FINAL GEOTECHNICAL DESKTOP STUDY
BALBOA AVENUE STATION AREA SPECIFIC PLAN
CITY OF SAN DIEGO

Submitted to:

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AGE Project No. 171 GS-15-A

January 22, 2018

AGE

Allied Geotechnical Engineers, Inc.

January 22, 2018

Ms. Diane L. Bathgate, AICP
Manager of Planning
RRM Design Group
2952 Main Street
San Diego, CA 92113

Subject: FINAL GEOTECHNICAL DESKTOP STUDY
BALBOA AVENUE STATION AREA SPECIFIC PLAN
CITY OF SAN DIEGO
AGE Project No. 171 GS-15-A

Dear Ms. Bathgate:

In accordance with your request, we are pleased to submit this Final Report which presents the findings, opinions and recommendations of a geotechnical desktop study that we have performed for the above-mentioned subject project. This report incorporates our response to the review comments that we received from the City of San Diego Development Services Department regarding our report dated November 7, 2016.

We greatly appreciate the opportunity to be of service on this important project for the City of San Diego. Should you have any questions or need further assistance, please feel free to give us a call.

Sincerely,

ALLIED GEOTECHNICAL ENGINEERS, INC.

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FINAL GEOTECHNICAL DESKTOP STUDY
BALBOA AVENUE STATION AREA SPECIFIC PLAN
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TABLE OF CONTENTS

Page No.

1.0 SITE AND PROJECT DESCRIPTION 1

2.0 OBJECTIVE AND SCOPE OF STUDY 2
2.1 Information Review 2
2.2 Site Reconnaissance 3
2.3 Data Evaluation and Reporting 3

3.0 GEOLOGIC CONDITIONS 3
3.1 Geologic Setting.. 3
3.2 Tectonic Setting 3
3.3 Geologic Units 4
3.3.1 Fill Materials. 4
3.3.2 Young Alluvial Deposits. 4
3.3.3 Young Colluvial Deposits. 5
3.3.4 Old Alluvial Deposits. 5
3.3.5 Old Paralic Deposits. 5
3.3.6 San Diego Formation. 5
3.3.7 Scripps Formation. 6
3.3.8 Ardath Shale.. 6
3.3.9 Mount Soledad Formation 6
3.4 Groundwater 6

TABLE OF CONTENTS

Page No.

4.0 GEOLOGIC HAZARDS 7
- 4.1 Local Faulting 7
- 4.2 Historical Seismicity 11
- 4.3 Seismic Design Parameters. 12
- 4.4 Liquefaction. 14
- 4.5 Fault Ground Rupture. 15
- 4.6 Landslides 15
- 4.7 Lateral Spread and Slope Stability. 15
- 4.8 Differential Seismic-Induced Settlement. 16
- 4.9 Ground Lurching. 16
- 4.10 Expansive Soils. 17
- 4.11 Compressible Soils. 17
- 4.12 Secondary Hazards.. 17

5.0 CONCLUSIONS AND RECOMMENDATIONS. 17

6.0 LIMITATIONS 20

7.0 REFERENCES 20

TABLE OF CONTENTS
(continued)

Page No.

Table

Table 1 Summary of Fault Parameters. 9

Table 2 Summary of Seismic Source Characteristics. 11

Table 3 Summary of Seismic Design Parameters. 13

Table 4 Summary of Geotechnical Design Criteria. 19

Figures

Figure 1 Project Location Map

Figures 2-1 through 2-3 Generalized Geologic Map

Figure 3 Geologic Hazards Map

Figures 4-1 and 4-2 Local Fault Map

Figure 5 Regional Fault Map

Figure 6 Design Response Spectrum

Figure 7 Risk-Targeted Maximum Considered Earthquake (MCE_R)

FINAL GEOTECHNICAL DESKTOP STUDY
BALBOA AVENUE STATION AREA SPECIFIC PLAN
CITY OF SAN DIEGO

1.0 SITE AND PROJECT DESCRIPTION

In accordance with the request of RRM Design Group (RRM), Allied Geotechnical Engineers, Inc. (AGE) has performed a geotechnical desktop study for the Balboa Avenue Station Area Specific Plan (BASASP) for the City of San Diego. The study was performed in conformance with AGE's proposal dated July 29, 2015, and the subconsultant agreement entered into by and between RRM and AGE on February 1, 2016.

Based on a review of the BASASP Second Screencheck Draft Environmental Impact Plan, dated December 2017, it is our understanding that the BASASP is intended to engage the community to establish transit-oriented development adjacent to the planned Balboa Avenue Trolley station and produce a Specific Plan and implementation program that addresses transportation demand, economic market analysis, urban design concepts, and multimodal improvement projects. The limits of the project study area are shown on the Project Location Map (Figure 1).

The project study area is located along the Interstate 5 (I-5) corridor within the Pacific Beach and Clairemont Mesa communities in the City of San Diego. The project study area is generally bounded by Morena Boulevard on the east, Rose Creek to the west, Grand Avenue and Mission Bay Drive to the south and approximately 900 feet north of Avati Drive to the north. Site elevations within the study area vary from approximately 10 feet to 145 feet above the mean sea level (msl). The study area encompasses a developed area with a mix of residential, commercial, and industrial uses. Existing major transportation routes within the project study area include the I-5 Freeway and the Metropolitan Transit System (MTS) Los Angeles to San Diego and San Luis Obispo (LOSSAN) Rail Corridor. Major roadways within the study area include Mission Bay Drive, Grand Avenue, Garnet/Balboa Avenue and Morena Boulevard.

The proposed BASASP analyzed in the Environmental Impact Report is a planning document that provides the policy framework to guide transit-oriented public and private development and multi-modal improvements in the vicinity of the proposed Balboa Avenue Trolley Station which are consistent with the City of San Diego’s General Plan City of Villages strategy. The proposed BASASP provides recommendations and guidelines for new mixed-use development and improvements to the public right-of-way (ROW) to develop access to the Balboa Avenue Trolley Station to capitalize on the new regional transit connection in the area. It proposes to increase residential density by redesignating and rezoning lands, and promotes an increase in transportation choices thereby decreasing dependence on single-occupancy vehicles and reducing traffic congestion at local intersections and roadways.

The approved Balboa Avenue Trolley Station Concept plan indicates that the proposed station will be located in an triangular-shaped parcel on the east side of the LOSSAN Rail Corridor, south of Balboa Avenue and west of Morena Boulevard. The scope of the proposed project will include the design and construction of the station itself, parking facility, retaining walls, and a pedestrian bridge across Balboa Avenue. The proposed station would be constructed as part of the Mid-Coast Corridor Light Rail Transit Project, which would extend the Blue Line from Old Town to Westfield UTC in the University City community.

2.0 OBJECTIVE AND SCOPE OF STUDY

The objective of this desktop study is to provide general information and to evaluate potential major geologic and geotechnical issues and constraints which could impact proposed developments in the study area. The scope of the desktop study includes the performance of several tasks/services which are more fully described below.

2.1 Information Review

For this task, we have reviewed information pertaining to the project area that was readily available from a variety of sources which include the following:

- AGE's in-house references and aerial photographs;
- Published geologic literature and maps, including geologic and fault maps published by the City of San Diego, Federal Emergency Management Agency, California Geological Survey and United States Geological Survey;
- Pertinent project-related information, including geotechnical reports prepared by others;
- BASASP Second Screencheck Draft Environmental Impact Report, prepared by RRM, dated December, 2017;
- Aerial photography available at Google Earth.

A listing of the references that were reviewed for this study is presented in Section 7.0.

2.2 Site Reconnaissance

The information obtained from our literature review was supplemented with visual observations gathered during our field reconnaissance visits conducted on August 15 and 24, 2016. The purpose of the site visits was to observe existing site conditions and geologic exposures within the project study area.

2.3 Data Evaluation and Reporting

This task involved a synthesis and evaluation of the data collected during the information review and field reconnaissance phases of this study, particularly with respect to known and anticipated geotechnical conditions and potential geologic hazards, such as faulting and seismicity; seismic-induced hazards, slope stability issues, and landslides. Based on an evaluation of the data, we have prepared this report to present a summary of our preliminary findings and opinions.

3.0 GEOLOGIC CONDITIONS

3.1 Geologic Setting

The project study area is located in the Peninsular Ranges geomorphic province, a north-south oriented mountain range which extends from the southern edge of the Los Angeles Basin into Baja California, Mexico. Basement rocks of the Peninsular Ranges province include Cretaceous crystalline rocks of the Southern California Batholith and Jurassic metasedimentary and metavolcanic rocks of the Santiago Peak Volcanics.

The project study area is situated in the western portion of the San Diego Embayment, a deep sedimentary-filled basin which is underlain at depth by the basement rock complex. The sedimentary formations consist of nearly flat-lying to gently southwest dipping, marine and non-marine sediments which range from Cretaceous to Holocene in age.

3.2 Tectonic Setting

Tectonically, the San Diego region is situated in a broad zone of northwest-trending, predominantly right-slip faults that span the width of the Peninsular Ranges and extend offshore into the California Continental Borderland Province west of California and northern Baja California. At the latitude of San Diego, this zone extends from the San Clemente fault zone, located approximately 50 miles to the west, to the San Andreas fault located about 90 miles to the east.

Major active regional faults of tectonic significance include the Coronado Bank, San Diego Trough, San Clemente, and Newport-Inglewood fault zones which are located offshore; the faults in Baja California, including the San Miguel-Vallecitos and Agua Blanca fault zones; and the faults located further to the east in Imperial Valley which include the Elsinore, San Jacinto and San Andreas fault zones. The active Rose Canyon Fault Zone (RCFZ) runs parallel to Interstate 5 freeway across the project study area.

3.3 Geologic Units

For site characterization purposes, the subsurface materials in the project study area can be categorized into nine (9) geologic units, which include (in order of increasing age): Fill materials; young alluvial deposits; young colluvial deposits; old alluvial deposits; old paralic deposits; San Diego Formation; Scripps Formation; Ardath Shale; and Mt. Soledad Formation. Each geologic unit can be distinguished by its origin or depositional character and has different compositional characteristics. Generalized geologic map is shown on Figures 2-1 through 2-3.

3.3.1 Fill Materials

Mapped fill materials are present in the study area, including the location of the proposed Balboa Avenue Station (Kennedy & Tan, 2005). These materials consist of both hydraulic and mechanically placed fill. Available background information and review of historic aerial photos indicates that much of present day Mission Bay previously consisted of a shallow tidal marsh with mud flats and sand bars that were occasionally covered by water during high tide. Dredging activities beginning in the mid 1940's and continuing through the early 1960's transformed the tidal marsh into the present day Mission Bay Park. Approximately twenty-five million cubic yards of sand and silt was dredged to create the bay and surrounding landforms (City of San Diego, 2016). Hydraulic fills encountered in soil borings by AGE (2015) in the western portion of Mission Bay Park generally consisted of dark gray, fine-grained, micaceous, poorly graded sand with silt containing appreciable amounts of granulated seashells.

3.3.2 Young Alluvial Deposits

Young alluvial deposits of Holocene age are mapped along the valley floor in Rose Canyon (Kennedy & Tan, 2005). The published map describes the alluvial deposits as poorly consolidated, poorly sorted permeable flood plain deposits consisting of sand and gravel with interbedded soft to firm silt and clay.

3.3.3 Young Colluvial Deposits

Although not shown on the published map, Holocene and late Pleistocene age young colluvial deposits were encountered in soil borings performed by AGE (2016) above the east bank of Rose Creek. These deposits were found to consist of brownish yellow, fine-grained silty sand and clayey sand with traces of sub-rounded to sub-angular gravel to 1-inch in maximum dimension. The deposits were found to be wet, with a loose to dense consistency.

3.3.4 Old Alluvial Deposits

Old alluvial deposits of late to middle Pleistocene age (Kennedy & Tan, 2005) are mapped above the east bank of Rose Creek in the northern portion of the study area. The deposits are described as moderately well consolidated, poorly sorted and permeable gravel, sand, silt and clay of fluvial origin that is commonly slightly dissected.

3.3.5 Old Paralic Deposits

Portions of the study area are underlain by old paralic deposits of late to middle Pleistocene age (Kennedy & Tan, 2005). These deposits are also referred to as the Bay Point Formation of late Pleistocene age (Kennedy, 1975). This formation is described as a marine and nonmarine, poorly consolidated fine to medium grained pale brown to reddish brown sandstone that is locally fossiliferous. Based on fossil assemblages, the unit has been assigned a late Pleistocene age (Kennedy, 1975). The old paralic deposits are typically sandy and friable, and readily excavated with conventional construction equipment.

3.3.6 San Diego Formation

The mid to late Pliocene age San Diego Formation is of limited areal extent in the study area. It is mapped at two separate localities to the southeast and northwest of the proposed Balboa Avenue Station site. The San Diego Formation generally consists of a light yellowish brown, friable, fine-grained marine sandstone with some calcium carbonate-cemented zones and fossiliferous beds also present (Kennedy, 1975). Localized zones of cobble-conglomerate may also be encountered within the sandstone. The formation is also known to contain thin beds of bentonite, marl, and brown mudstone.

3.3.7 Scripps Formation

The Scripps Formation is a middle Eocene age sandstone with occasional cobble-conglomerate interbeds (Kennedy, 1975). The unit is mapped on the mid to upper hillside area on the east side of Rose Canyon, south of Balboa Avenue. The combination of local cobble-conglomerate zones and strong cementation pose difficult excavation conditions even for heavy-duty construction equipment.

3.3.8 Ardath Shale

The Ardath Shale is lower to middle Eocene in age, generally consisting of a yellowish brown sandy siltstone (Kennedy, 1975). The formation is thinly bedded to massive, with local concreted zones and expansive claystone. The claystone facies of the Ardath Shale may pose landsliding and slope stability issues. This unit is mapped in the easternmost portion of the study area north of Balboa Avenue.

3.3.9 Mount Soledad Formation

The conglomerate facies of the Eocene age Mount Soledad Formation is exposed on the lower east and west walls of Rose Canyon, and was also encountered below colluvial deposits in soil borings performed by AGE (2016) near Rose Creek. The formation is described as a massive, reddish-brown cobble conglomerate and light brown, medium-grained sandstone that is the basal unit of the La Jolla Group (Kennedy & Tan, 2005). Distinctive red porphyritic rhyolite tuff clasts distinguish the Mount Soledad Formation from the underlying Cabrillo Formation (Kennedy, 1975). The Mount Soledad Formation unconformably overlies the Cabrillo Formation in the study area. The locally abundant gravels and cobbles may pose difficult excavation conditions even for heavy duty construction equipment.

3.4 Groundwater

AGE (2016) encountered groundwater at depths of 2 and 18 feet below the ground surface (bgs) in two borings and one test pit excavation near Rose Creek (approximate respective elevations of 23, 34 and 29 feet msl). HDR Engineering (2013) reportedly encountered groundwater at depths ranging from 10 feet to 24 feet bgs (elevations of 34.5 to 69 feet msl) in seven (7) exploratory borings performed in Rose Canyon near the alignment of the existing LOSSAN rail corridor.

Kleinfelder (2015a) reportedly encountered groundwater at depths ranging from 4 feet to 24 feet bgs (elevations of 30 to 39 feet msl) in ten (10) exploratory borings performed at the location of the proposed Rose Creek South Bridge.

The Geotracker website (www.Geotracker.com) database contains a groundwater monitoring report prepared by Cardno ERI (2013) for a former Mobil gasoline station which was located at 2780 Garnet Avenue. Cardno ERI installed 12 groundwater monitoring wells at this site and in the immediate surrounding area to assess the extent of hydrocarbon contamination. Cardno reportedly measured groundwater at approximate elevations of 10 to 12 feet msl in September of 2013.

The project study area is located in the Miramar Hydrologic Area of the Penasquitos Hydrologic Unit (California Regional Water Quality Control Board, San Diego Region 9, 1995). Groundwater in this area has been exempted by the Regional Board from the municipal use designation under the terms and conditions of State Board Resolution No. 88-63, "Sources of Drinking Water" policy. Groundwater in this zone has a potential beneficial use for industrial service supply.

The Penasquitos Hydrologic Unit is a triangular shaped area of approximately 170 square miles extending from Poway in the east to La Jolla in the west. The unit contains numerous creeks but no major streams. The Miramar storage reservoir, which contains mostly imported water, is located in the unit. The unit also includes Sorrento Lagoon and Mission Bay. Major population centers include Poway and La Jolla.

4.0 GEOLOGIC HAZARDS

Geologic hazards are those hazards that could impact a site due to local and regional geologic and seismic conditions. Based on the results of our study, several potential geologic hazards are identified within the project study area which are more fully described herein. AGE has prepared a Geologic Hazard Map which is presented on Figure 3 - Geologic Hazards Map (City of San Diego Seismic Safety Study, 2008).

4.1 Local Faulting

Several known (mapped) strands of the Rose Canyon fault zone (RCFZ) traverse the study area (Kennedy & Tan, 2005; Kleinfelder, 2015a and b; City of San Diego, 2008; and CDMG, 1991). Therefore, there is a significant potential for fault ground rupture impacting the study area during a major seismic event.

For the purpose of this project, we consider the RCFZ to represent the most significant seismic hazard. The RCFZ is a complex set of anastomosing and en-echelon, predominantly strike slip faults that extend from off the coast near Carlsbad to offshore south of downtown San Diego (Treiman, 1993). In San Diego Bay, this fault zone is believed to splay into multiple, subparallel strands; the most pronounced of which are the Silver Strand, Spanish Bight and Coronado Bank faults.

Previous geologic investigations on the RCFZ in the Rose Creek area (Rockwell et. al., 1991) and in downtown San Diego (Patterson et. al., 1986) found evidence of multiple Holocene earthquakes. Based on these studies, several fault strands within the RCFZ have been classified as active faults, and are included in Alquist-Priolo Special Studies Zones. The eastern portion of the project study area (east of Mission Bay Drive) is located within the Alquist-Priolo Special Studies Zone (Fault Zone 11) which is considered an active fault zone. A summary of the fault parameters is shown in Table 1 on the next page, and a local fault map is shown on Figures 4-1 and 4-2. The distances shown on Table 1 is based on fault distances to the Balboa Avenue Station site at latitude of 32.806327° and longitude -117.213983°.

Table 1
Summary of Fault Parameters

	Rose Canyon fault zone (San Diego Section)
Maximum Moment Magnitude	6.8
Fault Type	Strike-Slip (SS)
Fault Dip Angle	90 degree
Dip Direction	Vertical
Bottom of Rupture Plane	8 km
Top of Rupture Plane	0
Rrup*	0.055 km
Rjb*	0.054 km
Rx*	0.055 km
Fnorm*	0
Frev*	0

	Rose Canyon fault zone (Silver Strand section-Spanish Bight fault)
Maximum Moment Magnitude	6.8
Fault Type	Strike-Slip (SS)
Fault Dip Angle	90 degree
Dip Direction	Vertical
Bottom of Rupture Plane	8 km
Top of Rupture Plane	0
Rrup*	6.542 km
Rjb*	6.542 km
Rx*	1.669 km
Fnorm*	0
Frev*	0

Table 1 (Continued)
Summary of Fault Parameters

	Point Loma fault zone
Maximum Moment Magnitude	6.3
Fault Type	Normal (N)
Fault Dip Angle	50 degree
Dip Direction	East
Bottom of Rupture Plane	13 km
Top of Rupture Plane	0
Rrup*	4.226 km
Rjb*	1.573 km
Rx*	5.121 km
Fnorm*	0
Frev*	0

* **Definition of Terms in Table 1**

Rrup - Closest distance (km) to the fault rupture plane.
Rjb - Joyner-Boore distance: The shortest horizontal distance to the surface projection of the rupture area. Rjb is zero if the site is located within that area.
Rx - Horizontal distance to the fault trace or surface projection of the top of rupture plane. It is measured perpendicular to the fault (or the fictitious extension of the fault).
Fnorm - Fault normal
Frev - Fault reverse

The location of the project study area in relation to the active faults in the region is shown on the Regional Fault Map (Figure 5). The computer program EQFAULT (Blake, 2000, updated 2004) was used to approximate the distance of known faults to the project alignment. Seven (7) known active faults are identified within a search radius of 50 miles from the study area. A summary of seismic source characteristics for faults that present the most significant seismic hazard potential to the proposed BASASP are presented in Table 2 below.

Table 2
Summary of Potential Seismic Sources

Fault	Maximum Magnitude (Mw)	Slip Rate (mm/year)	Det. Peak Site Acceleration (g)	Closest Distance to Site (miles)
Rose Canyon	6.8	1.5	0.545	0
Coronado Bank	7.5	3	0.250	13.4
Newport Inglewood (offshore)	7.2	1	0.093	27.3
Elsinore (Julian)	7.7	3 - 5	0.075	38.1
Elsinore (Temecula)	7.7	3-5	0.057	41.1
Elsinore (Earthquake Valley)	6.9	1 - 2.5	0.042	44.9
San Clemente	7.5	2.5		47.7

It is our opinion that the major seismic hazards affecting the project area would be seismic-induced ground shaking. The project study area will likely be subject to moderate to severe ground shaking in response to a local or more distant large magnitude earthquake occurring during the life of the planned facilities. For project design purposes, we recommend that the RCFZ be considered as the dominant seismic source.

4.2 Historical Seismicity

EQSEARCH is a program that performs automated searches of a catalog of historical Southern California earthquakes. As the program searches the catalog, it computes and prints the epicentral distance from a selected site to each of the earthquakes within a specified radius (100 kilometers). From the computed distance, the program also estimates (using an appropriate attenuation relation) the peak horizontal ground acceleration that may have occurred at the site due to each earthquake. For the purpose of this report, we have performed the earthquake catalog search based on the proposed BASASP.

Based on the estimated shear wave velocities and our visual observations of the on-site geologic units, site Class D attenuation was used for all of our analysis. We used a combined earthquake catalog for magnitude 5.0 or larger events which occurred within 100 kilometers of the project alignment between 1800 and December 1999. The earthquake catalog for events prior to about 1933 is limited to the higher magnitude events.

The search results indicate that the nearest earthquake of magnitude 5.0 occurred on May 25, 1803 about 7.2 miles from the proposed BASASP site on an unmapped fault in the Allied Gardens area of San Diego. The seismic event resulted in a calculated ground acceleration of 0.137g. The largest site acceleration generated from this search is 0.224 g which was the result of a 5.9 magnitude earthquake which occurred on May 27, 1862 on a strand of the RCFZ located approximately 8.2 miles from the site. The largest magnitude earthquake reported was a magnitude 7.0 event in 1858, located 83.2 miles from the site on a strand of the Fontana Fault in the Riverside area of California which resulted in a calculated ground acceleration of 0.044 g.

4.3 Seismic Design Parameters

For structural design in accordance with the 2010 ASCE 7 procedures, the United States Geological Survey Design Maps (USGS, 2013) were used to calculate ground motion parameters for the project study area. The Risk-Targeted Maximum Considered Earthquake (MCE_R) ground motion response acceleration is calculated based on the most severe earthquake effects considered by ASCE 7-10 determined for the orientation that resulted in the largest maximum response to the horizontal ground motions and with adjustment to the targeted risk. The Maximum Considered Earthquake Geometric Mean (MCE_G) is determined for the geometric peak ground acceleration and without adjustment for the targeted risk. The MCE_G Peak Ground Acceleration (PGA) adjusted for site effects (PGA_M) should be used for design and evaluation of liquefaction, lateral spreading, seismic settlements, and other soil related issues.

The calculated seismic design parameters are presented in Table 3 on the next page. The design criteria are based on the soil profile type as determined by existing subsurface geologic conditions, on the proximity of the site to a nearby fault and on the maximum moment magnitude and slip rate of the nearby fault. The Design Response Spectrum and Risk-Targeted Maximum Considered Earthquake (MCE_R) Response Spectrum are shown on Figures 6 and 7, respectively.

Table 3
Summary of Seismic Design Parameters

REFERENCE	PARAMETER
Table 20.3-1 Site Classification	Site Class = D
Figure 22-1	Ss = 1.250 g
Table 11.4-1 Site Coefficient Fa	Fa = 1.000
Figure 22-2	S_1 = 0.483 g
Table 11.4-2 Site Coefficient Fv	Fv = 1.517
Equation 11.4-1	S_{MS} = 1.250 g
Equation 11.4-2	S_{M1} = 0.733 g
Equation 11.4-3	S_{DS} = 0.833 g
Equation 11.4-5	S_{D1} = 0.488 g
Figure 22-12	T_L = 8 seconds
Figure 22-7	PGA = 0.564 g
Equation 11.8-1	PGA_M = 0.564 g
Figure 22-17	C_{RS} = 0.842
Figure 22-18	C_{R1} = 0.876

Figure 22-1	Ss Risk-Targeted Maximum Considered Earthquake (MCER) Ground Motion Parameter for the Conterminous United States for 0.2 s Spectral Response Acceleration (5% of Critical Damping), Site Class B.
Figure 22-2	S1Risk-Targeted Maximum Considered Earthquake (MCER) Ground Motion Parameter for the Conterminous United States for 1.0 s Spectral Response Acceleration (5% of Critical Damping), Site Class B.
Figure 22-12	Mapped Long-Period Transition Period, TL (s), for the Conterminous United States.
Figure 22-7	Maximum Considered Earthquake Geometric Mean (MCEG) PGA, %g, Site Class B for the Conterminous United States.
Figure 22-17	Mapped Risk Coefficient at 0.2 s Spectral Response Period, CRS.
Figure 22-18	Mapped Risk Coefficient at 1.0 s Spectral Response Period, CR1.

4.4 Liquefaction

Seismic-induced soil liquefaction is a phenomenon during which loose, saturated granular materials undergo matrix rearrangement, develop high pore water pressure, and lose shear strength due to cyclic ground vibrations induced by earthquakes. Manifestations of soil liquefaction can include loss of bearing capacity below foundations, surface settlements and tilting in level ground, and instabilities in areas of sloping ground. Soil liquefaction can also result in increased lateral and uplift pressures on buried structures.

The western portion of the project study area is underlain by hydraulically placed fills which are classified as having a high liquefaction potential (Zone 31) in the City of San Diego Seismic Safety Study (2008). The study classifies the young alluvial deposits which are mapped in portions of Rose Canyon as having a low liquefaction potential. AGE (2015) encountered zones with moderate liquefaction potential in soil borings performed in Rose Canyon near the location of a proposed pedestrian bridge in the northern portion of the project study area.

Young colluvial deposits and old alluvial deposits, and localized zones of old paralic deposits may also possess moderate to high liquefaction potential. Soil materials belonging to the San Diego Formation, Scripps Formation, Ardath Shale, and Mt. Soledad Formation are considered non-liquefiable. The approximate limits of the liquefiable area is identified as Zone 31 on Figure 3.

4.5 Fault Ground Rupture

Several strands of the active RCFZ cross the eastern portion of the project study area, including the proposed Balboa Avenue Station (refer to Figures 4-1 and 4-2). Kleinfelder performed a fault rupture study for design of the "Elvira to Morena Double Track Project" which is located in the northern portion of the project study area (Kleinfelder, 2015). Based on the results of their study, Kleinfelder estimated a 4-foot horizontal displacement along the primary fault zone which crosses Rose Creek in the northernmost portion of the project study area. Vertical displacement is estimated to be on the order of 0.4 feet (10% of the horizontal displacement). It is our opinion that the potential for fault ground rupture displacement in the event of strong seismic events along these fault strands is considered high.

4.6 Landslides

Two known ancient landslides (Kennedy & Tan, 2005; Tan, 1995; City of San Diego, 2008) are mapped north of the project study area. There are no known (mapped) landslides within the limits of the project study area. In our opinion, landsliding does not appear to represent a significant potential hazard in the study area.

4.7 Lateral Spread and Slope Stability

The majority of the existing slopes within the project study area are located along the embankments of Rose Creek with slope gradients of 2 : 1 (horizontal : vertical) or flatter. Slopes, with gradients of 2 : 1 (horizontal : vertical) or flatter, are generally considered stable. Therefore, the potential for global instability and lateral spread along Rose Creek within the project study area is considered low. Due to the relatively gentle topography, the potential for lateral spread and slope instability are considered very low in the remainder of the project study area.

A slope with a maximum height of 45 feet is located along the east side of Morena Boulevard, south of the intersection with Balboa Avenue (adjacent to the southeastern boundary of the project study area). The slope is located east, across Morena Boulevard, from the proposed Balboa Avenue Trolley Station site. The majority of the slope was constructed with a slope gradient of 2 : 1 (horizontal : vertical) or flatter. However, the lower 10 to 15 feet was excavated at a 1 : 1 (horizontal : vertical) slope or steeper. The slope was likely constructed during widening of the Morena Boulevard. No visual indications of global instability were observed along this slope. However, our visual observations indicate that the slope is subject to erosion from surface run-off. The bottom of a concrete brow ditch constructed at mid-slope height is exposed along some sections of the slope, and erosion debris was observed along the toe of the slope. Erosion of the slope is not anticipated to impact the proposed station. The City of San Diego should perform regular slope maintenance to keep the brow ditch clean of debris and vegetation, and also repair the area where erosion has occurred and the bottom of the brow ditch is exposed.

4.8 Differential Seismic-Induced Settlement

Differential seismic settlement occurs when seismic shaking causes one type of soil to settle more than another type. It may also occur within a soil deposit with largely homogenous properties if the seismic shaking is uneven due to variable geometry or thickness of the soil deposit.

Much of the project study area is underlain by fill and alluvial soil materials of variable thickness and composition. These materials are considered to have a moderate to high potential of differential seismic-induced settlement. In areas that are not underlain by fill or alluvial soil materials, the prevailing geologic units consist of competent sedimentary formations which are not susceptible to this type of hazard.

4.9 Ground Lurching

Ground lurching is a permanent displacement or shift of the ground in response to seismic shaking. Ground lurching occurs in areas with high topographic relief, and usually occurs near the source of an earthquake. These displacements can result in permanent cracks in the ground surface. Considering the proximity of the active RCFZ, it is our opinion that ground lurching represents a potential hazard in the project study area. The areas most prone to ground lurching include steep slopes on the east side of the study area and the RCFZ corridor.

4.10 Expansive Soils

The majority of soil materials in the study area are non-expansive or possess a low expansion potential. Clayey soils possessing a moderate to high expansion potential may be locally encountered in colluvial deposits and in the Ardath Shale.

4.11 Compressible Soils

Hydraulically placed fill materials are present over much of the project study area. These soils are generally considered potentially compressible. AGE (2016) performed a subsurface geotechnical investigation for a pedestrian bridge in the northern portion of the project study area. Undocumented fill materials, colluvial deposits and old paralic deposits encountered in their soil borings were found to possess a low compression potential. Formational materials of the San Diego Formation, Scripps Formation, Ardath Shale, and Mount Soledad Formations are considered non-compressible.

4.12 Secondary Hazards

A review of the State of California Tsunami Inundation Map for Emergency Planning - La Jolla Quadrangle (2009) indicates that the project study area is not located within the tsunami inundation area. The map indicate that the closest limit of the inundation zone would be where Grand Avenue crosses the Rose Creek inlet. Therefore, the tsunami hazard risk in the project study area is considered very low. Based on the distance of the project study area from Mission Bay, the potential for inundation from a seiche event occurring as a reis also considered low.

The western portion of the study area is located within the Rose Creek floodplain. FEMA Flood Insurance Rate Map designate the Rose Creek floodplain as Zone AE. Zone AE is defined as a floodplain area (channel of a stream) and any adjacent floodplain areas with a 1 percent annual chance of being inundated by flooding up to the Base Flood Elevation of +6 feet to +35 msl within the project study area. Portion of the project study area located up to 0.25 mile east from the creek is located within the 500-year (0.2% annual chance) flood hazard zone (FEMA Flood Insurance Rate Map, 2012).

Localized erosion may occur as a result of seasonal channel flow in Rose Creek. Heavy rainstorm events may also result in localized erosion on steep slopes and on roadcuts.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The findings of this desktop study are based on a cursory evaluation of readily available information which is generally very limited and contain data gaps in many areas. The project study area is subject to multiple geologic hazards, we therefore recommend that site and project specific geotechnical studies be performed for final design of all projects located within the project study area. We recommend that a site specific seismic response analysis be performed for all proposed structures/facilities with Risk Categories III and IV, or fundamental period of more than 0.5 second which are located in the liquefiable zone (Zone 31 on Figure 3). We further recommend that fault trenching study be performed for all Risk Categories III and IV projects located within the special study zone boundaries (see Figures 3 and 4-1).

Based on the results of our study, it is our opinion that there no known significant geologic hazards within the BASASP study area which cannot be avoided or mitigated provided that the project is designed and constructed in accordance with the City of San Diego codes and regulations. Based on a review of the Environmental Impact Report (RRM, 2017), it is our opinion that the proposed land uses are compatible with the known level of geologic hazards, and that the policies and recommendations presented in the Environmental Impact Report do not impact or alter the geologic hazards identified in this report.

AGE is in agreement with the geologic and geotechnical information presented in the Environmental Impact Report (RRM, 2017). A summary of the relevant geotechnical criteria which should be considered in the design and construction of projects located in the project study area is presented in Table 4.

TABLE 4

SUMMARY OF GEOTECHNICAL DESIGN CRITERIA

Subsurface Materials	The majority of the project study area located west of Mission Bay Drive is underlain by hydraulically placed fill materials up to 10 feet in thickness. The hydraulic fill materials generally consist of silty sands and clayey sands containing local scattered gravels and broken seashells (AGE, 2016) with very loose to medium dense consistency. These fill materials are generally considered compressible and not capable of providing competent support for foundations in their current condition. The remainder of the project study area is underlain by fill materials that are associated with the realignment of Rose Creek and construction of Interstate 5, as well as young alluvial deposits, young colluvial deposits, old paralic deposits, Scipps Formation, Ardath Shale, Mount Soledad Formation and San Diego Formation. These soil materials are generally not considered compressible.
Approximate Depth to groundwater (feet bgs)	Groundwater depth below portion of the project study area located between Rose Creek and Interstate 5 is anticipated to range between 2 and 24 feet bgs (+23 to +69 feet msl). Groundwater depths below portions of the project study area that are located east of Interstate 5 are unknown, but it are anticipated to be below the depth of typical foundation excavations.
Fault Crossing	The eastern portion of the project study area (east of Mission Bay Drive) is located within the Alquist-Priolo Special Studies Zone (Figures 3 and 4-1). Several fault strands of the active RCFZ are mapped crossing the project study area (see Figure 4-2). The potential for fault ground rupture occurring within this zone during a major seismic event is considered high. We recommend that a fault trenching study be performed for all Risk Categories III and IV projects located within this zone. In the event that a fault is exposed in the vicinity of the proposed project, we recommend that a fault rupture study be performed, and the appropriate setback be developed based on the results of the study.
Liquefaction Susceptibility	The western portion of the project study area is underlain by hydraulically placed fills which are classified as having a high liquefaction potential. The approximate limit of the liquefiable zone is shown as Zone 31 on Figure 3. Site specific seismic response analysis should be performed for all proposed structures/facilities with Risk Categories III and IV, or fundamental period of more than 0.5 second, located in this zone.
Mapped Landslides	There are no known (mapped) landslides within the limits of the project study area. Landsliding does not appear to pose a significant potential hazard in the study area.
Lateral Spread and Slope Stability	The potential for lateral spread and slope instability are considered low within the project study area.
Differential Seismic Induced Settlement	Differential seismic induced settlement is primarily anticipated in the western portion of the project area which is underlain by hydraulic fills.
Ground Lurching	Ground lurching is considered a potential hazard in the Alquist-Priolo Special Studies Zone (Figures 3 and 4-1).
Expansive Soil	The majority of soil materials in the study area are considered non-expansive or possess a low expansion potential.
Other Unusual Conditions	Potential flood hazards (100- and 500-year flood zone), and possible presence of contaminated soil and/or groundwater conditions.

6.0 LIMITATIONS

This report has been prepared for the sole use of RRM and the City of San Diego for the preparation of the BASASP. This report is intended for preliminary planning purposes only and does not provide sufficient data for design and/or construction.

The geotechnical services provided by AGE for this project have been performed in accordance with generally accepted principles and practices of the local geotechnical profession at the time of report preparation. No other warranty, either expressed or implied, is made by AGE.

7.0 REFERENCES

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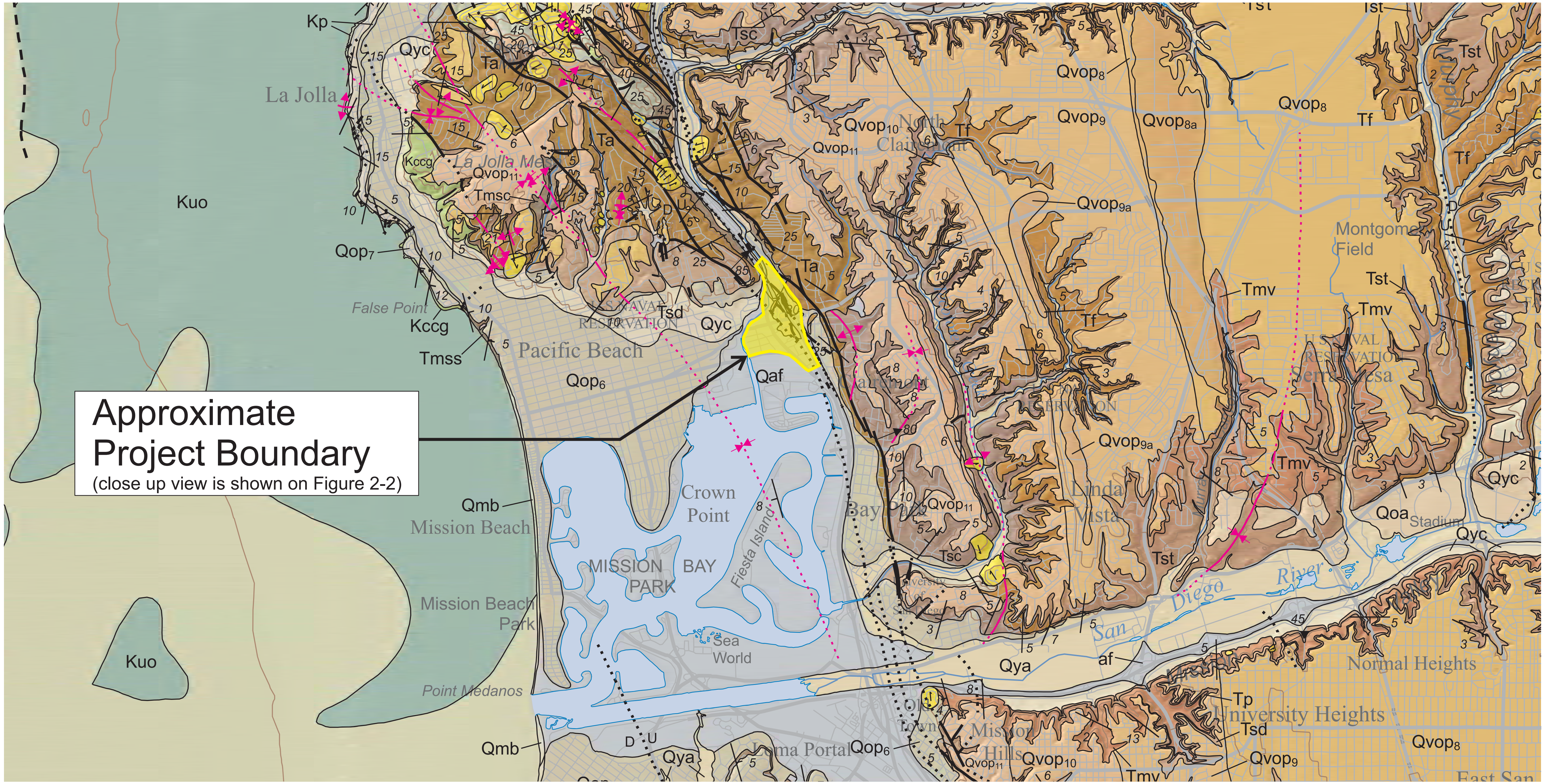
FIGURES

PROJECT LOCATION MAP
BALBOA AVENUE STATION AREA SPECIFIC PLAN

PROJECT NO. 171 GS-15-A	ALLIED GEOTECHNICAL ENGINEERS, INC.	FIGURE 1

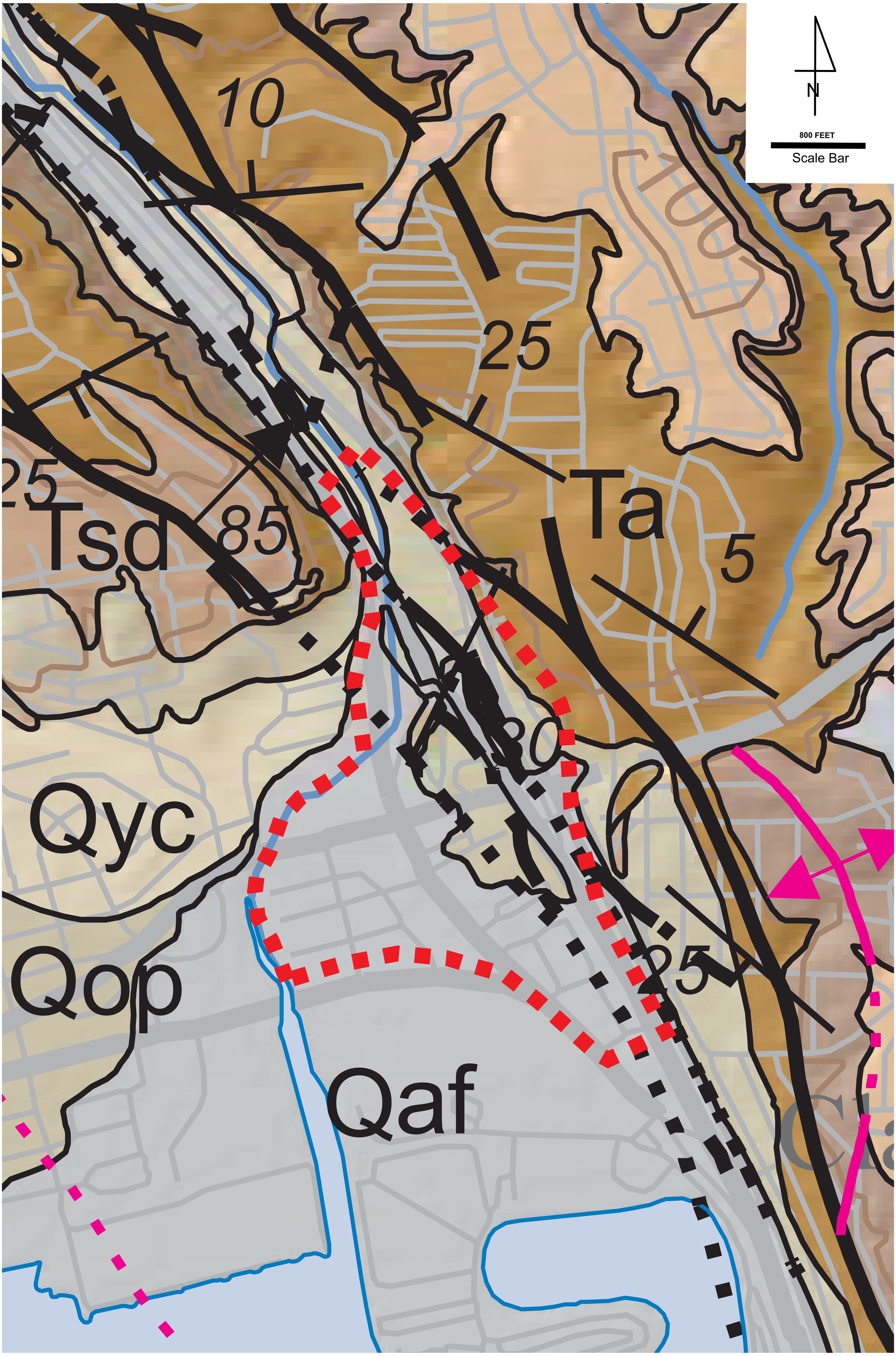


N

1 INCH = 5,000 FEET

Scale Bar

BALBOA AVENUE STATION AREA SPECIFIC PLAN	GENERALIZED GEOLOGIC MAP	
PROJECT NO. 171 GS-15-A	ALLIED GEOTECHNICAL ENGINEERS, INC.	FIGURE 2-1



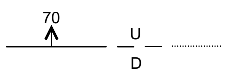
GENERALIZED GEOLOGIC MAP (CLOSE UP)
BALBOA AVENUE STATION AREA SPECIFIC PLAN

PROJECT NO. 171 GS-15-A	ALLIED GEOTECHNICAL ENGINEERS, INC.	FIGURE 2-2

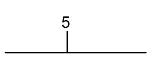
KEY TO GENERALIZED GEOLOGIC MAP

Qaf	Artificial fill - artificially placed sand and silt with locally abundant gravels and cobbles
Qya	Young alluvial deposits - poorly consolidated, poorly sorted permeable flood plain deposits comprised of sand, silt and clay with local gravels and cobbles
Qyc	Colluvial deposits - poorly consolidated, poorly sorted sand and silt slopewash deposits.
Qop	Old Paralic Deposits - poorly sorted, moderately permeable sandstone, siltstone and conglomerate
Tsmc	Mount Soledad Formation (conglomerate facies) - massive, reddish brown cobble conglomerate
Ta	Ardath Shale - mostly uniform weakly fissile silty shale.
Tsd	San Diego Formation - primarily fine- to medium-grained poorly indurated fossiliferous marine sandstone

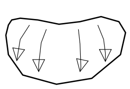
Contact between geologic units.



Fault - Solid where accurately located; dashed where approximately located, dotted where concealed. U - upthrown block, D - downthrown block. Arrow and number indicate direction and angle of dip fault plane



Strike and dip

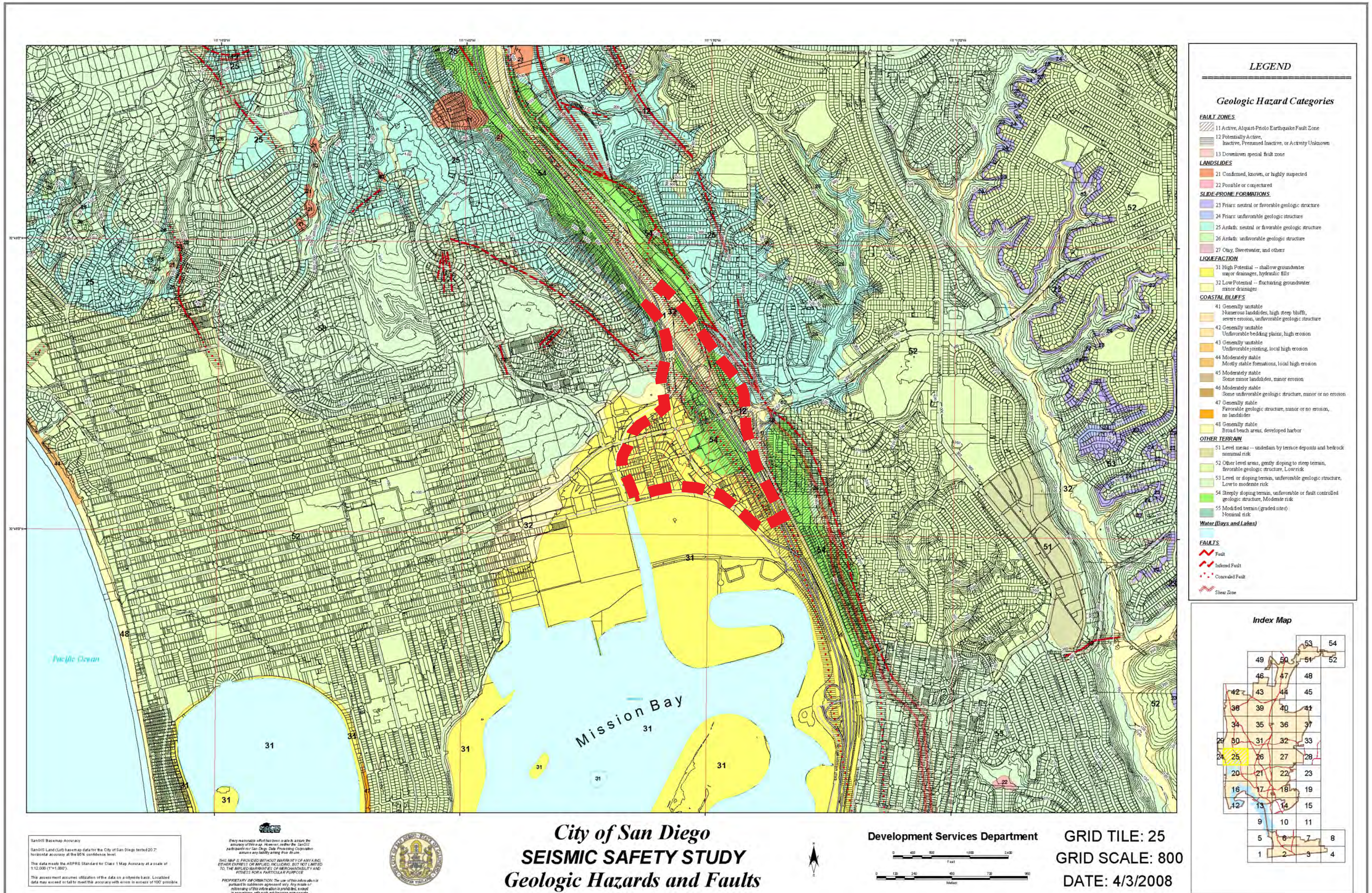


Landslide

Approximate Location of Project Boundary

KEY TO GENERALIZED GEOLOGIC MAP
BALBOA AVENUE STATION AREA SPECIFIC PLAN

PROJECT NO. 171 GS-15-A	**ALLIED GEOTECHNICAL ENGINEERS, INC.**	**FIGURE 2-3**

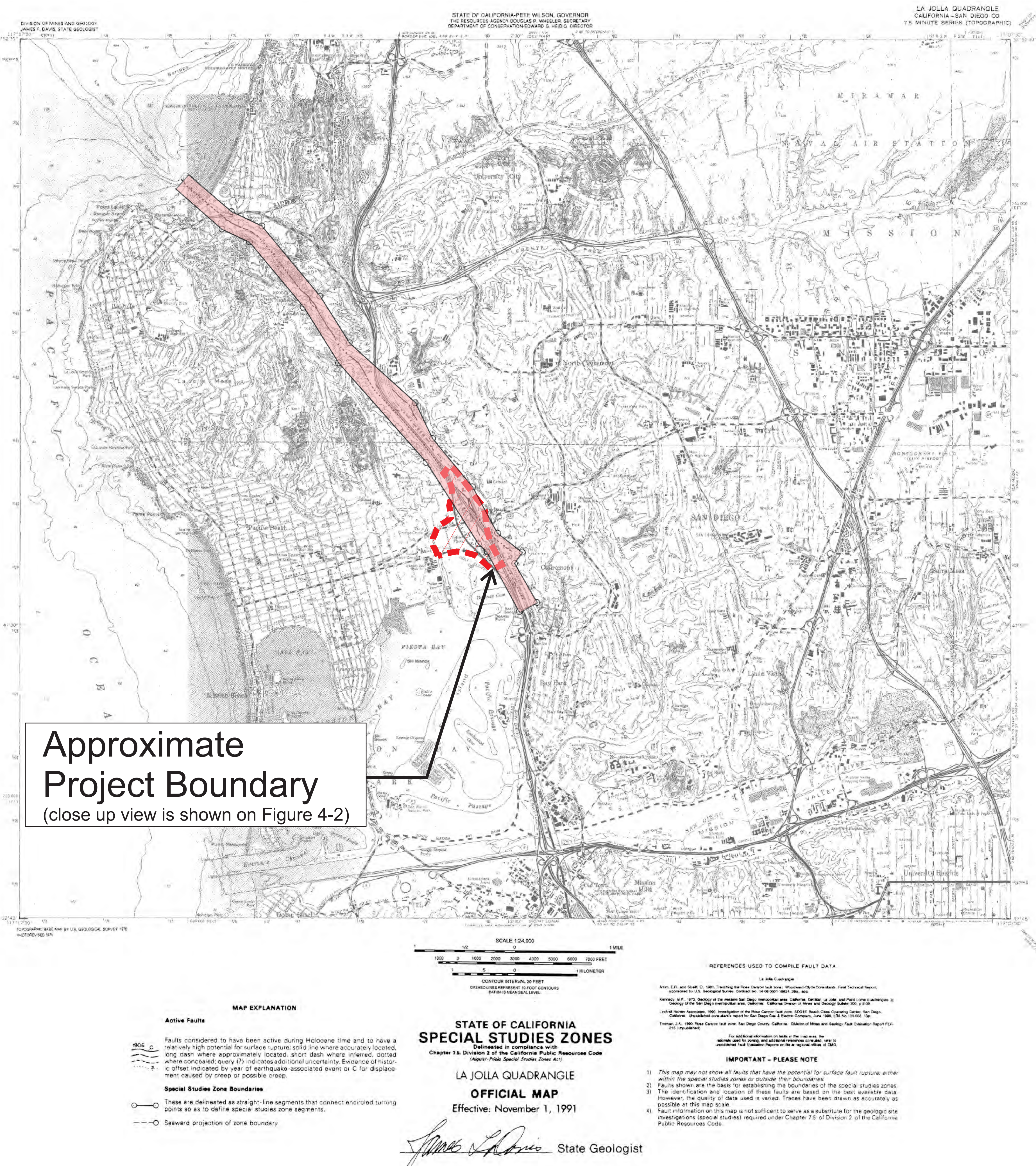


LEGEND

Approximate Project Boundary

BALBOA AVENUE STATION AREA SPECIFIC PLAN	GEOLOGIC HAZARD MAP

PROJECT NO. 171 GS-15-A	ALLIED GEOTECHNICAL ENGINEERS, INC.	FIGURE 3



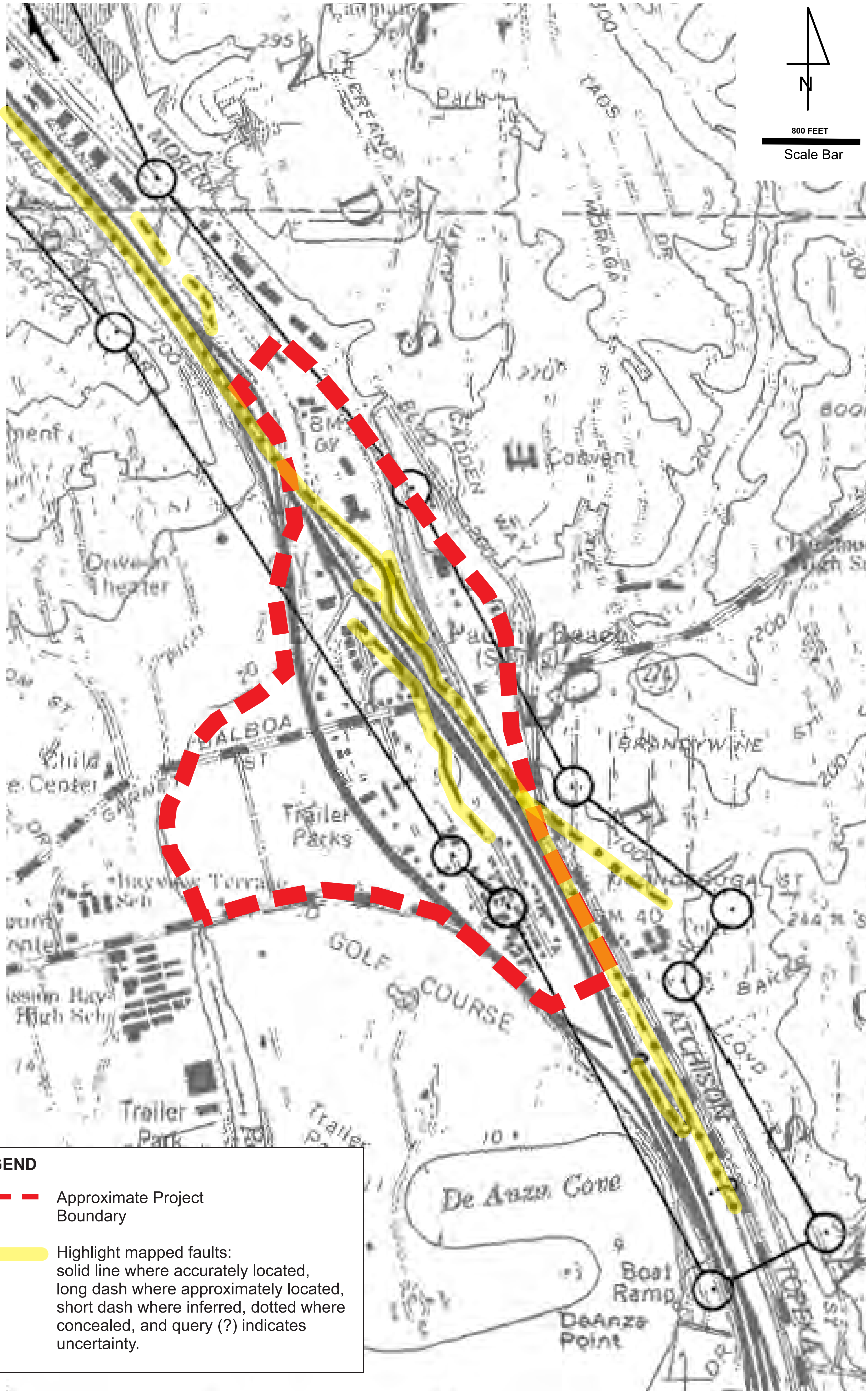
LEGEND

Approximate Project Boundary

Alquist Priolo Special Study Zone

LOCAL FAULT MAP
BALBOA AVENUE STATION AREA SPECIFIC STUDY

PROJECT NO. 171 GS-15-A	ALLIED GEOTECHNICAL ENGINEERS, INC.	FIGURE 4-1



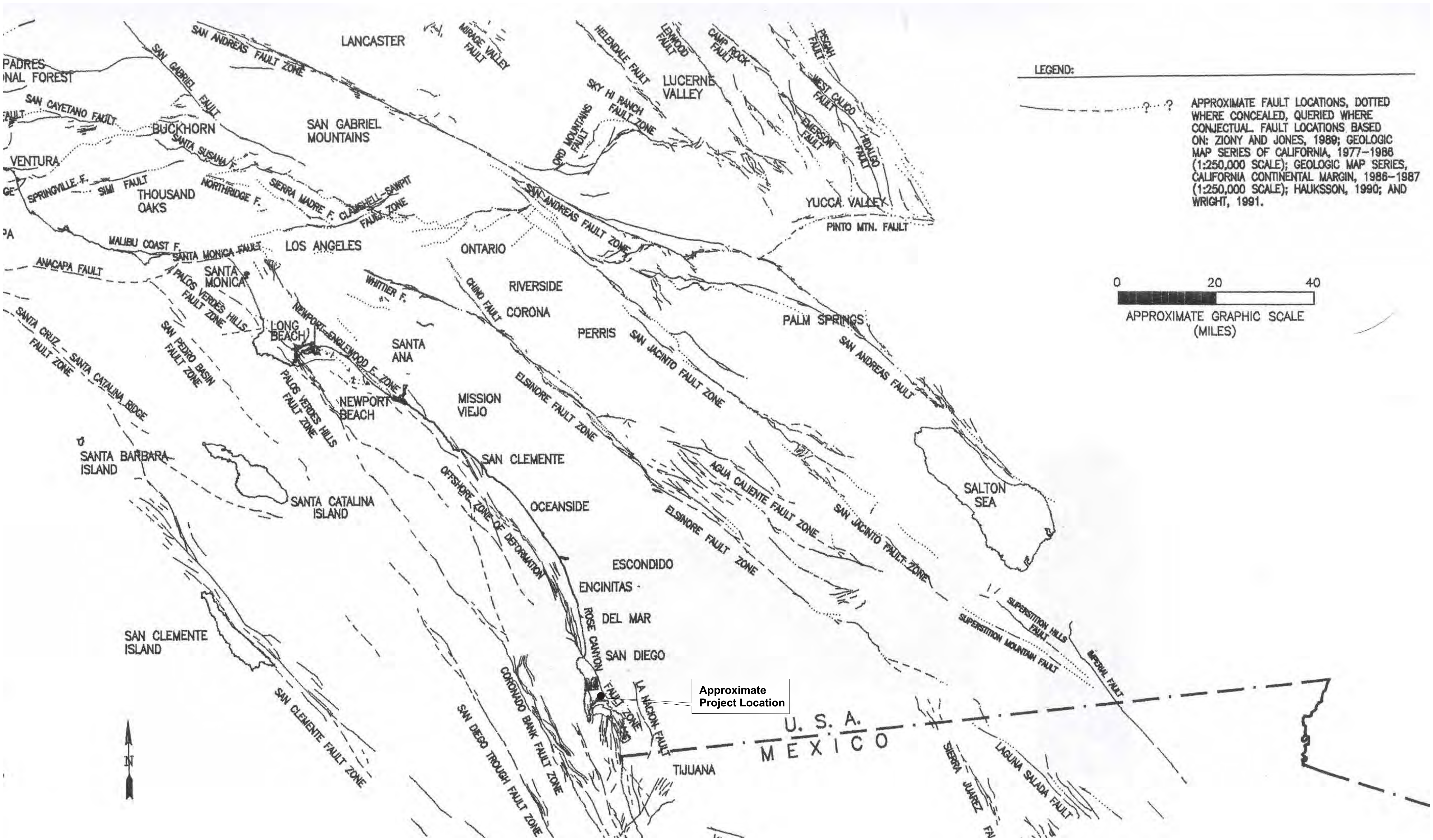
LEGEND

Approximate Project Boundary

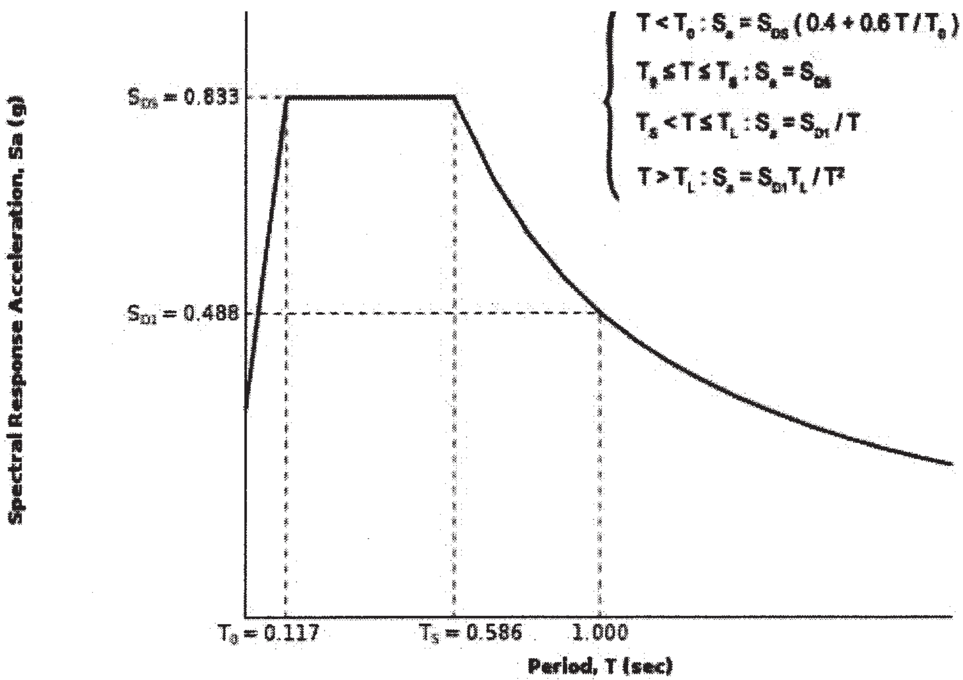
Highlight mapped faults: solid line where accurately located, long dash where approximately located, short dash where inferred, dotted where concealed, and query (?) indicates uncertainty.

LOCAL FAULT MAP (CLOSE UP)
BALBOA AVENUE STATION AREA SPECIFIC STUDY

PROJECT NO. 171 GS-15-A	ALLIED GEOTECHNICAL ENGINEERS, INC.	FIGURE 4-2

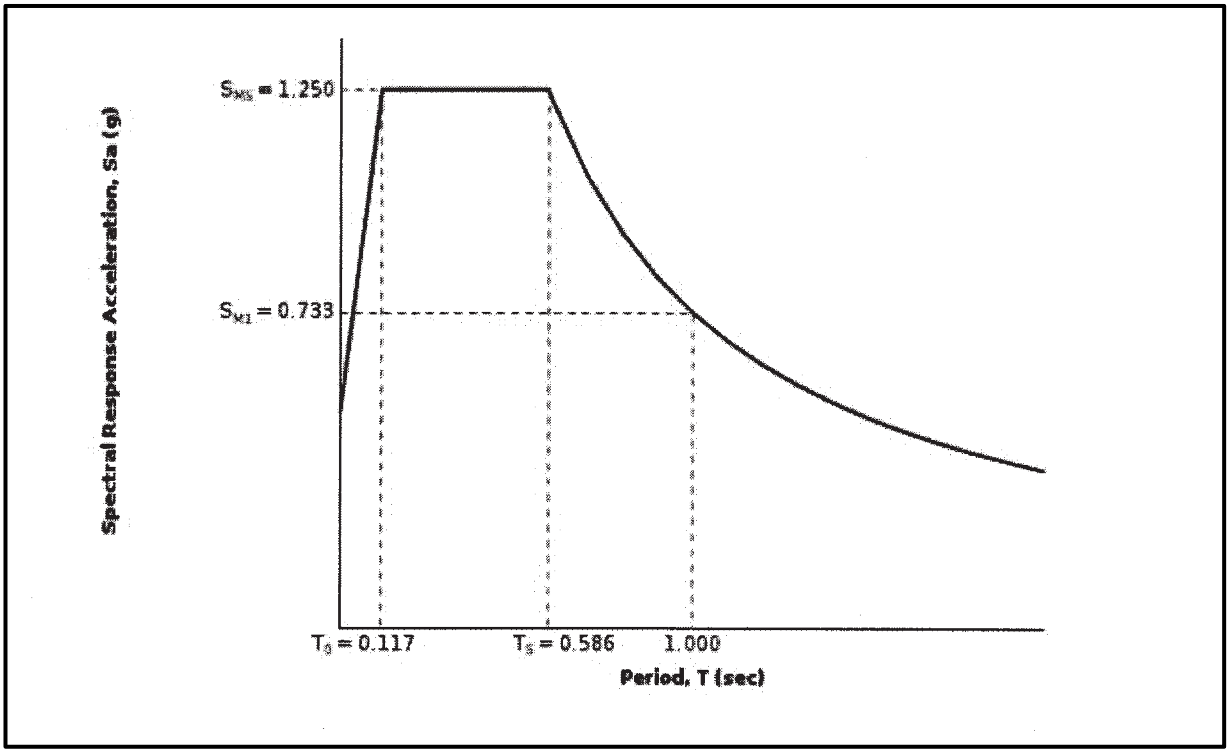


BALBOA AVENUE STATION AREA SPECIFIC STUDY	REGIONAL FAULT MAP	
PROJECT NO. 171 GS-15-A	ALLIED GEOTECHNICAL ENGINEERS, INC.	FIGURE 5



DESIGN RESPONSE SPECTRUM
BALBOA AVENUE STATION AREA SPECIFIC PLAN

PROJECT NO. 171 GS-15-A	ALLIED GEOTECHNICAL ENGINEERS, INC.	FIGURE 6



RISK-TARGETED MAXIMUM CONSIDERED EARTHQUAKE (MCE_R)
BALBOA AVENUE STATION AREA SPECIFIC PLAN

PROJECT NO. 171 GS-15-A	ALLIED GEOTECHNICAL ENGINEERS, INC.	FIGURE 7