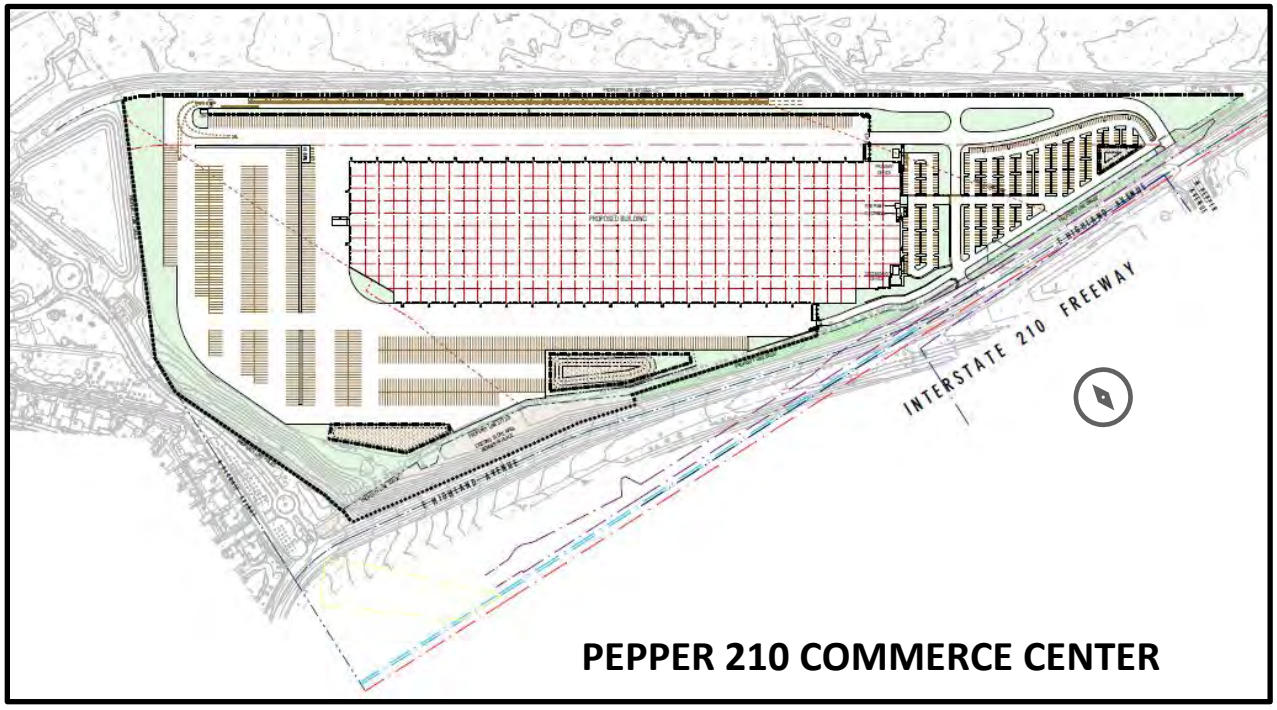
TETRA TECH

Geotechnical Engineering ● Engineering Geology

GEOTECHNICAL FEASIBILITY REPORT
PEPPER 210 COMMERCE CENTER
20080 N. Highland Avenue
Rialto, California 92377



Prepared for:

Carson Companies
100 Bayview Circle #3500
Newport Beach, California 92660

Prepared by:

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September 7, 2023
Project No. GEN 19-22E

TETRA TECH

Project No. GEN 19-22E
September 7, 2023

Mr. Dan Darnell
Carson Companies, Inc.
100 Bayview Circle #3500
Newport Beach, California 92660

Subject: **GEOTECHNICAL FEASIBILITY REPORT**
PEPPER 210 COMMERCE CENTER
20080 N. Highland Avenue
Rialto, California 92377

Dear Mr. Darnell:

Tetra Tech is pleased to submit this geotechnical feasibility report for the proposed Pepper 210 Commerce Center located at 20080 N. Highland Avenue in the City of Rialto, California. The purpose of this study was to evaluate the geotechnical feasibility of site development and to provide preliminary geotechnical conclusions and recommendations relative to the future site development. This report includes a brief description of the project site, discussions regarding Tetra Tech's past field and laboratory investigative efforts, description of geology and subsurface conditions, engineering seismology, fault setback criteria, and preliminary geotechnical conclusions and recommendations for the design and construction of the future site development. The appendices to the report include logs of exploratory borings and results of laboratory tests by Tetra Tech (2019), a complete copy of Tetra Tech 2022 fault investigation report, and a copy of Tetra Tech 2022 percolation investigation report.

We appreciate the opportunity to provide our professional services on this project. If you have any questions regarding this report or if we can be of further service, please do not hesitate to contact the undersigned.

Respectfully submitted,
Tetra Tech BAS, Inc.



Yonglang Li, PhD, GE
Senior Engineer



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Appendix B – Results of Laboratory Testing (Tetra Tech, 2019)
Appendix C – Fault Investigation Report (Tetra Tech, 2022a)
Appendix D – Percolation Investigation Report (Tetra Tech, 2022b)

1. INTRODUCTION

This report presents the findings of Tetra Tech geotechnical feasibility report for the proposed Pepper 210 Commerce Center located at 20080 N. Highland Avenue in the City of Rialto, California. The location of the site is shown in Figure 1 – Site Location Map.

The purpose of this study was to evaluate the geotechnical feasibility of the future site development and to provide preliminary geotechnical conclusions and recommendations. This report includes the findings and recommendations of Tetra Tech's earlier referenced geotechnical studies and comprehensive fault investigation and is intended to assist with conceptual site development and planning. While this report is comprehensive for the intended purpose, it is not sufficient for final design purposes. As such, an additional geotechnical design-level report will be required for final design and permitting.

2. SCOPE OF SERVICES

Tetra Tech's scope of services for this project consisted of the following tasks:

- Review of available background data, including Client-provided and in-house geotechnical data, geotechnical literature, geologic reports, publications and maps, and seismic hazard maps relevant to the subject site.

- A summary of the finding and conclusions presented within Tetra Tech's 2019 Geotechnical Data and Assessment Report for the subject site.

- A summary of the findings and conclusions presented within Tetra Tech's 2022 Fault Investigation report for the subject site.

- Engineering and geologic evaluation of the data collected to develop preliminary geotechnical recommendations and conclusions relevant to the future site development.

- Preparation of this geotechnical feasibility report, including the provision of reference maps and illustrations, a summary of the collected geologic and geotechnical data, and preliminary geotechnical recommendations and considerations for future site development.

3. SITE DESCRIPTION AND PROPOSED DEVELOPMENT

The site comprises an area of approximately 100 acres and is located north and northwest of the intersection of Highland Avenue and N. Pepper Avenue in the city of Rialto, California. The site is roughly triangular and is located within the western flood plain of Lytle Creek. The site is protected from the alignment of Lytle Creek by an Army Corps of Engineers flood control levee which bounds the property to the north – northeast. The site is also bounded by Highland Avenue to the south and an existing residential development and a new residential development currently under construction to the west (formerly a portion of the El Rancho Verde Country Club and golf course).

The site is currently utilized by Vulcan Materials Company (Vulcan) for processing and sale of construction aggregate, including sand, gravel, aggregate base and asphalt. Plant operations initiated during the 1940's and included open pit mining of the westerly half of the property to a depth of up to approximately 45 feet below the original ground surface. Much of the open pits have been backfilled and the eastern portion of the site is currently used for plant operations which include office and maintenance facilities, scale houses, employee parking, heavy equipment staging areas, crushing and conveyor belt operations, stockpiling and sorting areas, and asphalt production. The western portion of the site is currently used to store large stockpiles of various aggregate product for sale to the public. The stockpiles are separated by a network of gravel haul roads that are utilized for heavy equipment and loading of commercial trucks. The central portion of the site is currently used to maintain construction water ponds and for mixing, drying, and onsite disposal of wash plant fines and concrete debris. Overall, the site gently slopes to the southeast and drains to various detention basins within the property via graded earth swales with exception of the ponded areas within the central portion of the site.

Ascending slopes up to 58 feet in height border the southwestern perimeter of the site and generally vary from approximately 1.5(H):1(V) to 2(H):1(V) in gradient. The north and east perimeter of the site is bordered by Army Corps of Engineers flood control levee with 2(H):1(V) slopes rising about 20 feet above the adjacent grades.

Based on our discussions with representatives of the Carson Companies, pit reclamation grading operations will be initiated upon termination of the current aggregate operations (projected in 2027). At this time, all undocumented fill materials will be removed and replaced as engineered fill in conformance with recommendations to be provided within a separate geotechnical report for the site.

We understand that future site development will involve construction of large concrete tilt-up commercial warehouse building comprising about 1.2 million square feet, with queuing lanes, security kiosks, drive aisles, surface parking for commercial semi-trucks and employee and customer vehicles. Other appurtenant improvements are anticipated to include storm water retention basins, underground utilities, light standards, and retaining walls.

4. PREVIOUS GEOTECHNICAL AND GEOLOGIC STUDIES BY TETRA TECH

4.1. Geotechnical Investigation

In November 2019, Tetra Tech completed a geotechnical investigation for the subject property. The purpose of that study was to evaluate the existing fill conditions, estimate required cut/fill volumes, and provide preliminary geotechnical considerations relative to the future site development. As a part of this study, 8 exploratory borings were drilled at various locations within the property to depths ranging from about 11.5 to 51.5 feet. The approximate locations of the exploratory borings are shown on Figure 2 – Site Geology and Exploration Location Map. Logs of exploratory borings completed during this investigation are presented in Appendix A, and results of laboratory testing are presented in Appendix B.

4.2. Fault Investigation

During January 2021 and February 2022, Tetra Tech completed a comprehensive fault investigation within the subject property. The fault investigation included excavation and logging of 8 exploratory trenches measuring up to about 23 feet below the ground surface and totaling approximately 4,185 lineal feet. In addition to trenching, 1 seismic refraction traverse about 1,067 feet in length and reaching up to about 80 feet in depth was also completed along the northwesterly boundary of the site.

As part of this study, samples of charcoal and organic-rich sediments were collected from various trenches for laboratory radiocarbon age-dating tests. In-situ samples of select alluvial materials were also collected for Optically Stimulated Luminescence (OSL) testing.

The primary objective of this study was to determine whether Holocene-active faulting (rupture the ground surface within the last 11,700 yrs), as defined by the State of California Alquist-Priolo Earthquake Fault Zoning Act, is present beneath the site. Where Holocene-active faulting was identified or could not be ruled out through our study, building setback zones were established for the project. A copy of Tetra Tech's 2022 fault investigation report for the site is included within Appendix C. Recommended Building Setback Zones established for the subject site are presented on Plate 1.

4.3. Percolation Investigation

In August 2022, Tetra Tech completed a percolation investigation within predetermined locations within the site to assess infiltration rates of subsurface soils for the design and future construction of stormwater BMP's. For this investigation, Tetra Tech performed 7 borehole falling-head percolation tests in accordance with the borehole percolation test procedure described in Appendix D of the Technical Guidance Document for Water Quality Management Plans prepared for the County of San Bernardino Areawide Stormwater Program, dated September 19, 2013 (Technical Guidance document). The approximate locations of the 7 borehole percolation tests are shown on Figure 2 – Site Geology and Exploration Location Map. A copy of Tetra Tech's 2022 percolation investigation report for the site is included within Appendix D.

5. GEOLOGIC AND SUBSURFACE CONDITIONS

5.1. Regional Geology and Geomorphic Setting

Regionally, the subject site is located within the eastern part of the Upper Santa Ana River Valley, locally referred to as the San Bernardino Valley. The San Bernardino Valley is bounded on the west by the Fontana Plain, on the north and east by the San Gabriel and San Bernardino Mountains and the Crafton Hill and the badlands to the south (Dutcher & Garret, 1963). The Lytle Creek fan is the largest alluvial fan in the San Bernardino Valley, however, much of the fan is a relict that was initially formed in late Pleistocene as sediment carried down from the San Gabriel Mountains carved a path along the San Jacinto fault. Over time, the fan surface was intermittently dissected by concentrated flood events that created deep trenches as down-cutting advanced. As faulting, uplift and tilting progressed through recent time, the fan's drainage system was eventually beheaded, leaving behind alluvial terraces. Outflow to the fan was ultimately redirected through modern stream piracy to the eastern side of the fan (Clarke, 1989).

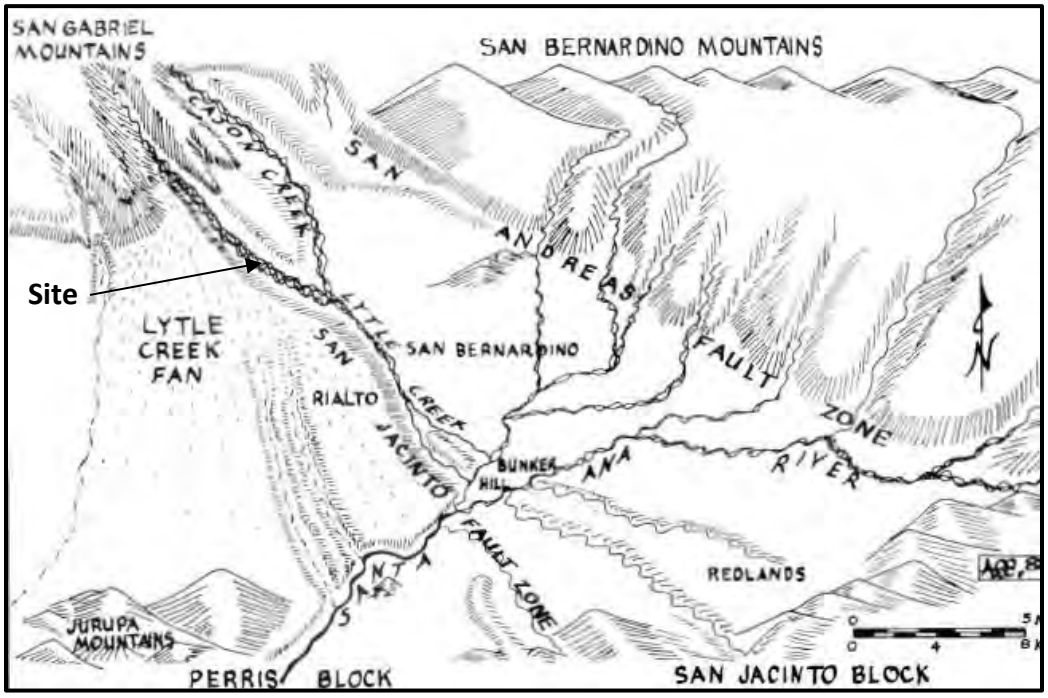


Illustration 1: Major Landforms of the San Bernardino Valley (Clarke, 1989)

Bedrock in the local mountain ranges consist predominately of igneous and metamorphic basement rocks, mantled locally in the lower reaches by both marine and non-marine sedimentary rocks. Recent drainage from the southeastern San Gabriel Mountains emanates though a complex braided stream environment. The resistant basement rock of the mountainous terrain provides the primary source rock of the gravel- and boulder-rich alluvium of the stream deposits. This alluvium is typically comprised of sub-rounded quartz diorite, granodiorite, well-banded gneiss and biotite and chlorite schist fragments with quartz- and feldspar- rich sand and silt that generally comprises the floodplain materials within Lytle Creek and Cajon Creek.

5.2. Site Geology

The site is located within the southwestern edge of the Lytle Creek flood plain and is underlain by thick sequences of alluvial deposits, as shown on Figure 3 – Regional Geologic Map. However, much of the ground surface has been modified by commercial aggregate operations since the 1950's. Past ground modifications included open pit mining of the westerly half of the property to depth of up to approximately 45 feet below the original ground surface. Backfilling of the open pits within the property has continued periodically over the decades. The central portion of the site is currently utilized to maintain construction water ponds and for mixing, drying and onsite disposal of wash plant fines and concrete debris. The eastern areas of the property are believed to have had little to no history of open pit mining. This area of the site is expected to be underlain by local accumulations of fill material associated with underground utilities and local structures. As a result, the distribution of the geologic units varies substantially across the site. The subsurface conditions described herein are based upon the findings of the exploration trenching completed for this study, the findings from the referenced 2019 geotechnical exploration by Tetra Tech, and site research.

The surficial geologic units encountered within the subject site consist of Holocene-age artificial fill (Af), colluvium (Qcol) and younger alluvium (Qaly). Pleistocene-age older alluvium (Qoal) was encountered locally at the ground surface and beneath the Holocene surficial units.

5.3. Geologic Units

Generalized descriptions of the geologic units encountered during Tetra Tech's past field investigations, from youngest to oldest, are provided below. Detailed descriptions of the soils encountered within exploratory borings and trench excavations completed by Tetra Tech are presented in Appendices A and C.

5.3.1. Artificial Fill (Af)

Variable thicknesses of artificial fill soils primarily associated with mine site reclamation backfill and spoils from past aggregate stockpiles and trucking operations are present throughout the site. The fill soil types very broadly and consist of onsite aggregate processing waste as well as of materials from offsite sources. The fill soils generally consist of brown to gray, loose to medium dense silty sand, poorly graded sand with silt, gravelly sand or olive brown to grayish brown, firm to very stiff lean clay, and silt or sandy silt. Varying amounts of cobbles and boulders up to 2 feet were also encountered. Locally, trace amount of refuse (e.g., plastic, nails, wire glass, etc.) was encountered within the fill.

Because of the history of the site, fill materials are ubiquitously present over most of the site. Although in the western half, significant thicknesses up to 50 feet of reclamation backfill of former mining pit excavations are anticipated based on comparison of topographic survey of the mining pit bottom and the current surface topography. Elsewhere, a thin veneer, typically less than 5 feet thick, was encountered.

5.3.2. Colluvium (Qcol)

Colluvium locally mantles the natural slopes and is also present as wedge-shaped deposits along the base of sloping terrain. Where encountered within the site, colluvial soils are comprised of dark grayish brown (2.5Y 4/2) to olive gray (5Y 4/2) silty sand that is typically fine grained with scattered gravel and occasional cobbles up to 8-inches in diameter. The colluvium is locally porous and contains scattered roots and rootlets. Up to 3.5 feet of colluvium was identified at various locations along the southwesterly perimeter of the site.

5.3.3. Younger Alluvium (Qaly)

Holocene-age younger alluvium (Qaly) is present within the perennial braided stream channels of Lytle Creek situated north of protective levee that currently surround the site. Prior to modern flood control improvements, historical storm and flooding events, such as the 1938 Great Flood, caused Lytle Creek to overflow its banks and deposit alluvium across various portions of the current flood plain. The historical alluvial deposits within the site were mostly indistinguishable due to past ground modifications associated with the aggregate plant operations.

Much thicker accumulations of the younger alluvium were deposited within the site by an ancestral Lytle Creek. Where observed in trench excavations completed for this study, these alluvial sediments varied in lithology and physical characteristics, both laterally and vertically, as a result of the chaotic depositional history associated with Lytle Creek outflow. The alluvium is commonly gray (2.5Y 6/1) to light gray (2.5Y 7/1) to light brownish gray (2.5Y 6/2) to olive brown (2.5Y 4/3) and is comprised of varying distributions of sand, silt, gravel, cobbles and boulders. The deposits are crudely stratified to well stratified, markedly channelized in areas, and locally cross-bedded. Clasts are subangular to subrounded and often imbricated. Fine-grained sequences of overbank materials comprised of sandy silt with trace clay and silty sand were typically encountered within the upper 10 feet of the ground surface and to a lesser extent at greater depths.

5.3.4. Older Alluvium (Qoal)

Older alluvium is buried beneath the younger alluvium within the site and is exposed locally at the ground surface within the southwestern perimeter of the site. In general appearance, the coarse-grained older alluvium is similar to the younger alluvium in that it is comprised of varying distributions of sand, silt, gravel, cobbles and boulders. The deposits are also crudely stratified to well stratified, markedly channelized in areas, and locally cross-bedded. Clasts are generally crystalline and subrounded, however, in many locations crystalline clasts exhibit in-place granular disintegration characteristics referred to as grus. The coarse-grained older alluvium sequences are generally less friable as compared to the younger alluvium and exhibit a weakly cemented texture with matrix materials varying in color from light yellowish brown (10YR 6/4 to 2.5Y6/3) and light olive brown (2.5Y 5/4).

Fine-grained sequences are fewer in the older alluvium, however, where encountered they are often yellowish brown (10YR 5/6) in color and exhibit moderate pedogenic characteristics associated with paleosol development. Individual ped surfaces show subangular blocky structure with clay coating and oxidation staining visible on ped surfaces. Similar studies conducted by others in the

Lytle Creek flood plain to the northwest have judged similar paleosol development to be at least 35,000 years old (Shlemon, 1994). No charcoal fragments were identified in the fine grained older alluvial deposits during this study. However, IRSL age dating test results from several sediment samples collected within the older alluvium at various trench locations provide compelling evidence for Pleistocene age of deposition for the older alluvium identified through this study.

5.4. Groundwater

Groundwater was not encountered in any of the exploratory borings or trenches completed by Tetra Tech to the maximum depths of exploration (51.5 feet). Additionally, the seismic refraction survey completed for this study within the northwestern portion of the site did not identify subsurface anomalies consistent with groundwater to depths of up to approximately 80 feet beneath the site.

The site is located within the Upper Santa Ana Valley Groundwater Basin. Based on groundwater records in the general vicinity of the site from the California Department of Water Resources website (updated Spring 2021), groundwater is anticipated to be at least 300 feet below the ground surface. It should be noted that groundwater levels may fluctuate due to seasonal variations in rainfall and snowfall, irrigation, or other factors. Evaluation of such factors is beyond the scope of this study.

6. SEISMOLOGY AND GEOLOGIC HAZARDS

6.1. Seismic Setting

The study area is located along the northern terminus of the Peninsular Ranges physiographic province which is characterized by northwest-trending ranges, valleys, and geomorphic features controlled by the San Andreas Fault Zone (SAFZ) and associated fault systems, including the San Jacinto fault. Collectively, the San Andreas fault and the San Jacinto fault transfer most of the Pacific – North America plate motion through southern California and produce recurrent surface rupturing earthquakes (Oskin & Rockwell, 2018). The study area is located southeast of the junction of the San Andreas and San Jacinto faults. These faults approach each other to the northwest within the Cajon Pass area between the San Gabriel and San Bernardino Mountains, where the northern terminus of San Jacinto fault forms approximately a 1- to 2-mile-wide releasing step with the San Andreas fault (Onderdonk et al, 2018). Instead of merging with the SAFZ, the surface trace of the San Jacinto fault terminates into a set of cross-cutting, high- and low-angle faults within the eastern San Gabriel Mountains.

The location of the SAFZ is well documented and clearly expressed by a series of subparallel linear escarpments and offset drainages displacing Holocene-age alluvium along the base of the San Bernardino Mountains. The San Jacinto fault zone consists of a series of sub parallel, right lateral, right-stepping faults that form the western margin of the San Jacinto Mountains. The fault zone has been mapped from its junction with the SAFZ in the Cajon Pass area, to the southeast for about 175 miles, where it transfers most of its motion to the Imperial fault within the Brawley area.

The location of the San Jacinto fault within the San Bernardino Valley, however, is poorly expressed at the ground surface. In the San Bernardino Valley, the San Jacinto fault zone consists of three named fault strands referred to as the Lytle Creek, San Jacinto and Glen Helen faults, from west to east, in a zone approximately 2 to 3 miles wide (Burnett & Hart, 1994). The uncertainty in location is reflected on most published geologic maps, including the Alquist-Priolo Earthquake Fault maps (CGS, 1974, 1995) for the study area that show the fault as dotted or dashed lines that are often queried. Many of surface traces are inferred based on tonal variations and weak lineaments expressed in aerial photographs, possible scarps along active and abandoned drainage channel boundaries and some based solely on interpreted groundwater barriers concealed at depth.

Historically, at least three moderate to large earthquakes have occurred in the northern portion of the San Jacinto fault, and at least one on the San Bernardino Valley segment (July 1923, Loma Linda, M6 to M6.3). Fault slip rate data on the northern, San Bernardino Valley, segment of the San Jacinto fault is not as well constrained as similar the southern sections of the fault, however a slip rate on the order of 13 to 18 mm per year has been considered reasonable by many researchers (Onderdonk et al, 2018).

Recent studies provide compelling paleoseismic records for the San Jacinto fault at Mystic Lake, about 22 miles southeast of the subject site. At this location, at least 13 surface earthquake ruptures were exposed over the past 2,000 years. The average recurrence interval has been estimated to be 160 ± 76 year for the northern San Jacinto fault during the last 2,000 years (Onderdonk, et al, 2018). Similar studies for sections of the San Jacinto fault further to the south at Hog Lake suggest

similar relatively short recurrence intervals for surface-rupturing earthquakes (Rockwell et al., 2014).

6.2. Seismicity

The Southern California region is known to be seismically active. Earthquakes occurring within approximately 60 miles of the project sites are considered capable of generating ground shaking of engineering significance to the proposed construction. The project area is located in the general proximity of several seismically active faults, as shown on Figure 4 – Regional Faults and Seismicity Map. Tables 1 provides a summary of known seismically active faults within approximately 40 miles of the project sites as modeled by the U.S.G.S. Earthquake Hazards Program, 2008 National Seismic Hazard Maps (https://earthquake.usgs.gov/cfusion/hazfaults_2008_search/query_main.cfm).

Table 1
Summary of Active Faults
Referenced Site Latitude and Longitude: 33.138863°, -117.359943°

Fault Name	Approximate Fault Distance to Site (miles)	Slip Sense	Maximum Moment Magnitude
San Jacinto	-	strike slip	7.7
S. San Andreas	4.60	thrust	7.7
Cucamonga	5.52	thrust	6.7
Cleghorn	9.84	strike slip	6.8
North Frontal (West)	13.32	reverse	7.2
San Jose	19.05	strike slip	6.7
Sierra Madre	21.86	reverse	7.2
Chino	22.93	strike slip	6.8
Elsinore	24.94	strike slip	7.2
Clamshell-Sawpit	28.75	reverse	6.7
Helendale – So Lockhart	31.48	strike slip	7.4
Puente Hills (Coyote Hills)	33.57	thrust	6.9
Raymond	36.19	strike slip	6.8
San Joaquin Hills	40.42	thrust	7.1

6.3. Historic Earthquakes

Historic earthquakes in Southern California of potential significance to the project are presented in Figure 4 – Regional Faults and Seismicity Map and summarized in Table 2 below:

Table 2
Historic Earthquakes in Southern California

Earthquake Name	Year	Fault and Fault Type	Earthquake Magnitude*	Epicenter	
				Latitude	Longitude
Ridgecrest	2019	Airport Lake Fault Zone (right-lateral strike-slip)	7.1 M_w	35.77°N	-117.60°W
Chino Hills	2008	Whittier and Chino faults (right-lateral strike-slip)	5.4 M_w	33.96°N	117.76°W
Northridge	1994	Northridge Thrust (blind thrust)	6.7 M_w	34.21°N	118.54°W
Landers	1992	Johnson Valley Fault (right-lateral strike-slip)	7.3 M_w	34.16°N	116.40°W
Sierra Madre	1991	Clamshell – Sawpit fault (left-lateral strike-slip)	5.6 M_L	34.26°N	116.40°W
Whittier Narrows	1987	Puente Hills Fault (blind thrust)	5.9 M_L	34.06°N	118.08°W
San Fernando	1971	San Fernando Fault (thrust)	6.5-6.7 M_w	34.42°N	118.37°W
Long Beach	1933	Newport-Inglewood Fault (right-lateral strike-slip)	6.4 M_w	33.63°N	118.00°W

*M_w refers to Moment Magnitude scale
M_L refers to Local Magnitude scale

6.4. Seismic Hazards and Potential for Surface Fault Rupture

The engineering seismology assessment for the site included a review of available local and regional faulting and historical earthquake data. The following engineering seismology issues are herein addressed:

Seismic Hazard Zones: Maps of seismic hazard zones are issued by the California Geological Survey (CGS, formerly California Department of Conservation, Division of Mines and Geology (CDMG)) in accordance with the Seismic Hazards Mapping Act enacted in April 1997. The intent of the Seismic Hazards Mapping Act is to develop a statewide seismic hazard mapping and technical advisory program to assist cities and counties in developing compliance requirements to protect the public health and safety from the effects of strong ground shaking, liquefaction, landslides, or other ground failure and other seismic hazards caused by earthquakes.

The project site is located in the San Bernardino North 7.5-Minute Quadrangle. This quadrangle has not yet been mapped by the State of California for liquefaction and earthquake induced

landslide hazards. Site-specific liquefaction assessment performed by Tetra Tech indicates that the site is not susceptible to liquefaction (discussed later in Section 6.5 of this report). Given the relatively flat finish grade at the majority of the site and conditions and favorable gradients of the existing perimeter slopes, earthquake-induced landsliding is also not considered a relevant hazard.

***Surface Fault Rupture*:** Official Maps of Earthquake Fault Zones were reviewed to evaluate the location of the project site relative to active fault zones. Earthquake Fault Zones (known as Special Studies Zones prior to 1994) have been established in accordance with the Alquist-Priolo Special Studies Zones Act enacted in 1972. The Act directs the State Geologist to delineate the regulatory zones that encompass surface traces of active faults that have a potential for future surface fault rupture. The purpose of the Alquist-Priolo Act is to regulate development near active faults in order to mitigate the hazard of surface fault rupture.

The site is located within a designated Earthquake Fault Zone associated with the San Jacinto fault (see Figure 5 – Earthquake Fault Zone Map). In accordance with State law, a site-specific fault investigation was completed by Tetra Tech to determine where active faults extend across the site. Where active faulting has been identified or cannot be ruled out, building setbacks for habitable structures have been established for future site development. A complete copy of Tetra Tech's 2022 fault investigation report is presented in Appendix C.

6.5. Liquefaction Potential and Seismic Settlement Potential

Liquefaction of saturated or near-saturated soils can be caused by ground shaking during earthquakes. Groundwater was not encountered in any of the exploratory borings and is anticipated to be at least 300 feet below the ground surface. Therefore, liquefaction is not considered a hazard at the site.

Seismic settlement can occur in saturated materials due to liquefaction or in dry materials due to densification of the soil matrix. The on-site native alluvial deposits are dense to very dense. All the on-site non-engineered reclamation fills will be overexcavated and recompacted as engineered fill. Therefore, seismic settlement of the onsite native alluvial soils and engineered fills is anticipated to be less than 1 inch.

6.6. Geologic Hazards

6.6.1. Lateral Spreading

Lateral spreading is a liquefaction-induced ground failure that occurs on gentle slopes or on nearly level (or gently inclined) ground with a free face (e.g., riverbank, road cuts). Due to absence of liquefaction at the site, lateral spreading is not considered to be a hazard at the site.

6.6.2. Landslides

Ascending slopes up to 58 feet in height border the southwestern perimeter of the site and generally vary from approximately 1.5(H):1(V) to 2(H):1(V) in gradient. The north and east perimeter of the site is bordered by a flood control levee with 2(H):1(V) slopes rising about 20 feet above the

adjacent grades. This levee is operated and maintained by the United States Army Corps of Engineers. These perimeter slopes generally consist of medium dense to dense granular soils.

The majority of the site is relatively flat and not subject to the landsliding. Proposed rough grading modifications around the perimeter of the site will result in granular cut and fill slopes inclined at gradients of 2(H):1(V) or flatter. Therefore, landsliding is not anticipated to be a geologic hazard at the site.

6.6.3. Expansive Soils

Expansive soils are characterized by their ability to undergo significant volume changes (shrink or swell) due to variations in moisture content. Changes in soil moisture content can result from precipitation, landscape irrigation, utility leakage, roof drainage, perched groundwater, drought, or other factors which can cause unacceptable settlement or heave that could adversely affect the performance of structures or slabs supported on grade.

Based on review of past laboratory testing and visual classification, the onsite native and fill soils are considered to be non-expansive.

6.6.4. Collapsible Soils

Collapse is typically exhibited in geologically young, unconsolidated, low-density, loose, dry soils commonly present in arid to semi-arid regions. Collapsible soils are usually composed of granular particles that are supported by a clay or silt matrix that can be chemically cemented in place creating a porous structure. The bonds supporting this porous structure have enough shear strength to support loads at low moisture contents, however, once water is introduced the cemented bond structure breaks down and the granular particles are re-arranged causing significant volume loss.

Subsequent to completion of the remedial grading recommendations presented in Section 7.2 of this report, collapsible soils are not considered a hazard at the project.

6.6.5. Flood Hazard

The project site is not located within an area mapped by the California Department of Water Resources and the County of San Bernardino within the 100-year and 200-year floodplains. The project has been mapped by both agencies within a 500-year floodplain (FEMA Zone X500), which is defined as areas of 0.2% annual flood, areas of the 1% chance of flood with average depths of less than 1 foot or with drainage areas less than 1 square mile. The X designation indicates the area is protected by a federal levee and possess a Moderate to Low Risk of flooding (https://gis.bam.water.ca.gov/bam/ and Hazard Overlay Maps – Land Use Services (sbcounty.gov)).

6.6.6. Tsunamis and Seiches

A tsunami is a sea wave generated by large-scale displacements of the ocean floor that causes a sudden surge of water onto the land. Tsunamis are most commonly caused by movement along faults and underwater landslides activated by earthquakes. Seiches are earthquake-induced

displacements of water within an enclosed or partially enclosed body of water such as a lake. Strong ground motions from an earthquake cause the water to oscillate back and forth onto land.

The project site is over 1300 feet above sea level, is not located near a lake or partially enclosed body of water and is located outside of a designated Tsunami Inundation Area. Therefore, hazards associated with a tsunami or seiches are not anticipated at the site.

6.6.7. Subsidence

Land subsidence is the lowering of the ground surface due to extraction or lowering of groundwater levels or other fluids (e.g., oil) within the subsurface soil pores. The fluid withdrawal causes the alluvial sediments in the basin to compact. Damage caused by subsidence can be visible soil cracks, fissures, or surface depression.

The site is located in an area mapped by the United States Geological Survey (USGS) where historical land subsidence has been recorded. The historical subsidence has been attributed to groundwater level declines due to irrigation wells to support agriculture and post-World War II urbanization through the mid-1950's. Current land usage and groundwater management practices have essentially mitigated man-induced land subsidence risk in the region of the project. Therefore, land subsidence is not considered a hazard at the site. (https://ca.water.usgs.gov/land_subsidence/california-subsidence-areas.html)

7. CONCLUSIONS AND RECOMMENDATIONS

7.1. General

Based on the results of past field exploration and engineering analyses, it is Tetra Tech's opinion that the future site development is feasible from a geotechnical standpoint. The primary considerations identified from the geotechnical standpoint include:

- The entire site lies within an Earthquake Fault Zone. In accordance with the State law, a fault investigation was completed by Tetra Tech to determine where active faults extend across the site. Where active faulting was identified or could not be ruled out, building setbacks for habitable structures have been established for future site development.

- The presence of variable thicknesses of non-engineered fill up to about 45 feet in the western portion of the site. Overexcavation and re-compaction of all non-engineered fill materials that will support structural improvements will be required prior to future site development.

- Removal and re-compaction of reclamation backfill and non-engineered fill materials will result in significant volume loss as a result of shrinkage. Careful consideration of shrinkage factors should be applied during design of final rough grading plans in order to balance earthwork operations as much as practical.

- Non-engineered fill materials are anticipated to be generally composed of coarse-grained and dry earth materials that will require significant volumes of water during engineered fill placement. To a lesser extent, some of the reclamation backfill materials may be locally composed of finer-grained silts and lean clay that may be very moist to wet. These materials will likely require drying prior to placement as compacted engineered fill.

- Oversized rock (over 12 inches in maximum dimension) will be generated locally within the reclamation backfill and alluvial soils. The oversize rock will require special handling and should be addressed in a future geotechnical design report.

- Non-engineered reclamation fills on the order of 45 feet in thickness exist within the former mining pit excavation (Winter Pit) beneath the westerly portions of the site. The non-engineered fills will require removal and replacement as engineered fills during future rough grading operations. To assess potential post-construction settlement of deep fills beneath the site, settlement monitoring is recommended prior to construction of structural improvements. Specific details regarding post-construction settlement monitoring will be addressed within the geotechnical design-level report for the site.

Based on the results of laboratory testing and our experience with similar soils, the majority of the on-site soils are considered non-expansive.

7.2. Earthwork Factors

Earthwork factors are an important parameter for determination of grading volumes. The volume change of excavated materials upon re-compaction is expected to vary with material types, in-situ density, and compaction effort. Due to the wide range of backfill densities, an accurate estimate of the earthwork factors is effectively impractical, therefore, a relatively wide range of shrinkage factors are herein provided in Table 3 below.

Table 3
Volume Changes during Fill Placement

Material & Relative Compaction	Volume Change
Non-Engineered Fill and Reclamation Fill (90 to 93%)	7% to 20% decrease (shrinkage)
Native Alluvial Soils (90 to 93%)	5% increase (bulkage) to 5% decrease (shrinkage)

These estimates are intended as a preliminary aid in estimating the required earthwork quantities and should be used with caution. They should not be a basis used for final budgeting.

7.3. Overexcavation and Recompaction

The onsite reclamation backfill is not suitable for structural support in its current condition. Overexcavation and recompaction is expected to be the most efficient method to facilitate the site redevelopment. All fill at the site, i.e., the reclamation backfill within the mining pit as well as any fill placed in association with the plant operations of the site, should be removed and replaced as compacted engineered fill. In general, earth materials excavated from the site may be used as fill provided they are free of deleterious materials and rocks greater than 12 inches in maximum dimension. *Within the* upper *5 feet of building pads, the fill material should not contain rocks greater than 3 inches in maximum dimension.* Rock size criteria for fill materials to be placed beneath drive aisle and parking area undercut sections or within influence of future underground utilities should be evaluated with respect to requirements of the appropriate jurisdiction to avoid costly screening and/or importing of future trench backfill materials. Details regarding handling and placement of oversize materials should be included in a future geotechnical design report.

Fill materials should be placed in lifts no greater than approximately 8 inches in loose thickness. The fills should contain sufficient finer granular materials to eliminate nesting of rock fragments as recommended by the geotechnical consultant during grading. Each lift should be watered or air dried as necessary to achieve a uniform moisture content of 100 to 125 percent of optimum, and then recompacted to a minimum relative compaction of 90 percent, or 93 percent for fill placed deeper than 40 feet below the finished grade. Each lift should be treated in a similar manner. Lifts should be maintained relatively level and should not exceed a gradient of 20(H):1(V). When placing fill on ground sloping steeper than 5(H):1(V), vertical benches should be excavated into the adjacent slope.

It should be noted that much of the eastern half of the site is underlain by shallow fills and the overexcavation and recompaction operations will be typical and routine. The overexcavation of the reclamation backfill within the deep mining pit excavation will require development of an efficient grading pattern to minimize double- or triple-handling of the material.

7.4. Fill slopes

Fill slopes should be constructed with a keyway having a minimum width of 15 feet and a minimum embedment of 5 feet into competent earth materials as determined by the Geotechnical Engineer. In order to adequately compact the face of fill slopes, it is recommended that the fill slopes be overbuilt by 1 to 2 feet and trimmed back to the final configuration. If this method is not practical, the contractor should be prepared to compact the outer slope edge and face to meet the compaction requirements. In addition, it is recommended that the outer 5 feet of the slope face be constructed with moderately cohesive soils having a fines content of at least 30 percent in order to minimize future erosion and maintenance.

7.5. Cut Slopes

All cut slopes should be inspected at intervals not exceeding 10 feet during grading by the Geotechnical Engineer to evaluate the competency of the slope and identify any potential hazard that will require mitigation measures. Corrective measures should be made as the slope is being constructed.

7.6. Temporary Slope and Trench Excavations

All slope and trench excavations should be performed in accordance with CalOSHA regulations. The onsite surficial soils may be considered a Type C soil, as defined the current CalOSHA soil classification. Due to the presence of potential running sand, temporary excavations deeper than 4 feet should be specifically evaluated by a Competent Person as defined by CalOSHA, or by the Geotechnical Engineer.

Unsurcharged excavations: Temporary excavations may be cut vertically up to a height of 4 feet provided that no adverse geologic conditions or surcharging of the excavations are present. Temporary excavations that are greater than 4 feet but less than 20 feet in height should be laid back at a maximum gradient of 1.5(H):1(V), provided no running sands are encountered. If running sands or temporary excavations greater than 20 feet in depth are required, the Geotechnical Engineer should provide specific recommendations based on proposed work and site conditions. All temporary excavations should conform to the requirements of CalOSHA.

Surcharge setback recommendations: Stockpiled (excavated) materials should be placed no closer to the edge of a trench excavation than a distance defined by a line drawn upward from the bottom of the trench at an inclination of 1(H):1(V), but no closer than 4 feet. A greater setback may be necessary when considering heavy vehicles, such as concrete trucks and heavy grading equipment. Tetra Tech should be advised of such heavy vehicle loadings so that specific setback requirements can be established for the used equipment. Alternatively, a shoring system may be designed to allow reduction in the setback distance.

7.7. Seismic Design Parameters

The seismic design coefficients provided below in Table 5 below are based on Chapter 16 Section 1613 of the 2022 California Building Code and obtained from the Structural Engineers Association of California (SEAOC) and the Office of Statewide Health Planning and Development (OSHPD) website application (https://www.seaoc.org/page/seismicdesignmaptool). According to Section 11.4.8 of ASCE 7-16, a site-specific ground motion hazard analysis shall be performed if structures on Site Class D have an S_1 greater than or equal to 0.2 unless the seismic coefficient *Cs* determined by Equation (12.8-2) is used for values of $T <= 1.5\ T_s$ and taken as equal to 1.5 times the value computed in accordance with either Equation (12.8-3) for $T_L >= T > 1.5\ T_s$ or Equation (12.8-4) for $T > T_L$. Tetra Tech can provide site-specific ground motion hazard analysis under a separate scope and budget.

Table 5
Site Class and 2022 California Building Code Site Coefficients
Site coordinates N34.139135º and W-117.361122º

Site Class Table 20.3-1 ASCE 7-16		D
Coefficients for the Maximum Considered Earthquake, MCE_R, for Site Class B	Short Period (0.2 seconds), S_S	2.408*
	1 Second Period, S_1	0.965*
Coefficients for the Maximum Considered Earthquake, MCE_R (Site Modified)	Short Period (0.2 seconds), S_{MS}	2.408*
	1 Second Period, S_{M1}	1.641**
Coefficients for the Design Earthquake	Short Period (0.2 seconds), S_{DS}	1.605*
	1 Second Period, S_{D1}	1.094**
Design PGA (risk-targeted maximum rotated direction)		0.642g*
Site Modified Peak Ground Acceleration PGA_M (geometric mean)		1.115g*

* Values obtained from Structural Engineers Association of California (SEAOC) and the Office of Statewide Health Planning and Development (OSHPD) website application, https://www.seaoc.org/page/seismicdesignmaptool based on ASCE7-16 and 2018 International Building Code.
** See requirements for site-specific ground motions in Section 11.4.8 of ASCE 7-16.

7.8. Building Setback Zones

As discussed earlier in Section 4.2 of this report, a detailed fault investigation was completed for the site by Tetra Tech (2022). Based on the findings of this investigation, structures intended for human occupancy should not be permitted over the traces of the San Jacinto fault splays identified within the westerly reaches of the subject site. Additionally, until such time that future site-specific geologic studies are completed to adequately evaluate the potential for surface fault rupture within the eastern reaches of the subject site, it is assumed that Holocene-active faulting could exist beyond the limits of this study. Therefore, temporary building setbacks should be established for portions of the subject site located beyond the easterly coverage limits of the project. Recommended building setback zones have been established as shown in red hatching on Plate 1.

It should be noted that the recommended building setback zones described above and shown on Plate 1 are based on the ground surface elevations present at the time of our fault investigation in 2022. Should significant grading changes occur during future phases of site development, these recommended building setback zones may require modification based on the depths of proposed cuts and fills.

7.9. Foundations for Buildings

As discussed in Section 7.3, the existing reclamation backfill of the mining pit is unsuitable for structural support and should be overexcavated and recompacted. This effort will effectively create standard foundation conditions and conventional footing foundation systems, i.e., shallow spread and continuous footings, may be adopted. The minimum width and embedment depth of footings should follow the minimum requirements per 2022 California Building Code.

Footing foundations and concrete slabs on grade should be designed and reinforced in accordance with the recommendations of the Structural Engineer and should conform to the requirements of the 2022 California Building Code.

Specific geotechnical design parameters for footing foundations will be provided in a geotechnical design report prior to permitting for rough grading.

7.10. Infiltration and BMP Design Considerations

On-site infiltration rates of storm water and runoff was assessed by Tetra Tech and reported under separate cover. Based on the finding of this investigation, onsite infiltration is considered feasible provided areas of the site that are underlain by more than about 10 feet of artificial fill are avoided for locating future BMP improvements and the bottom of future BMP's are founded entirely within native alluvial soils.

Specific details regarding test procedures, test results and recommendations for design and construction of future BMP's are provided in Tetra Tech report dated August 11, 2022. Future plans and construction documents for storm water BMP submittals should be reviewed by the Geotechnical Engineer to confirm compliance with this report.

7.11. Drainage Control

The intent of this section is to provide general information regarding the control of surface water. The control of surface water is essential to the satisfactory performance of the building construction and site improvements. Surface water should be controlled so that conditions of uniform moisture are maintained beneath and adjacent to the structure, even during periods of heavy rainfall. The following recommendations should be considered as minimal.

- Ponding and areas of low flow gradients should be avoided.

- Paved surfaces within 10 feet from the building foundation should be provided with a gradient of at least 2 percent sloping away from improvements.

- Bare soil, e.g., planters, within 10 feet of the structure should be sloped away from the improvement at a gradient of 5 percent.

- Positive drainage devices, such as graded swales, paved ditches, and/or catch basins should be employed to accumulate and convey water to appropriate discharge points.

- Concrete walks and flatwork should not obstruct the free flow of surface water.

- Area drains should be recessed below grade to allow free flow of water into the basin.

- Enclosed raised planters should be sealed at the bottom and provided with an ample flow gradient to a drainage device. Recessed planters and landscaped areas should be provided with area inlet and subsurface drainpipes.

- To the extent practicable, planters should not be located adjacent to structures. If planters are to be located adjacent to a structure, the planters should be positively sealed, should incorporate a subdrain, and should be provided with free discharge capacity to a drainage device.

- Planting areas at grade should be provided with positive drainage. Wherever possible, the grade of exposed soil areas should be established above adjacent paved grades. Drainage devices and curbing should be provided to prevent runoff from adjacent pavement or walks into planted areas.

- Gutter and downspout systems should be provided to capture discharge from roof areas. The accumulated roof water should be conveyed to an off-site disposal area by a pipe or concrete swale system.

- Landscape watering should be performed judiciously to preclude either soaking or desiccation of soils. The watering should be such that it just sustains plant growth without excessive infiltration. Sprinkler systems should be checked periodically to detect leakage and irrigation efforts should be reduced or halted during the rainy season.

8. LIMITATIONS

The conclusions, recommendations and opinions expressed in this report are based on Tetra Tech's review of background documents and on information obtained from field explorations and associated laboratory testing. It should be noted that this study did not evaluate the possible presence of hazardous materials on any portion of the site.

This report presents key geotechnical issues that could impact the proposed site development. The information presented herein is intended only for preliminary planning purposes and is not intended to satisfy the requirements of a site-specific geotechnical investigation required for foundation design and permitting. As such, additional geotechnical design-level reports will be warranted for the specific site development plan.

Due to the limited nature of the field explorations, conditions not observed and described in this report may be present on the site. Uncertainties relative to subsurface conditions can be reduced through additional subsurface exploration. Additional subsurface evaluation and laboratory testing can be performed upon request. It should be understood that conditions different from those anticipated in this report may be encountered during grading operations, for example, the extent of unsuitable soil and the associated additional effort required to mitigate them.

Site conditions can change with time as a result of natural processes or the activities of man at the subject site or at nearby sites. Changes to the applicable laws, regulations, codes, and standards of practice may occur as a result of government action or the broadening of knowledge. The findings of this report may, therefore, be invalidated over time, in part or in whole, by changes over which Tetra Tech has no control.

Tetra Tech's recommendations for this site are, to a high degree, dependent upon appropriate quality control of subgrade preparation, fill placement, and foundation construction. Accordingly, the recommendations are made contingent upon the opportunity for Tetra Tech to observe grading operations and foundation excavations for the proposed construction. If parties other than Tetra Tech are engaged to provide such services, such parties are automatically assuming complete responsibility as the Geotechnical Engineer of Record for the project and are deemed concurring with the recommendations in this report or are obligated to provide alternative recommendations.

This document is intended to be used only in its entirety. No portion of the document, by itself, is designed to completely represent any aspect of the project described herein. Tetra Tech should be contacted if the reader requires additional information or has questions regarding the content, interpretations presented, or completeness of this document. Reliance by others on the data presented herein or for purposes other than those stated in the text is authorized only if so permitted in writing by Tetra Tech. It should be understood that such an authorization may incur additional expenses and charges.

Tetra Tech has endeavored to perform its evaluation using the degree of care and skill ordinarily exercised under similar circumstances by reputable geotechnical professionals with experience in this area in similar soil conditions. No other warranty, either expressed or implied, is made as to the conclusions and recommendations contained in this report.

9. SELECTED REFERENCES

California Department of Conservation, Division of Mines and Geology, 2008, Guidelines for Evaluation and Mitigation of Seismic Hazards in California: Special Publication 117A.

California Department of Conservation, Division of Mines and Geology, 1974, State of California, Special Studies Zones, San Bernardino North Quadrangle, Revised Official Map, effective January 1, 1974, Scale 1:24,000.

Jennings, C. W., and Bryant, W. A., 2010, Fault Activity Map of California, California Geological Survey, Data Map No. 6, Map scale 1:750,000.

Tetra Tech, 2019, Geotechnical Data and Assessment Report, Vulcan Pit Redevelopment, Rialto, California, dated November 25, 2019.

Tetra Tech, 2022a, Fault Investigation Report, Vulcan Aggregate Pit Redevelopment Project, 20080 Highland Avenue, Rialto, California, dated February 28, 2022.

Tetra Tech, 2022b, Percolation Investigation, Pepper 210 Commerce Center, 20080 Highland Avenue, County of San Bernardino, California, dated August 11, 2022.

Figures



FIGURE 1

TETRA TECH
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PEPPER 210 COMMERCE CENTER - RIALTO, CA

SITE LOCATION MAP

JOB NO.	GEN 19-22E
DATE	SEPT 2023
DRAWN BY	SCM
CHECKED BY	PMK

EXPLANATION

- P-7 — Percolation Test Location (Tetra Tech, 2022)
- Surveyed trench location (Tetratech, 2021)
- Geophysical Line (Tetra Tech, 2020)
- TP-1 — Test Pit Location (Tetra Tech, 2020)
- B-8 — Hollow Stem Boring Location (Tetra Tech, 2019)
- Trench Location (ECI, 2013)
- Property Line
- Geologic Contact
- Fault (queried where uncertain)

Geologic Units

- af — Artificial Fill
- Qaly — Younger Alluvium
- Qoal — Older Alluvium

N

0 150 300 450 600 ft

1 inch = 200 feet

TETRA TECH 21700 Copley Drive, Suite 200, Diamond Bar, CA 91765 TEL 909.860.7777 www.tetratech.com	SITE GEOLOGY AND EXPLORATION LOCATION MAP	
	Site Location: Rialto, CA	
Project No.: GEN 19-22E	Date: September 2023	Figure 2

References:
Satellite image- ArcGIS, 2021
Topography- Historic Bottom Topo, Vulcan Materials Company, 4/27/2017.

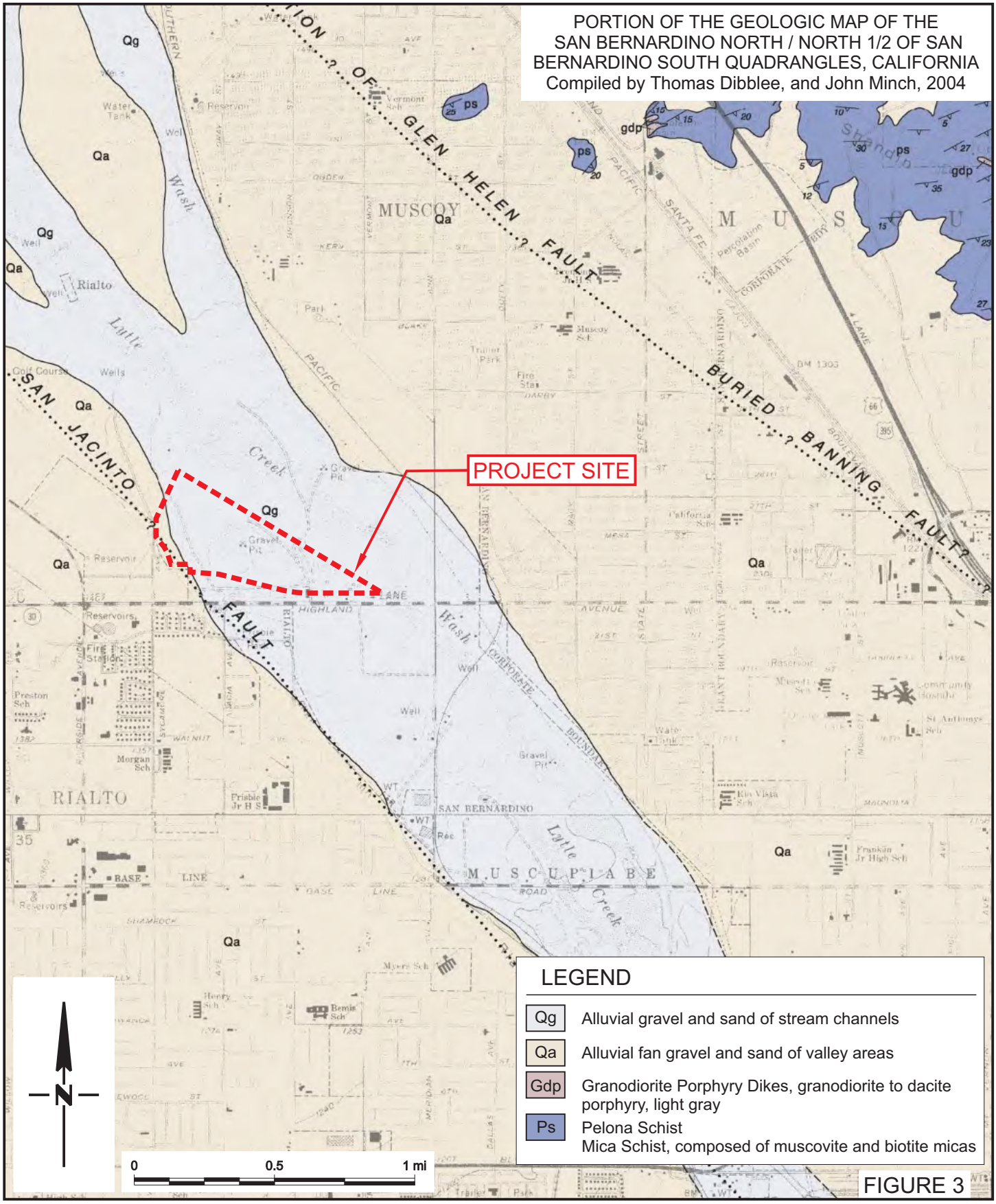


FIGURE 3

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PEPPER 210 COMMERCE CENTER - RIALTO, CA

REGIONAL GEOLOGIC MAP

JOB NO.	GEN 19-22E
DATE	SEPT 2023
DRAWN BY	TAS/SCM
CHECKED BY	PMK

EARTHQUAKE EPICENTERS

M 5.0 to 5.9

M 6.0 to 6.9

M 7.0 to 7.9

HISTORIC EARTHQUAKE EVENTS

1)	1812 Wrightwood	M7
2)	1827 Ventura County	M6
3)	1855 Los Angeles	M6?
4)	1858 San Bernardino	M6?
5)	1880 San Bernardino	M6
6)	1889 Monrovia	M5.5
7)	1893 San Fernando Valley	M5.9
8)	1894 n/o Pomona	M6
9)	1899 Cajon Pass	M6.5
10)	1899 San Jacinto	M6.4
11)	1907 San Bernardino	M6
12)	1910 Elsinore	M6
13)	1918 San Jacinto-Hemet	M6.8
14)	1920 Inglewood	M4.9
15)	1923 Loma Linda	M6
16)	1930 Santa Monica Bay	M5.2
17)	1933 Long Beach	M6.4
18)	1941 Gardena	M4.8
19)	1971 San Fernando	M6.7
20)	1973 Pt. Mugu	M5.9
21)	1979 Malibu	M5.2
22)	1981 Pt. Mugu	M6.0
23)	1986 N Palm Sprins	M6.2
24)	1987 Whittier-Narrows	M5.9
25)	1988 Pasadena	M5.0
26)	1989 Malibu	M5.0
27)	1990 Pomona	M5.3
28)	1991 Sierra Madre	M5.8
29)	1994 Northridge	M6.7
30)	1992 Landers	M7.3
31)	1992 Big Bear	M6.2
32)	2005 Chino Hills	M5.2

Map Reference: Excerpt of Jennings, C.W., and Bryant, W.A., 2010, Fault activity map of California; California Geologic Survey, Date Map No. 6, map scale ~ 1:750,00

Used in permission from California Geologic Survey.

Earthquake epicenters from SP 116

PROJECT SITE

EXPLANATION

Geologic Time Scale			Years Before Present (Approx.)	Fault Symbol	Recency of Movement	DESCRIPTION: ON LAND	DESCRIPTION: OFFSHORE
Quaternary	Late Quaternary	Historic				Displacement during historic time (e.g. San Andreas fault 1096). Includes areeas of known fault creep.	
			200				
		Holocene				Displacement during Holocene time.	Faults offsets sea floor sediments or strata of Holocene age.
			11,700				
		Pleistocene				Fault showing evidence of displacement during late Quaternary time.	Faults cuts strata of LatePleistocene age.
	Early Quaternary		700,000			Undivided Quaternary faults - most faults in this category show evidence of displacement during the last 1,600,00 years; possible exceptions are faults which displace rocks of undifferentiated Plio-Pleistocene age.	Faults cuts strata of Quaternary age.
			1,600,000				
Pre-Quaternary						Faults without recognized Quaternary displacement or showing evidence of no displacement during Quaternary time. Not necessarily inactive.	Faults cuts strata of Pliocene or older age.

MAP SYMBOLS

- Triangle - termination portion data. Square - fault creep slippage. Hachure - linear extent of fault creep. (other symbols - see below)
- Approximate located trace
- Location uncertain
- Bar and ball on dowthrown side
- Arrows along fault indicate relative or apparent direction of lateral movement.
- Direction of fault dip
- Low angle fault (barbs on upper plate)
- 171 Numbers refer to annotations listed in explanatory text of map.
- Subject Site Location

0 5 10 mi

FIGURE 4

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PEPPER 210 COMMERCE CENTER - RIALTO, CA

REGIONAL FAULTS AND SEISMICITY MAP

JOB NO.	GEN 19-22E
DATE	SEPT 2023
DRAWN BY	SCM
CHECKED BY	PMK

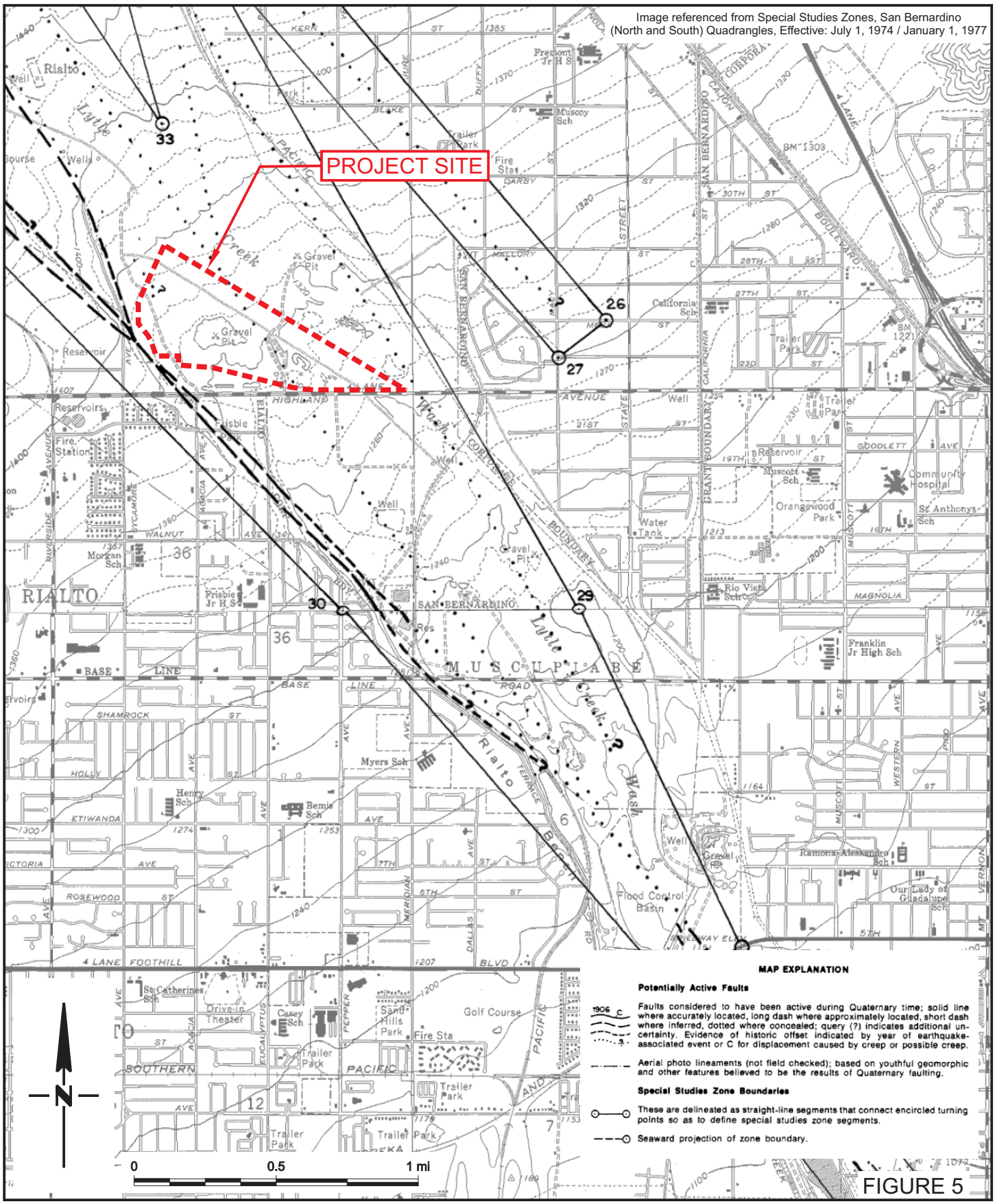


FIGURE 5

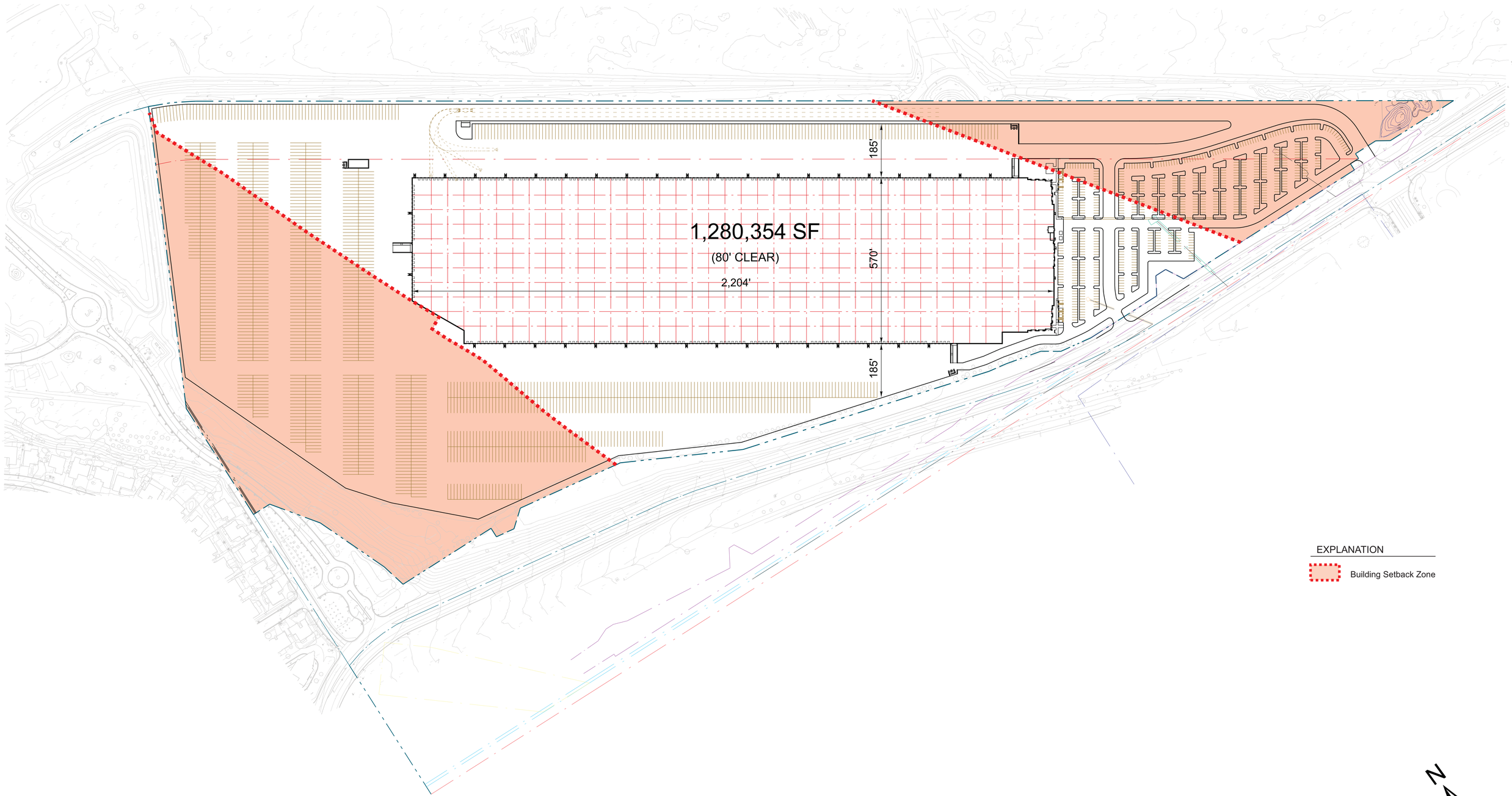
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PEPPER 210 COMMERCE CENTER - RIALTO, CA

EARTHQUAKE FAULT ZONE MAP

JOB NO.	GEN 19-22E
DATE	SEPT 2023
DRAWN BY	SCM
CHECKED BY	PMK

Plates



EXPLANATION

Building Setback Zone

0 150 300 ft

1 inch = 150 feet

N

References:
Base image- RGA, Pepper 210 Commerce Center, Sheet A1-1P, 2023.

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RECOMMENDED BUILDING SETBACK ZONES

Site Location: Rialto, CA

Project No.: GEN 19-22E | Date: September 2023 | Plate 1

Appendix A

Logs of Exploratory Borings

(Tetra Tech, 2019)

Project: **Vulcan Gravel Pit Redevelopment**
Project Location: **Rialto, CA**
Project Number: **GEN 19-22E**

Key to Log of Boring

Sheet 1 of 1

1 Elevation (feet)	2 Depth (feet)	3 Sample Type	4 Sample Number	5 Sampling Resistance, blows/ft	6 USCS Symbol	7 Graphic Log	8 MATERIAL DESCRIPTION	9 Water Content, %	10 Dry Unit Weight, pcf	11 REMARKS AND OTHER TESTS

COLUMN DESCRIPTIONS

1 Elevation (feet): Elevation (MSL, feet).
2 Depth (feet): Depth in feet below the ground surface.
3 Sample Type: Type of soil sample collected at the depth interval shown.
4 Sample Number: Sample identification number.
5 Sampling Resistance, blows/ft: Number of blows to advance driven sampler one foot (or distance shown) beyond seating interval using the hammer identified on the boring log.
6 USCS Symbol: USCS symbol of the subsurface material.
7 Graphic Log: Graphic depiction of the subsurface material encountered.
8 MATERIAL DESCRIPTION: Description of material encountered. May include consistency, moisture, color, and other descriptive text.
9 Water Content, %: Water content of the soil sample, expressed as percentage of dry weight of sample.
10 Dry Unit Weight, pcf: Dry weight per unit volume of soil sample measured in laboratory, in pounds per cubic foot.
11 REMARKS AND OTHER TESTS: Comments and observations regarding drilling or sampling made by driller or field personnel.

FIELD AND LABORATORY TEST ABBREVIATIONS

MATERIAL GRAPHIC SYMBOLS

- Lean CLAY, CLAY w/SAND, SANDY CLAY (CL)
- SILT, SILT w/SAND, SANDY SILT (ML)
- Silty SAND (SM)
- Poorly graded SAND (SP)
- Poorly graded SAND with Silt (SP-SM)

TYPICAL SAMPLER GRAPHIC SYMBOLS

- Auger sampler
- Bulk Sample
- 3-inch-OD California w/ brass rings
- CME Sampler
- Grab Sample
- 2.5-inch-OD Modified California w/ brass liners
- Pitcher Sample
- 2-inch-OD unlined split spoon (SPT)
- Shelby Tube (Thin-walled, fixed head)

OTHER GRAPHIC SYMBOLS

- Water level (at time of drilling, ATD)
- Water level (after waiting)
- Minor change in material properties within a stratum
- Inferred/gradational contact between strata
- Queried contact between strata

GENERAL NOTES

L:\02 - PROJECTS\2019 Projects\GEN 19-22E (4697-0001) Vulcan Gravel Pit Redevelopment - Rialto\03 Field & Lab\Boring logs 1-8.bg4[55 w 2 lab.tpl]

Figure A-1

Project: **Vulcan Gravel Pit Redevelopment** Project Location: **Rialto, CA** Project Number: **GEN 19-22E**	Log of Boring B-1 **Sheet 1 of 1**

Date(s) Drilled **10/15/2019**	Logged By **SCM**	Checked By **YL**
Drilling Method **Hollow-Stem Auger (HSA)**	Drill Bit Size/Type **8-inch**	Total Depth of Borehole **51.5 feet**
Drill Rig Type **Mobile B-61**	Drilling Contractor **Cal Pac Drilling**	Approximate Surface Elevation **1,350' (2019 topography)**
Groundwater Level and Date Measured **Not encountered**	Sampling Method(s) **Modified California, SPT**	Hammer Data **140 lb Auto trip hammer, 30-inch drop**
Borehole Backfill **Tamped Cuttings**	Location **Mining Pit; Latitude: 34.14086°, Longitude: -117.36425°**	

Elevation (feet)	Depth (feet)	Sample Type	Sample Number	Sampling Resistance, blows/ft	USCS Symbol	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Dry Unit Weight, pcf	REMARKS AND OTHER TESTS
1350	0				SP		[FILL] Poorly-graded SAND, medium dense, brown (10YR 4/3), damp, medium to coarse grained, trace gravel			
1345	5		R-1	12 21 24				4.1	123	
1340	10		SPT-2	3 3 4			@10'- loose	5.6		
1335	15		R-3	5 5 7			@15'- as above	6.4	97	G/S/F = 13/78/9%
1330	20		SPT-4	4 11 10			@20'- color change to dark gray (10YR 4/1), moist	6.2		
1325	25		R-5	4 6 9			@25'- as above	6.5	111	
					CL		Lean CLAY, firm, olive brown (2.5Y 4/3), damp, micaceous, trace silt and gravel			
1320	30		SPT-6	2 3 4				30.5		
1315	35		R-7	15 15 10			@36'- Sandy Lean CLAY, very stiff, trace gravel	28.4	94	
					SP		[NATIVE] Poorly-graded SAND with Gravel, dense, olive brown (2.5Y 4/4), damp, micaceous, medium to coarse grained, fine gravel			
1310	40		SPT-8	17 20 26				19.8		
1305	45		R-9	9 27 50-6"			@45'- very dense	2.7	118	DS
1300	50		SPT-10	18 25 20			@45'- very dense, coarse gravel	4.5		
1295	55						1) Total depth - 51.5 feet. 2) Groundwater not encountered. 3) Boring backfilled with tamped cuttings. 4) Boring location from commercial grade GPS.			

L:\02 - PROJECTS\2019 Projects\GEN 19-22E (4697-0001) Vulcan Gravel Pit Redevelopment - Rialto\03 Field & Lab\Boring logs 1-8.bg4[55 w 2 lab.tpl]

Project: **Vulcan Gravel Pit Redevelopment**
Project Location: **Rialto, CA**
Project Number: **GEN 19-22E**

Log of Boring B-2
Sheet 1 of 1

Date(s) Drilled **10/15/2019**	Logged By **SCM**	Checked By **YL**
Drilling Method **Hollow-Stem Auger (HSA)**	Drill Bit Size/Type **8-inch**	Total Depth of Borehole **11.5 feet**
Drill Rig Type **Mobile B-61**	Drilling Contractor **Cal Pac Drilling**	Approximate Surface Elevation **1,350' (2019 topography)**
Groundwater Level and Date Measured **Not encountered**	Sampling Method(s) **Modified California, SPT**	Hammer Data **140 lb Auto trip hammer, 30-inch drop**
Borehole Backfill **Tamped Cuttings**	Location **Northwest boundary; Latitude: 34.14169°, Longitude: -117.36255°**	

Elevation (feet)	Depth (feet)	Sample Type	Sample Number	Sampling Resistance, blows/ft	USCS Symbol	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Dry Unit Weight, pcf	REMARKS AND OTHER TESTS
1350	0				SP		[FILL]			
					SP		Poorly-graded SAND with Gravel, light brownish gray (10YR 6/2), damp, medium grained			
							[NATIVE]			
1345	5		SPT-1	5 12 28			Poorly-graded SAND with Gravel, dense, olive brown (2.5Y 4/3), damp, coarse grained sand, coarse gravel	1.1		
1340	10		R-2	17 20 27				1.2	119	DS
							1) Total depth - 11.5 feet.			
							2) Groundwater not encountered.			
1335	15						3) Boring backfilled with tamped cuttings.			
							4) Boring location from commercial grade GPS.			
1330	20									
1325	25									
1320	30									
1315	35									
1310	40									
1305	45									
1300	50									
1295	55									

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Project: **Vulcan Gravel Pit Redevelopment** Project Location: **Rialto, CA** Project Number: **GEN 19-22E**	Log of Boring B-3 **Sheet 1 of 1**

Date(s) Drilled **10/15/2019**	Logged By **SCM**	Checked By **YL**
Drilling Method **Hollow-Stem Auger (HSA)**	Drill Bit Size/Type **8-inch**	Total Depth of Borehole **40.9 feet**
Drill Rig Type **Mobile B-61**	Drilling Contractor **Cal Pac Drilling**	Approximate Surface Elevation **1,345' (2019 topography)**
Groundwater Level and Date Measured **Not encountered**	Sampling Method(s) **Modified California, SPT**	Hammer Data **140 lb Auto trip hammer, 30-inch drop**
Borehole Backfill **Tamped Cuttings**	Location **Southwest corner; Latitude: 34.13876°, Longitude: -117.36371°**	

Elevation (feet)	Depth (feet)	Sample Type	Sample Number	Sampling Resistance, blows/ft	USCS Symbol	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Dry Unit Weight, pcf	REMARKS AND OTHER TESTS
1345	0				SP		[FILL]			
					CL		Poorly-graded SAND with Gravel, light brownish gray (10YR 6/2), damp, medium grained			
							Lean CLAY, stiff, dark grayish brown (10YR 4/2), damp, micaceous, trace silt			
1340	5		SPT-1	3 4 5				24.5		
1335	10		R-2	6 14 14			@10'- as above, interlayered with Poorly-graded SAND, trace fine gravel	9.8	118	G/S/F = 12/60/28%
1330	15		SPT-3	3 4 5			@15'- as above	20.6		
					ML		SILT, stiff, dark grayish brown (10YR 4/2), damp, micaceous, trace clay			
1325	20		R-4	4 6 10				23.5	101	G/S/F = 0/17/83%
					CL		Lean CLAY, firm, dark grayish brown (10YR 4/2), damp, micaceous, trace silt and gravel			
1320	25		SPT-5	2 2 4				31.0		
1315	30		R-6	4 10 16			@30'- very stiff	22.7	102	G/S/F = 4/25/71%
					SP		[NATIVE]			
1310	35		SPT-7	50-6"			Poorly-graded SAND with Gravel, very dense, olive brown (2.5Y 4/3), damp, micaceous, coarse grained, fine gravel	3.3		
1305	40		R-8	18 50-5"				2.3	131	
							1) Total depth - 40.9 feet. 2) Groundwater not encountered. 3) Boring backfilled with tamped cuttings. 4) Boring location from commercial grade GPS.			
1300	45									
1295	50									
1290	55									

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Project: **Vulcan Gravel Pit Redevelopment** Project Location: **Rialto, CA** Project Number: **GEN 19-22E**	Log of Boring B-4 **Sheet 1 of 1**

Date(s) Drilled **10/16/2019**	Logged By **SCM**	Checked By **YL**
Drilling Method **Hollow-Stem Auger (HSA)**	Drill Bit Size/Type **8-inch**	Total Depth of Borehole **15.9 feet**
Drill Rig Type **Mobile B-61**	Drilling Contractor **Cal Pac Drilling**	Approximate Surface Elevation **1,305' (2019 topography)**
Groundwater Level and Date Measured **Not encountered**	Sampling Method(s) **Modified California, SPT**	Hammer Data **140 lb Auto trip hammer, 30-inch drop**
Borehole Backfill **Tamped Cuttings**	Location **Center of mining pit; Latitude: 34.13993°, Longitude: -117.36251°**	

Elevation (feet)	Depth (feet)	Sample Type	Sample Number	Sampling Resistance, blows/ft	USCS Symbol	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Dry Unit Weight, pcf	REMARKS AND OTHER TESTS
1305	0				ML		[FILL] Sandy SILT, very stiff, dark yellowish brown (10YR 4/4), damp, micaceous, trace gravel			
1300	5		R-1	9 15 25				14.4	119	
					SP		[NATIVE] Poorly-graded SAND with Gravel, very dense, olive brown (2.5Y 4/3), damp, micaceous, coarse grained, coarse gravel			
1295	10		SPT-2	16 24 29				3.3		
1290	15		R-3	23 50-5"				3.9	110	DS
							1) Total depth - 15.9 feet. 2) Groundwater not encountered. 3) Boring backfilled with tamped cuttings. 4) Boring location from commercial grade GPS.			
1285	20									
1280	25									
1275	30									
1270	35									
1265	40									
1260	45									
1255	50									
1250	55									

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Project: **Vulcan Gravel Pit Redevelopment** Project Location: **Rialto, CA** Project Number: **GEN 19-22E**	Log of Boring B-5 **Sheet 1 of 1**

Date(s) Drilled **10/16/2019**	Logged By **SCM**	Checked By **YL**
Drilling Method **Hollow-Stem Auger (HSA)**	Drill Bit Size/Type **8-inch**	Total Depth of Borehole **16.5 feet**
Drill Rig Type **Mobile B-61**	Drilling Contractor **Cal Pac Drilling**	Approximate Surface Elevation **1,303' (2019 topography)**
Groundwater Level and Date Measured **Not encountered**	Sampling Method(s) **Modified California, SPT**	Hammer Data **140 lb Auto trip hammer, 30-inch drop**
Borehole Backfill **Tamped Cuttings**	Location **Center of mining pit; Latitude: 34.13898°, Longitude: -117.36177°**	

Elevation (feet)	Depth (feet)	Sample Type	Sample Number	Sampling Resistance, blows/ft	USCS Symbol	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Dry Unit Weight, pcf	REMARKS AND OTHER TESTS
1303	0				SM		[FILL] Silty SAND, very dense, dark yellowish brown (10YR 4/4), damp, micaceous, trace gravel @0-2'- concrete rubble			
1298	5		SPT-1	13 26 38				8.6		
					SP		[NATIVE] Poorly-graded SAND with Gravel, very dense, olive brown (2.5Y 4/3), damp, micaceous, coarse grained, coarse gravel			
1293	10		R-2	32 50-3"				5.3	108	CONSOL
1288	15		SPT-3	9 20 29			@15'- dense	3.7		
							1) Total depth - 16.5 feet. 2) Groundwater not encountered. 3) Boring backfilled with tamped cuttings. 4) Boring location from commercial grade GPS.			
1283	20									
1278	25									
1273	30									
1268	35									
1263	40									
1258	45									
1253	50									
1248	55									

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Project: **Vulcan Gravel Pit Redevelopment** Project Location: **Rialto, CA** Project Number: **GEN 19-22E**	Log of Boring B-6 **Sheet 1 of 1**

Date(s) Drilled **10/15/2019**	Logged By **SCM**	Checked By **YL**
Drilling Method **Hollow-Stem Auger (HSA)**	Drill Bit Size/Type **8-inch**	Total Depth of Borehole **15.9 feet**
Drill Rig Type **Mobile B-61**	Drilling Contractor **Cal Pac Drilling**	Approximate Surface Elevation **1,326' (2019 topography)**
Groundwater Level and Date Measured **Not encountered**	Sampling Method(s) **Modified California, SPT**	Hammer Data **140 lb Auto trip hammer, 30-inch drop**
Borehole Backfill **Tamped Cuttings**	Location **South-central boundary; Latitude: 34.13741°, Longitude: -117.36058°**	

Elevation (feet)	Depth (feet)	Sample Type	Sample Number	Sampling Resistance, blows/ft	USCS Symbol	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Dry Unit Weight, pcf	REMARKS AND OTHER TESTS
1326	0				SM		[FILL] Silty SAND to Poorly-graded SAND with Silt, brown (10YR 4/3), damp, trace gravel			
1321	5		R-1	14 50-5"	SP		[NATIVE] Poorly-graded SAND with Gravel, very dense, olive brown (2.5Y 4/3), damp, micaceous, coarse grained, coarse gravel	5.3	126	
1316	10		SPT-2	12 28 25				2.4		Poor sample recovery
1311	15		R-3	20 50-6"			@15'- dense 1) Total depth - 16.0 feet. 2) Groundwater not encountered. 3) Boring backfilled with tamped cuttings. 4) Boring location from commercial grade GPS.	3.1	111	CONSOL
1306	20									
1301	25									
1296	30									
1291	35									
1286	40									
1281	45									
1276	50									
1271	55									

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Project: **Vulcan Gravel Pit Redevelopment** Project Location: **Rialto, CA** Project Number: **GEN 19-22E**	Log of Boring B-7 **Sheet 1 of 1**

Date(s) Drilled **10/15/2019**	Logged By **SCM**	Checked By **YL**
Drilling Method **Hollow-Stem Auger (HSA)**	Drill Bit Size/Type **8-inch**	Total Depth of Borehole **16.5 feet**
Drill Rig Type **Mobile B-61**	Drilling Contractor **Cal Pac Drilling**	Approximate Surface Elevation **1,325' (2019 topography)**
Groundwater Level and Date Measured **Not encountered**	Sampling Method(s) **Modified California, SPT**	Hammer Data **140 lb Auto trip hammer, 30-inch drop**
Borehole Backfill **Tamped Cuttings**	Location **Central portion of the site; Latitude: 34.13891°, Longitude: -117.35941°**	

Elevation (feet)	Depth (feet)	Sample Type	Sample Number	Sampling Resistance, blows/ft	USCS Symbol	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Dry Unit Weight, pcf	REMARKS AND OTHER TESTS
1325	0				SP-SM		[FILL] Poorly-graded SAND with Silt, light brownish gray (10YR 6/2), damp, coarse grained			
1320	5		SPT-1	45 41 50-4"	SP		@2'- boulders [NATIVE] Poorly-graded SAND with Gravel, very dense, olive brown (2.5Y 4/3), damp, micaceous, coarse grained, coarse gravel	5.4		
1315	10		R-2	23 17 50-6"						Cobble in top of sample
1310	15		SPT-3	11 17 20			@15'- dense	8.0		
1305	20						1) Total depth - 16.5 feet. 2) Groundwater not encountered. 3) Boring backfilled with tamped cuttings. 4) Boring location from commercial grade GPS.			
1300	25									
1295	30									
1290	35									
1285	40									
1280	45									
1275	50									
1270	55									

L:\02 - PROJECTS\2019 Projects\GEN 19-22E (4697-0001) Vulcan Gravel Pit Redevelopment - Rialto\03 Field & Lab\Boring logs 1-8.bg4[55 w 2 lab.tpl]

Project: **Vulcan Gravel Pit Redevelopment** Project Location: **Rialto, CA** Project Number: **GEN 19-22E**	Log of Boring B-8 **Sheet 1 of 1**

Date(s) Drilled **10/15/2019**	Logged By **SCM**	Checked By **YL**
Drilling Method **Hollow-Stem Auger (HSA)**	Drill Bit Size/Type **8-inch**	Total Depth of Borehole **25.1 feet**
Drill Rig Type **Mobile B-61**	Drilling Contractor **Cal Pac Drilling**	Approximate Surface Elevation **1,320' (2019 topography)**
Groundwater Level and Date Measured **Not encountered**	Sampling Method(s) **Modified California, SPT**	Hammer Data **140 lb Auto trip hammer, 30-inch drop**
Borehole Backfill **Tamped Cuttings**	Location **Plant area (eastern portion of the site); Latitude: 34.13778°, Longitude: -117.35564°**	

Elevation (feet)	Depth (feet)	Sample Type	Sample Number	Sampling Resistance, blows/ft	USCS Symbol	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Dry Unit Weight, pcf	REMARKS AND OTHER TESTS
1320	0				SP		[FILL] Poorly-graded SAND with Gravel, light brownish gray (10YR 6/2), damp, medium grained			
1315	5		R-1	50-6"				2.8	112	
					ML		SILT, very stiff, grayish brown (2.5Y 5/2), damp, micaceous, trace fine sand			
1310	10		SPT-2	11 12 15				13.9		
1305	15		R-3	5 11 20				11.4	105	G/S/F = 0/72/28%
1300	20		SPT-4	3 5 8			@20'- stiff	17.9		
1295	25		R-5	50-1"			Rig chatter, possible Native contact			No sample recovery
							1) Total depth - 25.1 feet. 2) Drilling refusal at 25.1 feet. 3) Groundwater not encountered. 4) Boring backfilled with tamped cuttings. 5) Boring location from commercial grade GPS.			
1290	30									
1285	35									
1280	40									
1275	45									
1270	50									
1265	55									

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Appendix B

Results of Laboratory Testing

(Tetra Tech, 2019)

HUSHMAND ASSOCIATES, INC.
Geotechnical and Earthquake Engineers

DIRECT SHEAR TEST

ASTM D3080

HAI Pr No.: TRT-19-011

Client: Tetra Tech BAS, Inc.

Project Name: Vulcan Gravel Pit Redevelopment

Project Number: 197-4697-0001

Boring No.: B1

Sample No.: R9

Sample Type: Undisturbed Ring

Depth (ft): 45-46.5

Soil description: Gray, Poorly Garded Sand with Silt and Gravel (SP-SM)

Type of test: **Consolidated, Drained**

Tested by: KL

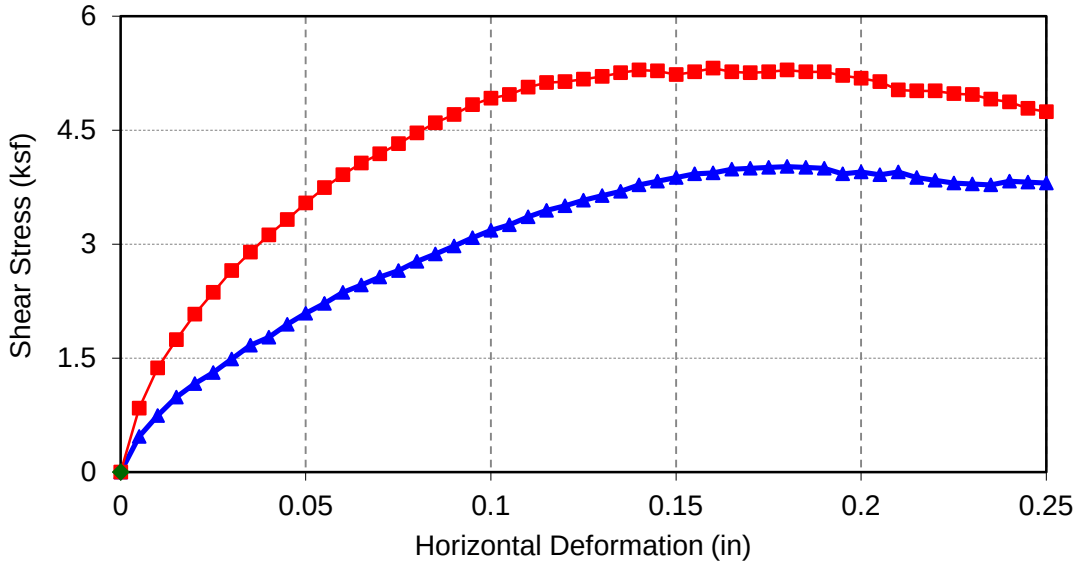
Checked by: MJ

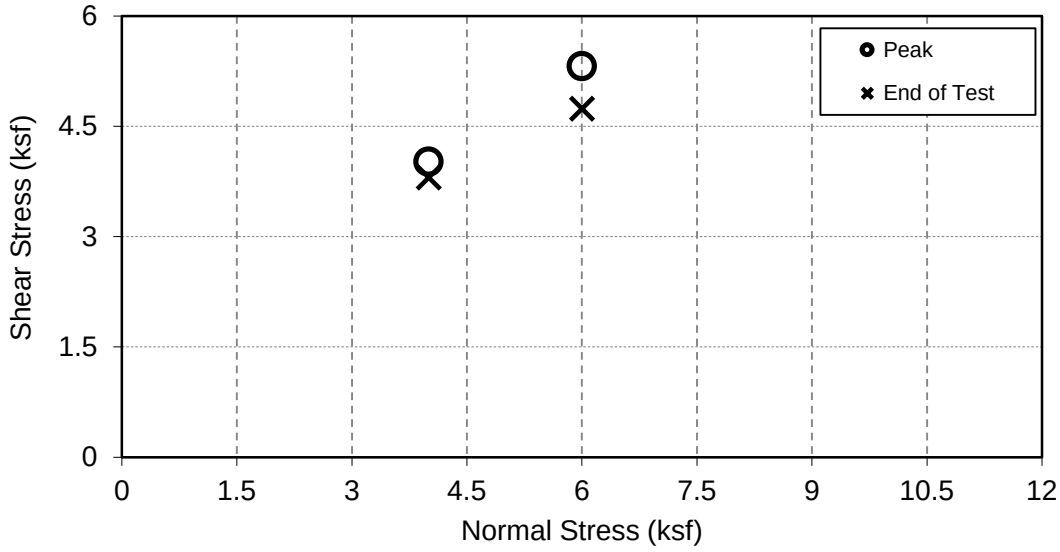
Date: 10/23/2019

Test No.	1	2
Symbol	▲	■
Normal Stress (ksf)	**4**	**6**
Deformation Rate (in/min)	**0.002**	**0.002**

Peak Shear Stress (ksf)	**O**	**4.02**	**5.32**
Shear Stress @ End of Test (ksf)	**X**	**3.80**	**4.74**

Initial Height of Sample (in)	1.000	1.000
Height of Sample before Shear (in)	0.9838	0.9802
Diameter of Sample (in)	2.416	2.416
Initial Moisture Content (%)	**2.7**	**2.7**
Final Moisture Content (%)	**11.3**	**12.8**
Dry Density (pcf)	**117.7**	**120.3**





HUSHMAND ASSOCIATES, INC.
Geotechnical and Earthquake Engineers

DIRECT SHEAR TEST

ASTM D3080

HAI Pr No.: TRT-19-011

Client: Tetra Tech BAS, Inc.

Project Name: Vulcan Gravel Pit Redevelopment

Project Number: 197-4697-0001

Boring No.: B2

Sample No.: R2

Sample Type: Undisturbed Ring

Depth (ft): 10-11.5

Soil description: Gray, Silty Gravel (GM)

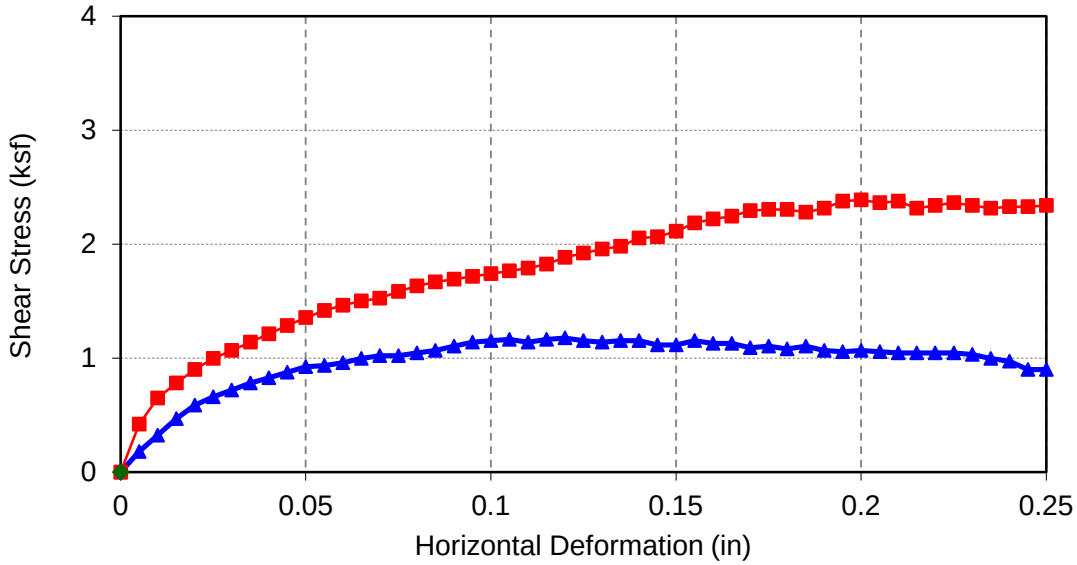
Tested by: KL

Checked by: MJ

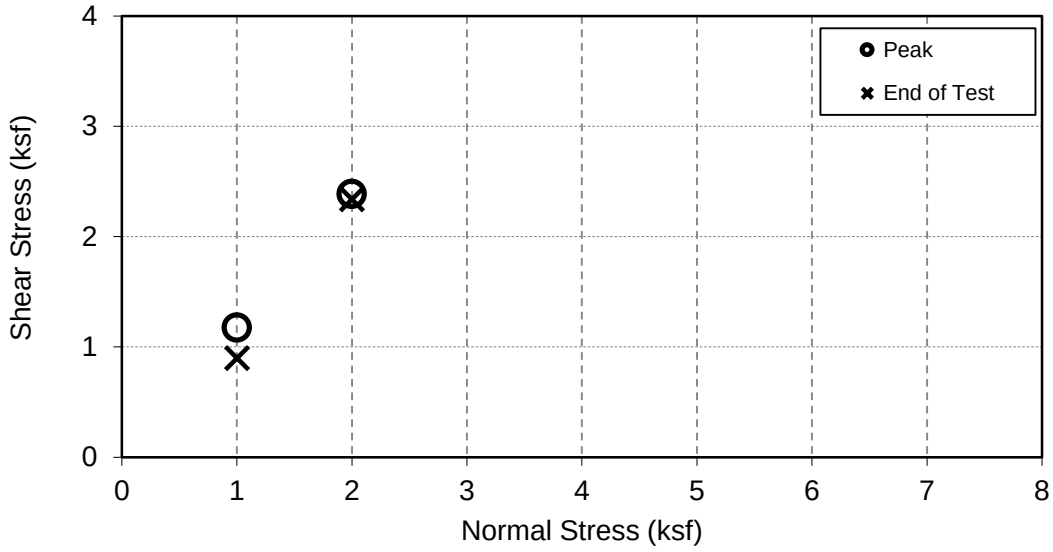
Date: 10/23/2019

Type of test: **Consolidated, Drained**

Test No.	1	2
Symbol	▲	■
Normal Stress (ksf)	**1**	**2**
Deformation Rate (in/min)	**0.002**	**0.002**



Peak Shear Stress (ksf)	**O**	**1.18**	**2.39**
Shear Stress @ End of Test (ksf)	**X**	**0.90**	**2.34**



Initial Height of Sample (in)	1.000	1.000
Height of Sample before Shear (in)	0.9961	0.9856
Diameter of Sample (in)	2.416	2.416
Initial Moisture Content (%)	**1.2**	**1.2**
Final Moisture Content (%)	**12.4**	**11.7**
Dry Density (pcf)	**119.2**	**121.1**

HUSHMAND ASSOCIATES, INC.
Geotechnical and Earthquake Engineers

DIRECT SHEAR TEST

ASTM D3080

HAI Pr No.: TRT-19-011

Client: Tetra Tech BAS, Inc.

Project Name: Vulcan Gravel Pit Redevelopment

Project Number: 197-4697-0001

Boring No.: B4

Sample No.: R3

Sample Type: Undisturbed Ring

Depth (ft): 15-15.9

Soil description: Gray, Silty Sand with Gravel (SM)

Tested by: KL

Checked by: MJ

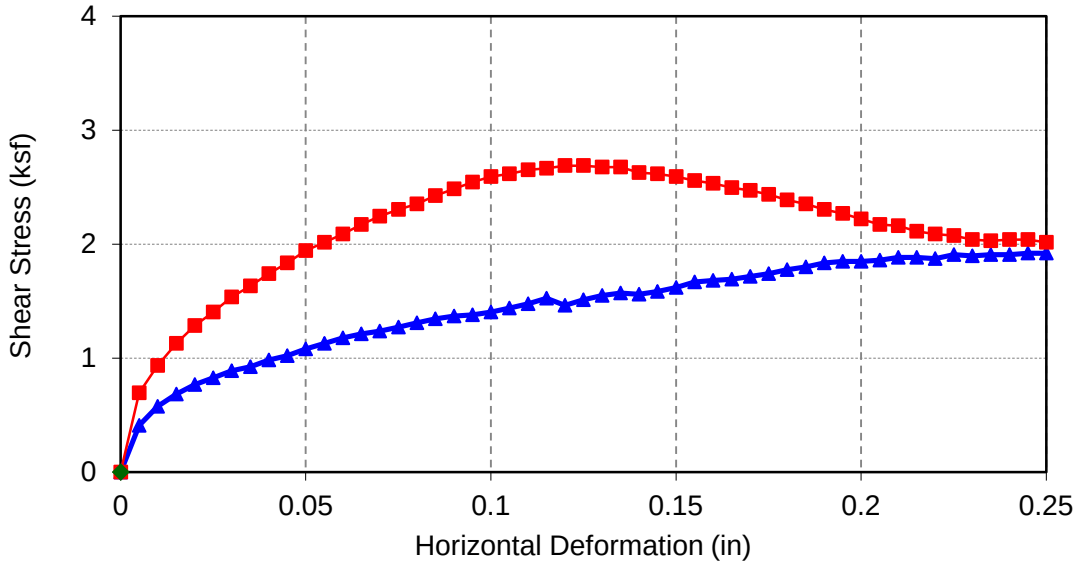
Date: 10/23/2019

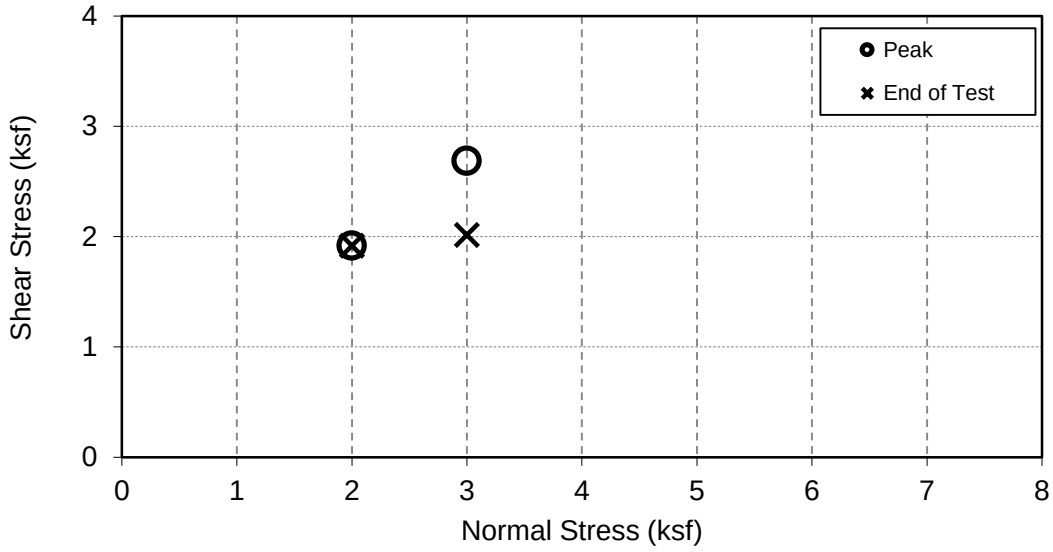
Type of test: **Consolidated, Drained**

Test No.	1	2
Symbol	▲	■
Normal Stress (ksf)	**2**	**3**
Deformation Rate (in/min)	**0.002**	**0.002**

Peak Shear Stress (ksf)	**O**	**1.92**	**2.69**
Shear Stress @ End of Test (ksf)	**X**	**1.92**	**2.02**

Initial Height of Sample (in)	1.000	1.000
Height of Sample before Shear (in)	0.9937	0.9827
Diameter of Sample (in)	2.416	2.416
Initial Moisture Content (%)	**3.9**	**3.9**
Final Moisture Content (%)	**13.7**	**15.2**
Dry Density (pcf)	**110.1**	**116.0**





CONSOLIDATION TEST

ASTM D2435

Client :	Tetra Tech BAS, Inc.	*HAI Project No.:*	TRT-19-011
Project Name:	Vulcan Gravel Pit Redevelopment	*Tested by:*	KL
Project Number:	197-4697-0001	*Checked by:*	MJ
Boring No.:	B5	*Date:*	10/23/19
Sample No.:	R2		
Type of Sample:	Undisturbed Ring		
Depth (ft):	10-10.8		
Soil Description:	Gray, Silty Gravel (GM)		

Initial Total Weight	Final Total Weight	Final Dry Weight
(g)	(g)	(g)
138.31	149.55	131.29

			Initial Conditions	Final Conditions
Height	H	(in)	1.014	0.919
Height of Solids	H_s	(in)	0.655	0.655
Height of Water	H_w	(in)	0.093	0.243
Height of Air	H_a	(in)	0.266	0.022
Dry Density		**(pcf)**	**107.5**	**129.1**
Water Content		**(%)**	**5.3**	**13.9**
Saturation		**(%)**	**26.0**	**91.8**

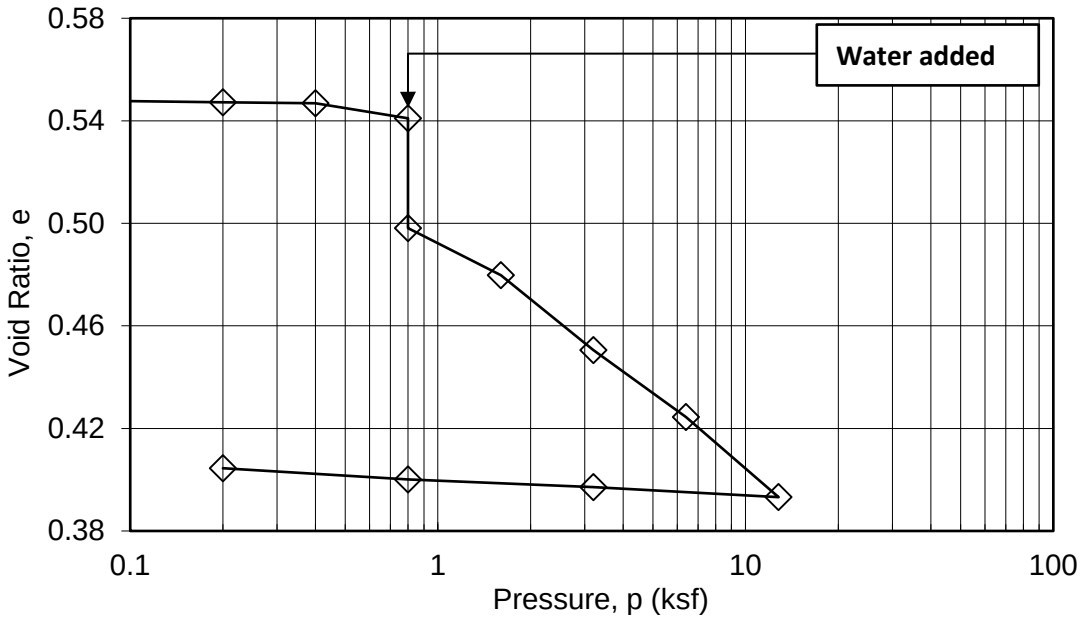
* Saturation is calcualted based on Gs= 2.67

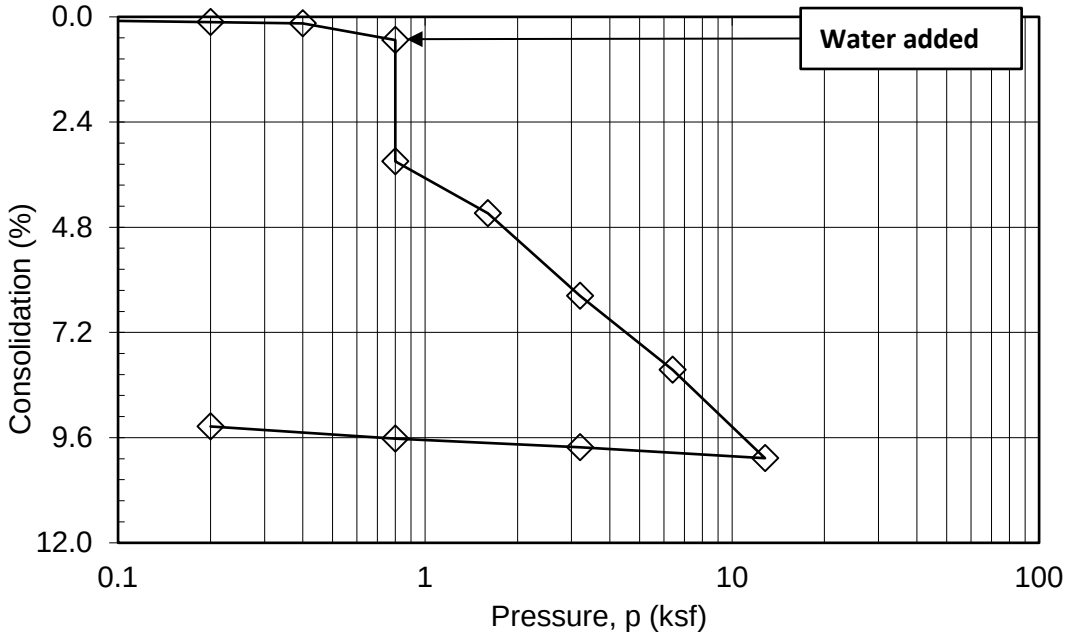
Load (ksf)	**δH (in)**	**H (in)**	**Voids (in)**	**e**	**Consol. (%)**	**a_v (ksf^{-1})**	**M_v (ksf^{-1})**	**Comment**
0.01	-------	1.0140	0.359	0.549	0			
0.2	0.0012	1.0128	0.358	0.547	0.1	1.0E-02	6.5E-03	
0.4	0.0015	1.0125	0.358	0.547	0.1	1.9E-03	1.2E-03	
0.8	0.0053	1.0087	0.354	0.541	0.5	1.5E-02	9.5E-03	
0.8	0.0334	0.9806	0.326	0.498	3.3	Water Added		
1.6	0.0454	0.9686	0.314	0.480	4.5	2.3E-02	1.5E-02	
3.2	0.0646	0.9495	0.295	0.451	6.4	1.8E-02	1.3E-02	
6.4	0.0817	0.9324	0.278	0.424	8.1	8.2E-03	5.7E-03	
12.8	0.1021	0.9119	0.257	0.393	10.1	4.9E-03	3.5E-03	
3.2	0.0996	0.9145	0.260	0.397	9.8	Unloaded		
0.8	0.0976	0.9165	0.262	0.400	9.6			
0.2	0.0948	0.9193	0.265	0.404	9.3			

CONSOLIDATION TEST

ASTM D2435

Client :	Tetra Tech BAS, Inc.	*HAI Project No.:*	TRT-19-011
Project Name:	Vulcan Gravel Pit Redevelopment	*Tested by:*	KL
Project Number:	197-4697-0001	*Checked by:*	MJ
Boring No.:	B5	*Date:*	10/23/19
Sample No.:	R2		
Type of Sample:	Undisturbed Ring		
Depth (ft):	10-10.8		
Soil Description:	Gray, Silty Gravel (GM)		





CONSOLIDATION TEST

ASTM D2435

Client :	Tetra Tech BAS, Inc.	*HAI Project No.:*	TRT-19-011
Project Name:	Vulcan Gravel Pit Redevelopment	*Tested by:*	KL
Project Number:	197-4697-0001	*Checked by:*	MJ
Boring No.:	B6	*Date:*	10/23/19
Sample No.:	R3		
Type of Sample:	Undisturbed Ring		
Depth (ft):	15-16		
Soil Description:	Brown, Poorly Graded Sand with Silt and Gravel (SP-SM)		

Initial Total Weight	Final Total Weight	Final Dry Weight
(g)	(g)	(g)
139.60	152.23	135.45

			Initial Conditions	**Final Conditions**
Height	H	(in)	1.017	0.966
Height of Solids	H_s	(in)	0.675	0.675
Height of Water	H_w	(in)	0.055	0.223
Height of Air	H_a	(in)	0.286	0.067
Dry Density		**(pcf)**	**110.6**	**120.6**
Water Content		**(%)**	**3.1**	**12.4**
Saturation		**(%)**	**16.2**	**76.8**

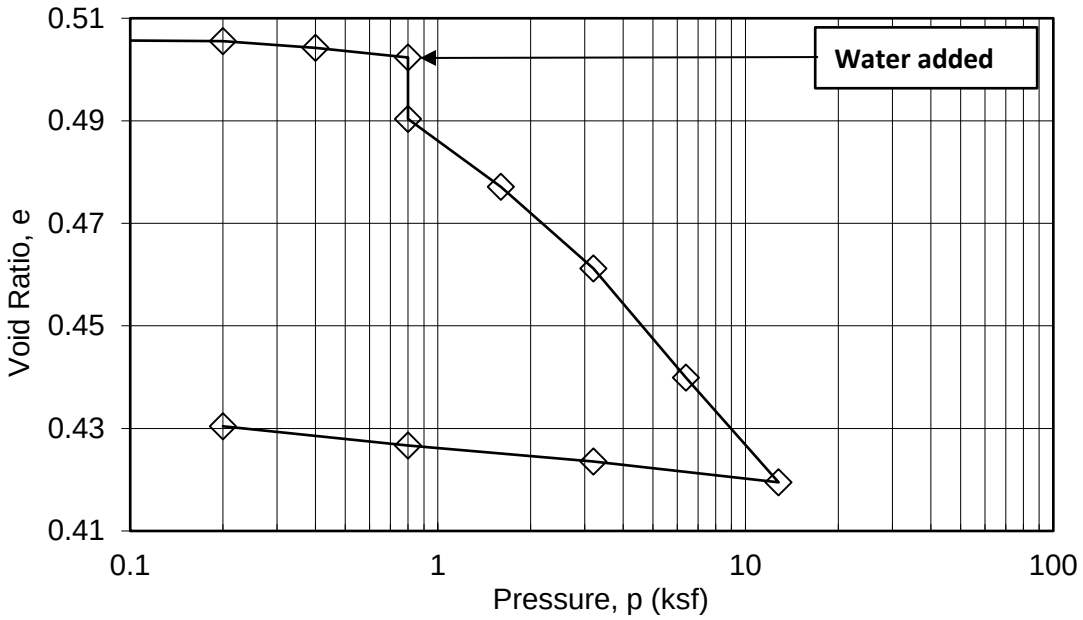
* Saturation is calcualted based on Gs= 2.67

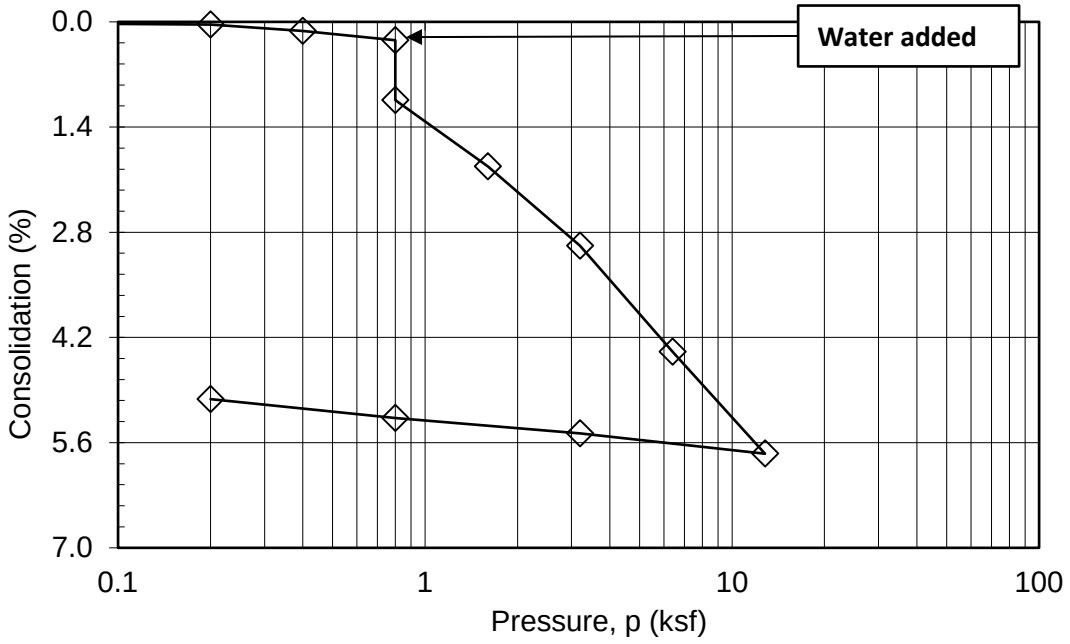
Load (ksf)	**δH (in)**	**H (in)**	**Voids (in)**	**e**	**Consol. (%)**	**a_v (ksf^{-1})**	**M_v (ksf^{-1})**	**Comment**
0.01	-------	1.0170	0.342	0.506	0			
0.2	0.0004	1.0167	0.341	0.506	0.0	2.7E-03	1.8E-03	
0.4	0.0013	1.0158	0.340	0.504	0.1	6.7E-03	4.4E-03	
0.8	0.0025	1.0145	0.339	0.502	0.2	4.6E-03	3.1E-03	
0.8	0.0106	1.0064	0.331	0.490	1.0	Water Added		
1.6	0.0196	0.9975	0.322	0.477	1.9	1.7E-02	1.1E-02	
3.2	0.0303	0.9867	0.311	0.461	3.0	9.9E-03	6.8E-03	
6.4	0.0447	0.9724	0.297	0.440	4.4	6.6E-03	4.6E-03	
12.8	0.0585	0.9586	0.283	0.419	5.7	3.2E-03	2.2E-03	
3.2	0.0557	0.9613	0.286	0.424	5.5	Unloaded		
0.8	0.0536	0.9634	0.288	0.427	5.3			
0.2	0.0511	0.9660	0.291	0.430	5.0			

CONSOLIDATION TEST

ASTM D2435

Client :	Tetra Tech BAS, Inc.	*HAI Project No.:*	TRT-19-011
Project Name:	Vulcan Gravel Pit Redevelopment	*Tested by:*	KL
Project Number:	197-4697-0001	*Checked by:*	MJ
Boring No.:	B6	*Date:*	10/23/19
Sample No.:	R3		
Type of Sample:	Undisturbed Ring		
Depth (ft):	15-16		
Soil Description:	Brown, Poorly Graded Sand with Silt and Gravel (SP-SM)		





Appendix C

Fault Investigation Report

(Tetra Tech, 2022a)

TETRA TECH

Geotechnical Engineering ● Engineering Geology

Fault Investigation Report

VULCAN AGGREGATE PIT REDEVELOPMENT PROJECT

20080 Highland Avenue
Rialto, California



100 Bayview Circle #3500
Newport Beach, California 92660

Prepared by:

Tetra Tech
21700 Copley Drive, Suite 200
Diamond Bar, California 91765

February 28, 2022
Project No. GEN 19-22E

TETRA TECH

Project No. GEN 19-22E
February 28, 2022

Mr. Todd Burnight
Carson Companies
100 Bayview Circle #3500
Newport Beach, California 92660

Subject: **FAULT INVESTIGATION REPORT**
VULCAN AGGREGATE PIT REDEVELOPMENT PROJECT
20080 Highland Avenue
Rialto, California

Dear Mr. Burnight:

Tetra Tech is pleased to submit the results of our comprehensive fault investigation report for the proposed redevelopment of the Vulcan Aggregate Pit located northwest of the intersection of Pepper Avenue and Highland Avenue, in the Rialto area of San Bernardino County, California. The subject property is located entirely within the boundaries of an Earthquake Fault Zone for the San Jacinto fault. Earthquake Fault Zones are delineated by the State of California to define areas where fault rupture hazard investigations are required prior to building structures intended for human occupancy. The purpose of this investigation was to evaluate the potential for surface fault rupture at the site associated with the San Jacinto fault and to provide appropriate mitigation recommendations including fault setbacks for the planning and construction of future site development. This report summarizes the findings, conclusions, and recommendations of the fault investigation at the site and was preprepared in general conformance with California Geological Survey (CGS) Note 49, "Guidelines for Evaluating the Hazard of Surface Fault Rupture" (2002) and the County of San Bernardino "Standard Procedure for Fault-Rupture Hazard Investigation and Report Standards" (2007).

We appreciate the opportunity to provide our professional services on this project. If you have any questions regarding this report, please do not hesitate to contact the undersigned.

Respectfully submitted,
Tetra Tech BAS, Inc.

Troy Carson
Staff Geolgist I

Shawn Morrish
Staff Geologist II





Bryan Petry, CEG
Project Geologist

Patrick M. Keefe, CEG
Supervising Engineering Geologist

Distribution: Addressee (pdf by email tburnight@carsoncompanies.com)
Filename: 2022-02-28 Carson Companies Rialto Fault Inv Report.docx.doc

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1. INTRODUCTION

This report presents the results of Tetra Tech's fault investigation for the proposed redevelopment of the Vulcan Aggregate Pit located at 20080 Highland Avenue, northwest of the intersection of Pepper Avenue and Highland Avenue in the Rialto area of San Bernardino County, California. The location of the site is shown on the Site Location Map, Figure 1.

The subject property is located entirely within the boundaries of an Earthquake Fault Zone (EFZ) associated with the San Jacinto fault, as indicated on Illustration 1. EFZ's are delineated by the State of California to define areas where fault rupture hazard investigations are required prior to building structures intended for human occupancy. The purpose of this investigation was to evaluate the potential for surface fault rupture at the site associated with the San Jacinto fault and to provide appropriate mitigation recommendations including building setbacks for the planning and construction of future site development. This report summarizes the findings, conclusions, and recommendations from the completed fault investigation and was preprepared in general conformance with CGS Note 49, "Guidelines for Evaluating the Hazard of Surface Fault Rupture" (2002) and the County of San Bernardino "Standard Procedure for Fault-Rupture Hazard Investigation and Report Standards" (2007).

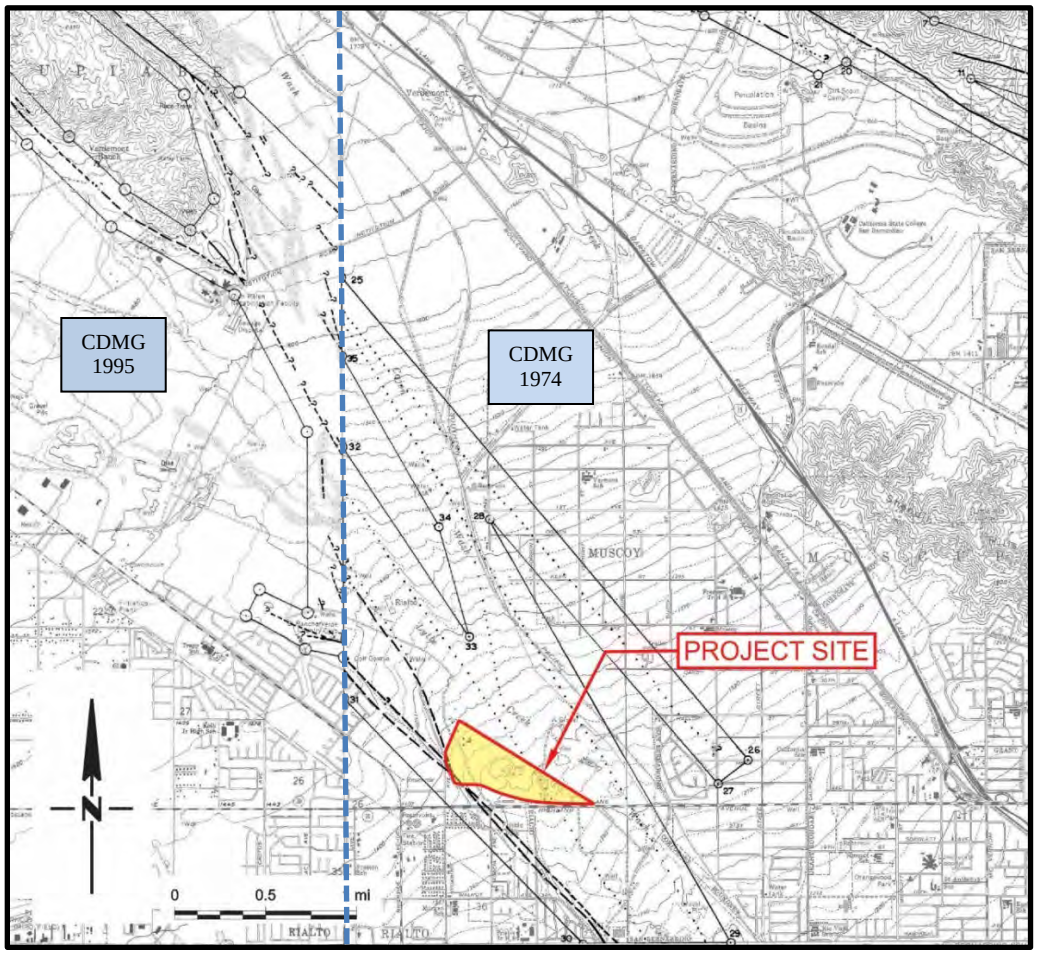


Illustration 1: Earthquake Fault Zones (from: CDMG, 1974 Special Studies Zones, San Bernardino North Quadrangle and CDMG, 1995 Earthquake Fault Zones, Devore Quadrangle).

2. SCOPE OF SERVICES

Tetra Tech's scope of services for this project consisted of the following:

- Research and review of available background data including seismic information, geologic literature and geologic maps, as well as in-house and client-provided geotechnical data for the site.
- A stereographic evaluation of historical aerial photographs relevant to the subject site.
- Review of previous fault investigation reports prepared by others for the site and it's vicinity.
- A field reconnaissance to observe site surface conditions and to select subsurface exploration locations.
- Notification of Underground Service Alert (USA) prior to subsurface excavation for clearance of buried onsite utilities.
- Performance of geophysical surveys for clearance of utilities beneath selected areas of the study area prior to subsurface exploration.
- Excavation, cleaning, and logging of two pilot test pits to assess the subsurface distribution and chronostratigraphic of deposition of alluvial soils within the northwesterly perimeter of the site.
- Excavation, cleaning, logging, and photo-documentation of 8 exploratory trenches measuring up to 23 feet below the existing grades and totaling approximately 4,185 lineal feet. Logs of the exploratory trenches are provided on Plates 2a through 2o.
- Collection of charcoal and organic sediment samples from the exploratory trenches for radiocarbon Accelerator Mass Spectrometry (AMS) age dating techniques.
- Collection of relatively undisturbed sediment samples from the exploratory trenches for age-dating testing using Optically Stimulated Luminescence (OSL) and post-infrared Infrared Stimulated Luminescence (pIR- IRSL) techniques.
- Periodic onsite meetings and peer review with County of San Bernardino reviewing geologist, Mr. Steven Kupferman.
- Geologic evaluation of the collected data.
- Preparation of this report, including the provision of reference maps, graphic logs, photographs, and illustrations, as well as a summary of the collected data with conclusions and recommendations relevant to fault-related mitigation for the planning and construction of future site development.

3. SITE DESCRIPTION AND PROPOSED DEVELOPMENT

The site comprises an area of approximately 100 acres and is located north and northwest of the intersection of Highland Avenue and N. Pepper Avenue in unincorporated San Bernardino County, California (USPS address: 20080 Highland Avenue, Rialto, California). The site is roughly triangular in shape and is located within the western flood plain of Lytle Creek. However, the site is protected from the current alignment of Lytle Creek Wash by an Army Corps of Engineers flood control levee which bounds the property to the north – northeast. The site is also bounded by Highland Avenue to the south and an existing residential development and a new residential development currently under construction to the west (formerly a portion of the El Rancho Verde Country Club and golf course).

The site is currently utilized by Vulcan Materials Company (Vulcan) for the processing and sale of construction aggregate, including sand, gravel, base and asphalt. The eastern portion of the site is used mainly for surface plant operations which include office and maintenance facilities, scale houses, employee parking, heavy equipment staging areas, crushing and conveyor belt operations, stockpiling and sorting areas, and asphalt production. The western portion of the site is currently used to store large stockpiles of various aggregate product for sale to the public. The stockpiles are separated by a network of gravel haul roads that are utilized for heavy equipment and loading of commercial trucks. The central portion of the site is currently used to maintain construction water ponds and for mixing, drying, and onsite disposal of wash plant fines and concrete debris.



Photograph 1: Vulcan Materials Plant, Rialto Area, San Bernardino, California (from Google Earth, 2021).

Overall, the site gently slopes to the southeast and drains to various detention basins within the property via graded earth swales with exception of the ponded areas within the central portion of the site.

Ascending slopes up to 58 feet in height border the southwestern perimeter of the site and generally vary from approximately 1.5(H):1(V) to 2(H):1(V) in gradient. The north and east perimeter of the site is bordered by a flood control levee with 2(H):1(V) slopes rising about 20 feet above the adjacent grades.

Based on our discussions with representatives of the Carson Companies, pit reclamation grading operations will be initiated upon termination of the current aggregate operations (projected in 2025). At this time, all undocumented fill materials will be removed and replaced as engineered fill in conformance with recommendations provided within a separate geotechnical report for the site. We understand that future site development will involve development of large commercial warehouse facilities with drive aisles, extensive staging areas and surface parking for commercial semi-trucks and employee vehicles.

4. SITE HISTORY

As previously discussed, the site is currently utilized for the production and sale of construction aggregate, including sand, gravel, base and asphalt. Plant operations initiated during the 1950's and initially included open pit mining of the westerly half of the property to depth of up to approximately 50 feet below the original ground surface. We understand that backfilling of the open pits within the property has continued periodically over the decades. A comparison of the topography of historic mining pit bottoms and the 2016 topographic expression of the site is shown on Illustration 2. Additional mining is not anticipated at the site during the remainder of the lease as materials are now being hauled to the site for processing from another Vulcan quarry located several miles to the north in the Cajon Creek floodplain.



Illustration 2: Comparison of topography from Historic bottom elevations and 2016 surface configuration (from Vulcan Materials Company, 2019).

5. BACKGROUND RESEARCH

5.1. Previous Geotechnical Studies by Tetra Tech

In November of 2019, Tetra Tech completed a geotechnical investigation for the subject property. The purpose of this study was to evaluate the general existing fill conditions, estimate required cut / fill volumes, and provide preliminary geotechnical conclusions and considerations relative to the future site development. As part of this study, 8 exploratory borings were drilled at various locations within the property to depths ranging from 11.5 to 51.5. Information relevant to a site-specific fault investigation was excluded from the scope of services at that time. Pertinent subsurface information collected from this study was utilized to assess the distribution and depths of the existing artificial fill at the site.

5.2. Relevant Fault Studies by Others

We reviewed numerous geologic investigation reports prepared by various private consultants for the site and nearby properties that addressed faulting associated with the San Jacinto fault. These investigation reports were generally made available through the client, the County of San Bernardino, CGS, or through our own independent research. The purpose of our review was to obtain pertinent geologic and seismic data to assess the location, structural characteristics and seismic potentials of the San Jacinto fault within the site and local vicinity. Relevant field data utilized from these sources to supplement this investigation are included in the Appendices A and B of this report. Approximate locations of selected exploratory trench excavations by others and/or relevant fault projections from published maps are presented on the Fault Exploration Map, Plate 1.

The following presents a summary of findings of the most pertinent reports that we reviewed and are summarized in order of relevance to this study. It should be noted that it is not our intent to summarize all the reports we reviewed. A complete listing of private consultant reports reviewed for this study is provided in the References section of this report.

Earth Consultants International, Inc.

In January 2013, Earth Consultants International (ECI) prepared a report summarizing the findings of their investigation to assess fault rupture potential within a portion of the subject site referred to as the Winter Pit. The Winter Pit was mined for sand and aggregate typically in the winter months and was located within the westerly portion of the site prior to backfilling. At the time of ECI's investigation, the bottom of the pit was about 35 feet lower than the surrounding terrain. Information from this study proved to be quite valuable as it provides critical subsurface information for a significant portion of the site that is essentially impractical to explore through conventional trenching methods at this time due to the depth of backfill.

ECI's subsurface investigation included excavation and logging of multiple trenches and test pits extending into alluvial soils. Samples were collected from selected trenches for radiocarbon and luminescence testing to assess chronostratigraphy of alluvial soils. From this study, ECI concluded that at least 2 zones of faulting exist beneath their study area. The westernmost breaks, identified

by ECI as F1 and F2, were determined to be discontinuous features that either terminate to the north or step to the west, beyond the limits of their study. ECI concluded that since Holocene-active faults have been identified by others to the northwest, the westernmost fault breaks (F1 and F2) could join with these faults and therefore, should be considered active, e.g. Holocene-active, unless additional future studies determine that these features are not active, e.g. pre-Holocene.

ECI also traced a northwesterly trending fault referred to by ECI as F3, approximately 300 to 350 feet east of faults F1 and F2. The fault was mapped in multiple overlapping trenches for a distance of approximately 500 feet until obstructions (Winter Pit boundary at that time) limited their ability to trench to the north and south. Based on multiple trench exposures, ECI concluded that fault F3 either has had only minimal amount of vertical displacement in the past ±11,000 years (the approximate age of alluvial sediments exposed at the top of the trench) or that the fault has not moved in several thousands of years. Since younger alluvial sediments were removed by mining operations within the bottom of the study area, a correlation regarding the timing of the last rupturing event along this section of fault could not be assessed. Therefore, ECI concluded that fault F3 be considered Holocene-active unless further studies provide compelling evidence to the contrary. ECI's faults F1, F2 and F3 are shown on the Fault Exploration Map, Plate 1.

It is our understanding that this fault study was prepared only for internal purposes and has not been submitted to any regulatory agency for commenting or approval. Since pertinent findings from this report were utilized to fill gaps between exploratory excavations completed by Tetra Tech for this study, a full copy of the ECI fault investigation report has been included in Appendix A for reference.

Gary Rasmussen & Associates, Inc.

Gary Rasmussen & Associates, Inc. (GRA) conducted numerous studies within the property north and northwest of the subject site. Of most significance were the studies to the northwest within and adjacent the former El Rancho Verde Country Club and golf course. These studies were conducted from 1979 through 1984 and included numerous overlapping trenches with a combined length of about 6700 lineal feet. Multiple fault traces identified by GRA were described as late Pleistocene- to Holocene-age although no absolute age dating techniques were conducted during their assessment. The southern projection of all the primary faults identified through the GRA study merge toward the western limits of the current Vulcan aggregate pit shown on the Fault Exploration Map, Plate 1.

GRA also conducted a limited fault study in 1984 within a City of Rialto public park know as Frisbee Park. This study included excavation of 3 relatively short and closely spaced exploratory trenches that extended to depths of up to 11 feet below the ground surface. While this study was limited to readily accessible areas within the southeastern portion of the park property, GRA concluded that evidence of fault rupture consistent with the trend and character of the San Jacinto fault was identified based on offset Holocene-age sediments juxtaposed against suspected Pleistocene-age sediments with apparent vertical offset up to at least 5 feet. This information was deemed relevant to our study since the faults identified by GRA proved to be useful in constraining the southeastern extension of faulting identified within the Vulcan plant.

Leighton & Associates, Inc.

Leighton and Associates, Inc. (L&A) conducted geologic studies and subsurface trenches in 1993 and 1994 to evaluate whether fault strands associated with the San Jacinto fault zone extended beneath proposed overpass structures associated with construction of the now-existing Interstate 210 eastern freeway corridor (L&A, 1995). This study included exploratory trenching at 4 locations (FT-1, FT-4, FT-6a1 and FT-6a2), where each location corresponded to a future overpass location. Of these exploratory trenches, FT-4 is most relative to this study since its position overlaps with Tetra Tech's exploratory trench FT-8 within the Vulcan plant. Additionally, L&A's FT-4 and Tetra Tech's FT-8 are positioned across the surface trace of a suspected concealed groundwater barrier identified by Dutcher and Garrett (1963) and modified by Sharp (1972). This feature is currently included on the latest Earthquake Fault Zones map for the San Bernardino North Quadrangle (CDMG, 1974) as a possible fault. L&A concluded that no faulting was identified in FT-4 to a maximum depth of 13 feet below the ground surface. Though the age of the oldest sediments collected by L&A in FT-4 were determined to be between 1,000 and 1,200 years old, they concluded that the relatively short recurrence intervals of 100 to 300 years would suggest that the sediments in the trench should have experienced at least three or four earthquakes, and possibly as many as ten. Since no evidence of faulting or fracturing was exposed in the exploratory trench, they concluded that the probability of fault rupture occurring through the trench location in the next earthquake event was very low.

Southern California Geotechnical

Most recently, Southern California Geotechnical (SCG) conducted a fault study in 2021 for an unimproved property located south of the Vulcan property, about 480 feet south of Interstate 210 freeway eastbound on ramp off Pepper Avenue, in the City of Rialto. This property is situated southeast (kitty corner) to the unimproved parcel of land identified herein as the Southern Parcel. In cooperation with our study, the owner of this property provided a copy of the 2021 SCG report for our review. Based on our review, SCG excavated two trenches (T-1 and T-2) roughly perpendicular to the mapped trace of the San Jacinto fault that projects through the site. The combined trench excavations totaled 1,378 lineal feet and varied in depth from 18 to 20 feet in depth. From their logging, SCG determined that there was no evidence of onsite faulting within the exploratory excavations completed for their study (SCG, 2021). Three charcoal samples were collected from T-2 between 16.5 to 17.5 feet below the ground surface and were submitted to a laboratory for Direct AMS radiocarbon dating. Results of the laboratory testing provided sediment depositional age correlations ranging from 1,967 to 2,171 years before present. From the findings of their study, SCG concluded that active faulting beneath the site could be ruled out since there was no observed offset within the deeper sediments that would have been subject to a 107 year recurrence interval over the last 2,100 years along the San Bernardino segment of the San Jacinto fault zone.

Though we are not aware if the SCG 2021 report was ever submitted to the City of Rialto for review and approval, the subsurface descriptions, results of radiometric age dating, and depositional sequences depicted and described on trench logs prepared by SCG appear similar to the findings observed by Tetra Tech for this study within the adjacent Southern Parcel to the northwest.

GeoSoils, Inc.

GeoSoils, Inc. (GSI) conducted multiple geologic studies and addendum reports from 1994 through 2014 to assess faulting associated with the San Jacinto fault for a planned residential community referred to as the Villages at Lytle Creek (southern portions currently under construction). This development originally included the former El Rancho Verde Country Club and golf course property along the northwest boundary of our study area, as well as several thousand acres of land situated in Sycamore Flat and the Lytle Creek flood plain further to the north and northwest of the golf course property.

The GSI 1994 report included excavation and logging of 8 widely spaced fault trenches that were positioned across interpreted photolineaments and mapped faults associated the San Jacinto fault zone extending from the northern reaches of the former golf course property, northwest approximately 4 miles, to the northwest side of Interstate 15 freeway. The study also included mapping and geologic evaluation of near vertical sidewall exposures within three sand and gravel quarries located within Lytle Creek wash approximately 2 miles to northwest of the subject site. Based on the findings of that study, GSI concluded that only one zone of Holocene-active faulting may exist within the northeast margin of their study area, within the Sycamore Flat area. All other areas explored by GSI reportedly did not show evidence of Holocene faulting, however, all trenches were excavated with sediments reported to range from mid to late Holocene-age.

We understand the GSI conducted a supplemental fault and seismic investigation in in 2007. A full copy of this report was not available for our review at the time of this report. However, we were able to review a copy of the accompanying Fault Setback Map (GSI - Plate 1) that was included in the 2007 report.

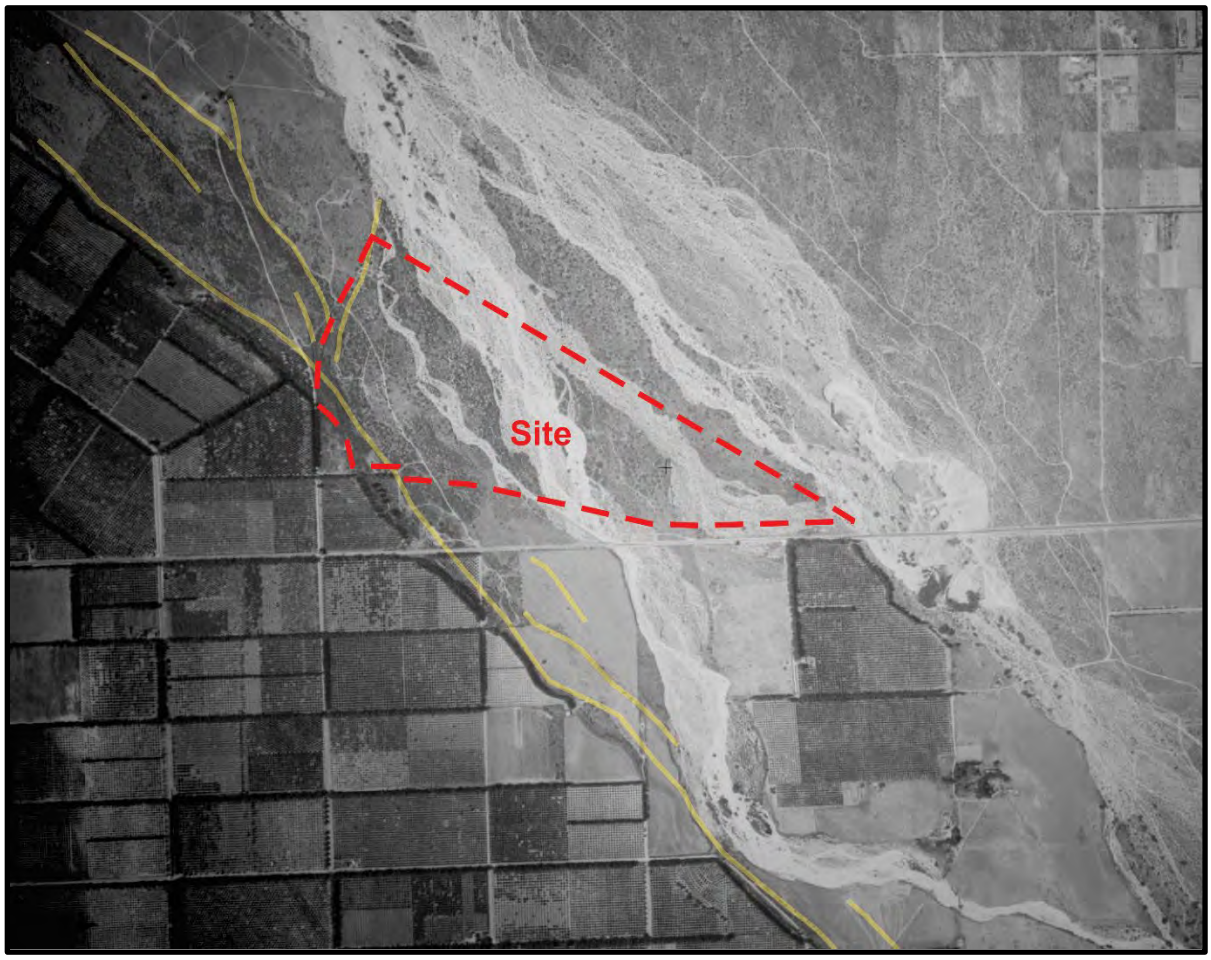
The map also indicates that 6 additional exploratory trenches were excavated within the northwesterly reaches of the former golf course property and extended about 3,000 lineal feet in a northeast direction into undeveloped portions the Lytle Creek Wash. From this supplemental trenching, it appears that GSI identified two fault zones referred to as Fault Zone 1 to the south and Fault Zone 2 to the north. Fault Zone 1 is depicted as a local zone of closely spaced, discontinuous faults within the northwesterly reaches of the former golf course property. Based on this zone of newly identified faults, GSI made slight adjustments to the setback zone originally recommended by GRA in along the northwesterly area of the former golf course.

Fault Zone 2 is depicted by GSI as a single fault break identified in two overlapping trenches along the northeastern limits of their supplemental trenching identified as FT-3 and FT-5. This fault was not traced further to the northwest apparently due to restrictions from a designated protected open space area nor was it traced further to the southeast where it would appear to intercept a future retention basin and property boundary.

5.3. Publications, Maps & Aerial Photographs

We reviewed geologic and seismic publications and maps prepared from a regional geologic perspective, as well as specific to the subject site. These publications and maps assisted in establishing our initial understanding of the regional geologic setting of the study area as well as the structural and seismic characteristics of the San Jacinto fault. A complete listing of reports, publications and maps reviewed for this study are provided in the References section of this report.

A review of stereographic aerial photographs taken of the site between 1930 and 1977 and surrounding areas was performed to evaluate geomorphic evidence of faulting within and near the site. Their usefulness specific to the site was somewhat limited as a result of various landform modifications associated with seasonal flooding events and more recent ground modifications associated with placement of flood control levees and mining operations. However, several features potentially related to surface faulting, such as lineaments associated with scarps and deflected drainages are visible within the western edge of the Lytle Creek flood plain along the northwesterly margin of the site, as well as to the north and south of the site. Prominent photolineaments identified for this study are identified on Photograph 2 below. A listing of the aerial photographs reviewed for this study is presented in the References section of this report.



Photograph 2: Prominent photolineament (highlighted with yellow lines) within western edge of Lytle Creek flood plain, (from Fairchild Aerial Surveys, 1936; C-4061, 28).

6. GEOLOGIC FRAMEWORK

6.1. Regional Geology and Geomorphic Setting

Regionally, the subject site is located within the eastern part of the Upper Santa Ana River Valley, locally referred to as the San Bernardino Valley. The San Bernardino Valley is bounded on the west by the Fontana Plain, on the north and east by the San Gabriel and San Bernardino Mountains and the Crafton Hill and the badlands to the south (Dutcher & Garret, 1963). The Lytle Creek fan is the largest alluvial fan in the San Bernardino Valley, however, much of the fan is a relict that was initially formed in late Pleistocene as sediment carried down from the San Gabriel Mountains carved a path along the San Jacinto fault. Over time, the fan surface was intermittently dissected by concentrated flood events that created deep trenches as down-cutting advanced. As faulting, uplift and tilting progressed through recent time, the fan's drainage system was eventually beheaded, leaving behind alluvial terraces. Outflow to the fan was ultimately redirected through modern stream piracy to the eastern side of the fan (Clarke, 1989).

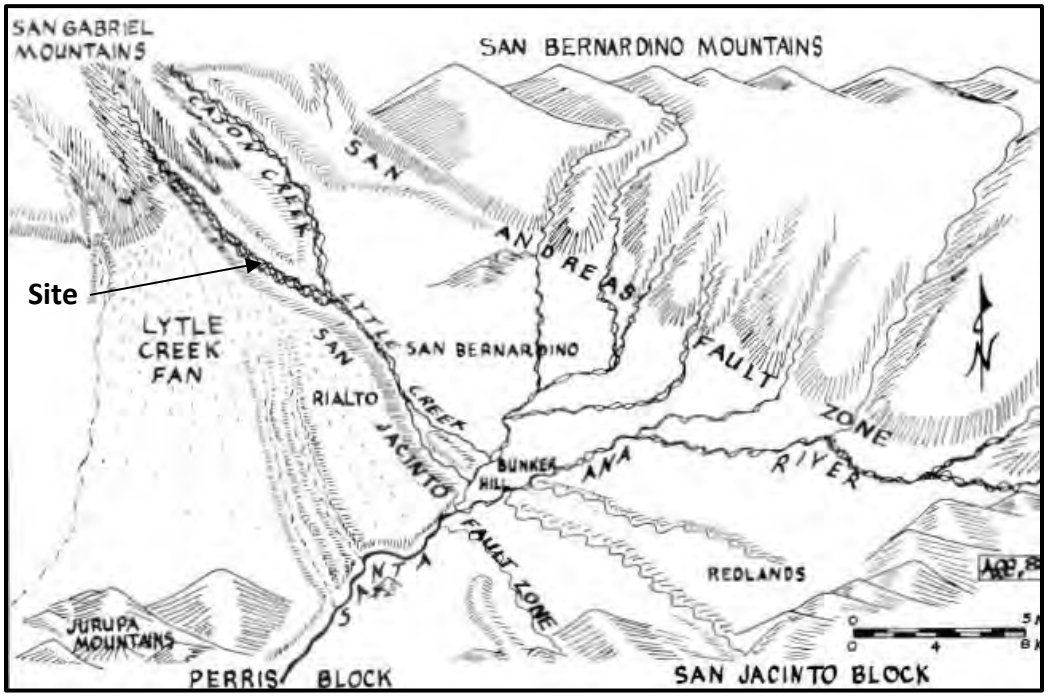
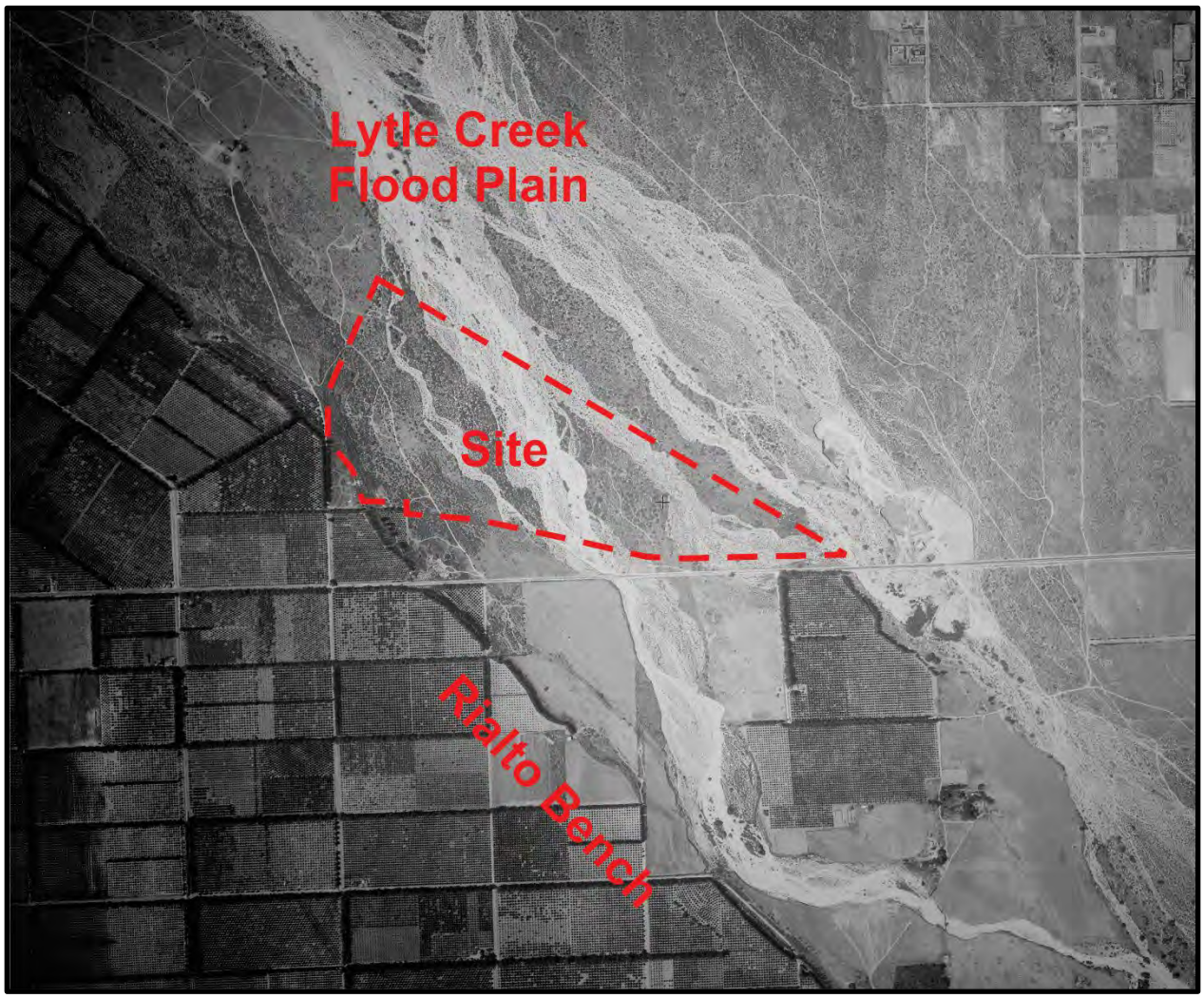


Illustration 3: Major Landforms of the San Bernardino Valley (from Clarke 1989).

Bedrock in the local mountain ranges consist predominately of igneous and metamorphic basement rocks, mantled locally in the lower reaches by both marine and non-marine sedimentary rocks. Recent drainage from the southeastern San Gabriel Mountains emanates though a complex braided stream environment. The resistant basement rock of the mountainous terrain provides the primary source rock of the gravel- and boulder-rich alluvium of the stream deposits. This alluvium is typically comprised of sub-rounded quartz diorite, granodiorite, well-banded gneiss and biotite and chlorite schist fragments with quartz- and feldspar- rich sand and silt that generally comprises the floodplain materials within Lytle Creek and Cajon Creek.

Lytle Creek has produced well-developed sequences of alluvial terraces along the eastern margins of the Lytle Creek fan near the study area for this investigation. One prominent geomorphic feature, referred to as the Rialto Bench, is a linear topographic escarpment up to about 65 feet in height that trends northwest–southeast along the west edge of the Lytle Creek floodplain and forms portions of the northwestern boundary of the subject site.



Photograph 3: Rialto Bench and Lytle Creek Flood Plain 1936 (from Fairchild Aerial Surveys, 1936; C-4061, 28).

Although, many researchers conclude that the escarpment owes its origin to faulting, there remains skepticism as to whether the present geomorphic feature is a product of faulting or merely a former stream bank of Lytle Creek (Schell, 2008). Nevertheless, the weathering and pedogenic soil development on the Rialto Bench and other younger terrace features provides useful correlation for relative age dating purposes for this study.

6.2. Tectonic Setting

The study area is located along the northern terminus of the Peninsular Ranges physiographic province which is characterized by northwest-trending ranges, valleys, and geomorphic features controlled by the San Andreas Fault Zone (SAFZ) and associated fault systems, including the San Jacinto fault. Collectively, the San Andreas fault and the San Jacinto fault transfer most of the Pacific – North America plate motion through southern California and produce recurrent surface rupturing earthquakes (Oskin & Rockwell, 2018). The study area is located southeast of the junction of the San Andreas and San Jacinto faults. These faults approach each other to the northwest within the Cajon Pass area between the San Gabriel and San Bernardino Mountains, where the northern terminus of San Jacinto fault forms approximately a 1- to 2-mile-wide releasing step with the San Andreas fault (Onderdonk et al, 2018). Instead of merging with the SAFZ, the surface trace of the San Jacinto fault terminates into a set of cross-cutting, high- and low-angle faults within the eastern San Gabriel Mountains.

The location of the SAFZ is well documented and clearly expressed by a series of subparallel linear escarpments and offset drainages displacing Holocene-age alluvium along the base of the San Bernardino Mountains. The San Jacinto fault zone consists of a series of sub parallel, right lateral, right-stepping faults that form the western margin of the San Jacinto Mountains. The fault zone has been mapped from its junction with the SAFZ in the Cajon Pass area, to the southeast for about 175 miles, where it transfers most of its motion to the Imperial fault within the Brawley area.

The location of the San Jacinto fault within the San Bernardino Valley, however, is poorly expressed at the ground surface. In the San Bernardino Valley, the San Jacinto fault zone consists of three named fault strands referred to as the Lytle Creek, San Jacinto and Glen Helen faults, from west to east, in a zone approximately 2 to 3 miles wide (Burnett & Hart, 1994). The uncertainty in location is reflected on most published geologic maps, including the Alquist-Priolo Earthquake Fault maps (CGS, 1974, 1995) for the study area that show the fault as dotted or dashed lines that are often queried. Many of surface traces are inferred based on tonal variations and weak lineaments expressed in aerial photographs, possible scarps along active and abandoned drainage channel boundaries and some based solely on interpreted groundwater barriers concealed at depth.

Historically, at least three moderate to large earthquakes have occurred in the northern portion of the San Jacinto fault (see Figure 4), and at least one on the San Bernardino Valley segment (July 1923, Loma Linda, M6 to M6.3). Fault slip rate data on the northern, San Bernardino Valley, segment of the San Jacinto fault is not as well constrained as similar the southern sections of the fault, however a slip rate on the order of 13 to 18 mm/yr has been considered reasonable by many researchers (Onderdonk et al, 2018).

Recent studies provide compelling paleoseismic records for the San Jacinto fault at Mystic Lake, about 22 miles southeast of the subject site. At this location, at least 13 surface earthquake ruptures were exposed over the past 2,000 years. The average recurrence interval has been estimated to be 160 ± 76 yr for the northern San Jacinto fault during the last 2,000 years (Onderdonk, et al, 2018). Similar studies for sections of the San Jacinto fault further to the south at Hog Lake suggest similar relatively short recurrence intervals for surface-rupturing earthquakes (Rockwell et al., 2014).



Illustration 4: Faults and paleoseismic sites (hexagons) along the San Andreas and San Jacinto Fault Zone of Southern California (from Rockwell, et al., 2014).

6.3. Seismicity

The Southern California region is known to be seismically active. Earthquakes occurring within approximately 60 miles of the project sites are considered capable of generating ground shaking of engineering significance to the proposed construction. The project area is located in the general proximity of several seismically active faults, as shown on Figure 2 – Regional Faults and Seismicity Map. Tables 1 provides a summary of known seismically active faults within approximately 40 miles of the project sites as modeled by the U.S.G.S. Earthquake Hazards Program, 2008 National Seismic Hazard Maps (https://earthquake.usgs.gov/cfusion/hazfaults_2008_search/query_main.cfm).

Table 1
Summary of Active Faults
Referenced Site Latitude and Longitude: 33.138863°, -117.359943°

Fault Name	Approximate Fault Distance to Site (miles)	Slip Sense	Maximum Moment Magnitude
San Jacinto	-	strike slip	7.7
S. San Andreas	4.60	thrust	7.7
Cucamonga	5.52	thrust	6.7
Cleghorn	9.84	strike slip	6.8
North Frontal (West)	13.32	reverse	7.2
San Jose	19.05	strike slip	6.7
Sierra Madre	21.86	reverse	7.2
Chino	22.93	strike slip	6.8
Elsinore	24.94	strike slip	7.2
Clamshell-Sawpit	28.75	reverse	6.7
Helendale – So Lockhart	31.48	strike slip	7.4
Puente Hills (Coyote Hills)	33.57	thrust	6.9
Raymond	36.19	Strike slip	6.8
San Joaquin Hills	40.42	thrust	7.1

7. INVESTIGATION

7.1. Investigative Approach

The primary objective of our study was to determine whether Holocene-active faulting (rupture the ground surface within the last 11,700 yrs), as defined by the State of California Alquist-Priolo Earthquake Fault Zoning Act, is present beneath the site. The numerous stockpiles of aggregate, office buildings, maintenance structures, underground utilities, and active aggregate production and trucking operations throughout much of the property created significant challenges in accessing and exploring the subsurface conditions in the ±100-acre active Vulcan Materials plant.

Additionally, much of the central and westerly portion of the site were historically mined for aggregate and subsequently backfilled with non-engineered fill up to 50 feet in depth. Through coordination with Vulcan personnel, various topographic maps of completed mining pit excavations were provided for our review. The historical maps were compared to recent topographic maps of the site to help position exploratory trenches along areas of the site that were not dramatically altered by the past mining operations.

Since continuous trenching across the site was determined to be impractical, we resolved that overlapping trenches would be the most practical approach to explore the subsurface conditions within the site. To minimize impacts to the daily plant operations, our trenching program was primarily focused along the margins of the Vulcan property. Furthermore, an undeveloped parcel of land located within the southeastern extension of Lytle Creek wash was also accessed for exploratory trenching. This parcel of land, referred to herein as the “Southern Parcel” on Plate 1, is under the same ownership as the Vulcan plant property and is positioned in a key location to supplement this study.

Ideally, exploratory trenches were excavated to depths that would expose pre-Holocene age geologic units. If pre-Holocene age units were observed to be continuous and unbroken (i.e., not offset), then the possibility of Holocene active faulting could be ruled out. Where pre-Holocene age units could not be reached through conventional trenching, but 15 to 20 feet of younger alluvium was determined to be un-faulted in the trench exposure, correlations between the age of deposits and recurrence intervals could be utilized to assess the potential risk of fault rupture through the trench.

7.2. Base Map Preparation

As part of our investigation, scaled topographic maps of historical mining pit bottom excavations were digitally configured to create a composite map depicting the limits and topographic expression of past mining operations that have since been backfilled within the site. Offsite topography was added for the surrounding terrain by processing available County of San Bernardino quadrangle Lidar imagery. The entire map has been enhanced by including a 2021 orthophoto image overlay. This map was utilized to compile geologic data from relevant referenced sources, as well as the findings of our subsurface exploration for this study.

7.3. Subsurface Exploration

Our subsurface exploration conducted for this study was essentially performed in three phases which initiated in August 2020 and was completed in December 2021. Each subsequent phase was built on the findings of the earlier phase of work. The following presents a summary of each phase:

7.3.1 Phase 1 – Test Pits

Initially, 2 test pits were excavated within the northwesterly boundary of the site in August of 2020 utilizing a standard rubber tire backhoe. The test pits were excavated up to 12 feet in depth at selected locations along the perimeter of the site where subtle grade breaks in the natural topography suggested the possibility of remnant terraces along the margins of Lytle Creek flood plain. Each test pit was logged by our Engineering Geologists to evaluate the subsurface distribution of alluvial sediments and to assess characteristics of soil development within the deeper / older sediments. To further assess sediment age distribution of the underlying alluvial sequences, relatively undisturbed samples of sand-rich deposits were collected at various depths for subsequent Optically Stimulated Luminescence (OSL) testing methods (described in detail within Appendix D1). No charcoal fragments were observe in the test pits that could be used for radiocarbon dating.

The test pits were also useful in planning for equipment needs during future phases of exploratory trenching. In particular, the initial test pits provided insight for our assessment of trench stability and safety, as well as determining the configuration and depth constraints for subsequent exploratory trenching phases of the study.

7.3.2 Phase 2 – Geophysical Seismic Refraction

A geophysical seismic refraction survey was conducted by Terra Geosciences along the northwesterly property boundary in advance of exploratory trenching. This location was chosen since our research indicated that significant known faulting and a possible concealed fault could be anticipated to cross beneath the site along this area of the site. Large stockpiles of aggregate and deep fills associated with backfilled mining excavations limited the orientation of the seismic traverse along a northeasterly trending perimeter access road.

The seismic refraction survey was conducted on a Sunday when the Vulcan operations were shut down to minimize background noise. A total of five, 24-channnel seismic refraction lines with 11- foot geophone spacings were placed to create on continuous subsurface profile about 1,067 feet in length and reach up to about 80 feet in depth. The purpose of the seismic refraction survey was to assess the general seismic velocity characteristics of the underlying earth materials to aid in evaluating the subsurface geologic structure and, possible groundwater conditions, based on seismic velocity distribution.

Details of the seismic refraction method used for this study and a graphic gradient model plot of the subsurface profile along the seismic traverses are presented in Appendix C.

7.3.4 Phase 3 – Exploratory Trenching

Excavation and Logging

The exploratory trenching phase of this study was performed from January 2021 through December 2021 and consisted of the excavation and geologic logging of 9 overlapping trenches, FT-1 through FT-5, FT-6a, FT-6b, FT-7, and FT-8. The trench locations were field established using a site topographic map and by measuring to known points and surface features. Completed trench excavations were surveyed by Tetra Tech's licensed surveyor. The trench locations are shown on the Fault Exploration Map, Plate 1.

The trenches excavated for this study were excavated by Tetra Tech's construction group under the observation and direction of Tetra Tech's geological staff. The trenches measured from 12 to about 50 feet in width and were excavated to depths ranging from 8 to 23 feet below the adjacent ground surface utilizing an 80,000-pound track-mounted excavator with 4 feet and 6 feet wide buckets. A Komatsu 380 rubber-tire loader and a Doosan 30-ton articulating rock truck were utilized to move spoils and transport them to designated stockpile areas within the site. A water hose and water truck provided by Vulcan were used periodically to control dust, particularly on windy days. Trenches more than 4 feet in depth were benched generally every 4 vertical feet for safety and stability.

Once excavated, benches were cleared of loose soil, cobbles and boulders utilizing hand shovels. Aluminum ladders were then placed at each bench and the trench walls were prepared for logging by removing all smeared materials with hand tools. A string and nail baseline was established with a bubble level throughout the length of the bottom of the trench. Station numbers were established on wood lath driven into the floor of the trench and marked on the sidewalls of the trenches every 10 lateral feet. The trenches were subsequently photographed and logged in detail by Tetra Tech's professional engineering geologists at a scale of 1-inch equals 5-feet (horizontal and vertical). Logging emphasis was placed on noting stratigraphic continuity and geologic features (lithologic contacts and planar features) that were measured by hand-held ruler from the baseline. Typically, only one wall of each trench was logged, but both walls were cleaned for observation by the geologists and comparison of exposures across the trench. Descriptions of the stratigraphic units were logged in general accordance with the United Soil Classification System (USCS) and colors variations were described using Munsell Color Notation. Once logged and photographed, the fault trenches and significant fault breaks and geologic contacts were surveyed verified by Tetra Tech's licensed surveyor. Graphic presentations of the trench logs are presented on Plates 2a to 2o.

Sampling and Laboratory Testing

During geologic logging, 14 samples of charcoal and organic-rich sediments, C-1 through C-14, were collected from the trenches for potential laboratory age-dating testing. Of the 14 total samples collected, 11 samples, C-1, C-3, C-4, C-6 through C-10, and C-12 through C-14, were sent to Beta Analytic, Inc. Miami, Florida laboratory for radiocarbon dating. The samples were pre-treated by Beta Analytic, Inc. and processed using Accelerator Mass Spectrometry (AMS) techniques to produce conventional radiocarbon ages.

In addition to the radiocarbon age dating, 18 sediment samples, OSL-1 through OSL-18, were collected from selected sand-rich deposits for potential age dating via Optically Stimulated Luminescence (OSL) testing. The sediment samples were collected in the field by driving 6-inch long, 1.5-inch diameter, metal tubes horizontally into the sidewalls of the trenches to obtain relatively undisturbed samples. The driven tubes were then removed from the trench sidewalls by slowly excavating the adjacent soils with hand tools so that the ends of the tube could be capped with minimal exposure to sunlight.

Of the 18 samples collected, 3 samples, OSL-1, OSL-2, and OSL-4, were sent to North Carolina State University (NCSU) for luminescence testing by Dr. Lewis Owens. Following initial sample treatment, Optically Stimulated Luminescence (OSL) testing was performed on samples OSL-1 and OSL-2. After further research and consultation with other experts performing similar studies in the area, OSL-4 was analyzed through post-infrared Infrared Stimulated Luminescence (pIR- IRSL) testing methods in lieu of OSL testing as recent studies have shown standard OSL testing often underestimates the ages of the deposits in tectonically active southern California (Lawson et. al., 2012). The remaining 8 samples OSL-3, OSL-7, OSL-8, OSL-10, OSL-11, OSL-13, OSL- 15, OSL-17, and OSL-18 were sent to California State University, Long Beach (CSULB) for luminescence testing by Dr. Nate Onderdonk. Following initial sample treatment, pIR- IRSL testing was performed on the remaining samples. The locations of the samples collected for age dating purposes are shown on the attached trench logs, Plates 2a to 2o.

The results of the radiocarbon dating, OSL dating, and post- pIR-IRSL dating are discussed in Sections 8.2.3 and 8.2.4 of this report and the associated reports prepared by Beta Analytic, NCSU and CSULB are included herein in Appendices D1 and D2.

Peer Review

Prior to and during the trenching phase of this study, regular communication was kept between Tetra Tech's Supervising Engineering Geologist and Mr. Steven Kupferman, Principal Consulting Geologist for the County of San Bernardino. This communication was vital to keep the reviewing geologist abreast of our findings and schedule over the 11-month period that was required to complete the exhaustive field investigation phase of our study. Based on our progress, Mr. Kupferman periodically visited the site to view selected trenches along with Tetra Tech staff which also allowed our team to discuss findings and strategies as we progressed with the study.

In addition, occasional communication was kept with Dr. Nate Onderdonk of CSULB during the course of this investigation. Dr. Onderdonk visited the site to observe fault exposures, collect earth material samples, and provide technical support with respect to age of deposits. Dr. Onderdonk's past research and publications regarding southern California seismicity along with his wealth of experience conducting similar subsurface investigations relative to the paleoseismic history of the San Bernardino section of the San Jacinto fault has been relied on in preparation and implementation of this study.

Trench Backfill and Site Restoration

Upon completion of geologic logging, photo-documentation, sampling, and peer review, trench excavations FT-1 through FT-5, and FT-8 were subsequently backfilled with trench spoils and periodically wheel rolled with heavy equipment to restore the surface to its original configuration. Trench excavation FT-7 was backfilled with trench spoils that were moisture-conditioned and periodically rolled with a steel drum compactor and/or rolled with heavy equipment to restore the surface to its original subgrade elevation. A minimum of 4-inches of aggregate base supplied by Vulcan was compacted above the subgrade soil. T Maus Paving was then subcontracted to place 3-inches of asphalt pavement to restore sections of the employee parking lot that were demolished during excavation of FT-7. Trenches FT-6a and FT-6b were backfilled with engineered fill. Details of the backfill operations for FT-6a and FT-6b, including compaction test results, will be provided under separate cover.

8. FINDINGS

8.1. Site Geology

The site is located within the southwestern edge of the Lytle Creek flood plain and is underlain by thick sequences of alluvial deposits, as shown on Figure 3 – Regional Geologic Map. However, much of the ground surface has been modified by commercial aggregate operations since the 1950's. Past ground modifications included open pit mining of the westerly half of the property to depth of up to approximately 50 feet below the original ground surface. Backfilling of the open pits within the property has continued periodically over the decades. The central portion of the site is currently utilized to maintain construction water ponds and for mixing, drying and onsite disposal of wash plant fines and concrete debris. The eastern areas of the property are believed to have had little to no history of open pit mining. This area of the site is expected to be underlain by local accumulations of fill material associated with underground utilities and local structures. As a result, the distribution of the geologic units varies substantially across the site. The subsurface conditions described herein are based upon the findings of the exploration trenching completed for this study, the findings from the referenced 2019 geotechnical exploration by Tetra Tech, and site research.

The surficial geologic units encountered within the subject site consist of Holocene-age artificial fill (Af), colluvium (Qcol) and younger alluvium (Qaly). Pleistocene-age older alluvium (Qoal) was encountered locally at the ground surface and beneath the Holocene surficial units.

8.2. Geologic Units

Generalized descriptions of the geologic units encountered, from youngest to oldest, are provided below. Detailed descriptions of the soils encountered during this investigation are presented on the trench logs, Plates 2a to 2o.

8.2.1 Artificial Fill (Af)

Variable thicknesses of artificial fill soils primarily associated with mine site reclamation backfill and spoils from past aggregate stockpiles and trucking operations are present throughout the site. The fill soil types very broadly and consist of onsite aggregate processing waste as well as of materials from offsite sources. The fill soils generally consist of brown to gray, loose to medium dense silty sand, poorly graded sand with silt, gravelly sand or olive brown to grayish brown, firm to very stiff lean clay, and silt or sandy silt. Varying amounts of cobbles and boulders up to 2 feet were also encountered. Locally, trace amount of refuse (e.g., plastic, nails, wire glass, etc.) was encountered within the fill.

Because of the history of the site, fill materials are ubiquitously present over most of the site. Although in the western half, significant thicknesses up to 50 feet of reclamation backfill of former mining pit excavations are anticipated based on comparison of topographic survey of the mining pit bottom and the current surface topography. Elsewhere, a thin veneer, typically less than 5 thick, was encountered.

8.2.2 Colluvium (Qcol)

Colluvium locally mantles the natural slopes and is also present as wedge-shaped deposits along the base of sloping terrain. Where encountered within the site, colluvial soils are comprised of dark grayish brown (2.5Y 4/2) to olive gray (5Y 4/2) silty sand that is typically fine grained with scattered gravel and occasional cobbles up to 8-inches in diameter. The colluvium is locally porous and contains scattered roots and rootlets. Up to 3.5 feet of colluvium was identified at various locations along the southwesterly perimeter of the site.

8.2.3 Younger Alluvium (Qaly)

Younger alluvium (Qaly) is present within the perennial braided stream channels of Lytle Creek situated north of protective levee that currently surround the site. Prior to modern flood control improvements, historical storm and flooding events, such as the 1938 Great Flood, caused Lytle Creek to overflow its banks and deposit alluvium across various portions of the current flood plain. The historical alluvial deposits within the site were mostly indistinguishable due to past ground modifications associated with the aggregate plant operations.

Much thicker accumulations of the younger alluvium were deposited within the site by an ancestral Lytle Creek. Where observed in trench excavations completed for this study, these alluvial sediments varied in lithology and physical characteristics, both laterally and vertically, as a result of the chaotic depositional history associated with Lytle Creek outflow. The alluvium is commonly gray (2.5Y 6/1) to light gray (2.5Y 7/1) to light brownish gray (2.5Y 6/2) to olive brown (2.5Y 4/3) and is comprised of varying distributions of sand, silt, gravel, cobbles and boulders. The deposits are crudely stratified to well stratified, markedly channelized in areas, and locally cross-bedded. Clasts are subangular to subrounded and often imbricated. Finer grained sequences overbank materials comprised of sandy silt with trace clay and silty sand were typically encountered within the upper 10 feet of the ground surface and to a lesser extent at greater depths. These deposits of fine-grained sediments were prevalent along down-dropped blocks between fault segments identified within FT-1. These deposits are believed to be associated with locally ponded areas trapped within hummocky terrain along historic fault scarps. The fine-grained sequences ranged from massive to laminated with some charcoal fragments and trace woody-organic matter.

Younger alluvium was encountered within exploratory trenches FT-1, FT-2, FT-3, FT-6a and 6b, FT-7 and FT-8. Based on the age dating test results, the younger alluvium within the site is estimated to have been deposited from approximately 100 years to more than 3,300 years before present (b.p.). The results of age date testing completed for the younger alluvium are provided in Appendix D1 and D2 and are summarized in Table 2a below.

Table 2a
Summary of Age Dating Testing for Younger Alluvium

Sample I.D.	Trench ID	Approx. Station Number	Sample Depth (ft)	Test Method	Calibrated Age (Ka ybp)[4]
C-1	FT-1	2+49	11.1	AMS	0.11[3]
C-3	FT-1	4+37	12.7	AMS[1]	0.10[3]
C-4	FT-1	7+28	9.6	AMS[1]	2.00
C-6	FT-3	0+65	14.0	AMS[1]	2.12
C-7	FT-6a	0+58	18.0	AMS[1]	2.48
C-8	FT-6a	0+61	12.0	AMS[1]	1.75
C-9	FT-6a	1+75	15.5	AMS[1]	2.47
C-10	FT-7	1+24	11.5	AMS[1]	1.60
C-12	FT-8	1+52	17.0	AMS[1]	2.00
C-13	FT-8	1+67	17.0	AMS[1]	2.42
C-14	FT-8	2+07	11.3	AMS[1]	1.19
OSL-1	TP-1	-	5.0	OSL[2]	3.30
OSL-2	TP-1	-	11.2	OSL[2]	3.10

Notes: [1]Per Beta Analytic
[2]Per NCSU
[3]Sample likely decayed root
[4]Calibrated ages do not reflect error ranges presented within laboratory results in Appendix D

8.2.4 Older Alluvium (Qoal)

Older alluvium was encountered in all exploratory excavations completed for this study except FT-8. Older alluvium is buried beneath the younger alluvium within the site and is exposed locally at the ground surface within the southwestern perimeter of the site. In general appearance, the coarse-grained older alluvium is similar to the younger alluvium in that it is comprised of varying distributions of sand, silt, gravel, cobbles and boulders. The deposits are also crudely stratified to well stratified, markedly channelized in areas, and locally cross-bedded. Clasts are generally crystalline and subrounded, however, in many locations crystalline clasts exhibit in-place granular disintegration characteristics referred to as grus. The coarse-grained older alluvium sequences are generally less friable as compared to the younger alluvium and exhibit a weakly cemented texture with matrix materials varying in color from light yellowish brown (10YR 6/4 to 2.5Y6/3) and light olive brown (2.5Y 5/4).

Finer grained sequences are fewer in the older alluvium, however, where encountered they are often yellowish brown (10YR 5/6) in color and exhibit moderate pedogenic characteristics

associated with paleosol development. Individual ped surfaces show subangular blocky structure with clay coating and oxidation staining visible on ped surfaces. Similar studies conducted by others in the Lytle Creek flood plain to the northwest have judged similar paleosol development to be at least 35,000 years old (Shlemon, 1994). No charcoal fragments were identified in the fine grained older alluvial deposits during this study. However, IRSL age dating test results from several sediment samples collected within the older alluvium at various trench locations provide compelling evidence for Pleistocene age of deposition for the older alluvium identified through this study. The results of age date testing completed for the older alluvium is provided in Appendix D2, pIR-IRSL and are summarized in Table 2b below.

Table 2b
Summary of Age Dating Testing for Older Alluvium

Sample I.D.	Trench ID	Approx. Station Number	Sample Depth (ft)	Test Method	Calibrated Age (Ka ybp)[3]
OSL-3	FT-1	1+44	11.4	pIR-IRSL[1]	36.60
OSL-4	FT-1	1+52	16.1	pIR-IRSL[2]	19.90
OSL-7	FT-1	9+76	14.9	pIR-IRSL[1]	19.40
OSL-8	FT-1	10+64	10.3	pIR-IRSL[1]	28.60
OSL-10	FT-1	12+29	16.0	pIR-IRSL[1]	41.10
OSL-11	FT-2	2+70	20.0	pIR-IRSL[1]	35.00
OSL-13	FT-3	2+00	20.0	pIR-IRSL[1]	22.00
0SL-15	FT-6b	0+53	18.0	pIR-IRSL[1]	20.60
OSL-17	FT-7	1+83	16.5	pIR-IRSL[1]	26.80
OSL-18	FT-8	1+52	17	pIR-IRSL[1]	23.60

Notes: [1]Per CSULB
[2]Per NCSU
[3] Calibrated ages do not reflect error ranges presented within laboratory results in Appendix D

8.3. Groundwater

Groundwater was not encountered in any of the exploratory trenches completed for this investigation nor within borings from our 2019 geotechnical assessment report to the maximum depths of exploration (51.5 feet). Additionally, the seismic refraction survey completed for this study within the northwestern portion of the site did not identify subsurface anomalies consistent with groundwater to depths of up to approximately 80 feet beneath the site.

At least one concealed groundwater barrier believed to be associated with faulting has been mapped through the site (Burnett & Hart, 1994). Exploratory trench FT-6a and FT-8 were intentionally positioned to bisect the alignment of the inferred fault to assess Holocene fault activity beneath the site. Based on our observations, no evidence of Holocene faulting or other

stratigraphic aquitards were identified. The possible groundwater barrier may be the result of an older, inactive fault alignment or deeper stratigraphic barrier not related to faulting.

The site is located within the Upper Santa Ana Valley Groundwater Basin. Based on groundwater records in the general vicinity of the site from the California Department of Water Resources website (updated Spring 2021), groundwater is anticipated to be at least 300 feet below the ground surface (see Illustration 5). It should be noted that groundwater levels may fluctuate due to seasonal variations in rainfall and snowfall, irrigation, or other factors.

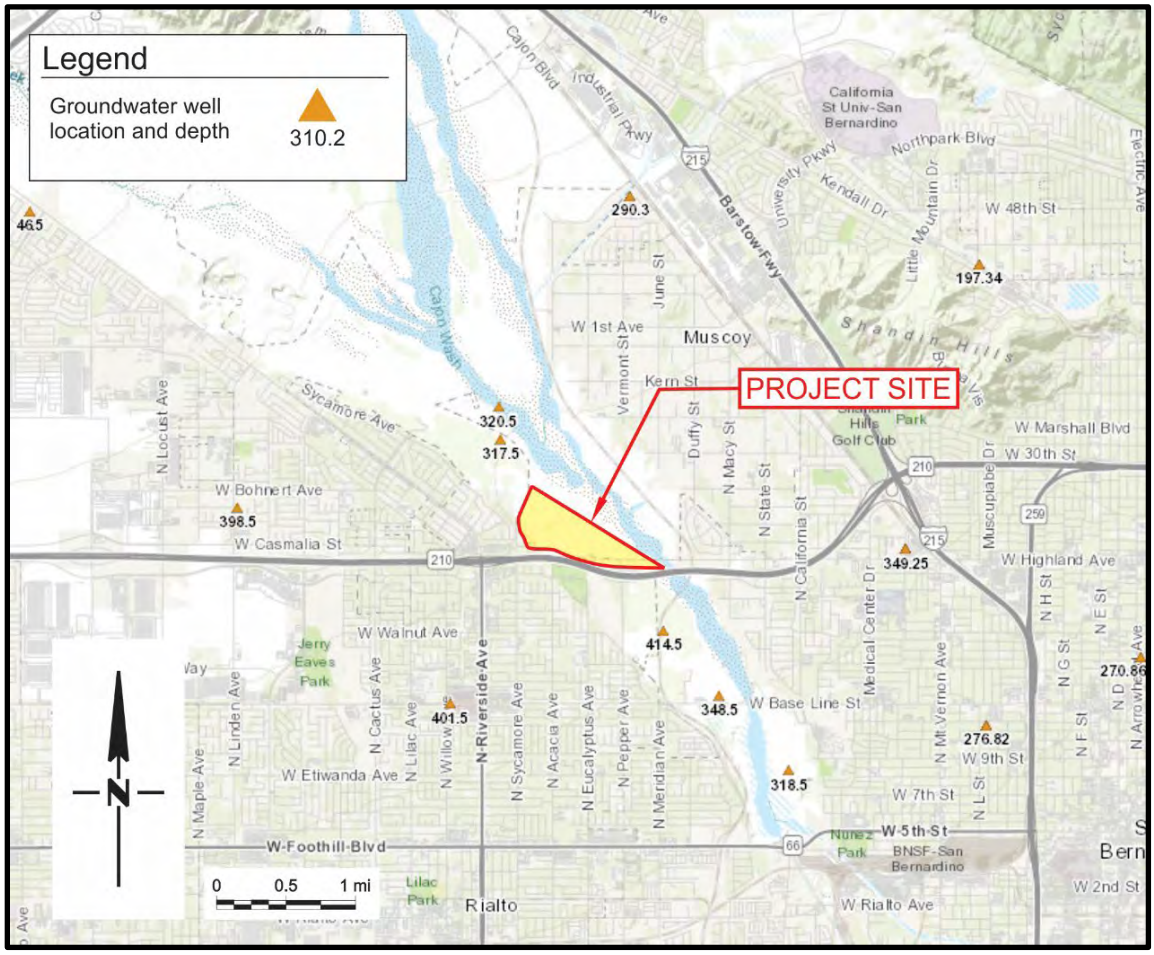


Illustration 5: Depths to groundwater within Upper Santa Ana Valley Groundwater Basin (from CDWR, 2021)

8.4. Evidence Against Holocene Active Faulting

As summarized in Section 7.0, the primary objective of our site study was to determine whether Holocene-active faulting (ruptured the ground surface within the last 11,700 yrs.), as defined by the state of California, Alquist-Priolo Earthquake Fault Zoning Act, is present beneath the site. Fortunately, in most instances during this study our exploratory trenches were excavated to depths that expose pre-Holocene age geologic units. Where pre-Holocene age units were observed to be continuous and unbroken (i.e., not offset), then the possibility of Holocene-active faulting could be ruled out. However, in few locations, pre-Holocene-age units could not be reached through conventional trenching due to depth restrictions of the equipment used for this study. Under some

circumstances, areas of the trench bottoms were locally deepened by hand excavation to reach the underlying older alluvium so that reasonable projections could be assumed. Where deepening of the trench was impractical, at least 15 to 20 feet of younger alluvium was exposed in the exploratory trench. Where detailed logging proved the full depth exposure of the younger alluvium to be un-faulted, correlations between the age of alluvial deposits and recurrence intervals were utilized to assess the potential risk of fault rupture through the trench. For example, radiocarbon dates acquired from multiple samples within various trenches indicate that the younger alluvium encountered at depth throughout the subject site and surrounding areas was deposited over the last 1,000 to 3,000 ybp. When we utilize a relatively conservative fault recurrence interval of 300 years for the San Bernardino section of the San Jacinto fault, the sediments in the trenches should have been subject to a minimum of 3 significant earthquake events in the trenches and as many as 10.

Based on the parameters summarized above, no evidence of Holocene-active faulting was identified within trenches FT-2, FT-3, and FT-6a, FT-6b, FT-7, and FT-8 completed by Tetra Tech for this study nor within trench FT-4 completed by L&A (1995) northeast of the Southern Parcel and T-1 and T-2 completed by SCG (2021) southeast of the Southern Parcel. Each of these trench locations are shown on the Fault Exploration Map, Plate 1. Detailed logs of Tetra Tech's trenches are graphically presented on Plates 2a through 2o. Pertinent trench logs by other consultants are presented in Appendix B. Descriptions of stratigraphic conditions identified in each these exploratory trenches along with opinions relative to Holocene active faulting are organized by trench as follows:

Tetra Tech Trench FT-2

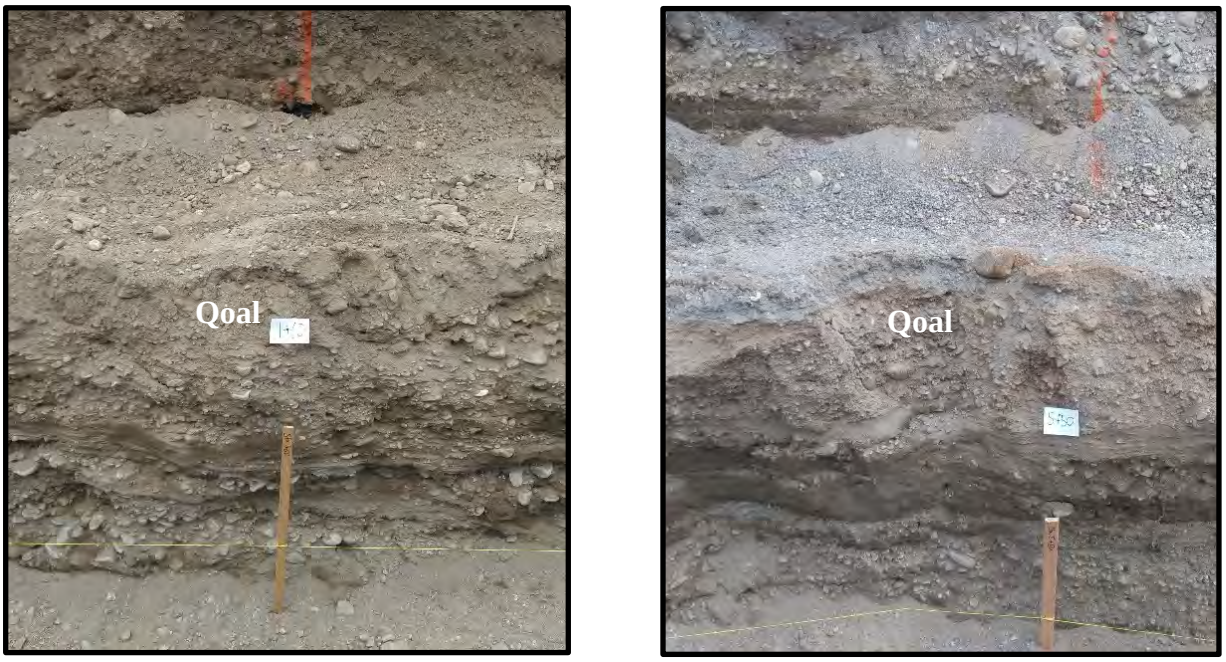
Fault trench FT-2 was excavated within the bottom of a detention basin along the southerly perimeter of the Vulcan plant site. By positioning the trench within the basin bottom we were able to avoid conflicts with Vulcan operations and the top of the trench would be up to about 15 feet lower than the surrounding terrain.



Photograph 4: View to the west, exploratory trench FT-2 within detention basin.

Sediments observed within FT-2 were comprised of artificial fill associated with debris within the basin bottom underlain by alluvial deposits. Through detailed logging and geologic evaluation, continuous and overlapping sequences of coarse-grained and fine-grained alluvial strata were identified throughout the length of the trench excavation, ruling out the possibility of faulting.

Based on soil texture and presence of scattered grus within the alluvial sediments, initial assessments indicated that the alluvium exposed within FT-2 was likely Pleistocene age. Confirmation pIR-IRSL testing was subsequently performed and provided age dates on the order of 35,000 ybp.



Photographs 5 & 6: FT-2 Station 1+60 (left) and Station 5+50 (right) showing continuous/unbroken strata within older alluvium (35ka ybp).

Tetra Tech Trench FT-3

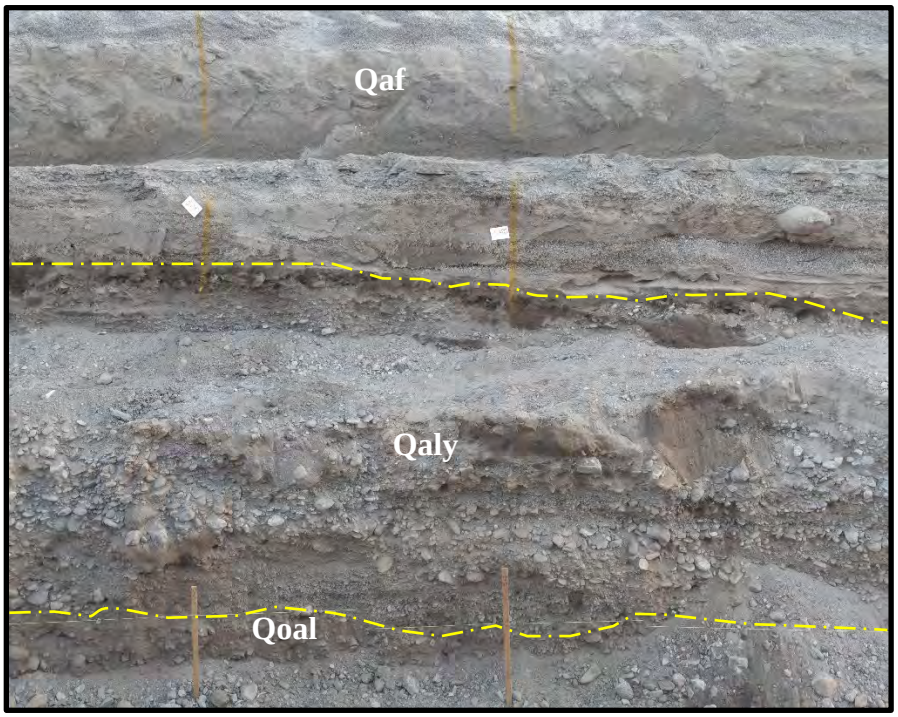
Fault trench FT-3 was excavated at the ground surface of the operating aggregate plant. The trench was situated west of FT-2 and was positioned to overlap with the west terminus of FT-2. Two large aggregate stockpiles were present to the north and south of this trench location. Based on the elevations of the older alluvium exposed in FT-2, FT-3 was excavated up to approximately 18 feet below the ground surface, the maximum reach of the excavator. Portions of the trench were shallowed to about 15 feet due to space constraints associated with the adjacent stockpiles.

FT-3 was mantled with approximately 3 to 8 feet of artificial fill associated with aggregate waste from stockpiles and trucking. At the western terminus of FT-3, the fill material abruptly thickened to the full depth of the trench. Based on our review of historic mining pit excavations, the abrupt thickening of the fill materials within the west end of the trench corresponds to the edge of the former Winter Pit backfill materials that are estimated to extend to a depth of 40 feet or more.



Photograph 7: Eastern terminus of exploratory trench FT-3. View to the west.

Two distinct alluvial bodies were exposed beneath the surficial fill materials. The upper alluvial body measured approximately 5 to 13 feet in thickness, however the surface and total thickness of the alluvium was clearly modified by past mining operations. Based on a lack of soil development and its stratigraphic position near the ground surface, initial assessments suggested a Holocene age for this alluvium. Subsequent radiocarbon testing of carbon flakes collected within finer-grained sediments within the mid-section of the younger alluvium placed an age of at least 2.12 ka ybp.



Photograph 8: Exploratory trench FT-3 (Sta. 3+80) depicting artificial fill associated with aggregate operations, underlain by Holocene younger alluvial deposits, underlain by Pleistocene older alluvium.

Alluvial sediments similar to those exposed in FT-2 were exposed beneath the younger alluvium throughout much of the trench excavation. By observation, the lower alluvial body was classified as Pleistocene age older alluvium. Subsequent IRSL testing of sediments collected just below the younger alluvium contact provided age dates of approximately 22,000 ybp. However, from stations 0+10 through station 1+28, the bottom of the trench exposed only younger alluvium to the maximum depth of the trench (El. = 1,310). Yet, after comparing the elevation of the upper contact of the older alluvium exposed within the overlapping section of FT-2 (El. = 1,308), it was determined that the older alluvial surface between stations 0+10 through station 1+28 was likely not reached by one to two feet due to depth limitations of the excavator. Other very local sections of the trench, between stations 3+00 through 3+52, did not penetrate the younger alluvial sediments due to trench depth limitations and local scouring. This section of trench was hand excavated/potholed to confirm the presence of older alluvial sediments within 1 to 2 feet of the bottom of the trench.

Upon further examination of FT-3 trench log presented on Plates 2h and 2i, the surface of the older alluvium gradually drops in elevation approximately 11 vertical feet over a horizontal distance of about 700 feet, from west to east. This gradual drop of the older alluvial surface (±1.6 %) is consistent with a component of the overall down gradient fall expected for an ancient Lytle Creek. Nevertheless, no evidence of faulting was identified within the Pleistocene age alluvium exposed within the length of FT-3.

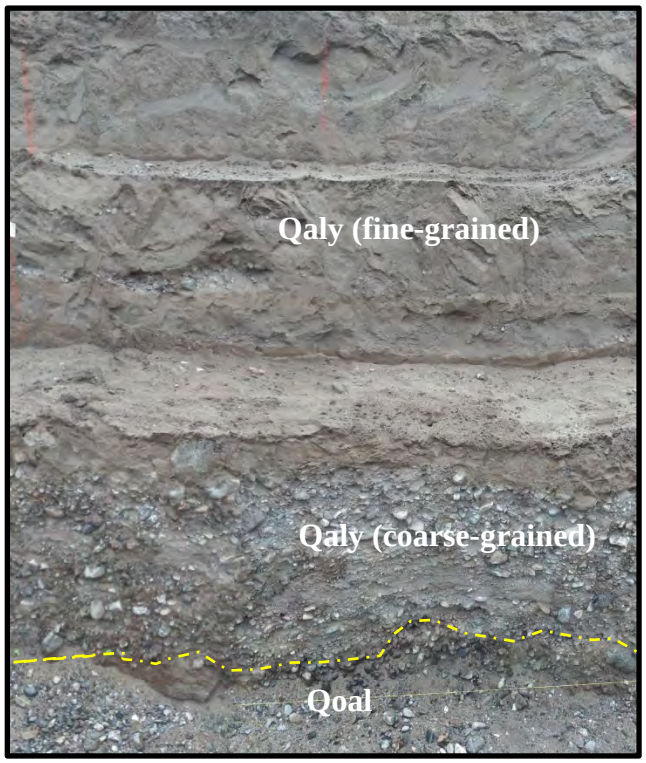
Tetra Tech Trench FT-6a and FT-6b

Fault trench FT-6a and FT-6b were excavated approximately 1,000 feet south of the Vulcan materials plant in a parcel located south of the eastbound Interstate 210 freeway offramp, referred to herein as the Southern Parcel. Though much of the property is bisected by the remnants of a tributary wash with protected vegetation and land use restrictions, the easterly portion of the property offered relatively unobstructed access to extend our overlapping exploratory trenching program to the east, in close proximity to the projection of the suspected faulted groundwater barrier. Trenching with this parcel was completed with two overlapping trench segments, FT-6a and FT-6b, to maximize our coverage within the property.

FT- 6a and FT-6b are mantled with minor accumulations of cultivated soil underlain by about 10 to 13 feet of finer-grained fluvial deposits and possibly some wind-blown aeolian deposits. This upper alluvial unit is comprised primarily of massive to thinly stratified silty sand and sandy silt deposits that are highly bioturbated with krotovina. The finer grained strata are locally incised by coarse-grained sand and gravelly sand channels with some cobble beds. This upper alluvial unit likely represents a low to intermediate energy depositional environment of the Lytle Creek flood plain during the late Holocene, likely on the order of several hundred years ago.

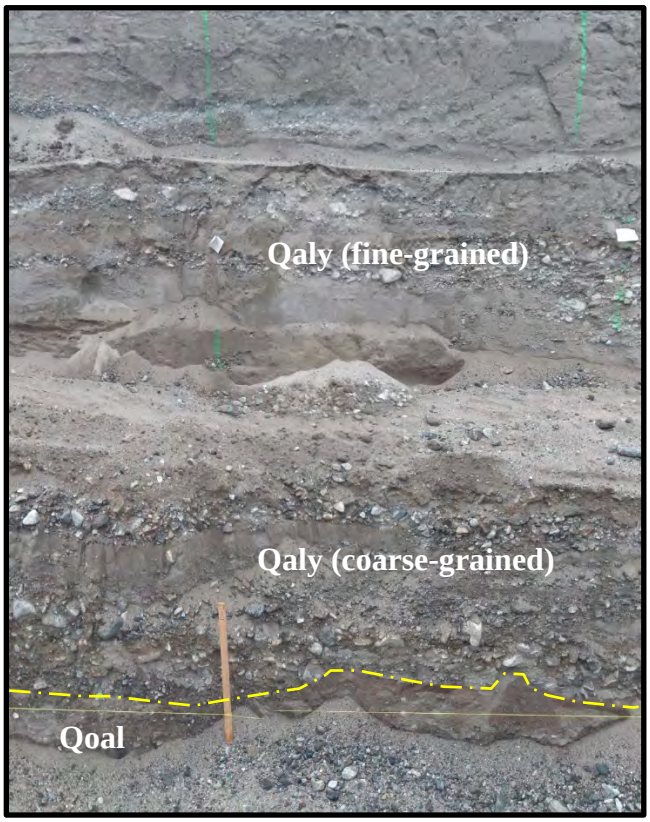
At depths below 10 to 13 feet, the alluvium becomes primarily coarse-grained with thick sequences of overlapping and channelized gravely sand and sandy gravel with abundant cobbles and few boulders. The coarse-grained sequences are generally friable and contain subangular to subrounded crystalline clast. Occasional carbon-rich, silty sand lenses up to 1 to 2 feet in thickness and continuous over tens of feet were encountered within this unit of braided stream deposits.

Based on radiocarbon test result from select carbon samples collected within FT-6a, this intermediate alluvial body was deposited from 1,750 to about 2,470 ybp.



Photograph 9: Exploratory trench FT-6a. Carbon samples from upper fine-grained sequences reflect AMS age dates of 1.75ka ybp. Manganese-stained coarse-grained older alluvial sediments (IRSL dated 20.6ka ybp).

Along the deepest sections of the trenches, about 1 to 2 feet of older alluvium was encountered within the western section of FT-6a (from about stations 2+21 through 3+11) and continues within much of FT-6b (from about stations 0+0 through 0+79). Where encountered, the older alluvium forms a distinct contact between the overlying younger alluvium. The contact is defined by a weakly cemented textural change that is distinctly less friable and includes mostly coarse-grained sediments that locally exhibit manganese staining with local accumulations of grus. A sediment sample collected from this alluvial body produced an pIR-IRSL age date 20,600 ybp confirming a late Pleistocene age of the older alluvium.



Photograph 10: Exploratory trench FT-6b (Sta. 0+40).

Upon assessment of detailed logging, overlapping stratigraphic continuity was identified within the younger alluvium exposed across the full width of trenches FT-6a and FT-6b to depths of up to 20 feet, with exception to a local area that was deeply incised by a channel identified between stations 10+00 and 20+00 within FT-6a. Since this section of the trench would possibly bisect the suspected faulted groundwater barrier shown on the Fault Exploration Map, Plate1, the trench was locally deepened by creating a lower platform during backfill operations so that the excavator could reach the trench bottom. By deepening the trench an additional 4 to 5 feet, stratigraphic continuity was identified within the younger alluvium beneath the channelized deposits. In addition, a near horizontal, unbroken older alluvium contact was exposed beneath the younger alluvium near the bottom of the deepened section the trench.

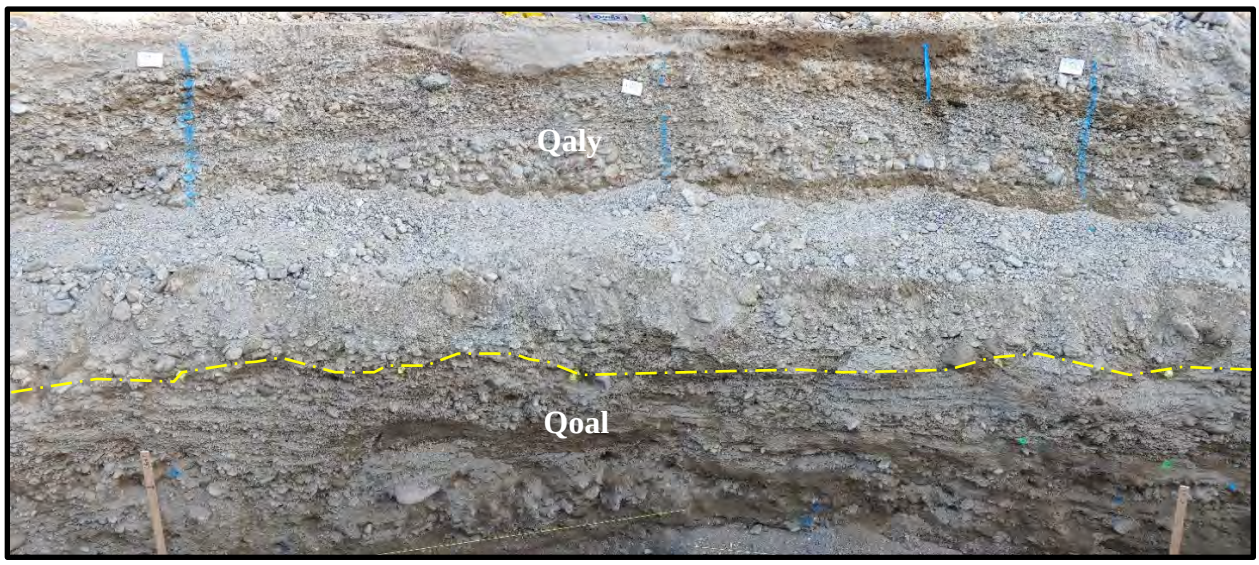
Based on this exposure, it is highly likely that the older alluvium exposed within the western section of the trench continues easterly just beneath the trench bottom and therefore, the probability for Holocene active faulting beneath FT-6a and FT-6b is remote.

Tetra Tech Trench FT-7

Exploratory trench FT-7 was excavated within a portion of the paved parking utilized by Vulcan personnel. The trench was positioned to overlap with the eastern extent of FT-2 and overlap the western projection of FT-6b.

Sediments observed within FT-7 were comprised of variable thickness of surficial artificial fill to depths of a few feet underlain by alluvial deposits. Alluvium, to depths of about 10 to 13 feet below the ground surface, are primarily coarse-grained and crudely stratified with sequences of overlapping and channelized gravely sand and sandy gravel with abundant cobbles. The coarse-grained sequences are generally friable and contain subangular to subrounded crystalline clast. Few sand lenses with minor accumulations of carbon fragments were identified. Based on observation and verified through radiocarbon testing of one carbon sample identified within FT-7, the upper alluvium is categorized as younger alluvium with an age of approximately at least 1,600 ybp.

As anticipated by our findings from FT-2 to the west, older alluvium was encountered beneath the younger alluvium throughout the lateral extent of the trench and forms a distinct contact between the overlying younger alluvium. The contact is defined by a weakly cemented textural change that is distinctly less friable and includes mostly coarse-grained sediments with accumulations of grus. Results of pIR- IRSL testing of granular sediments sampled within the older alluvium identified within FT- 7 provided a late Pleistocene age of deposition on the order of 26.8ka ybp. Upon assessment of detailed logging, no evidence of faulting was identified within FT-7.



Photograph 11: Exploratory excavation FT-7 between Sta. 1+20 – 1+40. Blue spray paint dots within older alluvium indicate grus.

Tetra Tech Trench FT-8

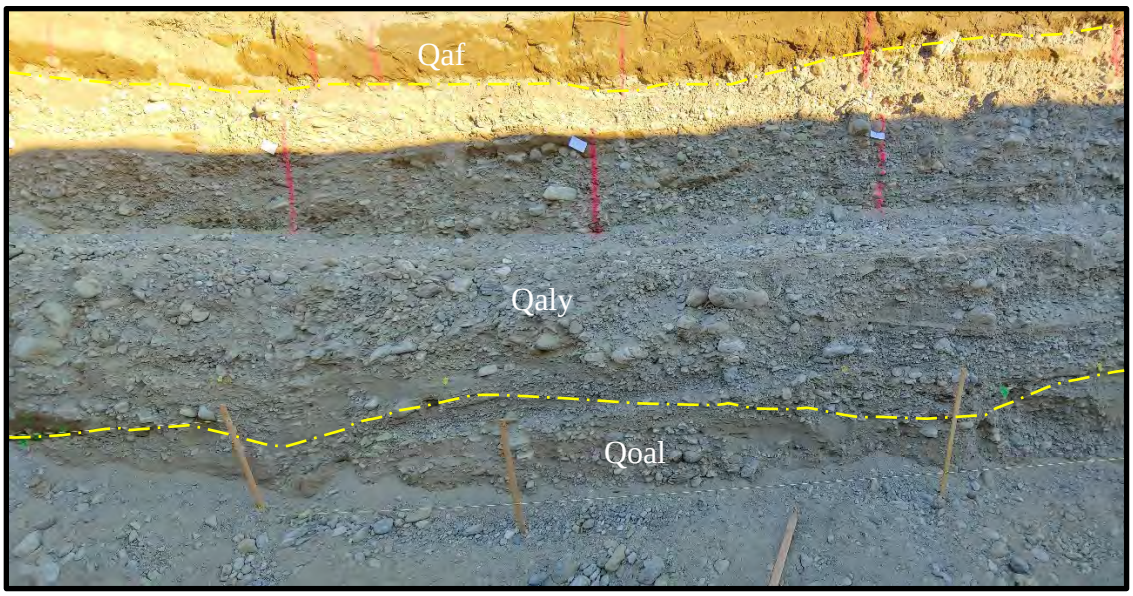
Exploratory trench FT-8 was positioned along the north-central border of the Vulcan site. The strategy for placement of FT-8 was that it would intercept a more northern projection of the suspected concealed faulted groundwater barrier and would also overlap and extend further east of the offsite trenching completed within the Southern Parcel (FT-6a and FT-6b).

FT-8 was also mantled with up to approximately 7 feet of artificial fill that is underlain by younger alluvial soils. The younger alluvium is primarily coarse-grained with thick sequences of overlapping and channelized gravely sand and sandy gravel with abundant cobbles and few

boulders. The coarse-grained sequences are generally friable and contain subangular to subrounded crystalline clast. Occasional carbon-rich, silty sand lenses up to 1 foot in thickness were encountered within this unit. Based on radiocarbon test results from select carbon samples collected within FT-8, this younger alluvial body ranges in age from approximately 1,190 to 2,420 ybp.

Beneath the younger alluvium, continuous sequences of coarse-grained alluvial strata were identified throughout the length of the trench. This older alluvial body also forms a distinct contact defined by a weakly cemented textural change that is distinctly less friable than the overlying alluvial body and exhibits slight color variations. Upon close examination, the coarse rock fragments exhibit in-place granular disintegration characteristics indicative of grus. Based on soil texture and presence of scattered grus within the alluvial sediments, initial assessments indicated that the alluvium is most likely Pleistocene age. Sediment samples of the older alluvium were collected and submitted to CSULB laboratory for confirmation pIR-IRSL testing. Laboratory test results confirmed an age of deposition on the order of 23.6ka ybp.

Upon assessment of detailed logging, strata within the younger and older alluvial bodies were found to be continuous or showed repetitive sequences of overlapping strata comprised of both coarse grained and fine-grained earth materials.



Photograph 12: Exploratory excavation FT-8 between Sta. 1+70 – 1+90. Carbon samples from Qaly range from 2.0 to 2.42ka ybp. IRSL date from Qoal sediments indicate Pleistocene age (23.6 ybp).

8.5. Evidence for Holocene Active Faulting

Tetra Tech Trench FT-1

Exploratory trench FT-1 was positioned along the northwestern border of the Vulcan plant site. The purpose for positioning FT-1 along this boundary of the site was to intercept the southerly extension of multiple Holocene active faults identified by earlier GRA studies and to extend our

fault study coverage further to the northeast. FT-1 was also positioned to intercept any throughgoing faults that were identified by ECI within the former Winter Pit as shown on the Fault Exploration Map, Plate 1.

FT-1 extended over 1,525 lineal feet and was the longest and most continuous exploratory trench excavated during this study. Geologic units identified within FT-1 included minor to moderate accumulation of surficial artificial fills and colluvium deposits. The fill materials appear to be associated with aggregate spoils and debris from past plant operations. Varying thicknesses of colluvium shed from the elevated terraces that border the western and northwestern perimeters of the site were also encountered near the ground surface.

Beneath the surficial units, younger alluvial soils varying in total thickness from as little as 3 feet to 16 feet or more were traced across the full length of FT-1. Three organic samples were collected from isolated fine-grained pockets within the coarse-grained alluvium for subsequent radiocarbon dating. Results of the radiocarbon dating for 2 of the samples (C-1 and C-3) returned unusually low age dates around 100 ybp. After discussions with laboratory personnel, it was determined that these initial samples were likely from decayed root matter. The third sample (C-4), however, returned with a date of approximately 2,000 ybp.

During our initial test pit exploration phase of this study, two sediment samples were collected from the younger alluvium (OSL-1 and OSL-2) that was later crossed by FT-1. OSL test results from these samples provided age dates ranging from 3,100 to 3,300 years b.p. The age range, soil characteristics and maximum thickness of the younger alluvium identified within FT-1 was found to correlate well with the same units identified over the extent of this study.

In most instances, older alluvium was identified beneath the younger alluvium exposed within FT- 1. A few exceptions included older alluvium juxtaposed over younger alluvium where significant faults were encountered and local areas of the trench where the younger alluvium appears to have scoured just below the reach of the equipment used for this study. The distinct soil textural characteristics, contrasting color variations and intact grusification of rock fragments identified within the older alluvial materials were the primary characteristics initially used to differentiate the younger and older alluvial units identified with FT-1. Subsequent pIR-IRSL laboratory testing provided estimates of sediment ages varying from 19,400 to 41,100 years b.p. to confirm a Pleistocene age of deposition for the older alluvium.



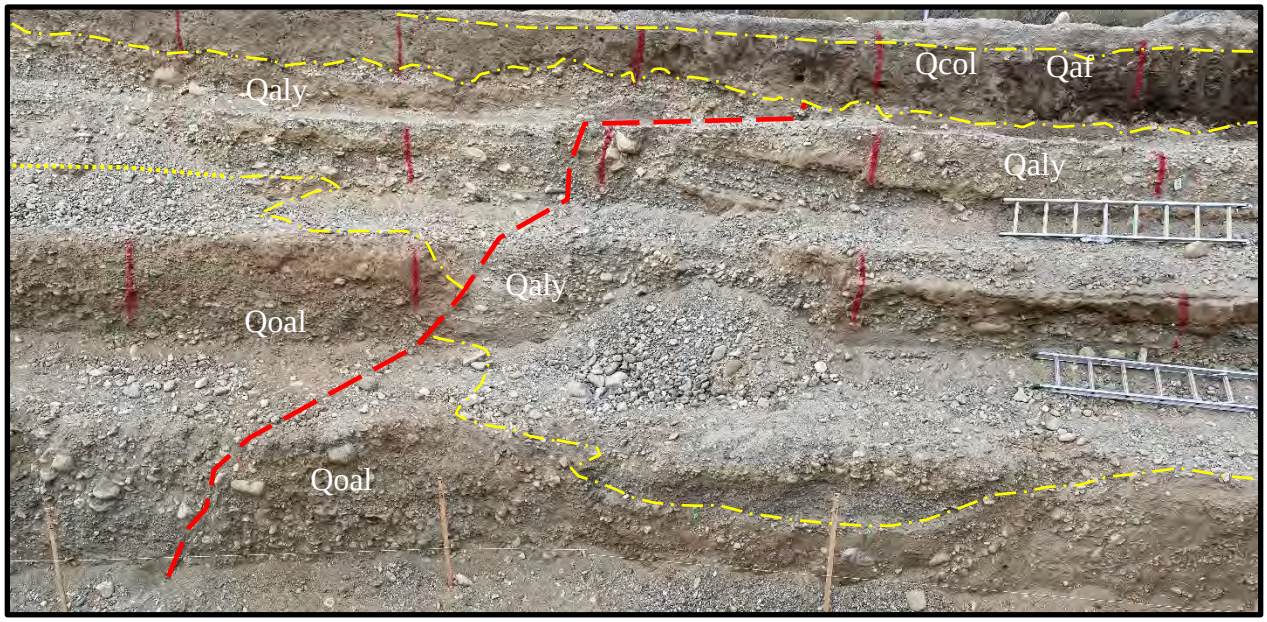
Photograph 13: Rock clast grusification (grus) identified in Qoal.

Faults were identified at various locations along the traverse of FT-1 and were carefully logged by Tetra Tech engineering geologists. Starting from the southerly end of the trench and continuing northward to about station 6+88, a total of 4 faults were identified. Unfortunately, the fault projections entered the trench at an oblique angle, rather than at a preferred more perpendicular angle, which required logging of the faults across wider sections of the trench. Therefore, for discussion purposes, the trench stationing references herein will refer to the lowest section of the trench rather than the top of the trench.

At about station 0+32, a near vertical fault was identified with a strike of N11W. The fault extends upwards through older alluvial and younger alluvial materials and terminates at the base of colluvial soil. The fault zone within the older and younger alluvium is represented by a 2- to 3- inch-wide zone of rotated clasts and warped strata. The apparent vertical offset between the older and younger alluvium was measured at approximately 2.8 feet with a reverse component of movement. The base of the overlying colluvium was not visibly offset, however, minor thickening of the colluvial soil was apparent at the intersection with the fault. Since this fault clearly ruptured younger alluvial sediments estimated to be approximately 2,000 to 3,000 years old, we designate this fault to be a Holocene-active fault as defined by the State of California, Alquist-Priolo Act.

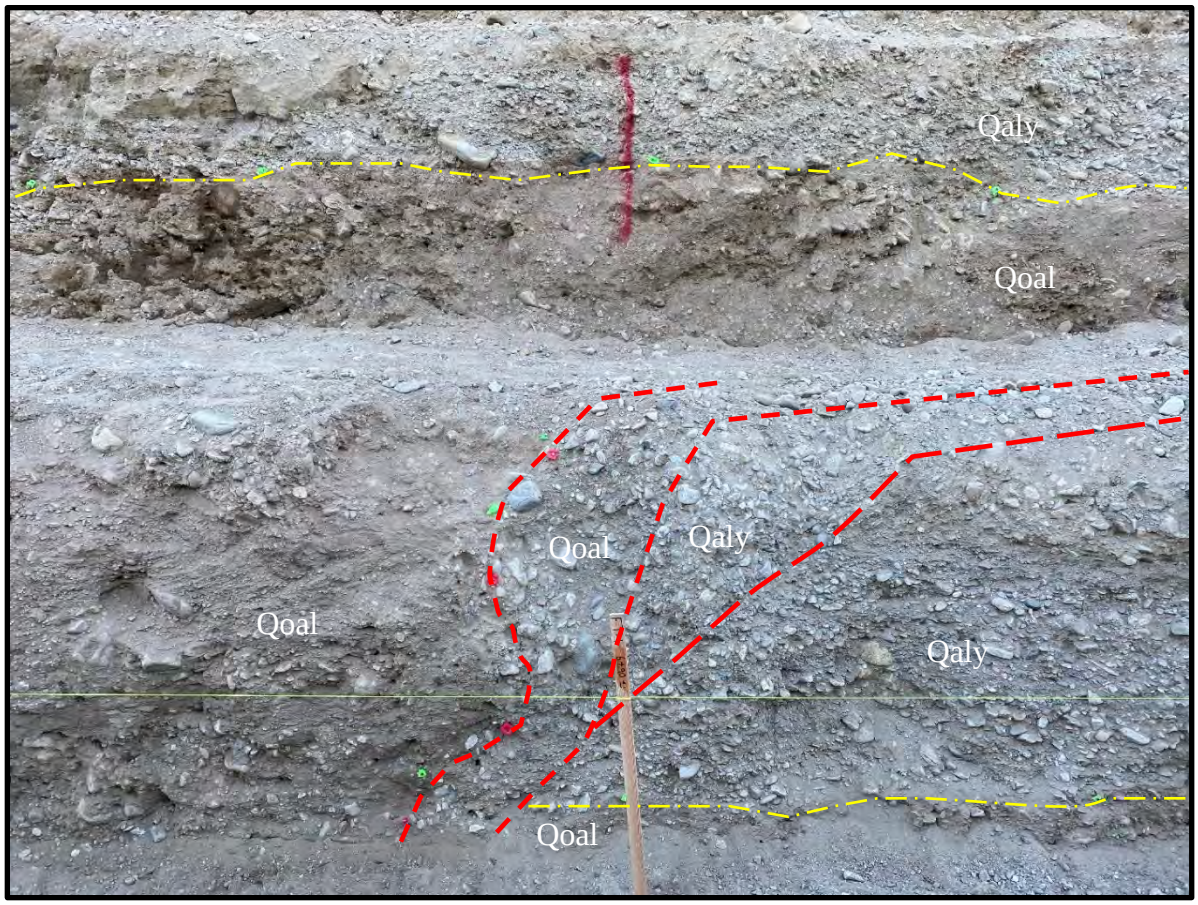
A less significant fault was identified at about station 1+20 within FT-1. This feature was identified only within the lower section of the older alluvium and was recognized by a very subtle presence of rotated clasts and a truncated gravel beds. The fault strikes N55W and dips 70NE to vertical. Though this fault is believed to die out within Pleistocene older alluvium, it lines up well with a similar questionable fault strand identified by GRA, and therefore, is graphically presented on the Fault Exploration Map, Plate 1.

The third fault identified at about station 1+83 within FT-1 is similar to the first fault identified at station 32+00 in that this fault strikes roughly N10W and dips 76SW and is represented by a 2- to 3-inch-wide zone of deformation, exhibiting 2- to 3-feet of apparent vertical offset with a reverse component of movement through the older alluvium / younger alluvium contact and up to the base of the overlying colluvium. Apparent vertical offset was impressively depicted by warping and offset of a well-developed, Pleistocene- age, 2- to 3-foot thick buried paleosol against coarse-grained gravel beds of the overlying younger alluvium. Offset of the colluvium could not be distinguished near the ground surface, however, the fault clearly offsets Holocene-age sediments within the younger alluvium estimated to range from 2,000 to 3,000 years b.p. As such, this fault is designated a Holocene-active fault by State definition.



Photograph 14: Holocene-active fault exposure within exploratory trench FT-1 (Sta. 1+80 – 1+90). Note offset and dragged older alluvial paleosol at middle bench and truncated cobble beds with rotated clasts along fault.

The fourth and final fault identified within FT-1 was somewhat unique as compared to the other faults identified within FT-1. This fault initiates as a rather broad zone of deformation and minor faulting starting at about station 6+60, and then forms a well-defined rupture zone at about station 6+88. The fault projects through the trench at a very oblique angle with a strike of N13E and vertical dip. Because of this oblique projection through the trench, the graphic depiction shown on the trench log, Plate 2b through 2o, is rather extensive across the horizontal component of the trench. However, coarse-grained and fine-grained sequences within the older and younger alluvium are warped and truncated along the primary fault with up to 7 feet of apparent vertical offset measured at the older alluvium / younger alluvium contacts. The fault projects to near the ground surface where it terminates at the base of artificial fill. Interestingly, gaps in the colluvium are present on both sides of the fill materials beneath the surface projection of this fault. In addition, the colluvium appears to thin on either side of the fault which may suggest a more recent ground rupturing event. Unfortunately, additional exposures would be warranted to corroborate this assumption. For the purposes of this study, this fault clearly ruptured younger alluvial sediments estimated to be approximately 2,000 years old and therefore, we designate this fault to be a Holocene-active fault as defined by the State of California, Alquist-Priolo Act. Lastly, the amount of apparent vertical displacement measured on this section of the fault may suggest multiple recurring events along the fault strand and its somewhat unique N13E strike could be evidence for a step-over or transfer of strain with the Glen Helen segment of the San Jacinto fault zone to the northeast.



Photograph 15: Holocene-active fault exposure within exploratory trench FT-1 (Sta. 6+90) exhibiting up to 7 feet of apparent vertical offset. Reverse sense of movement. Rotated clasts within fault gauge.

No other faulting was identified in the remaining sections of the trench that exposed both older alluvium and younger alluvium. In particular, the northwesterly extensions of fault F3 interpreted by ECI (2013) was not identified within FT-1, nor was the concealed faulted groundwater barrier reported by Dutcher and Garret (1963) and included within the San Bernardino North, Earthquake Fault Zone map (CDMG, 1974). However, as an additional level of caution, Tetra Tech has included the northwest projection of ECI's fault F-3 on the Fault Exploration Map, Plate 1.

Tetra Tech Trench FT-4

FT-4 was positioned within a narrow unimproved access road that leads to elevated portions of the southeast boundary of the site. On either side of the access road are various trees and shrubs designated as protected habitat. This location was chosen since it was the most extensive piece of natural terrain (located just beyond the limits of the backfilled Winter Pit) within the site that could intercept known southeast trending faults within the site.

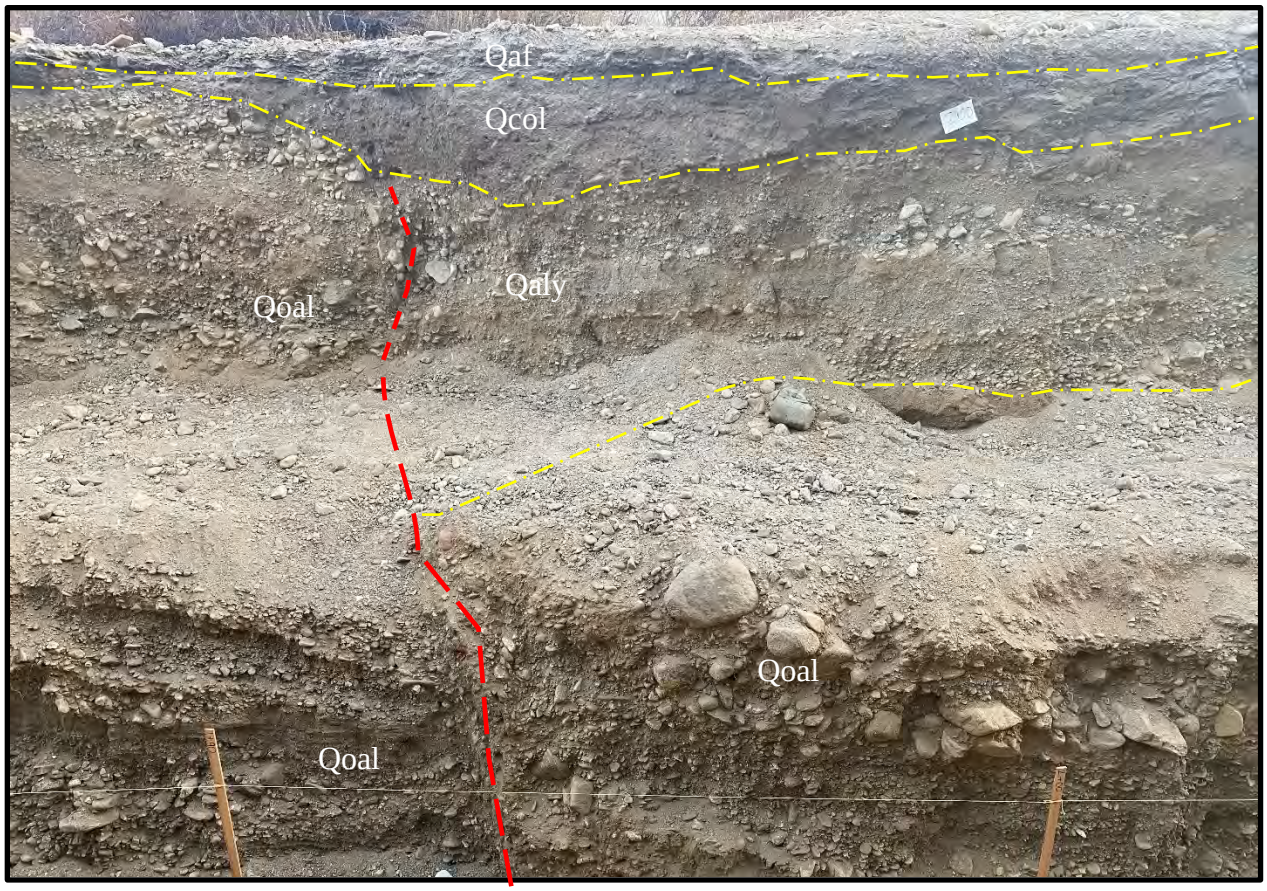


Photograph 16: Easterly view of exploratory fault trench FT-4 positioned on access road between protected habitat.

FT-4 extended approximately 371 lineal feet in a general east-west direction. Pleistocene-age older alluvium was exposed at or near the ground surface from about station 0+10 to about station 1+33 and then becomes incised by relatively thin deposits of younger alluvium. Colluvial soils

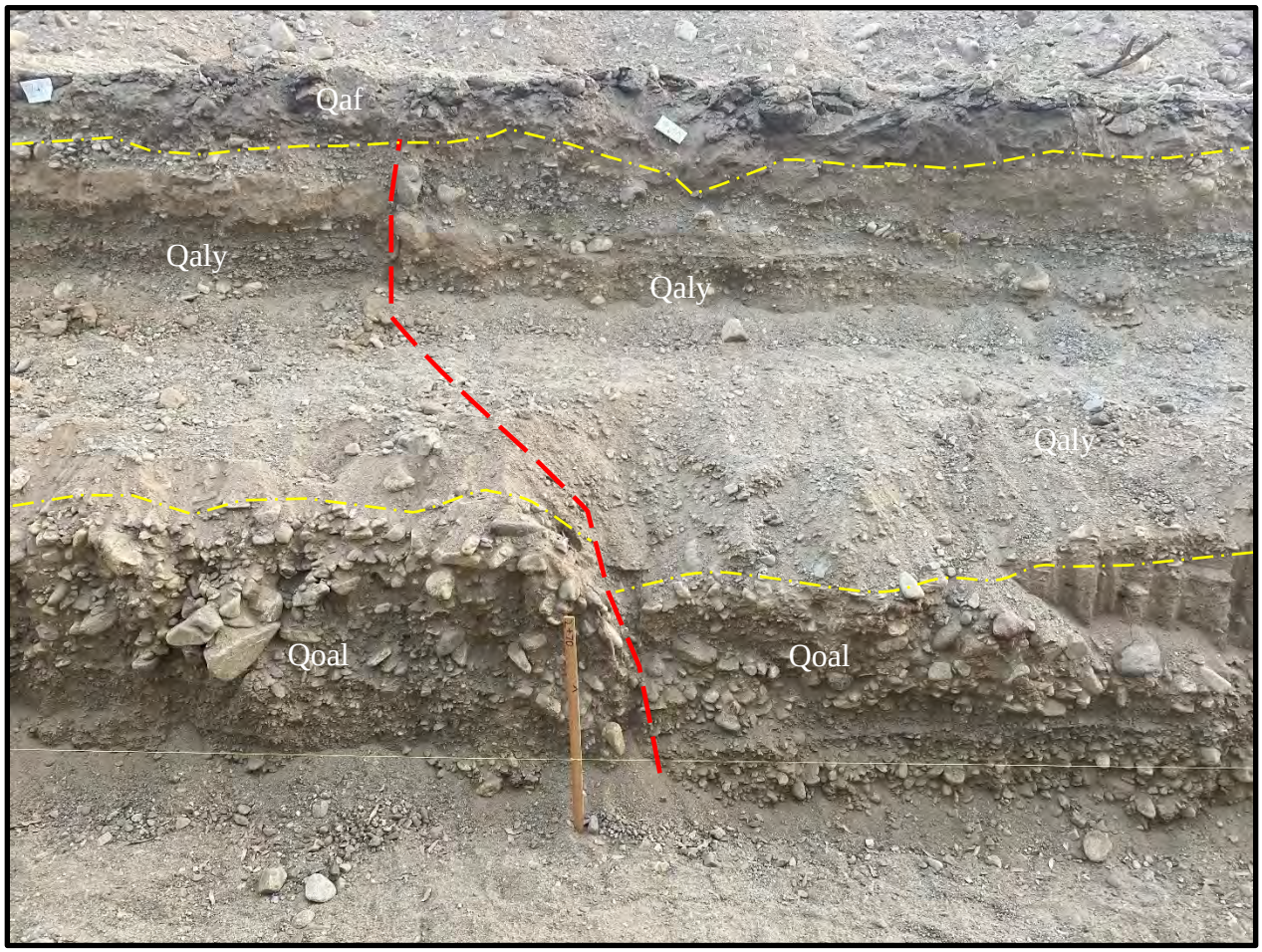
are locally present above the older alluvium beneath the west end of the trench. Two narrow faults identified beneath the colluvium extended upwards but did not appear to rupture the base of the colluvium. However, the colluvium locally thickens above the fault identified at about station 0+26.

Numerous high angle faults trending between N18 W to N20E with relatively narrow gouge zones and apparent vertical displacement ranging from a few inches to 1.7 feet were encountered in the older alluvial from the west end of the trench up to about station 1+92. At about station 1+92 a significant near vertical fault, trending N14 - 17W, with as much as 7 feet of apparent vertical offset was identified. The fault is represented as a 2- to 3-inch-wide gauge zone with rotated clasts and warped strata. The fault projects from the bottom of the trench and extends upward through older alluvium and younger alluvium and up to the base of a colluvial deposit positioned near the ground surface. The colluvium did not appear offset by the fault but its wedge-shaped geometry could suggest recent soil accumulation along a buried fault scarp at the ground surface.



Photograph 17: Exploratory trench FT- 4 (Sta. 1+90). Estimated 7 feet of apparent vertical displacement. Note rotated clasts and thickening of colluvial wedge along fault projection.

Only one other minor fault was identified in FT-4 at about station 2+71. No other faults were found beyond this station to the eastern terminus of the trench were deep artificial fills associated with the backfill of the former Winter Pit were encountered.



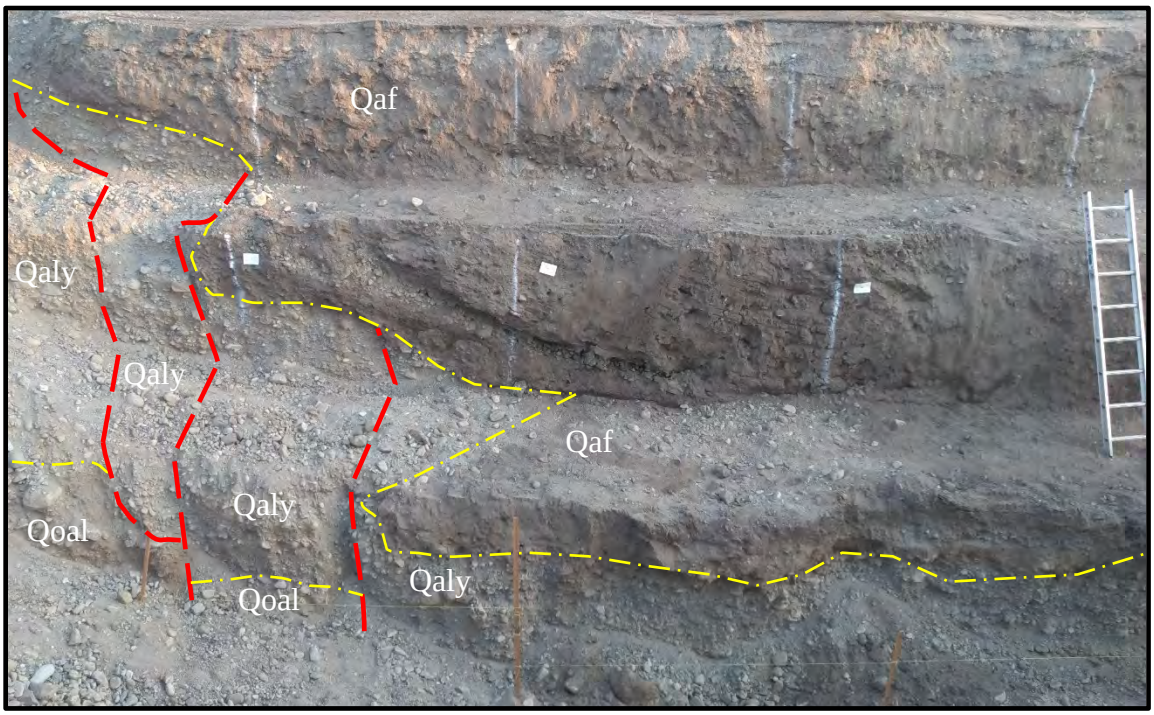
Photograph 18: Exploratory trench FT- 4 (Sta. 2+70). Estimated 0.80 feet of apparent vertical displacement. Note rotated clasts in older alluvium and offset silty sand bed within younger alluvium.

All faults identified within FT-4 have been designated Holocene-active fault as defined by the State of California, Alquist-Priolo Act.

Tetra Tech Trench FT-5

FT-5 was positioned on a narrow strip of natural terrain, located south of FT-1. The purpose of positioning FT-5 along this narrow strip of natural terrain was to attempt to intercept known and newly identified faults found within FT-1 during this study.

Only about 45 feet of FT-5 was useful since artificial fill depths increased substantially beyond this distance. At least two significant faults with as much as 4 to 5 feet of apparent vertical displacement were identified within the westerly extent of the trench. The identified faults trend from N21W with a vertical dip and N30W dipping 70NE. These faults have been interpreted as the southeasterly extension of Holocene-active faults identified in FT-1.



Photograph 19: Exploratory trench FT- 5 (Sta. 0+10). Holocene-active faulting truncated by artificial fill associated with backfill of Winter Pit.

Earth Consultants International, Inc., – 2013 Trenches

As summarized in Section 5.2 herein, Earth Consultants International, Inc. (ECI) completed numerous exploratory trenches within a portion of the subject site referred to as the Winter Pit prior to the pit being filled. From this study, three zones of northwest trending faults (F1, F2 and F3) were identified within the limits of their study. ECI concluded that fault F2 was likely no longer active or was associated with liquefaction. However, due to a lack of Holocene-age soils at the depths explored, fault F1 and fault F3 were determined by ECI to be age-undetermined faults and therefore must be considered a Holocene-active fault until proven otherwise (ECI, 2013).

S1 – Seismic Refraction Survey (Terra Geosciences, 2021)

Rather ambiguous evidence for faulting can be gleaned from the Seismic Refraction Survey, presented as Seismic Line S-1 in Appendix C. Though the relatively oblique fault angles crossing the seismic traverse make accurate fault interpretation difficult, the gradient model depicts seismic velocities suggestive of variable material properties expected in different generations of younger and older alluvial soils.

9. CONCLUSIONS AND RECOMMENDATIONS

9.1. Fault Rupture Potential

The San Jacinto fault is considered a Holocene-active fault under the State of California, Alquist-Priolo Earthquake Fault Zoning Act. The findings of this study provide compelling evidence of Holocene-active faulting within the southwesterly and western reaches of the subject site. Consequently, all faults identified within Tetra Tech's exploratory trenches FT-1, FT-4 and FT-5, as well as faults F1 and F3 identified by ECI (2013) and their interpreted surface projections indicated on the Fault Exploration Map, Plate 1 are designated as part of the San Jacinto fault zone. As such, the Holocene-active faults identified through this study are considered a risk of potential surface fault rupture in the event of a large magnitude earthquake on the San Jacinto fault zone. Therefore, structures intended for human occupancy should not be permitted over the trace of the San Jacinto fault breaks identified within the westerly reaches of the subject site.

Additionally, due to project constraints, site specific subsurface exploration and geologic evaluation of portions of the easterly reaches of the subject site could not be adequately explored to assess faulting at this time. Since the eastern reaches of the subject site are included within an Earthquake Fault Zone, it is assumed that Holocene-active faulting could exist beyond the limits of this study, unless proven otherwise through future site-specific geologic studies.

9.2. Building Setback Zones

As discussed above in Section 9.1, structures intended for human occupancy should not be permitted over the trace of the San Jacinto fault breaks identified within the westerly reaches of the subject site. Additionally, until such time that future site-specific geologic studies are completed to adequately evaluate the potential for surface rupture within the eastern reaches of the subject site, it is assumed that Holocene-active faulting could exist beyond the limits of this study. Therefore, temporary building setbacks should be established for portions of the subject site located beyond the easterly coverage limits of this study.

Recommended building setback zones have been established as shown in red hatching on the Fault Exploration Map, Plate 1and are discussed below.

- The interpreted traces of the San Jacinto fault zone within the westerly reaches of the subject property have been established based on the findings of this study. Since it was impractical to further assess the limits of faulting presented by ECI (2013) during this study, Tetra Tech has included the faults identified by ECI, as Holocene-active.

  Where sections of the San Jacinto fault are well constrained by exposures identified within exploratory trenches completed or reviewed for this study, Tetra Tech recommends a building setback of 50 feet from the eastern-most fault identified within a nearby trench exposure. Where faulting is projected more than 50 feet beyond the limit of a nearby trench exposure, a building setback of 100 feet should be established parallel to the fault projection shown on the Fault Exploration Map, Plate 1. If future site-specific geologic

studies are completed to adequately evaluate the northwesterly projection of ECI's fault F- 3, this building setback may be modified accordingly.

- A building setback of 50 feet should be established for portions of the subject site located beyond the easterly coverage limits of this study as shown on the Fault Exploration Map, Plate 1. If future site-specific geologic studies are completed to adequately evaluate the potential for surface rupture within the eastern reaches of the subject site that are beyond the limits of this study, this building setback may be modified accordingly.

It should be noted that the recommended building setback zones described above and shown on the Fault Exploration Map, Plate 1 are based on the ground surface elevations present at the time of this study. Should significant grading changes occur during future phases of site development, these recommended building setback zones may require modification based on depth of cuts and fills.

10. LIMITATIONS

This report is limited to addressing geologic hazards associated with fault rupture within the subject site. It does not include geotechnical engineering design parameters or engineering recommendations for construction of the proposed development.

The recommendations and opinions expressed in this report are based on Tetra Tech's review of background documents and on information obtained from field explorations. It should be noted that this study did not evaluate the possible presence of hazardous materials on any portion of the site.

This report is based on the proposed development and the geologic data as described herein. The geologic conditions interpreted from our field investigation and described in the referenced publications and reports are believed representative of the project area and the conclusions and recommendations contained in this report are presented on that basis. However, geologic conditions can vary in characteristics between points of exploration, both laterally and vertically, and those variations could affect the conclusions and recommendations contained herein. As such, observation by a California Professional Geologist during the grading phases of the project should be performed to confirm the basis of this report.

Changes to the applicable laws, regulations, codes, and standards of practice may occur as a result of government action or the broadening of knowledge. The findings of this report may, therefore, be invalidated over time, in part or in whole, by changes over which Tetra Tech has no control. Therefore, this report should be reviewed and recertified by Tetra Tech if it were to be used for a project design commencing more than two years after the date of issuance of this report.

This document is intended to be used only in its entirety. No portion of the document, by itself, is designed to completely represent any aspect of the project described herein. Tetra Tech should be contacted if the reader requires additional information or has questions regarding the content, interpretations presented, or completeness of this document. Reliance by others on the data presented herein or for purposes other than those stated in the text is authorized only if so permitted in writing by Tetra Tech. It should be understood that such an authorization may incur additional expenses and charges.

Tetra Tech has endeavored to perform its evaluation using the degree of care and skill ordinarily exercised under similar circumstances by reputable geologic and geotechnical professionals with experience in this area. No other warranty, either expressed or implied, is made as to the conclusions and recommendations contained in this report.

11. REFERENCES

Reports, Publications & Maps

Burnett, John L. and Hart, Earl W, 1994, "Holocene Faulting on the Cucamonga, San Jacinto, and related Faults, San Bernardino County, California," (California Division of Mines and Geology, Fault Evaluation Report FER-240, November 23, 1994) 34 p.

California Building Standards Commission, 2019 California Building Code, California Code of Regulations Title 24.

California Department of Conservation, Division of Mines and Geology, 2008, Guidelines for Evaluation and Mitigation of Seismic Hazards in California: Special Publication 117A.

California Department of Conservation, 2018, Earthquake Fault Zones – A Guide for Government Agencies, Property Owners/Developers, and Geoscience Practitioners for Assessing Fault Rupture Hazards in California: California Geological Survey Special Publication 42, revised 2018, 83 p., attachments.

California Geological Survey, 2002, Guidelines for Evaluating the Hazard of Surface Fault Rupture, 4 p., revised, California Geological Survey, Note 49.

California Public Resources Code, 1990, Division 2. Geology, Mines and Mining [2001-2815], amended by Stats. 1965, Chapter 1143, Seismic Hazards Mapping [2690-2699.6], Chapter 7.8 added by Stats. 1990, Chapter 1168, Section 3, Code §2690.

C.H.J., Incorporated, 1995, Subsurface Geologic/Geotechnical Investigation Proposed IBU Office Building Santa Fe Intermodal Facility, San Bernardino, California, prepared for Ragnar Benson, Inc., 28 p., attachments (Job No. 94137-3, dated June 7, 1995).

Clarke, Anthony Orr, 1989, Neotectonics And Stream Piracy On The Lytle Creek Alluvial Fan, Southern California, *California Geographical Society*, Vol XXIX, 1989, pp 21-42

Clopine, Gordon A., 1979, Proposed Development North of Baseline Ave. and Martin Road, West of Lytle Creek, San Bernardino, California, prepared for Mr. Edward L. Mason and Mr. Dave Crosswhite, 10 p., attachments (Dated November 13, 1979).

Clopine Geological Services, 1987, Geologic/Seismic Report for a 7.24-acre Parcel, Lassen Street and Baseline Avenue at Lytle Creek, City of San Bernardino, California, prepared for Fisher's Grading and Excavating, 21 p., attachments (Dated March 20, 1987).

Dutcher, L.C. and Garrett, A.A., 1963, Geologic and Hydrologic Features of the San Bernardino Area, California With Special Reference to Underflow Across the San Jacinto Fault, Geological Survey Water-Supply Paper 1419, prepared in cooperation with the San Bernardino County Flood Control District, 113 p.

Earth consultants International, Inc., 2013, Fault Trenching Study of the Western Portion of the Property Located at 2400 West Highland Avenue, in Unincorporated San Bernardino County, California, prepared for BBC Properties, LLC, 25 p., attachments (Project No. 3213, dated January 31, 2013).

Gary S. Rasmussen & Associates, 1977, Engineering Geology Investigation Tentative Tract Number 8230 and Adjacent Parcel to the East, 170Acre Parcel at NW Corner of Etiwanda Avenue and Terrace Road, San Bernardino, California, prepared for Summit Supply Company, 12 p., attachments (Project No. 1229, dated July 28, 1977).

Gary S. Rasmussen & Associates, 1982, Engineering Geology Investigation of Tentative Tract 11408, Northeast of Riverside Avenue and Southeast of El Rancho Verde Country Club, Rialto, California, prepared for Theodore C. King, 13 p., attachments (Project No. 1825, dated August 25, 1982).

Gary S. Rasmussen & Associates, 1984, Subsurface Engineering Geology Investigation of Proposed Snack Bar and Restroom Facilities, Frisbie Park, Rialto, California, prepared for City of Rialto Recreation Parks and Social Services, 12 p., attachments (Project No. 2057, dated October 3, 1984).

Gary S. Rasmussen & Associates, Inc., 1993, Engineering Geology Investigation and Geologic Update El Rancho Verde County Club Property Riverside Avenue and Country Club Drive, Rialto, California, prepared for The KTGY Group, 28 p., attachments (Project No. 3156, dated January 5, 1993)

Gary S. Rasmussen & Associates, Inc., 1993, Subsurface Engineering Geology Investigation El Rancho Verde Country Club Approximately 260 Acres, Rialto, California, prepared for Nitto America Co., Ltd., 50 p., attachments (Project No. 3156.1, dated June 9, 1994)

Geosoils, Inc., 1994, Preliminary Geologic Investigation Proposed Master Plan Development The Villages at Lytle Creek, Lytle Creek Development, San Bernardino County, California, prepared for Lytle Creek Land and Resources, 35 p., Volumes I, II, III, attachments (W.O. 159-A.1-AV, dated October 31, 1994).

Hart, Earl W., 1995, “Review of New Data on the San Jacinto and Lytle Creek Faults, Devore Quadrangle, San Bernardino County, California,” 22 p (California Division of Mine and Geology, Fault Evaluation Report FER-240 Supplement No. 1, March 8, 1995)

Jennings, C. W., and Bryant, W. A., 2010, Fault Activity Map of California, California Geological Survey, Data Map No. 6, Map scale 1:750,000.

Leighton & Associates, 1972, Geologic Feasibility Investigation of Tentative Tract 8612 and Adjacent Area, Riverside Avenue North of Galway Street, Rialto, California, prepared for Stubblefield Construction Company, 7 p., attachments (Project No. 2173, dated August 24, 1972).

Leighton and Associates, 1975, Supplemental Fault Investigation Study for Tract 8612 and Tentative Tract 9147, 9148, 9149, Rialto, California, prepared for Mr. John Boruchin, 3 p., attachments (Project No. 75368-1, dated December 12, 1975).

Leighton and Associates, 1976, Additional Fault Investigation Study for Tract 8612 and Tentative Tract 9147, 9148, 9149, Rialto, California, prepared for Mr. John Boruchin, 3 p., attachments (Project No. 75368-2, dated March 1, 1976).

Leighton and Associates, Inc., 1995, Fault Trenching Investigation, San Jacinto Fault Zone, Proposed State Route 30, Segment 10, Along Highland Avenue, Between Riverside Avenue and Macy Street, Cities of Rialto and San Bernardino, San Bernardino County, California, prepared for CH2M Hill, 27 p., attachments (Project No. 6930403-03, dated May 22, 1995).

LOR Geotechnical Group, Inc, 2006, Reconnaissance Level Geotechnical Feasibility Investigation, 348± Acres, BBC Properties, Rialto, North San Bernardino County, California, prepared for United Strategies, 19 p., attachments (Project No. 32209.1, dated January 25, 2006)

Li, Qingsong, and Liu, Mian, 2007, Initiation of the San Jacinto Fault and its Interaction with the San Andreas Fault: Insights from Geodynamic Modeling: Pure and Applied Geophysics 164, p. 1937-1945. https://doi.org/10.1007/s00024-007-0262-z

Onderdonk, N., McGill, S., and Rockwell, T., 2018, A 3700 yr paleoseismic record from the northern San Jacinto fault and implications for joint rupture of the San Jacinto and San Andreas faults: Geosphere, v. 14, no. 6, p. 2447-2468, https://doi.org/10.1130/GES01687.1.

Oskin, Michael, and Rockwell, Thomas, 2018, Paleoseismic Investigation of the Lytle Creek Ridge Fault: Evidence for Linked San-Jacinto-San Andreas Earthquake Ruptures, prepared for Southern California Earthquake Conference, 4 p.

Rockwell, Thomas K., Dawson, Timothy E., Ben-Horin, Jeri, and Seitz, Gordon, 2014, A 21-Event, 4000-Year History of Surface Rupture in the Anza Seismic Gap, San Jacinto Fault, and Implications for Long-term Earthquake Production on a Major Plate Boundary Fault: Pure and Applied Geophysics, V. 171, no. 9, pp. 2097-2532, 2014, https://doi.org/10.1007/s00024-014-0955-z

Sanders, Christopher, and Magistrale, Harold, 1997, Segmentation of the northern San Jacinto fault zone, southern California, *Journal Of Geophysical Research*, Vol. 102, No. B12, pp. 27453-27467, Dec 10, 1997

Schell, Bruce A., 2008, Holocene Faulting, San Bernardino Valley Area, San Bernardino County, California, *Environmental & Engineering Geoscience*, Vol. XIV, No. 2, May 2008, pp. 97-111

Shlemon, Roy J, 1994, Geomorphic and Soil Stratigraphic Age Assessments, Proposed Villages Development Aa Lytle Creek, Rialto Area, San Bernardino County, California, prepared for GeoSoils Inc on behalf of Lytle Creek Land and Resources.

Southern California Geotechnical, 2021, Fault Study Proposed Commercial/Industrial Building Pepper Avenue, South of Foothill Freeway, Rialto, California, prepared for Howard Industrial Partners, 13 p., attachments (Project No. 20G234-2, dated March 22, 2021).

Terra Geosciences, 1996, Evaluation of Surface Fault Rupture Hazard Proposed Office and Shop Buildings, J.B. Hunt Transportation BNSF Rail Yard, City of San Bernardino, California, prepared for Gittins Environmental & Engineering, Inc., 8 p., attachments (Project No. 96811-01, dated October 3, 1996).

Terra Geosciences, 1996, Geotechnical/Liquefaction Investigation Proposed Office and Shop Building, J.B. Hunt Transportation B.N.S.F. Rail Yard, City of San Bernardino, California, prepared for Gittins Environmental & Engineering, Inc., 11 p., attachments (Project No. 96811-02, dated November 7, 1996).

Tetra Tech, 2019, Geotechnical Data and Assessment Report, Vulcan Pit Redevelopment, Rialto, California, dated November 25, 2019 (Project No. GEN 19-22E).

USGS, 2018, Earthquake Hazards Program, Interactive Fault Database, https://earthquake.usgs.gov/static/lfs/nshm/qfaults/qfaults.kmz,

Aerial Photographs

Date	Film/ Flight #	Frames	Scale	Source[1]
3/25/1930	C-910	27,28,36,37	1:24,000	Fairchild Aerial Surveys
6/11/1936	C-4061	27,28	1:15,840	Fairchild Aerial Surveys
7/4/1938	AXL-1938	60-89	1:20,000	Laval Company Inc.
1/23/1953	AXL-1953B	31K-106,31K-107	1:20,000	Southwestern Aerial Surveys
10/18/1966	Universe-112-1	62,63	1:24,000	Universe Aerial Surveys, Inc.
8/21/1968	AXL-1968	11JJ-39	1:20,000	Cartwright Aerial Surveys
9/9/1968	AXL-1968	12JJ-12	1:20,000	Cartwright Aerial Surveys
9/19/1977	TG-7700	21-10,21-11	1:24,000	Teledyne Geotronics

Note: [1]Source: Aerial Photography, Special Research Collections, UCSB Library, University of California at Santa Barbara.

Figures



FIGURE 1

TETRA TECH
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TEL 909.860.7777 www.tetratech.com

VULCAN GRAVEL PIT REDEVELOPMENT - RIALTO, CA

SITE LOCATION MAP

JOB NO.	GEN 19-22E
DATE	FEB 2022
DRAWN BY	SCM
CHECKED BY	PMK

EARTHQUAKE EPICENTERS

M 5.0 to 5.9

M 6.0 to 6.9

M 7.0 to 7.9

HISTORIC EARTHQUAKE EVENTS

1)	1812 Wrightwood	M7
2)	1827 Ventura County	M6
3)	1855 Los Angeles	M6?
4)	1858 San Bernardino	M6?
5)	1880 San Bernardino	M6
6)	1889 Monrovia	M5.5
7)	1893 San Fernando Valley	M5.9
8)	1894 n/o Pomona	M6
9)	1899 Cajon Pass	M6.5
10)	1899 San Jacinto	M6.4
11)	1907 San Bernardino	M6
12)	1910 Elsinore	M6
13)	1918 San Jacinto-Hemet	M6.8
14)	1920 Inglewood	M4.9
15)	1923 Loma Linda	M6
16)	1930 Santa Monica Bay	M5.2
17)	1933 Long Beach	M6.4
18)	1941 Gardena	M4.8
19)	1971 San Fernando	M6.7
20)	1973 Pt. Mugu	M5.9
21)	1979 Malibu	M5.2
22)	1981 Pt. Mugu	M6.0
23)	1986 N Palm Sprins	M6.2
24)	1987 Whittier-Narrows	M5.9
25)	1988 Pasadena	M5.0
26)	1989 Malibu	M5.0
27)	1990 Pomona	M5.3
28)	1991 Sierra Madre	M5.8
29)	1994 Northridge	M6.7
30)	1992 Landers	M7.3
31)	1992 Big Bear	M6.2
32)	2005 Chino Hills	M5.2

Map Reference: Excerpt of Jennings, C.W., and Bryant, W.A., 2010, Fault activity map of California; California Geologic Survey, Date Map No. 6, map scale ~ 1:750,00

Used in permission from California Geologic Survey.

Earthquake epicenters from SP 116

PROJECT SITE

EXPLANATION

Geologic Time Scale			Years Before Present (Approx.)	Fault Symbol	Recency of Movement	DESCRIPTION: ON LAND	DESCRIPTION: OFFSHORE
Quaternary	Late Quaternary	Historic				Displacement during historic time (e.g. San Andreas fault 1096). Includes areeas of known fault creep.	
			200				
		Holocene				Displacement during Holocene time.	Faults offsets sea floor sediments or strata of Holocene age.
			11,700				
		Pleistocene				Fault showing evidence of displacement during late Quaternary time.	Faults cuts strata of LatePleistocene age.
	Early Quaternary		700,000			Undivided Quaternary faults - most faults in this category show evidence of displacement during the last 1,600,00 years; possible exceptions are faults which displace rocks of undifferentiated Plio-Pleistocene age.	Faults cuts strata of Quaternary age.
			1,600,000				
Pre-Quaternary				-?-		Faults without recognized Quaternary displacement or showing evidence of no displacement during Quaternary time. Not necessarily inactive.	Faults cuts strata of Pliocene or older age.

MAP SYMBOLS

- Triangle - termination portion data. Square - fault creep slippage. Hachure - linear extent of fault creep. (other symbols - see below)
- Approximate located trace
- Location uncertain
- Bar and ball on dowthrown side
- Arrows along fault indicate relative or apparent direction of lateral movement.
- Direction of fault dip
- Low angle fault (barbs on upper plate)
- 171 Numbers refer to annotations listed in explanatory text of map.
- Subject Site Location

0 5 10 mi

FIGURE 2

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VULCAN GRAVEL PIT REDEVELOPMENT - RIALTO, CA

REGIONAL FAULTS AND SEISMICITY MAP

JOB NO.	GEN 19-22E
DATE	FEB 2022
DRAWN BY	SCM
CHECKED BY	PMK

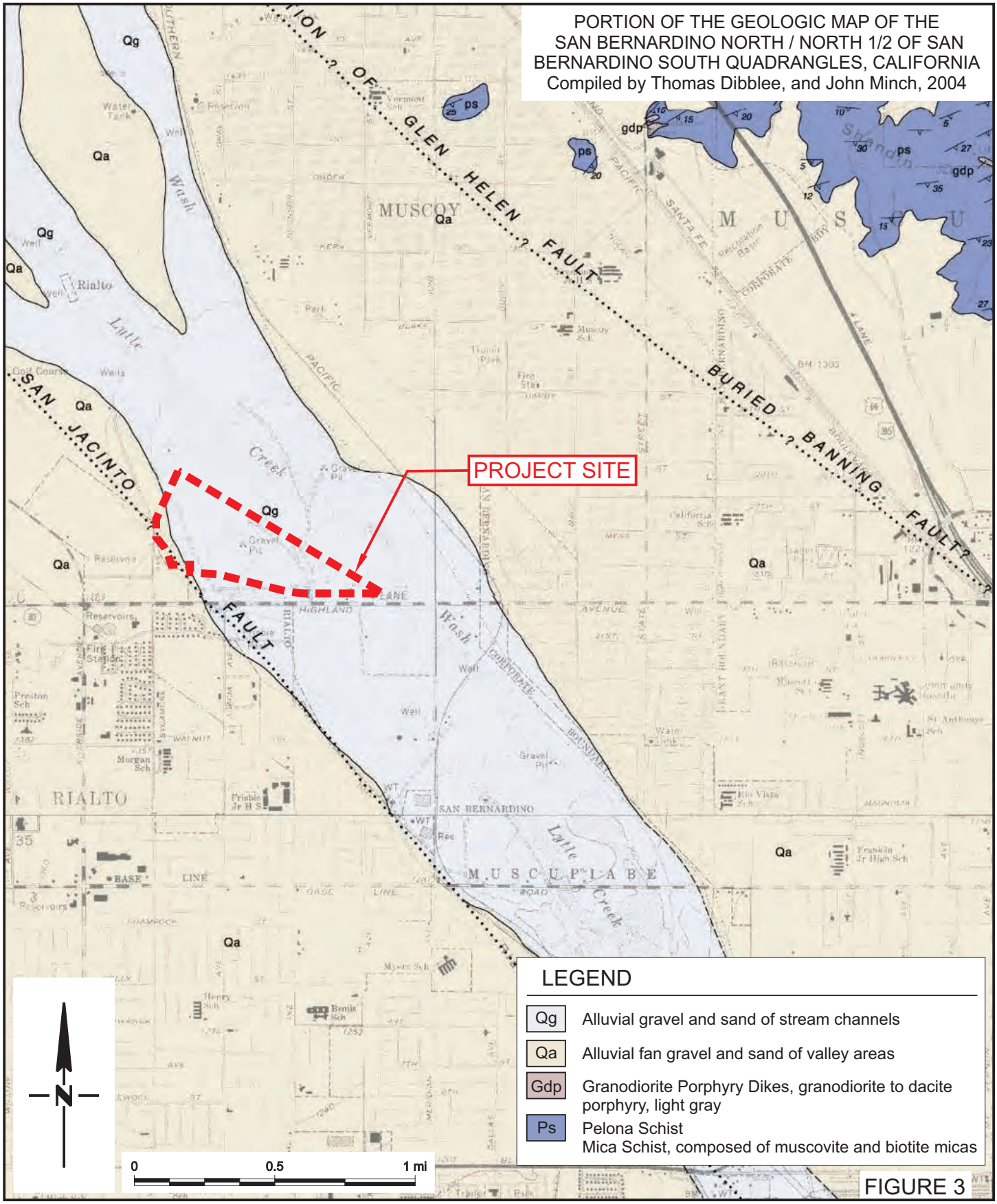


FIGURE 3

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VULCAN GRAVEL PIT REDEVELOPMENT - RIALTO, CA

REGIONAL GEOLOGIC MAP

JOB NO.	GEN 19-22E
DATE	FEB 2022
DRAWN BY	TAS/SCM
CHECKED BY	PMK

Plates

EXPLANATION

- Surveyed trench location (Tetratech, 2021)
- Geophysical Line (Terra Geosciences, 2020)
- TP-1 Test Pit Location (Tetra Tech, 2020)
- Trench Location (Southern California Geotechnical, 2021)
- Trench Location (ECI, 2013)
- Trench location (Leighton & Assoc., Inc., 1994)
- Trench Location (Rasmussen, 1980-94)
- Groundwater Lineament (CDMG, 1974) (dotted where concealed)
- Fault (queried where uncertain)
- Preliminary Building Setback Zone
- Property Line

N

0 150 300 450 600 ft

1 inch = 200 feet

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FAULT EXPLORATION MAP

Site Location: Rialto, CA

Project No.: GEN 19-22E | Date: February 2022 | Plate 1

References:
Satellite image- ArcGIS, 2021
Topography- Historic Bottom Topo, Vulcan Materials Company, 4/27/2017.

SYMBOLOGY

- Trench outline
- Trench bench
- Geologic contact
- String line
- Fault
- Carbon dating sample location
- OSL/IRSL dating sample location

UNIT DESCRIPTIONS

af — Artificial fill: Fill related to grading, mining, or utility backfill operations. Generally consists of brown to gray, loose to medium dense silty sand to gravelly sand, olive brown to grayish brown, with varying amounts of cobbles and boulders up to 2ft in dimension. Trace amounts of refuse encountered locally.

Qcol — Colluvium: Silty Sand, fine grained, scattered medium to coarse sand and gravel, dry to damp, loose, some pores, trace roots, weak ped development, gradational contact at base, dark grayish brown (2.5Y 4/2) to olive gray (5Y 4/2) when moist, light yellowish brown (2.5Y 6/3) when dry.

Qaly — Younger Alluvium: Channelized sand to gravelly sand with local cobble and trace boulder layers, fine to coarse grained, local silty sand layers, friable, poorly to well bedded, subangular to subrounded granitic and metamorphic clasts. Generally gray (2.5Y 6/1) to light gray (2.5Y 7/1) to light brownish gray (2.5Y 6/2) to olive brown (2.5Y 4/3).

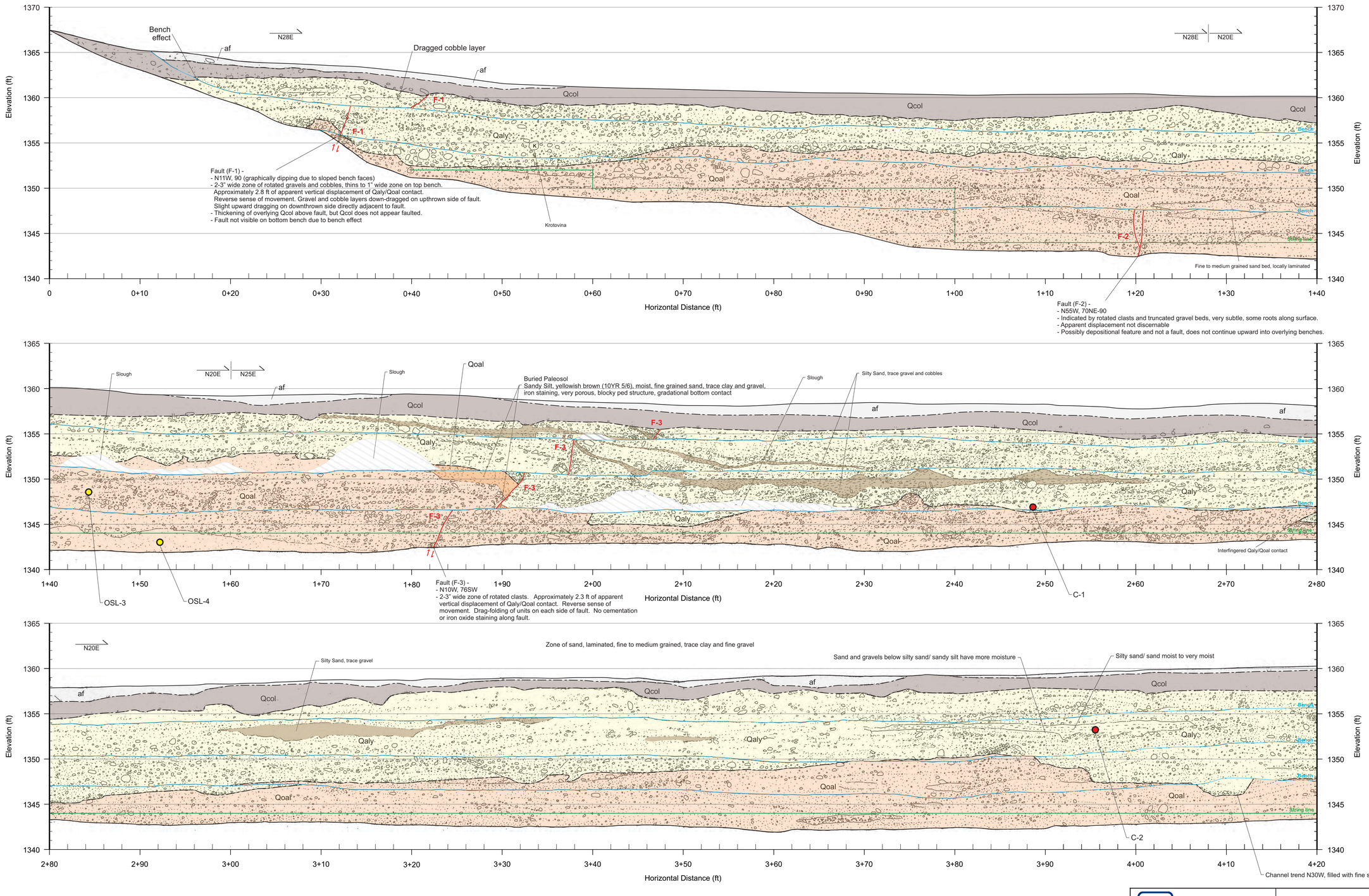
Qoal — Older Alluvium: Channelized deposits of gravelly sand and sandy gravel with varying amounts of silt and cobbles and trace boulders up to 2ft in dimension. Local silty sand and sand layers, primarily igneous and metamorphic subangular to subrounded clasts, feldspar rich igneous and metamorphic clasts are commonly weathered to grus, locally imbricated, massive to moderately layered, light olive brown (2.5Y 5/3) when moist, pale yellow (2.5Y 7/3) to light brownish gray (2.5Y 6/2) when dry. Coarse-grained sequences are generally less friable as compared to the younger alluvium and exhibit a weakly cemented texture.

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FAULT TRENCH LOG
UNIT DESCRIPTIONS

Site Location: Rialto, CA

Project No.: GEN 19-22E | Date: February 2022 | Plate 2a



*SEE PLATE 2A FOR UNIT DESCRIPTIONS

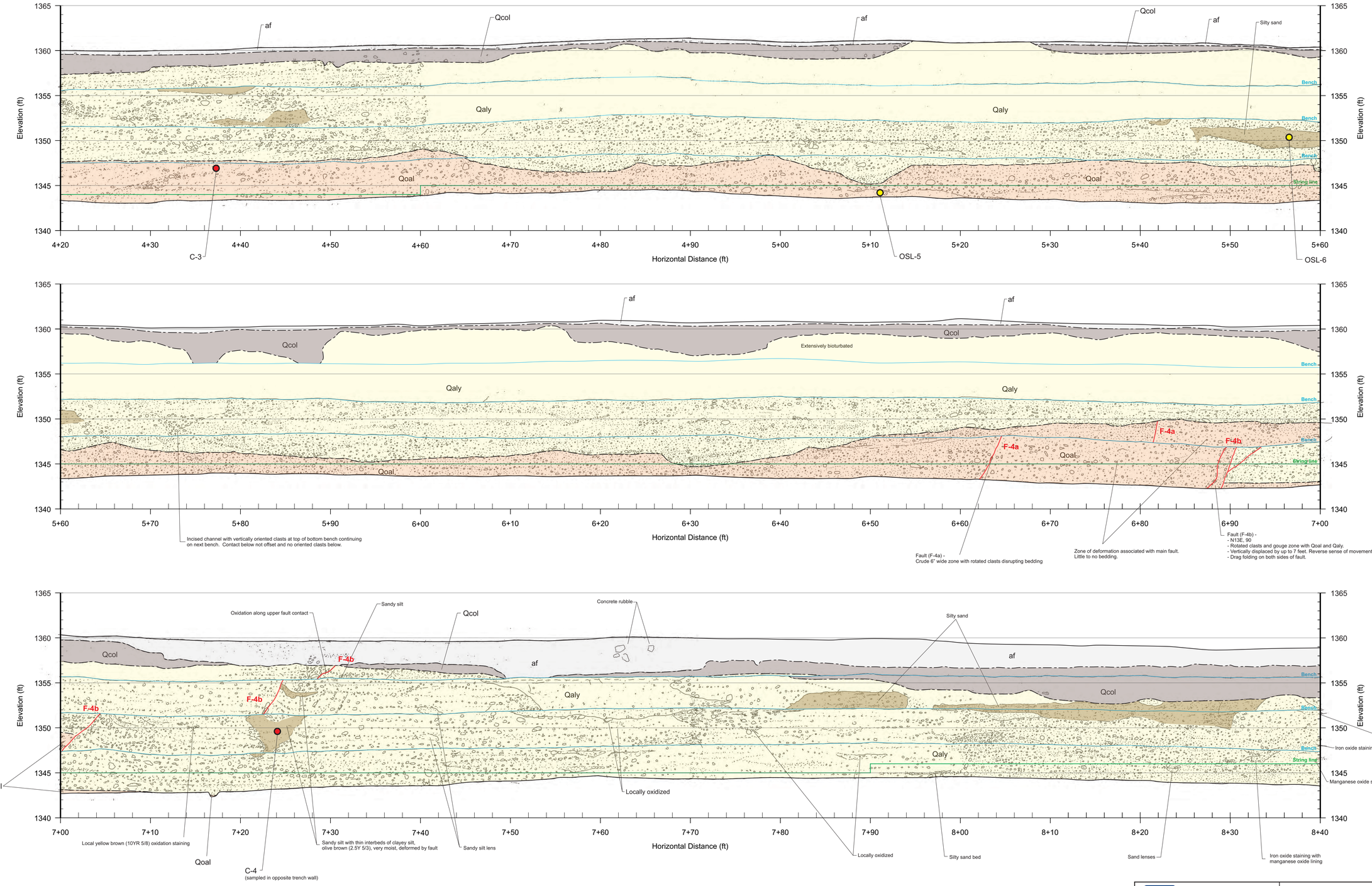
0 5'
1" = 5'

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TEL 909.860.7777 www.tetratech.com

FAULT TRENCH FT-1
(Sta 0+00 to 4+20)

Site Location: Rialto, CA

Project No.: GEN 19-22E | Date: February 2022 | Plate 2b



*SEE PLATE 2A FOR UNIT DESCRIPTIONS

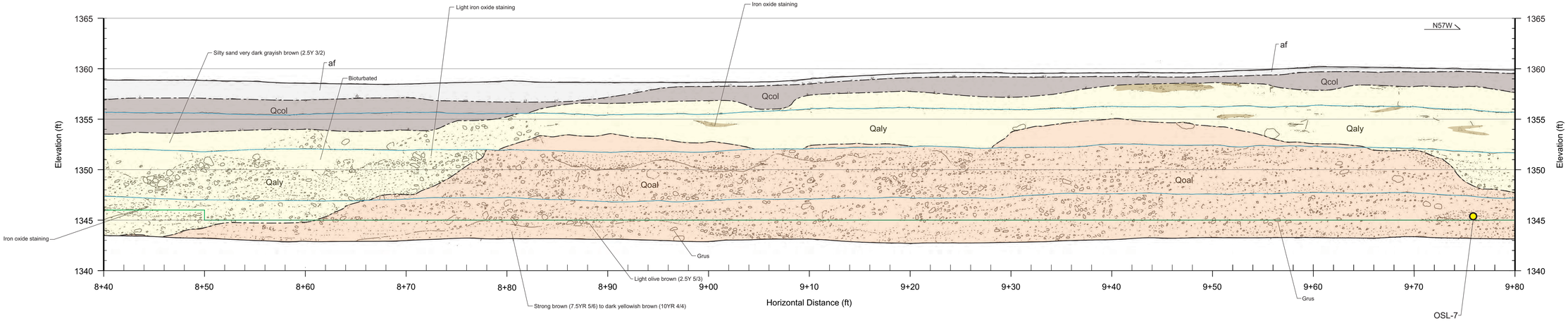
0 5'
1" = 5'

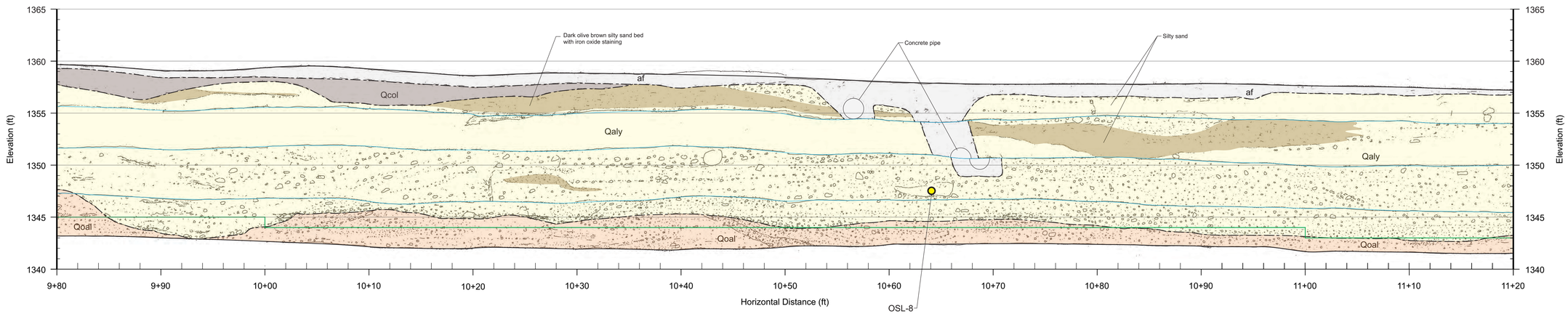
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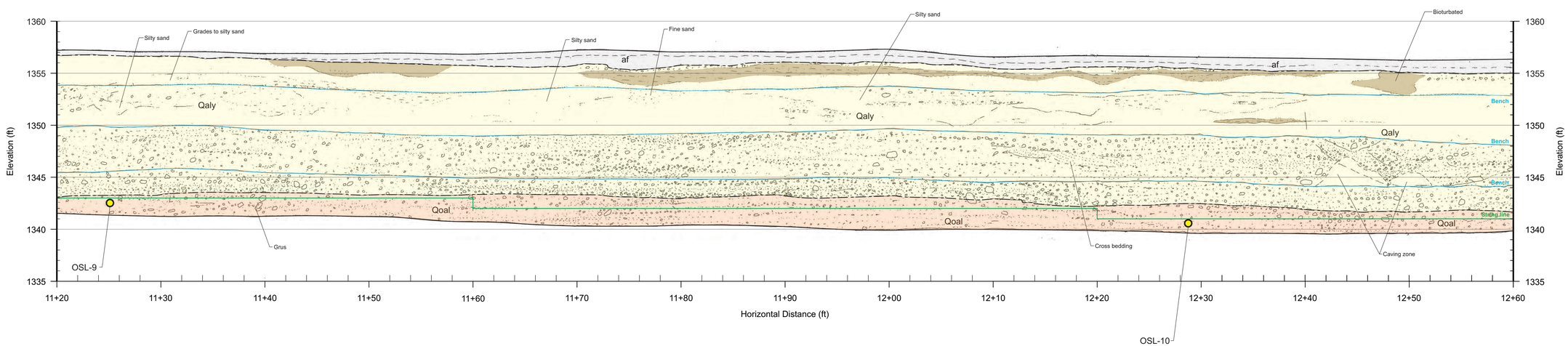
FAULT TRENCH FT-1
(Sta 4+20 to 8+40)

Site Location: Rialto, CA

Project No.: GEN 19-22E | Date: February 2022 | Plate 2c







*SEE PLATE 2A FOR UNIT DESCRIPTIONS

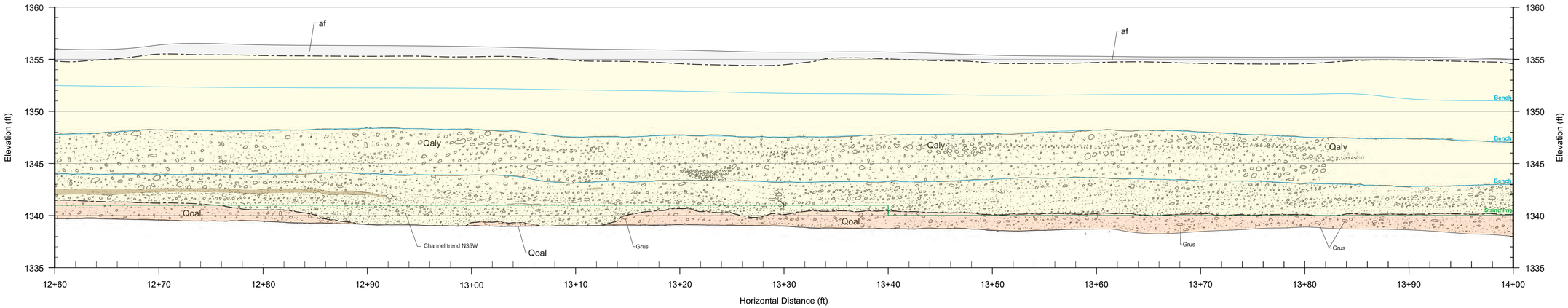
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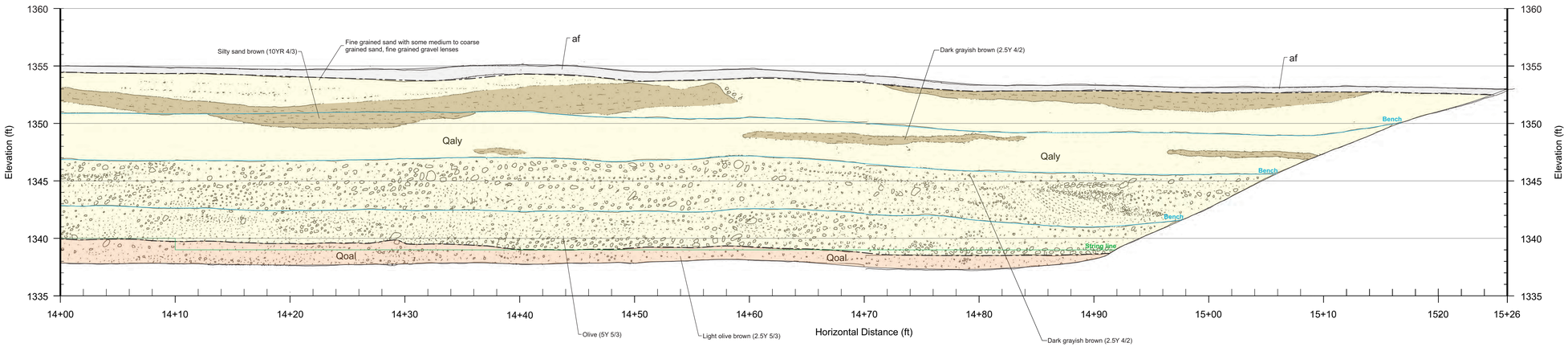
TETRA TECH
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FAULT TRENCH FT-1
(Sta 8+40 to 12+60)

Site Location: Rialto, CA

Project No.: GEN 19-22E | Date: February 2022 | Plate 2d





*SEE PLATE 2A FOR UNIT DESCRIPTIONS

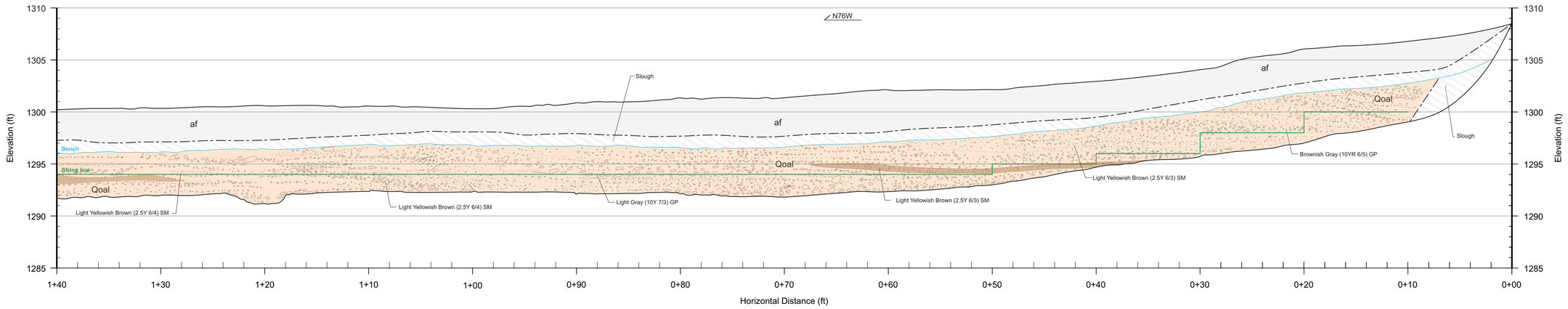
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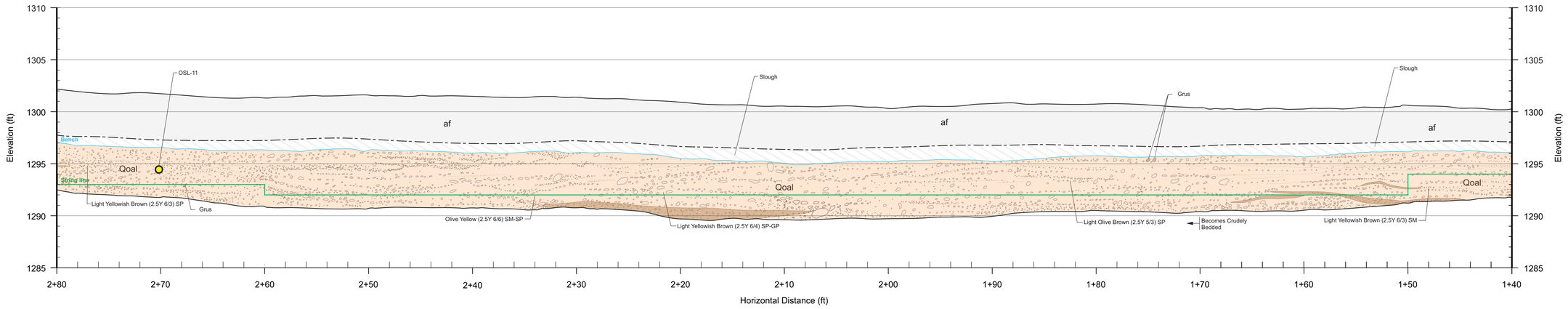
TETRA TECH
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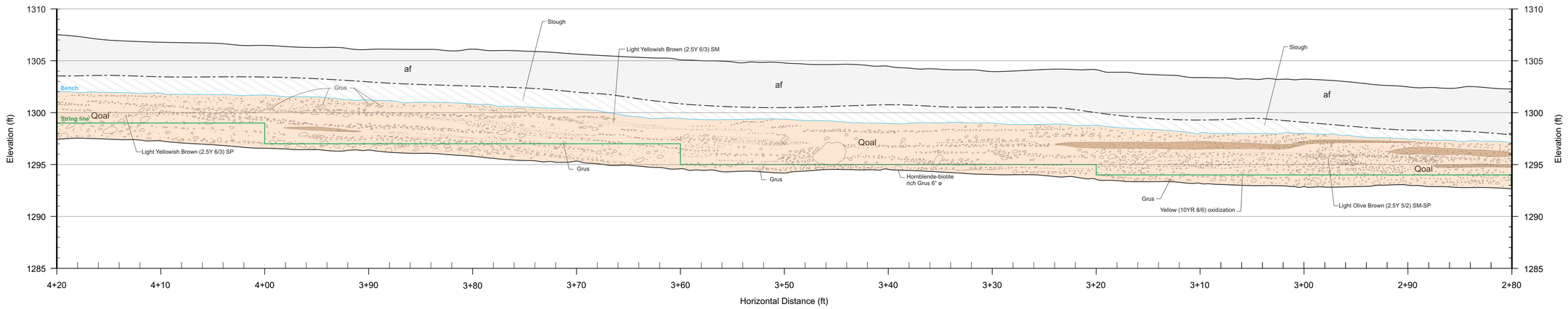
FAULT TRENCH FT-1
(Sta 12+60 to 15+26)

Site Location: Rialto, CA

Project No.: GEN 19-22E | Date: February 2022 | Plate 2e







*SEE PLATE 2A FOR UNIT DESCRIPTIONS

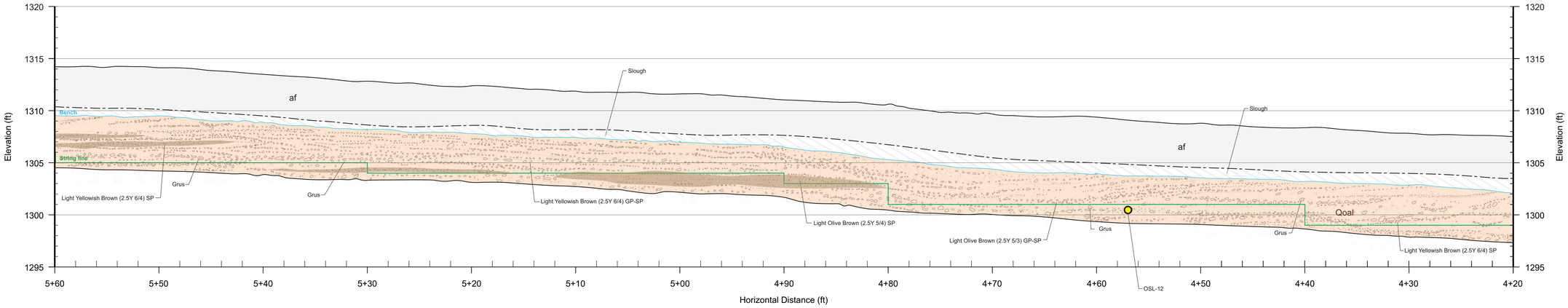
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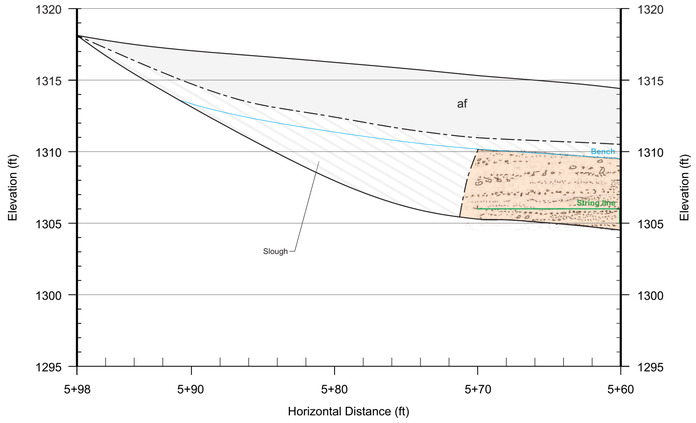
TETRA TECH
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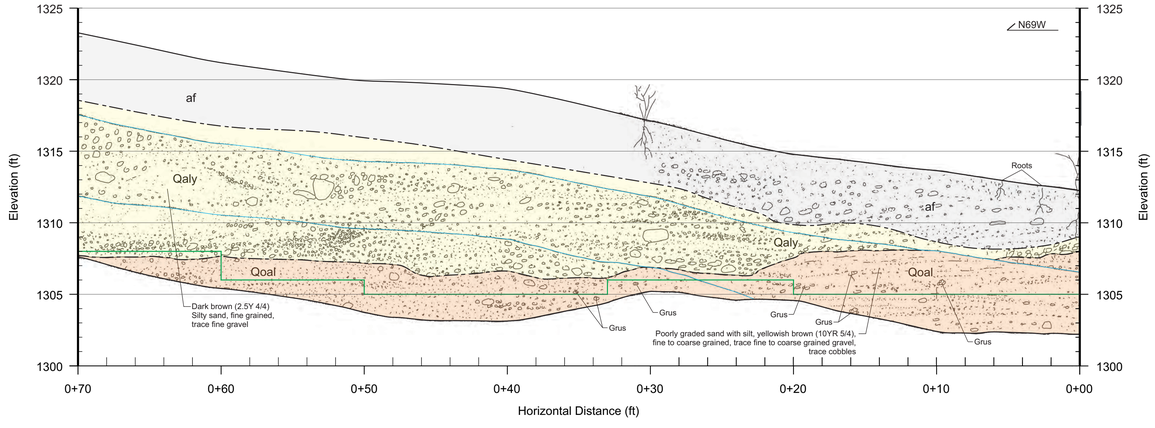
FAULT TRENCH FT-2
(Sta 0+00 to 4+20)

Site Location: Rialto, CA

Project No.: GEN 19-22E | Date: February 2022 | Plate 2f







*SEE PLATE 2A FOR UNIT DESCRIPTIONS

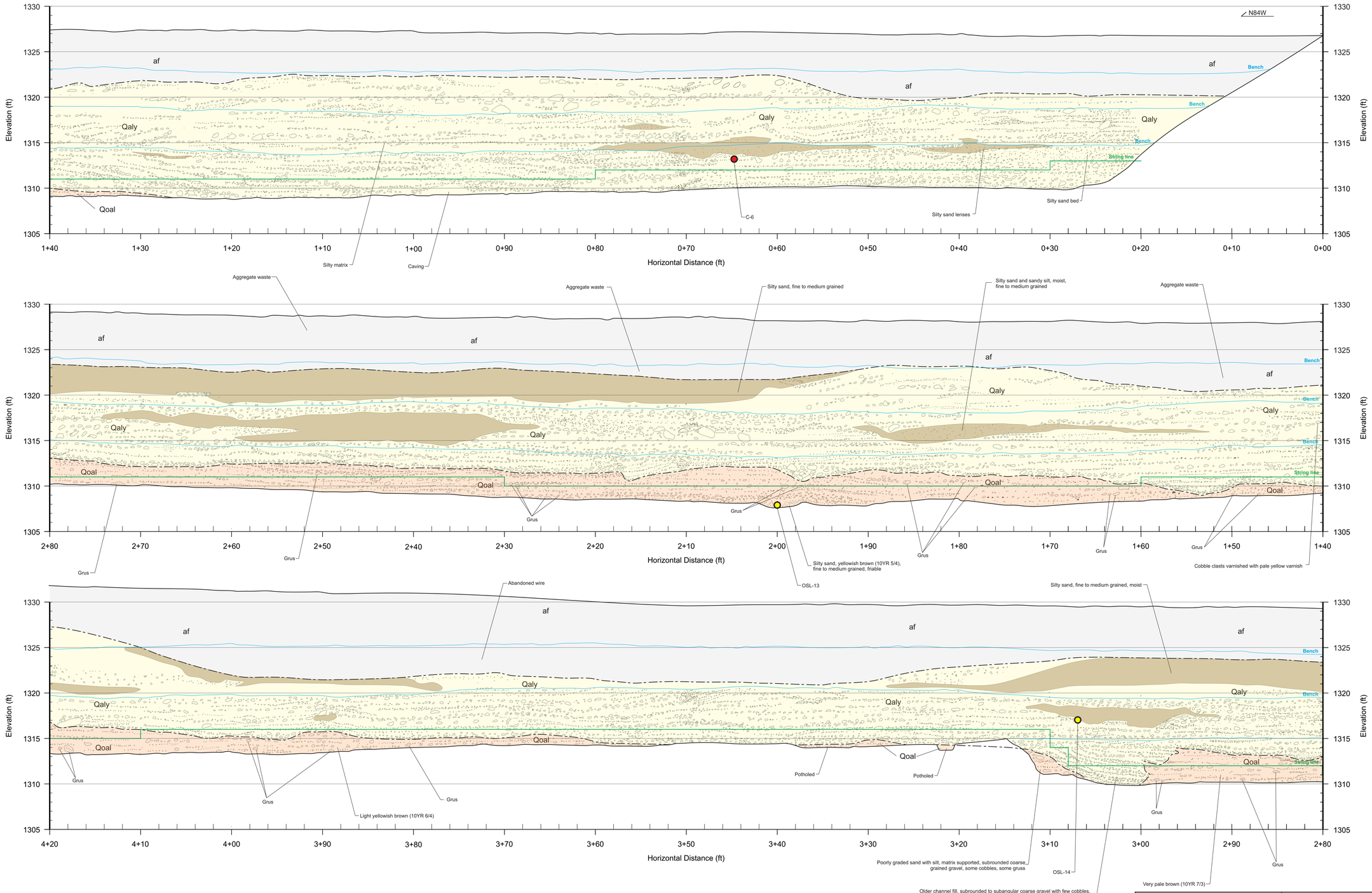
0 5'
1" = 5'

TETRA TECH
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TEL 909.860.7777 www.tetratech.com

FAULT TRENCH FT-2
(Sta 4+20 to 5+98)

Site Location: Rialto, CA

Project No.: GEN 19-22E | Date: February 2022 | Plate 2g



*SEE PLATE 2A FOR UNIT DESCRIPTIONS

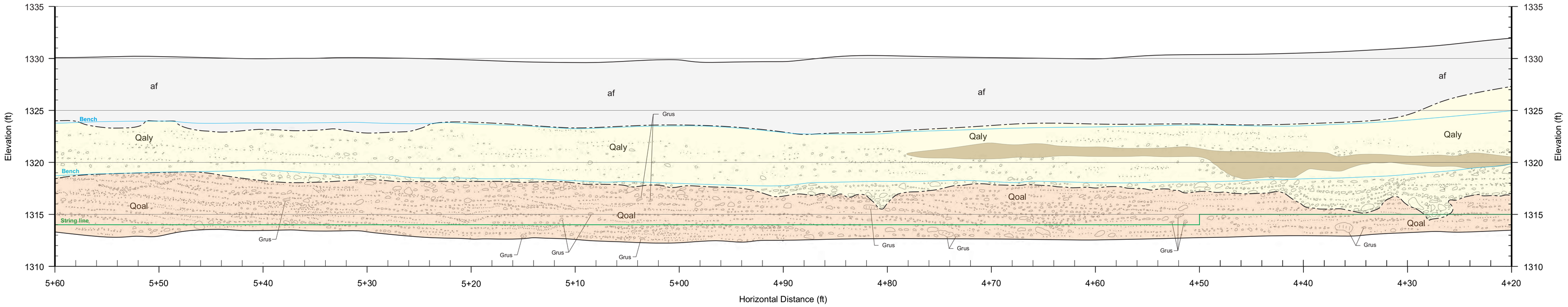
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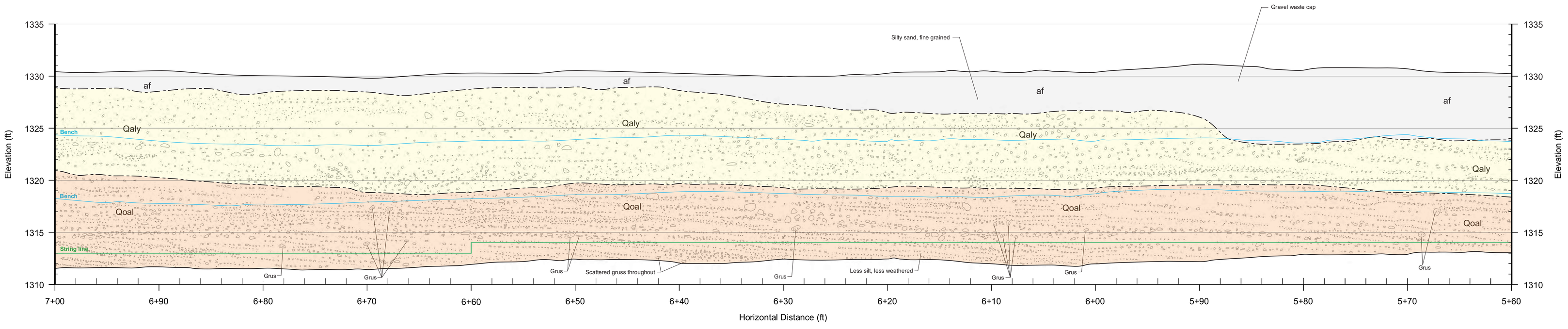
TETRA TECH
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TEL 909.860.7777 www.tetratech.com

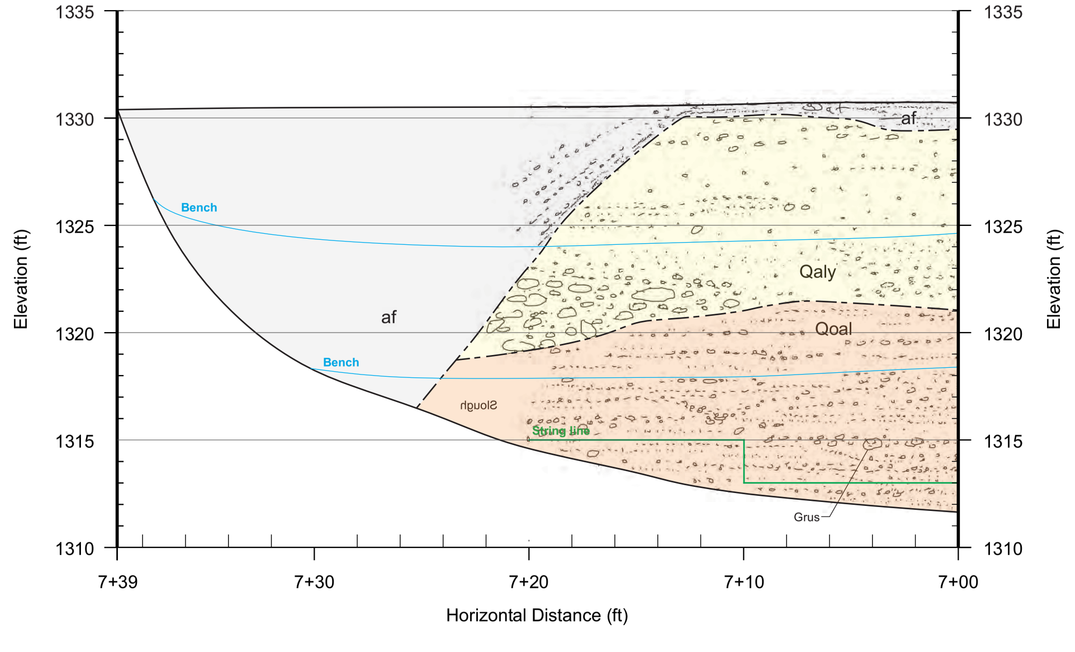
FAULT TRENCH FT-3
(Sta 0+00 to 4+20)

Site Location: Rialto, CA

Project No.: GEN 19-22E | Date: February 2022 | Plate 2h







*SEE PLATE 2A FOR UNIT DESCRIPTIONS

0 5'
1" = 5'

TETRA TECH
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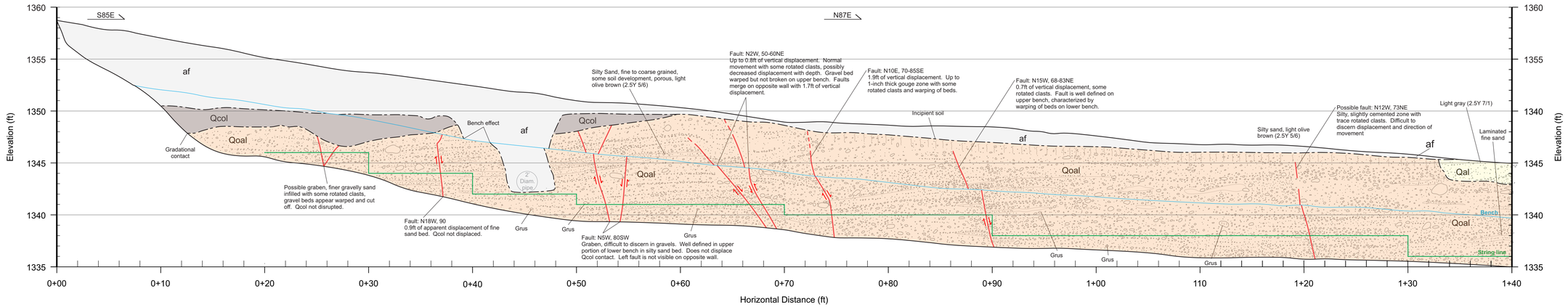
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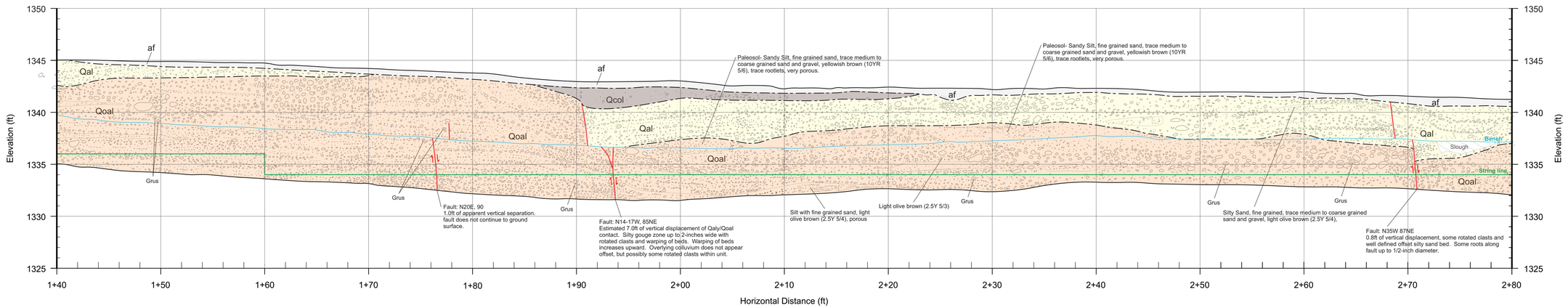
Site Location: Rialto, CA

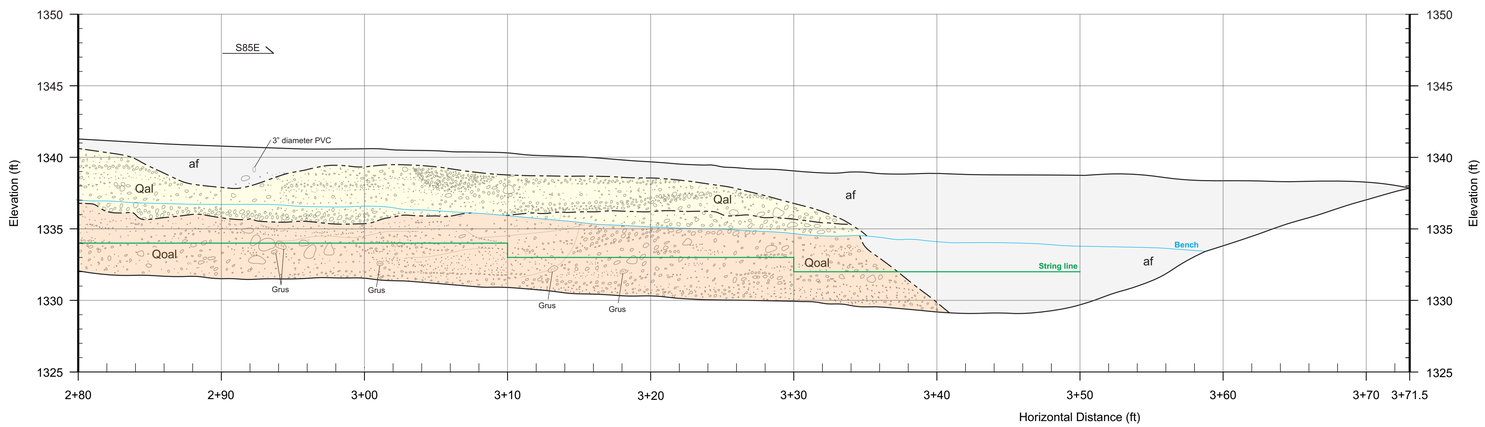
Project No.: GEN 19-22E

Date: February 2022

Plate 2i







*SEE PLATE 2A FOR UNIT DESCRIPTIONS

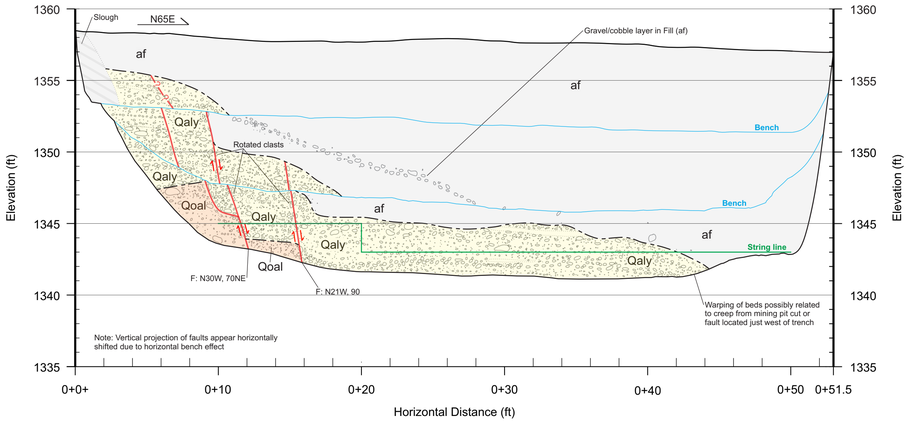
0 5'
1" = 5'

TETRA TECH
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FAULT TRENCH FT-4
(Sta 0+00 to 3+71.5)

Site Location: Rialto, CA

Project No.: GEN 19-22E | Date: February 2022 | Plate 2j



*SEE PLATE 2A FOR UNIT DESCRIPTIONS

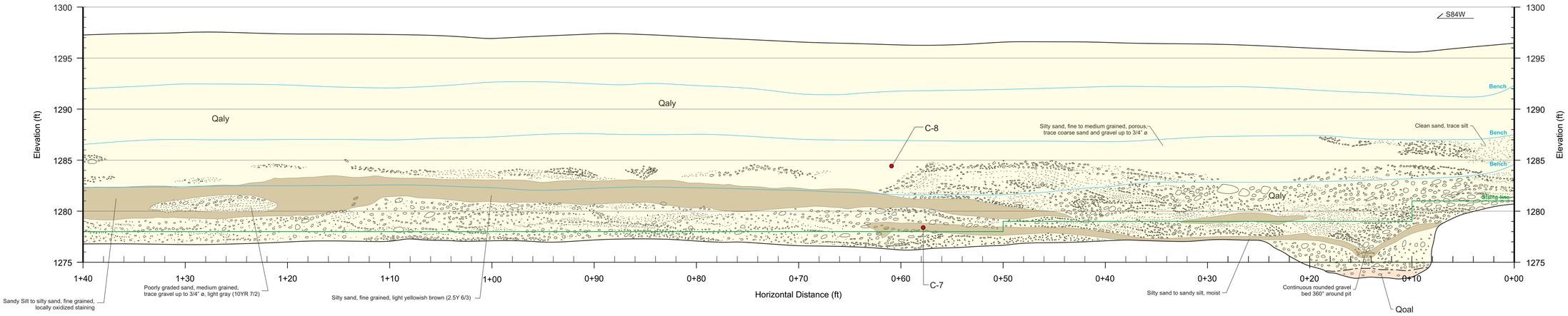
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1" = 5'

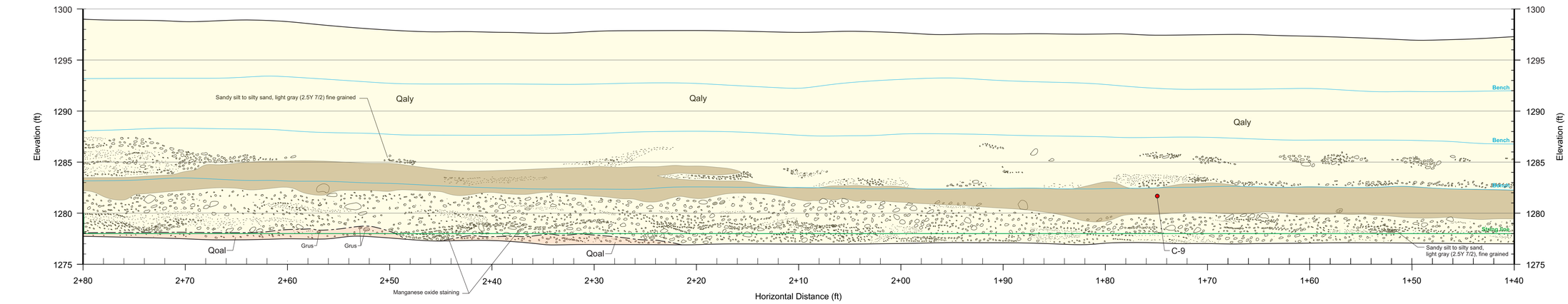
TETRA TECH
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TEL 909.860.7777 www.tetratech.com

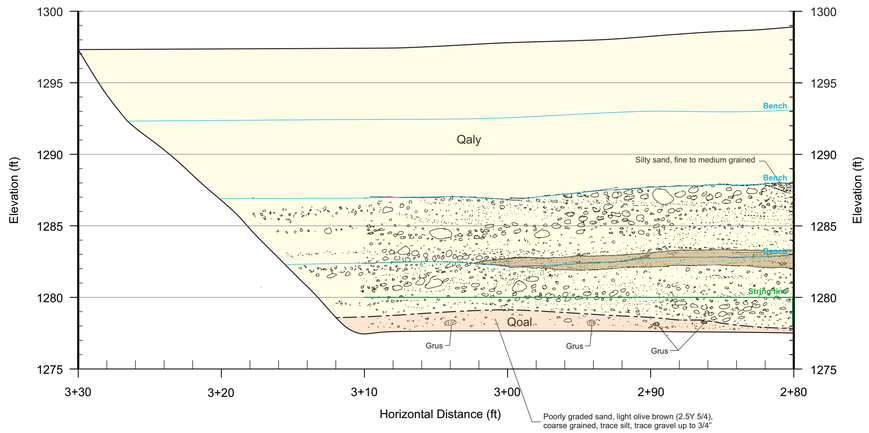
FAULT TRENCH FT-5
(Sta 0+00 to 0+51.5)

Site Location: Rialto, CA

Project No.: GEN 19-22E | Date: February 2022 | Plate 2k







*SEE PLATE 2A FOR UNIT DESCRIPTIONS

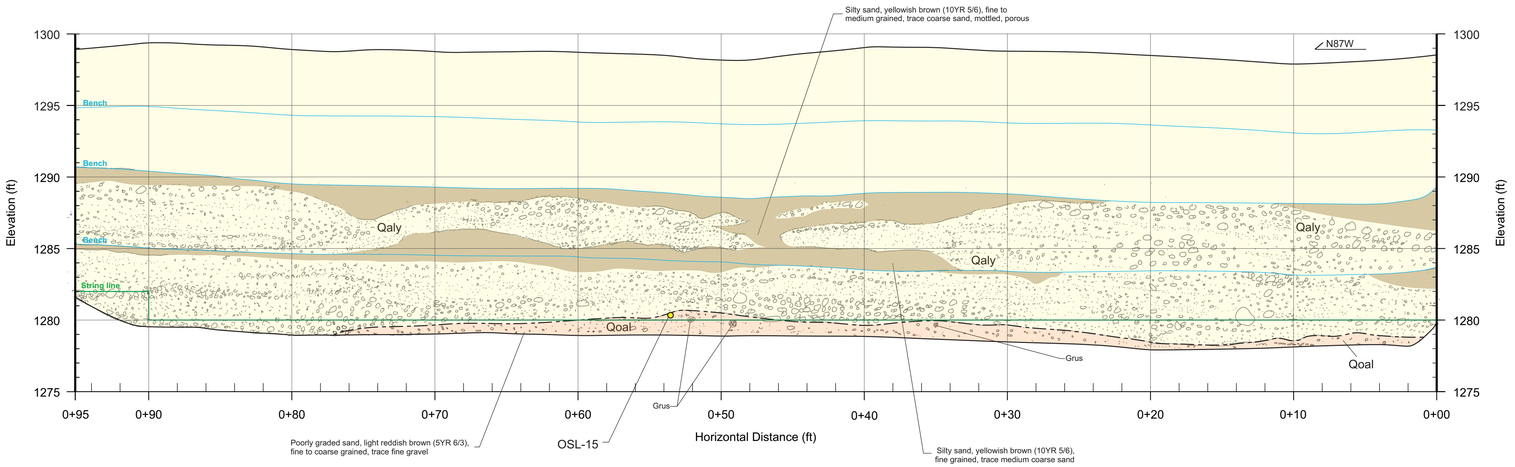
0 5'
1" = 5'

TETRA TECH
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FAULT TRENCH FT-6a (Sta 0+00 to 3+30)

Site Location: Rialto, CA

Project No.: GEN 19-22E | Date: February 2022 | Plate 2I



*SEE PLATE 2A FOR UNIT DESCRIPTIONS

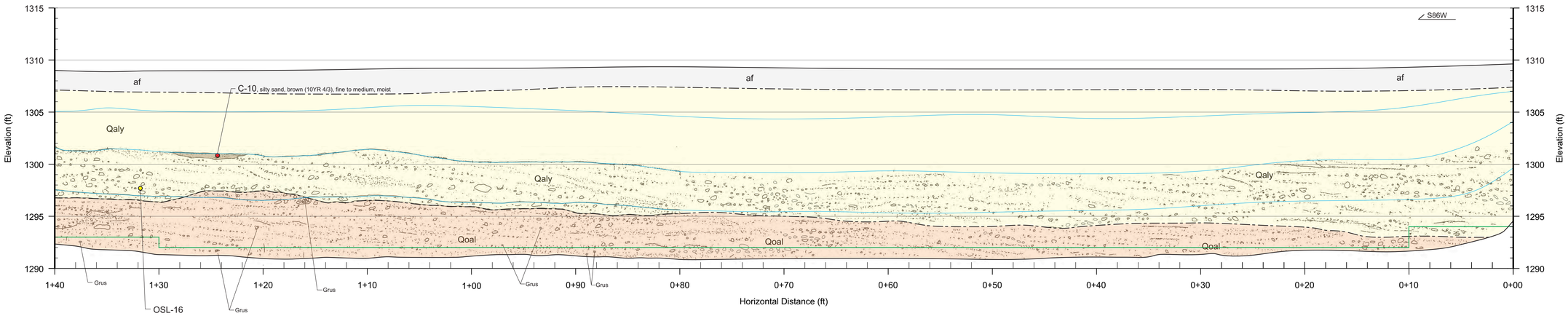
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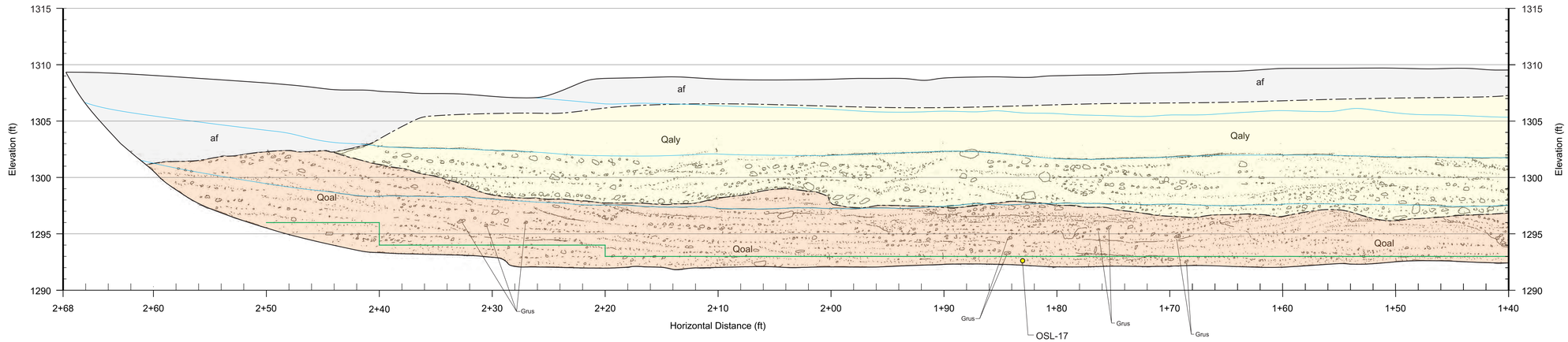
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FAULT TRENCH FT-6b
(Sta 0+00 to 0+95)

Site Location: Rialto, CA

Project No.: GEN 19-22E | Date: February 2022 | Plate 2m





*SEE PLATE 2A FOR UNIT DESCRIPTIONS

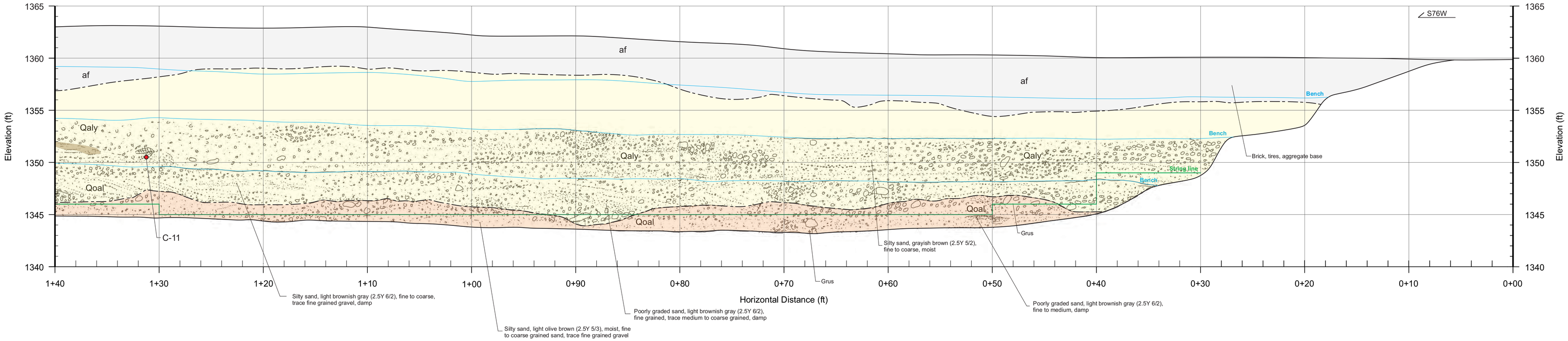
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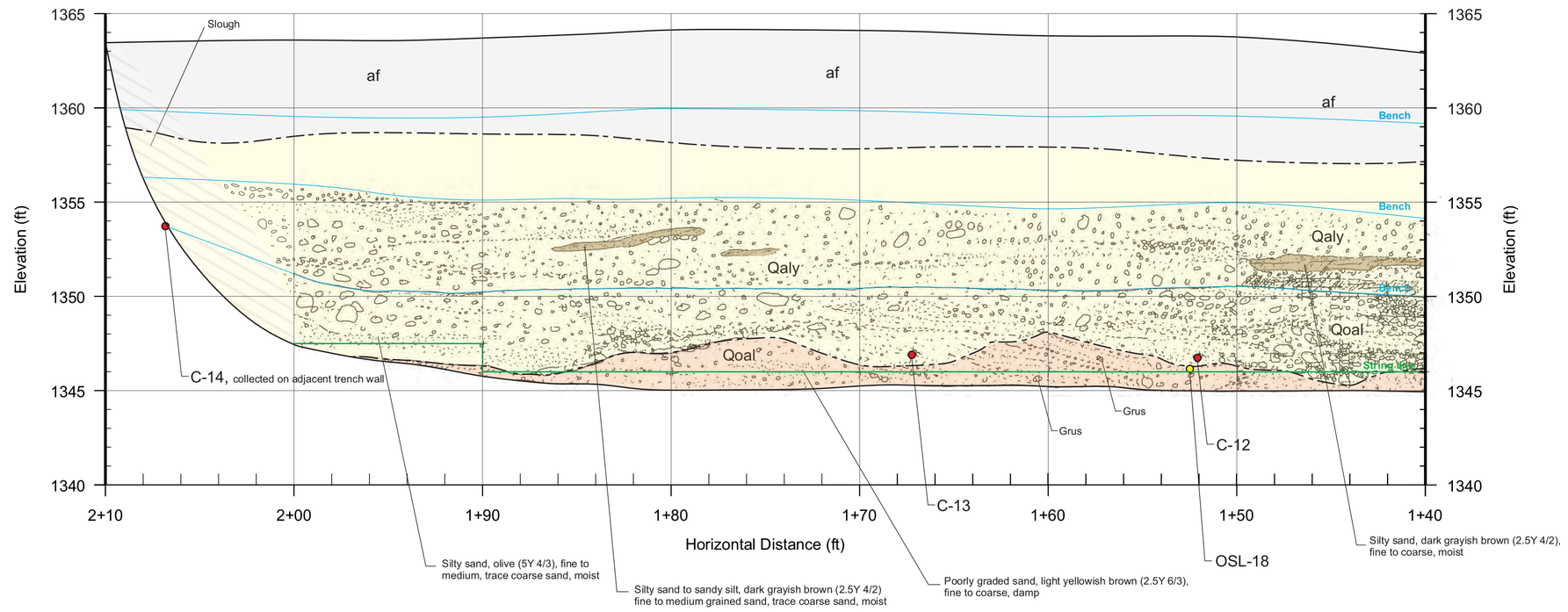
TETRA TECH
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TEL 909.860.7777 www.tetratech.com

FAULT TRENCH FT-7
(Sta 0+00 to 2+68)

Site Location: Rialto, CA

Project No.: GEN 19-22E | Date: February 2022 | Plate 2n





*SEE PLATE 2A FOR UNIT DESCRIPTIONS

0 5’
1” = 5’

TETRA TECH
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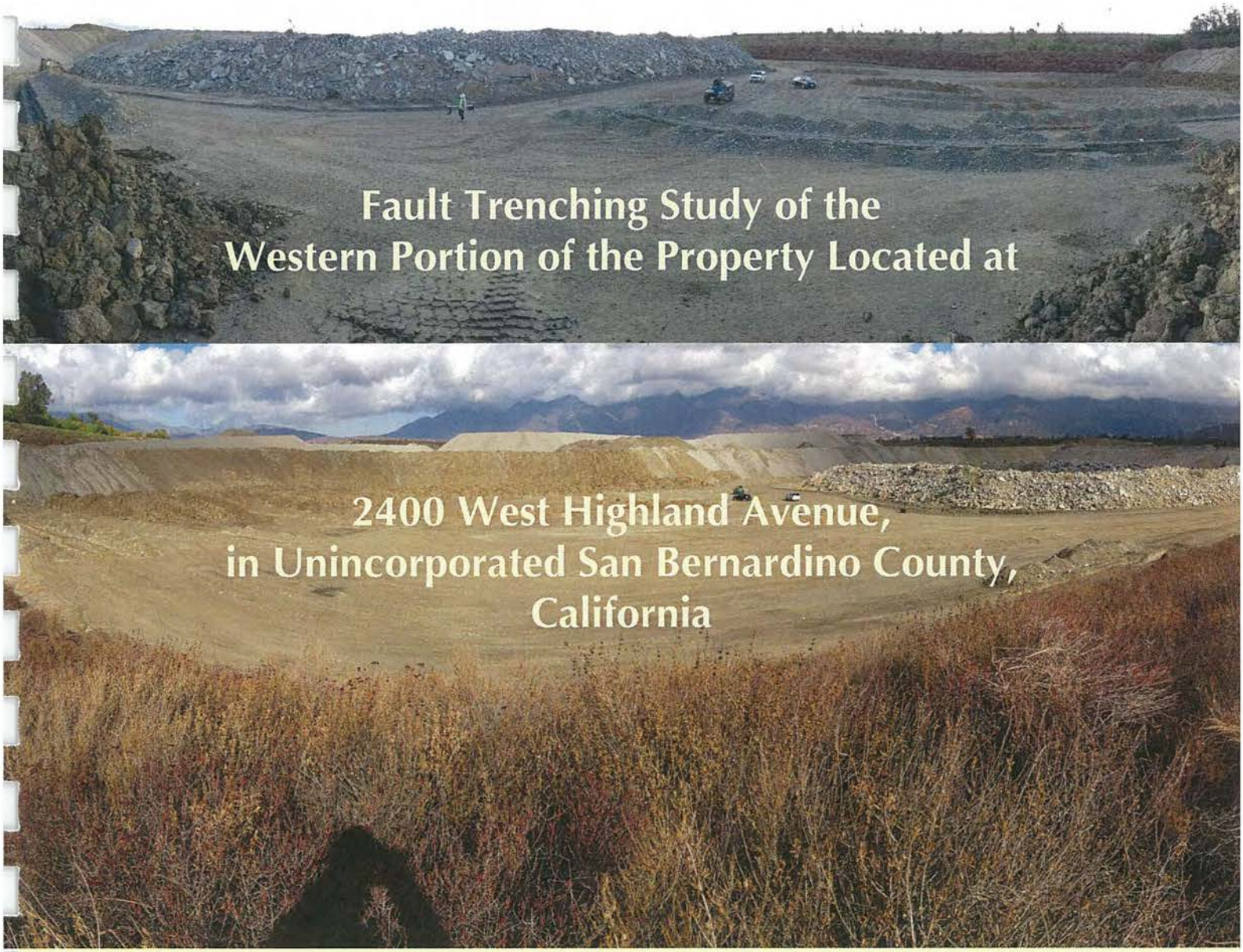
FAULT TRENCH FT-8
(Sta 0+00 to 2+10)

Site Location: Rialto, CA

Project No.: GEN 19-22E | Date: February 2022 | Plate 2o

Appendix A

Fault Trenching Study Report
Earth Consultants International, Inc
(dated January 31, 2013)



Fault Trenching Study of the Western Portion of the Property Located at 2400 West Highland Avenue, in Unincorporated San Bernardino County, California

Prepared by:

Earth Consultants International, Inc.

Project No. 3213
January 31, 2013

1642 E. 4th Street • Santa Ana • California • 92701
Telephone: (714) 544-5321 & (714) 412-2654
www.earthconsultants.com

Earth Consultants International

January 31, 2013 (FINAL)
Project No. 3213.02

To: **BBC Properties, LLC**
1407 South Holmby
Los Angeles, California 90024

Attention: Mr. Pete Rhein, Mr. Jeff Cohen, Mr. Tom Goldenberg and Mr. Rob Christensen

Subject: **Fault Trenching Study of the Western Portion of the Property Located at 2400 West Highland Avenue, North of the 210 Freeway, in Unincorporated San Bernardino County, California**

Gentlemen,

Per your request and authorization, Earth Consultants International has completed a fault trenching study of the western portion of the "Northern Parcel," a BBC Properties-owned parcel that is currently being operated as a crushed aggregate storage facility by Vulcan Materials. The entire property is located within the State-designated Alquist-Priolo Earthquake Fault Zone (AP Zone) for the San Jacinto fault. Geologic studies are required to be conducted in sites within an AP Zone before habitable structures can be built there. The purpose of this study was to determine whether or not active faults extend across the western portion of the parcel. This is the only portion of the site where trenching studies were feasible at this time, given that the rest of the property is currently occupied by several buildings and associated infrastructure, and trenching would have disrupted Vulcan Material's operations.

The site is in what has historically been part of the active wash of Lytle Creek. The site vicinity has been mined for sand and gravel since the 1930s, with the study area proper already showing substantial modifications to the ground surface in aerial photographs dating from 1959. The trenches were excavated in an area referred to as the "Winter Pit" that is now reportedly about 30 feet below the original, pre-mining ground surface. Thus, because our excavations were typically between 4.5 to 8 feet deep, the sediments exposed therein were originally about 35 to 40 feet below the ground surface. Age dating of these sediments as part of this study indicates that the deposits are only slightly older than about 11,000 years in age.

Our study was conducted in three phases. The first phase was primarily a desk-top study that involved the review of available data on the San Jacinto fault and fault trenching studies conducted by others in the site vicinity, in addition to a review of aerial photographs. Also as part of Phase 1 we collected sediment samples from the site that were dated using the Infra-Red Stimulated Luminescence method. The age analyses allowed us to determine that shallow trenching, to depths of 5 to 6 feet, would expose sediments deposited at least 11,000 years ago. Phases 2 and 3 consisted of the excavation of 15 trenches and test pits with a combined total length of about 2,300 feet. During the Phase 2 studies we excavated three trenches that together extended in an approximate east-west direction across the full width of the area that was the subject of this investigation. Three breaks in the stratigraphy interpreted as faults were exposed in the longest trench (trench FT-1), two near its western end, and one approximately in the middle. No faults were exposed in the other two trenches excavated at that time.

1642 E. Fourth Street ✆ Santa Ana ✆ California ✆ 92701
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✆ www.earthconsultants.com

During Phase 3 we excavated a series of test pits to locate and trace across the site the three faults exposed in trench FT-1, especially toward the north, given that the original trenches were excavated near the site's southern boundary. The test pits showed that the westernmost breaks (referred to as faults F1 and F2) are short, discontinuous features that die northward. Fault F1 appears to make a right step between test pit W1 and trench FT-1, and then extends northerly past test pit W2, but dies or steps left before reaching test pit W3. Unfortunately, aggregate piles prevented us from chasing these discontinuous breaks farther west and north. Given that previous fault studies to the north, in the Rancho Verde Country Club area, have projected faults through or near the site's western boundary, habitable structures should not be built in this portion of the site unless additional future studies determine that these features are not active faults. At this time, the area within approximately 250 feet of the site's western boundary is recommended as a Restricted Use Area.

Fault F2 was traced in a northeasterly direction for a distance of approximately 200 feet, between test pit W1 on the south, and the south wall of test pit W4. The fault could not be traced northward into the north wall of test pit W-4, and was also not observed in test pit W5. Sedimentary structures associated with it suggest that this may be a liquefaction-induced feature rather than a fault. And, given that the breaks in the stratigraphy could not be traced upward to the top of the test pit exposures, in sediments that are at least 11,000 years old, fault F2, if indeed a fault, is no longer active. For these reasons, a structural setback from this feature is not deemed necessary.

Fault F3 was traced in a northwesterly direction across the entire area where trenching was possible, for a distance of approximately 500 feet. In the southern half of the study area the fault has an average strike (orientation) of N17W, but in the northern half it trends more westerly, with an average strike of N25W. Observations made in some of the trenches suggest that fault F3 either has had only a minimal amount of vertical movement in the past about 11,000 years, or that it has not moved in several thousands of years. Since this segment of the San Jacinto fault has a recurrence interval of between about 200 and 250 years, it is possible that this fault has not moved in the last 20 or more earthquakes on the San Jacinto fault zone. However, there does not seem to be any areas left onsite where we could evaluate the impact that this fault may have on sediments 5,000 years old or younger, which would allow us to confirm this statement. Given this limitation, and in accordance with the current interpretation of the Alquist-Priolo Act, fault F3 would be considered active. While possible future changes in the definition of fault activity may provide the impetus to find a suitable trenching site where this fault may be studied further, structural setbacks and/or engineering strengthening of the foundations that straddle the fault zone may still be considered appropriate. These mitigation measures would be designed in cooperation with the project's geotechnical and structural engineers.

Should you have any questions regarding our report, or need any additional information or clarifications, please do not hesitate to contact us. We appreciate the opportunity to work for you on this project.

Respectfully submitted for
Earth Consultants International, Inc.



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Senior Consultant
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Senior Consultant
(714) 412-2666
trockwell@earthconsultants.com

Distribution: 4 Hard-copies and 2 Digital Copies to Addressee
1 Hard-copy and 1 Digital Copy to Roger Prend, Webb Associates

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Fault Trenching Study of the Western Portion of the Property Located at 2400 West Highland Avenue, North of the 210 Freeway, in Unincorporated San Bernardino County, California

1.0 INTRODUCTION

In accordance with your authorization, Earth Consultants International, Inc. (ECI) has conducted a fault trenching study of the southwestern section of the property referred to as the "Northern Parcel," located in the floodplain of Lytle Creek, north of Highland Avenue, and just north of the City of Rialto, in unincorporated San Bernardino County, California (see Figure 1). This study was conducted in order to assist you in planning the future use of the property and to comply with requirements of the State-mandated Alquist-Priolo Earthquake Fault Zoning Act. Fieldwork for this study was conducted in three phases, with the first phase conducted at the end of June, the second phase completed during the latter half of September, and the third phase conducted in early November 2012. This report summarizes our findings, interpretations, and conclusions regarding faulting within the section of the property that was the subject of these three phases of study.

1.1 PURPOSE OF THE STUDY

The entire approximately 105 acres that comprise the "Northern Parcel" property are located within the State-designated Alquist-Priolo Earthquake Fault Zone (AP Zone) for the San Jacinto fault (see Figure 2). In accordance with State law, geologic studies are required to be conducted to determine whether or not faults extend across the site, within the AP Zone, before habitable structures are planned in this area. The primary objective of this study was to assess the future surface fault rupture potential in the property by looking for evidence, through trenching, of past fault rupture in the area. However, the eastern and central portions of the site are currently occupied by several buildings and associated infrastructure, in addition to settling ponds and piles of aggregate and crushed concrete. Trenching studies in these areas were therefore not feasible at this time.

The southwestern portion of the site has been mined for sand and gravel, with the resulting pit being approximately 30 feet below original ground surface. This area is anticipated to be backfilled with artificial fill as part of the reclamation efforts that the mining operators are required to comply with prior to vacating the site. We conducted trenching in the mined area, referred to as the "Winter Pit," in advance of the area being backfilled. As an added benefit, trenching this area now allowed us to excavate shallow trenches, as the sediments exposed are older than the sediments that would have been exposed at original grade. The age of the sediments exposed in the trenches is discussed further in Section 3.1.

1.2 SCOPE OF WORK AND METHODOLOGY

To investigate the potential for surface fault rupture, we completed the following tasks, in three phases as follows:

Phase 1:

a) We obtained and reviewed pertinent maps and publications summarizing the regional geology, published and unpublished reports on the San Jacinto fault, and fault investigations conducted in the site vicinity (see Appendix A).

b) We obtained and reviewed aerial photographs of the area to look for potential fault-controlled lineaments extending through the study site, and to evaluate the amount of disturbance of the ground surface that has occurred over time as a result of the gravel quarry operations that have been ongoing in this area since at least the 1930s. Several of the photographs reviewed were provided to us by Vulcan Materials, the current gravel pit operator. Other more recent imagery reviewed for information regarding modifications to the ground surface come from Google Earth.

c) Dr. Ed Rhodes (University of California – Los Angeles) collected sediment samples from test pits that Mr. Floyd Sibole of Vulcan Materials excavated for us in the southwestern portion of the site, in the area where our trenches were later excavated. Dr. Rhodes dated the sediment samples using the Infra-Red Stimulated Luminescence (IRSL) method. The dating results are presented in the text of the report, and Dr. Rhodes' report is included as Appendix B. Sediment samples were also collected from the side of a stream bank on the "Southern Parcel," a property also owned by BBC Properties to the south of Highland Avenue, as shown on Figure 1.

d) Based on the data compiled from the literature, the review of aerial photographs, and the dating results, we prepared proposals and cost estimates to trench both the Northern and Southern parcels. As a result of biological concerns, trenching of the Southern parcel was delayed, and only the Northern parcel was investigated further at this time. This report addresses only the fault investigation we conducted in the southwestern portion of the Northern parcel.

Phase 2:

e) We excavated, cleaned, logged and photographed three trenches with a combined length of 970 feet (trench FT-1 was 845 feet long; FT-2, at the west end of the study area, was 75 feet long; and trench FT-3 was about 50 feet long – see Figure 3). The trenches were oriented east to east-northeast across the study area, approximately perpendicular to the regional trend of the San Jacinto fault zone. The west end of the study area was defined and constrained by a man-made slope of crushed aggregate that has been built by Vulcan Materials against the property's western boundary. The east end of trench FT-1 was terminated against a sediment settling pond that receives runoff from larger ponds to the east and northeast. Trench FT-2 was excavated to shadow the eastern end of trench FT-1 after its eastern end was flooded with water that overflowed the pond.

f) The trench locations, and the faults encountered therein, were surveyed by a crew of professional surveyors from Albert A. Webb Associates. Their survey data and map are incorporated by reference herein (see Appendix D).

g) We requested that Mr. Wes Reeder, the San Bernardino County geologist, review the trenches while still open. He conducted his field inspection on September 26, 2012.

h) Several samples of charred organic material suitable for dating using the radiocarbon method were collected from a fine-grained overbank deposit exposed in trench FT-1. Two of those samples were selected for dating and were sent to the radiocarbon

dating laboratory at University of California - Irvine. Specifics regarding the dating results are discussed in the text; the laboratory results are included in Appendix C.

i) Trench FT-1 was excavated using a track-mounted excavator with a 3-foot wide bucket and was benched for safety, where necessary. Deepening of some sections of trench FT-1, and excavation of trenches FT-2 and FT-3, was undertaken using a rubber-tire backhoe fitted with an extended hoe and a 3-foot wide bucket. Upon completion of the field work, the trenches were backfilled by Vulcan Materials personnel. It is our understanding that the backfill was not placed under engineering observation and testing.

Phase 3:

j) We excavated, cleaned, logged and photographed twelve additional trenches to trace the faults exposed during Phase 2 northward across the southwestern portion of the North Parcel. These trenches were excavated using the same rubber-tire backhoe used in Phase 2. The trenches varied in length between 60 and 275 feet, and between 4 and 8 feet in depth. Five of these trenches were excavated to trace the faults exposed in the western end of trench FT-1; these trenches are labeled W-1 through W-5 on Figure 3. Six trenches were excavated to trace the fault exposed in the central portion of trench FT-1; these are labeled E-1 through E-6 on Figure 3. Finally, trench FT-4 was excavated as far north and east as possible within the Winter Pit area, shadowing the eastern half of trench FT-1 and trench FT-3, to confirm our original findings regarding the lack of faults in the eastern half of the study area.

k) These additional trenches were surveyed by personnel from Albert A. Webb Associates. As with the first set of trenches, their survey data and map showing the locations of these trenches are included here.

l) Backfill of these trenches was also conducted by Vulcan Materials personnel. We did not observe or test the backfill.

m) We prepared this report summarizing our findings, conclusions, and recommendations regarding faulting in the area of the site covered by this study.

1.3 SITE DESCRIPTION

The property is located immediately north and northwest of the intersection of Highland Avenue and the northward extension of North Acacia Avenue, in unincorporated San Bernardino County, within the City of Rialto Sphere of Influence. The portion of the site that was investigated is currently undeveloped, but extensive modification of the ground, in the form of excavation and infilling has occurred. The south-central portion of the study area, where the trenches were emplaced, has been extensively mined for sand and gravel, so much so that the "Winter Pit," as the area is known, was at the time of our study reportedly approximately 30 feet below original ground surface. Fill slopes approximately 30 feet high bound this area to the south, west, north, and locally, to the east. Piles of crushed aggregate and recycled concrete were also scattered throughout the study area; the location and height of these piles changed throughout the duration of our study, with several piles placed in the area prior to us starting Phase 3. As a result, our final trench locations for Phase 3 differ from our proposed locations, given that we had to accommodate the test pits and trenches as best as possible among the piles

of aggregate. The piles of aggregate also prevented us from investigating the western margin of the study area during Phase 3.

Geomorphically, the site is located near the western edge of the floodplain of Lytle Creek Wash, just south of the convergence of Lytle and Cajon Creeks. The natural channel of Lytle Creek used to be roughly parallel to the trend of the San Jacinto fault, with splays of the fault mapped or inferred through both the channel itself, and the elevated fluvial terraces on the west side of the channel (see Figure 2). In the past century, the study area has been modified extensively, the result of gravel and sand mining operations that have been ongoing since at least the 1930s, and more recently, construction of Highway 210. Flow in the active channel has been forced toward the east end of the floodplain, away from the project area, by man-made levees that keep most runoff away from the buildings and gravel pits in the Vulcan Materials site. As the creek approaches Highland Avenue, levees constrain the flow into a relatively narrow channel that passes under bridged sections of both Highland Avenue and Highway 210. South of these transportation corridors, the channel is allowed to spread out some, before being constricted again to flow under Baseline Road.

Topographic relief across the project area prior to the excavation of the Winter Pit varied from about 1,360 feet above mean sea level (amsl) near the northwest corner, to about 1,310 feet amsl near the site's southeast corner (Figure 2). This area has reportedly been excavated down approximately 30 feet down from original grade.

1.4 PROPOSED PROJECT DESCRIPTION

It is our understanding that the property may be developed some time in the future. However, there are no development plans at the present time. The fault study was conducted at this time to take advantage of the fact that the site has been excavated down to significant depth, exposing sediments that are considerably older than the historical to very young alluvial deposits that would be exposed in shallow trenches had the site been in its natural state. It also made sense to study the site prior to it being backfilled with at least 30 feet of artificial fill.

2.0 BACKGROUND

2.1 REGIONAL TECTONIC SETTING

The project area is located near the northwestern terminus of the Peninsular Ranges physiographic and tectonic province, near the junction of the San Andreas and San Jacinto faults, and about 4 miles (6.4 km) south of the base of the San Gabriel Mountains. The Peninsular Ranges province is characterized by northwest-trending ranges, valleys and geologic features controlled by the San Andreas fault system, which includes the San Jacinto fault. The site is also less than 5.5 miles (8.8 km) from the eastern end of the Cucamonga fault.

The San Jacinto fault zone consists of a series of closely spaced faults that form the western margin of the San Jacinto Mountains (Figure 4). The zone is about 175 miles (280 km) in length and extends from its junction with the San Andreas fault at the base of the San Gabriel Mountains, southeasterly toward the Brawley area, where it transfers most of its displacement to the Imperial fault in the vicinity of the international border. The San Jacinto fault has historically produced more large earthquakes than any other fault in southern California,

although none of these earthquakes has been as large as the 1857 and 1906 earthquakes on the San Andreas fault.

Large faults, such as the San Andreas and San Jacinto faults, are often divided into segments or sections in order to evaluate their future earthquake potential. The sections are typically based on physical characteristics along the fault, particularly changes in orientation (strike) or inclination (dip), and style of faulting. Each fault section is assumed to have a characteristic slip rate, recurrence interval (time between moderate to large earthquakes), and displacement (amount of offset during an earthquake). Historical records and studies of prehistoric earthquakes show that it is possible for more than one section to rupture during a large earthquake or for ruptures to overlap into adjacent sections. For example, the last major earthquake on the southern San Andreas fault (and the largest earthquake reported in California) was the 1857 Fort Tejon (Mw 7.8) event. That earthquake ruptured the Cholame, Carrizo, Big Bend, and Mojave North and Mojave South sections of the fault, resulting in displacements of about 16 feet (5 m) along the rupture zone.

The definition and naming of the various sections, segments, fault strands and fault splays of the San Andreas and San Jacinto faults have varied over time, the result of many investigators working on different aspects and parts of the fault zones, and the recent efforts to compile these data into a unified model. In this report, the fault nomenclature used follows that defined by the 2007 Working Group on California Earthquake Probabilities (2008), and updated in the Unified California Earthquake Rupture Forecast, version 2 model (UCERF2) (Dawson et al., 2008), which includes the division of the San Jacinto fault zone into eight segments. From north to south these include the San Bernardino Valley, San Jacinto Valley, Anza, Clark, Coyote Creek, Borrego Mountain, Superstition Hills and Superstition Mountain sections or segments. Each section, in turn, may consist of multiple subparallel faults. The San Bernardino Valley segment, also referred to as the Claremont fault, is the section of the San Jacinto fault that extends through the project area.

The San Bernardino Valley segment extends from a point roughly coincident with the southern limit of the 1857 earthquake fault rupture on the adjacent San Andreas fault (WGCEP, 2008), to the northern end of the San Jacinto Valley at Mystic Lake. There are new paleoseismic data at Mystic Lake that indicate that the San Bernardino Valley segment fails in large earthquakes about every 200-250 years, with the most recent large surface rupture being about AD 1800 (either the November 22nd, 1800 or the December 11, 1812 earthquake, or an unknown large earthquake) (Onderdonk et al., 2013). Displacement data also have been collected for the past three large ruptures northwest of Mystic Lake, and these data suggest displacements in the 10-16 feet (3-5 m) in each of the past three earthquakes for the San Bernardino Valley segment (Onderdonk et al., 2012a, 2012b).

In the last century or so, three moderate to large earthquakes (>M6) have occurred in the northern half of the San Jacinto fault (Figure 4), one possibly on the San Bernardino Valley segment (July 22, 1923, M6.3), one on the San Jacinto Valley segment (December 25, 1899, M6.5) and one farther south along the north Clark fault (Anza segment) (April 21, 1918, M6.9), but only the 1918 earthquake has been documented to have ruptured the ground surface, producing a maximum displacement of about 7 feet in Blackburn Canyon south of Hemet (Salisbury et al., 2012).

Fault slip rates on the San Bernardino segment of the San Jacinto fault are not well constrained, but the data from farther south indicate right-lateral slip rates of $13.2^{+4.3}/_{-2.9}$ mm/yr for the Anza segment (Blisniuk et al., in press), decreasing southeastward to about 9 mm/yr in Rockhouse Canyon (Blisniuk et al., 2010). The slip rate for the northern San Jacinto fault, which includes the project area, is also probably in this range of 13-14 mm/y, and this is the rate adopted by the most recent UCERF3 efforts by SCEC and the CGS to assess statewide seismic hazard in California. This rate is broadly consistent with poorly constrained earlier estimates for this fault section; 17 mm/yr (Morton et al., 1986) and 6-13 mm/yr (Prentice and others, 1986), both determined for the San Bernardino Valley segment near San Bernardino, a few miles to the southeast of the project site. New rate estimates have also been determined for the southern part of the San Bernardino segment along the San Timoteo Badlands by dating offset landslide deposits (McGill et al., 2012), and although the rates have broad uncertainties, they are consistent with the determined slip rate farther southeast. Finally, Wesnousky et al. (1991) also trenched the fault near San Bernardino, but they did not expose all active strands of the fault, making their late-Holocene slip rate of 1.7-3.3 mm/yr a minimum value.

The best estimated slip rate of 13-14 mm/yr amounts to about 27% of the total slip between the North American and Pacific tectonic plates. The Working Group on California Earthquake Probabilities (1995) gave the San Bernardino Valley and San Jacinto Valley segments of the San Jacinto fault a 37% and 43% probability, respectively, of rupturing sometime between 1994 and 2024. These probabilities were reduced somewhat by the 2007 WGCEP (2008), to an average of 31% for all segments of the San Jacinto fault, and they are being reassessed by the current UCERF3 effort, but in all assessments, the San Jacinto fault is recognized as one of the most dangerous faults in southern California due to its high slip rate and proximity to large population centers.

The Anza segment to the south of the site is the best-studied segment of the San Jacinto fault. Detailed trenching studies at Hog Lake have revealed evidence for up to 20 earthquakes in the past about 4,000 years (Rockwell et al., 2010, 2011). The data indicate an average recurrence interval of about 220 years for this segment, with the most recent earthquake having occurred between about A.D. 1775 and A.D. 1805 and inferred to be the November 22nd, 1800 historical earthquake. Along with the Anza segment, event chronologies and recurrence intervals are available for the southern section of the Clark fault (Buga et al., 2012), the Superstition Mountain segment (Gurrola and Rockwell, 1996; Rockwell et al., 2000; Ragona, 2003), and the Superstition Hills fault (Hudnut and Sieh, 1989). All of the studied sections of the San Jacinto fault indicate a relatively short recurrence interval for surface rupturing earthquakes in the range of a few hundred years or less, with the most recent surface rupture having occurred either prehistorically or in the very early historic period for most of the length of the fault zone, highlighting this fault has one of the most hazardous in southern California.

2.2 GEOLOGIC SETTING

As indicated above, the project site is located in the floodplain of Lytle Creek Wash, a braided stream that follows the trace of the San Jacinto fault, and drains the southeastern San Gabriel Mountains. Rocks in these mountains consist primarily of plutonic rocks, biotite-rich gneisses and schists, and marine and non-marine sedimentary rocks (McFadden, 1982). Therefore, the sediments in the site area consist of gravelly to bouldery alluvium (stream-deposited) that contains rock fragments of diorite, gneiss, and schist, with sand and silt particles consisting predominantly of quartz and feldspar. Alluvium of Lytle Creek Wash also contains clasts of the

Pelona Schist formation, a distinctive dark blue-green to purple schist (Morton, 1975; Clarke, 1989). More detailed descriptions of the deposits exposed in the trenches excavated for this study, including the age of these sediments, are provided in Section 3.1.

2.3 AERIAL PHOTO AND GEOMORPHIC ANALYSIS OF THE SITE AREA

Aerial photo analysis of the site area for evidence of fault-related features is complicated by the extensive, man-made modifications to the ground that have been conducted in the site vicinity since about the 1930s, roughly coincident with the earliest available photographs. Furthermore, Lytle Creek Wash generally follows the trend of the San Jacinto fault zone, and as a result, geomorphic features in the wash can be related to either faulting or channeling. Nevertheless, several features potentially related to surface faulting, such as scarps and deflected drainages, can be observed in vintage photographs (see list of photographs in Appendix A).

Two main zones of faulting have been identified in the site vicinity; the Glen Helen fault zone which appears to extend to the east of, or near the eastern limits of the subject site, and the Lytle Creek fault, along the western edge of the site (see Figure 5). Evidence for the Glen Helen fault is localized, as this fault parallels the main channel and its surface expression has thus been erased by past flooding events, including the great flood of 1938. Nevertheless, in older photographs, the fault can be identified by a series of sub-parallel, primarily west-side-down fault scarps, shutter ridges, sag ponds and offset drainages north of the site. Southeast of the site, the fault may be defined by a series of lineaments that suggest a subtle southwest-facing scarp. Sharp also (1972) mapped a possible groundwater barrier in this area.

The Lytle Creek fault zone is thought to have created the scarp that forms the west bank of Lytle Creek Wash. Although the creek may have locally cut into and thus modified the scarp, the location of the scarp is thought to closely match the actual fault location. South of the site, the fault zone appears to be relatively well constrained along the base of what is referred to in topographic maps as the Rialto Bench, with some secondary scarps and lineaments in the wash locally suggesting a wider zone. North of the site, in the elevated area now occupied by the El Rancho Verde Country Club, there are several lineaments and aligned scarps that suggest a broad zone of faulting. Several of these have been trenched and indeed found to be fault-controlled (see Section 2.4 below, and compare Figures 5 and 6).

Based on their degree of dissection and amount of vegetation, at least four distinct alluvial surfaces can be identified in the immediate site vicinity. The oldest, and highest surface occurs to the west of the site, in the area around the intersection of Highland and Riverside avenues. Based on soil descriptions made in the Leighton and Associates (1994) trench FT-1 (see Figure 6), the sediments forming this surface are at least 13,000 years old, and possibly as much as 75,000 years old. The soils exhibited 7.5YR to 5YR Munsell color hues, and diffuse accumulations of calcium carbonate that are likely a Holocene overprint, characteristics typical of Pleistocene deposits in this region. Frisbee Park and the surface west of the Rialto Bench are located on the next youngest surface, which locally is elevated as much as 60 feet above the pre-mining channel of Lytle Creek Wash. To our knowledge, no absolute dating of these deposits has been made in the site vicinity. Leighton (1975, 1976a, 1976b) indicated that the sediments exposed in their trenches on this surface were late Pleistocene in age based in part on mapping by Dutcher (Plate 1 in Dutcher and Garrett, 1963), who mapped the underlying sediments as older alluvium.

Slightly elevated and more vegetated, pod-shaped areas within and at the margins of Lytle Creek Wash indicate the second youngest alluvial surfaces in the study area. These surfaces are Holocene in age, based on the radiocarbon dating results obtained from trenches FT-6a1 and FT-6a2 (Leighton and Associates, 1994). Samples collected from approximately 4 to 4.5 feet below the ground surface returned ages of about 300 to 650 years before present, whereas the sample collected at a depth of about 10 feet was about 1,250 years old.

The trenches excavated for this study were excavated in an area that was within the active channel of Lytle Creek Wash. Thus, the sediments near the ground surface that were removed by the gravel mining operations were most likely historical in age. In fact, the vintage aerial photographs reviewed show that the area was flooded during the catastrophic 1938 floods.

2.4 STUDIES CONDUCTED BY OTHERS IN THE SITE VICINITY

To our knowledge, no fault studies have been conducted previously at the subject site, but several geologic studies have been conducted in the vicinity. The most extensive studies were conducted by Gary Rasmussen & Associates (GRA) in the property to the northwest, in and around the El Rancho Verde Country Club and golf course. The GRA studies in this area began in 1979, with summary reports issued in 1993 and 1994 (Gary Rasmussen & Associates, 1982a, 1982b, 1993, 1994a). According to the 1994 report, a total of 33 trenches were excavated and logged, with a combined total length of more than 6,700 lineal feet. Nearly 20 of these trenches exposed faults that they described as late Pleistocene to Holocene in age, although no absolute age dating was conducted. The faults form a broad and complex zone of deformation. Most of the trenches excavated as part of these studies are shown on Figure 6. GRA's interpretation of how the faults exposed in their trenches connect across the area is also shown on Figures 6 and 7.

Leighton and Associates (1972, 1975, 1976a, 1976b) conducted geologic studies for a residential development north and northeast of North Sycamore Avenue, to the west of the site, and just south of the golf course described above. These studies included the excavation and logging of two trenches, both of which reportedly exposed continuous, unfaulted beds in older alluvium (Leighton and Associates, 1975, 1976a, 1976b). The sediments were considered to be late Pleistocene in age based on their topographic position above the active channel.

Leighton and Associates (1993, 1994) also conducted a geologic study (1993) and fault trenching investigation (1994) to evaluate whether or not fault strands associated with the San Jacinto fault zone extend through the bridge structures proposed for the now-constructed 210 Freeway. The fault investigation included the excavation of four trenches (FT-1, FT-2, FT-6a1, and FT-6a2). Only one of these trenches (FT-2) is pertinent to this study given its location to the southeast of the site (trench FT-1 was excavated near the southeastern corner of Riverside Avenue and the original location of Highland Avenue, whereas trenches FT-6a1 and FT-6a2 were excavated near the eastern margin of Lytle Creek Wash, near the intersection of Highland Avenue with the Southern Pacific Railroad grade and embankment; see Figure 6). The Leighton study was narrow in focus, with the trench locations and lengths selected so as to screen only the actual bridge structure footprints. Recognizing that the transportation corridor has to extend across the San Jacinto fault, and thus, that faulting through the embankments or the pavement is unavoidable, the project engineers' main concern was to avoid faulting through the bridge structures. No faults were exposed in the trenches excavated for that study.

Gary Rasmussen & Associates (1984) conducted a study of a section of Frisbee Park, to the south-southwest of the study area. As with the Leighton study, their trenching was limited in scope, designed to investigate whether or not active faults extend through the area where a snack bar and restrooms were proposed. Although faults were exposed near the northeastern end of their trenches, the GRA study is thought to have not extended far enough to the east to expose the entire zone of faulting, which in the golf course to the north was more than 135 feet wide. The main fault exposed affected Holocene-age deposits, with an apparent vertical displacement of at least 5 feet.

Farther away, to the northwest, Gary Rasmussen & Associates (1986a, 1986b, 1988, 1994b) conducted a series of geologic investigations, including fault trenching, for the area that includes the Glen Helen Rehabilitation Center and the San Bernardino County Sheriff's Training Center. The trenches excavated for these studies are outside the area covered in Figure 6. However, the findings of those studies prompted the California Division of Mines and Geology (CDMG - now known as the California Geological Survey) to review, modify, and re-issue the Alquist-Priolo Earthquake Fault Zoning Map for the Devore quadrangle (CDMG, 1995), immediately to the west-northwest of the study area.

Other geologic studies in the area include the geologic investigation, including trenching, conducted by Terra Geosciences (1994) off Blake Street, in the Muscoy area to the north-northeast of the site, and the GeoSoils, Inc. (1994, 1995) study for a master planned development in Lytle Creek Wash. The GeoSoils study area is to the north of the El Rancho Verde Country Club and west of the Glen Helen Rehabilitation Center site, and thus outside the region covered in Figure 6.

The Terra Geosciences (1994) trench, excavated to a depth of 11-12 feet, did not expose any faults. The sediments exposed were deemed to be Holocene in age, and probably no more than 2,000-years-old, to the bottom of the trench. Based on an analysis of aerial photographs, the consultant identified a possible fault to the east of the area where buildings were proposed. Trenching in that area was not conducted at that time, so the consultant chose to establish a structural setback from that potential feature, requiring more detailed geologic studies if habitable structures are proposed in that area some time in the future.

3.0 FINDINGS

3.1 GEOLOGIC UNITS EXPOSED IN THE TRENCHES

The trenches excavated for this study were emplaced in alluvial sediments that were deposited by an ancestral Lytle Creek. The alluvial sediments exposed in the trenches consist primarily of gray to light gray to light brownish gray (2.5Y 7/1, 2.5Y 6/1 and 2.5Y 6/2), loose to friable, silt, sand, gravel, pebbles and cobbles. Most fragments are subangular to subrounded, indicating that they have been transported some distance from their source. The deposits are crudely stratified to coarsely bedded; distinct nested channels were observed locally throughout the trenches. Finer-grained overbank deposits consisting of light brownish gray to brown sandy silt to silty sand were exposed locally in some sections of the trenches, as described in more detail in Section 3.2. Remnants of weakly developed topsoil and cambic (A and Bw) soil horizons were observed within these finer-grained deposits, indicating that they were exposed at the ground surface for a sufficiently long period of time to be modified by

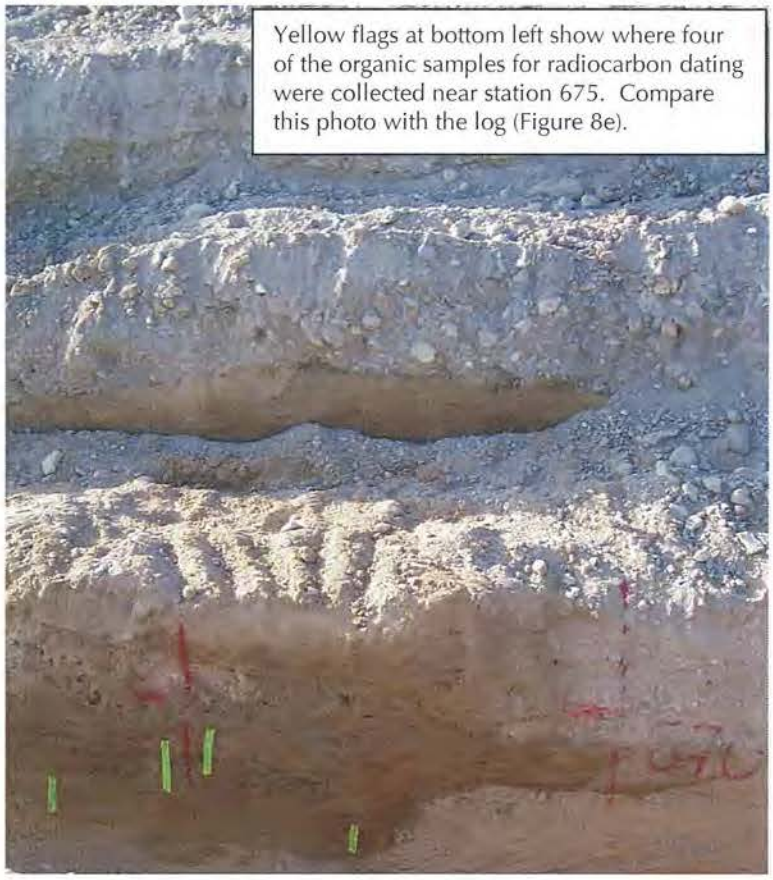
soil-forming processes. Small fragments of organic material were collected from these finer-grained sediments for radiocarbon dating, as discussed further below.

Reworked alluvial sediments, sometimes mixed with pieces of aggregate or metal, were observed locally as a thin veneer at the top of some of the trenches or sections of trenches. These materials were referred to as artificial fill (Afu) in the trench logs.

Dating of the alluvial deposits exposed in the study area was conducted in two phases and using two different types of tests. First, and prior to the actual trenching study, we retained Dr. Ed Rhodes from the University of California – Los Angeles, to collect sediment samples from two shallow test pits that Mr. Floyd Sibole of Vulcan Materials excavated for us near the location where Trench FT-1 was later opened (see Figure B2 in Appendix B). The purpose of this effort was to obtain data on how deep the trenches needed to be to expose Pleistocene (older than about 11,000-years-old sediments). Dr. Rhodes analyzed the sediment samples collected using the InfraRed Stimulated Luminescence (IRLS) method.

This technique measures the naturally occurring radiation that has been trapped within quartz and feldspar grains in the sediment since the deposit was buried, with the charge amount increasing with burial time. If the sediment is heated at relatively high temperatures (200-400°C) or briefly exposed to daylight (between about 1 to 100 seconds), the charges trapped in the grains are released, resetting the luminescence clock (Rhodes, 2011). Scientists like Dr. Rhodes take advantage of this to estimate the amount of time the sediment has been buried. They do this by conducting a controlled release, in the laboratory, of the radiation trapped in a sample of sediment and measuring the charge freed (referred to as the equivalent dose). If the radiation rate (dose rate) that the sample is exposed to naturally is known (this is measured in the field, at the time that the sediment samples are collected), then the age of the sample can be calculated by dividing the equivalent dose by the dose rate. For a more in-depth description of this method, the measurements made by Dr. Rhodes, and the sample locations, refer to Appendix B. For the ages of the samples, refer to Table 1 below.

In the process of cleaning and logging trench FT-1, we found organic materials suitable for dating using the radiocarbon (^{14}C) dating method in some of the overbank deposits exposed between Stations 670 and 700 (see Figure 8e and photo below). In total, we collected six samples of organic material from the south wall of the trench, at depths of between 5.0 and 7.5 feet. The two deepest and largest samples were selected for submittal to the Keck Carbon Cycle AMS radiocarbon dating facility at the University of California – Irvine. The age results are shown on Table 1; the report submitted to us by the laboratory is included in Appendix C.



Yellow flags at bottom left show where four of the organic samples for radiocarbon dating were collected near station 675. Compare this photo with the log (Figure 8e).

The two different methods used to date the deposits exposed in the trenches excavated at the site are remarkably consistent, indicating that the sediments approximately 30 to 38 feet below the original ground surface were deposited slightly more than 11,000 years ago, at or near the Holocene-Pleistocene boundary. Dr. Rhodes indicates in his discussion that "[T]hese age estimates appear to be consistent with deposition during the Younger Dryas period (approximately 11,300 – 12,700 years before present), a time of global unstable climate associated with increased rates of geomorphic processes." Thus, for the purposes of this fault study, and in conformance with the definition of active fault by the California State Mining and Geology Board (a fault that has had surface displacement within Holocene time, in the past about 11,000 years), the trenches excavated at the site were sufficiently deep to assess the hazard of fault rupture. In fact, given that this section of the San Jacinto fault is thought to have an earthquake recurrence interval of between 200 and 400 years, the sediments exposed in this area should have experienced, at a minimum, 27 surface-rupturing events, and thus, the active fault strands should be clearly exposed in the excavations.

Table 1: Age Dating Results

Sample Number	Dating Method	Approximate Depth (ft) (+30 feet approx.[α])	IR50 Age or ^{14}C Age (years BP)	PIRIP225 Age or Calibrated Age* (years BP)
BBCR12-OSL01	IRSL	7.4	10,600 ± 1,300	10,700 ± 1,300
BBCR12-OSL02	IRSL	5.4	12,400 ± 1,500	14,600 ± 1,700
BBCCR12-OSL04	IRSL	2.3	12,200 ± 1,500	10,600 ± 1,300
T1-14C-1	^{14}C	7.5	9,940 ± 30	11,245-11,599
T1-14C-4	^{14}C	6.8	9,990 ± 25	11,305-11,612

[α] A reminder that this area had been excavated down approximately 30 feet from original grade, and that the depths provided here were measured from that artificially derived surface.

* PIRIP225 refers to Post-InfraRed IRSL measurement at 225°C, a correction made to account for the effects of anomalous fading in potassium feldspar. The fading-corrected age estimates are provided in the last column. The ^{14}C age results were calibrated using the web-based OxCal calibration program (Version 4.1; http://c14.arch.ox.ac.uk/embed.php?File=oxcal.html), and the IntCal09 curve.

Internally there are some reversals in the ages obtained for the sediments, with the IRSL age for the sample collected from a depth of 5.4 feet having an older age than the sample collected at a depth of 7.4 feet. Discarding this sample, and using the higher and lower IRSL samples only, yields an age of 10,600 ± 1,300 years for the coarse-grained fluvial deposits that were exposed throughout the study area. Similarly, the ^{14}C-dated sample collected at a depth of 6.8 feet appears to be about the same age as the sample collected at a depth of 7.5 feet, consistent with the two dated samples being collected from the same fine-grained unit. Taking into consideration the dating uncertainties, the two samples are essentially of the same age. The data indicate that the fine-grained overbank deposits were exposed at the surface, where they were being acted on by soil-forming processes, about 11,300 to 11,600 years ago. This surface was locally cut into and quickly buried by coarser-grained, storm sediments 9,300 to 11,600 years ago. The luminescence (IRSL) data suggest that the entire package of coarse-grained sediments exposed in the trenches excavated for this study were deposited in a single depositional (storm) event, or in a series of closely spaced (in time) events.

3.2 DESCRIPTION OF FAULT TRENCHES

Once the trenches and test pits were dug, we used hand scrapers and brushes to clean the trench walls, removing smears left behind by the backhoe's bucket and exposing a fresh surface for logging. Both trench walls were cleaned and reviewed. During, and after we cleaned the trench walls, we reviewed the lateral continuity of the geologic units exposed in the trenches, and described the deposits. We carefully reviewed the exposures for faults and fractures, and for tilting of the sedimentary layers. We described the sediments and soils exposed in the trenches according to the characteristics and nomenclature set forth by the Soil Survey Staff (1975, 1992) and Birkeland (1984, 1999), and we used the Munsell Soil Color Chart (GretagMacbeth, 2000) to describe the colors of the sediments.

To prepare the trenches for logging we marked stations at 5-foot intervals using spray paint directly on the trench walls. We then measured the top and bottom of individual geologic layers, soils, and other stratigraphic and structural features observed in the trenches using a ZipLevel® altimeter, and prepared a log of each trench. The logs of the trenches were prepared at a scale of 1 inch equals 5 feet. The orientations of the geologic structures (faults), and the orientation (trend) of the trenches were measured using a Brunton compass. The trench locations were determined using both a hand-held GPS unit and by professional surveyors from Albert A. Webb Associates.

Each of the trench and test pit exposures is described below.

3.2.1 Trench FT-1 (Figures 8a through 8f)

Trench FT-1 was the first and longest trench excavated onsite. It was excavated in an easterly direction across the southern portion of the site, starting against the man-made hill of aggregate at the west end, and finishing against a sediment-settling pond to the east. The trench was approximately 870 feet long, and between 4 and 10 feet deep. Where deeper than 5 feet, the trench was benched and/or sloped back for safety.

The east end of trench FT-1 terminated against a sediment settling pond that receives runoff from larger ponds to the east and northeast. Unknown to us when we started the project, the water level in this pond varies daily, depending on how much water is used by Vulcan

Materials to wash their product. The pond overflowed its banks on the weekend of September 22-23, flooding the easternmost approximately 50 feet of trench FT-1 (thus the trench was logged only to Station 820 – see Figure 8f). Because we had cleaned but not logged that section of trench before it flooded, and given that the water level did not recede after three days, we made the decision to excavate a short parallel trench (trench FT-3) that shadowed the eastern end of trench FT-1.



View to the east-northeast of the eastern end of trench FT-1 showing the section of trench that was flooded when the sedimentation pond in the background overflowed its banks. Trench FT-3 was excavated to the north (left in this photo) to shadow the flooded area.

Trench FT-1 exposed a thin mantle of reworked deposits (labeled artificial fill – Afu, on the logs) that varied from 0 to 1.5 feet in thickness. Locally, the artificial fill was found to contain scattered pieces of metal and other debris. The western half of the trench, to about Station 395, exposed primarily coarse-grained fluvial deposits consisting predominantly of coarsely bedded, sub-horizontal, grayish brown to gray sand, gravel and cobbles. To the east of Station 400, we began to observe finer-grained sediments, locally with soil development, consisting of reddish brown silty sand to sandy silt, capping coarser-grained, poorly bedded sands and gravel. The grayer deposits approaching from the west cut into and covered these finer-grained deposits.

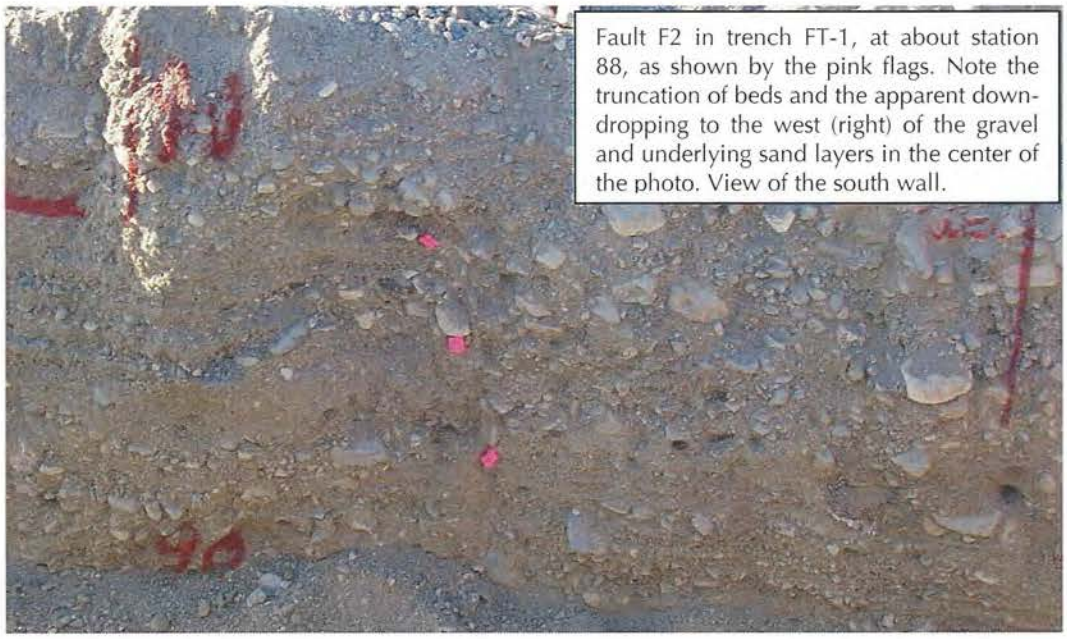
View of south wall of trench FT-1 between stations 390 and 395, showing gray fluvial deposits cutting into and capping more oxidized deposits below. Note the remnant overbank section consisting of silty sand at station 395 (behind vertical red line).



Two obvious but minor faults, and one less well-defined, but more significant fault were observed in trench FT-1. The three faults exposed are shown on Figures 8a and 8c, with their locations relative to the overall site shown in Figure 7. Fault F1 was observed at about station 0+40, F2 at station 0+88, and F3 at about station 3+40. The two westernmost faults (faults F1 and F2) showed apparent vertical separations of a few inches to less than 1 foot (see photos below).

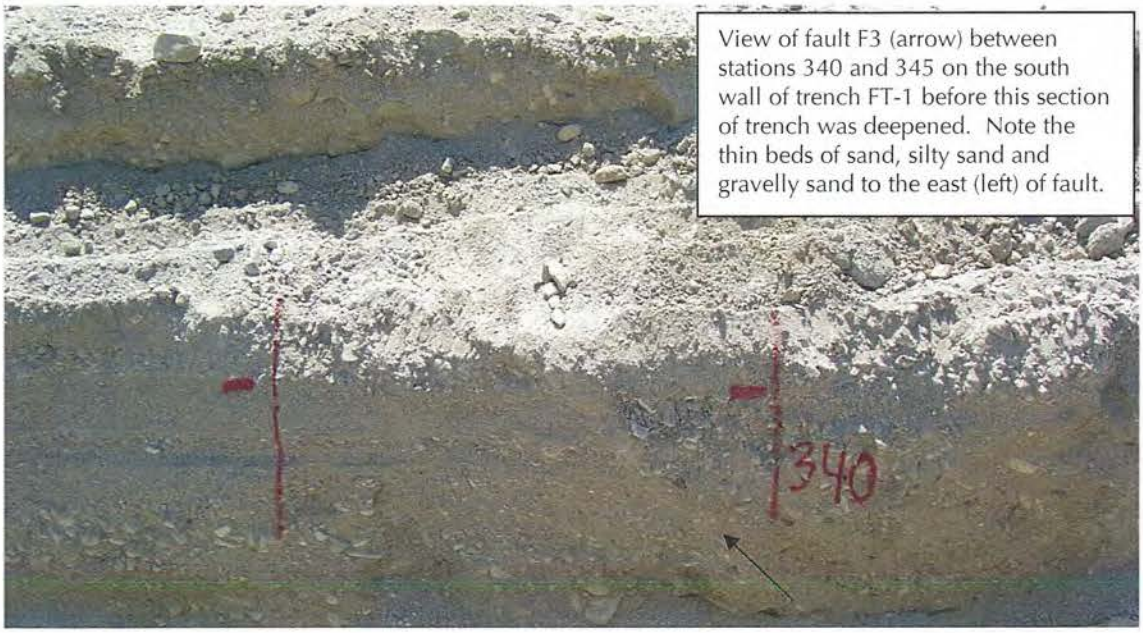
Fault F1 in trench FT-1, at station 40, shown by the pink flags. View of the south wall; west is to the right in photo.





Fault F2 in trench FT-1, at about station 88, as shown by the pink flags. Note the truncation of beds and the apparent down-dropping to the west (right) of the gravel and underlying sand layers in the center of the photo. View of the south wall.

The more significant fault in the central portion of the study area (F3) had greater vertical separation, and potentially larger offsets, as we could not confidently match stratigraphic units across it. This first suggested that the feature was a channel margin and not a fault, but deepening of the trench revealed that the feature became slightly steeper with depth, behavior more typical of a fault than a channel margin. Also, several clasts adjacent to the fault zone seemed to be rotated so that their long axes paralleled the fault (see photo). In the deepened section, a few potential correlations of geologic layers across the feature suggested a minimum of 2 to 3 feet of apparent vertical separation, and possibly substantial horizontal displacement. The orientation (strike) of each of these faults was measured in the field using a compass. All fault strikes measured trend northwesterly at between 10 and 30 degrees (N10-30W), and dip to the southwest.



View of fault F3 (arrow) between stations 340 and 345 on the south wall of trench FT-1 before this section of trench was deepened. Note the thin beds of sand, silty sand and gravelly sand to the east (left) of fault.



Close-up of a section of fault F3 (arrows) in trench FT-1 at station 340, after it was deepened, showing some of the rotated clasts observed near the fault zone. [See circles drawn on photo.]

3.2.2 **Trench FT-2** (Figures 9a and 9b)

This trench was excavated at the far west end of trench FT-1 for the purpose of extending the area of study as much as possible into the slope forming the southwestern margin of the site. The operator started high up in the slope and dug in a northeasterly direction down the slope until it reached the bottom. He then veered more easterly to extend the eastern end of the trench past the western end of trench FT-1, essentially overlapping the ends of both trenches. The trench was approximately 75 feet long, and 5.5 to 8 feet deep.



Excavator digging the south end of trench FT-2. Trench FT-2 was excavated partly in the fill-over-cut slope forming the south side of the site, and against the pile of aggregate (fill) defining the west margin of the study area. The west end of trench FT-1 can be observed in the bottom left side of the photo.

Figure 9a shows the log of this trench. Sub-horizontal, continuous beds of sand, gravel and cobbles were exposed from about Station 20 to the eastern end of the trench. No faults were observed in this section. Unusual, sloping sediments were exposed between about Stations 5 and 20, including a sharp contact between the horizontal beds at the southern end of the trench and the sloping beds described above. Unable to determine whether these tilted sediments were associated with faulting, channeling, or man-made infilling, we decided to deepen that section of the trench. The eastern end of the trench was backfilled, and the southern end was deepened to 11 feet. Figure 9b shows the log of the deepened section. The sloping beds were found to be the man-made backfill of what used to be a steeper cut-slope. Man-made debris including plastic bags, nails, and glass fragments were observed in the fill material. The bottom of this cut-slope was lined with roots. The native, horizontal layers of alluvium originally exposed at the end of the trench were found to extend across, unbroken, below the artificial fill. No evidence of faulting or tilting of the beds in the native alluvium was observed in this trench.



View of the southwest wall of the deepened section of trench FT-2, between Stations 5 and 10 (Station 5 defined by the vertical red-paint line on the right). Compare this photo with the corresponding section in Figure 9b. A thick bed of very fine sandy silt can be observed near the bottom of the trench on the right side of the photo, and underneath the number 10. The material above this bed is artificial fill. The bed of silty sand was underlain by alluvial sediments that extended unbroken below the fill the length of the trench. Notice some of the roots that lined the bottom of the cut.

3.2.3 **Trench FT-3** (Figure 10)

This trench was excavated to replace the flooded section of trench FT-1, with the station numbers assigned in this trench reflecting this by starting at Station 790 and extending in a northeasterly direction parallel to the east end of trench FT-1 (see Figure 10). Trench FT-3 was between 5.5 and 8 feet deep, benched in the deeper section, and approximately 60 feet long. The trench exposed sediments similar to those exposed in the eastern half of trench FT-1. Below a thin mantle of reworked sediments and fine-grained deposits associated with the nearby sedimentation pond, there was a bed of light brownish gray silty fine- to coarse-grained sand with scattered gravel and cobbles. This layer covered a package of weakly bedded to locally

cross-bedded sand and gravel that cut into the pale brown sandy silt overbank deposits described in trench FT-1. Below the silty sand we observed beds of coarser-grained sand, gravel and cobbles. All of these beds extended unbroken along the full length of the trench. No faults were observed in trench FT-3.



View to the west-southwest of the south wall of trench FT-3. Notice the gray, coarse-grained deposits in the top bench, overlying and incising into the bed of pale brown sandy silt at the top of the second bench. The silt bed overlies a packet of sand, gravel and cobbles near the bottom of the trench. The spoils pile for trench FT-1 can be seen in the upper-left portion of the photograph.

3.2.4 **Trench FT-4** (Figures 11a and 11b)

This trench was excavated during the third phase of our study, to shadow the eastern end of Trench FT-1 and Trench FT-3, and confirm that no faults extend from the north into this portion of the site. The trench was approximately 275 feet long and between 4 and 7.5 feet deep (Figure 11). The silty sand overbank deposit with soil development was exposed along the bottom of the trench from Station 0 (at the east end of the trench) to about Station 235. As with the other trenches to the south, the fine-grained overbank deposit was overlain by coarser-grained fluvial sediments consisting of cross-bedded sand, gravelly sand, and cobbly sand. These high-energy fluvial deposits locally incised into the underlying finer-grained deposits. Gravel and cobbles locally formed a stoneline at the contact between the two units. At the western end of the trench, where the silty sand bed extended below the bottom of the trench, the overlying coarse-grained sediments consisted of a massive package of cobbly sand. We reviewed this area carefully for aligned clasts, fractures, or other features that would suggest faulting. No faults were exposed in this trench.

3.2.5 Test Pits E1 through E6 (Figures 12a through 12f)

These test pits or short trenches were excavated to trace across the site the easternmost fault exposed in trench FT-1 (fault F3) (see Figure 7 and Figures 12a through 12f). Test pit E1, excavated south of FT-1, against the ascending slope defining the southern margin of the Winter Pit area, was 60 feet long and between 4.5 and 8 feet deep. The fault zone, exposed near the eastern end of the trench, between Stations 10 and 20, consisted of two splays (or branches). The faults were oriented about 17 to 20 degrees to the northwest, and dipped 53 to 55 degrees to the southeast.



Photo of the south wall of test pit E-1, showing the two fault splays (arrows) defining the fault zone between station 10 (to the left) and station 20. Compare with the log in Figure 12a. The faults were projected to the surface and marked with red lathes that were then surveyed by Albert A. Webb Associates.

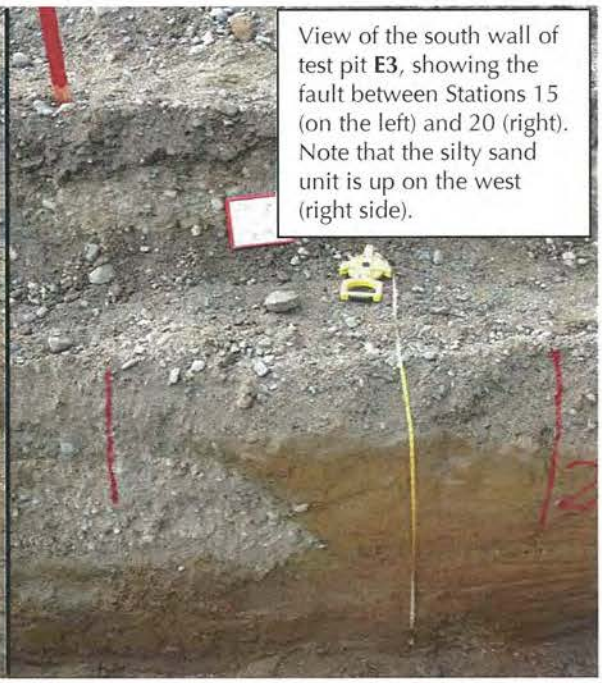
Test pit E2 was excavated about 100 feet to the north of trench FT-1. The test pit was approximately 65 feet long, and between 5 and 6.5 feet deep (Figure 12b). The fault zone in this test pit consisted of one distinct strand at about Station 48, and a second possible fault at Station 38. This second possible fault did not extend upwards to the top of the trench, and thus, if a fault, represents an older strand (a strand is part of a fault trace as exposed in a trench wall). The strike of the principal fault ranged from N14W to N24W, with a dip of 61-64 degrees to the southwest (see Photo on next page). We were not able to match units across the fault zone.

Test pit E3 was excavated approximately 110 feet to the north-northwest of test pit E2, on trend with the fault zone as exposed in test pit E2. This test pit was also 65 feet long, and between 4.5 and 6 feet deep. The fault zone was exposed near the eastern end of the trench, and consisted of one strand with a strike of N18W and a dip of 70 degrees to the southwest. An apparent vertical separation of 2 feet was measured at the top of the brown silty sand overbank deposit (see Figure 12c and Photo on next page).

Test pit E4 was excavated approximately 80 feet farther north (see Figure 7). This test pit was 75 feet long and 4.5 to 5 feet deep. As in test pit E3, the fault exposed here also consisted of one strand with a strike of N25W, and a dip of 60 to 70 degrees to the southwest. The top of the silty sand overbank deposit had an apparent vertical separation across the fault of about 1.5 feet.



View of the south wall of test pit **E2**, showing the fault at about Station 48.



View of the south wall of test pit **E3**, showing the fault between Stations 15 (on the left) and 20 (right). Note that the silty sand unit is up on the west (right side).

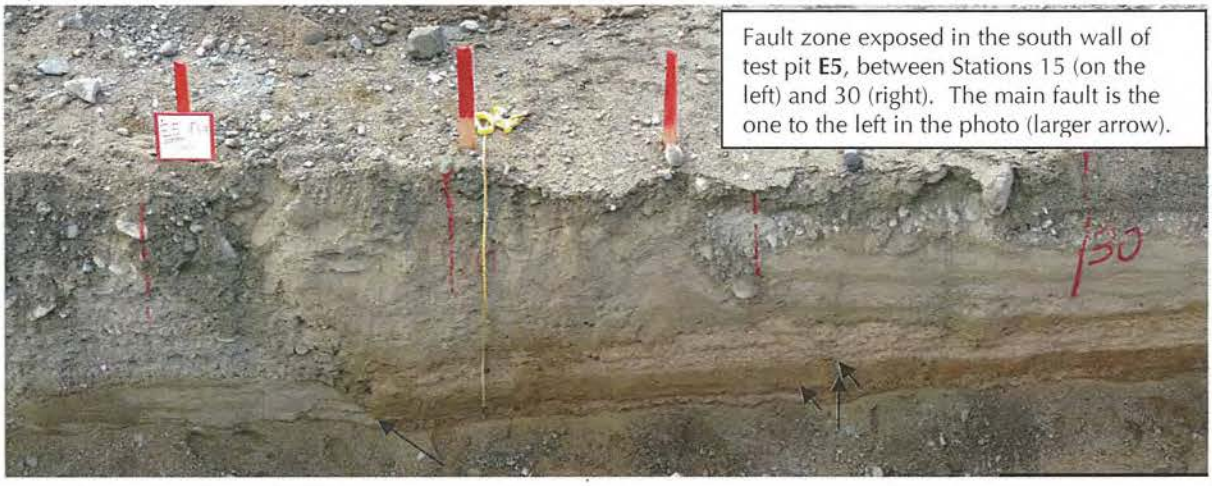


View of the south wall of test pit **E4** showing the fault zone at about Station 35 (vertical red line in the left-center of the photo).

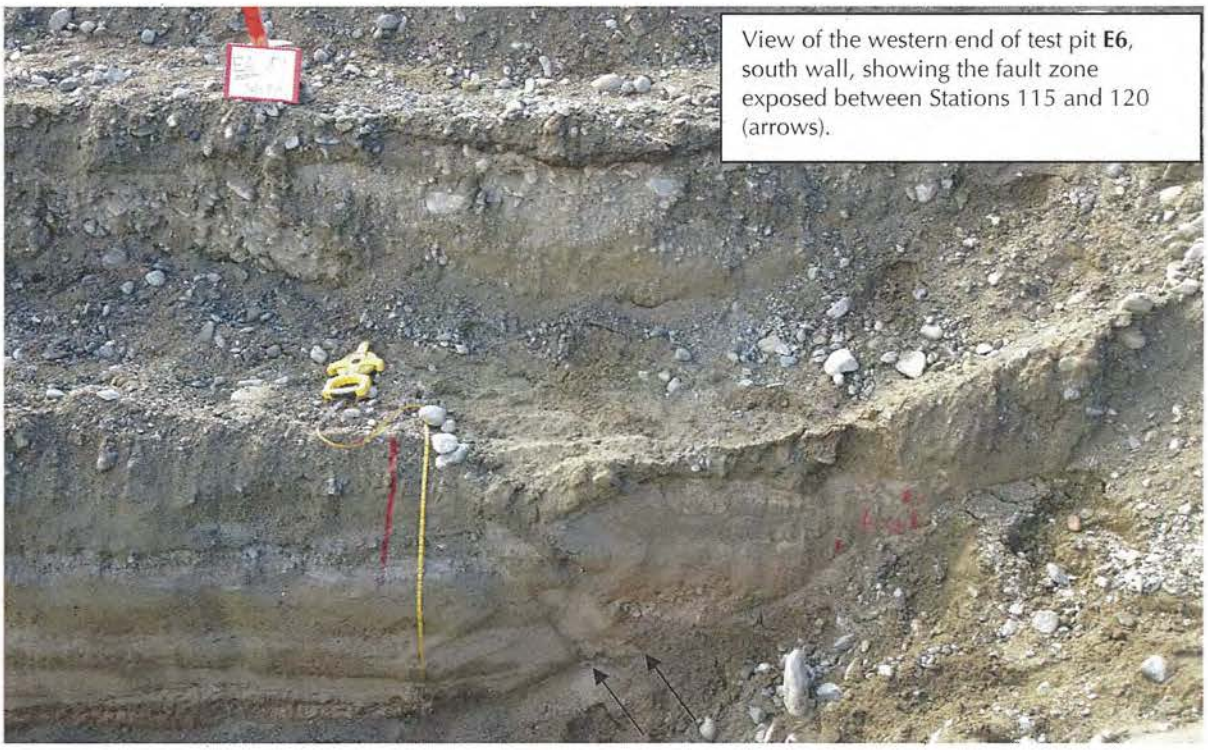
Test pit E5 to the north was approximately 95 feet long, and 4.5 to 5 feet deep. The fault zone in this test pit was 8 to 11 feet wide, and, in the south wall, consisted of at least five strands. Some of these fault strands could not be traced across the width of the test pit to its north wall, and had apparent vertical separations of only a few inches. The fault strand carrying most of the displacement is the easternmost fault, exposed at about Station 18 (see Figure 12e and photo on next page). This easternmost fault had a strike of N20W, and a dip of 47 degrees to the southwest. The westernmost fault was oriented North-South, and dipped 71 degrees to the east.

The last test pit in this series was test pit E6. This test pit was 123 feet long and between 4.5 and 6.5 feet deep. The fault zone was exposed near the western end of the excavation, between Stations 115 and 120 (the fault zone is becoming more westerly to the north). In this test pit, the

fault zone is a narrow zone 0.5 to 1 foot wide defined by two fault splays. A distinctive reddish brown sand bed near the bottom of the trench showed approximately 2 feet of apparent vertical separation across the fault zone. Beds higher up in the section displayed only about 0.5 feet of vertical separation. The strike of the faults was measured at between N10W and N27W, with dips to the southwest of 60 to 69 degrees. The trend of the fault zone across the width of the test pit was estimated at N20-30W.



Fault zone exposed in the south wall of test pit **E5**, between Stations 15 (on the left) and 30 (right). The main fault is the one to the left in the photo (larger arrow).



View of the western end of test pit **E6**, south wall, showing the fault zone exposed between Stations 115 and 120 (arrows).

3.2.6 Test Pits W1 through W5

These test pits were excavated to trace across the site the westernmost faults exposed in trench FT-1 (faults F1 and F2). **Test pit W1** was excavated south of trench FT-1. The test pit was approximately 100 feet long, and between 4 and 6 feet deep. Two minor faults and one possible

fault were observed in the test pit. The most significant of these, which is correlative with fault F2 in trench FT-1, was exposed near the eastern end of the test pit, at about Station 9 (see Figure 13a). The strike of the fault was measured as N5E, with a dip of 76 degrees to the west. At the scale of the trench log, it was not possible to show the irregular upper surface of a distinctive gray sand bed at the bottom of the trench (see Photo). Although some of these irregularities could be ascribed to scouring out by the channel that deposited the overlying gravelly sand, these features are also reminiscent of liquefaction-induced deformation.

The second fault was exposed near Station 61. This fault, with an apparent vertical separation of less than 6 inches, had an in-trench strike of N8W, and a dip of 80 degrees to the west-southwest. This feature either steps right or has a more northerly to slightly east of north regional trend if it corresponds with fault F1 in trench FT-1, as projection of this fault northward, using its strike of N8W, places it through sections of both trench FT-1 and test pit W-2 where no faults were exposed. A possible fault was interpreted on the south wall of the test pit between Stations 35 and 38. This feature, however, was not observed on the north wall.

View of the fault (arrows) interpreted near Station 9 on the south wall of test pit **W1**. Note the irregular upper surface of the gray sand bed at the bottom of the pit; some of these features resemble liquefaction-induced structures.

Oblique view of the fault (black arrows) interpreted near Station 61 on the south wall of test pit **W1**. Note the small amount of apparent vertical separation of the sand beds marked with white arrows.



Test pit W2 was excavated just north of trench FT-1. This test pit was 120 feet long and 4.5 to 5 feet deep. The fault that correlates with F2 was exposed at about Station 25, where it consisted of two fault splays in a zone about 1 foot wide at the bottom of the pit, and nearly 3 feet wide higher in the section. The faults could not be traced upwards to the top of the exposure. Apparent vertical separation on the lower beds was about 0.4 feet (<5 inches) on the eastern splay, and 0.3 feet (< 4 inches) on the western splay. The strike of the fault zone across the

trench was measured at N10E. The eastern fault splay had a strike of N9E, and a dip of 66 degrees to the northwest, whereas the western splay had a strike of N9E, and a dip of 85 degrees to the southeast.

Two other less-well defined, possible faults were observed in this test pit. One of these was exposed near Station 77 and the other near Station 111. The first of these had a regional trend (strike) of N6-7W, and a dip of 58 degrees to the southwest, and probably corresponds with fault F1 from trench FT-1 and test pit W1. The feature at Station 111 was very subtle. Apparent vertical separations across both of these features were difficult to discern, but appeared to be on the order of 0.4 feet (~5 inches). A feature similar to the one at Station 111 was not observed in trenches FT-1 and FT-2, or in test pit W1, suggesting that it is not through-going.

Test pit W3 was excavated approximately 80 feet north-northeast of test pit W2. The excavation was nearly 120 feet long and 4.5 to 6 feet deep. Only one fault with minor amount of vertical separation was observed near Station 17, consistent with the northeastward extension of fault F2. The strike of the fault across the width of the test pit was N10E, whereas the strike measured on the fault plane was N24E, with a dip of 61 degrees to the northwest. No faults coincident with the northward extension of fault F1 were exposed in the western portion of this test pit.

Fault zone at about Station 25 on the south wall of test pit **W2**. Two main fault splays (black arrows) were identified in this exposure, with vertical separations across them of no more than 4 to 5 inches.



Possible fault at about Station 17 on the south wall of test pit **W3**. The sand bed in the middle of the photo appears warped rather than faulted. The feature could not be traced up the section to the top of the trench.



Test pit W4 to the north-northeast was 68 feet long and 4 to 6.5 feet deep. Very weak evidence of faulting was observed on the south wall of the test pit at about station 27. The feature was not observed on the north wall, indicating that the fault (fault F2) is dying to the north. This was

confirmed with the excavation of test pit W5 farther north. **Test pit W5** was 130 feet long and 5 to 8 feet deep. We reviewed the exposure very carefully for evidence of faulting, warping or other deformation that would indicate that the northeast-trending zone of faulting exposed to the south continued into this area, but none was found.

4.0 DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

Earth Consultants International conducted a study of the western portion of a site located north of Highland Avenue, in unincorporated San Bernardino County, immediately north of the City of Rialto. The entire property is located within the State-defined Earthquake Fault Zone for the San Jacinto fault, and as a result, geologic studies to evaluate the hazard of fault rupture are required before habitable structures can be built onsite. The purpose of the study was to determine the potential for future surface rupture to occur in the southwestern portion of the site, the only section of the property that could be investigated by trenching at this time. Our findings are intended to help the property owners in planning the future use of the property.

Our study was conducted in three phases, with trenching conducted in Phases 2 and 3. In total, we excavated and logged 15 trenches or test pits in the study area, amounting to nearly 2,300 lineal feet of excavations. The trenches exposed slightly-older-than Holocene sediments (more than 11,000 years old), as determined from radiocarbon and luminescence dating testing. The deposits exposed were typically sufficiently well bedded to allow us to trace distinct units across and have a high degree of confidence that no faults extend through the areas where we did not observe faults.

Three discrete breaks in the stratigraphy interpreted as faults were exposed in the first and longest trench we excavated for this project (trench FT-1). The series of test pits that we excavated and logged during the third phase of the study were to be placed so as to trace these three fault zones northward across the study area. However, piles of aggregate placed along the western margin of the study area prevented us from evaluating the westernmost portion of the property, in the area where fault F1 could project to, although only very subtle features potentially suggestive of faulting were observed near the west end of test pit W2, and the better-defined of these, if through-going, should have been exposed near the west end of test pit W3, but was not. Nevertheless, and given that several faults have been projected through or near the western limits of the property as a result of studies conducted to the north-northwest, in the Rancho Verde Country Club property, the western end of the site, outside the area covered by this study, should not be developed with habitable structures unless additional studies can be conducted in the future in this area. We recommend that the westernmost about 250 feet of the site be considered a Restricted Use Area (RUA – see Figure 7).

The easternmost of the faults exposed in trench FT-1 (Fault F3) was found to be the most significant fault, extending in a northwesterly direction across the entire study area. In the southern half of the property, the fault has an average strike of N17W, but at about the latitude of test pit E3, the fault becomes more westerly, with an average strike of N25W. The fault dips to the southwest, with dip angles of between 42 and 70 degrees. Slip on this fault appears to be decreasing northward, with the fault breaking into several minor splays, each carrying only a small component of the total displacement. The fault exposure in test pit E6 also showed that whereas the deeper sediments appeared to have up to 2 feet of vertical separation, beds higher up in the section displayed only about 0.5 feet of vertical separation. Because the sediments

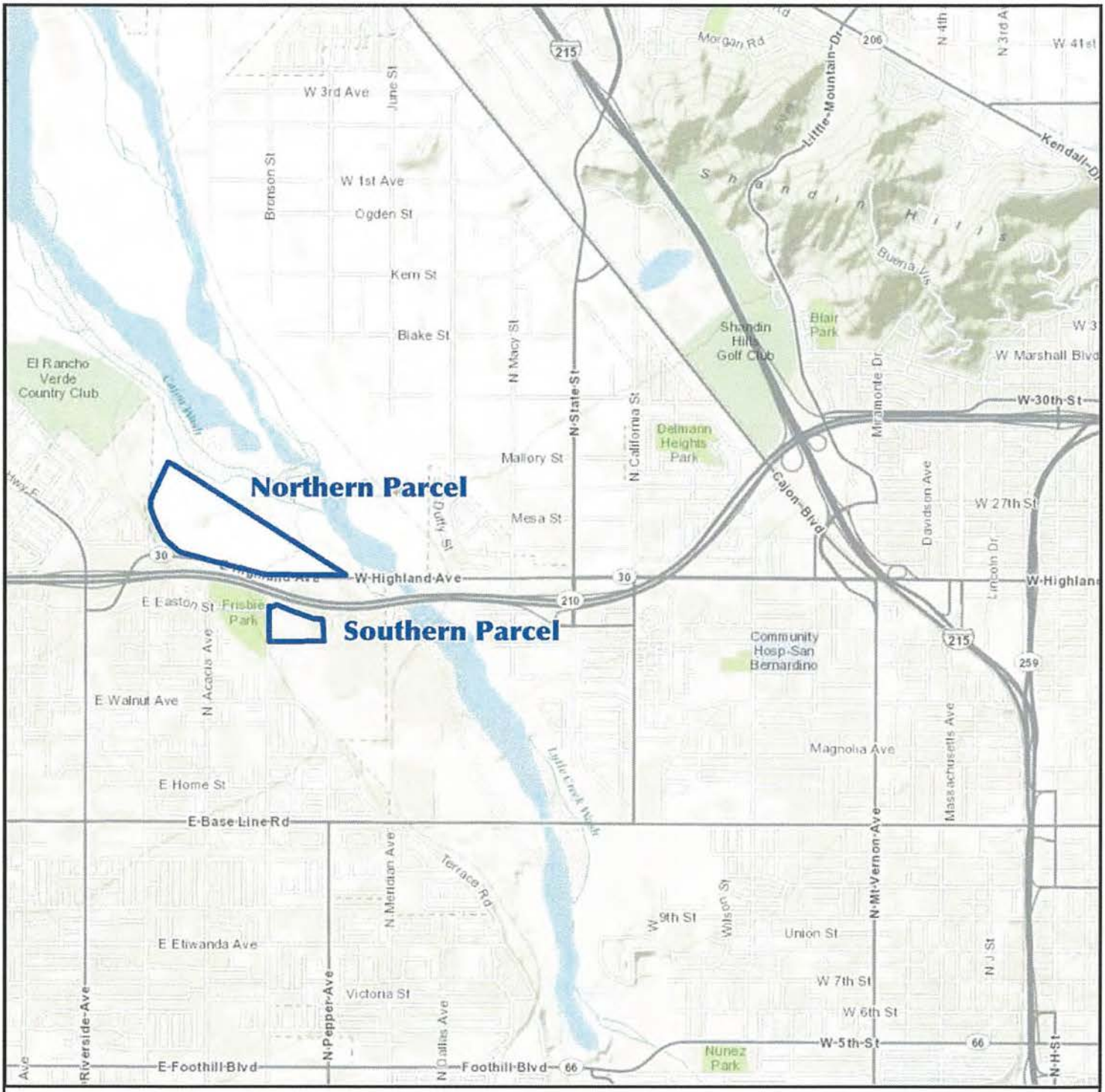
involved in the fault zone are about 11,000 years old, this indicates that only about 0.5 feet of vertical displacement has occurred in the past about 11,000 years, resolving into a very small amount of displacement per event if this fault is still active. An alternate, more plausible interpretation of these observations is that the fault has not moved in several thousand years, and is no longer active. However, given that sediments younger than about 11,000 years old have been removed from the study area, this second interpretation could not be confirmed as part of this study. Furthermore, a review of aerial photographs and cut and fill maps of the Winter Pit suggest that there are no areas on site where the recency of activity of this fault could be evaluated further.

Fault F2 was observed in trench FT-1 and the three test pits closest to this trench. The fault has a regional strike of N10E, and dips of between 61 and 76 degrees to the northwest. The fault displayed only minor vertical separations, and in test pit W1, was associated with features reminiscent of liquefaction structures. In test pit W4, the sediments on the south wall were slightly warped in the area where the fault was expected to be exposed, whereas the sediments on the north wall were not impacted by faulting or folding. The next exposure to the north, test pit W5, did not expose any features indicative of faulting. Thus, this fault terminated northward within the width of test pit W4. Where the fault was observed in some of the southern test pits, it typically could not be traced up to the top of the exposure, in sediments that are more than 11,000 years old. It is our conclusion therefore, that this fault, if a tectonic feature, and not the margin of a liquefaction-induced failure (a possible interpretation), is no longer active.

Given the data presented above, we conclude that none of the faults exposed in this study can be considered a significant main branch of the San Jacinto fault. Nevertheless, habitable structures should not be built in the westernmost portion of the site unless additional studies can be conducted in this area in the future. Faults F2, if a fault, is no longer active and is not anticipated to pose a constraint to development. Although fault F3 may no longer be active, confirming this onsite may not be possible, given that the entire western portion of the parcel has been extensively modified by the gravel and sand mining operations. Structural setbacks and/or engineering strengthening of foundations that straddle this fault zone may be appropriate. However, the location and width of such a structural setback cannot be defined at this time, given that the site is expected to be backfilled with a thick section of artificial fill. Since the fault is not vertical, the upward projection of the fault plane through the artificial fill will be dependent on the thickness of the fill, in addition to its geotechnical properties. Strengthened foundations are recommended for all habitable or sensitive structures that may be developed onsite, not only to accommodate small ground displacements associated with secondary faulting, but to resist the strong ground shaking that can be expected at the site and vicinity as a result of a large earthquake on the nearby San Jacinto, San Andreas or Cucamonga faults.

FIGURES

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Figure 2:	Site Location Map Showing the Alquist-Priolo Earthquake Fault Zone Boundaries
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Figures 9a-b:	Logs of Trench 2
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Figure 12f:	Log of Test Pit E6
Figure 13a:	Log of Test Pit W1
Figure 13b:	Log of Test Pit W2
Figure 13c:	Log of Test Pit W3
Figure 13d:	Log of Test Pit W4
Figure 13e:	Log of Test Pit W5



Base Map: Sure!Maps Raster, 1:24,000, 1995

N
W E
S

3000 0 3000
Feet

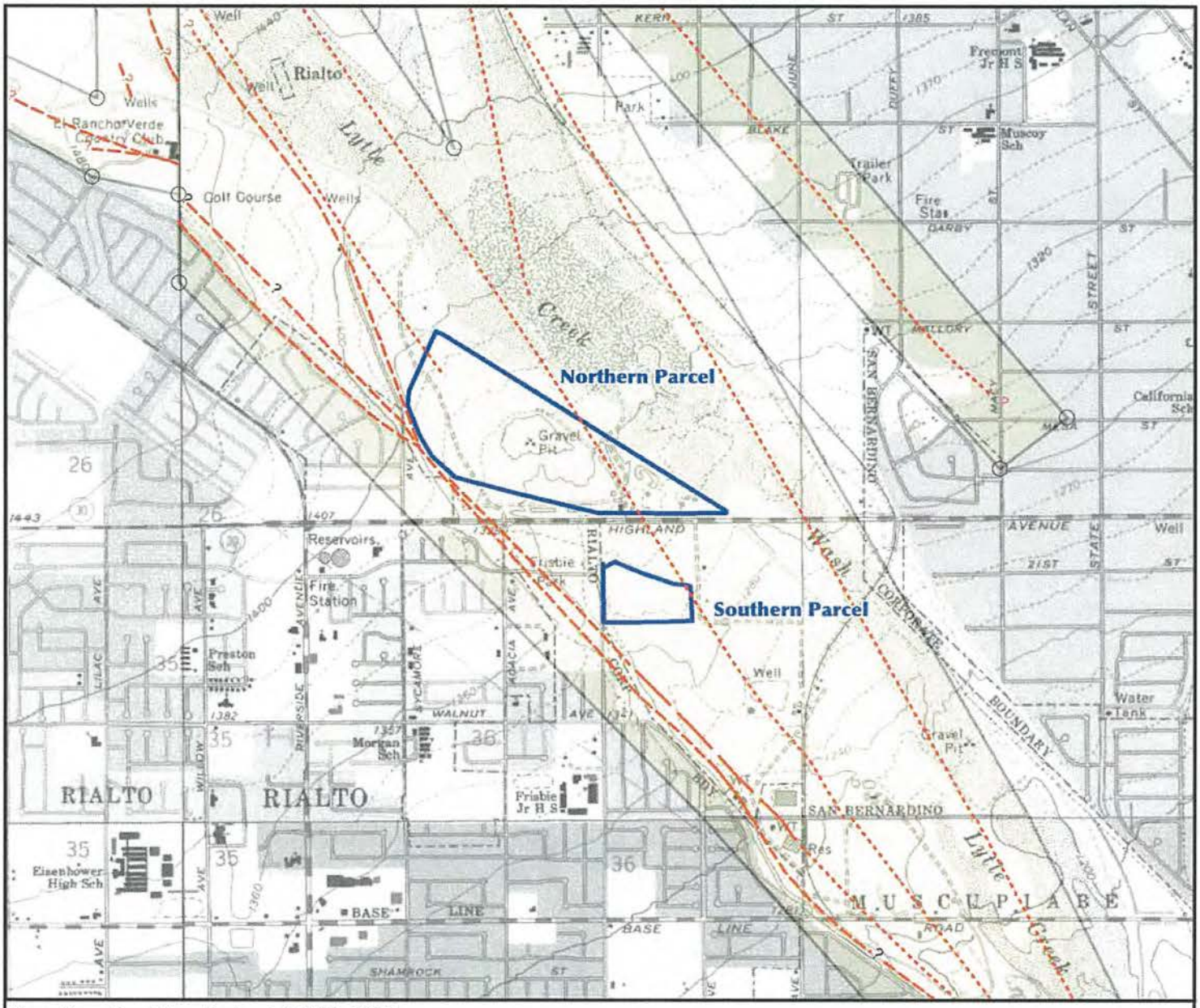
Scale: 1:36,000

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Date: January 2013

Site Location Map

Figure 1



Base Map: Sure!Maps Raster, 1:24,000, 1995

AP Zones: Reproduced with permission, California Geological Survey from CD-ROM 2001-05 (2002), Official Map of Alquist-Priolo Earthquake Fault Zones, San Bernardino South Quadrangle (1977), San Bernardino North Quadrangle (1974), and Devore Quadrangle (1995).

Explanation

Faults considered to have been active during Quaternary time; solid line where accurately located, long dash where approximately located, short dash where inferred, dotted where concealed.

Earthquake Fault Zone Boundaries delineated as straight-line segments that connect encircled turning points so as to define special studies zone segments.

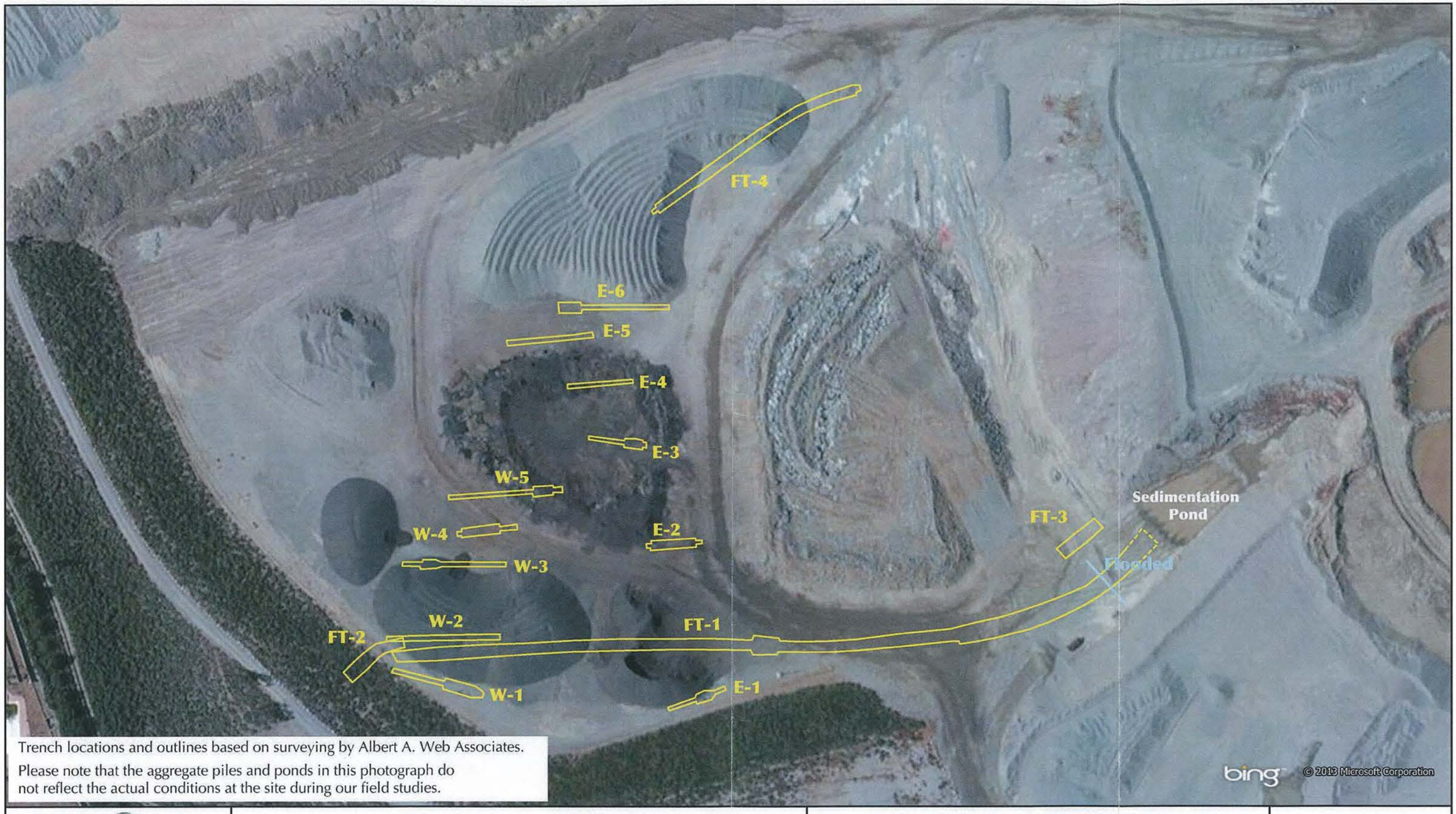
N
W E
S

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Date: January 2013

Site Location Map Showing the Alquist-Priolo Earthquake Fault Zone Boundaries

Figure 2



Trench locations and outlines based on surveying by Albert A. Web Associates.

Please note that the aggregate piles and ponds in this photograph do not reflect the actual conditions at the site during our field studies.

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N
W E
S

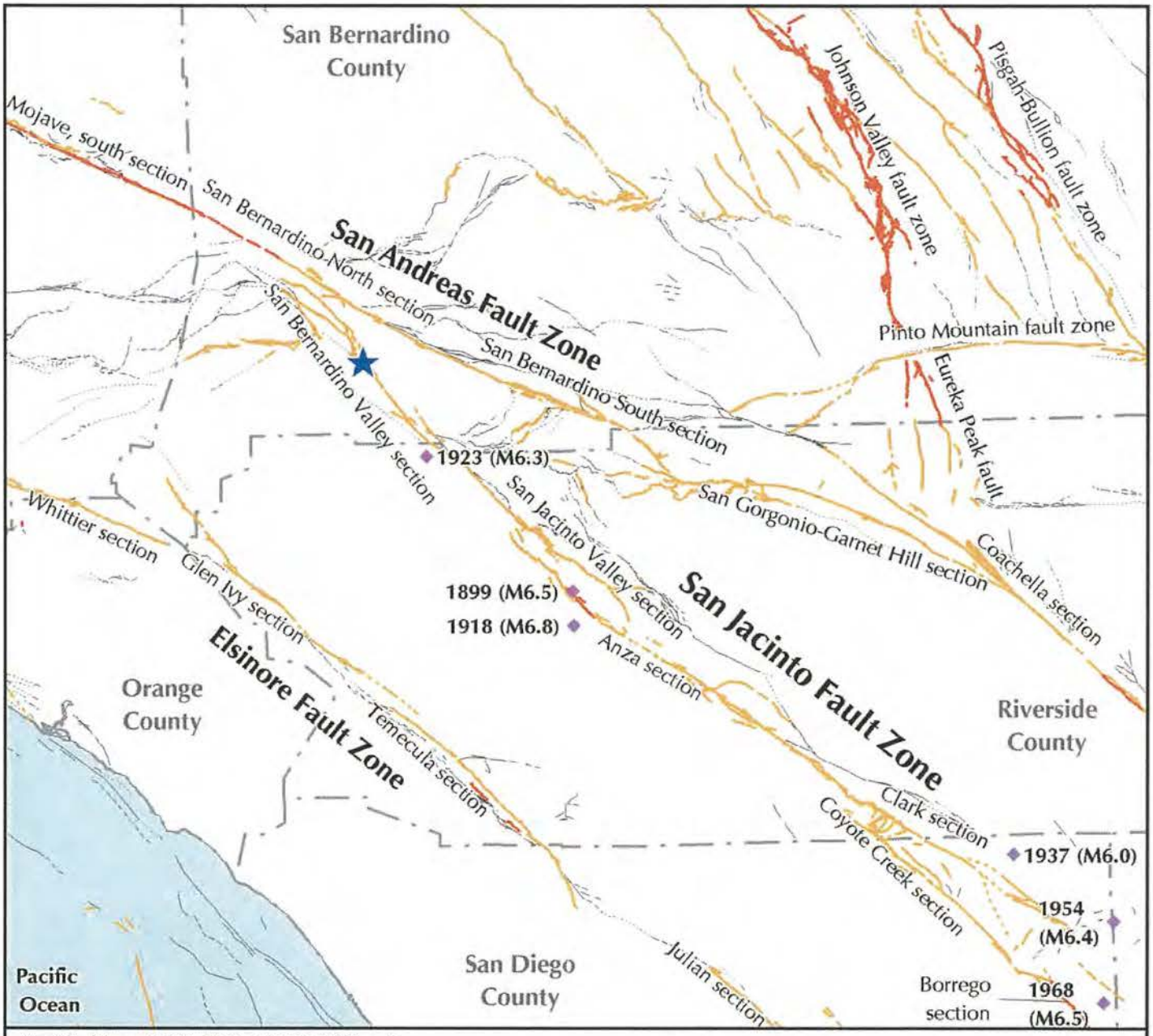
100 0 100 200
Feet

Scale: 1:1,200

Trench Location Map

BBC Properties' Northern Parcel, near Rialto, San Bernardino County

Figure 3



Modified from USGS, 2006; USGS, 2008 and Southern California Earthquake Center (January 1932 to December 2011); National Earthquake Information Center (1800 to 1931).

N
W E
S

0 15
Miles

Explanation

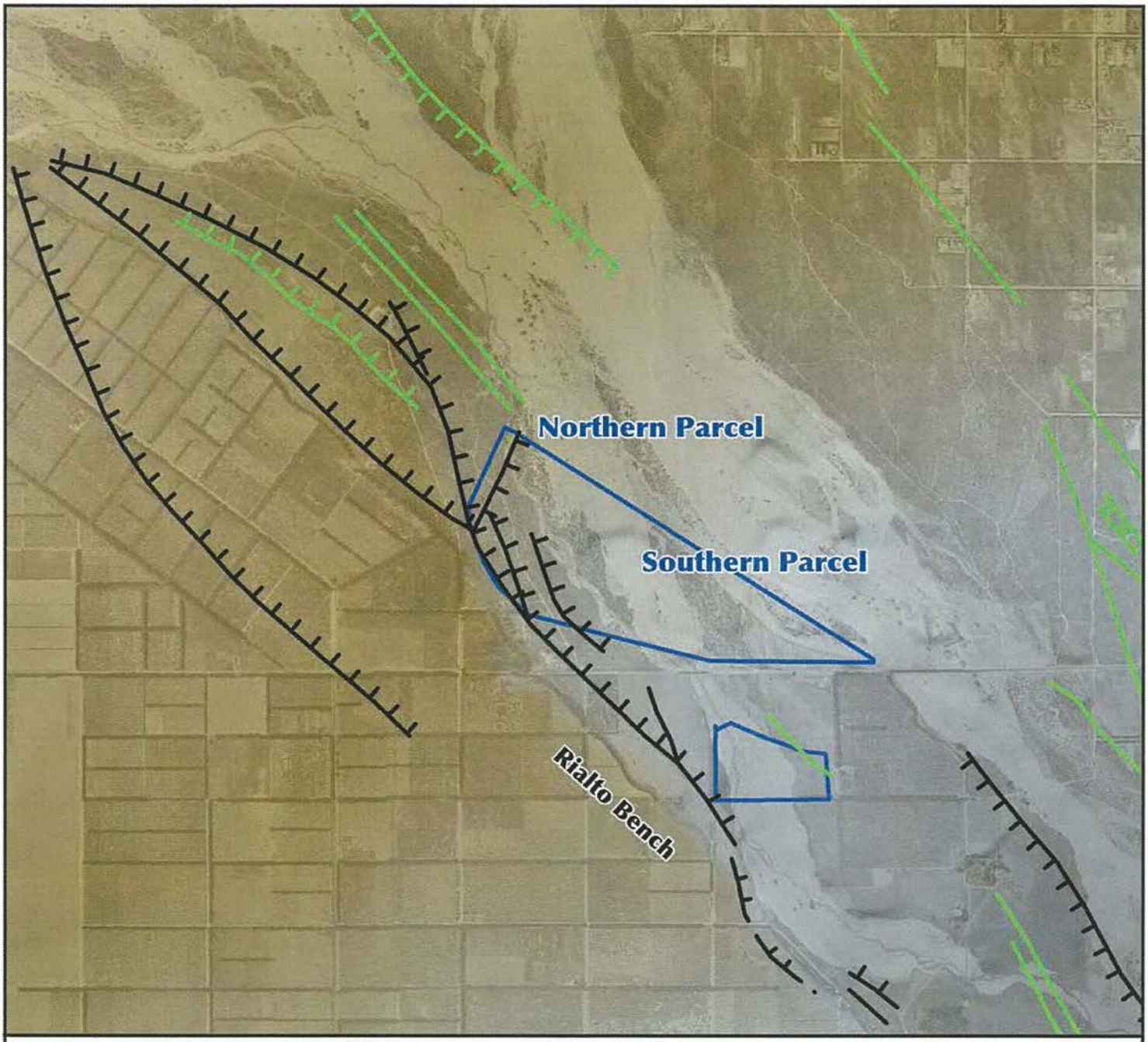
- Fault Showing Evidence of Historic Rupture (Active).
- Fault Showing Evidence of Holocene Rupture (Active).
- Fault Showing Evidence of Quaternary and Late Quaternary Rupture (Potentially Active).
- Site.
- Historical Earthquakes Magnitude >/= 6.0 on San Jacinto Fault.

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Local Active and Potentially Active Faults and Significant Historical Earthquakes on the San Jacinto Fault

Figure 4



Base Map: USGS 10m DEM and 1938 aerial photograph.

Explanation

Photo lineament; probably fault related; hachures indicate escarpment face.

Photo lineament; uncertain faulting/ fluvial origin; hachures indicate escarpment face.

N
W E
S

Scale: 1:36,000

3000 0 3000

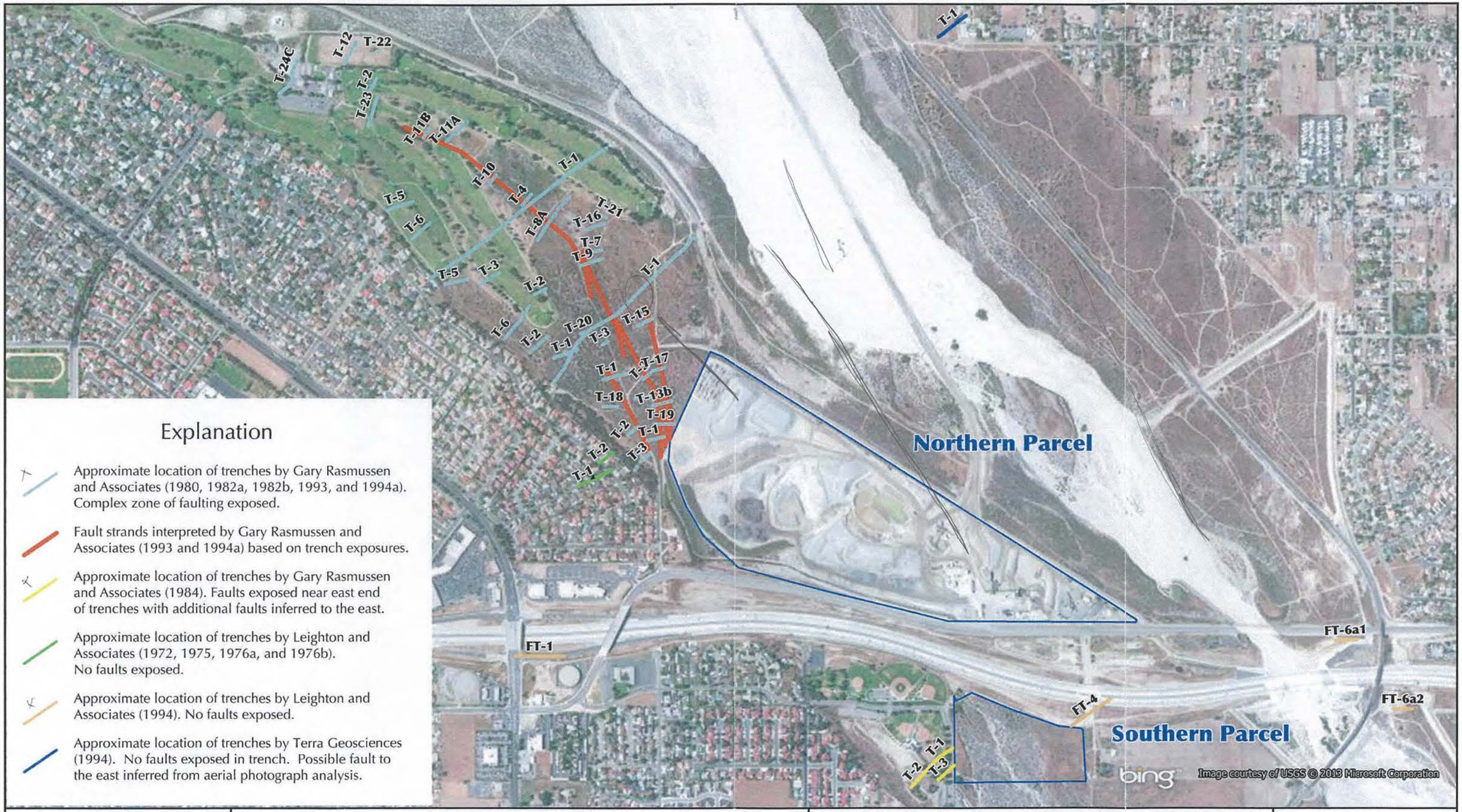
Feet

Earth Consultants International

Project Number: 3213
Date: January 2013

Geomorphic and Photo Lineament Map

Figure 5



Explanation

- Approximate location of trenches by Gary Rasmussen and Associates (1980, 1982a, 1982b, 1993, and 1994a). Complex zone of faulting exposed.
- Fault strands interpreted by Gary Rasmussen and Associates (1993 and 1994a) based on trench exposures.
- Approximate location of trenches by Gary Rasmussen and Associates (1984). Faults exposed near east end of trenches with additional faults inferred to the east.
- Approximate location of trenches by Leighton and Associates (1972, 1975, 1976a, and 1976b). No faults exposed.
- Approximate location of trenches by Leighton and Associates (1994). No faults exposed.
- Approximate location of trenches by Terra Geosciences (1994). No faults exposed in trench. Possible fault to the east inferred from aerial photograph analysis.

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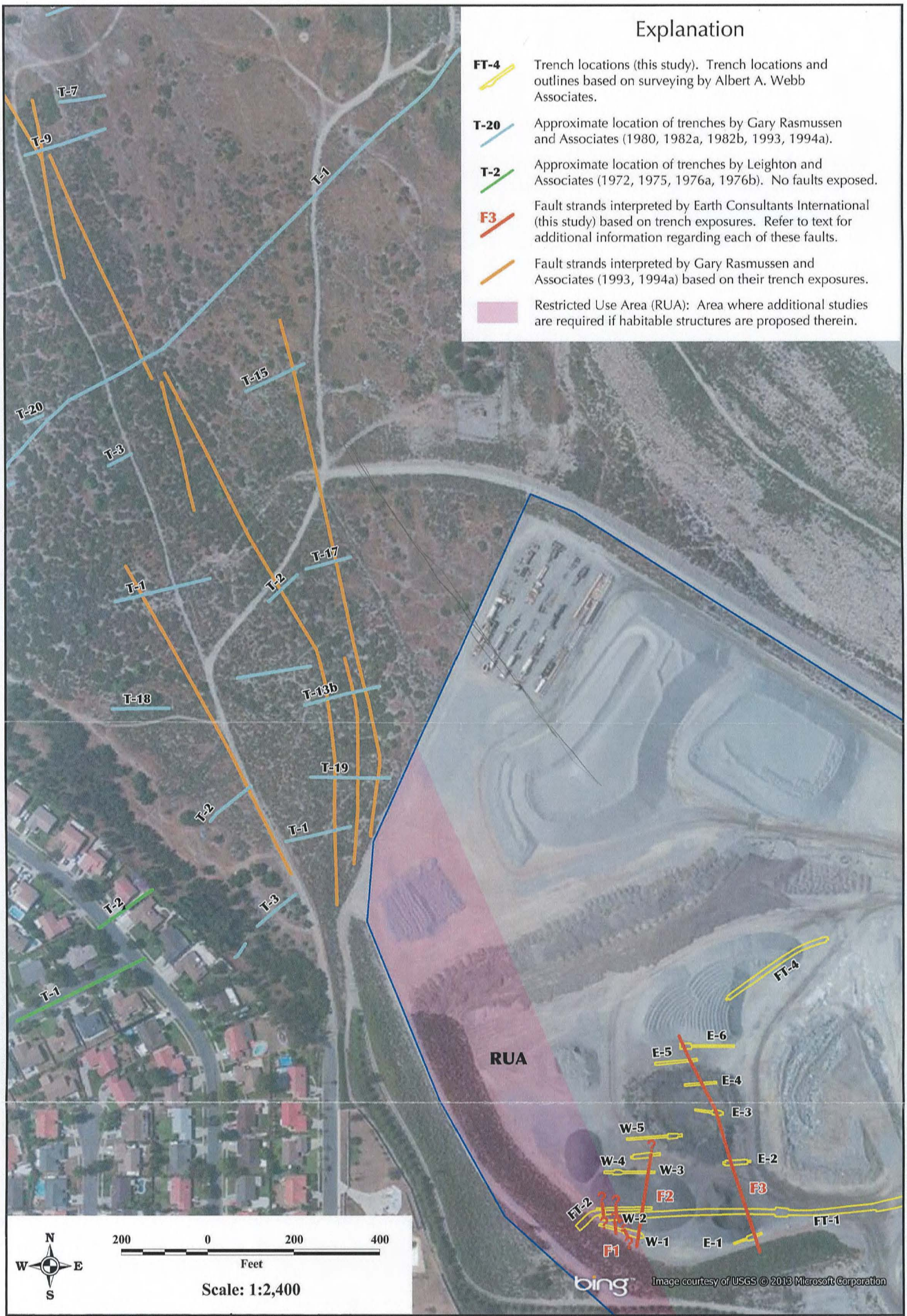
Project Number: 3213
Date: January 2013

N
W E
S

800 0 800 1600
Feet
Scale: 1:9,600

Studies Conducted by Others in the Site Vicinity

Figure 6



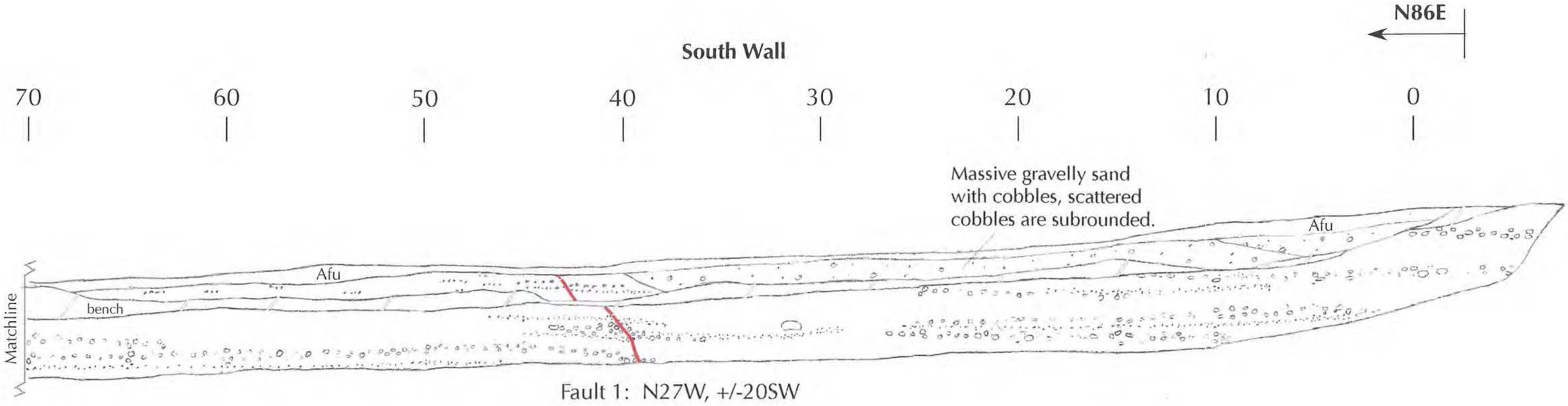
Earth Consultants International

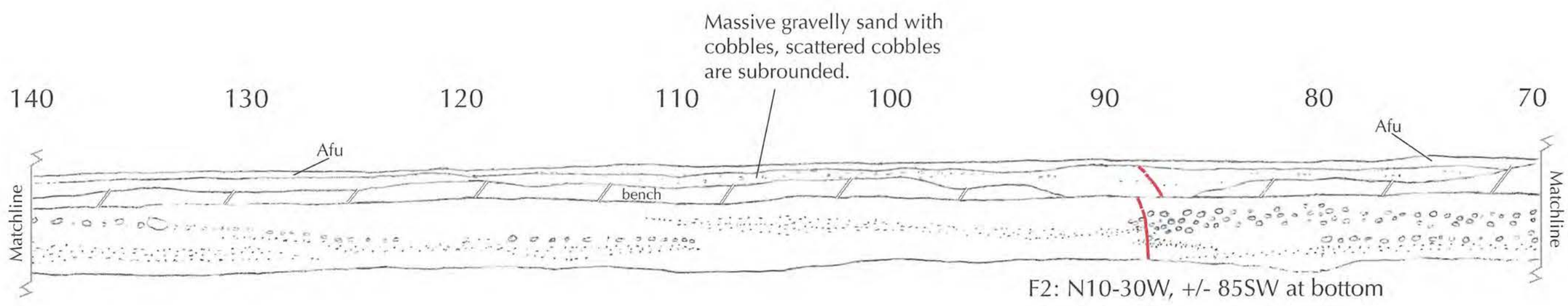
Project Number: 3213
Date: January 2013

Fault Map Showing Recommended Restricted Use Area

BBC Properties' Northern Parcel,
near Rialto, San Bernardino County

Figure 7





Sequence of nested channels, with subhorizontal, internally massive to poorly graded beds of sand, silty sand, fine to coarse gravel, and sandy to gravelly cobbles; silty sand beds are slightly harder (more cemented) than the coarser sand and gravel beds. In general, the section is single-grained and loose, gray (2.5Y 6/1); cobbles and coarse gravels are subrounded, fine gravels are subangular.

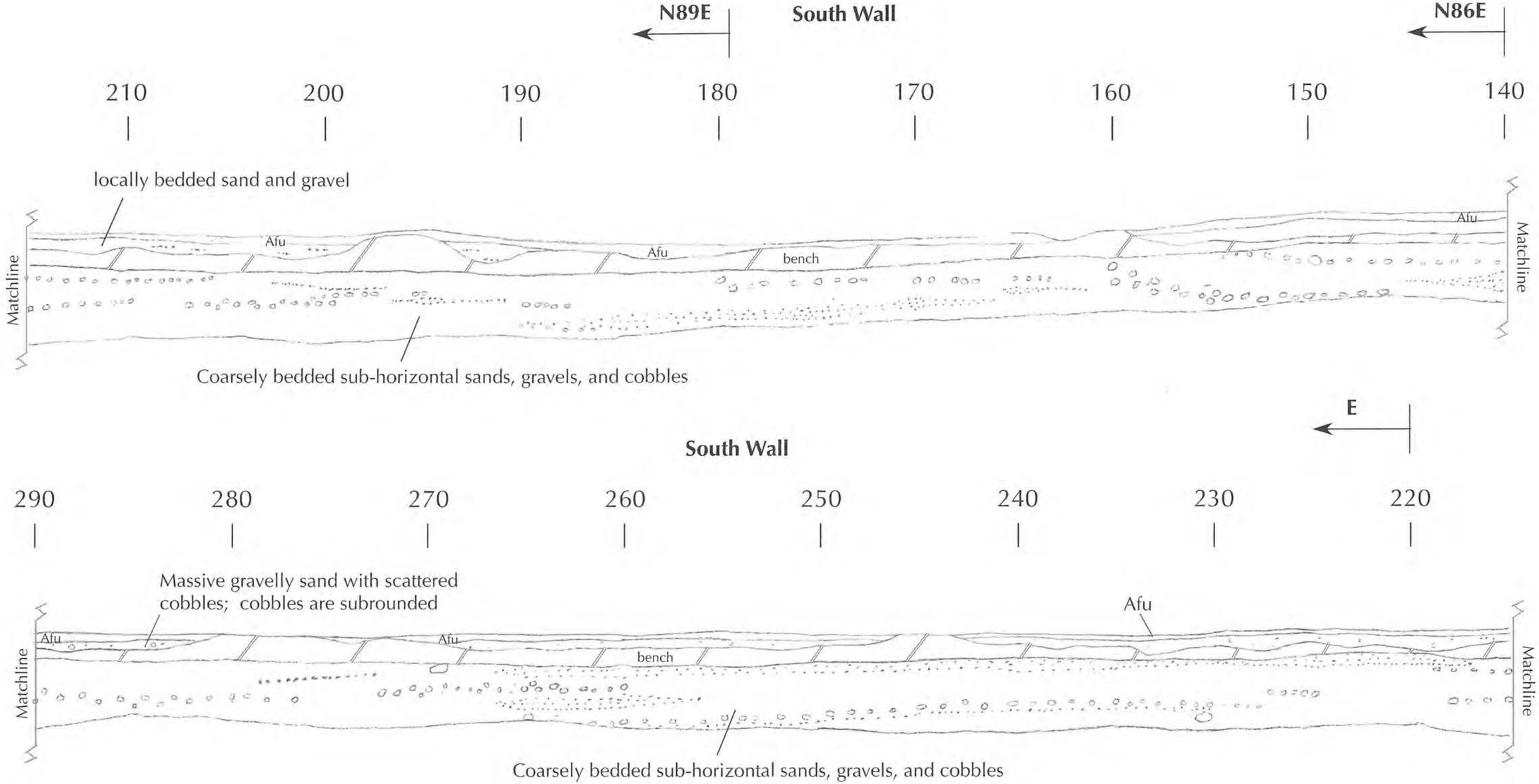
Log of Trench FT-1

BBC Properties, Northern Parcel
San Bernardino County, California

Earth Consultants International

Project Number: 3213
Date: January 2013

Figure 8a



Sequence of interbedded channels, sub-horizontal; coarsely bedded sand, silty sand, fine to coarse gravel, and sandy to gravely cobbles; section is generallly single grained to loose, grayish brown to gray (2.5Y 5/2 - 6/1); subrounded cobbles, subrounded to subangular gravel.

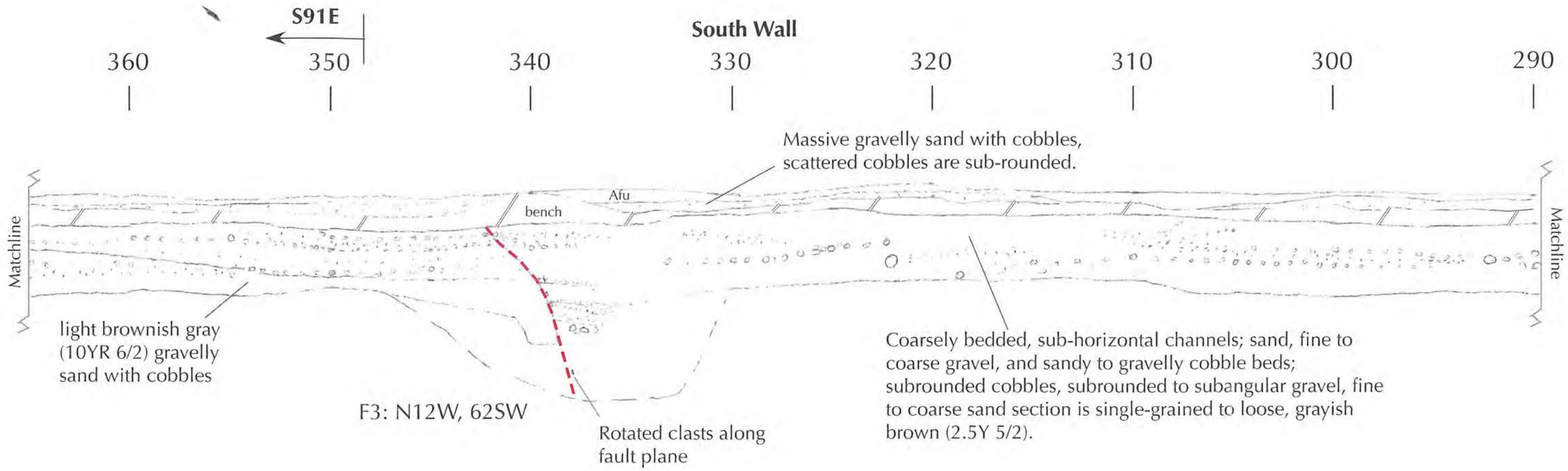
Log of Trench FT-1

BBC Properties, Northern Parcel
San Bernardino County, California

Earth Consultants International

Project Number: 3213
Date: January 2013

Figure 8b



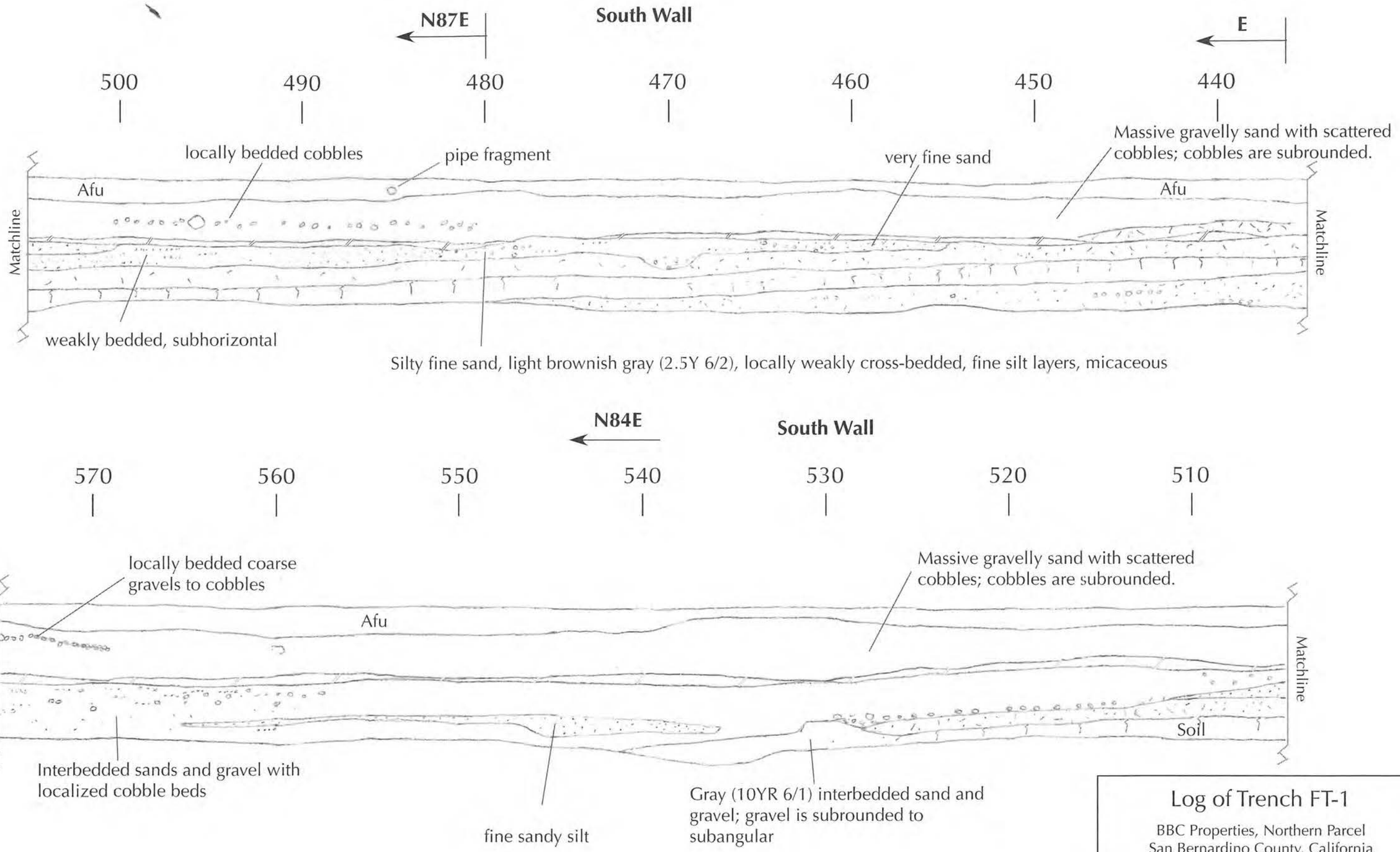
Log of Trench FT-1

BBC Properties, Northern Parcel
San Bernardino County, California

Earth Consultants International

Project Number: 3213
Date: January 2013

Figure 8c



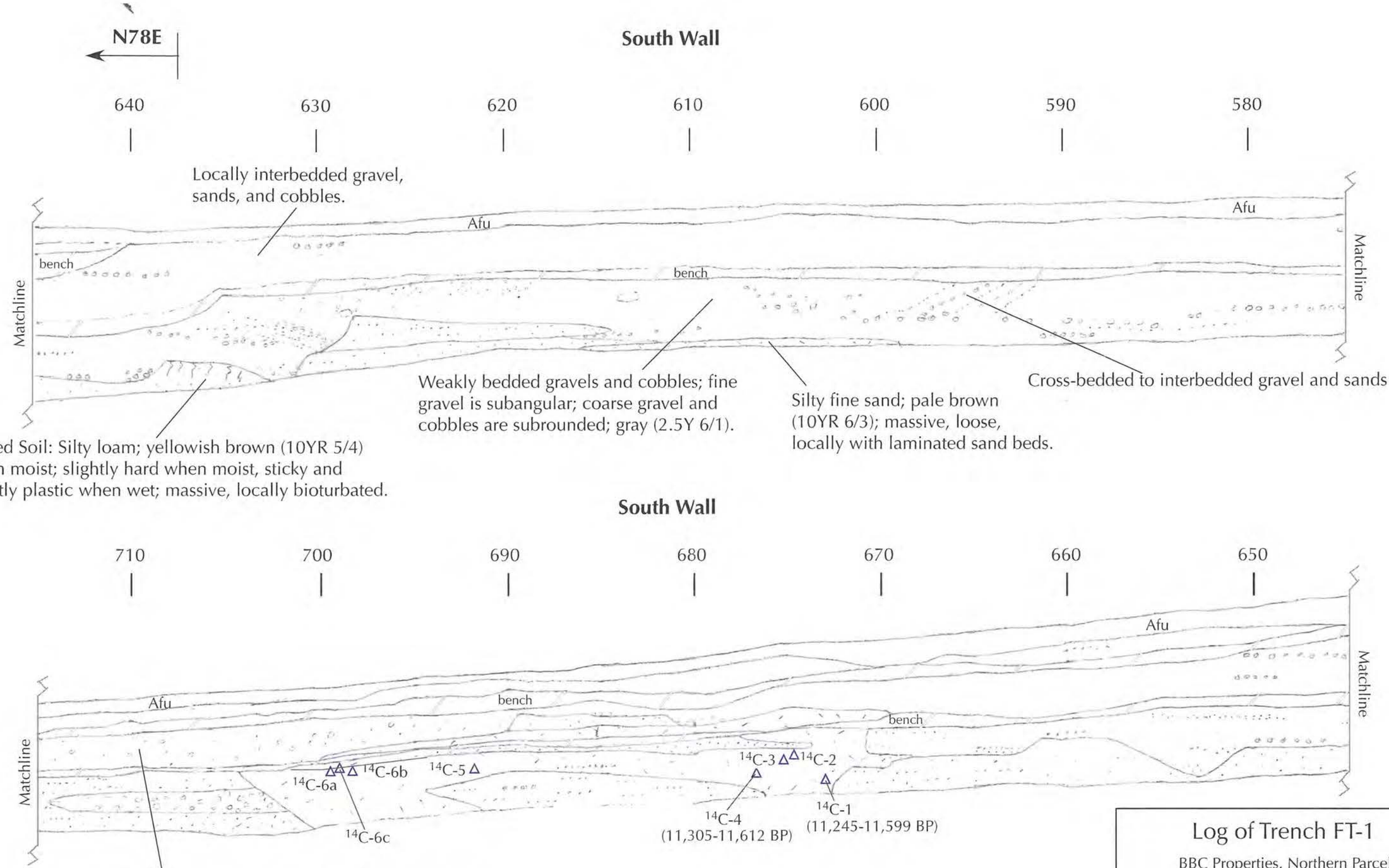
Log of Trench FT-1

BBC Properties, Northern Parcel
San Bernardino County, California

Earth Consultants International

Project Number: 3213
Date: 2012

Figure 8d



Log of Trench FT-1

BBC Properties, Northern Parcel
San Bernardino County, California

Earth Consultants International

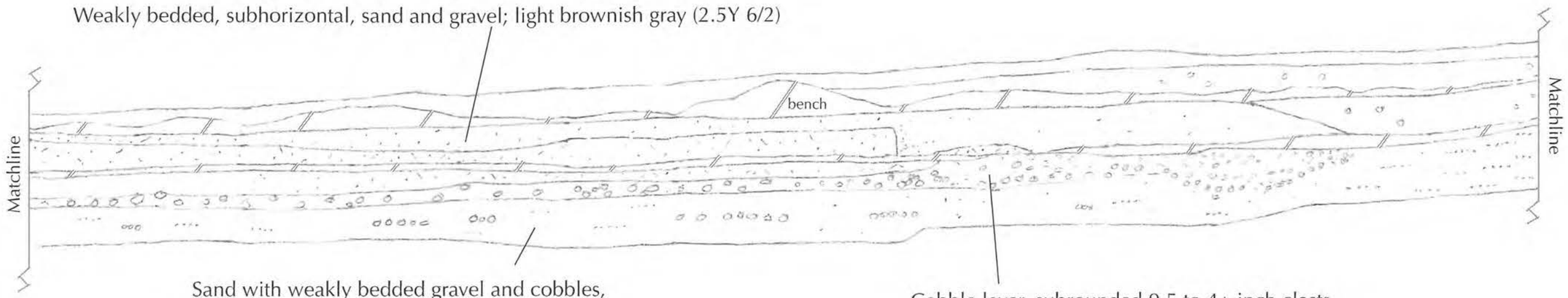
Project Number: 3213
Date: January 2013

Figure 8e

South Wall

N61E

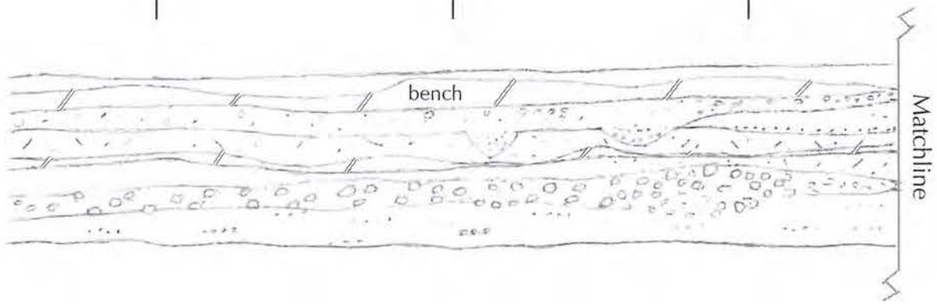
780 770 760 750 740 730 720



South Wall

N48E

810 800 790



Flooded beyond this point; Refer to FT-3 for additional coverage of this area.

Log of Trench FT-1

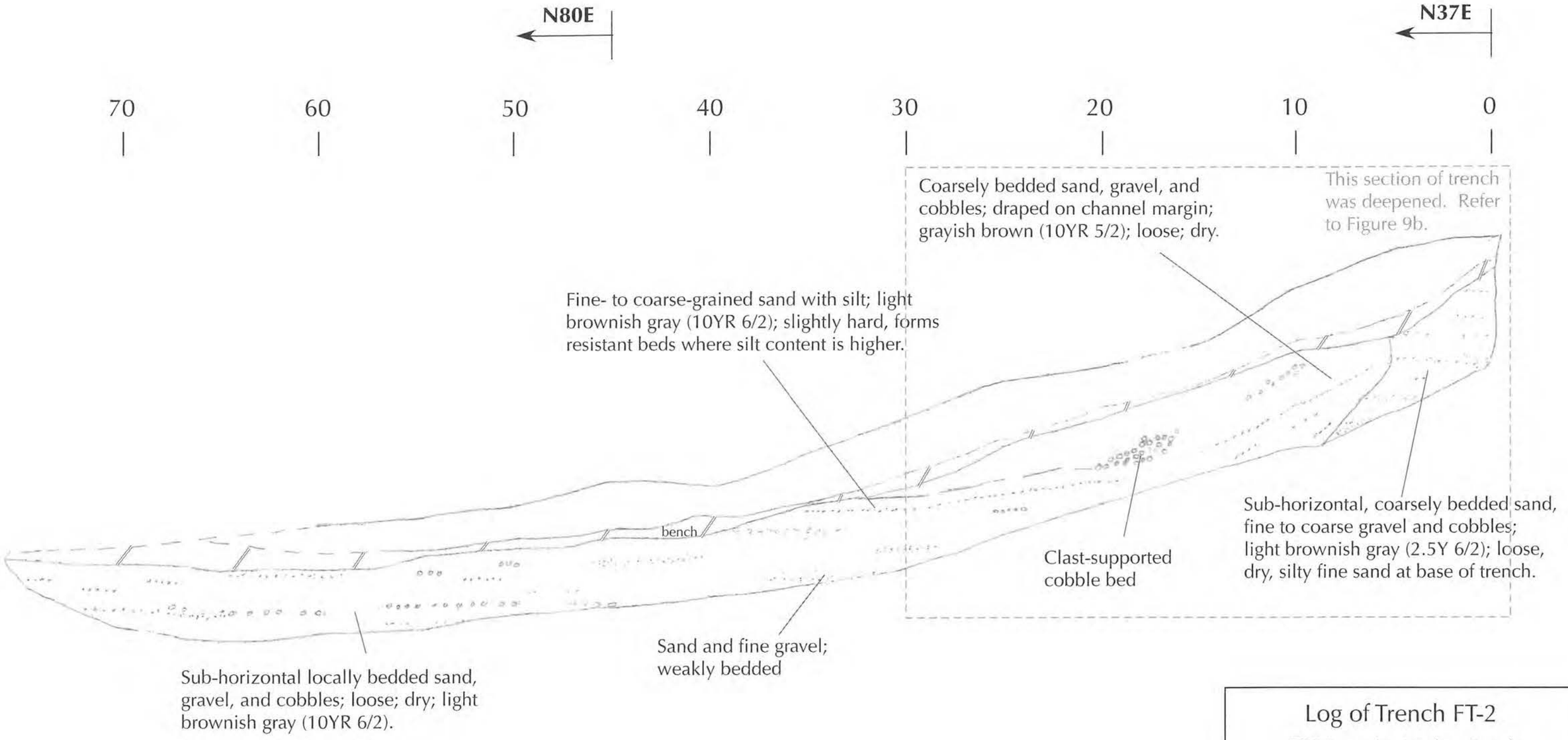
BBC Properties, Northern Parcel
San Bernardino County, California

Earth Consultants International

Project Number: 3213
Date: January 2013

Figure 8f

Southeast Wall



Log of Trench FT-2

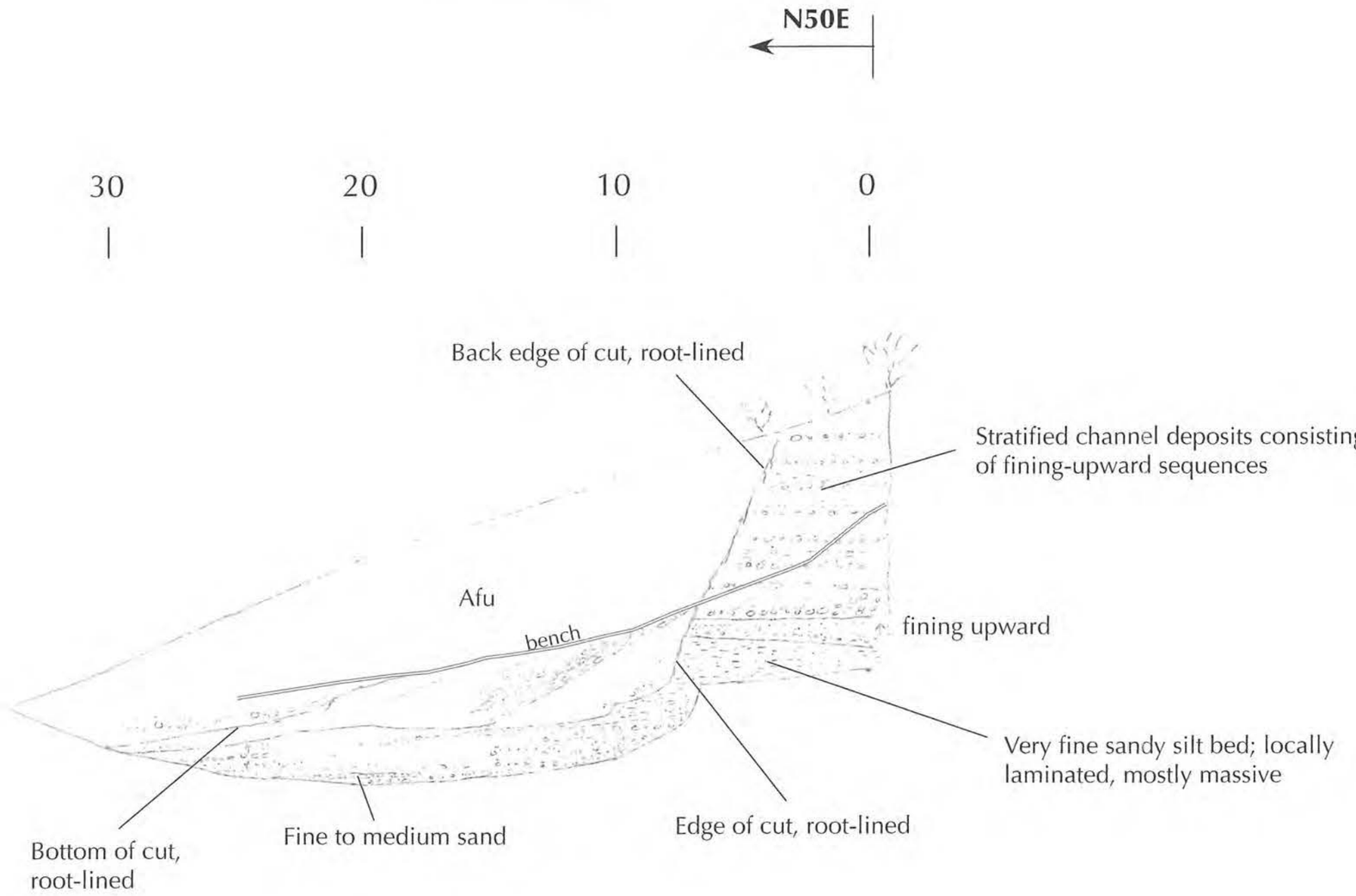
BBC Properties, Northern Parcel
San Bernardino County, California

Earth Consultants International

Project Number: 3213
Date: January 2013

Figure 9a

Southeast Wall



Log of Southernmost Section of Trench FT-2
BBC Properties, Northern Parcel
San Bernardino County, California

Earth Consultants International

Project Number: 3213
Date: January 2013

Figure 9b

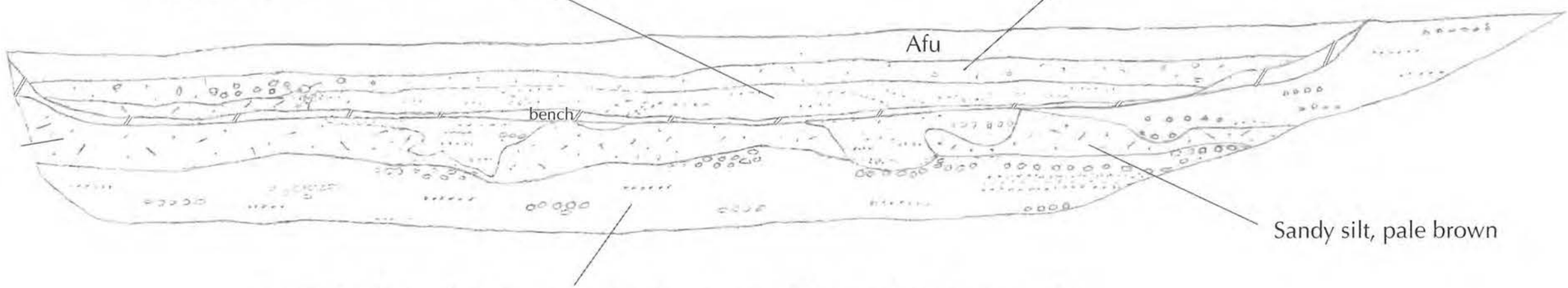
South Wall

N50E

840 830 820 810 800 790

Massive, silty fine- to coarse-grained sand, with scattered fine to coarse gravel and cobbles; dry; loose, larger clasts are subrounded; light brownish gray (2.5Y 6/2).

Weakly bedded to locally cross-bedded, sub-horizontal, sand and gravel; gray.



Sandy silt, pale brown

Sandy silt, pale brown

Weakly bedded, sub-horizontal, sand, gravel, and cobbles; redder than layers above.

Parallel to and approximately 40 feet North of FT-1.

Log of Trench FT-3

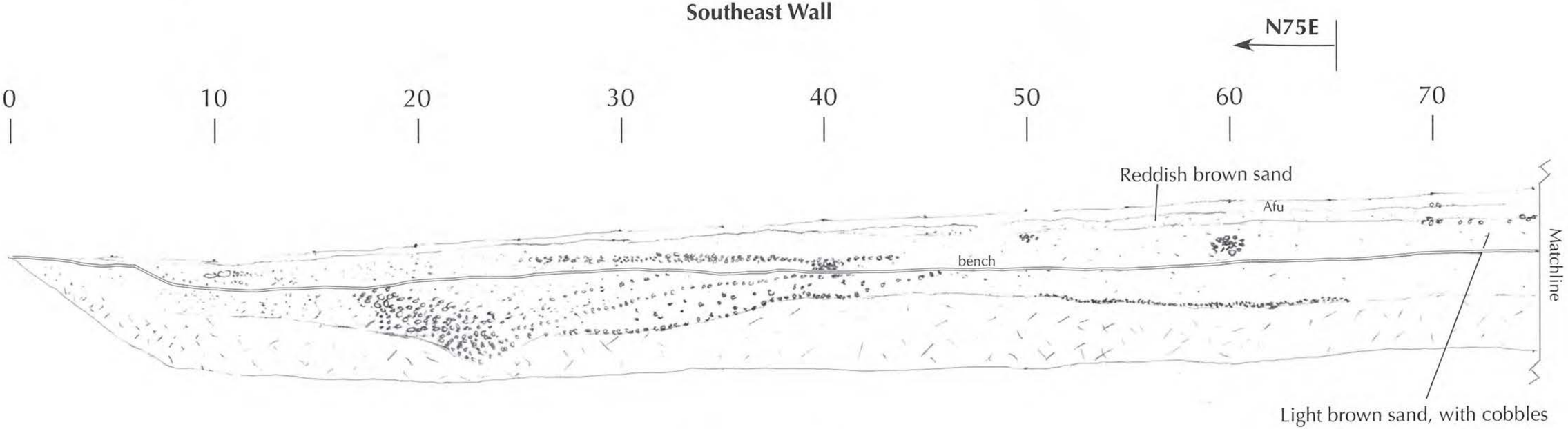
BBC Properties, Northern Parcel
San Bernardino County, California

Earth Consultants International

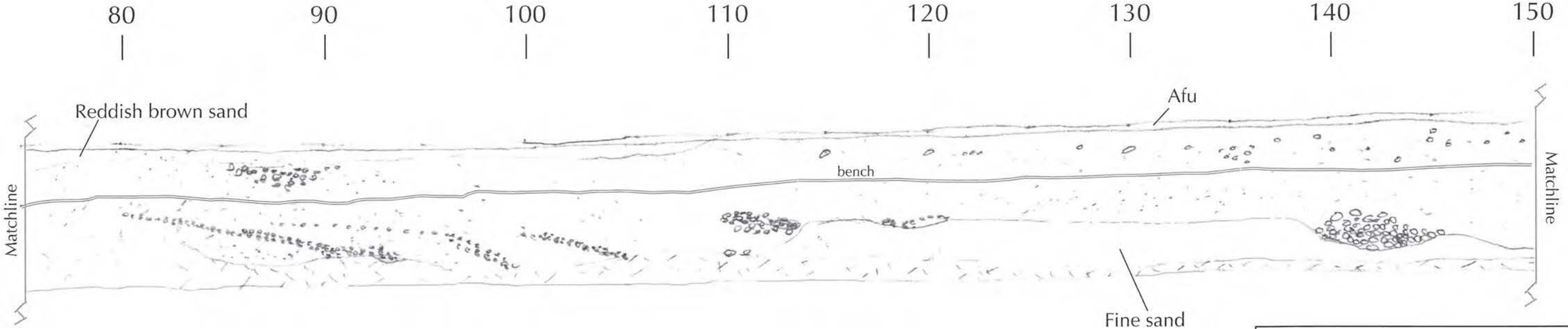
Project Number: 3213
Date: January 2013

Figure 10

Southeast Wall



Southeast Wall



Log of Trench FT-4

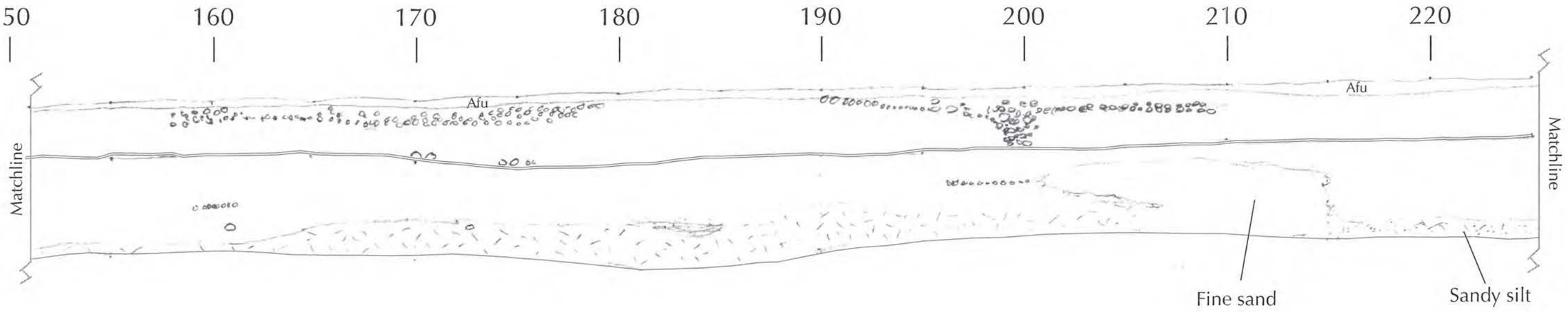
BBC Properties, Northern Parcel
San Bernardino County, California

Earth Consultants International

Project Number: 3213
Date: January 2013

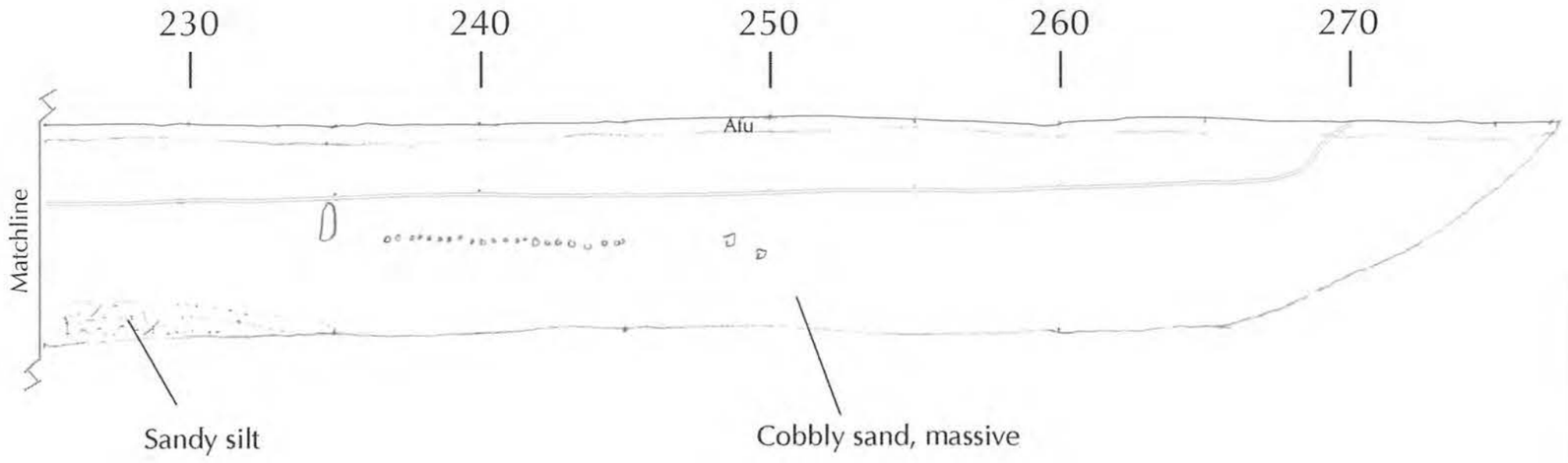
Figure 11a

Southeast Wall



Southeast Wall

N65E



Log of Trench FT-4

BBC Properties, North Parcel
San Bernardino County, California

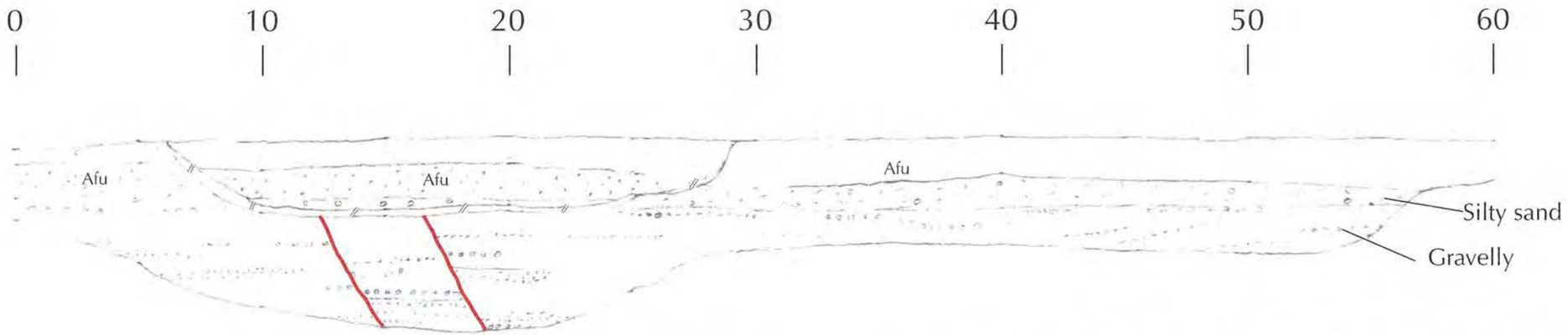
Earth Consultants International

Project Number: 3213
Date: January 2013

Figure 11b

N70E

South Wall



Fault: N20W, 53SW

Fault: N17W, 55SW

Interbedded channels, sub-horizontal, weakly to coarsely bedded sand, silty sand, fine to coarse gravel, and sandy to gravely cobbles; silty sand is slightly harder than sands and gravels; single-grained to loose; gray.

Log of Test Pit E-1

BBC Properties, Northern Parcel
San Bernardino County, California

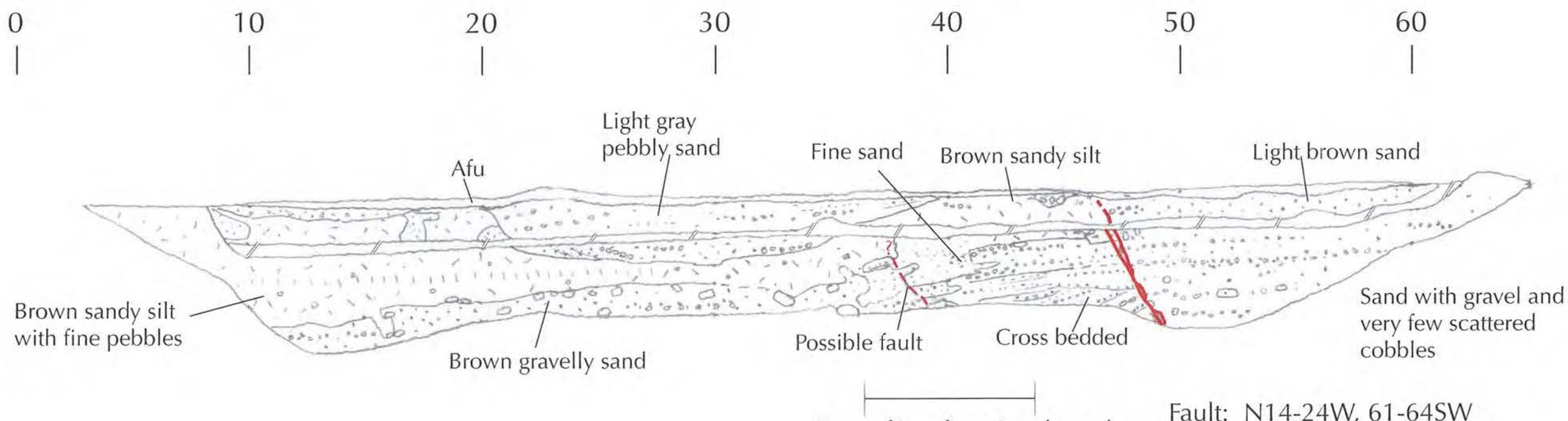
Earth Consultants International

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Date: January 2013

Figure 12a

South Wall

N85E



Fault: N14-24W, 61-64SW
[Strike of N10W measured in the bench]

Log of Test Pit E-2

BBC Properties, North Parcel
San Bernardino County, California

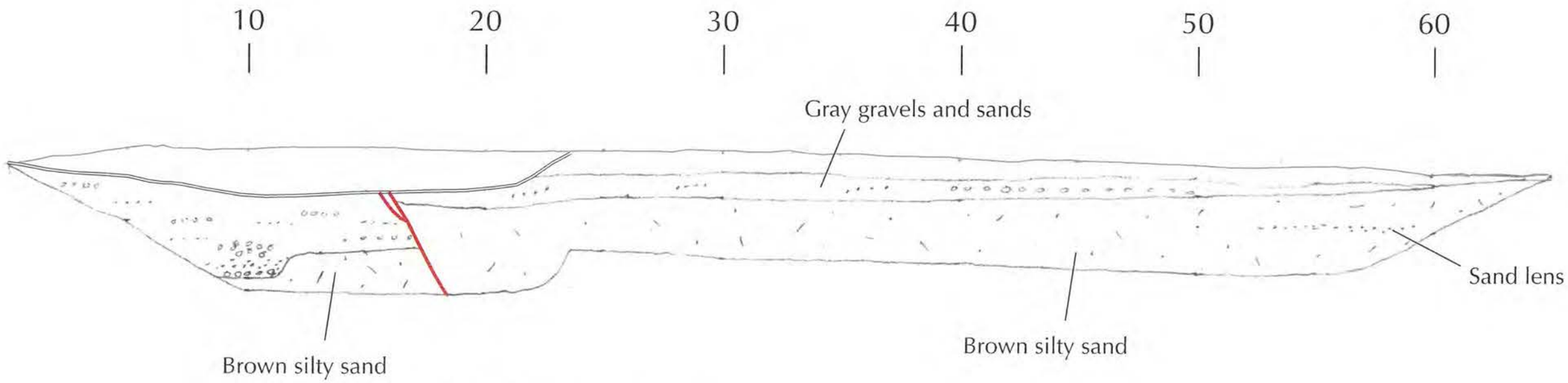
Earth Consultants International

Project Number: 3213
Date: January 2013

Figure 12b

South Wall

N82W



Fault: N18W, 70SW

Log of Test Pit E-3

BBC Properties, North Parcel
San Bernardino County, California

Earth Consultants International

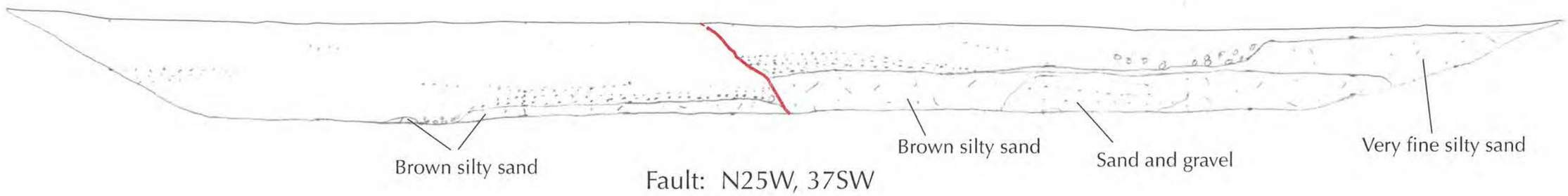
Project Number: 3213
Date: January 2013

Figure 12c

N86E

South Wall

0 10 20 30 40 50 60 70



Fault: N25W, 37SW

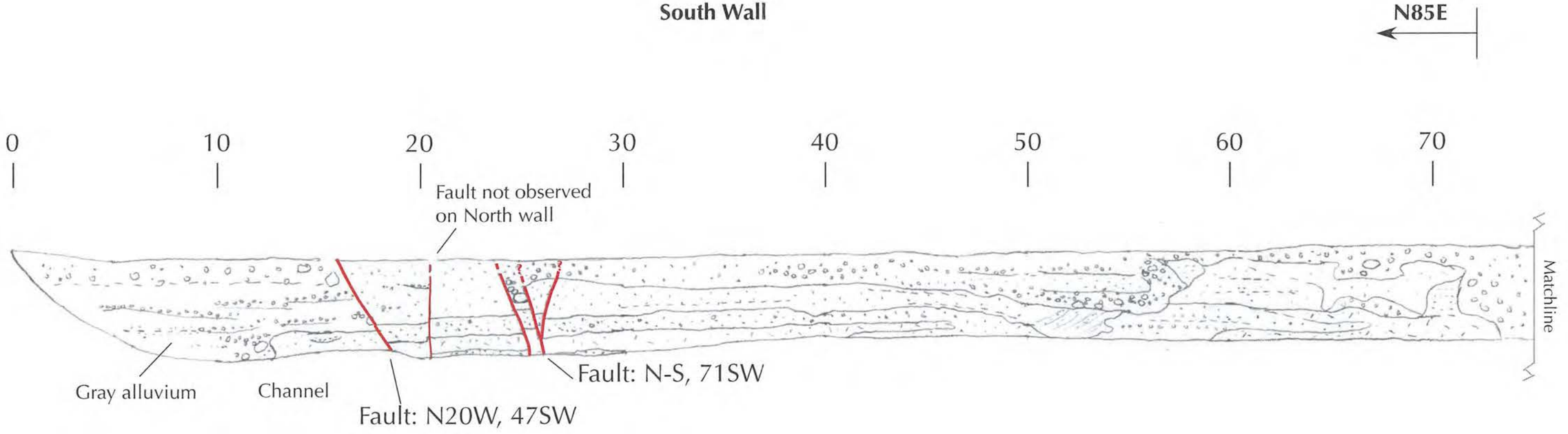
Log of Test Pit E-4

BBC Properties, North Parcel
San Bernardino County, California

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Project Number: 3213
Date: January 2013

Figure 12d



Log of Test Pit E-5

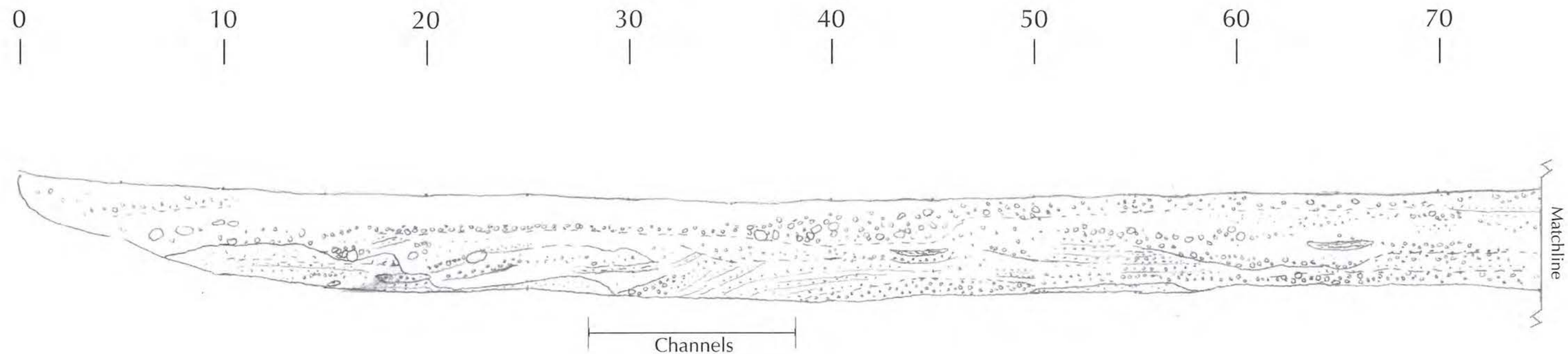
BBC Properties, North Parcel
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Project Number: 3213
Date: January 2013

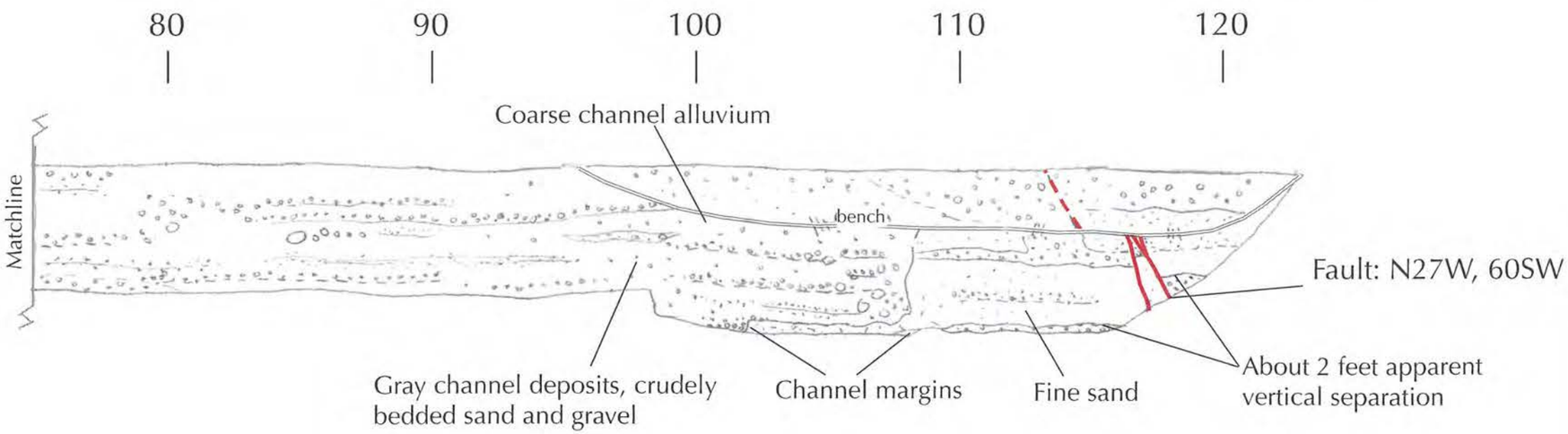
Figure 12e

South Wall



South Wall

E



Log of Test Pit E-6

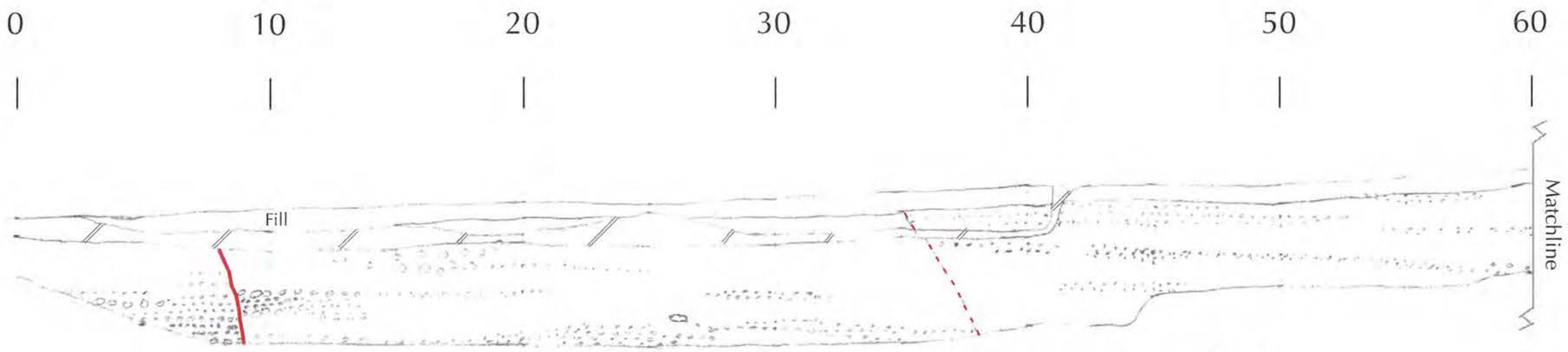
BBC Properties, North Parcel
San Bernardino County, California

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Project Number: 3213
Date: January 2013

Figure 12f

South Wall



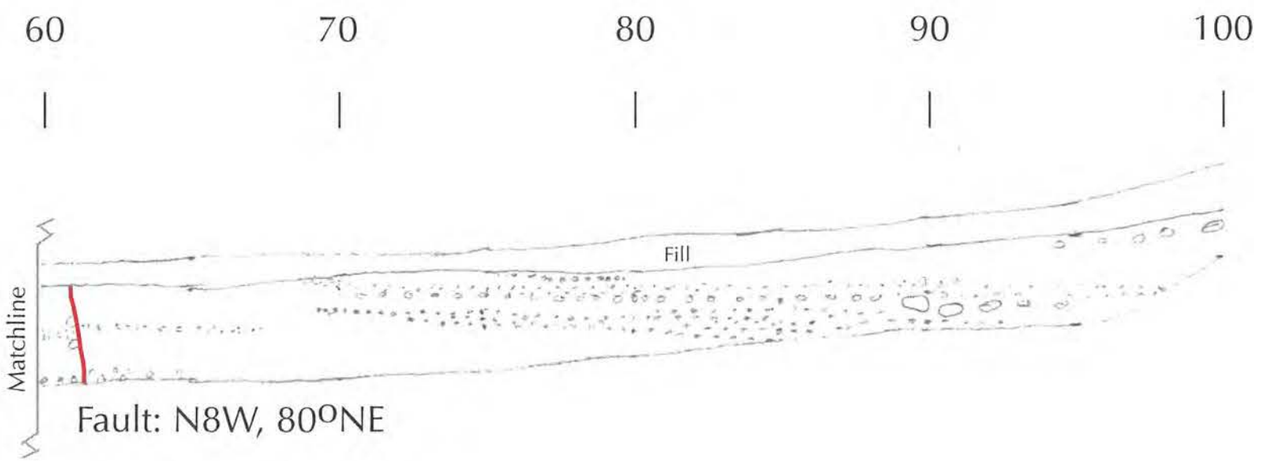
Fault: N5E, 76°SE

possible fault not visible on
North wall of trench

apparent dip: 57°W

N75W

South Wall



Fault: N8W, 80°NE

Log of Test Pit W-1

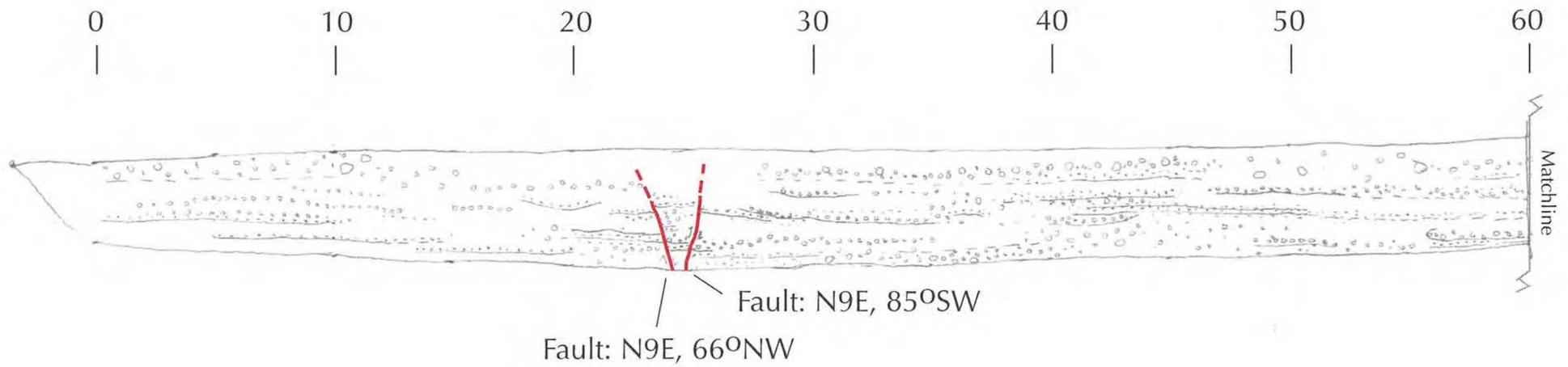
BBC Properties, North Parcel
San Bernardino County, California

Earth Consultants International

Project Number: 3213
Date: January 2013

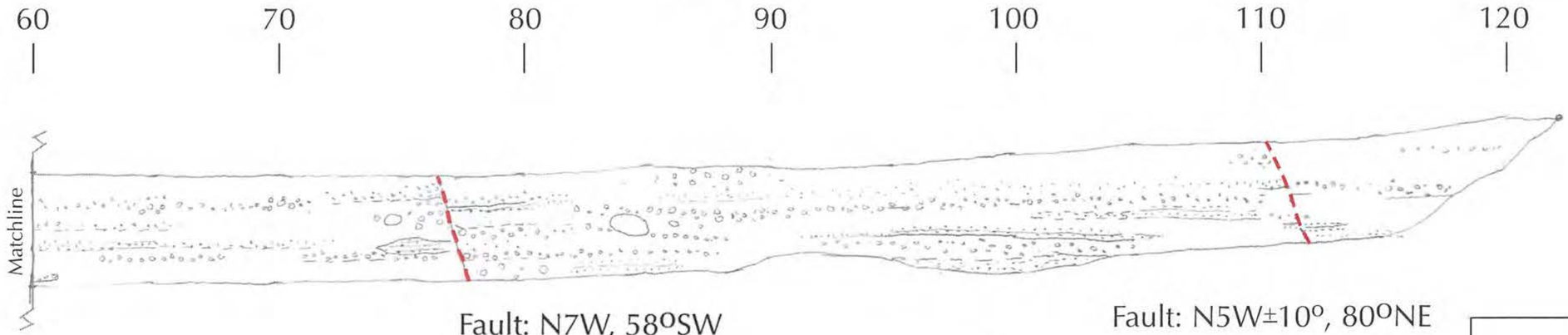
Figure 13a

South Wall



E

South Wall





~0.4' separation

Sketch of fault on
North wall

Log of Test Pit W-2

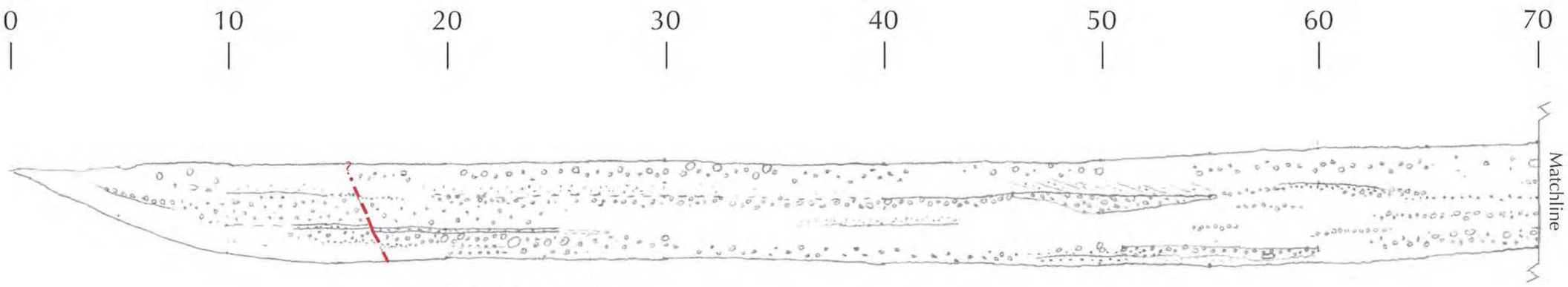
BBC Properties, North Parcel
San Bernardino County, California

Earth Consultants International

Project Number: 3213
Date: January 2013

Figure 13b

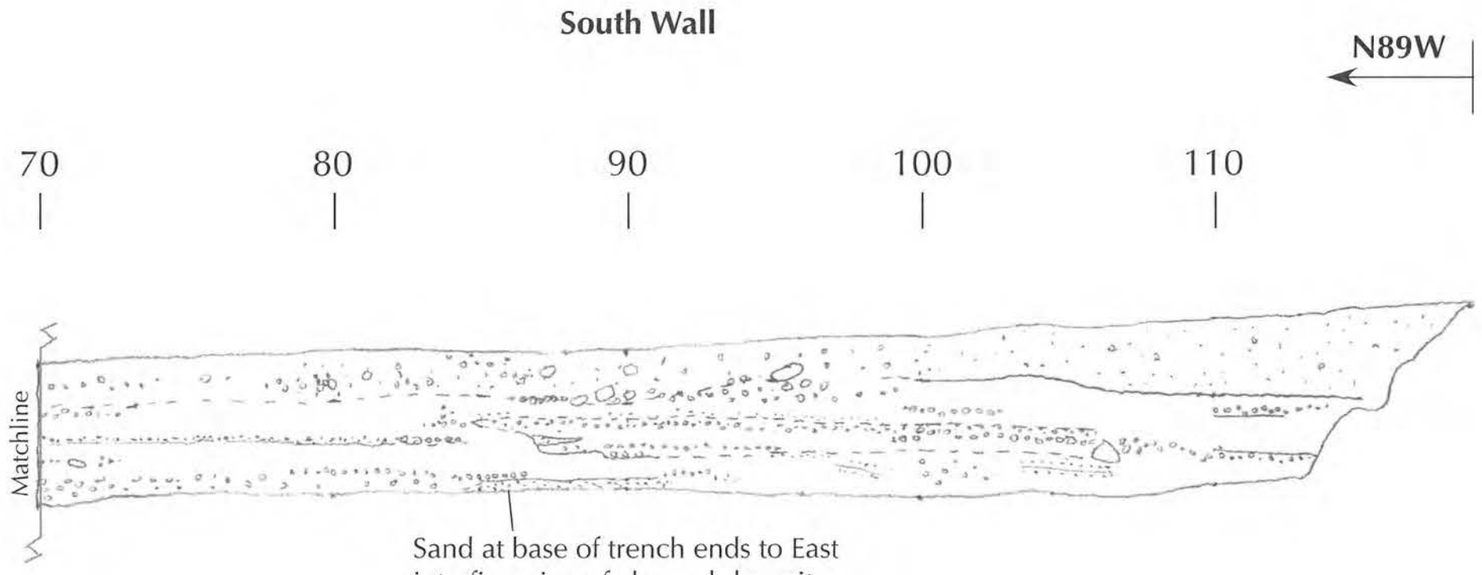
South Wall



Fault: N24E, 61°NW

South Wall

N89W



Sand at base of trench ends to East
interfingering of channel deposits

Log of Test Pit W-3

BBC Properties, North Parcel
San Bernardino County, California

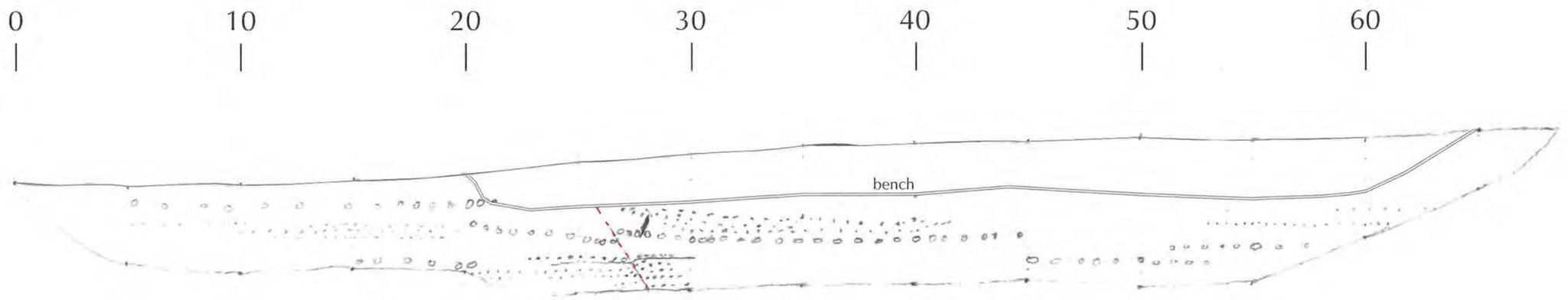
Earth Consultants International

Project Number: 3213
Date: January 2013

Figure 13c

N84E

South Wall



Very weak evidence of faulting,
not observed on North wall

Log of Test Pit W-4

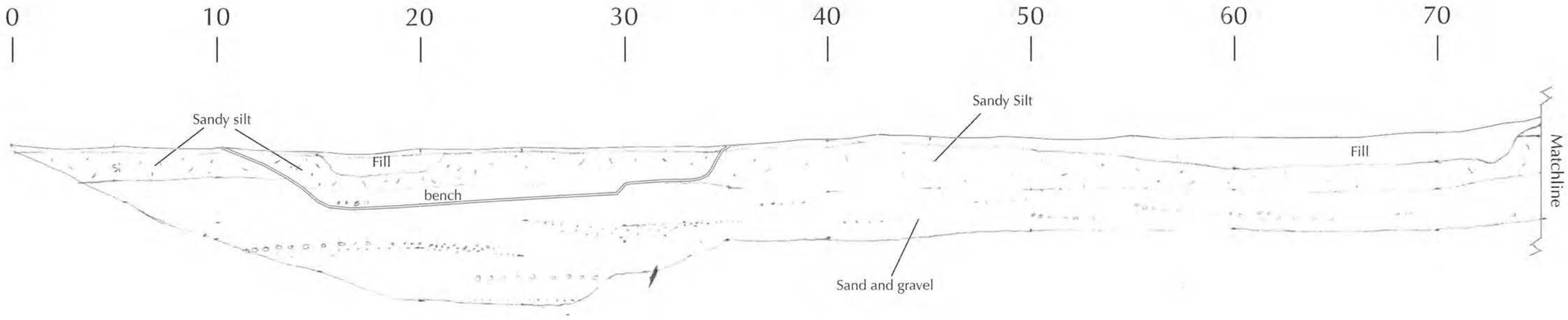
BBC Properties, North Parcel
San Bernardino County, California

Earth Consultants International

Project Number: 3213
Date: January 2013

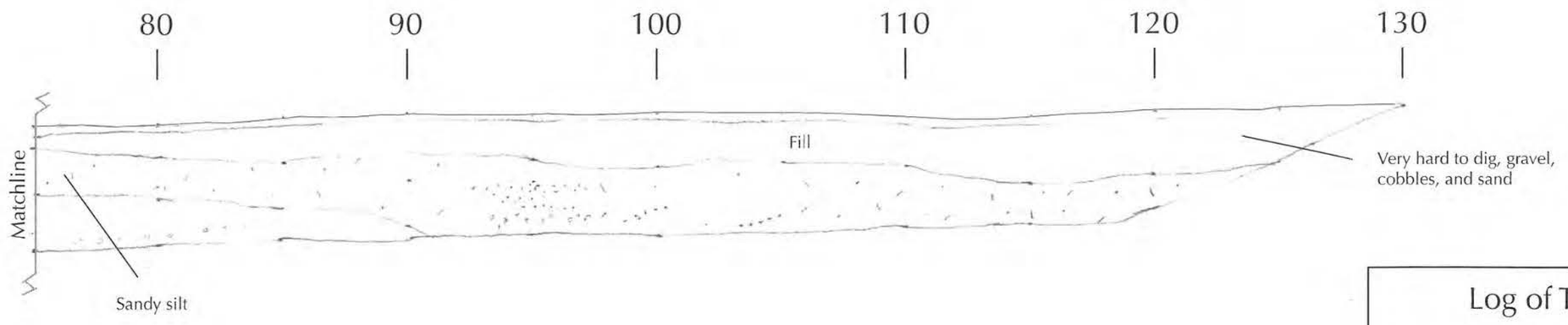
Figure 13d

South Wall



South Wall

N86E



Log of Test Pit W-5

BBC Properties, North Parcel
San Bernardino County, California

Earth Consultants International

Project Number: 3213
Date: January 2013

Figure 13e

APPENDIX A:
REFERENCES CITED

APPENDIX A:
REFERENCES CITED

Birkeland, P.W., 1984, Soils and Geomorphology: Oxford University Press, New York, 372p.

Birkeland, P.W., 1999, Soils and Geomorphology, Oxford University Press, Inc., 3rd edition, 430p.

Blisniuk, K., Oskin, M., Fletcher, K., Sharp, W., Rockwell, T., in press, Assessing the Reliability of U-series and ^{10}Be dating techniques on Alluvial Fans in the Anza Borrego Desert, California: Submitted to *Quaternary Geochronology*.

Blisniuk, K., Oskin, M.E., Rockwell, R., Sharp, W., and Fletcher, K., 2012, Temporally steady but spatially variable middle Pleistocene to Holocene slip rates across the San Jacinto fault zone: *Seismological Research Letters*, Vol. 83, No. 2, p. 436.

Blisniuk, K., Rockwell, T., Owen, L., Oskin, M., Lippincott, C., Caffee, M., and Dortch, J., 2010, Late Quaternary slip rate gradient defined using high-resolution topography and 10Be dating of offset landforms on the southern San Jacinto Fault zone, California: *Journal of Geophysical Research*, Vol. 115, B08401, doi:10.1029/2009JB006346.

Buga, M., Rockwell, T.K., and Salisbury, J.B., 2011, Preliminary Paleoseismic Results from Southern Clark Fault, San Jacinto Fault Zone, Southern California; Comparison to the Hog Lake Paleoseismic Record (Abstract T51B-2327): *American Geophysical Union* 2011 Fall Meeting, San Francisco, California, December 5-9.

Buga, M.T., Rockwell, T.K., and Salisbury, J.B., 2011, Preliminary Paleoseismic Results from Southern Clark Fault, San Jacinto Fault Zone, Southern California; Comparison to the Hog Lake Paleoseismic Record: 2011 Southern California Earthquake Center (SCEC) Annual Meeting, Poster A-148.

Buga, M.T., Rockwell, T.K., and Salisbury, J.B., 2012, Preliminary paleoseismic results from the southern Clark fault, San Jacinto fault zone, southern California: Comparison the Hog Lake paleoseismic record: *Seismological Research Letters*, Vol. 83, No. 2, pp. 436-437.

California Division of Mines and Geology (CDMG), 1974a, Alquist-Priolo Special Studies Zone, Devore 7.5 Minute Quadrangle, Scale: 1:24,000.

California Division of Mines and Geology (CDMG), 1974b, Alquist-Priolo Special Studies Zone, San Bernardino North 7.5 Minute Quadrangle, Scale 1:24,000.

California Division of Mines and Geology (CDMG), 1995, Alquist-Priolo Special Studies Zone, Devere 7.5 Minute Quadrangle, Scale 1:24,000.

Clarke, A.O., 1989, Neotectonics and Stream Piracy on the Lytle Creek Alluvial Fan, Southern California: *California Geographical Society*, Vol. 29, pp. 21-42.

Dawson, T.E., Weldon, R.J., II, and Biasi, G.P., 2008, Appendix B: Recurrence Interval and Event Age Data for Type A Faults: U.S. Geological Survey Open File Report 2007-1437B, California Geological Survey Special Report 203B, Southern California Earthquake Center Contribution #1138B, Version 1.0, 38p.

Dutcher, L.C., and Garrett, A.A., 1963, Geologic and hydrologic features of the San Bernardino area, California, with special reference to underflow across the San Jacinto fault: U.S. Geological Survey Water Supply Paper 1419.

GeoSoils, Inc., 1994, Preliminary Geologic Investigation, Proposed Master Plan Development, The Villages at Lytle Creek, Lytle Creek Development, San Bernardino County, California; Project No. 159-A.1-AV, dated October 31,1994.

GeoSoils, Inc. 1995, Response to County Review No. 638, Concerning GSI's Preliminary Geologic Investigation of the Proposed Master Plan Development, The Villas at Lytle Creek, San Bernardino County; Project No. 159-A.1-AV, dated February 15, 1995.

Gurrola, L.D. and Rockwell, T.K., 1996, Timing and slip for prehistoric earthquakes on the Superstition Mountain fault, Imperial Valley, southern California: *Journal of Geophysical Research*, Vol. 101, No. B3, pp. 5977-5985.

Hadley, D.M., and Smith, S.W., 1973, Two Geophysical Investigations in the San Bernardino Valley Area, California; in Geological Investigations of the San Jacinto Fault Zone and Socio-Economic Impact of Earthquakes in the Riverside-San Bernardino Area, California: University of California, Riverside Campus Museum Contribution No. 3, pp. 51-65.

Hart, E.W., and Bryant, W.A., 1999, Revision, Fault-Rupture Hazard Zones in California: California Division of Mines and Geology, Special Publication 42.

Hudnut, K.; and Sieh, K., 1989, Behavior of the Superstition Hills fault during the past 330 years: *Seismological Society of America Bulletin*, Vol. 79, pp. 304-329.

Leighton, F. Beach & Associates, 1972, Geologic Feasibility Investigation of Tentative Tract 8612 and Adjacent Areas, Riverside Avenue North of Galway Street, Rialto, California; Project No. 2173, dated August 24, 1972.

Leighton and Associates, 1975, Supplementary Fault Investigation for Tract 8612 and Tentative Tracts 9147, 9148 and 9149, Rialto, California; Project No. 75368-1, dated December 12, 1975.

Leighton and Associates, 1976a, Additional Fault Investigation Study for Tract 8612 and Tentative Tracts 9147, 9148, 9149, Rialto, California; Project No. 75368-2, dated March 1, 1976.

Leighton and Associates, 1976b, Answers to Questions Re our Report of March 1, 1976 (Tract 8612); Project No. 75368-2, dated March 10, 1976.

Leighton and Associates, 1993, Phase 1 Report: Evaluation of the Northern San Jacinto Fault Zone, in the Area of Segment 10 of the SR30, County of San Bernardino, California; Project No. 6930403-03, dated August 20, 1993.

Leighton and Associates, 1994, Fault Trenching Investigation, San Jacinto Fault Zone, Proposed State Route 30, Segment 10, Along Highland Avenue, Between Riverside Avenue and Macy Street, Cities of Rialto and San Bernardino, San Bernardino County, California; Project No. 6930403-03, dated September 9, 1994.

Lindsey, E.O., Sahakian, V.J., Fialko, Y., Bock, Y., and Rockwell, T.K., 2012, Space geodetic investigation of interseismic deformation along the San Jacinto fault: effects of heterogeneous elastic structure and fault geometry: *Seismological Research Letters*, Vol. 83, No. 2, p. 434.

Luptowitz, R., McGill, S., Onderdonk, N.W., Rockwell, T.K., Wechsler, N., Berg, J., Copeland, B., and Smith, M., 2012, Paleoseismology of the San Jacinto Fault Zone, Claremont segment, at Mystic Lake, California (Abstract for Poster Session): Southern California Earthquake Center Annual Meeting, September 9-12, Palm Springs, California.

Marliyani, G.I., Rockwell, T.K., Onderdonk, N. and McGill, S., 2012 in press, Straightening of the northern San Jacinto fault, California as seen in the fault structure evolution of the San Jacinto Valley step-over: Submitted to *Bulletin of the Seismological Society of America*, July, 2012, accepted with minor revisions Dec., 2012.

Matti, J.C., Morton, D.M., and Cox, B.F., 1992, The San Andreas Fault System in the Vicinity of the Central Transverse Ranges Province, Southern California: U.S. Geological Survey, Open File Report 92-354, 62p.

McFadden, L.D., 1982, The Impacts of Temporal and Spatial Climatic Changes on Alluvial Soil Genesis in Southern California: PhD Dissertation, Department of Geosciences, The University of Arizona, 430p.

McFadden, L.D., Tinsley, J.C., and Bull, W.B., 1982, Late Quaternary pedogenesis and alluvial chronologies of the Los Angeles Basin and San Gabriel Mountains areas, Southern California; in Tinsley, J.C., Matti, J.C., and McFadden, L.E., (editors), Guidebook: Late Quaternary Pedogenesis and Alluvial Chronologies of the Los Angeles and San Gabriel Mountains Areas, Southern California and Holocene Faulting and Alluvial Stratigraphy within the Cucamonga Fault Zone: A Preliminary View: 78th Annual Meeting of the Cordilleran Section of the Geological Society of America Field Trip No. 12, pp. 1-13.

McGill, S.F., Owen, L.A., Kent, E., Rockwell, T.K., Kendrick, K.J., Onderdonk, N., and Rhodes, E., 2012, Slip rate of the northern San Jacinto fault from offset landslides in the San Timoteo Badlands: *Seismological Research Letters*, Vol. 83, No. 2, p. 436.

Morton, D.M., 1975, Synopsis of the Geology of the Eastern San Gabriel Mountains, Southern California; in Morton, D.M. (editor), San Andreas Fault in Southern California: California Division of Mines and Geology, Special Report 118, pp. 170-176.

Morton, D.M., Matti, J.C., Miller, F.K., and Repenning, C.A., 1986, Pleistocene conglomerate from the San Timoteo Badlands, Southern California: Constraints on strike-slip displacements on the San Andreas and San Jacinto faults: Geological Society of America, Abstracts with Programs, Vol. 18, p. 161.

Munsell Soil Color Charts, 2000: GretagMacbeth, 617 Little Britain Road, New Windsor, NY 12553.

Onderdonk, N.W., McGill, S., Rockwell, T., Wechsler, N., Gordon, E. and Haaker , E., 2012a, Extending the paleoseismic record back in time at the Mystic Lake site on the Claremont fault, northern San Jacinto fault zone (Abstract for a poster session): Southern California Earthquake Center (SCEC) Annual Meeting, September 9-12, Palm Springs, California.

Onderdonk, N., McGill, S., and Rockwell, T., 2012b, Late Holocene slip rate and slip per event of the northern San Jacinto fault zone: *Seismological Research Letters*, Vol. 83, No. 2, p. 436.

Onderdonk, N., Rockwell, T.K., McGill, S., and Marliyani, G., 2013 in press, Evidence for seven surface ruptures in the past 1600 years on the Claremont fault at Mystic Lake, northern San Jacinto fault, California: *Bulletin of the Seismological Society of America*, Vol. 103, No. 1, doi: 10.1785/0120120060.

Prentice, C.S., Weldon, R.J., and Sieh, K.E., 1986, Distribution of slip between the San Andreas and San Jacinto faults near San Bernardino, southern California: *Geological Society of America*, Abstracts with Programs, Vol. 18, p. 172.

Ragona, D., 2003, A high resolution paleoseismic study in the southern San Jacinto fault zone, Imperial Valley, California: M.S. Thesis, San Diego State University, San Diego, California, 95p.

Rasmussen, Gary S. & Associates, Inc., 1982a, Engineering Geology Investigation of Tentative Tract 11408, Northeast of Riverside Avenue and Southeast of El Rancho Verde Country Club, Rialto, California; Project No. 1825, dated August 25, 1982.

Rasmussen, Gary S. & Associates, Inc., 1982b, Engineering Geology Investigation of Tentative Tract 10244, Northeast of Riverside Avenue and Immediately Southeast of El Rancho Verde Country Club, Rialto, California; Project No. 1830, dated August 26, 1982.

Rasmussen, Gary S. & Associates, Inc., 1984, Subsurface Engineering Geology Investigation of Proposed Snack Bar and Restroom Facilities, Frisbee Park, Rialto, California; Project No. 2057, dated October 3, 1984.

Rasmussen, Gary S. & Associates, Inc., 1986a, Preliminary Engineering Geology Investigation, Southern Glen Helen Ranch Property and Adjacent Lytle Creek Wash, Portions of Sections 9, 10, 11, 14, 15, 16, T1N, R5W, SBB&M, West of Verdemont, California; Project No. 2248, dated April 14, 1986.

Rasmussen, Gary S. & Associates, Inc., 1986b, Subsurface Engineering Geology Investigation, Proposed Maintenance Facility, San Bernardino Sheriff's Training Center, West of Verdemont, California; Project No. 2248.1, dated November 5, 1986.

Rasmussen, Gary S. & Associates, Inc., 1986c, Subsurface Engineering Geology Investigation, Proposed Women's Facility, San Bernardino Sheriff's Training Center, West of Verdemont, California; Project No. 2248.2, dated November 12, 1986.

Rasmussen, Gary S. & Associates, Inc., 1988, Subsurface Engineering Geology Investigation of Proposed Expansion of the San Bernardino County Sheriff's Training Center, West of Verdemont, California; Project No. 2248.3, dated May 4, 1988.

Rasmussen, Gary S. & Associates, Inc., 1993, Engineering Geology Investigation and Geologic Update of the El Rancho Verde Country Club Property, Riverside Avenue and Country Club Drive, Rialto, California; Project No. 3156, dated January 5, 1993.

Rasmussen, Gary S. & Associates, 1994a, Subsurface Engineering Geology Investigation, El Rancho Verde Country Club, Approximately 260 Acres, Rialto, California; Project No. 3156.1, dated June 9, 1994.

Rasmussen, Gary S. & Associates, 1994b, Preliminary Geologic Map of the Glen Helen Rehabilitation Center and Regional Training Center Expansion, Glen Helen Area, San Bernardino County, California; Project No. 2248.10, dated July 25, 1994.

Rhodes, E.J., 2011, Optically Stimulated Luminescence dating of sediments over the past 200,000 years: *Annual Review of Earth and Planetary Sciences*, Vol. 39, pp. 461-488, doi: 10.1146/annurev-earth-040610-133425.

Rockwell, T.K., Dewhurst, J.A., Walls, C.W., Pollard, W.J., Orgil, A., Faneros, G., and Dawson, T.E., 2000, High-resolution paleoseismology in southern California: Investigation of segment controls on the rupture history of the southern San Jacinto fault; in Okumura, Takada, K., and Goto, H. (editors), Active Fault Research for the New Millenium: Proceedings of the Hokudan International Symposium and School on Active Faulting, Letter Press Ltd., Hiroshima, Japan, pp. 413-419.

Rockwell, T.K., Onderdonk, N., McGill, S.F., Buga, M., Salisbury, J.B., and Pandey, A., 2012, Summary of paleoseismic observations along the San Jacinto fault: Seismological Research Letters, Vol. 83, No. 2, pp. 435-436.

Rockwell, T., Seitz, G., Young, J., Dawson, T., 2010, Late Holocene Earthquake History of the Anza Seismic Gap | Central San Jacinto Fault Zone, Southern California: Final Technical Report, U.S. Geological Survey Grant No. 04-HQ-GR-0083, 13p.

Rockwell, T., Seitz, G., Salisbury, J. B., and Buga, M., 2011, Confirming and Extending the Holocene Event History at Hog Lake, San Jacinto Fault: Testing San Andreas – San Jacinto Fault Interactions: Final Technical Report, U.S. Geological Survey Grant No. 08HQGR0063, 14p.

Salisbury, J.B., Rockwell, T.K., Middleton, T.J., and Hudnut, K.W., 2012, LiDAR and Field Observations of Slip Distribution for the Most Recent Surface Ruptures Along the Central San Jacinto Fault: *Bulletin of the Seismological Society of America*, Vol. 102, No. 2, pp. 598-619. doi: 10.1785/0120110068.

Sharp, R.V., 1972, Map Showing Recently Active Breaks Along the San Jacinto Fault Zone Between the San Bernardino area and Borrego Valley, California: U.S. Geological Survey, Miscellaneous Geologic Investigations Map I-675, scale 1:24,000.

Sharp, R.V., 1981, Variable rates of late Quaternary strike slip on the San Jacinto fault zone, southern California

Soil Survey Staff, 1975, Soil Taxonomy - A Basic System of Soil Classification for Making and Interpreting Soil Surveys: U.S. Department of Agriculture, Agricultural Handbook No. 436, Washington D.C., 754p.

Soil Survey Staff, 1992, Soil Taxonomy, U.S. Department of Agriculture, Agricultural Handbook No. 18, Washington, D.C., 437p.

Terra Geosciences, 1994, Geologic/Fault Investigation, Pal Center Facility, APN 263-151-09, 10, 12 & 15, 2450 Blake Street, Muscoy, San Bernardino County, California; Project No. 94566-01, dated March 2, 1994.

Toppozada, T.R. and Parke, D.L., 1982, Areas damaged by earthquakes, 1900-1949: California Division of Mines and Geology, Open-File Report, pp. 82-17.

Wesnousky, S.G., Prentice, C.S., and Sieh, K.E., 1991, An offset Holocene stream channel and the rate of slip along the northern reach of the San Jacinto fault zone, San Bernardino Valley, California: *Geological Society of America Bulletin*, Vol. 103, pp. 700-709.

Wills, C.J., Weldon II, R.J., and Bryant, W.A., 2008, Appendix A: California fault parameters for the National Seismic Hazard Maps and Working Group on California Earthquake Probabilities 2007: U.S. Geological Survey Open File Report 2007-1437A, California Geological Survey Special Report 203A, Southern California Earthquake Center Contribution #1138A, Version 1.0, 48p.

Working Group on California Earthquake Probabilities (WGCEP), 1995, Seismic Hazards in Southern California: Probable Earthquakes, 1994 to 2024: Bulletin of the Seismological Society of America, Vol. 85, No. 2, pp. 379-439.

2007 Working Group on California Earthquake Probabilities, 2008, The Uniform California Earthquake Rupture Forecast, Version 2 (UCERF 2): USGS Open File Report 2007-1437, CGS Special Report 203, SCEC Contribution #1138, Version 1.0.

Aerial Photographs Reviewed

Date	Flight or Job No./ Frames	Type	Approximate Scale	Source
1930	C-910 / 28-29		1:21,000	Fairchild Collection
07/04/1938	AXL / 60-89 to 60-92		1:20,000	Fairchild Collection
1938	18050	B&W, vertical	1:10,200	Vulcan Materials
04/09/1953	C-18930 / 1:19 to 1:22		1:9,600	Fairchild Collection
1959	18051	B&W, vertical	1:10,200	Vulcan Materials
1968	18052	B&W, vertical	1:10,200	Vulcan Materials
1979	18055-T	B&W, vertical, annotated	1:10,200	Vulcan Materials
1980	18053	B&W, vertical	1:10,200	Vulcan Materials
10/03/1995		B&W, vertical		Google Earth
5/22/2002		B&W, vertical		Google Earth
2005	18054	Color, vertical	1:10,200	Vulcan Materials
12/31/2005		Color, vertical		Google Earth
11/16/2009		Color, vertical		Google Earth
06/08/2012		Color, vertical		Google Earth

APPENDIX B:
IRSL SEDIMENT DATING RESULTS

APPENDIX B:
IRSL Sediment Dating Results, BBC Rialto Site, California
By Dr. Edward J. Rhodes

Introduction

This report details results of single grain Infra-Red Stimulated Luminescence (IRSL) dating measurements made for sediment samples collected from the site of BBC Rialto site, California. Measurements were conducted at the site, and samples were collected for subsequent laboratory determinations at UCLA (University of California, Los Angeles). An overview of luminescence dating techniques is provided by Rhodes (2011).

Project summary

The aims of this project were to determine the depositional age of sediments at selected locations in the north parcel and close to the south parcel.

Five sediment samples were prepared, selected from a suite of seven collected. IRSL measurements based on K-feldspar grains were conducted, including equivalent dose determinations and detailed fading measurements. Three samples from the northern parcel provide single grain equivalent dose results that allow age estimates to be calculated. The results are relatively consistent between the three samples, and this stratigraphic consistency provides an additional degree of confidence in the reliability of the age estimates. Two samples collected close to the southern parcel, in sediments that form this area, provide clear evidence of mixed dose populations, though it is not clear from the luminescence measurements alone what the cause of this mixing was. These two estimates are not considered to represent reliable depositional ages for this sediment.

Detailed fading determinations were made for every single grain measured for two samples, and less precise determinations made for the remaining samples. The detailed determinations, consistent between the two samples, indicate relatively low fading values for the IRSL signal measured at 50°C, in contrast to results from some other sites in southern California. These new detailed fading measurements have now been incorporated into previous equivalent dose determinations to provide updated sediment ages estimates.

Measurements were made using a version of the newly developed Post-Infra-Red IRSL method of Buylaert et al. (2009), in which signals less prone to fading are also measured. Post-IR IRSL values measured at 225°C are in reasonable agreement with fading-corrected values measured at 50°C, providing support for the results obtained. Caveats and uncertainties, and guidance in the interpretation of these age estimates, are included below.

IRSL dating sample collection and preparation

Luminescence dating sample locations were identified during the site visit; locations considered likely to provide sediment suitable for dating were selected. These comprised sandy, moderately well-sorted fluvial sediments, in some cases containing mm-scale laminations. Three samples were processed from a suite of five collected from sediments exposed with a backhoe trench in the north parcel (BBCR12-OSL01, OSL02 and OSL04;

Table B1). Two samples were collected from a natural exposure close to the south parcel, within sediments that appeared to form an extensive terrace unit (BBCR12-OSL06, OSL07). These sediments displayed a significantly greater degree of soil formation and weathering, and showed indications of bioturbation by plant roots and animal burrows, as observed during sample collection.

At each sampling position, steel tubes were inserted horizontally into the exposed sediment section. When filled, tubes were withdrawn, capped and placed in light-tight bags. At each sampling location, the hole was deepened using a hand auger, and direct measurements of the environmental dose rate made using a calibrated portable NaI microNomad EG&G gamma spectrometer.

In the laboratory at UCLA, sample tubes were opened under controlled laboratory lighting conditions. Sediment from both ends of each tube was removed, and not included in the dating sample, as it had been subject to light exposure during the collection process. Each sample was wet-sieved using disposable nylon mesh screens, and grains of 175-250 μm were selected. These were subsequently treated with dilute HCl to remove carbonate. Grains of density less than 2.58 $g.cm^{-3}$ were separated using a dense solution of lithium metatungstate (LMT), incorporating centrifugation and freezing with liquid nitrogen. IRSL signals from this material are considered to be dominated by those from feldspar rich in potassium. Individual grains were sprinkled into small holes within a number of anodized aluminium discs, and excess grains brushed off. This mineral fraction was selected for age determination as quartz in several Southern Californian locations can display low sensitivity, often making quartz OSL age determination difficult and less precise than when applied elsewhere, whilst K-feldspar typically has a significantly higher sensitivity. Quartz OSL age estimates have also been reported as providing unreliable age determinations in Southern California, possibly as a result of signal contamination by small mineral inclusions with quartz grains, and no quartz fractions have been separated for samples from this site.

IRSL measurement

Luminescence measurements were performed using a Risø TL-DA-20D automated reader with a combination of BG3 and BG39 optical filters to provide a luminescence emission window in the blue part of the spectrum. Between 200 and 300 single grains were measured for five samples collected within or close to the BBC site in Rialto, California. Samples were measured using a SAR IRSL protocol developed by Buylaert et al. (2009) that provides both a conventional IRSL measurement at 50°C (IR50), and a "post-IR" IRSL measurement at 225°C (PIRIR225). Details have been modified slightly for single grain application. Sediment dose rate calculations are based on in-situ gamma spectrometer readings.

Table B1 provides sample locations and depths, along with field and laboratory codes, and fading-corrected age estimates. Note that an assumed previous burial depth of 40' (12.19m) has been used in cosmic dose rate estimation for the samples from the north parcel; sample depths in Table 1 are shown so that the depths from the contemporary surface can be easily comprehended. For the samples from the north parcel, the age estimates are based on the lowest equivalent dose (D_e) values (in Gy) for the most sensitive group of grains in each sample, corrected using measured fading values for samples J0272 (BBCR12-OSL04) and J0274 (BBCR12-OSL06). This latter correction is

made to allow for the effects of anomalous fading, a common characteristic of K feldspar, caused by quantum mechanical tunnelling of electrons from traps within the crystal lattice. For samples from close to the south parcel (BBC12-OSL06 and OSL07), clear trends within the single grain equivalent dose distributions were not observed, and the minimum age estimates are based solely on the lowest values observed; results from these two samples are not considered reliable.

Table B1: Age Estimate Results

Field code	Lab code	Depth (m)	Dose rate (mGy/yr)	1 sigma uncertainty	IR50 age estimate (yr)	1 sigma uncertainty	PIRIR225 age estimate (yr)	1 sigma uncertainty
North parcel - results appear reliable								
BBCR12-OSL01	J0269	2.25 + 12.19	3.92	± 0.20	10600	± 1300	10700	± 1300
BBCR12-OSL02	J0270	1.65 + 12.19	3.78	± 0.20	12400	± 1500	14600	± 1700
BBCR12-OSL04	J0272	0.70 + 12.19	3.95	± 0.21	12200	± 1500	10600	± 1300
South parcel - results not considered reliable - minimum values shown								
BBCR12-OSL06	J0274	2.60	3.83	± 0.20	150	± 20	380	± 50
BBCR12-OSL07	J0275	1.00	3.88	± 0.21	330	± 40	280	± 30

The dose values used for these age estimates are taken from plots of equivalent dose (D_e) vs rank order sensitivity. That is, the first grain (aliquot 1 in Figure B1) is the most sensitive, aliquot 2 the next, and so on. The value used in age estimation is the intercept of the red line in Figure B1 with the y-axis.

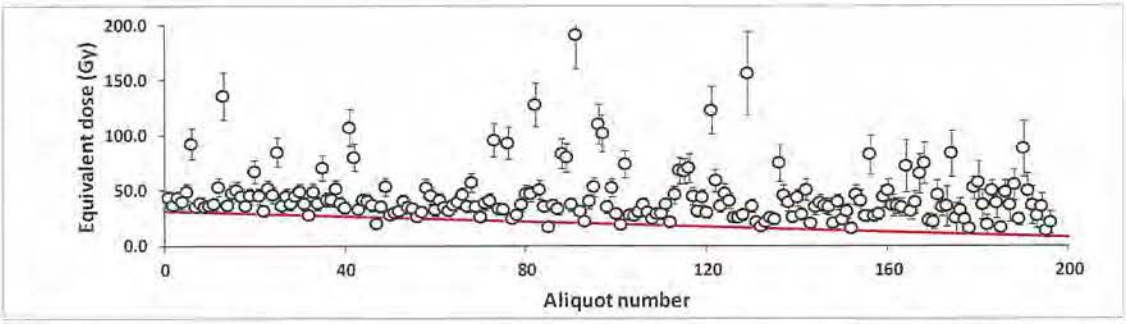


Figure B1. Equivalent dose (D_e) in Gy for single grain IRSL measured at 50°C for sample J0269 (BBCR12-OSL01), presented in rank order of grain sensitivity, with aliquot 1 representing the most sensitive grain. The red line is a construction line used to assist assessment of the data.

Fading corrections applied to the raw equivalent doses are based on g-values of 0.03 for the IR50 determinations and 0.00 for the PIRIR225 data. The g-value corrects for a logarithmic signal loss, and represents the signal loss per decade (that is for each factor of 10 increase in time; Auclair et al., 2003). The g-values used provide age estimates for the two signals (IR 50 and PIRIR225) that are similar for the three north parcel samples.

Discussion and interpretation

The samples from the north parcel and the south parcel for two very different datasets, although the IRSL characteristics of the K-feldspar grains do not differ significantly between these two sites.

For the north parcel sites, a relatively regular pattern of behaviour is observed, compatible with observations made for samples from other sites. The direct determinations of g-value are lower than those observed at other sites, reducing the size of the fading correction required. Two features are striking; firstly the internal consistency (within estimated uncertainty limits) of the age estimates for the three different samples, collected in closely spaced fluvial sediments that probably represent different phases of single depositional event. Secondly, the fading-corrected IRSL age estimates based on the IRSL measured at 50°C (g-value of 0.03 ± 0.003; age correction factor of 1.34) and the post-IR IRSL measured at 225°C (g-value of 0.00 ± 0.003; no age correction applied) agree reasonably well. A slightly older apparent age for sample BBCR12-OSL02 (J0270) for the post-IR IRSL at 225°C probably represents the effects of slight incomplete zeroing. These age estimates appear to be consistent with deposition during the Younger Dryas period (approximately 11,300 – 12,700 years before present), a time of global unstable climate often associated with increased rates of geomorphic processes.

For the south parcel samples (BBCR12-)SL06 and OSL07; J0274, J0275), much lower minimum equivalent dose values are observed, the results are stratigraphically inverted, and are not consistent between the two IRSL measurements (at 50°C and 225°C). Many different equivalent dose values are observed, including many much higher values, and these samples do not display regular patterns. These samples were collected in sediments interpreted in the field as forming the terrace unit that forms the major part of the land surface for the south parcel. Rather than forming an approximately linear relationship between equivalent dose and rank sensitivity, represented by the red line in Figure B1 for sample J0269 (BBCR12-OSL01), these two samples have many very low values even for some more sensitive grains. The clear departure from this pattern for samples J0274 and 275 from the southern parcel location, is interpreted as possibly representing the effects of grain mixing by bioturbation at the exposed terrace edge over an extended period. A possible alternative explanation is that these sediments include a significant proportion of dumped material. This latter interpretation is not consistent with the relatively regular features observed during sample collection, most notably the uniformity and lateral extent of individual horizons. It seems clear that data for these two samples (BBCR12-OSL06 and OSL07) represent a later depositional age than for the north parcel samples, most likely Holocene, and have been subject to post-depositional grain mixing effects. However, the minimum age estimates quoted may not represent true depositional ages, and these age values must be treated with caution.

Summary and conclusions

Analysis of detailed fading data for these samples show lower fading rates (g-values) than at other sites, reducing the magnitude of the age correction applied. The age estimates presented in Table 1 represent the best estimate of depositional age available at this time. The measurements for the two samples from close to the south parcel (J0274 and 275) clearly highlight a significant difference in response, interpreted as probably representing a younger depositional age followed by an extended period of grain mixing by bioturbation.

Appendix B1
Table B2: Summary of Values Used in Age Calculations

Sample number K-FELDSPAR	SG J0269 IR 50	SG J0270 IR 50	SG J0272 IR 50	SG J0274 IR 50	SG J0275 IR 50	SG J0269 IR 225	SG J0270 IR 225	SG J0272 IR 225	SG J0274 IR 225	SG J0275 IR 225
De (Gy)	41.54	46.90	48.24	0.56	1.29	55.00	55.00	42.00	1.46	1.07
uncertainty	4.64	5.24	5.39	0.06	0.14	6.15	6.15	4.70	0.16	0.12
measured	2.08	2.35	2.41	0.03	0.06	2.75	2.75	2.10	0.07	0.05
0.100	4.154	4.690	4.824	0.056	0.129	5.500	5.500	4.200	0.146	0.107
RAW										
Grain size										
Min. grain size (μm)	175	175	175	175	175	175	175	175	175	175
Max grain size (μm)	200	200	200	200	200	200	200	200	200	200
External gamma-dose (Gy/ka)	1.473	1.356	1.442	1.335	1.341	1.473	1.356	1.442	1.335	1.341
error	0.004	0.003	0.004	0.002	0.003	0.004	0.003	0.004	0.002	0.003
INTERNAL K content (% K)	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50
error	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
INTERNAL Dose rate	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
error	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046
Measured concentrations										
standard fractional error	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
% K	1.962	2.028	2.090	2.009	1.998	1.962	2.028	2.090	2.009	1.998
error (%K)	0.235	0.243	0.251	0.241	0.240	0.235	0.243	0.251	0.241	0.240
Th (ppm)	9.547	8.161	8.900	8.565	8.549	9.547	8.161	8.900	8.565	8.549
error (ppm)	1.146	0.979	1.068	1.028	1.026	1.146	0.979	1.068	1.028	1.026
U (ppm)	2.303	1.949	2.189	1.696	1.769	2.303	1.949	2.189	1.696	1.769
error (ppm)	0.115	0.097	0.109	0.085	0.088	0.115	0.097	0.109	0.085	0.088
Cosmic dose calculations										
Depth (m)	14.400	13.800	12.900	2.600	1.000	14.400	13.800	12.900	2.600	1.000
error (m)	2.000	2.000	2.000	0.250	0.250	2.000	2.000	2.000	0.250	0.250
Average overburden density (g.cm^3)	1.900	1.900	1.900	1.900	1.900	1.900	1.900	1.900	1.900	1.900
error (g.cm^3)	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
Latitude (deg.), north positive	34	34	34	34	34	34	34	34	34	34
Longditude (deg.), east positive	-117	-117	-117	-117	-117	-117	-117	-117	-117	-117
Altitude (m above sea-level))	415	415	415	389	389	415	415	415	389	389
Soft Cosmic	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cosmic dose rate (Gy/ka)	0.049	0.051	0.055	0.158	0.195	0.049	0.051	0.055	0.158	0.195
error	0.008	0.008	0.009	0.019	0.051	0.008	0.008	0.009	0.019	0.051
Moisture content										
Moisture (water / wet sediment)	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075
error	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Total dose rate, Gy/ka	**3.92**	**3.78**	**3.95**	**3.83**	**3.88**	**3.92**	**3.78**	**3.95**	**3.83**	**3.88**
error	**0.20**	**0.20**	**0.21**	**0.20**	**0.21**	**0.20**	**0.20**	**0.21**	**0.20**	**0.21**
% error	**5.04**	**5.35**	**5.28**	**5.24**	**5.30**	**5.04**	**5.35**	**5.28**	**5.24**	**5.30**
AGE (ka)	**10.60**	**12.40**	**12.20**	**0.15**	**0.33**	**14.03**	**14.55**	**10.62**	**0.38**	**0.28**
error	**1.30**	**1.54**	**1.51**	**0.02**	**0.04**	**1.72**	**1.80**	**1.31**	**0.05**	**0.03**
% error	**12.26**	**12.39**	**12.36**	**12.35**	**12.37**	**12.26**	**12.39**	**12.36**	**12.35**	**12.37**



N
W E
S

600 0 600

Feet

Explanation

- Approximate location of IRSL samples
- Approximate location of radiocarbon dating samples

Earth Consultants International

Project Number: 3213
Date: January 2013

Locations of IRSL and Radiocarbon Dating Samples

Figure B-2

APPENDIX C:
RADIOCARBON DATING RESULTS

APPENDIX C
Table C1: Radiocarbon Dating Results
KECK CARBON CYCLE AMS FACILITY
EARTH SYSTEM SCIENCE DEPT, UC IRVINE

^{14}C results | Rockwell/Akciz | Nov 8 2012

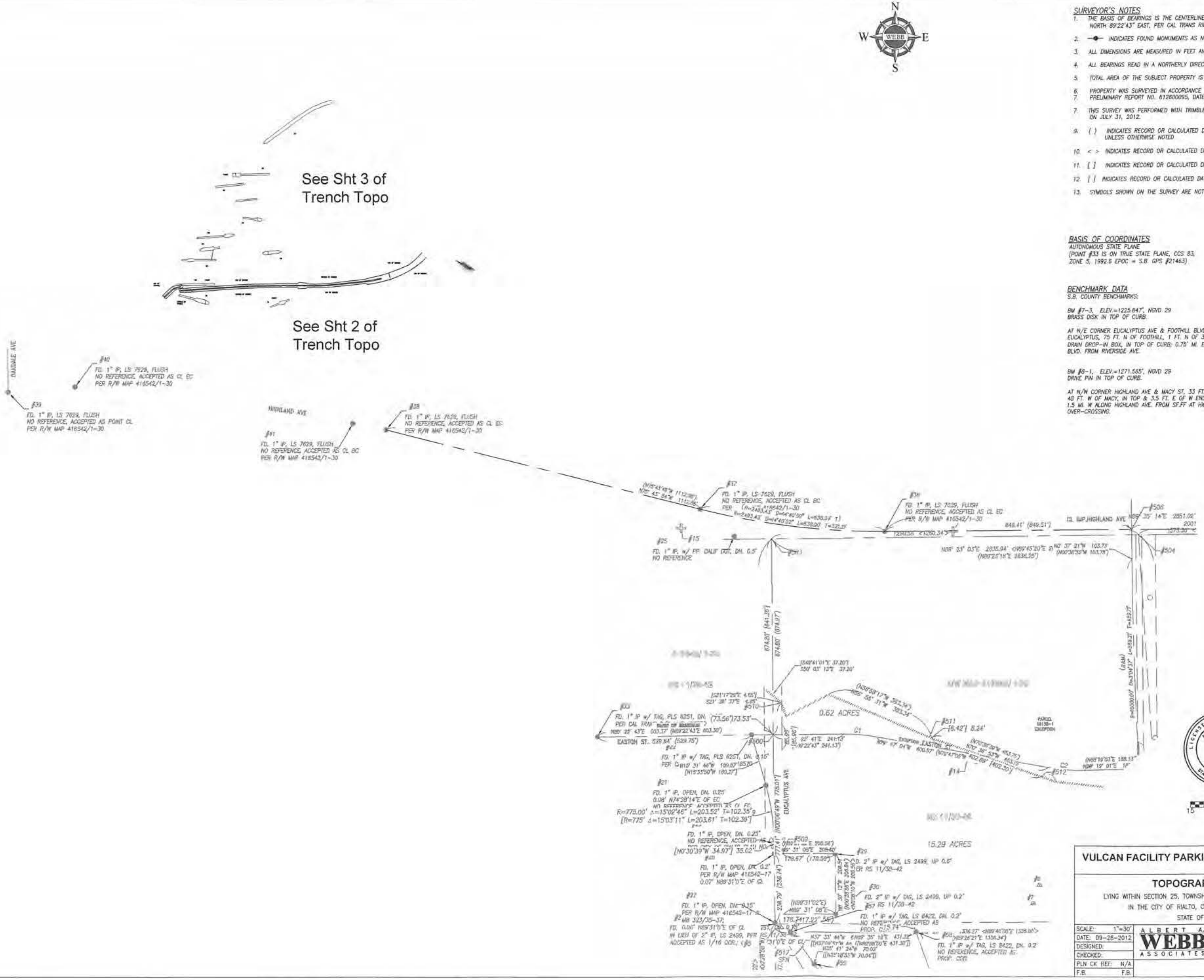
UCIAMS #	Sample name	Other ID	$d^{13}C$ (‰)	±	fraction Modern	±	$D^{14}C$ (‰)	±	^{14}C age (BP)	±
117133	Rialto SJFZ T1-14C-1; 94.5				0.2902	0.0010	-709.8	1.0	9940	30
117134	Rialto SJFZ T1-14C-4; 8				0.2884	0.0008	-711.6	0.8	9990	25

Radiocarbon concentrations are given as fractions of the Modern standard, $D^{14}C$, and conventional radiocarbon age, following the conventions of Stuiver and Polach (Radiocarbon, Vol. 19, pp. 355, 1977).

Sample preparation backgrounds have been subtracted, based on measurements of ^{14}C-free wood.

All results have been corrected for isotopic fractionation according to the conventions of Stuiver and Polach (1977), with $d^{13}C$ values measured on prepared graphite using the AMS spectrometer. These can differ from $d^{13}C$ of the original material, if fractionation occurred during sample graphitization or the AMS measurement, and are not shown.

APPENDIX D:
SURVEY DATA
(By Albert A. Webb Associates)



LICENSED LAND SURVEYOR
ANDREW Y. OROSCO
NO. 5491
STATE OF CALIFORNIA

SURVEYOR'S NOTES

1. THE BASIS OF BEARINGS IS THE CENTERLINE OF EASTON AVENUE, TAKEN AS NORTH 89°22'43" EAST, PER CAL TRANS RIGHT OF WAY MAP 416542-16.
2. —●— INDICATES FOUND MONUMENTS AS NOTED.
3. ALL DIMENSIONS ARE MEASURED IN FEET AND DECIMAL PARTS THEREOF.
4. ALL BEARINGS READ IN A NORTHERLY DIRECTION UNLESS OTHERWISE NOTED.
5. TOTAL AREA OF THE SUBJECT PROPERTY IS 15.91 MORE OR LESS.
6. PROPERTY WAS SURVEYED IN ACCORDANCE WITH LAWYERS TITLE COMPANY,
7. PRELIMINARY REPORT NO. 612600095, DATED MAY 4, 2012.
7. THIS SURVEY WAS PERFORMED WITH TRIMBLE 5800 GPS RECEIVERS, AND COMPLETED ON JULY 31, 2012.
9. ( ) INDICATES RECORD OR CALCULATED DATA PER CAL TRANS R/W MAP 416542/1-30, UNLESS OTHERWISE NOTED
10. < > INDICATES RECORD OR CALCULATED DATA PER RS 11/38-42.
11. [ ] INDICATES RECORD OR CALCULATED DATA PER CITY OF RIALTO PLAN NO. GT0029.
12. [ ] INDICATES RECORD OR CALCULATED DATA PER REPORT NO. 612600095
13. SYMBOLS SHOWN ON THE SURVEY ARE NOT DRAFTED TO SCALE.

BASIS OF COORDINATES

AUTONOMOUS STATE PLANE
(POINT #33 IS ON TRUE STATE PLANE, CCS 83,
ZONE 5, 1992.6 EPOC = S.B. GPS #21463)

BENCHMARK DATA

S.B. COUNTY BENCHMARKS:

BM #7-3, ELEV.=1225.847', NGVD 29
BRASS DISK IN TOP OF CURB.

AT N/E CORNER EUCALYPTUS AVE & FOOTHILL BLVD, 21 FT. E OF EUCALYPTUS, 75 FT. N OF FOOTHILL, 1 FT. N OF 3 X 7 FT. STORM DRAIN DROP-IN BOX, IN TOP OF CURB; 0.75' MI. E ALONG FOOTHILL BLVD. FROM RIVERSIDE AVE.

BM #8-1, ELEV.=1271.585', NGVD 29
DRIVE PIN IN TOP OF CURB.

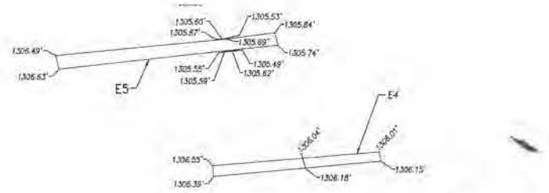
AT N/W CORNER HIGHLAND AVE & MACY ST, 33 FT. N OF HIGHLAND, 48 FT. W OF MACY, IN TOP & 3.5 FT. E OF W END CURB RETURN; 1.5 MI. W ALONG HIGHLAND AVE. FROM SF.FF AT HIGHLAND OVER-CROSSING.

VULCAN FACILITY PARKING LOT-BBC PROPERTIES

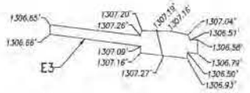
TOPOGRAPHICAL MAP

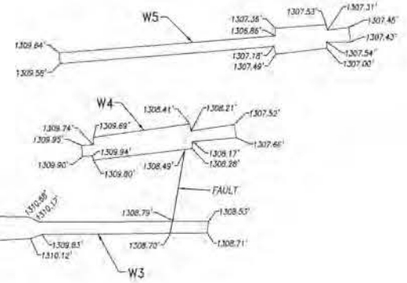
LYING WITHIN SECTION 25, TOWNSHIP 1 NORTH, RANGE 5 WEST, S.B.M.,
IN THE CITY OF RIALTO, COUNTY OF SAN BERNARDINO,
STATE OF CALIFORNIA

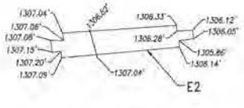
SCALE: 1"=30'	ALBERT A. WEBB ASSOCIATES	ENGINEERING CONSULTANTS 3788 McCRAY STREET RIVERSIDE CA. 92506 PH. (951) 686-1070 FAX (951) 788-1256	W.O. 12-094
DATE: 09-26-2012			SHEET 1
DESIGNED:			
CHECKED:			OF 3 SHEETS
PLN CK REF: N/A			DWG. NO.
F.B. F.B.			

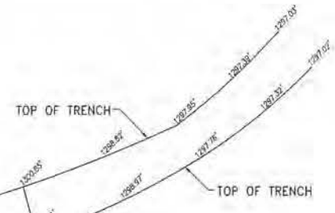


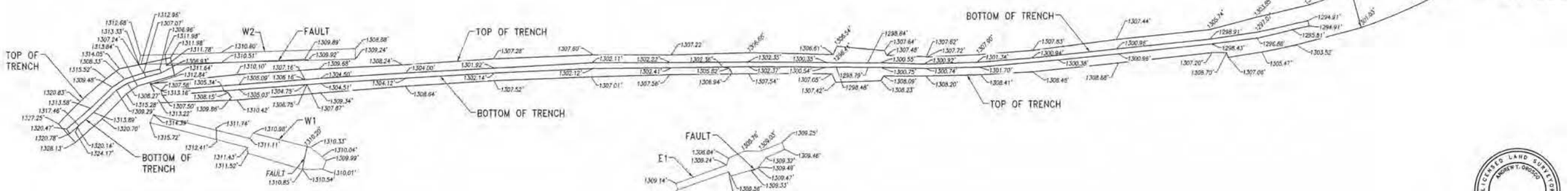
See Sht 3













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LICENSED LAND SURVEYOR
ANDREW T. GROSSO
NO. 5491
STATE OF CALIFORNIA

1" = 30'
15 0 30

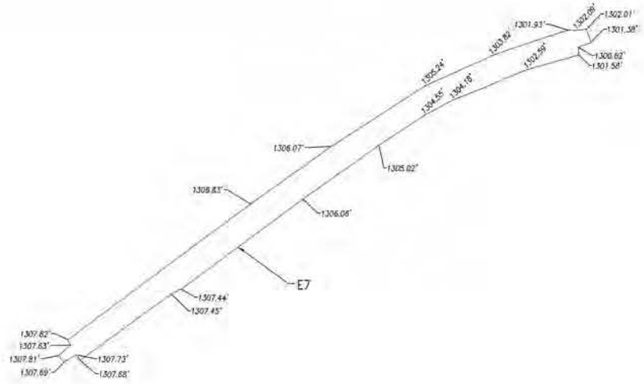
VULCAN FACILITY PARKING LOT-BBC PROPERTIES

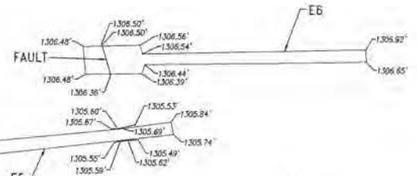
TOPOGRAPHICAL MAP

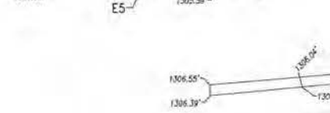
LYING WITHIN SECTION 25, TOWNSHIP 1 NORTH, RANGE 5 WEST, S.B.M., IN THE CITY OF RIALTO, COUNTY OF SAN BERNARDINO, STATE OF CALIFORNIA

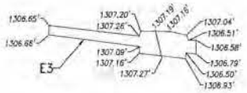
SCALE: 1"=30'	ALBERT A. WEBB ASSOCIATES	W.O.	12-094
DATE: 09-26-2012	ENGINEERING CONSULTANTS 3788 McCRAY STREET RIVERSIDE, CA. 92506 PH. (951) 686-1070 FAX (951) 788-1256	SHEET	2
DESIGNED:		OF	3 SHEETS
CHECKED:			
PLN CK REF: N/A		DWG. NO.	
F.B. F.B.			

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See Sht 2



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BASIS OF COORDINATES

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(POINT #33 IS ON TRUE STATE PLANE, CCS 83,
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1" = 30'
15 0 30

VULCAN FACILITY PARKING LOT-BBC PROPERTIES

TOPOGRAPHICAL MAP

LYING WITHIN SECTION 25, TOWNSHIP 1 NORTH, RANGE 5 WEST, S.B.M., IN THE CITY OF RIALTO, COUNTY OF SAN BERNARDINO, STATE OF CALIFORNIA

SCALE: 1"=30'	ALBERT A. WEBB ASSOCIATES	ENGINEERING CONSULTANTS 3788 McCRAY STREET RIVERSIDE CA. 92506 PH (951) 686-1070 FAX (951) 788-1256	W.O. 12-094
DATE: 09-26-2012			SHEET 3
DESIGNED:			OF 3 SHEETS
CHECKED:			
PLN CK. REF: N/A			DWG. NO.
F.B. F.B.			

L:\LOT\12-094\Survey\12-094 Plotted 9/14/2012 8:00 AM

Coordinate Table				
Point #	Northing	Easting	Elevation	Description
1	1873633.01	6802422.40	1294.91	BTTM of Fault
7	1871481.34	6804660.55	1293.13	Autonomous Setup
8	1871545.20	6804682.78	1293.79	2X2HUB
15	1872774.70	6803452.15	1316.04	Scribed X
40	1873261.61	6801373.25	1391.60	FD. 1" IP w/Tag
47	1873297.71	6801472.43	1389.26	Magnail
48	1873253.56	6801781.83	1374.24	2X2HUB
109	1872772.13	6805589.65	1289.47	Magnail
115	1872774.74	6803452.15	1315.95	Scribed X
133	1872765.44	6806397.36	1284.11	Brass Disk
140	1873261.61	6801373.26	1391.62	1"IP w/Tag
7000	1873654.06	6802447.83	1300.85	Top of Fault WTR Ends
7001	1873723.21	6802561.04	1297.03	Top of Fault WTR Beg
7002	1873701.95	6802540.37	1297.39	Top of Fault
7003	1873681.51	6802516.11	1297.95	Top of Fault
7004	1873667.48	6802483.89	1298.82	Top of Fault
7005	1873645.45	6802421.37	1302.35	Top of Fault
7006	1873636.18	6802421.70	1294.91	BTTM of Fault
7007	1873629.44	6802391.11	1297.07	BTTM of Fault
7008	1873638.50	6802390.70	1303.85	Top of Fault
7009	1873630.89	6802362.26	1305.74	Top of Fault
7010	1873625.18	6802362.26	1298.91	BTTM of Fault
7011	1873619.38	6802306.34	1300.96	BTTM of Fault
7012	1873625.06	6802306.31	1307.44	Top of Fault
7013	1873618.52	6802256.35	1307.83	Top of Fault
7014	1873613.85	6802255.60	1300.94	BTTM of Fault
7015	1873611.40	6802222.88	1301.34	BTTM of Fault
7016	1873616.08	6802224.23	1307.90	Top of Fault
7017	1873614.80	6802192.98	1307.72	Top of Fault
7018	1873610.57	6802191.41	1300.92	BTTM of Fault
7019	1873611.47	6802165.60	1300.55	BTTM of Fault
7020	1873611.38	6802157.47	1298.84	BTTM of Fault
7021	1873611.53	6802138.85	1298.41	BTTM of Fault
7022	1873611.56	6802133.05	1300.35	BTTM of Fault
7023	1873612.00	6802085.13	1302.35	BTTM of Fault
7024	1873609.29	6802085.92	1302.37	BTTM of Fault
7025	1873608.75	6802132.40	1300.54	BTTM of Fault
7026	1873608.92	6802138.80	1298.48	BTTM of Fault
7027	1873608.76	6802157.85	1298.79	BTTM of Fault
7028	1873608.67	6802165.63	1300.75	BTTM of Fault
7029	1873611.77	6802038.47	1302.22	BTTM of Fault
7030	1873608.65	6802039.34	1302.41	BTTM of Fault
7031	1873611.66	6801992.16	1302.11	BTTM of Fault
7032	1873608.20	6801992.51	1302.12	BTTM of Fault
7033	1873608.45	6801933.48	1301.92	BTTM of Fault
7034	1873605.57	6801933.61	1302.14	BTTM of Fault
7035	1873605.71	6801880.74	1304.09	BTTM of Fault
7036	1873602.56	6801880.85	1304.12	BTTM of Fault
7037	1873602.59	6801829.69	1304.50	BTTM of Fault
7038	1873599.50	6801829.89	1304.51	BTTM of Fault
7039	1873598.94	6801780.95	1305.09	BTTM of Fault
7040	1873595.92	6801781.18	1305.03	BTTM of Fault
7041	1873595.24	6801734.37	1307.58	BTTM of Fault
7042	1873592.46	6801735.10	1307.50	BTTM of Fault
7043	1873599.57	6801729.85	1312.84	Top of Fault
7044	1873604.96	6801779.66	1310.10	Top of Fault
7045	1873608.29	6801825.70	1309.68	Top of Fault
7046	1873610.50	6801876.57	1309.24	Top of Fault
7047	1873614.08	6801933.08	1307.28	Top of Fault
7048	1873616.42	6801992.65	1307.60	Top of Fault
7049	1873618.37	6802039.23	1307.22	Top of Fault
7050	1873617.63	6802086.65	1306.68	Top of Fault
7051	1873616.37	6802136.83	1306.61	Top of Fault
7052	1873621.40	6802139.28	1306.54	Top of Fault
7053	1873618.73	6802167.69	1307.64	Top of Fault
7054	1873615.88	6802169.07	1307.48	Top of Fault
7055	1873615.07	6802192.75	1307.62	Top of Fault
7056	1873588.01	6801733.80	1313.22	Top of Fault
7057	1873589.68	6801779.60	1310.42	Top of Fault
7058	1873593.88	6801829.72	1309.34	Top of Fault
7059	1873597.70	6801880.27	1308.64	Top of Fault
7060	1873600.97	6801933.40	1307.52	Top of Fault
7061	1873603.18	6801991.46	1307.01	Top of Fault
7062	1873604.53	6802038.60	1307.56	Top of Fault
7063	1873604.85	6802086.70	1307.54	Top of Fault

Coordinate Table				
Point #	Northing	Easting	Elevation	Description
7064	1873604.87	6802136.07	1307.05	Top of Fault
7065	1873599.78	6802138.49	1307.42	Top of Fault
7066	1873600.68	6802185.49	1308.23	Top of Fault
7067	1873603.45	6802187.24	1308.09	Top of Fault
7068	1873603.38	6802192.32	1308.20	Top of Fault
7069	1873603.91	6802225.18	1308.41	Top of Fault
7070	1873605.59	6802256.33	1308.48	Top of Fault
7071	1873610.96	6802307.68	1308.68	Top of Fault
7072	1873617.07	6802363.70	1307.20	Top of Fault
7073	1873617.05	6802372.38	1306.70	Top of Fault
7074	1873614.19	6802373.31	1307.06	Top of Fault
7075	1873617.48	6802393.63	1305.47	Top of Fault
7076	1873621.84	6802414.90	1303.52	Top of Fault
7077	1873631.92	6802453.45	1301.03	Top of Fault Wtr Beg
7078	1873648.13	6802492.57	1298.97	Top of Fault
7079	1873666.41	6802525.67	1297.78	Top of Fault
7080	1873687.68	6802554.79	1297.32	Top of Fault
7081	1873707.46	6802575.83	1297.02	Top of Fault Wtr End
7082	1873630.81	6802412.41	1295.81	BTTM of Fault
7083	1873628.16	6802390.51	1296.88	BTTM of Fault
7084	1873622.32	6802363.41	1298.43	BTTM of Fault
7085	1873616.42	6802307.54	1300.96	BTTM of Fault
7086	1873612.72	6802271.56	1300.38	BTTM of Fault
7087	1873608.62	6802224.47	1301.70	BTTM of Fault
7088	1873607.91	6802192.28	1300.74	BTTM of Fault
7089	1873609.22	6802070.13	1302.36	BTTM of Fault 1
7090	1873608.24	6802073.98	1305.82	Mid of Fault 3
7091	1873605.49	6802075.83	1306.94	Top of Fault 3
7092	1873597.84	6801822.00	1307.87	Top of Fault 2
7093	1873598.47	6801821.38	1306.75	Mdl of Fault 2
7094	1873598.96	6801820.85	1304.75	BTTM of Fault 2
7095	1873602.01	6801819.89	1306.16	BTTM of Fault 2B
7096	1873602.54	6801820.13	1307.16	Top of Fault 2B
7097	1873591.28	6801776.36	1309.86	Top of Fault 1
7098	1873594.04	6801774.32	1308.15	Mdl of Fault 1
7099	1873595.14	6801772.13	1305.34	Bttm of Fault 1
7100	1873570.37	6801683.35	1324.17	Top of Fault 0
7101	1873573.22	6801684.53	1320.14	Mid of Fault 0
7102	1873574.50	6801685.41	1317.46	Bttm of Fault 0
7103	1873604.49	6801742.45	1311.84	Top
7104	1873598.05	6801720.34	1313.84	Top
7105	1873593.54	6801713.76	1315.28	Top
7106	1873578.39	6801699.26	1320.70	Top
7107	1873564.25	6801683.31	1328.13	Top
7108	1873575.40	6801673.21	1327.25	Top
7109	1873588.74	6801686.14	1320.83	Top
7110	1873602.55	6801701.76	1315.52	Top
7111	1873608.44	6801709.54	1314.05	Top
7112	1873611.13	6801722.47	1312.96	Top
7113	1873615.12	6801740.11	1311.88	Top
7114	1873599.52	6801727.76	1313.16	Top
7115	1873606.03	6801734.76	1306.93	BTTM
7116	1873605.26	6801733.80	1306.86	BTTM
7117	1873605.93	6801723.92	1307.07	BTTM
7118	1873603.45	6801725.55	1307.24	BTTM
7119	1873599.70	6801714.27	1308.27	BTTM
7120	1873602.27	6801712.67	1308.33	BTTM
7121	1873595.50	6801707.70	1309.29	BTTM
7122	1873597.48	6801705.45	1309.48	BTTM
7123	1873584.68	6801692.30	1313.59	BTTM
7124	1873582.21	6801694.19	1313.88	BTTM
7125	1873569.53	6801679.83	1320.78	BTTM
7126	1873572.30	6801678.04	1320.47	BTTM
7127	1873563.56	6802105.76	1309.25	E1
7128	1873558.69	6802093.29	1309.03	E1
7129	1873558.45	6802082.88	1308.76	E1
7130	1873554.29	6802073.71	1308.84	E1
7131	1873550.27	6802072.45	1309.24	E1
7132	1873539.18	6802042.09	1309.14	E1
7133	1873535.39	6802043.17	1309.42	E1
7134	1873546.13	6802073.69	1309.37	E1
7135	1873543.62	6802075.08	1309.56	E1
7136	1873548.29	6802091.15	1309.47	E1
7137	1873554.57	6802096.11	1309.32	E1
7138	1873559.47	6802107.27	1309.46	E1

Coordinate Table				
Point #	Northing	Easting	Elevation	Description
7139	1873548.78	6802092.34	1309.49	Fault
7140	1873546.62	6802087.39	1309.33	Fault
7141	1873725.37	6802079.26	1306.05	E2
7142	1873724.57	6802072.79	1305.86	E2
7143	1873721.63	6802072.81	1306.14	E2
7144	1873717.33	6802036.25	1307.04	Fault
7145	1873716.94	6802020.50	1307.09	E2
7146	1873719.84	6802020.18	1307.20	E2
7147	1873719.50	6802016.37	1307.15	E2
7148	1873724.71	6802015.51	1307.08	E2
7149	1873724.79	6802021.42	1307.06	E2
7150	1873728.08	6802020.85	1307.04	E2
7151	1873729.38	6802033.94	1306.82	Fault
7152	1873731.41	6802071.63	1306.33	E2
7153	1873728.84	6802071.86	1306.28	E2
7154	1873729.18	6802078.73	1306.12	E2
7155	1873833.68	6802014.82	1306.79	E3
7156	1873834.22	6802010.37	1306.50	E3
7157	1873831.59	6802010.07	1306.93	E3
7158	1873831.88	6801999.48	1307.27	Fault
7159	1873834.05	6801989.43	1307.16	E3
7160	1873836.98	6801989.52	1307.09	E3
7161	1873842.45	6801949.26	1306.88	E3
7162	1873846.59	6801949.38	1306.85	E3
7163	1873841.70	6801989.39	1307.26	E3
7164	1873843.98	6801990.14	1307.20	E3
7165	1873844.34	6801996.65	1307.19	Fault
7166	1873843.72	6802003.24	1307.18	E3
7167	1873842.10	6802010.52	1307.04	E3
7168	1873839.82	6802011.54	1306.51	E3
7169	1873839.89	6802014.79	1306.58	E3
7170	1873907.09	6801999.14	1306.15	E4
7171	1873903.66	6801965.64	1306.18	Fault
7172	1873900.18	6801924.70	1306.39	E4
7173	1873904.99	6801924.40	1306.55	E4
7174	1873910.22	6801963.83	1306.04	Fault
7175	1873911.19	6801998.31	1306.01	E4
7176	1873958.70	6801953.36	1305.74	E5
7177	1873956.32	6801937.60	1305.49	Fault
7178	1873956.03	6801933.08	1305.82	Fault
7179	1873955.67	6801929.69	1305.59	Fault
7180	1873955.17	6801926.98	1305.55	Fault
7181	1873948.21	6801856.13	1306.63	E5
7182	1873954.24	6801854.64	1306.48	E5
7183	1873961.39	6801930.60	1305.69	E5
7184	1873961.30	6801925.67	1305.67	Fault
7185	1873961.28	6801918.60	1305.60	Fault
7186	1873963.16	6801936.31	1305.53	Fault
7187	1873964.28	6801952.18	1305.84	E5
7188	1873990.75	6802039.17	1306.65	E6
7189	1873989.97	6801940.53	1306.44	E6
7190	1873985.95	6801939.35	1306.39	E6
7191	1873955.41	6801925.42	1306.36	Fault
7192	1873985.82	6801914.31	1306.48	E6
7193	1873998.14	6801913.28	1306.48	E6
7194	1873989.38	6801921.42	1306.50	Fault
7195	1873999.41	6801922.16	1306.50	Fault
7196	1873998.76	6801938.53	1306.56	E6
7197	1873994.78	6801939.53	1306.54	E6
7198	1873998.34	6802038.85	1306.92	E6
7199	1874098.88	6802020.13	1307.69	E7
7200	1874102.25	6802025.82	1307.73	E7
7201	1874099.86	6802027.58	1307.68	E7
7202	1874129.28	6802068.05	1307.45	E7
7203	1874131.45	6802072.47	1307.44	E7
7204	1874171.65	6802126.63	1306.06	E7
7205	1874195.48	6802160.45	1305.02	E7
7206	1874208.74	6802181.03	1304.55	E7
7207	1874215.48	6802193.61	1304.18	E7
7208	1874228.97	6802226.93	1302.58	E7
7209	1874235.50	6802249.89	1301.58	E7
7210	1874238.92	6802249.66	1300.62	E7
7211	1874241.01	6802255.38	1301.35	E7
7212	1874247.00	6802253.38	1302.01	E7
7213	1874246.48	6802248.86	1302.05	E7

Coordinate Table				
Point #	Northing	Easting	Elevation	Description
7214	1874246.50	6802245.01	1301.93	E7
7215	1874235.40	6802211.43	1303.82	E7
7216	1874221.80	6802181.28	1305.24	E7
7217	1874195.14	6802139.30	1306.07	E7
7218	1874189.43	6802103.25	1306.83	E7
7219	1874108.99	6802022.14	1307.82	E7
7220	1874106.81	6802023.37	1307.63	E7
7221	1874102.03	6802018.10	1307.81	E7
7222	1873614.10	6801850.41	1309.24	W2
7223	1873613.82	6801822.40	1309.92	Fault
7224	1873613.99	6801820.04	1309.89	Fault
7225	1873812.00	6801770.15	1310.51	Fault
7226	1873610.46	6801737.61	1311.78	Fault
7227	1873611.06	6801721.17	1313.33	W2
7228	1873620.43	6801850.53	1308.88	w2
7229	1873618.11	6801770.18	1310.60	w2
7230	1873617.07	6801736.83	1311.86	Fault
7231	1873616.44	6801722.20	1312.68	W2
7232	1873702.13	6801781.91	1310.17	W3
7233	1873704.36	6801779.83	1310.68	W3
7234	1873704.52	6801782.19	1310.81	W3
7235	1873701.44	6801761.51	1310.71	W3
7236	1873701.41	6801739.30	1311.82	W3
7237	1873696.90	6801736.82	1311.88	W3
7238	1873696.52	6801758.98	1310.94	W3
7239	1873693.70	6801759.56	1310.70	W3
7240	1873694.64	6801777.75	1310.12	W3
7241	1873696.49	6801782.92	1309.83	W3
7242	1873696.14	6801839.62	1308.70	Fault
7243	1873697.08	6801856.30	1308.71	W3
7244	1873702.28	6801856.86	1308.53	W3
7245	1873702.56	6801841.03	1308.79	Fault
7246	1873733.99	6801846.39	1308.49	Fault
7247	1873739.61	6801869.30	1307.80	W4
7248	1873745.56	6801868.46	1307.52	W4
7249	1873742.69	6801849.17	1308.21	W4
7250	1873745.88	6801848.54	1308.41	W4
7251	1873739.92	6801805.81	1309.69	W4
7252	1873736.59	6801805.69	1309.74	W4
7253	1873736.28	6801800.56	1309.95	W4
7254	1873731.31	6801800.93	1309.90	W4
7255	1873731.69	6801805.39	1309.94	W4
7256	1873729.65	6801805.72	1309.80	W4
7257	1873734.87	6801849.61	1308.28	W4
7258	1873737.98	6801849.85	1308.17	W4
7259	1873782.22	6801920.16	1307.43	W5
7260	1873782.30	6801908.47	1307.54	W5
7261	1873779.50	6801909.46	1307.69	W5
7262	1873776.85	6801886.75	1307.49	W5
7263	1873780.37	6801886.07	1307.18	W5
7264	1873772.84	6801790.93	1309.58	W5
7265	1873777.63	6801790.56	1309.64	W5
7266	1873785.04	6801886.60	1306.88	W5
7267	1873788.48	6801886.59	1307.36	W5
7268	1873789.98	6801909.22	1307.53	W5
7269	1873787.61	6801909.75	1307.31	W5
7270	1873788.82	6801919.31	1307.45	W5
7271	1873553.21	6801832.93	1309.99	W1
7272	1873555.54	6801830.54	1310.04	W1
7273	1873561.21	6801823.56	1310.33	W1
7274	1873561.51	6801821.53	1310.20	Fault
7275	1873569.74	6801789.44	1310.98	W1
7276	1873566.60	6801787.35	1311.11	W1
7277	1873572.84	6801787.24	1311.74	Fault
7278	1873580.69	6801729.92	1314.39	W1
7279	1873576.06	6801727.70	1315.72	W1
7280	1873564.61	6801767.46	1312.41	Fault
7281	1873561.14	6801786.01	1311.43	W1
7282	1873557.66	6801786.19	1311.52	W1
7283	1873548.02	6801818.79	1310.54	W1
7284	1873548.05	6801831.08	1310.01	W1
7285	1873547.60	6801818.67	1310.85	Fault

VULCAN FACILITY PARKING LOT-BBC PROPERTIES

TOPOGRAPHICAL MAP

LYING WITHIN SECTION 25, TOWNSHIP 1 NORTH, RANGE 5 WEST, S.B.M.,
IN THE CITY OF RIALTO, COUNTY OF SAN BERNARDINO,
STATE OF CALIFORNIA

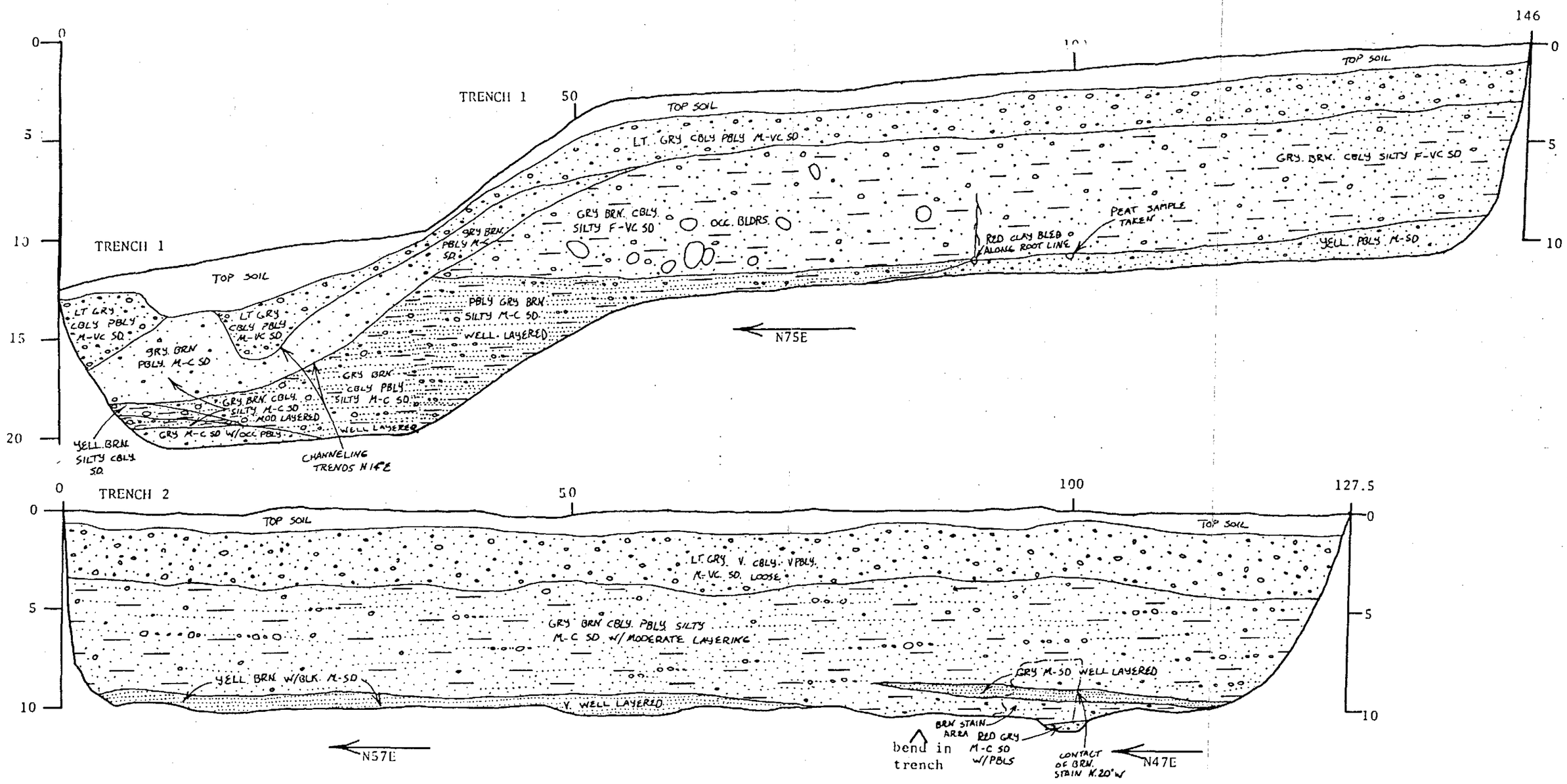
SCALE: 1"=30'	ALBERT A. WEBB ASSOCIATES	ENGINEERING CONSULTANTS 3788 McCRAY STREET RIVERSIDE, CA. 92506 PH. (951) 686-1070 FAX (951) 788-1256	W.O. 12-094
DATE: 09-26-2012			SHEET 4
DESIGNED:			OF 4 SHEETS
CHECKED:			
PLN CK REF: N/A			DWG. NO.
F.B. F.B.			

Appendix B

Pertinent Fault Trench Logs by Other Consultants

Logged by ELB

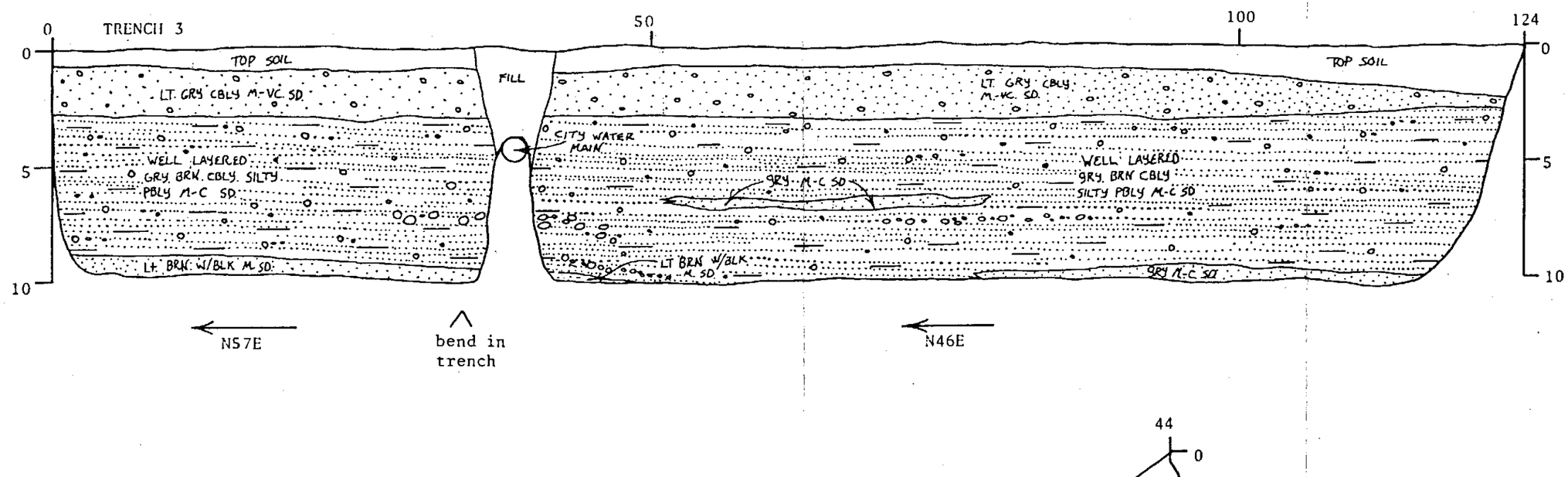
Horizontal scale 1"=10'
Vertical scale 1"=5'

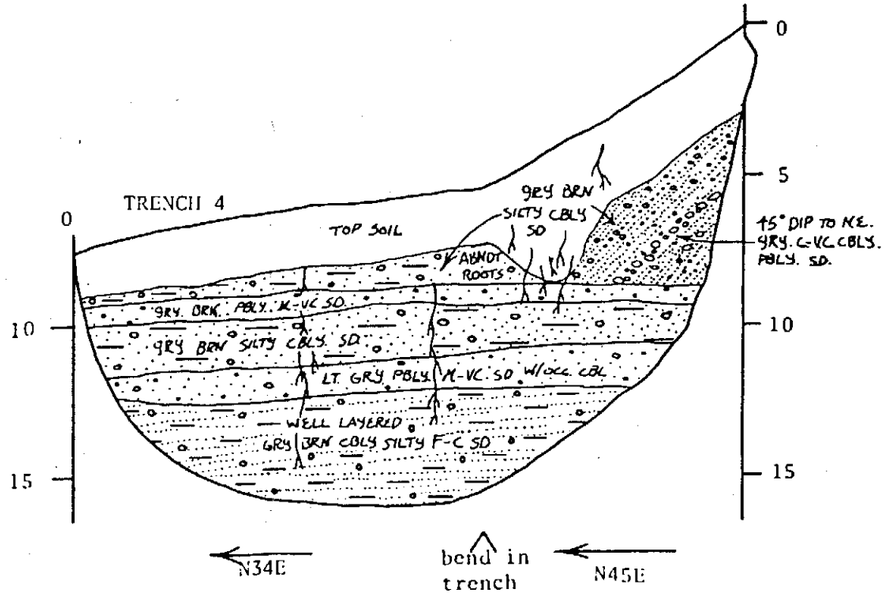


ENCLOSURE 2
TRENCH LOGS (from Project No. 1558)
Gary S. Rasmussen & Associates, Inc.
The KTGY Group - El Rancho Verde Country Club
Rialto, California
Project No. 3156

logged by ELB

Horizontal scale 1"=10'
Vertical scale 1"=5'





ENCLOSURE 2
TRENCH LOGS (from Project No. 1558)
Gary S. Rasmussen & Associates, Inc.
The KTGY Group - El Rancho Verde Country Club
Rialto, California
Project No. 3156

ENCLOSURE 3
TRENCH LOG UNIT DESCRIPTIONS
(from Project Nos. 1825 and 1830)
Gary S. Rasmussen & Associates, Inc.
The KTGY Group - El Rancho Verde Country Club
Rialto, California
Project No. 3156

Unit	General Description
1	Topsoil - organic materials intermixed with silty sands and occasional gravel, pebbles or cobbles; color: (10YR 4/2) to (10YR 6/2) unless otherwise indicated. Often is gradational into Unit 13.
2	Fill - disturbed alluvium
3	Silty sands - fine grained with clean medium-coarse sand interbeds and occasional interbeds of clay
4	Medium-coarse sands finely laminated, often cross-bedded with occasional interbeds of coarser sands and/or gravels and cobbles
5	Gravels and cobbles with many cobbles greater than 1-foot diameter
6	Gravels and cobbles interbedded with lenses of medium-coarse sands and silty sands with many clasts greater than 1-foot diameter
7	Silty sands with clay (probably representing relic paleosols)
8	Gravels - similar to Unit 5 except finer grained, greater than 50% 1-6" diameter clasts by volume
9	Gravels - (Unit 8) interbedded with lenses of medium-coarse sands and silty sands
10	Fine-medium sands with silt and minor amounts of clay (similar to Unit 7 except with depositional characteristics)
11	Coarse sands, gravels and cobbles, differentially stained with iron oxides along various, more permeable, interbeds
12	Depositional unit which occurs within the eastern portion of the property, broken into four members: a. Partial aquiclude to ground water, grades from medium-coarse sands near its base (5GY6/1) upwards to fine sands with silt and moderate amounts of clay (5Y2/1) b. Fine to medium sands with occasional coarse sand interbeds, color grades from (10YR 5/4) at its base upwards to (10YR 6/6) c. Fine sands with silt and minor amounts of clay (5Y 7/2) d. Fine sands with silt (5Y 5/1)
13	Dark silty sands with minor to moderate amounts of gravel and/or cobbles, especially near its base. Often is gradational into the base of Unit 1. Color: (5Y 6/1) to 5Y 4/1). Probably contains some wind-blown materials
14	Fine-medium silty sands with gravel and occasional cobbles (similar to unit 4 except with increased silt)

(10YR 4/1)	color indication
1/13	vertical gradational change
5 - - ►6	lateral gradational change

Sediment Color Designations

5Y 2/1	Olive black
5Y 4/1	Olive gray
5Y 5/1	Intermediate (5Y 4/1 - 5Y 6/1)
5Y 5/2	Light olive gray
5Y 6/1	Light olive gray
5Y 6/4	Dusky yellow
5Y 7/2	Yellowish gray
5Y 7/3	Intermediate (5Y 7/2 - 5Y 7/6)
5Y 7/4	Intermediate (5Y 8/4 - 5Y 6/4)
5Y 7/5	Intermediate (5Y 7/2 - 5Y 7/6)
5Y 7/6	Moderate yellow
5Y 8/1	Yellowish gray
5Y 8/4	Grayish yellow
5YR 5/3	Intermediate (5YR 5/2 - 5YR 5/6)
5YR 5/6	Light olive brown
5GY 6/1	Greenish gray
10Y 6/2	Pale olive
10YR 4/2	Dark yellowish brown
10YR 5/4	Moderate yellowish brown
10YR 6/2	Pale yellowish brown
10YR 6/4	Intermediate (10YR 5/4 - 10YR 7/4)
10YR 6/6	Dark yellowish orange
10YR 7/4	Grayish orange
10YR 8/2	Very pale orange

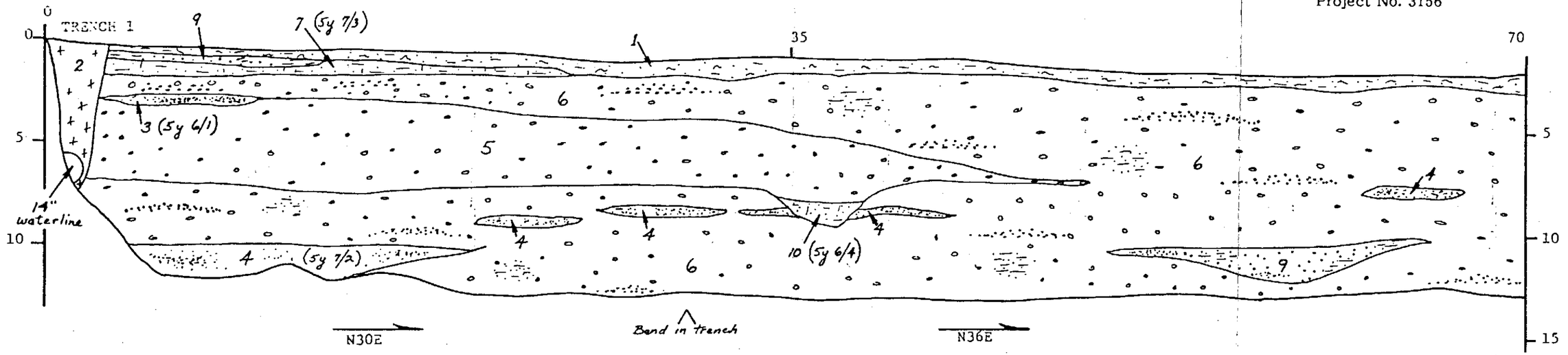
10YR5/4	10YR (Hue)	5(Value)	4(Chroma)

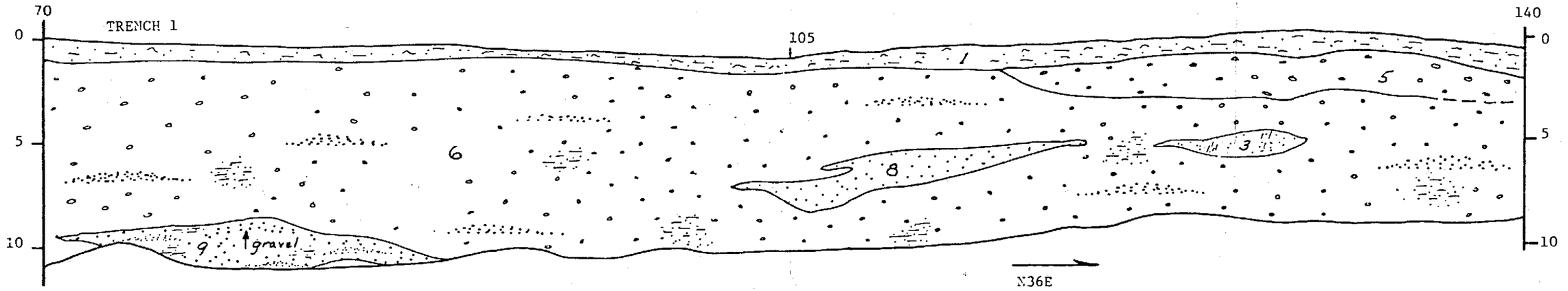
Color determination of the sediments observed within the trenches was based upon the Rock Color Chart (Goddard *et al.*, 1980)

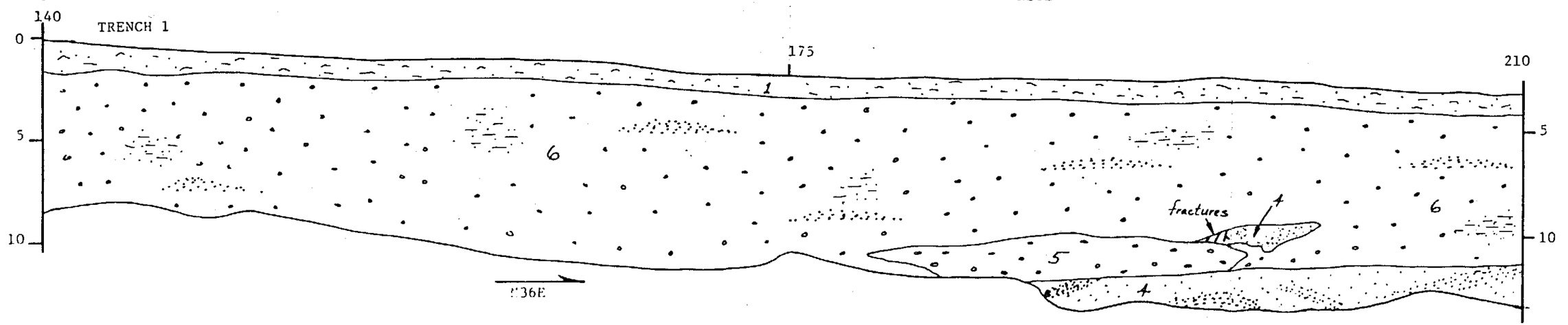
Logged by WAR

Horizontal and Vertical scale 1"=5'

ENCLOSURE 3
TRENCH LOGS (from Project Nos. 1825 and 1830)
Gary S. Rasmussen & Associates, Inc.
The KTGY Group - El Rancho Verde Country Club
Rialto, California
Project No. 3156



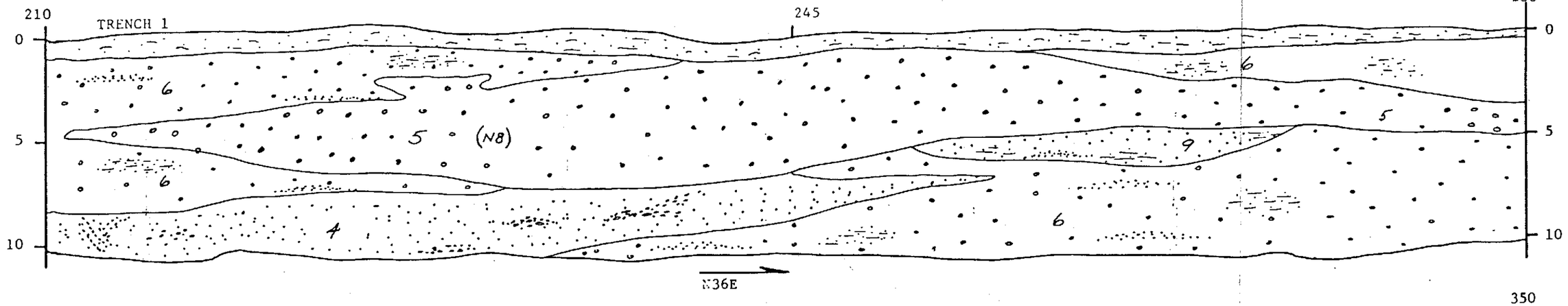


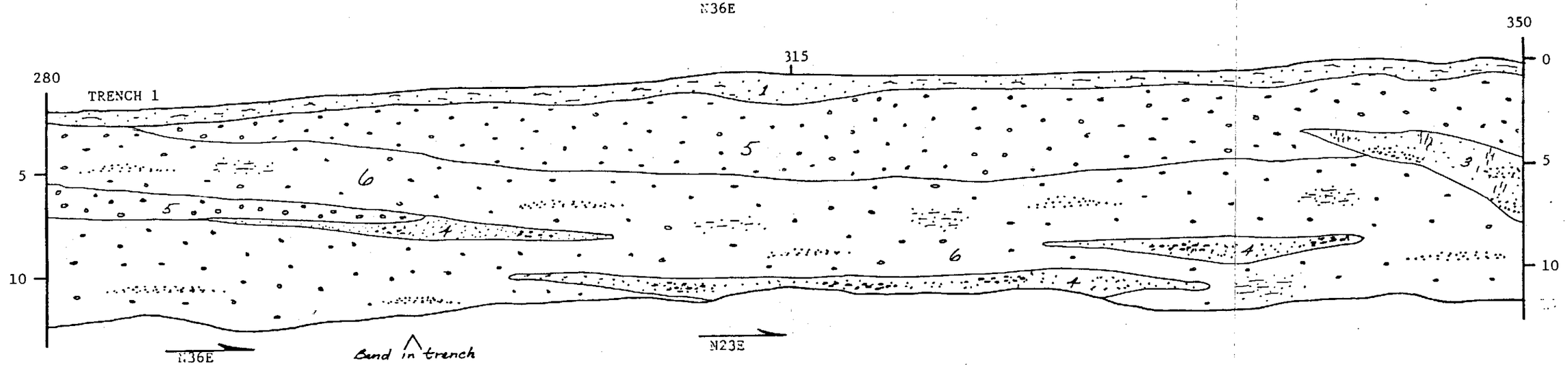


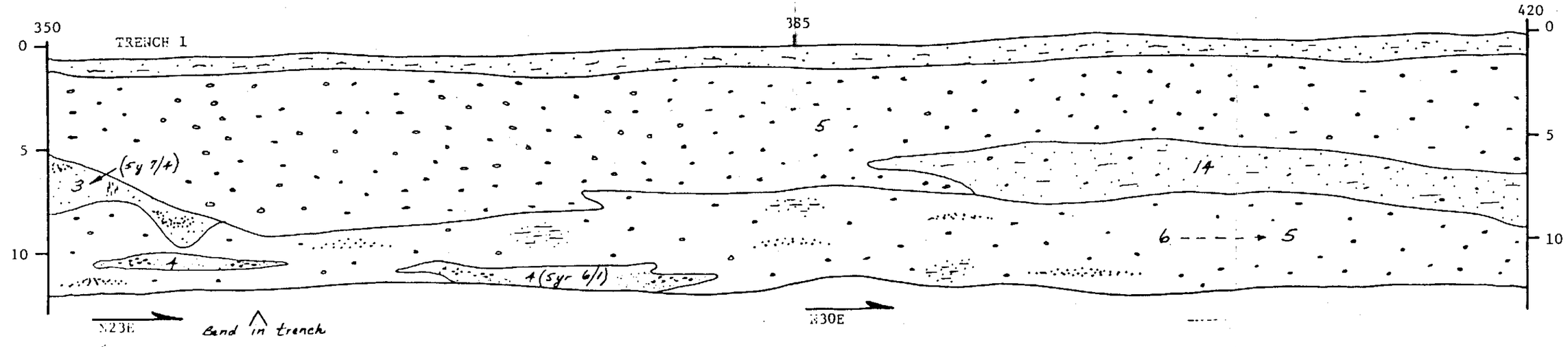
ENCLOSURE 3
TRENCH LOGS (from Project Nos. 1825 and 1830)
Gary S. Rasmussen & Associates, Inc.
The KTGY Group - El Rancho Verde Country Club
Rialto, California
Project No. 3156

Logged by WAR

Horizontal & Vertical scale 1"=5'



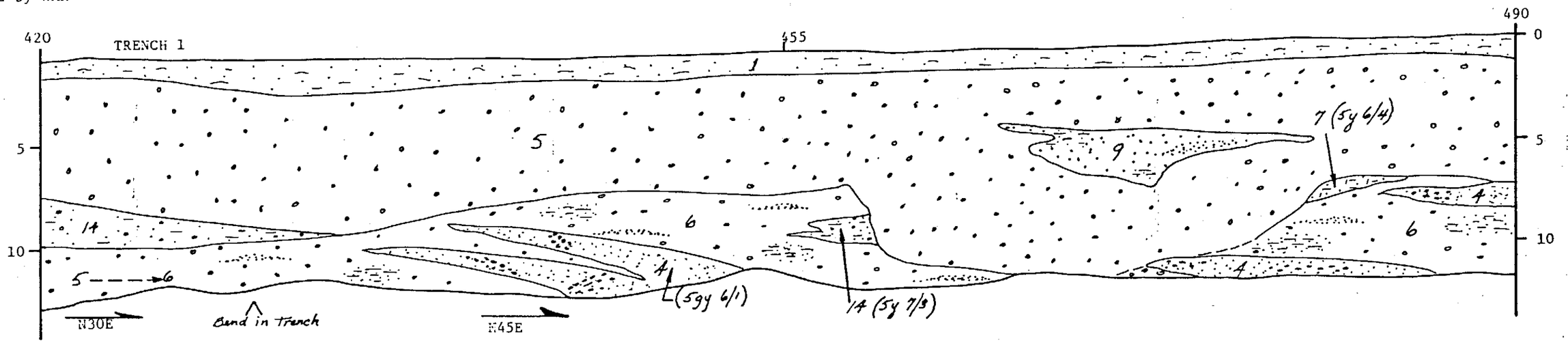


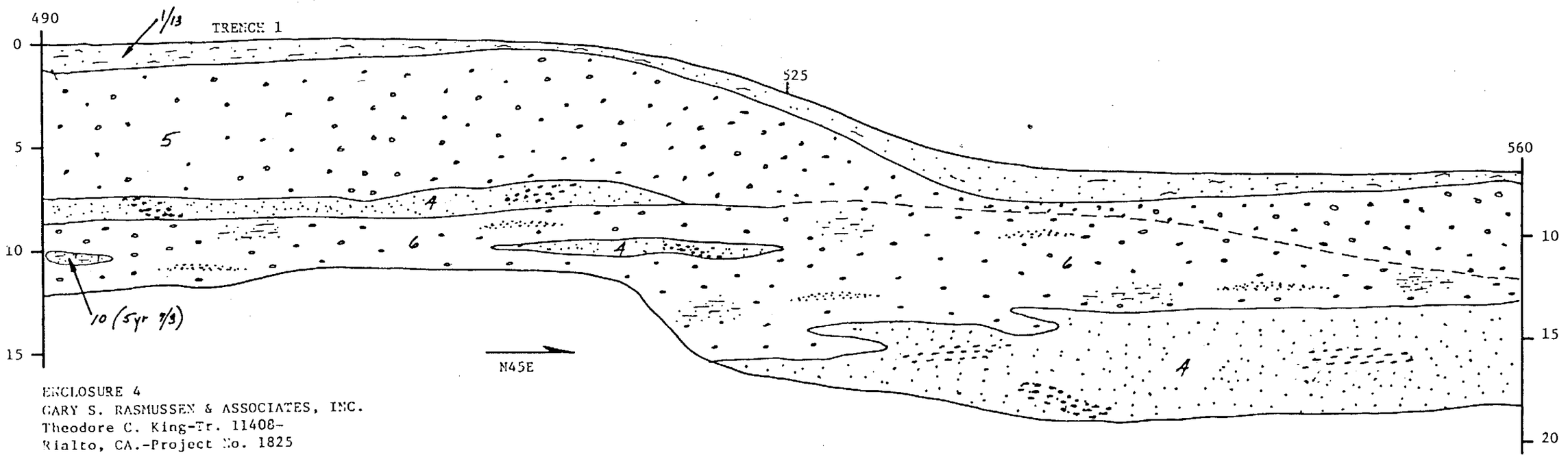


ENCLOSURE 3
TRENCH LOGS (from Project Nos. 1825 and 1830)
Gary S. Rasmussen & Associates, Inc.
The KTGY Group - El Rancho Verde Country Club
Rialto, California
Project No. 3156

Logged by WAR

Horizontal and Vertical scale 1"=5'



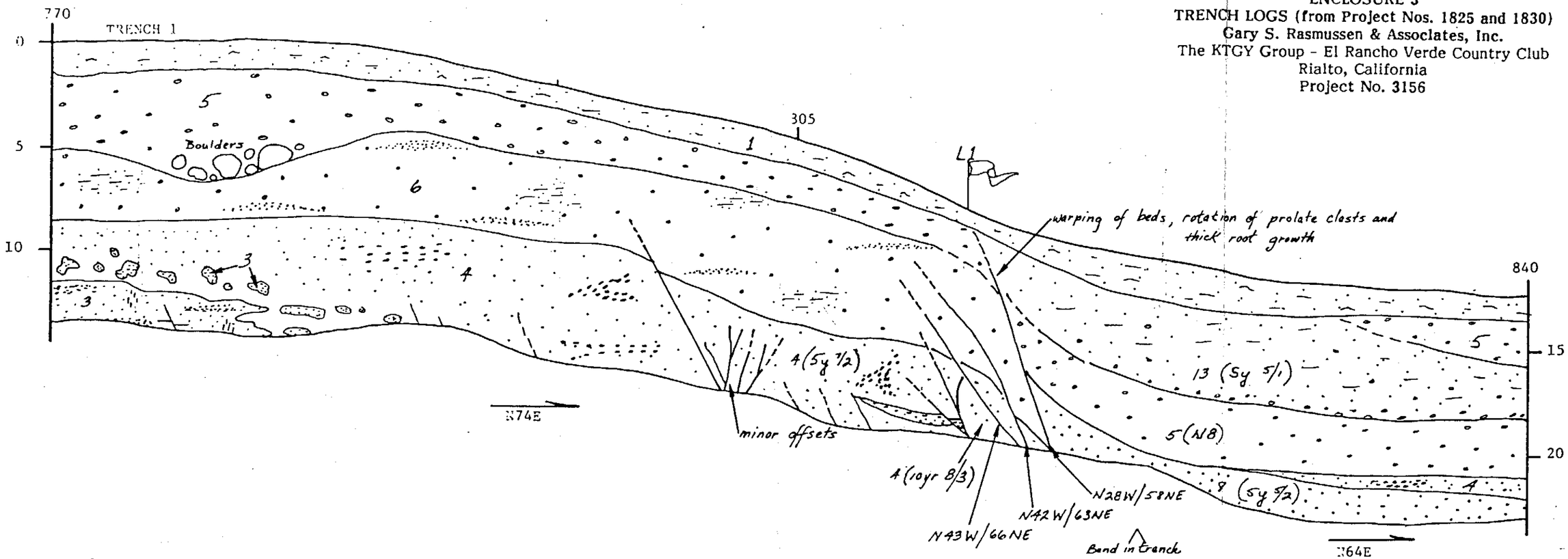


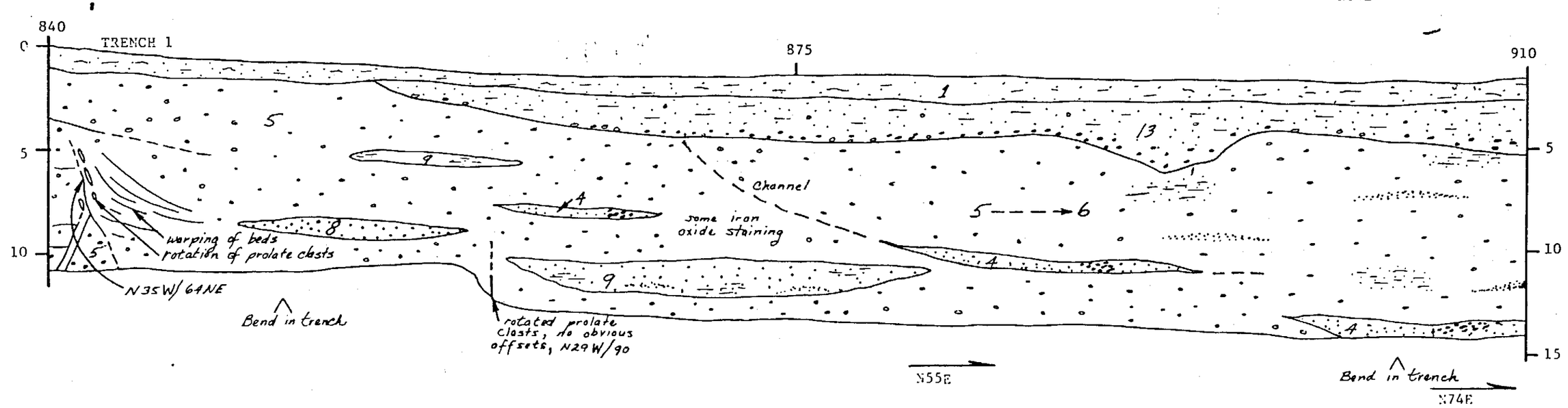
ENCLOSURE 4
GARY S. RASMUSSEN & ASSOCIATES, INC.
Theodore C. King-Tr. 11408-
Rialto, CA.-Project No. 1825

Logged by WAR

Horizontal & Vertical scale 1"=5'

ENCLOSURE 3
TRENCH LOGS (from Project Nos. 1825 and 1830)
Gary S. Rasmussen & Associates, Inc.
The KTGY Group - El Rancho Verde Country Club
Rialto, California
Project No. 3156

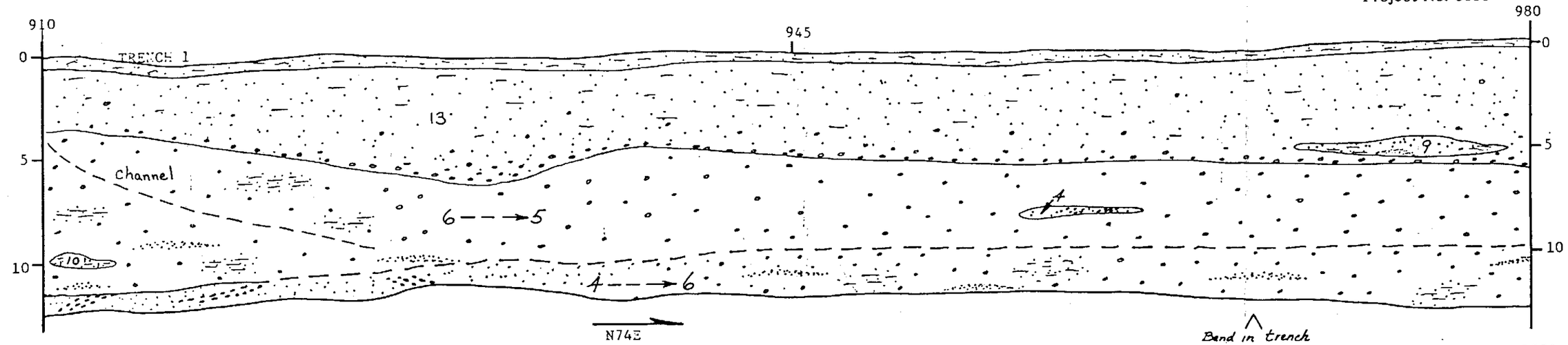


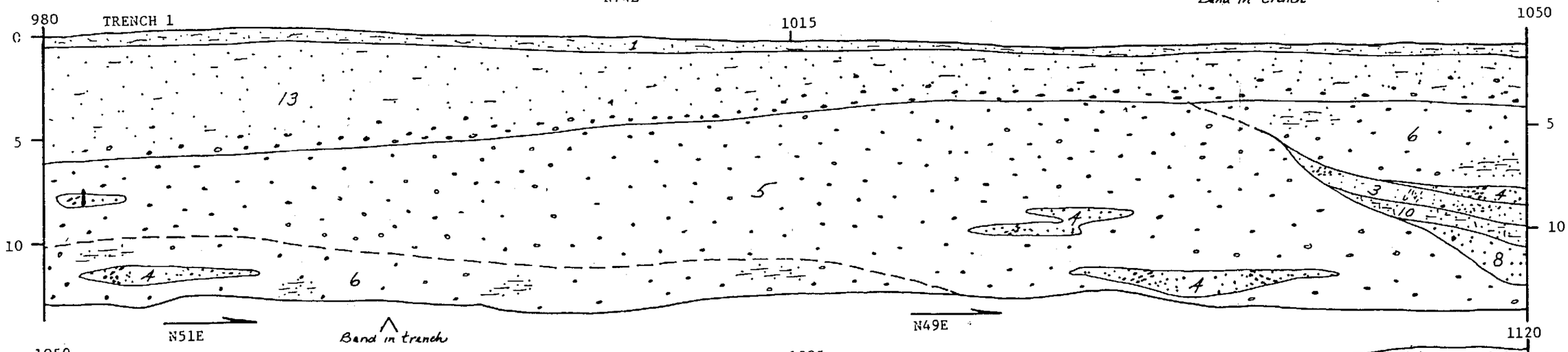


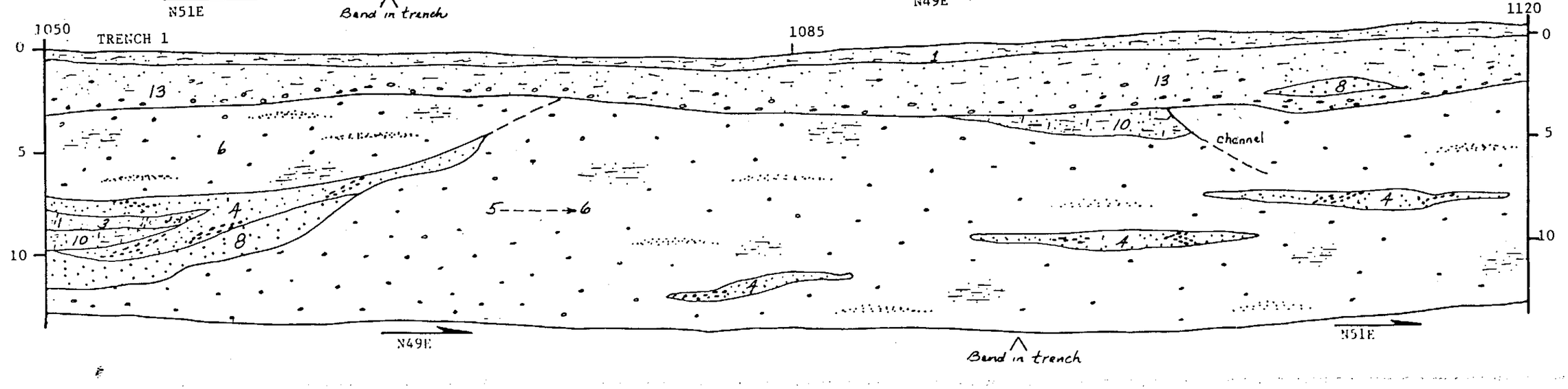
Logged by WAR

Horizontal & Vertical scale 1"=5'

ENCLOSURE 3
TRENCH LOGS (from Project Nos. 1825 and 1830)
Gary S. Rasmussen & Associates, Inc.
The KTGY Group - El Rancho Verde Country Club
Rialto, California
Project No. 3156



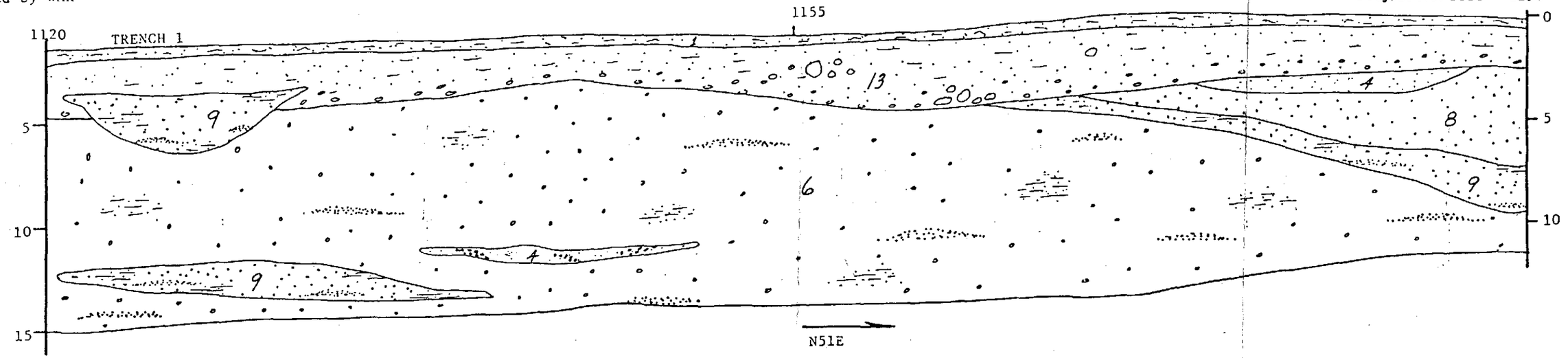


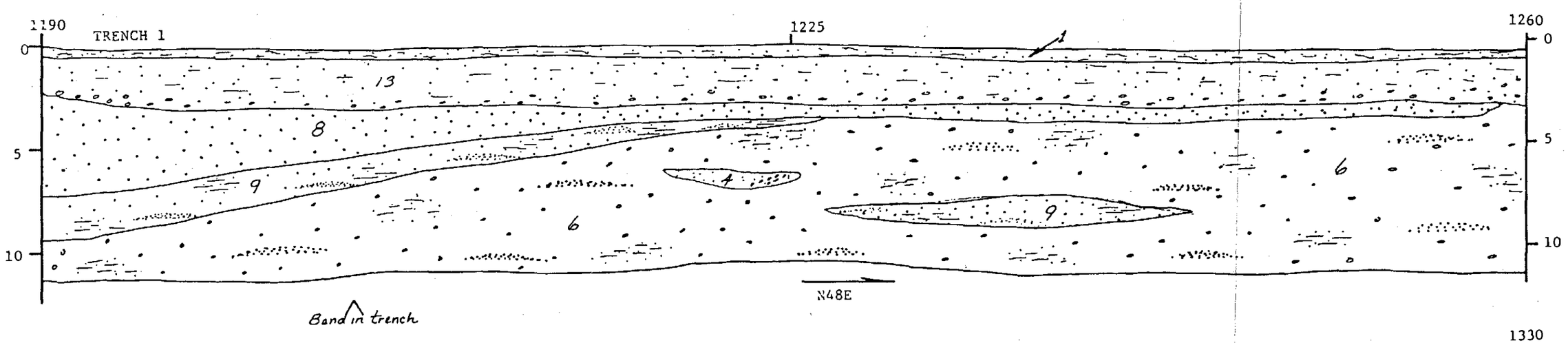


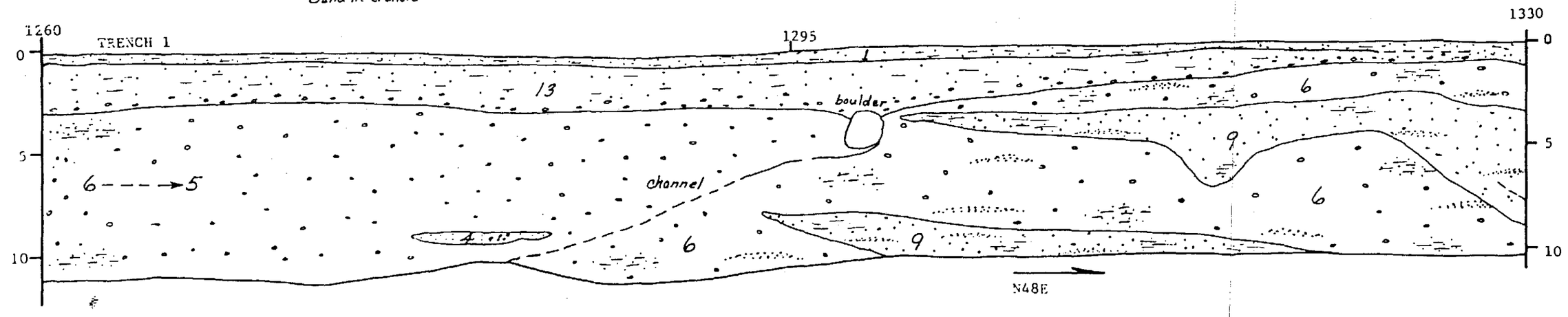
ENCLOSURE 3
TRENCH LOGS (from Project Nos. 1825 and 1830)
Gary S. Rasmussen & Associates, Inc.
The KTGY Group - El Rancho Verde Country Club
Rialto, California
Project No. 3156

Logged by WAR

Horizontal & Vertical scale 1"=5'







ENCLOSURE 3
TRENCH LOGS (from Project Nos. 1825 and 1830)
Gary S. Rasmussen & Associates, Inc.
The KTGY Group - El Rancho Verde Country Club
Rialto, California
Project No. 3156

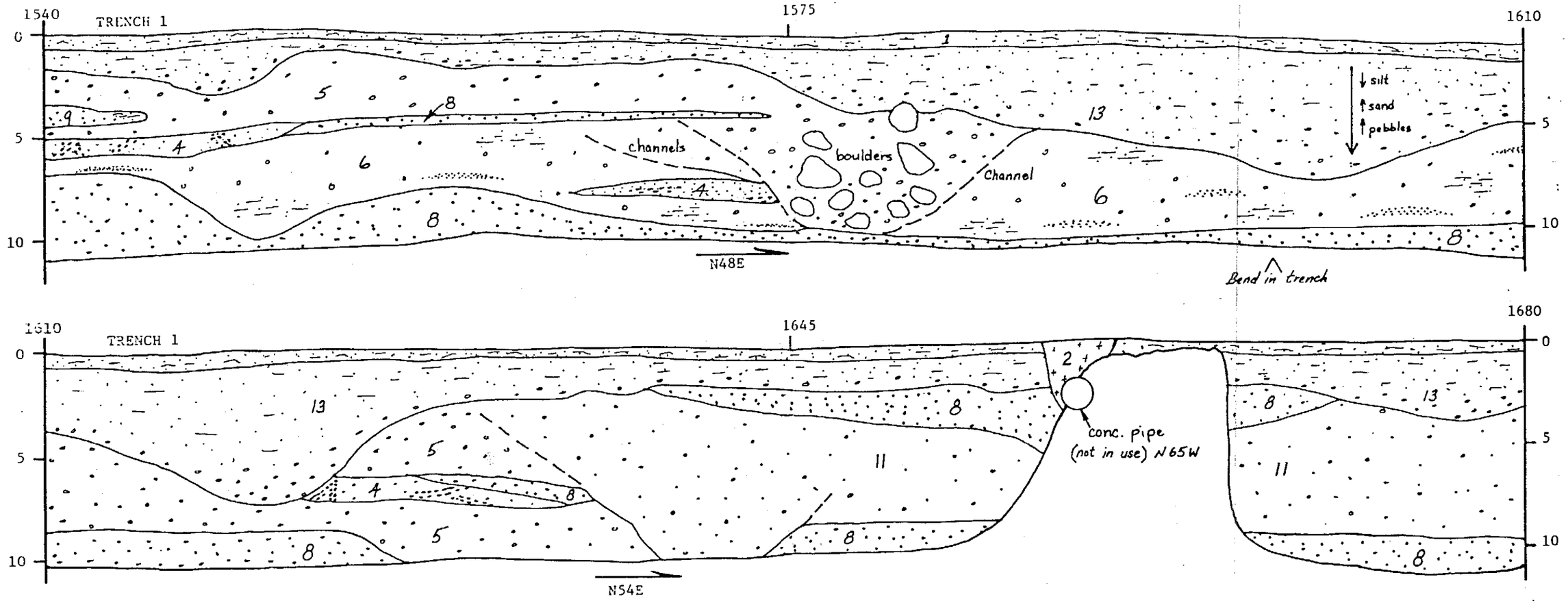
Logged by WAR

Horizontal & Vertical scale 1"=5'

ENCLOSURE 3
TRENCH LOGS (from Project Nos. 1825 and 1830)
Gary S. Rasmussen & Associates, Inc.
The KTGY Group - El Rancho Verde Country Club
Rialto, California
Project No. 3156

Logged by WAR

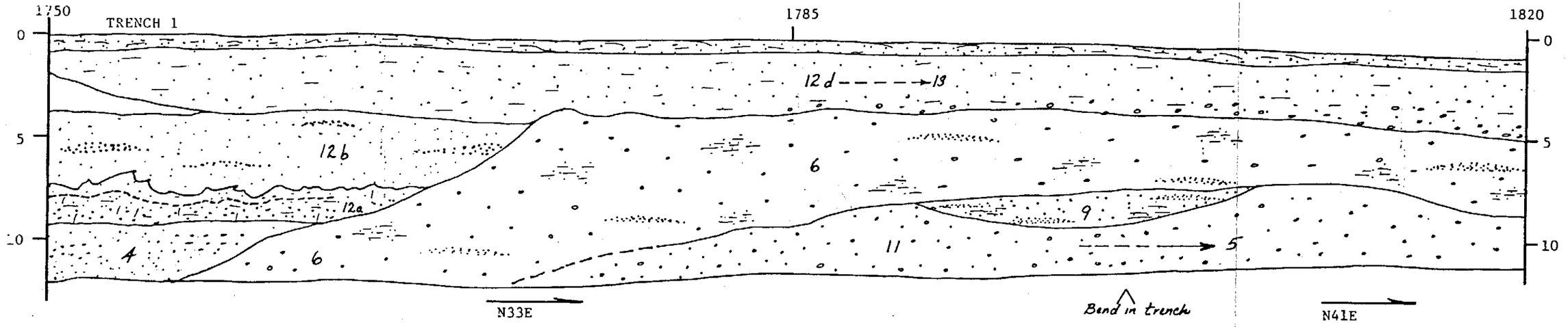
Horizontal & Vertical scale 1"=5'

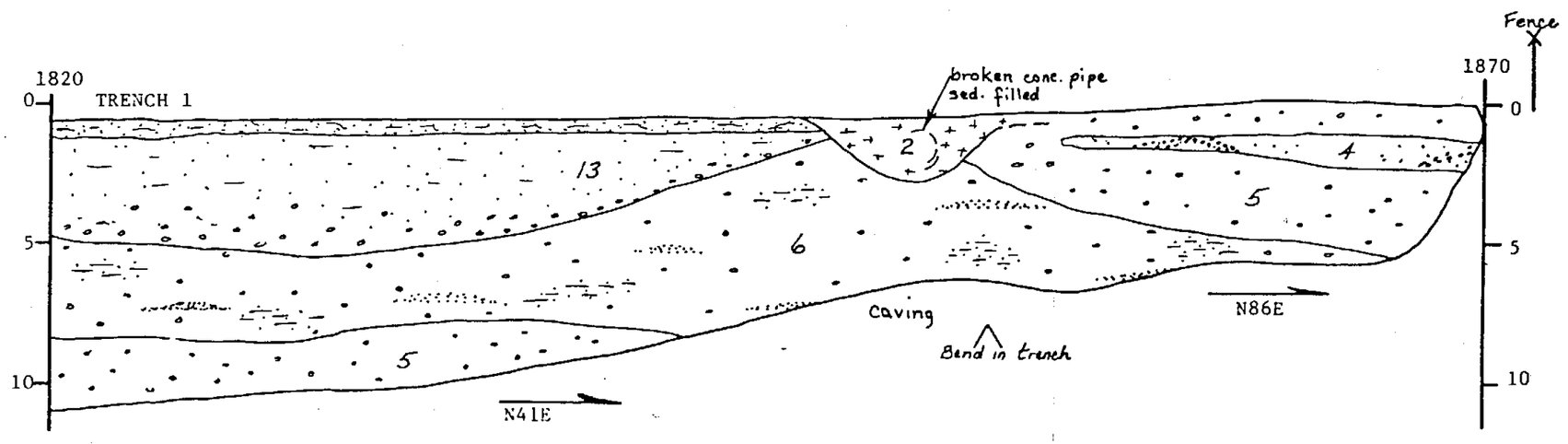


Logged by WAR

Horizontal & Vertical scale 1"=5'

ENCLOSURE 3
TRENCH LOGS (from Project Nos. 1825 and 1830)
Gary S. Rasmussen & Associates, Inc.
The KTGY Group - El Rancho Verde Country Club
Rialto, California
Project No. 3156

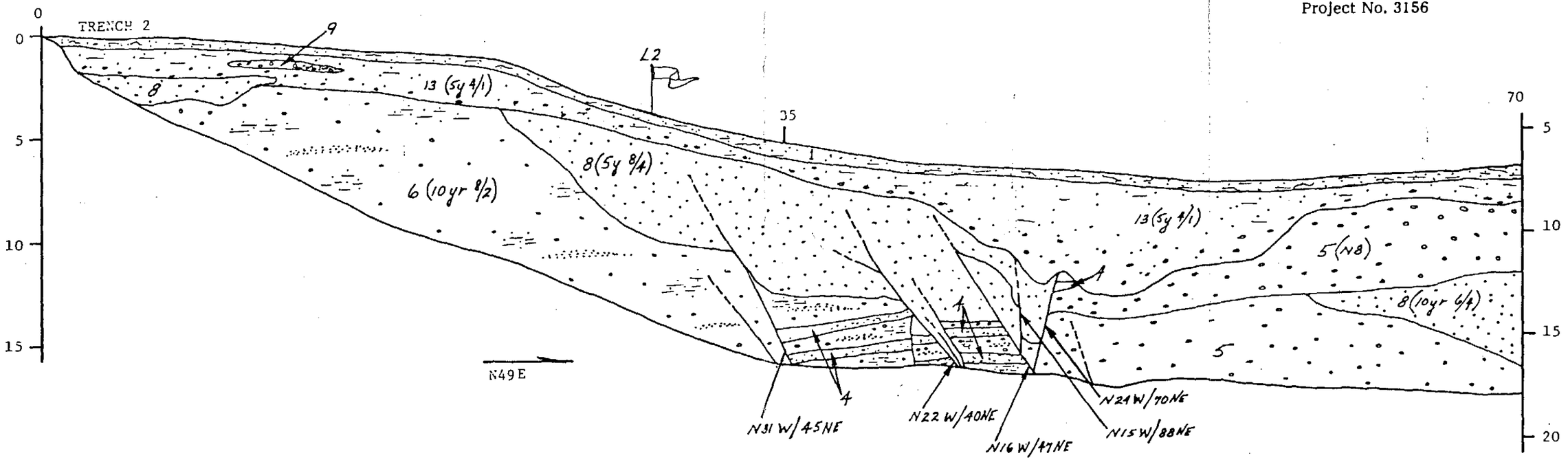


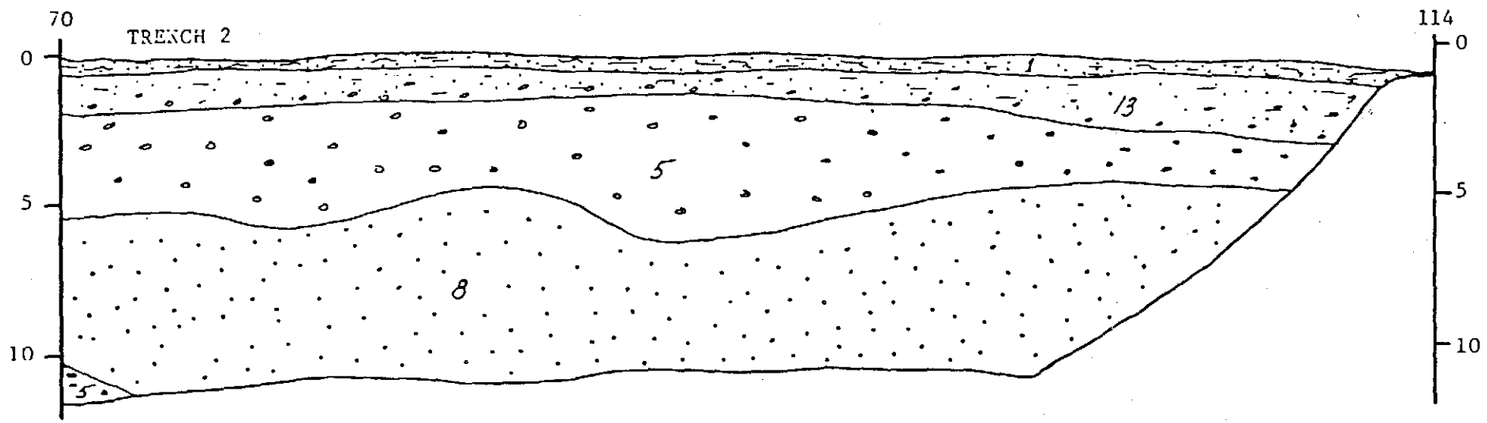


Logged by WAR

Horizontal & Vertical scale 1"=5'

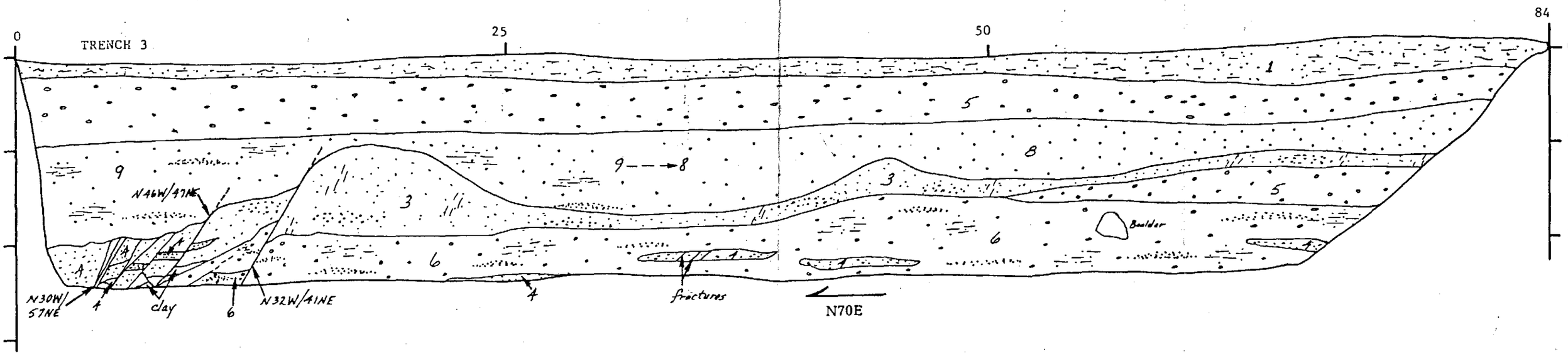
ENCLOSURE 3
TRENCH LOGS (from Project Nos. 1825 and 1830)
Gary S. Rasmussen & Associates, Inc.
The KTGY Group - El Rancho Verde Country Club
Rialto, California
Project No. 3156





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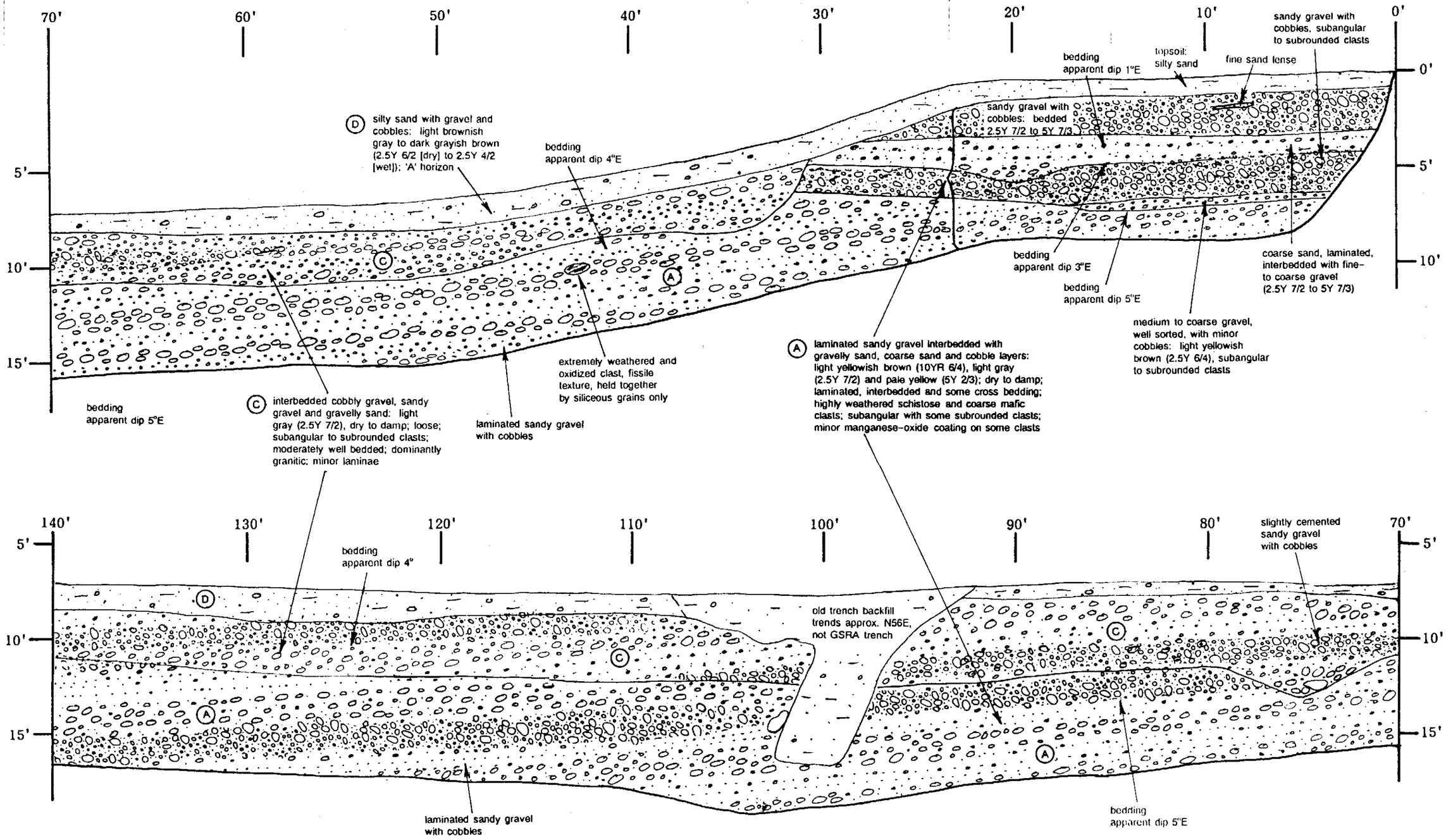
Horizontal & Vertical scale 1"=5'



ENCLOSURE 3
TRENCH LOGS (from Project Nos. 1825 and 1830)
Gary S. Rasmussen & Associates, Inc.
The KTGY Group - El Rancho Verde Country Club
Rialto, California
Project No. 3156

Trench 13A
Logged by TSB
Drafted by PAG

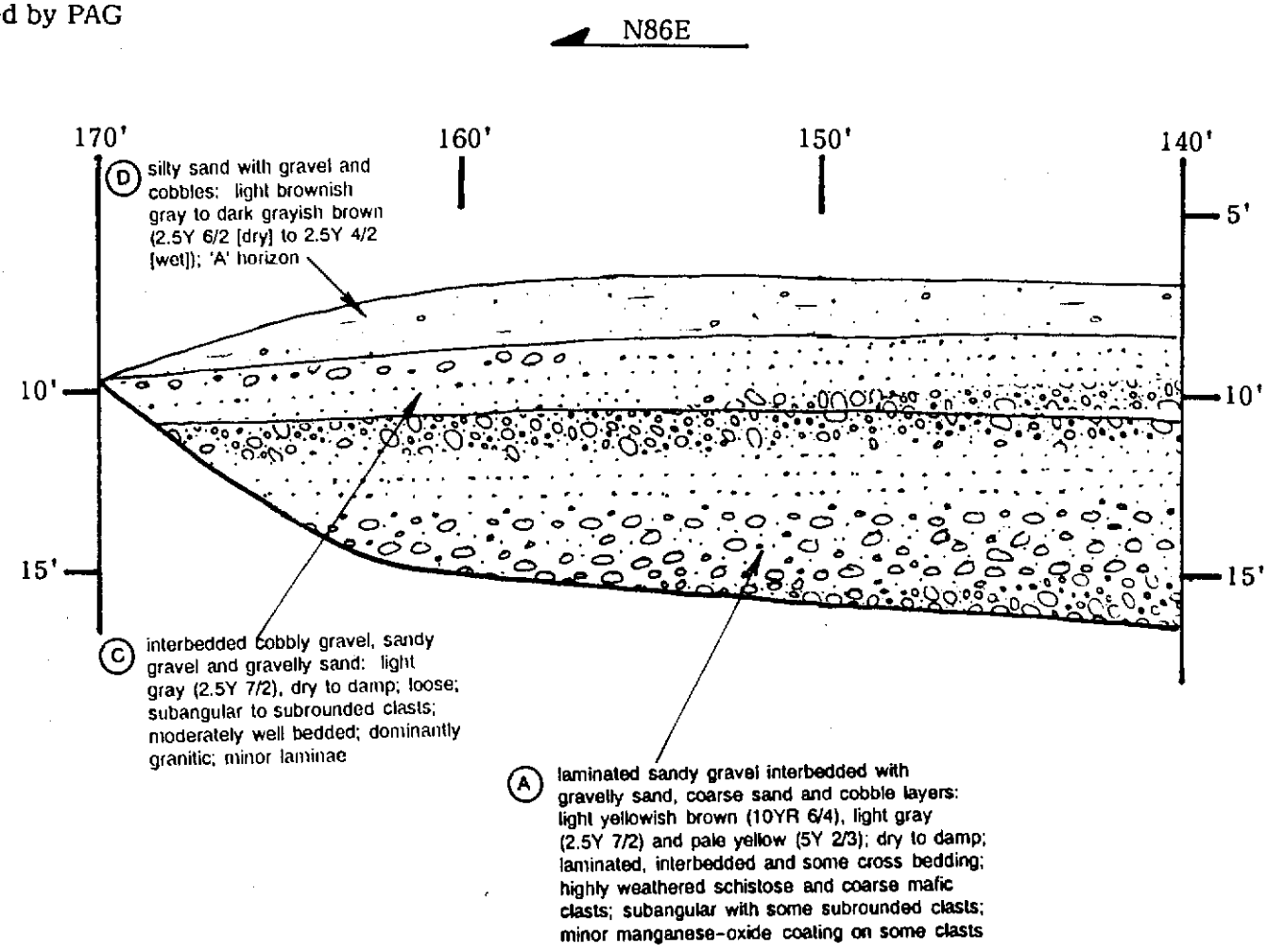
N86E
South wall



Horizontal & Vertical Scale: 1" = 5'

ENCLOSURE 6
TRENCH LOGS
Gary S. Rasmussen & Associates, Inc.
Nitto America Co. - El Rancho Verde Country Club
Rialto, California
Project No. 3156.1

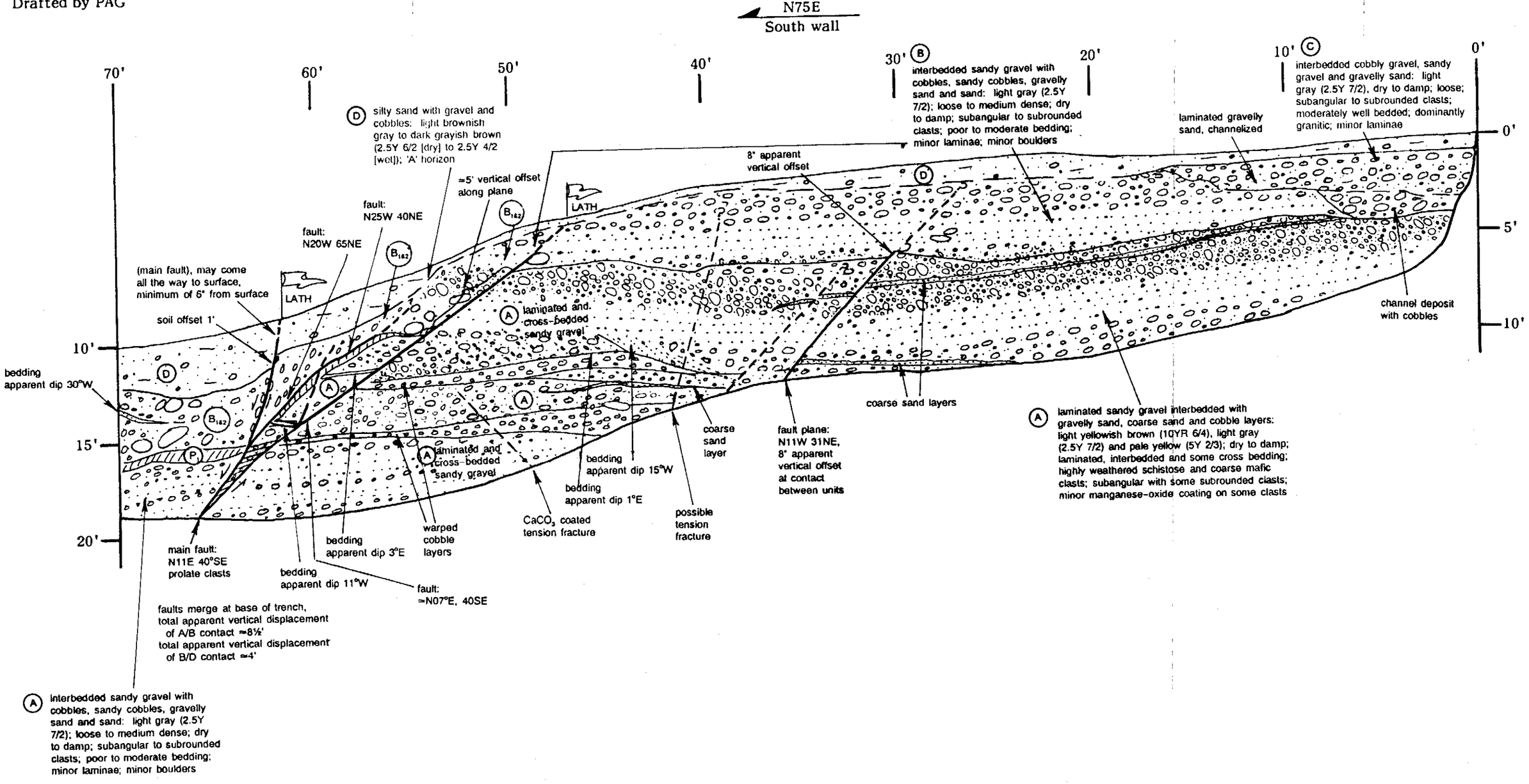
Trench 13A (continued)
Logged by TSB
Drafted by PAG



Horizontal & Vertical Scale: 1" = 5'

ENCLOSURE 6
TRENCH LOGS
Gary S. Rasmussen & Associates, Inc.
Nitto America Co. - El Rancho Verde Country Club
Rialto, California
Project No. 3156.1

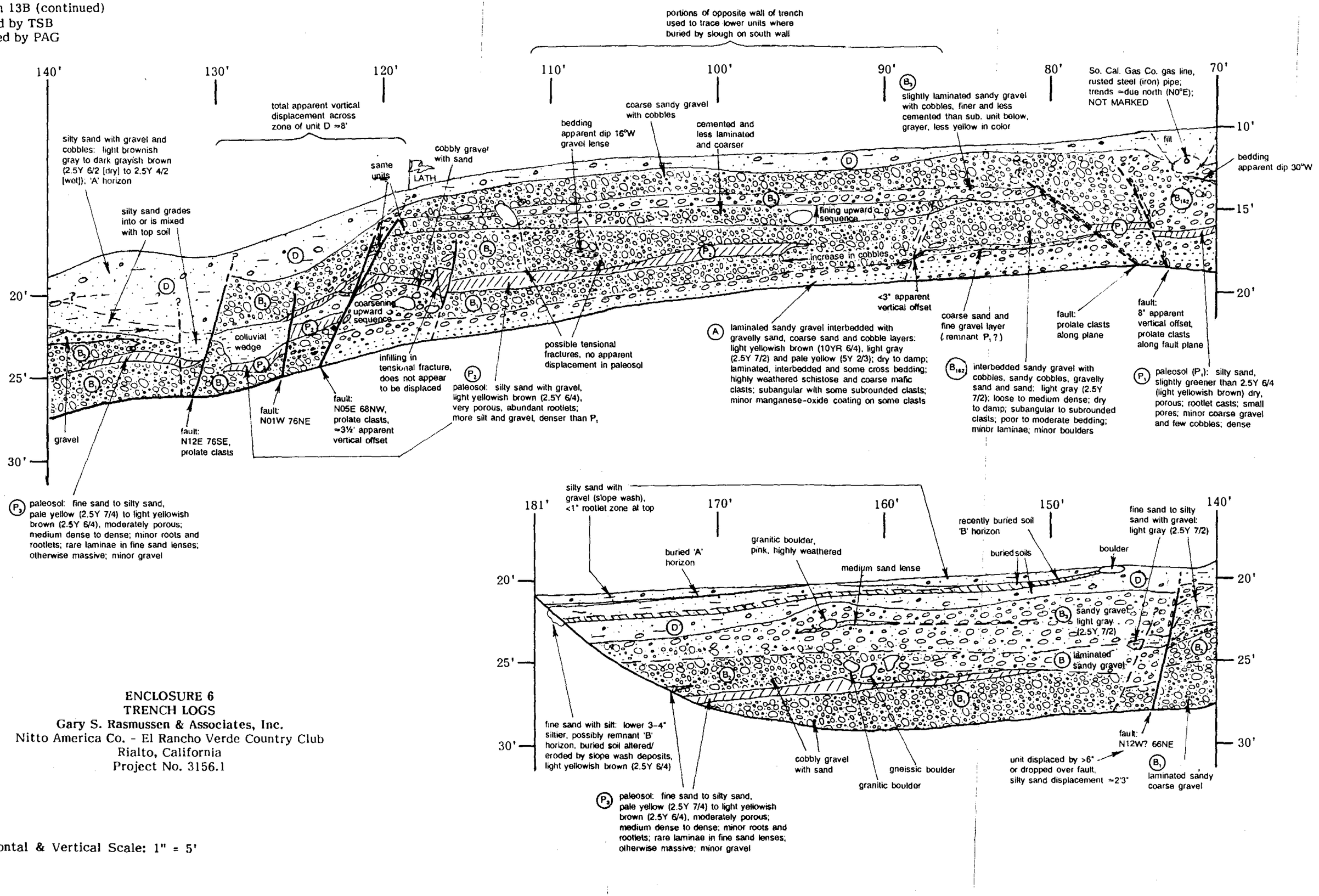
Trench 13B
Logged by TSB
Drafted by PAG



Horizontal & Vertical Scale: 1" = 5'

ENCLOSURE 6
TRENCH LOGS
Gary S. Rasmussen & Associates, Inc.
Nitto America Co. - El Rancho Verde Country Club
Rialto, California
Project No. 3156.1

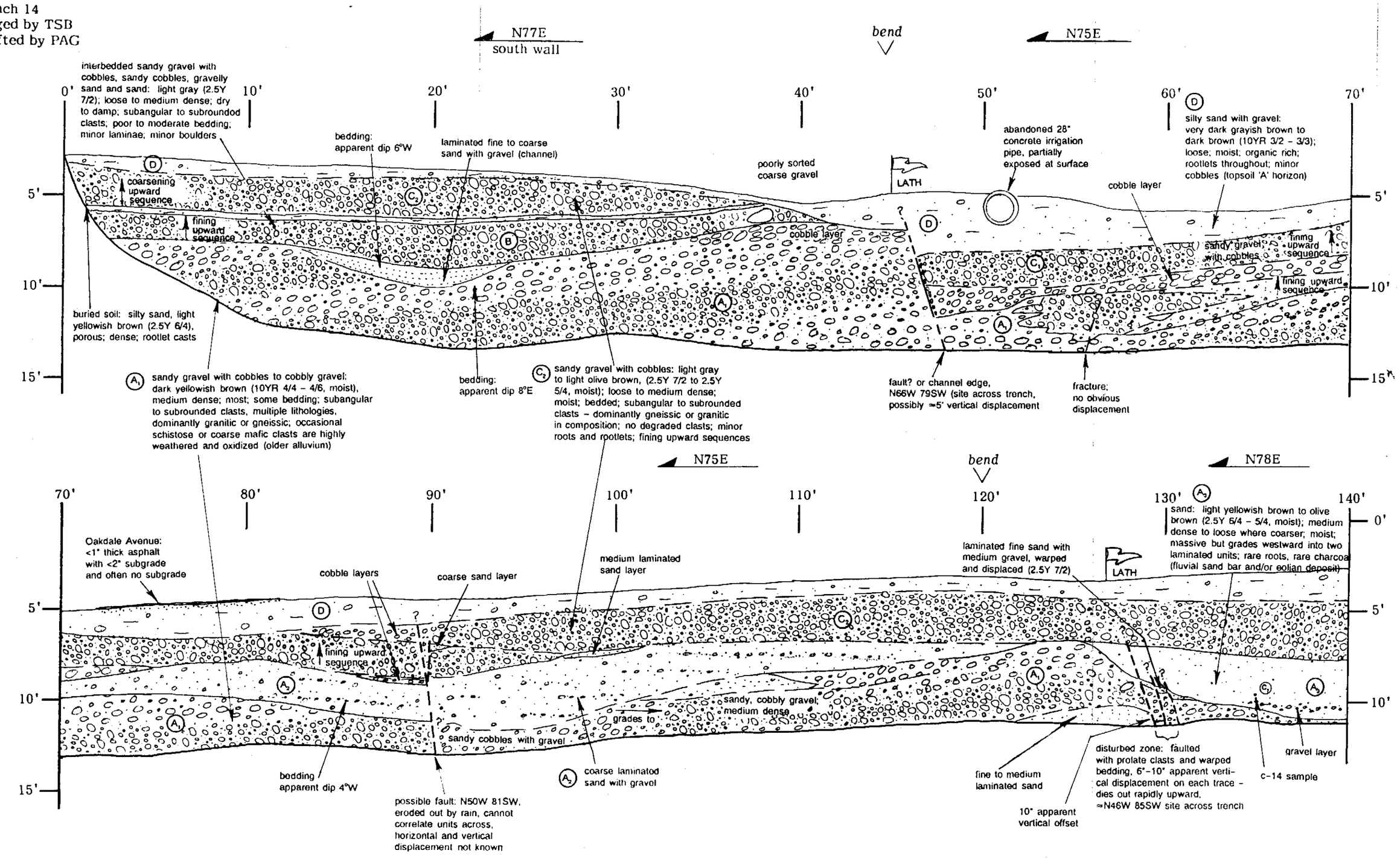
Trench 13B (continued)
Logged by TSB
Drafted by PAG



ENCLOSURE 6
TRENCH LOGS
Gary S. Rasmussen & Associates, Inc.
Nitto America Co. - El Rancho Verde Country Club
Rialto, California
Project No. 3156.1

Horizontal & Vertical Scale: 1" = 5'

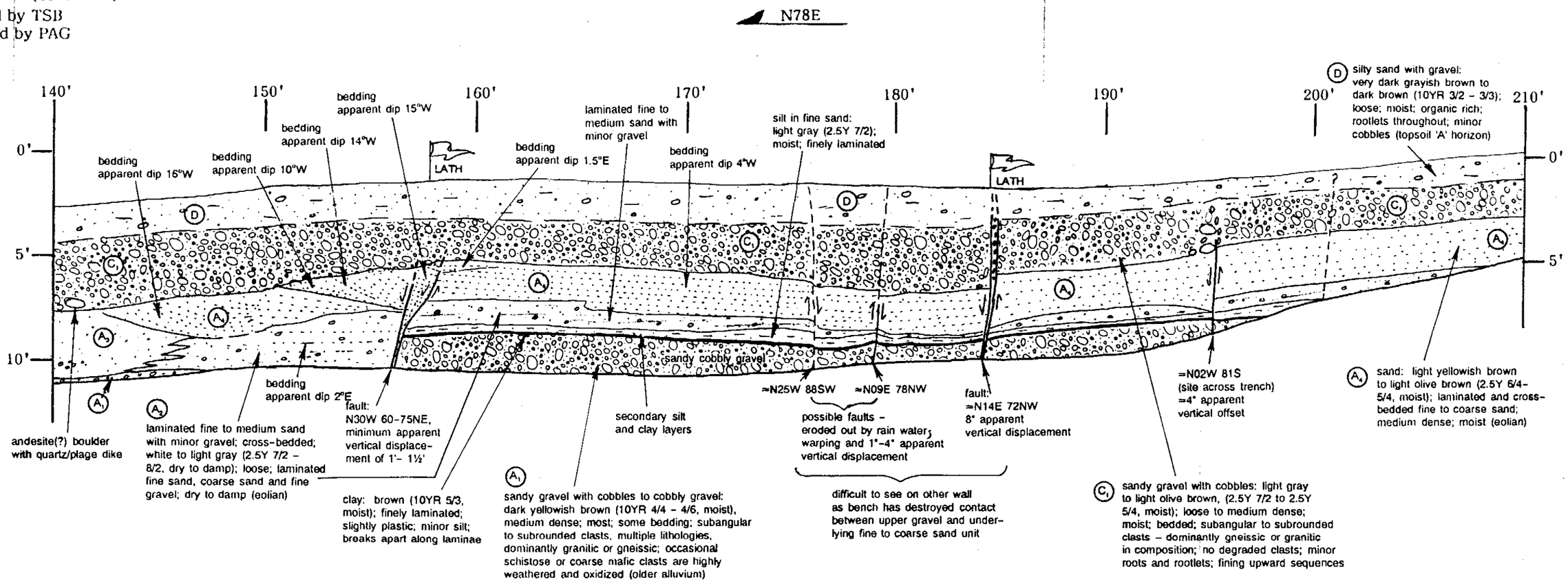
Trench 14
Logged by TSB
Drafted by PAG

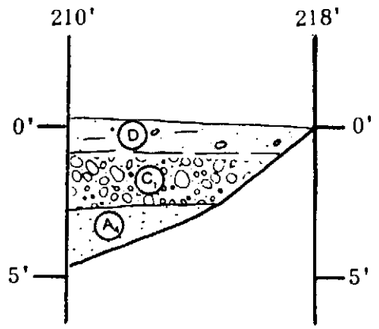


Horizontal and Vertical Scale: 1" = 5'

ENCLOSURE 6
TRENCH LOGS
Gary S. Rasmussen & Associates, Inc.
Nitto America Co. - El Rancho Verde Country Club
Rialto, California
Project No. 3156.1

Trench 14 (continued)
Logged by TSB
Drafted by PAG



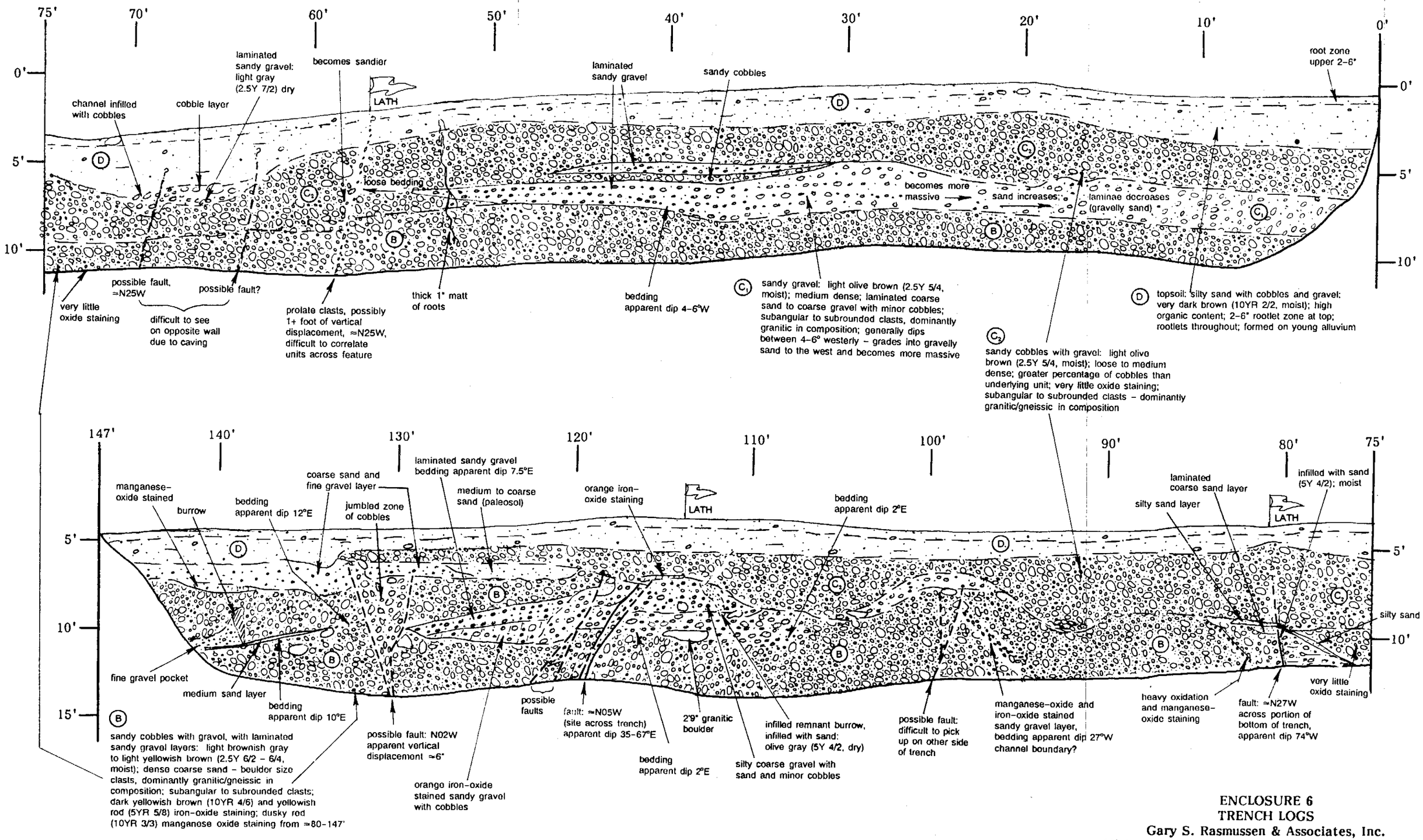


Horizontal and Vertical Scale: 1" = 5'

ENCLOSURE 6
TRENCH LOGS
Gary S. Rasmussen & Associates, Inc.
Nitto America Co. - El Rancho Verde Country Club
Rialto, California
Project No. 3156.1

Trench 15 Logged by TSB
Drafted by PAG

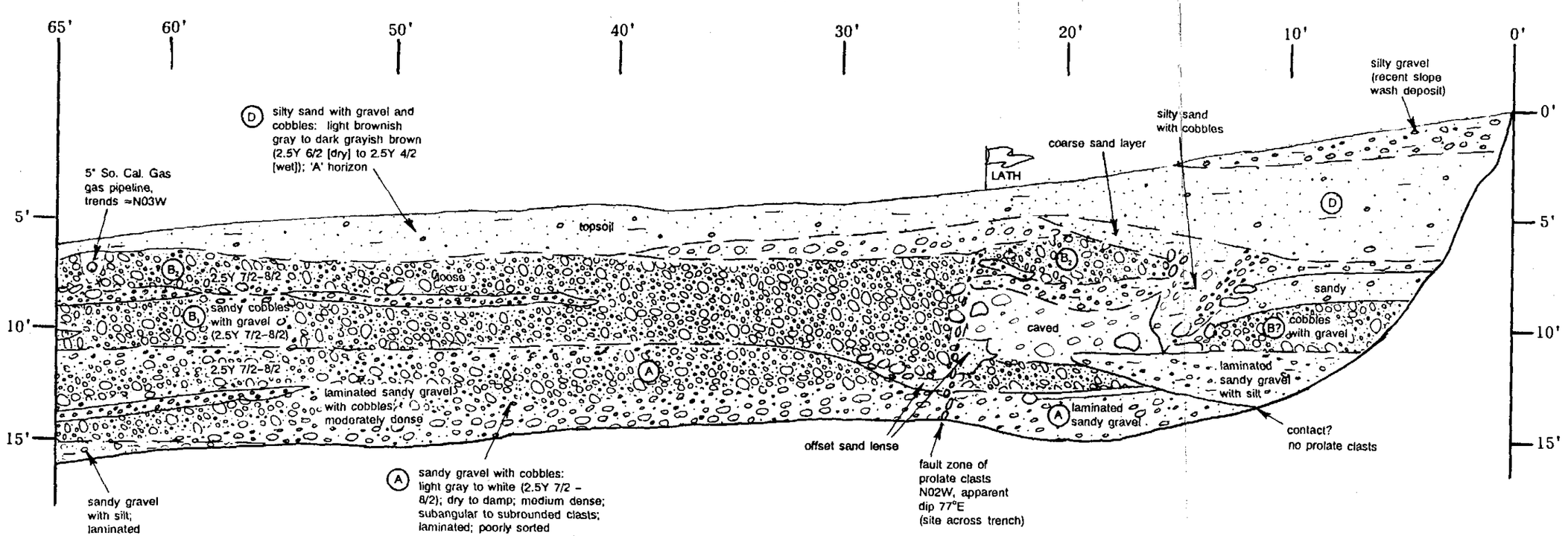
N66E
Southwest wall

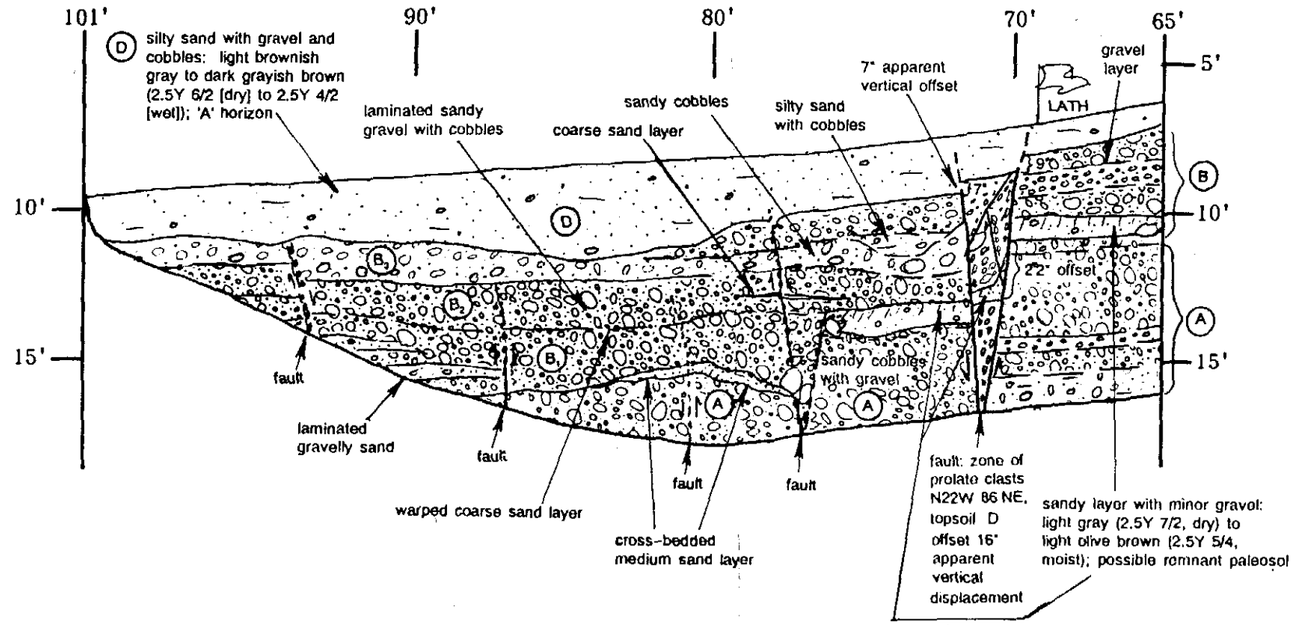


Horizontal & Vertical Scale: 1" = 5'

ENCLOSURE 6
TRENCH LOGS
Gary S. Rasmussen & Associates, Inc.
Nitto America Co. - El Rancho Verde Country Club
Rialto, California
Project No. 3156.1

Trench 17
Logged by TSB
Drafted by PAG





MAIN FAULT
N22W 86NE

A total apparent vertical offset ≈2'10"

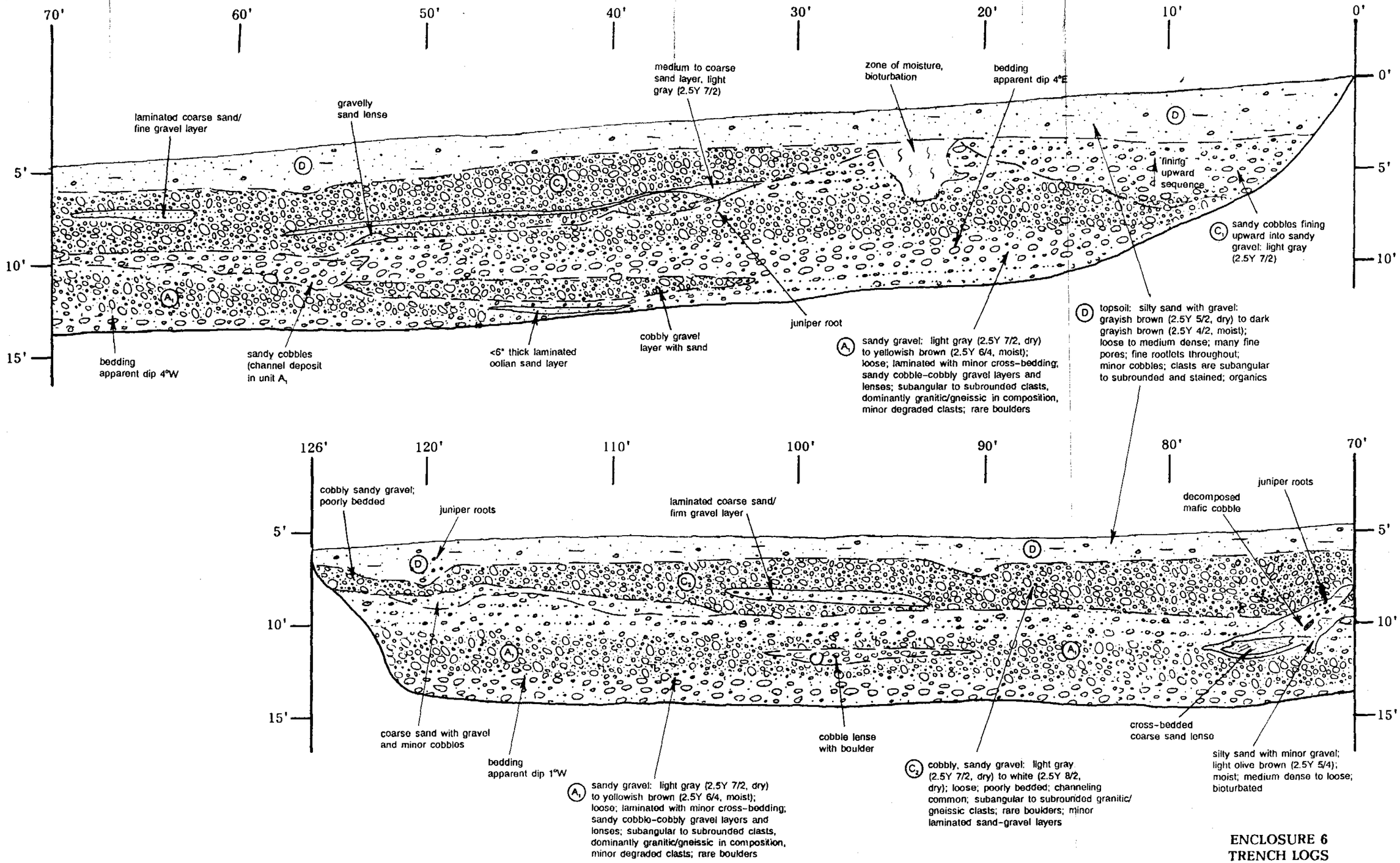
B total apparent vertical offset ≈1'5"

D total apparont vertical offset ≈1'4"

ENCLOSURE 6
TRENCH LOGS
Gary S. Rasmussen & Associates, Inc.
Nitto America Co. - El Rancho Verde Country Club
Rialto, California
Project No. 3156.1

Horizontal and Vertical Scale: 1" = 5'

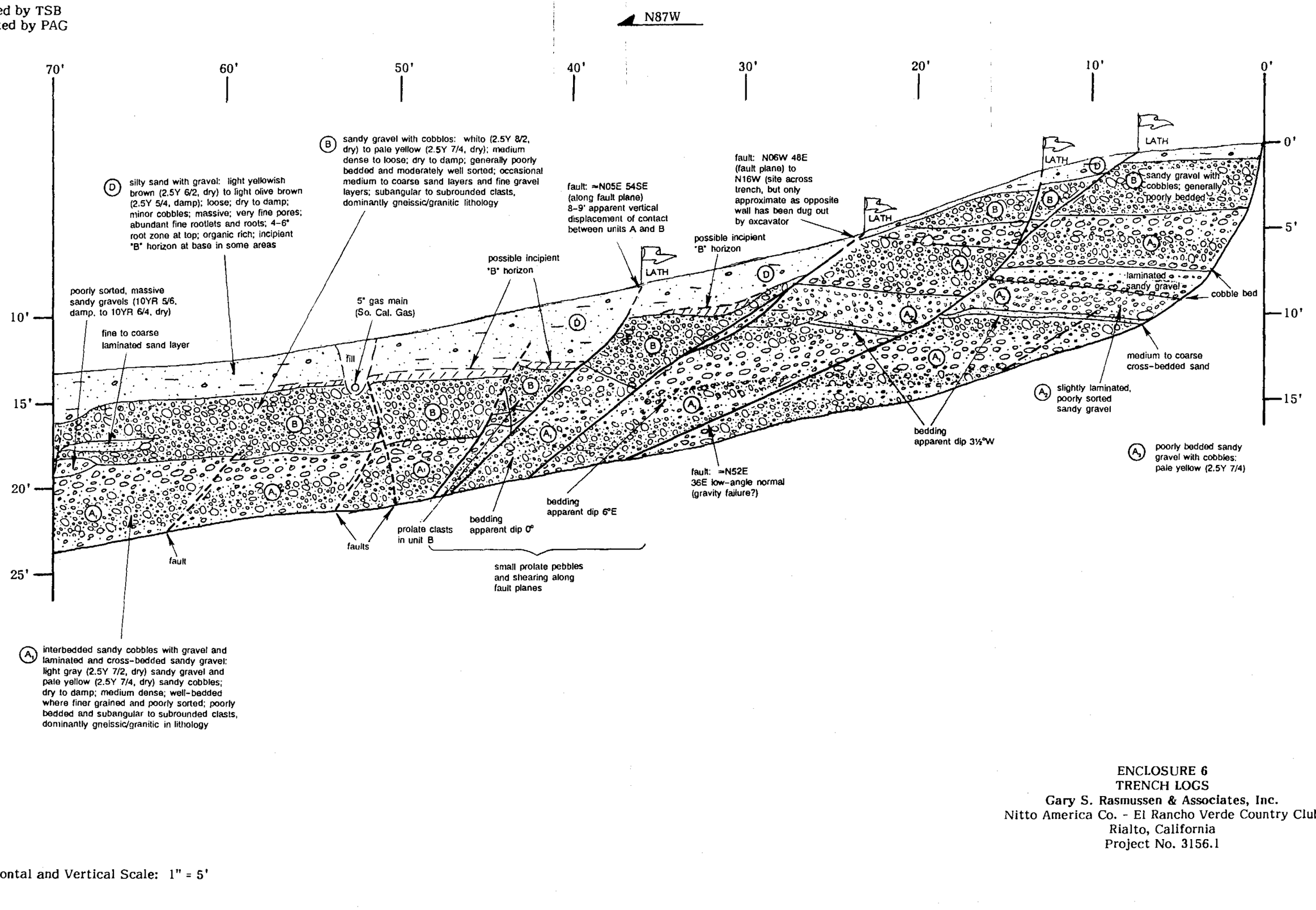
Trench 18
Logged by TSB
Drafted by PAG



Horizontal and Vertical Scale: 1" = 5'

ENCLOSURE 6
TRENCH LOGS
Gary S. Rasmussen & Associates, Inc.
Nitto America Co. - El Rancho Verde Country Club
Rialto, California
Project No. 3156.1

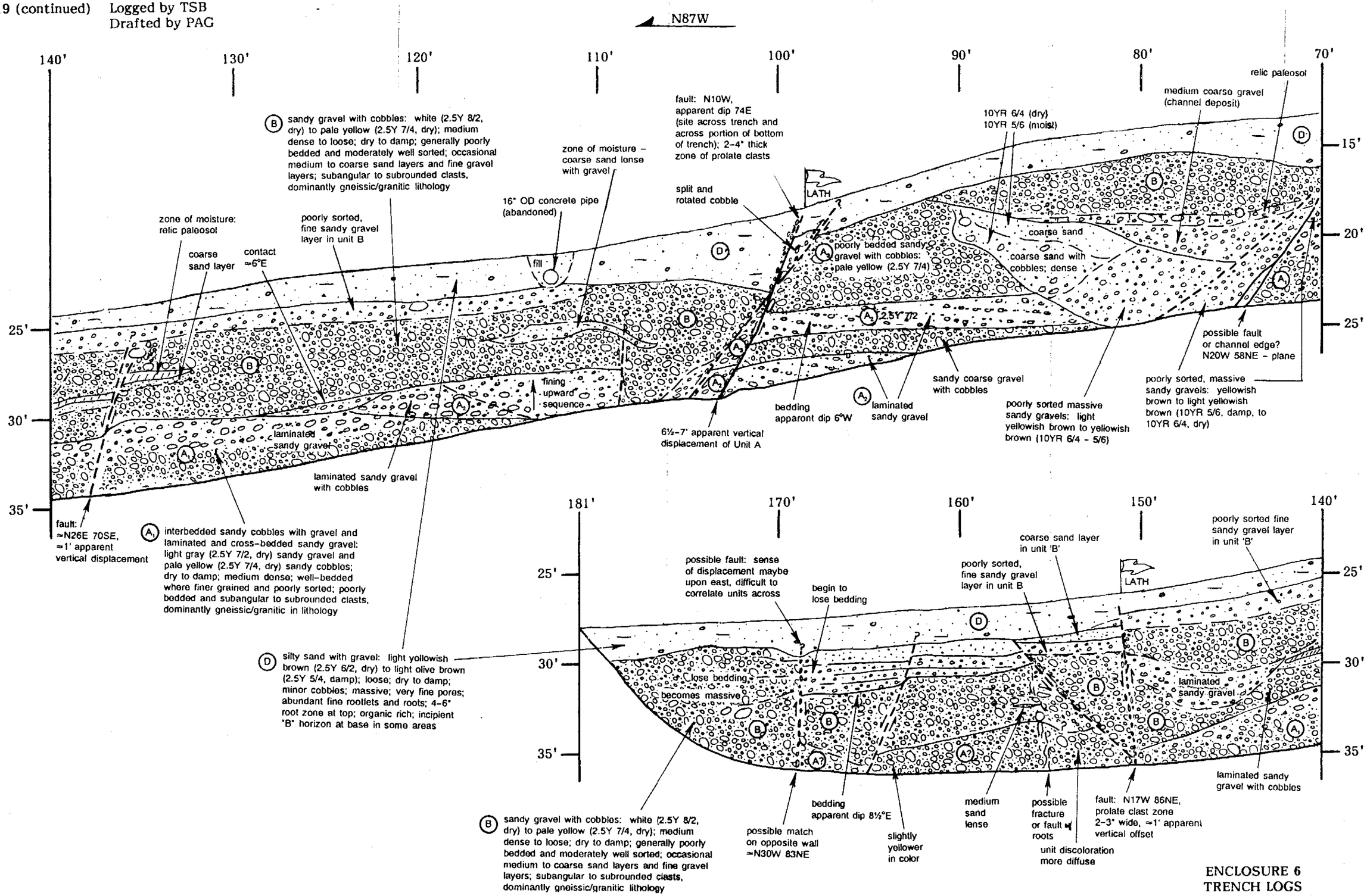
Trench 19
Logged by TSB
Drafted by PAG



Horizontal and Vertical Scale: 1" = 5'

ENCLOSURE 6
TRENCH LOGS
Gary S. Rasmussen & Associates, Inc.
Nitto America Co. - El Rancho Verde Country Club
Rialto, California
Project No. 3156.1

Trench 19 (continued) Logged by TSB
Drafted by PAG

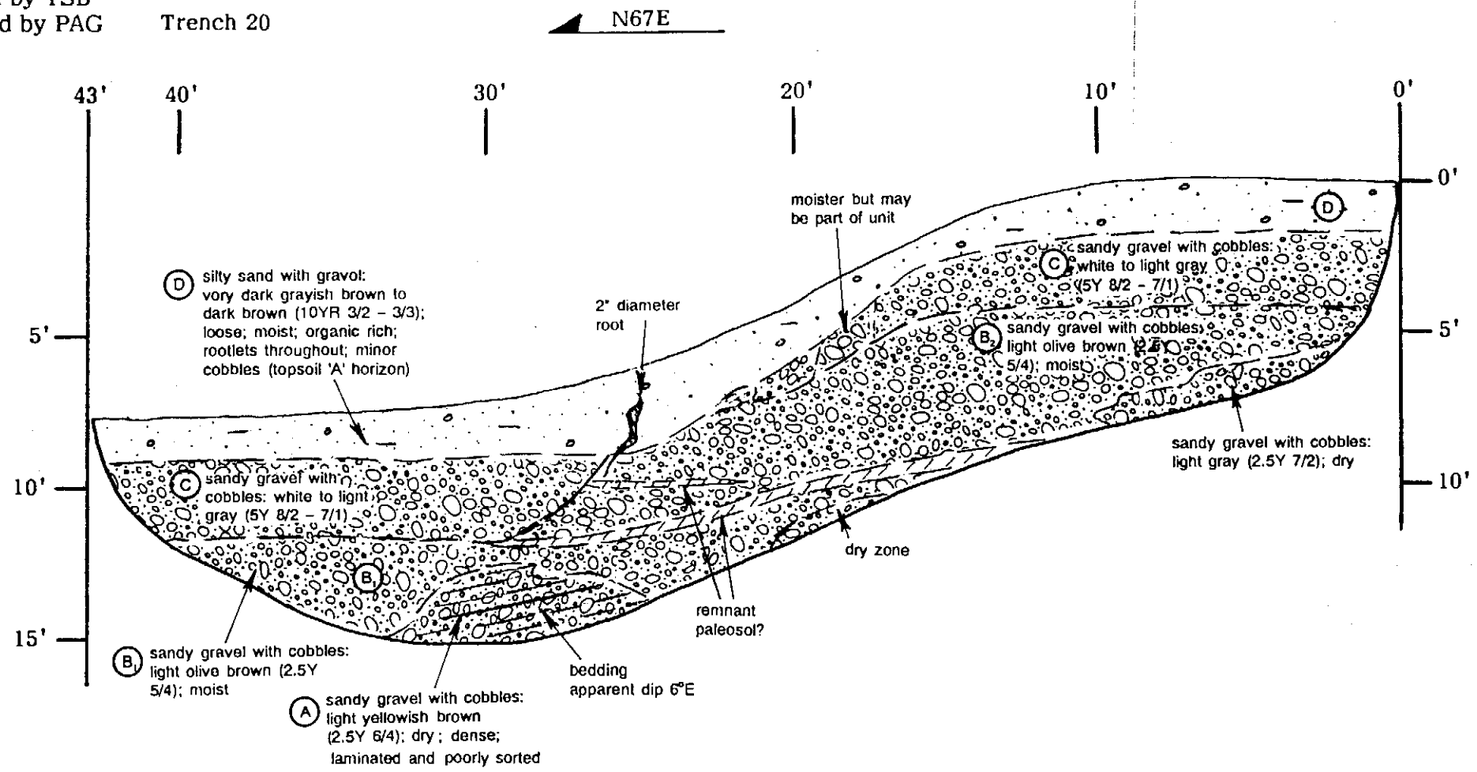


Horizontal and Vertical Scale: 1" = 5'

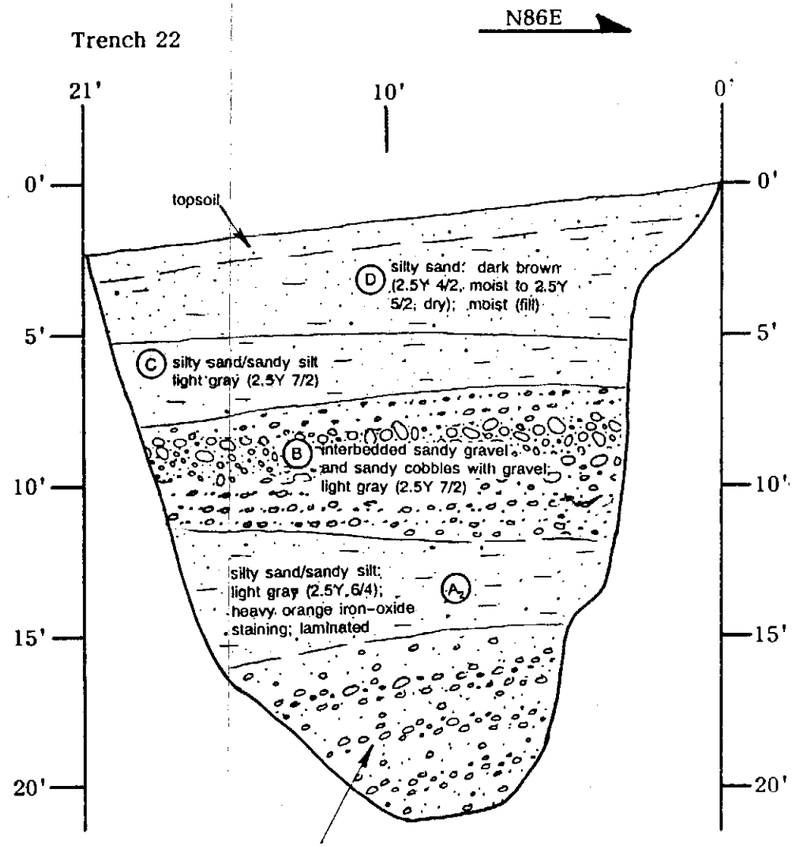
ENCLOSURE 6
TRENCH LOGS
Gary S. Rasmussen & Associates, Inc.
Nitto America Co. - El Rancho Verde Country Club
Rialto, California
Project No. 3156.1

Logged by TSB
Drafted by PAG

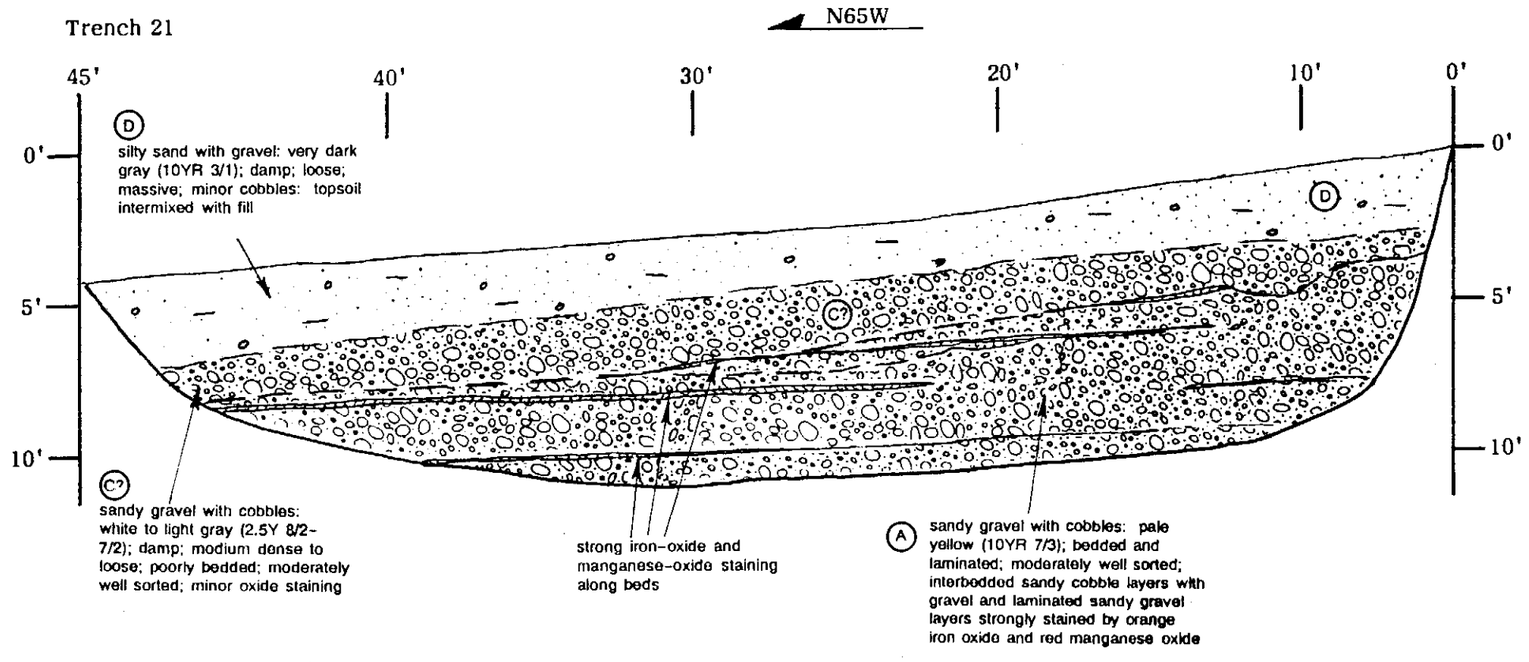
Trench 20



Trench 22



Trench 21



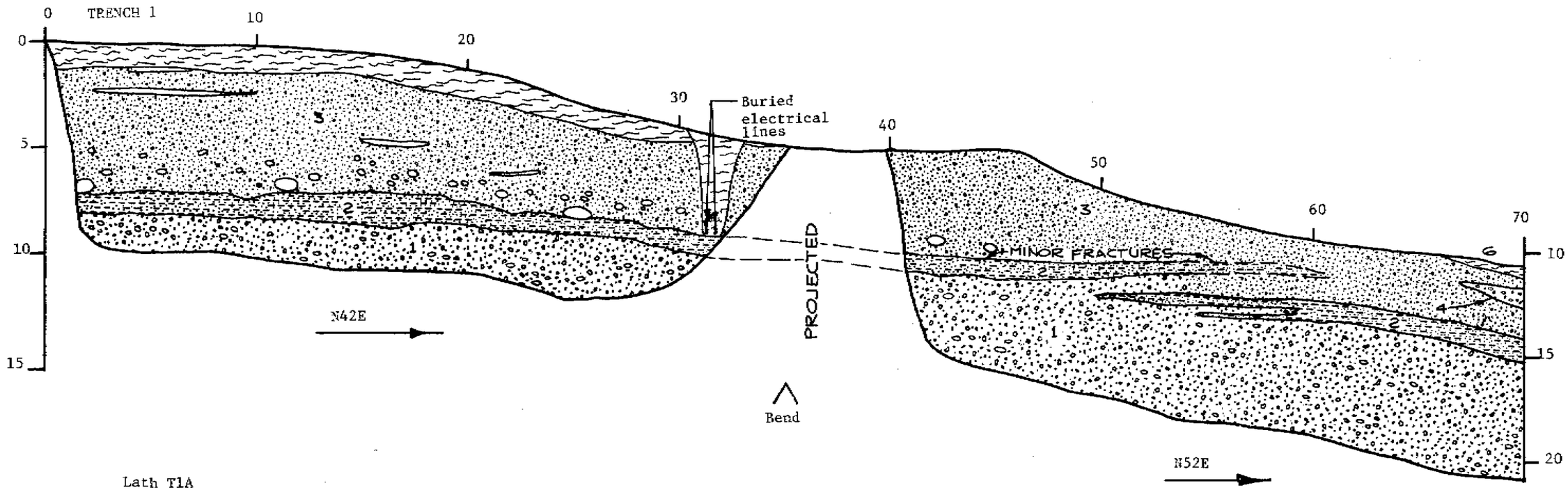
Horizontal and Vertical Scale: 1" = 5'

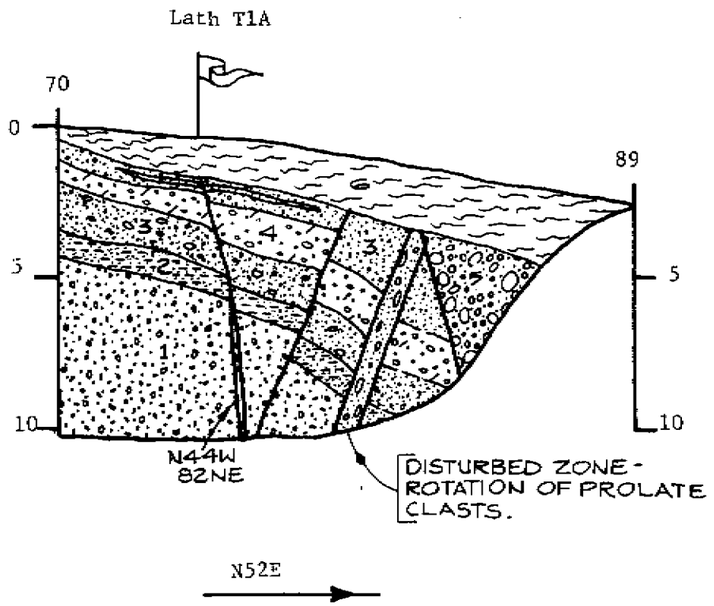
ENCLOSURE 6
TRENCH LOGS
Gary S. Rasmussen & Associates, Inc.
Nitto America Co. - El Rancho Verde Country Club
Rialto, California
Project No. 3156.1

Logged by JJM

Scale: 1"=5'

ENCLOSURE 4
GARY S. RASMUSSEN & ASSOCIATES, INC.
Trench Logs
City of Rialto - Frisbie Park
Rialto, California, Project No. 2057

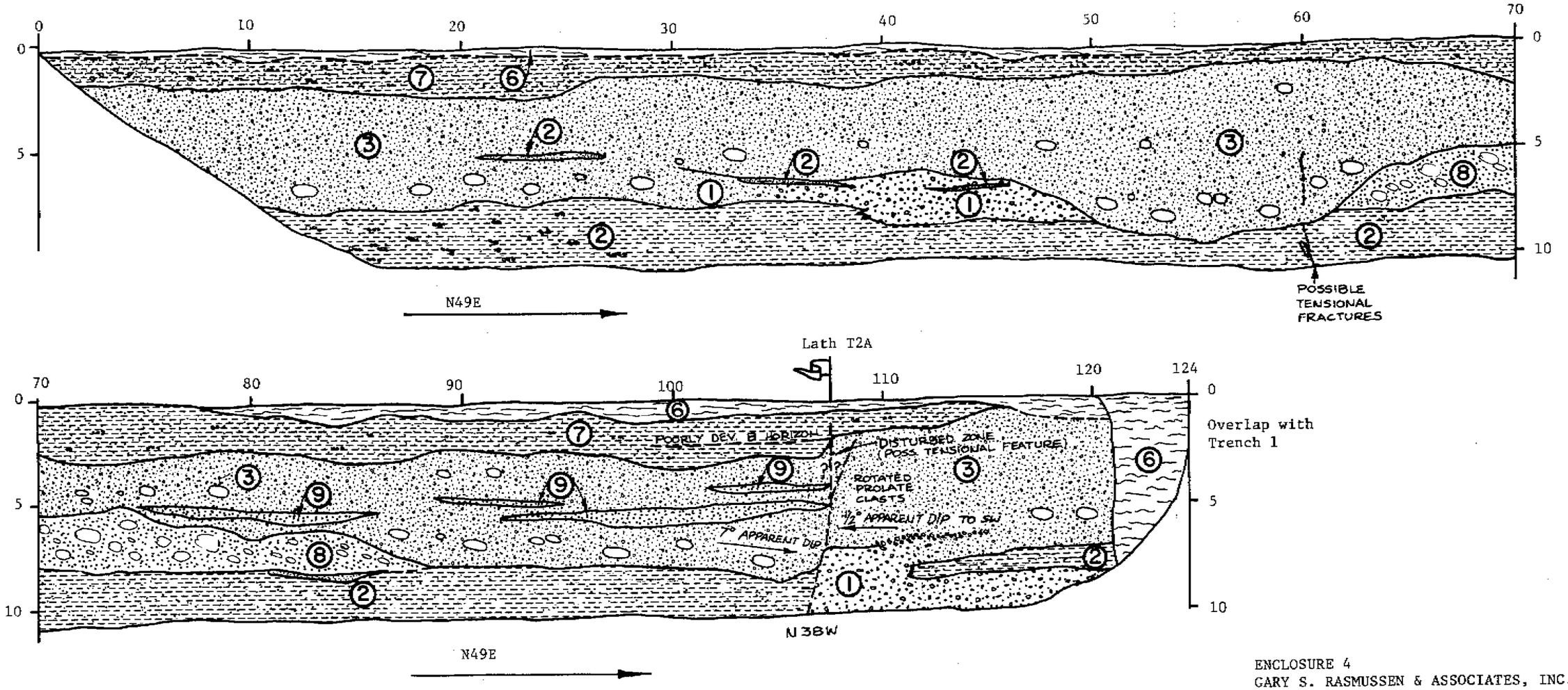




Unit	General Description of Units
1.	Gravels and cobbles, medium to coarse sand matrix, few coarse sand lenses, slightly consolidated.
2.	Silty sands, medium to coarse with few gravel lenses, laminated to thin bedded, abundant cross-beds, slightly consolidated, occasional dark, micaceous, highly weathered cobbles.
3.	Gravels, medium to coarse sand matrix, minor cobbles and boulders, lenses of coarse sands and darker lenses of coarse silty sands with minor amounts of clay. Slightly consolidated.
4.	Coarse sands and pebbles with minor amounts of clay, slightly consolidated.
5.	Gravels, well graded, unconsolidated.
6.	Fill

Logged by JJM

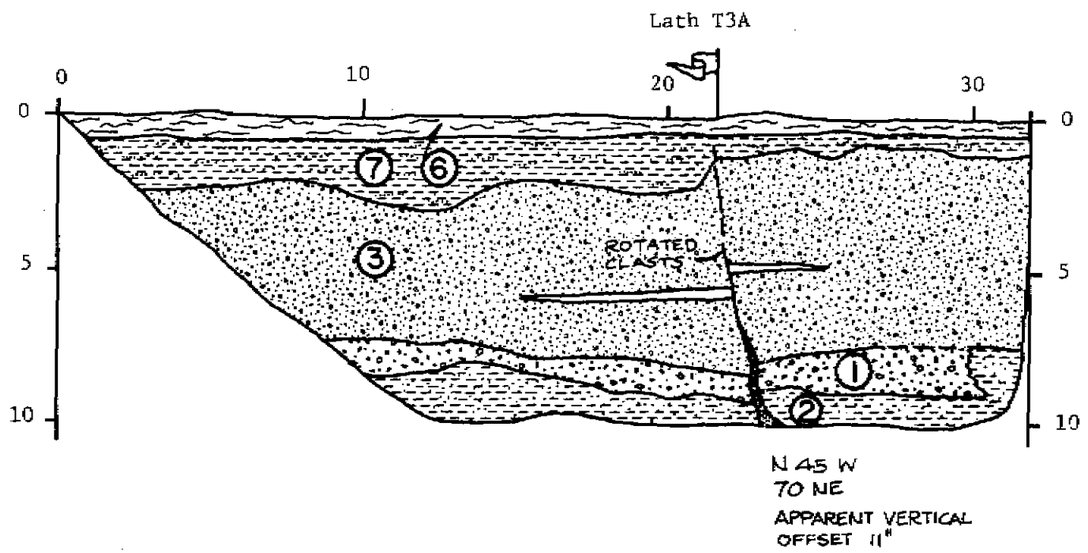
Scale: 1"=5'



ENCLOSURE 4
GARY S. RASMUSSEN & ASSOCIATES, INC.
Trench Logs
City of Rialto - Frisbie Park
Rialto, California - Project No. 2057

Logged by JJM

Scale: 1"=5'

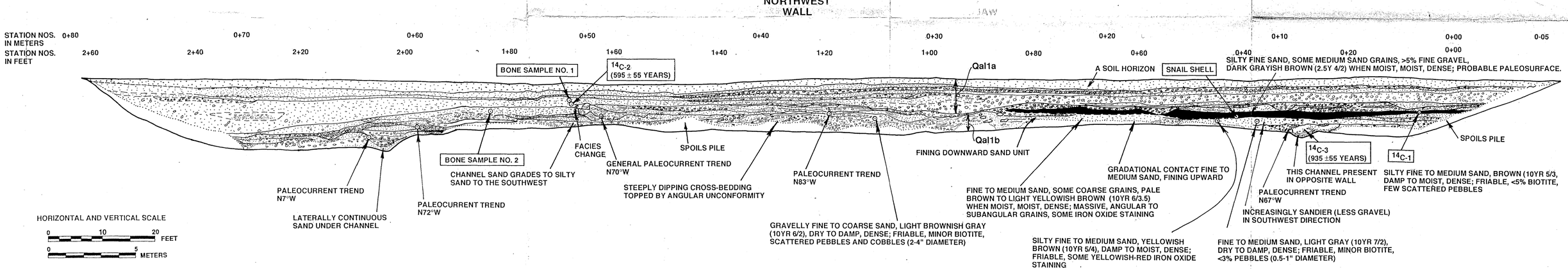


N45E

ENCLOSURE 4
GARY S. RASMUSSEN & ASSOCIATES, INC.
Trench Logs - City of Rialto - Frisbie Par
Rialto, California-Project No. 2057

FT-4

N39°E
NORTHWEST
WALL



HORIZONTAL AND VERTICAL SCALE

0 10 20 FEET

0 5 METERS

NOTE:
AGE OF ORGANIC CARBON SAMPLES ARE REPORTED AS C-13 ADJUSTED, RADIOCARBON YEARS BEFORE 1950 A.D.

GENERALIZED STRATIGRAPHIC DESCRIPTIONS

A SOIL HORIZON:
FINE TO MEDIUM SANDY LOAM , brown (10YR 5/3) when moist, pale brown (10 YR 6/3) when dry, massive breaking to weak fine to medium subangular blocky structure, soft to loose when dry, very friable to loose when wet, non-sticky, non-plastic, no clay films observed, many fine roots and rootlets.

OLDER ALLUVIUM (Qal 1a):
Fining upward sequence of trough cross-bedded and planar bedded sands locally incised by fining upward gravelly sand channels with a pebbly basal lag. Entire section is capped by the modern A soil horizon described above.

OLDER ALLUVIUM (Qal 1b):
Fining upward sequences of channel lag cobbles, trough cross-bedded gravelly sand channel infilling and minor silty sand sections infilling abandoned channels. Unit is locally capped by a massive silty sand deposit that probably represents a weekly developed buried A soil horizon, indicating a brief period of non-deposition and soil development (a paleosurface) between deposition of the two older alluvial deposits exposed. Laterally continuous units are described above.

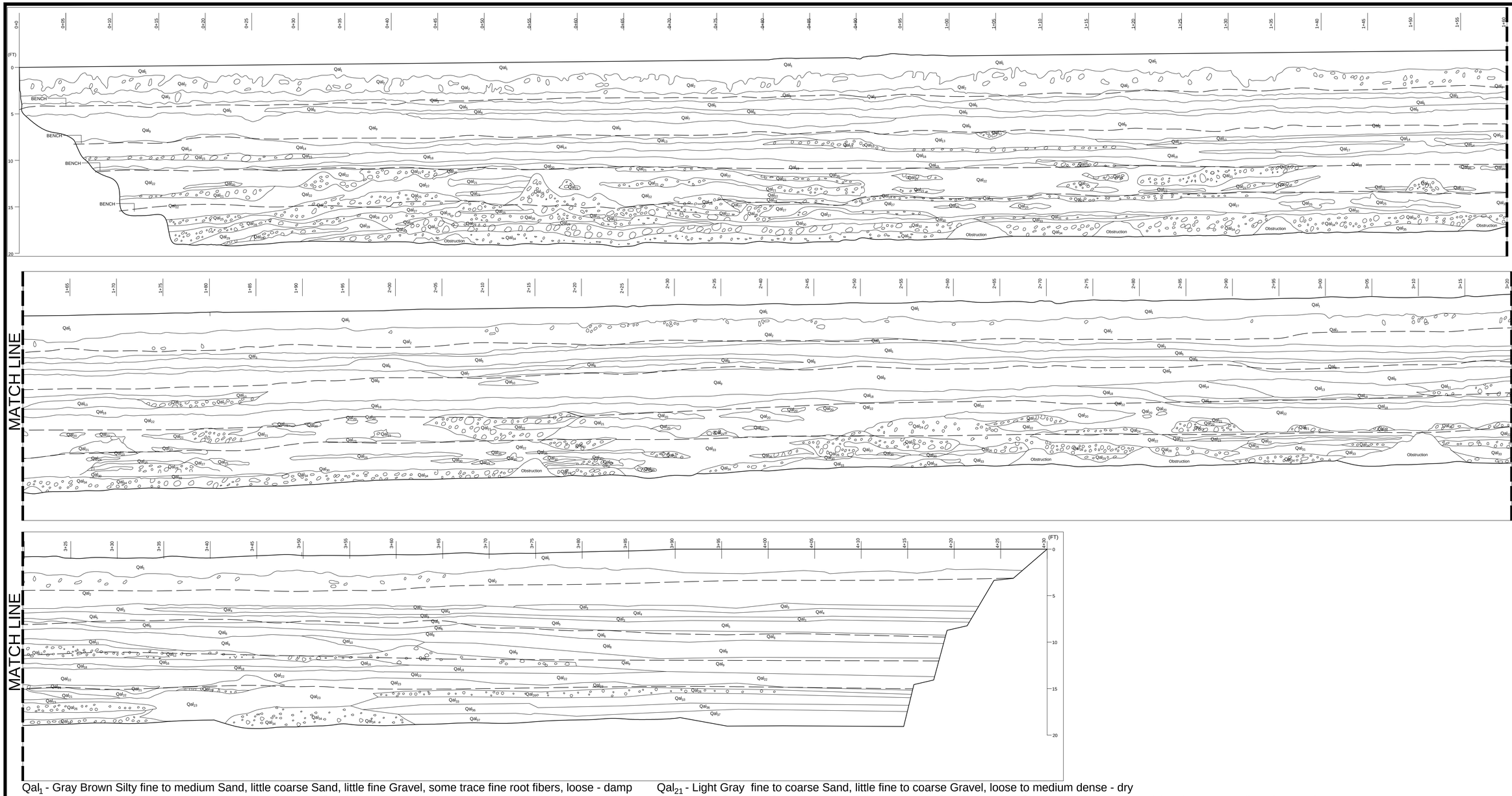
Logged By: REL/MCH/TKG
Date: 5/4/94-5/5/94

PLATE 3

GEOLOGIC LOG OF TRENCH FT-4,
STATE ROUTE 30, SEGMENT 10,
RIALTO AND SAN BERNARDINO,
CALIFORNIA

Proj.: 6930403-03	Scale: As Shown	Date: 5/22/95	
Engineer/Geologist: GEM/EMG	Drafting By: lah		

LEIGHTON AND ASSOCIATES, INC.



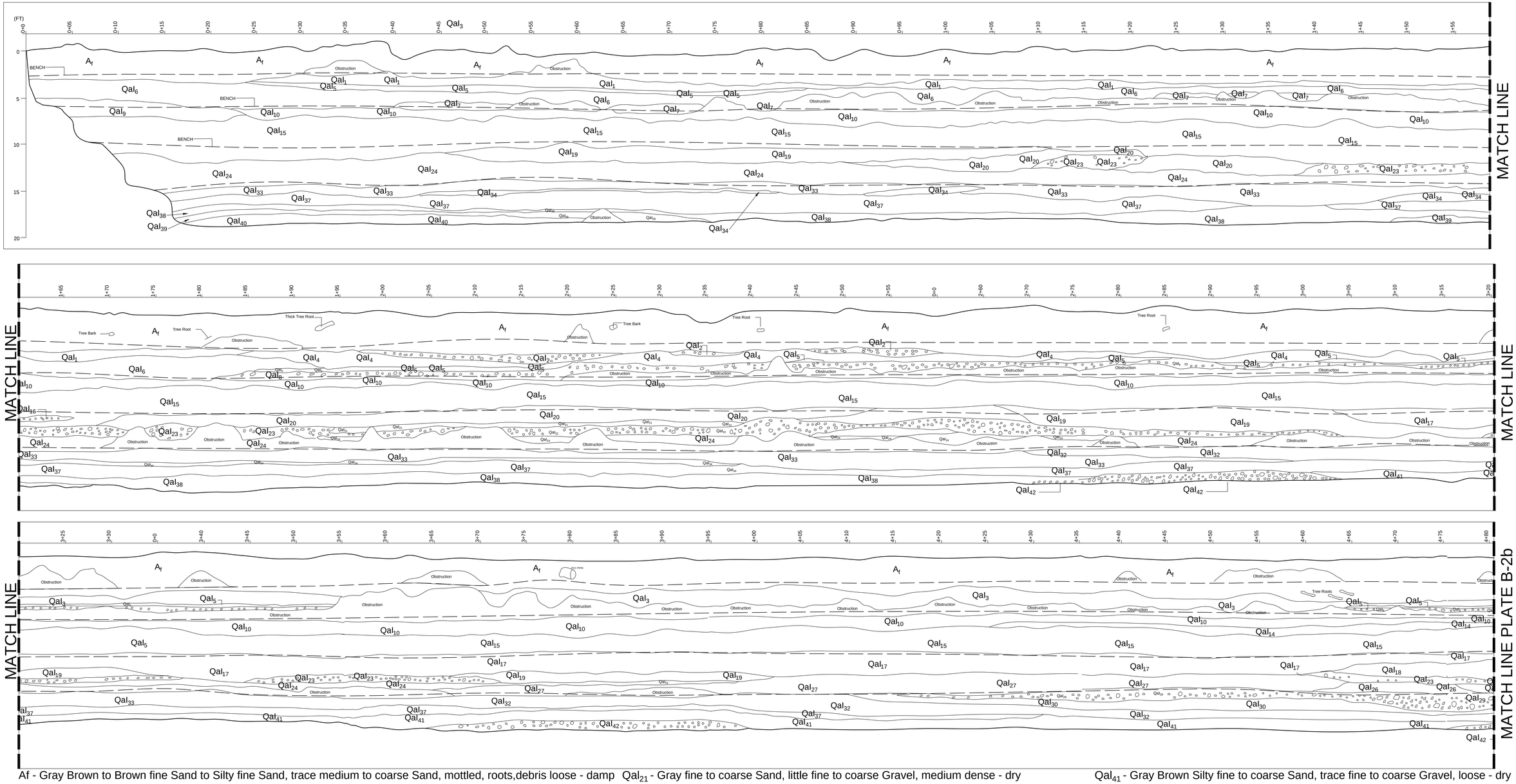
Qal_1 - Gray Brown Silty fine to medium Sand, little coarse Sand, little fine Gravel, some trace fine root fibers, loose - damp
Qal_2 - Light Gray fine Sand, trace to little medium to coarse Sand, little Iron oxide staining, loose - dry to damp
Qal_3 - Light Gray Silty fine Sand, trace fine root fibers, porous, loose to damp
Qal_4 - Light Gray fine Sandy Silt, porous, loose - damp
Qal_5 - Light Gray Brown fine Sand, trace medium to coarse Sand, trace fine Gravel, loose - dry
Qal_6 - Brown Silty fine Sand, pourous, loose - damp
Qal_7 - Gray Brown fine to coarse Sand, trace to little Iron oxide staining, loose - dry
Qal_8 - Gray to Gray Brown fine Sandy Silt, trace to little calcarous veins, porous, loose - damp
Qal_9 - Light Gray Brown Silty fine to coarse Sand, trace fine to coarse Gravel, occasional Cobbles, loose - dry to damp
Qal_{10} - Brown Silty fine Sand, loose - damp
Qal_{11} - Gray fine Sandy Silt, little calcarous veins, porous, loose - dry to damp
Qal_{12} - Gray fine to coarse Sand, some fine to coarse Gravel, occasional Cobbles, loose - dry
Qal_{13} - Gray Brown fine to coarse Sand, trace fine Gravel, loose - dry
Qal_{14} - Gray Brown fine Sand, little Iron oxide staining, loose - dry
Qal_{15} - Light Gray Gravelly fine to coarse Sand, occasional Cobbles, loose to medium dense - dry to damp
Qal_{16} - Light Gray fine Sandy Silt, porous, medium dense - dry
Qal_{17} - Gray fine to coarse Sand, little fine to coarse Gravel, loose - dry
Qal_{18} - Brown to Gray Brown Silty fine Sand, loose to medium dense - damp
Qal_{19} - Brown Silty fine to coarse Sand, trace fine to coarse Gravel, loose - damp
Qal_{20} - Brown Silty fine Sand, loose - damp
Qal_{21} - Light Gray fine to coarse Sand, little fine to coarse Gravel, loose to medium dense - dry
Qal_{22} - Light Gray fine Sand, trace to medium to coarse Sand, trace fine Gravel, little Iron oxide staining, loose to medium dense - damp
Qal_{23} - Brown Silty fine Sand, loose - damp
Qal_{24} - Light Gray Brown fine to coarse Sand, little fine to coarse gravel, medium dense - damp
Qal_{25} - Brown Silty fine Sand, medium dense - damp
Qal_{26} - Gray Gravely fine to coarse Sand, occasional to extensive Cobbles, medium dense - damp
Qal_{27} - Gray fine to medium Sand, trace coarse Sand, trace fine Gravel, medium dense - dry
Qal_{28} - Gray Gravelly fine to coarse Sand, occasional Cobbles, medium dense - dry
Qal_{29} - Light Gray fine to coarse Sand, trace fine to coarse Gravel, medium dense - dry
Qal_{30} - Brown Silty fine Sand, medium dense - damp
Qal_{31} - Gray fine to coarse Sand, medium dense - dry
Qal_{32} - Light Gray Gravelly fine to coarse Sand, extensive Cobbles, medium dense - dry
Qal_{33} - Gray fine Sand, medium dense - dry
Qal_{34} - Gray Gravelly fine to coarse Sand, extensive Cobbles, medium dense - dry
Qal_{35} - Gray fine Sand, trace medium to coarse Sand, trace fine Gravel, medium dense - dry
Qal_{36} - Light Gray fine Sand, trace medium Sand, little Silt, little Iron oxide Staining, loose - damp
Qal_{37} - Light Gray fine Sand, trace Silt, little Iron oxide staining, loose - dry

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SCALE: 1" = 5'
DRAWN: DRK
CHKD: RGT
SCG PROJECT
20G234-2

TRENCH T-1
PROPOSED COMMERCIAL/INDUSTRIAL BUILDING
RIALTO, CALIFORNIA

PLATE
B-1



Af - Gray Brown to Brown fine Sand to Silty fine Sand, trace medium to coarse Sand, mottled, roots,debris loose - damp

Qal_1 - Brown Silty fine Sand, trace medium to coarse Sand, loose - dry to damp

Qal_2 - Light Gray Gravelly fine to coarse Sand, occasional to extensive Cobbles, loose - dry

Qal_3 - Gray Silty fine to coarse Sand, trace to little fine to coarse Gravel, loose - dry

Qal_4 - Light Gray fine Sand, trace medium to coarse Sand, trace fine to coarse Gravel, loose - dry

Qal_5 - Dark Gray Brown Silty fine Sand, loose - dry to damp

Qal_6 - Gray Brown fine Sand, trace to little medium to coarse Sand, little Iron oxide staining, loose - dry

Qal_7 - Light Gray fine to coarse Sand, loose - dry

Qal_8 - Light Gray fine to medium Sand, little coarse Sand, trace fine to coarse Gravel, occasional Cobbles, loose - dry

Qal_9 - Gray fine to coarse Sand, little fine to coarse Gravel, occasional Cobbles, loose - dry

Qal_{10} - Gray Brown fine to medium Sand, trace coarse Sand, little Silt, loose - dry to damp

Qal_{11} - Light Gray fine Sand, little medium to coarse Sand, trace fine to coarse Gravel, loose - dry

Qal_{12} - Gray fine Sandy Silt, trace calcareous veining, loose to medium dense - damp

Qal_{13} - Gray Brown Silty fine Sand, loose to medium dense - damp

Qal_{14} - Light Gray fine Sand, little Iron oxide staining, loose - dry

Qal_{15} - Gray Brown Silty fine Sand, little Iron oxide staining, trace Calcareous nodules, loose - dry

Qal_{16} - Light Gray Gravelly fine to coarse Sand, loose - dry

Qal_{17} - Light Gray Brown fine Sand, trace medium to coarse Sand, little Iron oxide staining, loose - dry

Qal_{18} - Light Gray Brown Silty fine Sand, trace medium to coarse Sand, trace fine Gravel, medium dense - damp

Qal_{19} - Light Gray Brown fine to medium Sand, trace coarse Sand, little Iron oxide staining, loose - damp

Qal_{20} - Light Gray fine Sand, extensive Iron oxide staining, loose - dry to damp

Qal_{21} - Gray fine to coarse Sand, little fine to coarse Gravel, medium dense - dry

Qal_{22} - Gray fine Sand, little Iron oxide staining, medium dense - dry

Qal_{23} - Brown Silty fine Sand, loose to medium dense - damp

Qal_{24} - Gray fine to coarse Sand, little fine to coarse Gravel, medium dense - damp

Qal_{25} - Light Gray fine Sand, laminated, Iron oxide staining, loose - dry

Qal_{26} - Gray Brown Silty fine to coarse Sand, little fine to coarse Gravel, occasional Cobbles, loose - dry to damp

Qal_{27} - Light Gray fine Sand, little Iron oxide staining, loose - dry to damp

Qal_{28} - Gray Gravelly fine to coarse Sand, extensive Cobbles, loose - dry

Qal_{29} - Light Gray Brown Gravelly fine to coarse Sand, extensive Cobbles, loose - dry

Qal_{30} - Light Gray Brown fine Sandy Silt, slightly porous, trace organics, medium dense - dry

Qal_{31} - Light Gray fine to medium Sand, little coarse Sand, little fine to coarse Gravel, loose - dry

Qal_{32} - Gray Brown Silty fine to coarse Sand, little Iron oxide staining, loose - dry

Qal_{33} - Light Brown fine Sand, trace to little medium to coarse Sand, little Silt, little Iron oxide Staining, loose - damp

Qal_{34} - Light Gray Brown Silty fine Sand, little Iron oxide Staining. loose - damp

Qal_{35} - Light Gray fine to medium Sand, trace coarse Sand, loose - dry

Qal_{36} - Light Gray Gravelly fine to coarse Sand, extensive Cobbles, loose - dry

Qal_{37} - Light Gray fine to coarse Sand, little Iron oxide staining, loose - dry

Qal_{38} - Light Gray Brown Silty fine Sand, little Iron oxide staining, loose - damp

Qal_{39} - Light Gray fine to medium Sand, trace coarse Sand, little Iron oxide staining, loose - damp

Qal_{40} - Light Gray Brown Silty fine Sand, little Iron oxide staining, loose - damp to moist

Qal_{41} - Gray Brown Silty fine to coarse Sand, trace fine to coarse Gravel, loose - dry

Qal_{42} - Gray Brown Gravelly fine to coarse Sand, extensive Cobbles, loose - dry

Qal_{43} - Light Gray fine to coarse Sand, trace fine Gravel, loose - dry

Qal_{44} - Light Gray Brown fine Sand, trace medium Sand, little Silt, little Iron oxide staining, loose- damp

Qal_{45} - Light Gray Brown Silty fine Sand, trace medium Sand, little Iron oxide staining medium dense - dry

Qal_{46} - Light Gray Gravelly fine to coarse Sand, occasional Cobbles, trace Iron oxide staining, loose - dry

Qal_{47} - Light Gray fine Sand, little Iron oxide staining, loose - dry

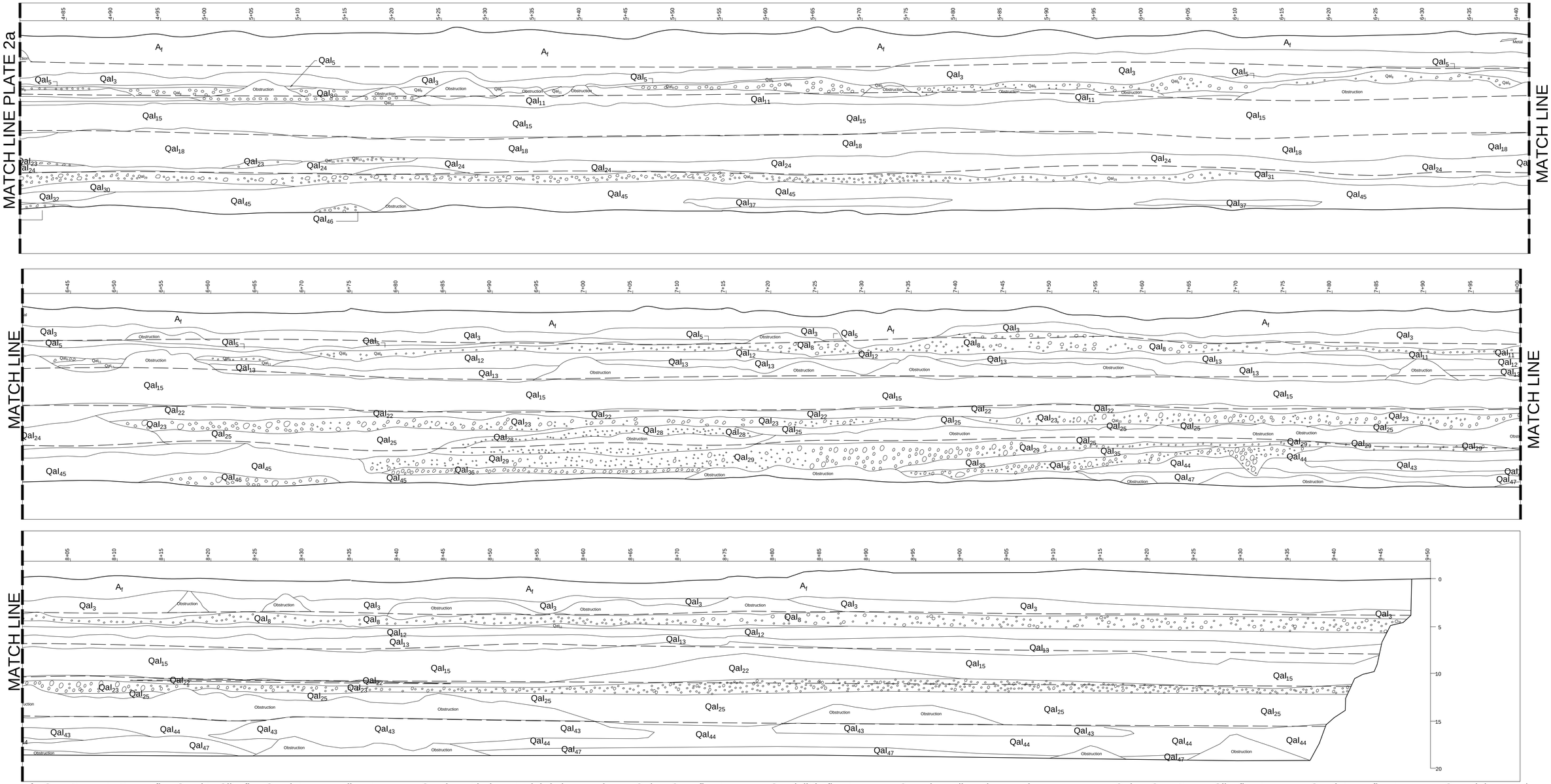
Qal_{48} - Light Gray Brown fine Sand, trace Silt, little Iron oxide staining, loose - damp

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CHKD: RGT
SCG PROJECT 20G234-2

TRENCH T-2
PROPOSED COMMERCAIL/INDUSTRIAL BUILDING
RIALTO, CALIFORNIA

PLATE B-2a



Af - Gray Brown to Brown fine Sand to Silty fine Sand, trace medium to coarse Sand, mottled, roots,debris loose - damp

Qal_1 - Brown Silty fine Sand, trace medium to coarse Sand, loose - dry to damp

Qal_2 - Light Gray Gravelly fine to coarse Sand, occasional to extensive Cobbles, loose - dry

Qal_3 - Gray Silty fine to coarse Sand, trace to little fine to coarse Gravel, loose - dry

Qal_4 - Light Gray fine Sand, trace medium to coarse Sand, trace fine to coarse Gravel, loose - dry

Qal_5 - Dark Gray Brown Silty fine Sand, loose - dry to damp

Qal_6 - Gray Brown fine Sand, trace to little medium to coarse Sand, little Iron oxide staining, loose - dry

Qal_7 - Light Gray fine to coarse Sand, loose - dry

Qal_8 - Light Gray fine to medium Sand, little coarse Sand, trace fine to coarse Gravel, occasional Cobbles, loose - dry

Qal_9 - Gray fine to coarse Sand, little fine to coarse Gravel, occasional Cobbles, loose - dry

Qal_{10} - Gray Brown fine to medium Sand, trace coarse Sand, little Silt, loose - dry to damp

Qal_{11} - Light Gray fine Sand, little medium to coarse Sand, trace fine to coarse Gravel, loose - dry

Qal_{12} - Gray fine Sandy Silt, trace calcareous veining, loose to medium dense - damp

Qal_{13} - Gray Brown Silty fine Sand, loose to medium dense - damp

Qal_{14} - Light Gray fine Sand, little Iron oxide staining, loose - dry

Qal_{15} - Gray Brown Silty fine Sand, little Iron oxide staining, trace Calcareous nodules, loose - dry

Qal_{16} - Light Gray Gravelly fine to coarse Sand, loose - dry

Qal_{17} - Light Gray Brown fine Sand, trace medium to coarse Sand, little Iron oxide staining, loose - dry

Qal_{18} - Light Gray Brown Silty fine Sand, trace medium to coarse Sand, trace fine Gravel, medium dense - damp

Qal_{19} - Light Gray Brown fine to medium Sand, trace coarse Sand, little Iron oxide staining, loose - damp

Qal_{20} - Light Gray fine Sand, extensive Iron oxide staining, loose - dry to damp

Qal_{21} - Gray fine to coarse Sand, little fine to coarse Gravel, medium dense - dry

Qal_{22} - Gray fine Sand, little Iron oxide staining, medium dense - dry

Qal_{23} - Brown Silty fine Sand, loose to medium dense - damp

Qal_{24} - Gray fine to coarse Sand, little fine to coarse Gravel, medium dense - damp

Qal_{25} - Light Gray fine Sand, laminated, Iron oxide staining, loose - dry

Qal_{26} - Gray Brown Silty fine to coarse Sand, little fine to coarse Gravel, occasional Cobbles, loose - dry to damp

Qal_{27} - Light Gray fine Sand, little Iron oxide staining, loose - dry to damp

Qal_{28} - Gray Gravelly fine to coarse Sand, extensive Cobbles, loose - dry

Qal_{29} - Light Gray Brown Gravelly fine to coarse Sand, extensive Cobbles, loose - dry

Qal_{30} - Light Gray Brown fine Sandy Silt, slightly porous, trace organics, medium dense - dry

Qal_{31} - Light Gray fine to medium Sand, little coarse Sand, little fine to coarse Gravel, loose - dry

Qal_{32} - Gray Brown Silty fine to coarse Sand, little Iron oxide staining, loose - dry

Qal_{33} - Light Brown fine Sand, trace to little medium to coarse Sand, little Silt, little Iron oxide Staining, loose - damp

Qal_{34} - Light Gray Brown Silty fine Sand, little Iron oxide Staining. loose - damp

Qal_{35} - Light Gray fine to medium Sand, trace coarse Sand, loose - dry

Qal_{36} - Light Gray Gravelly fine to coarse Sand, extensive Cobbles, loose - dry

Qal_{37} - Light Gray fine to coarse Sand, little Iron oxide staining, loose - dry

Qal_{38} - Light Gray Brown Silty fine Sand, little Iron oxide staining, loose - damp

Qal_{39} - Light Gray fine to medium Sand, trace coarse Sand, little Iron oxide staining, loose - damp

Qal_{40} - Light Gray Brown Silty fine Sand, little Iron oxide staining, loose - damp to moist

Qal_{41} - Gray Brown Silty fine to coarse Sand, trace fine to coarse Gravel, loose - dry

Qal_{42} - Gray Brown Gravelly fine to coarse Sand, extensive Cobbles, loose - dry

Qal_{43} - Light Gray fine to coarse Sand, trace fine Gravel, loose - dry

Qal_{44} - Light Gray Brown fine Sand, trace medium Sand, little Silt, little Iron oxide staining, loose- damp

Qal_{45} - Light Gray Brown Silty fine Sand, trace medium Sand, little Iron oxide staining medium dense - dry

Qal_{46} - Light Gray Gravelly fine to coarse Sand, occasional Cobbles, trace Iron oxide staining, loose - dry

Qal_{47} - Light Gray fine Sand, little Iron oxide staining, loose - dry

Qal_{48} - Light Gray Brown fine Sand, trace Silt, little Iron oxide staining, loose - damp

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TRENCH T-2
PROPOSED COMMERCIAL/INDUSTRIAL BUILDING
RIALTO, CALIFORNIA

PLATE
B-2b

Appendix C

S-1 - Seismic Refraction Survey
(by Terra Geosciences, 2021)

TERRA GEOSCIENCES

December 18, 2020

Tetra Tech BAS, Inc.
21700 Copley Drive, #200
Diamond Bar, California 91765

Attention: Mr. Jeffrey Williams, Controller

Regarding: Proposal for Seismic Refraction Survey
Vulcan Materials Project
20350 East Highland Avenue
Rialto, San Bernardino County, California

INTRODUCTION

As requested, we have prepared this proposal for the above-referenced site. We understand that subsurface seismic data is being requested for the Vulcan Materials project, in Rialto, California. The purpose of the seismic refraction survey will be to assess the general seismic velocity characteristics of the underlying earth materials that will aid in evaluating the subsurface geologic structure and associated seismic velocity distribution.

The seismic refraction method is used to estimate the layering, structure, and seismic acoustic velocities of subsurface horizons. Seismic waves travel down and through the soils and rocks, and when the wave encounters a contact between two earth materials having different velocities, some of the wave's energy travels along the contact at the velocity of the lower layer. The fundamental assumption is that each successively deeper layer has a velocity greater than the layer immediately above it. This assumption is satisfied in most field applications. As the wave travels along the contact, some of the wave's energy is refracted toward the surface where it is detected by a series of motion-sensitive transducers (geophones). The arrival time of the seismic wave at the geophone locations can be related to the underlying stratigraphic/lithologic conditions, in addition to any geologic structures that may be related to subsurface faulting.

SCOPE OF WORK

Based on the above information, the scope of our work will include:

- ***Review of available published and unpublished geologic/geophysical data in our files pertinent to the site.***

- ***Perform a total of five 24-channel seismic refraction survey lines (with 11-foot geophone spacings), that will be overlapped to create one 1,067 long continuous subsurface profile, which will in turn provide subsurface imaging to a depth of at least 80± feet.***

- ***Processing of the acquired field data including preparation of the supportive seismic image profile and a map showing the location of our seismic survey traverse.***

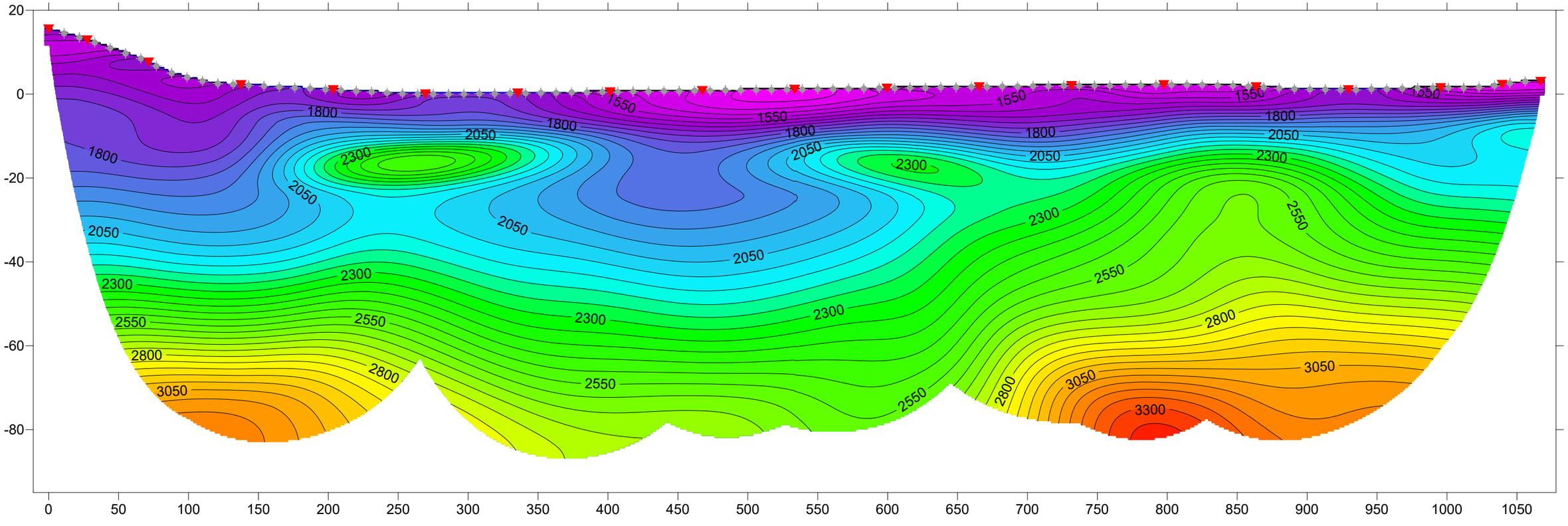
- ***Preparation of a final report presenting our findings with respect to the subsurface structure and seismic velocity distribution of the underlying earth materials locally.***

Provided on Figure 1 below, is a Google Earth image, showing the location of the proposed seismic traverse, as discussed with you. At this time, we are proposing five overlapped survey lines to provide one long continuous high-resolution subsurface profile, that should image down to depths of at least 80± feet.



FIGURE 1- CUP Map showing the proposed 1,067-foot long seismic survey line (red).

SEISMIC LINE S-1 RMS error 2.3%=1.47ms 125 WET itr. 50Hz Width 25.0% initial GRADIENT.GRD v. 4.01



Appendix D1

Carbon Dating Results by Beta Analytic (2021)

Beta Analytic, Inc.
4985 SW 74th Court
Miami, FL 33155 USA
Tel: 305-667-5167
Fax: 305-663-0964
info@betalabservices.com

ISO/IEC 17025:2017-Accredited Testing Laboratory

February 16, 2021

Mr. Shawn Morrish
Tetra Tech
21700 Copley Drive
Diamond Bar, CA 91765
United States

RE: Radiocarbon Dating Results

Dear Mr. Morrish,

Enclosed is the radiocarbon dating result for one sample recently sent to us. As usual, specifics of the analysis are listed on the report with the result and calibration data is provided where applicable. The Conventional Radiocarbon Age has been corrected for total fractionation effects and where applicable, calibration was performed using 2013 calibration databases (cited on the graph pages).

The web directory containing the table of results and PDF download also contains pictures, a cvs spreadsheet download option and a quality assurance report containing expected vs. measured values for 3-5 working standards analyzed simultaneously with your samples.

The reported result is accredited to ISO/IEC 17025:2017 Testing Accreditation PJLA #59423 standards and all pretreatments and chemistry were performed here in our laboratories and counted in our own accelerators here in Miami. Since Beta is not a teaching laboratory, only graduates trained to strict protocols of the ISO/IEC 17025:2017 Testing Accreditation PJLA #59423 program participated in the analysis.

As always Conventional Radiocarbon Ages and sigmas are rounded to the nearest 10 years per the conventions of the 1977 International Radiocarbon Conference. When counting statistics produce sigmas lower than +/- 30 years, a conservative +/- 30 BP is cited for the result unless otherwise requested. The reported d13C was measured separately in an IRMS (isotope ratio mass spectrometer). It is NOT the AMS d13C which would include fractionation effects from natural, chemistry and AMS induced sources.

When interpreting the result, please consider any communications you may have had with us regarding the sample. As always, your inquiries are most welcome. If you have any questions or would like further details of the analysis, please do not hesitate to contact us.

Thank you for prepaying the analysis. As always, if you have any questions or would like to discuss the results, don't hesitate to contact us.

Sincerely,



Chris Patrick
Vice President of Laboratory Operations

Beta Analytic, Inc.
4985 SW 74th Court
Miami, FL 33155 USA
Tel: 305-667-5167
Fax: 305-663-0964
info@betalabservices.com

ISO/IEC 17025:2017-Accredited Testing Laboratory

REPORT OF RADIOCARBON DATING ANALYSES

Shawn Morrish — Report Date: February 16, 2021

Tetra Tech — Material Received: February 03, 2021

Laboratory Number	Sample Code Number	Conventional Radiocarbon Age (BP) or Percent Modern Carbon (pMC) & Stable Isotopes	
Beta - 583698	**C-1**	**108.70 +/- 0.41 pMC**	IRMS δ13C: -27.2 o/oo

(87.9%) 1999 - 2002 cal AD (-50 - -53 cal BP)
(7.5%) 1956 - 1957 cal AD (-7 - -8 cal BP)

Submitter Material: Woody Material
Pretreatment: (wood) acid/alkali/acid
Analyzed Material: Wood
Analysis Service: AMS-Standard delivery
Conventional Radiocarbon Age: -670 +/- 30 BP
Fraction Modern Carbon: 1.0870 +/- 0.0041
D14C: 86.98 +/- 4.06 o/oo
Δ14C: 77.69 +/- 4.06 o/oo (1950:2021)
Raw pMC: (without d13C correction): 108.20 +/- 0.41 pMC
Calibration: BetaCal4.20: HPD method: INTCAL13 + NHZ2

Results are ISO/IEC-17025:2017 accredited. No sub-contracting or student labor was used in the analyses. All work was done at Beta in 4 in-house NEC accelerator mass spectrometers and 4 Thermo IRMSs. The "Conventional Radiocarbon Age" was calculated using the Libby half-life (5568 years), is corrected for total isotopic fraction and was used for calendar calibration where applicable. The Age is rounded to the nearest 10 years and is reported as radiocarbon years before present (BP), "present" = AD 1950. Results greater than the modern reference are reported as percent modern carbon (pMC). The modern reference standard was 95% the 14C signature of NIST SRM-4990C (oxalic acid). Quoted errors are 1 sigma counting statistics. Calculated sigmas less than 30 BP on the Conventional Radiocarbon Age are conservatively rounded up to 30. d13C values are on the material itself (not the AMS d13C). d13C and d15N values are relative to VPDB-1. References for calendar calibrations are cited at the bottom of calibration graph pages.

Calibration of Radiocarbon Age to Calendar Years

(High Probability Density Range Method (HPD): INTCAL13 + NHZ2)

(Variables: d13C = -27.2 o/oo)

Laboratory number **Beta-583698**

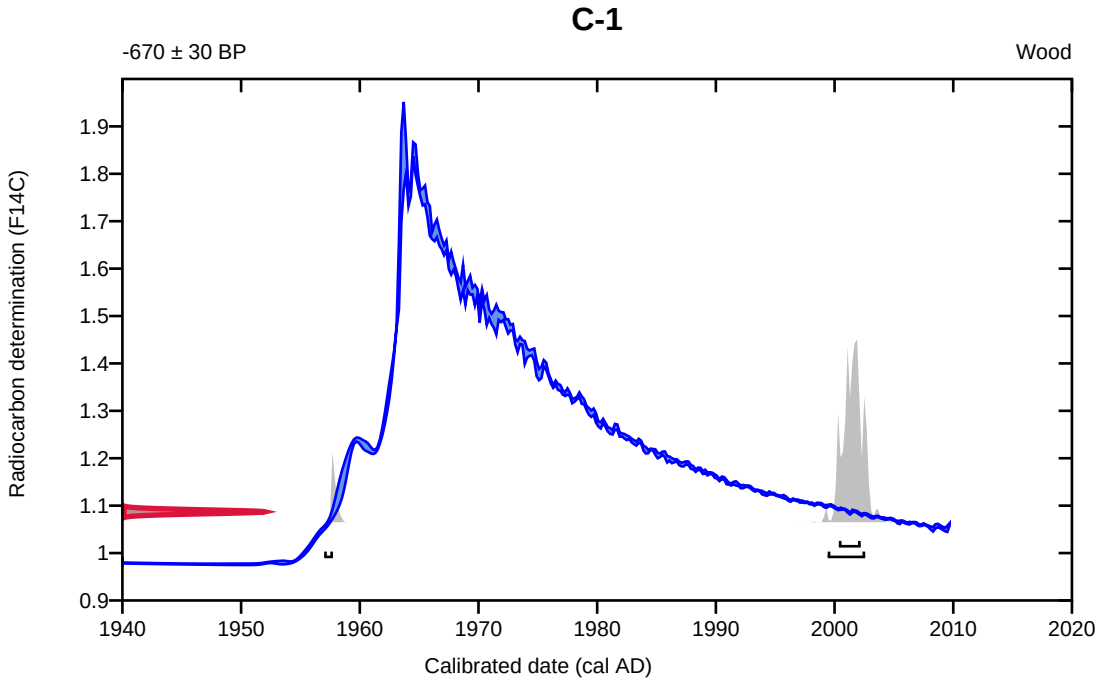
Percent modern carbon **108.70 +/- 0.41 pMC**

95.4% probability

(87.9%)	1999 - 2002 cal AD	(-50 - -53 cal BP)
(7.5%)	1956 - 1957 cal AD	(-7 - -8 cal BP)

68.2% probability

(68.2%)	2000 - 2002 cal AD	(-51 - -53 cal BP)



Database used

INTCAL13 + NHZ2

References

References to Probability Method

Bronk Ramsey, C. (2009). Bayesian analysis of radiocarbon dates. Radiocarbon, 51(1), 337-360.

References to Database INTCAL13 + NHZ2

Hua, et.al.,2013, Radiocarbon, 55(4). Reimer, et.al., 2013, Radiocarbon55(4).

Beta Analytic Radiocarbon Dating Laboratory

4985 S.W. 74th Court, Miami, Florida 33155 • Tel: (305)667-5167 • Fax: (305)663-0964 • Email: beta@radiocarbon.com

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4985 SW 74 Court
Miami, Florida 33155
Tel: 305-667-5167
Fax: 305-663-0964
info@betalabservices.com

ISO/IEC 17025:2005-Accredited Testing Laboratory

Quality Assurance Report

This report provides the results of reference materials used to validate radiocarbon analyses prior to reporting. Known-value reference materials were analyzed quasi-simultaneously with the unknowns. Results are reported as expected values vs measured values. Reported values are calculated relative to NIST SRM-4990B and corrected for isotopic fractionation. Results are reported using the direct analytical measure percent modern carbon (pMC) with one relative standard deviation. Agreement between expected and measured values is taken as being within 2 sigma agreement (error x 2) to account for total laboratory error.

Report Date: March 04, 2021
Submitter: Mr. Shawn Morrish

QA MEASUREMENTS

Reference 1	
Expected Value:	129.41 +/- 0.06 pMC
Measured Value:	129.43 +/- 0.35 pMC
Agreement:	Accepted
Reference 2	
Expected Value:	0.42 +/- 0.04
Measured Value:	0.42 +/- 0.03 pMC
Agreement:	Accepted
Reference 3	
Expected Value:	96.69 +/- 0.50 pMC
Measured Value:	96.13 +/- 0.27 pMC
Agreement:	Accepted

COMMENT: All measurements passed acceptance tests.

Validation: Chris Patrick
Digital signature on file

Date: March 04, 2021

Beta Analytic, Inc.
4985 SW 74th Court
Miami, FL 33155 USA
Tel: 305-667-5167
Fax: 305-663-0964
info@betalabservices.com

ISO/IEC 17025:2017-Accredited Testing Laboratory

February 11, 2021

Mr. Shawn Morrish
Tetra Tech
21700 Copley Drive
Diamond Bar, CA 91765
United States

RE: Radiocarbon Dating Results

Dear Mr. Morrish,

Enclosed is the radiocarbon dating result for one sample recently sent to us. As usual, specifics of the analysis are listed on the report with the result and calibration data is provided where applicable. The Conventional Radiocarbon Age has been corrected for total fractionation effects and where applicable, calibration was performed using 2013 calibration databases (cited on the graph pages).

The web directory containing the table of results and PDF download also contains pictures, a cvs spreadsheet download option and a quality assurance report containing expected vs. measured values for 3-5 working standards analyzed simultaneously with your samples.

The reported result is accredited to ISO/IEC 17025:2017 Testing Accreditation PJLA #59423 standards and all pretreatments and chemistry were performed here in our laboratories and counted in our own accelerators here in Miami. Since Beta is not a teaching laboratory, only graduates trained to strict protocols of the ISO/IEC 17025:2017 Testing Accreditation PJLA #59423 program participated in the analysis.

As always Conventional Radiocarbon Ages and sigmas are rounded to the nearest 10 years per the conventions of the 1977 International Radiocarbon Conference. When counting statistics produce sigmas lower than +/- 30 years, a conservative +/- 30 BP is cited for the result unless otherwise requested. The reported d13C was measured separately in an IRMS (isotope ratio mass spectrometer). It is NOT the AMS d13C which would include fractionation effects from natural, chemistry and AMS induced sources.

When interpreting the result, please consider any communications you may have had with us regarding the sample. As always, your inquiries are most welcome. If you have any questions or would like further details of the analysis, please do not hesitate to contact us.

Our invoice has been sent separately. Thank you for your prior efforts in arranging payment. As always, if you have any questions or would like to discuss the results, don't hesitate to contact us.

Sincerely,



Chris Patrick
Vice President of Laboratory Operations

Beta Analytic, Inc.
4985 SW 74th Court
Miami, FL 33155 USA
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Fax: 305-663-0964
info@betalabservices.com

ISO/IEC 17025:2017-Accredited Testing Laboratory

REPORT OF RADIOCARBON DATING ANALYSES

Shawn Morrish — Report Date: February 11, 2021

Tetra Tech — Material Received: February 03, 2021

Laboratory Number	Sample Code Number	Conventional Radiocarbon Age (BP) or Percent Modern Carbon (pMC) & Stable Isotopes	
Beta - 583699	**C-3**	**104.84 +/- 0.39 pMC**	IRMS δ13C: -28.8 o/oo

(65.2%) 2007 - 2009 cal AD (-58 - -60 cal BP)
(30.2%) 1955 - 1956 cal AD (-6 - -7 cal BP)

Submitter Material: Woody Material
Pretreatment: (wood) acid/alkali/acid
Analyzed Material: Wood
Analysis Service: AMS-PRIORITY delivery
Conventional Radiocarbon Age: -380 +/- 30 BP
Fraction Modern Carbon: 1.0484 +/- 0.0039
D14C: 48.44 +/- 3.92 o/oo
Δ14C: 39.48 +/- 3.92 o/oo (1950:2021)
Raw pMC: (without d13C correction): 104.03 +/- 0.39 pMC
Calibration: BetaCal4.20: HPD method: INTCAL13 + NHZ2

Results are ISO/IEC-17025:2017 accredited. No sub-contracting or student labor was used in the analyses. All work was done at Beta in 4 in-house NEC accelerator mass spectrometers and 4 Thermo IRMSs. The "Conventional Radiocarbon Age" was calculated using the Libby half-life (5568 years), is corrected for total isotopic fraction and was used for calendar calibration where applicable. The Age is rounded to the nearest 10 years and is reported as radiocarbon years before present (BP), "present" = AD 1950. Results greater than the modern reference are reported as percent modern carbon (pMC). The modern reference standard was 95% the 14C signature of NIST SRM-4990C (oxalic acid). Quoted errors are 1 sigma counting statistics. Calculated sigmas less than 30 BP on the Conventional Radiocarbon Age are conservatively rounded up to 30. d13C values are on the material itself (not the AMS d13C). d13C and d15N values are relative to VPDB-1. References for calendar calibrations are cited at the bottom of calibration graph pages.

Calibration of Radiocarbon Age to Calendar Years

(High Probability Density Range Method (HPD): INTCAL13 + NHZ2)

(Variables: d13C = -28.8 o/oo)

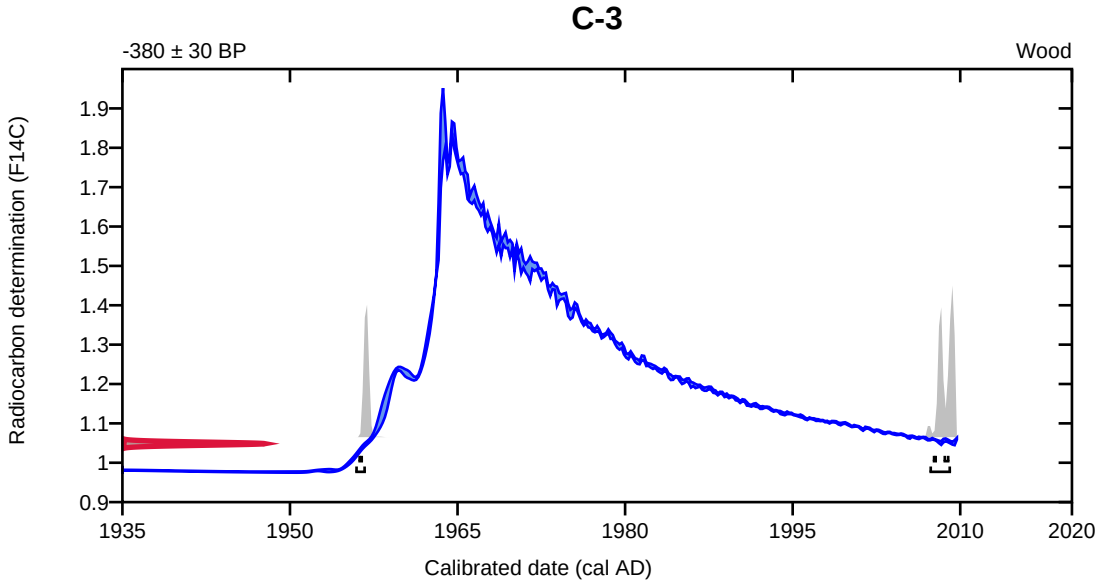
Laboratory number	**Beta-583699**
Percent modern carbon	**104.84 +/- 0.39 pMC**

95.4% probability

(65.2%)	2007 - 2009 cal AD	(-58 - -60 cal BP)
(30.2%)	1955 - 1956 cal AD	(-6 - -7 cal BP)

68.2% probability

(28.6%)	2008 - 2009 cal AD	(-59 - -60 cal BP)
(21%)	1956 cal AD	(-7 cal BP)
(18.5%)	2007 cal AD	(-58 cal BP)



Database used

INTCAL13 + NHZ2

References

References to Probability Method

Bronk Ramsey, C. (2009). Bayesian analysis of radiocarbon dates. Radiocarbon, 51(1), 337-360.

References to Database INTCAL13 + NHZ2

Hua, et.al.,2013, Radiocarbon, 55(4). Reimer, et.al., 2013, Radiocarbon55(4).

Beta Analytic Radiocarbon Dating Laboratory

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ISO/IEC 17025:2005-Accredited Testing Laboratory

Quality Assurance Report

This report provides the results of reference materials used to validate radiocarbon analyses prior to reporting. Known-value reference materials were analyzed quasi-simultaneously with the unknowns. Results are reported as expected values vs measured values. Reported values are calculated relative to NIST SRM-4990B and corrected for isotopic fractionation. Results are reported using the direct analytical measure percent modern carbon (pMC) with one relative standard deviation. Agreement between expected and measured values is taken as being within 2 sigma agreement (error x 2) to account for total laboratory error.

Report Date: February 11, 2021
Submitter: Mr. Shawn Morrish

QA MEASUREMENTS

Reference 1	
Expected Value:	129.41 +/- 0.06 pMC
Measured Value:	129.43 +/- 0.39 pMC
Agreement:	Accepted
Reference 2	
Expected Value:	0.42 +/- 0.04
Measured Value:	0.43 +/- 0.03 pMC
Agreement:	Accepted
Reference 3	
Expected Value:	96.69 +/- 0.50 pMC
Measured Value:	96.63 +/- 0.40 pMC
Agreement:	Accepted

COMMENT: All measurements passed acceptance tests.

Validation: Chris Patrick
Digital signature on file

Date: February 11, 2021

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ISO/IEC 17025:2017-Accredited Testing Laboratory

February 22, 2021

Mr. Shawn Morrish
Tetra Tech
21700 Copley Drive
Diamond Bar, CA 91765
United States

RE: Radiocarbon Dating Results

Dear Mr. Morrish,

Enclosed is the radiocarbon dating result for one sample recently sent to us. As usual, specifics of the analysis are listed on the report with the result and calibration data is provided where applicable. The Conventional Radiocarbon Age has been corrected for total fractionation effects and where applicable, calibration was performed using 2020 calibration databases (cited on the graph pages).

The web directory containing the table of results and PDF download also contains pictures, a cvs spreadsheet download option and a quality assurance report containing expected vs. measured values for 3-5 working standards analyzed simultaneously with your samples.

The reported result is accredited to ISO/IEC 17025:2017 Testing Accreditation PJLA #59423 standards and all pretreatments and chemistry were performed here in our laboratories and counted in our own accelerators here in Miami. Since Beta is not a teaching laboratory, only graduates trained to strict protocols of the ISO/IEC 17025:2017 Testing Accreditation PJLA #59423 program participated in the analysis.

As always Conventional Radiocarbon Ages and sigmas are rounded to the nearest 10 years per the conventions of the 1977 International Radiocarbon Conference. When counting statistics produce sigmas lower than +/- 30 years, a conservative +/- 30 BP is cited for the result unless otherwise requested. The reported d13C was measured separately in an IRMS (isotope ratio mass spectrometer). It is NOT the AMS d13C which would include fractionation effects from natural, chemistry and AMS induced sources.

When interpreting the result, please consider any communications you may have had with us regarding the sample. As always, your inquiries are most welcome. If you have any questions or would like further details of the analysis, please do not hesitate to contact us.

The cost of analysis was previously invoiced. As always, if you have any questions or would like to discuss the results, don't hesitate to contact us.

Sincerely,



Chris Patrick
Vice President of Laboratory Operations

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ISO/IEC 17025:2017-Accredited Testing Laboratory

REPORT OF RADIOCARBON DATING ANALYSES

Shawn Morrish — Report Date: February 22, 2021

Tetra Tech — Material Received: February 15, 2021

Laboratory Number	Sample Code Number	Conventional Radiocarbon Age (BP) or Percent Modern Carbon (pMC) & Stable Isotopes	
Beta - 584743	**C-4**	**2000 +/- 30 BP**	IRMS δ13C: -22.9 o/oo

(90.8%) 50 cal BC - 84 cal AD (1999 - 1866 cal BP)
(4.6%) 96 - 116 cal AD (1854 - 1834 cal BP)

Submitter Material: Charcoal
Pretreatment: (charred material) acid/alkali/acid
Analyzed Material: Charred material
Analysis Service: AMS-Standard delivery
Percent Modern Carbon: 77.96 +/- 0.29 pMC
Fraction Modern Carbon: 0.7796 +/- 0.0029
D14C: -220.40 +/- 2.91 o/oo
Δ14C: -227.07 +/- 2.91 o/oo (1950:2021)
Measured Radiocarbon Age: (without d13C correction): 1960 +/- 30 BP
Calibration: BetaCal4.20: HPD method: INTCAL20

Results are ISO/IEC-17025:2017 accredited. No sub-contracting or student labor was used in the analyses. All work was done at Beta in 4 in-house NEC accelerator mass spectrometers and 4 Thermo IRMSs. The "Conventional Radiocarbon Age" was calculated using the Libby half-life (5568 years), is corrected for total isotopic fraction and was used for calendar calibration where applicable. The Age is rounded to the nearest 10 years and is reported as radiocarbon years before present (BP), "present" = AD 1950. Results greater than the modern reference are reported as percent modern carbon (pMC). The modern reference standard was 95% the 14C signature of NIST SRM-4990C (oxalic acid). Quoted errors are 1 sigma counting statistics. Calculated sigmas less than 30 BP on the Conventional Radiocarbon Age are conservatively rounded up to 30. d13C values are on the material itself (not the AMS d13C). d13C and d15N values are relative to VPDB-1. References for calendar calibrations are cited at the bottom of calibration graph pages.

Calibration of Radiocarbon Age to Calendar Years

(High Probability Density Range Method (HPD): INTCAL20)

(Variables: d13C = -22.9 o/oo)

Laboratory number **Beta-584743**

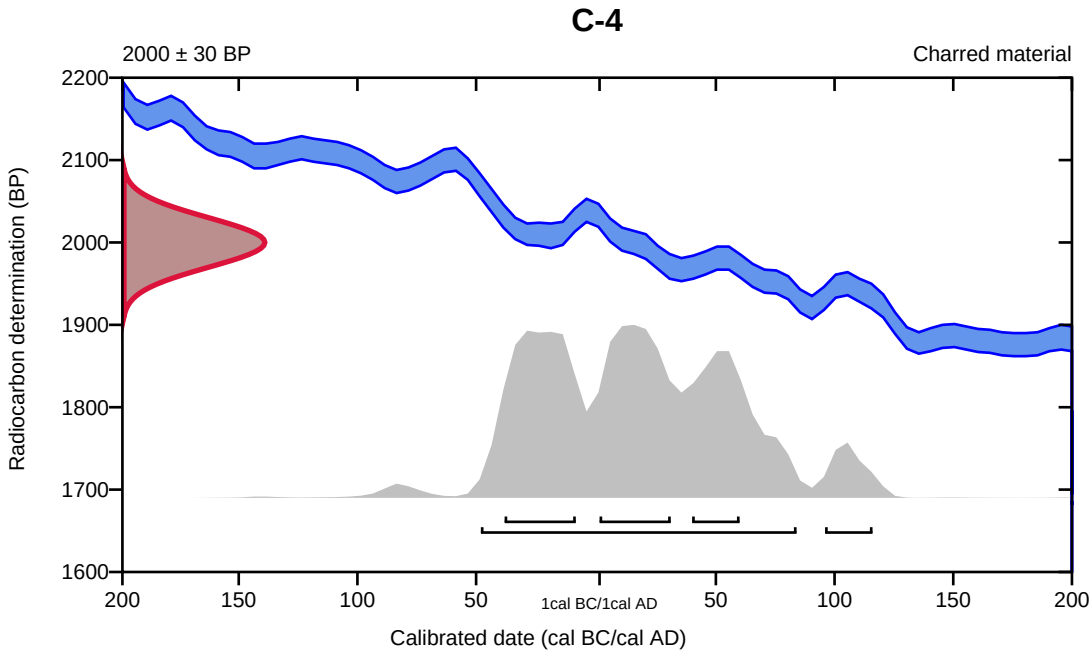
Conventional radiocarbon age **2000 ± 30 BP**

95.4% probability

(90.8%)	50 cal BC - 84 cal AD	(1999 - 1866 cal BP)
(4.6%)	96 - 116 cal AD	(1854 - 1834 cal BP)

68.2% probability

(26.3%)	40 - 10 cal BC	(1989 - 1959 cal BP)
(26.3%)	1cal BC/1cal AD - 31 cal	(1949 - 1919 cal BP)
(15.6%)	40 - 60 cal AD	(1910 - 1890 cal BP)



Database used

INTCAL20

References

References to Probability Method

Bronk Ramsey, C. (2009). Bayesian analysis of radiocarbon dates. Radiocarbon, 51(1), 337-360.

References to Database INTCAL20

Reimer, et al., 2020, Radiocarbon 62(4):725-757.

Beta Analytic Radiocarbon Dating Laboratory

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ISO/IEC 17025:2005-Accredited Testing Laboratory

Quality Assurance Report

This report provides the results of reference materials used to validate radiocarbon analyses prior to reporting. Known-value reference materials were analyzed quasi-simultaneously with the unknowns. Results are reported as expected values vs measured values. Reported values are calculated relative to NIST SRM-4990B and corrected for isotopic fractionation. Results are reported using the direct analytical measure percent modern carbon (pMC) with one relative standard deviation. Agreement between expected and measured values is taken as being within 2 sigma agreement (error x 2) to account for total laboratory error.

Report Date: March 15, 2021
Submitter: Mr. Shawn Morrish

QA MEASUREMENTS

Reference 1	
Expected Value:	96.69 +/- 0.50 pMC
Measured Value:	97.30 +/- 0.29 pMC
Agreement:	Accepted
Reference 2	
Expected Value:	0.42 +/- 0.04
Measured Value:	0.43 +/- 0.02 pMC
Agreement:	Accepted
Reference 3	
Expected Value:	129.41 +/- 0.06 pMC
Measured Value:	129.40 +/- 0.37 pMC
Agreement:	Accepted

COMMENT: All measurements passed acceptance tests.

Validation: Chris Patrick
Digital signature on file

Date: March 15, 2021

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ISO/IEC 17025:2017-Accredited Testing Laboratory

July 26, 2021

Mr. Shawn Morrish
Tetra Tech
21700 Copley Drive
Diamond Bar, CA 91765
United States

RE: Radiocarbon Dating Results

Dear Mr. Morrish,

Enclosed is the radiocarbon dating result for one sample recently sent to us. As usual, specifics of the analysis are listed on the report with the result and calibration data is provided where applicable. The Conventional Radiocarbon Age has been corrected for total fractionation effects and where applicable, calibration was performed using 2020 calibration databases (cited on the graph pages).

The web directory containing the table of results and PDF download also contains pictures, a cvs spreadsheet download option and a quality assurance report containing expected vs. measured values for 3-5 working standards analyzed simultaneously with your samples.

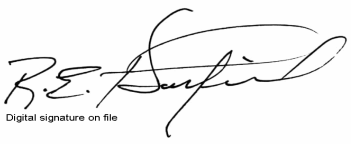
The reported result is accredited to ISO/IEC 17025:2017 Testing Accreditation PJLA #59423 standards and all pretreatments and chemistry were performed here in our laboratories and counted in our own accelerators here in Miami. Since Beta is not a teaching laboratory, only graduates trained to strict protocols of the ISO/IEC 17025:2017 Testing Accreditation PJLA #59423 program participated in the analysis.

As always Conventional Radiocarbon Ages and sigmas are rounded to the nearest 10 years per the conventions of the 1977 International Radiocarbon Conference. When counting statistics produce sigmas lower than +/- 30 years, a conservative +/- 30 BP is cited for the result unless otherwise requested. The reported d13C was measured separately in an IRMS (isotope ratio mass spectrometer). It is NOT the AMS d13C which would include fractionation effects from natural, chemistry and AMS induced sources.

When interpreting the result, please consider any communications you may have had with us regarding the sample. As always, your inquiries are most welcome. If you have any questions or would like further details of the analysis, please do not hesitate to contact us.

Thank you for prepaying the analysis. As always, if you have any questions or would like to discuss the results, don't hesitate to contact us.

Sincerely,



Ronald E. Hatfield President

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ISO/IEC 17025:2017-Accredited Testing Laboratory

REPORT OF RADIOCARBON DATING ANALYSES

Shawn Morrish — Report Date: July 26, 2021

Tetra Tech — Material Received: July 15, 2021

Laboratory Number	Sample Code Number	Conventional Radiocarbon Age (BP) or Percent Modern Carbon (pMC) & Stable Isotopes	
Beta - 597851	**C-6**	**2120 +/- 30 BP**	IRMS δ13C: -24.1 o/oo

(89.4%)	**201 - 49 cal BC**	**(2150 - 1998 cal BP)**
(6.0%)	**343 - 322 cal BC**	**(2292 - 2271 cal BP)**

Submitter Material: Charcoal
Pretreatment: (charred material) acid/alkali/acid
Analyzed Material: Charred material
Analysis Service: AMS-Standard delivery
Percent Modern Carbon: 76.80 +/- 0.29 pMC
Fraction Modern Carbon: 0.7680 +/- 0.0029
D14C: -231.96 +/- 2.87 o/oo
Δ14C: -238.53 +/- 2.87 o/oo (1950:2021)
Measured Radiocarbon Age: (without d13C correction): 2110 +/- 30 BP
Calibration: BetaCal4.20: HPD method: INTCAL20

Results are ISO/IEC-17025:2017 accredited. No sub-contracting or student labor was used in the analyses. All work was done at Beta in 4 in-house NEC accelerator mass spectrometers and 4 Thermo IRMSs. The "Conventional Radiocarbon Age" was calculated using the Libby half-life (5568 years), is corrected for total isotopic fraction and was used for calendar calibration where applicable. The Age is rounded to the nearest 10 years and is reported as radiocarbon years before present (BP), "present" = AD 1950. Results greater than the modern reference are reported as percent modern carbon (pMC). The modern reference standard was 95% the 14C signature of NIST SRM-4990C (oxalic acid). Quoted errors are 1 sigma counting statistics. Calculated sigmas less than 30 BP on the Conventional Radiocarbon Age are conservatively rounded up to 30. d13C values are on the material itself (not the AMS d13C). d13C and d15N values are relative to VPDB-1. References for calendar calibrations are cited at the bottom of calibration graph pages.

Calibration of Radiocarbon Age to Calendar Years

(High Probability Density Range Method (HPD): INTCAL20)

(Variables: d13C = -24.1 o/oo)

Laboratory number **Beta-597851**

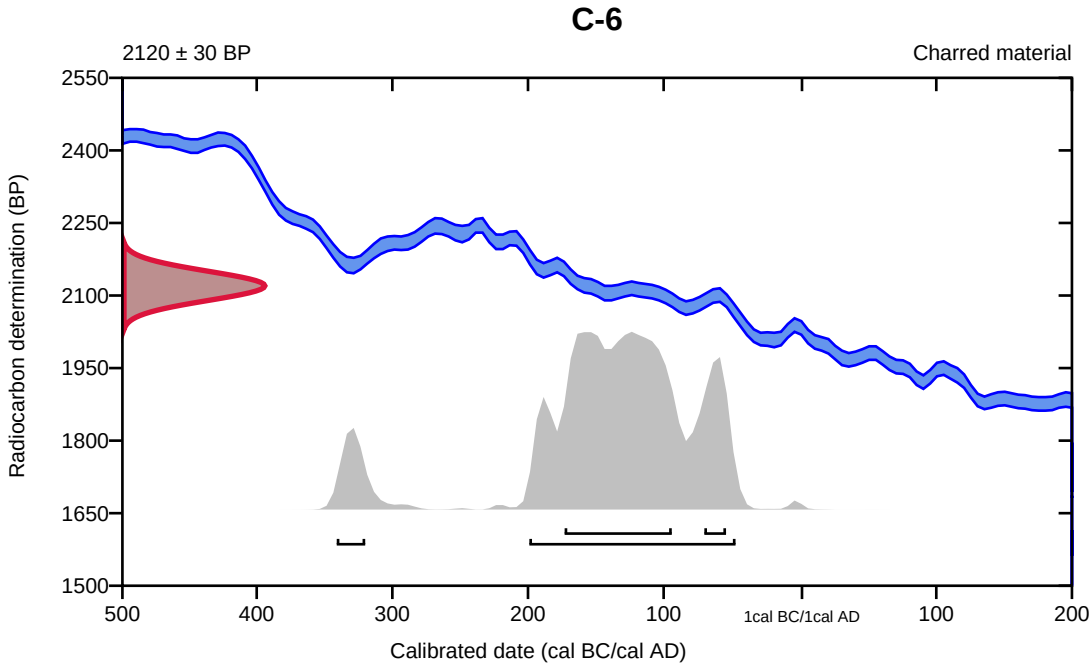
Conventional radiocarbon age **2120 ± 30 BP**

95.4% probability

(89.4%)	201 - 49 cal BC	(2150 - 1998 cal BP)
(6%)	343 - 322 cal BC	(2292 - 2271 cal BP)

68.2% probability

(58.3%)	175 - 96 cal BC	(2124 - 2045 cal BP)
(9.9%)	72 - 56 cal BC	(2021 - 2005 cal BP)



Database used

INTCAL20

References

References to Probability Method

Bronk Ramsey, C. (2009). Bayesian analysis of radiocarbon dates. Radiocarbon, 51(1), 337-360.

References to Database INTCAL20

Reimer, et al., 2020, Radiocarbon 62(4):725-757.

Beta Analytic Radiocarbon Dating Laboratory

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ISO/IEC 17025:2005-Accredited Testing Laboratory

Quality Assurance Report

This report provides the results of reference materials used to validate radiocarbon analyses prior to reporting. Known-value reference materials were analyzed quasi-simultaneously with the unknowns. Results are reported as expected values vs measured values. Reported values are calculated relative to NISTSRM-1990C and corrected for isotopic fractionation. Results are reported using the direct analytical measure percent modern carbon (pMC) with one relative standard deviation. Agreement between expected and measured values is taken as being within 2 sigma agreement (error x 2) to account for total laboratory error.

Report Date: July 26, 2021
Submitter: Mr. Shawn Morrish

QA MEASUREMENTS

Reference 1	
Expected Value:	96.69 +/- 0.50 pMC
Measured Value:	96.73 +/- 0.29 pMC
Agreement:	Accepted
Reference 2	
Expected Value:	0.44 +/- 0.10 pMC
Measured Value:	0.46 +/- 0.03 pMC
Agreement:	Accepted
Reference 3	
Expected Value:	129.41 +/- 0.06 pMC
Measured Value:	129.02 +/- 0.37 pMC
Agreement:	Accepted

COMMENT: All measurements passed acceptance tests.

Validation: Digital signature on file

Date: July 26, 2021

Beta Analytic, Inc.
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ISO/IEC 17025:2017-Accredited Testing Laboratory

August 18, 2021

Mr. Shawn Morrish
Tetra Tech
21700 Copley Drive
Diamond Bar, CA 91765
United States

RE: Radiocarbon Dating Results

Dear Mr. Morrish,

Enclosed are the radiocarbon dating results for three samples recently sent to us. As usual, the method of analysis is listed on the report with the results and calibration data is provided where applicable. The Conventional Radiocarbon Ages have all been corrected for total fractionation effects and where applicable, calibration was performed using 2020 calibration databases (cited on the graph pages).

The web directory containing the table of results and PDF download also contains pictures, a cvs spreadsheet download option and a quality assurance report containing expected vs. measured values for 3-5 working standards analyzed simultaneously with your samples.

Reported results are accredited to ISO/IEC 17025:2017 Testing Accreditation PJLA #59423 standards and all chemistry was performed here in our laboratory and counted in our own accelerators here. Since Beta is not a teaching laboratory, only graduates trained to strict protocols of the ISO/IEC 17025:2017 Testing Accreditation PJLA #59423 program participated in the analyses.

As always Conventional Radiocarbon Ages and sigmas are rounded to the nearest 10 years per the conventions of the 1977 International Radiocarbon Conference. When counting statistics produce sigmas lower than +/- 30 years, a conservative +/- 30 BP is cited for the result unless otherwise requested. The reported d13C values were measured separately in an IRMS (isotope ratio mass spectrometer). They are NOT the AMS d13C which would include fractionation effects from natural, chemistry and AMS induced sources.

When interpreting the results, please consider any communications you may have had with us regarding the samples.

The cost of analysis was previously invoiced. As always, if you have any questions or would like to discuss the results, don't hesitate to contact us.

Sincerely,



Chris Patrick
Vice President of Laboratory Operations

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ISO/IEC 17025:2017-Accredited Testing Laboratory

REPORT OF RADIOCARBON DATING ANALYSES

Shawn Morrish — Report Date: August 18, 2021

Tetra Tech — Material Received: August 04, 2021

Laboratory Number	Sample Code Number	Conventional Radiocarbon Age (BP) or Percent Modern Carbon (pMC) & Stable Isotopes	
Beta - 599493	**C-7**	**2480 +/- 30 BP**	IRMS δ13C: -22.0 o/oo

(95.4%) 772 - 478 cal BC (2721 - 2427 cal BP)

Submitter Material: Charcoal
Pretreatment: (charred material) acid/alkali/acid
Analyzed Material: Charred material
Analysis Service: AMS-Standard delivery
Percent Modern Carbon: 73.44 +/- 0.27 pMC
Fraction Modern Carbon: 0.7344 +/- 0.0027
D14C: -265.62 +/- 2.74 o/oo
Δ14C: -271.90 +/- 2.74 o/oo (1950:2021)
Measured Radiocarbon Age: (without d13C correction): 2430 +/- 30 BP
Calibration: BetaCal4.20: HPD method: INTCAL20

Results are ISO/IEC-17025:2017 accredited. No sub-contracting or student labor was used in the analyses. All work was done at Beta in 4 in-house NEC accelerator mass spectrometers and 4 Thermo IRMSs. The "Conventional Radiocarbon Age" was calculated using the Libby half-life (5568 years), is corrected for total isotopic fraction and was used for calendar calibration where applicable. The Age is rounded to the nearest 10 years and is reported as radiocarbon years before present (BP), "present" = AD 1950. Results greater than the modern reference are reported as percent modern carbon (pMC). The modern reference standard was 95% the 14C signature of NIST SRM-4990C (oxalic acid). Quoted errors are 1 sigma counting statistics. Calculated sigmas less than 30 BP on the Conventional Radiocarbon Age are conservatively rounded up to 30. d13C values are on the material itself (not the AMS d13C). d13C and d15N values are relative to VPDB-1. References for calendar calibrations are cited at the bottom of calibration graph pages.

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ISO/IEC 17025:2017-Accredited Testing Laboratory

REPORT OF RADIOCARBON DATING ANALYSES

Shawn Morrish — Report Date: August 18, 2021

Tetra Tech — Material Received: August 04, 2021

Laboratory Number	Sample Code Number	Conventional Radiocarbon Age (BP) or Percent Modern Carbon (pMC) & Stable Isotopes	
Beta - 599494	**C-8**	**1750 +/- 30 BP**	IRMS δ13C: -27.8 o/oo

(94.6%)	**240 - 384 cal AD**	**(1710 - 1566 cal BP)**
(0.8%)	**398 - 401 cal AD**	**(1552 - 1549 cal BP)**

Submitter Material: Charcoal
Pretreatment: (charred material) acid/alkali/acid
Analyzed Material: Charred material
Analysis Service: AMS-Standard delivery
Percent Modern Carbon: 80.42 +/- 0.30 pMC
Fraction Modern Carbon: 0.8042 +/- 0.0030
D14C: -195.76 +/- 3.00 o/oo
Δ14C: -202.63 +/- 3.00 o/oo (1950:2021)
Measured Radiocarbon Age: (without d13C correction): 1800 +/- 30 BP
Calibration: BetaCal4.20: HPD method: INTCAL20

Results are ISO/IEC-17025:2017 accredited. No sub-contracting or student labor was used in the analyses. All work was done at Beta in 4 in-house NEC accelerator mass spectrometers and 4 Thermo IRMSs. The "Conventional Radiocarbon Age" was calculated using the Libby half-life (5568 years), is corrected for total isotopic fraction and was used for calendar calibration where applicable. The Age is rounded to the nearest 10 years and is reported as radiocarbon years before present (BP), "present" = AD 1950. Results greater than the modern reference are reported as percent modern carbon (pMC). The modern reference standard was 95% the 14C signature of NIST SRM-4990C (oxalic acid). Quoted errors are 1 sigma counting statistics. Calculated sigmas less than 30 BP on the Conventional Radiocarbon Age are conservatively rounded up to 30. d13C values are on the material itself (not the AMS d13C). d13C and d15N values are relative to VPDB-1. References for calendar calibrations are cited at the bottom of calibration graph pages.

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ISO/IEC 17025:2017-Accredited Testing Laboratory

REPORT OF RADIOCARBON DATING ANALYSES

Shawn Morrish — Report Date: August 18, 2021

Tetra Tech — Material Received: August 04, 2021

Laboratory Number	Sample Code Number	Conventional Radiocarbon Age (BP) or Percent Modern Carbon (pMC) & Stable Isotopes	
Beta - 599495	**C-9**	**2470 +/- 30 BP**	IRMS δ13C: -24.1 o/oo

(93.3%)	**766 - 465 cal BC**	**(2715 - 2414 cal BP)**
(2.1%)	**436 - 422 cal BC**	**(2385 - 2371 cal BP)**

Submitter Material: Charcoal
Pretreatment: (charred material) acid/alkali/acid
Analyzed Material: Charred material
Analysis Service: AMS-Standard delivery
Percent Modern Carbon: 73.53 +/- 0.27 pMC
Fraction Modern Carbon: 0.7353 +/- 0.0027
D14C: -264.71 +/- 2.75 o/oo
Δ14C: -270.99 +/- 2.75 o/oo (1950:2021)
Measured Radiocarbon Age: (without d13C correction): 2450 +/- 30 BP
Calibration: BetaCal4.20: HPD method: INTCAL20

Results are ISO/IEC-17025:2017 accredited. No sub-contracting or student labor was used in the analyses. All work was done at Beta in 4 in-house NEC accelerator mass spectrometers and 4 Thermo IRMSs. The "Conventional Radiocarbon Age" was calculated using the Libby half-life (5568 years), is corrected for total isotopic fraction and was used for calendar calibration where applicable. The Age is rounded to the nearest 10 years and is reported as radiocarbon years before present (BP), "present" = AD 1950. Results greater than the modern reference are reported as percent modern carbon (pMC). The modern reference standard was 95% the 14C signature of NIST SRM-4990C (oxalic acid). Quoted errors are 1 sigma counting statistics. Calculated sigmas less than 30 BP on the Conventional Radiocarbon Age are conservatively rounded up to 30. d13C values are on the material itself (not the AMS d13C). d13C and d15N values are relative to VPDB-1. References for calendar calibrations are cited at the bottom of calibration graph pages.

Calibration of Radiocarbon Age to Calendar Years

(High Probability Density Range Method (HPD): INTCAL20)

(Variables: d13C = -22.0 o/oo)

Laboratory number **Beta-599493**

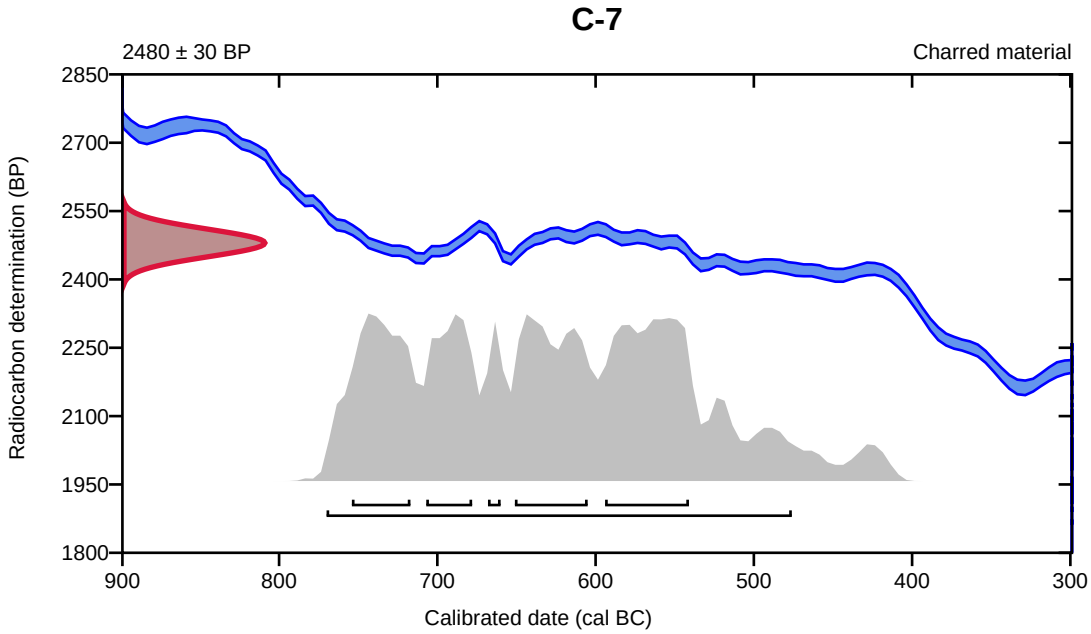
Conventional radiocarbon age **2480 ± 30 BP**

95.4% probability

(95.4%)	772 - 478 cal BC	(2721 - 2427 cal BP)

68.2% probability

(21.4%)	596 - 543 cal BC	(2545 - 2492 cal BP)
(18%)	653 - 607 cal BC	(2602 - 2556 cal BP)
(14.5%)	756 - 719 cal BC	(2705 - 2668 cal BP)
(11.3%)	709 - 680 cal BC	(2658 - 2629 cal BP)
(3%)	670 - 662 cal BC	(2619 - 2611 cal BP)



Database used

INTCAL20

References

References to Probability Method

Bronk Ramsey, C. (2009). Bayesian analysis of radiocarbon dates. Radiocarbon, 51(1), 337-360.

References to Database INTCAL20

Reimer, et al., 2020, Radiocarbon 62(4):725-757.

Calibration of Radiocarbon Age to Calendar Years

(High Probability Density Range Method (HPD): INTCAL20)

(Variables: d13C = -27.8 o/oo)

Laboratory number **Beta-599494**

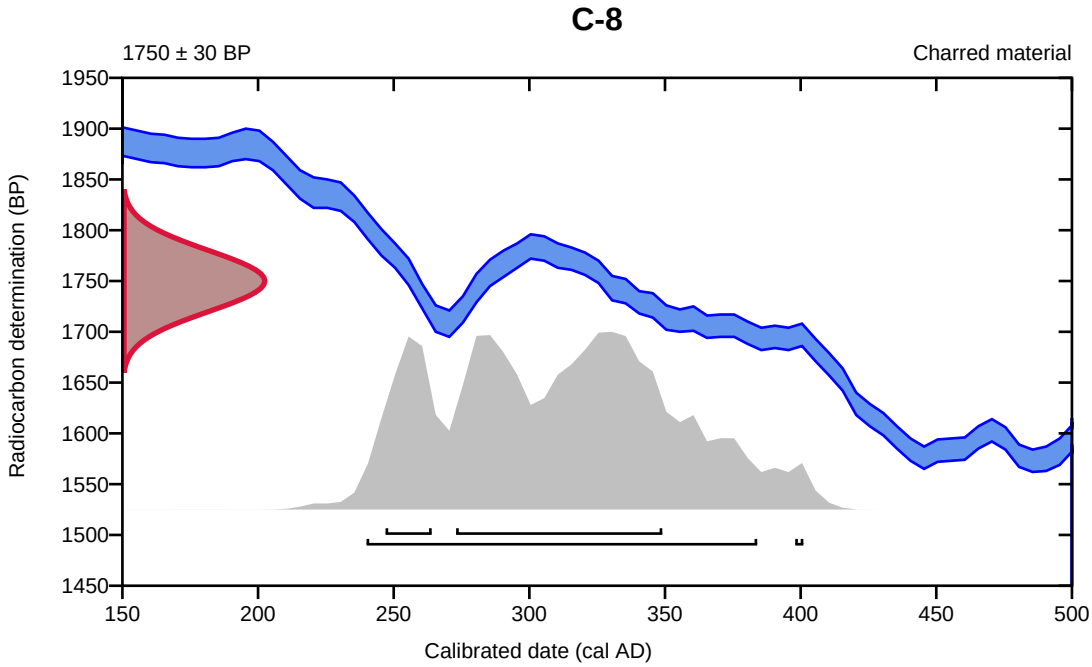
Conventional radiocarbon age **1750 ± 30 BP**

95.4% probability

(94.6%)	240 - 384 cal AD	(1710 - 1566 cal BP)
(0.8%)	398 - 401 cal AD	(1552 - 1549 cal BP)

68.2% probability

(55.5%)	273 - 349 cal AD	(1677 - 1601 cal BP)
(12.7%)	247 - 264 cal AD	(1703 - 1686 cal BP)



Database used

INTCAL20

References

References to Probability Method

Bronk Ramsey, C. (2009). Bayesian analysis of radiocarbon dates. Radiocarbon, 51(1), 337-360.

References to Database INTCAL20

Reimer, et al., 2020, Radiocarbon 62(4):725-757.

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Calibration of Radiocarbon Age to Calendar Years

(High Probability Density Range Method (HPD): INTCAL20)

(Variables: d13C = -24.1 o/oo)

Laboratory number **Beta-599495**

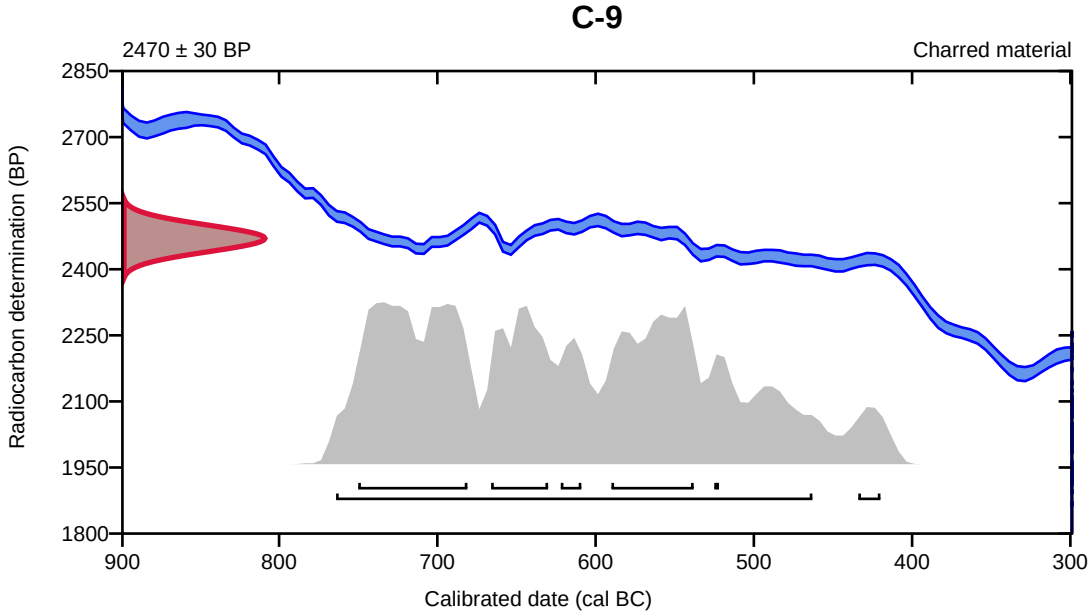
Conventional radiocarbon age **2470 ± 30 BP**

95.4% probability

(93.3%)	766 - 465 cal BC	(2715 - 2414 cal BP)
(2.1%)	436 - 422 cal BC	(2385 - 2371 cal BP)

68.2% probability

(29.1%)	752 - 683 cal BC	(2701 - 2632 cal BP)
(20.2%)	592 - 540 cal BC	(2541 - 2489 cal BP)
(13.8%)	668 - 632 cal BC	(2617 - 2581 cal BP)
(4.2%)	624 - 611 cal BC	(2573 - 2560 cal BP)
(0.9%)	527 - 524 cal BC	(2476 - 2473 cal BP)



Database used

INTCAL20

References

References to Probability Method

Bronk Ramsey, C. (2009). Bayesian analysis of radiocarbon dates. Radiocarbon, 51(1), 337-360.

References to Database INTCAL20

Reimer, et al., 2020, Radiocarbon 62(4):725-757.

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Quality Assurance Report

This report provides the results of reference materials used to validate radiocarbon analyses prior to reporting. Known-value reference materials were analyzed quasi-simultaneously with the unknowns. Results are reported as expected values vs measured values. Reported values are calculated relative to NISTSRM-1990C and corrected for isotopic fractionation. Results are reported using the direct analytical measure percent modern carbon (pMC) with one relative standard deviation. Agreement between expected and measured values is taken as being within 2 sigma agreement (error x 2) to account for total laboratory error.

Report Date: August 18, 2021
Submitter: Mr. Shawn Morrish

QA MEASUREMENTS

Reference 1	
Expected Value:	0.44 +/- 0.10 pMC
Measured Value:	0.45 +/- 0.03 pMC
Agreement:	Accepted
Reference 2	
Expected Value:	129.41 +/- 0.06 pMC
Measured Value:	129.41 +/- 0.35 pMC
Agreement:	Accepted
Reference 3	
Expected Value:	96.69 +/- 0.50 pMC
Measured Value:	96.78 +/- 0.29 pMC
Agreement:	Accepted

COMMENT: All measurements passed acceptance tests.

Validation: Digital signature on file

Date: August 18, 2021

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ISO/IEC 17025:2017-Accredited Testing Laboratory

December 08, 2021

Mr. Shawn Morrish
Tetra Tech
21700 Copley Drive
Diamond Bar, CA 91765
United States

RE: Radiocarbon Dating Results

Dear Mr. Morrish,

Enclosed are the radiocarbon dating results for four samples recently sent to us. As usual, the method of analysis is listed on the report with the results and calibration data is provided where applicable. The Conventional Radiocarbon Ages have all been corrected for total fractionation effects and where applicable, calibration was performed using 2020 calibration databases (cited on the graph pages).

The web directory containing the table of results and PDF download also contains pictures, a cvs spreadsheet download option and a quality assurance report containing expected vs. measured values for 3-5 working standards analyzed simultaneously with your samples.

Reported results are accredited to ISO/IEC 17025:2017 Testing Accreditation PJLA #59423 standards and all chemistry was performed here in our laboratory and counted in our own accelerators here. Since Beta is not a teaching laboratory, only graduates trained to strict protocols of the ISO/IEC 17025:2017 Testing Accreditation PJLA #59423 program participated in the analyses.

As always Conventional Radiocarbon Ages and sigmas are rounded to the nearest 10 years per the conventions of the 1977 International Radiocarbon Conference. When counting statistics produce sigmas lower than +/- 30 years, a conservative +/- 30 BP is cited for the result unless otherwise requested. The reported d13C values were measured separately in an IRMS (isotope ratio mass spectrometer). They are NOT the AMS d13C which would include fractionation effects from natural, chemistry and AMS induced sources.

When interpreting the results, please consider any communications you may have had with us regarding the samples.

Thank you for prepaying the analyses. As always, if you have any questions or would like to discuss the results, don't hesitate to contact us.

Sincerely,



Ronald E. Hatfield President

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REPORT OF RADIOCARBON DATING ANALYSES

Shawn Morrish — Report Date: December 08, 2021

Tetra Tech — Material Received: November 22, 2021

Laboratory Number	Sample Code Number	Conventional Radiocarbon Age (BP) or Percent Modern Carbon (pMC) & Stable Isotopes	
Beta - 610270	**C-10**	**1600 +/- 30 BP**	IRMS δ13C: -23.9 o/oo
(95.4%)	**416 - 545 cal AD**	**(1534 - 1405 cal BP)**	

Submitter Material: Charcoal
Pretreatment: (charred material) acid/alkali/acid
Analyzed Material: Charred material
Analysis Service: AMS-Standard delivery
Percent Modern Carbon: 81.94 +/- 0.31 pMC
Fraction Modern Carbon: 0.8194 +/- 0.0031
D14C: -180.60 +/- 3.06 o/oo
Δ14C: -187.60 +/- 3.06 o/oo (1950:2021)
Measured Radiocarbon Age: (without d13C correction): 1580 +/- 30 BP
Calibration: BetaCal4.20: HPD method: INTCAL20

Results are ISO/IEC-17025:2017 accredited. No sub-contracting or student labor was used in the analyses. All work was done at Beta in 4 in-house NEC accelerator mass spectrometers and 4 Thermo IRMSs. The "Conventional Radiocarbon Age" was calculated using the Libby half-life (5568 years), is corrected for total isotopic fraction and was used for calendar calibration where applicable. The Age is rounded to the nearest 10 years and is reported as radiocarbon years before present (BP), "present" = AD 1950. Results greater than the modern reference are reported as percent modern carbon (pMC). The modern reference standard was 95% the 14C signature of NIST SRM-4990C (oxalic acid). Quoted errors are 1 sigma counting statistics. Calculated sigmas less than 30 BP on the Conventional Radiocarbon Age are conservatively rounded up to 30. d13C values are on the material itself (not the AMS d13C). d13C and d15N values are relative to VPDB. References for calendar calibrations are cited at the bottom of calibration graph pages.

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REPORT OF RADIOCARBON DATING ANALYSES

Shawn Morrish — Report Date: December 08, 2021

Tetra Tech — Material Received: November 22, 2021

Laboratory Number	Sample Code Number	Conventional Radiocarbon Age (BP) or Percent Modern Carbon (pMC) & Stable Isotopes	
Beta - 610272	**C-12**	**2000 +/- 30 BP**	IRMS δ13C: -26.4 o/oo

(90.8%) 50 cal BC - 84 cal AD (1999 - 1866 cal BP)
(4.6%) 96 - 116 cal AD (1854 - 1834 cal BP)

Submitter Material: Charcoal
Pretreatment: (charred material) acid/alkali/acid
Analyzed Material: Charred material
Analysis Service: AMS-Standard delivery
Percent Modern Carbon: 77.96 +/- 0.29 pMC
Fraction Modern Carbon: 0.7796 +/- 0.0029
D14C: -220.40 +/- 2.91 o/oo
Δ14C: -227.07 +/- 2.91 o/oo (1950:2021)
Measured Radiocarbon Age: (without d13C correction): 2020 +/- 30 BP
Calibration: BetaCal4.20: HPD method: INTCAL20

Results are ISO/IEC-17025:2017 accredited. No sub-contracting or student labor was used in the analyses. All work was done at Beta in 4 in-house NEC accelerator mass spectrometers and 4 Thermo IRMSs. The "Conventional Radiocarbon Age" was calculated using the Libby half-life (5568 years), is corrected for total isotopic fraction and was used for calendar calibration where applicable. The Age is rounded to the nearest 10 years and is reported as radiocarbon years before present (BP), "present" = AD 1950. Results greater than the modern reference are reported as percent modern carbon (pMC). The modern reference standard was 95% the 14C signature of NIST SRM-4990C (oxalic acid). Quoted errors are 1 sigma counting statistics. Calculated sigmas less than 30 BP on the Conventional Radiocarbon Age are conservatively rounded up to 30. d13C values are on the material itself (not the AMS d13C). d13C and d15N values are relative to VPDB. References for calendar calibrations are cited at the bottom of calibration graph pages.

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REPORT OF RADIOCARBON DATING ANALYSES

Shawn Morrish — Report Date: December 08, 2021

Tetra Tech — Material Received: November 22, 2021

Laboratory Number	Sample Code Number	Conventional Radiocarbon Age (BP) or Percent Modern Carbon (pMC) & Stable Isotopes	
Beta - 610273	**C-13**	**2420 +/- 30 BP**	IRMS δ13C: -25.1 o/oo

(75.5%)	**566 - 402 cal BC**	**(2515 - 2351 cal BP)**
(13.9%)	**748 - 688 cal BC**	**(2697 - 2637 cal BP)**
(6.0%)	**666 - 643 cal BC**	**(2615 - 2592 cal BP)**

Submitter Material: Charcoal
Pretreatment: (charred material) acid/alkali/acid
Analyzed Material: Charred material
Analysis Service: AMS-Standard delivery
Percent Modern Carbon: 73.99 +/- 0.28 pMC
Fraction Modern Carbon: 0.7399 +/- 0.0028
D14C: -260.11 +/- 2.76 o/oo
Δ14C: -266.44 +/- 2.76 o/oo (1950:2021)
Measured Radiocarbon Age: (without d13C correction): 2420 +/- 30 BP
Calibration: BetaCal4.20: HPD method: INTCAL20

Results are ISO/IEC-17025:2017 accredited. No sub-contracting or student labor was used in the analyses. All work was done at Beta in 4 in-house NEC accelerator mass spectrometers and 4 Thermo IRMSs. The "Conventional Radiocarbon Age" was calculated using the Libby half-life (5568 years), is corrected for total isotopic fraction and was used for calendar calibration where applicable. The Age is rounded to the nearest 10 years and is reported as radiocarbon years before present (BP), "present" = AD 1950. Results greater than the modern reference are reported as percent modern carbon (pMC). The modern reference standard was 95% the 14C signature of NIST SRM-4990C (oxalic acid). Quoted errors are 1 sigma counting statistics. Calculated sigmas less than 30 BP on the Conventional Radiocarbon Age are conservatively rounded up to 30. d13C values are on the material itself (not the AMS d13C). d13C and d15N values are relative to VPDB. References for calendar calibrations are cited at the bottom of calibration graph pages.

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REPORT OF RADIOCARBON DATING ANALYSES

Shawn Morrish — Report Date: December 08, 2021

Tetra Tech — Material Received: November 22, 2021

Laboratory Number	Sample Code Number	Conventional Radiocarbon Age (BP) or Percent Modern Carbon (pMC) & Stable Isotopes	
Beta - 610274	**C-14**	**1190 +/- 30 BP**	IRMS δ13C: -23.8 o/oo

(87.9%)	**770 - 896 cal AD**	**(1180 - 1054 cal BP)**
(5.8%)	**922 - 952 cal AD**	**(1028 - 998 cal BP)**
(1.6%)	**708 - 722 cal AD**	**(1242 - 1228 cal BP)**

Submitter Material: Charcoal
Pretreatment: (charred material) acid/alkali/acid
Analyzed Material: Charred material
Analysis Service: AMS-Standard delivery
Percent Modern Carbon: 86.23 +/- 0.32 pMC
Fraction Modern Carbon: 0.8623 +/- 0.0032
D14C: -137.69 +/- 3.22 o/oo
Δ14C: -145.06 +/- 3.22 o/oo (1950:2021)
Measured Radiocarbon Age: (without d13C correction): 1170 +/- 30 BP
Calibration: BetaCal4.20: HPD method: INTCAL20

Results are ISO/IEC-17025:2017 accredited. No sub-contracting or student labor was used in the analyses. All work was done at Beta in 4 in-house NEC accelerator mass spectrometers and 4 Thermo IRMSs. The "Conventional Radiocarbon Age" was calculated using the Libby half-life (5568 years), is corrected for total isotopic fraction and was used for calendar calibration where applicable. The Age is rounded to the nearest 10 years and is reported as radiocarbon years before present (BP), "present" = AD 1950. Results greater than the modern reference are reported as percent modern carbon (pMC). The modern reference standard was 95% the 14C signature of NIST SRM-4990C (oxalic acid). Quoted errors are 1 sigma counting statistics. Calculated sigmas less than 30 BP on the Conventional Radiocarbon Age are conservatively rounded up to 30. d13C values are on the material itself (not the AMS d13C). d13C and d15N values are relative to VPDB. References for calendar calibrations are cited at the bottom of calibration graph pages.

Calibration of Radiocarbon Age to Calendar Years

(High Probability Density Range Method (HPD): INTCAL20)

(Variables: d13C = -23.9 o/oo)

Laboratory number **Beta-610270**

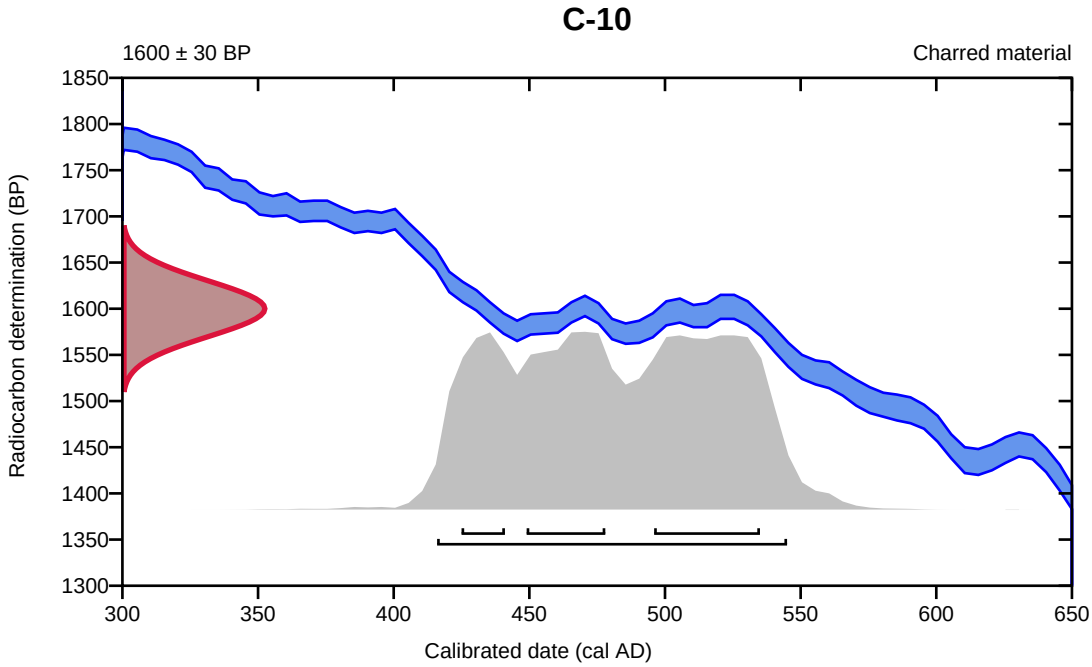
Conventional radiocarbon age **1600 ± 30 BP**

95.4% probability

(95.4%)	416 - 545 cal AD	(1534 - 1405 cal BP)

68.2% probability

(32%)	496 - 535 cal AD	(1454 - 1415 cal BP)
(23.4%)	449 - 478 cal AD	(1501 - 1472 cal BP)
(12.7%)	425 - 441 cal AD	(1525 - 1509 cal BP)



Database used

INTCAL20

References

References to Probability Method

Bronk Ramsey, C. (2009). Bayesian analysis of radiocarbon dates. Radiocarbon, 51(1), 337-360.

References to Database INTCAL20

Reimer, et al., 2020, Radiocarbon 62(4):725-757.

Calibration of Radiocarbon Age to Calendar Years

(High Probability Density Range Method (HPD): INTCAL20)

(Variables: d13C = -26.4 o/oo)

Laboratory number **Beta-610272**

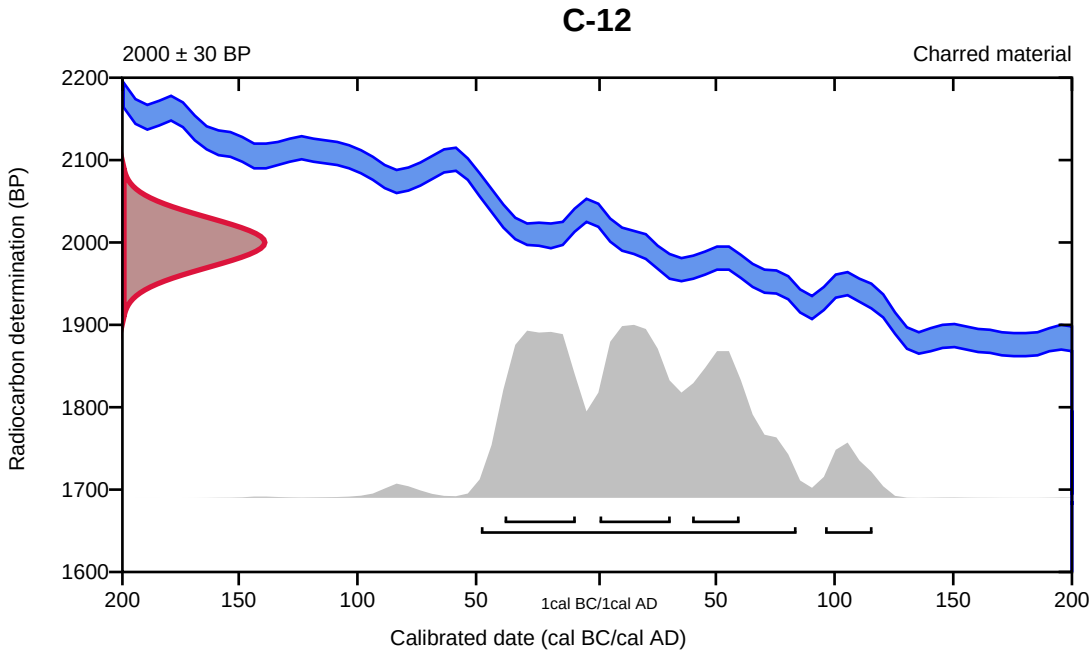
Conventional radiocarbon age **2000 ± 30 BP**

95.4% probability

(90.8%)	50 cal BC - 84 cal AD	(1999 - 1866 cal BP)
(4.6%)	96 - 116 cal AD	(1854 - 1834 cal BP)

68.2% probability

(26.3%)	40 - 10 cal BC	(1989 - 1959 cal BP)
(26.3%)	1cal BC/1cal AD - 31 cal	(1949 - 1919 cal BP)
(15.6%)	40 - 60 cal AD	(1910 - 1890 cal BP)



Database used

INTCAL20

References

References to Probability Method

Bronk Ramsey, C. (2009). Bayesian analysis of radiocarbon dates. Radiocarbon, 51(1), 337-360.

References to Database INTCAL20

Reimer, et al., 2020, Radiocarbon 62(4):725-757.

Calibration of Radiocarbon Age to Calendar Years

(High Probability Density Range Method (HPD): INTCAL20)

(Variables: d13C = -25.1 o/oo)

Laboratory number **Beta-610273**

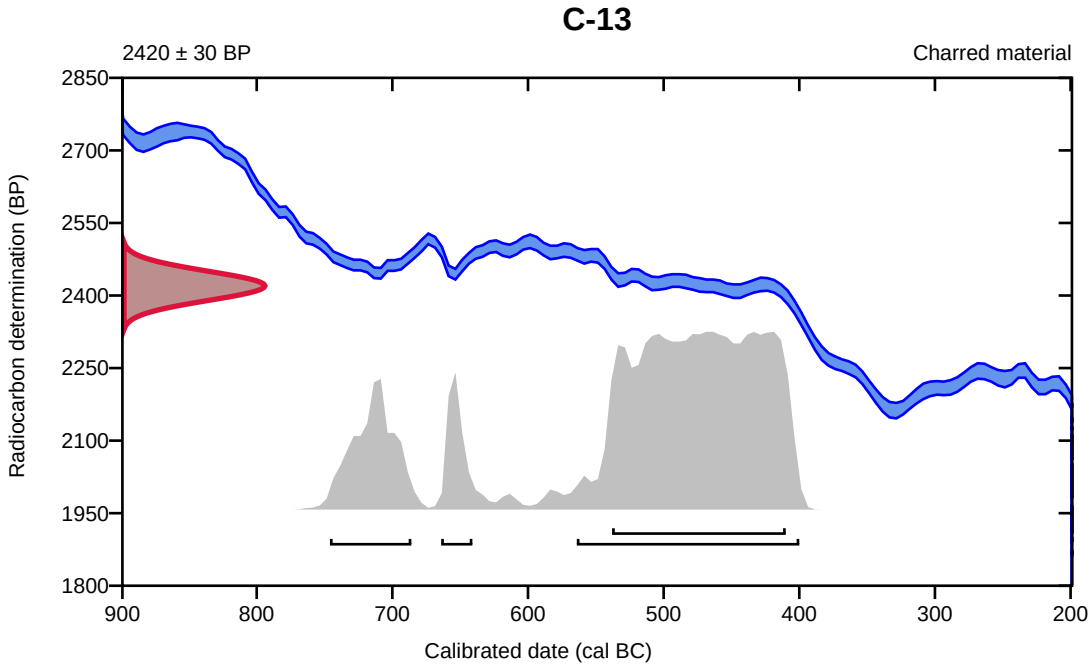
Conventional radiocarbon age **2420 ± 30 BP**

95.4% probability

(75.5%)	566 - 402 cal BC	(2515 - 2351 cal BP)
(13.9%)	748 - 688 cal BC	(2697 - 2637 cal BP)
(6%)	666 - 643 cal BC	(2615 - 2592 cal BP)

68.2% probability

(68.2%)	540 - 412 cal BC	(2489 - 2361 cal BP)



Database used

INTCAL20

References

References to Probability Method

Bronk Ramsey, C. (2009). Bayesian analysis of radiocarbon dates. Radiocarbon, 51(1), 337-360.

References to Database INTCAL20

Reimer, et al., 2020, Radiocarbon 62(4):725-757.

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Calibration of Radiocarbon Age to Calendar Years

(High Probability Density Range Method (HPD): INTCAL20)

(Variables: d13C = -23.8 o/oo)

Laboratory number **Beta-610274**

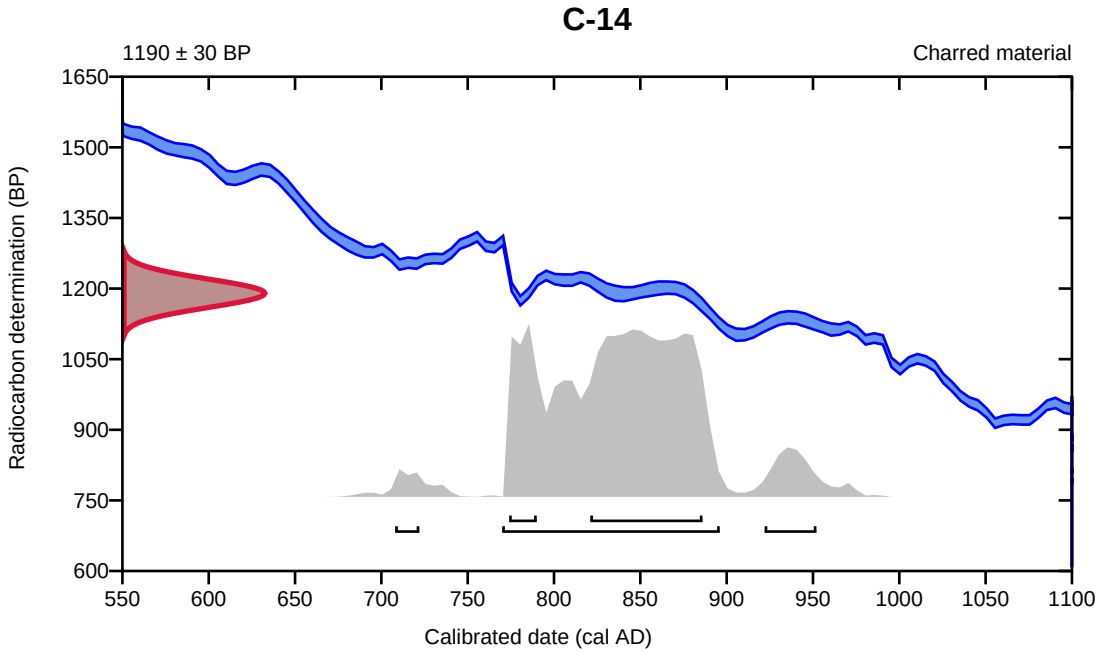
Conventional radiocarbon age **1190 ± 30 BP**

95.4% probability

(87.9%)	770 - 896 cal AD	(1180 - 1054 cal BP)
(5.8%)	922 - 952 cal AD	(1028 - 998 cal BP)
(1.6%)	708 - 722 cal AD	(1242 - 1228 cal BP)

68.2% probability

(54.4%)	821 - 886 cal AD	(1129 - 1064 cal BP)
(13.8%)	774 - 790 cal AD	(1176 - 1160 cal BP)



Database used

INTCAL20

References

References to Probability Method

Bronk Ramsey, C. (2009). Bayesian analysis of radiocarbon dates. Radiocarbon, 51(1), 337-360.

References to Database INTCAL20

Reimer, et al., 2020, Radiocarbon 62(4):725-757.

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Report Date: December 08, 2021
Submitter: Mr. Shawn Morrish

QA MEASUREMENTS

Reference 1	
Expected Value:	0.42 +/- 0.04 pMC
Measured Value:	0.42 +/- 0.03 pMC
Agreement:	Accepted
Reference 2	
Expected Value:	41.14 +/- 0.10 pMC
Measured Value:	41.27 +/- 0.17 pMC
Agreement:	Accepted
Reference 3	
Expected Value:	129.41 +/- 0.06 pMC
Measured Value:	129.48 +/- 0.37 pMC
Agreement:	Accepted

COMMENT: All measurements passed acceptance tests.

Validation: Chris Patrick
Digital signature on file

Date: December 08, 2021

Appendix D2

Optically Stimulated Luminescence & Infrared Luminescence Result

(by California State University, Long Beach, 2021 & North Carolina State University, 2021)

Optically Stimulated Luminescence Dating of Quaternary Sediments

By:

Lewis Owen, Ph.D.

Professor of Geology

Department of Marine, Earth, and Atmospheric Sciences

North Carolina State University

Raleigh, NC 27695

Phone: 513-4102339

Email: Lewis.Owen@ncsu.edu

For:

Mr. Shawn Morrish

Tetra Tech BAS GeoScience

21700 Copley Drive #200

Diamond Bar, CA 91765

Shawn.morrish@tetratech.com

Draft October 14, 2020

Background

Optically Stimulated Luminescence (OSL) dating determines the time elapsed since a sediment sample was last exposed to daylight (Aitken, 1998). The method relies on the interaction of ionizing radiation with electrons in semi-conducting minerals within buried sediment, which results in metastable accumulation of charge. Illumination of the sediment releases the charge as a measurable emission of photons (luminescence). The methods assume that mineral grains during or immediately prior to the transport were exposed to daylight to set them to their geological zero residual level. Upon burial, day light exposure ceases and essentially the luminescence signal begins to accumulate due to the radiation arising from the decay of ambient radioisotopes that include U, Th, Rb and K, and from cosmic rays. Given that, as a first approximation, the radiation exposure (dose rate - D_R) is constant over the timescales of interest, luminescence builds up (equivalent dose - D_E) in the minerals in proportion to the duration of burial and the concentration of the radioisotopes in the sample environment and the cosmic dose. The depositional age (A) of the sample is thus a ratio of luminescence acquired and the rate of luminescence acquisition, i.e., $A=D_E/D_R$ (Aitken, 1998; Murray and Olley, 2002; Singhvi and Porat, 2008).

Preparation and measurement

The sediment samples were prepared for quartz OSL dating. The OSL samples were provided in steel tubes. The samples were opened in the Luminescence Dating Laboratory at the North Carolina State University under safe light conditions. Approximately 150 g of sediment was removed from ends of each tube and was dried to determine the water content for each sample. The sediment was then crushed and sent to the Activation Laboratories Limited in Ancaster, Ontario, Canada for Major Elements Fusion ICP/MS/Trace Elements analysis to determine the U, Th and K concentrations for D_R calculations (Table 1).

The reminding sediment was pretreated with 10% HCl and 10% H_2O_2 to remove carbonates and organic matter, respectively. The pretreated samples were rinsed in water, dried and sieved to attract the 90–150 μm particle size fraction. A sub-fraction (~20 g) of sample was etched using 44% HF acid for 80 minutes to remove the outer alpha irradiated layer from quartz particles. This treatment also helps dissolves any feldspars present. Any fluorides precipitated during HF treatment were removed using concentrated HCl for 30 min. The quartz sample was then rinsed in distilled water and acetate, and dried and sieved to obtain grain size 90–150 μm in diameter. Next, a low field controlled Frantz isodynamic magnetic separator (LFC Model-2) was used to separate feldspar and magnetic minerals from quartz in the 90–150 μm particle size

fraction following the methods of Porat (2006) with the forward and side slopes were set at 100° and 10°, respectively, within a variable magnetic field. The samples were checked for feldspar contamination using infrared stimulated luminescence (IRSL) at room temperature and then sieved using a 90 μm mess to remove any grains smaller than 90 μm, so that the 90–150 μm could be used for OSL measurement.

An automated Riso OSL reader model TL-DA-20 was used for OSL measurements and irradiation. Aliquots, containing approximately several hundred grains of the samples, were mounted onto ~ 6 mm-diameter stainless steel discs as a central circle ~ 4 mm in diameter. Aliquots of samples were illuminated with blue LEDs stimulating at a wavelength of 470 nm (blue light stimulated luminescence – BLSL). The detection optics comprised Hoya U-340 and Schott BG-39 color glass filters coupled to an EMI 9235 QA photomultiplier tube. The samples were irradiated using a $^{90}Sr/^{90}Y$ beta source. The single aliquot regeneration (SAR) method of (Murray and Wintle, 2000, 2003) was used to determine the D_E for age estimation. Only aliquots that satisfy the criterion of a recycling ratio not more than 10% were used in determining D_E. A preheat of 240 °C for 10s was used and the OSL signal was recorded for 40 s at 125 °C. OSL sensitivity of the samples had a high signal to noise ratio. Dose recovery tests (Wintle and Murray, 2006) indicate that a laboratory dose for 100 seconds could be recovered to within ~10% by the SAR protocol suggesting that the protocol was appropriate.

Results

Table 1 presents the radioisotope, water content, and cosmic dose, D_R, D_E and OSL age for the samples. Dose rate calculations follows the details highlighted in the footnotes of Table 1 and confirmed using the Dose Rate and Age Calculator (DRAC) of Duncan et al. (2015). Dose rates for samples were 3.3±0.2 and 3.1±0.2 Gy/ka, which is within the normal range for terrestrial sediments. The Th/U is consistent with the expected values suggesting that leaching has not been a significant problem at the sites. For the water content, we assumed a conservative value with a large uncertainty (10±5%) to reflect possible changes in water content over the geologic history, especially accounting for wetter glacial times in the past and drying out of the trench faces during excavation and sampling.

The natural OSL signal for all aliquots a magnitude greater than the background signal. Examples of IRSL tests and “shine down” curves for the samples are shown in Figure 1. The shine down curves (luminescence stimulated in the laboratory for 40 s of exposure to light) for all aliquots showed fast decay patterns that confirm that the signal is the fast component of luminescence, which is dominant in quartz. This also helps

to provide confidence that sample would have likely been bleached quickly if only briefly exposed to sunlight for a few minutes. Figure 1 shows examples of examples of the regenerative curves, illustrating good growth and recuperation. Dose rate recovery tests for the samples shows that they have somewhat of a mixed recovery, but most tested aliquots are within the 10% uncertainty of the laboratory dose (Figure 2).

The spread of D_E varied between samples and are shown in Figure 1. The spread of D_E values for each sample has a dispersion >20%, so a two mixing age model using the radial plotter of Vermeesch, P. (2009) was applied and the minimum peak distribution is used to calculate the ages (minimum age model). The average and weighted average ages are also presented for reference and statically they are identical to the minimum age model (Table 1). The weighted average age skews the ages towards a younger age because aliquots with low D_E values have lower associated uncertainties. The preferred age for TP-OSL1 is 3.3±0.2 ka and TP-OSL2 is 3.1±0.2 ka and are highlighted in bold in Table 1. Statistically these ages are identical to each other.

References

Aitken, M.J., 1998. An introduction to Optical dating: The Dating of Quaternary Sediments by the Use of Photon-stimulated Luminescence. Oxford University press, USA, New York, 280 pp.

Duncan, J.A., King, G.E., Duller, G.A.T. (2015) DRAC: Dose Rate and Age Calculator for trapped charge dating. Quaternary Geochronology, 28, 54-61

Jain, M., Choi, J.H. and Thomas, P.J., (2008). "The ultrafast OSL component in quartz: Origins and implications". *Radiation Measurements* **(doi:10.1016/j.radmeas.2008.01.005)**.

Murray, A.S. and Olley, J.M., (2002). "Precision and accuracy in the optically stimulated luminescence dating of sedimentary quartz: a status review". *Geochronometria* **21**( ): pp11-16.

Murray, A.S. and Wintle, A.G., (2000). "Luminescence dating of quartz using an improved single-aliquot regenerative-dose protocol". *Radiation Measurements* **32**(1): pp57-73.

Murray, A.S. and Wintle, A.G., (2003). "The single aliquot regenerative dose protocol: potential for improvements in reliability". *Radiation Measurements* **37**(4-5): pp377-381.

Porat, N., (2006). "Use of magnetic separation for purifying quartz for luminescence dating". *Ancient TL* **24**(2): pp33-36.

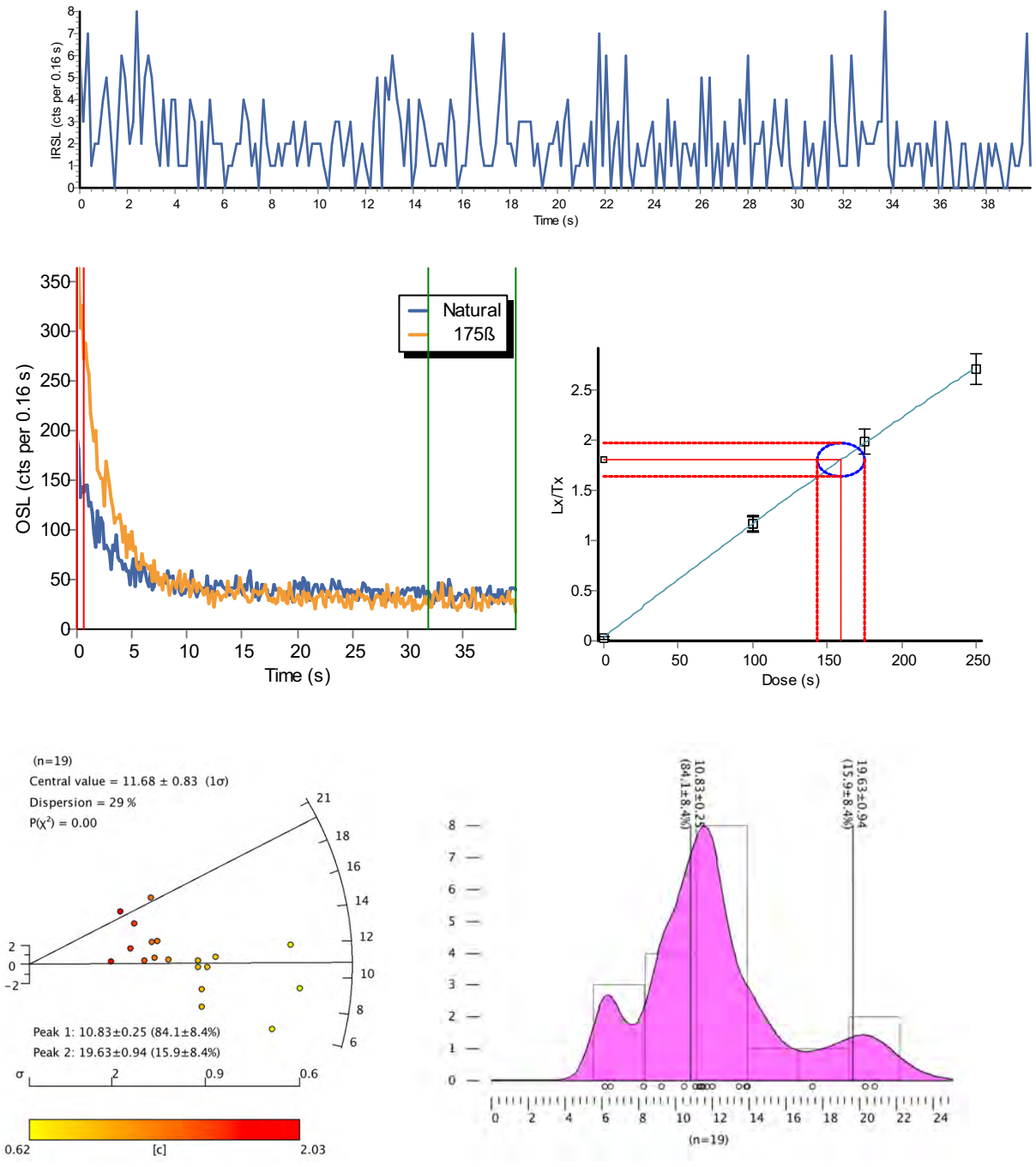
Prescott, J.R. and Hutton, J.T., (1994). "Cosmic ray contributions to dose rates for luminescence and ESR dating: Large depths and long-term time variations". *Radiation Measurements* **23**(2-3): pp497-500.

Singhvi, A.K. and Porat, N., (2008). "Impact of luminescence dating on geomorphological and palaeoclimate research in drylands". *Boreas* **37**(4): pp536-558.

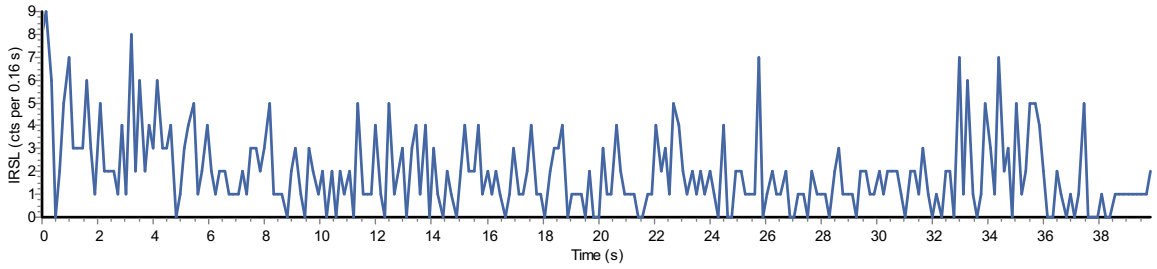
Wintle, A.G. and Murray, A.S., (2006). "A review of quartz optically stimulated luminescence characteristics and their relevance in single-aliquot regeneration dating protocols". *Radiation Measurements* **41**(4): pp369-391.

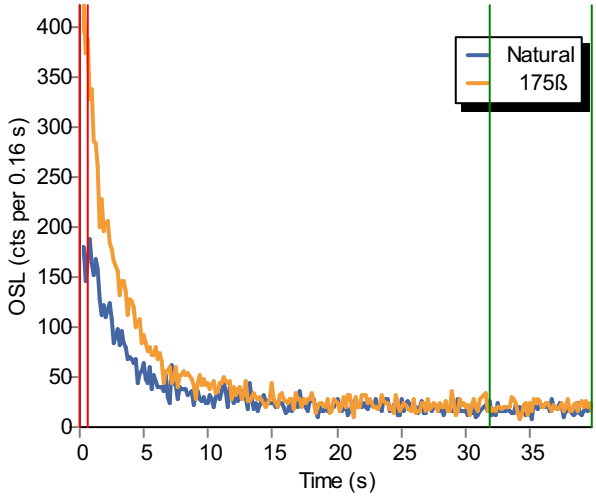
Vermeesch, P. (2009). RadialPlotter: a Java application for fission track, luminescence and other radial plots. *Radiation Measurements*, **44**, 4, 409-410.

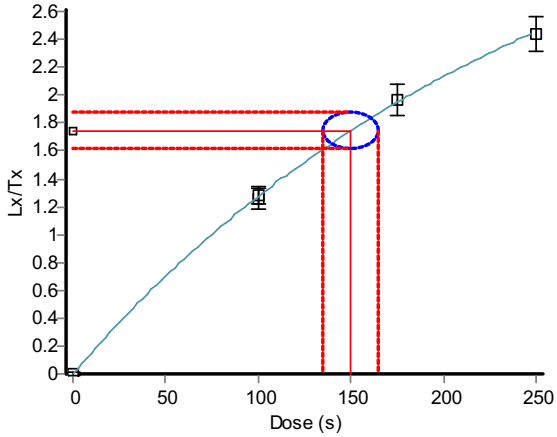
Figure 1. Examples of ISRL test for feldspar (top), typical OSL shine down curves (middle left), regenerative curves (middle right), probability distribution graphs (bottom left [in seconds]) and radial plots (bottom right [in seconds]) and for each dated sample. The probability distribution graphs and radial plots are not provided for samples that were saturated. Units for the probability distribution graphs and radial plots are provided in Grays.

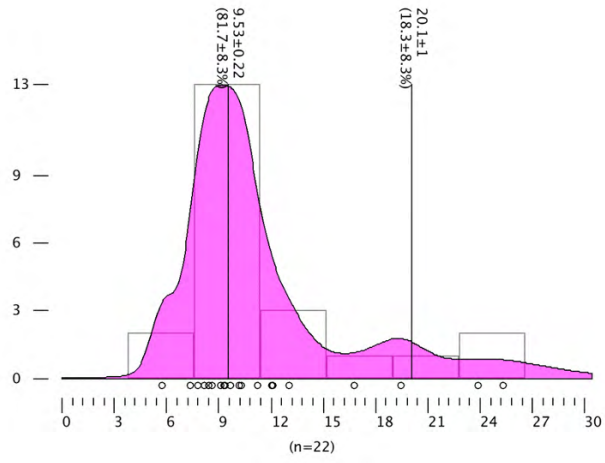


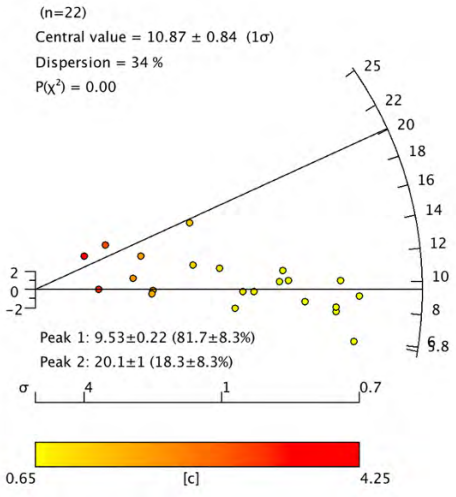
SAMPLE: TP-OSL1











SAMPLE: TP-OSL2

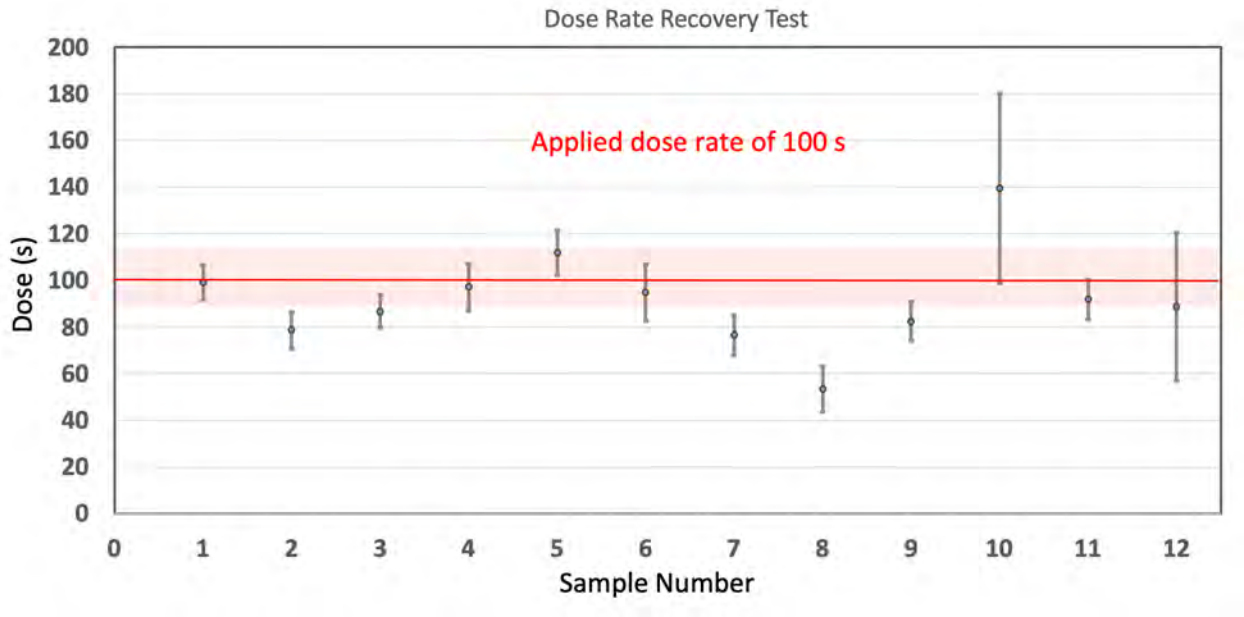


Figure 2. Dose rate recovery test for sample TP-OSl1 (1 through 6) and TP-OSL2 (7 through 12).

Table 1: Summary of OSL dating results for samples from extracted from sediment, sample locations, radioisotopes concentrations, moisture contents, total dose-rates, D_E estimates and optical ages. Preferred ages are shown in bold.

Sample number	Location (ºN/ºW)	Altitude (m asl)	Depth (cm)	U[a] (ppm)	Th[a] (ppm)	K[a] (%)	Rb[a] (ppm)	Cosmic[b, c] (Gy/ka)	Dose-rate[b, c, d] (Gy/ka)	n[e]	Average equivalent dose[f] (Gy)	Weighted average equivalent dose[h] (Gy)	2-mixed model equivalent dose[i] (Gy)	Average OSL Age[f,j,] (ka)	Weighted average OSL Age[h,j] (ka)	2-mixing model OSL Age[h,i,j] (ka)
TP-OSL1	34.1413/ 117.3654	412	152	2.0	12.1	2.1	87	0.18±0.02	3.25±0.21	19(30) [84%]	12.17±0.90	10.72±0.23	10.83±0.25 (29%)	3.7±0.4	3.3±0.2	**3.3±0.2**
TP-OSL2	34.1414/ 117.3654	410	341	2.1	10.3	2.1	84	0.13±0.02	3.12±0.20	22(30) [82%]	11.70±1.10	9.49±0.21	9.53±0.22 (34%)	3.7±0.4	3.0±0.2	**3.1±0.2**

[a] Elemental concentrations from ICP-MS of whole sediment measured at Activation Laboratories Limited Ancaster, Ontario Canada.

[b] Estimated fractional day water content for whole sediment is taken as 10% and with an uncertainty of ± 5%.

[c] Estimated contribution to dose-rate from cosmic rays calculated according to Prescott and Hutton (1994). Uncertainty taken as ±10%.

[d] Total dose-rate from beta, gamma and cosmic components. Beta attenuation factors for U, Th and K compositions incorporating grain size factors from Mejdahl (1979). Beta attenuation factor for Rb is taken as 0.75 (cf. Adamiec and Aitken, 1998). Factors utilized to convert elemental concentrations to beta and gamma dose-rates from Adamiec and Aitken (1998) and beta and gamma components attenuated for moisture content. Dose rates calculation was confirmed using the Dose Rate and Age Calculator (DRAC) of Duncan et al. (2015).

[e] Number of replicated equivalent dose (D_E) estimates used to calculate D_E. These are based on recuperation error of < 10%. The number in the parentheses is the total measurements made including failed runs with unusable data. The number in square parentheses is the percentage of aliquots used for minimum age 2-mixing model.

[f] Average equivalent dose (D_E) determined from replicated single-aliquot regenerative-dose (SAR; Murray and Wintle, 2000) runs. The uncertainty is the standard error and includes an uncertainty from beta source estimated of ±2.5%.

[h] Weighted average equivalent dose (D_E) determined from replicated single-aliquot regenerative-dose (SAR; Murray and Wintle, 2000) runs. The uncertainty is the standard error and includes an uncertainty from beta source estimated of ±2.5%.

[i] Age based on minimum population in 2-mixing model using the program of Vermeesch (2009). Values in parentheses are the dispersion of the aliquots.

[j] Uncertainty incorporate all random and systematic errors, including dose rates errors and uncertainty for the D_E.

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Project: **Tetra Tech- Lytle Creek/San Jacinto fault zone - Rialto, CA**
Client Contact: **Bryan Petry**
Date: **April 13 2021**
Report by: **Nate Onderdonk (nate.onderdonk@csulb.edu)**

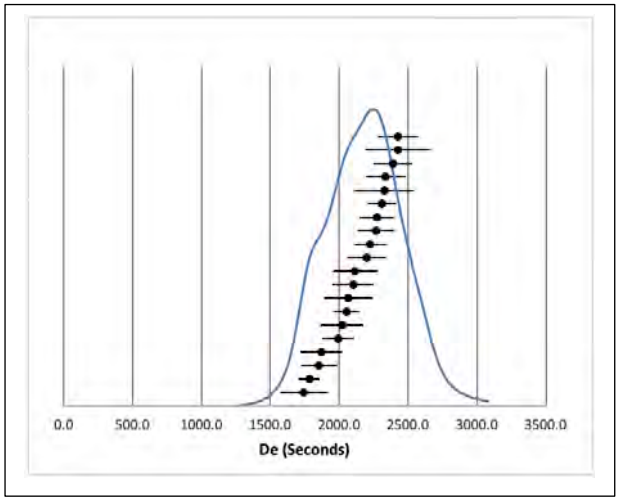
Results

Sample	**Elemental Concentrations** from Activation Laboratories, Ontario, Canada			**Measured Water Content**	**Dose Rate (Gy/ka)** Using $H_20\%$ Max= 20 Min= 2		**Equivalent Dose and Error** Central Age Model		**Number of Aliquots**	**Age (Ka)**	**Error (Ka)**
	K (%)	U (ppm)	Th (ppm)	$H_20\%$	Max	Min	E_d (sec)	Error (sec)			
OSL3	2.67	1.80	10.7	2.62	5.53	4.54	2170	51	22	**36.6**	**4.4**
OSL8	2.59	1.40	8.2	2.81	4.87	4.01	1477	23	22	**28.6**	**3.2**
OSL10	2.79	1.50	8.3	2.38	5.12	4.28	2269	57	21	**41.4**	**5.1**

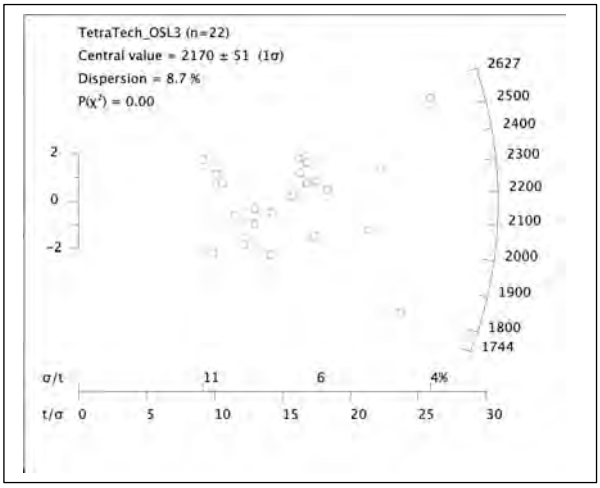
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Equivalent dose analyses

Sample OSL3



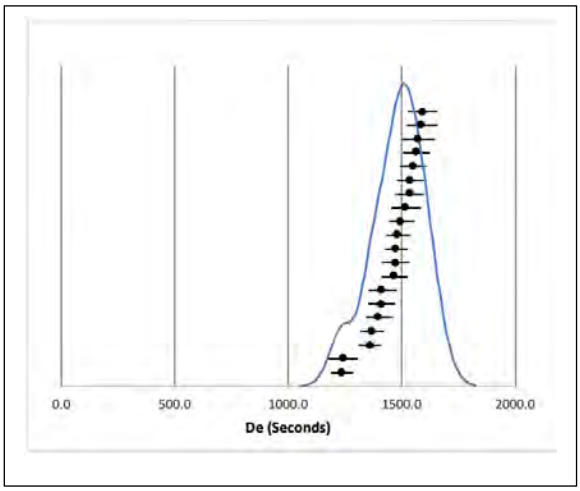
PDF plot of aliquot Equivalent Dose in seconds



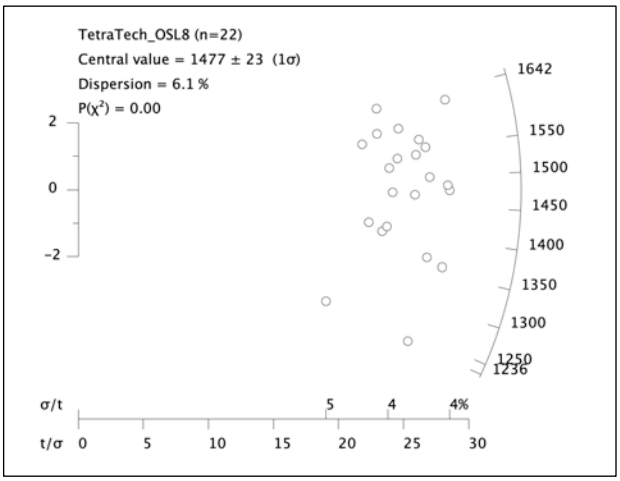
Radial plot of aliquot Equivalent Dose in seconds

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Sample OSL8



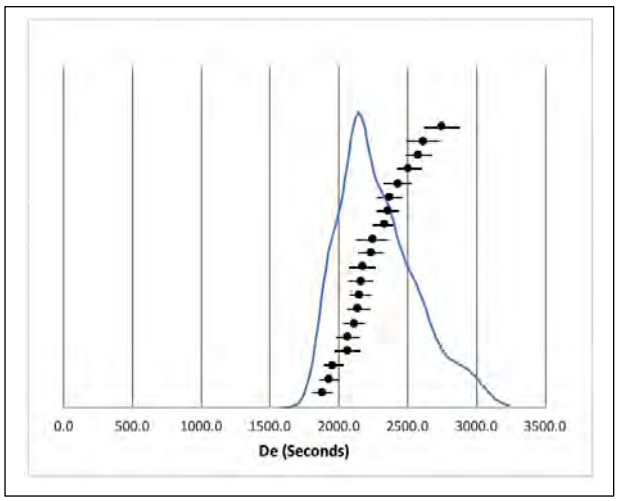
PDF plot of aliquot Equivalent Dose in seconds



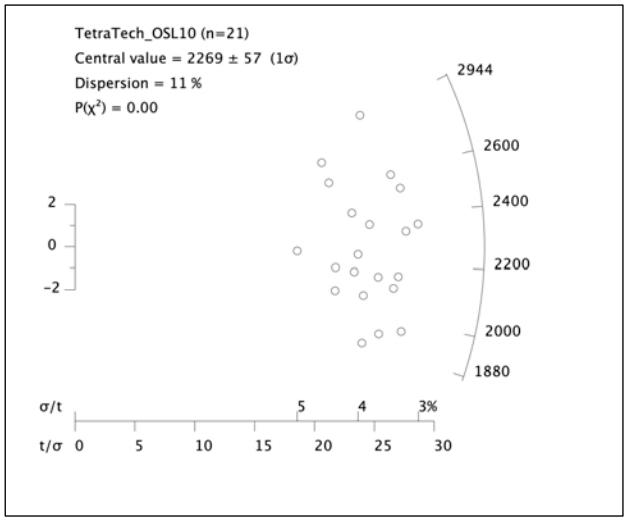
Radial plot of aliquot Equivalent Dose in seconds

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Sample OSL10



PDF plot of aliquot Equivalent Dose in seconds



Radial plot of aliquot Equivalent Dose in seconds

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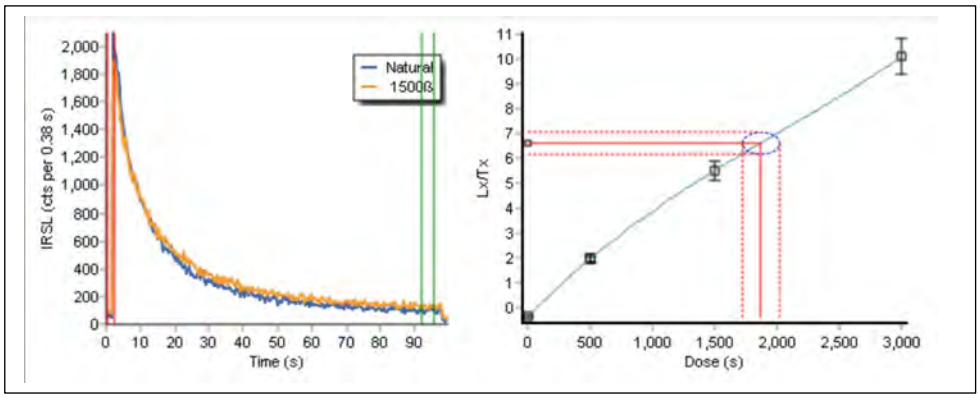
Methodology

Samples were delivered to CSULB in capped and sealed metal pipes. Samples were opened and prepared under orange-light conditions in the CSULB Luminescence lab dark room. Preparation involved disaggregation, treatment to remove carbonates and organic material from the samples, and grain size separation to isolate the 1 to 8 micron component for fine-grain polymineral analysis.

We used the pIR-IRSL (post infrared- infrared stimulated luminescence) protocol from Rhodes (2011) to measure the infrared luminescence signal of multiple grains and determine burial age of the sample. The pIR-IRSL protocol eliminates the anomalous fading problem that often affected previous IRSL protocols.

Multi-grain single-aliquot regenerative dose protocol (SAR) was used for equivalent dose determination. Each sample was divided into 24 aliquots. Two aliquots from each sample were used for preliminary equivalent dose measurements, followed by 20 to 22 aliquots for detailed equivalent dose determination. Equivalent dose is calculated for each aliquot based on the measured natural energy release and a sensitivity/repeatability correction that consists of repeated laboratory doses to the aliquot at 5 different levels; below, at, and above the estimated equivalent dose, along with a zero dose and a repeated dose to confirm stability of the signal (see example below from OSL3, aliquot 3). Probability Density Function and Radial plots were generated to display statistics of the aliquots for each sample and to calculate the equivalent dose measurements. Equivalent dose values for each sample were determined from the aliquot data

using a Central Age Model (Galbraith and Roberts, 2012; Kars et al., 2012). Equivalent dose values are determined in seconds of irradiation time by a $^{90}Sr/^{90}Y$ beta radiation source in the Risø OSL reader. Errors are reported in 1 sigma.



Example of a radiation curve (left) and regenerative interpretation of equivalent dose (right) for an aliquot from OSL3

Measurements of the radioactive contents of the sampled material (concentrations of K, U, Th) were provided by Tetra Tech and determined by Activation Laboratories in Ontario, Canada. Dose rates were determined using the concentrations of these elements along with the sample depth and altitude provided by Tetra Tech, and the full range of possible moisture content history. Moisture contents were determined in the lab, but we use a range of moisture content to better approximate changes in moisture content over the life of the samples, primarily to take into account wetter conditions during late Pleistocene time.

Equivalent dose measurements are translated from seconds of equivalent dose (Sec) to Grays (Gy) according to the machine radiation source rate, which was 0.084 Gy/Sec at the time of analysis. Sample ages were then determined by dividing the range in dose rates by the range in equivalent dose. Errors in sample ages represent the full range of possible age based on equivalent dose error and dose rate maximum and minimum.

Optically Stimulated Luminescence Dating of Quaternary Sediments

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Background

Optically Stimulated Luminescence (OSL) dating determines the time elapsed since a sediment sample was last exposed to daylight (Aitken, 1998). The method relies on the interaction of ionizing radiation with electrons in semi-conducting minerals within buried sediment, which results in metastable accumulation of charge. Illumination of the sediment releases the charge as a measurable emission of photons (luminescence). The methods assume that mineral grains during or immediately prior to the transport were exposed to daylight to set them to their geological zero residual level. Upon burial, day light exposure ceases and essentially the luminescence signal begins to accumulate due to the radiation arising from the decay of ambient radioisotopes that include U, Th, Rb and K, and from cosmic rays. Given that, as a first approximation, the radiation exposure (dose rate - D_R) is constant over the timescales of interest, luminescence builds up (equivalent dose - D_E) in the minerals in proportion to the duration of burial and the concentration of the radioisotopes in the sample environment and the cosmic dose. The depositional age (A) of the sample is thus a ratio of luminescence acquired and the rate of luminescence acquisition, i.e., $A=D_E/D_R$ (Aitken, 1998; Murray and Olley, 2002; Singhvi and Porat, 2008).

Preparation and measurement

The sediment samples were prepared for feldspar post-IR IRSL dating. The samples were provided in steel tubes. The samples were opened in the Luminescence Dating Laboratory at the North Carolina State University under safe light conditions. Approximately 150 g of sediment was removed from ends of each tube and was dried to determine the water content for each sample. The sediment was then crushed and sent to the Activation Laboratories Limited in Ancaster, Ontario, Canada for Major Elements Fusion ICP/MS/Trace Elements analysis to determine the U, Th and K concentrations for D_R calculations (Table 1).

The reminding sediment was pretreated with 10% HCl and 10% H_2O_2 to remove carbonates and organic matter, respectively. The pretreated samples were rinsed in water, dried and sieved to attract the 150–250 μm particle size fraction. A sub-fraction (~20 g) of sample was etched using

10% HF acid for 10 minutes to remove the outer alpha irradiated layer from quartz particles. Any fluorides precipitated during HF treatment were removed using 17% HCl for 45 min. The sample was then rinsed in distilled water. Next, a low field-controlled Frantz isodynamic magnetic separator (LFC Model-2) was used to separate non-magnetic minerals following the methods of Porat (2006). Density separation using lithium polytungstate (LST) at densities of 2.565, 2.58, 2.62, 2.68 was used to extract K-feldspar at a density of 2.565-2.58. The samples were then sieved using a 150 μm mess to remove any grains smaller than 90 μm, so that the 150–250 μm could be used for IRSL measurements.

An automated Riso OSL reader model TL-DA-20 was used for OSL measurements and irradiation. Aliquots, containing approximately several hundred grains of the samples, were mounted onto ~ 6 mm-diameter stainless steel discs as a central circle ~ 4 mm in diameter. Aliquots of samples were illuminated with IR LEDs stimulating at a wavelength of 830 nm (infrared stimulated luminescence – IRSL). The detection optics comprised Hoya U-340 and Schott BG-39 color glass filters coupled to an EMI 9235 QA photomultiplier tube. The samples were irradiated using a $^{90}Sr/^{90}Y$ beta source. The single aliquot regeneration (SAR) method of (Murray and Wintle, 2000, 2003) was used to determine the D_E for age estimation. Only aliquots that satisfy the criterion of a recycling ratio not more than 10% were used in determining D_E. A preheat of preheat 250°C for 60s and 159 stimulation temperatures of 50°C and 225°C. IRSL sensitivity of the samples had a very high signal to noise ratio. The samples were tested for the presence of anomalous thermal fading (Huntley and Lamothe, 2001) for timescales ranging from ~300 seconds to 1 day.

Results

Table 1 presents the radioisotope, water content, and cosmic dose, D_R, D_E and age for the samples. Dose rate calculations follows the details highlighted in the footnotes of Table 1 and confirmed using the Dose Rate and Age Calculator (DRAC) of Duncan et al. (2015). Dose rates for samples were 4.1±0.3 and 3.6±0.3 Gy/ka, which is within the normal range for terrestrial sediments. The Th/U is consistent with the expected values suggesting that leaching has not been a significant problem at the sites. For the water content, we assumed a conservative value with a large uncertainty (10±5%) to reflect possible changes in water content over the geologic history,

especially accounting for wetter glacial times in the past and drying out of the trench faces during excavation and sampling.

The natural IRSL signal for all aliquots a several magnitudes greater than the background signal. Examples of "shine down" curves for the samples are shown in Figure 1. Figure 1 also shows examples of the regenerative curves, illustrating good growth and recuperation. None of the samples showed fading and no correction was needed (e.g., Buylaert et al., 2009; Figure 2).

The spread of D_E varied between samples and are shown in Figure 1. The spread of D_E values for each sample has a dispersion >20%, so a two-mixing age model using the radial plotter of Vermeesch (2009) was applied and the minimum peak distribution is used to calculate the ages (minimum age model). The average and weighted average ages are also presented for reference and statically they are identical to the minimum age model (Table 1). The weighted average age skews the ages towards a younger age because aliquots with low D_E values have lower associated uncertainties. The preferred age for FT1-OSL4 is 19.9±1.4 ka and FT1-OSL7 is 19.4±1.5 ka and are highlighted in bold in Table 1.

References

Aitken, M.J., (1998). An introduction to Optical dating: The Dating of Quaternary Sediments by the Use of Photon-stimulated Luminescence. Oxford University press, USA, New York, 280 pp.

Buylaert, J. P., Murray, A. S., Thomsen, K. J., & Jain, M. (2009). Testing the potential of an elevated temperature IRSL signal from K-feldspar. *Radiation Measurements* **44**, 560–565.

Duncan, J.A., King, G.E., Duller, G.A.T. (2015) DRAC: Dose Rate and Age Calculator for trapped charge dating. *Quaternary Geochronology* **28**, 54-61

Huntley, D., & Baril, M. (1997). The K content of the K-feldspars being measured in optical dating or in thermoluminescence dating. *Ancient TL*, **15**, 11–13.

Huntley, D. J., & Lamothe, M. (2001). Ubiquity of anomalous fading in K-feldspars and the measurement and correction for it in optical dating. *Canadian Journal of Earth Sciences* **1106**, 1093–1106.

Jain, M., Choi, J.H. and Thomas, P.J., (2008). The ultrafast OSL component in quartz: Origins and implications. *Radiation Measurements* **43,** 709-714.

Murray, A.S. and Olley, J.M., (2002). Precision and accuracy in the optically stimulated luminescence dating of sedimentary quartz: a status review. *Geochronometria* **21**, 11-16.

Murray, A.S. and Wintle, A.G., (2000). Luminescence dating of quartz using an improved single-aliquot regenerative-dose protocol. *Radiation Measurements* **32,** 57-73.

Murray, A.S. and Wintle, A.G., (2003). The single aliquot regenerative dose protocol: potential for improvements in reliability. *Radiation Measurements* **37**, 377-381.

Porat, N., (2006). Use of magnetic separation for purifying quartz for luminescence dating. *Ancient TL* **24**(2): pp33-36.

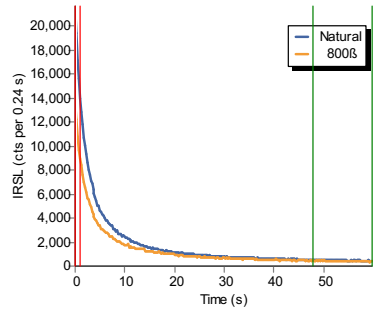
Prescott, J.R. and Hutton, J.T., (1994). Cosmic ray contributions to dose rates for luminescence and ESR dating: Large depths and long-term time variations. *Radiation Measurements* **23**, 497-500.

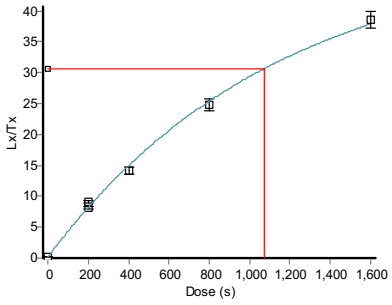
Singhvi, A.K. and Porat, N., (2008). Impact of luminescence dating on geomorphological and palaeoclimate research in drylands. *Boreas* **37**, 536-558.

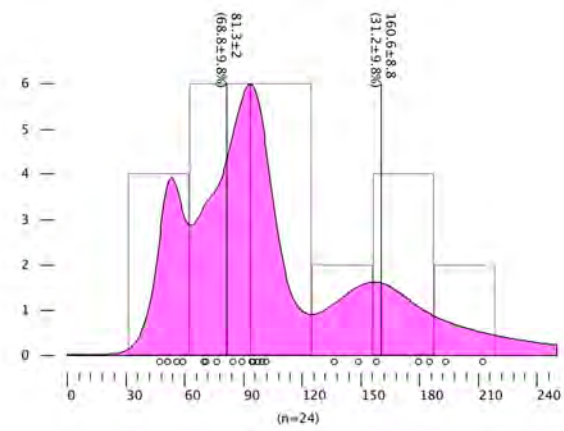
Wintle, A.G. and Murray, A.S., (2006). A review of quartz optically stimulated luminescence characteristics and their relevance in single-aliquot regeneration dating protocols. *Radiation Measurements* **41**, 369-391.

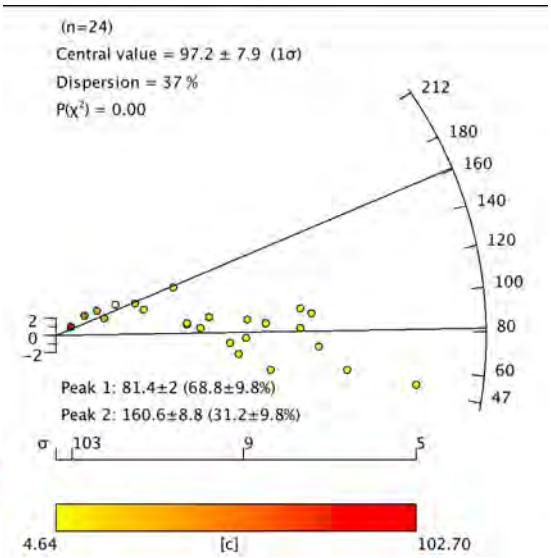
Vermeesch, P. (2009). RadialPlotter: a Java application for fission track, luminescence and other radial plots. *Radiation Measurements*, **44**, 409-410.

Figure 1. Examples of typical OSL shine down curves (middle left), regenerative curves (middle right), probability distribution graphs (bottom left [in seconds]) and radial plots (bottom right [in seconds]) and for each dated sample. The probability distribution graphs and radial plots are not provided for samples that were saturated. Units for the probability distribution graphs and radial plots are provided in Grays.

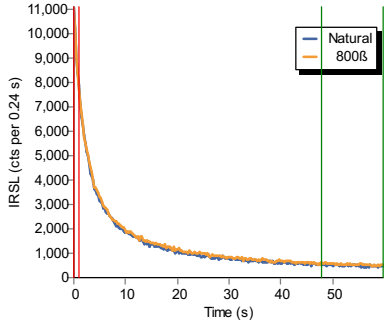


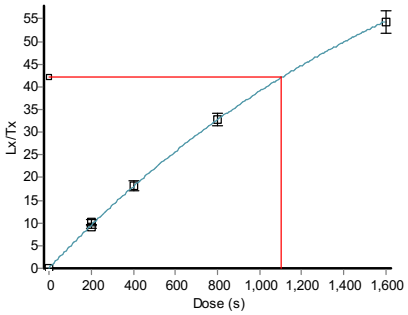


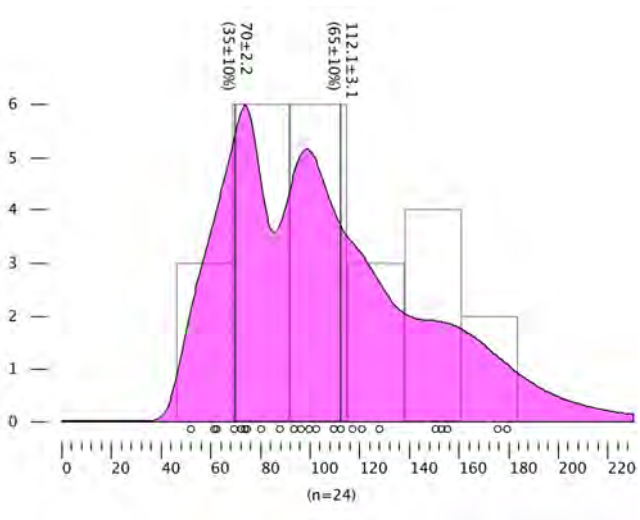


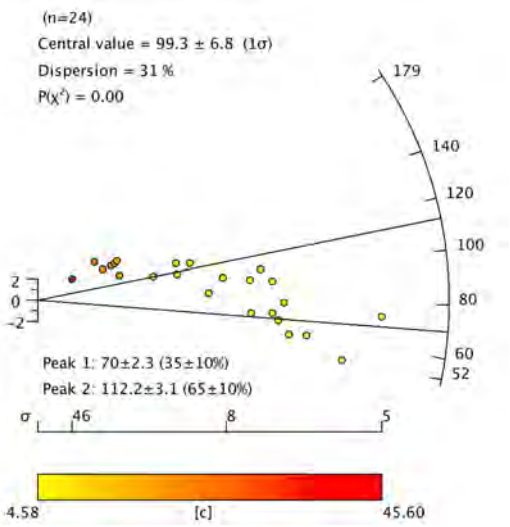


SAMPLE: TP-OSL 1









SAMPLE: TP-OSL2

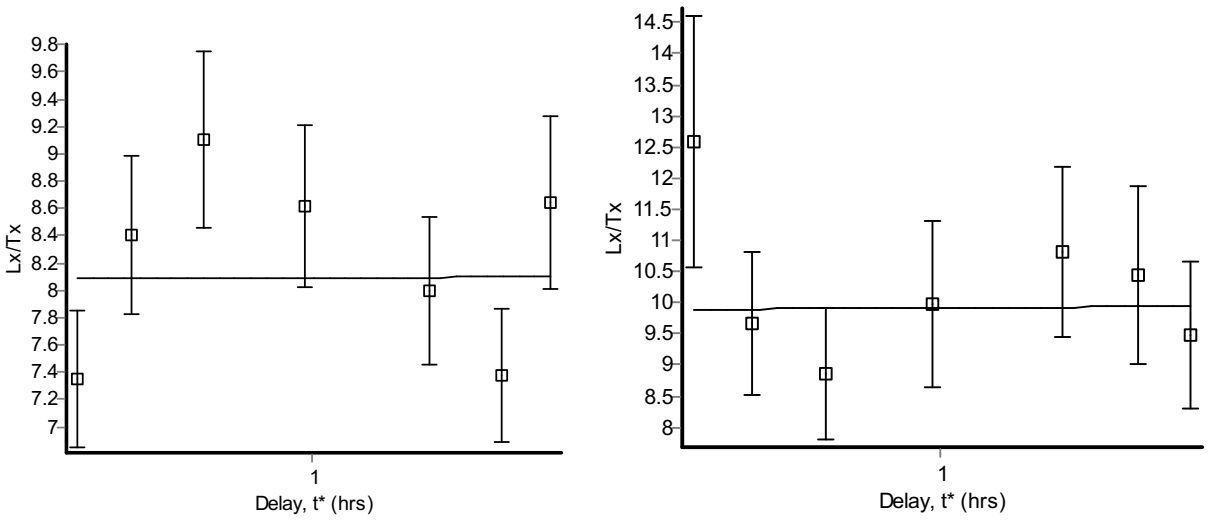


Figure 2. Examples of fading test for A) OSL 4 (g-value = -0.07+/-3.78) and B) OSL 4 (g-value -0.27+/-7.55) plotted on a long scale of time.

Table 1: Summary of post IR-IRSL dating results for samples from extracted from sediment, sample locations, radioisotopes concentrations, moisture contents, total dose-rates, D_E estimates and ages. Preferred ages are shown in bold.

Sample number	Location (°N/°W)	Altitude (m asl)	Depth (cm)	U[a] (ppm)	Th[a] (ppm)	K[a] (%)	Rb[a] (ppm)	Cosmic[b, c] (Gy/ka)	Dose-rate[b, c, d] (Gy/ka)	n[e]	Average equivalent dose[f] (Gy)	Weighted average equivalent dose[h] (Gy)	2-mixed model equivalent dose[i] (Gy)	Average Age[f,j,] (ka)	Weighted average Age[h,j] (ka)	2-mixing model Age[h,i,j] (ka)
FT1-OSL4	34.1406/ 117.3646	414	491	2.2	11.3	2.2	97	0.13±0.01	4.09±0.27	24(30) [37%]	107.30±9.87	77.62±1.88	81.40±2.00 (29%)	26.2±3.0	19.0±1.3	**19.9±1.4**
FT1-OSL7	34.1427/ 117.3646	409	454	1.7	9.3	1.9	88	0.13±0.01	3.60±0.26	24(30) [31%]	107.42±7.67	81.69±1.67	70.00±2.30 (34%)	29.8±3.0	22.7±1.7	**19.4±1.5**

[a] Elemental concentrations from ICP-MS of whole sediment measured at Activation Laboratories Limited Ancaster, Ontario Canada.

[b] Estimated fractional day water content for whole sediment is taken as 10% and with an uncertainty of ± 5%.

[c] Estimated contribution to dose-rate from cosmic rays calculated according to Prescott and Hutton (1994). Uncertainty taken as ±10%.

[d] Total dose-rate from beta, gamma and cosmic components. Beta attenuation factors for U, Th and K compositions incorporating grain size factors from Mejdahl (1979). Beta attenuation factor for Rb is taken as 0.75 (cf. Adamiec and Aitken, 1998). Internal 12.5±0.5 wt% is assumed for internal K using Huntley and Baril (1997). Factors utilized to convert elemental concentrations to beta and gamma dose-rates from Adamiec and Aitken (1998) and beta and gamma components attenuated for moisture content. Dose rates calculation was confirmed using the Dose Rate and Age Calculator (DRAC) of Duncan et al. (2015).

[e] Number of replicated equivalent dose (D_E) estimates used to calculate D_E. These are based on recuperation error of < 10%. The number in the parentheses is the total measurements made including failed runs with unusable data. The number in square parentheses is the percentage of aliquots used for minimum age 2-mixing model.

[f] Average equivalent dose (D_E) determined from replicated single-aliquot regenerative-dose (SAR; Murray and Wintle, 2000) runs. The uncertainty is the standard error and includes an uncertainty from beta source estimated of ±2.5%.

[h] Weighted average equivalent dose (D_E) determined from replicated single-aliquot regenerative-dose (SAR; Murray and Wintle, 2000) runs. The uncertainty is the standard error and includes an uncertainty from beta source estimated of ±2.5%.

[i] Age based on minimum population in 2-mixing model using the program of Vermeesch (2009). Values in parentheses are the dispersion of the aliquots.

[j] Uncertainty incorporate all random and systematic errors, including dose rates errors and uncertainty for the D_E.

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Department of Geological Sciences
California State University, Long Beach
1250 Bellflower Blvd., Long Beach, CA, 90840

Project: **TetraTech**
Client Contact: **Bryan Petry**
Date: **October 7 2021**
Report by: **Nate Onderdonk (nate.onderdonk@csulb.edu)**

Summary

This report contains results from luminescence dating of three samples provided by Tetra Tech from a fault trenches at Vulcan Materials in Rialto, CA. The Results section below presents a table of the calculated ages, followed by PDF and radial plots of the data for each sample. This is followed by a Methods section that outlines the methods used in the determination of the burial ages of the samples.

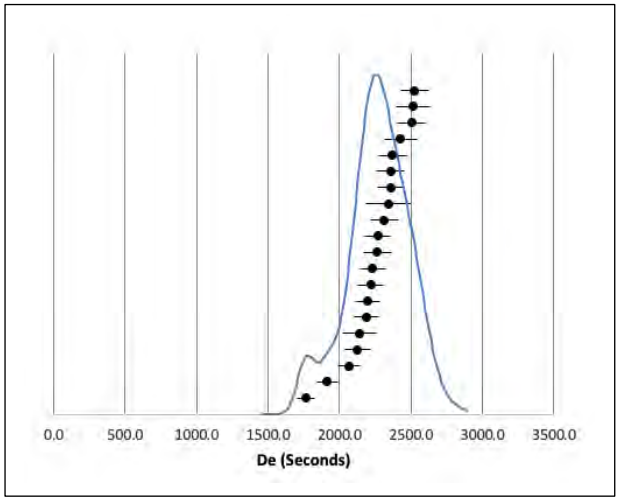
Results

Sample	**Elemental Concentrations** from Activation Labs, Canada			**Measured Water Content** from sampling tube	**Dose Rate (Gy/ka)** Using $H_20\%$ Max= 20 Min= 2		**Equivalent Dose and Error** Central Age Model		**Number of Aliquots**	**Age (ka)**	**Error (ka)**
	K (%)	U (ppm)	Th (ppm)	$H_20\%$	Max	Min	E_d (sec)	Error (sec)			
OSL-11	2.26	2.6	18.2	2.3	5.95	4.8	2254	46	21	**35**	**4.2**
OSL-13	2.15	2.17	24.1	2.15	7.04	5.7	1671	45	21	**22**	**2.9**
OSL-15	1.57	2.55	23.8	1.6	7.8	6.4	1740	66	22	**20.6**	**2.8**

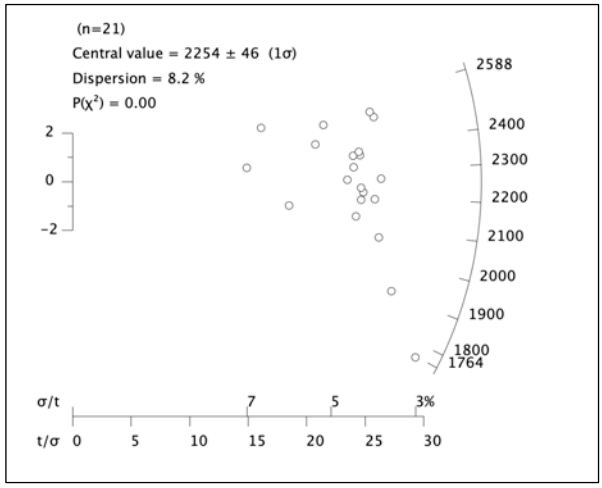
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Equivalent dose analyses

Sample OSL-11



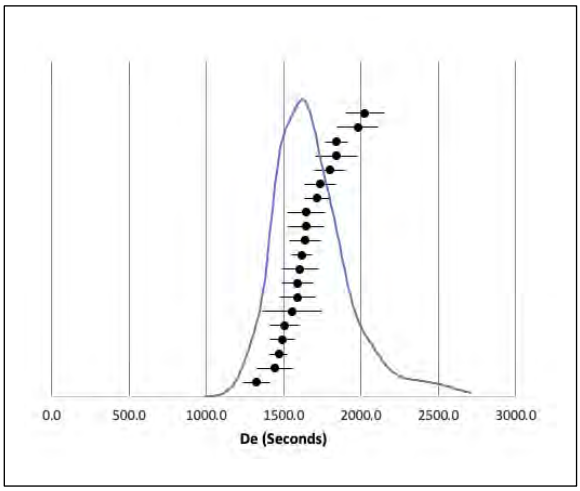
PDF plot of aliquot Equivalent Dose in seconds



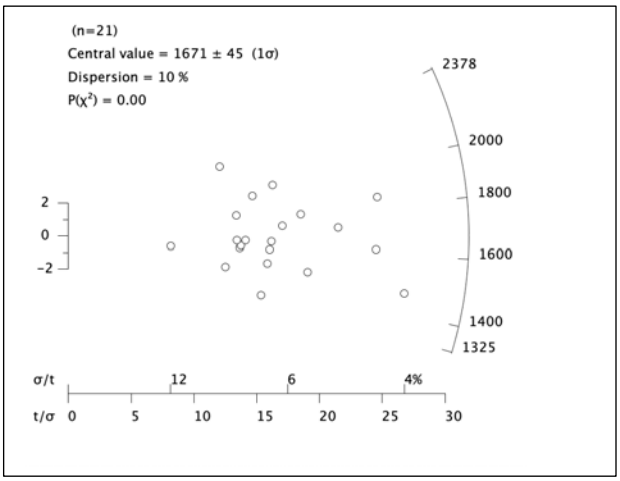
Radial plot of aliquot Equivalent Dose in seconds

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Sample OSL-13



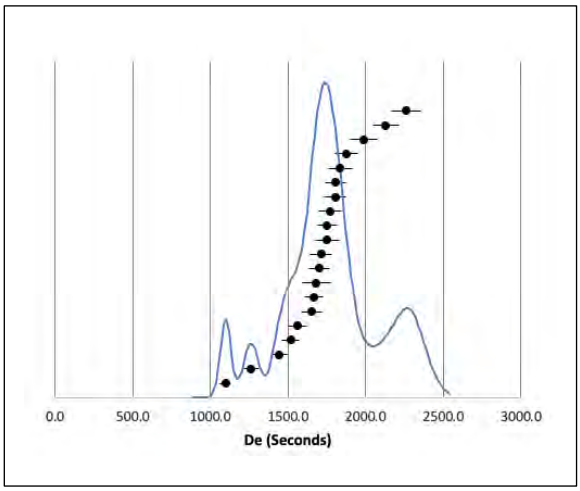
PDF plot of aliquot Equivalent Dose in seconds



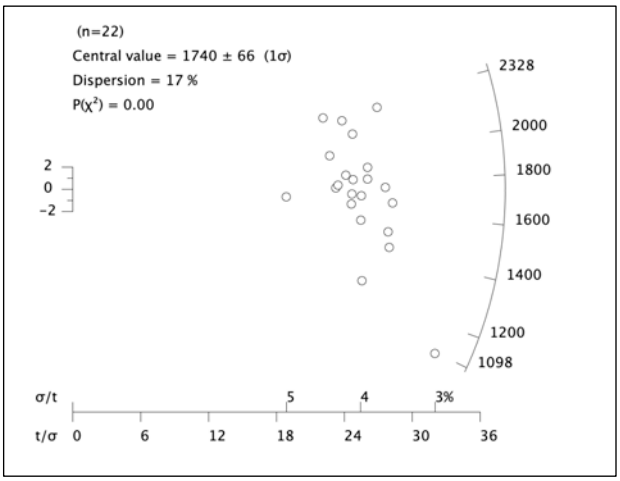
Radial plot of aliquot Equivalent Dose in seconds

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Sample OSL-15



PDF plot of aliquot Equivalent Dose in seconds



Radial plot of aliquot Equivalent Dose in seconds

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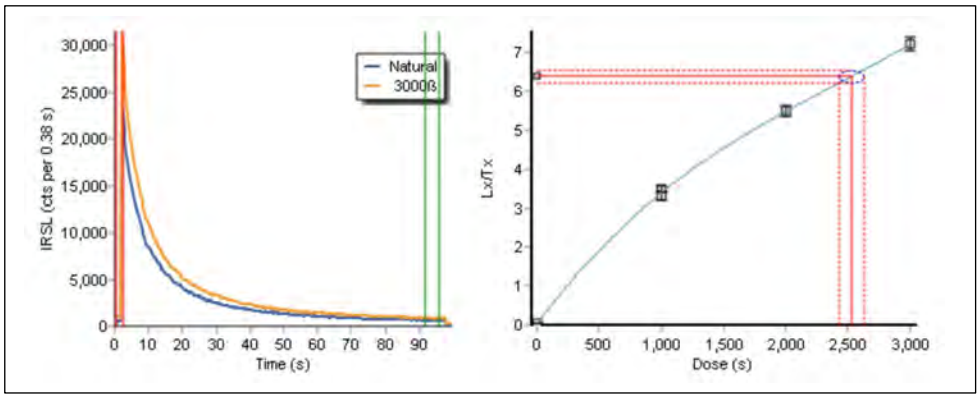
Methodology

Samples were delivered to CSULB in capped and sealed metal pipes. Samples were opened and prepared under orange-light conditions in the CSULB Luminescence lab dark room. Preparation involved disaggregation, treatment to remove carbonates and organic material from the samples, and grain size separation to isolate the 1 to 8 micron component for fine-grain polymineral analysis.

We used the pIR-IRSL (post infrared- infrared stimulated luminescence) protocol from Rhodes (2011) to measure the infrared luminescence signal of multiple grains and determine burial age of the sample. The pIR-IRSL protocol eliminates the anomalous fading problem that often affected previous IRSL protocols.

Multi-grain single-aliquot regenerative dose protocol (SAR) was used for equivalent dose determination. Each sample was divided into 24 aliquots. Two aliquots from each sample were used for preliminary equivalent dose measurements to determine the approximate equivalent dose range (in seconds of irradiation). This was followed by a refined sequence applied to 21- 22 aliquots for detailed equivalent dose determination. Equivalent dose is calculated for each aliquot based on the measured natural energy release and a sensitivity/repeatability correction that consists of repeated laboratory doses to the aliquot at 5 different levels; below, at, and above the estimated equivalent dose, along with a zero dose and a repeated dose to confirm stability of the signal (see example below from OSL-11, aliquot 18). Probability Density Function and Radial plots were generated to display statistics of the aliquots for each sample and to calculate the equivalent dose. Equivalent dose values for each sample were determined from the aliquot data

using a Central Age Model from a radial plot (Galbraith and Roberts, 2012; Kars et al., 2012). Equivalent dose values are determined in seconds of irradiation time by a $^{90}Sr/^{90}Y$ beta radiation source in the Risø OSL reader. Errors are reported in 1 sigma.



Example of a radiation curve (left) and regenerative interpretation of equivalent dose (right) for an aliquot from OSL-11

Measurements of the radioactive contents of the sampled material (concentrations of K, U, Th) were provided by Tetra Tech (from Activation Labs). Dose rates were determined using the concentrations of these elements along with the sample depth and altitude provided by Tetra Teach, and the full range of possible moisture content history. Moisture contents were determined in the lab, but we use a range of moisture content (2% to 20%) to account for possible changes in moisture content over the life of the samples.

Equivalent dose measurements are translated from seconds of equivalent dose (Sec) to Grays (Gy) according to the machine radiation source rate, which was 0.083 Gy/Sec at the time of analysis. Sample ages were then determined by dividing the range in dose rates by the range in equivalent dose. Errors in sample ages represent the full range of possible age based on equivalent dose error and dose rate maximum and minimum.

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Project: **TetraTech**
Client Contact: **Bryan Petry**
Date: **March 9 2022**
Report by: **Nate Onderdonk (nate.onderdonk@csulb.edu)**

Summary

This report contains results from luminescence dating of two samples provided by Tetra Tech from fault trenches at Vulcan Materials in Rialto, CA. The Results section below presents a table of the calculated ages, followed by PDF and radial plots of the data for each sample. This is followed by a Methods section that outlines the methods used in the determination of the burial ages of the samples.

Results

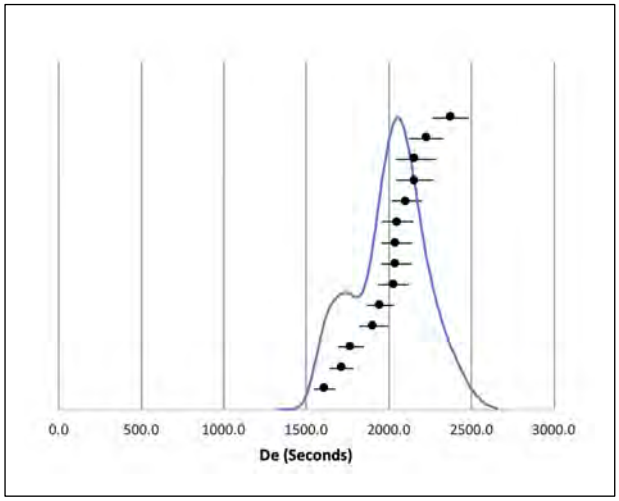
Sample	**Elemental Concentrations** from Activation Labs, Canada			**Measured Water Content** from sampling tube	**Dose Rate (Gy/ka)** Using $H_20\%$ Max= 20 Min= 2		**Equivalent Dose and Error** Central Age Model		**Number of Aliquots**	**Age (ka)**	**Error (ka)**
	K (%)	U (ppm)	Th (ppm)	$H_20\%$	Max	Min	E_d (sec)	Error (sec)			
OSL-17	*2.33*	*3.5*	*22*	2.3	*8*	*5*	1996	56	14	**26.8**	**7**
OSL-18	*2.33*	*3.5*	*22*	2.15	*8*	*5*	1761	31	14	**23.6**	**5.9**

NOTE: blue italics text= average K, U, Th, and dose rates from previous samples collected at the site

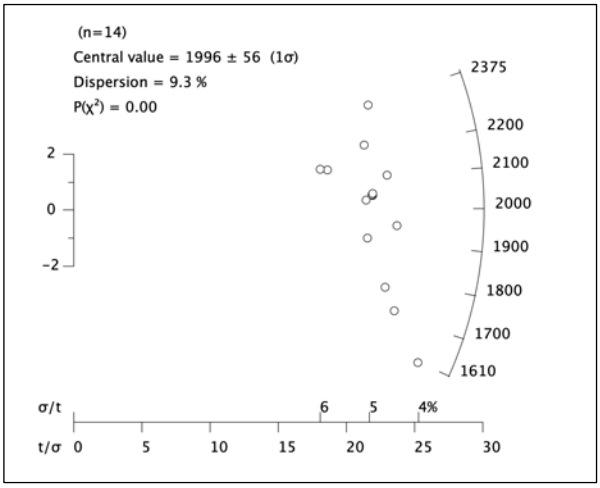
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Equivalent dose analyses

Sample OSL-17



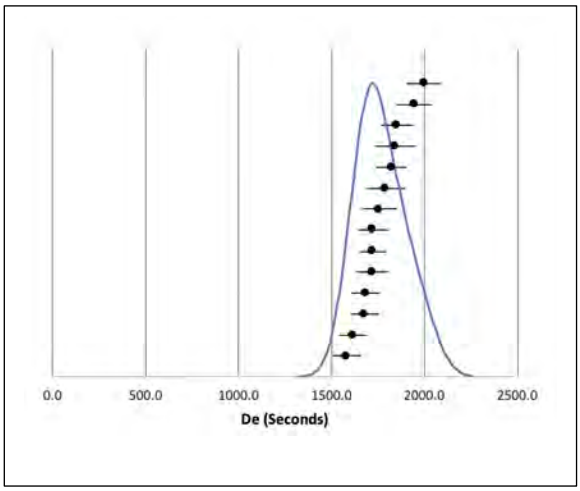
PDF plot of aliquot Equivalent Dose in seconds



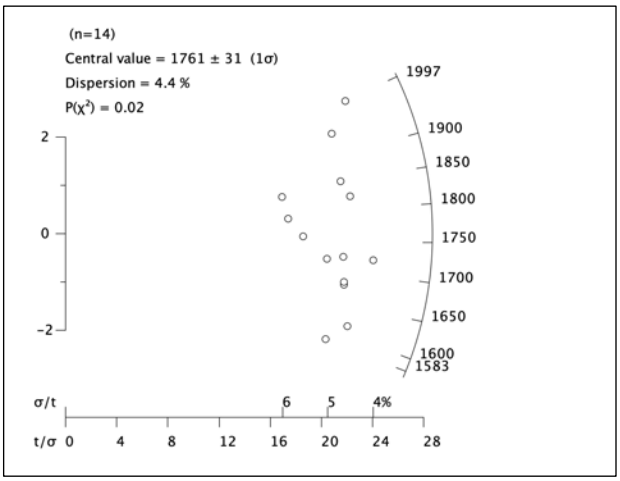
Radial plot of aliquot Equivalent Dose in seconds

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Sample OSL-18



PDF plot of aliquot Equivalent Dose in seconds



Radial plot of aliquot Equivalent Dose in seconds

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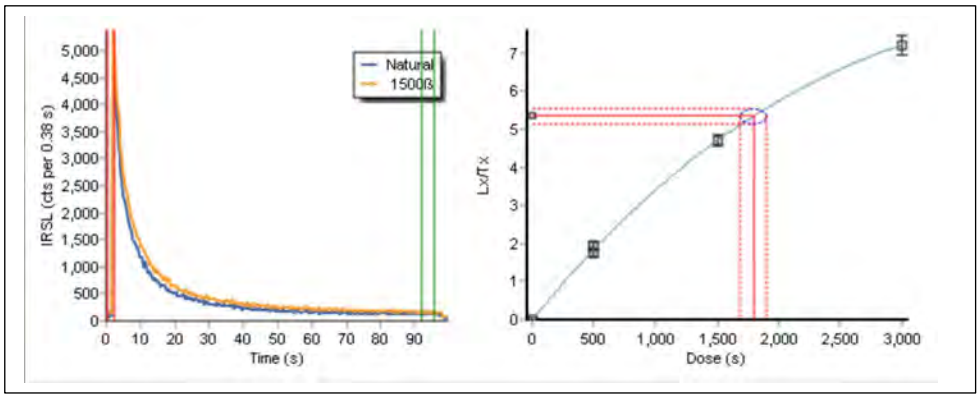
Methodology

Samples were delivered to CSULB in capped and sealed metal pipes. Samples were opened and prepared under orange-light conditions in the CSULB Luminescence lab dark room. Preparation involved disaggregation, treatment to remove carbonates and organic material from the samples, and grain size separation to isolate the 1 to 8 micron component for fine-grain polymineral analysis.

We used the pIR-IRSL (post infrared- infrared stimulated luminescence) protocol from Rhodes (2011) to measure the infrared luminescence signal of multiple grains and determine burial age of the sample. The pIR-IRSL protocol eliminates the anomalous fading problem that often affected previous IRSL protocols.

Multi-grain single-aliquot regenerative dose protocol (SAR) was used for equivalent dose determination. Each sample was divided into 22 aliquots. Two aliquots from each sample were used for preliminary equivalent dose measurements to determine the approximate equivalent dose range (in seconds of irradiation). This was followed by a refined sequence applied to 14 aliquots for detailed equivalent dose determination. Equivalent dose is calculated for each aliquot based on the measured natural energy release and a sensitivity/repeatability correction that consists of repeated laboratory doses to the aliquot at 5 different levels; below, at, and above the estimated equivalent dose, along with a zero dose and a repeated dose to confirm stability of the signal (see example below from OSL-18, aliquot 14). Probability Density Function and Radial plots were generated to display statistics of the aliquots for each sample and to calculate the equivalent dose. Equivalent dose values for each sample were determined from the aliquot data

using a Central Age Model from a radial plot (Galbraith and Roberts, 2012; Kars et al., 2012). Equivalent dose values are determined in seconds of irradiation time by a $^{90}Sr/^{90}Y$ beta radiation source in the Risø OSL reader. Errors are reported in 1 sigma.



Example of a radiation curve (left) and regenerative interpretation of equivalent dose (right) for an aliquot from OSL-18

Measurements of the radioactive contents of the sampled material (concentrations of K, U, Th) were based on previous samples collected from the same deposits at the site. These previous samples were analyzed for concentrations of K, U, Th provided by Activation Labs. Dose rates were determined using the concentrations of these elements along with the sample depth and altitude provided by Tetra Teach, and the full range of possible moisture content history. Moisture contents were determined in the lab, but we use a range of moisture content (2% to 20%) to account for possible changes in moisture content over the life of the samples.

Equivalent dose measurements are translated from seconds of equivalent dose (Sec) to Grays (Gy) according to the machine radiation source rate, which was 0.082 Gy/Sec at the time of analysis. Sample ages were then determined by dividing the range in dose rates by the range in equivalent dose. Errors in sample ages represent the full range of possible age based on equivalent dose error and dose rate maximum and minimum.

Appendix D

Percolation Investigation Report

(Tetra Tech, 2022b)

TETRA TECH

Project No. GEN 19-22E
August 11, 2022

Mr. Dan Darnell
Carson Companies
100 Bayview Circle #3500
Newport Beach, California 92660

Subject: **PERCOLATION INVESTIGATION**
PEPPER 210 COMMERCE CENTER
20080 Highland Avenue
County of San Bernardino, California

References: Fault Investigation Report, Vulcan Aggregate Pit Redevelopment Project, 20080 Highland Avenue, Rialto, California, prepared by Tetra Tech, dated February 28, 2022.

Geotechnical Data and Assessment Report, Vulcan Pit Redevelopment, Rialto, California, prepared by Tetra Tech, dated November 25, 2019.

Dear Mr. Darnell:

This report presents the results of Tetra Tech's field percolation testing performed at various locations within the subject property located at 20080 Highland Avenue, within the County of San Bernardino, California. The purpose of this investigation was to document field percolation test results and provide geotechnical parameters and recommended infiltration rates for the design and construction of both surface and below grade stormwater BMP improvements.

SITE DESCRIPTION AND HISTORY

The site comprises an area of approximately 101 acres and is located north and northwest of the intersection of Highland Avenue and N. Pepper Avenue in unincorporated San Bernardino County, California. The site is roughly triangular and is located within the western flood plain of Lytle Creek, however, it is protected from the current alignment of Lytle Creek Wash by an Army Corps of Engineers flood control levee which bounds the property to the north – northeast. The property is bounded by Highland Avenue to the south and an existing residential development and a new residential development currently under construction to the west (formerly a portion of the El Rancho Verde Country Club and golf course).

The site is currently utilized for the production and sale of construction aggregate, including sand, gravel, aggregate base, and asphalt. Plant operations initiated during the 1950's and initially included open pit mining of the westerly half of the property to depths of up to approximately 50 feet below the original ground surface. We understand that backfilling of the open pits within the property has continued periodically over the decades. A comparison of the topography of historic mining pit bottoms and the 2016 topographic expression of the site is shown on Figure 1. Further deep mining is not anticipated during the remainder of the property lease.

Overall, the site gently slopes to the southeast and drains to various detention basins within the property via graded earth swales with exception of the ponded areas within the central portion of the site.

Ascending slopes up to 58 feet in height border the southwestern perimeter of the site and generally vary from approximately 1.5(H):1(V) to 2(H):1(V) in gradient. The north and east perimeter of the site is bordered by a flood control levee with 2(H):1(V) slopes, rising about 20 feet above the adjacent grades.

PROJECT DESCRIPTION

We understand that pit reclamation grading operations will be initiated upon termination of the current aggregate operations (projected in 2025). At that time, all undocumented fill materials will be removed and replaced as engineered fill in conformance with recommendations provided in a separate geotechnical report for the site.

Based on the conceptual site plan prepared by RGA (undated), the site will be developed with a building with about 1,280,354 square feet of office and warehouse space and truck loading docks along the building perimeter. Other site improvements will include drive aisles, auto and truck parking, underground utilities, decorative flatwork, exterior lighting, and landscaping elements (see Figure 1 – Site Plan and Percolation Test Location Map).

PREVIOUS GEOTECHNICAL AND GEOLOGIC STUDIES BY TETRA TECH

In November of 2019, Tetra Tech completed a geotechnical investigation for the subject property. The purpose of that study was to evaluate the general existing fill conditions, estimate required cut / fill volumes, and provide preliminary geotechnical conclusions and considerations relative to the future site development. As part of that study, 8 exploratory borings were drilled at various locations within the property to depths ranging from about 11.5 to 51.5 feet.

During January 2021 and February 2022, Tetra Tech also completed a comprehensive fault investigation within the subject property. The fault investigation included excavation and logging of 8 exploratory trenches measuring up to about 23 feet below the ground surface and totaling approximately 4,185 lineal feet.

Pertinent subsurface information collected from these studies was utilized to assess the distribution and depths of the existing artificial fill at the site. Additionally, the borings and trenching allowed for an assessment of the soil types, engineering properties, and stratigraphic distribution of the native alluvial soils beneath the site.

FIELD PERCOLATION TESTING

To evaluate the infiltration characteristics of the near surface native alluvial soils and to determine suitable borehole locations for field percolation testing, the limits of the historical mining pit bottoms and areas underlain by more than 10 feet of artificial fill were avoided. Tetra Tech performed 7 borehole falling-head percolation tests denoted as P-1 through P-7 on June 21, 2022,

in accordance with the borehole percolation test procedure described in Appendix D of the Technical Guidance Document for Water Quality Management Plans prepared for the County of San Bernardino Areawide Stormwater Program, dated September 19, 201 (Technical Guidance document). Eight-inch diameter boreholes were drilled utilizing a hollow stem auger drill rig to depths varying from about 9.5 to 10 feet. The approximate locations of the boreholes are presented on Figure 2 – Site Plan and Percolation Test Location Map.

A 3-inch-diameter perforated PVC pipe with 5/8-inch-diameter holes was installed in the percolation borings. The casing was wrapped in a protective cloth filter sock to limit the migration of soil particles into the pipe. The pipe was surrounded by a free-draining gravel pack comprised of 3/8-inch p-gravel.

Percolation boreholes were presoaked to a depth of approximately 5 times the hole radius for at least 1 hour before the test. After the presoak period, an initial water head of approximately 1 foot was introduced above the bottom of the borehole. Percolation testing was then conducted by recording the time required for the borehole to completely empty as monitored by a stopwatch and well sounder. After each reading, the borehole was re-filled and the procedure was repeated. The process was continued until a stabilized drop rate was stabilized. After completion of the percolation testing, the PVC pipes were removed and the boreholes were backfilled with tamped soil cuttings.

The design infiltration rates of the on-site soils, expressed in inches per hour, were then calculated by applying a Factor of Safety, in accordance with Worksheet H of the San Bernardino County Technical Guidance document, to the measured field infiltration rates corrected for the porosity of the gravel. The Factors of Safety reflect:

- Suitability of underlying soils for infiltration
  - soil assessment methods
  - predominant soil texture
  - site soil variability
  - depth to groundwater/impervious layer

- The infiltration system design
  - tributary area size
  - level of pretreatment/expected sediment load
  - redundancy
  - compaction during grading

For this study, a Factor of Safety of 2 was applied to account for site suitability considerations, and a Factor of Safety of 2.5 was applied to account for the infiltration system design considerations, resulting in a combined factor of safety of 5. The calculated infiltration rates of the on-site soils are summarized in Table 1. The percolation test data sheets utilized to determine measured field infiltration rates for each borehole are attached in Appendix A of this report.

Table 1
Summary of Design Infiltration Rates

Percolation Test No.	Approximate Borehole Depth (feet)	Approximate Test Depth Intervals (feet)	Measured Infiltration Rate (inches / hour)	Design Infiltration Rate (inches / hour)
P-1	9.5	8.5 - 9.5	172.7	34.5
P-2	9.0	8.0 – 9.0	113.5	22.7
P-3	9.5	8.5 - 9.5	165.5	33.1
P-4	9.6	8.6 – 9.6	91.3	18.3
P-5	9.6	8.6 – 9.6	40.1	8.0
P-6	9.5	8.5 - 9.5	73.6	14.7
P-7	9.9	8.9 – 9.9	96.9	19.4
Recommended Design Infiltration Rate:				**8.0**

RECOMMENDED DESIGN INFILTRATION RATE AND BMP LOCATIONS

Results of percolation testing indicate that the calculated infiltration rates of the on-site native alluvial soils range from about 34.5 to 8.0 inches per hour. Based on our review of the underlying stratigraphic conditions, the lowest infiltration rate (8.0 in/hr) can likely be attributed to local/isolated sequences of finer-grained alluvial lenses identified within our past borings and exploratory trench exposures. Though the finer-grained / less permeable alluvial lenses are local deposits in comparison to the predominate sand and gravel deposits beneath the site, they occur in an unpredictable distribution and should be considered in the BMP design. Therefore, a design infiltration rate 8.0 inches per hour is recommended for the design of the stormwater BMP's with an invert elevation at approximately 9 to 10 feet below grade of the primary drive aisles within the plant.

As summarized herein, aggregate operations in the past included open pit mining of the westerly half of the property to depths of up to approximately 50 feet below the original ground surface. Areas of the site that are underlain by more than about 10 feet of artificial fill should be avoided for locating future BMP improvements to ensure infiltration within native alluvial soils. A comparison of the topography of historic mining pit bottoms and the 2016 topographic expression of the site is shown on Figure 1 and should be referenced in determining layout of BMP improvements. Future plans and construction documents for storm water BMP submittals should be reviewed by the Geotechnical Engineer to confirm compliance with this report.

LIMITATIONS

The conclusions, recommendations, and opinions expressed in this report are based on Tetra Tech's review of background documents and on information obtained from field percolation testing. Due to the limited nature of the field percolation testing, conditions not observed and

described in this report may be present on the site. Uncertainties relative to subsurface conditions can be reduced through additional subsurface exploration and testing. Additional subsurface evaluation and testing can be performed upon request.

This report presents key geotechnical issues that could impact the proposed site development. The information presented herein is intended only and preliminary planning purposes and is not intended to satisfy the requirements of a site-specific and detailed geotechnical investigation required for foundation design and permitting. As such, additional geotechnical design-level reports will be warranted for the specific site development plan.
This document is intended to be used only in its entirety. No portion of the document, by itself, is designed to completely represent any aspect of the project described herein. Tetra Tech should be contacted if the reader requires additional information or has questions regarding the content, interpretations presented, or completeness of this document.

Tetra Tech has endeavored to perform its evaluation using the degree of care and skill ordinarily exercised under similar circumstances by reputable geotechnical professionals with experience in this area in similar soil conditions. No other warranty, either expressed or implied, is made as to the conclusions and recommendations contained in this report.

CLOSURE

We appreciate the opportunity to provide our professional services on this project. If you have any questions regarding this report or if we can be of further service, please do not hesitate to contact the undersigned.

Respectfully submitted,
Tetra Tech BAS, Inc.



Yonglang Li, PhD, GE
Senior Engineer



Patrick Keefe, CEG
Supervising Engineering Geologist

Peter Skopek, Ph.D., G.E.
Principal



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ATTACHMENTS

Figures 1 & 2
Appendix A – Field Percolation Test Data

FIGURES



HISTORIC BOTTOM TOPO



5/16/2016 TOPO/PHOTO

Figure 1

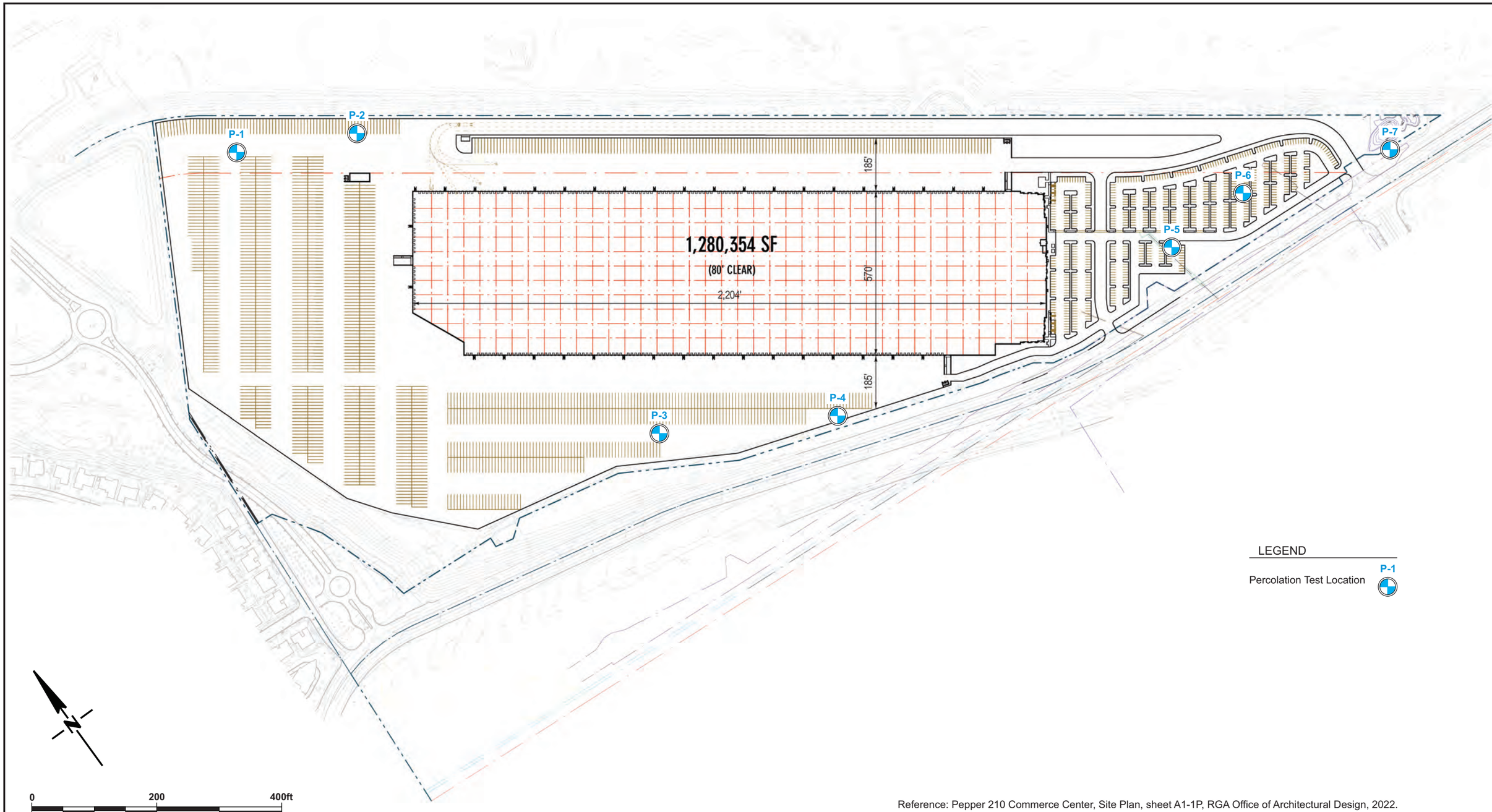
TETRA TECH
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VULCAN GRAVEL PIT REDEVELOPMENT - RIALTO, CA

Comparison of Topography From Historic Bottom Elevations and 2016 Surface Configuration

(from Vulcan Materials Company, 2019)

JOB NO.	GEN 19-22E
DATE	AUG 2022
DRAWN BY	SCM
CHECKED BY	PMK



Reference: Pepper 210 Commerce Center, Site Plan, sheet A1-1P, RGA Office of Architectural Design, 2022.

FIGURE 2

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VULCAN GRAVEL PIT REDEVELOPMENT - RIALTO, CA

SITE PLAN AND PERCOLATION TEST LOCATION MAP

JOB NO.	GEN 19-22E
DATE	AUG 2022
DRAWN BY	SCM
CHECKED BY	PMK

APPENDIX A

Field Percolation Test Data

PERCOLATION DATA SHEET

Project:	Pepper 210 Commerce Center, Rialto, CA		Job No:	GEN 19-22E	
Test Hole No:	**P-1**		Date Excavated:	Monday, June 20, 2022	
Test Hole Depth (feet):	9.5	feet	Soil Classification:	Gravel with Sand (GP)	
Stick up Length (feet):	0.5	feet	Gravel Porosity:	0.35	
Sandy Soil Criteria Tested By:	PMK		Presoak Date:	Monday, June 20, 2022	
Actual Percolation Tested By:	TC		Test Date:	Tuesday, June 21, 2022	
Test Hole Diameter (inches):	8	inches	Latitude:	34.142163°	Longitude: -117.364090°
Casing Diameter (inches):	3	inches	Elevation:	1351 ft	

PERCOLATION TEST (presoaking for at least 1 hour)

Time	Time Interval (min)	Initial Reading (feet below the top of the pipe)	Final Reading (feet below the top of the pipe)	Initial Water Level (feet above bottom of hole)	Final Water Level (feet above bottom of hole)	Δ in Water Level (inches)	Measured Raw Percolation Rate (inches/hour)
	0.46	9.00	10.00	1.00	0.00	12.00	172.7
	0.52	9.00	10.00	1.00	0.00	12.00	152.8
	0.43	9.00	10.00	1.00	0.00	12.00	184.8
	0.43	9.00	10.00	1.00	0.00	12.00	183.5
	0.46	9.00	10.00	1.00	0.00	12.00	172.7
	0.45	9.00	10.00	1.00	0.00	12.00	176.6
	0.45	9.00	10.00	1.00	0.00	12.00	176.6
	0.46	9.00	10.00	1.00	0.00	12.00	172.7

Suitability of underlying soils for infiltration	2.0	FACTORS OF SAFETY	Measured field infiltration rate (in/hr)= 172.7
Infiltration system design	2.5		

Technical Guidance Document for Water Quality Management Plans prepared for the County of San Bernardino Areawide Stormwater Program, dated September 19, 2013.

Corrected Design Percolation Rate = 34.5 in/hour

PERCOLATION DATA SHEET

Project:	Pepper 210 Commerce Center, Rialto, CA		Job No:	GEN 19-22E	
Test Hole No:	**P-2**		Date Excavated:	Monday, June 20, 2022	
Test Hole Depth (feet):	9.0	feet	Soil Classification:	Gravel with Sand (GP)	
Stick up Length (feet):	1.0	feet	Gravel Porosity:	0.35	
Sandy Soil Criteria Tested By:	PMK		Presoak Date:	Monday, June 20, 2022	
Actual Percolation Tested By:	TC		Test Date:	Tuesday, June 21, 2022	
Test Hole Diameter (inches):	8	inches	Latitude:	34.141692°	Longitude: -117.362794°
Casing Diameter (inches):	3	inches	Elevation:	1360 ft	

PERCOLATION TEST (presoaking for at least 1 hour)

Time	Time Interval (min)	Initial Reading (feet below the top of the pipe)	Final Reading (feet below the top of the pipe)	Initial Water Level (feet above bottom of hole)	Final Water Level (feet above bottom of hole)	Δ in Water Level (inches)	Measured Raw Percolation Rate (inches/hour)
	0.60	9.00	10.00	1.00	0.00	12.00	132.4
	0.63	9.00	10.00	1.00	0.00	12.00	126.1
	0.68	9.00	10.00	1.00	0.00	12.00	116.8
	0.65	9.00	10.00	1.00	0.00	12.00	122.2
	0.70	9.00	10.00	1.00	0.00	12.00	113.5

Suitability of underlying soils for infiltration	2.0	FACTORS OF SAFETY	Measured field infiltration rate (in/hr)= 113.5
Infiltration system design	2.5		

Technical Guidance Document for Water Quality Management Plans prepared for the County of San Bernardino Areawide Stormwater Program, dated September 19, 2013.

Corrected Design Percolation Rate = 22.7 in/hour

PERCOLATION DATA SHEET

Project:	Pepper 210 Commerce Center, Rialto, CA		Job No:	GEN 19-22E	
Test Hole No:	**P-3**		Date Excavated:	Monday, June 20, 2022	
Test Hole Depth (feet):	9.5	feet	Soil Classification:	Silty Sand and Gravel with Sand (SM/GP)	
Stick up Length (feet):	0.5	feet	Gravel Porosity:	0.35	
Sandy Soil Criteria Tested By:	PMK		Presoak Date:	Monday, June 20, 2022	
Actual Percolation Tested By:	TC		Test Date:	Tuesday, June 21, 2022	
Test Hole Diameter (inches):	8	inches	Latitude:	34.137717°	Longitude: -117.361698°
Casing Diameter (inches):	3	inches	Elevation:	1342 ft	

PERCOLATION TEST (presoaking for at least 1 hour)

Time	Time Interval (min)	Initial Reading (feet below the top of the pipe)	Final Reading (feet below the top of the pipe)	Initial Water Level (feet above bottom of hole)	Final Water Level (feet above bottom of hole)	Δ in Water Level (inches)	Measured Raw Percolation Rate (inches/hour)
	0.43	9.00	10.00	1.00	0.00	12.00	184.8
	0.47	9.00	10.00	1.00	0.00	12.00	169.0
	0.48	9.00	10.00	1.00	0.00	12.00	165.5
	0.43	9.00	10.00	1.00	0.00	12.00	184.8

Suitability of underlying soils for infiltration	2.0	FACTORS OF SAFETY	Measured field infiltration rate (in/hr)= 165.5
Infiltration system design	2.5		

Technical Guidance Document for Water Quality Management Plans prepared for the County of San Bernardino Areawide Stormwater Program, dated September 19, 2013.

Corrected Design Percolation Rate = 33.1 in/hour

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PERCOLATION DATA SHEET

Project:	Pepper 210 Commerce Center, Rialto, CA		Job No:	GEN 19-22E	
Test Hole No:	**P-4**		Date Excavated:	Monday, June 20, 2022	
Test Hole Depth (feet):	9.6	feet	Soil Classification:	Silty Sand and Gravel with Sand (SM/GP)	
Stick up Length (feet):	0.4	feet	Gravel Porosity:	0.35	
Sandy Soil Criteria Tested By:	PMK		Presoak Date:	Monday, June 20, 2022	
Actual Percolation Tested By:	TC		Test Date:	Tuesday, June 21, 2022	
Test Hole Diameter (inches):	8	inches	Latitude:	34.136965°	Longitude: -117.359866°
Casing Diameter (inches):	3	inches	Elevation:	1323 ft	

PERCOLATION TEST (presoaking for at least 1 hour)

Time	Time Interval (min)	Initial Reading (feet below the top of the pipe)	Final Reading (feet below the top of the pipe)	Initial Water Level (feet above bottom of hole)	Final Water Level (feet above bottom of hole)	Δ in Water Level (inches)	Measured Raw Percolation Rate (inches/hour)
	0.72	9.00	10.00	1.00	0.00	12.00	110.4
	0.85	9.00	10.00	1.00	0.00	12.00	93.5
	0.87	9.00	10.00	1.00	0.00	12.00	91.3
	0.83	9.00	10.00	1.00	0.00	12.00	95.7

Suitability of underlying soils for infiltration	2.0	FACTORS OF SAFETY	Measured field infiltration rate (in/hr)= 91.3
Infiltration system design	2.5		

Technical Guidance Document for Water Quality Management Plans prepared for the County of San Bernardino Areawide Stormwater Program, dated September 19, 2013.

Corrected Design Percolation Rate = 18.3 in/hour

PERCOLATION DATA SHEET

Project:	Pepper 210 Commerce Center, Rialto, CA		Job No:	GEN 19-22E	
Test Hole No:	**P-5**		Date Excavated:	Monday, June 20, 2022	
Test Hole Depth (feet):	9.6	feet	Soil Classification:	Silty Sand and Gravelly Sand (SM/SP)	
Stick up Length (feet):	0.4	feet	Gravel Porosity:	0.35	
Sandy Soil Criteria Tested By:	PMK		Presoak Date:	Monday, June 20, 2022	
Actual Percolation Tested By:	TC		Test Date:	Monday, June 20, 2022	
Test Hole Diameter (inches):	8	inches	Latitude:	34.136633°	Longitude: -117.355559°
Casing Diameter (inches):	3	inches	Elevation:	1313 ft	

PERCOLATION TEST (presoaking for at least 1 hour)

Time	Time Interval (min)	Initial Reading (feet below the top of the pipe)	Final Reading (feet below the top of the pipe)	Initial Water Level (feet above bottom of hole)	Final Water Level (feet above bottom of hole)	Δ in Water Level (inches)	Measured Raw Percolation Rate (inches/hour)
	1.33	9.00	10.00	1.00	0.00	12.00	59.7
	1.53	9.00	10.00	1.00	0.00	12.00	51.9
	1.82	9.00	10.00	1.00	0.00	12.00	43.7
	1.92	9.00	10.00	1.00	0.00	12.00	41.4
	1.96	9.00	10.00	1.00	0.00	12.00	40.5
	1.92	9.00	10.00	1.00	0.00	12.00	41.4
	1.98	9.00	10.00	1.00	0.00	12.00	40.1
	1.97	9.00	10.00	1.00	0.00	12.00	40.3

Suitability of underlying soils for infiltration	2.0	FACTORS OF SAFETY	Measured field infiltration rate (in/hr)= 40.1
Infiltration system design	2.5		

Technical Guidance Document for Water Quality Management Plans prepared for the County of San Bernardino Areawide Stormwater Program, dated September 19, 2013.

Corrected Design Percolation Rate = 8.0 in/hour

PERCOLATION DATA SHEET

Project:	Pepper 210 Commerce Center, Rialto, CA		Job No:	GEN 19-22E	
Test Hole No:	**P-6**		Date Excavated:	Monday, June 20, 2022	
Test Hole Depth (feet):	9.5	feet	Soil Classification:	Silty Sand and Gravel with Sand (SM/GP)	
Stick up Length (feet):	0.5	feet	Gravel Porosity:	0.35	
Sandy Soil Criteria Tested By:	PMK		Presoak Date:	Monday, June 20, 2022	
Actual Percolation Tested By:	TC		Test Date:	Monday, June 20, 2022	
Test Hole Diameter (inches):	8	inches	Latitude:	34.136708°	Longitude: -117.354540°
Casing Diameter (inches):	3	inches	Elevation:	1308 ft	

PERCOLATION TEST (presoaking for at least 1 hour)

Time	Time Interval (min)	Initial Reading (feet below the top of the pipe)	Final Reading (feet below the top of the pipe)	Initial Water Level (feet above bottom of hole)	Final Water Level (feet above bottom of hole)	Δ in Water Level (inches)	Measured Raw Percolation Rate (inches/hour)
	0.80	9.00	10.00	1.00	0.00	12.00	99.3
	0.90	9.00	10.00	1.00	0.00	12.00	88.3
	1.02	9.00	10.00	1.00	0.00	12.00	77.9
	1.07	9.00	10.00	1.00	0.00	12.00	74.3
	1.05	9.00	10.00	1.00	0.00	12.00	75.7
	1.05	9.00	10.00	1.00	0.00	12.00	75.7
	1.08	9.00	10.00	1.00	0.00	12.00	73.6

Suitability of underlying soils for infiltration	2.0	FACTORS OF SAFETY	Measured field infiltration rate (in/hr)= 73.6
Infiltration system design	2.5		

Technical Guidance Document for Water Quality Management Plans prepared for the County of San Bernardino Areawide Stormwater Program, dated September 19, 2013.

Corrected Design Percolation Rate = 14.7 in/hour

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PERCOLATION DATA SHEET

Project:	Pepper 210 Commerce Center, Rialto, CA		Job No:	GEN 19-22E	
Test Hole No:	**P-7**		Date Excavated:	Monday, June 20, 2022	
Test Hole Depth (feet):	9.9	feet	Soil Classification:	Sand and Gravel with Sand (SW/GP)	
Stick up Length (feet):	0.1	feet	Gravel Porosity:	0.35	
Sandy Soil Criteria Tested By:	PMK		Presoak Date:	Monday, June 20, 2022	
Actual Percolation Tested By:	TC		Test Date:	Monday, June 20, 2022	
Test Hole Diameter (inches):	8	inches	Latitude:	34.136319°	Longitude: -117.352829°
Casing Diameter (inches):	3	inches	Elevation:	1299 ft	

PERCOLATION TEST (presoaking for at least 1 hour)

Time	Time Interval (min)	Initial Reading (feet below the top of the pipe)	Final Reading (feet below the top of the pipe)	Initial Water Level (feet above bottom of hole)	Final Water Level (feet above bottom of hole)	Δ in Water Level (inches)	Measured Raw Percolation Rate (inches/hour)
	0.63	9.00	10.00	1.00	0.00	12.00	126.1
	0.73	9.00	10.00	1.00	0.00	12.00	108.8
	0.78	9.00	10.00	1.00	0.00	12.00	101.9
	0.82	9.00	10.00	1.00	0.00	12.00	96.9
	0.80	9.00	10.00	1.00	0.00	12.00	99.3
	0.82	9.00	10.00	1.00	0.00	12.00	96.9

Suitability of underlying soils for infiltration	2.0	FACTORS OF SAFETY	Measured field infiltration rate (in/hr)= 96.9
Infiltration system design	2.5		

Technical Guidance Document for Water Quality Management Plans prepared for the County of San Bernardino Areawide Stormwater Program, dated September 19, 2013.

Corrected Design Percolation Rate = 19.4 in/hour