Appendix F

Seismic and Geologic Technical Background Report

SEISMIC AND GEOLOGIC TECHNICAL BACKGROUND REPORT FOR THE CITY OF SAN DIEGO MIDWAY-PACIFIC HIGHWAY AND OLD TOWN COMMUNITY PLAN UPDATES, AND ENVIRONMENTAL IMPACT REPORT, CITY OF SAN DIEGO, SAN DIEGO COUNTY, CALIFORNIA

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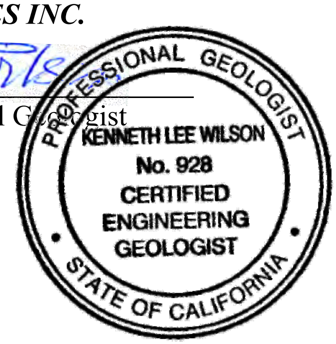

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1 INTRODUCTION

1.1 Overview and Summary of Planning Issues

1.1.1 Overview

Compliance with State CEQA Guidelines for General Plan and Community Plan documents and related environmental impact reports (EIR) requires analysis of a wide range of potential seismic, geologic, soils, and flood related topics in order to provide an adequate understanding of geotechnical and engineering geologic issues affecting land use planning decisions. The City of San Diego 2011 guidelines for geotechnical reports (including engineering geology and flood topics) related to environmental documents suggests referring to California Geological Survey (CGS) Note 46 for a checklist of items that should be addressed. In this report we have considered CGS Note 46 (the 1986 version is currently under revision) and Note 52 (CGS, 2001) to provide a checklist (Table G-1) with the following broad topics:

- Earthquake Phenomena
- Slope and/or Foundation Instability
- Erosion, Sedimentation, and Flooding
- Land Subsidence
- Waste Disposal Problems
- Water and Soil Pollution Problems
- Loss of Mineral Resources
- Volcanic Hazards

A more comprehensive list of issues within these broader topics is presented in Section 1.2.

This technical background report is designed to support preparation of the Midway-Pacific Highway Community Plan and Old Town Community Plan Updates (CPU) and joint EIR for the City of San Diego. As such the document contains up-to-date information on the seismic, geologic, and flood conditions within and around the Midway Community Plan Area (CPA; Midway CPA includes the Midway and Pacific Highway subareas) and the Old Town CPA (collectively the Project Area), which will potentially affect the persons and properties in the Project Area in the event of a local geologic hazard or a major earthquake in this portion of southern California.

As the City of San Diego undertakes expansion, redevelopment, and in-fill within the Project Area the technical conditions mentioned above must be taken into account. Existing building codes and land use planning requirements can address most of the hazards inherent in the seismic, geologic, and flood setting of the Project Area. As newer, more accurate seismic, geologic, and flood information has been developed since the last Midway-Pacific Highway and Old Town Community Plans were prepared, it is possible to better identify the hazard areas and to account for them in future development. Sources for this information include generalized regional reports and maps, and existing City and County Safety (and Seismic Safety) Elements.

1.1.2 Summary of Planning Issues

Figures G-1 through G-5 depict the seismic, geologic, and flooding conditions and associated hazards within the Midway and Old Town CPAs. Tables G-1 through G-8 provide primarily detailed geologic and seismic data to support the figures and text discussions. The broad topics from the referenced checklists are the bulleted items in the overview above. Waste Disposal Problems and Water and Soil Pollution Problems would be covered in other technical reports, while Volcanic Hazards are not an issue for the Project Area; therefore, these topics are not discussed in this report. Discussions in the report focus on the Project Area as a whole, and also delineate conditions and hazards that may have a more significant effect on the Old Town CPA, the Midway subarea, or the Pacific Highway subarea. The following paragraphs provide in bulleted format a brief consolidated summary for these three areas.

Old Town CPA
The Old Town CPA has the largest number of potential geologic, seismic, and flooding hazards.

- The active/potentially active Rose Canyon fault zone trends north-south and northwest-southeast through the center of the CPA (Figures G-1 and G-4), which affects approximately 20% of the CPA that will require fault activity investigations for habitable structures; setbacks or special foundations may be required.
- Liquefaction potential is high over the western 40% of the CPA (Figure G-4) and will require standard liquefaction analysis and, depending upon the structure, special foundations and possibly dewatering.
- One mapped landslide (Figure G-1) and areas of low to moderate slope instability risk (Figure G-4) cover 60% of the CPA; standard geologic/geotechnical investigations and remedial measures would apply.
- Artificial fill (Figure G-1) placed decades ago with minimal to no engineering controls underlies the CPA coincident with the high liquefaction potential area (approximately 40% of the CPA) and would likely require special investigation techniques and foundation considerations for larger and/or more critical facilities.
- No FEMA 100-year flood zones are within the CPA and a very small 500-year flood zone is in the far northeast portion of the area (Figure G-3).
- Potential dam inundation flood areas (Figure G-3) from the San Vicente and El Capitan reservoirs cover approximately 17% and 48%, respectively, of the western portion of the CPA.
- Other geotechnical/soils engineering conditions, erosion potential, mineral resource conflicts, and earthquake shaking affects present minimal to no hazard beyond what is covered by standard code compliance.

Midway CPA—Midway Subarea
The Midway subarea forms the largest portion of the Midway CPA immediately west of the Old Town CPA. This subarea has several potential geologic, seismic, and flooding hazards.

- One strand of the active/potentially active Rose Canyon fault zone trends northwest-southeast across the far southern portion of the subarea (Figures G-1 and G-4) and will require fault activity investigations for habitable structures; setbacks or special foundations may be required.
- The potential for liquefaction is high for approximately 75% of the subarea (Figure G-4) and low potential for approximately 5%; these areas will require standard liquefaction analysis and, depending upon the structure, special foundations and possibly dewatering.
- Areas of low slope instability risk (Figure G-4) cover only approximately 5% of the subarea along the western boundary; standard geologic/geotechnical investigations and remedial measures would apply.
- Artificial fill (Figure G-1) as described for the Old Town CPA underlies approximately 90% of the subarea and would likely require special investigation techniques and foundation considerations for larger and/or more critical facilities.
- Less than one percent of the subarea (immediately adjacent to the San Diego River) is within a FEMA 100-year flood zone and a larger (approximately 9% of the subarea) 500-year flood zone occupies the north and north central area adjacent to the river (Figure G-3).
- Approximately 60% (San Vicente reservoir) and 70% (El Capitan reservoir) of the subarea consist of potential dam inundation flood areas (Figure G-3).
- As with the Old Town CPA, other geotechnical/soils engineering conditions, erosion potential, mineral resource conflicts, and earthquake shaking affects present minimal to no hazard beyond what is covered by standard code compliance.

Midway CPA--Pacific Highway Subarea
The Pacific Highway subarea has the fewest number of potential geologic, seismic, and flooding hazards.

- One strand of the active/potentially active Rose Canyon fault zone trends northwest-southeast through the northeast one-half of the subarea (Figures G-1 and G-4) and will require fault activity investigations for habitable structures; setbacks or special foundations may be required.
- Approximately 10% of the northwestern most corner of subarea has high, and some low, liquefaction potential (Figure G-4); these areas will require standard liquefaction analysis and, depending upon the structure, special foundations and possibly dewatering.
- Areas of low to moderate slope instability risk (Figure G-4) cover approximately 40% of the central portion of the subarea; standard geologic/geotechnical investigations and remedial measures would apply.
- Artificial fill (Figure G-1) as described for the Old Town CPA underlies approximately 50% of the subarea and would likely require special investigation techniques and foundation considerations for larger and/or more critical facilities.
- There are no FEMA 100-year or 500-year flood zone areas within the subarea and also no areas with the potential for dam inundation flooding (Figure G-3).
- As with the Old Town CPA and Midway subarea, other geotechnical/soils engineering conditions, erosion potential, mineral resource conflicts, and earthquake shaking affects present minimal to no hazard beyond what is covered by standard code compliance.

1.2 Seismic, Geologic, and Flood Hazard Planning Considerations

Seismic, geologic, and flood hazards play an important role in the planning process with regard to the selection of development locations, the definition of processes necessary to develop safe projects, and the studies necessary to design a project to avoid or withstand the affects of natural hazards. The Project Area Community Plan Updates provide guidance to accomplish these steps and to provide information useful to begin the development planning process. Seismic hazards result from the primary action of an earthquake (primarily strong ground shaking and surface fault rupture) and the secondary affects caused by the earthquake shaking (mainly liquefaction induced settlement and lateral spreads, landslides, ground fissures, tsunamis and seiches). Laws, regulations, and codes are established to ensure that proper precautions are taken in advance of development to prevent unreasonable levels of damage, injuries, or fatalities.

Table G-1 indicates the potential seismic, geologic, and flood hazards considered based on a combination of information from CDMG Notes 46 and 52. Later subsections discuss the potential seismic, geologic, and flood hazards in the order of most widespread potential effect within the City.

Seismic ground motion (earthquake shaking) hazard concerns at a specific location increase with the increasing importance of a development or an individual structure. The importance may relate to essential services (hospitals, police and fire, 911 capability, traffic management centers), schools, critical lifelines (pipelines, freeways, aqueducts), high-occupancy structures (hotels, multi-story office buildings), or concentrated residential development. Often, engineers and geologists consider in their seismic design calculations the largest earthquake that is thought possible for a particular fault to create a “deterministic” earthquake calculation for the maximum (most severe) earthquake effects on a development or within a section of a City. This maximum magnitude earthquake (M_{max}), sometimes referred to as the Upper Bound Earthquake (UBE), ground motion has a statistical recurrence interval of 949 years and would produce earthquake ground motion “intensity” with a 10 percent probability of being exceeded in 100 years. This is a stringent design standard used for public schools, hospitals, and other critical facilities (e.g., dams, reservoirs, power plants). A lesser although still stringent, standard is the maximum probable earthquake (MPE) or Design Basis Earthquake (DBE), which has a statistical recurrence interval of 475 years and would produce ground motions with a 10 percent probability of being exceeded in 50 years. These two fault-specific design standards are embodied in the building codes adopted by State organizations and local jurisdictions as applied to a development project when considering the importance of a facility and its proposed use, as well as its projected design life. Two percent in 50 year ground motion is also considered.

Table G-1 - Seismic, Geologic/Geotechnical, and Hydrologic Problems and Issues Checklist [1]

GEOLOGIC, SEISMIC, AND HYDROLOGY ISSUES OF CONCERN			
GENERAL PROBLEMS AND ISSUES	***SPECIFIC ISSUES POTENTIALLY CAUSING PROBLEMS OR RAISING CONCERNS***	**GENERAL PROBLEMS AND ISSUES**	***SPECIFIC ISSUES POTENTIALLY CAUSING PROBLEMS OR RAISING CONCERNS***
EARTHQUAKE PHENOMENA	Ground Shaking	EROSION. SEDIMENTATION AND FLOODING	Erosion of Graded Areas and Sedimentation
	Landslides and Rockfalls		Alteration of Existing Runoff
	Fault Rupture and Tectonic Warping		Increased Impervious Surfaces
	Differential Compaction/Seismic Settlement		Unprotected Drainage Ways
			FEMA Flood Zones
	Liquefaction and Lateral Spreads	LAND SUBSIDENCE	Extraction of Groundwater, Gas, Oil, or Geothermal Energy
	Tsunamis and Seiches		Hydro-compaction or Peat Oxidation
	Flooding due to Dam or Levee Failure		Fault Rupture / Ground Cracking
SLOPE AND/OR FOUNDATION INSTABILITY	Landslides and Mudflows	LOSS OF MINERAL RESOURCES	Loss of Access
	Unstable Cut and Fill Slopes		Deposits Covered by Changed Land Use
	Collapsible and Expansive Soil		Zoning Restrictions
	Trench-Wall Stability		

1. Table modified after 1986 CDMG Note 46 (currently under revision by CGS) and supplemented from CDMG Note 52 (2001) based on problems and issues potentially applicable to the study area. "Waste Disposal" and "Water and Soil Pollution Problems" are part of the checklist, but would be addressed in Hazards and Hazardous Materials and Hydrology and Water Quality sections. Volcanic Hazards are part of the checklist, but do not impact the Project Area and are not discussed further.

Professionals responsible for the planning, design, construction, and operation of development projects use these (and other) earthquake design levels to provide the necessary margin of safety for the project being considered. Another approach to defining the seismic design parameters (earthquake peak horizontal and vertical ground acceleration, earthquake wave period, and the duration of strong ground motion) is Probabilistic Seismic Hazard Assessment (PSHA). This method considers all faults, and their characteristic earthquakes within, say, 100 kilometers (62 miles) of a site or a development area. The seismic design parameters are computed considering the probability of exceeding a certain "intensity" of each parameter (similar to the fault-specific UBE and DBE earthquake ground motions); this approach is generally applied to important facilities and is also embodied in building codes.

Earthquake intensity is often presented as a measure of the effects (either actual or predicted) of an earthquake at a particular location, including actual/potential damage (e.g., light or severe), one's perception of shaking (e.g., felt or unable to stand), and permanent topographic changes (e.g., uplift, landslides, or fault rupture). In the United States the most commonly cited intensity scale in the Modified Mercalli Intensity Scale (MMI) developed in 1931 and modernized over time largely to reflect changes in the types of structures that may be damaged. Roman numerals represent increasingly more intense shaking from MMI I (not felt) through MMI XII (damage total). Seismologists have also related these general categories to ranges of peak ground acceleration and peak ground velocity. Variations in intensities depend upon the distance from the earthquake to the site, the site rock and soil conditions, and variations in the propagation of earthquake waves due to subsurface complexities (e.g., local alluvial basin depth and shape).

Geologic (including surface fault rupture), geotechnical (soils), and flood hazards and issues, in contrast to seismic ground motion hazards, are more susceptible to direct observation and testing to determine the degree of hazard, and to specify a remediation or avoidance strategy. These hazards and geologic issues include relative surface fault activity, potentially unstable slopes, landslides, mudflows, severe erosion, radon gas, mineral resources, flooding, subsidence, expansive and compressible soils, and shallow groundwater. Several secondary seismic hazards potentially arising from these conditions are mentioned above.

In summary, seismic, geologic, and flood hazards must be considered in all phases of the development cycle from the earliest conceptual planning to the operations and eventual decommissioning of a facility. Building codes and general plan documents provide regulations, specifications, and strategies to cover most hazard conditions, if the proper detailed studies are performed to recognize the hazards, to define their potential severity, and to provide an adequate design that considers the importance, use, and life span of the facility. Information about the planning and regulatory setting for the Project Area is presented in Appendix A.

2 EXISTING SEISMIC, GEOLOGIC, AND FLOOD SETTING

For considerations in this report, the Midway CPA area is divided into two subareas, the Midway and Pacific Highway, based land use considerations. The Midway subarea portion is northwest of West Washington Street and the Pacific Highway portion is to the southeast. The Old Town CPA lies east of the Midway CPA. The Project Area ranges in elevation between approximately 10 feet and 180 feet above mean sea level (amsl; elevations estimated from USGS La Jolla [1974] and Point Loma [1997] 1:24000 scale topographic maps).

Seismic, geologic, and flood conditions in the Project Area (City of San Diego, 2008; Kennedy and Tan, 2008; Bedrossian and others, 2010) are similar to other locales and cities along the coast north and south of the Project Area (e.g., Oceanside, Carlsbad, Solana Beach-Del Mar, National City, and Chula Vista), and that generally border Interstate 5 (I-5). Several million years of regional uplift and consequent erosion of the predominantly Eocene and lesser Cretaceous sedimentary bedrock formations (Figure G-1) have formed the topography described above. Uplift and gentle folding of the geologic formations in the coastal area is evidenced in the sedimentary bedding in the Cretaceous-age bedrock bordering the western Midway subarea adjacent to Point Loma, and the Eocene-age formations bordering the Old Town CPA and Pacific Highway subarea on the east. Artificial fill (overlying young and older alluvium) and various ages of marine terrace/older alluvium deposits underlie well over 95 percent of the Project Area.

Natural hillsides along the eastern edge of the Project Area are somewhat susceptible to surficial slope failures where soils are thickest on the steeper slopes. Eocene formations may be susceptible to landslide failures where slopes are over-steepened or where formation bedding is tilted out-of-slope. Artificial fill and underlying young alluvium are susceptible to liquefaction and lateral spread landslides, as well as, consolidation, settlement and subsidence exacerbated by earthquakes, all of which can lead to damage to overlying man-made structures.

The Project Area is not within a producing groundwater basin in this very near-coast location; historically shallow groundwater is reported within the areas of artificial fill, young alluvium, and older alluvium at depths of less than approximately 25 feet.

Statutory flood zones (e.g., 100- year and 500-year) have some impact within and near the Project area, as does the potential for tsunami. Man-made water tanks and water reservoirs (San Vicente and El Capitan) located within or up stream from the Project Area have the potential to fail and release floodwaters to inundate local areas.

The City of San Diego is potentially affected by numerous active and potentially active faults (Figure G-2). While the City has experienced mild to moderate earthquake shaking in the historic past, it generally has a lower potential for strong ground shaking than other areas of southern California. A few less well known and/or poorly located historic local earthquake events (e.g., 1803, 1862, 1956, and 1986) caused slight to substantial ground shaking and some damage to normal structures. Instrumentally recorded events centered some distance from the City (e.g., 1992 Landers and Big Bear, and 1994 Northridge) were felt, but did not lead to local disruptions. Minor damage was sustained in the City of San Diego as a result of the 2010 Sierra El Mayor earthquake in Baja California, Mexico.

Substantial disruption from these earthquakes occurred nearer the epicenters reminding southern California residents that every several years another area of southern California is vulnerable to a "direct hit." With earthquake prediction still a distant goal, it is important that each City and citizen do what is within its means and power to create policies that will maximize the protection of lives and property.

2.1 Geologic, Soil, and Water Conditions

2.1.1 Physiography and Topography

Existing Conditions

The City of San Diego is located within the Peninsular Ranges geomorphic province, which is characterized by generally northwest trending mountains and valleys, located south of the Transverse Ranges, and west of the Mojave and Colorado Deserts. Offshore continental borderland areas south of the Transverse Ranges also are included within the Peninsular Ranges. Landforms and topography (physiography) around the Project Area are controlled by the distribution and character of geologic units, by fault movements, and by climate and erosion, all of which contribute to the sculpture of the landscape. The generally north to northwest trending coastline and mountains to the east are influenced by the Newport-Inglewood-Rose Canyon and the Elsinore-Julian fault zones, respectively.

In the Midway subarea west of Old Town elevations are predominantly between 10 feet and 15 feet with topography forming gentle slopes to the northwest and southwest (USGS, 1975 [La Jolla] and 1997 [Point Loma] quadrangles). Locally somewhat steeper slope areas in the extreme southwest and northeast of this portion of the Midway-Pacific Highway CPA reach elevations of 20 to 50 feet. In the western and northern portions of Old Town, elevations are in the range of 15 feet to 20 feet up to the Mission Hills at Presidio Park. Most of the remainder of the developed portion of Old Town to the south ranges in elevation between 20 feet and 40 feet. The Mission Hills bordering Old Town on the east range between elevations 40 feet and 180 feet (in Presidio Park). The narrow portion of the Midway-Pacific Highway CPA to the southeast along Interstate-5 and the Southern Pacific railroad corridor ranges from 10 feet to 20 feet in elevation along the southwest edge and 40 feet to 125 feet along the northeast edge.

Pre-1950s Topography and Depositional Environments

Several vintage land survey maps and charts of the San Diego Mission and San Diego Bay indicate the general (not precise) topographic and geologic conditions in existence in the period before the Project Area was developed. Reports suggest that at the time of Spanish exploration "that at high tide the waters of the North and South Bays met," with the North Bay being False or Mission Bay, and South Bay San Diego Bay. These topographic conditions were modified as settlements continued to develop in the mission area. The 1782, 1853, and 1857 maps indicate that the San Diego River turned south at the north edge of Old Town and drained through one or two substantial drainage courses into San Diego Bay. The drainages passed through Old Town and the eastern portion of the Midway area, generally east of Camino del Rio West. Secondary drainages branched of to the west and northwest to Mission Bay west of Camino del Rio West.

These low-gradient, meandering drainages passed through an estuary-type environment very close to sea-level in the southern and northwestern reaches of the Project Area. In the 1800s, the course of the San Diego River (Kuhn and Shepard, 1984) changed due to natural causes (flooding) and works of man (levee/embankment). Before 1821 the river usually flowed south past Old Town into San Diego Harbor, however, a flood changed the river channel so that most of the flow went to Mission Bay. During the next

40 years flow returned predominantly back to San Diego Bay. In 1876-1877 the levee was constructed directing flow to Mission Bay where it has remained.

Young sedimentary sedimentary deposits (e.g., river, flood plain, and estuarine) persisted with some modification into the early 1900s (U. S. Coast and Geodetic Survey [USCGS], 1902 and 1903 topographic maps) and as late as 1930 when the San Diego River no longer flowed south, but just west into Mission Bay. By 1939 to 1943 the Project Area was filled north of roughly Sports Arena Drive and probably south as well. Sedimentary/geologic deposits underlying these fill areas likely consist of saturated fine- to medium-grained sand, silt, and clay becoming progressively finer-grained proceeding to the west and south from Old Town.

2.1.2 Geologic Formations

Table G-2 presents a summary of the distribution of geologic formations within the Project Area by CPA designation. Published geologic maps reviewed for this study include the U. S. Geological Survey (Kennedy and Tan, 2008; Figure G-1) and the California Geological Survey (CGS; Bedrossian and others, 2010). The USGS authors Kennedy and Tan (2008) compiled a regional geologic map, which in the Project Area includes geologic structure (bedding attitudes) and a reasonably simple view of the distribution of geologic units (distinguishing bedrock and surficial into broad groupings) as shown on Figure G-1. Bedrossian and others (2010) used the same underlying geologic formation boundaries, but reclassified the units to simplify the terminology and removed the bedding attitude information. Table G-2 provides a brief description of these geologic formations (Kennedy and Tan, 2008), from youngest to oldest, present in each of the three Project Area subareas, as well as the acreages and percentages of each unit.

Surficial Deposits-General Descriptions

Table G-2 provides a generalized description of the age, percent occurrence, and physical properties of the surficial units. Though not a true geologic deposit, artificial (man-placed) fill materials (symbol af) consist of reconstituted geologic materials placed either with or without engineering compaction and controls. By far, the greatest portion of the Project Area (78 percent and 87 percent of the Midway CPA) is underlain by both non-engineered and engineered fill. These deposits are generally poorly to well consolidated, poorly sorted and permeable, sand, silt, gravel, and clay derived from the local bays and river beds. For non-engineered fill the potential for compressibility, excessive moisture, seismic instability, and settlement are typically similar to young alluvium. Except for artificial fill compacted with engineering controls (not specifically differentiated by Kennedy and Tan, 2008), the suitability for construction may range from poor to fair.

Surficial deposits consist of relatively recent (geologically young), old, and very old sedimentary formations formed by alluvial and near-shore marine processes in streams, on alluvial fans, in estuaries, and in the marine coastal zone. These deposits have been laid down over a range of geologic time; in general the uppermost surficial units (e.g., af and Qls) are Holocene (less than 10,000-12,000 years old) in age, and the Qop_6 and $Qvop_{11}$ units are late to early Pleistocene (approximately 120,000 to 700,000 years old) in age. It was not determined that any deposits within the Project Area have been age-dated by absolute methods. In general, the younger the age of the surficial deposit the less adequate the engineering properties are for construction purposes.

The distribution of surficial units on Figure G-1 indicates that the majority of deposits within and immediately adjacent to the Project Area are af, Qop_6, and $Qvop_{11}$ (Kennedy and Tan, 2008). The older $Qvop_{11}$ unit comprises no more than a few percent of the Project Area. Colluvium is unmapped but would be found mainly on the lower and intermediate hillslopes between the Qop_6 and higher elevation $Qvop_{11}$ and bedrock formations on the east and southwest portions of the Project Area.

Table G-2 - Summary of Geologic Formation Characteristics by Project Area

GEOLOGIC FORMATIONS/MAP SYMBOLS [From Youngest to Oldest]	PROJECT AREA ACRES (1-Midway CPU Area, 2-Old Town CPU Area)	PROJECT AREA PERCENT (1-Midway CPU Area, 2-Old Town CPU Area)	GENERAL LOCATION, LITHOLOGIC, STRUCTURAL, AND ENGINEERING CHARACTERISTICS (Kennedy and Tan, 2008, Description of Map Units)
Surficial Units			
(a)-Artificial Fill (af-historic) and Immediately Underlying Surficial Deposits (b)-Young Alluvium (Qal-along the San Diego River in Midway)	1-804.26 2-116.21	1-87.46 2-43.65	(a)-Deposits of artificial fill resulting from human construction activities; includes compacted engineered and non-compacted, non-engineered fill. (919.1 acres and 77.1%) Artificial fill is underlain by young alluvial deposits as follows: (1) (b)-wash deposits--unconsolidated boulder to sandy alluvium in previously active river/washes (1.37 acres and 0.15%); (2) paralic estuarine deposits--unconsolidated, composed mostly of fine-grained sand and clay; (3) flood plain deposits--mostly poorly consolidated, poorly sorted sands, permeable; and (4) colluvial deposits--poorly consolidated, poorly sorted sand and silt slope wash deposits. Qal and af susceptible to liquefaction, settlement, dynamic consolidation, slope instability, and poor foundation characteristics.
Landslide Deposits (Qls-Pleistocene to Holocene)	1-0 2-15.11	1-0 2-5.67	Highly fragmented to largely coherent; can vary from unconsolidated to moderately well-consolidated. Susceptible to settlement, dynamic consolidation, slope instability, and poor foundation characteristics.
Old Paralic Deposits Unit 6 (Qop_6 or Bay Point Formation-late to middle Pleistocene)	1-110.33 2-100.87	1-12 2-37.88	Mostly poorly sorted, moderately permeable, reddish-brown, interfingered strandline, beach, estuarine and colluvial deposits composed of siltstone, sandstone and conglomerate. These deposits rest on the 22-23 meter Nestor terrace. Possibly susceptible to liquefaction, settlement, dynamic consolidation, slope instability, and poor to very good foundation characteristics.
Very Old Paralic Deposits Unit 11 ($Qvop_{11}$ or Lindavista Formation-middle to early Pleistocene)	1-0.67 2-8.05	1-0.07 2-3.02	Mostly poorly sorted, moderately permeable, reddish-brown, interfingered strandline, beach, estuarine and colluvial deposits composed of siltstone, sandstone and conglomerate; upper surfaces may be capped by moderate to well-developed pedogenic soils. These deposits rest on the 92-94 meter Clairemont terrace. Not susceptible to liquefaction, possibly susceptible to settlement, dynamic consolidation, expansive soils, and slope instability, and likely possesses good to excellent foundation characteristics.
Bedrock Units			
San Diego Formation (Tsd-early Pleistocene and late Pliocene age)	1-0.12 2-8.79	1-0.01 2-3.3	Predominantly yellowish-brown and gray, fine- to medium-grained, poorly indurated fossiliferous marine sandstone found with reddish-brown, transitional marine and non-marine pebble and cobble conglomerate in areas where sandstone and conglomerate are undivided (Tsd). Approximately 75 meters of marine and 9 meters of non-marine sedimentary rocks. Not susceptible to liquefaction, possibly susceptible to settlement, dynamic consolidation, and slope instability, and likely possesses good to excellent foundation characteristics.
(a)-Pomerado Formation (Tp-middle Eocene age) (b)-Mission Valley Formation (Tmv-middle Eocene age)	1-0 2-17.24	1-0 2-6.48	(a)-Massive cobble conglomerate with a dark-yellowish-brown, coarse-grained sandstone matrix. (1.12 acres and 0.4%) (b) Predominantly light-olive-gray, soft and friable, fine- to medium- grained marine and non-marine sandstone containing cobble conglomerate in discontinuous beds. Has a maximum thickness of 60 meters. (16.12 acres and 6.1%) See San Diego Formation for engineering properties.
Mt. Soledad Formation (Tmss-mid Eocene age)	1-4.23 2-0	1-0.46 2-0	Massive, light-brown, medium-grained sandstone. See San Diego Formation for engineering properties.
TOTAL AREA	1-919.61 2-266.28	1-100 2-100	

The California Building Code was updated and revised in 2010, and effective January 1, 2011. As with past revisions the geologic subgrade classification system (Site Class A through Site Class F) is used to classify soil properties according to their physical attributes. Under this geologic subgrade site classification, non-engineered artificial fill (af) and the young alluvium (Qa) would likely be classified as Site Class E or possibly Site Class F, (a soft to very soft soil profile) and the old units (Qls and Qop_6) would likely be classified as Site Class D or Site Class E, which is a stiff to soft soil profile. Engineered artificial fill and older alluvium ($Qvop_{11}$) would likely be classified as Site Class C or Site Class D, which is a very dense to stiff soil profile, while bedrock formations would likely be Site Class C or better. These classifications will affect seismic coefficients for earthquake design as shown by geotechnical design reports.

<u>Bedrock Units</u>
Based on the Kennedy and Tan (2008) geologic map, the three bedrock formations are exposed within the Project Area and together their area totals less than one percent of the total Project Area. From oldest to youngest these are the Mount Soledad Formation (Tmss-middle Eocene age), the Mission Valley Formation (Tmv-middle Eocene age), and the San Diego Formation (Tsd-early Pleistocene and late Pliocene age), all sedimentary units (Figure G-1).

Bedrock units are exposed over a limited portion (30.4 acres and 2.6%) of the Project Area (Table G-2). The San Diego and Mission Valley Formations are found at the far eastern, higher relief margins of the Old Town CPA. The Mount Soledad Formation has very minor exposures in the far western portion of the Midway CPA. It can be expected that these relatively soft bedrock formations would be encountered in the subsurface adjacent to the surface exposures within these two subareas. The layering/bedding in these formations tilts/dips out of the slopes bordering the Project Area at angles less than approximately 10-degrees. This condition suggests potential bedding plane slope instability, however these formations are predominantly sandstone and conglomerate with minor claystone and siltstone that would suggest a lesser the potential for slope instability.

2.1.3 Groundwater

The Project Area is in the Pueblo San Diego watershed and overlies the lower extreme of the Mission Valley groundwater basin (CDWR, 2003). Water was first developed here by the Spaniards from the adjacent San Diego River. There is no known active groundwater withdrawal in the Project Area by the City of San Diego as a member agency of the San Diego County Water Authority (SDCWA). Water bearing materials are the young and older alluvium and bedrock units discussed above within the watershed. The San Diego Formation is an approximately 100 feet thick water-bearing unit east of the Rose Canyon fault zone and is also present at a much greater thickness beneath the Project Area west of the RCFZ. The alluvium reportedly (CDWR, 2004) reaches a thickness of 80 to 100 feet within the San Diego River and is recharged by infiltration from rainfall, ephemeral stream flow, and water applied to landscaping. Groundwater depth is expected to be near sea level, at roughly 10 to 20 feet deep, over most of the Project Area (Figure G-4 unit 31). Local groundwater levels can change in response to changes in precipitation and runoff, and water quality is subject to impacts by seawater intrusion.

2.1.4 Surface Water and Flooding

<u>Precipitation, Runoff, and FEMA Flooding</u>
The City of San Diego participates in the Federal Flood Insurance Study to determine the mandatory insurance necessary for identified properties. As shown on Federal Insurance Rate Maps (FIRMs), flood areas that have a 1 percent annual chance of flooding are in the “100-year floodplain.” Federal Emergency Management Agency (FEMA) designated 100-year floodplains and floodways are identified north of the Project Area in the San Diego River drainage. Some portions of the Project Area (7.4% all in the Midway subarea and 0.29% of the Old Town CPA) are within designated Zone X 500-year floodplain (Figure G-3; City of San Diego, 2011b) indicating that the Project Area is protected from the 500-year flood by a levee along the south side of the San Diego River. The City of San Diego and San Diego County maintain an extensive storm drain system that would normally divert any excessive rainfall into appropriate channels. However, a significant rain event could cause flooding in the 500-year flood zone identified on Figure G-3 if the nearby river levee were to fail. The City coordinates with the San Diego County Flood Control District to maintain the necessary flood control and stormwater management.

Dam Failure Inundation

Two upstream dams potentially retain sufficient surface water in their reservoirs to cause flooding within the Project Area should these dams fail at near reservoir capacity. San Vicente, El Capitan, and Murray dams lie approximately 22 miles, 26 miles, and 10 miles, respectively, upstream from the Project Area. San Vicente Dam is being raised 117 feet (San Diego County Water Authority, 2011) so that the reservoir will have a new capacity of approximately 242,000 acre-feet from the current 90,000 acre-feet (City of San Diego--Water, 2011c). El Capitan Reservoir has a capacity of approximately 112,807 acre- feet and Murray Reservoir a capacity of approximately 4,684 acre- feet.

The County of San Diego (Figure G-3; SanGIS, 2011b) indicates that with present reservoir capacities, the two larger reservoirs could flood up to 63% of the Midway subarea and the western portion (up to 48%) of the Old Town CPA. Since the current maps are based on the existing capacity at San Vicente, the flood area would increase the flood levels within the Midway and Old Town CPAs by some undetermined amount and would likely leave the Pacific Highway subarea unaffected. The flooding would not result so much in standing water, but flood waters that could move across the affected portions of the Project Area with significant velocity.

Tsunami and Seiche

There are numerous reports with lists of tsunamis that have affected San Diego. The effects indicated are usually wave amplitude, wave height, or wave runup. For purposes of this report we assume this reported value indicates the increase in the elevation of the sea surface above the tidal elevation at the time. The Port of San Diego reports that the mean high water is 1.47 meters (4.8 feet) and the highest observed tide was 2.4 meters (7.9 feet). A very recent assessment of tsunami risk in San Diego (Barberopoulou and others, 2010) was conducted considering regional/local and distant sources capable of generating damaging tsunamis. They indicate that past tsunami reports (18 examples) indicate the highest wave amplitude, 1.5 meters (4.9 feet) was from the 1960 M9.5 Chile earthquake. Records for the March 11, 2011 M9.0 Honshu, Japan earthquake indicate 0.1 meter (0.33 foot) wave amplitude (NOAA, 2011) in San Diego Harbor. There is a report (California Office of Emergency Services, 2005) of an 8/23/1856 tsunami generated by an earthquake at southeast Hokkaido Island, Japan produced a 3.6 meter (11.8 feet) tsunami at San Diego, however it is noted that this is likely an "Exaggerated report and/or erroneous date."

Barberopoulou and others (2010; their Figures 4 and 5) determined that the largest tsunami from a distant source would be from a hypothetical magnitude (M) 9.4 earthquake on the Alaska-Aleutians Subduction Zone (AASZ) generating a roughly 2.5 meter (8.2 feet) wave height in the harbor. The largest wave height (at least 1 meter [3.28 feet]) from local offshore events would be from a M7.8 earthquake on the Coronado Bank fault, or large landslides in the Coronado Canyon or Thirtymile Bank areas.

2.1.5 Mineral Resources and Radon

The Project Area lies within a portion of the City that has been developed for various commercial, industrial, governmental, and residential uses. Recovery of mineral resources is not ongoing within the Project Area, which is predominantly within a State Mineral Resource Zone (MRZ) 1 indicating "Areas where adequate information indicates that no significant mineral deposits are present, or where it is judged that there is little likelihood for their presence" (Miller, 1996). Small areas in the eastern one-third of the Old Town CPA are within MRZ-2 ("Areas where adequate information indicates that significant mineral deposits are present or where it is judged that there is a high likelihood for their presence.") and small area within the western portion of the Midway subarea are within an MRZ-3 classification ("Areas containing mineral deposits, the significance of which cannot be evaluated from available data."). These classifications are related to sand and gravel resource potential due to the nature of the geologic formations described above. The MRZ classification is normally in reference to sand, gravel, stone, and precious or semi-precious minerals or metals found in other areas of San Diego County. With regard to oil, natural gas, and geothermal resources, none are mapped in or immediately adjacent to the Project Area (California Department of Conservation, 2001). The MRZ-2 and MRZ-3 areas are beneath developed areas, and activities within the Project Area would not affect future mineral resource availability or production.

Radon is a cancer causing gas. Based on the USGS (2011b) "Some types of rocks have higher than average uranium content. These include light-colored volcanic rocks, granites, dark shales, sedimentary rocks that contain phosphate, and metamorphic rocks derived from these rocks. These rocks and their soils may contain as much as 100 parts per million (ppm) uranium. Layers of these rocks underlie various parts of the United States." The bedrock formations adjacent to and underlying the Project Area are sandstones and conglomerates containing granitic and metamorphic materials, and their derivative soils. The California Department of Health Services (CDHS, 2011) indoor radon test database indicates 12 tests have been performed in the vicinity of the Project Area (zip codes 92110 and 92111) and 3 tests in 92111 had results indicating greater than 4 picocuries per liter of radon, which is the level of concern where CDHS recommends that action be taken to reduce radon levels in a home. While the CDHS test results may not be statistically significant, they indicate that geologic conditions are such that radon may be expected in the older geologic formations in the vicinity of the Project Area.

2.2 Seismic Conditions

2.2.1 Faults

As mentioned, two types of fault impacts are important to consider for faults affecting the Project Area within the City of San Diego. Fault-generated earthquake ground shaking is the most critical impact due to its widespread effects, and to the severe damage resulting in economic losses and the injury or death of people. The other important impact relates to ground movement, e.g., co-seismic uplift, ground lurching, ground cracking, and liquefaction. Surface fault rupture is an additional issue in the Project Area based on available data for the Rose Canyon fault zone (Figure G-1). North and south of the Project Area (Figure G-2) the Rose Canyon fault zone has an Alquist-Priolo Earthquake Fault Zone (APEFZ) designation. While these other ground movement effects are more limited in extent than strong ground shaking, the impacts on structures and on the public can be severe depending upon the size and proximity of the causative earthquake.

In cases where earthquakes are large or hypocenters (the epicenter at depth) are shallow, ground rupture can occur along the source fault plane where it intersects the earth's surface. The potential for surface fault rupture hazard in the Project Area varies from very low to high. "Active" faults (demonstrated offset of Holocene materials [less than 10,000-12,000 years ago] or significant seismic activity) and "potentially active" (Pleistocene [greater than 10,000-12,000 but less than 1,600,000 years ago]) faults (as defined by the CGS) must be considered as potential sources for fault rupture. In general, the younger the last movement is on a fault, the higher the potential for future movement on that fault.

Only one surface fault zone is documented to directly underlie the Project Area. The potentially active Rose Canyon fault zone (RCFZ) is within the eastern portion of the Project Area (Kennedy and Tan, 2008; City of San Diego, 2008) passing through the Old Town CPA, the southern Midway subarea, and the Pacific Highway subarea. Two fault strands, the Mission Bay and the Old Town, have been named in the Project Area within the RCFZ. Each has different potential impacts, and differing levels of information regarding their degree of activity and damage-generating potential. See Figure G-2 and Table G-3 for locations and characteristics of regional and local faults. The RCFZ is discussed further below.

<u>Rose Canyon Fault Zone</u>
The Rose Canyon fault zone (RCFZ) is considered the southern extension of the Newport-Inglewood structural zone originating at the Santa Monica Mountains and continuing south-southeast into the offshore at Huntington Beach, then returning onshore near La Jolla and Soledad Mountain (Figure G-2). Following Rose Canyon and the east side of Mission Bay, the RCFZ passes through the Project Area and continues southward as several active branches through San Diego Bay towards northern Baja where it appears to

connect with either the offshore Descanso and onshore Agua Blanca fault zone (Rockwell, 2011), or the Vallecitos-San Miguel fault zone. The RCFZ is zoned as an APEFZ several miles to the north and to the south of the Project Area (CDMG, 1991; CGS, 2003). In between these APEFZs, including the Project Area, the fault is considered active by the City of San Diego (2008) and the County of San Diego (2010a) in their respective Safety Elements.

The RCFZ in the vicinity of the Project Area is up to approximately one kilometer wide and has fault segments with both strike-slip (lateral) and dip-slip (vertical) senses of movement. This is attributed to portions of the zone exhibiting compressional stresses and other portions extensional stresses (Treiman, 1993). Lindvall and Rockwell (1995) performed a fault trench study on the RCFZ north of Mission Bay and determined that at least three significant earthquakes occurred during the Holocene epoch (approximately the last 10,000 years) and probably six such events (Rockwell, 2011). The fault zone shows geomorphic features indicating recent activity, such as offset and linear drainages, scarps, pressure ridges, and sag ponds. South of the Project Area in San Diego Bay, offshore (marine) seismic studies (Kennedy and Welday, 1980; Kennedy, M. P., and Clarke, S. H., 1999) defined three major active RCFZ strands (Spanish Bight, Coronado, and Silver Strand from west to east).

The active Rose Canyon fault zone (RCFZ) is within the eastern portion of the Project Area (Figure G-1, Kennedy and Tan, 2008; City of San Diego, 2008) passing through the Old Town CPA and Midway subarea. Based on Kennedy and Tan (2008), two fault strands, the Mission Bay and the Old Town, have been named in the Project Area as part of the RCFZ. These strands diverge as they trend into the Project Area from the north, with the Old Town fault trending southeasterly and apparently dying out in that direction, and the Mission Bay fault trending south to southwest toward the Spanish Bight fault. Each fault appears to have a different level of information regarding their degree of activity. The City of San Diego Safety Element (2008, their Figure PF-9) shows a greater number of fault segments within the Old Town CPA apparently due to the compilation of the USGS and CGS sources onto the existing SanGIS data base, which has likely caused some duplication of fault segments. Based on the data for Figure G-4, the RCFZ segments are defined with 200-feet wide zones (100-feet on each side) in the Old Town CPA and the southern portion of the Midway subarea. Considering these zones, a total of 66 acres is affected, mostly within the Old Town CPA (55 acres and 21% of the CPA).

Based on the most recent mapping (Kennedy and Tan, 2008) the Mission Bay fault enters the Project Area as two segments within the central portion of the Old Town CPA east of the I-5. These segments continue southward to cross, trend parallel to, and lie within the Midway subarea. Both segments are buried (not exposed at the surface) within the Old Town CPA. East of the Old Town CPA the eastern segment is exposed in the Eocene Mission Valley Formation and the Pliocene San Diego Formation, forming a fault contact between these two geologic units. The City Geologic Hazards maps (SanGIS, 2011) show the Mission Bay fault segments in slightly different locations than Kennedy and Tan. Within the Project Area there is no apparent evidence that the Mission Bay fault offsets Pleistocene or Holocene geologic units.

The Old Town fault (Treiman, 1991 and 1993; Kennedy and Tan, 2008) is located within the Old Town CPA and east of the Mission Bay fault segments. The fault enters the Project Area from the north and crosses the northeastern corner of the subarea passing through the Presidio Park portion of the Old Town CPA. Kennedy (in Section A of Kennedy and Petersen, 1975) indicates the Old Town fault is one of several youthful faults that vertically offset sediments approximately 100,000 years old by more than 20 meters, indicating late Quaternary activity. In an abstract presented in 2007, Stroh (2007) indicates that fault exploration observed a faulted buried soil horizon with an early Holocene-age (7,000 to 9,000 years BP) charcoal radiocarbon age date and that the main fault is south of the site studied. Although the original consulting report was not located, this suggests that the Old Town fault should be considered active unless specifically demonstrated otherwise. Although no fault investigation reports are known for the Mission Bay fault segments in the Old Town CPA portion of the Project Area, a similar consideration should be made.

TABLE G-3 - Major Faults within Approximately 100-Miles of the Project Area

FAULT NAME (In Order of Nearest Distance From the Site)	APPROXIMATE DISTANCE FROM SITE (mi [km])	FAULT LENGTH (km)	FAULT DIP	SLIP RATE (mm/yr)	TYPE OF FAULT	MAGNITUDE (Mw) OF MAXIMUM EARTHQUAKE	AGE AND EVIDENCE OF LATEST SURFACE FAULTING
Rose Canyon	0.76 (1.2)	70	90°	1.0 to 2.0	Strike Slip	6.7-6.9	Historic (1986 M5.3 and many >M4)
Coronado Bank	11.9 (19.1)	186	90°	2.0 to 4.0	Strike Slip	7.3-7.4	Seafloor and young sediment offsets
Newport-Inglewood (Offshore)	30.9 (49.8)	66	90°	1.0 to 2.0	Strike Slip	6.8-7.0	Historic (1933 Long Beach EQ)
Elsinore (Julian)	41.9 (67.4)	76	84° NE	2.0 to 4.0	Strike Slip	7.3-7.4	Late Quaternary; Holocene
Elsinore (Temecula)	42.4 (68.2)	52	90°	3.0 to 7.0	Strike Slip	6.9-7.1	Late Quaternary; Holocene
Earthquake Valley	46.6 (75.0)	20	90°	1.0 to 3.0	Strike Slip	6.6	Holocene
Elsinore (Coyote Mountain)	52.7 (84.9)	39	82° NE	2.0 to 5.0	Strike Slip	6.7-6.9	Several documented Holocene EQ events
Palos Verdes	55.2 (88.8)	99	90°	2.0 to 4.0	Strike Slip	7.2-7.3	Holocene
Elsinore (Glen Ivy)	60.7 (97.7)	37	90°	3.0 to 7.0	Strike Slip	6.7-6.9	Late Quaternary; Holocene
San Jacinto (Coyote Creek)	62.7 (101.0)	43	90°	2.0 to 6.0	Strike Slip	6.8-7.0	Marked by scarps, linear and deflected drainages, and benches
San Joaquin Hills	64.5 (103.8)	27	23° SW	1.2 to 1.3	Blind Thrust-Reverse	6.9-7.1	Late Quaternary uplift San Joaquin Hills
San Jacinto (Anza)	64.9 (104.4)	71	90°	8.0 to 10.0	Strike Slip	7.2-7.3	Recent seismicity
San Jacinto (Clark)	64.9 (104.5)	47	90°	12.0 to 16.0	Strike Slip	6.9-7.1	Recent seismicity
San Jacinto (Borrego)	66.0 (106.2)	34	90°	2.0 to 6.0	Strike Slip	6.6-6.8	Historic (1968 M6.6 Borrego and 1987 M6.6 Superstition Hills)
San Jacinto (Superstition Mountain)	75.3 (121.1)	26	90°	12.0 to 16.0	Strike Slip	6.5-6.7	Recent seismicity
Laguna Salada	76.9 (123.7)	100	90°	3.5	Strike Slip	7.2-7.3	Historic (1892 and 2010 EQs)
Elsinore (Whittier)	77.8 (125.2)	46	75° NE	1.5 to 3.5	Strike Slip	6.8-7.0	Late Quaternary NW of Brea Canyon
Superstition Hills	78.5 (126.4)	36		3.0 to 5.0	Strike Slip	6.6-6.8	Historic (1987 M6.2 Elmore Ranch)
Chino-Central Avenue (Elsinore)	79.4 (127.8)	24	60° - 65° SW	1.0	Reverse Right Oblique	6.4-6.7	Late Quaternary
Elmore Ranch	80.7 (129.9)	29		1.0	Strike Slip	6.5-6.7	Historic (1987 M6.6 Superstition Hills)
San Andreas (San Gorgonio)	85.7 (137.9)	56	90°	16.0	Strike Slip	7.0-7.1	Recent seismicity, geomorphic features
San Andreas (So. San Bernardino)	86.5 (139.2)	43	90°	16.0	Strike Slip	6.7-6.9	Recent seismicity, geomorphic features
San Andreas (So. from Cajon Pass)	86.5 (139.2)	203	90°	12.0 to 24.0	Strike Slip	8.0-8.1	Recent seismicity, geomorphic features

The primary source of information: USGS, 2008, Wills and others, 2008, Cao and others 2003, and SCEC, 2011. Fault distances from USGS, 2008; faults beyond approximately 100 kilometers were not deemed critical to the earthquake risk in the City.

La Nación Fault Zone

La Nación fault zone is a nearly north-south trending fault located approximately 6 miles east of the Project Area (Figure G-2). Seismic activity is associated with the fault zone and various fault investigations at different sites have found youngest faulted deposits of either Holocene or late Quaternary age. Faults are generally moderate- to high-angle normal faults that extend from Mission Valley on the north for about 20 miles to near the Mexico–United States border. According to Artim and Pinckney (1973) vertical offset of Pleistocene formations is as much as 85 meters and offset Holocene alluvium has been proven at two localities.

Stroh (2008) indicates that exploration trenches showed shearing of colluvium within the main fault contact, very linear contacts between the colluvium and the fault, and a colluvial filled fissure extending approximately 2 feet below the base of the colluvial contact. The fault zone may pose a local earthquake hazard, but does not project toward the Project Area.

Point Loma Fault Zone

The Point Loma fault is a north-northwest trending late Quaternary normal fault approximately 12 kilometers long located along the east side of Point Loma Peninsula (Figures G-1 and G-2; Kennedy in Kennedy and Petersen, 1975). A fault branching to the northeast off of the Point Loma fault projects toward the extreme northwest portion of the Midway subarea. The main fault and the small northeast striking branch fault displace the late Pleistocene Bay Point Formation in excess of 30 meters. The smaller northeast trending fault displaces the Bay Point formation about 3 meters. On this basis the Point Loma fault is considered potentially active.

Elsinore-Julian Fault Zone

The Elsinore-Julian fault zone is a major right-lateral shear system parallel to the southern San Andreas fault in the southeast portion of the Peninsular Ranges approximately 42 miles east-northeast of the Project Area (Figure G-2). Total strike-slip is likely 10 to 15 kilometers and total vertical separation is about 200 meters along this 79 kilometer section oriented approximately north 56° west and dipping from near-vertical to 45° to the northeast. Holocene alluvium and Quaternary alluvial deposits (as young as 1.2±0.5 thousand years (ka) are offset near Julian. The geomorphic expression of the fault includes deflected drainages, shutter ridges, hillside benches and scarps in alluvium (Treiman, 1998). Documented Holocene activity suggests a slip rate around 4 to 5 mm/yr. This zone may be capable of an earthquake of approximately M7.3 (Petersen and others, 2008).

Offshore Faults

Several potentially significant earthquake faults are located in the offshore continental borderland (Figure G-2), including the Coronado Bank, San Diego Trough, San Clemente, San Mateo-San Onofre-Carlsbad, and Oceanside (blind thrust) faults (Ryan and others, 2009). The Oceanside blind thrust (not shown on Figure G-2) is a buried low-angle thrust fault dipping approximately 14- to 25-degrees (Rivero and others, 2000; Crouch and Suppe, 1993; Bohannon and Geist, 1998; Mueller and others, 1998) to the northeast and identified in the offshore from roughly Dana Point south to the U.S.-Mexico border. The onshore projection of the OBT may lie at a depth of roughly 8-kilometers beneath the City of San Diego (based on Rivero and others, 2000). Based on many factors Rivero and others (2000) conclude that the potential exists for a M7+ earthquake on the Oceanside blind thrust with a recurrence interval of 600 to 8800 years depending upon the scenario chosen. Currently the extent and earthquake potential of the Oceanside blind thrust are not settled.

The Coronado Bank, San Diego Trough, and San Clemente fault zones form a wide zone of northwest-southeast trending strike-slip, oblique slip, and normal faults that lie between 15 miles and 42 miles offshore from the Project Area. These faults are of significant length and are documented by marine geophysical methods to have offset either the shallowest seafloor sediments or the seafloor itself (Ryan and others, 2009), demonstrating the potential for very large earthquake events with a long expected return period. Based on Ryan and others (2009) and Petersen and others (2008), these faults have a slip rate in the range of 1 to 3 millimeters per year (mm/yr) and for the Coronado fault a M7.3 to 7.4 earthquake. This suggests M7+ earthquakes are possible (see Table G-3) across these fault zones.

The expected return period for M7+ earthquake events is very long and may be considered outside the City planning horizon except for critical and important facilities. Various levels of uncertainty characterize the offshore continental borderland faults relative to the location and the potential for future movement within a timeframe that may impact planned development in the Project Area. The USGS and CGS have an active program to determine the nature of earthquake fault sources in southern California and the offshore borderland.

Faults in Baja California

As demonstrated by the M7.2 Sierra El Mayor (or El Mayor-Cucapah) earthquake of April 4, 2010, earthquake faults in Mexico can cause significant shaking in the U. S. Onshore and offshore faults south of the U. S.-Mexico border within approximately 62.5 miles (100 kilometers) of the Project Area include the offshore Descanso, and onshore Vallecitos-San Miguel, Bahia Soledad, San Isidro, and Agua Blanca faults (Figure G-2; Ryan and others, 2009; Rockwell, 2011).The RCFZ appears to be tectonically related to the Vallecito-San Miguel and/or the Agua Blanca. In either case, this suggests an extensive length for more than one active fault reasonably near the Project Area. The onshore faults (Vallecitos-San Miguel, and Agua Blanca faults) have been studied to some degree and show geomorphic and subsurface evidence of offsets in Holocene deposits as well as surface geomorphic features similar to those summarized for the RCFZ (Rockwell, 2011).

Since these Baja faults are less studied, the earthquake characteristics are less well known and they are not as likely to be incorporated into standard earthquake design analyses in the California. Consideration of these faults would likely increase somewhat the level of design earthquake chosen for the Project Area. However, it is unlikely that these onshore and offshore Baja faults can produce sufficiently larger and more frequent earthquakes to overshadow the design influence of the better studied California onshore and offshore faults discussed above.

2.2.2 Historic Earthquakes and Ground Shaking

Earthquakes generally occur on faults, which are planar features within the earth. Numerous regional and local faults are capable of producing severe earthquakes of magnitude (M) of 6.0 or greater. Some historic earthquakes in southern California have been of a sufficiently high magnitude to be felt in San Diego; a measure of the local shaking intensity of earthquakes is the Modified Mercalli Intensity scale (MMI; Table G-4).

Figure G-2 (USGS, 2008 and SCEC, 2009) indicates the events above M3.25 within 100-kilometers of the Project Area and the most significant of those are shown in Table G-5. (Magnitudes are generally expressed as M for Richter magnitude [equals M_L for local magnitude]; M_W for moment magnitude may be used in some instances. The specific method of computing each magnitude is available from numerous sources.) The most recent significant southern California and northern Mexico earthquakes are the 1933 Long Beach (Mw = 6.4), the 1992 Landers (Mw = 7.3) and Big Bear (M_L = 6.5), the 1994 Northridge (Mw = 6.7), and the 2010 Sierra El Mayor (Mw = 7.2 in northern Baja) earthquakes. Some of these earthquakes were felt in the City, but it is believed that none caused damage or injuries except for minor damage from the 2010 Sierra El Mayor.

Table G-4 - Modified Mercalli Intensity Scale (Abridged Version) [1]

Average Peak Velocity (cm/sec)	Intensity Value and Description		Average Peak Acceleration (% gravity)
<0.1	I.	Not felt except by a very few under especially favorable circumstances (I Rossi-Forel scale).	<0.17
0.1 – 1.1	II.	Felt only by a few persons at rest, especially on upper floors of high-rise buildings. Delicately suspended objects may swing. (I to II Rossi-Forel scale).	0.17 – 1.4
0.1 – 1.1	III.	Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing automobiles may rock slightly. Vibration like passing of truck. Duration estimated. (III Rossi-Forel scale).	0.17 – 1.4
1.1 – 3.4	IV.	During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensation like a heavy truck striking building. Standing automobiles rocked noticeably. (IV to V Rossi-Forel scale).	1.4 – 3.9
3.4 – 8.1	V.	Felt by nearly everyone, many awakened. Some dishes, windows, and so on broken; cracked plaster in a few places; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop. (V to VI Rossi-Forel scale).	3.9 – 9.2
8.1 - 16	VI.	Felt by all, many frightened and run outdoors. Some heavy furniture moved, few instances of fallen plaster and damaged chimneys. Damage slight. (VI to VII Rossi-Forel scale).	9.2 - 18
16 - 31	VII.	Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving cars. (VIII Rossi-Forel scale).	18 – 34
31 - 60	VIII.	Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, and walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving cars disturbed. (VIII+ to IX Rossi-Forel scale).	34 - 65
60 - 116	IX.	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken. (IX+ Rossi-Forel scale).	65 – 124
> 116	X.	Some well-built wooden structures destroyed; most masonry and frame structures destroyed; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed, slopped over banks. (X Rossi-Forel scale).	> 124
> 116	XI.	Few, if any, (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.	> 124
> 116	XII.	Damage total. Waves seen on ground surface. Lines of sight and level distorted. Objects thrown into air.	> 124

1. Middle column Bolt (1993); outer columns Wald and others. (1999).

INTENSITY	I	II-III	IV	V	VI	VII-VIII		IX	X+
SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy

A list of the "top ten" historic earthquakes felt within 100-miles of the Project Area (considered latitude 32.74982° north, longitude 117.20602° west) is provided in Table G-5. The ten highest magnitude earthquakes produced none of the highest estimated MMI values due to their substantial distances from the Project Area. The five highest estimated MMI/peak horizontal acceleration values, all greater or equal to VI and all prior to modern recordings (1800 and 1920) were for earthquakes within 3.5 to 18.1 miles of Project Area ranging in magnitude from 5.0 to 6.5. The 1862 earthquake (IX), probably near the City of Coronado, had the highest estimated intensity and may have been located within approximately 3.5 miles of the Project Area. Based on the statistical distribution of earthquake magnitudes during the period 1800-2002, the return periods for greater than M5.5, M6, M6.5, and M7 are approximately 5-, 10-, 30-, and 215-years, respectively.

Table G-5 - Top Ten Earthquakes within Approximately 100 Miles of the Project Area: 1800-2011 Sorted by Magnitude and by Peak Acceleration/Estimated Modified Mercalli Intensity (MMI) [1]

FILE CODE	NORTH LATITUDE (degrees)	WEST LONGITUDE (degrees)	DATE (month/day/year)	TIME (UTC/GMT) (hr min sec)	~DEPTH (kilometers)	EARTHQUAKE MAGNITUDE (approximate)	ACCELERATION AT SITE (force of gravity)	ESTIMATED SITE MMI	APPROXIMATE DISTANCE FROM THE SITE Miles (kilometers)
Sorted by Magnitude (within 100 miles)									
MGI	34	117.5	12/16/1858	10 0 0.0	0	7	0.027	V	88.0 (141.6)
DMG	33.75	117	4/21/1918	22 32 25	0	6.8	0.032	V	70.1 (112.8)
DMG	32.7	116.3	2/24/1892	7 20 0.0	0	6.7	0.044	VI	52.7 (84.9)
DMG	32.733	115.5	5/19/1940	4 36 40.9	0	6.7	0.018	IV	99.1 (159.4)
DMG	32.967	116	10/21/1942	16 22 13	0	6.5	0.024	V	71.5 (115.1)
DMG	33.933	116.383	12/4/1948	23 43 17	0	6.5	0.016	IV	94.5 (152.0)
DMG	33.19	116.129	4/9/1968	22 8 59.1	11.1	6.4	0.023	IV	69.4 (111.7)
DMG	33.8	117	12/25/1899	12 25 0.0	0	6.4	0.021	IV	73.5 (118.2)
DMG	33.2	116.2	5/28/1892	11 15 0.0	0	6.3	0.022	IV	66.0 (106.3)
DMG	33.4	116.3	2/09/1890	12 6 0.0	0	6.3	0.021	IV	69.0 (111.1)
Sorted by Estimated MMI Intensity and Peak Acceleration (within 100 miles)									
DMG	32.7	117.2	5/27/1862	20 0 0.0	0	5.9	0.329	IX	3.5 (5.6)
DMG	33	117.3	11/22/1800	21 30 0.0	0	6.5	0.142	VIII	18.1 (29.1)
T-A	32.67	117.17	12/00/1856	0 0 0.0	0	5	0.13	VIII	5.9 (9.5)
T-A	32.67	117.17	10/21/1862	0 0 0.0	0	5	0.13	VIII	5.9 (9.5)
T-A	32.67	117.17	5/24/1865	0 0 0.0	0	5	0.13	VIII	5.9 (9.5)
MGI	32.7	117.2	4/19/1906	0 28 0.0	0	4.3	0.119	VII	3.5 (5.6)
MGI	32.8	117.1	5/25/1803	0 0 0.0	0	5	0.112	VII	7.1 (11.4)
MGI	32.7	117.2	9/8/1915	7 42 0.0	0	4	0.097	VII	3.5 (5.6)
MGI	32.7	117.2	5/20/1920	13 30 0.0	0	4	0.097	VII	3.5 (5.6)
T-A	32.67	117.17	1/25/1863	10 20 0.0	0	4.3	0.078	VII	5.9 (9.5)

1. Risk Engineering (2011) and Blake (2011).

Several large historic/pre-instrumental (i.e., before modern seismographs) earthquakes shown in Table G-5 are reported to have occurred within the selected 100-mile radius. The epicenter locations of each of these events are considered very uncertain since they are based on damage reports and the felt intensity of shaking. Damage and intensity can be highly affected by local geology and not just distance to the epicenter.

2.2.3 Scenario Earthquakes: Rose Canyon and Elsinore-Julian Fault Zones

The U. S. Geological Survey "ShakeMaps" present estimates of the geographic distribution of MMI ground shaking intensity, as well as peak ground acceleration and other ground shaking parameters for both historic earthquakes and for potential future "scenario" earthquakes. An analysis of the Rose Canyon fault M6.9 scenario earthquake (CISN, 2006) indicates that for planning purposes the Project Area may experience an

MMI intensity of VI to VII and a PGA of 0.14 to 0.21g. A scenario analysis for the more likely M7.8 on the southern San Andreas fault zone suggests much lower values of MMI intensity II-IV and PGA of less than 0.1g. The scenario analysis for M6.8 on the Elsinore-Julian fault zone suggests an MMI intensity of VI to VII and a PGA of 0.15g. Future consideration may be given to the northeast dipping Oceanside blind thrust (Rivero and others, 2000) possibly capable of a M7+ earthquake located offshore and potentially lying beneath the City of San Diego. Depending upon the facility or structure being considered it is possible that one of these significant faults would control the earthquake design considerations for the longer period structures.

2.3 Seismic, Geologic and Flood Hazards, and Possible Mitigations

Potential hazards have been divided into three categories, seismic, geologic (non-seismic including engineering geologic and soil hazards), and flooding. Seismic hazards require an earthquake. The magnitude of an earthquake should be at least M5.0 and nearby for some significant effects to be triggered, although lesser magnitude earthquakes have activated hazards and caused damage.

Taken together, seismic, geologic, and flood hazard conditions in the Project Area are somewhat lower than, or about average for, coastal areas in southern California. Since active or potentially active faults traverse the Project Area, surface fault rupture potential is an issue of concern. Earthquake ground shaking potential from active faults in the onshore and offshore regions is considered moderate, with the most significant threat being the Rose Canyon fault zone, which lies beneath the Old Town CPA and southern Midway/Pacific Highway subarea portions of the Project Area. This potential should be considered in the design of all facilities. Liquefaction potential and locally lateral spreading landslide potential must be considered in the man-placed artificial fill and underlying young alluvium most prevalent in the Midway subarea, but older, denser formations around the margins of the Project Area should not be liquefaction-prone.

The presence of one mapped landslide and potentially adverse out-of-slope bedding dips in some bedrock formations suggests slope instability potential around the periphery of the Old Town CPA. Geotechnical and soil hazards (consolidation and expansion prone materials) are most likely in the artificial fill areas most prevalent in the Midway subarea. Formations in the areas with more topographic slope (Pacific Highway subarea, far western Midway subarea, and eastern portions of the Old Town CPA) have low soil slip susceptibility, with only very small areas having a moderate susceptibility. Radon is not expected to be a significant hazard within the Project Area.

Flood hazard from dam failure inundation is an issue for nearly all of the Project Area except the far eastern Old Town CPA and southwestern portions of the Midway subarea. Flooding potential from rainfall runoff is very low without a failure of the San Diego River levee along the north edge of the Midway subarea. Local water tank/reservoir failure due to earthquake shaking or seiching should be evaluated on a case-by-case basis, but is not believed to be a significant issue for development. The threat of tsunami appears to be low, except if there were simultaneously the largest potential tsunami and the highest tidal elevations.

The following subsections describe in more detail the seismic, geologic, and flooding hazards that may impact the Project Area. Table G-6 provides a visual summary of the potential seismic, geologic, and flood hazards considered, along with the degree of hazard or relative severity of each issue. Also shown are possible mitigation approaches that can reduce the potential hazards to less than significant. These relative severity ratings and possible mitigations indicate a sense of the construction and operational issues that may be associated with development in the various geologic formations, but do not substitute for the proper planning and implementation of seismic, geotechnical/engineering geologic, and flood investigations necessary for compliance with City, County, and State regulations. These general descriptions are not suitable for site-specific decisions related to the presence or absence of a specific seismic, geologic, or flood-related hazard or issue.

Table G-6 - Seismic, Geologic/Geotechnical, and Hydrologic Problems and Issues Checklist with Potential Mitigation Approaches [1]

GEOLOGIC, SEISMIC, AND HYDROLOGY ISSUES OF CONCERN		DEGREE OF HAZARD OR PROBLEM [2]				POSSIBLE MITIGATION APPROACHES		
GENERAL PROBLEMS AND ISSUES	***SPECIFIC ISSUES POTENTIALLY CAUSING PROBLEMS OR RAISING CONCERNS***	*None*	*Slight*	*Moderate*	*Severe*	*Code Conformance*	*Code Conformance and Special Work* [3]	*Advance Planning, Avoidance, and/or Restrictions*
EARTHQUAKE PHENOMENA	Ground Shaking		X	X		X		
	Landslides and Rockfalls	X	X			X		
	Fault Rupture and Tectonic Warping		X		X	X	X	X
	Differential Compaction/Seismic Settlement		X	X		X		
	Liquefaction and Lateral Spreads			X	X	X	X	X
	Tsunamis and Seiches	X	X			NA		X
	Flooding due to Dam or Levee Failure		X	X		X		X
SLOPE AND/OR FOUNDATION INSTABILITY	Landslides and Mudflows	X	X			X	X	X
	Unstable Cut and Fill Slopes		X	X		X		
	Collapsible and Expansive Soil		X	X		X		
	Trench-Wall Stability		X	X		X		
EROSION. SEDIMENTATION AND FLOODING	Erosion of Graded Areas and Sedimentation	X		X		X		
	Alteration of Existing Runoff	X		X		X		
	Increased Impervious Surfaces		X			X		
	Unprotected Drainage Ways		X			X		
	FEMA Flood Zones	X	X			X	X	
LAND SUBSIDENCE	Extraction of Groundwater, Gas, Oil, or Geothermal Energy	X				NA		
	Hydro-compaction or Peat Oxidation	X				X		
	Fault Rupture	X				X		
LOSS OF MINERAL RESOURCES	Loss of Access	X				NA		
	Deposits Covered by Changed Land Use	X				NA		
	Zoning Restrictions	X				NA		

1. Table modified after 1986 CDMG Note 46 (currently under revision by CGS) and supplemented from CDMG Note 52 (2001) based on problems and issues potentially applicable to the study area. "Waste Disposal Problems" and "Water and Soil Pollution Problems" from the source tables would be addressed in Hazards and Hazardous Materials technical background report and CEQA section. 2. The "X" marks in two or more of the degree-of-hazard cells indicates the expected range of conditions across the Project Area. 3. Special work can include additional investigation, special site preparation, and/or special foundations.

2.3.1 Seismic Hazards

<u>Ground Shaking</u>

The faults listed on Table G-3 that are nearest to the City should have the most adverse ground shaking effects for the estimated maximum earthquakes. Table G-7 presents a deterministic analysis of the potential earthquake ground shaking effects from the maximum magnitude earthquakes for those faults from Table G-3 that would produce Modified Mercalli Intensities of VI to IX, which ranges from light to heavy damage to ordinary substantial structures (explained in Table G-4). These generally correspond to peak horizontal ground acceleration levels of greater than 10 percent gravity (0.1g).

Table G-7 - Deterministic Earthquake Ground Shaking Parameters for Potentially Critical Earthquake Faults within Approximately 100-Kilometers of the Project Area [1]—Minimum MMI of VI [2]

Fault Name	Distance Miles (Kilometers)	Maximum Magnitude	Peak Horizontal Ground Acceleration	Estimated Modified Mercalli Intensity [3]
Rose Canyon	0.76 (1.2)	6.7-6.9	0.37-0.56	VIII
Coronado Bank	11.9 (19.1)	7.3-7.4	0.21-0.33	VII
Newport-Inglewood (Offshore)	30.9 (49.8)	6.8-7.0	0.11-0.18	VI
Elsinore (Julian)	41.9 (67.4)	7.3-7.4	0.10-0.17	VI
Elsinore (Temecula)	42.4 (68.2)	6.9-7.1	0.09-0.15	VI
Earthquake Valley	46.6 (75.0)	6.6	0.07-0.11	VI
Elsinore (Coyote Mountain)	52.7 (84.9)	6.7-6.9	0.07-0.11	VI
Palos Verdes	55.2 (88.8)	7.2-7.3	0.08-0.13	VI
San Jacinto (Coyote Creek)	62.7 (101.0)	6.8-7.0	0.06-0.10	VI
San Joaquin Hills	64.5 (103.8)	6.9-7.1	0.07-0.12	VI
San Jacinto (Anza)	64.9 (104.4)	7.2-7.3	0.07-0.11	VI
San Jacinto (Clark)	64.9 (104.5)	6.9-7.1	0.06-0.10	VI

1. USGS, 2008 and 2011a. Latitude 32.74982 ^{o} north, and longitude -117.20602^{o} west. 2. Faults (Risk Engineering, 2011; Blake, 2011) were selected if they may cause a Modified Mercalli Intensity (MMI) level of VI or greater. 3. MMI estimated using Bolt, B. A., 1993; Table G-3. 4. These values are suitable for general planning purposes, but should not be used for site-specific design. Ground motions determined for a specific project will vary based on numerous factors, including earthquake location relative to the project location, distance from the causative fault, directivity of energy release, local geologic conditions, and other technical factors.

No instrumentally recorded earthquake of greater than M6.0 has occurred within 50 miles the Project Area; the 1968 Borrego Mountain earthquake on the San Jacinto-Coyote Mountain fault near Ocotillo Wells was about 69 miles away. It is estimated that this earthquake caused an MMI shaking intensity effect of IV classified as minor shaking and no damage to structures. General background seismicity (Figure G-2; SCEC, 2011) is considered low in this portion of San Diego County with earthquake activity of greater than M3.25 concentrated on faults to the east (Elsinore and San Jacinto fault zones), to the south (Baja and unmapped offshore faults), and offshore to the west (Coronado Bank and San Diego Trough fault zones)

The highest peak ground accelerations and MMI intensities would be produced by the Rose Canyon, Newport-Inglewood (Offshore), Elsinore (Julian and Temecula segments), and Coronado Bank faults with anticipated peak ground accelerations of 0.14g to 0.22g, and MMI intensities of VII to IX. For critical facilities it may be necessary to consider the larger Maximum Considered Earthquake (MCE; based on the 2% in 50 years PGA) and to analyze the San Andreas fault zone (the southern section). Maximum magnitude updates are available from California Geological Survey (e.g., Wills and others, 2008) and USGS (e.g., 2011a and Petersen and others, 2008).

As previously mentioned the Oceanside blind thrust fault is not well studied or understood, therefore is not part of the formal database used to formulate Tables G-2 and G-7. Based on the data available and making the conservative assumption that a magnitude 6.5 to 7 (M6.5-7) earthquake could occur beneath the general region of the City, it is possible that peak horizontal ground acceleration (PGA) and MMI intensities could exceed those shown for the faults in Table G-7.

Seismic/earthquake shaking risk/hazard estimates can be developed using either a deterministic or a probabilistic analysis. Deterministic analyses can be considered “conservative” or “worst-case”, i.e. an earthquake event of a specified magnitude (associated with an estimated return period) is assumed to occur on a given fault(s) at the location along the fault(s) that causes the highest ground shaking at a site (Table G-7 below). A probabilistic analysis considers the full range of possible earthquakes, their location and frequency of occurrence, size, and the propagation of the earthquake motion from the rupture zone to the site, thereby providing a more "realistic" evaluation. Two commonly used frequencies of occurrence for a probabilistic analysis are 10 percent chance of being exceeded in 50 years and a 2 percent in 50 years, corresponding to earthquake return periods of 475 years and 2,475 years, respectively.

Considering the entire Project Area, a planning level 10% in 50 years estimate of the peak ground accelerations and of the spectral accelerations for 0.2-second and 1.0-second frequencies (short and moderately long periods, respectively) for the central portion of the Project Area are provided (Table G-8). The values for 10% probability of being exceeded in 50 years were developed using the California Geological Survey estimation procedures for a "design basis earthquake" and should only be used as planning estimates, not for design. The 2010 CBC uses a 2% probability in 50 years in seismic design and the USGS has prepared corresponding National Seismic Hazards Maps updated in 2008 (Figure G-5); these maps indicate 0.50g to 0.60g peak ground acceleration or about 1.5 times the 10% in 50 years PGA values for alluvium shown in Table G-8.

Table G-8 - Estimated Probabilistic Earthquake Ground Acceleration Parameters in the Project Area (CGS, 2011)[1]

Ground Motion	Firm Rock	Soft Rock	Alluvium[4]
Central Midway Subarea[2]			
Peak Ground Acceleration (PGA; in "g" force of gravity)	**0.28**	**0.30**	**0.34**
Spectral Acceleration[3] (0.2 sec)	**0.66**	**0.71**	**0.81**
Spectral Acceleration (1.0 sec)	**0.25**	**0.31**	**0.39**

1. California Geological Survey, 2011. 2. Latitude 32.74982, Longitude -117.20602; near the Intersection of Midway Drive and Rosecrans Street. 3. Sa = Spectral Acceleration; 0.2 second generally represents the natural period for short (1- to 3-story) buildings, and 1.0 second for tall buildings (generally ~10 stories). Bridges are generally within the range of 0.3 to 1.2 seconds. 4. Shading denotes the predominant earth material throughout the Project Area.

Local soil conditions (as characterized by shear wave velocity in the upper 30 meters—V_{S30}) have a strong influence on ground shaking during an earthquake due to amplification affects. The National Earthquake Hazards Reduction Program (NEHRP—USGS, 2011b) classifies geologic and soil deposits, based on V_{S30}, into Site Classes A through F from higher to lower velocities. Table G-8 has three columns, each provide estimates for different geologic conditions based on the California Geological Survey website (CGS, 2011). Each ground motion value is shown for the three possible site conditions that are found in the 2010 California Building Code: firm rock (conditions on the boundary between building code categories B and C), soft rock (category C), and alluvium (category D).

The vast majority of the Project Area is artificial fill underlain by young wash, alluvial fan, and estuarine deposits (Figure G-1) that likely have a V_{S30} equivalent to Site Class D, E, or possibly F. The remaining older alluvial (Qop_6 and $Qvop_{11}$) and soft bedrock formations likely fall into Site Class B or C. If the majority of the Project Area is assumed to have the Site D, the modified geometric mean 2% in 50 years PGA is approximately 0.58g using the USGS (2011b) web-based ground motion calculator and the 10% in 50 years is estimated to be 0.39g. These estimates of ground motion are approximate and differ somewhat from the CGS values above. None of these estimates consider structure type, spectral response accelerations (short versus long period), or near-source factors that may be applicable.

The specifics of the seismic design method are explained in the 2010 CBC. The upcoming 2010 American Society of Civil Engineers (ASCE) Standard 7 and the 2009 National Earthquake Hazards Reduction Program (NEHRP--USGS) recommended seismic provisions (not current code) for design of structures to be based on the 2% in 50 years PGA, which is defined for the MCE with the 2,475 year statistical return period.

Surface Fault Rupture and Tectonic Warping

Fault rupture and surface fold scarps that pass through or very near a structure would very likely cause irreparable damage and may cause collapse of walls and ceilings. Normal foundations would be dislocated and rendered unusable. Combined with strong ground shaking, these are potentially very serious hazards. Utilities could be severed causing water, natural gas, electrical, storm drain, and sewer system outages. Streets could be passable with some difficulty if fault motion is strike-slip (horizontal). Vertical fault offsets could render streets impassable for emergency traffic. The potential for such damage within the eastern portion of the Project Area, the Old Town CPA and Midway subarea, is considered sufficiently probable that investigations and possibly mitigation measures are required.

There is an Alquist-Priolo Earthquake Fault Zone (APEFZ) within the City along portions of the Rose Canyon fault zone (RCFZ); however the APEFZ boundaries do not extend into the Project Area. Three separate RCFZ fault strands are mapped cross the Old Town CPA by Kennedy and Tan (2008). The City Safety Element (2008, hazard classification 12) and County SanGIS (2011) show three fault strands with different locations than Figure G-1 (see Figure G-4; neither source shows the western strand of Kennedy and Tan) and notes the strands can be classified as potentially active. Figure PF-9 in the City Safety Element (2008) shows an extension of the Spanish Bight fault extending into the Project area at the intersection of Pacific Highway and Barnett Avenue. The City considers the RCFZ strands to be active, to have the potential for surface fault rupture, and surface fault rupture investigations may be required for certain projects or subdivision maps in geologic hazard category 12 (Figure G-4). The potentially active Point Loma fault zone is outside the Project Area to the west, with a short potentially active segment projecting toward the northwester most portion of the Midway CPA (Kennedy and Tan, 2008; Figure G-1).

The Oceanside blind thrust (OBT) fault may underlie the City and surrounding communities; the location and characteristics of this fault are much less well known than for surface faults. If movement were to occur on a buried blind thrust fault, the most likely result would be regional uplift. Some local differential uplift and ground tilting may be possible. The OBT subsurface characteristics are not as well studied as other blind thrusts beneath Los Angeles and Orange counties, which appear to have higher slip rates (Wills and others, 2008), therefore without additional characterization in the San Diego area comparisons with the OBT are speculative. It is concluded that little or no consideration of the OBT has been made with regard to co-seismic deformation. Due to the uncertainties associated with the OBT location and depth, and the low likelihood of a large magnitude earthquake, future consideration of the OBT should be weighed against the risks posed to future development.

The most reasonable surface fault rupture mitigation method is to avoid placing any structures on, or too close to, active fault traces by establishing a setback distance between the fault and the proposed structure. While not a City-designated setback, Figure G-4 shows 100-feet wide zones around the RCFZ segments in the Old Town CPA and the southern portion of the Midway subarea. A geologic investigation, usually including literature and aerial photo review, field mapping and possibly geophysics and/or trench excavations, and alluvial deposit age dating, is required if structures designed for human occupancy are proposed within proximity to an active or potentially active fault. The State CGS has developed general guidelines for fault hazard evaluations that are contained in CGS Note 49 (2002). Essential facilities, public schools, hospitals, and other facilities deemed critical or important are judged to higher standards than residential developments (see CGS Note 48).

In addition to avoidance, research conducted over the past decade or so has demonstrated that it is possible to develop reasonable design mitigation measures to accommodate some level of fault related deformation without compromising the functionality of the structures. This necessitates determining in some detail the consequences of movement on distinct faults and distributed shearing due to bedrock or alluvial deposit warping associated with faulting (e.g., co-seismic uplift, and surface tilting or folding). Design measures involving specially constructed artificial fill using geogrids and geotextiles, and heavily reinforced foundations and slabs can be developed to accommodate some fault related deformation. Design determinations rely mainly on geologic and geotechnical field data, observations of the performance of similar structures, and some level of numerical modeling.

Earthquake-Induced Landslides
The California Seismic Hazard Mapping Program (SHMP) delineates the approximate boundaries of areas susceptible to earthquake-induced landslides and other slope failures (e.g., rockfalls). Most typically these are in hillside areas with steep slopes, and in bedrock formations with clay layers and out-of-slope bedding plane dip angles. The SHMP mapping has not been completed for all areas of the state and no maps have been prepared for the City of San Diego. However, areas with known landslides, and bedrock formations more susceptible to landslides and surficial (soil-slip) failures (see Figures G-3 and G-4) are the most susceptible to earthquake-induced landslides. Such slope movement often occurs under static conditions with substantial rainfall. Structures, engineered slopes, roadways, utilities, and the general population located on or below these hazard areas could be subject to severe damage or injury.

Figure G-1 shows one landslide deposit (Qls) likely within the Mission Valley Formation (Tmv) at the north edge of the Old Town CPA. Figure G-3 shows the very limited areas (less than one percent) designated by the USGS (Morton and others, 2003) within the Project Area as having moderate susceptibility to soil slippage such as surficial landslides or debris flows. Other bedrock formations (Figure G-4) in the Old Town CPA (approximately 56%) show some low angle out-of-slope bedding dip components with low to moderate risk and depending upon the particular slope and bedrock composition could generate a slope failure.

In hillside terrain an appropriate engineering geology and geotechnical investigation (performed by properly licensed professionals), including field data collection, laboratory testing, and slope stability analysis, should be conducted considering both static and dynamic (earthquake) forces. Development projects within a zone susceptible to earthquake-induced landslides must be evaluated using California Geological Survey guidelines that describe study methods and mitigation options. Mitigation options include, but are not limited to, building setbacks, landslide debris removal/replacement, slope angle reduction, earth or engineered buttresses, protective barriers, retaining/slough walls, debris fences, and run-out/catchment areas.

Liquefaction and Lateral Spreads
Liquefaction-induced ground failure can involve a complex interaction among seismic, geologic, soil, topographic, and groundwater factors. Failures can include ground fissures, sand boils, ground settlement, and loss of bearing strength, buoyancy effects, ground oscillation, flow failure, and complex lateral spread landslides (Bartlett and Youd, 1992). These, in turn, can have affects on surface and subsurface structures. Lateral spread is a liquefaction-induced landslide of a fairly coherent block of soil and sediment deposits that moves laterally (along the liquefied zone) by gravitational force, sometimes on the order of 10 feet, often toward a topographic low such as a depression or a valley area. The three key factors that indicate whether an area is potentially susceptible to liquefaction are the capacity for severe ground shaking, shallow groundwater, and low-density granular deposits (mainly finer grained sands). In these areas, where alluvium is sufficiently loose and groundwater is sufficiently shallow that strong earthquake shaking could cause sediments to loose bearing capacity, severe settlement of surface facilities and in some cases uplift of buried structures (e.g., large pipelines) could occur.

The 2008 City of San Diego Safety Element (see Figure G-4) delineates geologic units within the Project Area that are deemed susceptible to liquefaction (hazard class 31 and to a lesser extent hazard class 32); the high liquefaction hazard boundaries correspond to areas of artificial fill and alluvium beneath much (approximately 75%) of the Midway subarea, the west portion (39%) of the Old Town CPA, and the southern edge (about 10%) of the Pacific Highway subarea. The bedrock and older alluvium areas are not considered susceptible to liquefaction.

Liquefaction areas have potential land use constraints and liquefaction assessments must be made for important projects. The depth and intensity of study will naturally vary depending on the location, type, and importance of the project. Potential liquefaction induced lateral spread landslides are more of a concern in the areas adjacent to the San Diego River on the north and the channel extending north from San Diego Bay toward Lytton Street and Barnett Avenue. This is because liquefaction-induced lateral spread failures are more prevalent adjacent to topographic depressions or valley areas that form unsupported slopes or "free faces." Such failures have occurred in areas with very low topographic slope gradients. For example, the lateral spread landslide (approximately 1100 feet wide and 3000 feet long) at Juvenile Hall and the Sylmar Converter Station in Sylmar (1971 San Fernando earthquake) had an average ground surface gradient of 1.5 degrees and a maximum of 3 degrees (O'Rourke, Roth and Hamada, 1992a). Lateral spreads in the San Francisco earthquake of 1906 occurred associated with surface gradients of 0.4 to 2.10 percent, or about 0.2 to 1 degree (O'Rourke, Beaujon, and Scawthorn, 1992b). In the latter case, the slope of the liquefied subsurface layer may have been as low as zero degrees. Of primary concern in the Project Area is the interface between the artificial fill (likely placed hydraulically) and underlying young alluvium, which should slope to the north and northwest toward the San Diego River, and to the south and southwest toward the afore-mentioned channel.

The Seismic Hazards Mapping Program (CGS, 2008) and other publications (e.g., Idriss and Boulanger, 2008) provide guidelines and implementation procedures for the evaluation and mitigation of liquefaction conditions within a liquefaction hazard zone. These guidelines and procedures require registered professionals (California Registered Civil Engineer or Certified Engineering Geologist) to conduct the evaluations, establish the site-specific mitigation, and participate in the implementation process. The evaluation determines the controlling earthquake parameters, the liquefaction depth, the thickness, and lateral extent of the liquefiable layer affecting the proposed development, and the type and estimated amount of vertical and horizontal ground deformation. In addition, quantitative estimates of liquefaction potential require specific data from geotechnical borings and/or cone penetration tests (preferred), laboratory testing, and groundwater level measurements.

Ground improvement (densification and hardening) and structural (foundation) design are the two basic classes of liquefaction mitigation. Ground densification methods include vibro-compaction, vibro-replacement (also known as vibro-stone columns), deep dynamic compaction, and compaction (pressure) grouting. Hardening methods reduce the void space in the liquefiable soil by introducing grout materials either through permeation grouting, mechanical soil mixing, or jet grouting. Structural mitigation may have little or no effect on strengthening the soil itself. For heavy structures, the preferred mitigation is deep caissons or pile foundations to penetrate through the liquefiable material, or a mat foundation may be feasible. For lighter structures continuous spread footings having isolated footings interconnected with grade beams, mat foundations, and post-tensioned slabs may be appropriate. Dewatering and drainage systems may be part of the mitigation process. Lateral spread hazards are not as readily mitigated with structural solutions and may require use of retaining structures, removal or treatment of liquefiable soils, modification of site geometry, or drainage to lower the groundwater levels. Whether a single type of mitigation technique or a combination of techniques is needed will depend on size and scope of the project, and the site-specific geotechnical conditions.

Dynamic Consolidation and Seismic Settlement

Dry to partially saturated sediments not susceptible to liquefaction may be susceptible to dynamic consolidation and local ground subsidence. This consolidation or densification occurs in loose cohesionless sediments as the void spaces are diminished due to intense seismic shaking. Hazard maps are not normally created for this condition, and there are no specific data in the City/Project Area that allow prediction of the locations or magnitudes of potential consolidation and subsidence. Post-earthquake observations reported in the other areas of southern California suggest that earthquake-induced consolidation, ground subsidence, and building settlement may reach a meter (3+ feet) or more; however, settlements of 5 to 30 centimeters (2 to 12 inches) are rather common. The resultant ground failures are manifest as ground cracks with relative vertical displacements as indicated above. When structures overlie these local subsidence areas, ground cracking may be translated through foundations and slabs causing severe structural damage.

In the Project Area, areas of artificial fill and the underlying young alluvium (Figure G-1 and Table G-2) would be the most susceptible to dynamic consolidation effects. Older alluvium (Qop_6 and $Qvop_{11}$) and soft bedrock formations could be somewhat susceptible, but much less so due to the higher in-place density and presence of some cementation. In areas where artificial fill may have been placed without proper engineering controls and inspections (e.g., hydraulic fills), the materials may be susceptible to dynamic consolidation and subsidence. This may be a concern in areas where thick artificial fill masses have been placed against much denser old alluvium or bedrock materials associated with any number of residential and some commercial developments within the Project Area.

Earthquake-induced consolidation and structure settlements are normally less severe than liquefaction ground deformations; however the previously described mitigation measures for liquefaction could apply. Based on a thorough geotechnical investigation by licensed professionals, recommendations are provided, with the most common being over-excavation of the loose soils and replacement by compacted soils meeting standard geotechnical specifications. The depth of over-excavation will depend on the nature and thickness of the loose soils, but critical areas are the contacts between formations of varying density where differential settlement is most common. For example, where alluvium and bedrock, or artificial fill and any denser geologic formation are in contact over-excavation/recompaction along the contact is used to provide a uniform surface for recompacted soils or foundations. On fill slopes, the use of geogrid in the outer portions of the slopes and a greater fill placement density criterion should diminish the potential for slope face deformation and surface settlement.

2.3.2 Geologic and Soil Hazards

The nature of the topography and the geologic formations in the Project Area suggest that geologic and soil (non-seismic) hazards should have a relatively manageable set of impacts on development and redevelopment considering that building code regulations require complete geotechnical and engineering geology studies in the areas of less competent artificial fill, alluvium and weak bedrock, and in the minor hillside areas (Figures G-1, G-3, and G-4; Table G-2). The potential for weak bedrock landslides and surficial deposit slope failures does exist at the margins of, and immediately adjacent to, the Project Area but are not widespread significant factors. Geotechnical issues related to weak soils and unstable slopes are present, but are manageable within current regulations. Shallow subsurface water can impact shallow and deep excavations. Large-scale subsidence due to fluid withdrawal (water or oil) is not an issue since the Project Area does not overlie an actively pumped groundwater aquifer or an oil field. Dam failure inundation/flooding potential exist in very local areas where precautions for certain facilities should be taken. Radon likely has a very low hazard potential and is manageable under current regulations. There is no local threat of volcanic hazard.

<u>Slope Instability: Landslides, Mudslides, Debris Flows, and Cut/Fill Slopes</u>
Slope instability under non-earthquake (static) conditions is considered to be a potentially significant hazard in the hillside and artificial cut/fill slope areas of the Project Area. Landslides, debris flows, and soil-slips/surficial material failures affect both the area where the material originates and the down slope “run-out” areas where the landslide debris accumulates. Damage to structures can be severe in either location with structures being dislocated a few to many tens of feet. Figure G-1 (Kennedy and Tan, 2008) shows one landslide deposit (Qls) assumed to be within the Mission Valley Formation (Tmv) where bedrock is overlain by the old paralic deposits (Qop_6) in the northernmost portion of the Old Town CPA. Figure G-3 shows very minor areas designated by the USGS (Morton and others, 2003) as having susceptibility to soil-slips or surficial landslides or debris flows.

Mission Valley Formation (Tmv; Figure G-1) landslides may be bedding plane controlled or may break through the weaker units within the formation. Further landslides in the east one-half of the Old Town CPA may be possible; this area is in hazard class 53, which is level or sloping terrain with unfavorable geologic structure (i.e., out-of-slope bedding planes; City of San Diego, 2008). There appear to be limited slopes underlain by Tmv, but other west-facing slopes in small portions of the Old Town CPA and along the east edge (just outside) of the Pacific Highway subarea are underlain by very old paralic deposits ($Qvop_{11}$) and San Diego Formation (Tsd) deposits with out-of-slope bedding attitudes. Where there is no clear relationship to mapped bedding plane attitudes, failures may occur on over-steepended slopes and trench excavations if materials are sufficiently weak and saturated.

In moderately sloping and steep hillside terrain an appropriate engineering geology and geotechnical investigation (performed by properly licensed professionals), including field data collection, laboratory testing, and slope stability analysis, should be conducted considering both static and dynamic (earthquake) forces. Mitigation options include, but are not limited to, building setbacks, removing vulnerable deposits (e.g., soil, colluvium, fractured/weather bedrock) and replacement with compacted fill, slope angle reduction, engineered earth or other buttresses, protective barriers (e.g., impact diversion or deflection structures—channels or walls), retaining/slough walls, debris fences, avoidance (i.e., placing structures outside the path of potential slides and associated run-out/catchment areas).

Geotechnical Material Foundation Hazards: Collapsible, Expansive, and Unstable Soils

Collapsible and expansive soil issues are recognized in standard geotechnical investigations mandated by the City and other regulatory bodies. Collapsible soils undergo a volume reduction when the pore spaces become saturated causing loss of grain-to-grain contact and possibly dissolution of interstitial cement holding the grains apart. The weight of overlying structures can cause uniform or differential settlement, and consequently damage to foundations and walls. Expansive soils are found associated with soils, alluvium, and bedrock formations that contain clay minerals susceptible to expansion under wetting conditions and contraction under drying conditions. Depending upon the type and amount of clay present in a geologic deposit, these volume changes (shrink and swell) can cause severe damage to slabs, foundations, and concrete flatwork.

Due to the generally finer-grained nature of the artificial fill and paralic deposits (af, Qop_6, and $Qvop_{11}$), these deposits may be more likely to have expansive clays. These deposits are also more susceptible to consolidation resulting in structure settlement. The most likely locations for collapsible soils are within the extensive artificial fill materials shown on Figure G-1.

Expansive, collapsible, and settlement-prone soil damage can be mitigated by delineation of the soils during a geotechnical investigation, over-excavation of the subject soils and recompaction of new engineered fill material, possibly pre-saturating the subject soils (if expansive), and providing for proper surface drainage away from structures and building foundations.

Erosion and Sedimentation

Severe erosion can cause extensive gully formation and destabilize otherwise stable geologic units. Transported materials can accumulate to cause issues in the down gradient areas. The properties of soil influencing erosion by rainfall and runoff are the infiltration capacity of a soil and the resistance of the soil particles to detachment and transport by falling or flowing water. Soils with high infiltration rates and high permeability reduce the amount of runoff. Low density soils containing high percentages of fine sands and silt are generally the most erodible. The less erodible soil types and properties (see Table G-2) generally coincide with bedrock and older alluvial units; however these units are in the areas of steeper topography that increases erosion susceptibility.

Due to the nature of the existing widespread development in the Project Area and the likely types of future development that could occur, substantial soil erosion or the loss of topsoil is not expected. The low topographic gradients, and the physical characteristics and surficial unit properties for the artificial fill (af) and older alluvial formations (Qop_6 and $Qvop_{11}$) would result in minimal erosion potential in the Midway subarea and the western portion of the Old Town CPA. The eastern portion of the Old Town CPA and the Pacific Highway subarea have steeper topography, and would therefore be more susceptible to severe erosion. Severe erosion can be minimized or prevented by implementation of standard investigation, analysis, design, and construction techniques, which are required by existing City building codes and regulations.

Shallow Groundwater
Data on shallow groundwater is discussed in an earlier section and reviewed in the liquefaction discussion. The concern is the potential to intercept shallow groundwater in subsurface excavations, such a basements, subterranean parking, utility trenches, deep foundations, or tunnels. No existing database is known to delineate current or historic shallow groundwater depths within the Project Area. Examination of data from geotechnical bore holes within the Project Area would likely show the extensive artificial fill areas (and underlying alluvial deposits; Figure G-1) and older alluvium have unconfined groundwater at depths ranging from 10 to 20 feet. In such areas, planning for each project should consider shallow water levels in determining how to best implement construction or exploration programs.

Surface excavations (open cuts and pits) or underground openings (tunnels, vertical large-diameter borings) can encounter inflows of shallow groundwater potentially affecting excavation stability, and therefore short- and long-term safety for workers, as well as post-construction stability of structures associated with these excavation areas. The degree of hazard for the Project Area is generally moderate and should be determined on a case-by-case basis if projects requiring moderate to deep excavations are proposed in the artificial fill and alluvial deposits. Geotechnical investigation requirements will mandate that projects proposing such excavations would be very carefully studied in areas with shallow groundwater. Dewatering may be a necessary mitigation measure for deeper excavations (e.g., subterranean basements or garages).

Radon
If discovered in bedrock formations, radon reduction techniques can include methods to prevent radon from entering a structure and reducing radon levels after it has entered. Various soil suction methods prevent radon from entering a structure by removing radon from beneath the structure and venting it to the open air. The type of structure (e.g., slab-on-grade, raised floor, basement) will affect the choice of a radon reduction system. Typical radon reduction methods include subslab suction, drain tile suction, sump hole suction, block wall suction, submembrane suction, active crawlspace depressurization, passive crawlspace ventilation, sealing, house/room pressurization, heat recovery ventilation, and natural ventilation (USEPA, 2011).

2.3.3 Flood Hazards

FEMA Floodways and Floodplains
As described above, the Project Area is outside 100-year flood hazard zones as mapped on a FEMA Federal Insurance Rate Maps (FIRMs); these zones would be the most susceptible to damage from rapidly flowing water, severe erosion, and floating debris. The Project Area would only be impacted by 500-year floods with failure of the levee along the San Diego River floodplain, which is subject to flooding during very heavy rainfall (Figure G-3). Culverts, surface swales, and man-made barriers could locally deflect flow in ways not obvious without more investigation and analysis. Primary flood mitigation is to create building spaces at least one-foot above estimated flood levels and to provide erosion protection for these areas.

Dam Failure Inundation/Flooding
The past dam failures (Baldwin Hills and St. Francis) and near-failures (Van Norman) of southern California dams point out the importance of considering dam safety related to flooding. Dams may fail for seismic or geologic reasons, either of which could lead to the results described in this section. Section 8589.5 of the California Government Code requires dam owners to provide the Governor's Office of Emergency Services with an inundation map showing the extent of damage to life and property that would occur, given a complete and sudden dam failure at full capacity. San Vicente and El Capitan dams lie approximately 22 miles and 26 miles upstream from the Project Area, respectively. Inundation hazards can range from high to low with greater distances away from these reservoirs; these substantial distances from the Project Area suggest the most likely effects would be from moderate velocity flow, rising water, and accumulation of

debris. Man-made barriers, such as cross-cutting roadways and closely-spaced buildings, would locally deflect flow in ways not obvious without site-specific investigation and analysis. Smaller reservoirs, holding ponds, and water tanks may be up stream from buildings and populations within the Project Area and do not have inundation maps prepared, therefore potential flooding impacts are not documented.

San Vicente, El Capitan, and Murray dams are regulated and monitored for structural safety by the California Department of Water Resources Division of Safety of Dams in accordance with Division 3 of the California State Water Code. This is due to the dam height being greater than 25 feet or the storage capacity greater than 50 acre-feet. Modern water tanks are designed to high standards to prevent failure during severe earthquakes. For severe flooding to result from failure of a dam or water tank, the earthquake and the high water levels would have to occur simultaneously, which makes the chances more remote. The most effective mitigation of future flooding would entail evaluating the structural integrity of these dams (e.g., with the raising of the San Vicente dam) and water tanks, and performing upgrades as needed to provide an added safety margin for all but the most severe earthquake events. In addition, an analysis of flooding potential at each proposed Project Area facility could be performed and evacuation procedures could be developed for those facilities where flooding threatens property and populations.

<u>Tsunamis and Seiches</u>
A tsunami is a long wavelength ocean wave generated by sudden displacement of the seafloor normally by earthquake faulting, volcanism, or a large submarine landslide. Initially the tsunami creates a drop in water level at the shoreline, followed by a rapid rise with attendant run up on the shore, surges into and out of shallow coastal inlets and harbors, and substantial rising of the water in deeper water ports and harbor areas. A seiche is a seismically induced water wave that "sloshes" back and forth in water tanks and enclosed basins such as harbors. This phenomenon also results from an earthquake. For the Project Area, tsunami damage is by far the more serious with potential damages caused in water surging in and out, and debris colliding with fixed structures.

Based on the studies cited above, the likelihood of a tsunami encroaching into the Project Area appears low. Under extreme conditions of a magnitude 9.4 earthquake on the Alaska-Aleutians Subduction Zone coincident with either mean high water (4.8 feet) or the highest observed tide (7.9 feet), tsunami runup could reach the 10 to 15 feet elevation range (a very unlikely and low probability combination of events) affecting a large portion of the Project Area. Regarding mitigation for such low likelihood events, additional analysis of tsunami flood potential could be performed and evacuation procedures could be developed for those facilities where tsunami flooding would threaten property and populations.

2.3.4 Hazard Reduction

Seismic, geologic, and flood hazard reduction will mainly be attained through the proper implementation of existing building codes and regulations related to natural hazards (e.g., 2010 California Building Code, 2008 City Public Facilities Element, and the 2010 County Multi-jurisdiction Hazard Mitigation Plan). Certain of the natural hazards that have previously been either unrecognized or not risen to prominence (e.g., liquefaction and lateral spread landslides) could be subject to special zoning and land use policies. Potentially hazardous buildings can be identified and depending upon their quality and use (e.g., community center, fire station, or senior center), may be suitable for retrofit.

<u>Building Codes</u>
Adoption of the most rigorous building codes governing seismic safety and structural design will be the most effective means to mitigate future earthquake damage from strong ground shaking. The most recent 2010 California Building Code incorporates lessons from the most severe earthquakes to hit California in the past 24 years, in particular San Fernando-Sylmar (1971), Loma Prieta (1989), and Northridge (1994) and has been adopted by the City of San Diego. Continued use of the 2010 State Historic Building Code for historic structure seismic retrofit, and the CBC for retrofit of other potentially hazardous structures will continue the trend of reduction in the loss of life in future earthquakes. In addition, as population pressures lead to

increased development in more hazard prone areas of the Project Area and as the existing building inventory ages, the active implementation of these codes will reduce the earthquake hazard risk within the Project Area.

Special Hazard Zones

The State (California Geological Survey--CGS) creates maps for the use of cities and other jurisdictions that define hazardous areas for "active" faults, liquefaction, and earthquake-induced landslides. In addition, the CGS and the USGS create maps that define the potential levels of seismic ground shaking that can be expected. Together these represent "special hazard zones" that have regulatory meaning and may require certain studies and precautions before development can be approved. Presently no CGS seismic hazard maps for liquefaction and earthquake-induced landslides have been prepared for the City of San Diego including the Project Area. If such maps are prepared in the future, landslide and liquefaction-prone areas currently delineated on City of San Diego maps (Figure G-4) may be revised and updated if necessary to accommodate changes and additions based on more recent information. It is suggested that the City continue to update all of its geologic and geotechnical hazard maps to assure a comprehensive understanding of the nature of these hazards within the Project Area, with the goal of determining whether future developments may have additional avoidance, hazard delineation, or special zoning needs.

Building Retrofit

The City should consider, or consider further, implementation of a program within the Project Area to identify potentially hazardous buildings (generally pre-1971 in age) not yet seismically retrofitted, and to identify potential funding sources to rehabilitate and strengthen these structures as redevelopment, infill, and new development proceed. Upgrades should be made that will ensure the survivability and function of these facilities in design level earthquake events.

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APPENDIX A
PLANNING AND REGULATORY SETTING

SEISMIC, GEOLOGIC AND FLOOD HAZARD REGULATORY SETTING

For planning purposes, geologic, soils, and seismic hazards play an important role in the selection of development locations, of the process necessary to develop a safe project, and of the studies necessary to design a project to avoid or withstand natural hazards. The General Plan Safety Element provides guidance to accomplish these steps and information useful to begin the development planning process. Geologic and soils hazards potentially affecting the City of San Diego include slope instability, severe erosion, and geotechnical constraints such as expansive, corrosive, organic-rich and collapsible-compressible soils, as well as seismic events (earthquakes). Seismic hazards result from the primary action of an earthquake (e.g., strong ground shaking and surface fault rupture) and from the secondary effects of the earthquake shaking (e.g., liquefaction, induced settlement, landslides, ground fissures, dam failure inundation, tsunami, and seiche).

Regulations, codes, and laws ensure that proper precautions are taken in advance of development to prevent unreasonable levels of damage, injuries, or fatalities. The primary applicable regulatory measures are:

--1970 California Environmental Quality Act
--1972 Alquist-Priolo Special Studies Zones Act 1971
--1986 Unreinforced Masonry Law
--1990 Seismic Hazards Mapping Act
--1999 Natural Hazards Disclosure Act
--2001 State Historical Building Code, and
--2010 California Building Code adopted as San Diego Municipal Code Section 145.0103.

Federal

Federal Disaster Mitigation Act of 2000

The Disaster Mitigation Act of 2000 (Public Law 106-390) provides the legal basis for FEMA mitigation planning requirements for State, local and Indian Tribal governments as a condition of mitigation grant assistance. The act provided a new set of mitigation plan requirements that emphasize State and local jurisdictions to coordinate disaster mitigation planning and implementation. States are encouraged to complete a "Standard" or an "Enhanced" Natural Mitigation Plan. "Enhanced" plans demonstrate increased coordination of mitigation activities at the State level, and if completed and approved, will increase the amount of funding through the Hazard Mitigation Grant Program. California's updated State Hazard Mitigation Plan (SHMP; California Emergency Management Agency, 2010) was approved by the Federal Emergency Management Agency (FEMA) Region IX on October 6, 2010. As an Enhanced State Mitigation Plan, the SHMP represents California's primary hazard mitigation guidance document and provides an updated and comprehensive description of the state's historical and current hazard analysis, mitigation strategies, goals and objectives. The City of San Diego is one of the communities covered by the 2010 County of San Diego Multi-jurisdictional Hazard Mitigation Plan, which is a countywide plan that identifies risks posed by natural and manmade disasters (County of San Diego, 2010b).

National Flood Insurance Program

FEMA administers the National Flood Insurance Program (NFIP), and participating jurisdictions must exercise land use controls and purchase flood insurance as a prerequisite for receiving funds to purchase or build a structure in a flood hazard area. The NFIP provides federal flood insurance subsidies and federally financed loans for eligible property owners in flood-prone areas. San Diego has participated in the program since 1979 and as of 2011. Some special (100-year) flood hazard areas were identified in the City on the NFIP Flood Insurance Rate Maps, as well as zones such as Zone X, areas subject to minimal flooding, and Zones AE and A, 100-year flood zones with base elevations determined and not determined, respectively.

State

Alquist-Priolo Earthquake Fault Zoning Act

The 1972 Alquist-Priolo Special Studies Zones Act 1971 resulted from the consequences of the Sylmar-San Fernando earthquake and seeks to mitigate the hazard of fault rupture by prohibiting the location of structures for human occupancy across the trace of an active fault. The Act was renamed in 1994 to the Alquist-Priolo Earthquake Fault Zoning (APEFZ) Act. The Sylmar-San Fernando earthquake produced surface fault rupture damage along a zone that might have been identified in advance of the earthquake had the proper studies been mandated.

The best and most feasible surface rupture mitigation is avoidance of the causative fault. Thus, the APEFZ Act mandates that cities and counties (lead agencies) require that within an APEFZ geologic investigations must be performed to demonstrate that potential development sites are not threatened by surface fault displacements from future earthquakes. To aid the various jurisdictions that function as lead agencies for project approvals in California, the California Geological Survey (CGS, formerly the California Division of Mines and Geology-CDMG) must delineate Earthquake Fault Zones on standard U. S. Geological Survey topographic maps (1-inch equals 2000-feet scale) along faults that are "sufficiently active and well defined" as defined in the Act. Quoting from the implementation guide, Special Publication 42 (Hart and Bryant, 1997; a 2007 interim revision has been updated to reflect changes in the index map and the listing of additional effected cities):

> “Zone boundaries on early maps were positioned about 660 feet (200 meters) away from the fault traces to accommodate imprecise locations of the faults and possible existence of active branches. The policy since 1977 is to position the EFZ boundary about 500 feet (150 meters) away from major active faults and about 200 to 300 feet (60 to 90 meters) away from well-defined, minor faults. Exceptions to this policy exist where faults are locally complex or where faults are not vertical.”

Lead agencies are responsible to regulate most development projects within the APEFZ as described in the Act, but may enact more stringent regulations. Certain smaller residential developments can be exempt. While there are APEFZs in the area for the Rose Canyon fault, there is no APEFZ within the Project Area.

Seismic Hazards Mapping Act

The 1990 Seismic Hazards Mapping Act (SHMA) addresses the primary earthquake hazard, strong ground shaking, as well as the secondary hazards of liquefaction, earthquake-induced landslides, and in some areas zones of amplified shaking. As with the APEFZ Act, the California Geological Survey is the primary State agency charged with implementing the SHMA, and CGS provides local jurisdictions with the 1-inch equals 2000-feet scale seismic hazard zone maps that identify areas susceptible to liquefaction, earthquake-induced landslides, and in some areas amplified shaking. Site-specific hazard investigations are required by the SHMA when a development project is located within one of the Seismic Hazard Mapping Zones (SHMZ) defined as a zone of required investigation.

Lead agencies with the authority to approve projects shall ensure that:

> “The geotechnical report shall be prepared by a registered civil engineer or certified engineering geologist, having competence in the field of seismic hazard evaluation and mitigation. The geotechnical report shall contain site-specific evaluations of the seismic hazard affecting the project, and shall identify portions of the project site containing seismic hazards. The report shall also identify any known off-site seismic hazards that could adversely affect the site in the event of an earthquake.”

And:

> “Prior to approving the project, the lead agency shall independently review the geotechnical report to determine the adequacy of the hazard evaluation and proposed mitigation measures and to determine the requirements of

> Section 3724(a), above, are satisfied. Such reviews shall be conducted by a certified engineering geologist or registered civil engineer, having competence in the field of seismic hazard evaluation and mitigation."

CGS Special Publication 117 (CGS, 2008) covers the investigation, analysis, implementation, and review processes for liquefaction and earthquake-induced landslides evaluations and reports as updated effective September 2008 in order to provide detailed guidance for lead agencies to review SHMA reports. The overall goal is to protect the public by minimizing property damage and the loss of life.

The City of San Diego has not been mapped pursuant to the SHMA and therefore the zones of required investigation for liquefaction and earthquake-induced landslide hazards in the City are those defined by the City of San Diego in its Public Facilities, Services and Safety Element (2008).

Natural Hazards Disclosure Act

The Natural Hazards Disclosure Act (effective June 1, 1998 and as amended June 9, 1998), requires:

> "that sellers of real property and their agents provide prospective buyers with a "Natural Hazard Disclosure Statement" when the property being sold lies within one or more state-mapped hazard areas, including a Seismic Hazard Zone."

The SHMA specifies two ways in which this disclosure can be made:

> "c. In all transactions that are subject to Section 1103 of the Civil Code, the disclosure required by subdivision (a) of this section shall be provided by either of the following means:
>
> 1. The Local Option Real Estate Transfer Disclosure Statement as provided in Section 1102.6a of the Civil Code.
> 2. The Natural Hazard Disclosure Statement as provided in Section 1103.2 of the Civil Code."

The Local Option Real Estate Disclosure Statement can be substituted for the Natural Hazards Disclosure Statement if it contains substantially the same information and substantially the same warning as the Natural Hazards Disclosure Statement. Both the APEFZ Act and the SHMA require that real estate agents, or sellers of real estate acting without an agent, disclose to prospective buyers that the property is located in an APEFZ or SHMZ.

California Environmental Quality Act (CEQA)

The 1970 California Environmental Quality Act (CEQA) ensures that local agencies consider and review the environmental impacts of development projects within their jurisdictions. CEQA requires that an environmental document (e.g., Environmental Impact Report [EIR], Mitigated Negative Declaration [MND]) be prepared for projects that are judged in an Initial Study (IS) to have potentially significant effects on the environment. Environmental documents (IS, MND, EIR) must consider, and analyze as deemed appropriate, geologic, soils, and seismic hazards. If impacts are considered potentially significant, recommendations for mitigation measures are made to reduce seismic, geologic, and flood hazards to less than significant. This allows early public review of proposed development projects and provides lead agencies the authority to regulate development projects in the early stages of planning.

Local

Building Code

The San Diego City Council adopted the 2010 California Building Code (municipal code Chapter 14, Article 5, Division 1), based on the International Building Code (IBC) 2010 Edition, Chapters 1 through 35 and Appendices A, C, E, F, G, K-1 through K-10, and K-12--as published by the International Code Council, together with other modifications and amendments provided in municipal code Chapter 14. As of January 1, 2011 all new residential, commercial, and light industrial construction is governed by the IBC, which the City of San Diego has amended and provided additions to. Chapter 14 Article 2, Division 1 (Grading

Regulations) sets forth rules and regulations to control excavation, grading and earthwork construction, including fills and embankments; establishes the administrative procedure for issuance of permits; and provides for approval of plans and inspection of grading construction. Chapter 14 Article 4, Division 2 (Tentative Map Regulations) set for engineering geologic and geotechnical requirements related to the subdivision process.

International and national model code standards adopted into Title 24 apply to all occupancies in California except for modifications adopted by state agencies and local governing bodies. Facilities and structures such as power plants, freeways, emergency management centers (e.g., traffic management, 911 centers), and dams are regulated under criteria developed by various California and Federal agencies.

<u>City of San Diego Geotechnical Report Requirements</u>
City of San Diego Geotechnical Report Requirements (City of San Diego, 2011a) for environmental impact report and environmental planning documents are considered reports for Discretionary Projects. The City guidelines for discretionary project reports indicates "For environmental documents, the scope of the geotechnical investigation must be sufficient to identify existing and potential geologic hazards, determine potential impacts, recommend mitigation measures, and/or identify significant unmitigated geologic impacts. The geotechnical consultant should refer to California Geological Survey Note 46 for a checklist of items that should be addressed." For discretionary projects, the geotechnical consultant should be prepared to defend their findings, conclusions, or recommendations in a public hearing, if necessary.

For non-discretionary projects the City recognizes two basic types of geotechnical studies, preliminary geotechnical reports and as-built or as-graded geotechnical reports. These reports do not apply to the subject study since at this stage the study does not address a proposed project. However, for the content of a discretionary report, preliminary reports that address development or construction plans at the level of a geologic reconnaissance reports have the nearest application to the present study. Since Note 46 (CDMG, 1986) is not currently available and is being revised, Note 52 (CDMG, 2001) has been used to define the checklist items and issues of concern for this report.

<u>County of San Diego Multi-jurisdictional Hazard Mitigation Plan</u>
To comply with the Disaster Mitigation Act of 2000 the County of San Diego prepared the Multi-jurisdictional Hazard Mitigation Plan, which serves as both a countywide plan and a plan for local jurisdictions (e.g., City of San Diego) that identifies risks posed by natural and manmade disasters before a hazard event occurs (County of San Diego, 2010b). The Plan includes overall goals and objectives shared by many jurisdictions, as well as specific goals, objectives, and mitigation action items for each of the participating jurisdictions developed to help minimize the effects of the specified hazards that potentially affect their jurisdiction. Goals, objectives and action items were presented for the City of San Diego.

Hazards were mapped on a regional basis, generally at a scale of 1-inch equals 7 miles. Geology-related mapping of interest to the City of San Diego included Tsunami, Dam Failure, Earthquake, Flood, Landslide, and Liquefaction. The countywide analysis in 2009 included application of the FEMA HAZUS software, a model developed to determine earthquake loss estimates, for earthquake and flood damage assessment. This model integrates data on building stock, population, and the regional economy with hazard models using GIS. The 2003 update of this model (HAZUS-MH for Multiple Hazard) was used to model the above hazards (County of San Diego, 2010b, Section 5.16 and Table 5.16-1). Hazard maps prepared in this manner cannot indicate specific data sources for each hazard shown covering the City of San Diego.

APPENDIX B
FIGURES 1 THROUGH 5

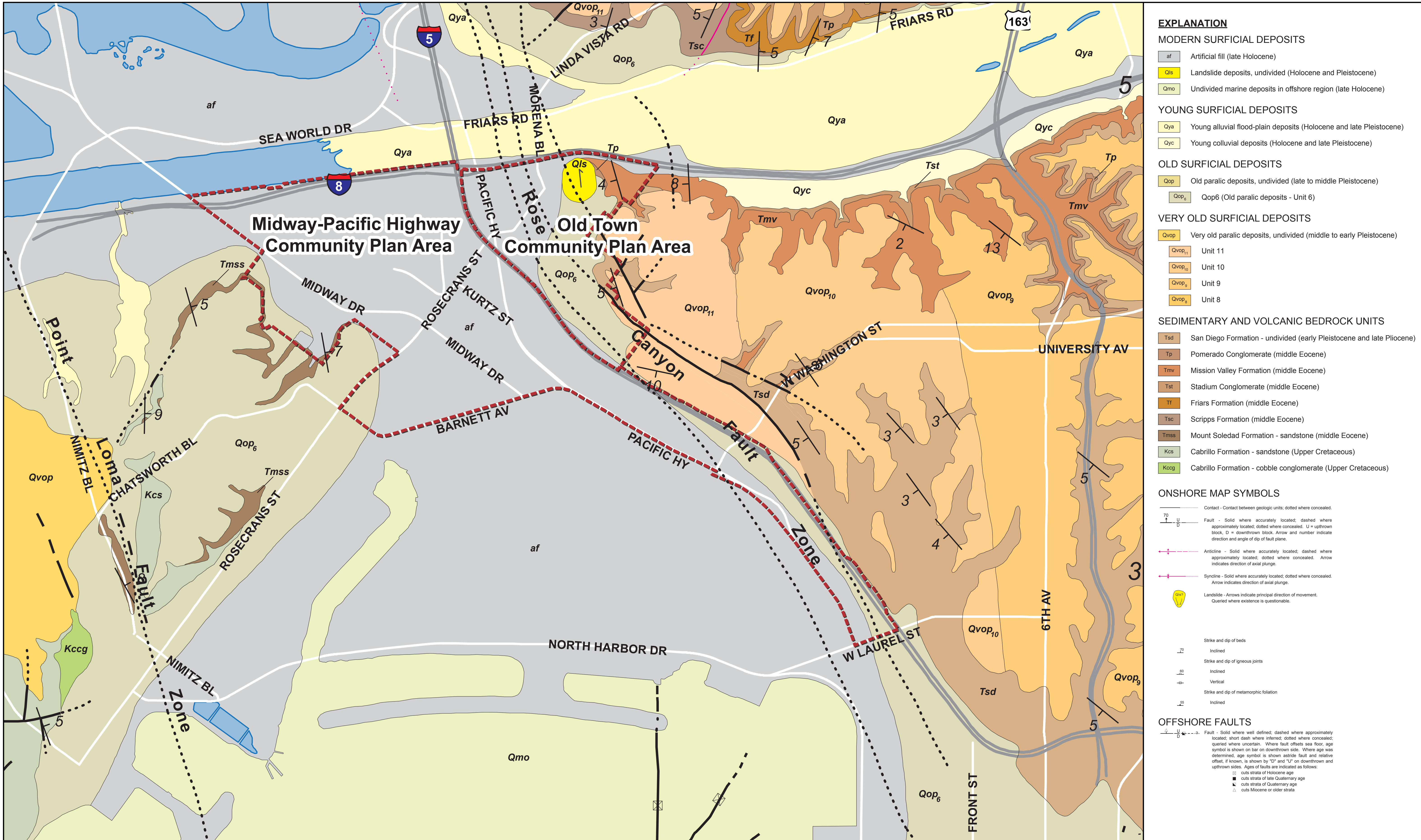

Figure 1: Geologic Conditions

Source: Kennedy and Tan, 2008

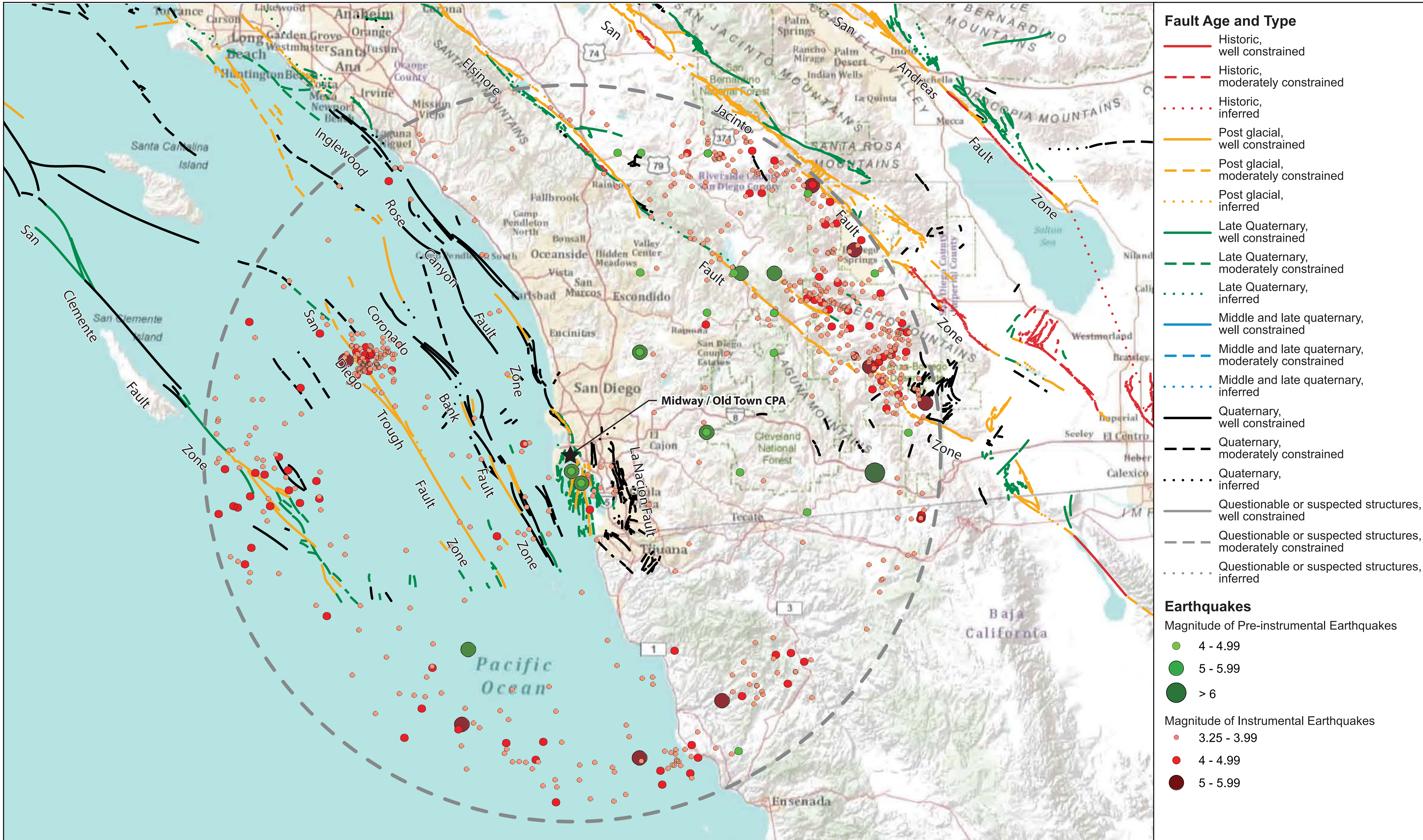

Figure 2: Regional Faults and Earthquakes (Magnitude > 3.25 within 100km)

Source: USGS and CGS, 2010

0 7.5 15 Miles
0 12.5 25 Kilometers

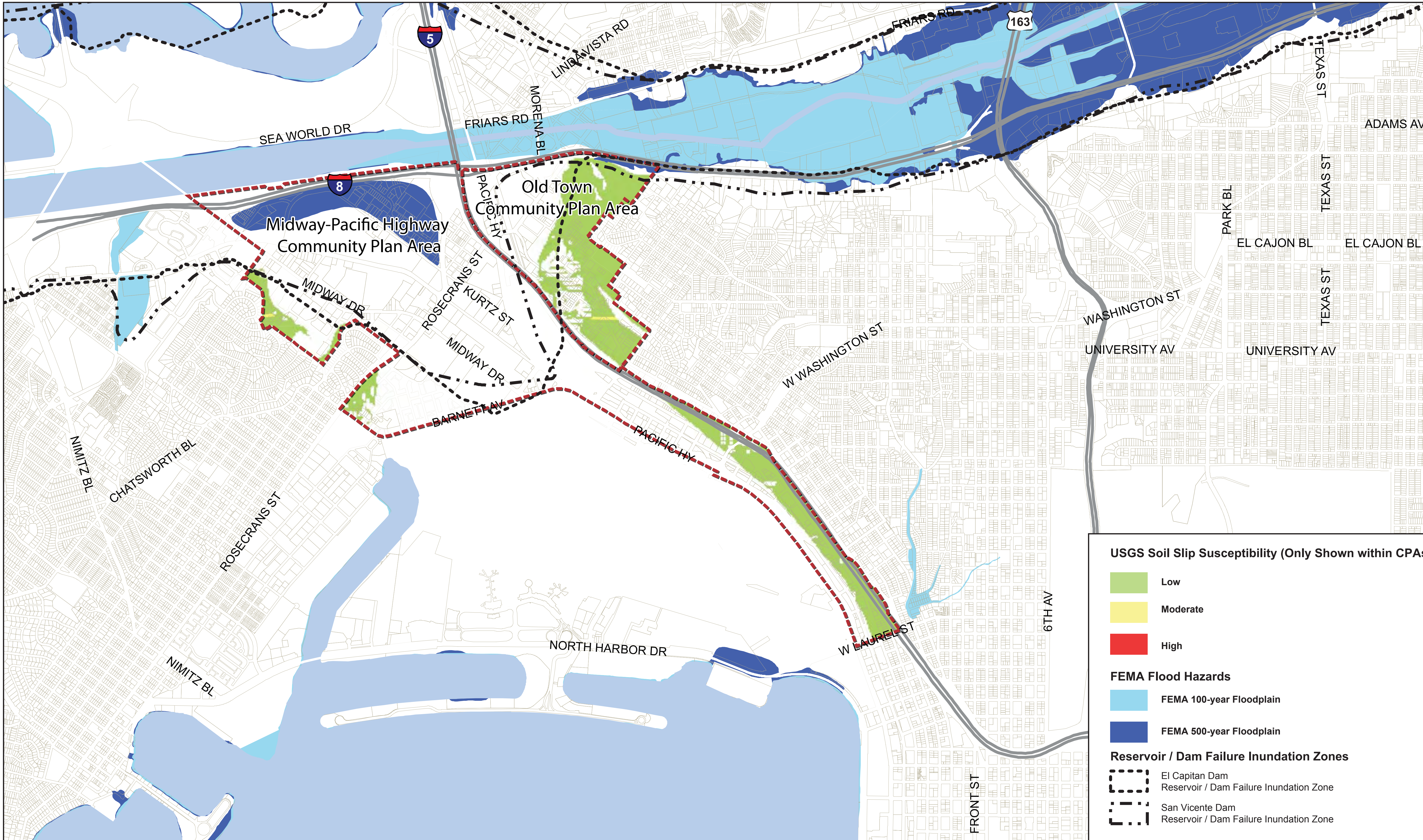

Figure 3: FEMA Flood Hazards, Reservoir/Dam Failure Inundation Zones, USGS Soil Slip Susceptibility

Source: SanGIS, 2011

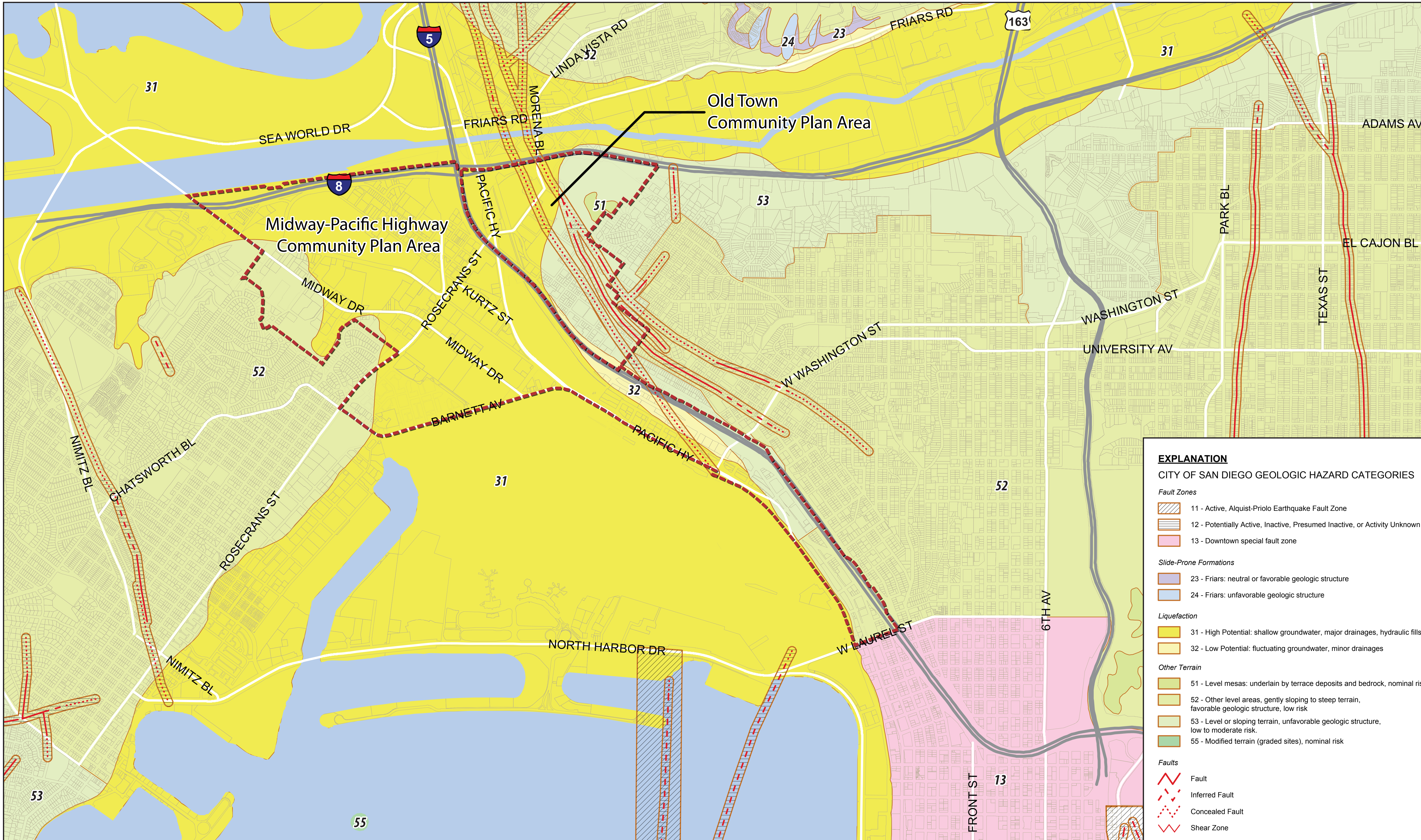

Figure 4: City of San Diego Geologic Hazards

Source: SanGIS, City of San Diego, 2011

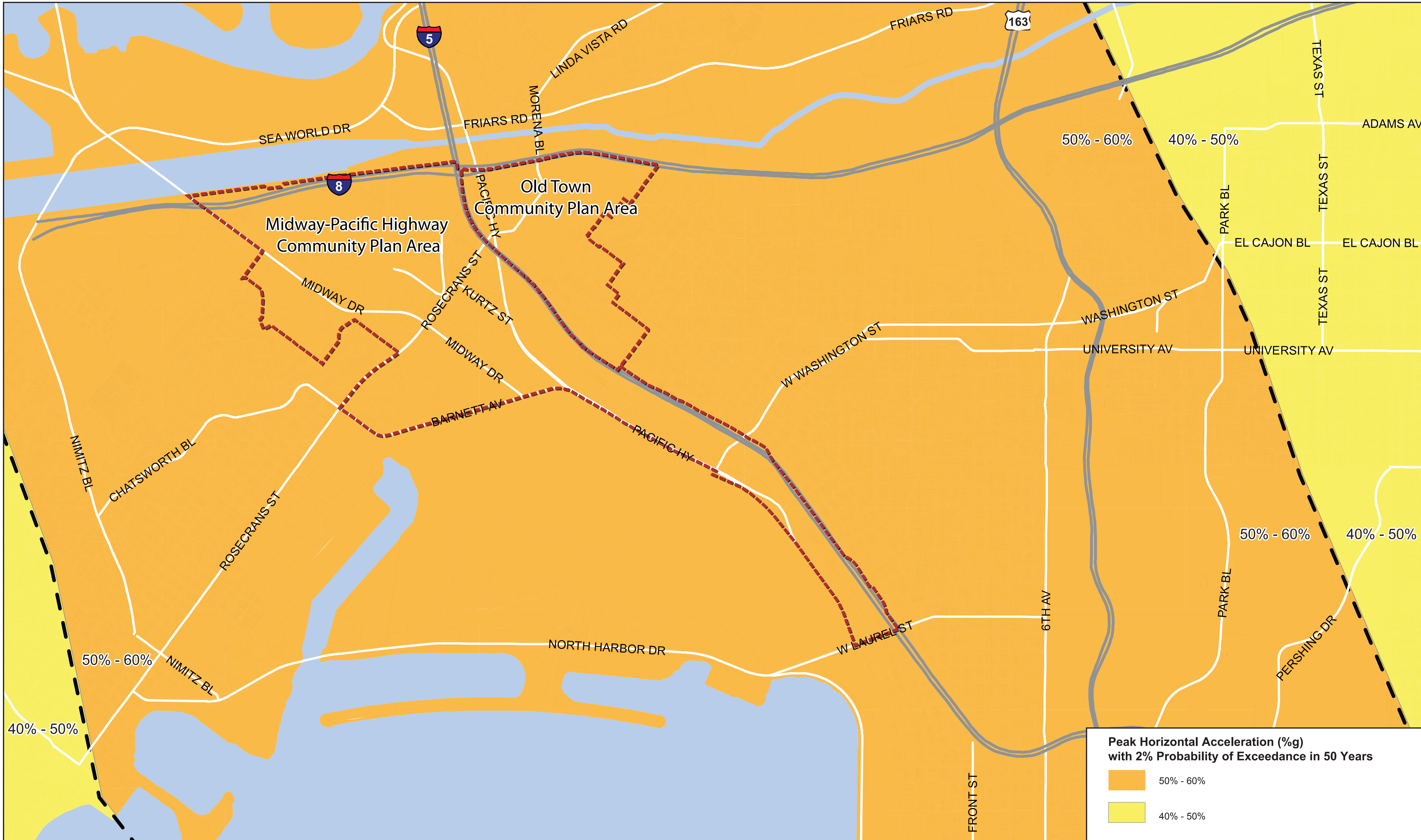

Figure 5: Seismic Shaking Potential

Source: USGS, 2008

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Subject: Update of Seismic and Geologic Technical Background Report for the City of San Diego Midway-Pacific Highway and Old Town Community Plan Updates, and Environmental Impact Report, City of San Diego, San Diego County, California
AECOM Project No. 60486380

Dear Ms. White:

AECOM is pleased to present this update of the "Seismic and Geologic Technical Background Report for the City of San Diego Midway-Pacific Highway and Old Town Community Plan Updates, and Environmental Impact Report, City of San Diego, San Diego County, California" prepared by Wilson Geosciences, Inc (Wilson) and dated April 2012. This letter presents our review and update of that report in support of the EIR process for the Midway-Pacific Highway and Old Town Community Plan Updates (CPU).

We have reviewed the 2012 Wilson report and are in general agreement with the findings and characterization of the conditions in the project area as presented in the report. However, there are some important fault hazard data that have become available since the issuance of the Wilson report that should be addressed. Specifically, there have been some recent paleosiesmic studies along the Rose Canyon Fault Zone in the Old Town area that add to the understanding of fault hazard in that area. The recent studies are summarized below.

Paleoseismic investigations were performed at the Presidio Hill golf course in Old Town in two phases with an initial phase of work performed in 2012. This work was performed as part of a seismic research effort performed for Southern California Edison. The initial phase of work was summarized in a December, 2012 report (Rockwell, et al.). The investigations consisted of detailed logging of excavated fault trenches that exposed young geologic strata (layers). Numerous radiocarbon samples were dated to constrain the timing of fault rupturing earthquakes evidenced in the trench exposures. Evidence for multiple late Holocene earthquakes was suggested by the initial phase of work performed on the north side of the golf course.

A second phase of fault trenching was performed in 2016 that confirmed the evidence for multiple late Holocene earthquakes on the Rose Canyon fault in the Old Town area and located the active strand of the fault on the south side of the golf course. This second phase of work was summarized in an abstract (Singleton, D.M., et al., 2017) presented during the May 2017 Geological Society of America annual meeting.

The significance of these studies with regard to local regulatory issues is that the fault is now well located and clearly established as an active fault in this area. This new data will necessitate revisions to the City of San Diego Seismic Safety Study, Geologic Hazards and Faults Maps (2008) to revise

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and update the location and the activity level of the fault mapped in this area. It is likely that these studies will also result in an expansion of the Alquist-Priolo Earthquake Fault Zone by the State Geologist. The CPU does not currently include Alquist-Priolo fault zones.

In addition to the fault-related items discussed above, we note that structural design should be performed in accordance with the most recent version of the California Building Code (CBC), currently the 2016 version, or the current guidelines accepted by the City of San Diego.

In light of the updates presented here with regard to geologic hazards, we have reviewed and edited the Midway-Pacific Highway and Old Town Community Plan Updates, and Environmental Impact Reports. We concur with the information presented in the CPU documents.

References.

Rockwell, T.K., Murbach, M., Murbach, D., Rockwell, K., Haaker, E., 2012, Paleoseismic assessment of the late Holocene rupture history of the Rose Canyon fault zone in San Diego: Southern California Edison, San Onofre Nuclear Generating Station, Seismic Source Characterization Research Project.

Singleton, D.M., Rockwell, T.K., Murbach, D., Murbach, M., Maloney, J., Marquez, E., Weidman, L., Levy, Y., Rugg, S., (2017), Timing of late Holocene earthquakes on the Rose Canyon fault at Old Town, San Diego, CA: Geological Society of America Abstracts with Programs, v. 49, no. 4, doi: 10.1130/abs/2017CD-292564

Sincerely,

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