stiff to hard clay with scattered sand and gravel. The clay is interpreted as being part of the glacial transitional beds, which are commonly associated with slope instability. Previous stabilization work has been completed in the historic landslide area as described below.

  During initial construction of I-405, the project required cutting into the east (uphill) slope of I-405 (northbound lanes). This activity initiated slope movement, and a riprap buttress was constructed along the cut to stabilize the movement. Additionally, three levels of horizontal drains (finger drains) were drilled into the hillside to collect groundwater[6]. Subsequently, a series of drainage ditches were constructed to transport the groundwater collected from the horizontal drains.

  Another stabilization feature included the construction of a large embankment fill on the west (downhill) side of I-405 (southbound lanes). Riprap ribs (rock-filled trenches designed to enhance drainage in the area) were oriented parallel and perpendicular to the slope and were installed at the base of the embankment fill. Perforated pipes were added to the riprap ribs that run perpendicular to the slope to collect groundwater seepage. These pipes are tightlined into a storm drain system.

  Based on available WSDOT records reviewed during the I-405, SR 520 to SR 522 Stage 2 Nickel Package (Kirkland Stage 2) Geotechnical Baseline Report, no slope movement (uphill or downhill of I-405) or pavement distress has been observed since the stabilization work was completed (GeoEngineers, May 2005). Approximately two years ago, WSDOT maintenance crews removed some loose riprap that had fallen onto a sign bridge support base on the uphill side of I-405. A block wall was installed around the sign bridge column to protect it from future rock fall.

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[4] This feature is not on shown on publicly available maps but was identified during field reconnaissance.

[5] GeoEngineers reviewed and analyzed approximately 450 soil explorations (test pits and borings) as part of the "Geotechnical Baseline Report, I-405, SR 520 to SR 522 Stage 2 Nickel Package (Kirkland Stage 2), Kirkland, Washington," dated May 31, 2005. The I-405 project team provided the exploration logs and analytical data, which were completed by others between the late-1960s to 2003.

[6] The drains consist of a 1-inch-diameter PVC pipe within a 6-inch-diameter corrugated metal pipe. The horizontal drains range in length from about 100 to 200 feet and were installed with a lateral spacing of approximately 50 feet. The slope of the horizontal drains ranges from 1 to 2 percent.

The mapped areas most susceptible to landsliding occur south of the I-405/SR 522 interchange from MP 23.2 to MP 23.5. Additional landslide hazard areas are mapped from MP 25.10 to MP 25.60, MP 27.30 to MP 27.75, MP 28.05 to MP 28.35, MP 29.45 to MP 29.65, and from MP 29.90 to MP 29.95, as shown on Exhibit B-3, sheets 4 through 8 (King County Landslide Hazard GIS Data, 2003).

- **Seismic hazard** – The primary seismic hazard in the project area is associated with the risk of ground shaking or deformation during an earthquake. This concern largely presents itself in soft ground and loose sand areas below the groundwater table where soils can undergo the process of liquefaction[7] during a seismic event.

  Mapped seismic hazard areas are located along the project corridor surrounding the I-405/SR 522 interchange from MP 23.55 to MP 24.6, as shown on Exhibit B-3, sheet 5 and from MP 15.9 to MP 16.5, as shown on Exhibit B-3, sheet 1 (King County Seismic Hazard GIS Data, 1997). These hazards largely coincide with the alluvial depositional areas.

- **Soft ground areas** – Soft ground areas generally coincide with mapped alluvial and glacial lake associated soils (see Exhibit 6 for a description of the soil units, and the accompanying maps in Exhibit B-1 . These areas typically consist of soft clay, silt, or highly organic soil such as peat. Localized areas of compressible soils may also be encountered elsewhere along the alignment. These soils will likely be only a few feet thick and will generally overlie competent glacial soils, such as till and advance outwash. The horizontal and vertical extent of these localized, compressible soils is likely to be small.

- **Steep slope hazard** – Some areas along the I-405 project corridor have steep slopes that may be associated with landslide and erosion hazards. Steep slopes are defined here as slope inclinations greater than 40 percent, with a height of 10 feet or more. Steep slopes were calculated using LiDAR data (GeoEngineers, 2006). Several steep slope hazard areas are mapped along the project corridor (See Exhibit B-3, sheets 1 through 8). Their locations are:
  - MP 15.0 to MP 15.2 along the western side of the corridor
  - MP 15.25 to MP 15.35 along the eastern side of the corridor
  - MP 16.05 to MP 16.3 along the eastern side of the corridor
  - MP 19.15 to MP 19.2 along the western side of the corridor at Forbes Creek
  - MP 21.6 to MP 21.95 along the eastern side of the corridor
  - MP 21.85 to MP 21.95 along the western side of the corridor

[7] Liquefaction is a phenomenon where soils experience a rapid loss of internal strength as a consequence of strong ground shaking.

- MP 22.9 to MP 23.45 south of the I-405/SR 522 interchange
- MP 25.6 to MP 26.1 along the western side of the corridor
- MP 25.6 to MP 26.2 along the eastern side of the corridor
- MP 27.5 to MP 27.7 along the eastern and western sides of the corridor
- MP 28.2 to MP 28.5 along the western side of the corridor
- MP 28.9 to MP 30.2, which is at the northern project limit

Exhibit 5: Description of soil units

Unit	Map symbol[8]	Description
Alderwood Gravelly Sandy Loam	1, 2, 3, AgB, AgC and AgD	The Alderwood series is made up of moderately well-drained soils that have a weakly-consolidated to strongly-consolidated substratum at a depth of 24 to 40 inches. These soils are found on uplands and formed under conifers in glacial deposits. Slopes are 0 to 30 percent. In a representative profile, the surface layer and subsoil are very dark brown, dark brown and grayish-brown gravelly sandy loam about 27 inches thick. The substratum is grayish-brown, weakly-consolidated to strongly-consolidated glacial till that extends to a depth of 60 inches and more. Permeability is moderately rapid in surface layer and slow through the substratum. Available water capacity is low. The runoff is slow to medium and the hazard of water erosion is moderate to severe, increasing with slope percentage. In slopes of 15 to 30 percent, the potential for slippage is moderate.
Alderwood-Everett Gravelly Sandy Loams	4	This unit is about 60 percent Alderwood gravelly sandy loam and about 25 percent Everett gravelly sandy loam. It is mapped on till plains, terraces and outwash plains. Slopes are 25 to 70 percent. Permeability varies from rapid to slow, decreasing with depth. The available water capacity is low with rapid runoff and moderate to high water erosion hazard. The seasonal perched water table is 18 to 36 inches from January to March.
Alderwood-Urban Land Complex	5 and 6	This unit is about 60 percent Alderwood gravelly sandy loam and about 25 percent Urban land. Slopes are 2 to 15 percent. Permeability of the Alderwood soil is moderately rapid above the hardpan and very slow through it. The available water capacity is low. The runoff is slow, and the hazard of water erosion is slight.
Arents, Alderwood Material	AmC	Arents, Alderwood material consists of Alderwood soils that have been so disturbed through urbanization that they no longer can be classified with the Alderwood series. These soils, however, have many similar features. The upper part of the soil, to a depth of 20 to 40 inches, is brown to dark brown gravelly sandy loam. Below this is a grayish-brown, consolidated and impervious substratum. Runoff of this soil is medium and the water erosion hazard is moderate to severe. Slopes generally range from 6 to 15 percent.
Bellingham Silt Loam	Bh	This unit is poorly drained soil located in depressions on upland glacial till plains and formed in alluvium, under grass and sedges. Slopes are less than 2 percent. In a representative profile, the surface layer is very dark brown silt loam to depth of 11 inches. The substratum extends to depth of 60 inches and is a mottled gray silty clay loam. Permeability of this soil is slow. The available water capacity is high, with a seasonal water table near the surface. The runoff is slow and the hazard of water erosion is slight.

[8] The Map Symbol is an abbreviation of the unit as shown in the map exhibits.

Unit	Map symbol[8]	Description
Custer Fine Sandy Loam	13	This unit is a very deep, poorly drained soil located on basins of outwash plains and formed in glacial outwash. Slopes are 0 to 2 percent. In a representative profile, the surface layer is approximately 16 inches thick and is very dark grayish brown fine sandy loam to loamy fine sand with depth. The subsoil is gray and olive sand with iron-cemented concretions that form a discontinuous hardpan and extends to a depth of 35 inches. The substratum extends to depth of 60 inches or more and is gray sand over gravelly coarse sand. The permeability of Custer soil is moderately slow in the discontinuous hardpan and rapid below it. The available water capacity is low. The runoff is slow and ponding may occur in the wet season.
Earlmont Silt Loam	Ea	This unit is composed of somewhat poorly-drained soil that formed in diatomaceous material and is located in flood plains. Slopes are less than 1 percent. In a representative profile, the surface layer is approximately 9 inches thick and a dark grayish-brown silt loam. This unit is underlain by grayish-brown, light brownish-gray, and brown silt loam and silty clay loam about 35 inches thick. The substratum extends to a depth of 60 inches or more and is a stratified very fine sandy loam, muck and diatomite. The permeability of the soil is moderate with a seasonal water table 2 to 3 feet below the surface. The available water capacity is high. Runoff is slow and the water erosion hazard is slight.
Everett Gravelly Sandy Loam	17, 18, 19, EvB, EvC and EvD	This unit is made up of somewhat excessively-drained soil that formed by glacial outwash. It is found on terraces and outwash plains. Slopes are 0 to 30 percent. In a representative profile, the surface layer and subsoil are dark brown gravelly to extremely gravelly sandy loam to a depth of 60 inches. Gravel content increases with depth. In some areas the substratum is weakly cemented. Permeability of the soil is rapid and available water capacity is low. Runoff is slow to medium and the hazard of water erosion is slight to moderate, increasing with the steepness of the slope.
Indianola Loamy Sand	26, InA and InC	This unit formed in sandy recessional stratified glacial drift and is composed of somewhat excessively-drained soil on terraces and outwash plains. Slopes are 0 to 25 percent. In a representative profile, the surface is typically very dark grayish-brown loamy sand with a 2-inch covering of forest duff. The subsoil is dark yellowish-brown loamy fine sand to a depth of 26 to 30 inches. The substratum is light olive gray and grayish-brown sand and extends to a depth of 60 inches or more. Permeability of the soil is rapid and available water capacity is low to moderate. Increasing respectively with slope steepness, the runoff is slow to medium, and the hazard of water erosion is slight to severe.
Kitsap Silt Loam	27, 28, KpB and KpD	This unit is a very deep, moderately well-drained soil located on terraces and formed in glacial lake deposits. Slopes are 0 to 30 percent. In a representative profile, the surface layer is dark grayish-brown, dark yellowish-brown and dark brown silt loam to a depth of 33 inches. The substratum extends to a depth of 60 inches or more and is light olive brown silty clay loam.

Unit	Map symbol[8]	Description
		The permeability of Kitsap soil is moderate in the surface layer and slow through the substratum. The available water capacity is moderate to high. Increasing respectively with slope steepness, the runoff is slow to rapid and the hazard of water erosion is slight to severe. The soil is subject to severe hillside slippage on 15 to 30 percent slopes.
Lynnwood Loamy Sand	30	This very deep, somewhat excessively-drained soil located on terraces and outwash plains was formed in glacial outwash. Slopes are 0 to 3 percent. In a representative profile, the surface is covered with forest duff and grayish-brown loamy sand. The subsoil is dark brown to yellowish-brown loamy sand to depth of 32 inches below the surface. The substratum is grayish-brown sand and extends to a depth of 60 inches or more. In some areas the surface layer and subsoil are sandy loam. The permeability of the soil is rapid and available water capacity is low. The runoff is slow and the hazard of water erosion is slight.
Mckenna Gravelly Silt Loam	32	This unit consists of moderately deep, poorly-drained soils located in depressional areas and drainage ways on till plains. The McKenna series was formed in glacial till. Slopes are 0 to 8 percent. In a representative profile, the surface layer is approximately 33 inches thick and is a very dark grayish-brown to light olive brown gravelly silt loam. The layer is underlain by olive, dense glacial till that extends to 40 inches. The permeability of the soil is slow and the available water capacity is moderate. The runoff is slow and the hazard of water erosion is slight. Ponding may occur from November to April due to a high perched water table.
Mukilteo Muck	34	This is a very deep, very poorly-drained soil located in depressional areas and formed of organic material. Slopes are 0 to 1 percent. In a representative profile, layers are composed of dark reddish-brown muck and black organic material. The thickness of the layers is approximately 64 inches. The underlying later extends to a depth of 124 inches or more and is composed of olive-gray fine sandy loam. Some areas contain a large amount of wood in the lower profile. The permeability of the soil is moderate and available water capacity is high. Runoff is typically ponded in the unit.
Norma Loam	39 and No	This unit consists of very deep, poorly drained soils located in depressional areas on outwash plains and till plains. The Norma loam was formed in alluvium. Slopes are 0 to 2 percent. In a representative profile, the upper layer is a very dark gray to black loam approximately 10 inches thick. The underlying layer is a dark grayish-brown to dark gray sandy loam to a depth of 60 inches. The permeability of the soil is moderately rapid and available water capacity is moderate to high. The runoff is slow and the hazard of water erosion is slight. Ponding may occur from November to April, due to a high water table.
Pits	51 and PITS	These features consist of open pit mines, some of which were used as hard-rock quarries. None of the pits were underground mines.
Puget Silty Clay Loam	Pu	This unit is a very deep, poorly drained soil located in floodplains and formed in material deposited by water. Slopes are 0 to 1 percent.

Unit	Map symbol[8]	Description
		In a representative profile, the surface layer is about 7 inches thick and very dark to dark grayish-brown silt loam and silty clay loam. The subsoil is dark grayish-brown and greenish-gray silty clay loam that extends to a depth of 45 inches. The substratum is gray silty clay and approximately 15 inches thick. The permeability of the soil is slow with a high seasonal water table. This soil is subject to long, frequent periods of flooding from December to March. The available water capacity is high, resulting in slow runoff and ponding with a slight hazard of water erosion.
Puyallup Fine Sandy Loam	56	This unit is a very deep, well drained soil located on stream terraces. This unit was formed in alluvium. Slopes are 0 to 3 percent. In a representative profile, the upper layer is very dark grayish-brown to olive-brown sandy to fine sandy loam approximately 30 inches thick. The underlying layer is dark grayish-brown sand and extends to depth of 60 inches or more. The permeability of the soil is moderately rapid and available water capacity is moderate. The runoff is usually slow and the hazard of water erosion is slight. Rare flooding may occur in the wet season.
Ragnar-Indianola Association	RdC and RdE	This unit is about 50 percent Ragnar fine sandy loam and 50 percent Indianola loamy fine sand. It is mapped on till plains, terraces and outwash plains. Slopes are 2 to 25 percent. Ragnar series is composed of well-drained soils located on dissected glacial outwash terraces. In a representative profile, the upper layer is a very dark grayish-brown to yellowish-brown fine sandy loam and is approximately 27 inches thick. The underlying layer is olive brown loamy sand that extends to a depth of 60 inches or more. Runoff is medium to rapid and the erosion hazard is severe.
Renton Silt Loam	Re	This is a very deep, very poorly drained soil and formed in the alluvium of river valleys. Slopes are 0 to 1 percent. In a representative profile, the surface layer is approximately 6 inches thick and is very dark grayish-brown silt loam. The underlying layer is dark grayish-brown very fine to fine sandy loam approximately 10 inches thick. The substratum is mottled black sand that extends to a depth of 60 inches or more. The permeability of the soil is moderately rapid in the surface layer and rapid in the substratum. A seasonal water table is 1 to 2 feet below the surface. The available water capacity is moderate to moderately high. The runoff is slow and the water erosion hazard is slight.
Seattle Muck	Sk	This unit is composed of very poorly-drained organic soil that formed in decomposing sedges and is located in depressions and valleys on the glacial till plain and also in river and stream valleys. Slopes are 0 to 1 percent. In a representative profile, the surface layer is approximately 11 inches thick and is black muck. This unit is underlain by dark reddish-brown to black muck and mucky peat. The permeability of the soil is moderate with a high seasonal water table. The available water capacity is high. The runoff tends to pond and there is no hazard of water erosion.
Snohomish Silty Loam	So	The Snohomish series is made up of poorly-drained soils that formed in the alluvium of stream valleys. Slopes are 0 to 2 percent.

Unit	Map symbol[8]	Description
		In a representative profile, the surface layer and subsoil are very dark grayish-brown to grayish-brown silt loam and clay loam about 17 inches thick. Below this is black mucky peat about 10 inches thick. The substratum is dark gray loamy fine sand that extends to a depth of 60 inches or more. The permeability of the soil is moderate in the upper portion and moderately rapid in the lower layer. The seasonal water table is at or near the surface. The available water capacity is high resulting in slow runoff and a slight hazard of water-related erosion. Stream-bank overflow is a severe hazard in these soil conditions.
Terric Medisaprists	69	This unit is a very deep, very poorly-drained soil located in depressional areas on till plains. This unit was formed in alluvium and organic material. Slopes are 0 to 3 percent. In a representative profile, the upper layer is dark brown to black organic material approximately 28 inches thick. The underlying layer varies in short distances, ranging from dark brown to very dark gray clay to gravelly loamy sand. The permeability of the soil is moderate and available water capacity is moderate. The runoff is usually ponded and the hazard of water erosion is slight.
Tokul Gravelly Loam	72 and 73	This is a moderately deep, moderately well-drained soil located on till plains and formed in glacial till and volcanic ash. Slopes are 8 to 15 percent. In a representative profile, the surface is covered with forest duff approximately 2 inches thick. The subsoil is strong brown to dark yellowish/olive brown gravelly loam with increased fine sand content at 24 inches below the surface. The subsoil extends to a depth of 33 inches. Hardpan or compact glacial till ranges in depth from 20 to 40 inches. The permeability of the soil is moderate to the hardpan layer and very slow through it. The available water capacity is moderate. The runoff is usually slow and the hazard of water erosion is slight.
Tukwila Muck	Tu	The Tukwila series is made up of very poorly-drained organic soils that formed in decomposing sedges, bushes, grasses, and shrubs. These soils are in wet basins of upland depressions and on stream bottoms. Slopes are 0 to 1 percent. In a representative profile, dominantly black to very dark brown muck extends to a depth of 60 inches or more. The permeability of the soil is moderate. The seasonal water table is at or near the surface. The available water capacity is high. The runoff is usually ponded and the hazard of water erosion is slight.
Urban Land	78 and Ur	Urban land refers to soil that has been artificially modified by additions of fill material several feet thick to accommodate large industrial and housing installations, streets and parking lots. The erosion hazard of this material is slight to moderate.

Exhibit 6: Description of geologic units

Unit	Map symbol	Description
Artificial Fill	Qf	Soil that has been modified by disturbance of the natural layers with additions of fill material several feet thick to accommodate large industrial and housing installations.
Mass-Wasting Deposits	Qls	Primarily landslide deposits including talus, colluvium, protalus ramparts, and rock glaciers.
Alluvium	Qa	Alluvium deposits formed in Holocene period river flows. The deposits consist of loose to medium dense, stratified sand and gravel with minor silt and clay layers. The deposits in the Totem Lake area contain large thicknesses of soft silt, organic silt and peat. Alluvial deposits with relatively high fines content will be moisture sensitive and will become muddy and unstable when the amount of moisture in the soil rises above the optimum moisture content. Infiltration rates into alluvial or recessional outwash deposits typically range from moderate to high (1 inch per hour to greater than 10 inches per hour) depending on the silt content of the sandy soils and the presence of interbedded silt layers. The presence of interbedded organic layers or large thicknesses of organic layers will significantly decrease the rate of infiltration.
Continental Glacial Outwash	Qgo	These deposits are glaciofluvial sediment deposited during the retreat of continental glaciers. Typically, these deposits consist of loose to dense silty sand to sandy gravel with cobbles and boulders and are commonly interbedded with sandy silt to silty clay.
Continental Glacial Till	Qgt	These materials were deposited along the base of the Vashon stade glacial ice and are generally heterogeneous, yet often exhibit considerable variation in composition over short distances. Along the alignment, the till may range from a very dense, nonstratified, silty fine to coarse sand with fine to coarse gravel, to dense sandy silt with gravel and boulders. Both boulders and cobbles are commonly encountered in till. The majority of the alignment is underlain by till and is commonly overlain by a thin, typically 4 foot or less, layer of recessional outwash.
Advance Continental Glacial Outwash	Qga	Advance outwash consists chiefly of dense to very dense, stratified sand with gravel and some cobbles and boulders. Advance outwash deposits often contain relatively low fines content. Locally, the advance outwash can be silty and contain layers of fine-grained sands and silts. Advance outwash soils are typically less moisture sensitive than glacial till soils. Moderate to high infiltration rates (1 inch per hour to greater than 10 inches per hour) but the infiltration rate depends on the silt content of the soil and the presence of interbedded layers with higher silt contents.
Transitional Advance Continental Glacial Outwash	Qga(t)	This unit is located beneath the Vashon advance continental glacial outwash and deposited in proglacial lake(s) and fluvial systems. The unit consists of very stiff to hard clay, silty clay, clayey silt or silt with interbeds of fine sand. Peaty sand and gravel may occupy the lower portion. The unit accumulated during the transitional period near the close of the pre-Fraser interglacial time and into the early Fraser age.

POTENTIAL EFFECTS

Will the project affect soils or geology?

The anticipated conditions along the alignment are not unusual for the Puget Sound area. WSDOT routinely encounters these types of conditions and resolves them by implementing standard BMPs. Relevant construction conditions along the study area include:

- disturbance of moisture sensitive soils;
- cuts through landslide-prone areas;
- increased erosion potential; and
- vibration effects of construction equipment.

These effects will be avoided or minimized by using proper design and construction techniques. Unavoidable effects to local soils and geology resulting from project construction will be mitigated by following standard WSDOT construction practices and the I-405 Programmatic Commitments. Based on WSDOT's commitments in these compliance measures, effects from soils and geology will be few, if any. No substantial adverse effects to soils and geology are anticipated from either of the two project build alternatives.

Will soils or geology affect the project construction or operation?

The project will be constructed in a variable geologic environment with dense geologic materials and a relatively shallow groundwater table. The majority of the alignment is underlain by glacial till (in the southern and northern limits) and glacial outwash (in the majority of the project corridor). The roadway alignment crosses several drainages and lowlands underlain by softer, looser soils. Soft ground areas generally require different design and construction considerations than those characterized by dense to stiff glacial soils. Within the study area, soft and loose soils are found adjacent to Totem Lake at the NE 124th Street interchange and the section between SR 522 and NE 195th Street (MP 23.6 to MP 24.5) as shown on Exhibit B-2, sheet 5. In addition, landslide hazard areas are situated along the corridor just south of the SR 522 interchange (MP 22.8 to MP 23.5) as shown on Exhibit B-3, sheet 5.

WSDOT has routinely managed these types of conditions on other projects, including the original construction of I-405. Once construction is complete and the highway is in use, soils and geology should have essentially no effects on the built project.

Specific conditions that may be encountered during construction and operation of the NE 6th Street to I-5 Improvement Project are described below, along with examples of techniques that are typically used to mitigate effects.

Soils and erosion

The majority of the soil types in the study area are susceptible to erosion and erosion hazard areas exist in areas of proposed reconstruction of the alignment. Erosion risk is typically assessed by assessing the steepness of a slope in combination with the soil type. However, since hillside cuts may create steep slope conditions during construction, cut areas, even if not rated as having a high erosion risk, can become susceptible to erosion. Fill placed to widen existing embankments may be susceptible to erosion during storm events, particularly when stockpiled prior to being placed during construction.

During construction, WSDOT will encounter moisture-sensitive soils such as alluvium, till, glacial outwash, and existing embankment fills. Heavy earthmoving equipment tracking on moisture-sensitive soils during wet weather, in areas of seepage, or in areas of shallow groundwater, will tend to degrade the subgrade into a soft, unstable material. WSDOT is aware of these types of conditions and routinely uses a variety of methods to minimize adverse effects.

Landslide hazard areas

The proposed widening described in Build Alternatives 1 and 2 includes cutting into hillsides where landslide activity has been documented. These cuts will likely remove portions of existing buttress and drainage systems. Cuts into landslide-prone slopes may further destabilize the slopes. Landslides, should they occur, could exert lateral loads on retaining walls and other structures. Landslide debris, if not properly contained, could also block the roadway. WSDOT will require that the design for cuts and retaining walls through the landslide-prone areas address the potential for slope destabilization and provide sufficient support.

Steep slope hazard areas

Several mapped areas with steep slope hazards (slopes greater than 40 percent) are located along the project corridor in the area to be reconstructed, and may be associated with landslide and erosion activity.

Seismic hazard areas

Mapped seismic hazard areas are located in the area of MP 15.9 to MP 16.5, as shown on Exhibit B-3, sheet 1 and from MP 23.55 to MP 24.6, as shown on Exhibit B-3, sheet 5. The NE 132nd Street area in the vicinity of MP 20.9 is also a seismic hazard area. These are considered seismic hazard areas because their soils are prone to liquefaction. New structures, such as retaining walls and fill embankments, supported above or within liquefiable soils, can be subject to loss of bearing support and settlement should the underlying soils liquefy during a seismic event. In addition, fill embankments are susceptible to lateral spreading (slope deformations) should soils below the embankments liquefy.

Soft ground areas

The soft, compressible soils located in the project area will settle under new loads such as those imposed by retaining walls and fill embankments. Project designs will account for such soft ground conditions. Soft compressible soils underlying transportation corridors are common in the region, and WSDOT has considerable experience designing new improvements to address these types of soils.

What are the unavoidable adverse effects?

Unavoidable adverse effects include the disturbance of moisture sensitive soils, cuts in landslide-prone areas, increased erosion potential, and vibration effects of construction equipment. These effects will be minimal because standard WSDOT construction practices will be followed.

MEASURES TO AVOID OR MINIMIZE EFFECTS

What will be done to avoid or minimize adverse effects from the project?

WSDOT will avoid or minimize the majority of potential adverse effects associated with the construction and operation of the project by strictly adhering to BMPs, following the procedures outlined in the WSDOT Geotechnical Design and Bridge Design Manuals, and following the I-405 Programmatic Commitments. Avoidance measures are discussed below.

WSDOT will incorporate into the project design and implementation all commitments contained in policy guidance, interagency agreements, and WSDOT Standard Specifications M 41-10 (as amended by special provisions based on the judgment of the Design Engineer). The project design and operation will also incorporate best practices and mitigation measures as outlined in the Environmental Procedures Manual (M 31-11) in Sections 610 Environmental Requirements in Construction, 620 Environmental Requirements During Construction, 710 Environmental Requirements in Maintenance and Operations, and 720 Technical Guidance.

BMPs and other measures will be incorporated into construction specifications to control or reduce construction-related erosion and sedimentation and increase infiltration, where appropriate. Design solutions to avoid, minimize, or mitigate disturbance to geologic hazards will be implemented.

The project will require gravel imported from sources outside of the study area. WSDOT practice requires that imported materials come from approved sources whose operations comply with all applicable laws.

Vibration effects of construction equipment

The use of heavy equipment on the project will cause ground vibrations. WSDOT will determine acceptable limits for off-site, construction-related vibration before construction begins. WSDOT will ensure that off-site ground vibrations are within the limits set for the project.

WSDOT will mitigate effects of construction vibrations by restricting the hours that construction may occur, or limiting the operation of certain types of equipment to times when they are least likely to disturb nearby residences and businesses. In some cases, WSDOT may also increase the distance between the source and the receptor. Effects at specific locations where the proposed transportation improvements are close to existing facilities will be evaluated during the design phase of the project. For example, a drilled pile could be substituted for a driven pile to reduce vibrations in some instances. Other effects associated with drilled piles (e.g., disposal of drilled spoils, potential for

groundwater impacts, and cost) will be considered before specifying drilled rather than driven piles. Potential effects to structures and people will be evaluated on a site-specific basis during the design phase of the project.

Soils and erosion

WSDOT will prepare and implement a temporary erosion and sediment control (TESC) plan. A TESC plan consists of operational and structural measures to control the transport of sediment. Operational measures consist of standard construction practices such as removing mud and dirt from trucks before they leave the site, covering fill stockpiles or disturbed areas, using temporary or permanent erosion control blankets, mulching, adding soil amendment to promote plant growth, and avoiding unnecessary vegetation clearing. Structural measures may involve constructing temporary structures to reduce the transport of sediment such as detention ponds, ditches, silt fences, or sediment traps. WSDOT will take appropriate action to ensure that BMPs and other operations function to minimize erosion.

WSDOT will reduce the potential for impacting moisture-sensitive soils by performing major earthwork in such locations during drier conditions, typically from late spring through early fall. WSDOT will maintain proper surface drainage to avoid and minimize ponding of surface water or groundwater, minimize ground disturbance by limiting the use of heavy equipment, limiting turns and tracking directly on the subgrade, and by covering the final subgrade elevation with a working mat of crushed rock and/or geotextile for protection. Mixing a soil admix such as cement into the subgrade may also add strength and stabilize the ground.

Landslide hazard areas

WSDOT will implement construction procedures identified in the Geotechnical Design Manual to reduce slope instability in areas potentially underlain by landslide-prone materials. WSDOT will require analyses of slope stability and develop mitigation measures such as retaining walls, buttresses, and groundwater control for excavations or embankments on hillsides. WSDOT will design retaining walls for undercut and potentially unstable slopes. Cleared slopes will be covered per permit requirements during periods of wet weather.

Facilities in landslide hazard areas will be designed for safe construction and operation. Cuts through landslide-prone materials will be limited in height or avoided, requiring the use of special retaining wall systems for earth retention. Walls will be designed for lateral pressures to limit soil movement. Subsurface drainage will be needed to increase slope stability. Light-weight fill, bridging structures, or realignment and relocation of improvements will be used to avoid excessive loading on slopes.

WSDOT will ensure that earthwork and wall placement sequencing adheres to BMPs, construction drainage plans, and a slope monitoring program, especially in known landslide-prone areas. During construction, areas of observed or suspected groundwater seepage will be drained to reduce the risk of landslides and surface sloughing through the use of gravel drainage blankets, French drains, horizontal drains, placement of a surface rock facing, or through other similar methods.

Any future design and construction in historic landslide areas will include an evaluation of the effectiveness of the horizontal drains and replacement of the drains, if necessary. Additionally, any changes to grade or slope configuration in this area may further destabilize the landslide and may require stabilization measures (e.g. rock buttressing, retaining walls, etc.).

Seismic hazard areas

In accordance with the WSDOT Geotechnical Design Manual, retaining walls supporting the traveled way, or retaining walls greater than 10 feet in height and within 10 feet of the roadway, will be designed to remain stable under seismic loading conditions and anticipated displacements associated with liquefaction. Mitigation, such as constructing walls on deep foundations, or improving the underlying soils to achieve overall stability, may be necessary.

Soft ground areas

During the design phase of the project, WSDOT will assess potential settlement problems associated with existing utilities or structures and design appropriate solutions. These include underpinning structures by supporting them on deep foundations below the compressible soils, and protecting and relocating utilities. Other techniques that may be employed include staging construction of embankments so the soil has time to strengthen, using wicking drains to hasten consolidation and gain strength, constructing embankments of light-weight materials to minimize loading, reinforcing embankments with geosynthetics to add strength and minimize the footprint, inducing settlement of the underlying soils through the use of preloads prior to constructing the infrastructure, constructing on pile supports, and increasing grades to keep the pavement above groundwater.

ACRONYMS AND ABBREVIATIONS

Acronym	Meaning
BMPs	Best management practices
BRT	bus rapid transit
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
FHWA	Federal Highway Administration
GIS	Geographic Information System
HOV	high-occupancy vehicle
LiDAR	Light Distance and Ranging
MP	milepost
SOV	Single-occupant vehicle
SR	State Route
TESC	Temporary Erosion and Sediment Control
USGS	United States Geological Survey
WSDOT	Washington State Department of Transportation

GLOSSARY

Term	Meaning
admix	A product, such as cement or kiln dust that is mixed into soil to improve the characteristics of the soil during construction.
Alluvium	Sediment deposited by a stream or river, either along the stream bed or in the floodplain.
bedrock	Bedrock is referred to as the rock underlying gravel and/or soil and is sometimes visible on the surface as outcrops.
best management practice (BMP)	Innovative and improved environmental protection tools, practices, and methods that have been determined to be the most effective, practical means of avoiding or reducing environmental impacts.
Cobble	Rock fragment smaller than boulder and larger than gravel; arbitrarily 1 to 50 pounds or 2 to 8 inches in diameter.
colluvium	Loose, heterogeneous mass of soil and/or rock fragments deposited on the ground surface by rain wash, sheet wash, or soil creep.
drainage ditch	An open channel designed and constructed to convey water. This may include modifications of natural drainages or man-made historic channels incorporated in a system design.
Effect	Something brought about by a cause or agent; a result. This may include ecological, aesthetic, historic, cultural, economic, social, health or other effects, whether direct, indirect, or cumulative. Effects may include those resulting from actions that may have both beneficial and detrimental effects.
Erosion	The wearing away of soil or rock by the action of running water, wind, ice, or geologic agents. For this analysis, erosion relates primarily to stormwater runoff.
express toll lane	A limited-access freeway lane that is actively managed through a variable toll system to regulate its use and thereby maintain express travel speeds and reliability. Toll prices rise or fall in real time as the lane approaches capacity or becomes less used. This ensures that traffic in the express toll lane remains flowing at express travel speeds of 45 to 60 miles per hour. Transit and carpools do not pay a toll. See also: "managed lane."
Federal Highway Administration (FHWA)	One of several agencies in the U.S. Department of Transportation, the FHWA provides federal financial assistance to the states through the Federal Aid Highway Program, the purpose of which is to construct and improve the National Highway System, urban and rural roads, and bridges.
fill	Any material placed in an area to increase surface elevation.

Term	Meaning
geographic information system (GIS)	A digital computer mapping system that can overlay a wide variety of data such as land use, utilities, and vegetative cover, and provide a spatial analysis.
glaciation	The process of ice growth and retreat within a glacier.
glacier	A major body of ice that moves under the influence of gravity.
general-purpose lane	A freeway or arterial lane available for use by all traffic.
groundwater	That portion of the water below the ground surface that is free flowing within the soil particles. Groundwater typically moves slowly, generally at a downward angle because of gravity, and eventually enters into streams, lakes, and oceans.
high-occupancy vehicle (HOV)	High-occupancy vehicle is a special designation for a bus, carpool, or vanpool provided as an encouragement to increase ride-sharing. Specially designated HOV lanes and parking are among the incentives for persons to pool trips, use fewer vehicles, and make the transportation system more efficient. HOV lanes are generally inside (left-side) lanes, and are identified by signs and a diamond on the pavement. Currently, two or more (2+) occupants are required to use the I-405 HOV lanes. Motorcycles are allowed to use freeway HOV lanes as well.
infiltration	The passage of water through the soil surface into the subsoil.
LiDAR	Light Detecting And Ranging. A technique used to detect atmospheric constituents or related parameters such as atmospheric extinction coefficient. Light is produced in a modulated source and the resulting backscattered or reflected light is analyzed to quantify some property of the atmosphere.
liquefaction	Transformation of a granular soil material from a solid state into a liquefied state, often as a consequence of strong earthquake shaking.
loam	Soil that contains a combination of sand, silt, organic matter, and clay.
mitigation	An effort to: (1) avoid the impact altogether by not taking a certain action or parts of an action; (2) minimize the impact by limiting the magnitude of the action and its implementation, by using technology or by taking affirmative steps; (3) rectify the impact by repairing, rehabilitating, or restoring the affected environment; (4) reduce or eliminate the impact over time by preservation and maintenance operations; (5) compensate for the impact by replacing, enhancing or providing substitute resources or environments; and/or (6) monitor the impact and taking appropriate corrective measures.

Term	Meaning
outwash	Sediment deposited by flowing water originating from glacial meltwaters. Outwash that is deposited and then subsequently overrun by an advancing ice sheet is known as advance outwash. Outwash that is not overrun is commonly called recessional outwash. Outwash typically consists of sand and gravel sized particles.
permeability	A measure of how quickly a fluid (in this case, water) can move through sediment or other subsurface material.
programmatic commitments	These are assurances or obligations identified in the Environmental Impact Statement for the overall I-405 Corridor Program and intended for implementation by WSDOT and/or the other project sponsors, as appropriate.
retaining wall	A structure used to hold earth in place where the natural grade cannot be maintained.
right-of-way	Land purchased prior to the construction of transportation improvements along with land for sound walls, retaining walls, stormwater facilities, and other project features. This also includes permanent or temporary easements for construction and maintenance. Vacant land may also be set aside for future highway expansion under certain circumstances.
riprap	A manmade armoring, facing layer, or protective mound of rocks placed to prevent erosion or sloughing of a stream bank or structure due to flow of surface and stormwater runoff.
runoff	Rainwater or snowmelt that leaves an area as a surface drainage.
scarp	A topographic feature defined as a distinct change in slope or a near-vertical surface marking the edge of a landslide mass. This can be caused by movement of landslide material away from undisturbed material or by differential movements within a landslide mass.
sediment	Material that originates from weathering and erosion of rocks, dirt, or unconsolidated deposits and organic material. Sediment is carried and deposited by wind, ice or water. It is often transported by stormwater runoff and may be suspended within the water.
silty loam	A type of soil that is rich in organic materials mixed with fine clay-like particles.
single-occupant vehicle (SOV)	A vehicle having one occupant (i.e., the driver).
slope	The change in elevation over a distance, or an inclined land form.
stade	A period within glacial retreat marked by a glacial re-advance.

Term	Meaning
stormwater	The portion of precipitation that does not naturally percolate into the ground or evaporate, but flows overland, in channels, or in pipes into a defined surface water channel or a constructed stormwater facility.
stratified	Arranged or deposited in layers.
study area	The area specifically evaluated for environmental effects.
subgrade	The in-place material on which pavement or embankment fills are placed.
till	An unsorted and non-stratified deposit of clay to boulder-sized sediment deposited by a glacier. Till deposited at the base of a glacier is usually hard or very dense. Till is often referred to as hardpan.
topography	The physical features of a geographic area taken collectively; especially, the variations in elevation of the earth's surface.
underpinning	A method of increasing the load-bearing capacity of a foundation by adding piles under the structure.
vehicle	Any car, truck, van, motorcycle, or bus designed to carry passengers or goods. Bicycles and other pedestrian-oriented vehicles are not included in this definition.