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PRELIMINARY GEOLOGIC AND GEOTECHNICAL STUDY REPORT

LOS ALAMOS TRUNK SEWER REPLACEMENT
SANTA ROSA, CALIFORNIA

Project Number:

1148.42.04.1

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November 7, 2017

TABLE OF CONTENTS

INTRODUCTION

This report presents the results of our preliminary geologic and geotechnical study for the proposed Los Alamos Trunk Sewer replacement project on the eastern side of Santa Rosa, California. The planned sewer alignment is shown on Plate 1 in Appendix A.

We understand that the multi-phased project will ultimately replace approximately 16,000 lineal feet of existing sewer main with a larger main. It is currently planned to design and realign approximately 3,800 lineal feet of the Los Alamos sewer trunk from Streamside Drive to Elaine Drive, which is referred to as Phase 1. In addition, preliminary work will be performed on the remainder of the 16,000 lineal feet of pipeline. We understand that, as currently planned, there are three unculverted crossings of creeks. Reports presenting the subsurface conditions at each creek crossing and the particle size analysis for the creek bottom materials will be presented under separate cover.

The purpose of our study as outlined in our proposal dated September 18, 2015, was to evaluate the geologic hazards within the planned alignment and comment on the geotechnical feasibility of the project. In addition, we were to recommend the geotechnical services needed for actual development, design and construction of the project.

SCOPE

Our scope of work included a brief site reconnaissance, a review of selected published geologic data pertinent to the site, and preparation of this report. Based on the geologic literature review and site reconnaissance, we were to develop the following information:

1. A brief description of geologic, surface soil, and spring or conditions observed during our reconnaissance;

2. Distance to nearby active faults and a discussion of geologic hazards that may affect the proposed project; and

3. Preliminary conclusions and recommendations concerning:

    a. Primary geotechnical engineering concerns and possible mitigation measures, as applicable; and

    b. Supplemental geotechnical engineering services.

STUDY

We reviewed our previous geotechnical studies in the vicinity and selected geologic references pertinent to the site. The geologic literature reviewed is listed in Appendix B. The published geology along the trunk sewer alignment is presented on the Geologic Map (Plates 2 and 3 in Appendix A). On March 1, 2016, our professional geologist and geotechnical engineer conducted a surficial reconnaissance of the pipeline alignment to observe exposed topographic features, surface soils, rock outcroppings and cut banks.

SITE CONDITIONS

General

Sonoma County is located within the California Coast Range geomorphic province. This province is a geologically complex and seismically active region characterized by sub-parallel northwest-trending faults, mountain ranges and valleys. The oldest bedrock units are the Jurassic-Cretaceous Franciscan Complex and Great Valley sequence sediments originally deposited in a marine environment. Subsequently, younger rocks such as the Tertiary-age Sonoma Volcanics group, the Plio-Pleistocene-age Clear Lake Volcanics and sedimentary rocks such as the Guinda, Domengine, Petaluma, Wilson Grove, Cache, Huichica and Glen Ellen formations were deposited throughout the province. Extensive folding and thrust faulting during late Cretaceous through early Tertiary geologic time created complex geologic conditions that underlie the highly varied topography of today. In valleys, the bedrock is covered by thick alluvial soils.

Geology

Published geology maps (McGlaughlin et al., 2008) indicate the proposed alignment is underlain predominantly by the following geologic units in no particular order: Holocene and Pleistocene age Alluvial deposits, undivided (Qt), Holocene age Alluvium, undivided (Qha), Holocene Channels (Qhc), Young Holocene alluvial fan and fluvial terrace deposits (Qhf_1), Old Holocene alluvial fan and fluvial terrace deposits (Qtf_2), and Pliocene age fluvial and lacustrine deposits of the Humbug Creek (Tgp). These geologic units along with others in the vicinity are shown along the pipeline alignment on Plates 2 and 3. Description of each of the map units are also presented on Plates 2 and 3.

Soils

Mapping by the Natural Resources Conservation Service (2017) has classified the upper 5 feet of soil along the proposed alignment as belonging primarily to the Yolo clay loam soil unit. In addition, the alignment will run through the Haire clay loam unit and the Clear Lake loam unit. These soils are classified as a lean clay (CL) according to the United Soil Classification System (USCS) and are said to exhibit medium plasticity (LL = 41, 47, 53, respectively; PI = 22, 24, 27, respectively). Additionally, the soils near the planned creek crossings belong to the Manzanita gravelly silt loam, Positas gravelly loam, and Riverwash soil units. According to the USCS, these units are classified as a clayey gravel (GC), a silty-clayey gravel (GC-GM), and a well graded gravel (GW), respectively. These soils exhibit very low to medium plasticity (LL = 35, 25, 0, respectively; PI = 14, 12, 0, respectively). The hazard of erosion is low to moderate depending on slope. The risk of corrosion ranges from low to high for uncoated steel and low to moderate for concrete, depending on the soil unit in the planned alignment. Performing corrosivity tests to verify these values was not part of our requested and/or proposed scope of work. Should the need arise, we would be pleased to provide a proposal to evaluate these characteristics.

Groundwater

Our experience along and in the vicinity of the alignment has found groundwater ranging from about 7 to 13 feet. Our experience also found that groundwater rises to higher elevations after periods of rain. Fluctuation in the groundwater level typically occurs because of a variation in rainfall intensity, duration and other factors such as flooding and periodic irrigation.

Landslides

Published maps (McLaughlin, et al., 2008; and Dwyer, 1976) do not indicate large-scale slope instability along the proposed alignment. Huffman and Armstrong (1980) indicate potential landslides at the eastern end of the alignment, adjacent to Melita Drive at Los Alamos Road. The landslides are shown to be on the southern side of the creek and may underlie Channel Drive. As discussed, these landslides are not shown on Dwyer (1976) and the more current McLaughlin, et al. (2008) map. In addition, we did not observe any landslides along the alignment during our reconnaissance.

Faulting/Historic Seismicity

The deformational processes and seismicity of the coast ranges immediately north of San Francisco Bay are dominated by the San Andreas fault system, a series of right lateral strike slip faults that include the San Andreas, Hayward-Rodgers Creek, Healdsburg, Maacama, Concord-Green Valley, Cordelia, Konocti, Hunting Creek, and West Napa faults. The San Andreas Fault System is responding to the strain produced by the relative motions of the Pacific and North American Tectonic Plates. This strain is relieved by right lateral strike slip faulting on the San Andres and related faults. The effects of this deformation include mountain building, basin development, and generation of earthquakes. The proposed alignment is not within a current Alquist-Priolo Earthquake Fault Zone for active faults as defined by California Geologic Survey (CGS). CGS defines active faults as those exhibiting evidence of surface displacement during Holocene time (last 11,000 years). The nearest active earthquake fault is the Healdsburg-Rogers Creek fault located approximately 1½ miles southwest of the western end of the alignment.

Earthquakes of magnitude 6.5 or greater in the Coast Ranges immediately north of San Francisco Bay include the 1892 Winters/Vacaville Earthquakes (M6.6), associated with a system of low angle thrust faults along the western margin of Great Valley; the 1898 Mare Island Earthquake (M6.4), at the southern end of the Rodgers Creek fault; the 1906 San Francisco Earthquake (M7.8); and the 1923, 1994, and 1995 Cape Mendocino Earthquakes (M7.2, M7.1, and M6.8, respectively) on the northern segment of the San Andreas fault. In addition, the epicenters of the 1969 Santa Rosa Earthquake (M5.6) at the northern end of the Rodgers Creek fault occurred within 3 miles of the pipeline alignment.

<u>Rodgers Creek Fault</u> - The Rodgers Creek fault is a right lateral, en echelon, strike slip fault. It is believed to comprise the northern continuation of the Hayward fault zone. The surface expression of the fault extends from just north of Highway 37 on the south to approximately 3½ miles southeast of Healdsburg on the north. Geomorphic features in late Holocene alluvial deposits, including offset and beheaded streams, shutter ridges, pressure ridges, sag ponds and fault scarps, are indicative of Holocene activity. In addition, the epicenters of the 1969

Santa Rosa Earthquakes and the 1898 Mare Island Earthquake were located on the Rodgers Creek fault. As a result, the California Geological Survey (CGS) has zoned the Rodgers Creek fault as active. CGS has calculated a M_{max} for the Rodgers Creek fault of 7.0 (Petersen et. al., 1996).

The Santa Rosa earthquakes consisted of two earthquakes, (magnitude 5.6 and 5.7, respectively) in the evening of October 1, 1969. The City of San Rosa and surrounding areas experienced Modified Mercalli Intensities of VI to VIII (Steinbrugge et. al., 1970). A Modified Mercalli Intensity of VI corresponds to moderate shaking with objects falling off shelves, pictures falling off walls, and cracks in plaster or masonry walls. An Intensity of VIII comprises very strong shaking with partial collapse of some masonry structures, and damage to chimneys and masonry walls. Maps of areas of damage to buildings and utilities (Steinbrugge et al., 1970) indicate that the area of the pipeline alignment suffered only minor damage during the 1969 Santa Rosa Earthquake.

The Mare Island Earthquake had an estimated magnitude of 6.7. At Mare Island several buildings collapsed. Similar damage occurred on Tubbs Island and in Schellville (Toppozada et. al., 1992). In Vallejo and Petaluma hundreds of chimneys fell.

Surface

The planned alignment extends primarily over relatively level to gently sloping terrain, and will run under paved public roads and through more than 30 private properties. The creek crossings will be constructed near or on moderately to steeply sloping banks. The vegetation consists of seasonal grasses, shrubs, and dense trees along Santa Rosa and Oakmont Creek. Drainage consists of overland flow over the ground surface that concentrates in man-made drainage elements such as roadside gutters and storm drains, and natural drainage elements such as swales and the Santa Rosa and Oakmont Creeks.

DISCUSSION AND CONCLUSIONS

Geologic Hazards

Landslides

The landslide maps and our observations do not indicate large scale slope instability along the alignment. Therefore, we believe the risk of landslides impacting the proposed pipeline alignment is low.

Fault Rupture

We did not observe landforms within the area that would indicate the presence of active faults and the site is not within a current Alquist-Priolo Earthquake Fault Zone (Bryant and Hart, 2007). Therefore, we believe the risk of fault rupture along the alignment is low.

Strong Ground Shaking

As described previously, the site is within an area affected by strong seismic activity with several northwest-trending Earthquake Fault Zones existing in close proximity to and within several miles of the alignment. Therefore, future seismic shaking should be anticipated along the alignment. It will be necessary to design and construct the proposed pipeline in strict adherence with current standards for earthquake-resistant construction.

Liquefaction

Liquefaction is a rapid loss of shear strength experienced in saturated, predominantly granular soils below the groundwater level during strong earthquake ground shaking due to an increase in pore water pressure. The occurrence of this phenomenon is dependent on many complex factors including the intensity and duration of ground shaking, particle size distribution and density of the soil. The proposed alignment is predominantly located within an area delineated as being highly susceptible to liquefaction (Witter, 2006). The extent of the alignment within a high liquefaction zone is shown on Plate 4. Therefore, we judge that there is the potential for liquefaction along the proposed alignment. However, the hazard of liquefaction is no greater than it is for the existing pipeline.

Lurching/Lateral Spreading

Seismic slope failure or lurching/lateral spreading is a phenomenon that occurs during earthquakes when slopes or man-made embankments yield and displace in the unsupported direction. This phenomenon can occur in tandem with liquefaction. Segments of the pipeline alignment are adjacent to creeks, and there are three unculverted creek crossings. Creek banks are sloping conditions where lurching/lateral spreading occurs. Therefore, we judge that there is potential for lurching/lateral spreading along the pipeline alignment. However, the hazard of lurching/lateral spreading is no greater than it is for the existing pipeline.

Geotechnical Issues

Based upon the results of our geologic data review and reconnaissance, we judge that it is geotechnically feasible to construct the planned sewer. The primary geotechnical considerations and potential mitigating measures recommended for the alignment are discussed in the following sections of the report. These conclusions are preliminary and will need to be verified or modified during final design.

High Groundwater

Groundwater will likely be encountered within the planned excavation depths for the pipeline. Therefore, dewatering will likely be required to accomplish the planned excavations. The dewatering system can consist of series of well points spread along the pipeline alignment. Water is pumped from these well points and discharged into the storm drain or sanitary sewer system, if allowed, or a storage tank for disposal off site. Dewatering will likely need to occur prior to excavation of the trenches in order to lower the groundwater level below the proposed excavation bottoms. Groundwater typically needs to be lowered to at least 3 feet below the bottom of the excavation and at least 3 feet beyond the sidewalls.

Excavation Stability

Excavations can appear to be stable when first exposed but will lose strength over time and will fail unpredictably if left unsupported. This can happen whether the soil is silt, clay, sand or gravel. The geologic units along the pipeline will yield various combinations of these soils. This is further complicated by the fact that these geologic units have the potential to liquefy, which means there is the potential for loose sand and gravel. Based on the groundwater information, the soil along the alignment could be saturated at various times of the year. It has been our experience that when the confinement for sand is removed, the saturated sand can flow into the trench. Trenches will need to be shored during construction in accordance with OSHA regulations.

Excavation Bottoms

Saturated sand that is encountered in bottom of trench excavations can become very unstable and exhibit “pumping” behavior when it is unloaded by the removal of the confining pressure of the spoils above and adjacent to it. It may be necessary to overexcavate a portion of these soils and replace them with additional bedding material to achieve the desired support of the pipeline. This condition is especially critical for gravity lines that are sensitive to settlement.

Cobbles, Boulders and Bedrock

We anticipate that cobbles, boulders and bedrock may be encountered in trench excavations deeper than 7 to 8 feet and at creek crossings. Due to the nature of these materials, excavations can be expected to yield oversize materials and have irregular excavation walls. If large material is not broken up within the excavation limits, nearby utilities may be disrupted by movement of these materials. Trench limits will probably be difficult to control.

We anticipate there is potential for failure within the walls of trench excavations through these materials. Failures would likely consist of blocks of rock or cobbles/boulders falling into the trench. Depending on how the trench is shored, it could be possible for blocks of rock and/or cobbles/boulders between shores to fall into the trench. Bedrock will need to be evaluated during excavation to determine if adverse fracture and bedding orientations exist that could potentially lead to rockfall failures along the trench walls. The contractor should follow the guidelines set by OSHA and should have a Competent Person, as defined by OSHA, on site to review the excavation conditions.

LIMITATIONS

This report has been prepared by RGH for the exclusive use of Brelje and Race and their consultants to evaluate the geotechnical feasibility of the proposed sewer alignment.

Our services consist of professional opinions and conclusions developed in accordance with generally accepted geotechnical engineering principles and practices. We provide no other warranty, either expressed or implied. Our conclusions and recommendations are based on the information provided to us regarding the proposed parcel split: the results of our field reconnaissance, data review: and professional judgment. As such, our conclusions and recommendations should be considered preliminary and for feasibility and planning purposes only. A subsurface study, such as recommended herein, may reveal conditions different from those inferred by surface observation and data review only. Such subsurface study may warrant a revision to our preliminary conclusions.

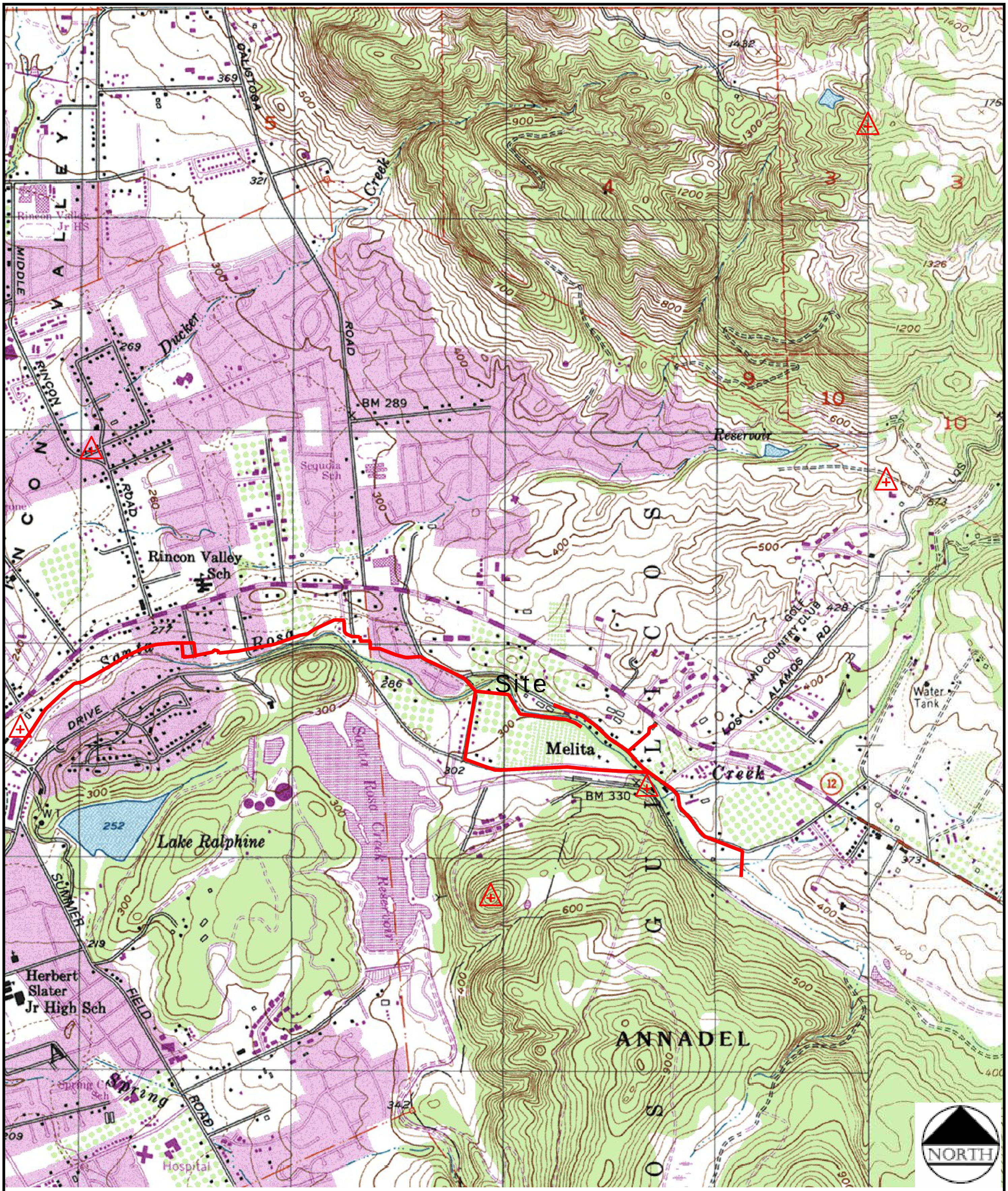
Site conditions and cultural features described in the text of this report are those existing at the time of our field exploration on March 1, 2016, and may not necessarily be the same or comparable at other times.

It should be understood that slope failures including landslides, debris flows and erosion are on-going natural processes which gradually wear away the landscape. Residual soils and weathered bedrock can be susceptible to downslope movement, even on apparently stable sites. Such inherent hillside and slope risks are generally more prevalent during periods of intense and prolonged rainfall, which occasionally occur in northern California and/or during earthquakes. Therefore, it must be accepted that occasional slope failure and erosion and deposition of the residual soils and weathered bedrock materials are irreducible risks and hazards of building upon or near the base of any hillside or steep slope throughout northern California. By accepting this report, the client and other recipients acknowledge their understanding and acceptance of these risks and hazards.

The scope of our services did not include an environmental assessment or a study of the presence (or absence) of hazardous, toxic or corrosive materials in the soil, surface water, groundwater or air on, below, or around this site, nor did it include an evaluation or study for the presence (or absence) of wetlands.

APPENDIX A - PLATES

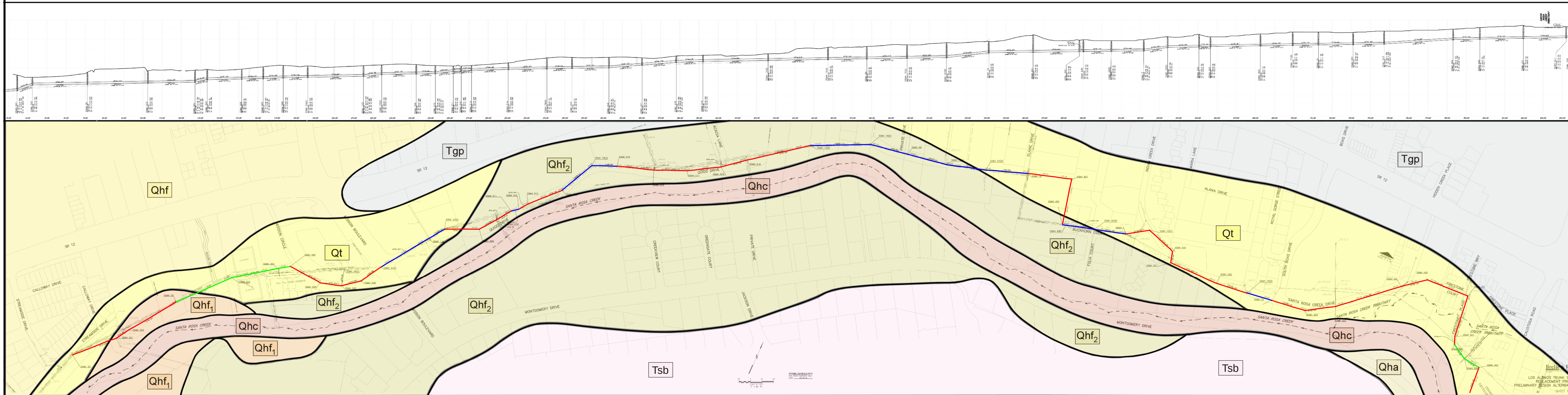
LIST OF PLATES



Reference: Maptech Topoquad, Santa Rosa, California Quadrangle

Scale: 1" = 2000'

RGH CONSULTANTS	**SITE LOCATION MAP** Los Alamos Trunk Replacement Brey Road Santa Rosa, California	PLATE **1**
Job No: 1148.42.04.1 / Date: NOV 2017		



DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

af **Artificial Fill**

Qha **Alluvium, undivided (Holocene)**

Qhc **Channels (Holocene)**–Incise older deposits

Qhf **Alluvial fan and fluvial terrace deposits, undivided (Holocene)** sand and silt, derived primarilly from Pleistocene and older non-marine gravel, late Tertiary volcanic rocks, and Mesozoic bedrock units of the Franciscan Complex, Coast Range ophiolite and Great Valley sequence. Unit may be further subdivided into the following units.

Qhf$_1$ **Young Holocene alluvial fan and fluvial terrace deposits**–Inset into old Holocene alluvial fans and fluvial terraces and pre-Holocene deposits

Qhf$_2$ **Old Holocene alluvial fan and fluvial terrace deposits (Holocene?)**–Inset into older Holocene and pre-Holocene deposits

Qoa **Older alluvium, undivided (Pleistocene)**–Generally uplifted and dissected, isolated surfaces and alluvial fills of small basins, sag ponds, and marshes

Qt **Alluvial deposits, undivided (Holocene and Pleistocene)**–Includes undivided Holocene and Pleistocene terrace deposits

TERTIARY ROCKS

Tgp **Fluvial and lacustrine deposits of Humbug Creek (Pliocene)**–Gravel, sandstone, siltstone, mudstone, nonmarine diatomite, and locally mapped intercalated siliceous tuff (Tst). In Santa Rosa and western Kenwood quadrangles, unit consists largely of boulder, cobble and pebble gravel, and sand and silt derived from underlying Mesozoic rocks and from Tertiary volcanic rocks and exhibits primarily west-northwest directed paleoflow. On the basis of stratigraphy and the ages of underlying and interbedded volcanic units, we interpret the age of the fluvial and lacustrine deposits of Humbug Creek to be 3.3-4.4 Ma. Unit may be unconformably overlain by Pleistocene and Pliocene fluvial and lacustrine deposits (QTg) in Rincon Valley

LATE TERTIARY VOLCANIC ROCKS

Tsbt **Andesitic to dacitic tuff, breccia and minor flows**–Includes air fall and ash flow tuffs and some possibly reworked waterlain tuff (Higgins, 1983). Unit underlies basaltic andesite flows dated at 4.7 ± 0.03 Ma. Andesitic tuff breccia also overlies andesitic flows and breccias (Tsb) and rhyolitic rocks (Tsr) northeast of Bennett Mountain, that are probably correlative with the obsidian of Annadel State Park (4.5 ± 0.01 Ma)

Tsb **Andesite, basaltic andesite and basalt**–Subaerial andesitic to basaltic flows, flow breccia and tuff-breccia, local waterlain andesitic tuff and minor dacitic ash-flow tuff, aerially between the Healdsburg and southern Rodgers Creek segments of the Rodgers Creek Fault Zone and the Mark West Fault Zone. Unit may compose a relatively thin cover to pre-Miocene basement (cross sections A-C). Andesitic rocks are intercalated with and underlain by the Petaluma Formation and the numerous named and unnamed rhyodacitic to andesitic tuffs (Tst), and local rhyodacitic flows and intrusive rocks (Tsr) of the Sonoma

Dated andesitic rocks in the Santa Rosa 7.5' quadrangle (table 2.2, and figure 2.2) span a significantly narrower age range than the tephra units (Tst). Andesite along Fountain Grove Parkway northeast of the Healdsburg Fault Zone is dated at 5.0 ± 0.4 Ma. Basaltic andesite from the Cloverleaf Ranch area yielded a plateau age of 4.53 ± 0.04 Ma. Andesitic flows in an area of abandoned cobblestone quarries east of Lake Ralphine are dated at 4.4 ± 0.03 Ma. East of the Bennett Valley Fault in Annadel State Park, a lithologically and texturally similar

Near the northeast corner of Santa Rosa 7.5' quadrangle, porphyritic basaltic andesite that overlies the 4.83 Ma Lawlor Tuff, is dated at 4.63 ± 0.02 Ma. Collectively, andesitic rocks northeast of the Rodgers Creek-Healdsburg Fault Zone and southwest of the Maacama Fault appear to range in age from ~5.4 to 4.4 Ma

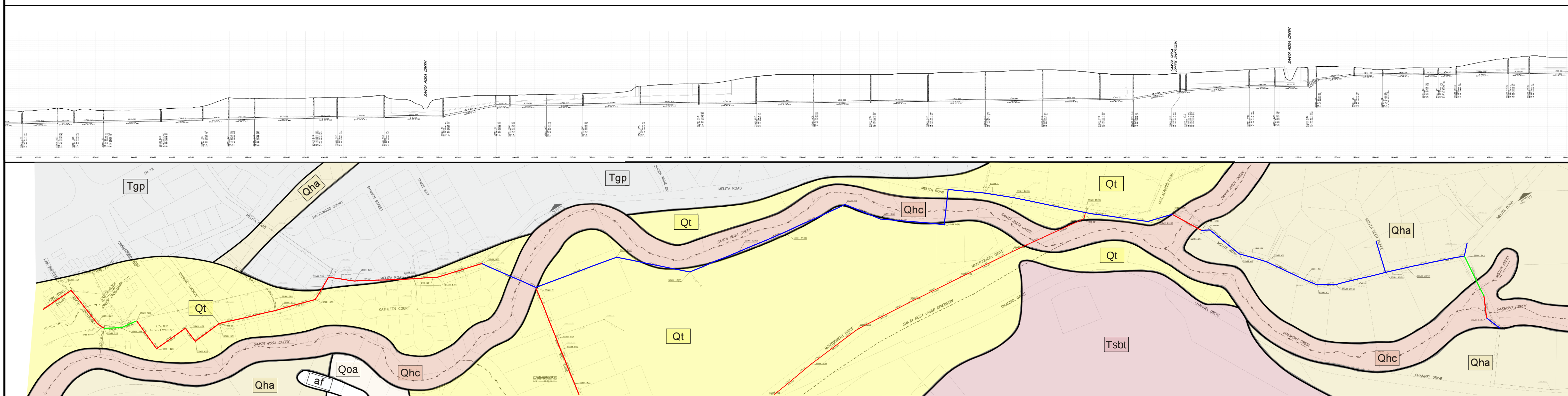
Reference: Base- Los Alamos Trunk Sewer Replacement Project, Preliminary Design, Sheet 1, Brele & Race
Geology- Geologic and Geophysical Framework of the Santa Rosa 7.5' Quadrangle, McGlaughlin et al., 2008

N

500 0 500 1000 feet

Scale: 1" = 500'

RGH CONSULTANTS	**GEOLOGIC MAP** Los Alamos Trunk Replacement Santa Rosa, California	PLATE 2
Job No: 1148.42.04.1 Date: NOV 2017		



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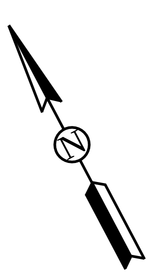

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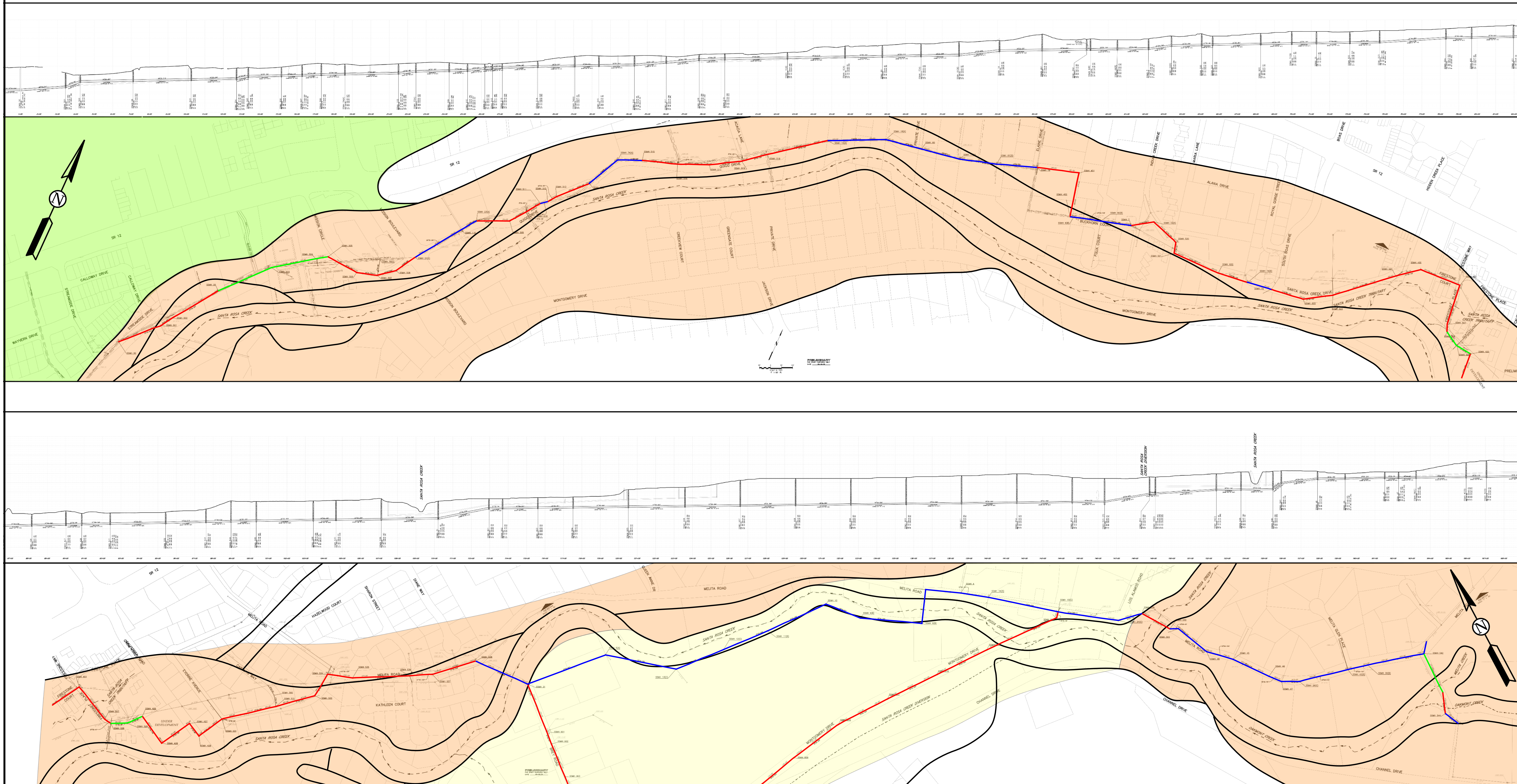
Scale: 1" = 500'

Reference: Base- Los Alamos Trunk Sewer Replacement Project, Preliminary Design, Sheet 2, Brele & Race
Geology- Geologic and Geophysical Framework of the Santa Rosa 7.5' Quadrangle, McGlaughlin et al., 2008

RGH CONSULTANTS Job No: 1148.42.04.1 Date: NOV 2017	**GEOLOGIC MAP** Los Alamos Trunk Replacement Santa Rosa, California	PLATE 3



500 0 500 1000 feet

Scale: 1" = 500'

Liquifaction Susceptibility Explanation

- Low
- Medium
- High

Reference: Base- Los Alamos Trunk Sewer Replacement Project, Preliminary Design, Sheets 1 & 2, Brele & Race

RGH CONSULTANTS	**LIQUEFACTION SUSCEPTIBILITY MAP** Los Alamos Trunk Replacement Santa Rosa, California	PLATE **4**
Job No: 1148.42.04.1 | Date: NOV 2017		

APPENDIX B - REFERENCES

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APPENDIX C - DISTRIBUTION

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