

I-405, Tukwila to Renton Improvement Project (I-5 to SR 169 – Phase 2)



Corridor Program
Congestion Relief & Bus Rapid Transit Projects

GEOLOGY AND SOILS TECHNICAL MEMORANDUM

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Summary

The purpose of this technical memorandum is to present an assessment of the soils and geologic conditions in the I-405, Tukwila to Renton Improvement Project (I-5 to SR 169 – Phase 2), referred to as Tukwila to Renton Project. Describing the natural setting prior to construction is important because it can be a major factor impacting project design (e.g., foundations, pavement sections, retaining walls, bridges, etc.).

Identifying and evaluating possible impacts of the project on the geology and soils during the planning stages allows the Washington State Department of Transportation (WSDOT) to develop mitigation measures utilizing existing best management practices (BMPs) and procedures outlined in the WSDOT Geotechnical Design Manual, dated December 2006, and the WSDOT Bridge Design Manual, dated November 17, 2006. Possible mitigation measures include changing the alignment (avoidance), designing project structures or components to accommodate the geologic and soils conditions, and implementing protective measures and techniques that reduce impacts to environmental conditions.

The Tukwila to Renton Project lies in a heavily populated area located within the Green-Duwamish River valley. The majority of the near-surface soil material in the study area along the I-405 and SR 167 corridors has been modified by the addition of fill material and is classified as Urban Land or Modified Fill. The fill is underlain by relatively loose, soft soil with a shallow groundwater table. The local surface geology in the study area also includes wetland deposits, glacial deposits, and sandstone bedrock.

The soils and geology in the project area combined with the topography result in several geologic hazards along the corridor, including erosion, landslide, steep slope, soft ground, and coal mine subsidence hazards.

The project will be constructed in a highly variable geologic environment. Potential project impacts on the geology and soils during construction include disturbance of moisture sensitive soils, increased erosion potential, and vibration effects of construction equipment; these issues are routinely encountered by WSDOT and are resolved with the implementation of standard BMPs. The presence of erosion hazard areas, soft ground areas, liquefaction-prone soils, and mine subsidence hazards may affect the project and will be prominent design and construction considerations. 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 not affect 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 BMPs and by following the procedures outlined in the WSDOT Geotechnical Design Manual, dated December 2006, and Bridge Design Manual, dated November 17, 2006.

While WSDOT will avoid the majority of potential effects from the project on the geology and soils by using standard WSDOT procedures and implementing BMPs, WSDOT will likely face a few unavoidable adverse erosion effects.

Project Description

WSDOT is proposing to construct the I-405, Tukwila to Renton Improvement Project (I-5 to SR 169 – Phase 2), referred to as the Tukwila to Renton Project, to relieve congestion. Relieving congestion will benefit the public by:

- Lowering the number of accidents, thus improving safety.
- Increasing overall speeds through this section of freeway.
- Improving response times for emergency service vehicles using I-405.
- Improving access to and from I-405 and local circulation.

The Tukwila to Renton Project extends approximately four and one-half miles along I-405, from I-5 to SR 169, and approximately two miles along SR 167, from I-405 to SW 43rd Street. The project adds capacity to both I-405 and SR 167; improves the SR 181 and SR 169 interchanges; reconstructs the SR 167 interchange consisting of general-purpose direct-connector ramp from southbound I-405 to southbound SR 167, HOV direct-connector ramps from northbound SR 167 to northbound I-405 and from southbound I-405 to southbound SR 167, and a split-diamond interchange at Lind Avenue and Talbot Road with connecting frontage roads. These improvements represent the second phase of the I-405 Corridor Program for this portion of I-405. The first phase consists of improvements in the Renton Nickel Improvement Project, which is considered as the baseline condition for the Tukwila to Renton Project.

The analysis in this technical memorandum describes the baseline conditions, how the project may affect those conditions, and what measures will be taken to mitigate effects. To understand what improvements are being proposed as part of this project, the following presents the main features of the Build Alternative followed by a brief explanation of the No Build Alternative.

Build Alternative

The Tukwila to Renton Project improvements from west to east (northbound) along the study area are as follows:

I-405 from I-5 to SR 181 Interchange

- Remove the existing northbound I-405 Tukwila Parkway on-ramp.
- Realign I-405 mainline slightly to the south beginning just west of the existing northbound I-405 Tukwila Parkway on-ramp to the SR 181 interchange.
- Improve the SR 181 interchange:
 - Remove the existing SR 181 on-ramp to northbound I-405.
 - Extend Tukwila Parkway from the intersection with 66th Avenue east over the Green River to SR 181.
 - Construct new northbound I-405 on-ramp from Tukwila Parkway just east of the new crossing over the Green River (replaces the two existing on-ramps).
 - Reconstruct the 66th Avenue S bridge over I-405 on a new alignment to the west and reconstruct the intersections with Southcenter Boulevard and Tukwila Parkway.
 - Reconstruct the off-ramp from northbound I-405 to SR 181.
 - Improve local arterials within the interchange area such as Southcenter Boulevard and Interurban Avenue.

- Reconstruct five bridges and build one new bridge over the Green River.
- Lower the Duwamish-Green River Trail.
- Reconstruct the I-405 structures over SR 181.
- Realign the Interurban Trail.

I-405 from East of SR 181 to SR 167 Interchange

- Realign I-405 to provide a smooth transition onto the new Springbrook Creek/Oakesdale Avenue bridge that was constructed under the Renton Nickel Improvement Project.
- Construct one additional general-purpose lane in each direction on I-405 from SR 181 through SR 167.
- Stripe lanes to provide a buffer between HOV and general-purpose lanes along I-405.
- Reconstruct the I-405 structures over the Burlington Northern Santa Fe (BNSF) and Union Pacific railroads.
- Stripe the bridges over Springbrook Creek/Oakesdale Avenue for five lanes in both directions.

SR 167 from I-405 to SW 43rd Street On-ramp

- Construct an auxiliary lane on northbound SR 167 from SW 43rd Street to I-405.
- Stripe lanes to provide a buffer between HOV and general-purpose lanes along SR 167.
- Reconstruct SR 167 between SW 27th Street and I-405 to accommodate the reconstructed SR 167 interchange.
- Reconstruct East Valley Road to the west of its current alignment between SW 23rd Street and SW 16th Street to accommodate the reconstructed SR 167 interchange.

I-405 Interchange with SR 167

The interchange improvements affect both freeway to freeway access and local access.

Freeway to Freeway Access

- Construct a general-purpose direct-connector ramp from southbound I-405 to southbound SR 167, replacing the existing loop ramp.
- Reconstruct exterior ramps from northbound I-405 to southbound SR 167 and from northbound SR 167 to northbound I-405, replacing the existing ramps. This project will also add a general-purpose lane to both ramps.
- Construct HOV direct-connector ramps from southbound I-405 to southbound SR 167 and from northbound SR 167 to northbound I-405.
- Maintain existing loop ramp from northbound SR 167 to southbound I-405.

Local Access

Shift local access between I-405 and Renton from SR 167 to the Lind Avenue/Talbot Road split diamond interchange. WSDOT will:

- Construct a new half-diamond interchange at Lind Avenue.
- Construct a new half-diamond interchange at SR 515 (Talbot Road).
- Construct southbound and northbound frontage roads connecting Lind Avenue to Talbot Road.

- Remove exterior ramps to/from SR 167 north of I-405 and loop ramps south of I-405.
- Reconstruct the Lind Avenue bridge over I-405.
- Reconstruct I-405 structures over Talbot Road.
- Improve local street intersections.
- Provide new connection to Grady Way from S Renton Village Place.

I-405 from East of SR 167 Interchange to North of SR 169

- Construct two additional general-purpose lanes in each direction on I-405 from SR 167 through SR 169.
- Stripe lanes to provide a buffer between HOV and general-purpose lanes along I-405.
- Reconstruct S 14th Street south of its existing location.
- Cantilever the I-405 structures over Main Avenue.
- Reconstruct three bridges over the Cedar River: southbound and northbound I-405 and a pedestrian bridge.
- Relocate the BNSF railroad bridge over the Cedar River west of its current alignment.
- Close off Houser Way as a cul-de-sac just south of the Cedar River and remove the bridge over the river. Northbound traffic will be rerouted via Bronson Way, which will be striped to accommodate the new traffic pattern. Two options are being considered for northbound traffic between Houser Way and Bronson Way. The first option stripes Mill Avenue as a one-way street to provide two lanes northbound from the intersection of Houser Way and Mill Avenue to Bronson Way. Emergency vehicles will still be allowed to travel southbound on Mill Avenue from 2nd Street to Houser Way. The second option leaves Mill Avenue as a two-way street up to the intersection with 2nd Street where it will be striped for one-way traffic northbound and reconfigures Main Avenue, a one-way street southbound, for two-way traffic. Main Avenue would be widened and striped for two-way traffic to provide access from the south to Bronson Way.
- Reconstruct the two local street accesses to Renton Hill. Two local access points will be maintained by reconstructing the Renton Avenue bridge over I-405 and reconstructing Mill Avenue as a stacked structure that also provides access to Renton Hill. The existing Cedar Avenue bridge will be removed.
- Construct a pedestrian pathway from Renton Hill to City parks and trails.

No Build Alternative

The No Build Alternative assumes that the improvements associated with the Renton Nickel Improvement Project are constructed as does the baseline condition. Only routine activities such as road maintenance, repair, and safety improvements would be expected to take place between 2014 and 2030. This alternative does not include improvements that would increase roadway capacity or reduce congestion beyond baseline conditions. For these reasons, it does not satisfy the project's purpose to reduce congestion on I-405 between I-5 in Tukwila and SR 169 in Renton. The No Build Alternative has been evaluated in this technical memorandum as a comparison for the effects associated with the Build Alternative.

Baseline Conditions

What are the geology and soils of the study area?

The Tukwila to Renton Project lies in a heavily populated area located within the Green-Duwamish River and Cedar River valleys. These valleys are underlain by relatively loose geologic materials with a shallow groundwater table. The geology of the study area consists of a variety of soil types and bedrock. A more detailed description of the soil and geologic units is provided in Exhibits 1 and 2, respectively, and maps of local soil and geologic conditions are presented on Exhibits 3 through 10 (soil units) and 11 through 18 (surface geologic conditions). The soils and geology in the area combined with the topography result in several geologic hazards along the corridor, including erosion, landslide, steep slope, soft ground, and coal mine subsidence hazards. These geologic hazard areas are shown on Exhibits 19 through 34. The baseline conditions presented in this section were gathered from a review of available documents, including the Renton Nickel Improvement Project Soils, Geology and Groundwater Discipline Report and the Geotechnical Baseline Report as referenced in Appendix A.

Soils

The majority of the near-surface soil material in the study area along the I-405 and SR 167 corridors has been modified by the addition of fill material and is classified as Urban Land or Modified Fill. Naturally occurring, undisturbed soils in the project area span from well drained, gravelly sandy loam to poorly drained silty clay loam and muck. These materials have predominantly been derived from glacial till or alluvial deposits. A description of these soil units is provided in Exhibit 1 and the mapped soil units along the project corridor are depicted on Exhibits 3 through 10.

Geology

The I-405 project corridor is located within the central Puget lowland bordered by the Cascade mountains to the east and the Olympic mountains to the west. The Puget lowland is a north-south trending trough consisting of Holocene period deposits generally overlying a sequence of relatively unweathered glacial and interglacial soil deposited during the ice ages of the Quaternary period. This region has experienced at least six glaciations in the past 2 million years.

In the central Puget lowland, the most complete geologic record of the Quaternary period exists for the most recent glaciation, the Vashon stade of the Fraser glaciation. The advance and retreat of the Vashon age Puget glacial lobe, 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. As the glacier advanced southward, streams deposited sediment that formed a broad plain in front of the advancing glacier. Gravel-size material was deposited close to the glacier, while silt and clay material was transported farther from the glacier. The advance deposits, therefore, grade from coarse to fine with increasing depth, with silts and clays (lake deposits) at the base, then coarse-grained sand and gravel at the top.

Lodgement till, consisting of a non-stratified, well-graded deposit of particle sizes ranging from clay to large boulders, was deposited directly from the glacier itself. The most conspicuous aspect of glacial till is its consolidation, the result of being overridden by the glacial ice. The maximum ice thickness was roughly 3,000 feet in the project vicinity.

As the glacier retreated, the depositional sequence was repeated in the reverse order of the glacial advance, with first coarse-grained gravel and sand, then 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 nor are they as densely compacted because they were not overridden by the glacial ice.

Following the Fraser glaciation, Holocene period sediments were deposited over the glacial soils. These deposits typically consist of alluvial soils in river valleys, beach and marine deposits along shorelines and colluvial deposits (landslide materials) along slopes. Peat and other organic soils occur in numerous depressional areas at the surface. Some of these Holocene period sediments have been modified by human activity, including overexcavation and replacement beneath portions of the I-405 project corridor.

The majority of the bedrock in the study area is Renton Formation sandstone. Outcrops of this unit occur along the project corridor in three areas: 1) along the north side of I-405 to just east of the Green River (between I-405 milepost [MP] 0.3 to MP 0.6 and between MP 0.75 to MP 0.9), 2) at the southeast interchange of SR 167 and I-405, and 3) along I-405 west of Benson Road (MP 2.8) to approximately Cedar Avenue (MP 3.65). In the Green River valley (between the two outcrop areas) the bedrock is located at depths greater than 100 feet below the existing ground surface (Yount et al., 1985).

The local surface geology in the study area is depicted on Exhibits 11 through 18 and includes engineered and non-engineered fill, stream and river sediment (alluvial), wetland deposits, glacial deposits and bedrock. Peat and other organic soils occur in numerous depressional areas at the surface. A description of these geologic units is provided in Exhibit 2.

Geologic Hazard Areas

Geologic hazard areas in the vicinity of the study area include erosion hazards, mine subsidence hazards, steep slope hazards, landslide hazards, seismic hazards, and soft ground areas. These hazard areas are shown in Exhibits 19 through 34 and are described below.

- **Erosion Hazard** – 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 weathered sandstone and glacial soils on slopes greater than 15 percent. Erosion hazard areas exist east of SR 167, along Panther Creek¹, near South 15th Street and Talbot Road, adjacent to I-405 from MP 3 to MP 3.15, and along the Cedar River and SR 169, as shown on Exhibits 22, 23, 25 and 26.
- **Landslide Hazard** – There does not appear to be large-scale active landsliding within the project area. As with most slopes in western Washington, shallow surficial sliding is possible, particularly when the ground is saturated. Surficial slides typically occur in the upper 2 to 5 feet of soil or weathered bedrock on steep slopes and movement occurs episodically, generally in response to heavy rainfall. Earthquake shaking would tend to increase the size of the surficial slide area as well as the frequency of movement.
- **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 typically defined as areas possessing slope inclinations greater than 40 percent with a vertical height of 10 feet or more. Several steep slope hazard areas are mapped along the project corridor (see Exhibits 19 through 26). Their locations are presented below (GeoEngineers, 2006).
 - Immediately west of the Green River at MP 0.8
 - West of the Green River along the southern edge of Interurban Avenue
 - Along both sides of I-405 between MP 1.0 and MP 1.4
 - At the southeastern interchange between SR 167 (MP 27.5) and I-405 (MP 2.6)
 - Along both sides of I-405 from Talbot Road (MP 2.8) to the Cedar River (MP 3.75)

¹ Panther Creek is located east of SR 167 approximately 0.2 miles south of SR 167 MP 25, as shown on Exhibits 6 and 7.

- **Soft Ground Areas** – Portions of the study area are underlain by soft ground areas that generally consist of soft clay, silt, or highly organic soil such as peat. These areas are likely to be encountered adjacent to younger alluvial or wetland deposits. Soft ground areas are located along both sides of the project corridor on SR 167 from MP 26.1 to MP 27.3. The soft ground areas are shown with respect to planned construction disturbance in Exhibits 30 through 32.
- **Seismic Hazard** – Seismic hazards are generally considered to be areas with a severe risk of ground shaking or deformation during an earthquake. Loose sand areas below the groundwater table can undergo a process called liquefaction² during a seismic event.

Mapped seismic areas are located along the majority of the project area and areas planned to be disturbed by construction, with the exception south of SW 41st Street on SR 167 and the I-405 corridor from SR 167 to 225 feet south of the Cedar River, as shown in Exhibits 27 through 34. Areas with a high seismic hazard are located along I-405 south of MP 0.7 and from MP 1.7 to MP 2.2.

- **Coal Mine Subsidence Hazard** – The Renton Formation has been mined for coal throughout the Renton area since the late 1800s. Mine subsidence hazard areas within the project area are located south of the I-405 interchange along the eastern side of SR 167 to approximately SW 23rd Street. They are also located along I-405 near MP 3.0 as shown on Exhibits 22, 23, 24, 25 and 26. Two large retaining walls, which in some areas may be up to 70 to 80 feet tall, are located along the cut walls of Thunder Creek and are associated with a new on-ramp from Talbot Road to northbound I-405 (see MP 3.05 on Exhibit 25). This area is within a mine subsidence hazard area. Recent borings and geophysical explorations indicate the upper 25 feet of the cut associated with the retaining wall will be through coal mine spoils over a portion of the wall alignment. Sandstone bedrock was encountered below the mine spoils in the explorations; however, a 3.5-foot void was encountered within the sandstone about 35 feet below the ground surface in one boring completed near the proposed wall alignment.

Based on historical maps available from the Washington State Department of Natural Resources (DNR), a coal mine tunnel entrance (Renton Coal Mine) was situated near Benson Road, about 300 feet west of the I-405 right-of-way near MP 3. Field notes from the original construction of I-405 suggest the mine tunnel was encountered during grading operations for I-405 and that the tunnel was backfilled. How much of the tunnel was backfilled is uncertain. The prevailing dip of the coal seams in the area suggests that the mine workings likely dip downward toward the east at approximately 10 degrees. So the old mine workings would generally be expected to be below the level of the bottom of the Thunder Creek retaining walls and the associated widening of I-405 to the east. However, there is some uncertainty regarding the exact location of the old mine workings, and caving of the open spaces from the mine workings may propagate upwards resulting in loosened rock and soils above the mine workings and possible void spaces.

² Liquefaction is a phenomenon where soils experience a rapid loss of internal strength as a consequence of strong ground shaking.

Exhibit 1: Description of Soil Units

Unit	Map Symbol¹	Description
Alderwood gravelly sandy loam	AgC, AgD	<p>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 on uplands and formed under conifers, in glacial deposits. Slopes are from 0 to 70 percent.</p> <p>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.</p>
Alderwood and Kitsap soils	AkF	<p>This unit is about 50 percent Alderwood gravelly sandy loam and 25 percent Kitsap silt loam. Slopes are 25 to 70 percent.</p> <p>Drainage and permeability vary. Runoff is rapid to very rapid, the erosion hazard is severe to very severe, and the slippage potential is severe.</p> <p>In a representative profile of Kitsap soils, 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.</p> <p>The permeability of this 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.</p>
Arents, Alderwood material	AmC	<p>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. Slopes generally range from 0 to 15 percent.</p> <p>Since these soils have been disturbed, there is no representative profile.</p>
Arents, Everett material	An	<p>Arents, Everett material consists mainly of Everett soils that have been so disturbed through urbanization that they can no longer be classified with the Everett series. The soil is level to gently sloping dark brown to olive brown gravelly sandy loam.</p> <p>Permeability is rapid in the soil and the erosion hazard is slight.</p> <p>Since these soils have been disturbed, there is no representative profile.</p>
Beausite gravelly sandy loam	BeC, BeD	<p>The Beausite series is made up of well-drained gravelly sandy loam that was underlain by sandstone at a depth of 20 to 40 inches. These soils formed in glacial deposits and are rolling to very steep with Slopes ranging from 6 to 75 percent.</p> <p>In a representative profile, the surface layer and the upper part of the subsoil are dark brown.</p>

1. The Map Symbol is an abbreviation of the unit as shown in the map exhibits.

Exhibit 1: Description of Soil Units (Continued)

Unit	Map Symbol¹	Description
Everett gravelly sandy loam	EvC and EvD	<p>This unit is made up of somewhat excessively drained soil that was formed by glacial outwash and is located on terraces and outwash plains. Slopes range from 5 to 30 percent.</p> <p>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.</p> <p>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.</p>
Indianola loamy sand	InC and InD	<p>This unit formed in sandy recessional stratified glacial drift and is composed of somewhat excessively drained soil on terraces and outwash plains. Slopes are 4 to 15 percent.</p> <p>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.</p> <p>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. This unit is mainly used as woodland and for urban development.</p>
Newberg silty loam	Ng	<p>The Newberg series is made up of well-drained soils that formed in alluvium in stream valleys, and under grass, hardwoods, and conifers. Slopes are 0 to 2 percent.</p> <p>In a representative profile, the surface layer is very dark grayish-brown silt loam and very fine sandy loam about 20 inches thick. It is underlain, to a depth of 60 inches or more, by stratified very fine sandy loam, loamy very fine sand, loamy sand and silt loam.</p>
Pilchuck loamy fine sand	Pc	<p>The Pilchuck series is made up of excessively drained soils that formed in alluvium on low stream terraces. Slopes are 0 to 2 percent.</p> <p>In a representative profile, layers of very dark gray, dark grayish-brown, and dark gray fine and loamy fine sand extend to a depth of about 38 inches. Below this is black gravelly sand that extends to a depth of 60 inches or more.</p>
Pits	PITS	<p>These features consist of open pit mines some of which were used as hard-rock quarries. None of the pits were underground mines.</p>
Puget silty clay loam	Pu	<p>The Puget series is made up of poorly drained soils that formed in alluvium in small depressions of river valleys. Slopes are 0 to 1 percent.</p> <p>In a representative profile, the soil is dominantly mottled dark grayish-brown and grayish-brown silty clay loam to a depth of about 45 inches. The substratum is gray silty clay that extends to a depth of 60 inches or more.</p>

1. The Map Symbol is an abbreviation of the unit as shown in the map exhibits.

Exhibit 1: Description of Soil Units (Continued)

Unit	Map Symbol¹	Description
Puyallup fine sandy loam	Py	<p>The Puyallup series is made up of well-drained soils that formed in alluvium, under grass, hardwoods, and conifers. These soils are on the natural levees adjacent to streams in the river valleys. Slopes are 0 to 2 percent.</p> <p>In a representative profile, very dark grayish-brown and dark grayish-brown fine sandy loam and very fine sandy loam extend to a depth of about 34 inches. The substratum, at a depth of 60 inches or more, is very dark grayish-brown, dark grayish-brown, and dark brown medium sand, loamy sand, and sand.</p>
Riverwash	Rh	<p>Riverwash consists of long, narrow areas of sand, gravel, and stones along channels of the larger streams. Some areas are barren of vegetation, and others support scattered cottonwoods, willows, and other trees and shrubs. Overflow and alteration by severe erosion and deposition are frequent.</p> <p>Since these soils have been disturbed, there is no representative profile.</p>
Seattle muck	Sk	<p>The Seattle series is made up of very poorly drained organic soils that formed in material derived primarily from sedges. These soils are in depressions and valleys on the glacial till plain and also in the river and stream valleys. Slopes are 0 to 1 percent.</p> <p>In a representative profile, the surface layer is black muck about 11 inches thick. It is underlain by dark reddish-brown, black, very dark brown and dark brown muck and mucky peat that extends to a depth of 60 inches or more.</p>
Snohomish silt loam	So	<p>The Snohomish series is made up of poorly drained soils that formed in alluvium in stream valleys. Slopes are 0 to 2 percent.</p> <p>In a representative profile, the surface layer and subsoil are very dark grayish-brown and 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.</p>
Tukwila muck	Tu	<p>The Tukwila series is made up of very poorly drained organic soils that formed in decomposing sedges, rushes, grasses, and shrubs. These soils are in wet basins of upland depressions and on stream bottoms. Slopes are 0 to 1 percent.</p> <p>In a representative profile, dominantly black to very dark brown muck extends to a depth of 60 inches or more.</p>
Urban land	Ur	<p>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. In the Green River valley the fill ranges from about 3 to more than 12 feet in thickness, and from gravelly sandy loam to gravelly loam in texture. The erosion hazard is slight to moderate.</p> <p>Since these soils have been disturbed, there is no representative profile.</p>
Woodinville silt loam	Wo	<p>The Woodinville series is made up of nearly level and gently undulating, poorly drained soils that formed under grass and sedges, in alluvium, and on stream bottoms. Slopes are 0 to 2 percent.</p> <p>In a representative profile, gray silt loam, silty clay loam, and layers of peaty muck extend to a depth of about 38 inches. This is underlain by greenish-gray silt loam that extends to a depth of 60 inches and more.</p>

1. The Map Symbol is an abbreviation of the unit as shown in the map exhibits.

Exhibit 2: Description of Geologic Units

Unit	Map Symbol¹	Description
Alluvium	Qa	Primarily composed of sand, silt and clay deposited by the Green River and sand and gravel with thin beds of silt and clay deposited by the Cedar River. Locally, alluvial deposits contain thin peat lenses.
Glacial Till	Qgt	Very dense, nonsorted mixture of clay, silt, sand, gravel, cobbles, and boulders. Upper 2 to 5 feet is often weathered and typically medium dense to dense.
Glaciolacustrine Deposits	Qgl	Clay, silt, silty clay, and silty fine sand with local dropstones; blue-gray or gray, weathered to pale yellowish-brown; locally contains thick beds of structureless, clast-rich diamicton that may be flow till or iceberg melt-out contact zones; also locally contains lenses and beds of fine- to medium-grained sand; stiff or dense; well sorted.
Intrusive Rocks (bedrock)	Oian	Irregular masses of porphyritic andesite and basalt. Material is generally intersected by numerous faults and joints, and by veins of montmorillonite, calcite, quartz and other minerals.
Mass-wasting Deposits	Qls	Primarily landslide deposits, but locally includes talus, colluvium, protalus ramparts, and rock glaciers.
Recessional Outwash	Qgo	Silty fine sand to clean coarse gravel with occasional cobbles and boulders. Due to the fluvial nature of deposition of recessional outwash, materials are generally stratified.
Renton Formation (bedrock)	Ec(2r)	Fine- to medium-grained arkosic and feldspathic, micaceous sandstone, but includes some siltstone, sandy shale, and beds of coal and carbonaceous shale. Sandstone is highly variable and ranges from completely weathered to fresh. Also contains seams and zones, which are poorly lithified or even uncemented.
Tiger Mountain Formation (bedrock)	Ec(2t)	Light-colored, medium grained, micaceous feldspathic subquartzose sandstone interbedded with siltstone, minor pebble conglomerate and coal beds.
Tukwila Formation (bedrock)	Evc(t)	Volcanic sedimentary rocks mostly composed of volcanic sandstone, siltstone, and shale; also include some volcanic conglomerate, tuff, tuffaceous sandstone, and siltstone, and a few carbonaceous shales. Fragments of wood and other plant remains are common throughout. Most are various shades of brown; some of the finer grained tuffs, however, are light gray to light dusky yellow, and a few are almost white. For the most part, they are poorly sorted; some of the finer grained tuffaceous rocks, however, are thinly bedded and well sorted. The sedimentary rocks are composed chiefly of subangular to subrounded fragments of andesite and basaltic andesite, and grains of plagioclase, pyroxene, and small amounts of quartz in a matrix of silt, iron oxide, and clay minerals.
Undifferentiated Glacial Drift	Qgpc	Thin deposits of recessional outwash overlying glacial till (described above).
Wetland Deposits	Qp	Peat and organic material with minor amounts of silt and clay or mixtures of silt, clay, sand, and peat. Some deposits also contain a thin layer of volcanic ash. Where mapped, the peat and organic material is consistently 3 feet or more thick.

1. The Map Symbol is an abbreviation of the unit as shown in the map exhibits.

Potential Effects

Will the project affect soils or geology?

The anticipated construction conditions along the alignment are not unusual for the Puget Sound area. These types of conditions are routinely encountered by WSDOT and are resolved with implementation of standard BMPs. Relevant construction conditions along the study area include:

- Disturbance of moisture sensitive soils,
- Temporary 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 commitment in following these compliance measures, effects from soils and geology will be few, if any. No substantial adverse affects 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 highly variable geologic environment. The majority of the project is located within the Green-Duwamish and Cedar River valleys, which are underlain by relatively loose soil and a shallow groundwater table. The conditions along the alignment are not unusual for the Puget Sound area and generally present conditions routinely encountered by WSDOT in their design, construction, operation, and maintenance plans. However, the presence of erosion hazard areas and erosion susceptible soils, soft ground areas, liquefaction-prone soils, and mine subsidence hazards may affect the project and will be prominent design and construction considerations. 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, geology and soils should have essentially no affects on the built project.

Soils and Erosion

Erosion risk is usually assessed by looking at 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 a storm event, particularly when stockpiled prior to being placed during construction.

In addition, most of the soils that will be encountered during construction are moisture sensitive. These soils include alluvium, till, weathered bedrock 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.

Landslide Hazard Areas

Cuts into landslide-prone slopes may destabilize slopes creating landslide hazard areas. 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.

Soft Ground Areas

Soft, compressible soils will settle under new loads such as those imposed by new bridges, retaining walls and fill embankments if they are not designed to account for the soft ground conditions. Soft compressible soils underlying transportation corridors are common in the region and WSDOT has considerable experience designing new improvements to accommodate these types of soils.

Seismic Hazard Areas

The majority of the project area is considered to be a seismic hazard area because soils in those areas are prone to liquefaction. The project will widen, construct, or reconstruct numerous bridges. All of these bridges (proposed and existing) may be underlain by soils considered to be moderately to highly susceptible to liquefaction. New structures, such as bridges, 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 such as approaches to bridges are susceptible to lateral spreading (slope deformations) if soils below the embankments liquefy. Lateral spreading of bridge approach fills could subsequently increase lateral loads to the adjacent bridge piers.

Mine Subsidence Hazard Areas

Mine spoils near the top of the proposed cut for the Thunder Creek retaining walls are loose and would be unstable if cut too steeply. Therefore, retaining wall designs and construction techniques must be able to accommodate both loose soils along the top of the wall and dense sandstone in the lower half of the wall. Voids associated with the previous mine workings could impact wall stability and result in long-term settlement of the roadway.

What are the unavoidable adverse effects?

Unavoidable adverse effects include disturbance of moisture-sensitive soils, cuts in landslide-prone areas, increased erosion potential, wall stability and long-term settlement of the roadway 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?

The majority of potential adverse effects associated with the construction and operation of the project will be avoided or minimized through the use of BMPs, from following the procedures outlined in the WSDOT Geotechnical Design Manual (GDM) and Bridge Design Manual, and from following the I-405 Programmatic Commitments. Avoidance measures are discussed below in the following sections.

The effects described in the previous section 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 commitment in following these compliance measures, effects from soils and geology will be few, if any. No substantial adverse effects to soils and geology are anticipated from the project build alternative.

BMPs and other measures will be incorporated into construction specifications to control or reduce construction related erosion and sedimentation, increase infiltration (where appropriate), reduce seismic and soft ground hazards, improve safety in landslide hazard areas, and address collapsed mine openings or underground rooms associated with historic mining activities. Design solutions to avoid, minimize, or mitigate disturbance to geologic, seismic, and mine hazard areas will be implemented.

Gravel from imported sources outside of the study area will be required. Standard WSDOT contract language requires imported materials to come from approved sources whose operations comply with all applicable laws.

Vibration Effects of Construction Equipment

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 and increase the distance between source and receptor. For example, a drilled pile could be substituted for a driven pile to reduce vibrations in some instances. Potential impacts to structures and people will be evaluated on a site-specific basis during design.

Erosion and Soils

WSDOT will prepare and implement a temporary erosion and sedimentation control (TESC) plan. A TESC plan consists of operational and structural measures to control the transport of sediment. Operational measures consist of good housekeeping practices, such as removing mud and dirt from trucks before they leave the site, covering fill stockpiles or disturbed areas, use of temporary or permanent erosion control blankets, mulching, or soil amendment to promote plant growth, and avoiding unnecessary vegetation clearing. Structural measures consist of the construction of temporary structures to reduce the transport of sediment, such as detention ponds, ditches, silt fences, or sediment traps. Should any BMP or other operation not function as intended, WSDOT will take additional action to minimize erosion.

WSDOT will reduce degradation of moisture-sensitive soils by maintaining proper surface drainage to avoid surface water ponding; by minimizing ground disturbance through limiting the use of heavy equipment, limiting turns, and/or not tracking directly on the subgrade; and by covering the final subgrade elevation with a working mat of crushed rock and/or geotextile for protection. Soil admixtures such as lime or cement may also be mixed into the subgrade to add strength and stabilize the ground.

Landslide Hazard Areas

Analyses of slope stability and design of mitigation measures, such as retaining walls, buttresses, and groundwater control, will be performed during the design of excavations or embankments on hillsides. WSDOT will design retaining walls for undercut and potentially unstable slopes. Cleared slopes will be covered per permit requirements in the rainy season.

Facilities in landslide hazard areas can be designed to be safely constructed and operated. 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.

WSDOT will have earthwork and wall placement sequencing plans, construction drainage plans, and a slope monitoring program. During construction, areas of observed or suspected groundwater seepage will be drained to reduce the risk of landslide and surface sloughing through the use of gravel drainage blankets, French drains, horizontal drains and/or placement of a surface rock facing or similar methods.

Soft Ground Areas

During the design process, WSDOT will assess potential settlement problems associated with existing utilities or structures and design appropriate solutions, such as underpinning of structures by supporting them on deep foundations gaining support below the compressible soils and protecting or relocating utilities. Other techniques that may be employed are to stage construction of embankments so the soil has

time to gain strength; wick drains to hasten consolidation and strength gain; construct embankments of light-weight materials to minimize loading; reinforce embankments with geosynthetics to add strength and minimize the footprint; induce settlement of the underlying soils through the use of preloads prior to constructing the infrastructure; construct on pile supports; and increase grades to keep pavement above groundwater. Soft ground hazards at bridge locations will be mitigated by founding the structures on deep foundations.

Seismic Hazard Areas

Bridges constructed on liquefaction-prone soils will be founded on deep foundations and/or the soil under the bridges will be improved so that they are no longer susceptible to liquefaction. Soil improvement measures will likely consist of stone columns, compaction grouting, or similar soil densification techniques. Approach embankments within 100 feet of bridge abutments will also be designed for seismic conditions, including liquefaction. These measures will be implemented to minimize damage during an earthquake. WSDOT will select measures that will minimize the effect on adjacent properties.

In accordance with the WSDOT GDM, retaining walls will be designed to remain stable under seismic loading conditions and anticipated displacements associated with liquefaction. Mitigation, such as founding walls on deep foundations or improving the underlying soils, to achieve overall stability may be required. Likewise, bridge structures and approach embankments within 100 feet of bridge abutments will be designed for seismic loading and to resist or accommodate liquefaction-induced displacements, according to the WSDOT GDM. WSDOT will select measures that will minimize the effect on adjacent properties.

Mine Subsidence Hazard Areas

WSDOT will design the project to avoid adverse settlement or subsidence effects from abandoned mine workings. If necessary, avoiding settlement or subsidence may be accomplished by bridging over these areas with a structural slab or by backfilling the voids. 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.

For design of the Thunder Creek retaining walls and the adjacent widened I-405 lanes, design standards will be followed to ensure the soils will retain enough bearing to accept the load of the wall and roadway. If there appears to be a possibility of a collapsed mine opening or underground room near the proposed facilities, the design will include measures to bridge over these areas, fill them in, or otherwise mitigate the subsidence potential.

Acronyms and Abbreviations

Acronym	Meaning
BMPs	Best management practices
BNSF	Burlington Northern Santa Fe Railway
DNR	Washington State Department of Natural Resources
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
HOV	High-occupancy vehicle
LIDAR	Light Distance and Ranging
MP	Milepost
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.
advance outwash	Layered and sorted sediments (chiefly sand and gravel) washed out from an advancing glacier by melt-water streams and deposited beyond the margin of the glacier. The coarser material is deposited nearer to the glacier.
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.
colluvium	Loose, heterogeneous mass of soil and/or rock fragments deposited on the ground surface by rain wash, sheet wash, or soil creep.
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.
fault	A fracture or zone of fractures of the earth's crust along which displacement has occurred parallel to the fracture.
fill	Any material placed in an area to increase surface elevation.
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.
glacial till	The mass of rocks and finely ground material carried by a glacier and then deposited when the glacial ice melts. This creates an unstratified material of varying composition.
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.
impervious surface	Pavement, roofs, and other compacted or hardened areas that do not allow the passage of rainfall or runoff into the ground.

infiltration	The passage of water through the soil surface into the subsoil.
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.
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.
reconnaissance-level field survey	A qualitative investigation, where the biologist walks the site, photographs key areas, and makes observations of plants and wildlife, to assess overall site conditions.
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.
runoff	Rainwater or snowmelt that leaves an area as a surface drainage.
saturated soil conditions	A condition in which all easily drained voids (pores between soil particles) in the root zone are filled with water to the soil surface.
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.
sedimentary rock	A rock type composed of sediments weathered from pre-existing rocks, from the chemical precipitation of dissolved minerals, or the accumulation of living material. Examples of sedimentary rocks include sandstone, shale, coal, and limestone.
seep	A spot where water trickles out of the ground to form a pool or wet area.
seismicity	The frequency or magnitude of earthquake activity in a given area.
silty loam	A type of soil that is rich in organic materials mixed with fine clay-like particles.
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.
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.
sub-basin	A smaller portion, or sub-area, of a watershed or catchment area.
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.
Vashon Stade	The most recent Pleistocene glacial advance and retreat in the Puget Sound region, occurring approximately 14,000 years ago.
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.

References

GIS Data Sources

Exhibits 3 thru 10

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Exhibits 19 thru 26

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Exhibits 27 thru 34

King County Standard GIS Data Disk, extract:

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Base Data

All GIS exhibits contain one or more of the following as base layers:

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King County Standard GIS Data Disk, extract June 2006:

- 2004 Cities with annexations.
- 2005 Open Water.
- 2006 Parks in King County. Data updated by I-405 staff to match data from cities of Renton and Tukwila.
- 2005 Streams and Rivers. Data updated by I-405 staff to match fieldwork, 2002 LiDAR, and orthorectified aerial photography.
- 2005 Trails in King County. Data updated by I-405 staff to match fieldwork, 2002 LiDAR and orthorectified aerial photography.

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Yount, J.C., Dembroff, G.R., and Barats, G.M.

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Exhibit 3: Soil Units, Sheet 1

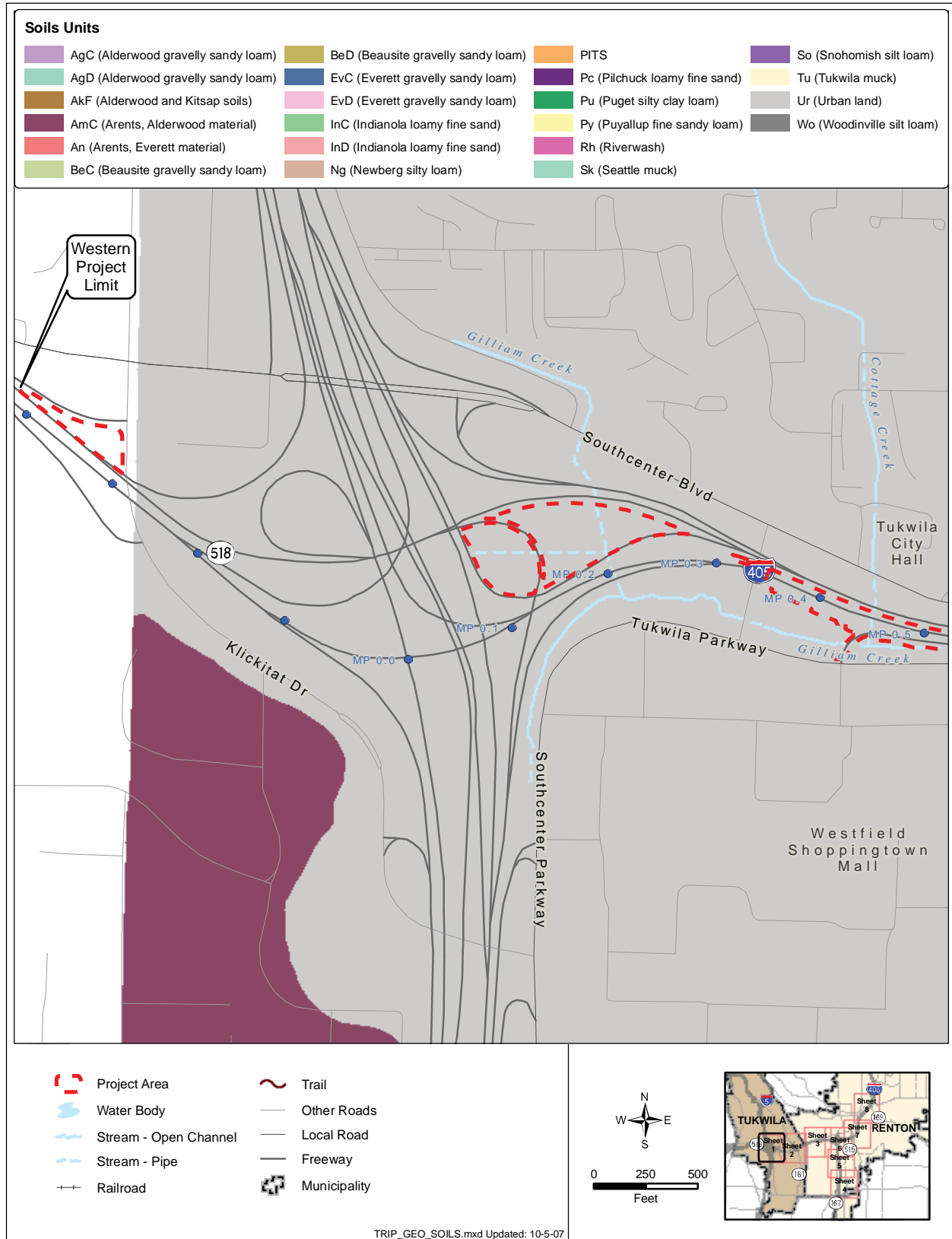


Exhibit 4: Soil Units, Sheet 2

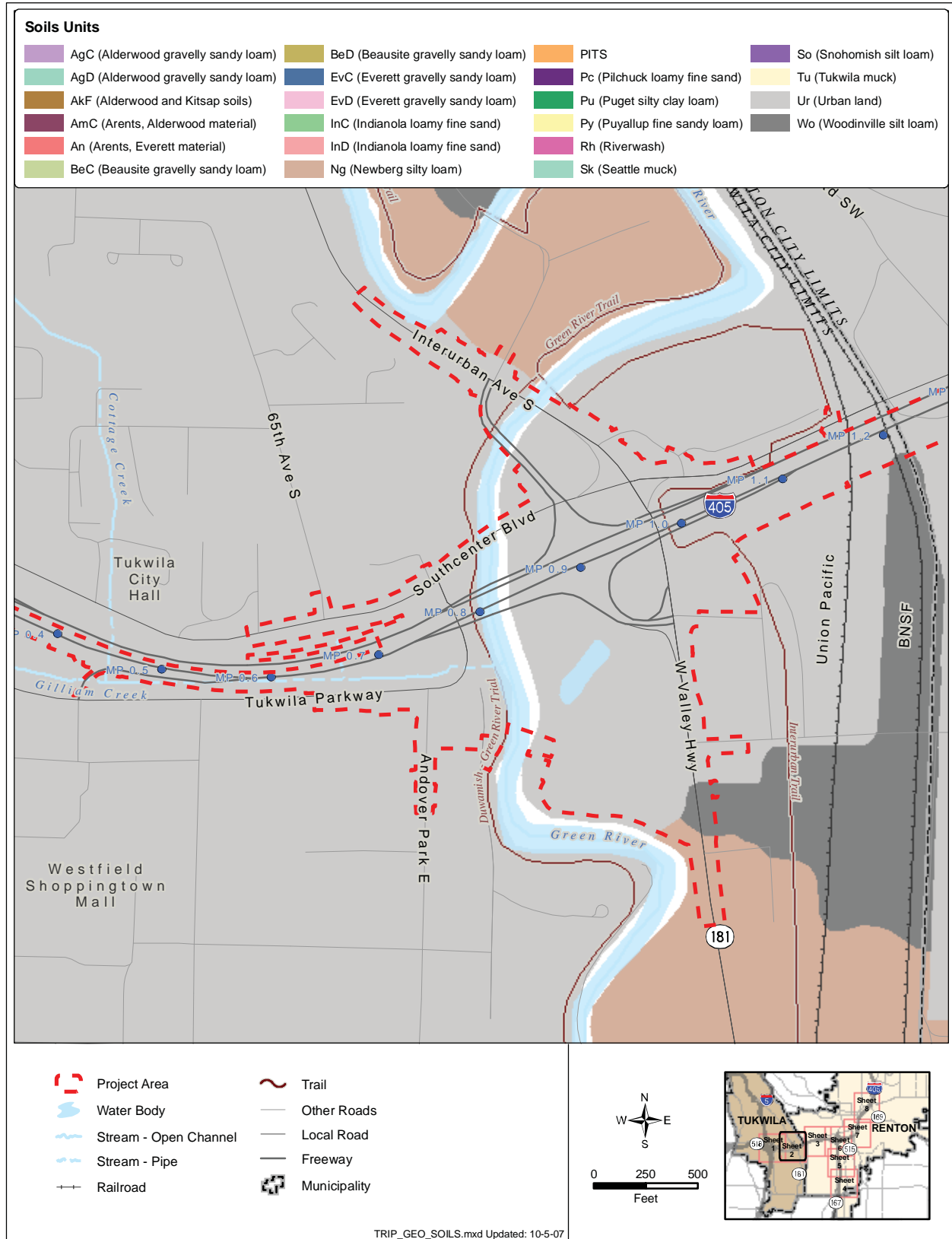


Exhibit 5: Soil Units, Sheet 3

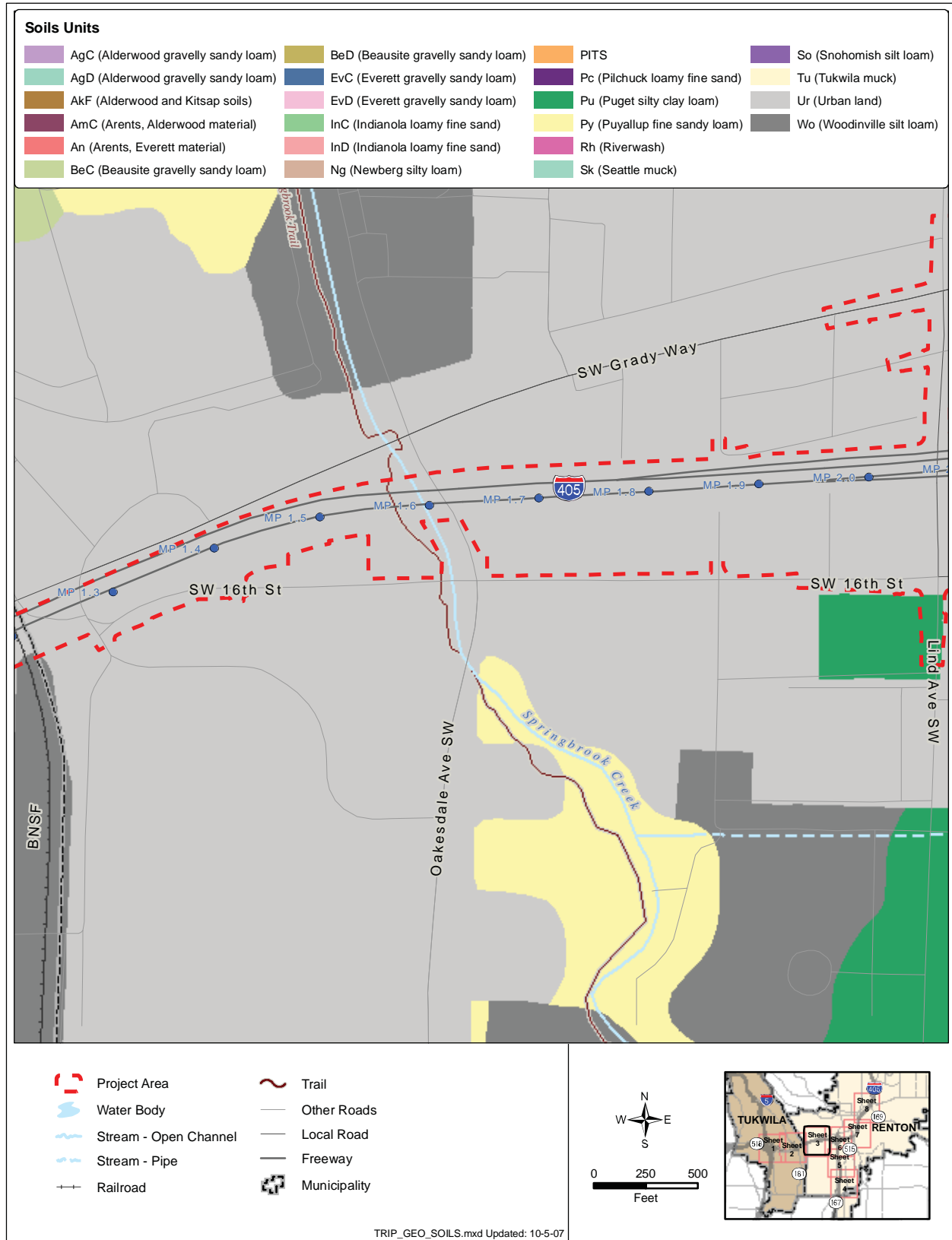


Exhibit 6: Soil Units, Sheet 4

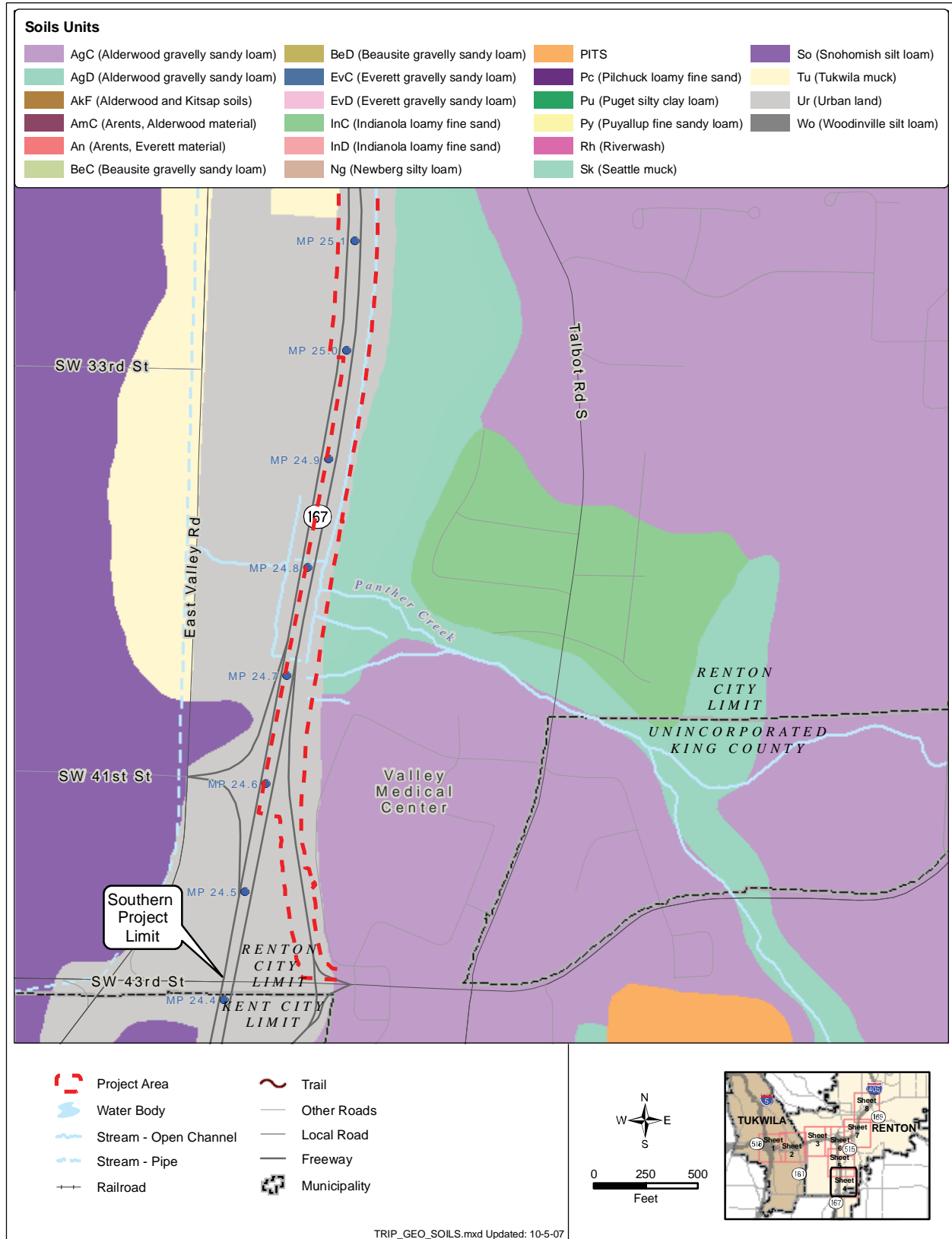


Exhibit 7: Soil Units, Sheet 5

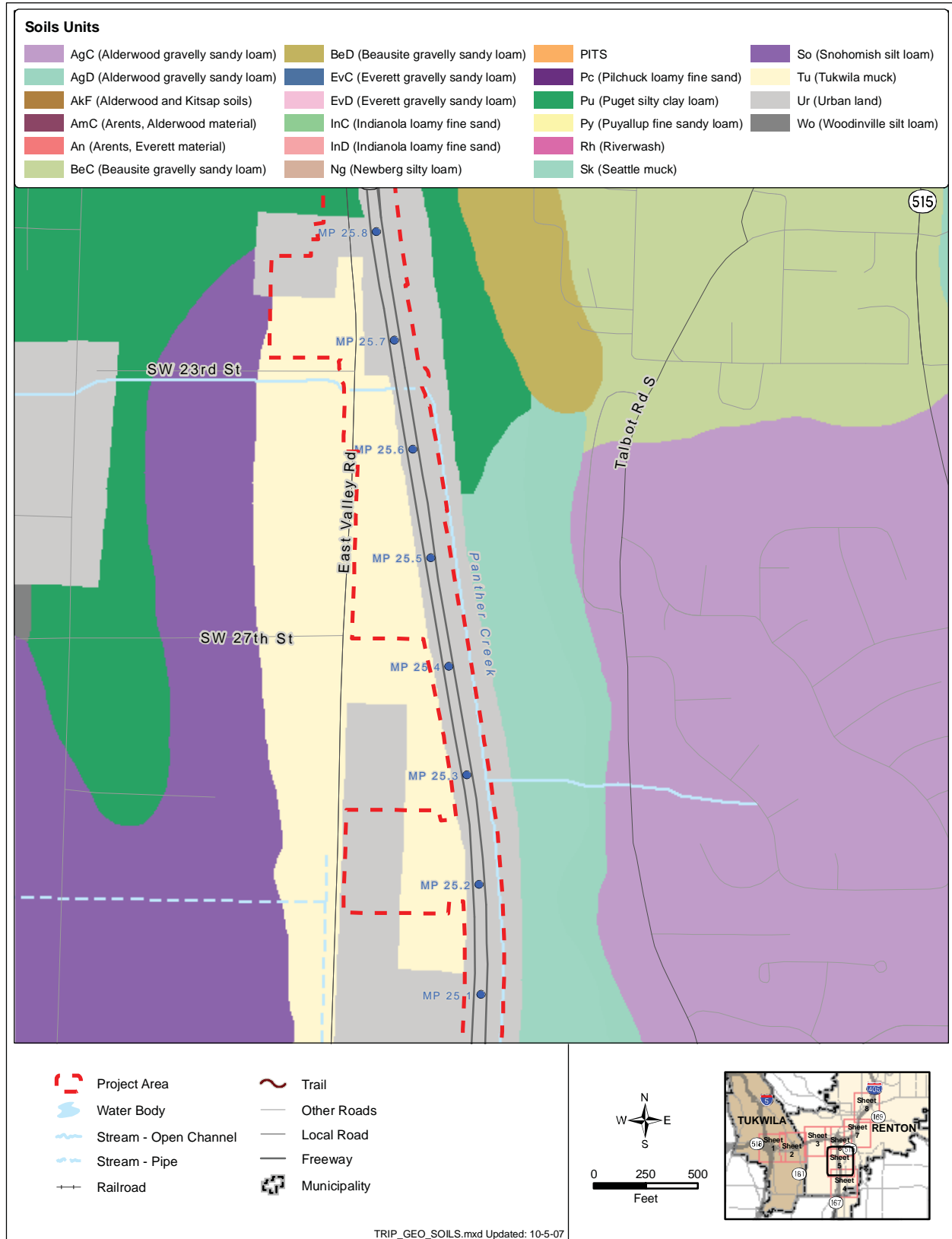


Exhibit 8: Soil Units, Sheet 6

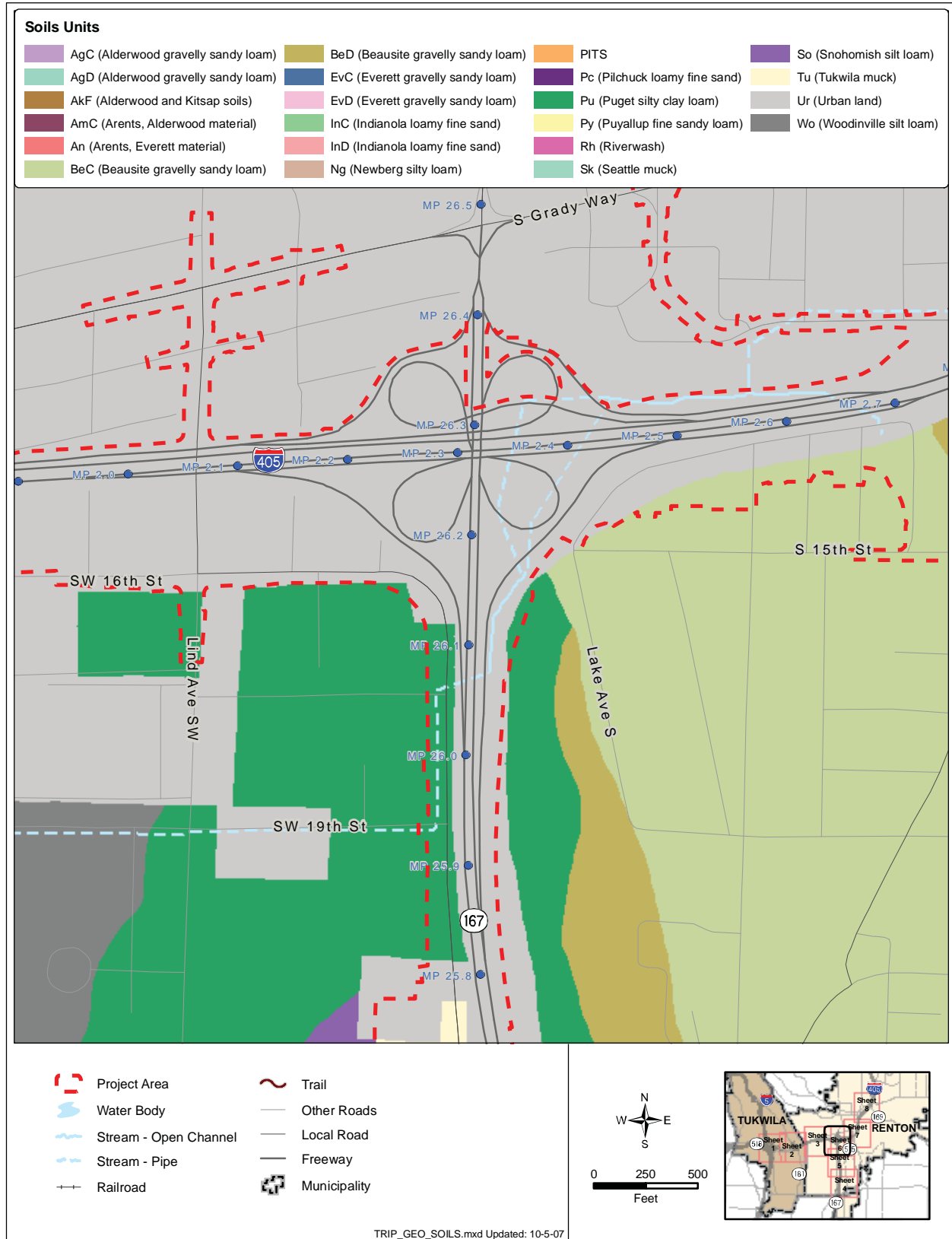


Exhibit 9: Soil Units, Sheet 7

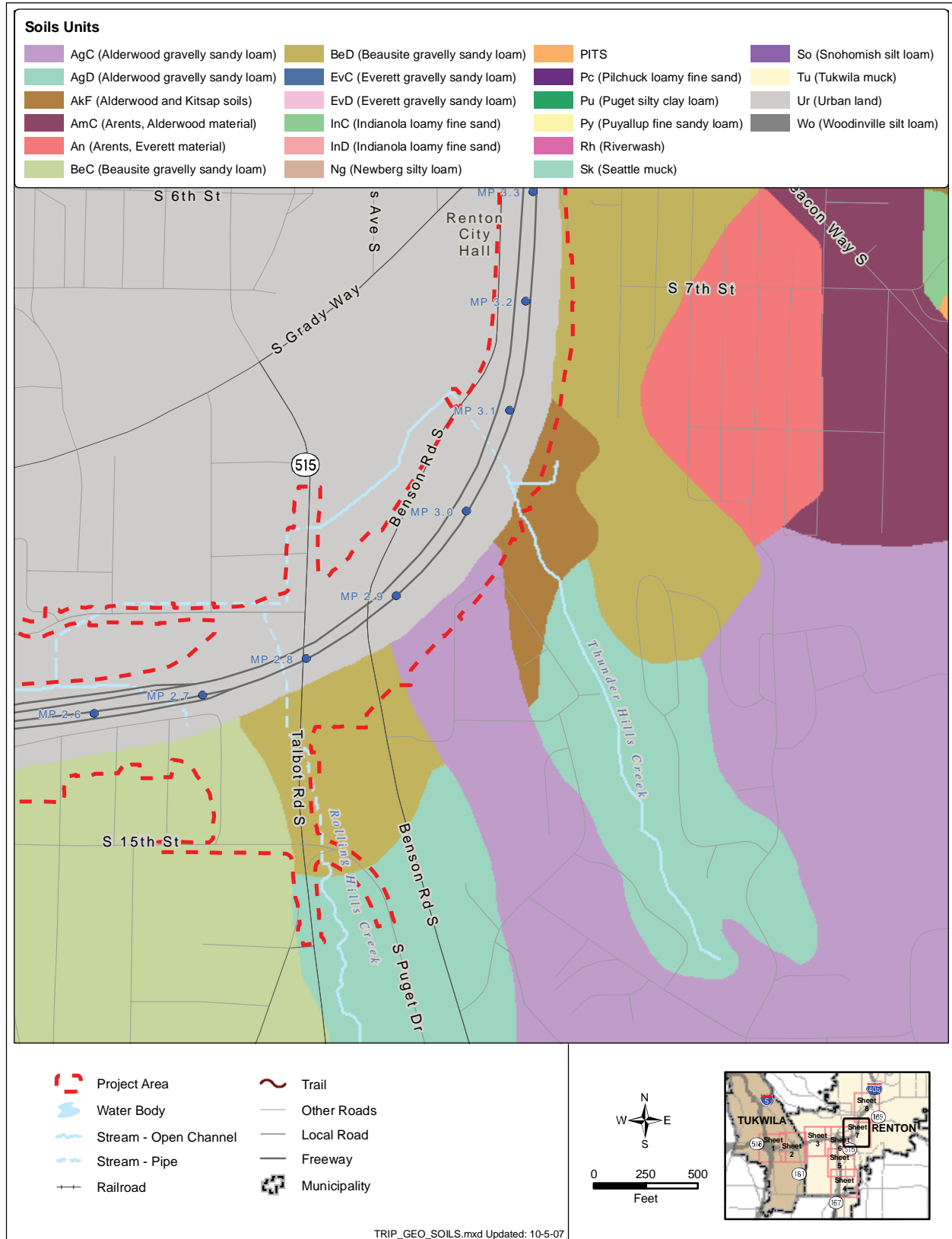


Exhibit 10: Soil Units, Sheet 8

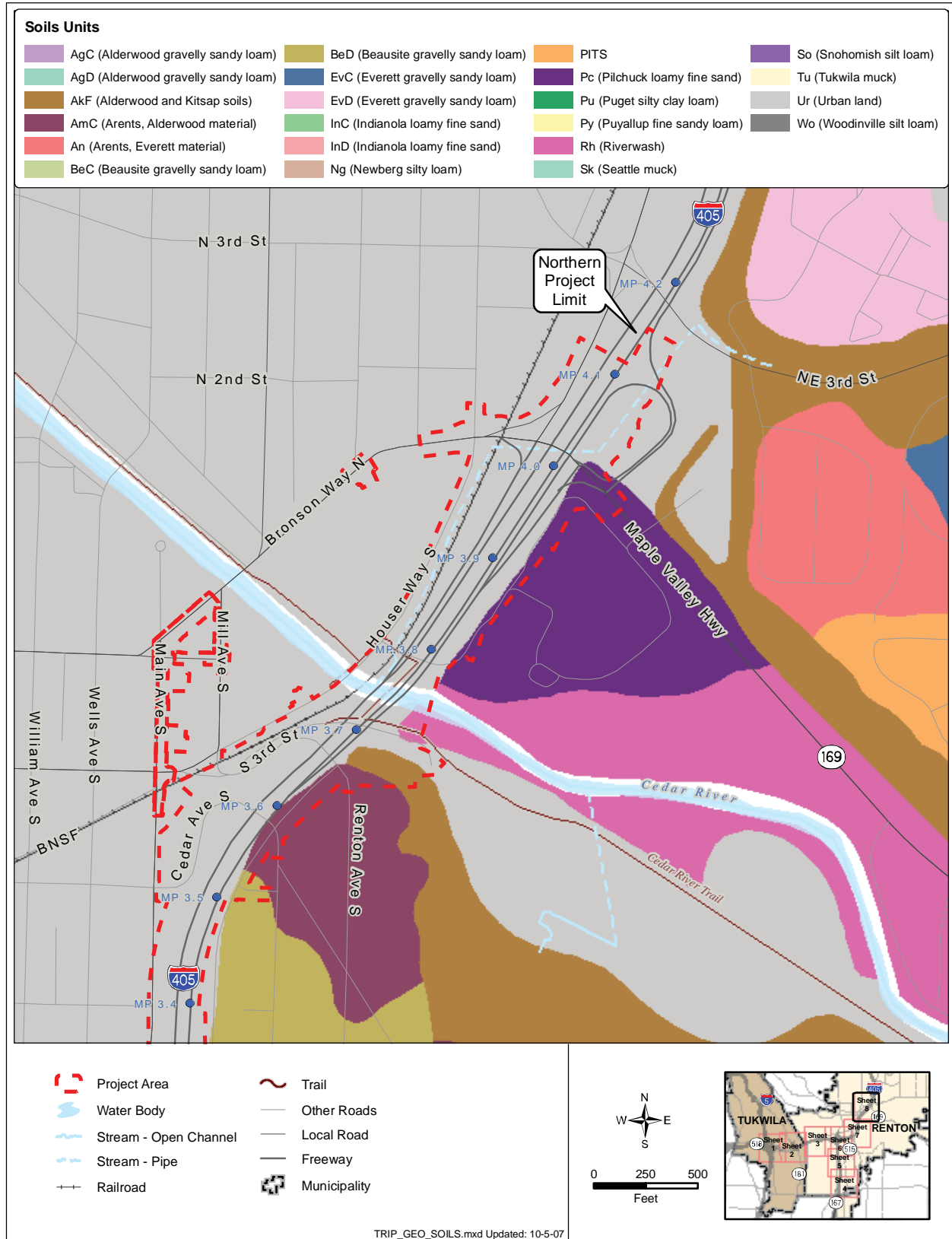


Exhibit 11: Surface Geologic Units, Sheet 1

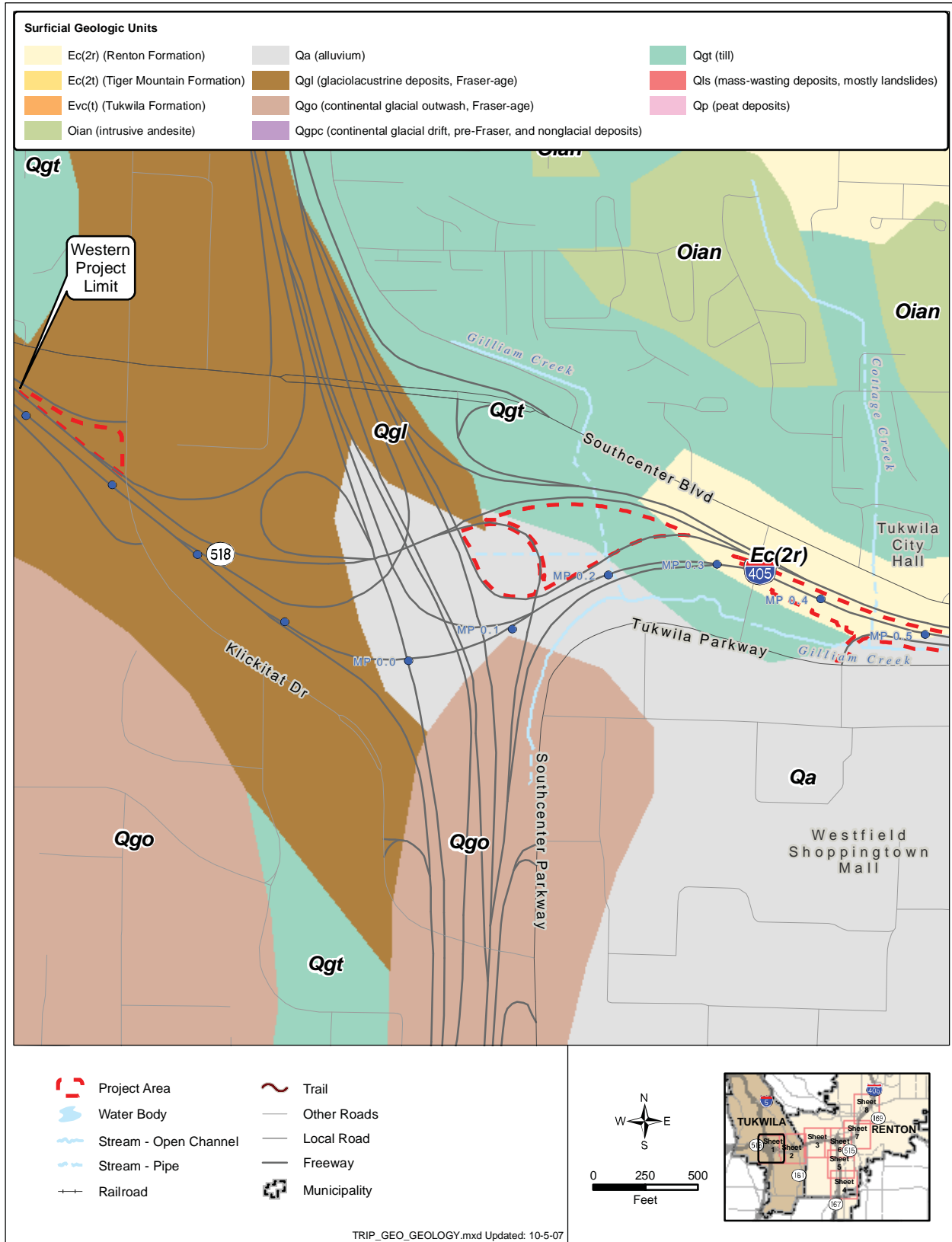


Exhibit 12: Surface Geologic Units, Sheet 2

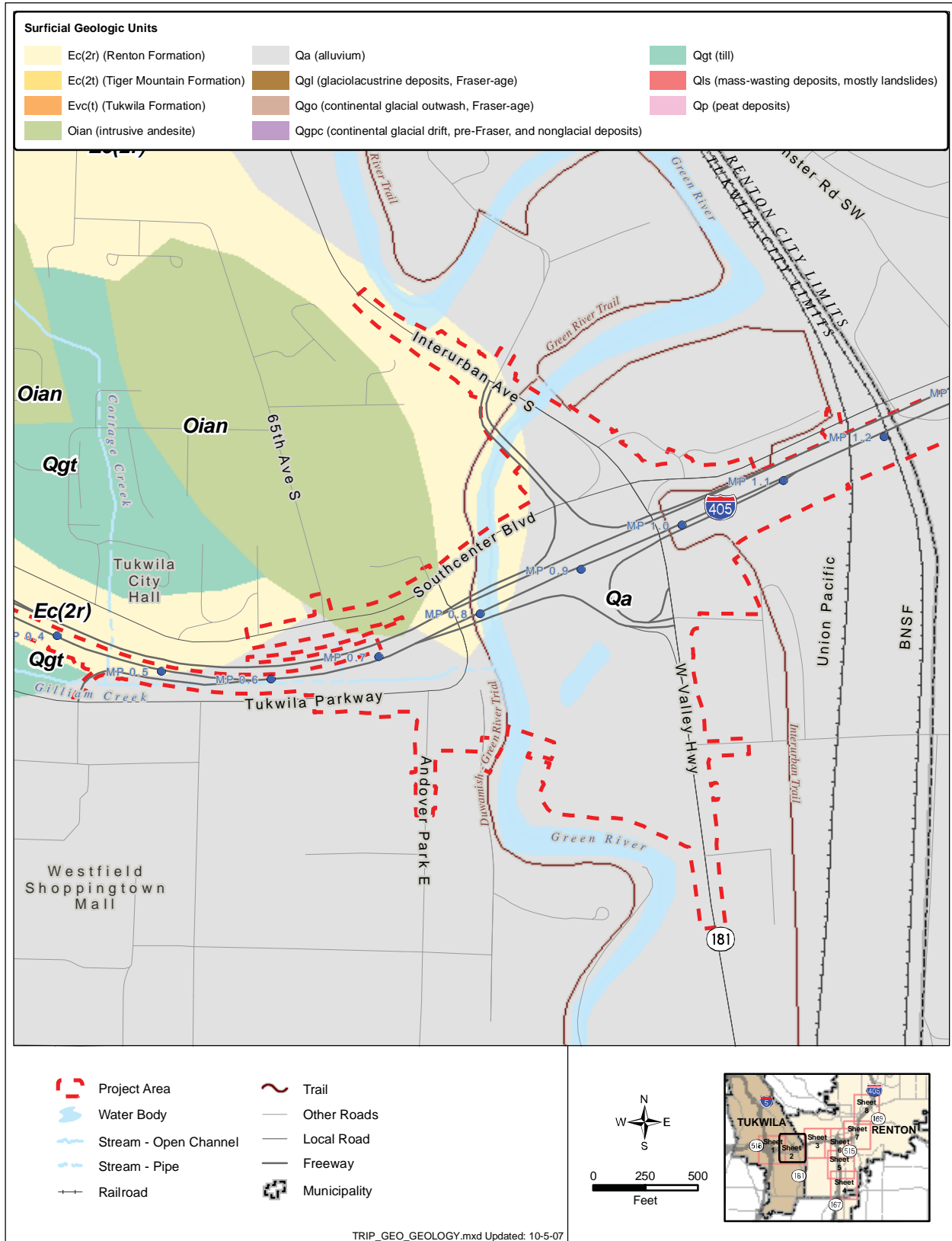


Exhibit 13: Surface Geologic Units, Sheet 3

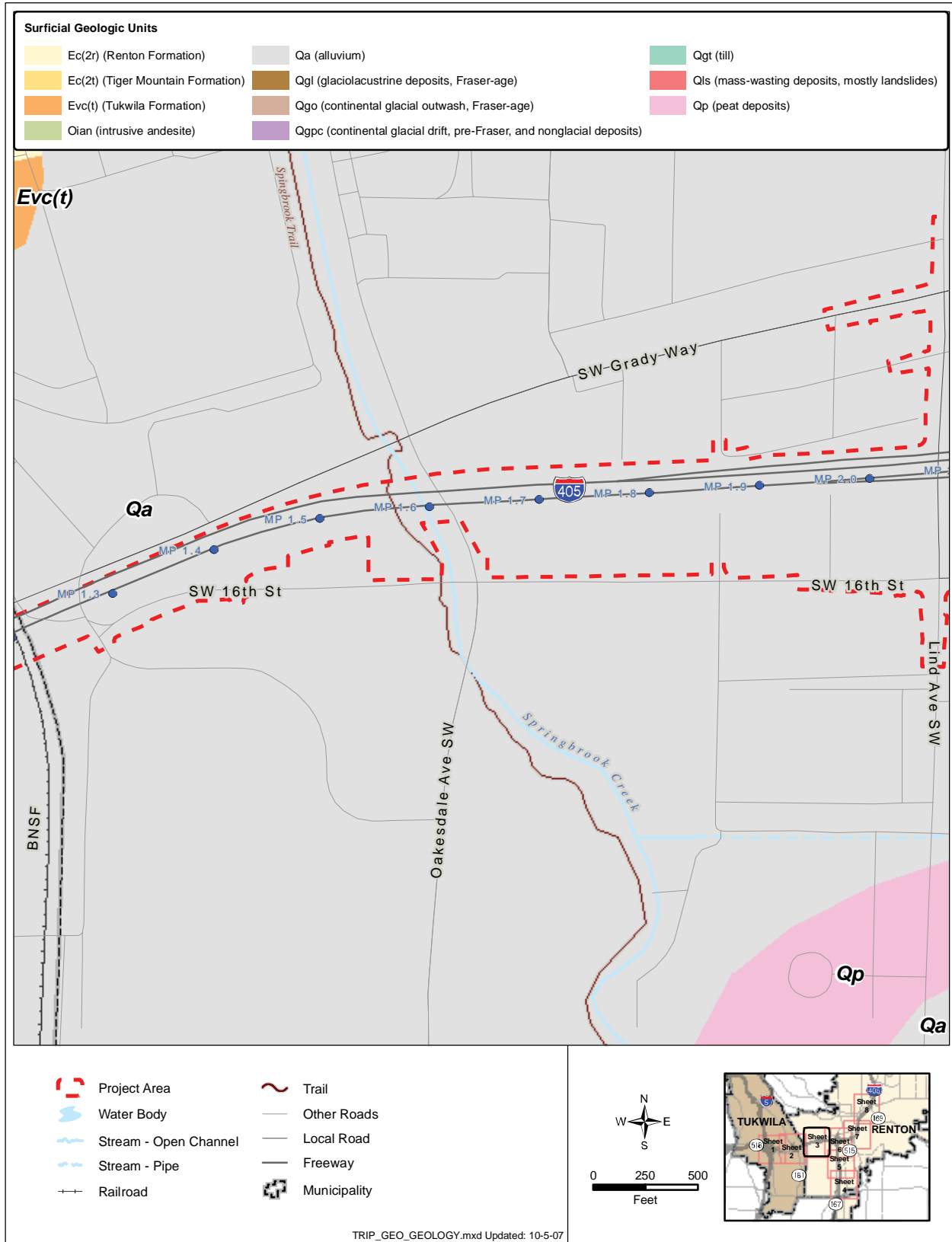


Exhibit 14: Surface Geologic Units, Sheet 4

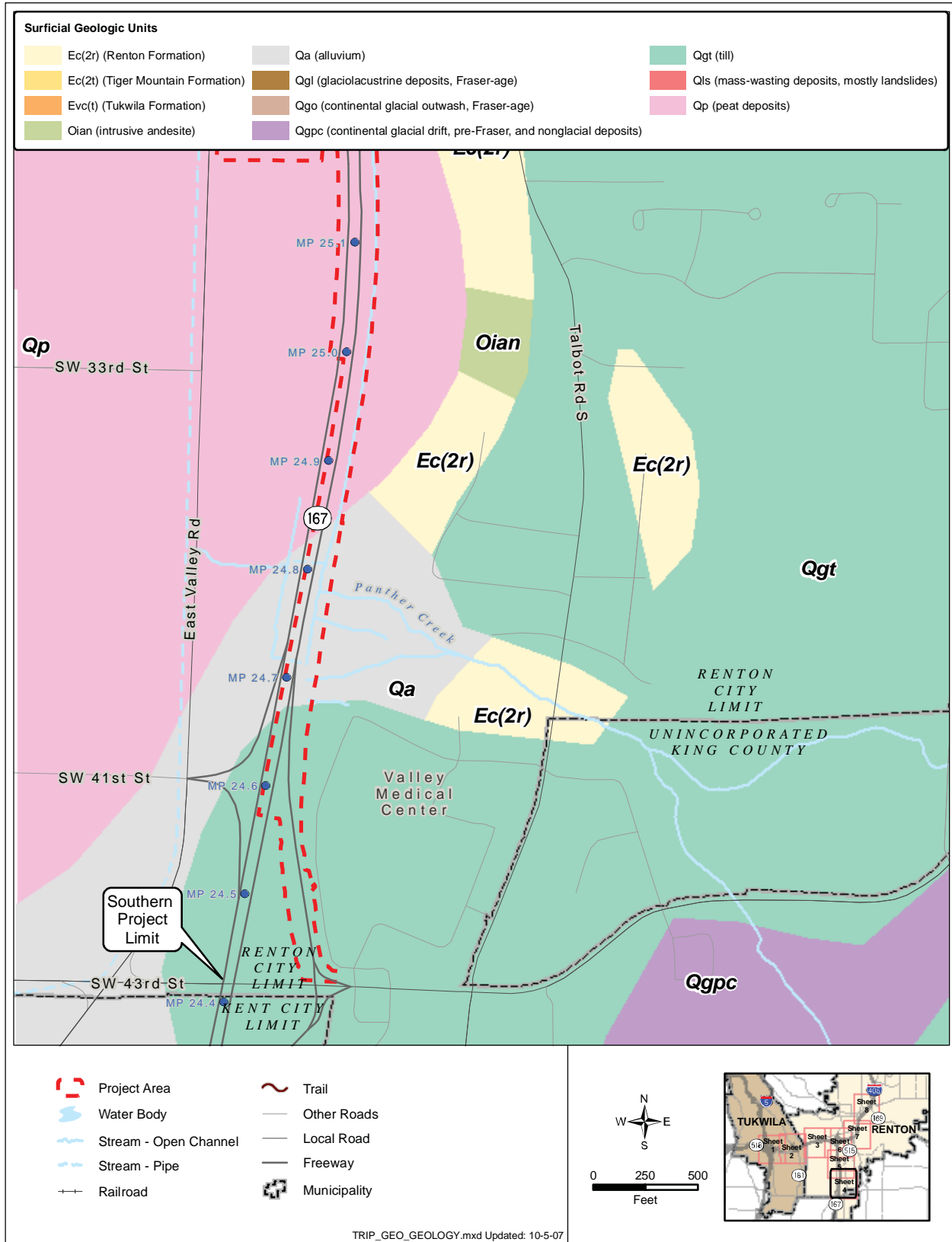


Exhibit 15: Surface Geologic Units, Sheet 5

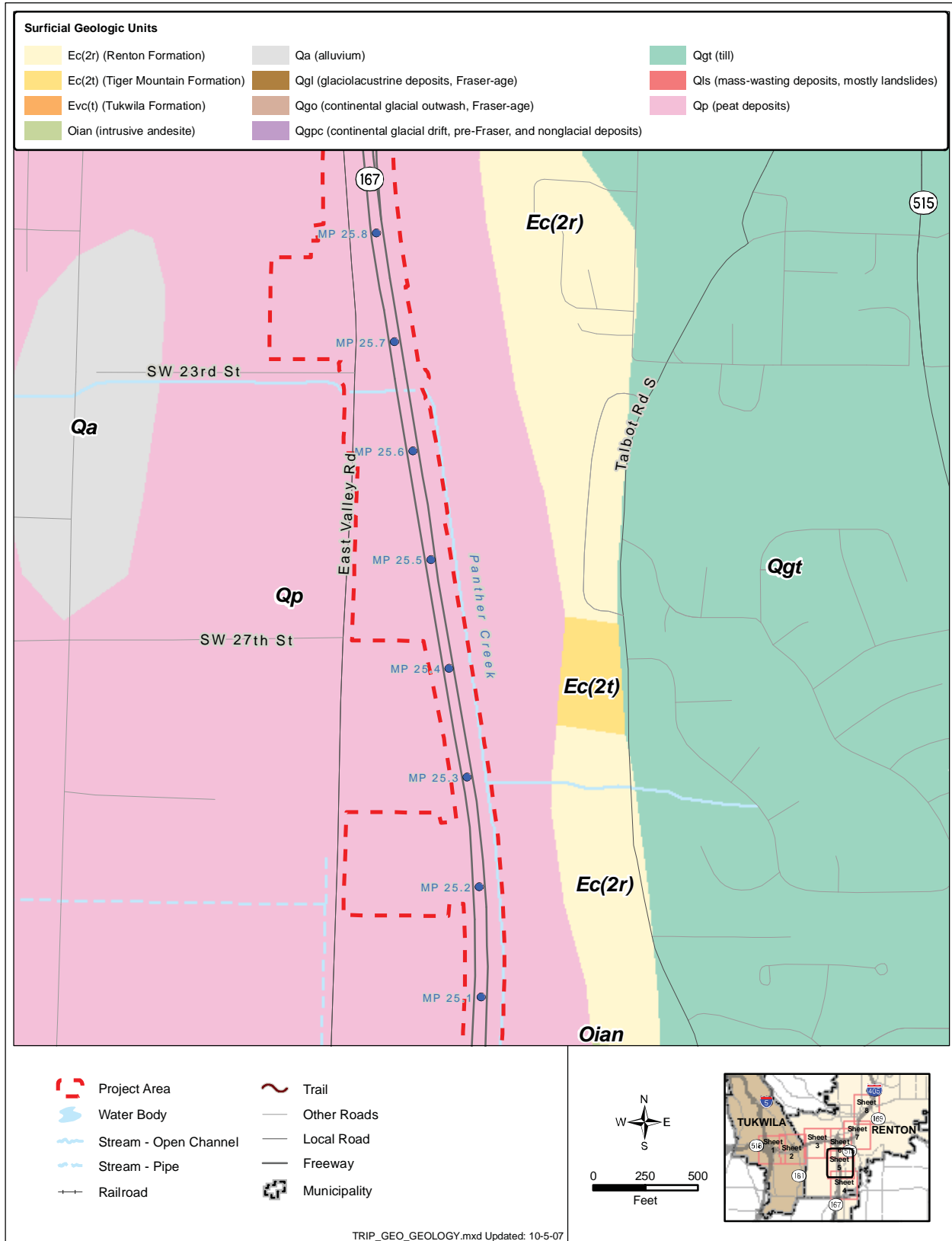


Exhibit 16: Surface Geologic Units, Sheet 6

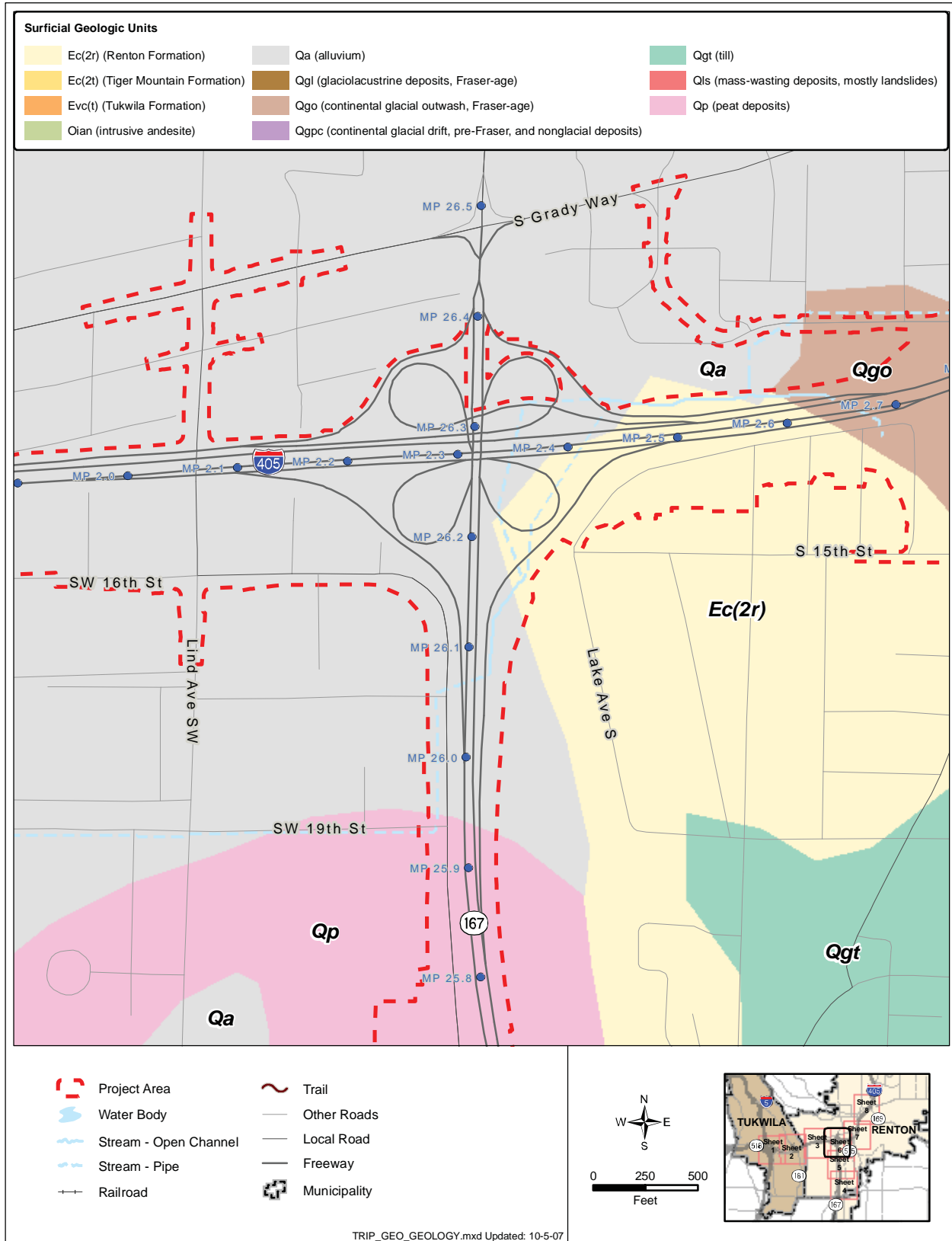


Exhibit 17: Surface Geologic Units, Sheet 7

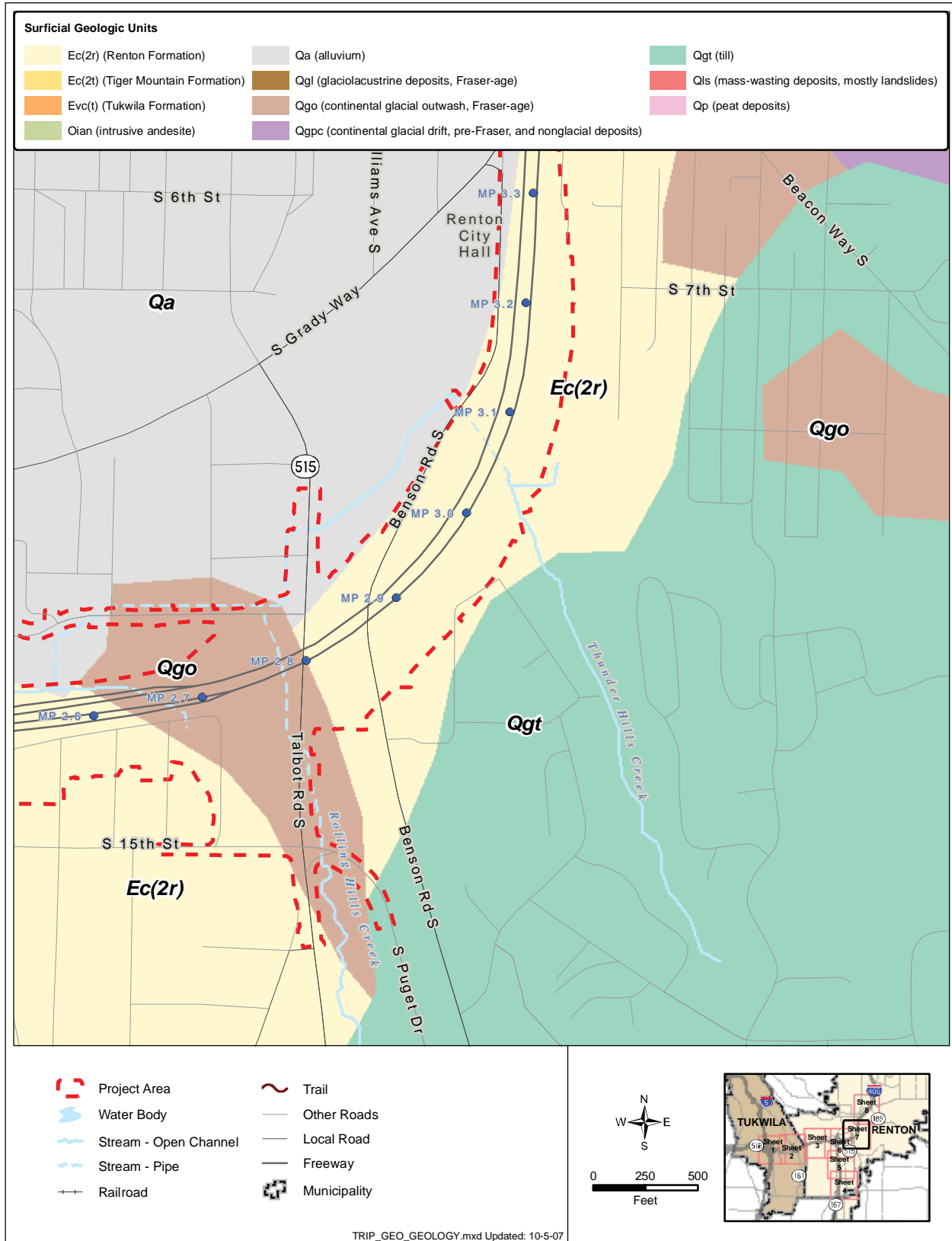


Exhibit 18: Surface Geologic Units, Sheet 8

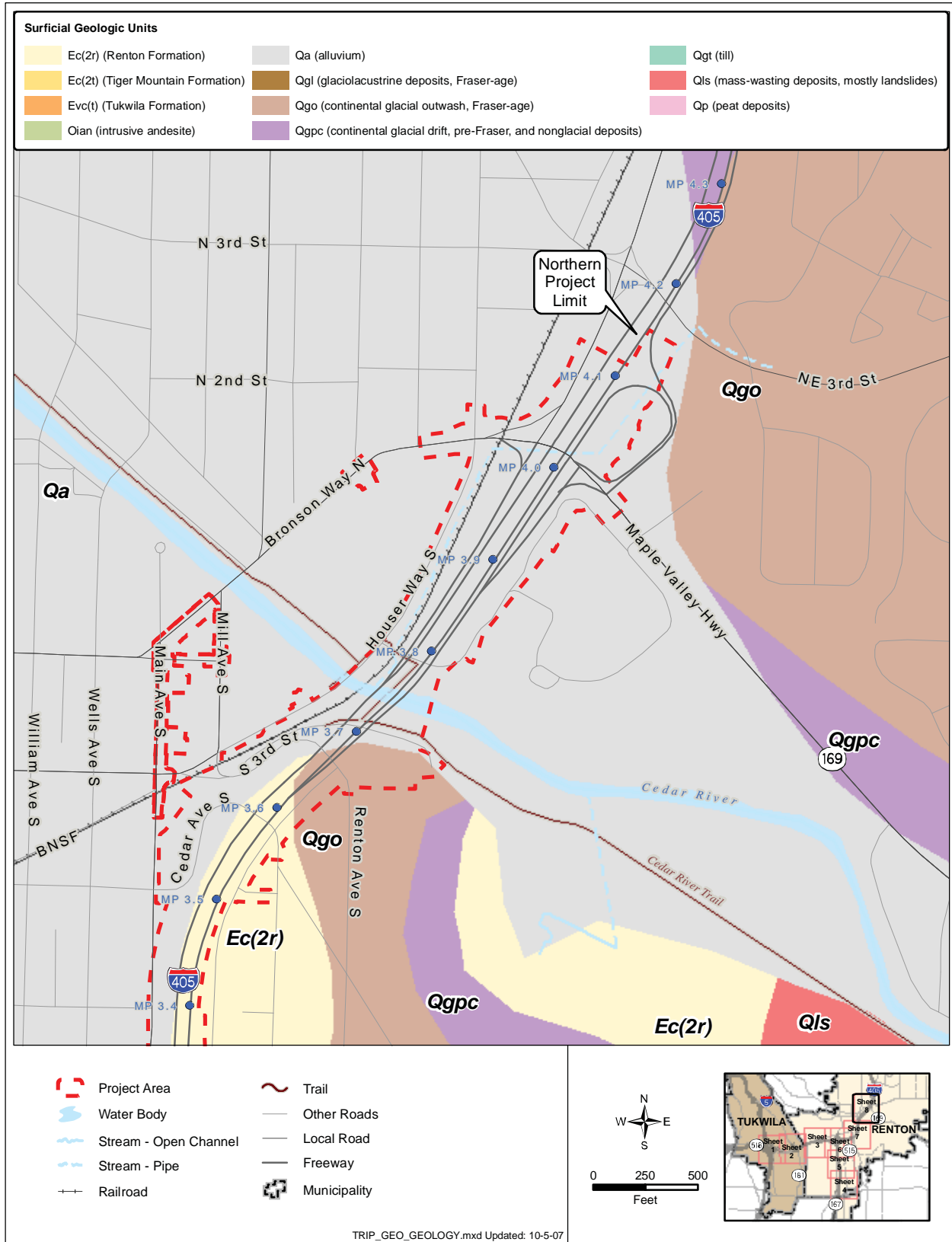


Exhibit 19: Geologic Hazard Areas, Sheet 1

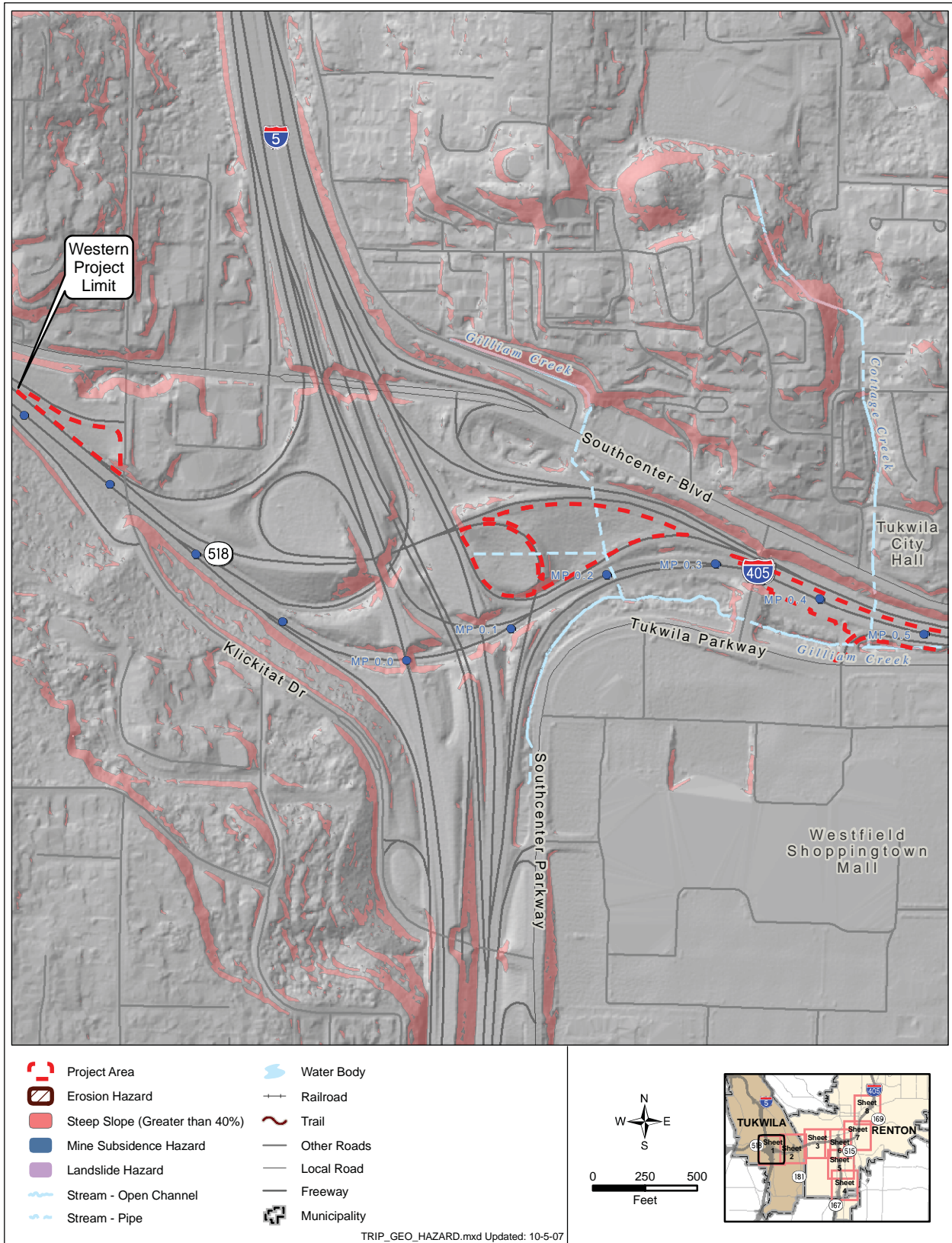


Exhibit 20: Geologic Hazard Areas, Sheet 2

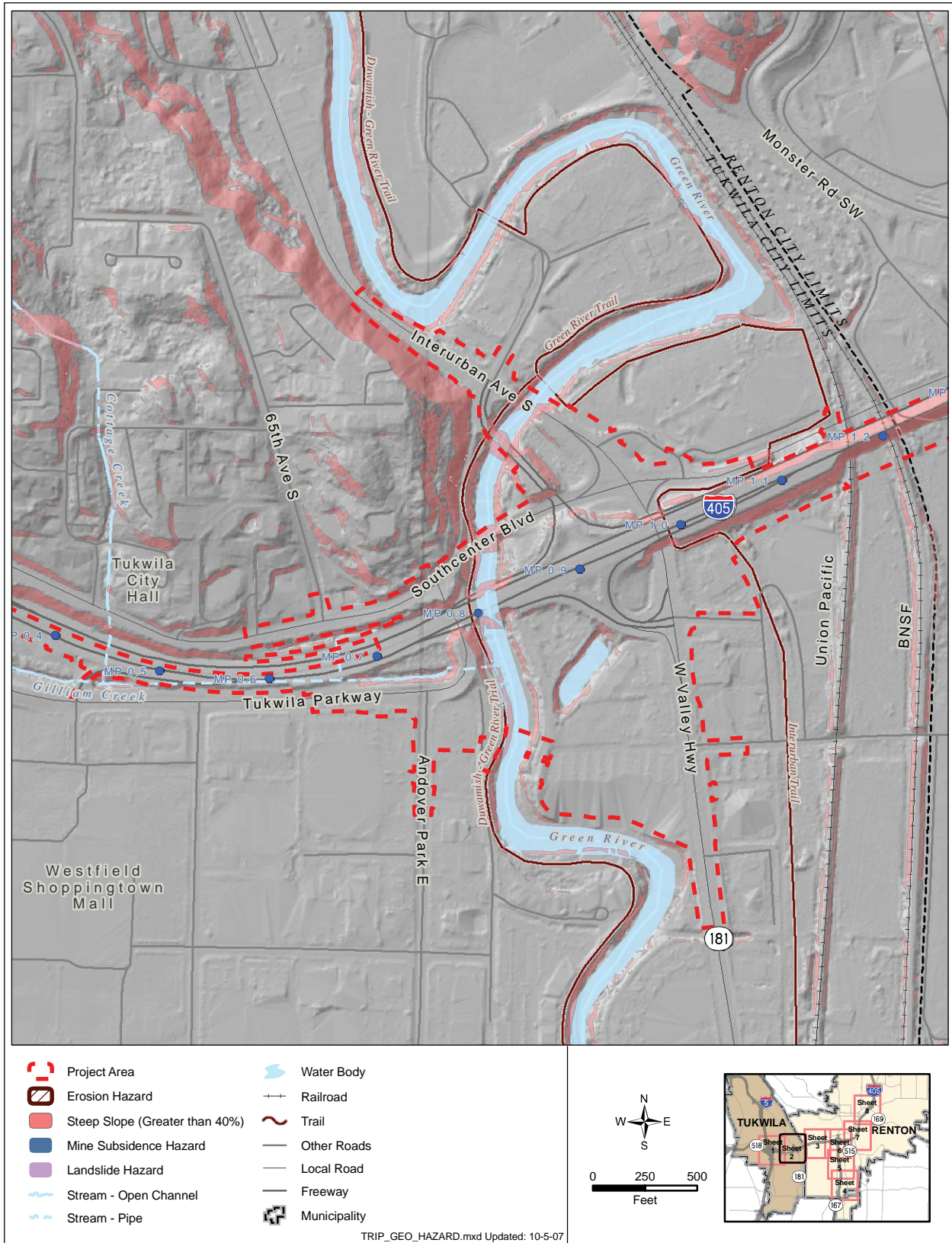


Exhibit 21: Geologic Hazard Areas, Sheet 3

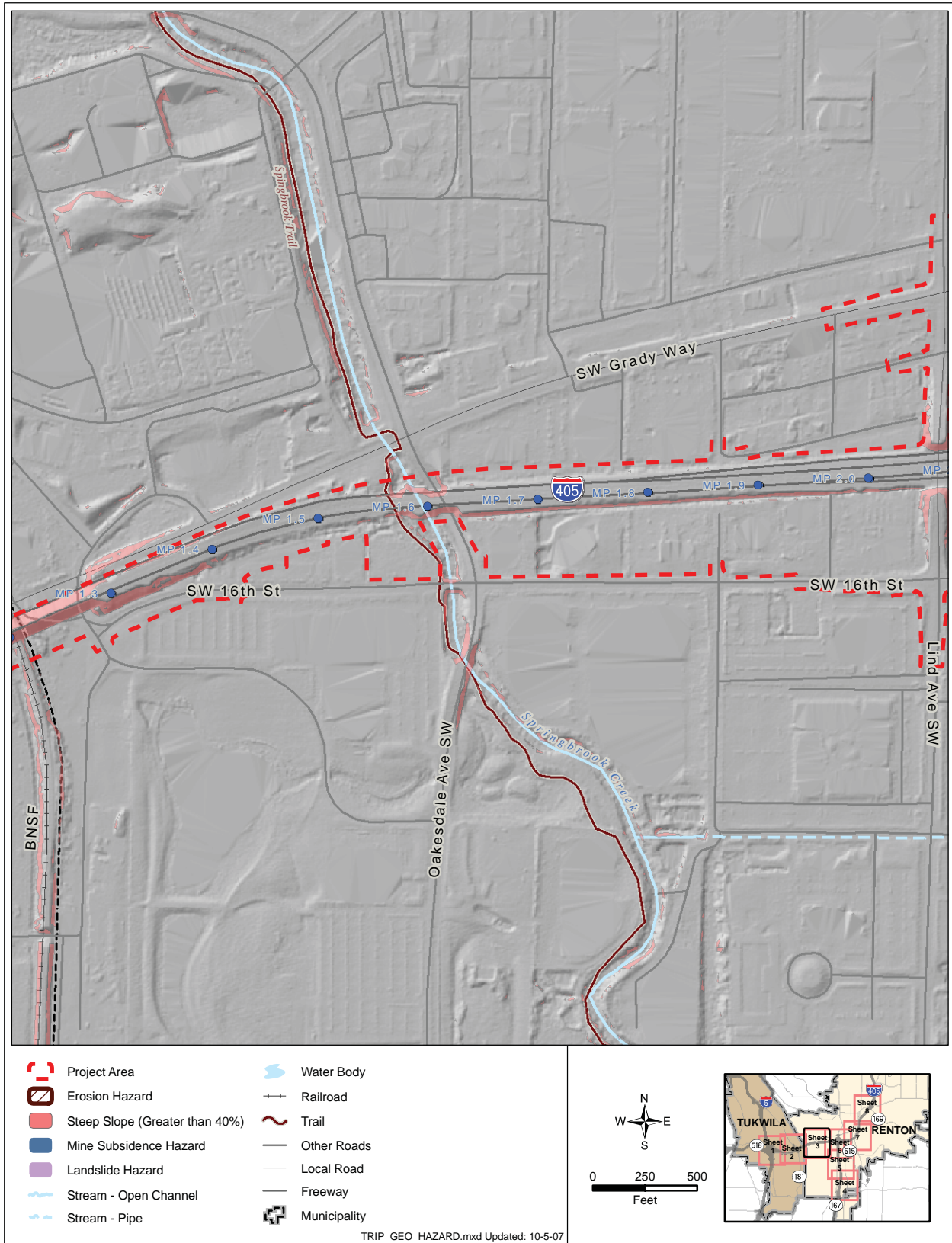


Exhibit 22: Geologic Hazard Areas, Sheet 4

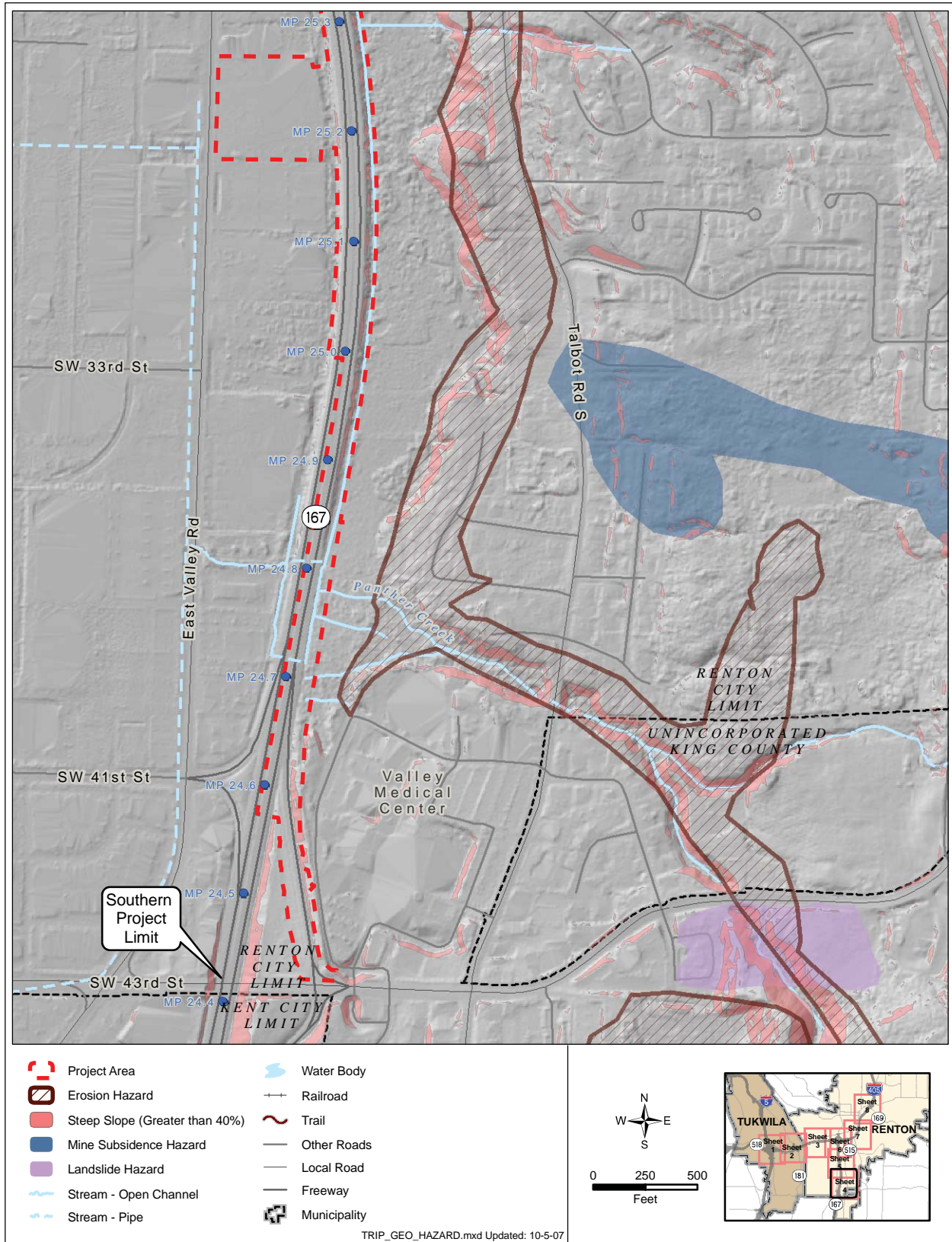


Exhibit 23: Geologic Hazard Areas, Sheet 5

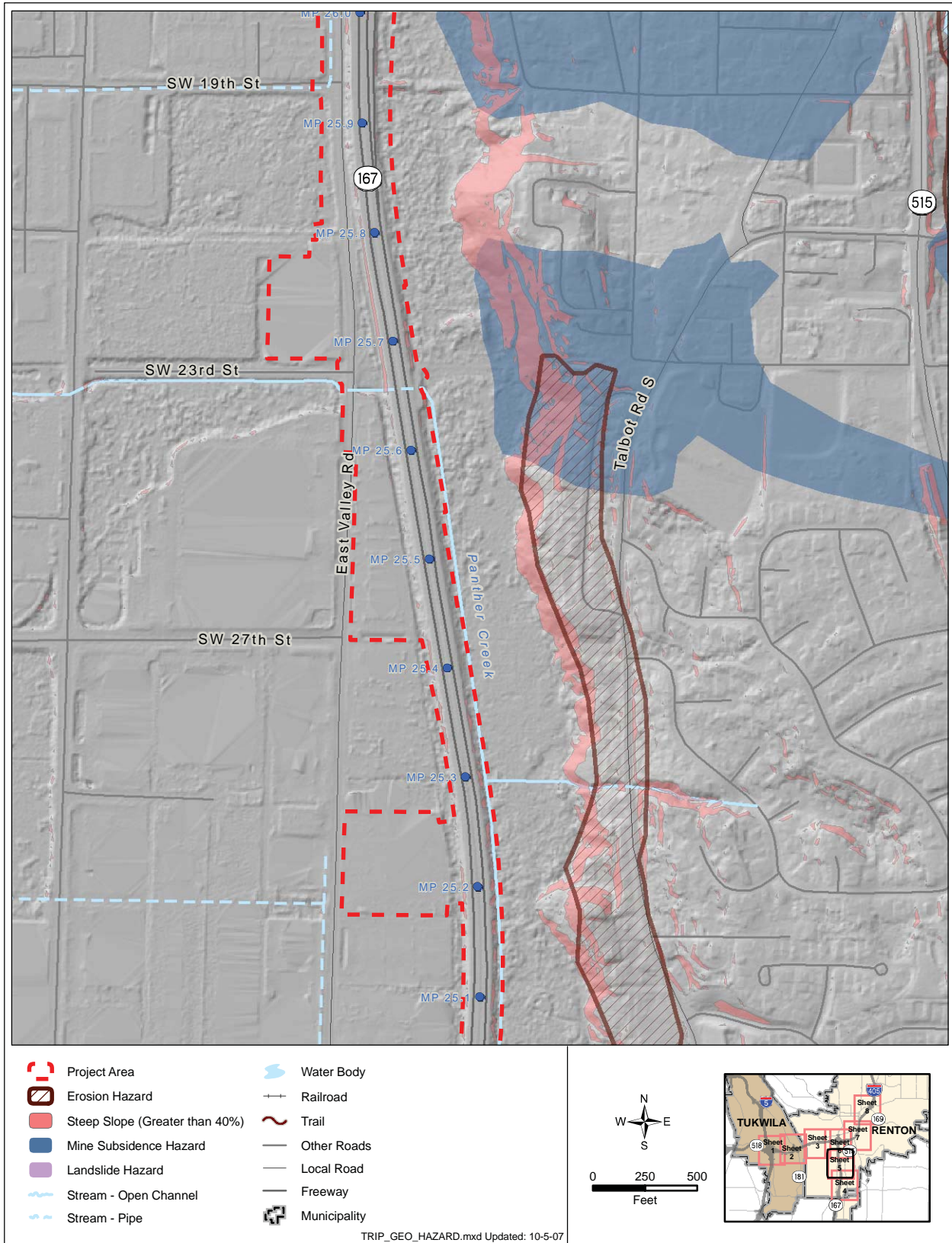


Exhibit 24: Geologic Hazard Areas, Sheet 6

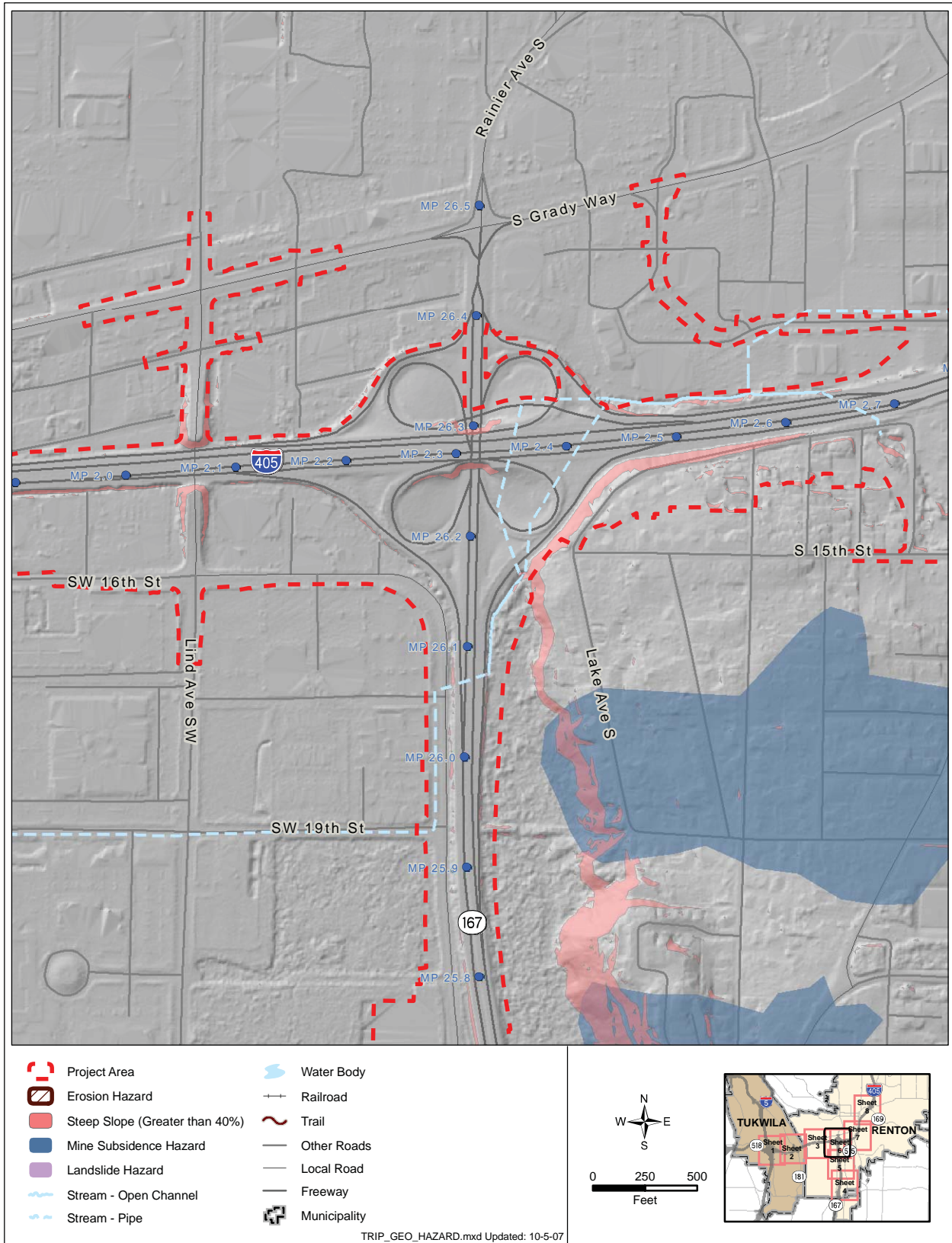


Exhibit 25: Geologic Hazard Areas, Sheet 7

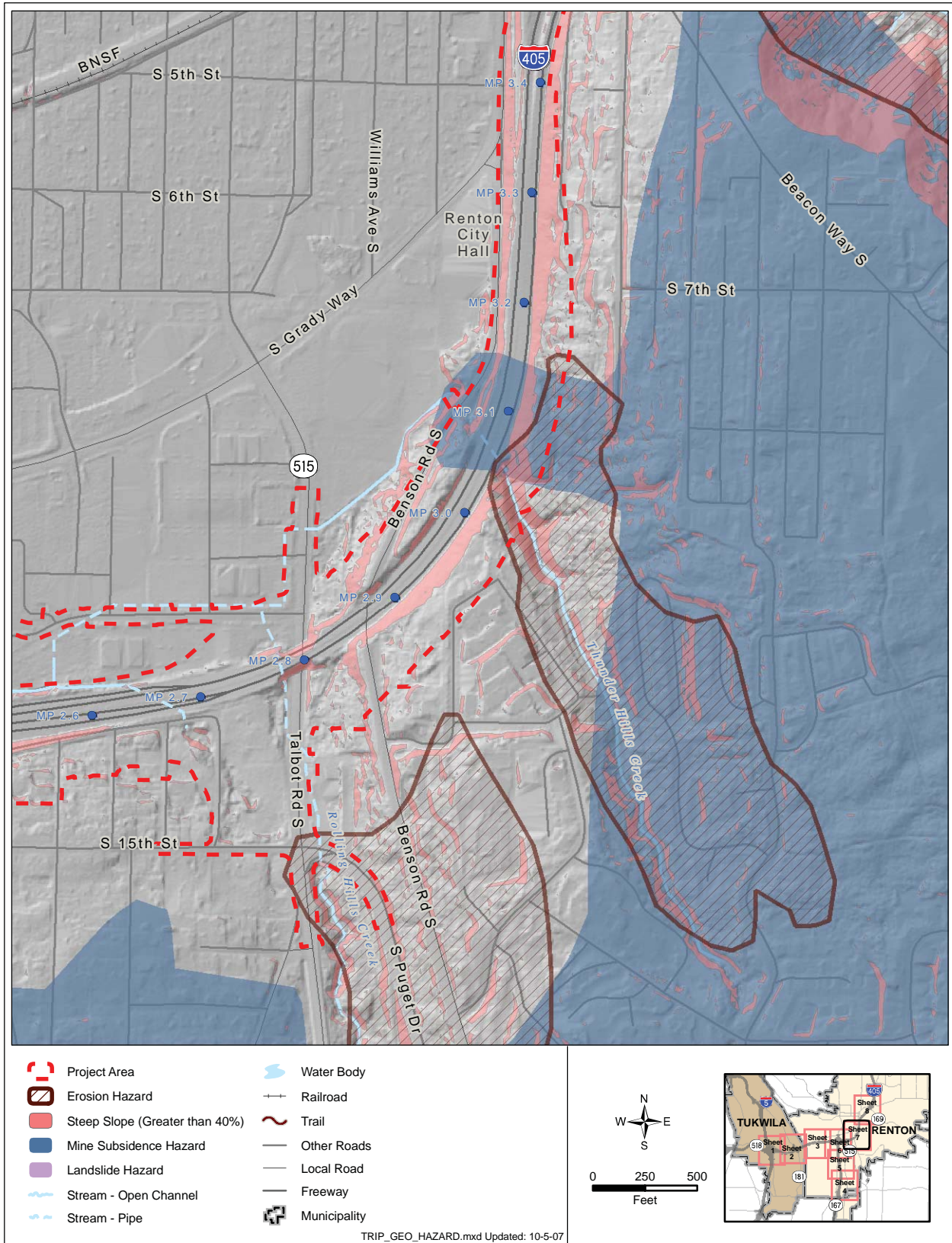


Exhibit 26: Geologic Hazard Areas, Sheet 8

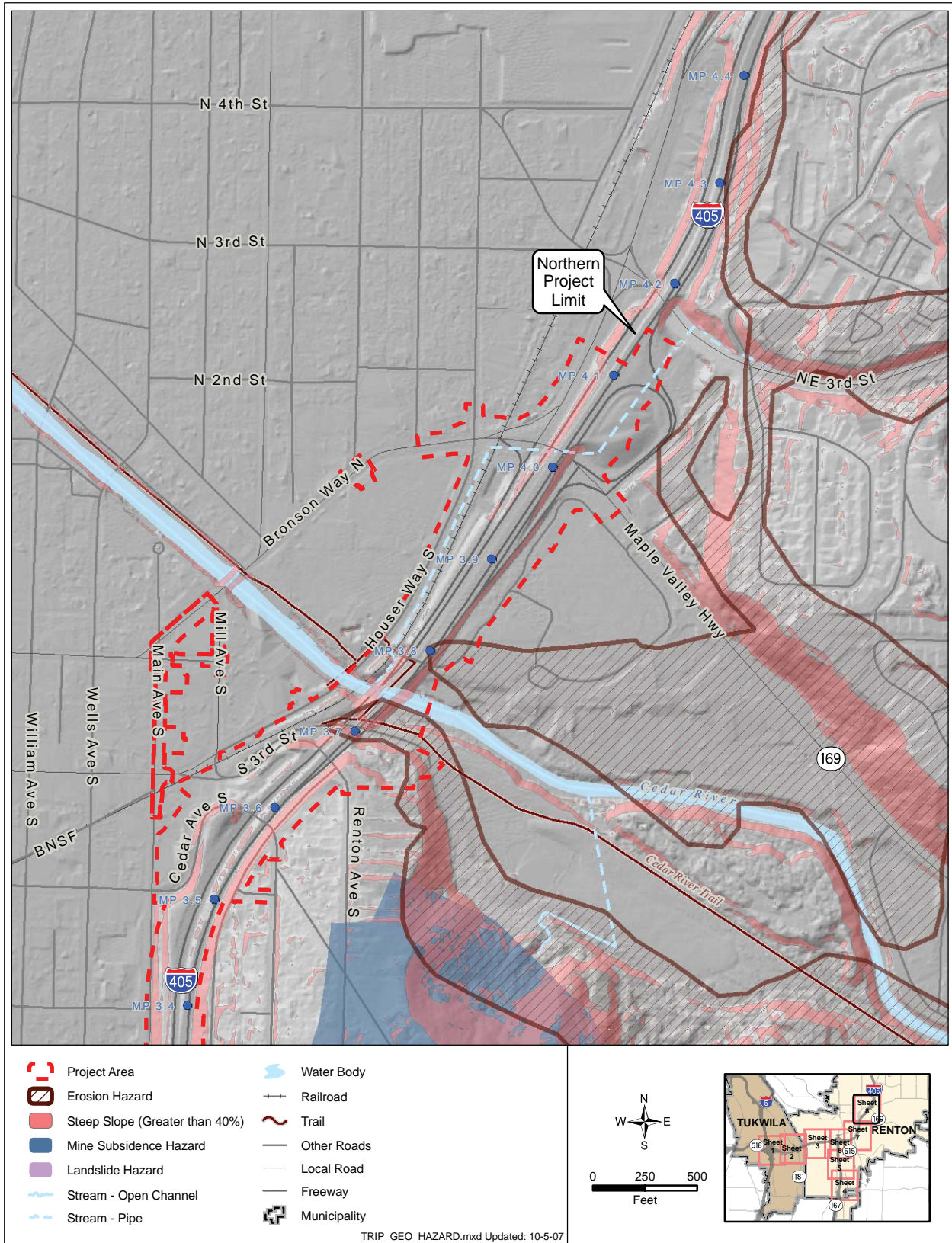


Exhibit 27: Soft Ground and Seismic Hazard Areas, Sheet 1

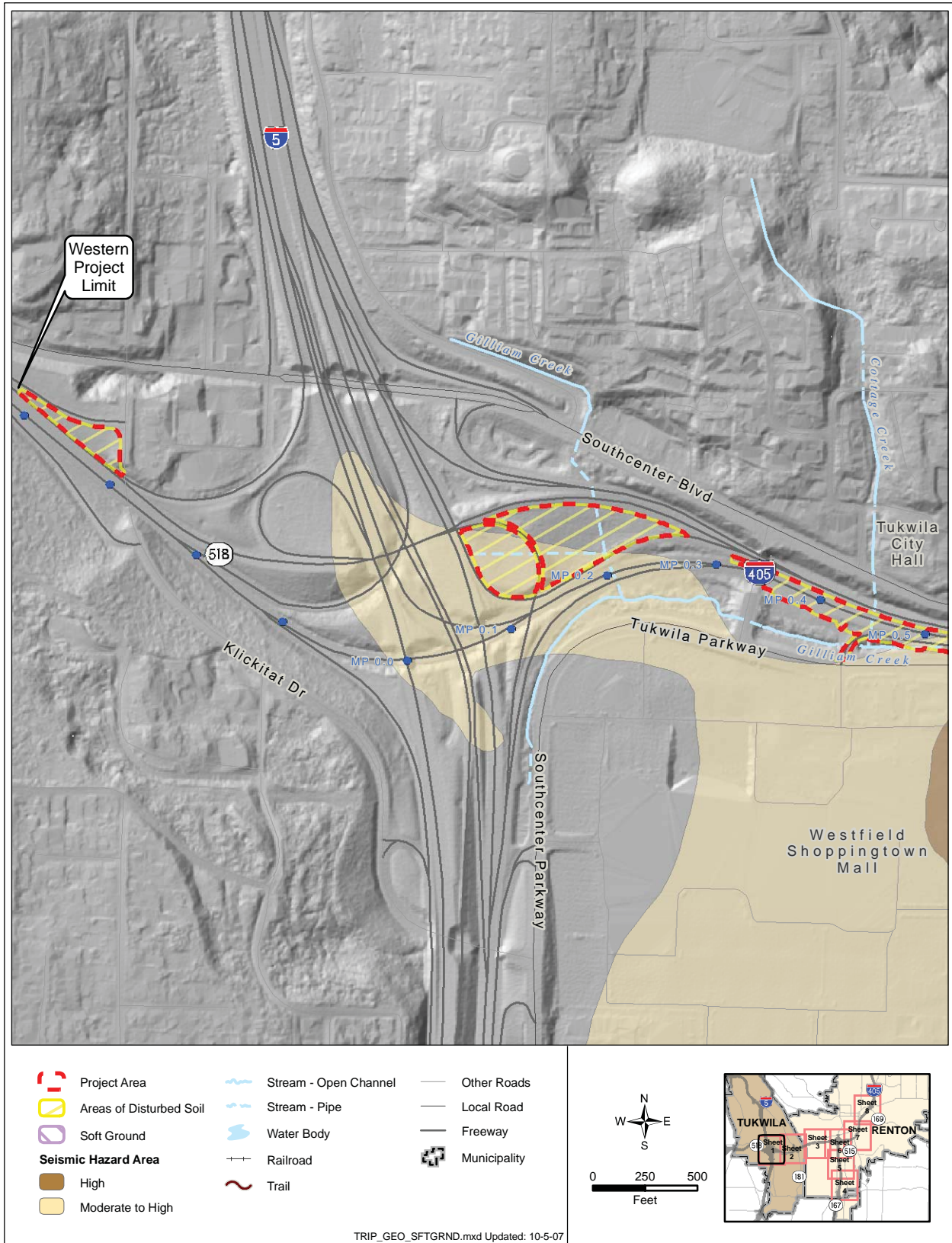
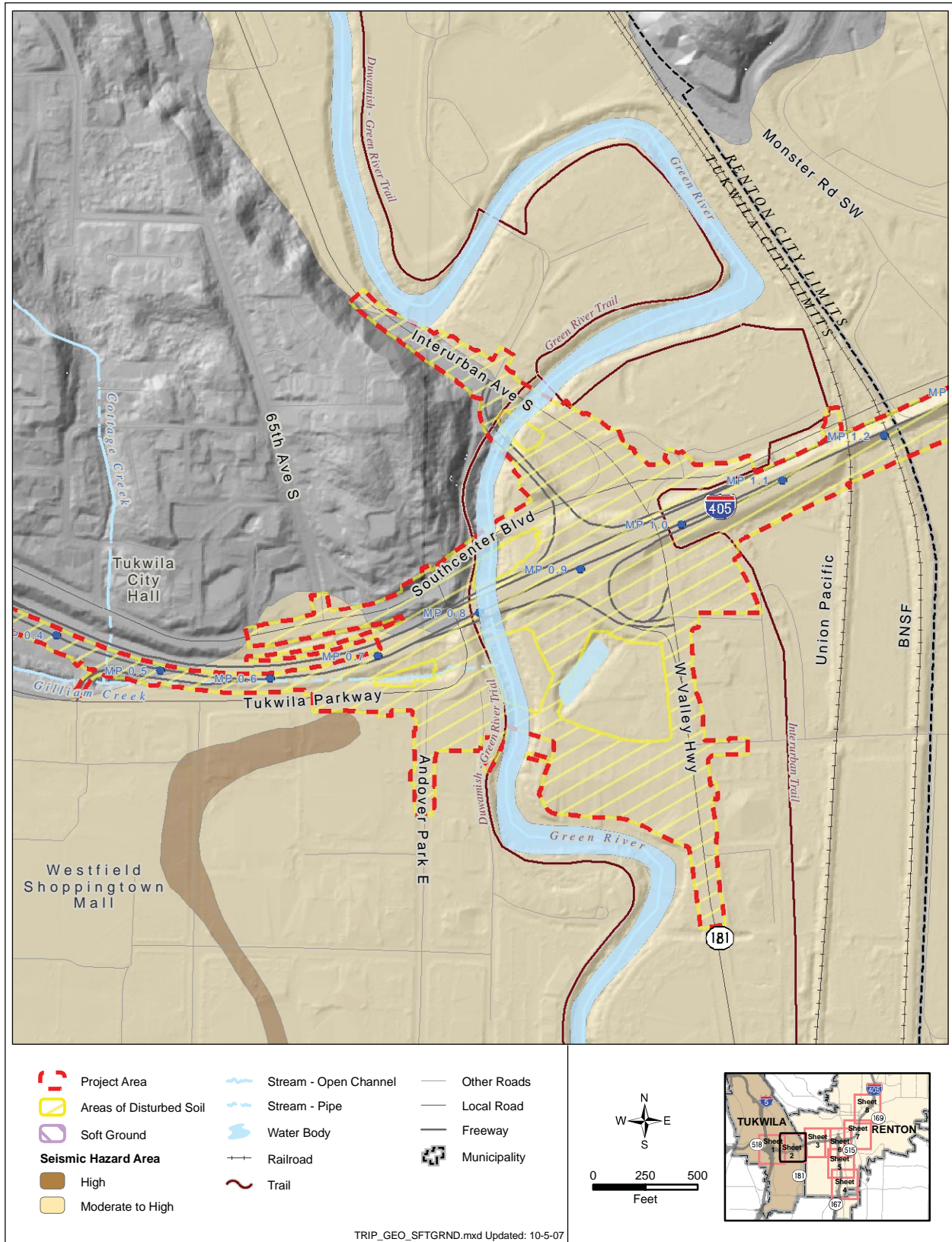


Exhibit 28: Soft Ground and Seismic Hazard Areas, Sheet 2



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Exhibit 29: Soft Ground and Seismic Hazard Areas, Sheet 3

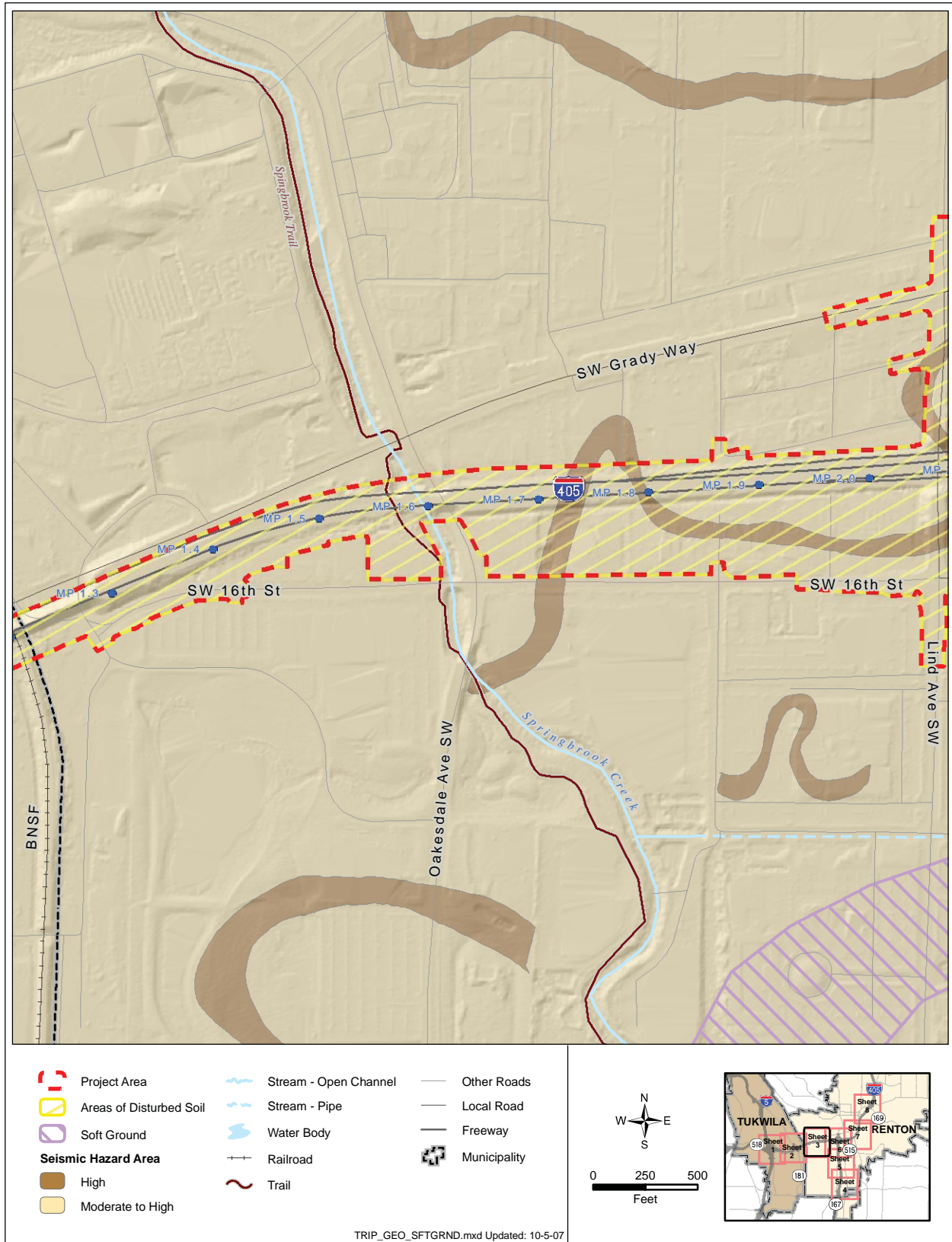


Exhibit 30: Soft Ground and Seismic Hazard Areas, Sheet 4

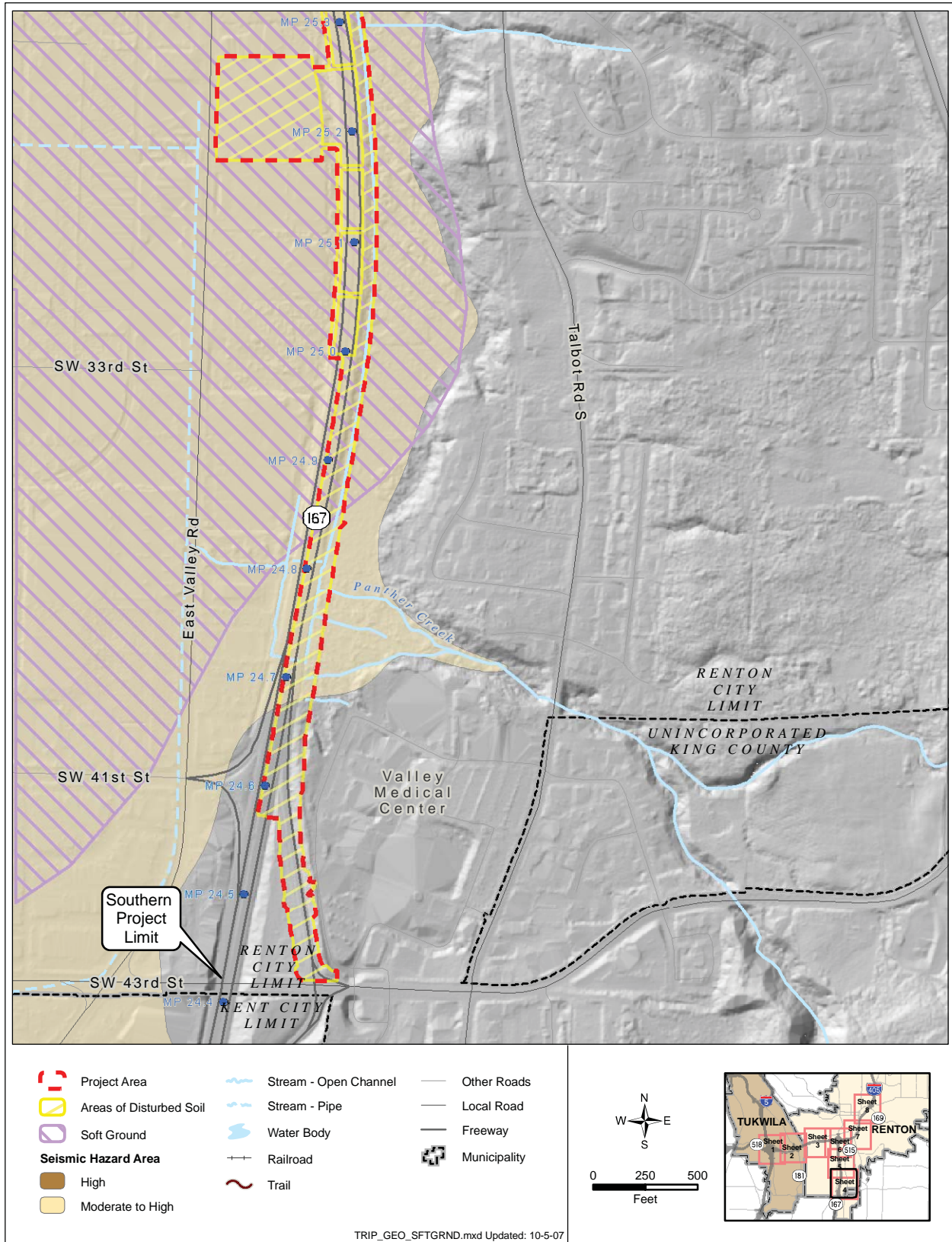


Exhibit 31: Soft Ground and Seismic Hazard Areas, Sheet 5

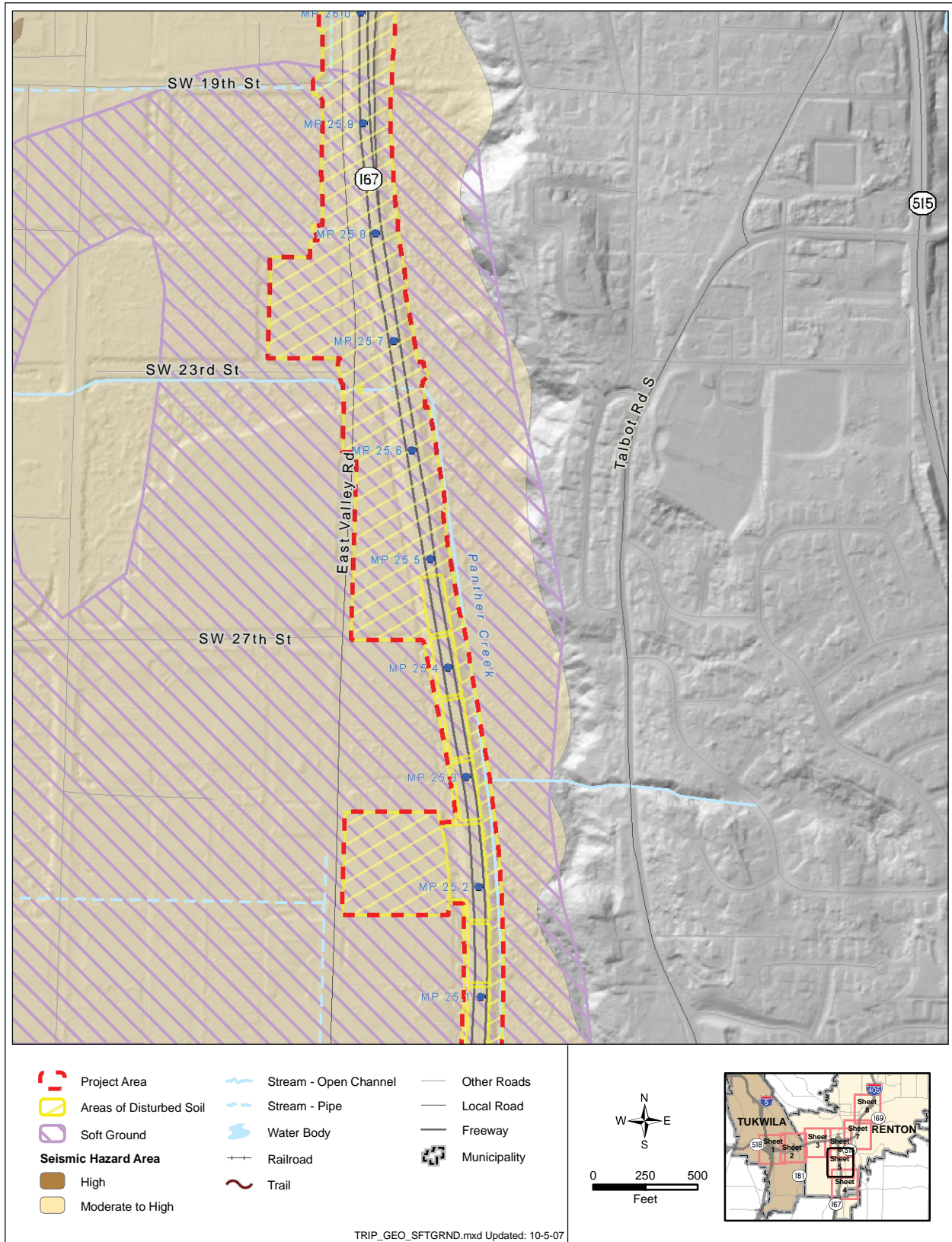


Exhibit 32: Soft Ground and Seismic Hazard Areas, Sheet 6

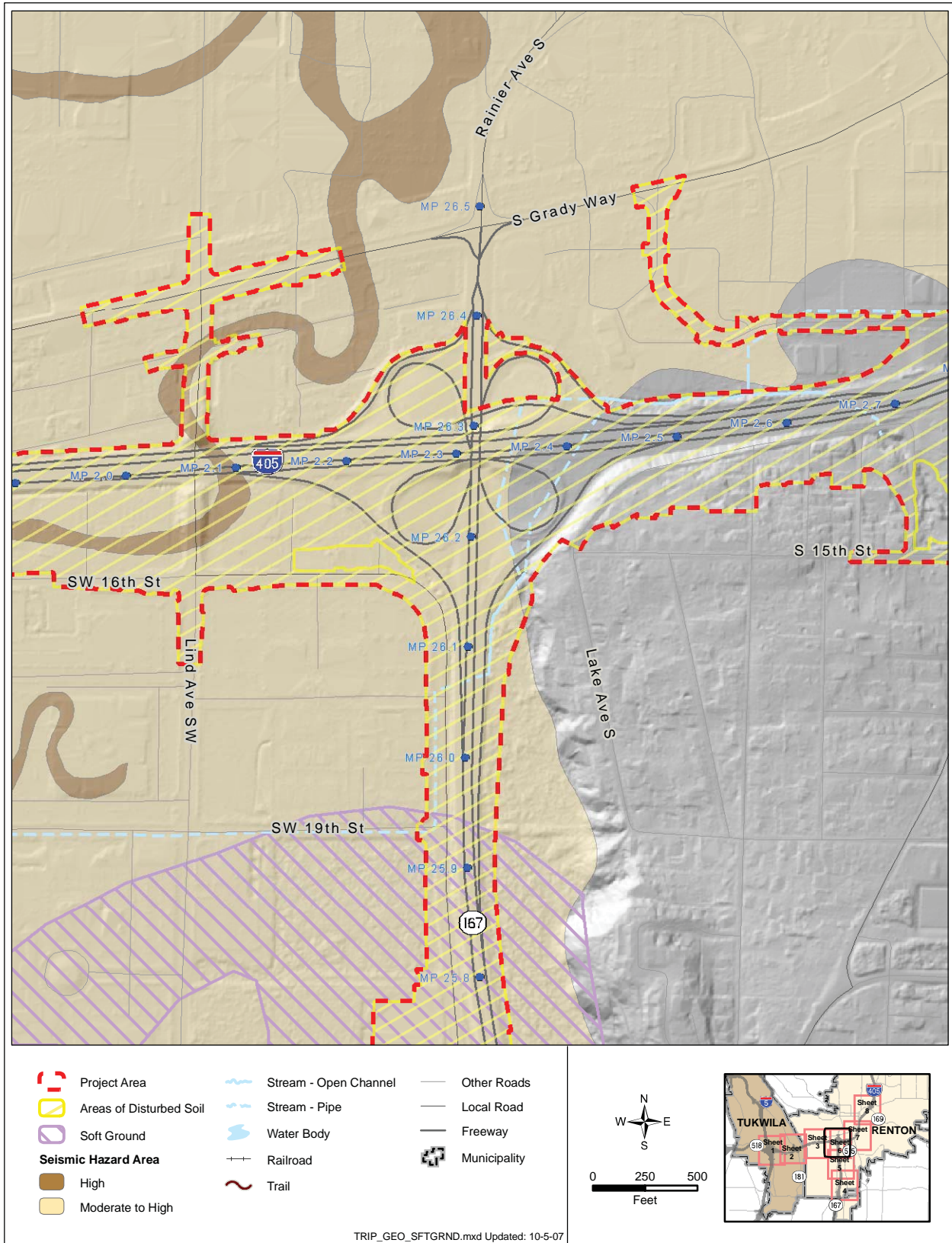


Exhibit 33: Soft Ground and Seismic Hazard Areas, Sheet 7

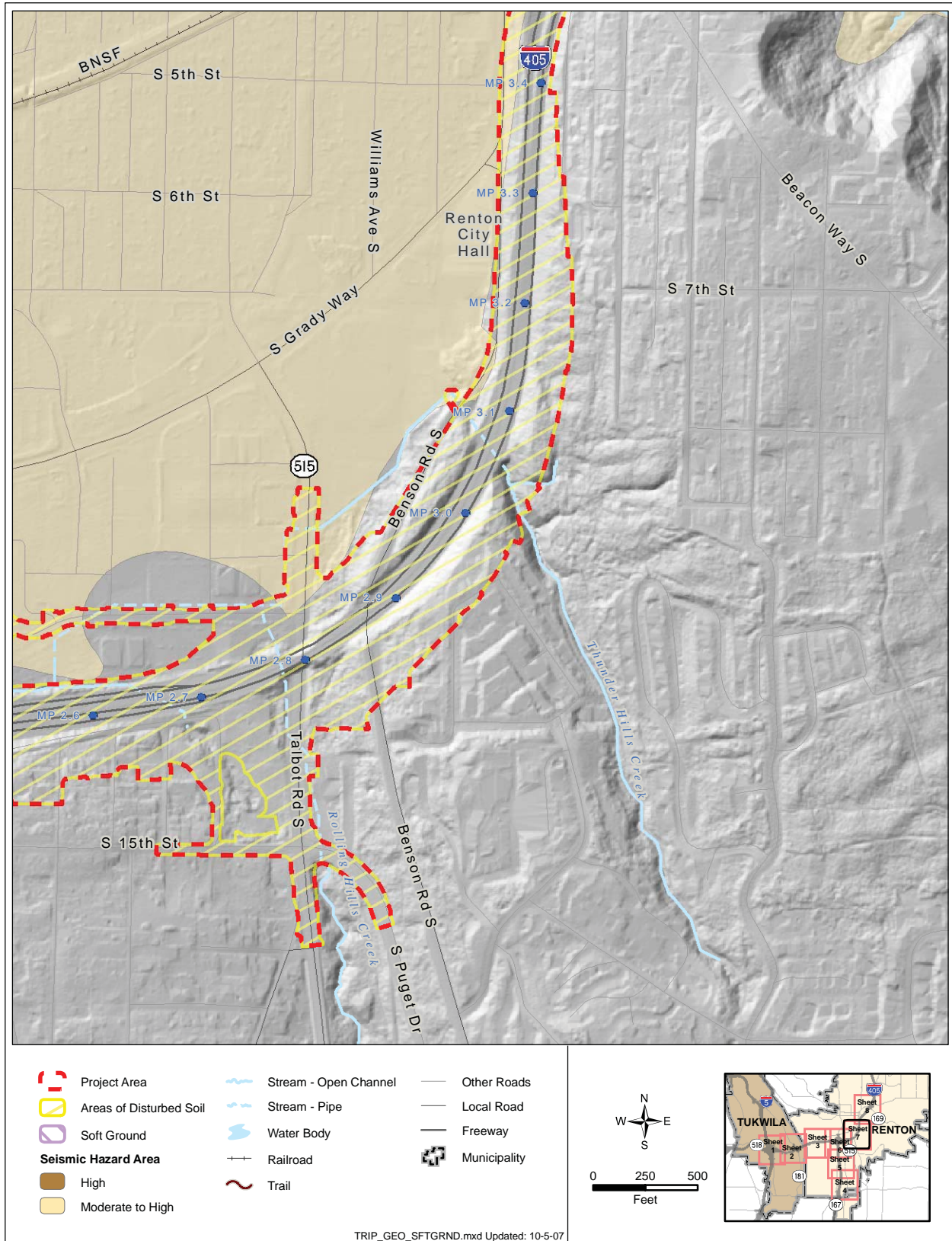
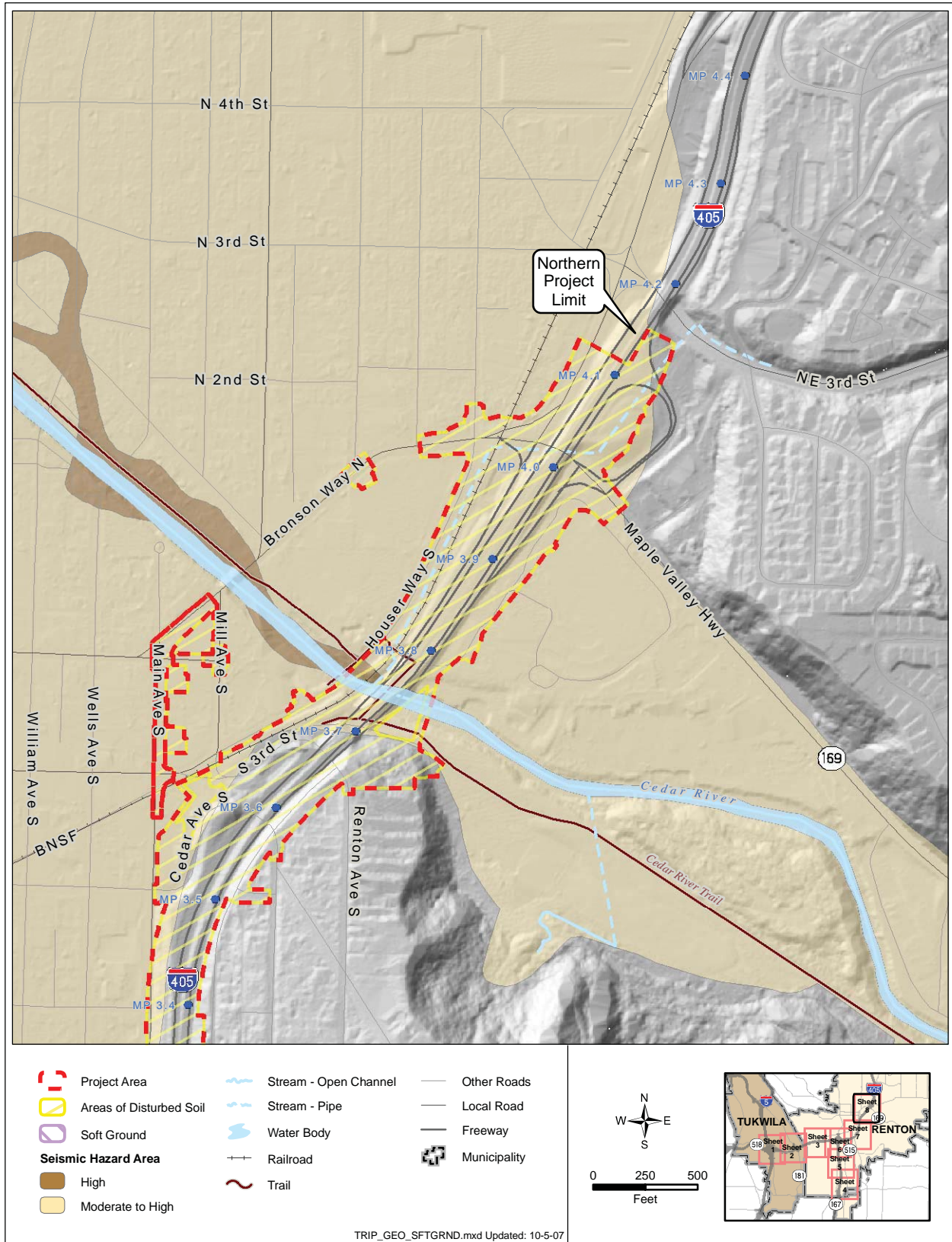


Exhibit 34: Soft Ground and Seismic Hazard Areas, Sheet 8



Appendix A: Methodology

How did we collect information on geology and soils for this report?

The I-405 Corridor Team collected information for this technical memorandum by reviewing the following data sources:

- Previous investigations along I-405 and SR 167 conducted by Washington State Department of Transportation (WSDOT) and others, including the borehole logs for these investigations.
- I-405, Renton Nickel Improvement Project, Geotechnical Baseline Report.
- I-405, Renton Nickel Improvement Project, Soils, Geology and Groundwater Discipline Report.
- Public data such as LiDAR, stereographic aerial photographs, soil conservation service (now known as the National Resource Conservation Service) soil maps, geologic maps, coal mine maps, and liquefaction susceptibility maps.
- Published articles from the U.S. Geological Survey (USGS), local purveyor reports, Washington State Department of Ecology (Ecology), U.S. Environmental Protection Agency (EPA), King County and other agencies.
- Agency web sites for geology and soil conditions.
- Applicable WSDOT Standards, such as those contained in the revised WSDOT Geotechnical Design Manual.

A complete list of the sources that were reviewed for this report is provided in the References section. In addition to the literature review, we completed a site reconnaissance to observe physical features to aid with interpreting subsurface conditions and to “field truth” the information gleaned from the literature review to the extent possible.

Baseline Conditions Evaluation

Following our compilation of this information, we evaluated baseline conditions within the study area. Baseline conditions were evaluated directly from the data sources and by evaluating information from multiple sources using standard geologic and geotechnical principles. For example, identifying areas that will likely be underlain by soft soils by reviewing and compiling published information and evaluating boring logs from previous investigations.

Potential Effects Evaluation

The methods used to evaluate the project’s potential effects included:

- Reviewing the proposed project design concept and likely construction methods.
- Evaluating the potential effects of the geology and soils on the project based on the baseline site conditions and standard WSDOT practices.
- Evaluating the potential effects of the project on the geology and soils based on the baseline site conditions and standard WSDOT practices.

The evaluations are based primarily on our experience, our expert judgment, and WSDOT practices and sound engineering principles. WSDOT’s 2006 Geotechnical Design Manual discusses many WSDOT design and construction practices for various geological conditions.