APPENDIX F: GEOLOGY AND SOILS TECHNICAL MEMORANDUM

I-405, NE 8th Street to SR 520 Improvement Project

INTERSTATE 405 Corridor Program

Congestion Relief & Bus Rapid Transit Projects

GEOLOGY AND SOILS TECHNICAL MEMORANDUM

April 2008

Washington State Department of Transportation

U.S. Department of Transportation
Federal Highway Administration

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Summary

The purpose of this technical memorandum is to present an assessment of the soils and geologic conditions in the Interstate 405 (I-405), NE 8th Street to State Route 520 (SR 520) Improvement Project. Describing the existing conditions of the natural setting prior to construction is important because it can be a major factor affecting project design (e.g., foundations, pavement sections, retaining walls, bridges, etc.). The soils and geology of the area combined with the topography result in several geologic hazards along the corridor, including erosion, steep slopes, seismic, and soft ground.

The project will be constructed in a highly variable geologic environment. Potential project effects on the geology and soils during construction include excavation and fill placement, disturbance of moisture-sensitive soils[1] and increased erosion potential. These issues are routinely encountered by the Washington State Department of Transportation (WSDOT) and are resolved using best management practices (BMPs) described in various design manuals. The presence of erosion hazard areas, soft ground areas, seismic hazard areas, and steep slopes may affect project design and construction considerations. WSDOT has managed these types of conditions on several other projects, including the original construction of I-405 and SR 520. Once the construction phase is complete and the highway is in use, the project will have no overall effects on the soils and geology because these conditions are generally not prone to impacts from properly designed and constructed roadway improvements.

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 the WSDOT *Bridge Design Manual*, dated November 17, 2006.

While WSDOT will avoid the majority of potential effects from the project on geology and soils by using standard WSDOT procedures and implementing BMPs, WSDOT will likely face a few minimal unavoidable adverse effects, such as, the disturbance of moisture-sensitive soils and increased erosion potential.

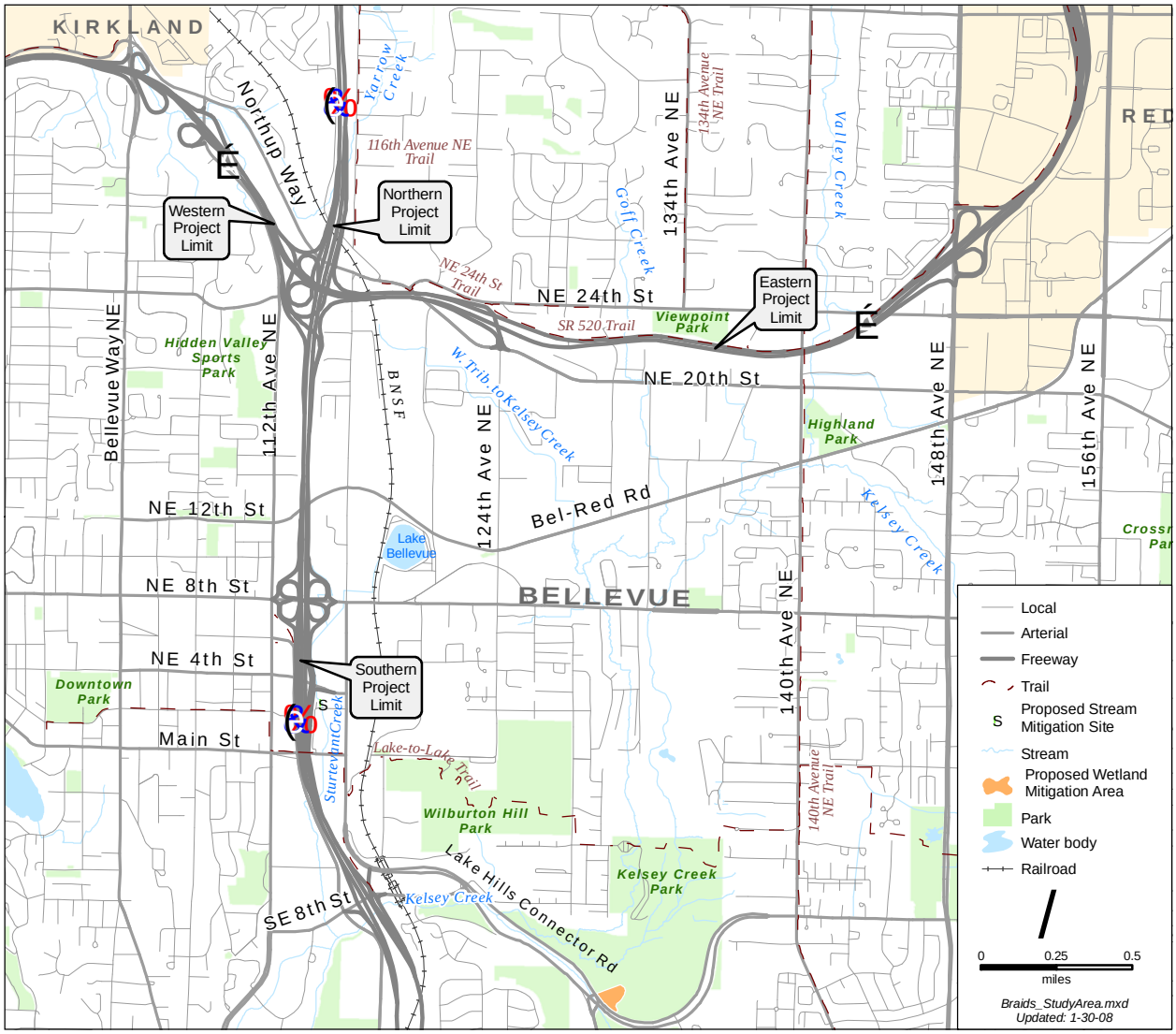
[1] Moisture-sensitive soils may become muddy and unstable with a small increase in moisture content and operation of equipment on these soils can be difficult.

Project Description

WSDOT is proposing to construct the I-405, NE 8th Street to SR 520 Improvement Project to improve safety and reduce congestion in the vicinity of the I-405 and SR 520 interchange within the city of Bellevue. As shown in Exhibit 1, the project extends approximately 1.5 miles north along I-405, from south of NE 8th Street to the SR 520 interchange, and approximately 1.6 miles east along SR 520, from the I-405 interchange to east of 134th Avenue NE.

The improvements will benefit the public by reducing congestion for the public and freight vehicles, improving safety, improving access and circulation to and from local streets, and providing opportunities for environmental improvements.

Exhibit 1: Project Location and Vicinity



This technical memorandum analyzes two alternatives, the Build Alternative and the No Build Alternative. The proposed roadway improvements for the Build Alternative, from south to north on I-405, and west to east on SR 520, are described below.

Build Alternative

Northbound I-405 to Eastbound SR 520 Improvements

- Reconfigure the existing northbound NE 4th Street on-ramp to become an auxiliary lane that exits to SR 520 and northbound I-405 as part of a two-lane exit ramp.
- Reconstruct portions of the NE 8th Street on- and off-ramps to northbound I-405. The on-ramp will be reconstructed at a lower grade than the I-405 mainline.
- Rebuild the NE 12th Street bridge crossing over I-405 to accommodate the new ramps.
- Construct a northbound on-ramp to SR 520 from a new NE 10th Street bridge crossing; the bridge crossing will be constructed as part of a separate project prior to constructing the on-ramp.
- Construct grade-separated ramps to divide traffic entering northbound I-405 from NE 8th Street and traffic exiting I-405 to SR 520.
- Construct grade-separated ramps to divide traffic entering eastbound SR 520 from northbound I-405 and traffic exiting eastbound SR 520 to 124th Avenue NE.
- Shift eastbound SR 520 mainline travel lanes toward the median.
- Extend the ramp from northbound I-405 to eastbound SR 520 on a collector-distributor system through the 124th Avenue NE interchange to merge with the existing eastbound SR 520 mainline just east of 134th Avenue NE.
- Reconstruct the 124th Avenue NE interchange off-ramp.
- Relocate an existing noise barrier. The new barrier will be approximately 1,585 feet long and 20 feet high.
- Construct several retaining walls needed to allow for the proposed widening of I-405.

SR 520 to Southbound I-405 Improvements

Reconfigure the ramps from SR 520 to southbound I-405 to improve traffic flow. The westbound SR 520 to southbound I-405 ramp will become a dedicated auxiliary lane, and on-ramp traffic will no longer be required to immediately merge with southbound I-405 mainline traffic. The eastbound SR 520 to southbound I-405 ramp will merge with the dedicated auxiliary lane.

Southbound I-405 to SR 520 Improvements

- Realign the southbound I-405 to eastbound SR 520 loop ramp.
- Realign eastbound SR 520 to match the proposed improvements.

Other Improvements

Other improvements proposed along the I-405 and SR 520 corridors within the project limits include retaining walls, relocating an existing noise barrier, stormwater culvert improvements, and stormwater management system improvements. Adverse effects on wetlands and their buffers will be compensated for at a wetland mitigation site located within the boundaries of Kelsey Creek Park southeast of the southern project limits. Mitigation at this site was approved as part of the I-405 Bellevue Nickel Improvement Project. Mitigation for unavoidable effects on an unnamed tributary to Sturtevant Creek will be in-kind and will be located within WSDOT right-of-way on the east side of I-405 and south of NE 4th Street. The location of the wetland and stream mitigation site is shown in Exhibit 1.

Construction Staging

Construction funding is currently available for only some of the proposed improvements in the Build Alternative. Consequently, the project will be constructed in stages. The funded first stage will include the northbound I 405 improvements, including the braided ramps, the NE 12th Street bridge reconstruction, and the northbound NE 10th Street on-ramp. Additionally, one of the three proposed collector-distributor lanes from northbound I 405 to eastbound SR 520 will be constructed. This collector-distributor lane will cross over the existing NE 124th Street on-ramp before merging with SR 520. Construction of these funded improvements is scheduled to begin in 2009 and will be completed in approximately 3 years.

The unfunded project improvements will include the remaining two lanes of the three-lane collector-distributor system, improvements from southbound I 405 to the eastbound SR 520 collector-distributor, and the improvements from eastbound and westbound SR 520 to southbound I 405. Construction of these remaining improvements depends on when project funding becomes available.

No Build Alternative

The No Build Alternative assumes the new NE 10th Street bridge across I-405 that is being constructed as part of another project will be in place. The No Build Alternative assumes that only routine activities such as road maintenance, repair, and minor safety improvements would take place over the next 20 years. The No Build Alternative does not include improvements that would increase roadway capacity, reduce congestion, or improve safety on I-405 or SR 520. For these reasons, it does not satisfy the project's purpose—to reduce congestion created by weaving traffic on I-405 and SR 520.

The No Build Alternative has been evaluated in this technical memorandum to establish a reference point for comparing the effects associated with the Build Alternative.

Background

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

The natural conditions needs to be understood in order to identify the risks associated with the physical environment within the I-405 and SR 520 corridors between the project limits; these risks may include sloughing and gravelling from steep slopes, liquefaction and erosion. Identifying and evaluating possible effects of the project on the soils and geology during the planning stages allows WSDOT to develop mitigation measures and utilize existing BMPs and design manuals specific to these conditions. Possible mitigation measures include: changing the project alignment (avoidance), designing project structures or components to provide for the geologic and soils conditions, and implementing protective measures and techniques that reduce effects to environmental conditions.

Existing Conditions

What are the soils and geology of the study area?

The I-405, NE 8th Street to SR 520 Improvement Project lies in a densely populated area located along an upland separating the Lake Washington and Lake Sammamish troughs. The area is mostly underlain by dense geologic materials with a relatively shallow groundwater table. The soils and geology in the study area are variable in nature. A detailed description of the soil and geologic units is provided below and summarized in Exhibits 1 and 2, respectively. Maps of local soil and geologic conditions are presented on Exhibit 4, Sheets 1 through 6 (soil units) and Exhibit 5, Sheets 1 through 6 (surface geologic conditions). Four types of geologic hazards were identified in the study area: erosion hazards, steep slope hazards, seismic hazards, and soft ground areas. The geologic hazard areas are presented in Exhibit 6, Sheets 1 through 6.

The existing conditions presented in this section were gathered and interpreted from a review of available documents and a field reconnaissance, as specified in the Methodology Section of this memorandum, which is included as Appendix A.

Soils

The majority of the near-surface soil material in the study area is naturally occurring, undisturbed soils and modified land. The study area crosses four drainage areas and a portion is located on top of lowland underlain by softer and looser soils. Naturally occurring, undisturbed soils in the study area span from well drained, gravelly sand 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 2; soil units are mapped on Exhibit 4, Sheets 1 through 6.

Geology

The study area is located within the central Puget lowland, which is 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 sediments 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 18,000 to 13,000 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.

Glacial 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.

The majority of the highway alignment within the study area is underlain by glacial till (I-405) and glacial outwash (SR 520), as shown on Exhibit 5, Sheets 1 through 6. Descriptions of these geologic units are provided in Exhibit 3.

Geologic Hazard Areas

Geologic hazard areas in the vicinity of the study area include erosion hazard, soft ground and steep slope hazard areas. These hazard areas are presented in Exhibit 6, Sheets 1 through 6 and are described below.

- **Steep Slope Hazard** – A steep slope analysis was performed using GIS data which determined that there are areas along the study area that have slopes greater than 40 percent (GeoEngineers, Inc. [GIS Data] Steep Slope Analysis, 2007). Depending on the immediate underlying soils, geology, and groundwater seepage, these steep slope areas may be associated with landslide and erosion hazards. However, these steep slope areas do not necessarily represent areas of potential erosion or landslide hazards based on the soil and/or geological substrate. Steep slope areas are presented below and shown in Exhibit 6, Sheets 1 through 6. Some of these areas were verified at the time of a January 2007 windshield survey, but not all were accessible because of traffic constraints:
    - I-405 MP 13.9 to MP 14.1 along the western portion of I-405 (this area was verified in the January 2007 windshield survey);
    - I-405 MP 14.12 along the north and south portions of NE 12th Street;
    - I-405 MP 14.35 to MP 14.55 along the western portion of I-405;
    - I-405 MP 14.5 to MP 14.75 along the eastern portion of I-405;
    - Along the westbound SR 520 exit/entrance ramp;
    - SR 520 MP 6.9 to MP 7.0 along the northern portion of SR 520 (this area was verified in the January 2007 windshield survey);
    - I-405 MP 14.95 to MP 15.1 along both sides of I-405;
    - SR 520 MP 7.05 to MP 8.2 along both sides of SR 520 (this area was verified in the January 2007 windshield survey).

- **Erosion Hazard** – An erosion hazard is the measure of the susceptibility of an area of land to prevailing agents of erosion (Houghton and Chapman, 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 glacial soils on slopes greater than 15 percent. The mapped high erosion-prone zones are located southeast of the I-405 and SR 520 interchange in the area immediately north and south of the West Tributary to Kelsey Creek as shown on Exhibit 6, Sheets 2 and 3 (King County Erosion Hazard GIS Data, 1997). High erosion-prone areas are located within the alignment on both sides of SR 520 between MP 7.55 and MP 7.7 (Exhibit 6, Sheet 4) and near MP 8.2 (Exhibit 6, Sheet 5).

  Landslide Hazard – Available public maps indicate that there are no potential, active, or historic landslides in the study area (King County Landslide Hazard GIS Data, 2003). However, as with most steep 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 and movement occurs episodically, generally in response to heavy rainfall. Earthquake shaking would tend to increase the size of a surficial slide area as well as the frequency of movement. During a windshield survey completed in January 2007, the I-405 Team observed evidence of surficial sliding in the following steep slope areas, as shown in Exhibit 6, Sheets 3 through 6:

  - A pistol butt tree was observed on the north side of SR 520, beneath I-405. Pistol butt trees typically have a curved base caused by the tree attempting to grow vertically on a downward-creeping slope;
  - Small slumps (1 to 3 feet long) and leaning trees on the south side of SR 520, between MP 7.3 and MP 7.4;
  - Small slumps (1 to 3 feet long) and a pistol butt tree north of SR 520 between MP 7.55 and MP 7.7 in the area mapped as high erosion, which is immediately east of the 124th Avenue NE interchange ramp;
  - Pistol butt and/or leaning trees and water seepage on the south side of SR 520 between MP 8.05 and MP 8.15;
  - Small slumps (1 to 3 feet long) north of SR 520 near MP 8.3 in the area mapped as high erosion.

  In addition to the surficial sliding features observed during the windshield survey, groundwater seepage was observed off the southern slope of SR 520 between MP 8.05 and MP 8.15. Three 6- to 10-inch-diameter trees were observed to have uprooted on the slope. This area is shown on Exhibit 6, Sheet 5.

- **Seismic Hazard Areas –** There are no high seismic hazard areas mapped along the project corridor surrounding the I-405/SR 520 interchange. However, moderate seismic hazard areas are mapped along SR 520 from MP 7.15 to MP 7.25 as well as in the area immediately north and south of the West Tributary to Kelsey Creek, as shown on Exhibit 6, Sheet 3.

  Seismic hazards are generally considered to be areas with a severe risk of ground shaking or deformation during an earthquake. Soft ground and loose sand areas below the groundwater table can undergo a process called liquefaction during a seismic event.

- **Soft Ground Areas –** Soft ground areas generally coincide with highly organic soil such as peat and are generally not suitable for roadway and bridge foundations. These areas are likely to be

encountered adjacent to younger alluvial or wetland deposits. Localized areas of compressible soils may also be encountered elsewhere along the alignment in locations not mapped as alluvial soils, but as recessional outwash or even glacial till. These areas of compressible soils will likely be only a few feet thick and will generally overlie competent glacial soils, such as glacial till and advance outwash. The horizontal and vertical extent of these localized, compressible soils is likely to be small.

Compressible soils (Seattle Muck and Tukwila Muck) were mapped by USDA and verified with WSDOT boring explorations along SR 520 on both sides of the alignment between MP 7.1 and MP 7.2, as well as in the area immediately north and south of the West Tributary to Kelsey Creek, as shown on Exhibit 6, Sheet 3.

Exhibit 2 – Description of Soil Units

Unit	Map Symbol	Description
Alderwood gravelly sandy loam	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 on uplands and formed under conifers in glacial deposits. Slopes are 0 to 30 percent (AgB = 0 to 6 percent; AgC = 6 to 15 percent; AgD = 15 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. The slippage potential of slopes 15 to 30 percent is moderate.
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. Slopes generally range from 6 to 15 percent. Runoff of this soil is medium and the water erosion hazard is moderate to severe.
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. The 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.
Everett Gravelly Sandy Loam	EvC and EvD	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 are 5 to 30 percent (EvC = 5 to 15 percent; EvD = 15 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

Exhibit 2 – Description of Soil Units		
Unit	**Map Symbol**	**Description**
		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	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 4 to 15 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 moderate. This unit is mainly used as woodland and for urban development.
Kitsap Silt Loam	KpB and KpD	This unit is a very deep, moderately well-drained soil located on terraces and formed in glacial lake deposits. Slopes are 2 to 8 percent (KpB) and 15 to 30 percent (KpD). 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. 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. The soil is subject to severe hillside slippage on 15 to 30 percent slopes.
Norma Loam	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

Exhibit 2 – Description of Soil Units		
Unit	**Map Symbol**	**Description**
		high water table.
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 is 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 and the runoff tends to pond and there is no hazard of water erosion.
Shalcar Muck	Sm	This unit is made up of very poorly drained organic soils that are stratified with mineral soils and overlie mineral soils 16 to 30 inches below the surface. These deposits formed in sedge peat and alluvium located in streams and rolling glaciated uplands. Slopes are 0 to 1 percent. In a representative profile, this soil type is a very dark brown muck that may be 14 inches thick. This layer is underlain by 5 inches of grayish-brown silt loam and dark gray very fine sandy loam, which is underlain by 5 inches of black to very dark brown muck. The substratum extends to a depth of 60 inches or more mottled grayish-brown, dark gray, black, and very dark grayish-brown silt loam to loamy sand. The permeability of the soil is moderate in the organic layers and moderate to rapid through the substratum. The seasonal water table is at or near the surface. The available water capacity is high and the runoff is usually ponded. There is no hazard of water erosion.
Tukwila Muck	Tu	The Tukwila series is made up of very poorly drained organic soils that were formed from 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 and the runoff is usually ponded and the hazard of water erosion is slight.
Urban Land	Ur	Urban land is considered to be soil that has been modified by disturbance of the natural layers with additions of fill material several feet thick to accommodate large industrial, housing installations, streets and parking lots. The erosion hazard is slight to moderate. There is no capability for woodland classification of this soil type.

Exhibit 3 – Description of Geologic Units

Unit	Map Symbol	Description
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 substantially decrease the rate of infiltration.
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 is dependent 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.
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 a 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.

Potential Effects

Will the project affect soils or geology?

WSDOT routinely encounters the types of soils and geologic conditions within the study area, which are typical of the Puget Sound Region. Potential effects to the soils and geology due to construction activities generally include:

- Disturbance of moisture-sensitive soils;
- Increased erosion potential; and
- Vibration effects of construction equipment that may destabilize soft-ground areas.

No substantial adverse effects to soils and geology are anticipated from the Build Alternative.

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 (along I-405) and glacial outwash (along SR 520). Specific conditions that may be encountered during construction and operation of the I-405, NE 8th Street to SR 520 Improvement project are described below.

Once construction is complete and the highway is in use, soils or geology should have essentially no overall effects on the project because proper mitigation techniques will be followed.

Soils and Erosion

Erosion risk is typically assessed by looking at the steepness of a slope in combination with the soil type. In addition, fill placed to widen existing embankments may also be susceptible to erosion. Fill, particularly when stockpiled prior to being placed during construction, can be eroded during a storm event.

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 use a variety of methods to minimize and/or mitigate against adverse effects. High erosion potential areas are shown in Exhibit 6, Sheets 4, 5 and 6.

Steep Slope Hazard Areas

Steep slope hazard areas are more prevalent in the study area than landslide hazard areas. Several mapped areas with steep slope hazards (slopes greater than 40 percent) are located in the study area and may be associated with landslide and erosion activity under certain conditions. There are steep slope and erosion hazard areas that may affect the project at virtually all roadway improvement features (i.e., ramps, bridges and the reconstruction of the SR 520 eastbound mainline), as shown on Exhibit 6, Sheets 1 through 6. Although these features may be affected by steep slopes, they do not appear to be in landslide hazard areas.

According to a windshield survey completed in January 2007, potential areas for slope destabilization are in the I-405 and SR 520 interchange and on the eastbound lanes of SR 520 from MP 7.3 to MP 7.4 and MP 8.05 to MP 8.15 and along the westbound lanes of SR 520 from MP 7.55 (immediately east of the

124th Avenue NE interchange ramp) to MP 7.75 and at MP 8.2. These areas of potential destabilization are discussed in the "Existing Conditions" section and are shown on Exhibit 6, Sheets 3, 4, and 5.

Seismic Hazard Areas

Low to moderate seismic hazard areas are mapped along SR 520 from MP 7.15 to 7.25 as well as in the area west of the West Tributary to Kelsey Creek at 116th Avenue NE, as shown on Exhibit 6, Sheet 3. These areas are considered to be seismic hazards 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) if soils below the embankments liquefy.

Soft Ground Areas

Soft, compressible soils located in the project area will settle under new loads such as those that may be imposed by grade-separated ramps, retaining walls and fill embankments if these improvements are not designed to account for the soft ground conditions. Soft ground areas, are mapped along SR 520 between MP 7.1 and MP 7.2, which is immediately west of and in the vicinity of the reconstruction of the SR 520 eastbound mainline reconstruction (Exhibit 6, Sheet 3). WSDOT is aware of these types of conditions and routinely use a variety of design and construction methods to minimize adverse effects.

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, follow procedures outlined in the WSDOT *I-405 Corridor Program NEPA/SEPA Final Environmental Impact Statement*, *Geotechnical Design Manual* and *Bridge Design Manual*, and follow the I-405 Programmatic Commitments and the October 2002 I-405 Corridor Program Record-of-Decision (ROD).

WSDOT will incorporate into the project design and implementation all commitments contained in policy guidance, interagency agreements, and its 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 from the Environmental Procedures Manual M 31-11 as described 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.

Fill material imported from 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

A vibration analysis is being addressed in the Noise and Vibration discipline report associated with this project. However, the severity of vibrations is strongly linked to the underlying soils, so the topic is addressed herein as well.

Heavy equipment use on construction projects will cause ground vibrations, and depending upon the underlying soil conditions, these vibrations may be amplified or attenuated. Softer soils will tend to dampen high frequency vibrations and amplify low frequency vibrations. Firm soils will tend to dampen low frequency vibrations, but may amplify high frequency vibrations. WSDOT can mitigate effects of construction vibrations by restricting the hours construction may occur, or limit the operation of certain types of equipment to times when they will least likely disturb nearby residences and businesses. In some cases, WSDOT may also increase the distance between source and receptor or choose construction equipment that is better suited for the underlying soil conditions. Effects at specific locations where the proposed transportation improvements are close to existing facilities will be evaluated during the design phase of construction. 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 alteration and cost) should 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 construction.

Soils and Erosion

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 may involve constructing 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 fabric for protection. Soil admix such as cement may also be mixed into the subgrade to add strength and stabilize the ground.

Steep Slope Hazard Areas

Several steep slopes have been identified in the project area, and some were observed to exhibit minor sloughing and graveling during 2006/2007 wet season. WSDOT will implement construction procedures identified in the *Geotechnical Design Manual* to maintain or enhance slope stability in areas potentially underlain by landslide-prone soils. During construction, areas of observed or suspected groundwater seepage will be drained to reduce the risk of surface sloughing through the use of gravel drainage blankets, French drains, horizontal drains, and/or placement of a surface rock facing, or through similar methods.

Seismic Hazard Areas

Seismic hazard areas will be addressed in accordance with the WSDOT *Geotechnical Design Manual*.

Soft Ground Areas

Soft ground areas generally require different design and construction considerations than those characterized by dense to stiff glacial soils. During the construction design phase process, WSDOT will assess potential settlement problems associated with existing and proposed new utilities or structures. WSDOT will design appropriate solutions; such as underpinning structures by supporting them on deep foundations to gain support below the compressible soils, and/or relocating utilities. Other techniques that may be employed are: staging construction of embankments so the soil has time to gain strength; wicking drains to hasten consolidation and strength gain; constructing embankments of light-weight materials to minimize loading; reinforcing embankments with geosynthetics to add strength and minimize the footprint; inducing settlement of the underlying soils through the use of preloads prior to constructing the infrastructure; performing construction on pile supports; and increasing grades to keep pavement above groundwater.

Unavoidable Adverse Effects

While WSDOT will avoid and mitigate against the majority of potential effects from the project on geology and soils 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 and increased erosion potential. However, these effects are expected to be minimal.

Acronyms and Abbreviations

Acronym	Meaning
BMPs	best management practices
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
LiDAR	light distance and ranging
MP	Milepost
ROD	Record-of-Decision
SR	State Route
TESC	Temporary Erosion and Sediment Control (Plan)
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.
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.
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.
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.
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 effect altogether by not taking a certain action or parts of an action; (2) minimize the effect by limiting the magnitude of the action and its implementation, by using technology or by taking affirmative steps; (3) rectify the effect by repairing, rehabilitating, or restoring the affected environment; (4) reduce or eliminate the effect over time by preservation and maintenance operations; (5) compensate for the effect by replacing, enhancing or providing substitute resources or environments; and/or (6) monitor the effect 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.
Record of Decision (ROD)	A document prepared by the federal lead agency that presents the basis for the decision reached after completion of the Final EIS. The ROD summarizes any mitigation measures that will be incorporated into the project, and documents any required Section 4(f) or other approvals.
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.
seep	A spot where water trickles out of the ground to form a pool or wet 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

Exhibit 1

WSDOT. 2006 – 2007. I-405 Staff; project limits.

Exhibit 4

NRCS (Natural Resources Conservation Service, United States Department of Agriculture). May 2005. Soils. Soil Survey Geographic (SSURGO) Database for King, County.

WSDOT (Washington State Department of Transportation). 2006 – 2007. I-405 Staff; proposed right-of-way, existing right-of-way and project footprint.

Exhibit 5

WSDNR (Washington State Department of Natural Resources), Geology and Earth Resources Division. Surface Geology, 2003.

WSDOT (Washington State Department of Transportation). 2006 – 2007. I-405 Staff; proposed right-of-way, existing right-of-way and project footprint.

Exhibit 6

King County Standard GIS Data Disk, extract June 2006:

2004. Seismic Hazard Areas.
2003. Landslide Hazard Areas.
1997. Erosion Hazards.

Puget Sound LiDAR Consortium, LiDAR, 2002. http://pugetsoundlidar. ess. washington. edu/About_PSLC. htm

2006. Steep Slopes. Created by GeoEngineers, Inc. using the Puget Sound LiDAR Consortium data.

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Base data

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

Bellevue. 2006. Lakes, Parks, Streams.

GDT (Geographic Data Technology, Inc.), April 2005. GDT – Dynamap Transportation.

King County Standard GIS Data Disk, extract June 2006:

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.

2004. Cities with annexations.

USGS (United States Geological Survey). June 2002. Color Aerial Photography. http://edc.usgs.gov/products/aerial/hiresortho.html

WSDOT (Washington State Department of Transportation). 2006 – 2007. I-405 Staff; Tenth Mile Posts, NE 10th St Bridge, Project Area.

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GeoEngineers, Inc. 2004. *Geotechnical Baseline Report, Interstate 405 Kirkland Segment, Design-Build Project, Stage 1 – Nickel Package, Kirkland, Washington*. Washington State Department of Transportation. June 14, 2004.

GeoEngineers Inc. 1990. *Report, Geotechnical Services, HOV Widening for Bridges, 405/45 East and West, 405/46 East and West, 405/47 East and West, 405/48 East and West, Bellevue, Washington*. for State Department of Transportation. July 1990.

GeoEngineers Inc. 1987. *Report, Geotechnical Engineering Services, MSC Site-Parcel "A", 2033 – 120th Avenue Northeast, Bellevue, Washington.* City of Bellevue. April 1987

Houghton, P.D. & Charman, P.E.V. 1986. *Glossary of Terms Used in Soil Conservation, Soil Conservation Service of NSW, Sydney*.

Minard, James. 1983. Geologic Map of the Kirkland Quadrangle, Washington, Department of the Interior United States Geologic Survey.

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WSDOT. December 2006. *Geotechnical Design Manual*. Publication M 46-03.

WSDOT. February 2005. *I-405 SR 520 to SR 522-Kirkland Nickel Project Geology, Soils, and Groundwater Discipline Report*, Appendix T.

WSDOT. 2002. *I-405 Corridor Program NEPA/SEPA Final Environmental Impact Statement*.

WSDOT. 2002. *I-405 Corridor Programmatic Commitments and Record of Decision*.

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 conducted by Washington State Department of Transportation (WSDOT) and others, including the borehole logs for these investigations.
- I-405, Kirkland Nickel Project *Phase I, Geotechnical Baseline Report*.
- I-405, Kirkland Nickel 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, 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, WSDOT 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.

Existing Conditions Evaluation

Following our compilation of this information, WSDOT evaluated existing conditions within the study area. Existing 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 existing site conditions and standard WSDOT practices.
- Evaluating the potential effects of the project on the geology and soils based on the existing 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.

Exhibit 4. Soil Units, Sheet 1of 6

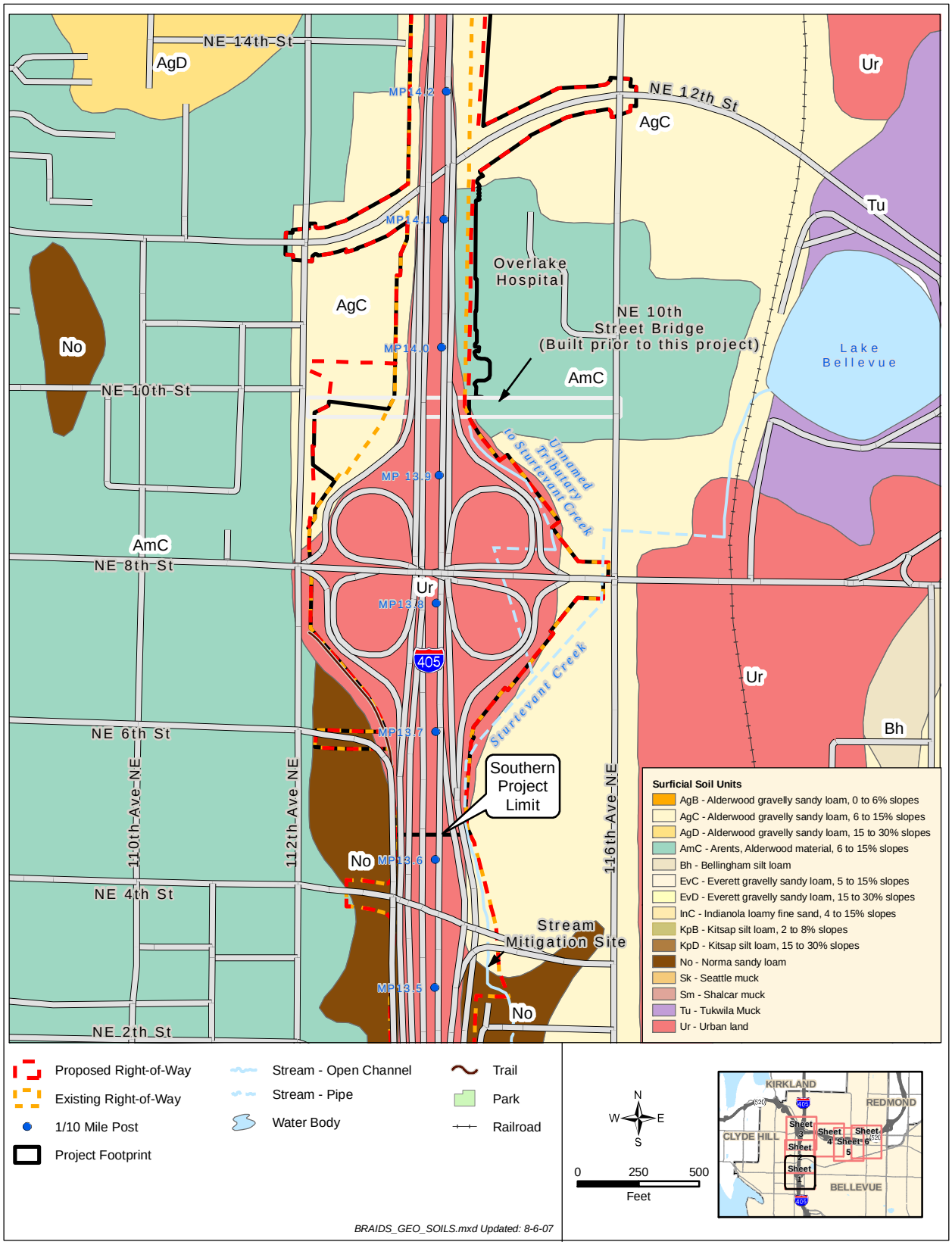
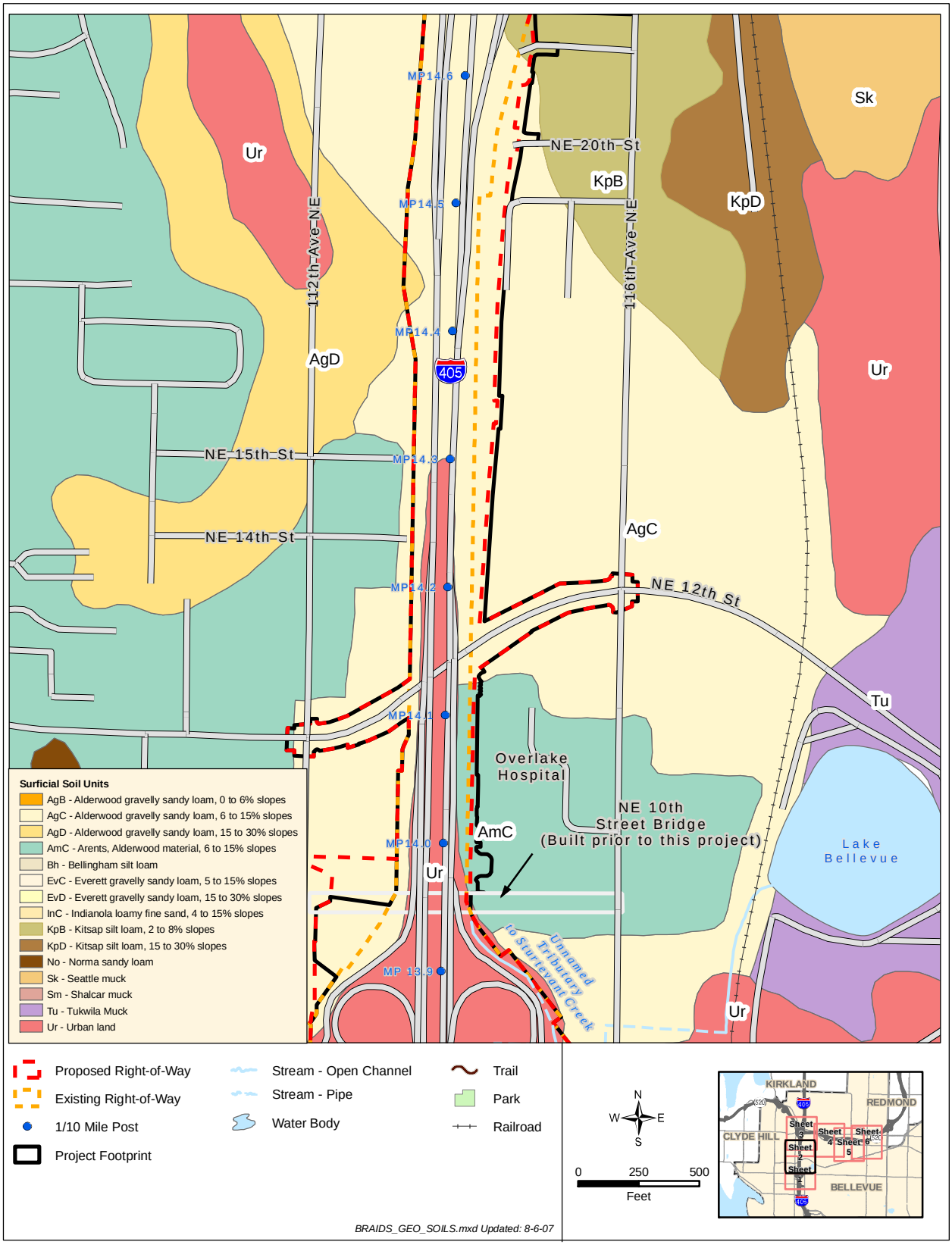


Exhibit 4. Soil Units, Sheet 2 of 6



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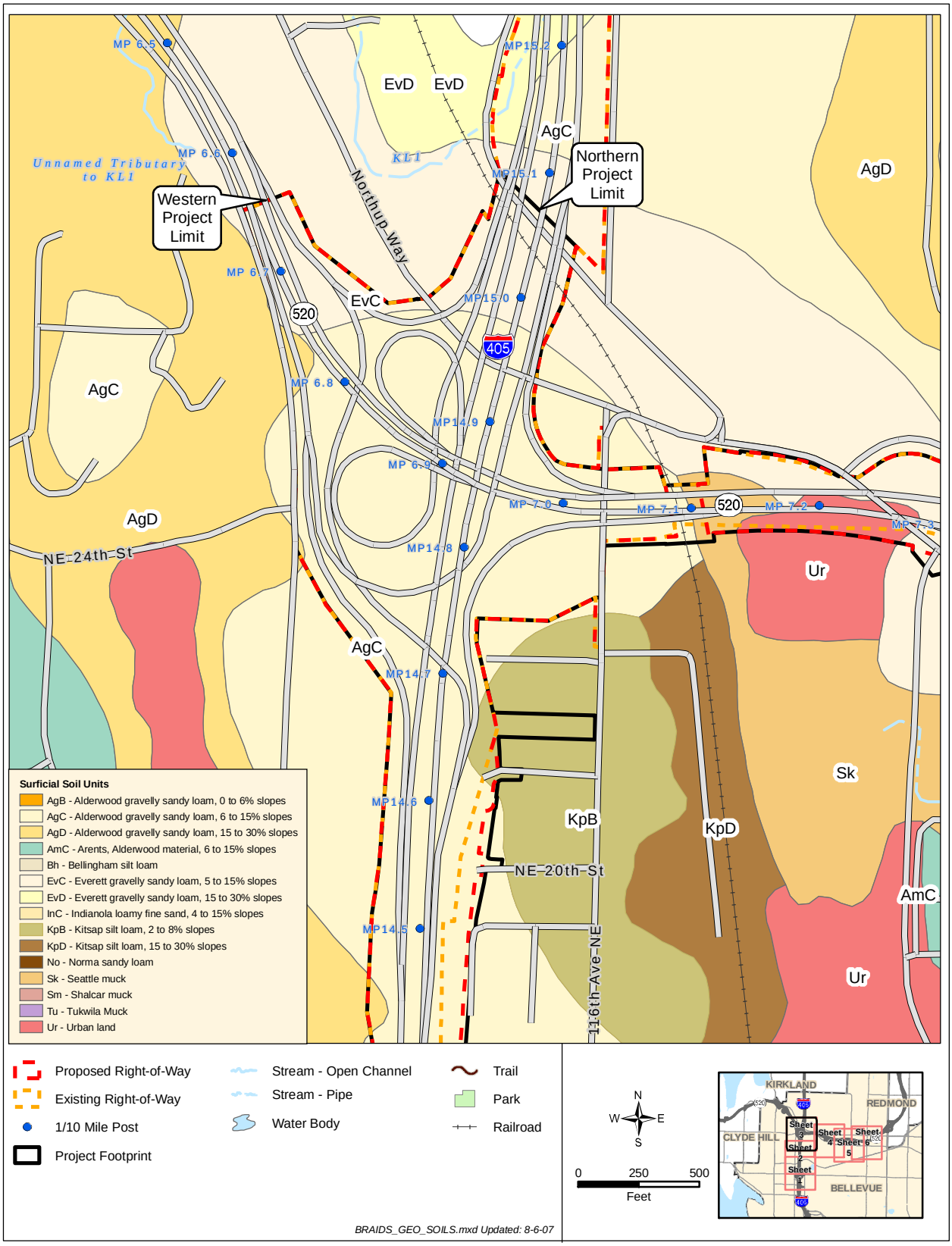

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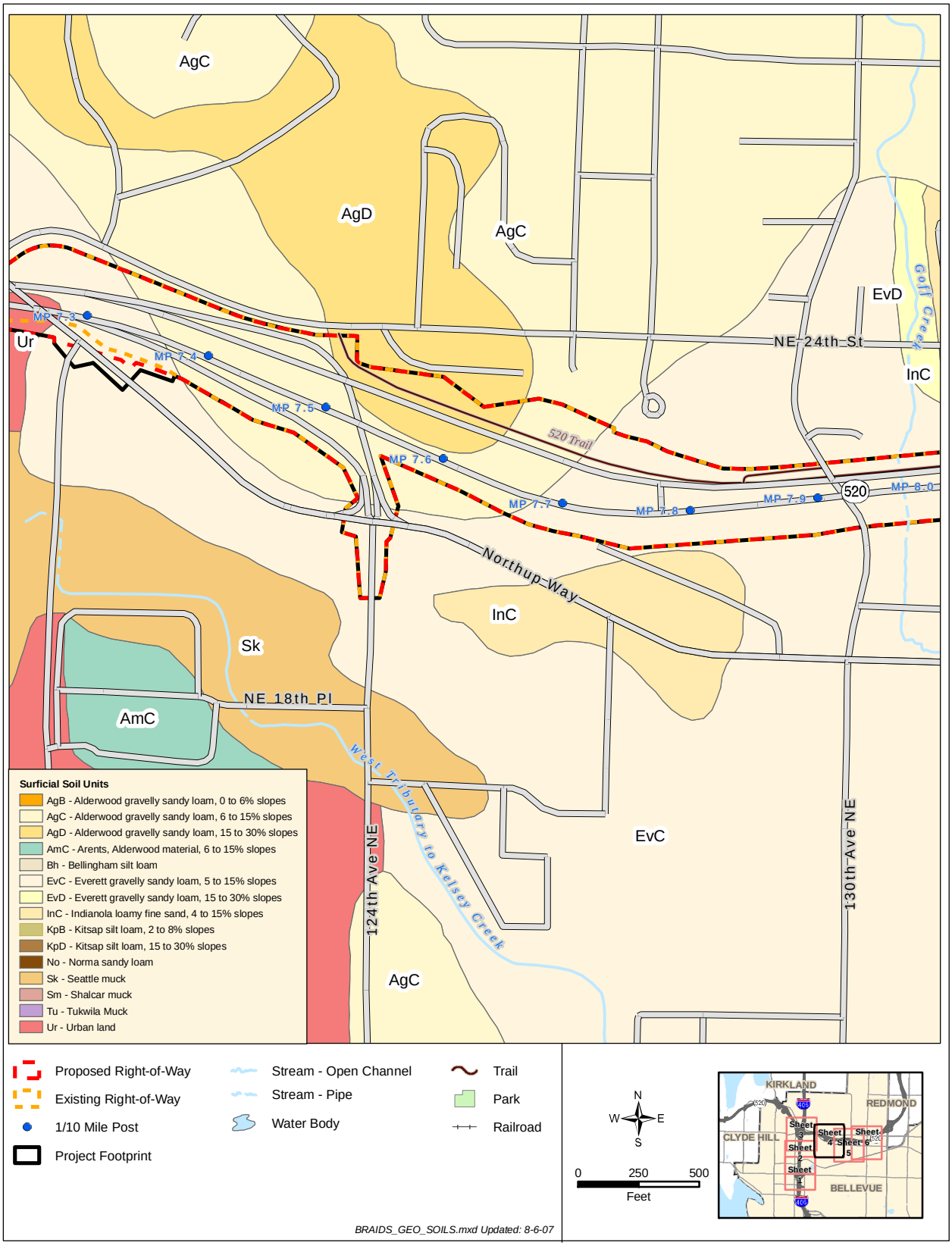

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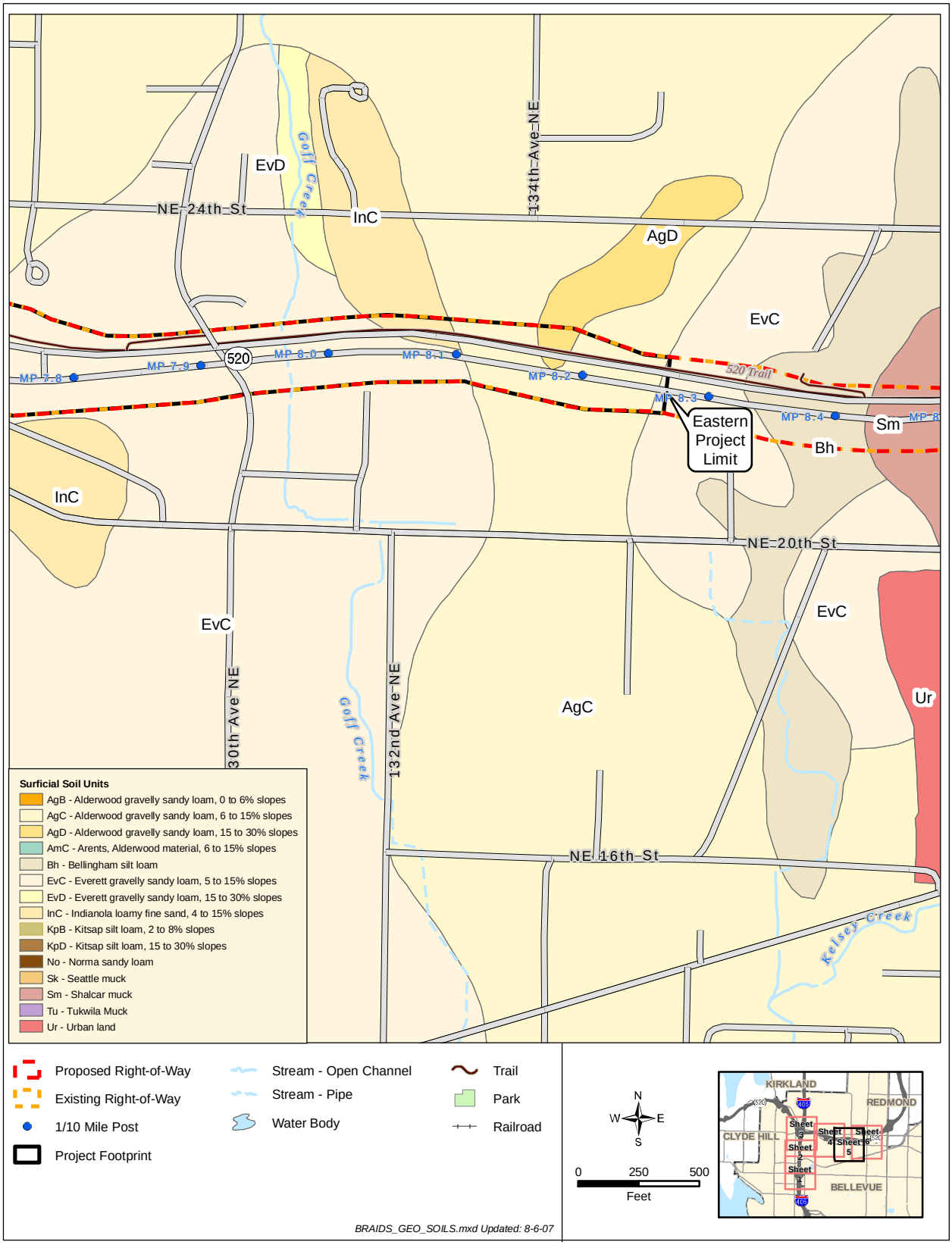

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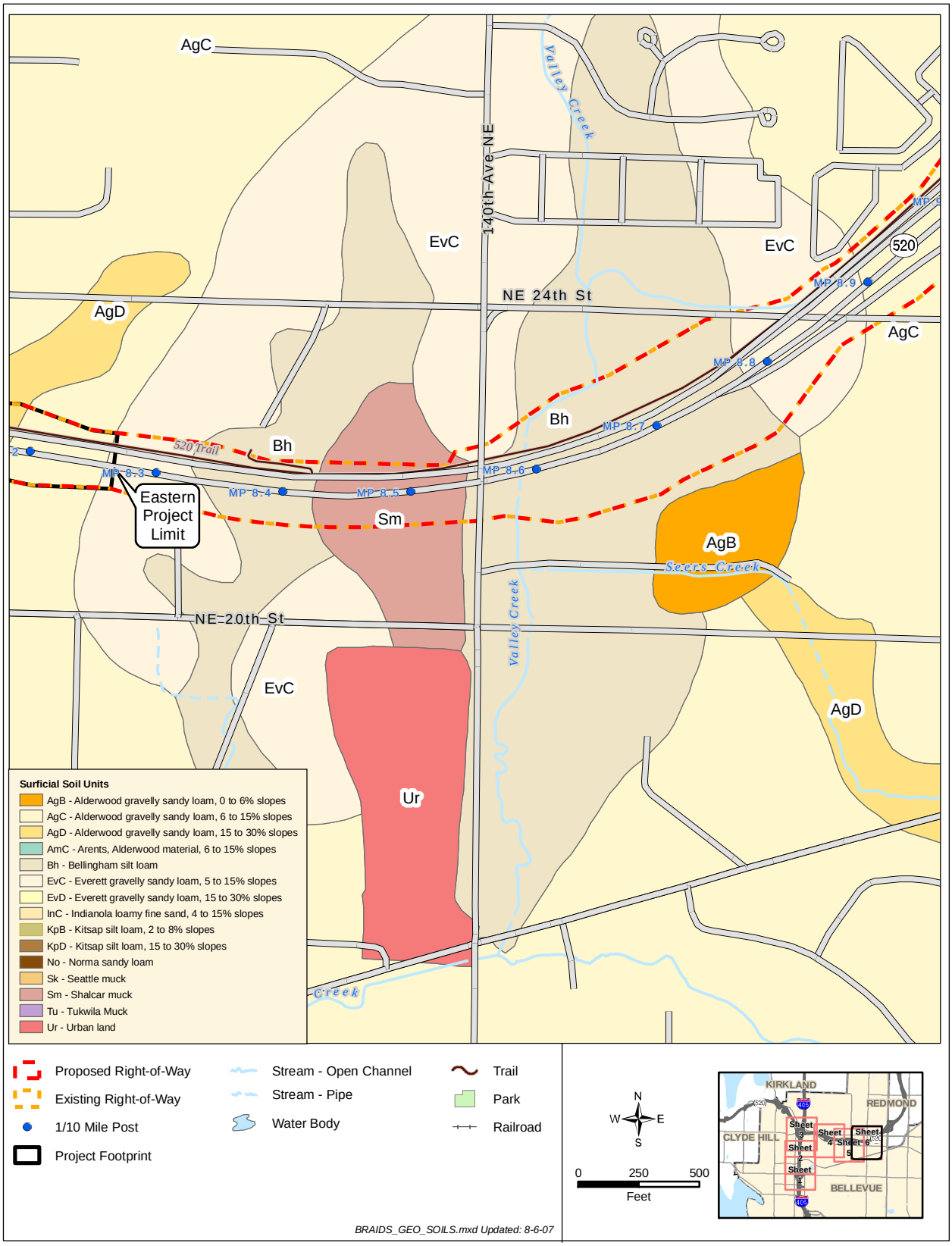
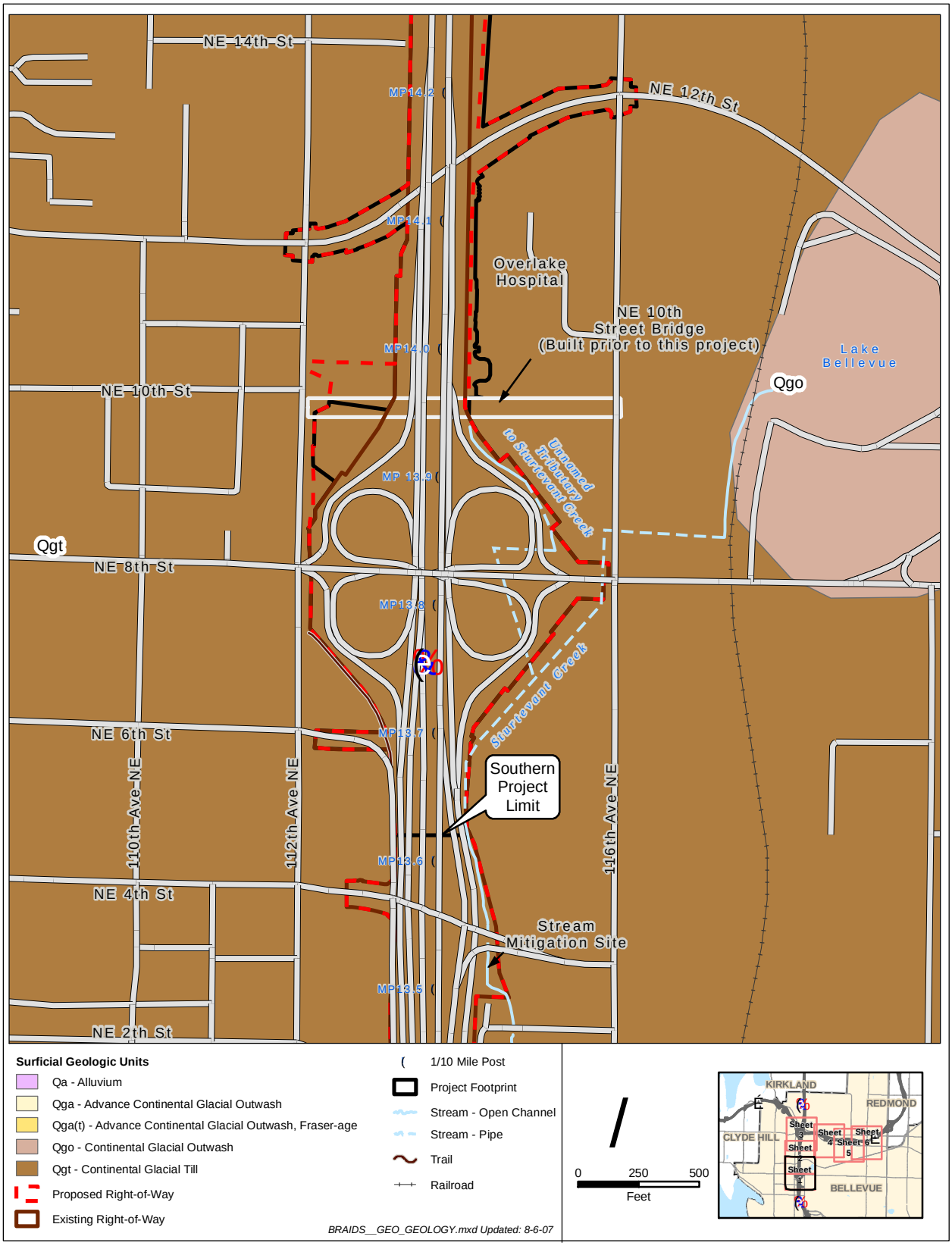


Exhibit 5. Surficial Geologic Units, Sheet 1 of 6



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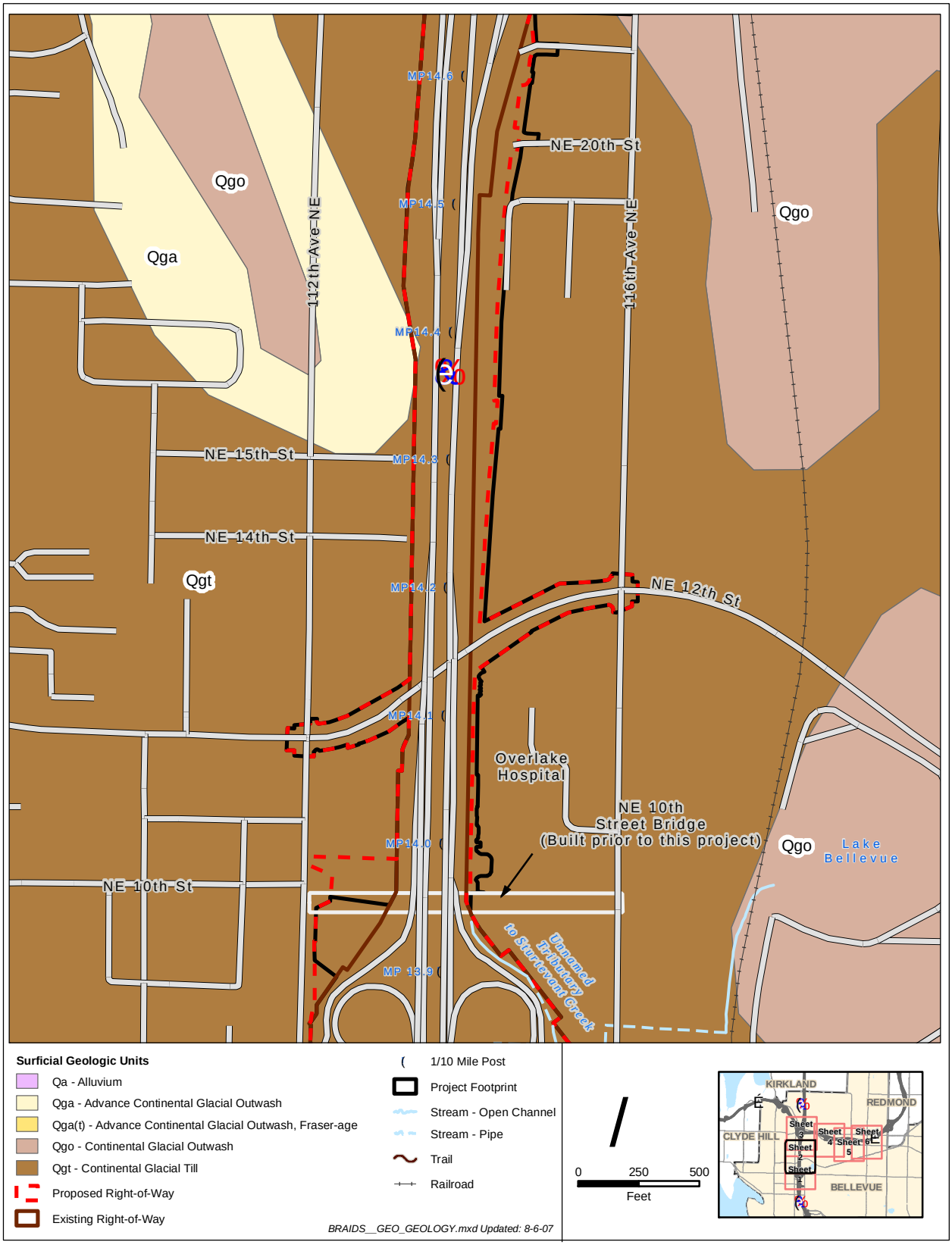

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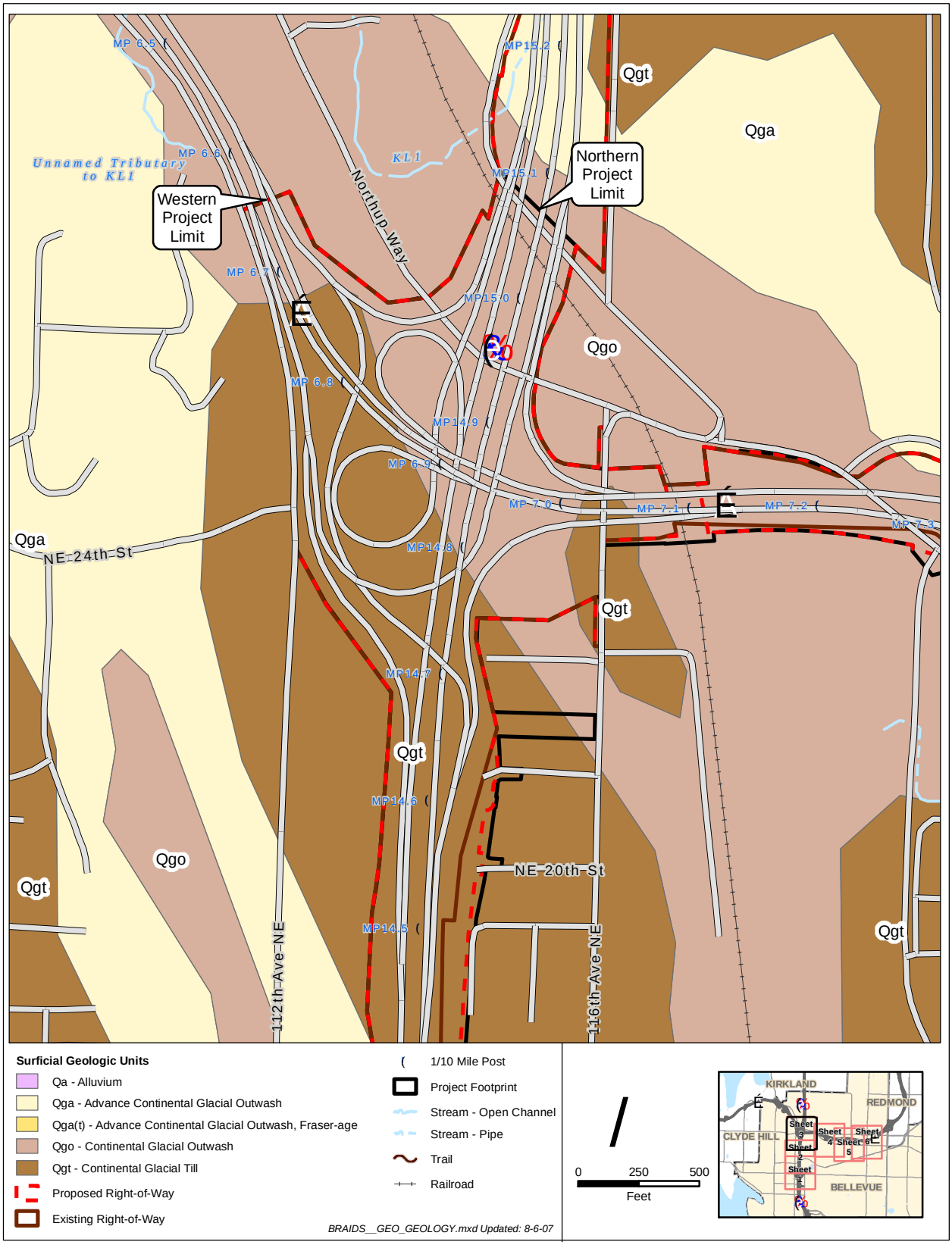

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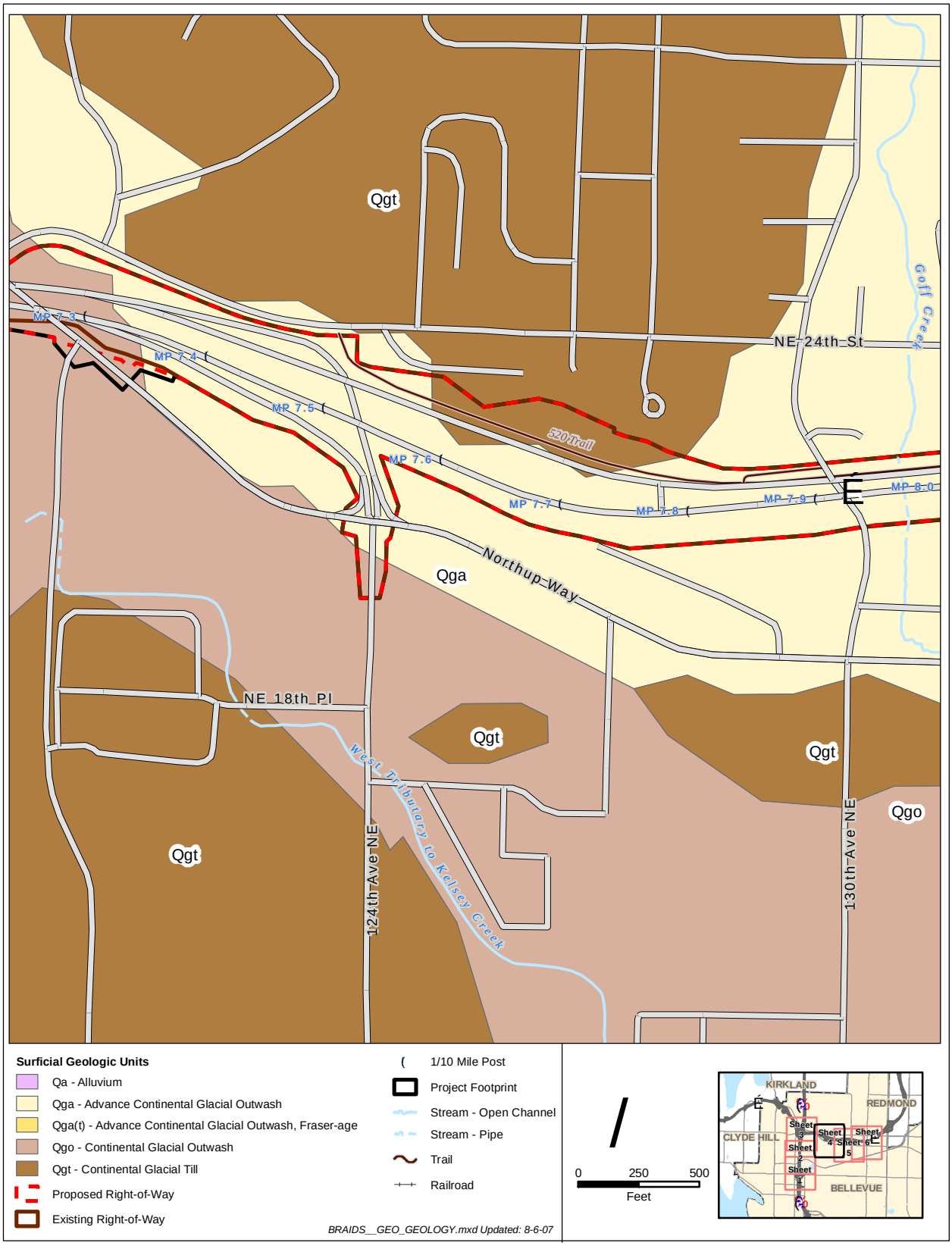

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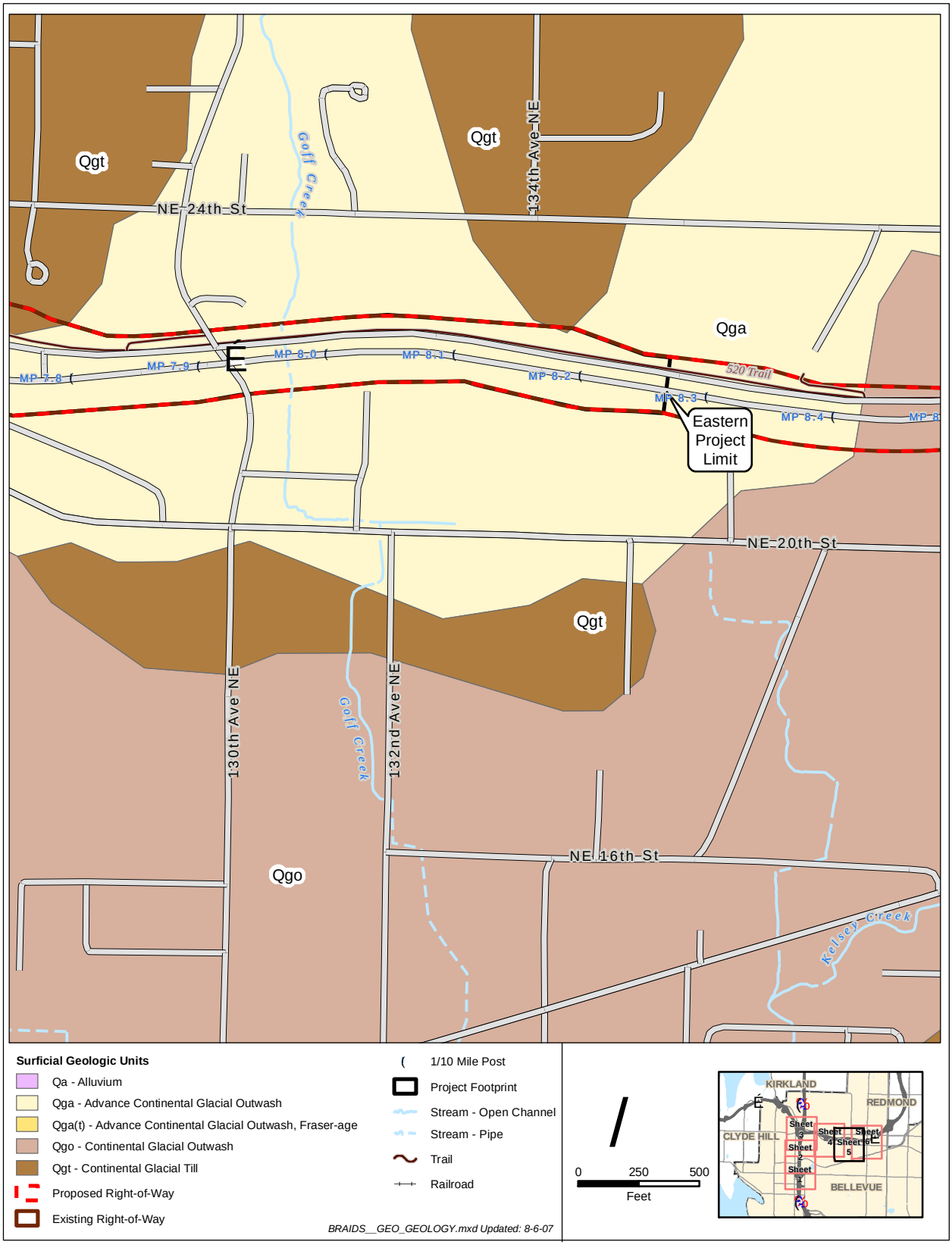

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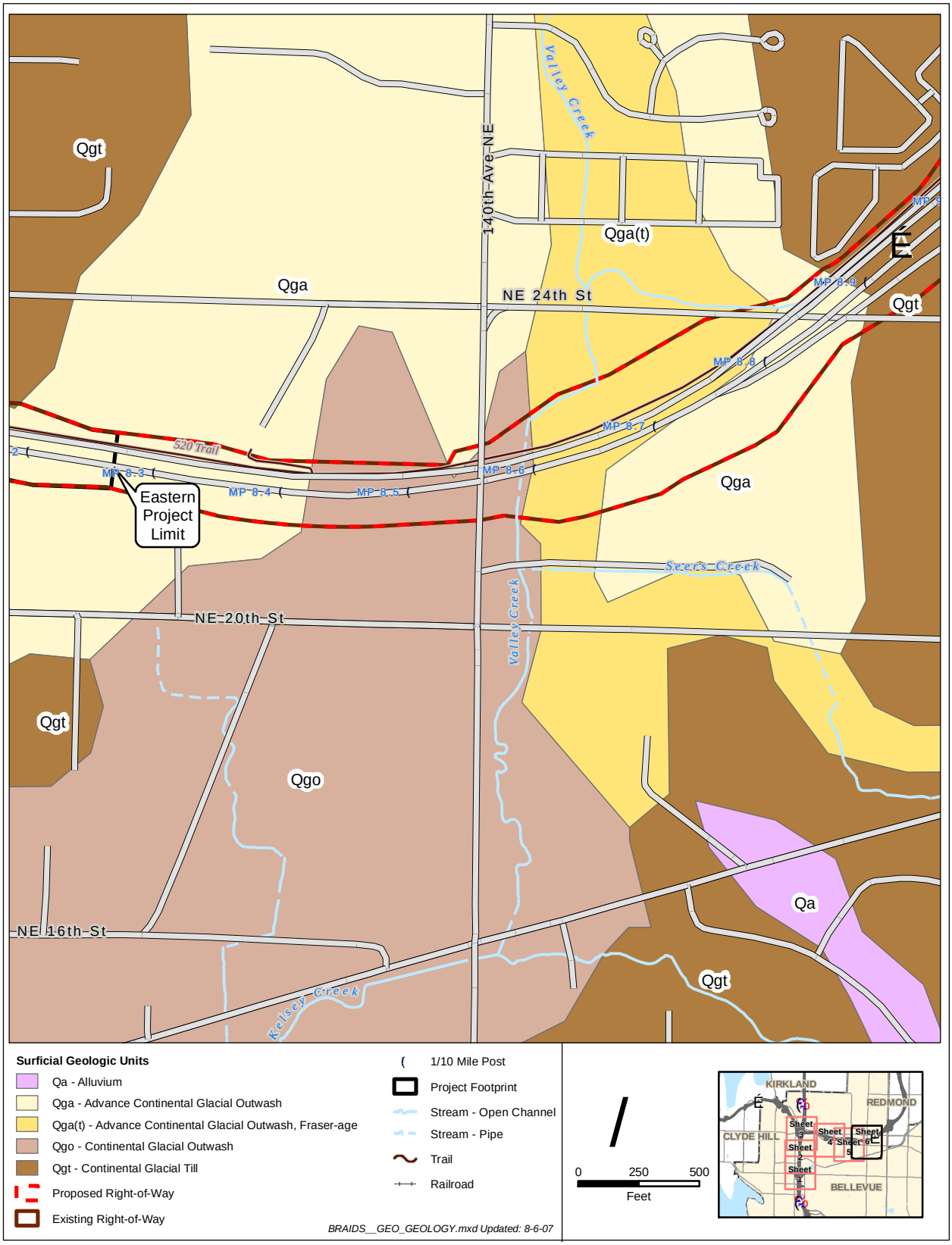
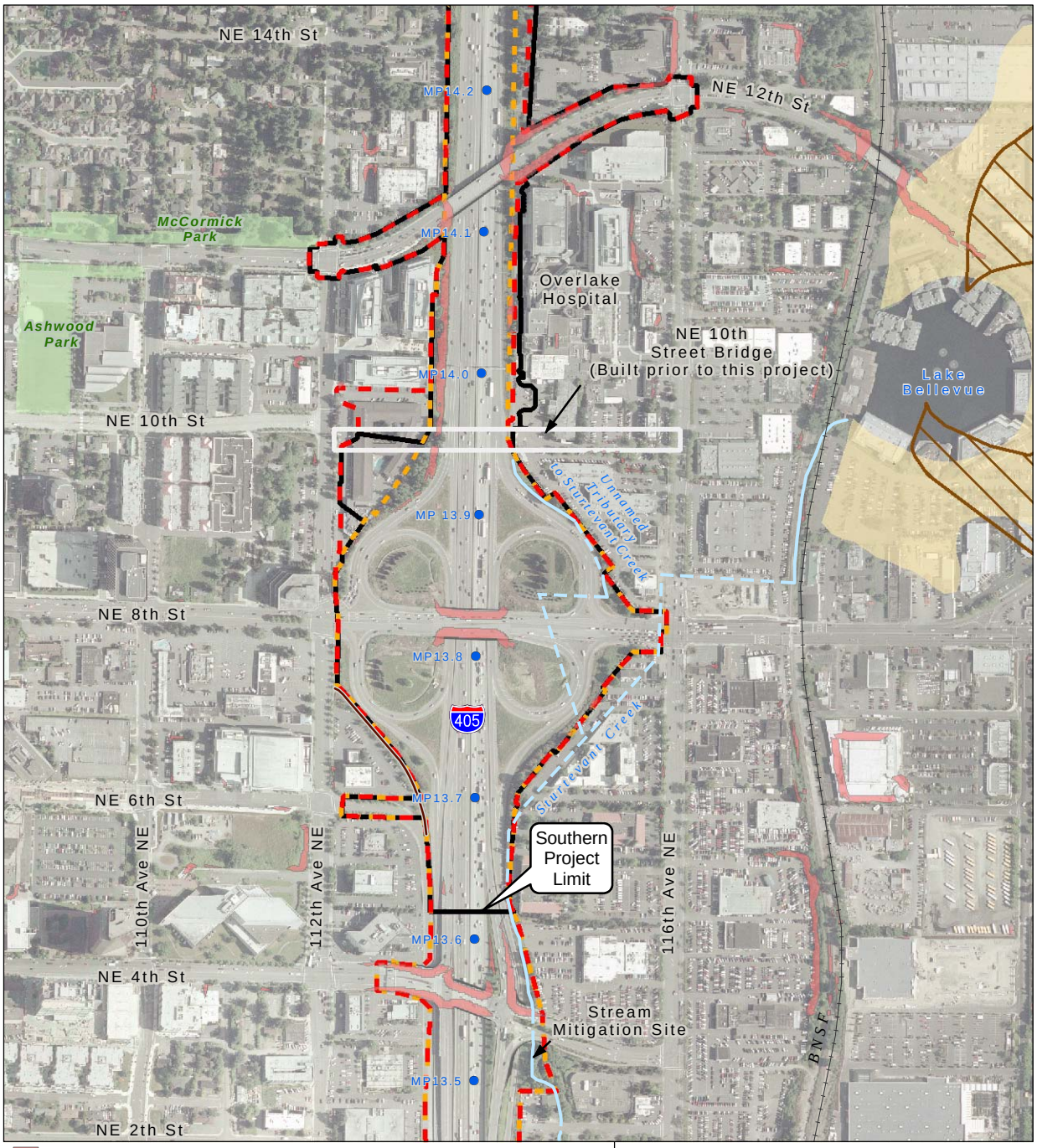


Exhibit 6. Geologic Hazard Areas, Sheet 1 of 6



Steep Slope (Greater than 40%)
Soft Ground Area
Liquefaction - Low to moderate
Erosion Hazard
Observation of Instability in Steep Slope Areas
Proposed Right-of-Way
Existing Right-of-Way
1/10 Mile Post
Project Footprint
Stream - Open Channel
Stream - Pipe
Trail
Park
Railroad

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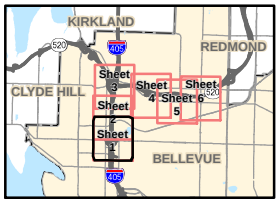

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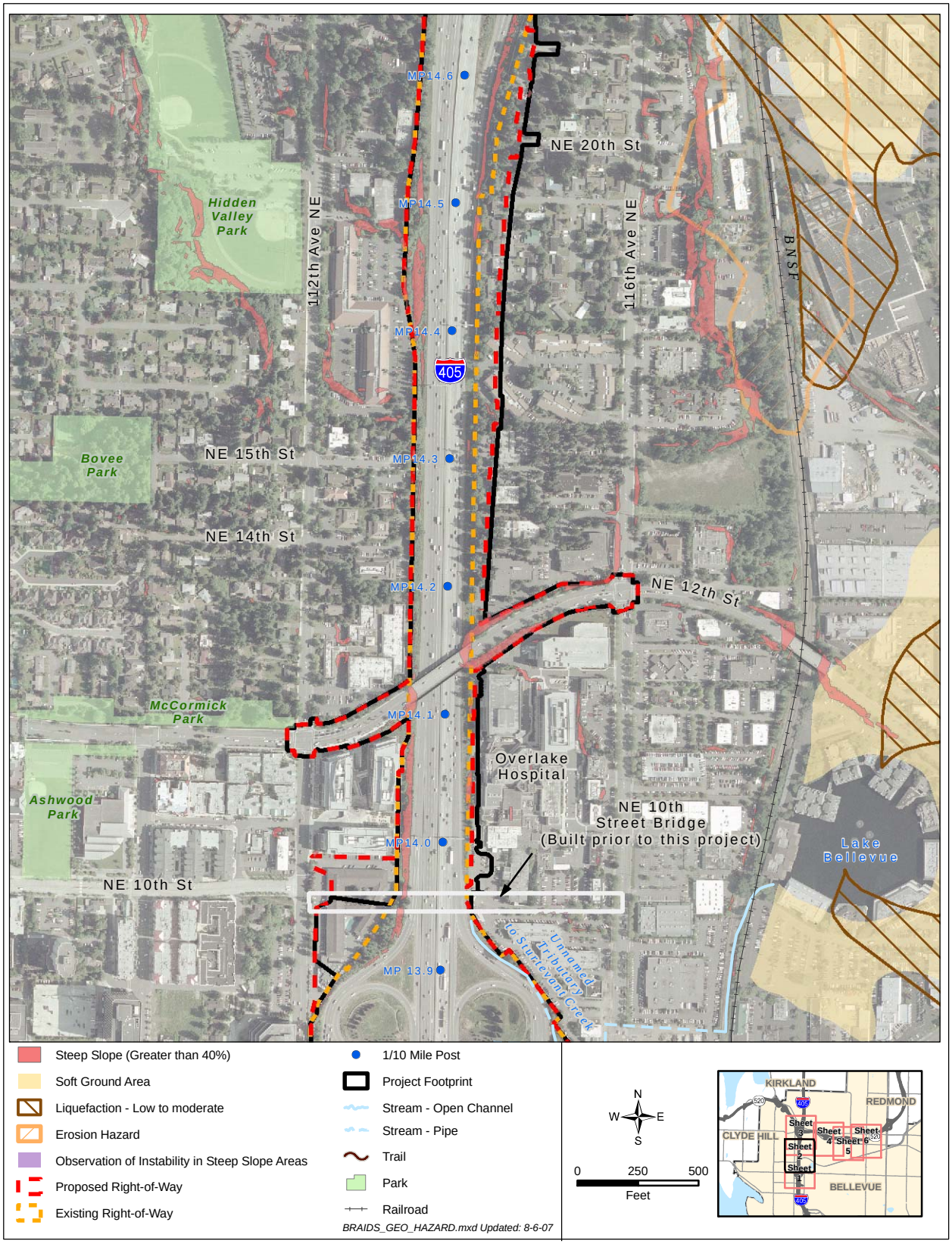

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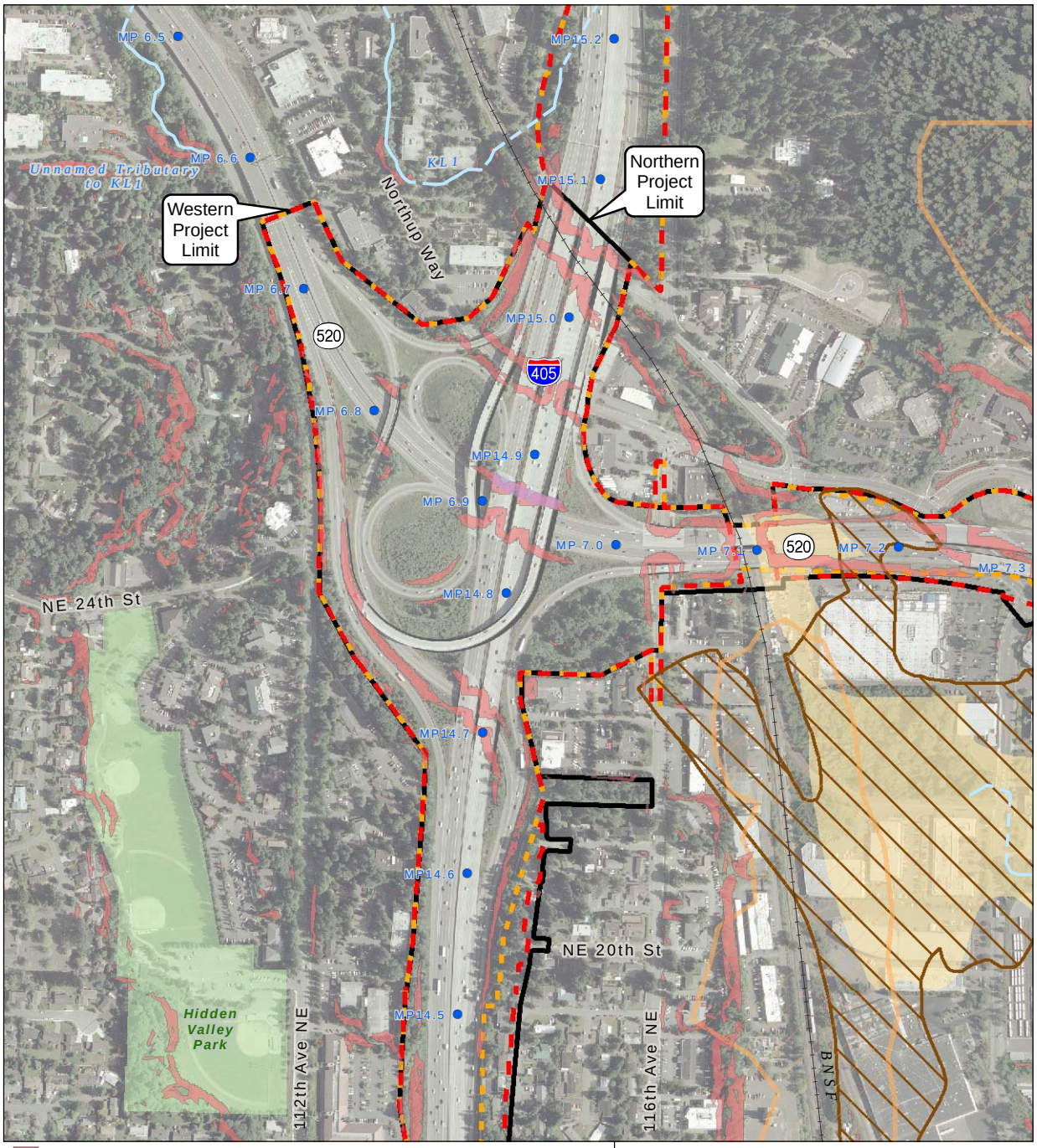

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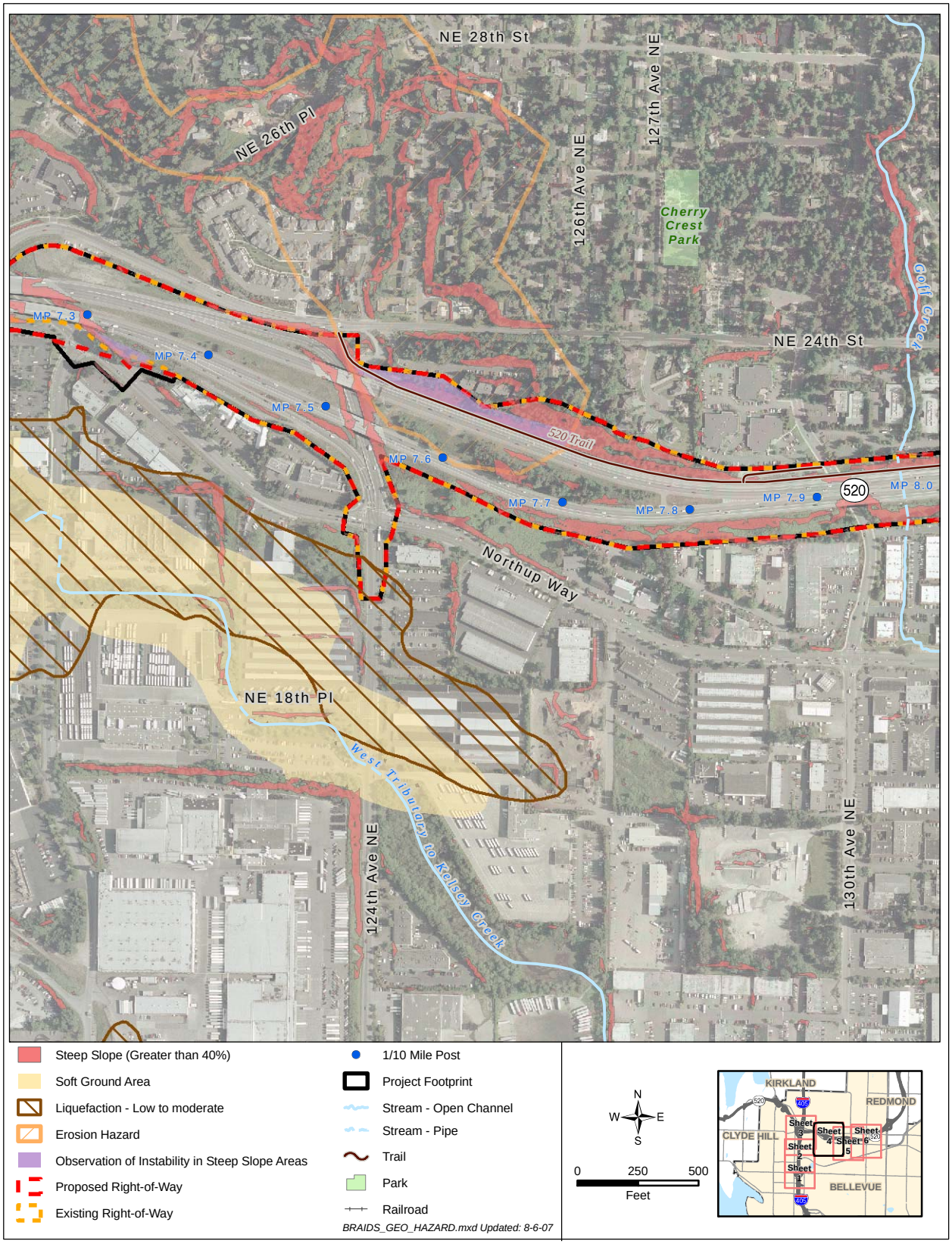

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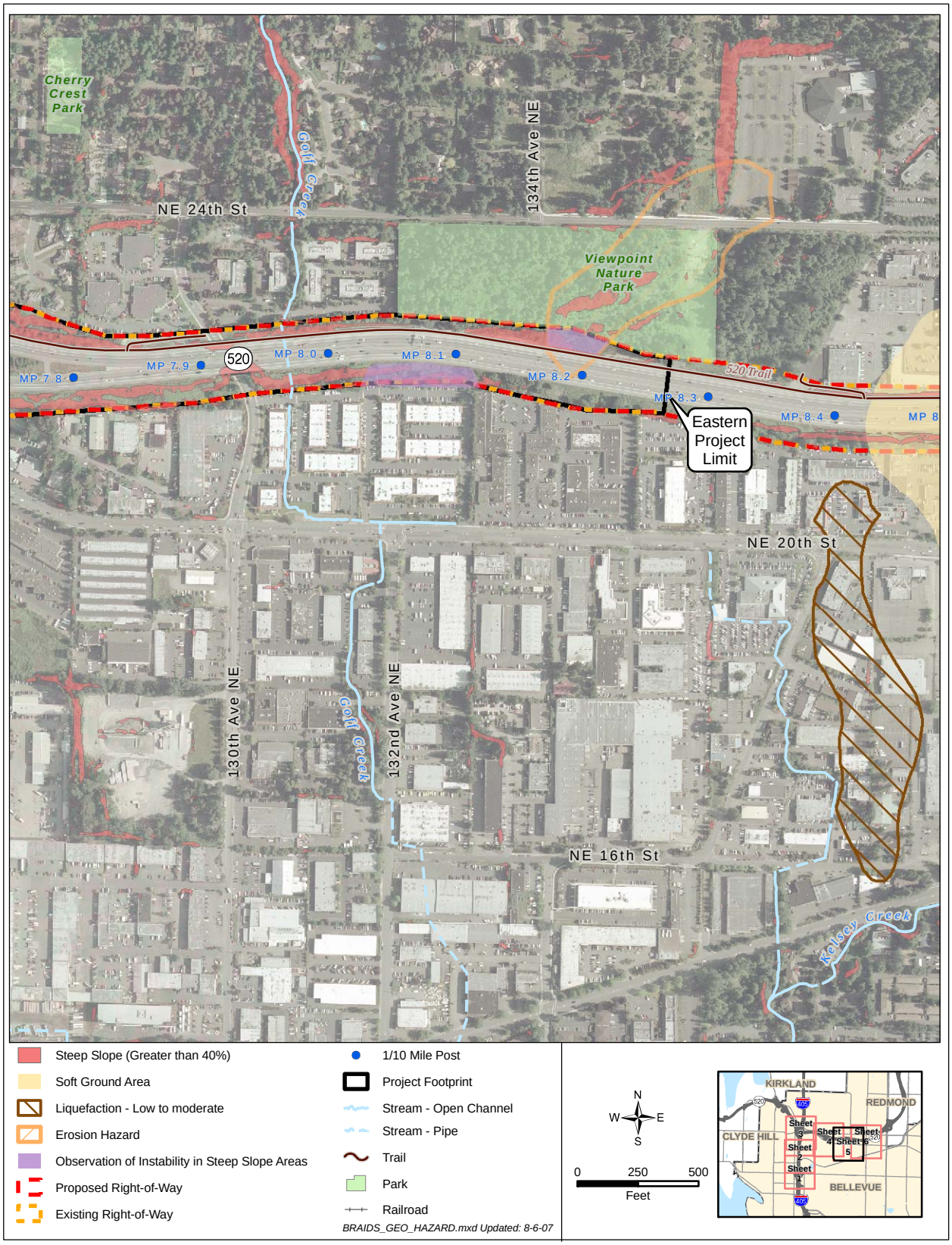
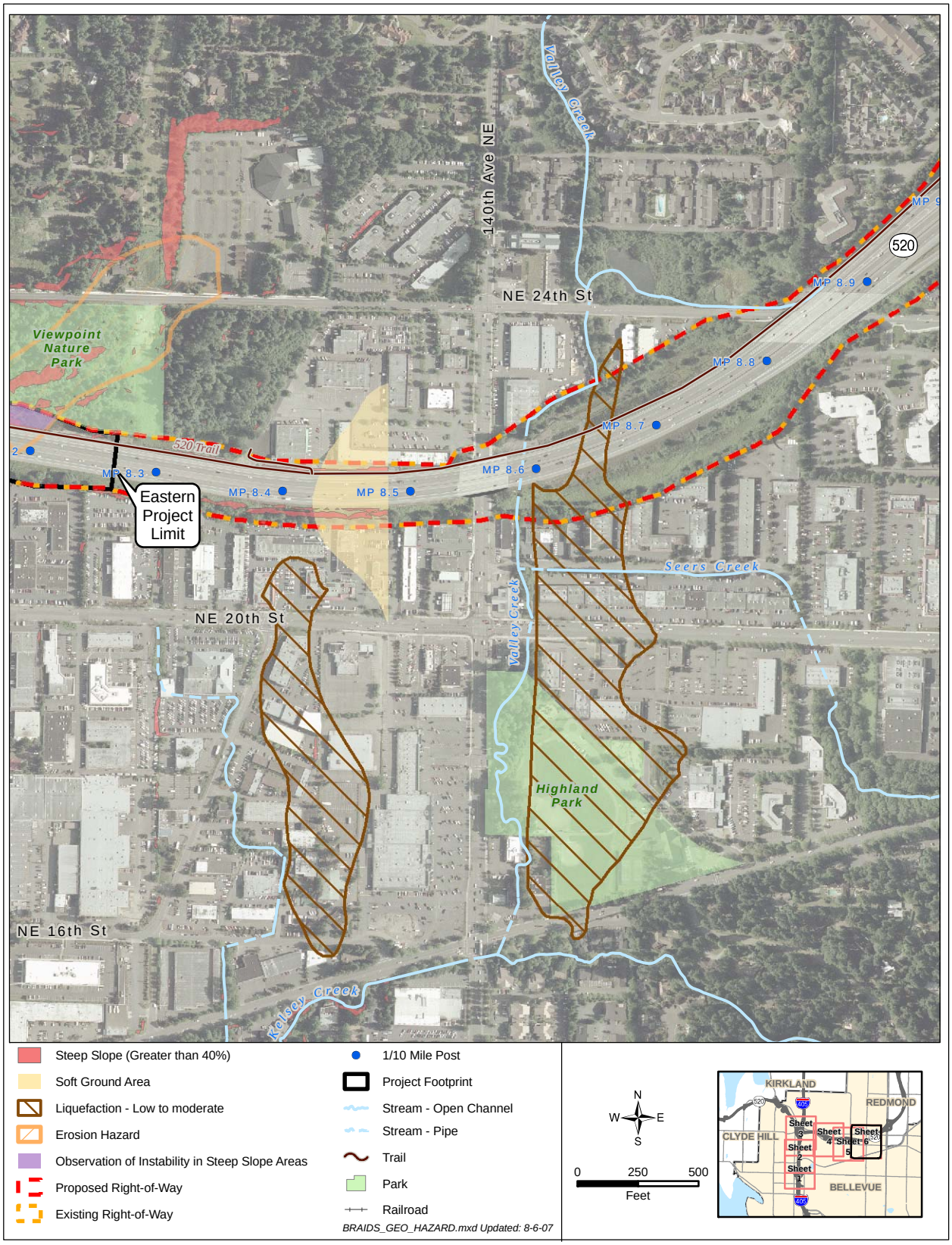
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