Appendix E2 Geotechnical Trenching Fault Assessment (LOR Geotechnical)

Appendices

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LOR GEOTECHNICAL GROUP, INC.
Soil Engineering ▲ Geology ▲ Environmental

INITIAL FAULT INVESTIGATION
FOR THE PROPOSED
WILSON CREEK BUSINESS PARK SPECIFIC PLAN
YUCAIPA, CALIFORNIA

PROJECT NO. 12829.31
SEPTEMBER 25, 2013

Prepared for:

City of Yucaipa
34272 Yucaipa Boulevard
Yucaipa, California 92399

Attention: Mr. Jim Morrissey

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September 25, 2013

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34272 Yucaipa Blvd.
Yucaipa, California 92399

Project No. 12829.31

Attention: Mr. Jim Morrissey

Subject: Initial Fault Investigation, Proposed Wilson Creek Business Park Specific Plan, Yucaipa, California.

LOR Geotechnical Group, Inc. is pleased to present this report summarizing our Initial Fault Investigation for the proposed Wilson Creek Business Park Specific Plan located southeast of the intersection of Oak Glen Blvd and 2nd Street in the city of Yucaipa, California. Our study was based upon a scope of services generally outlined in our Work Authorization Agreement, dated December 21, 2012, and other written and verbal communications with you.

The scope of our study included a review of published and unpublished literature, interpretation of aerial photographs, surface mapping of the site, geophysical investigation of the site using seismic refraction methods and preparation of this report.

In summary, the results of our investigation found no evidence of any fault splays crossing the site. However, as is the case throughout the majority of the Southern California area, any development at the site should anticipate moderate to severe seismic shaking during the lifetime of the development.

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Appendix B- Geophysical Survey Report by Terra Geosciences

INTRODUCTION

During August and September of 2013, this firm conducted an Initial Fault Investigation for the proposed Wilson Creek Business Park Specific Plan located within the northern portion of the City of Yucaipa, California. The purpose of this study was to collect geologic and geophysical data related to the site in order to evaluate the potential for active faulting within the property. Information was obtained through research of available published information and through the use of geophysical investigation techniques to identify any anomalies that may suggest the presence of onsite active faults.

The scope of work for our Initial Fault Investigation at the site included:

- A review of recently published and un-published literature, maps, and records concerning geologic conditions of the site;
- Stereoscopic interpretation of aerial photographs of the site and immediate surrounding region;
- Surface observations including geologic mapping of the site by an engineering geologist from this firm;
- Geophysical investigation of the site using seismic refraction methods and conducted by a State of California licensed professional geophysicist. In total, 5 seismic refraction lines, overlapped to provide the detail and depth required, were completed and then spliced into one uninterrupted seismic refraction line. Prior to the start of our geophysical investigation work, we had our subcontractor clear brush along the length of the line location using backhoe equipment.
- Preparation of this report summarizing our findings, and providing conclusions.

The approximate location of the site is shown on the attached Index Map, Enclosure A-1, within Appendix A.

PROJECT CONSIDERATIONS

Planning for development of the subject site by the city of Yucaipa has included retaining this firm to evaluate the potential presence for two possible concealed faults which were previously mapped and plotted upon the city of Yucaipa's Fault-Rupture Hazard Zones map (City of Yucaipa, 2000). As outlined in our proposal dated December 21, 2012, the scope of work described above was completed with the results presented herein.

Conceptual layouts for the property are in the process of being developed and no specific grading or site development plans have been finalized at this time. Site development is anticipated to consist of the construction of several commercial buildings within the northern portion and a combination park and water storage/recharge basin in the southern portion. Paved parking and street areas will also be constructed. Although information pertaining to the types of buildings to be constructed is also not available at this time, one to two-story, concrete tilt-up or steel frame type structures will likely be proposed. It is also likely that moderate to significant amounts of grading will be required to create the site.

The site is not located within the limits of an Alquist-Priolo Earthquake Fault Zone. These zones are established by the State of California to prohibit the location of structures for human occupancy across the traces of active faults and require the State Geologist to delineate wide zones around known, well defined, active earthquake faults. The act defines a fault as sufficiently active if there is evidence of activity within the last 11,000 years. A fault is considered to be well defined if it is clearly detectable at or near the surface by a trained geologist. Enclosure A-5, within Appendix A is a small section of the Earthquake Fault Zones shown on the Yucaipa Quadrangle, prepared by the State of California (Hart and Bryant, 1997).

As previously mentioned, however, work by and/or for the city of Yucaipa led to plotting of two concealed faults across the subject property. These faults are thought to be related to the Chicken Hill fault that has been documented as present as an active fault in areas located to the southwest of the subject site.

EXISTING SITE CONDITIONS

Wilson Creek Business Park Specific Plan consists of an irregularly shaped parcel of land located southeast of the intersection of Oak Glen Road and 2nd Street in the northern portion of the City of Yucaipa, California. At the time of our investigation, the site included a borrow site used by the County of San Bernardino within the west-northwest portion with the remainder of the site otherwise vacant. The land generally slopes gently to the west-southwest with overall gradients of about 5 to 10 percent with a high elevation of approximately 2,750 feet along the eastern side and a low elevation of approximately 2,610 feet near the southwest corner. Locally, the topography has been incised by shallow to moderately deep and steeply sided drainage channels that trend northeast to southwest. These mainly consist of what is referred to as Wilson Creek, which traverses the northwest portion and Oak Glen Creek, which crosses the south-central portion of the site. These two drainage courses merge near the southwest corner of the property, just before existing the property and continuing to the southwest as Oak Glen Creek. Through the cutting and removal of onsite soils, the onsite borrow operations have also modified the onsite topographic conditions. These borrow operations have also created minor fills in the form of stockpiles and through the construction of haul roads.

Vegetation across the majority of the site is light to moderate and consists of field grasses, weeds and brush. Within the northeast and southeast portions of the site, the brush is locally thick and trees exist in some areas, particularly along the drainage courses. The site is bordered on the west by 2nd Street, on the north by Oak Glen Road, on the northeast by a church and a fire station, on the east by Bryant Street and on the south by single-family residences.

AERIAL PHOTOGRAPH ANALYSIS

During our investigation we reviewed a series of aerial photographs on file at the San Bernardino County Flood Control and Transportation Department, aerial photography collection. The photographs we reviewed were generally large scale regional photographs taken of the site and surrounding area between 1938 and 2005.

The aerial photographs reviewed consisted of vertical aerial stereographic photograph pairs of varying scales. These photographs were viewed using stereoscopes with magnifications of 2X and 4X for three dimensional enhancement. Due to the relatively

large photograph scales involved, the analysis and subsequent interpretation of detail from aerial photographs sometimes requires a degree of subjective judgment. The degree of certainty on the interpretation of details depends upon such factors as the scale and the quality of the photograph. A complete list of the aerial photographs reviewed is presented within the References at the end of this report.

The aerial photographs were examined in detail to assess the local and regional geologic and geomorphic characteristics of the site and vicinity, During our review, we also noted major changes that occurred onsite throughout this time span. A brief summary of the site and surrounding conditions at the various times and as reflected in the photographs is given below.

1. **July 4,1938, Flight No. USDA AXL-61, Photo No's. 58 and 59, Scale 1" = 2,000'**
August 10, 1938, Flight No. USDA AXL-79, Photo No's 96 - 98, Scale 1" = 2,000'

In these earliest available photographs, the site appears to be in a largely natural condition and covered with a moderate growth of chaparral. Wilson Creek, which cuts across the northwest portion of the site as a broad, shallow alluvial wash, and Oak Glen Creek, which traverses the south-central portion of the property as a narrower, steeper banked alluvial wash, are both relatively free of vegetation, although scattered small trees/bushes appear to be present locally along Oak Glen Creek. These two creeks merge near the southwest corner of the site and continue on as Oak Glen Creek to the southwest. Within the northwest portion of the site is a continuous trail or a low berm that meanders back and forth forming tight turns and long straightaways. This feature is likely part of a flood control percolation/groundwater infiltration system with a feed line or ditch extending to this area from the point where Wilson Creek meets Oak Glen Road. A straight dirt road (over a utility line?) that starts at the intersection of Oak Glen Road and Bryant Street to the northeast, extends diagonally across the site and continues to the southwest after exiting the western site boundary a couple of hundred feet north of Oak Glen Creek. There is a non-linear dirt road in the general area of today's 2nd Street, but 2nd Street has not been built yet. A few dirt roads/trails also cross portions of the southern part of the site. These are for unknown purpose but could serve as access to an area in the east-southeast portion of the property that may be being farmed (brush/plants appear to be in poorly defined rows in this area). In the south-central portion of the site, south of Oak Glen Creek, there is a large, irregularly shaped patch of dense chaparral or a

burned area. In the far southwest corner of the site, the vegetation within and area of approximately 2 acres has been cleared. The site is bordered on the west and northeast by vacant, natural ground; on the south by an ascending bench with farmland above, and on the east by Bryant Street.

Drainage across the site and adjacent areas to the north, east and west, consists of braided stream channels that drain to the southwest within the local area known as the North Bench. Within these photographs, the numerous separate drainage courses and raised alluvial terraces that typify this region are apparent as they have largely been unaffected by development at this time. Within the site area, in the southwestern portion of the site, a linear band of locally heavier brush appears to be located along the north side of an elevated terrace of older alluvium, just south of an older, poorly defined stream channel. Both the vegetational lineament and the old channel are aligned parallel to upstream and adjacent drainage patterns. This linear feature, although possibly indicative of a fault, is likely just a band of vegetation formed as a result of local drainage and topographic conditions. Note that this area is now followed by the later re-routed and re-aligned Wilson Creek. No other possible fault related features were noted to be present within the site or adjacent areas in these aerial photographs or subsequent aerial photographs that we reviewed.

2. August 20, 1948, Flight No. U-37, Photo No. 192, Scale 1" = 1,400'

Portions of the relatively flat areas in the east-northeast portion of the site have been cleared of vegetation and are now being dry-land farmed as has been the rectangular parcel that is located adjacent to the northeast portion of the site and extends to the southwest corner of Oak Glen Road and Bryant Street. The broad, shallow drainage that defined Wilson Creek across the northwest portion of the site, is re-vegetating following the 1938 flood event which apparently removed much of the pre-existing vegetation from this area. The previously mentioned diagonal road scar across the site is now barely discernible. 2nd Street, although still a dirt road, is now located approximately along its present day location. The percolation area in the northwest portion of the site is not being maintained and is returning to natural conditions. The property to the northeast of the site is being dry land farmed but most areas around the site appear as in the previous photographs. The developed area of Yucaipa has expanded noticeably in areas south of the site.

3. **February 16, 1953, Flight No. AXL-42K, Photo No's. 83 and 84, Scale 1" = 2,000'**

A residence/ranch has been established just south of the south-central site boundary. Otherwise, the site and immediate surrounding region appear as previously described.

4. **November 8, 1955, Flight No. F-35, Photo No's. 2-10, 2-11, 2-120 (2-120 missing), Scale 1" = 1,700'**

The site and adjacent areas generally appear as described for the previous photographs.

5. **October 16, 1959, Flight No. AXL-17W, Photo No's. 131 - 133, Scale 1" = 2,000'**

A new road/trail now extends across the southwest portion, around the ridge that divides Wilson and Oak Glen Creeks and then up to the northeast, roughly along Wilson Creek. Chaparral across many areas of the site appears to be getting thicker and, due to this, Wilson Creek is now poorly defined as a drainage course. A development (poultry ranch?) Is now located to the west of the northwest portion of the site.

6. **August 2, 1965, Flight No. EPH-4, Photo No. 177 and 178, Scale 1" = 2,000'**

A borrow site is now in operation within the west-northwest portion of the site and this is accessed via a dirt road that extends southeast from the southeast corner of the intersection of 2nd Street and Oak Glen Road. The borrow site is mainly located within the (original) Wilson Creek drainage and a dozer scar/road has been cut diagonally across a portion of the site, just east of the borrow site. Also, there is now a small building (well?) located west of 2nd Street and west of the south end of the property.

7. **March 1, 1968, Flight No. C-149, Photo No's. 17 - 19, Scale 1" = 2,000'**

The southern portion of the borrow site has expanded slightly to the southeast. Otherwise, the site and vicinity appears much as described for the previous photographs.

8. **August 8, 1968, Flight No. AXL-9JJ, Photo Nos. 56 and 57, Scale 1" = 2,000'**

The site and vicinity generally appears as described for the previous photographs.

9. **August 4, 1975, Flight No. NBS, Photo Nos. 102 - 104, Scale 1" = 400'**

The borrow site has again expanded and shifted slightly to the east-southeast. A fresh scar across former borrow areas and along the approximate former alignment of Wilson Creek has been created, likely as a result of the 1969-70 flood event. The across road(s) for the borrow site are now locally paved. Numerous off-road trails are now present in the north-central portion of the site. Many new residences have been built in areas to the southwest and southeast of the site.

10. **June 8, 1979, Flight No. C-289, Photo Nos. 8 and 9, Scale 1" = 2,000'**

Clearing of the ground at the southeast corner of 2nd Street and Oak Glen Road has taken place as part of the start of construction of the City of Yucaipa maintenance yard. Also, a rectangular area north of the northeast portion of the site, on the west side of Bryant Street has been recently graded. Additional residences have been built to the south of the site.

11. **February 25, 1986, Flight No. C-450, Photo Nos. 41-43 and 75, Scale 1" = 2,000'**

Channelization of some of the onsite drainages is taking place. The city yard is now well established adjacent to the northwest corner of the site and the fire station has been built on the graded site north of the east end of the site. By this time, continued development in the region has obliterated much of the geomorphology that could be seen in the earliest aerial photographs.

12. **July 1, 1991, Flight No. C-487, Photo Nos. 91 and 92, Scale 1" = 2,000'**

The present day configuration of Wilson Creek drainage across the site is clearly shown on these photographs to be the result of continued grading (borrow) operations in the site. Virtually all of Wilson Creek in its present location onsite is artificial and man-made.

13. **April 20, 1996, Flight No. C-528, Photo Nos. 128, 129, and 131 (130 missing), Scale 1" = 2,000'**

Only partial coverage of the site available in these photographs. However, Wilson Creek clearly shows up as a dozer/borrow path. Borrow operations have been expanded to the south and east.

14. **June 15, 2001, Flight No. C-541, Photo Nos. 100 - 102, Scale 1" = 2,000'**

Borrow operations are still being conducted, however, this activity appears to have slowed somewhat with present activity mainly limited to the northwest and southeast portions of the existing, affected borrow areas. Areas around the site appear much as previously described.

15. **January 18, 2005, Flight No. C-553, Photo Nos. 10-61 and -62, Scale 1" = 1,000'**

Onsite conditions remain much the same except that the borrow operations are now mainly concentrated within the northeastern part of the borrow site.

SEISMIC REFRACTION INVESTIGATION

The main method of investigation utilized to assist in evaluation of the possible presence of subsurface faults across the site, as depicted on the City of Yucaipa Fault Hazard Zone Map (Enclosure A-6 in Appendix A), consisted of five connected seismic refraction lines placed in a northwest to southeast orientation, roughly perpendicular to the mapped, concealed fault locations. The purpose of the seismic refraction survey was to determine whether subsurface anomalies indicative of faulting were present within sediments underlying site. The location of the seismic refraction traverse is shown on our Geologic Map (Enclosure A-2 in Appendix A). The northwest end of the profile was placed across what is interpreted as thick, relatively young alluvium while the southeast end crosses old axial-valley alluvial deposits.

The seismic refraction line data indicate that there are generally three units of varying density. The upper layer represents the youngest, near surface alluvium, stream channel deposits and local fill soils while the middle layer is a higher velocity, denser and older alluvial material. The lowermost layer is of high velocity and likely represents saturated older alluvium.

The unit designations correspond to changes in velocity. Although their contact locations or contact depths are somewhat arbitrary, the contact lines shown between the three units are relatively constant in terms of their definition/velocity. Following this arrangement, identification of breaks and/or anomalies in the profiles is thus discernible. Breaks and/or anomalies typically reveal changes in stratigraphy or lithology across a given area. Where the changes are relatively abrupt, the cause is often attributed to faulting. Abrupt changes in the lithology were not observed in the profile generated and no evidence suggesting the presence of faults in the subsurface beneath the area of this investigation was found. The geophysical investigation report prepared by our subconsultant, Terra Geosciences, is included at the end of this report as Appendix B.

GEOLOGIC CONDITIONS

Regional Geologic Setting

The subject site is located within a large geomorphic province of southern California referred to as the Peninsular Ranges. The site is located along the northern end of the Peninsular Ranges near the junction with the adjacent Transverse Ranges geomorphic province. These two provinces cover a large majority of southern California stretching from the Pacific coast inland to the San Andreas fault, south of the San Gabriel-San Bernardino Mountain ranges, and extending southward to the Mexican border and beyond.

The Peninsular Ranges province is characterized by a series of generally small northwesterly trending mountains ranges, such as the Santa Ana Mountains and the San Jacinto Mountains, separated by wide flat valleys. These extend from the Los Angeles region southeastward into Baja California. As previously noted, at the far northern end, this province meets the San Bernardino and the San Gabriel mountains which have a predominately east-west trend that is transversely oriented in regards to the predominately northwest structural grain of much of California; hence the name Transverse Ranges.

In the Yucaipa region, the San Andreas fault acts as the boundary between the Peninsular and Transverse Ranges provinces, with the site located southwest of this boundary. Here, the motion on this feature has typically resulted in the Peninsular

Ranges Block sliding to the northwest in relation to the Transverse Ranges. While this motion is distributed along a very wide shear zone of various other major faults in the region, perhaps as much as one half of the total offset is thought to have occurred along the San Andreas fault.

Although the trend of the San Andreas fault is predominately a relatively straight line across much of California, in the area just north of Indio, the San Andreas fault has an approximately 15-mile wide step-over zone, stepping to the west and cutting across the San Gorgonio Pass then up to the eastern end of the city of Yucaipa. Beyond this area and to the northwest, the trend of the fault once again resumes a northwesterly course. The tectonic setting is complex and not completely understood, however, the general result is that along the San Gorgonio pass the motion changes from right lateral strike slip to thrusting. Within the Yucaipa region, this complex motion has resulted in several types of movement, including extension with the formation of fault grabens (down-dropped basins) in the area of the site and areas to the southwest and northeast of the site. Tectonic activity including essentially all types of fault motions, from right lateral strike slip, or horizontal, to thrusting and normal, or tensional faulting is evident locally. The Banning fault, lying along the base of the San Bernardino Mountains, appears to be the dominate thrust in the western end of the pass, joining the San Gorgonio Pass fault zone further to the east.

Local Geologic Setting

The site is located within Yucaipa Valley which is a northeast trending area of accumulated alluvial sediments situated southeast of the local Crafton Hills and part of the Yucaipa Graben Complex mapped by Matti, et al. (2003). Arcuate fault scarps resulting from normal, dip-slip faults define this graben and it is believed that the graben itself formed due to localized extension in a regional zone of right step between the San Jacinto and San Andreas fault zones. Both Wilson and Oak Glen Creeks, the two main local drainage courses in this valley, traverse the site and merge near the southwest corner of the property. In general, Pleistocene age sediments form the older, elevated surfaces in the site area and these have been incised by the local drainage courses to create the younger, typically low-lying, Holocene age alluvial deposits.

Although we have not conducted any investigation of the property utilizing excavation equipment, we have mapped the general geology as noted within onsite exposures of surficial materials. We have followed the nomenclature presented by Matti, et al. (2003) to create our Geologic Map of the property (Enclosure A-2). In general, the geologic materials within the site consist of young axial-valley sediments of Wilson and Oak Glen Creeks and become progressively younger in proximity to the natural drainages. Old axial-valley deposits are present along the southern margin and as a ridge in the drainage divide between the two onsite stream courses.

The youngest axial-valley sediments consist of recent stream channel deposits and these were observed to be mainly gravelly sands with silt. Away from the main active channels, the alluvial deposits become older and slightly indurated and cemented. The oldest onsite materials, consisting of old axial deposits that are late to middle Pleistocene in age, were observed to consist of dense, yellowish-brown silty sand with subrounded gravels and cobbles.

FAULT RUPTURE HAZARD

As shown on Enclosure A-5 in Appendix A, the site is not located within an Alquist-Priolo Earthquake Fault Zone (APZ) designated by the State of California to include traces of suspected active faulting. However, as shown on Enclosure A-6 in Appendix A, two concealed fault traces associated with the Chicken Hill fault are mapped through the site and are included on the Fault-Rupture Hazard Zones map prepared by the City of Yucaipa (2000). The southerly of these two concealed faults is at the same location as an inferred/concealed fault depicted on the geologic map for the Yucaipa quadrangle prepared by Matti, et al. (2003). Several subsurface investigations of faulting have been conducted across the mapped location of these faults in nearby areas and, as outlined below, there is little evidence supporting a potential for surface fault rupture hazard at the site.

PREVIOUS NEARBY FAULT INVESTIGATIONS

As part of our research and review of the geologic conditions for the site and vicinity, we reviewed both in-house documents and those available through and on-file with the City of Yucaipa. A brief summary of the relevant reports that were available through the city is presented below.

The earliest available investigation, by Gary S. Rasmussen & Associates (1985), consisted of excavation and logging of a 155-foot long subsurface fault investigation trench across the projection of the Chicken Hill fault and within an APZ at a site located on the south side of Yucaipa Blvd., between Oak Glen Road and 7 th Street. Their conclusion was that no faults or fault related features were encountered or observed and that ground rupture through the site due to surface faulting is not expected during the lifetime of the proposed structures.

Pacific Soils, Inc., conducted fault investigation along the trend of the Chicken Hill fault for the approximately 1,012 acre Chapman Ranch project in the late 1980's. This large-scale commercial and residential project is located north of Yucaipa Boulevard and east-southeast of Oak Glen Road. Although we were unable to obtain a copy of the fault investigation report by Pacific Soils, Inc., CHJ, Inc. (2007a) summarizes the findings of the Pacific Soils, Inc., report by stating that: "A zone of northeast-trending, right-stepping faults was revealed in Holocene sediments at a depth of approximately 8 feet below the ground surface (existing at the time of the investigation) by Pacific Soils, Inc. This zone was observed to extend for a lateral distance of approximately 1,200 feet and was interpreted to terminate approximately 1.7 miles southwest of the subject site. Faulting was observed to be absent in trenches located northeast of and across the trend of the identified fault zone." The 1.7 mile distance for termination of the fault zone mentioned above corresponds to an approximate distance of approximately 1.4 miles southwest of the subject site of this report.

Terra Geosciences (1995) conducted a fault investigation within the APZ for the Chicken Hill fault and across the mapped trace of the fault within this zone. The property is located at the northwest corner of the intersection of Yucaipa Blvd and D Street, close to the site investigated previously by Gary S. Rasmussen & Associates (1985). No subsurface evidence of active faulting was observed.

In 2007, two separate fault investigation reports were prepared for adjacent sites by CHJ, Inc. (2007a and 2007b). One of these sites was located just northeast of the subject site at the northwest corner of Oak Glen Road and Bryant Street (2007a) and the other was located at the northeast corner of Oak Glen Road and Bryant Street (2007b). Trenches excavated for these investigations extended to depths of 25 to 30 feet below the ground surface and a seismic refraction survey was conducted within one of the sites (2007a) to profile the onsite soils and aid in the identification

of anomalies that could indicate the presence of faults. Both of these reports reached the same general conclusion that the inferred, concealed fault traces mapped through the sites were not observed in the exploratory trenches or through any other means and that building setbacks are not required for the proposed developments.

A church facility has been recently constructed adjacent to the northeast portion of the Wilson Creek Business Park site. Geologic and geotechnical investigation of the church property was conducted by Southern California Geotechnical in September of 2007. They concluded that specific investigation of the site for fault rupture hazard was not needed based upon the 'shadow' cast upon the site by the previous investigations by CHJ Inc., (2007a and 2007b). Their conclusions were accepted and the church facility built with the conclusions in their report presented as follows:

> "Plate 3, enclosed in Appendix A of this report, presents a graphic depiction of the location of the subject site, the proposed structures, the mapped traces of the Chicken Hill Fault, and the previous fault trenches performed by CHJ. From Plate 3, it can be seen that the fault trenches performed by CHJ effectively "shadow" the subject site, with respect to the mapped orientation of the traces of the Chicken Hill Fault. Therefore, the results and conclusions of the fault studies performed by CHJ are considered applicable to the subject site. Since CHJ identified unfaulted sediments of Pleistocene age, the Chicken Hill fault is either not present within the limits of the limits of the subject site, or if present, has not been active within the Holocene period. Furthermore, as noted above, the subject site is not located within a designated Alquist-Priolo earthquake fault zone, indicating that the State Geologist does not consider this area to possess a significant hazard for surface fault rupture. During the performance of the geotechnical investigation for the Wildwood Calvary Chapel site, no evidence of faulting was observed. This includes borings performed at the site, observations of the ground surface, and review of available aerial photographs. Based on research performed by SCG and our review of the CHJ reports, no mitigation relative to potential fault rupture, such as building setbacks, are recommended for this project."

Our review of in-house documents reveals that we have conducted one fault investigation along the projected trace of the Chicken Hill fault which did reveal some evidence for the potential for fault rupture (LOR, 2001). This investigation was for a project associated with the work previously done by Pacific Soils, Inc., and was

located within the Chapman Ranch project area, just east of the intersection of Oak Glen Road and Yucaipa Blvd., about 3 miles southwest of the site. Fractures observed in the subsurface at this location are thought to be associated with the fault zone identified by Pacific Soils, Inc., and a local building setback zone was established based upon this conclusion.

REGIONAL TECTONIC SETTING

The San Andreas fault is considered to be the major tectonic feature of California, separating the Pacific plate and the North American plate. The sense of movement is that the Pacific plate moves northwest relative to the North American plate. This type of motion is called right lateral strike slip. While estimates vary, the San Andreas fault is generally thought to have an average slip range on the order of 24 mm/yr and capable of generating large magnitude events on the order of 7.5 or greater.

In the Yucaipa region Matti, Morton, and Cox (1992) recognized at least four strands of this fault. These are: the Mill Creek, Wilson Creek, Mission Creek, and finally the San Bernardino segment which runs along the base of the local Mountains. From a location several miles northwest of the site, the San Bernardino segment extends along the base of the mountains in a north 70 degrees west trend across the entire San Bernardino Valley. However, southeast of the San Bernardino Valley, the San Bernardino segment becomes much more complex. Matti et al (2003) suggests that in this area, the San Andreas fault is continuing the left stepping motion with a tendency for en echelon strands.

The San Jacinto fault zone, located approximately 14.5 kilometers (9 miles) to the southwest, is a sub-parallel branch of the San Andreas fault zone, extending from the northwestern San Bernardino area, southward into the El Centro region. This fault has been active in recent times with several large magnitude events. It is believed that the San Jacinto fault is capable of producing an earthquake magnitude on the order of 6.5 or greater.

Other faults in the area include the Western Heights fault which is located about 1.6 kilometers (1 mile) to the northwest, along the southeast side of the Crafton Hills. On the opposite side of the Crafton Hills, about 6.5 kilometers (4 miles) to the west-northwest, the Reservoir Canyon (Crafton) fault forms the northwest boundary of these hills. As previously mentioned, the closest mapped portion of the Chicken Hill fault is located approximately 1.4 miles to the southwest.

Current standards of practice included a discussion of all potential earthquake sources within a 100 kilometer (62 mile) radius. However, while there are other large earthquake faults within a 100 kilometer (62 mile) radius of the site, none of these are considered as relevant to the site as the faults described above, due to their greater distance and/or smaller anticipated magnitudes.

HISTORICAL SEISMICITY

In order to obtain a general perspective of the historical seismicity of the site and surrounding region, a search was conducted for seismic events at and around the area within various radii. This search was conducted utilizing the historical seismic search program by EPI Software, Inc. This program conducts a search of a user selected cataloged seismic events database, within a specified radius and selected magnitudes, and then plots the events onto an overlay map of known faults. For this investigation the database of seismic events utilized by the EPI program was obtained from the Southern California Seismic Network (SCSN) available from the Southern California Earthquake Center. At the time of our search, the data base contained data from January 1, 1932 through December, 2010.

In our first search, the general seismicity of the region was analyzed by selecting an epicenter map listing all events of magnitude 4.0 and greater, recorded since 1932, within a 100 kilometer (62 mile) radius of the site, in accordance with guidelines of the California Division of Mines and Geology. This map illustrates the regional seismic history of moderate to large events. As depicted on Enclosure A-7, within Appendix A, the site lies within a relatively active region of southern California with numerous events located in the region. The San Jacinto fault appears especially active to the southeast, along the west side of the Salton Sea. The Landers and Big Bear events to the northeast of the site are also notable. Of all these events, the closest was a magnitude 4.0 located approximately 1.2 kilometer (0.7 mile) southeast of the site that occurred on June 16, 2005.

In the second search, the micro seismicity of the area lying within a 15 kilometer (9 mile) radius of the site was examined by selecting an epicenter map listing events on the order of 1.0 and greater since 1978. In addition, only the "A" events, or most accurate events were selected. Caltech indicates the accuracy of the "A" events to be approximately 1 km. The results of this search is a map that presents the seismic history around the area of the site with much greater detail, not permitted on the larger map. The reason for limiting the events to the last 35 ± years on the detail map

is to enhance the accuracy of the map. Events recorded prior the mid 1970's are generally considered to be less accurate due to advancements in technology. As depicted on this map, Enclosure A-8, the subject site lies within an area with very numerous small events in the general area.

SOILS AND SEISMIC DESIGN CRITERIA (California Building Code)

Section 1613 of Chapter 16 of the 2010 California Building Code (CBC) contains the procedures and definitions for the calculations of the earthquake loads on structures and non structural components that are permanently attached to structures and their supports and attachments.

It should be noted that the classification of use and occupancy of all proposed structures at the site, and thus design requirements, shall be the responsibility of the structural engineer and the building official.

CBC Earthquake Design Summary

The following earthquake design criteria have been formulated for the site utilizing the source referenced above. However, these values should be reviewed and the final design should be performed by a qualified structural engineer familiar with the region.

CBC 2010 SEISMIC DESIGN SUMMARY Site Location (WGS 84) 34.0463, -117.0407, Occupancy Category II	
Site Class Definition (Table 1613.2)	D
S_S Mapped Spectral Acceleration at 0.2s Period (Figure 1613.5(3))	1.851
S_1 Mapped Spectral Acceleration at 1.0s Period (Figure 1613.5(4))	0.843
F_A Short Period Site Coefficient at 0.2s Period (Table 1613.5.3(1))	1.0
F_V Long period Site Coefficient at 1.0s Period (Table 1613.5.3(2))	1.5
S_{MS} Adjusted Spectral Response Acceleration at 0.2s Period (eq. 16-37)	1.851
S_{M1} Adjusted Spectral Response Acceleration at 1.0s Period (eq. 16-38)	0.264
S_{DS} Design Spectral Response Acceleration at 0.2s Period (eq. 16-39)	1.234
S_{D1} Design Spectral Response Acceleration at 1.0s Period (eq. 16-40)	0.843
Seismic Design Category, Short Period (Table 1613.5.6 (1))	E
Seismic Design Category, Long Period (Table 1613.5.6 (2))	E

CONCLUSIONS

No evidence was noted in our study to indicate that the inferred, concealed fault traces mapped through the site, as associated with the Chicken Hill fault, are present. The closest known, documented evidence for the Chicken Hill fault is located about 1.4 miles to the southwest of the site. Fault investigations conducted immediately northeast of the subject site also did not encounter or detect evidence for the possible presence of the same concealed fault traces. The site is not included in an Alquist-Priolo Earthquake Fault Zone. Therefore, building setbacks for mitigation of fault hazard are not required for the proposed project.

The effects of ground shaking anticipated at the subject site should be at a minimum mitigated by the seismic design requirements and procedures outlined in Chapter 16 of the California Building Code. However, it should be noted that the current building code requires the minimum design to allow a structure to remain standing after a seismic event, in order to allow for safe evacuation. A structure built to code may still sustain damage which might ultimately result in the demolishing of the structure (Larson and Slosson, 1992).

LIMITATIONS

This report contains geotechnical conclusions and recommendations developed solely for use by the City of Yucaipa and their design consultants for the purposes described earlier. It may not contain sufficient information for other uses or the purposes of other parties. The contents should not be extrapolated to other areas or used for other facilities without consulting LOR Geotechnical Group, Inc.

The report was prepared using generally accepted geotechnical engineering practices under the direction of a state licensed geotechnical engineer. No warranty, expressed or implied, is made as to conclusions and professional advice included in this report. Any persons using this report for bidding or construction purposes should perform such independent investigations as deemed necessary to satisfy themselves as to the surface and subsurface conditions to be encountered and the procedures to be used in the performance of work on this project.

TIME LIMITATIONS

The findings of this report are valid as of this date. Changes in the condition of a property can, however, occur with the passage of time, whether they be due to natural processes or the work of man on this or adjacent properties. In addition, changes in the Standards-of-Practice and/or Governmental Codes may occur. Due to such changes, the findings of this report may be invalidated wholly or in part by changes beyond our control. Therefore, this report should not be relied upon after a significant amount of time without a review by LOR Geotechnical Group, Inc., verifying the suitability of the conclusions and recommendations.

CLOSURE

It has been a pleasure to assist you with this project. This report contains geotechnical conclusions and recommendations developed solely for use by the client for the purposes described earlier. It may not contain sufficient information for other uses or the purposes of other parties. The contents should not be extrapolated to other areas or used for other facilities without consulting LOR Geotechnical Group, Inc.

The report was prepared using generally accepted geotechnical engineering practices under the direction of a state licensed geotechnical engineer. No warranty, expressed or implied, is made as to conclusions and professional advice included in this report.

Should you have any questions regarding this report, please feel free to contact us at your earliest convenience.

Respectfully submitted,
LOR Geotechnical Group, Inc.

REGISTERED PROFESSIONAL ENGINEER
JOHN P. LEUER
NO. 2030
EXPIRATION DATE
09/30/15
GEOTECHNICAL
STATE OF CALIFORNIA

John P. Leuer, GE 2030
President

PROFESSIONAL GEOLOGIST
ROBERT M. MARKOFF
No. 2073
CERTIFIED ENGINEERING GEOLOGIST
STATE OF CALIFORNIA

Robert M. Markoff, CEG 2073
Engineering Geologist

RMM:JPL/amp

Distribution: Addressee (4)

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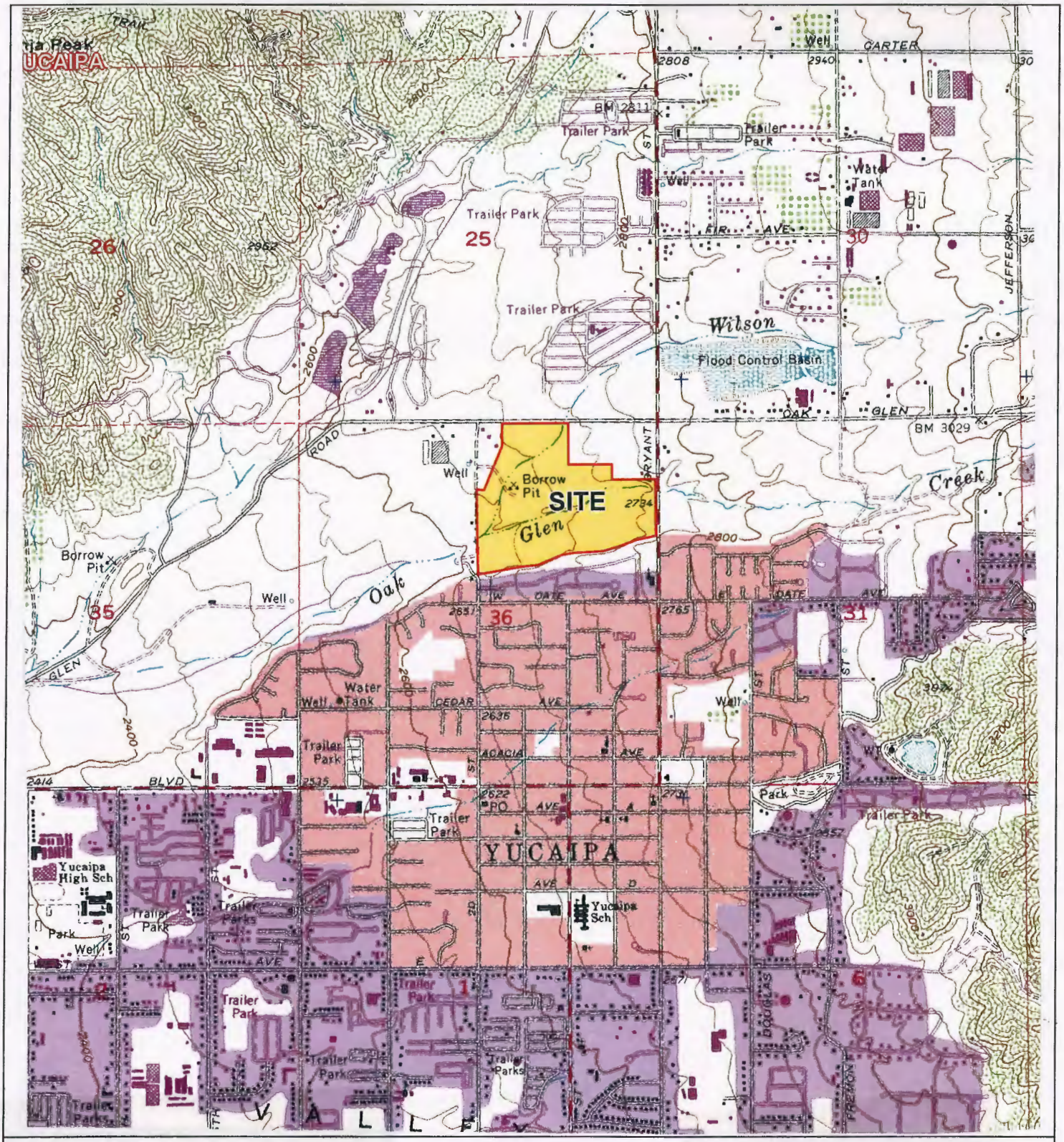
APPENDIX A

Index Map, Geologic Map, Regional Geologic Map, Description of Geologic Units, Earthquake Fault Zone Map City of Yucaipa Fault-Rupture Hazard Zone Map and EPI Seismicity Maps



INDEX MAP

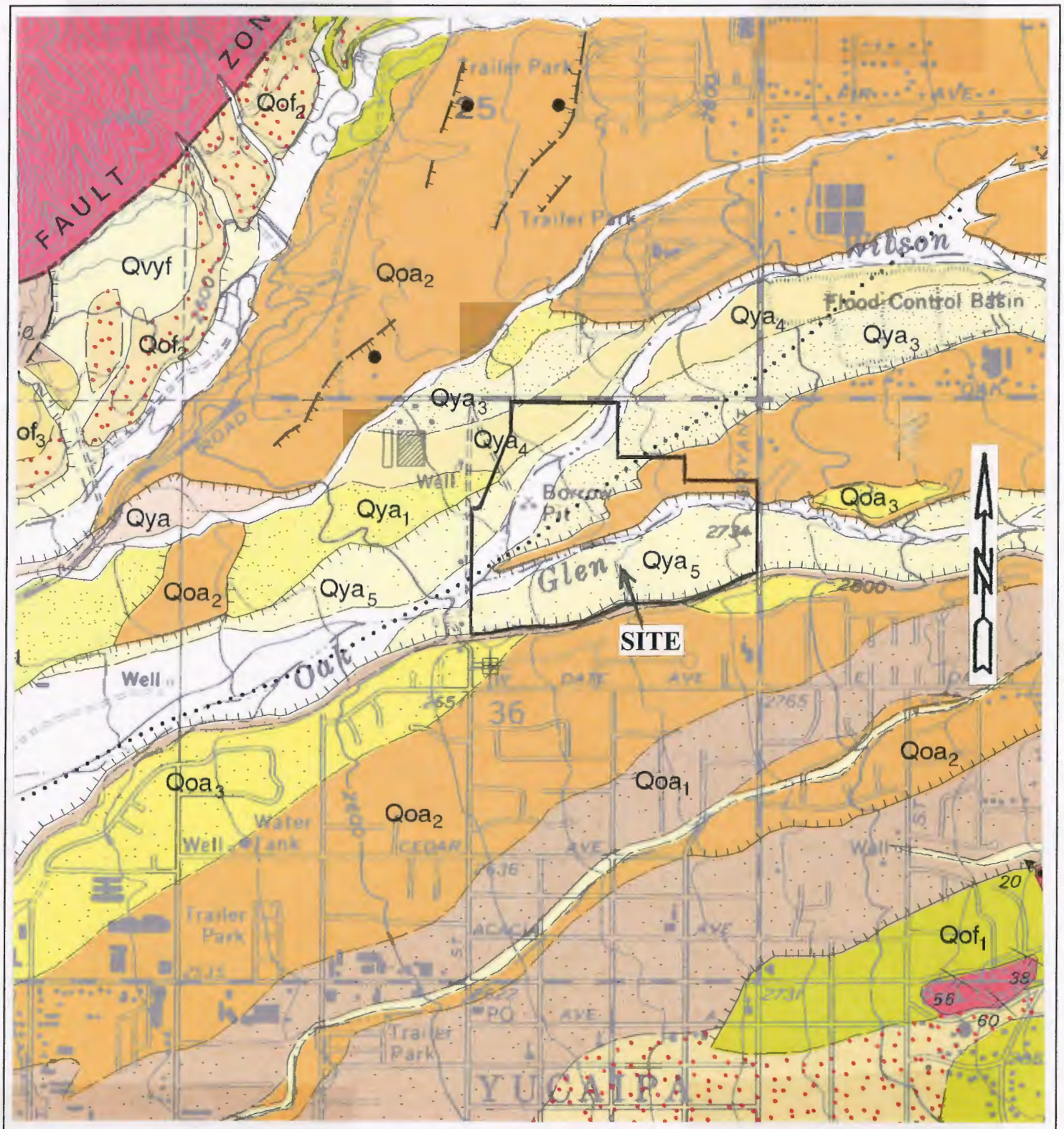
PROJECT:	WILSON CREEK BUSINESS PARK SPECIFIC PLAN	PROJECT NO.:	12829.3
CLIENT:	CITY OF YUCAIPA	ENCLOSURE:	A-1
LOR Geotechnical Group, Inc.		DATE:	SEPTEMBER, 2013
		SCALE:	1" = 2,000'

GEOLOGIC MAP

PROJECT:	WILSON CREEK BUSINESS PARK SPECIFIC PLAN, YUCAIPA, CALIFORNIA	**PROJECT NO:**	12829.3
CLIENT:	CITY OF YUCAIPA	**ENCLOSURE:**	A-2
		DATE:	SEPTEMBER, 2013

LOR Geotechnical Group, Inc.

1" = 200'



REGIONAL GEOLOGIC MAP (MATTI, ET AL, 2003)

PROJECT:	WILSON CREEK BUSINESS PARK SPECIFIC PLAN	PROJECT NO.:	12829.3
CLIENT:	CITY OF YUCAIPA	ENCLOSURE:	A-3
LOR Geotechnical Group, Inc.		DATE:	SEPTEMBER, 2013
		SCALE:	1" = 1,260'

DESCRIPTION OF MAP UNITS

VERY YOUNG SURFICIAL DEPOSITS—Sediment recently transported and deposited in channels and washes, on surfaces of alluvial fans and alluvial valleys, and on hillslopes. Soil-profile development is non-existant to minimal. Includes:

Qvyw — **Very young wash deposits, active (latest Holocene)**—Unconsolidated sand and gravel deposits in active washes

Qya — **Young axial-valley deposits (Holocene and latest Pleistocene)**—Slightly to moderately consolidated silt, sand, and gravel. Units distinguished from each other on the basis of soil-profile development and relative position in local terrace-riser succession. Includes:

Qya5 — **Young axial-valley deposits, Unit 5 (latest Holocene)**

Qya4 — **Young axial-valley deposits, Unit 4 (late Holocene)**

Qya3 — **Young axial-valley deposits, Unit 3 (middle Holocene)**

Qya1 — **Young axial-valley deposits, Unit 1 (early Holocene and latest Pleistocene)**

Old axial-valley deposits (late to middle Pleistocene)—Moderately to well consolidated silt, sand, and gravel. Units distinguished from each other on the basis of soil-profile development and relative position in local terrace-riser succession. Includes:

Qoa3 — **Old axial-valley deposits, Unit 3 (late to middle Pleistocene)**

Qoa2 — **Old axial-valley deposits, Unit 2 (late to middle Pleistocene)**

Qoa1 — **Old axial-valley deposits, Unit 1 (late to middle Pleistocene)**

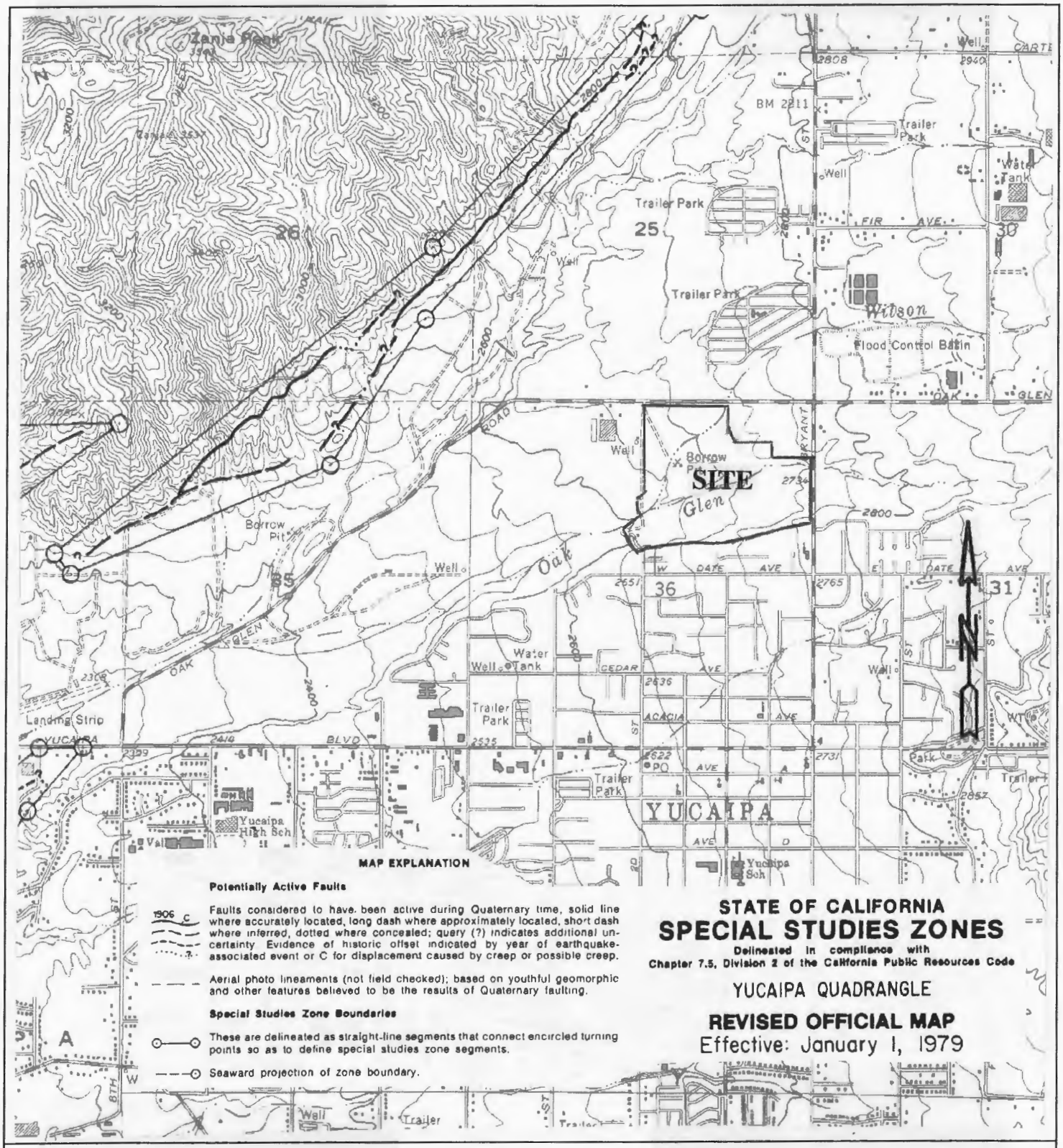
Contact—Separates geologic-map units. Solid where meets map-accuracy standard; dashed where may not meet map-accuracy standard; dotted where concealed

Contact—Separates terraced alluvial units where younger alluvial unit is incised into older alluvial unit; hachures at base of slope, point toward topographically lower surface. Solid where meets map-accuracy standard; dashed where may not meet map-accuracy standard

20 ...?... **Fault**—Solid where meets map-accuracy standard; dashed where may not meet map-accuracy standard. Dotted where concealed by mapped covering unit; queried where existence uncertain. Hachures indicate scarp, with hachures on down-dropped block. Paired arrows indicate relative movement; single arrow indicates direction and amount of fault-plane dip. Bar and ball on down-thrown block

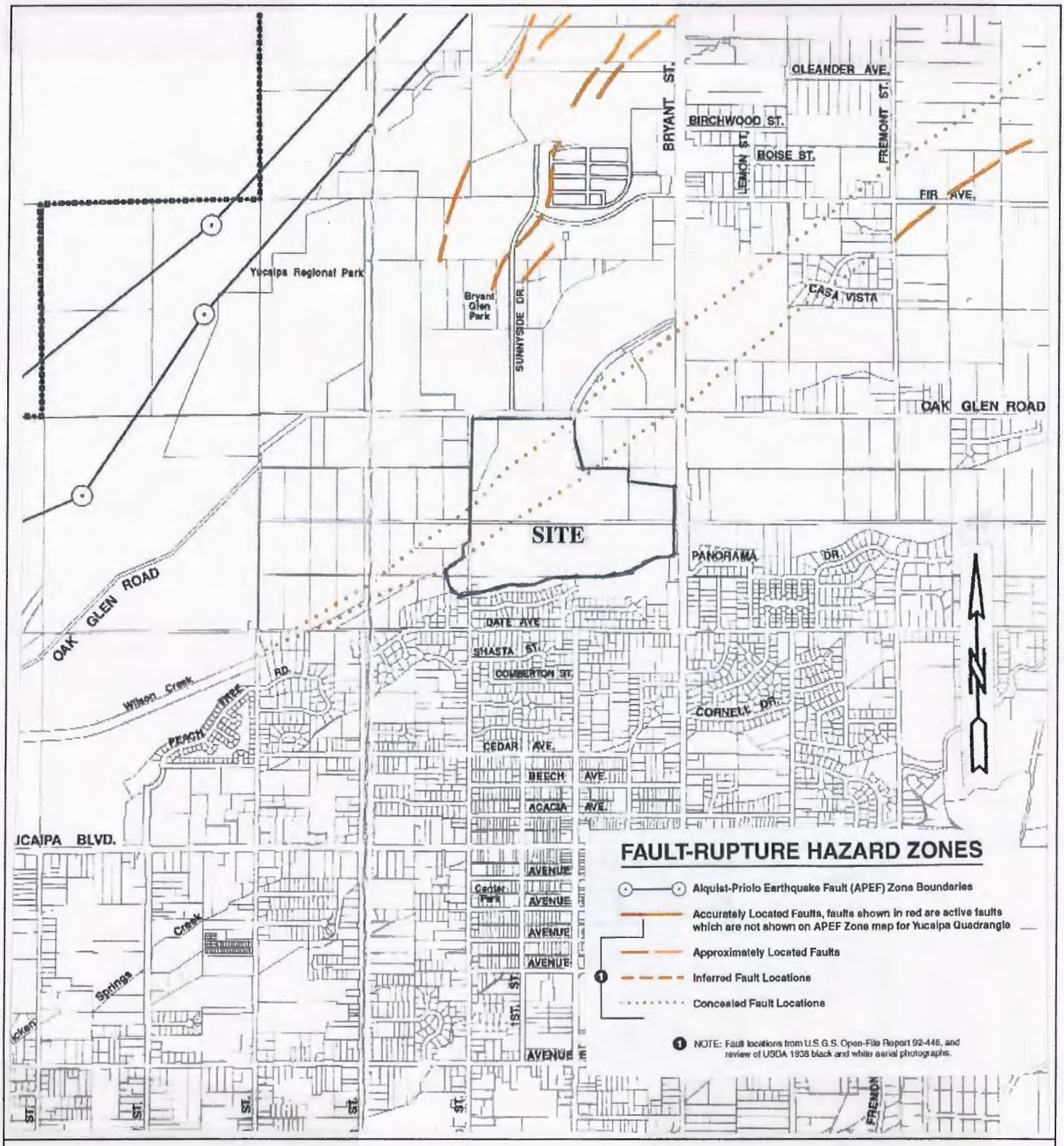
DESCRIPTION OF UNITS

PROJECT:	WILSON CREEK BUSINESS PARK SPECIFIC PLAN	PROJECT NO.:	12829.3
CLIENT:	CITY OF YUCAIPA	ENCLOSURE:	A-4
LOR Geotechnical Group, Inc.		DATE:	SEPTEMBER, 2013
		SCALE:	N/A



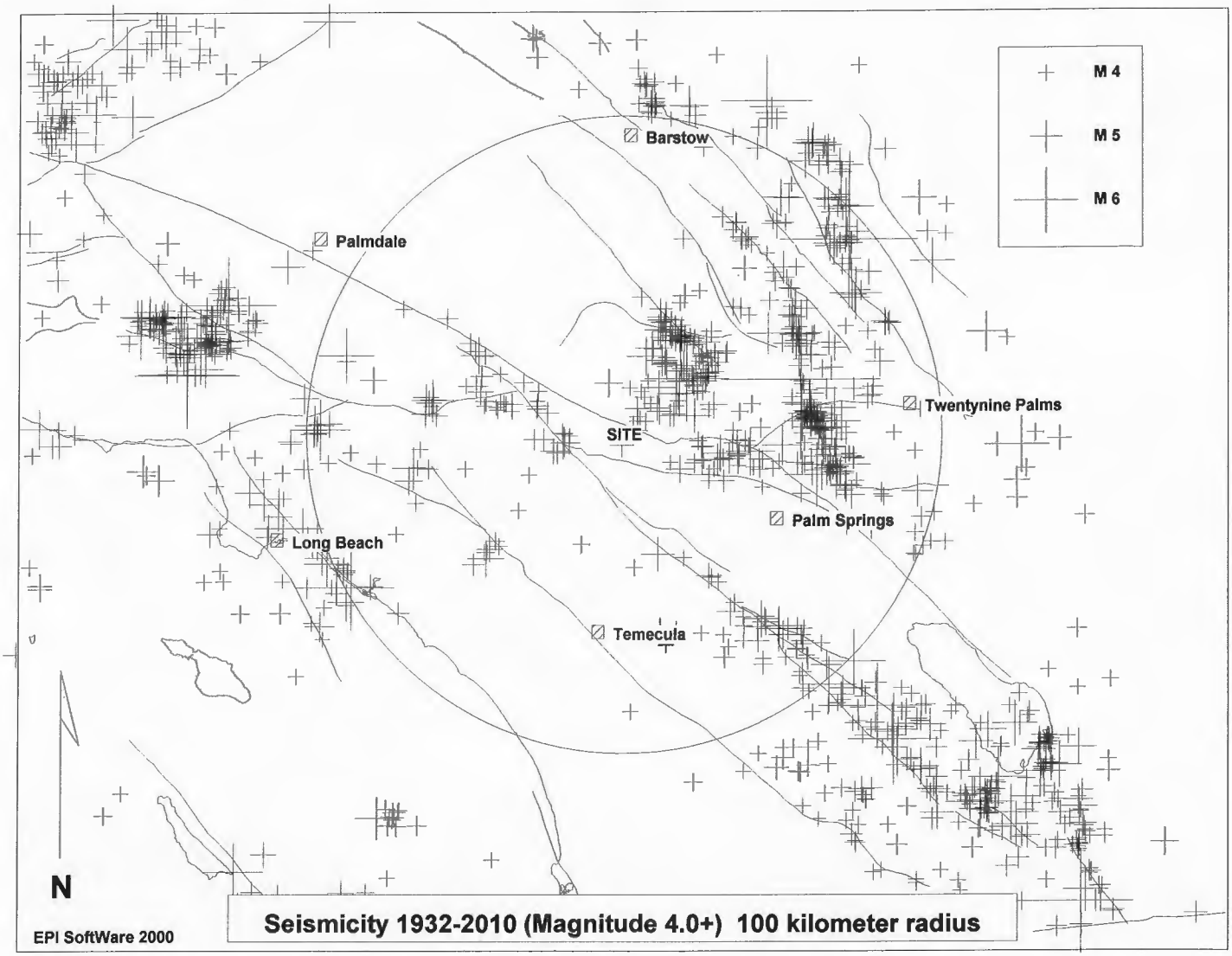
EARTHQUAKE FAULT ZONE MAP

PROJECT:	WILSON CREEK BUSINESS PARK SPECIFIC PLAN	PROJECT NO.:	12829.3
CLIENT:	CITY OF YUCAIPA	ENCLOSURE:	A-5
LOR Geotechnical Group, Inc.		DATE:	SEPTEMBER, 2013
		SCALE:	1" = 2,100'



CITY OF YUCAIPA FAULT-RUPTURE HAZARD ZONES MAP

PROJECT:	WILSON CREEK BUSINESS PARK SPECIFIC PLAN	PROJECT NO.:	12829.3
CLIENT:	CITY OF YUCAIPA	ENCLOSURE:	A-6
LOR Geotechnical Group, Inc.		DATE:	SEPTEMBER, 2013
		SCALE:	1" = 1,750'



SITE LOCATION: 34.0463 LAT. -117.0407 LONG.

MINIMUM LOCATION QUALITY: C

TOTAL # OF EVENTS ON PLOT: 1499

TOTAL # OF EVENTS WITHIN SEARCH RADIUS: 572

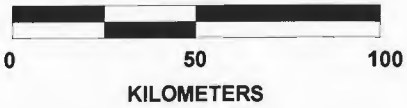
MAGNITUDE DISTRIBUTION OF SEARCH RADIUS EVENTS:

4.0- 4.9 : 518
5.0- 5.9 : 48
6.0- 6.9 : 4
7.0- 7.9 : 2
8.0- 8.9 : 0

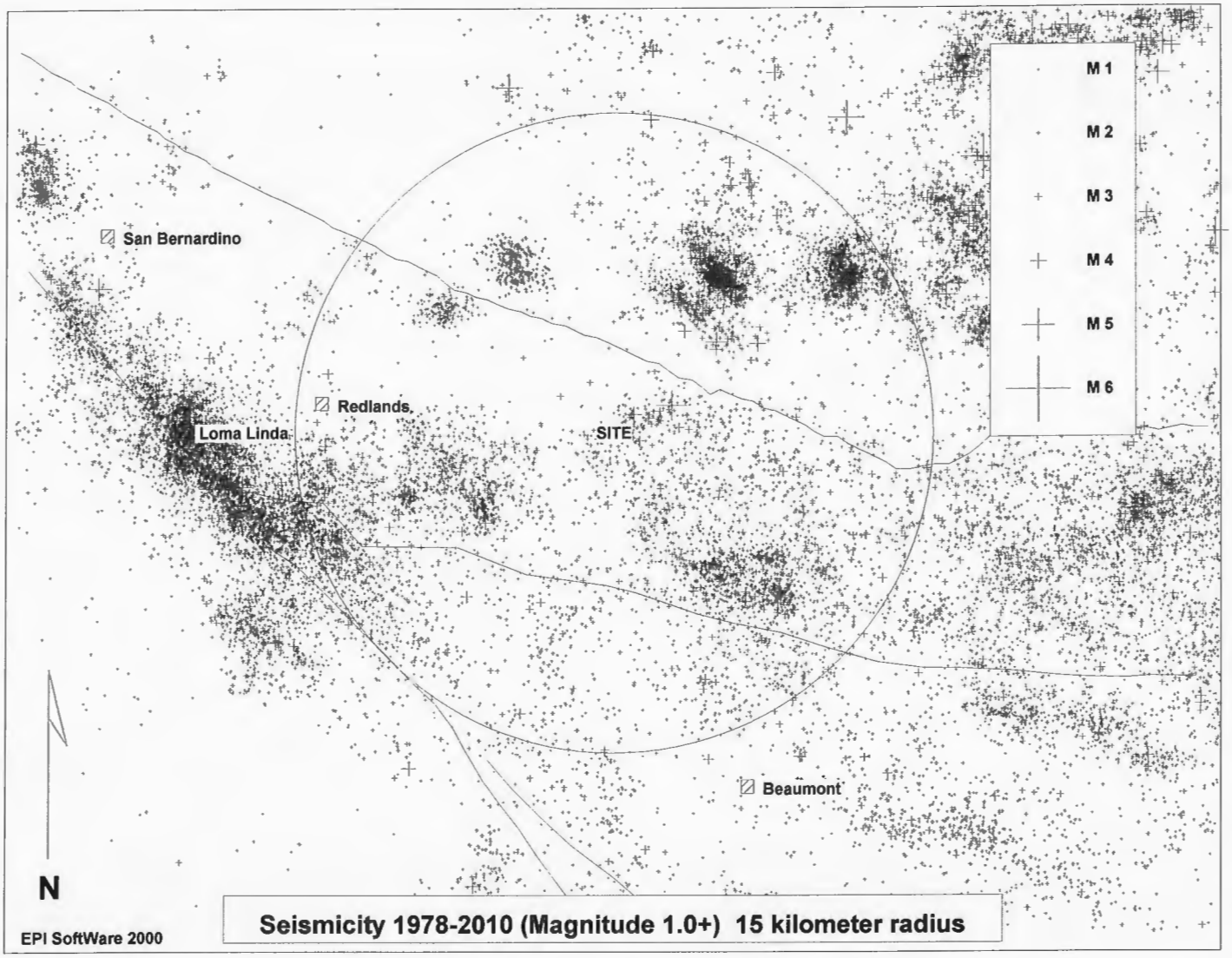
CLOSEST EVENT: 4.0 ON MONDAY, JUNE 27, 2005 LOCATED APPROX. 1.2 KILOMETERS NORTHEAST OF THE SITE

LARGEST 5 EVENTS:

7.3 ON SUNDAY, JUNE 28, 1992 LOCATED APPROX. 58 KILOMETERS EAST OF THE SITE
7.1 ON SATURDAY, OCTOBER 16, 1999 LOCATED APPROX. 93 KILOMETERS NORTHEAST OF THE SITE
6.4 ON SUNDAY, JUNE 28, 1992 LOCATED APPROX. 26 KILOMETERS NORTHEAST OF THE SITE
6.4 ON SATURDAY, MARCH 11, 1933 LOCATED APPROX. 98 KILOMETERS SOUTHWEST OF THE SITE
6.1 ON THURSDAY, APRIL 23, 1992 LOCATED APPROX. 67 KILOMETERS EAST OF THE SITE



Enclosure A-7



SITE LOCATION: 34.0463 LAT. -117.0407 LONG.

MINIMUM LOCATION QUALITY: A

TOTAL # OF EVENTS ON PLOT: 21330

TOTAL # OF EVENTS WITHIN SEARCH RADIUS: 7600

0 7 15
KILOMETERS

MAGNITUDE DISTRIBUTION OF SEARCH RADIUS EVENTS:

1.0- 1.9 : 6210
2.0- 2.9 : 1288
3.0- 3.9 : 91
4.0- 4.9 : 11
5.0- 5.9 : 0
6.0- 6.9 : 0
7.0- 7.9 : 0
8.0- 8.9 : 0

CLOSEST EVENT: 1.8 ON FRIDAY, SEPTEMBER 03, 1982 LOCATED APPROX. .1 KILOMETER OF THE SITE

LARGEST 5 EVENTS:

4.9 ON THURSDAY, JUNE 16, 2005 LOCATED APPROX. 2 KILOMETERS NORTHEAST OF THE SITE
4.7 ON THURSDAY, OCTOBER 01, 1998 LOCATED APPROX. 13 KILOMETERS NORTHEAST OF THE SITE
4.7 ON SUNDAY, AUGUST 16, 1998 LOCATED APPROX. 13 KILOMETERS NORTHEAST OF THE SITE
4.6 ON MONDAY, JUNE 29, 1992 LOCATED APPROX. 9 KILOMETERS NORTHEAST OF THE SITE
4.4 ON TUESDAY, JUNE 30, 1992 LOCATED APPROX. 6 KILOMETERS NORTHEAST OF THE SITE

Enclosure A-8

APPENDIX B

Geophysical Survey Report by Terra Geosciences

GEOPHYSICAL SURVEY

WILSON CREEK BUSINESS PARK SPECIFIC PLAN

CITY OF YUCAIPA, CALIFORNIA

Project No. 132666-1

September 5, 2013

Prepared for:

LOR Geotechnical Group, Inc.
6121 Quail Valley Court
Riverside, CA 92507

Consulting Engineering Geology & Geophysics

P.O. Box 1090, Loma Linda, CA 92354 • 909 796-4667

LOR Geotechnical Group, Inc.
6121 Quail Valley Court
Riverside, CA 92507

Attention: Mr. John Leuer, President

Regarding: Seismic Refraction Survey
Wilson Creek Business Park Specific Plan
City of Yucaipa, California
LOR Project No. 12829.3

INTRODUCTION

In accordance with your request, we have completed a geophysical survey using the seismic refraction method within a portion of the subject site as referenced above. We understand that there are two concealed fault traces that have been mapped to traverse along a northeast-southwest direction through the subject site and that non-invasive geophysical methods have been deemed appropriate in order to aid in evaluating the deeper subsurface geological structure with respect to any faulting potentials. This report will describe in further detail the seismic refraction methodology, field procedures used, data processing of the various seismic modeling programs utilized, and the results of this survey, along with the representative composite geologic seismic model (Seismic Line S-1) being presented on Plate 1. The location of the seismic traverse has been approximated on a captured Google™ Earth image (Google™ Earth, 2013) which is presented as the Seismic Line Location Map, Figure 1. As authorized by you, the following services were performed during this study:

- **Review of available pertinent published and unpublished geologic and geophysical data in our files pertaining to the site, along with a field reconnaissance.**
- **Conducting a geophysical survey, using the seismic refraction method, to aid in evaluating the deeper subsurface lithology and geologic structure present beneath the subject site. The field survey and the data analysis were performed by a licensed State of California Professional Geophysicist.**
- **Preparation of a representative geologic seismic model displaying a composite model created from a compilation of various computer data analytical programs.**
- **Preparation of this report, presenting the results of our interpretation of the geophysical data with respect to any possible anomalous features at depth.**

Accompanying Map, Illustrations, and Appendix

Figure 1 - Seismic Line Location Map
Figure 2 - Time-Distance Plot
Plate 1 - Seismic Line S-1
Appendix A - References

PROJECT SUMMARY

As requested, we have performed a geophysical survey using the seismic refraction method within a portion of the proposed Wilson Creek Business Park as referenced above. The subject study area is generally located just southeast of the intersection of Oak Glen Road and 2nd Street, in the City of Yucaipa, California. The purpose of this geophysical study was to provide both a qualitative and quantified geophysical analysis of the subsurface geologic structure, using the seismic refraction method, in order to discern and any anomalous geologic structures that may be related to faulting beneath the subject site. Our study involved using various seismic refraction computer modeling programs for both quality control and comparative purposes, which allowed for an unbiased and more thorough analysis. Each of these modeling programs, as described in more detail further in this report, have both strengths and limitations and it was our intention to compile these models to form a more coherent representation of the interpreted subsurface geologic structure.

As requested, the seismic traverse was placed along a roughly perpendicular direction to the two concealed fault trends as mapped by the City of Yucaipa (2000) and also the singular fault trace as mapped by Matti et al. (2003), in order to evaluate the nature of these mapped features and possible correlation with structural faulting controls at depth. A pathway for the seismic line traverse was cleared of vegetation to insure that there were no deviations in the line orientation or elevations that could introduce error into the survey line geometry. Since a base map was not available to display the seismic traverse, the approximate location is presented on a captured Google™ Earth (2013) image as presented on the Seismic Line Location Map (see Figure 1). Additionally, a representative photograph of this traverse is also presented on Figure 1 for visual and reference purposes.

The surficial earth materials mantling the survey traverse, as mapped by Matti et al. (2003), consist of young axial-valley deposits of middle to latest Holocene age, and are generally described as being comprised of slightly- to moderately-consolidated silt, sand, and gravel. Locally along the wash that traverses the central portion of the survey line, latest Holocene age very young wash deposits have been mapped consisting of unconsolidated sand and gravel deposits. Mapped along the southern-most portion of the survey traverse are old axial-valley deposits (late to middle Pleistocene age), generally comprised of moderately- to well-consolidated silt, sand, and gravel.

SUMMARY OF SEISMIC REFRACTION SURVEY

Methodology

The seismic refraction method is well suited to identify whether there is a distinct velocity change at depth which could represent a possible subsurface structural differential. The seismic refraction method consists of measuring (at known points

along the surface of the ground) the travel times of compressional waves generated by an impulsive energy source and can be 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. 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 each of the geophone locations can be related to the relative seismic velocities of the subsurface layers in feet per second (fps), which can then be used to aid in interpreting both the depth and type of materials encountered.

Field Procedures

One refraction survey line was performed (Seismic Line S-1) along a general northwest to southeast direction being in a near-perpendicular orientation to the mapped concealed faults that traverse through the subject property. The survey line was located in the field using existing cultural and topographic features which were clearly visible on the Google™ Earth (2013) imagery, in addition to obtaining Global Positioning System (GPS) coordinates. Although the seismic traverse was not surveyed at the time this report was prepared, the location as presented on the Google™ Earth image (see Figure 1) is considered to be fairly accurate. This survey line was strategically placed so that both mapped concealed faults would be traversed. Seismic Line S-1 consisted of a series of five individual shorter survey spreads (each being 230 feet in length) which were overlapped and combined to produce one continuous 970-foot survey line. All of the individual spreads consisted of a series of twenty-four geophones that were spaced at 10-foot centers, with six common geophones overlapped between each spread. These overlapped lines allowed for seismic wave depth penetration of over 100 feet while providing a continuous, unbroken subsurface profile between the overlapped spreads therefore maintaining a higher resolution model.

To produce the seismic wave energy, a 16-pound sledge-hammer was used as the energy source and a series of 14-Hertz geophones were employed to detect both the direct and refracted waves. Seven shot points (each using multiple hammer impacts to increase the signal to noise ratio) were utilized along each of the individual spreads using forward, reverse, and several intermediate locations in order to obtain high resolution survey data for velocity analysis and depth modeling purposes. The seismic wave arrivals were digitally recorded in SEG-2 format on a Geometrics StrataVisor™ NZXP model signal enhancement refraction seismograph. The data was acquired using a sampling rate of 0.0625 milliseconds having a record length of 0.16 seconds with no acquisition filters. The data on the display screen were used to analyze the arrival time of the primary seismic “P”-waves at each geophone station for quality control purposes in the field. In all, this survey traverse utilized a total of 35 shot points with 96 fixed geophone /receiver locations, with a resultant of 840 traces being modeled.

Data Reduction

All of the recorded seismic data was subsequently transferred to our office computer for further processing and analyzing, using the computer programs **SIPwin** (**S**eismic Refraction **I**nterpretation **P**rogram for **Win**dows) developed by Rimrock Geophysics, Inc. (2004); **Refractor** (Geogiga, 2001-2013); **SeisOpt™@2D** (Optim, Inc., 2008), and **Rayfract™** (Intelligent Resources, Inc., 1996-2013), and are summarized below.

- **SIPwin** is a ray-trace modeling program that evaluates the subsurface using layer assignments based on time-distance curves and is better suited for layered media, using the "Seismic Refraction Modeling by Computer" method (Scott, 1973). The first step in the modeling procedure is to compute layer velocities by least-squares techniques. Then the program uses the delay-time method to estimate depths to the top of layer-2. A forward modeling routine traces rays from the shot points to each geophone that received a first-arrival ray refracted along the top of layer-2. The travel time of each such ray is compared with the travel time recorded in the field by the seismic system. The program then adjusts the layer-2 depths so as to minimize discrepancies between the computed ray-trace travel times and the first arrival times picked from the seismic waveform record. The process of ray tracing and model adjustment is repeated a total of three times to improve the accuracy of depths to the top of layer-2.

- **Refractor** is seismic refraction software that also evaluates the subsurface using layer assignments utilizing interactive and interchangeable analytical methods that include the Delay-Time method, the ABC method, and the Generalized Reciprocal Method (GRM). These methods are used for defining irregular non-planar refractors and are briefly described below.

    1. The *Delay-Time* method will measure the delay time depth to a refractor beneath each geophone rather than at shot points. Delay-time is the time spent by a wave to travel up or down through the layer (slant path) compared to the time the wave would spend if traveling along the projection of the slant path on the refractor.

    2. The *ABC* (intercept time) method makes use of critically refracted rays converging on a common surface position. This method involves using three surface to surface travel times between three geophones and the velocity of the first layer in an equation to calculate depth under the central geophone and is applied to all other geophones on the survey line.

    3. The *GRM* method is a technique for delineating undulating refractors at any depth from in-line seismic refraction data consisting of forward and reverse travel-times and is capable of resolving dips of up to 20% and does not over-smooth or average the subsurface refracting layers. In addition, the technique provides an approach for recognizing and compensating for hidden layer conditions.

- **SeisOpt™@2D** models the subsurface velocity gradient using discrete velocity "cells." This program is an automatic refraction interpretation package that performs velocity model optimization and visualization using a nonlinear optimization technique called adaptive simulated annealing which involves repeated forward modeling. Test velocity models are created, through which travel times are calculated and are compared with the observed data, and are optimized. The optimal solution is the velocity model with the minimum travel-time error between the calculated and observed data.

- **Rayfract™** is seismic refraction tomography software that models subsurface refraction, transmission, and diffraction of acoustic waves which generally indicates the relative structure and velocity distribution of the subsurface using first break energy propagation modeling. An initial 1D gradient model is created using the Delta-t-V method which gives a good initial fit between modeled and picked first breaks. This initial model is then refined automatically with a true 2D WET (Wavepath Eikonal Traveltime) tomographic inversion (Schuster and Quintus-Bosz, 1993). WET tomography models multiple signal propagation paths contributing to one first break, whereas conventional ray tracing tomography is limited to the modeling of just one ray per first break.

The combined use of these computer programs provided a more thorough analysis of the subsurface structure and velocity characteristics with respect to identifying any anomalous features that may be suggestive of subsurface faulting. Each computer program has a specific purpose based on the objective of the analysis. **SeisOpt™@2D** and **Rayfract™** provided tomographic velocity and structural imaging that is very conducive to detecting strong lateral velocity characteristics, while **SIPwin** and **Refractor** are generally based on detecting layered media with some lateral velocity contrast being imaged.

All of the computer programs perform their analysis using exactly the same input data which includes first-arrival "P"-waves and survey line geometry. The resultant travel-time curve for the seismic line that was developed from picking of the primary seismic "P"-wave data is presented on Figure 2 for reference and appears as the Time-Distance Plot, which presents both the raw data points and the assigned velocity layers

SUMMARY OF DATA ANALYSIS

As previously discussed, the primary purpose of the seismic refraction survey was to aid in evaluating any possible anomalous geologic structures at depth such as offset stratigraphic units (i.e., lateral velocity contrasts) that may be suggestive of subsurface faulting. For this survey we used four different computer processing software methods in order to produce one coherent and comprehensive seismic model of which is described in more detail below, along with the representative model (Seismic Line S-1) being presented on Plate 1.

To produce the final seismic model, initial preliminary layer models were created from the computer programs **SIPwin** and **Refractor**, with three distinct seismic velocity layers being imaged. The uppermost velocity layer V1 is most likely comprised of undifferentiated younger alluvial type deposits (i.e., fan or valley alluvium, wash deposits, and/or artificial fill materials from previous quarry activities) that have an average weighted velocity of 1,558 fps. This velocity is characteristic of most unconsolidated, surficial earth material deposits. The intermediate V2 velocity layer has an average weighted velocity of 2,576 fps, which is believed to represent older alluvial deposits, such as exposed along the southern-most portion of the survey traverse and as mapped by Mattie et al. (2003). This velocity is very typical for most locally indurated and consolidated older alluvial-type earth materials found in the southern California region. These older alluvial deposits most likely are continuous at depth beneath the younger alluvial deposits as suggested by the seismic model presented on Plate 1.

The lower V3 velocity layer was found to have average weighted velocity of 5,601 fps and could possibly correspond to saturated older alluvial deposits, with the boundary between V2 and V3 layers representing the approximate top of the groundwater table. Wet, poorly-consolidated materials typically have velocities a little greater than that of water (approximately 4,600 to 4,900 fps) and the top of the water table is often a prominent seismic interface (Milson, 1989). Saturated coarse-grained sediments typically have velocities ranging from 5,000 fps to 7,000 fps, depending on the lithologic and consolidated nature of the subsurface materials. Other natural earth materials with velocities greater than 5,000 fps would include crystalline igneous and metamorphic bedrock (i.e. granite, gneiss, schist, etc.) and some varieties of well-consolidated sedimentary bedrock (i.e. sandstone, limestone, etc.). Based on the velocity obtained of 5,601 fps and the presumed absence of any crystalline or sedimentary bedrock at depth within the local area, it is believed that this velocity most likely represents saturated older alluvial deposits.

The layered seismic information (velocity and depth boundaries) as discussed above was then integrated with the **Rayfract™** tomographic model of which created the subsurface shape of the composite seismic model (Seismic Line S-1), based on the seismic wave ray coverage that was sampled. The data of this ray coverage appeared to be of very good quality which was verified by having a Root Mean Square Error (RMS) of 1.4 percent (see Plate 1). The RMS error (misfit between picked and modeled first break times) is automatically calculated during the processing routine, with a value of less than 2.0% being preferred. The tomographic models (including **SeisOpt™@2D**) indicated a relatively smooth and planar velocity structure with the velocity gradient gradually increasing with depth. No lateral velocity contrasts were noted.

In summary, the final model presented as Seismic Line S-1, was created by integrating the average-weighted seismic velocities and depth boundaries onto the shape of the tomographic model using the actual ray coverage, providing the most comprehensive model possible. It should be noted that estimates of the layer velocity boundaries are generally considered to be within 10± percent of the total depth of the contact.

SUMMARY OF FINDINGS AND CONCLUSIONS

The raw field data was considered to be of very good quality with minor amounts of ambient “noise” that was introduced during our survey most likely from vehicular traffic on nearby roads. Analysis of the data and picking of the primary “P”-wave arrivals was therefore performed with very little difficulty, with very minor to no interpolation of the data being necessary.

Based on the results of our comparative seismic analyses of the computer programs **SIPwin**, **Refractor**, **SeisOpt™@2D**, and **Rayfract™**, these models appeared to generally coincide with one another, with some minor variances due to the methods that these programs process and integrate the input data. The layer velocity models did not indicate any significant lateral velocity boundary differentials across the profiles. Additionally, it was noted that the velocity boundaries were generally planar and consistent on all of the models, along with similar velocities for each of the layers, suggesting generally uniform, undisturbed stratigraphy. The tomographic models were also found to have overall relatively planar structural velocity contouring with no sharp lateral velocity offsets or anomalies. There are some local very minor inflections that may be due to internal stratigraphic complexities such as channeling. The consistency between the various models made it relatively easy to integrate the data to create the composite geologic seismic model as presented on Plate 1.

In summary, based on the data obtained, there do not appear to be any observable anomalous conditions from a geophysical standpoint that would suggest that subsurface faulting is present within the limits of our survey traverses. Based on the data obtained during this study, it is most likely that the V2/V3 layer boundary contact represents the local groundwater surface based on the velocities obtained and the local geologic setting. This boundary does not appear to be impeded by any subsurface barrier.

CLOSURE

The field survey was performed by the undersigned on August 21, 2013 using "state of the art" geophysical equipment and techniques along the selected portion of the subject study area as directed by you. The seismic data was evaluated using various seismic inversion computer programs, including using recently developed tomographic inversion techniques to provide a more thorough analysis and understanding of the subsurface structural conditions. It should be noted that our data was obtained along only one specific location therefore other areas in the local vicinity beyond the limits of our seismic lines may contain different velocity layers, depths, and structures not encountered during this field survey.

It is important to understand that the fundamental limitation for seismic refraction surveys is known as nonuniqueness, wherein a specific seismic refraction data set does not provide sufficient information to determine a single “true” earth model. Therefore,

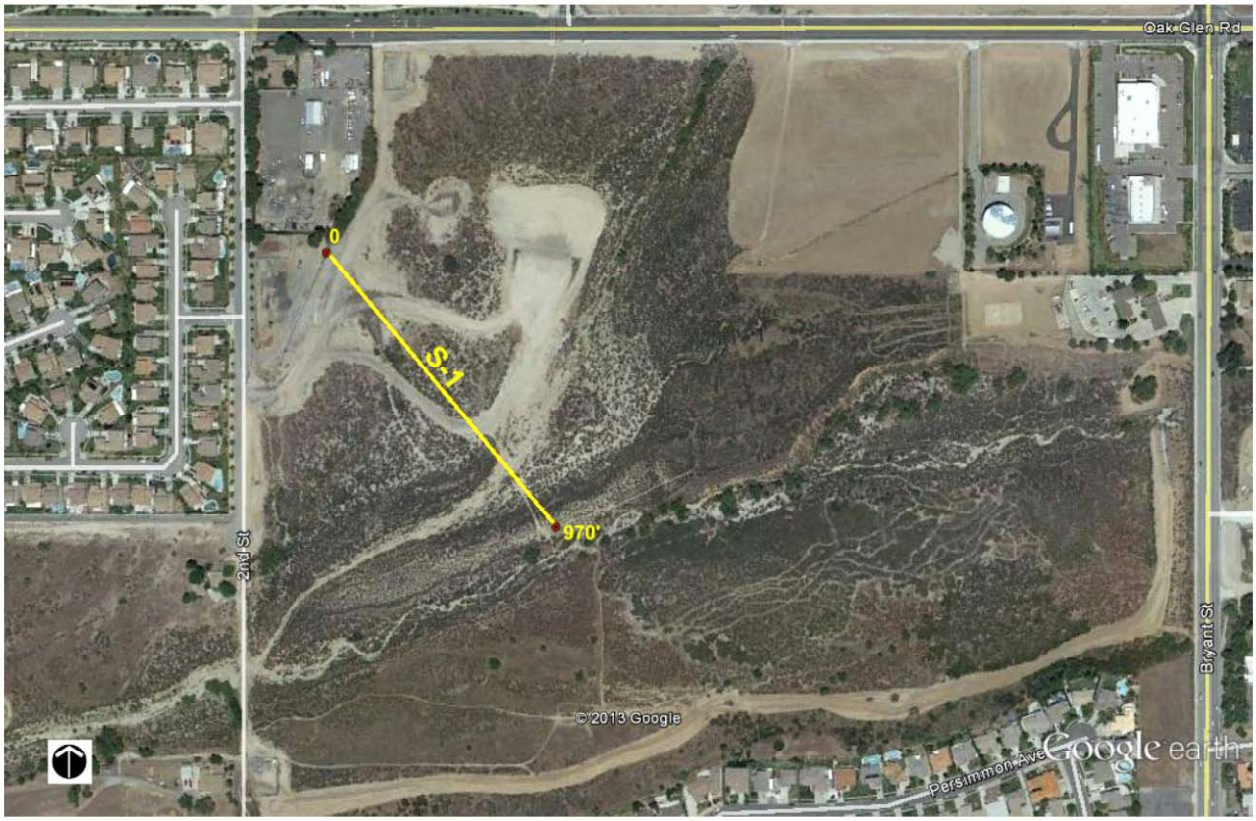
the interpretation of any seismic data set uses “best-fit” approximations along with the geologic models that appear to be most reasonable for the local area being surveyed. Client should also understand that when using the theoretical geophysical principles and techniques discussed in this report, sources of error are possible in both the data obtained and in the interpretation and that the results of this survey may not represent actual subsurface conditions. These are all factors beyond **Terra Geosciences** control and no guarantees as to the results of this survey can be made. We make no warranty, either expressed or implied. If the client does not understand the limitations of this geophysical survey, additional input should be sought from the consultant.

This opportunity to be of service is sincerely appreciated. If you should have any questions regarding this report or do not understand the limitations of this study or the data that is presented, please do not hesitate to contact our office at your earliest convenience.

Respectfully submitted,
TERRA GEOSCIENCES

Donn C. Schwartzkopf
Professional Geophysicist
PGP 1002

SEISMIC LINE LOCATION MAP

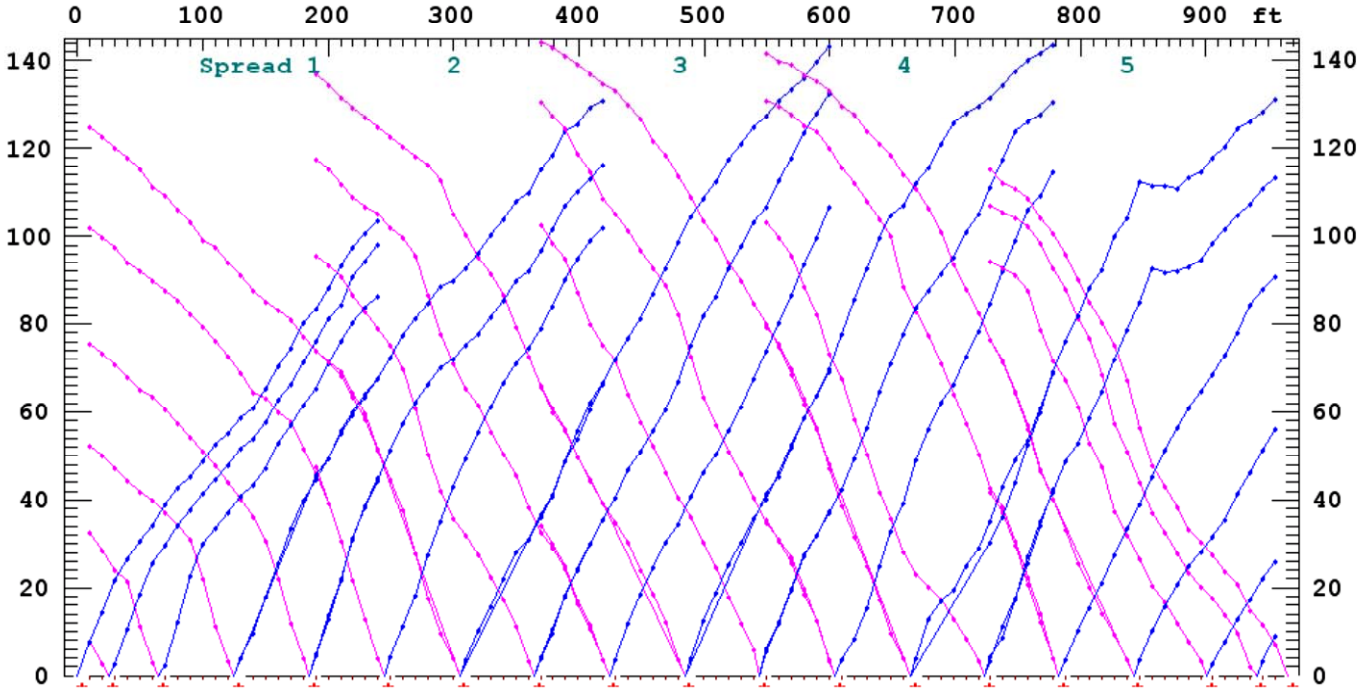


View looking northwest along Seismic Line S-1.

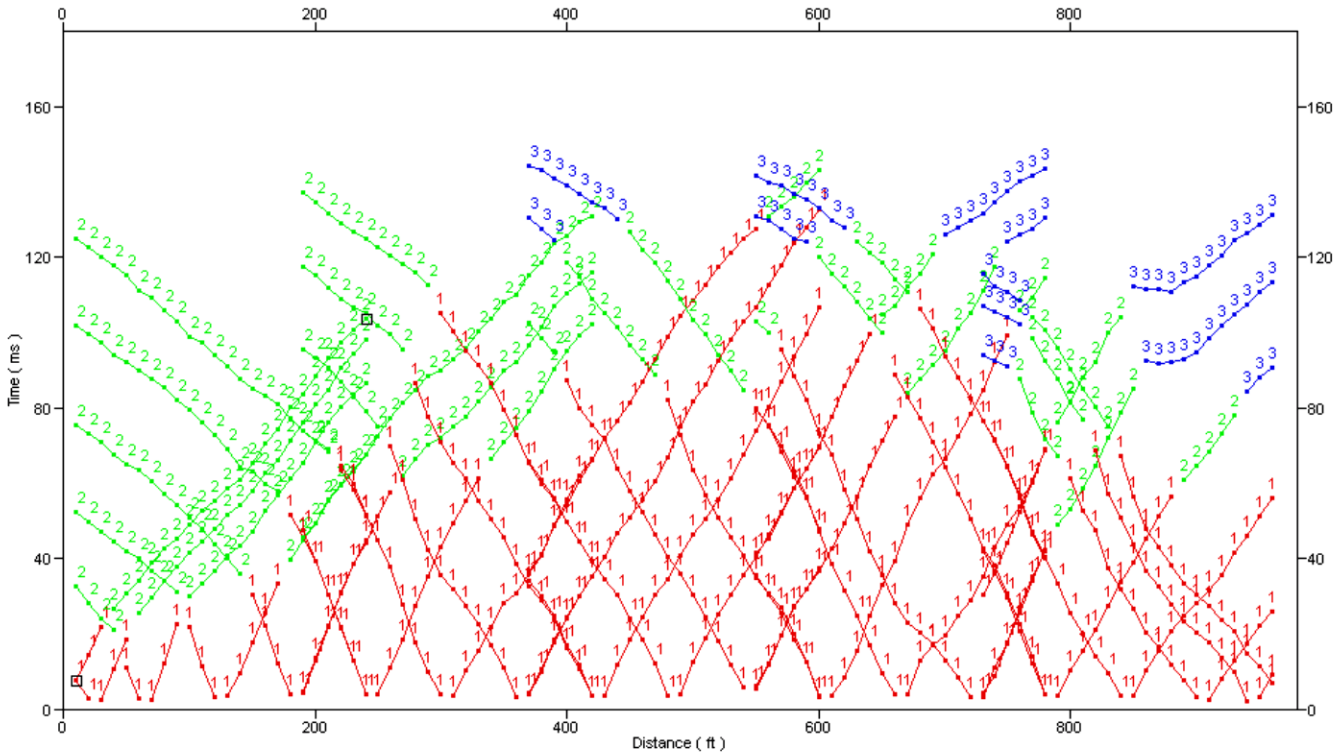
PROJECT NO. 132666-1

FIGURE 1

TIME-DISTANCE PLOT



T-D Plot with Raw Data Points

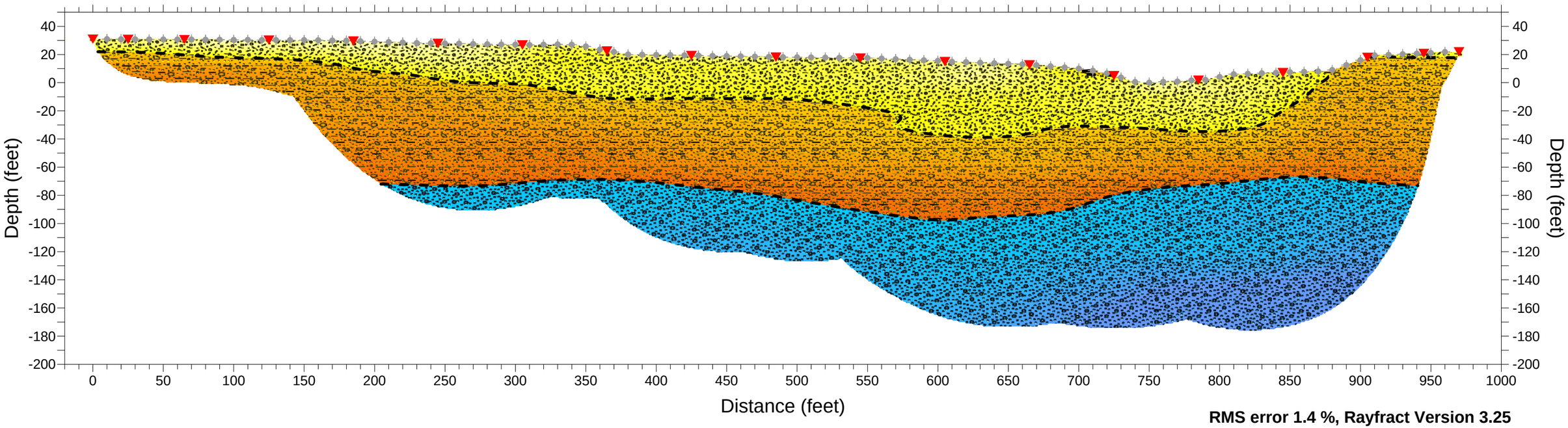


T-D Plot with Assigned Layers

SEISMIC LINE S-1

South 40° East →

COMPOSITE GEOLOGIC SEISMIC MODEL



RMS error 1.4 %, Rayfract Version 3.25

▼ **Seismic Source**

✦ **Geophone Reciever**

V1	V2	V3
1558	2576	5601

P-Wave Velocity (feet/second)

Wilson Creek Business Park
City of Yucaipa, California

PLATE 1

APPENDIX A

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REFERENCES

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