Appendix E2

Preliminary Geotechnical/ Geologic Evaluation

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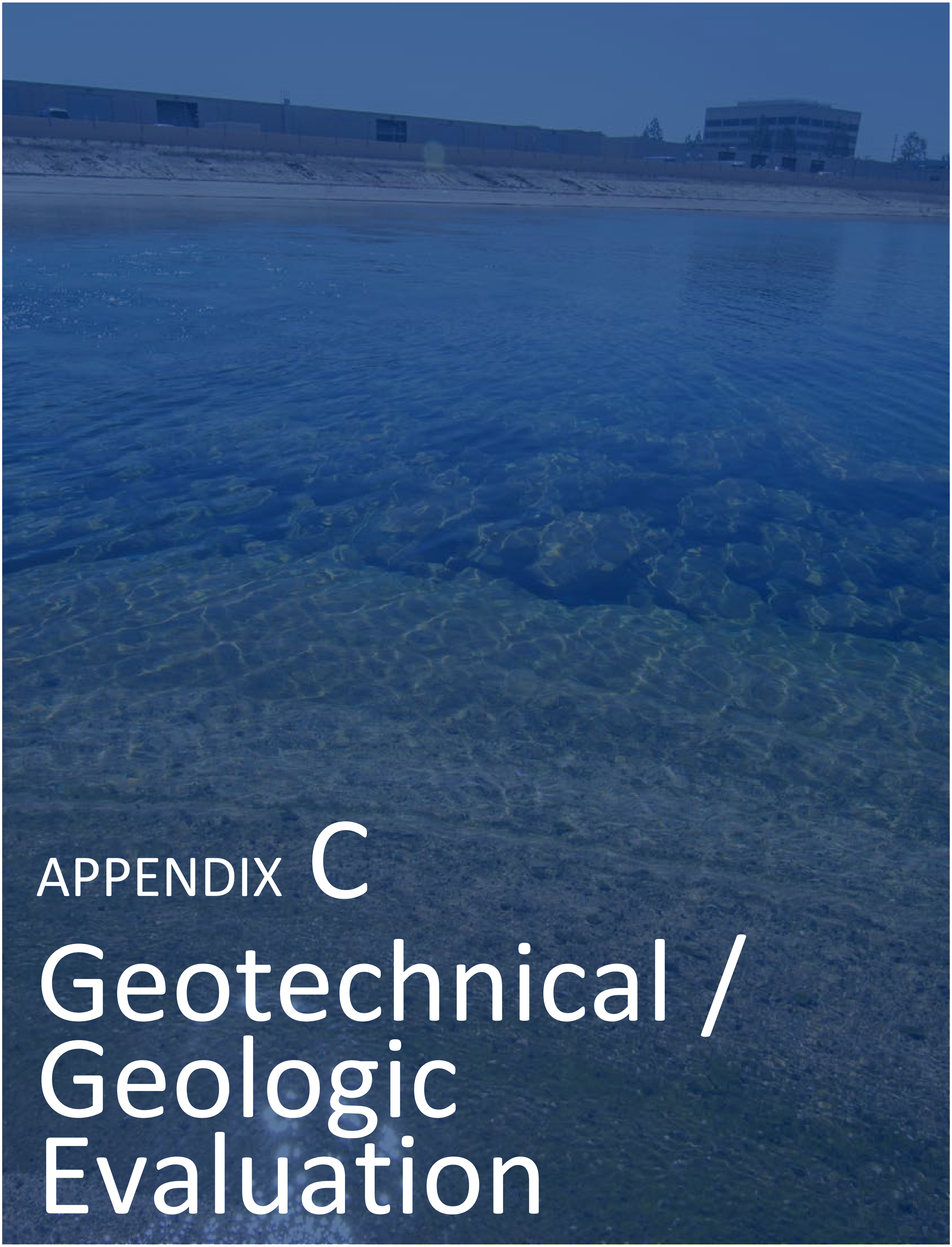

APPENDIX C

Geotechnical / Geologic Evaluation

DRAFT

Preliminary Geotechnical/Geologic Evaluation
Proposed Regional Recycled Water Supply Program
Metropolitan Water District of Southern California

Prepared for
Black and Veatch
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September 6, 2018

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September 6, 2018
Project No.: 16001A

Mr. Andrew Stanton, PE
Black and Veatch Corp.
800 Wilshire Ave., Suite 600
Los Angeles, CA 90017

Subject: **Draft Preliminary Geotechnical/Geologic Evaluation Report**
Proposed Regional Recycled Water Supply Program
Metropolitan Water District of Southern California

Dear Mr. Stanton:

In general accordance with the provisions of our agreement for professional services, we are presenting our draft preliminary geotechnical/geologic evaluation report for the subject project for your review. The report provides preliminary geologic conditions and geotechnical recommendations for design and construction of the project in accordance with the information that has been provided to us. The report provides tables and figures that summarize the findings of our "desk-top" study. Site specific field investigations will be necessary as the project advances beyond this current preliminary phase of work.

Thank you for providing GeoPentech the opportunity to participate on this project. If you have any questions or require additional information, please call.

Very truly yours,
GeoPentech, Inc.

E R Fordham

Eric Fordham, PG, CEG, CHg
Principal

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1.0 INTRODUCTION

This report presents the results of a preliminary desktop geologic and geotechnical evaluation of Metropolitan Water District of Southern California's (Metropolitan's) conveyance alignment alternatives for the proposed Regional Recycled Water Supply Program (RRWSP conveyance project). This desktop evaluation, as shown on Figure 1, focuses on the "Preferred" alignment along with recommended pipe diameters. Figure 1 also shows the Alignment Alternatives that were considered as part of the RRWSP conveyance project. Steel pipe ranging from 4.5 feet to 7 feet in diameter is recommended for the three main segments of the RRWSP conveyance project.

1.1 Purpose and Scope of Study

The purpose of this study is to assess the general geotechnical/geological conditions along Metropolitan's proposed conveyance alignment alternatives for the RRWSP conveyance project with a focus on the Preferred Alignment (Figure 1). A description of the conveyance project features are provided by Black and Veatch Corporation's (B&V) engineering report for which this report provides supporting geological and geotechnical information. The geological and geotechnical conditions presented in this report are based on a desktop-type evaluation that is preliminary and high-level.

The information gathered and used in the evaluation is from published literature, government agency websites and in-house records. Specifically, this report summarizes the mapped surficial geologic units, soil types reported for borings up to 100 feet in depth, shallowest historic depths to groundwater, location of oil and gas fields, seismic hazards, earthquake fault zones, and Quaternary faults mapped along the alternative alignments. We understand that the gathered geotechnical and geologic information and our geotechnical evaluation of these data will be used by B&V and Metropolitan as input for project planning including conceptual design and cost estimating, and California Environmental Quality Act (CEQA) documentation in support of the proposed program. As the program progresses beyond this conceptual design level, collection of site specific geologic and geotechnical data along the Preferred Alignment will be needed.

1.2 Documents Reviewed

B&V provided GeoPentech with the proposed conveyance segment and alignment alternatives for the RRWSP as shown on Figure 1 along with possible trenchless/tunnel undercrossing locations. The alignment data were provided in tabular and geographic information systems (GIS) format. The available technical documents and maps that cover the RRWSP conveyance project area reviewed for this study include the following:

- Geologic units from geologic maps of Long Beach and Los Angeles, California produced by the California Geologic Survey (CGS) and of Orange County from the Santa Ana – San Bernardino map produced by the United States Geological Survey (USGS).

- CGS Seismic Hazard Zones Maps and Evaluation Reports for the following 7.5-minute quadrangles: Yorba Linda, Anaheim, Orange, Los Alamitos, Torrance, Long Beach, Inglewood, Los Angeles, Hollywood, Southgate, Whittier, El Monte, Baldwin Park and Azusa.
- Faults from the USGS Quaternary Fault and Fold Database (2006) as well as from the third Uniform California Earthquake Rupture Forecast (UCERF3; USGS, CGS and Southern California Earthquake Center) are plotted on the maps in this report for identification of Quaternary to Recent age faults.
- Depth-to-groundwater data was reviewed from several sources, including USGS National Water Information System (NWIS), the State of California Water Resources Control Board's GeoTracker GAMA program (Groundwater Ambient Monitoring & Assessment Program), the CGS Borehole database, and the CGS Seismic Hazards Evaluation reports and maps. The GAMA groundwater data is the most recent shallow groundwater data of all the sources. The USGS data is primarily from production wells, and mostly represents groundwater levels in groundwater aquifers that are generally deeper than 200 feet below ground surface. The CGS groundwater contour maps provide a broad coverage of the highest historic groundwater that is perched or semi-perched within shallow alluvial sediments across the conveyance project area.
- Soil type was compiled from the CGS borehole database, summarized and plotted spatially along the conveyance alignment alternatives for evaluation.

1.3 Data Summary Organization

The data collected and reviewed for this study are summarized on figures and tables for the conveyance project area. Regional-scale maps combine like information from various sources showing the following information:

- Geology and Quaternary Faults (Figure 2; Table 1a, b)
- Seismic Hazards (Figure 3)
- Alquist-Priolo Earthquake Fault Zones (Figure 4)
- Groundwater Depth (Figure 5)
- Oil and Gas Fields (Figure 6)
- Soil Characteristics less than 20 feet below ground surface representative of pipeline trenching conditions (Figure 7a), and
- Soil Characteristics greater than 20 feet below ground surface representative of trenchless/tunnel pipeline placement conditions (Figure 7b).

Ground conditions relevant to cut and cover pipeline and undercrossing (trenchless/tunnel excavation) construction for the RRWSP conveyance alignment alternatives are summarized in Tables 2 and 3. Geotechnical conditions for cut and cover trenching and trenchless/tunnel undercrossing pipeline construction are summarized on Figures 8A and 8B, respectively, and discussed following the data review. Potential right-of-way issues associated with cut and cover trenching and trenchless/tunnel undercrossing pipeline construction from a geotechnical perspective, are discussed in Section 3.1.

2.0 SUMMARY OF DATA REVIEW

The following sections summarize our review of the available data for the RRWSP conveyance alignment alternatives. The data presented include regional geology and Quaternary faults, seismic hazards, earthquake fault zones designated for special studies, depth-to-groundwater, oil and gas fields crossed by the conveyance alignment alternatives, and the distribution of soil types within the depths of planned excavation for pipelines and undercrossings.

2.1 Regional Geology

The RRWSP conveyance alignment alternatives traverse portions of the Los Angeles, San Gabriel and Orange County basins. Figure 2 shows a compilation of geology maps produced by the CGS and USGS that cover the conveyance project area (Figure 2A provides an explanation of the geologic units shown on Figure 2). The majority of the conveyance alignment alternatives are located within Quaternary-age alluvial and fluvial sediments that were deposited in the basins from the foot of the San Gabriel and San Bernardino mountains to the Pacific Ocean along the Los Angeles, San Gabriel, Rio Hondo and Santa Ana rivers and their associated tributaries. The Quaternary-age alluvial and fluvial sediments mapped along the alignment are composed mainly of sand, gravel and cobble at the northern end of the alignment with fine-grained sediments present at depth less than about 20 feet; sand, silty sand and silt in the central and eastern alignment areas; and silty sand, silt and clay in the south and southwestern portion of the conveyance project area.

Outcrops of Pleistocene-age and older bedrock units occur in the Puente, Montebello and Signal hills through which the alignment passes. Bedrock units in the Puente and Montebello hills are composed of shale, siltstone, sandstone, pebbly sandstone, and conglomerate of the Sespe, Topanga, Puente and Fernando formations. Bedrock units exposed in the Signal Hill area are composed of sandy silt, sandstone and pebbly sandstone of the Lakewood Formation, Palos Verdes Sand and San Pedro Formation. Within the Los Angeles coastal plain, shallow groundwater less than 50 feet below the ground surface occurs perched on fine-grained alluvial deposits that range in depth from about 60 to 100 feet.

2.2 Quaternary Faults

Figure 2 shows that the conveyance alignment alternatives cross the Newport-Inglewood Fault Zone, the Los Alamitos Fault and possibly, though not shown, a buried fault trace that connects the Whittier and East Montebello faults. The Newport-Inglewood and Los Alamitos faults have experienced surface rupture in the late Quaternary (<130,000 years before present) as defined in the USGS Quaternary Fault and Fold Database. Tables 1a and 1b provide a summary of fault geometry and deformation characteristics for those faults shown on Figure 2 that occur within the RRWSP conveyance alignment alternatives area.

The alternative alignments cross the Newport-Inglewood Fault from about the intersection of the 405 and 710 freeways to the intersection of Cherry Avenue and the 405 freeway. The Newport-Inglewood Fault Zone is Holocene active as evidenced by many geotechnical studies as well as the M_W 6.3 Long Beach Earthquake of 1933. This fault is estimated to have probable earthquake magnitudes in the range of M_W 6.0 to 7.4 with surface rupture likely to occur above M_W 6.0. The Newport-Inglewood Fault has right-lateral displacement with a best estimate of 2 meters (6.5 feet) average displacement.

The Los Alamitos Fault crosses the alignment, near the intersection of Wardlow Road and Los Coyotes Diagonal. The Los Alamitos Fault is not known to be active in the Holocene (<11,700 years before present) although this fault is considered to have last ruptured the surface in the Late Quaternary (less than 700,000 years before present; Southern California Earthquake Data Center). The Los Alamitos Fault is theorized to deform with movement on the larger Compton Blind Thrust fault system (Leon, et al., 2009) Southern California Earthquake Data Center, 2016).

In the Puente Hills southeast of the alignment, the Whittier Fault is Holocene active as corroborated by many geotechnical studies in the surrounding hills. This fault is estimated to have probable earthquake magnitudes in the range of M_W 6.0 to 7.2 with surface rupture likely to occur above M_W 6.0. The Whittier Fault has right-lateral displacement with a best estimate of 1.9 meters (6 feet) average displacement.

Within the Whittier Narrows between Beverly Boulevard and the 60 Freeway, the alignment crosses the projection of the Whittier Fault and East Montebello Fault. Although the projection of the Whittier Fault through the Narrows is speculative due to the lack of clear geomorphic features (e.g. Yerkes, 1972; Smith, 1977), Holocene-aged sediments in the Narrows have likely been significantly reworked by the San Gabriel River removing any fault related features that may have existed. At depth beneath the Narrows, the fault has been shown to offset Miocene/Pliocene and older sedimentary deposits (Yerkes, 1972). While direct evidence of Holocene fault rupture within the Whittier Narrows does not exist, there may be potential for fault offset in this area to occur as a result of a large magnitude earthquake (i.e. M_W 7 or greater) on the Whittier Fault.

There are no other late Quaternary or Holocene active faults currently mapped at the surface along other portions of the proposed conveyance alignment alternatives considered for this study. Although, at least four blind thrust faults exist beneath the alignment area that have recent seismic activity. These are the Compton, Puente Hills and Peralta Hills blind thrust systems.

It was generally considered that M_W 6.0 is the approximate lower limit of earthquakes capable of producing fault surface displacements. However, experience gained through recent analyses by the Jet Propulsion Laboratory in Pasadena of ground surface fault displacements that occurred during the March 28, 2014 M_W 5.1 La Habra Earthquake, whose epicenter was about 2 miles north of the eastern portion of the proposed alignment, will likely shift this surface fault rupture lower limit down to $\approx M_W$ 5.0. Although the surface fault displacements observed following this event were reported to be generally in the millimeter/centimeter range, if larger earthquakes (M_W 6) are generated by the thrust faults underlying the proposed alignment alternatives, surface displacement in the range of centimeters to tens of centimeters may occur.

The subsurface geometry of the blind thrust system is uncertain, and demonstrating Holocene activity on blind thrusts is often difficult; however, Leon et al. (2007, 2009) report evidence for Holocene-aged sediments folded by coseismic slip on the Puente Hills and Compton blind thrust systems. Furthermore, the 1987 M_W 6.0 Whittier Narrows earthquake has been attributed to slip on the central section of the Puente Hills blind thrust fault (Leon et al., 2007). Large earthquakes on the Puente Hills and Compton blind thrust systems are not known to rupture the surface, but distributed coseismic deformation is possible, with potential for differential uplift spanning a few centimeters to tens of centimeters across a broad area (tens of square kilometers).

2.3 Seismic Hazards

The California Seismic Hazard Zonation program is a state regulatory program that produces maps delineating areas where investigation is required to assess potential impacts of liquefaction or seismically induced landsliding. Detailed geotechnical/geologic investigations are required for projects that are proposed in these zones to identify the extent and potential consequences of these hazards for the proposed work. The implementation of the requirement is left to local jurisdictions, although CGS Special Publication 117 (2008) is typically used for guidance.

Figure 3 shows that the majority of the conveyance alignment alternatives cross over several Liquefaction Hazard Zones that have been defined by the CGS. The alternative alignments as they are currently proposed do not pass through Earthquake-Induced Landslide Hazard Zones, but are within 1 mile of these zones in the Montebello/Pico Rivera area.

2.4 Earthquake Fault Zone (AP Zone)

In response to the 1971 San Fernando Earthquake, the Alquist-Priolo Act was signed into law in 1972. The act established a program to produce maps of Earthquake Fault Zones that delineate the surface trace of active faults as well as buffer zones where special studies are required to ensure structures for human occupancy do not cross the fault. It should be noted that the act does not directly address structures without human occupancy or infrastructure facilities such as pipelines or tunnels. However, this information is included here for reference purposes.

As shown on Figure 4, the proposed conveyance alignment alternatives cross the Newport-Inglewood Earthquake Fault Zone as defined by the CGS, approximately between about the intersection of the 710 and 405 freeways and the intersection of Cherry Avenue and the 405 Freeway. Other identified Alquist-Priolo (A-P) Earthquake Fault Zones that are near the proposed conveyance alignment alternatives include the Whittier-Elsinore Fault Zone and East Montebello Fault near the center of the alignments, and the Sierra Madre Fault Zone just north of the alignments in the San Gabriel Valley. The other fault that is crossed by the alternative conveyance alignments is the Los Alamitos Fault, though this fault has not been identified by the CGS as a possible Holocene-active fault and, therefore, is not designated as an A-P Earthquake Zone.

2.5 Groundwater Occurrence

The depth to shallowest historic groundwater contours (as produced in the CGS seismic hazard evaluation maps) were digitized and are provided on Figure 5. These levels represent perched or semi-perched groundwater within the uppermost alluvial deposits of the San Gabriel Valley and Los Angeles Coastal Plain. The CGS depths to shallowest historic groundwater contours are reasonably consistent with the more recent GAMA depth to groundwater measurements and CGS Borehole database values. The GeoTracker GAMA depths to groundwater values that were reviewed represent the shallowest depth to groundwater measurement from each GeoTracker site. GeoTracker sites are soil and groundwater monitoring sites, often associated with hazardous waste contamination and where many monitoring wells have been installed at each site. The advantage of the GeoTracker, GAMA and CGS Borehole database groundwater elevations is that they are often a good representation of first-encountered or shallow groundwater, which can be beneficial in assessing the need to dewater excavations for pipeline trenches and undercrossings. Regional groundwater levels provided by water agencies such as the Water Replenishment District of Southern California, generally represent the piezometric level within deep aquifers of the Los Angeles basin, which have little bearing on the shallow sediments where dewatering is a concern.

As shown on Figure 5, shallow groundwater with depths of 20 feet or less is found primarily within alluvial sediments throughout most the conveyance project area with exceptions including Signal Hill, the area east of the intersection of the 91 and 5 freeways in Orange County and north of Ramona Boulevard in the San Gabriel Valley. The shallow groundwater generally coincides with CGS mapped Liquefaction Hazard Zones. Based on review of compiled groundwater levels and local experience, shallow groundwater that occurs within the uppermost alluvial deposits may vary up to 10 feet between dry and wet years and several feet seasonally. Also, areas influenced by tides (e.g. near Los Angeles Harbor and Los Angeles River south of Willow

Street), or short term changes in river stage due to rainfall (e.g. Dominguez Channel, San Gabriel River from Santa Fe Dam south to about Downey, and near the Santa Ana River) may also be influenced by changes in groundwater on the order of several feet.

2.6 Oil and Gas Fields

As shown on Figure 6, the proposed conveyance alignment alternatives overlie oil and gas fields in the cities of Wilmington, Long Beach, Signal Hill, Industry, Montebello, Whittier, Santa Fe Springs, Buena Park and Placentia. Issues associated with pipeline and undercrossing tunnel construction in areas overlying oil and gas fields include the potential accumulation of hazardous gasses, including methane and hydrogen sulfide in underground excavations and tunnels, oil residuals in soil, legacy contamination associated with oil and gas production activities and encountering abandoned well casings.

2.7 Soil Characteristics

The distribution of soil types along the proposed conveyance alignment alternatives is shown for depths less than 20 feet below ground surface in Figure 7A, which relates to the anticipated depth of excavation for pipeline construction and greater than 20 feet in Figure 7B, which relates to depths of trenchless/tunneling excavation methods to cross under existing infrastructure. The figures show the locations of borings compiled from the CGS Borehole database along with the prevalent soil type for the shallow (less than 20 feet) and deep (greater than 20 feet) intervals. In general, shallow soils throughout the conveyance project area are composed of sand silt and clay while the deeper soils tend to be coarse grained (sand, gravel, cobbles and boulders) in the northern portion of the alignment and finer grained to the south consistent with alluvial and fluvial deposition that is sourced from the mountains north of the project. Deep soils within the eastern portion of the proposed conveyance project area (i.e. within Orange County) tend to be predominantly sand with some fine-grained silts and clays in the shallow zone.

3.0 GEOTECHNICAL CONSIDERATIONS

Table 2 provides key geotechnical conditions that are considered for the cut and cover and undercrossing pipeline construction elements of the proposed RRWSP conveyance alignment alternatives. In addition, the following geotechnical issues that will likely be a consideration of future pipeline and trenchless/tunnel alignment designs are discussed in more detail. For reference, Figures 8A and 8B provide a summary of shallow (less than 20 feet) and deep (greater than 20 feet) ground conditions interpreted throughout the proposed conveyance project area.

3.1 Cut and Cover Pipeline and Undercrossing Pit Excavations

1) Temporary Shoring

Temporary shoring will likely be necessary for most pipeline and pit excavations due to the fact that the alignment is along existing public rights-of-way such as roads and highways. Where the pipeline is located in areas with adequate space that can accommodate open-cut trenching to access the existing structure, the trench excavation can be sloped back. Typically, excavations in clayey material are anticipated to stand steeper than in sandy material. In addition, areas where the groundwater level is high, open-cut trenching and pit excavation may be difficult without adequate dewatering.

Temporary shoring such as speed-shores, slide rails, trench boxes, cantilever sheet piles, soldier piles with lagging, and internal bracing could be used throughout the alignment combined with adequate dewatering where necessary. An exception is that the use of cantilever sheet piles would likely not be appropriate in areas where outcropping rock occurs such as in the areas near Signal Hill where bedrock is outcropping or is close to the ground surface as the necessary embedment may be difficult to achieve. Non-interlocking shoring is not appropriate in areas where shallow groundwater and sandy materials are not adequately dewatered ahead of the excavation as windows between shoring may allow soil and groundwater intrusion into the excavation, potentially destabilizing the excavation walls.

2) Excavation and Soil Reuse

In general, excavation of the alluvial or fluvial materials that are present along the majority of the proposed alternative alignments should not require special equipment. Where the alignment enters the Signal Hill area where outcropping bedrock is present heavy ripping equipment, such as a Caterpillar D-9 or D-10 dozer equipped with a ripper shank may be necessary. Based on our experience, blasting would not be necessary for excavation sites in this area.

Reuse of excavated material for backfill should be evaluated on a case by case basis depending on the soil type present at the proposed excavation sites and the possible occurrence of contamination/hazardous substances, specifically in the areas near oil and gas fields. Generally, non-contaminated alluvial or fluvial materials should be acceptable for reuse provided that oversize material is removed and the material is appropriately moisture conditioned and compacted.

Note that the requirements for backfill material will depend on the anticipated use of the site and any conditions imposed by the design or the local jurisdiction. As general guidance material with a liquid limit less than 40 and a plastic limit less than 12, or alternatively, with a sand equivalent less than 30 would likely be acceptable. Generally, this excludes clays with moderate to high plasticity, but may allow reuse of some low plasticity clays and silts. Actual requirements would depend on the soil properties, design criteria, and local jurisdictional restrictions.

Note that in some portions of the proposed conveyance project area, soil boring logs reviewed identified some material that would not likely be acceptable for reuse. This included particular references to material characterized as "Gumbo silt" which was noted in logs from specification No. 722 for Metropolitan's Second Lower Feeder Project in the Los Alamitos area. It is not clear whether this material was only present locally and therefore was not noted in other logs, or if the particular description is a unique expression from the person(s) who documented these boreholes. Our experience at other projects in this area suggests that fine-grained sediments would be appropriate for reuse. However, it does appear that "Gumbo silt" would not be reusable based on the textural descriptions in the logs. Increased cost for imported backfill material should be included in cost estimates for areas where "Gumbo silt" or contaminated material has been identified.

3) Dewatering

Most of the proposed conveyance alignment alternatives appear to have relatively shallow groundwater with depths ranging from about 8 feet to 20 feet below ground surface. Groundwater that is less than 20 feet below ground surface will likely require dewatering for pipeline trench construction. This is shown by the hatched stippled pattern on Figure 8A. Groundwater that is less than 50 feet below ground surface will require dewatering or watertight support of excavation with sump pumping for undercrossing pit construction. This is shown by the stippled pattern on Figure 8B.

Dewatering is a viable means for controlling groundwater flow into open excavations for most of the alignment; however a specific assessment of seepage rates into excavations is beyond the scope of this study. Groundwater inflow is dependent on local soil conditions as more clayey soils in the zone of the excavation would expect to have less flow compared to sandy soils that would have higher flow. Also, the use of interlocking sheet piles for shoring may be helpful in reducing groundwater flow into excavations and should be considered for undercrossing pits where appropriate. In general, the sandy to cobbley deposits that occur at the northern end of the conveyance project area and the sands on the eastern end will require higher pumping rates than the finer grained deposits that occur in the south and southwestern areas of the proposed alternative alignments. Where dewatering is required, right of way will need to be acquired for dewatering wells, associated conveyance piping, and effluent treatment and discharge.

4) Bearing Capacity for Pipe Jacking Equipment

The use of pipe jacking for pipe installation by jack and bore or microtunneling may be required to cross under existing infrastructure. This process will require winching or jacking equipment whose size depends on the length and diameter of the undercrossing. Pipe jacking equipment will likely bear on either native soils or on prepared temporary foundation elements that in turn bear on the native soils. In general, the portions of the alignment near outcropping rock such as within Signal Hill will likely have relatively high bearing capacities. The remainder of the proposed conveyance project area is situated in relatively softer alluvial and fluvial deposits that may not have sufficient bearing capacities unless modified through ground treatment.

Ground preparation for areas with softer soils could include using engineered fill, rat/mud slabs, or stabilization using crushed rock or geotextiles in order to provide a more stable base. The requirements will depend on the size of the equipment needed and the soil conditions encountered.

5) ***Liquefaction***

As described previously, a significant portion of the proposed conveyance project area is located within mapped liquefaction hazard zones. Due to the deeper depth of groundwater in the portions of the conveyance alignment alternatives in Signal Hill, north of Arrow Highway in the San Gabriel Valley and between Euclid Street and Kraemer Boulevard in Orange County, liquefaction hazards in these sections are considered relatively low and not likely. However, liquefaction hazards are moderate to high on a regional basis for the remaining portions of the proposed conveyance alignment alternatives. Sections that pass through mapped liquefaction hazard zones should be prioritized for evaluation and the remaining areas should be screened to establish whether there is relatively high groundwater present and potentially susceptible soils (i.e. loose granular soils with low plasticity). Areas where these hazards are known to exist should be evaluated to estimate potential settlements or deformation for design or whether flotation of the pipeline could be a risk.

6) ***Seismically Induced Landsliding***

Most of the proposed alternative alignments cross relatively flat terrain through the Los Angeles, San Gabriel and Orange County basins and are not near areas where seismically induced landslide zones are mapped.

7) ***Fault Offset***

The pipeline crosses three known Quaternary-age faults, the Newport-Inglewood Fault, the Los Alamitos Fault, and the projection of the Whittier Fault as well as three blind thrust fault systems, the Compton, Puente Hills and Peralta Hills. The portion of the pipeline that crosses the Newport-Inglewood Fault is in a mapped Alquist-Priolo Zone. While this may not require a special fault study on the basis that the pipeline is not a human occupancy structure, these fault crossings should be recognized during the design of the project. Table 1b provides a summary of estimated average displacement and relative motion for the faults crossed by the proposed alternative alignments. Due to the likely consequences of pipeline failure given a fault offset at any of these identified locations, evaluation of pipeline resiliency for a given seismic event should be considered for future pipeline design.

8) ***Oil and Gas Fields***

The proposed conveyance alignment alternatives cross known oil and gas fields in Wilmington, Long Beach, Signal Hill, City of Industry, Montebello, Whittier, Santa Fe Springs, Buena Park and Placentia (Figure 6). In these areas where occurrences of explosive and hazardous gases are possible, positive ventilation along with intrinsically safe and explosion-proof equipment should be used. In addition, pre-design hazardous chemical assessments should be completed to identify if legacy soil contamination exists in the project area. A review of California's Division of Oil and Gas records should be completed in these areas to identify the possible presence of abandoned well casings, and prior to construction geophysical means should be used to clear the planned extent of excavations of buried objects. For the purpose of this study, all alignment segments crossing Oil and Gas Fields should be considered gassy and will require utilization of specialized explosion-proof equipment.

3.2 Pipeline Undercrossing Excavation

Table 3 provides a summary of undercrossings along the "Preferred" conveyance alignment for alternatives that extend from Harbor City into Orange County and the San Gabriel Basin. The locations of the undercrossings are shown on Figure 8B by their ID number. The table provides the pipe diameter of the undercrossing along with its likely length and minimum depth of cover. Inferred ground conditions at the identified undercrossings shown on the table are based on soil type at nearby borings from the CGS Borehole Database, mapped geologic units, potential for fault and seismic hazards, oil and gas field occurrence, and need for dewatering based on depth to groundwater.

Based on our understanding of the undercrossing design and inferred ground conditions, excavation methods including Jack and Bore, Microtunneling, Conventional Tunneling and Horizontal Directional Drilling (HDD) are considered. Table 3 presents methods that are considered feasible based on the information presented. Methods that are not applicable for a specific reach may have been excluded due to limitations in meeting pipe diameter, length requirements, bending radii, separation distance required from undercrossing obstacle, elevation difference between entrance and exit locations, or the methods ability to control the inferred ground conditions at the undercrossing location.

The geotechnical criteria used to evaluate the feasibility of the alternative excavation methods consider the following:

- Pipeline design (i.e. diameter, depth and length) and applicability considering engineering constraints,
- Construction access such as launching and receiving pits,
- Anticipated soil conditions along undercrossing such as mixed face with cobbles and boulders and potential running ground,
- Ability to control groundwater along undercrossing.

General capabilities and limitations of the four considered excavation methods for the undercrossings include the following:

Jack and Bore: Pipe diameters up to 48 to 72 inches are most common but diameters up to 120 inches are possible. Drive length is generally less than 1,000 ft and typically limited to short undercrossings such as beneath roadways, intersections, or railroads. Jack and bore is best suited for stable ground conditions. This method can accommodate excavation in clays, silts, sands and fine gravels, cobbles and boulders. Although cobbles and boulders are challenging, jack and bore is one of the most favorable trenchless methods for cobbles and boulders as access to the face of the excavation can be provided to remove obstructions. In general, jack and bore is feasible where boulders are less than about one-third the size of the bore diameter. Where excavation is below the groundwater table, dewatering or watertight support of excavation may be required for launching and receiving pits. Also, dewatering would be required along the length of the excavation if high groundwater inflows are expected or if groundwater is expected to destabilize the ground. For undercrossings in transmissive soils such as sands and gravels, access for dewatering wells along the alignment are necessary to control groundwater inflows and to limit the potential for running or flowing ground from entering the excavation. For freeway undercrossings beneath the water table in transmissive soils, dewatering and ground control may be challenging for this method. Jack and bore is generally not suitable for river undercrossings.

Microtunneling: Pipe diameters up to 120 inches and lengths between jacking pits of 1,500 to 2,000 ft with total drive lengths over 10,000 feet are feasible. A more sophisticated trenchless method than jack and bore, microtunneling can accommodate excavation in clays, silts, sands, gravels, cobbles and boulders, though cobbles and boulders may be challenging. Unlike jack and bore, access to the face of the excavation is not readily available in diameters less than 72 inches. Where excavation is below the groundwater table, dewatering or watertight support of excavation may be required for launching and receiving pits. Bentonite and/or polymer slurry at the face of the Microtunneling machine is typically used to control the ground and groundwater along the length of the excavation and reduce the friction along the advancing jacking pipe. This method is ideal for long undercrossings such as for freeways and rivers and is well suited where excavation is beneath the water table in transmissive soils.

Conventional Tunnel Excavation: Best suited for large diameter and long drive lengths, conventional tunneling is capable of installing pipelines as small as 60 inch diameter although smaller diameter pipe can be installed within a larger excavation if necessary. Due to equipment constraints conventional tunneling is not considered for short lengths, such as beneath intersections, where jack and bore or microtunneling is more suitable. Where excavation is beneath the water table, groundwater control or watertight support of excavation may be required for entrance and exit shafts.

Along the tunnel, ground and groundwater control can be provided through a number of methods. The equipment utilized in conventional tunneling can provide proactive or reactive ground and groundwater support. Excavation with an earth pressure balance machine (EPBM) or slurry machine can provide proactive ground and groundwater support. Excavation with an open style tunnel boring machine (TBM) does not provide proactive support but can support the ground behind the excavation with an initial support system. Excavations classified as gassy will require proper ventilation and intrinsically safe equipment.

Horizontal Directional Drilling (HDD): This method of undercrossing excavation can accommodate pipe diameters up to 60 inches with lengths over 10,000 feet feasible between access points. This method can accommodate excavation in clays, silts, sands, gravels, cobbles and boulders, though gravel, cobbles, and boulders are challenging. Consistency in the geology along the excavation is critical to success as crossing between disparate geologic units while maintaining alignment and grade with HDD can be challenging. Launching and receiving pits, such as are required for other tunneling methods, are not required for this method, negating the need to dewater. Bentonite and/or polymer slurry is used to stabilize the ground and reduce friction for drill pipe, backreaming and to pull the pipe into place. This method is ideal for long undercrossings such as for freeways and rivers and is well suited where excavation is beneath the water table in transmissive soils. The HDD method requires enough area to lay down and weld the finished pipe prior to pulling the pipe back through the reamed HDD hole. Considering that for the RRWSP conveyance project, steel pipe with diameters from 4.5 to 7 feet are required, undercrossings less than about 1,800 ft are generally not considered for HDD due to equipment constraints related to the angle of approach and required bending radii.

4.0 GENERAL CONDITIONS

The conclusions and recommendations presented in this report are based upon our review of the documents provided to us and our relevant previous experience. No field exploration, laboratory testing, or analyses were performed as part of this review. In addition, we have relied on data such as boring logs or groundwater levels collected by others. As such, the findings summarized in this report are preliminary and subject to change when additional information or further investigations become available.

The information presented in this report is intended to be used for project planning purposes only. This information is subject to change once the specific details or features of the proposed project are identified and/or undergo changes.

Professional judgments presented in this report are based on an evaluation of the technical information gathered and GeoPentech's general experience in the fields of geotechnical engineering and geology. GeoPentech does not guarantee the performance of the project in any respect, only that the engineering work and judgment rendered meet the standard of care of the geotechnical profession at this time.

5.0 REFERENCES

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TABLE 1a
FAULT CHARACTERISTICS - GEOMETRY
Regional Recycled Water Supply Program

	Column 1	*Column 2*	*Column 3*	*Column 4*	*Column 5*	*Column 6*	*Column 7*
Fault	Style	M_{char} (M_w)	Length (km)	Dip, Dir. (deg, -)	TOR (km)	BOR (km)	Total Area (sq km)
Whittier-Elsinore Whittier Segment Only	OBL	7.0	46	75 NE	0	13.0	623
Newport-Inglewood	SS	7.4	157	85, NE	0	15.0	2,359
Compton	OBL	6.9	65	28, NE	5.0	10.0	613
Puente Hills (unsegmented)	OBL	7.3	44	27, NE	3.0	17.0	1,357
Puente Hills (Alternate #2) Coyote Hills Segment Only	OBL	6.7	17	27, NE	3.0	17.0	537
Peralta Hills	RV	6.4	14	50, N	0.3	14.0	249

Key To Fault Parameters

Column 1	Style of faulting: SS = Strike-slip; RV = Reverse; OBL = Oblique.
Column 2	Best-estimate moment magnitude (Mw) characteristic earthquake generated by fault; based on literature review of peer-reviewed journal publications and discussions with academic experts.
Column 3	Fault length; based on WGCEP (2013a,b), literature review of peer-reviewed journal publications, and discussions with academic experts.
Column 4	Fault dip and dip direction; based on WGCEP (2013a,b), literature review of peer-reviewed journal publications, and discussions with academic experts.
Column 5	Depth to top of rupture (non-zero values indicate blind fault); based on WGCEP (2013a,b), literature review of peer-reviewed journal publications, and discussions with academic experts.
Column 6	Depth to bottom of rupture; based on WGCEP (2013a,b), literature review of peer-reviewed journal publications, and discussions with academic experts.
Column 7	Area of fault plane, based on geometry in Columns 3 through 6.

References: Akciz et al., 2014; Brankman and Shaw, 2009; Brothers et al., 2015; Dolan et al., 2001; Freeman et al., 1992; Fumal et al., 2002; Grant-Ludwig et al., 2015; Grant et al., 1997; Gurrola and Rockwell, 1996; Leon et al., 2009; Leon et al., 2007; Leonard, 2010; McNeilan et al., 1996; Rockwell, pers. comm., 2015; Rockwell et al., 2012; Sahakian et al., 2015; Shaw, 2009; Shaw and Suppe, 1996; Weldon et al., 1996; WGCEP, 2008, 2013; Yule and Sieh, 2001.

TABLE 1b
FAULT CHARACTERISTICS - DEFORMATIONS AND RATES
Regional Recycled Water Supply Program

	Column 1	*Column 2*	*Column 3*	*Column 4*
Fault	Best-Estimate Avg. Disp. (m)	Best-Estimate Slip Rate (mm/yr)	MRE (cal. yrs)	Best-Estimate RI (yrs)
Whittier-Elsinore Whittier Segment Only	right-lateral: 1.9	2 to 3	200 BC to 600 AD	1,400
Newport-Inglewood	right-lateral: 2.0	1.8	1933 (no surf. rupt.) M_{char} since 2300 BC	2,000 to 3,000
Compton	uplift: 1.0 along-plane: 2.2	1.2	250 AD to 1300 AD	2,200
Puente Hills (unsegmented)	uplift: 1.6 along-plane: 3.5	0.9 to 1.6 (Santa Fe Springs Segment)	since 2200 BC (Santa Fe Springs Seg.)	3100 (Santa Fe Springs Seg.)
Puente Hills (Alternate #2) Coyote Hills Segment Only	uplift: 0.5 along-plane: 1.1	0.9 to 1.6	since 2200 BC	3,100
Peralta Hills	uplift: 0.4 along-plane: 0.9	0.4	within last ~14,000 yrs	6,000 to 7,000

Key To Fault Parameters

Column 1	Best-estimate average coseismic displacement for characteristic earthquake in Column 2; based on literature review of peer-reviewed journal publications and discussions with academic experts.
Column 2	Best-estimate average fault slip rate; based on literature review of peer-reviewed journal publications and discussions with academic experts.
Column 3	Most recent surface-rupturing earthquake (MRE) in calendar years; based on literature review of peer-reviewed journal publications and discussions with academic experts.
Column 4	Best-estimate average recurrence interval for characteristic earthquake in Column 3; based on literature review of peer-reviewed journal publications and discussions with academic experts.

References: Akciz et al., 2014; Brankman and Shaw, 2009; Brothers et al., 2015; Dolan et al., 2001; Freeman et al., 1992; Fumal et al., 2002; Grant-Ludwig et al., 2015; Grant et al., 1997; Gurrola and Rockwell, 1996; Leon et al., 2009; Leon et al., 2007; Leonard, 2010; McNeilan et al., 1996; Rockwell, pers. comm., 2015; Rockwell et al., 2012; Sahakian et al., 2015; Shaw, 2009; Shaw and Suppe, 1996; Weldon et al., 1996; WGCEP, 2008, 2013; Yule and Sieh, 2001.

TABLE 2

Geotechnical Conditions for Cut and Cover and Undercrossing Pipeline Sections

Ground Condition	Cut and Cover Pipeline	Undercrossing Pipeline
Depth to Groundwater	Areas with depth to water less than 20 feet as shown on the Ground Conditions map (Figure 8A) will likely require dewatering; this includes approximately 80% of the alignment.	Areas with depth to water less than 50 feet as shown by the stippled area on the Ground Conditions map (Figure 8B) will likely require dewatering for jack and bore and conventional tunneling methods; this includes 29 of the 35 proposed undercrossings for the "Preferred" alignment.
Running or Flowing Ground	Areas with groundwater less than 20 feet and sandy soil with little or no silt as shown on the Ground Conditions map as "Sand-Gravel-Cobbles-Boulders," "Sand," and "Sand with Silt" (Figure 8A) have the potential to run where unconsolidated in open excavations; shoring or cut slopes and dewatering will be required in these areas.	Areas with groundwater less than 50 feet as shown by the stippled area on the Ground Conditions map and with sandy soil with little or no silt as identified as "Sand-Gravel-Cobbles-Boulders," "Sand," and "Sand with Silt" (Figure 8B) have the potential to run where unconsolidated in an unsupported tunnel face. Tunneling method that counteracts running ground conditions will be required for these ground types.
High Permeability	Areas with groundwater less than 20 feet and sandy soil with little or no silt as shown on the Ground Conditions map as "Sand-Gravel-Cobbles-Boulders," "Sand," and "Sand with Silt" (Figure 8A) are likely highly permeable and may yield high volumes of groundwater during dewatering (e.g. greater than 500 gpm combined pump rates with close density of extractions wells along excavation may be needed).	Areas with groundwater less than 50 feet as shown by the stippled area on the Ground Conditions map and with sandy soil with little or no silt as identified as "Sand-Gravel-Cobbles-Boulders," "Sand," and "Sand with Silt" (Figure 8B) are likely highly permeable and may yield high inflows of groundwater during tunneling. Dewatering in advance of jack and bore or conventional tunnel excavation, or other means of groundwater control will be required in these areas.

TABLE 2

Geotechnical Conditions for Cut and Cover and Undercrossing Pipeline Sections

Ground Condition	Cut and Cover Pipeline	Undercrossing Pipeline
Organic/Soft Soils	Organic and or soft soil conditions may be present where "Sand-Silt-Clay" soils are shown on the Ground Conditions map (Figure 8A). Ground preparation and or treatment will be likely in these areas.	Organic and or soft soil conditions may be present where "Sand-Silt-Clay" soils are shown on the Ground Conditions map (Figure 8B). Undercrossing excavation method used will require guidance system to maintain line and grade control. Soil modification will be necessary to stabilize the ground to improve bearing capacity for launching/receiving pits.
Gassy Conditions & Oil Fields	The Ground Conditions Map (Figure 8A) shows the extent of known Oil and Gas fields in the project alignment area; gassy ground conditions, abandoned well casings and legacy soil contamination may be present within these areas of the proposed pipeline alignments.	The Ground Conditions Map shows the extent of known Oil and Gas fields in the project alignment area (Figure 8B); gassy ground conditions, abandoned well casings and legacy soil contamination may be present within these areas of the proposed pipeline alignments.
Corrosive Soil	Corrosive soils are known to exist within the planned pipeline alignments though they currently have not been mapped.	Corrosive soils are known to exist within the planned tunnel alignments though they currently have not been mapped.
Liquefaction	Areas with groundwater less than 50 feet as shown by the stippled area on the Ground Conditions map and with sandy soil with little or no silt identified as "Sand-Gravel-Cobbles-Boulders," "Sand," and "Sand with Silt" (Figure 8A) have the potential to liquefy where not dense. Pipeline design should take into account potential ground deformations in these areas.	Areas with groundwater less than 50 feet as shown by the stippled area on the Ground Conditions map and with sandy soil with little or no silt as identified as "Sand-Gravel-Cobbles-Boulders," "Sand," and "Sand with Silt" (Figure 8B) have the potential to liquefy where not dense. Undercrossing design should take into account potential ground deformations in these areas.

TABLE 2

Geotechnical Conditions for Cut and Cover and Undercrossing Pipeline Sections

Ground Condition	Cut and Cover Pipeline	Undercrossing Pipeline
Faults	The proposed pipeline alignments cross the Newport Inglewood Fault Zone, The Los Alamitos Fault, Whittier Fault, and possibly the East Montebello Fault (Figure 8A); though not mapped, the alignment also overlies the Puente Hills, Peralta Hills and Compton blind thrust system. Ground deformation and possibly displacement should be considered in the pipeline design for these areas.	The proposed undercrossing tunnel sections cross the Newport Inglewood Fault Zone, The Los Alamitos Fault, and Whittier Fault (Figure 8B); though not mapped, undercrossing tunnel alignments also overlie the Puente Hills, Peralta Hills and Compton blind thrust system. Ground deformation and possibly displacement should be considered in the pipeline undercrossing design for these areas.
Mixed Face Conditions	Ground with cobbles and boulders are common in the Upper San Gabriel Valley and, although not shown on the Ground Conditions Map (Figure 8A), these sized clasts may be encountered during pipeline excavation.	Ground with cobbles and boulders as identified on the Ground Conditions map as "Sand-Gravel-Cobbles-Boulders" (Figure 8B) are common in the Upper San Gabriel Valley and may be encountered during tunnel excavation. Tunneling means and methods must be able to accommodate these mixed face conditions.

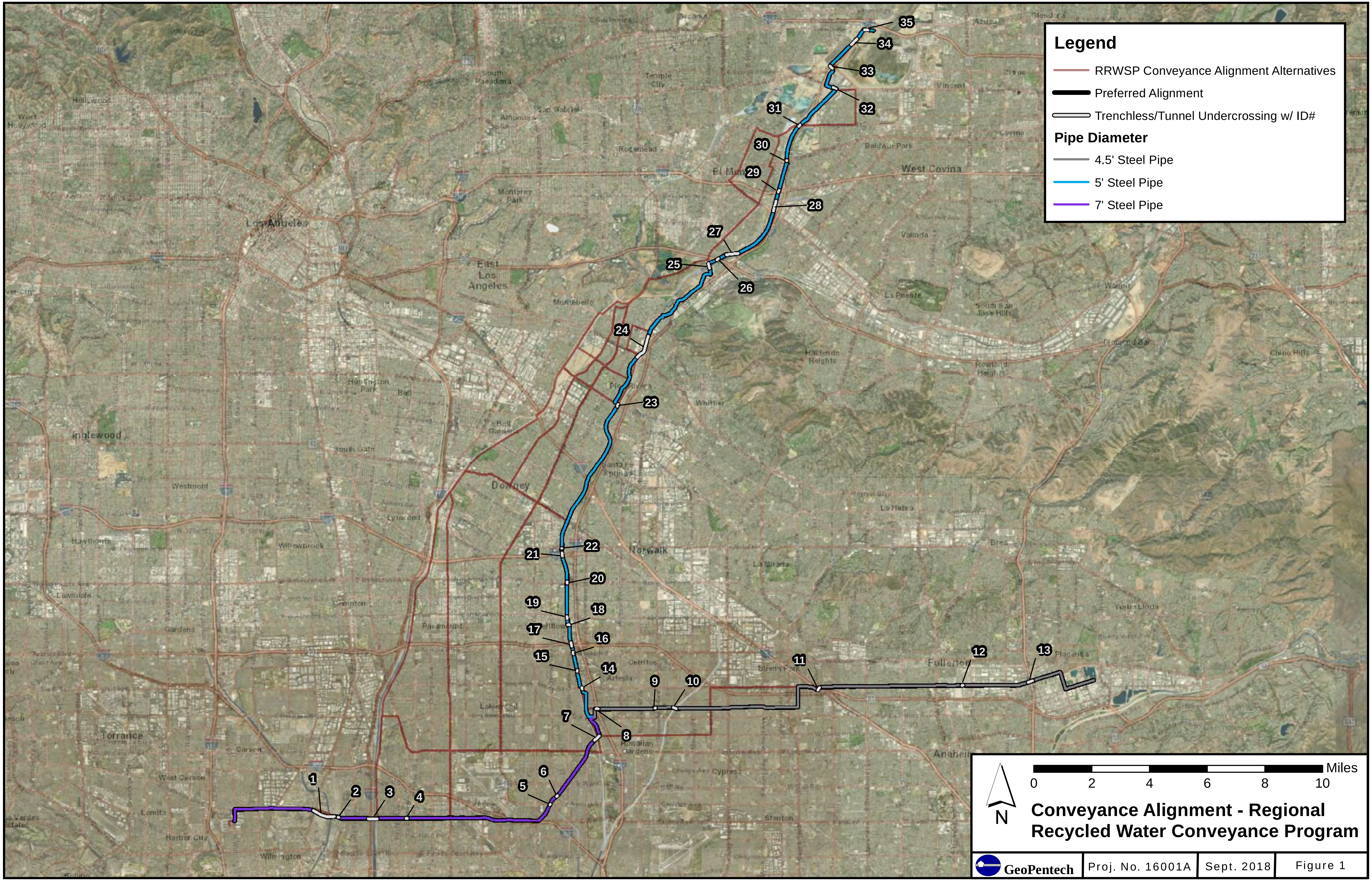
Table 3
Undercrossing Summary and Alternative Excavation Methods

Undercrossing Conceptual Layout					Ground Conditions within Undercrossing	GW Level Above Tunnel	Alternative Excavation Method[3]			
Tunnel ID	**Length (ft)**	**Undercrossing Description**	**Diameter (ft)**	**Minimum Cover (ft)[2]**			**A Jack & Bore**	**B Micro Tunneling**	**C Traditional**	**D Horizontal Directional Drilling (HDD)**
1	3,442	Intersection/ railroad/river	7	31	**Alluvium:** Sand (SP), Silty Sand (SM) with trace gravel and clay, Clay (CL) and Clayey Sand (SC)	Yes	Not Applicable	Applicable	Applicable	Not Applicable
2	88	Railroad	7	21	**Alluvium:** Sand (SP), Silty Sand (SM) with trace gravel and clay, Clay (CL) and Clayey Sand (SC)	Yes	Applicable	Applicable	Not Applicable	Not Applicable
3	1,418	River	7	21	**Alluvium:** Loose Sand (SP), Silty Sand (SM) and Sandy Silt (ML)	Yes	Not Applicable	Applicable	Not Applicable	Not Applicable
4	222	Intersection/ railroad	7	21	**Alluvium, San Pedro Fm. and Palos Verdes Sand:** Clayey Silt (ML), dense Sand (SP), dense Silty Sand (SM); **Long Beach Oil & Gas Field**	Yes	Applicable	Applicable	Not Applicable	Not Applicable
5	166	River	7	21	**Alluvium:** Silty Sand (SM), Silty Clay (CL), Clayey Silt (ML) with fine sand, Clayey Sand (SC) with silt	Yes	Applicable	Applicable	Not Applicable	Not Applicable
6	200	River	7	21	**Alluvium:** Silty Sand (SM), Silty Clay (CL), Clayey Silt (ML) with fine sand, Clayey Sand (SC) with silt	Yes	Applicable	Applicable	Not Applicable	Not Applicable
7	1,006	River	7	21	**Alluvium:** compact Sand (SP), loose to compact Silty Sand (SM), soft Silt (ML)	Yes	Not Applicable	Applicable	Not Applicable	Not Applicable
8	351	Freeway	4.5	13.5	**Alluvium:** fine Sandy Silt (ML), compact Sand (SP), dense Silty Sand (SM), Clayey Silt (ML), loose Silty Sand (SM)	Yes	Not Applicable	Applicable	Not Applicable	Not Applicable
9	134	River	4.5	27.5	**Alluvium:** fine Sand (SP), Silt (ML), Silty Clay (CL), loose fine Sand (SP), soft Silty Clay (CL) with sand, loose fine Sand (SP)	Yes	Not Applicable	Applicable	Not Applicable	Not Applicable
10	478	River	4.5	29.5	**Alluvium:** fine Sand (SP), Silt (ML), Silty Clay (CL), loose fine Sand (SP), soft Silty Clay (CL) with sand, loose fine Sand (SP)	Yes	Not Applicable	Applicable	Not Applicable	Not Applicable
11	518	Freeway	4.5	13.5	**Alluvium:** Sand (SP), Silt (ML); **Buena Park East Oil & Gas Field**	Yes	Applicable	Applicable	Not Applicable	Not Applicable
12	201	Railroad	4.5	13.5	**Alluvium:** Sand (SP), Silt (ML)	No	Applicable	Applicable	Not Applicable	Not Applicable
13	1,050	Freeway	4.5	13.5	**Alluvium:** Sand (SP), Silt (ML); **Richfield Oil & Gas Field**	No	Not Applicable	Applicable	Not Applicable	Not Applicable
14	206	Intersection	5	15	**Alluvium:** Clayey Silt (ML), Silty Clay (CL), Silty Sand (SM), interbedded Sand (SP) and Clay (CL)	Yes	Applicable	Applicable	Not Applicable	Not Applicable
15	169	Intersection	5	15	**Alluvium:** Clayey Silt (ML), loose to dense Silty Sand (SM), Silt (ML) with some fine sand	Yes	Applicable	Applicable	Not Applicable	Not Applicable
16	249	Intersection	5	15	**Alluvium:** compact Silty Sand (SM), soft Clayey Silt (ML)	Yes	Applicable	Applicable	Not Applicable	Not Applicable
17	585	Freeway	5	15	**Alluvium:** compact Silty Sand (SM), soft Clayey Silt (ML), fine to medium Sand (SP), fine Silty Sand (SM)	Yes	Not Applicable	Applicable	Not Applicable	Not Applicable
18	275	River	5	15	**Alluvium:** very fine to fine Silty Sand (SM), medium to coarse Sand (SP), fine to medium Sand (SP), interbedded Silt (ML) and fine Silty Sand (SM), compact interbedded fine Sand (SP) and fine Silty Sand (SM)	Yes	Applicable	Applicable	Not Applicable	Not Applicable
19	280	Intersection	5	15	**Alluvium:** very fine to fine Silty Sand (SM), medium to coarse Sand (SP), fine to medium Sand (SP), interbedded Silt (ML) and fine Silty Sand (SM), compact interbedded fine Sand (SP) and fine Silty Sand (SM)	Yes	Applicable	Applicable	Not Applicable	Not Applicable
20	205	Intersection	5	15	**Alluvium:** compact to dense fine to medium Sand (SP), compact Silty fine Sand (SM), medium to coarse Sand (SP), stiff Sandy Clay (CL)	Yes	Applicable	Applicable	Not Applicable	Not Applicable
21	472	Freeway	5	15	**Alluvium:** compact to dense fine to medium Sand (SP), compact Silty fine Sand (SM), medium to coarse Sand (SP), stiff Sandy Clay (CL)	Yes	Not Applicable	Applicable	Not Applicable	Not Applicable
22	102	Dam	5	15	**Alluvium:** compact to dense fine to medium Sand (SP), compact Silty fine Sand (SM), medium to coarse Sand (SP), stiff Sandy Clay (CL)	Yes	Applicable	Applicable	Not Applicable	Not Applicable

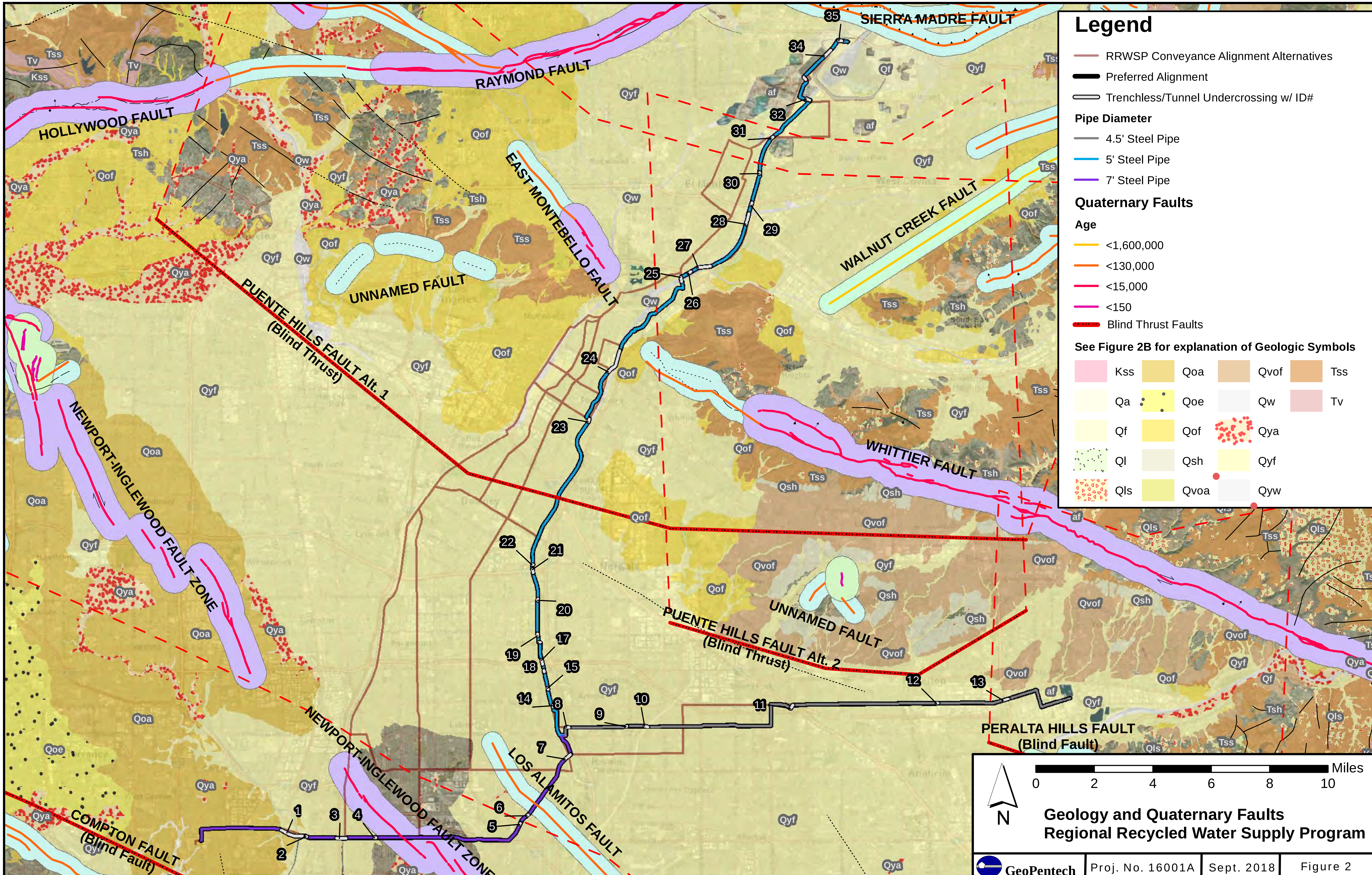
Table 3 (continued)
Undercrossing Summary and Alternative Excavation Methods

Undercrossing Conceptual Layout					Ground Conditions within Undercrossing	GW Level Above Tunnel	Alternative Excavation Method[3]			
Tunnel ID	Length (ft)	Undercrossing Description	Diameter (ft)	Minimum Cover (ft)[2]			A Jack & Bore	B Micro Tunneling	C Traditional	D Horizontal Directional Drilling (HDD)
23	422	River	5	15	**Alluvium:** medium to coarse Sand (SP) with lenses of gravel grading to very fine Silty Sand (SM), fine to very coarse Sand (SW) with occasional gravel, fine to coarse Sand (SW), Sandy Silt (ML)	Yes	Not Applicable	Applicable	Not Applicable	Not Applicable
24	3,779	River/Railroad	5	31	**Alluvium:** fine to medium Sand (SP), fine to coarse Sand (SW); **Whittier Oil & Gas Field**	Yes	Not Applicable	Applicable	Applicable	Applicable
25	666	River	5	15	**Alluvium:** compact interbedded very fine Silty Sand (SM) and soft very fine Sandy Silt (ML), dense Sand (SP) and Sandy Gravel (GP) interbedded with compact very fine Silty Sand (SM) and very fine Sand (SP), compact Gravelly Sand (SP) and Sandy Gravel (GP), stiff Silty Clay (CL), dense to very dense coarse Sand (SP) with scattered gravel, well graded Sand (SW); **Lapworth Oil & Gas Field**	Yes	Not Applicable	Applicable	Not Applicable	Not Applicable
26	336	Freeway	5	15	**Alluvium:** compact interbedded very fine Silty Sand (SM) and soft very fine Sandy Silt (ML), loose to dense Sand (SP) and Sandy Gravel (GP) interbedded with compact very fine Silty Sand (SM), compact Gravelly Sand (SP) and Sandy Gravel (GP), stiff Silty Clay (CL), interbedded Silt (ML) and fine sand (SP)	Yes	Not Applicable	Applicable	Not Applicable	Not Applicable
27	1,826	River	5	15	**Alluvium:** compact interbedded very fine Silty Sand (SM) and soft very fine Sandy Silt (ML), loose to dense Sand (SP) and Sandy Gravel (GP) interbedded with compact very fine Silty Sand (SM), compact Gravelly Sand (SP) and Sandy Gravel (GP), stiff Silty Clay (CL), interbedded Silt (ML) and fine sand (SP)	Yes	Not Applicable	Applicable	Not Applicable	Applicable
28	1,629	River	5	15	**Alluvium:** gravelly sand (SW), poorly sorted fine sand with trace coarse sand (SW), fine to medium silty sand w/ interbedded fine to coarse gravelly sand beds (SM), fine to medium sand (SP), compact silty fine sand (SM) with interbedded clean sand and gravel layer, compact to dense clean medium to coarse sand and interbedded very fine to fine sand (SP), slightly compact clean medium to coarse sand and scattered cobbles (SP)	Yes	Not Applicable	Applicable	Not Applicable	Not Applicable
29	325	Freeway	5	15	**Alluvium:** gravelly sand (SW), poorly sorted fine sand with trace coarse sand (SW), fine to medium silty sand w/ interbedded fine to coarse gravelly sand beds (SM), fine to medium sand (SP), compact silty fine sand (SM) with interbedded clean sand and gravel layer, compact to dense clean medium to coarse sand and interbedded very fine to fine sand (SP), slightly compact clean medium to coarse sand and scattered cobbles (SP)	Yes	Not Applicable	Applicable	Not Applicable	Not Applicable
30	130	Intersection	5	15	**Alluvium:** dense to very dense Sand (SP) and coarse Gravel (GP), Gravelly Sand (SW)	Yes	Applicable	Applicable	Not Applicable	Not Applicable
31	287	Intersection	5	15	**Alluvium:** very dense coarse Gravel (GP) with scattered cobbles, dense to very dense Sand (SP), dense to very dense gravelly Silty Sand (ML) with cobbles and boulders	No	Applicable	Applicable	Not Applicable	Not Applicable
32	530	River	5	15	**Alluvium:** very dense Sandy Gravel (GW) with cobbles and boulders	No	Not Applicable	Applicable	Not Applicable	Not Applicable
33	517	Freeway	5	15	**Alluvium:** very dense Sandy Gravel (GW) with cobbles and boulders	No	Not Applicable	Applicable	Not Applicable	Not Applicable
34	1,215	Dam	5	15	**Alluvium:** dense to very dense Sand (SP) and Gravel (GP) with cobbles and scattered boulders, dense to very dense fine to medium Sand (SP) with scattered gravel	No	Not Applicable	Applicable	Not Applicable	Not Applicable
35	508	Freeway	5	15	**Alluvium:** dense to very dense Sand (SP) and Gravel (GP) with cobbles and boulders, dense to very dense fine to medium Sand (SP) with scattered gravel and cobbles	No	Not Applicable	Applicable	Not Applicable	Not Applicable

Notes:
1. Tunnel ID number correspond with undercrossing number on Figures 1, 7B and 8B.
2. Depth below ground surface or river channel thalweg to top of pipe or crown of tunnel; generally equal to 3 pipe diameters.
3. Applicability of excavation method based on inferred ground conditions.



Conveyance Alignment - Regional Recycled Water Conveyance Program

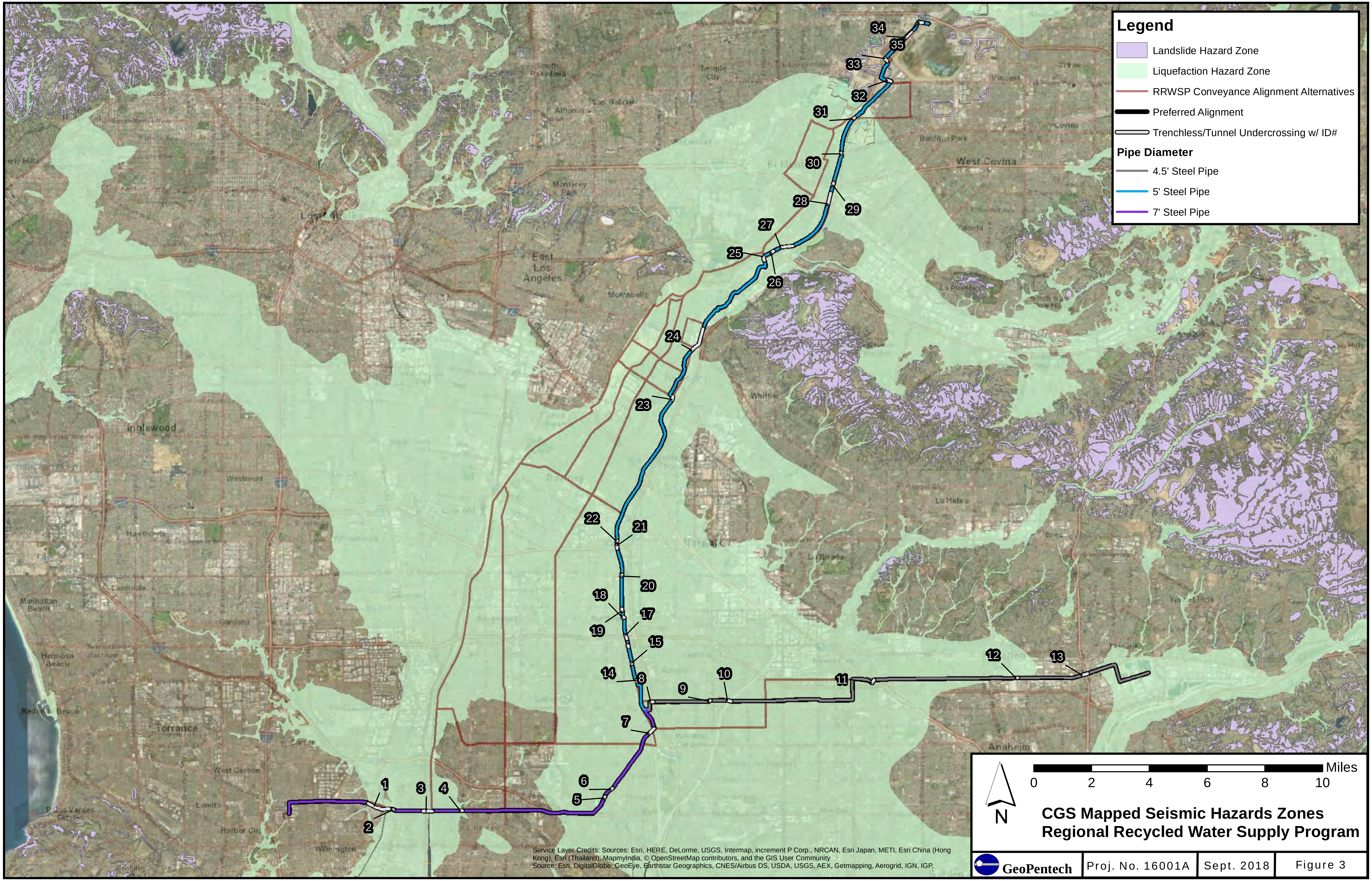

Legend
RRWSP Conveyance Alignment Alternatives
Preferred Alignment
Trenchless/Tunnel Undercrossing w/ ID#
Pipe Diameter
4.5' Steel Pipe
5' Steel Pipe
7' Steel Pipe
Quaternary Faults
Age
<1,600,000
<130,000
<15,000
<150
Blind Thrust Faults
See Figure 2B for explanation of Geologic Symbols
Kss
Qoa
Qvof
Tss
Qa
Qoe
Qw
Tv
Qf
Qof
Qya
Ql
Qsh
Qyf
Qls
Qvoa
Qyw
SIERRA MADRE FAULT
RAYMOND FAULT
HOLLYWOOD FAULT
EAST MONTEBELLO FAULT
UNNAMED FAULT
PUENTE HILLS FAULT Alt. 1
(Blind Thrust)
WALNUT CREEK FAULT
WHITTIER FAULT
NEWPORT-INGLEWOOD FAULT ZONE
PUENTE HILLS FAULT Alt. 2
(Blind Thrust)
UNNAMED FAULT
PERALTA HILLS FAULT
(Blind Fault)
LOS ALAMITOS FAULT
NEWPORT-INGLEWOOD FAULT ZONE
COMPTON FAULT
(Blind Fault)
Miles
0
2
4
6
8
10
N
Geology and Quaternary Faults
Regional Recycled Water Supply Program
GeoPentech
Proj. No. 16001A
Sept. 2018
Figure 2

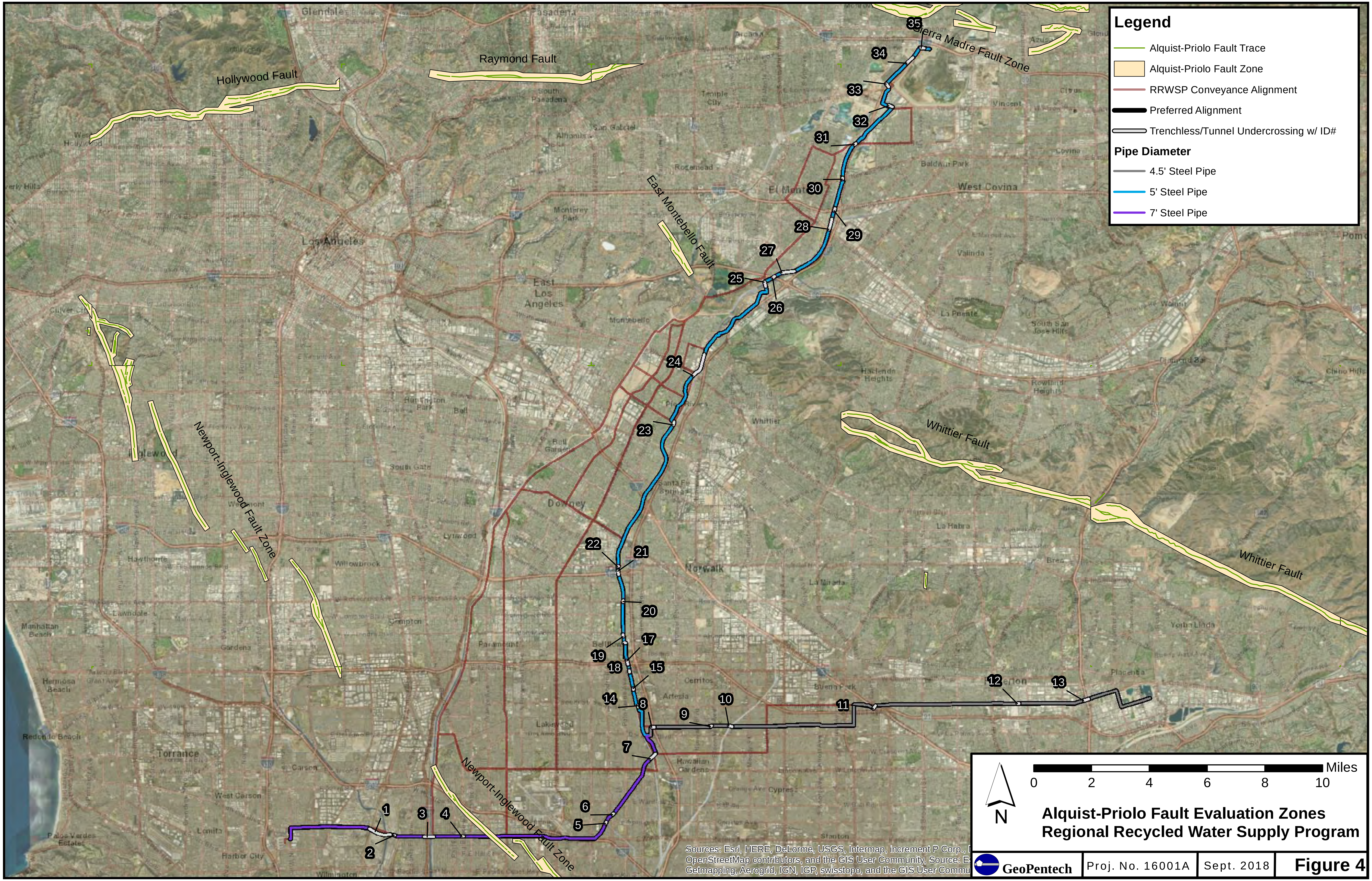
Geologic Units

- Kss - Coarse-grained Cretaceous age formations of sedimentary origin
- Qa - Quaternary age Alluvial Valley Deposits
- Qb - Quaternary age Beach Deposits
- Qe - Quaternary age Eolian and Dune Deposits
- Qf - Quaternary age Alluvial Fan Deposits
- Ql - Quaternary age Lacustrine, Playa and Estuarine (Paralic) Deposits
- Qls - Quaternary age Landslide Deposits; may include debris flows and older landslides
- Qoa - Quaternary age Old Alluvial Valley Deposits
- Qoe - Quaternary age Old Eolian and Dune Deposits
- Qof - Quaternary age Old Alluvial Fan Depoists
- Qsh - Fine-grained formations of Quaternary age; includes fine-grained sandstone, siltstone, mudstone, shale, siliceous and calcareous sediments
- Qvoa - Quaternary age Very Old Alluvial Valley Deposits
- Qvof - Quaternary age Very Old Alluvial Fan Deposits
- Qw - Quaternary age Alluvial Wash Deposits
- Qya - Quaternary age Young Alluvial Valley Deposits
- Qyf - Quaternary age Young Alluvial Fan Deposits
- Qyw - Quaternary age Young Alluvial Wash Deposits
- Tss - Coarse-grained Tertiary age formations of sedimentary origin
- Tv - Tertiary age formations of volcanic origin

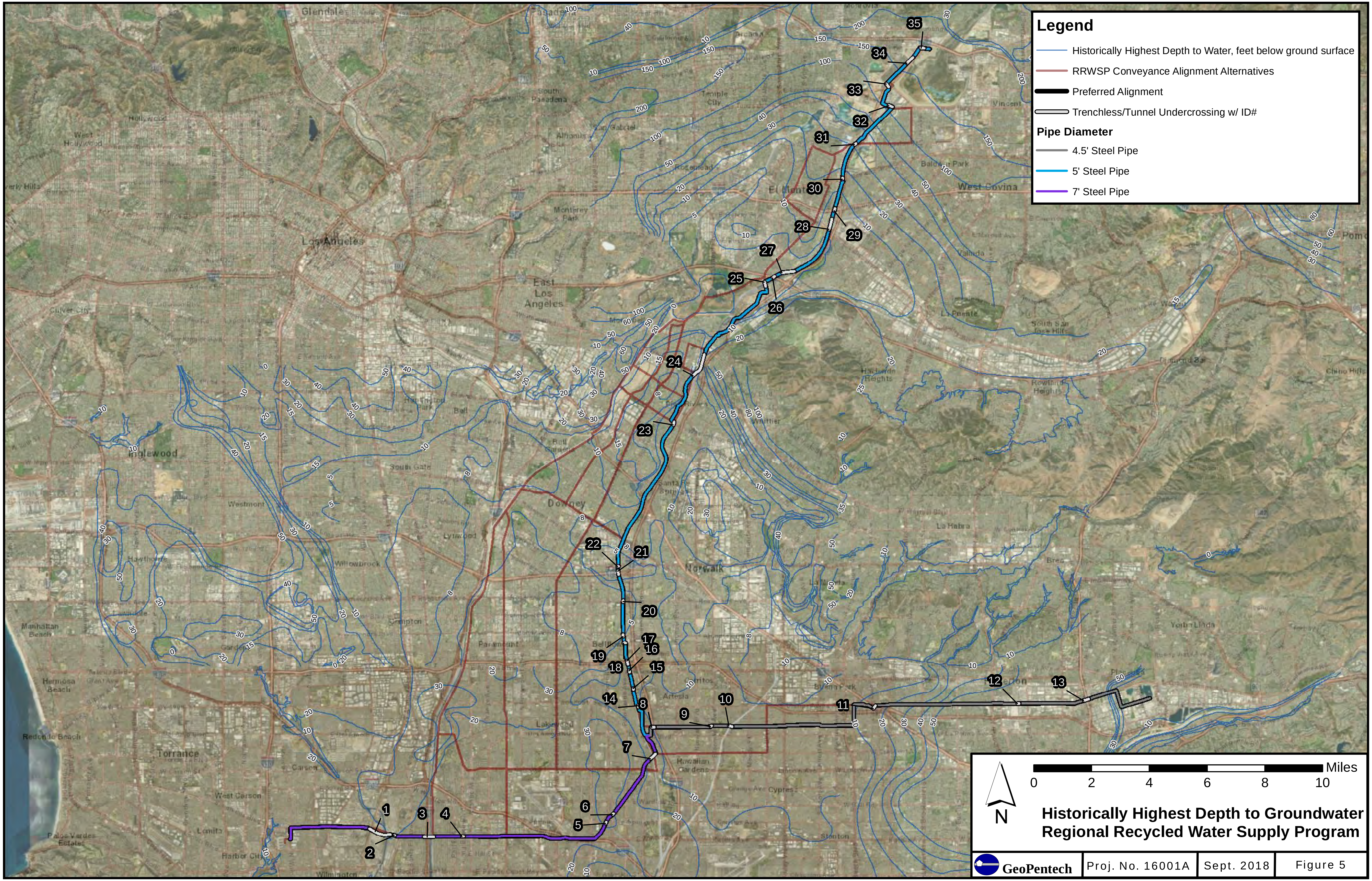
GEOLOGY KEY

GeoPentech	Proj. No. 16001A	Oct 2017	Figure 2a


Legend
Landslide Hazard Zone
Liquefaction Hazard Zone
RRWSP Conveyance Alignment Alternatives
Preferred Alignment
Trenchless/Tunnel Undercrossing w/ ID#
Pipe Diameter
4.5' Steel Pipe
5' Steel Pipe
7' Steel Pipe
Miles
0 2 4 6 8 10
N
CGS Mapped Seismic Hazards Zones
Regional Recycled Water Supply Program
GeoPentech
Proj. No. 16001A
Sept. 2018
Figure 3
Service Layer Credits: Sources: Esri, HERE, DeLorme, USGS, Intermap, increment P Corp., NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), MapmyIndia, © OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP.
East Los Angeles
Montebello
Monterey Park
Alhambra
San Gabriel
Temple City
Baldwin Park
West Covina
Whittier
La Habra
La Mirada
Inglewood
Westmont
Hawthorne
Lawndale
Gardena
Manhattan Beach
Hermosa Beach
Redondo Beach
Torrance
West Carson
Lomita
Wilmington
Harbor City
Anaheim
Yorba Linda
Brea
Valinda
La Puente
Vincent
Covina

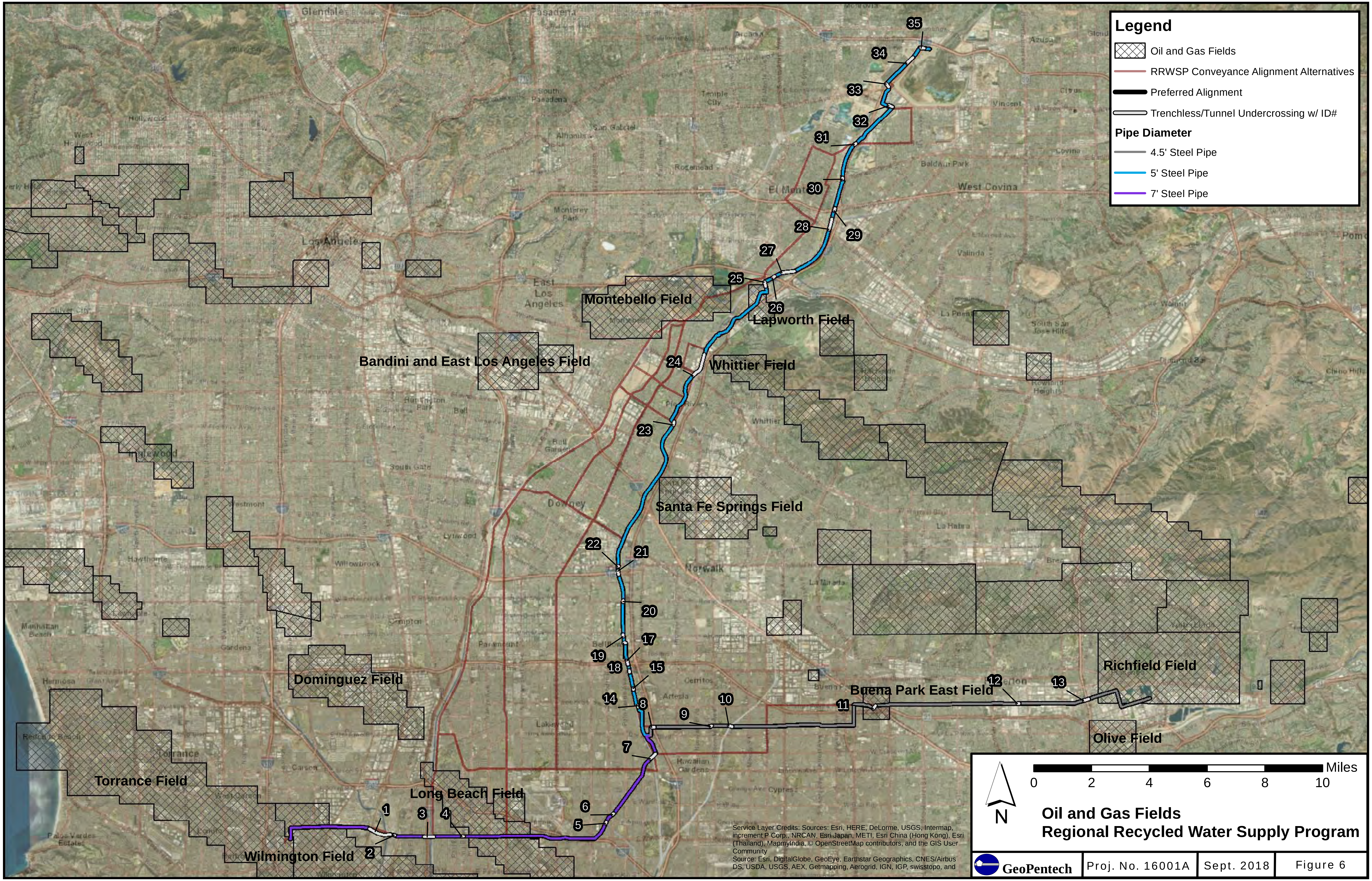


Legend
Alquist-Priolo Fault Trace
Alquist-Priolo Fault Zone
RRWSP Conveyance Alignment
Preferred Alignment
Trenchless/Tunnel Undercrossing w/ ID#
Pipe Diameter
4.5' Steel Pipe
5' Steel Pipe
7' Steel Pipe
Hollywood Fault
Raymond Fault
Sierra Madre Fault Zone
East Montebello Fault
Newport-Inglewood Fault Zone
Whittier Fault
Whittier Fault
Newport-Inglewood Fault Zone
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
Miles
0 2 4 6 8 10
N
Alquist-Priolo Fault Evaluation Zones
Regional Recycled Water Supply Program
GeoPentech
Proj. No. 16001A
Sept. 2018
Figure 4
Sources: Esri, HERE, DeLorme, USGS, Intermap, increment P Corp., OpenStreetMap contributors, and the GIS User Community, Source: Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community



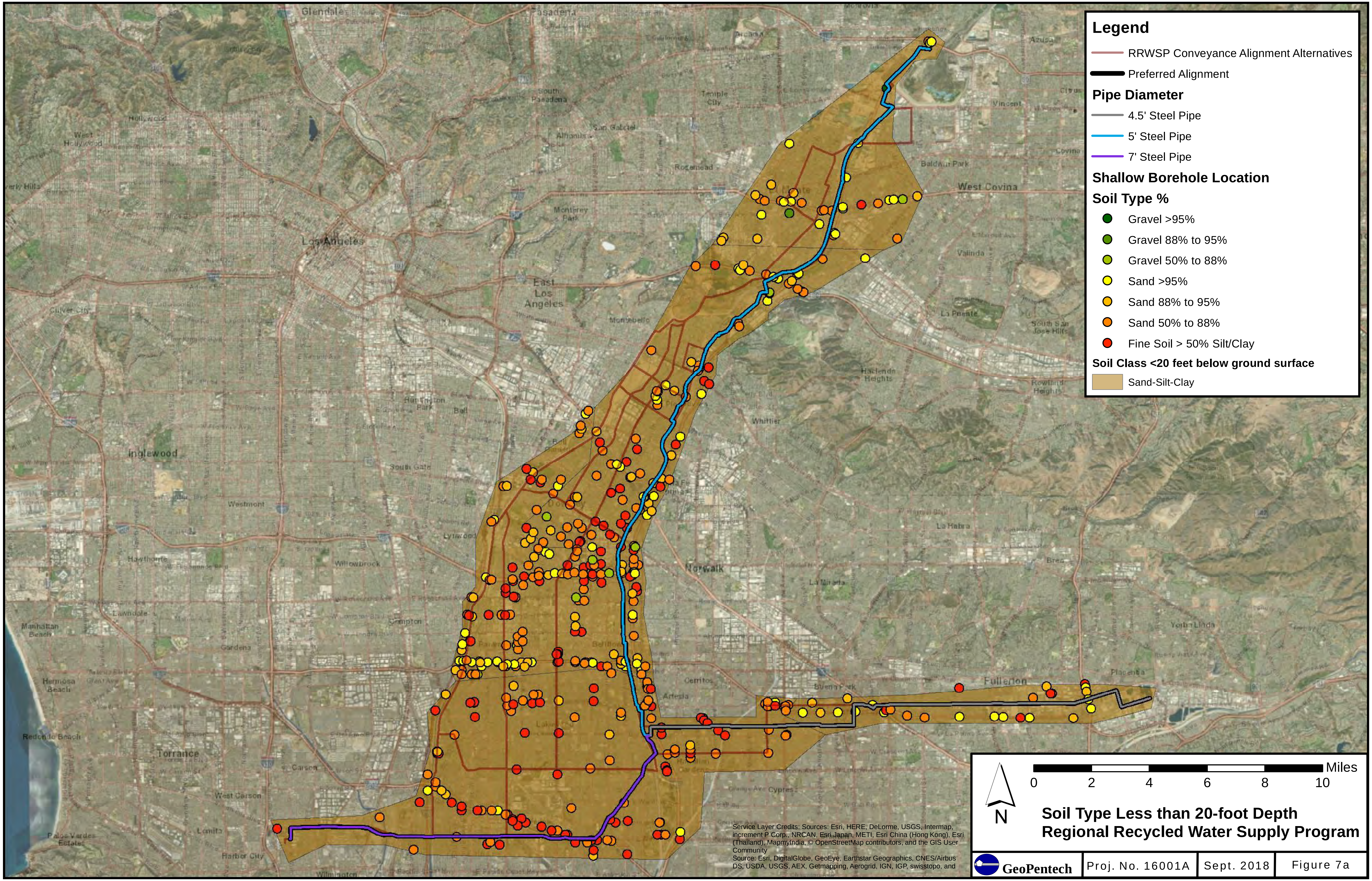
Historically Highest Depth to Groundwater
Regional Recycled Water Supply Program

GeoPentech	Proj. No. 16001A	Sept. 2018	Figure 5



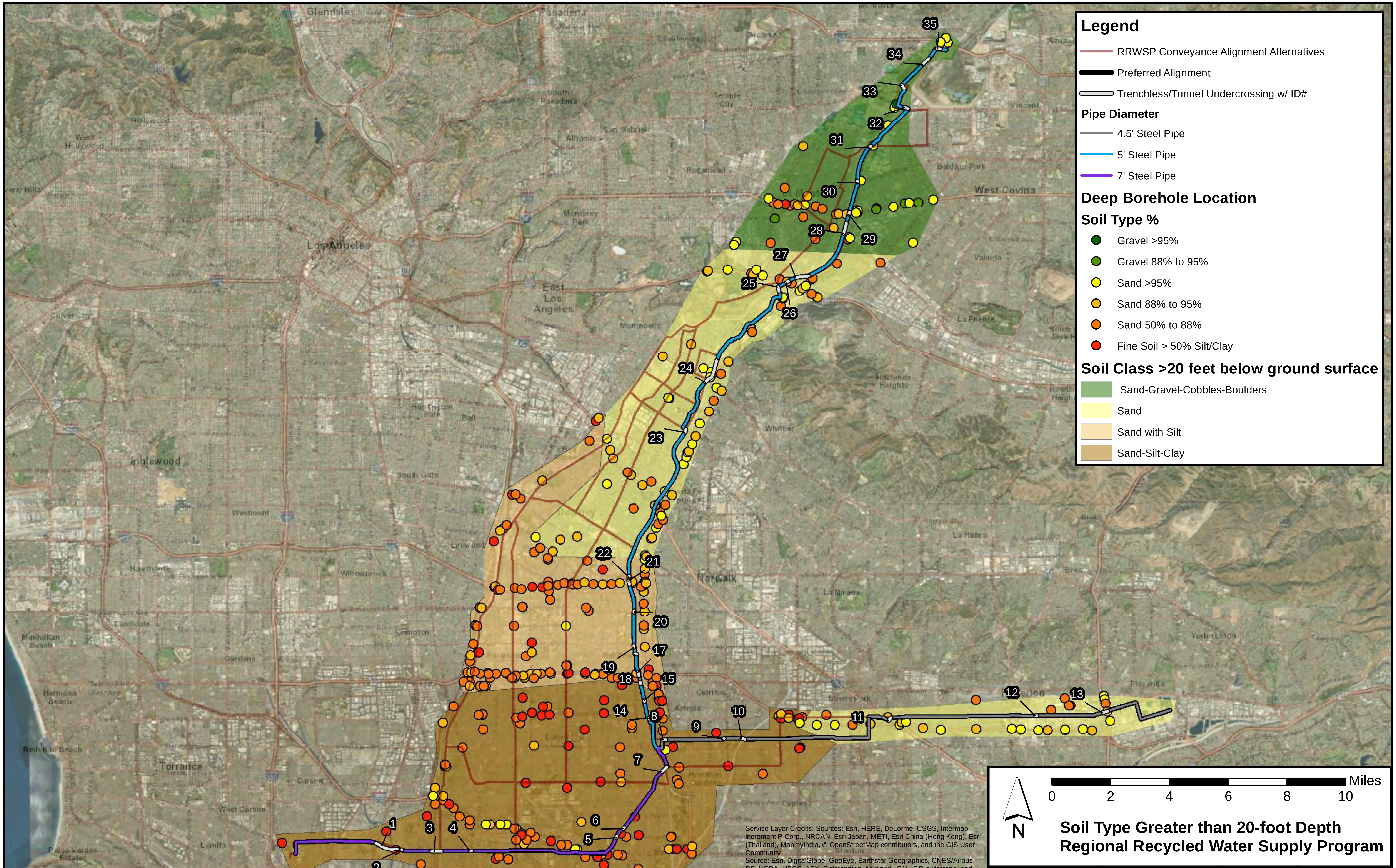
Oil and Gas Fields
Regional Recycled Water Supply Program

Figure 6



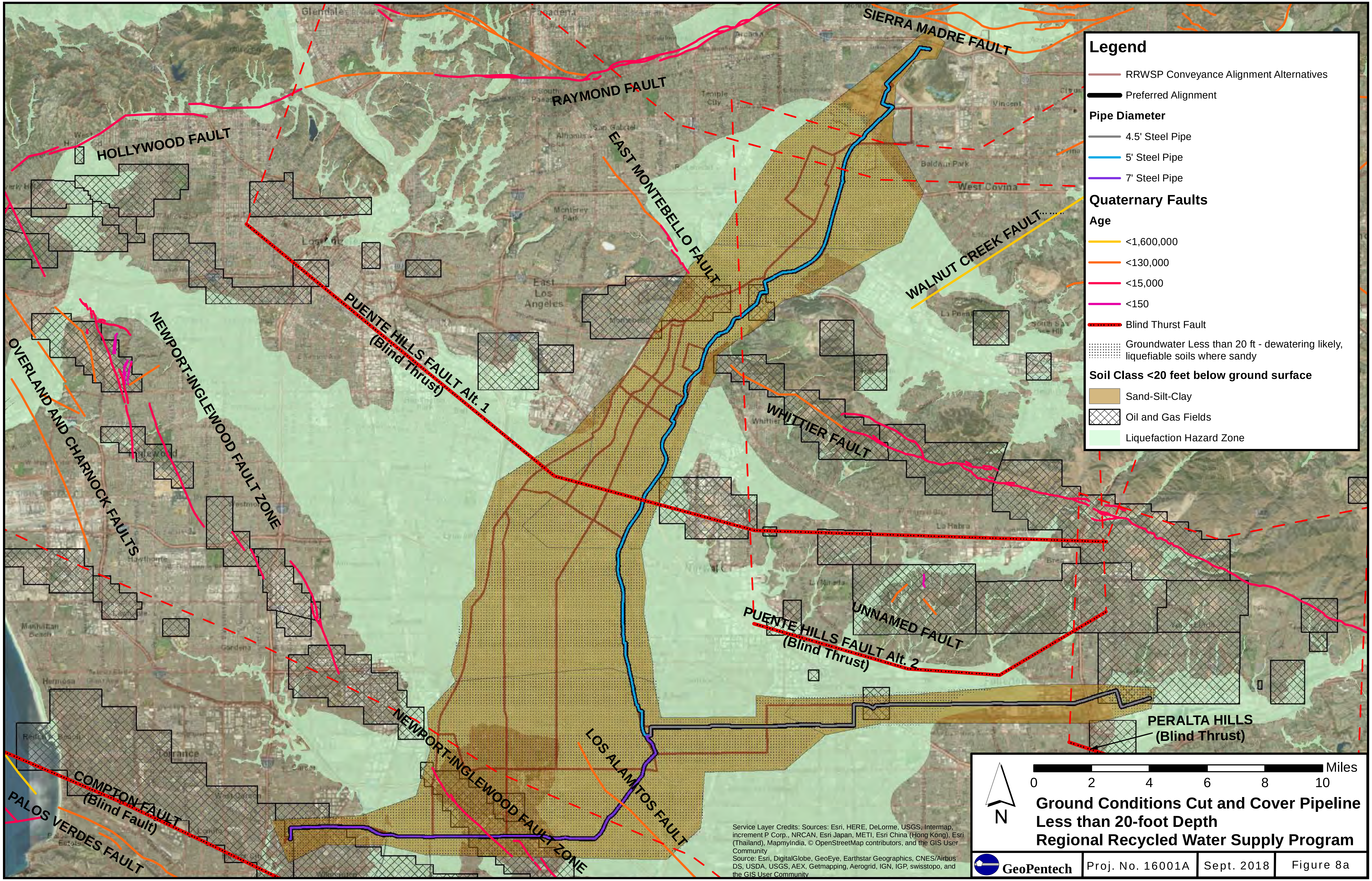
Soil Type Less than 20-foot Depth
Regional Recycled Water Supply Program

GeoPentech	Proj. No. 16001A	Sept. 2018	Figure 7a



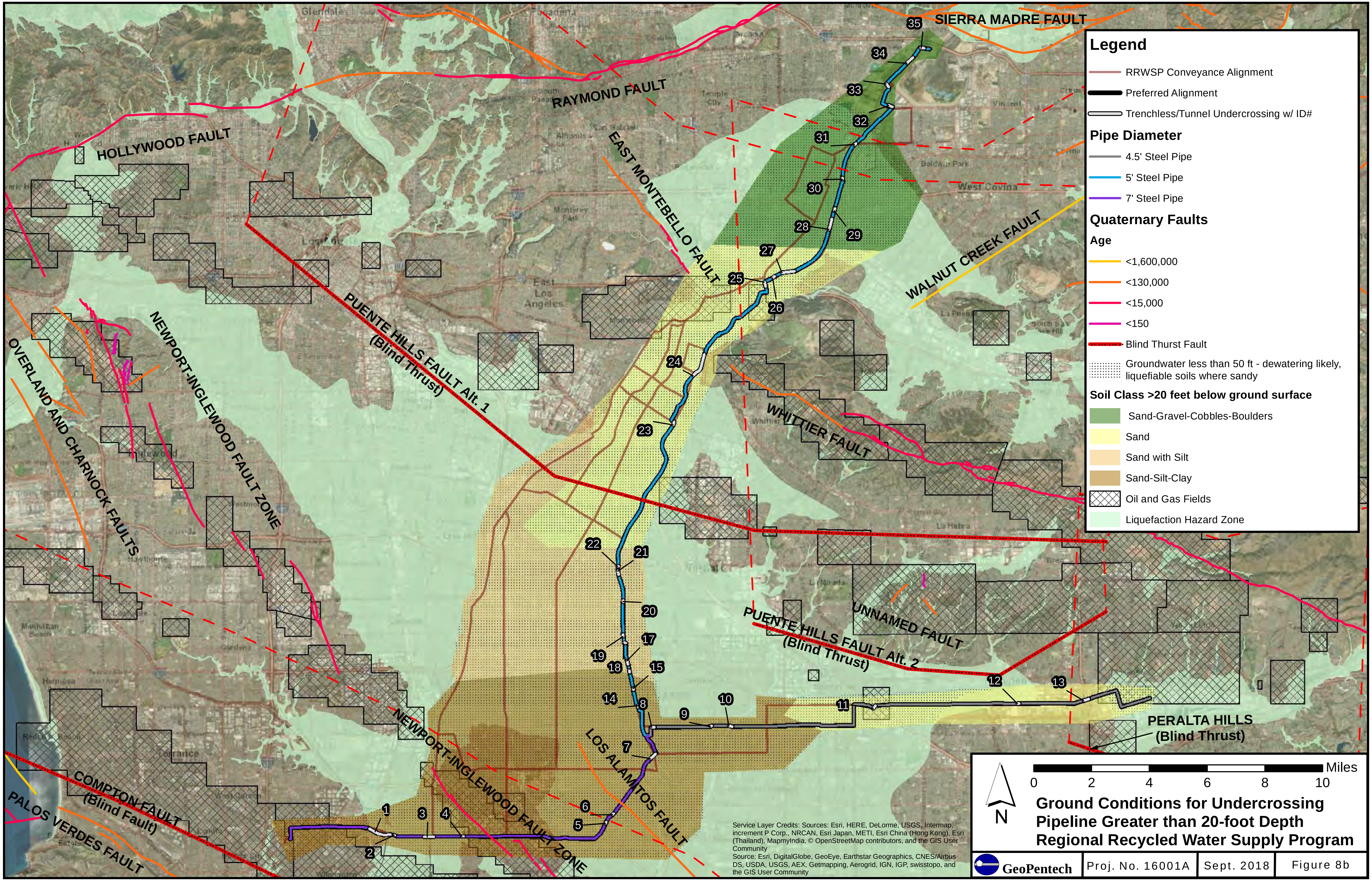
Soil Type Greater than 20-foot Depth
Regional Recycled Water Supply Program

GeoPentech	Proj. No. 16001A	Sept. 2018	Figure 7b



Ground Conditions Cut and Cover Pipeline Less than 20-foot Depth
Regional Recycled Water Supply Program

GeoPentech | Proj. No. 16001A | Sept. 2018 | Figure 8a



Ground Conditions for Undercrossing Pipeline Greater than 20-foot Depth
Regional Recycled Water Supply Program

GeoPentech	Proj. No. 16001A	Sept. 2018	Figure 8b