4.5 GEOLOGY AND SEISMICITY

INTRODUCTION

This section identifies the potential for geologic and seismic hazards to occur on or near the proposed project site. Issues of concern include suitability of soil for development; geologic faults; direct and indirect seismic hazards such as subsidence, liquefaction, landslides, seiches, and tsunamis. This section was prepared utilizing documents and maps published by the United State Geological Survey (USGS), California Department of Conservation, California Geological Survey (CGS), the City of Redlands, as well as other applicable sources.

EXISTING SETTING

Geologic Materials and Soils

The City of Redlands lies within the San Bernardino Valley, a geologically young basin located south of the San Bernardino Mountains and north of the northwest trending hills and mountains of the Peninsular Ranges. The Peninsular Ranges are one of California's eleven geomorphic provinces, each of which displays distinct geology, fault, climate, and topographic features. The Peninsular Ranges are made up of granite and older metamorphic rocks separated by northwest trending valleys and are present in San Bernardino, Riverside, Orange, and San Diego counties, as well as throughout the Los Angeles Basin and Baja California. The San Bernardino Mountains represent the eastern extension of the Transverse Ranges, an east-west trending series of steep mountain ranges and valleys (e.g. Santa Monica Mountains, San Fernando Valley, etc.).[1] The project site ranges from approximately 1,313 feet above mean sea level along Texas Street in the west to approximately 1,400 feet above mean sea level along Church Street in the east.[2] The topography in the general Redlands area slopes downward to the southwest, yet the project site is fairly level.

The United States Department of Agriculture (USDA), National Cooperative Soil Survey for San Bernardino County indicates that the project site is located in an area of alluvial fans. Soils situated on alluvium foundation are typically characterized by unconsolidated, poorly sorted sand, gravel, and silt. The majority of the City rests on a wide variety of alluvium soils. The majority of the project site is situated on Pleistocene Alluvium, with a small portion of the northern section of the project site located on Holocene Wash (unconsolidated sand, gravel, pebbles, and/or boulders). The project site consists of four different types of soils: Tujunga, Hanford, Greenfield, and Ramona Association soils.[3, 4] A majority of the project site consists of Hanford Association soil, which is characterized by two to nine percent sloping alluvial fans made up of pale-brown, coarse sandy loam. The northwest portion of the project site consists of Tujunga Association soil, which is characterized by brown or gray loamy sand with zero to five percent slopes. The southwest portion of the project site consists of Greenfield Association soil, which is characterized by pale-brown, sandy loam with two to nine percent slopes. Ramona Association soils exist on the southern portion of the project site and consist of brown and/or red heavy loam or sand with two to nine percent slopes. All of these soil types are known to exhibit good natural drainage and

[1]California Department of Conservation, California Geological Survey, *California Geomorphic Provinces, Note 36*, 2002, available at: http://www.consrv.ca.gov/CGS/information/publications/cgs_notes/note_36/note_36.pdf, accessed: November 10, 2009.

[2]United States Geological Survey (USGS), *Redlands (CA) Topographic Map*, 1999-2003, available at: www.topozone.com, accessed: November 3, 2009.

[3]A soil association is made up of one or more extensive soils similar in general characteristics, and includes minor areas of soils that may or may not be like the dominant soils within the area. Soil associations differ from one another by having contrasting soil properties or differing in potentialities.

[4]United States Department of Agriculture, Natural Resources Conservation Service, *National Cooperative Soil Survey (Web Soil Survey)*, 2006, available at: http://soils.usda.gov/survey/, accessed: November 5, 2009.

possess slight erosion hazards. Tujunga Association soil is an exception because it is known for exhibiting somewhat excessive natural drainage.[5]

Shrink-swell or expansive behavior occurs when soils swell as they become wet and shrink as they dry out. This phenomenon can occur in hillside areas as well as low-lying alluvial basins. Expansive soils can cause cracked foundations, interior and exterior wall separations, and ruptured utilities.

Seismicity

Considering that the project site is within the seismically-active Southern California area, earthquakes and other seismically-induced effects are constant potential hazards. The project site could be exposed to strong ground shaking during a seismic event. Issues of concern relating to earthquakes include fault rupture, strong ground shaking, liquefaction, landslides, seiches, and tsunamis, as described below.

Fault Rupture. All of the populated areas of San Bernardino County (primarily the western portion) contain active faulting systems. A fault is a fracture in the earth's crust along which rocks on one side have moved relative to those on the other side. Most faults are the result of repeated displacement over long periods of time.[6] Fault rupture occurs when there is a change in surface elevation along a fault or a portion of a fault. **Figure 4.5-1** illustrates the regional faults near the City and surrounding areas. Active faults known to be present in the Redlands area include the San Andreas and San Jacinto fault zones. The Earth's crust is made up of a series of fractured "plates" which, for the past millions of years, have been moving very slowly over the Earth's surface. The San Andreas Fault zone consists of the boundary between two of these moving plates in western California including San Bernardino County, the North American Plate on the east and the Pacific Plate on the west.[7] The northwest-southeast trending San Andreas Fault zone is located approximately 4.8 miles north of the project site, beneath the San Bernardino Mountains. This section of the San Bernardino Mountains represents the eastern extension of the Transverse Ranges. These mountains have been displaced to the south along the San Andreas Fault. The Transverse Ranges are experiencing intense north-south compression, and as a result, is one of the most rapidly rising geomorhpic regions on Earth.[8] The San Andreas fault system is a system of abutting northwest and southeast plates which extend from 100 miles northwest of San Francisco, southeast to the northern border of the Salton Sea.

The San Jacinto fault zone (San Bernardino section) branches away from the San Andreas Fault zone (San Bernardino Mountains section) near the Cajon Pass of the San Bernardino Mountains, approximately 20 miles northwest of the project site. The San Jacinto fault zone transects the southwestern portion of the City, approximately 3.7 miles southwest of the project site.[9] In addition, the following potentially active faults and fault systems transect the City limits: 1) segments of the Crafton Hills fault system including the Western Heights Fault and the Chicken Hills Fault, 2) the Greenspot fault, located within the San Andreas Fault system.[10]

[5]Los Angeles County, *General Soils Map and Document*, 1969.

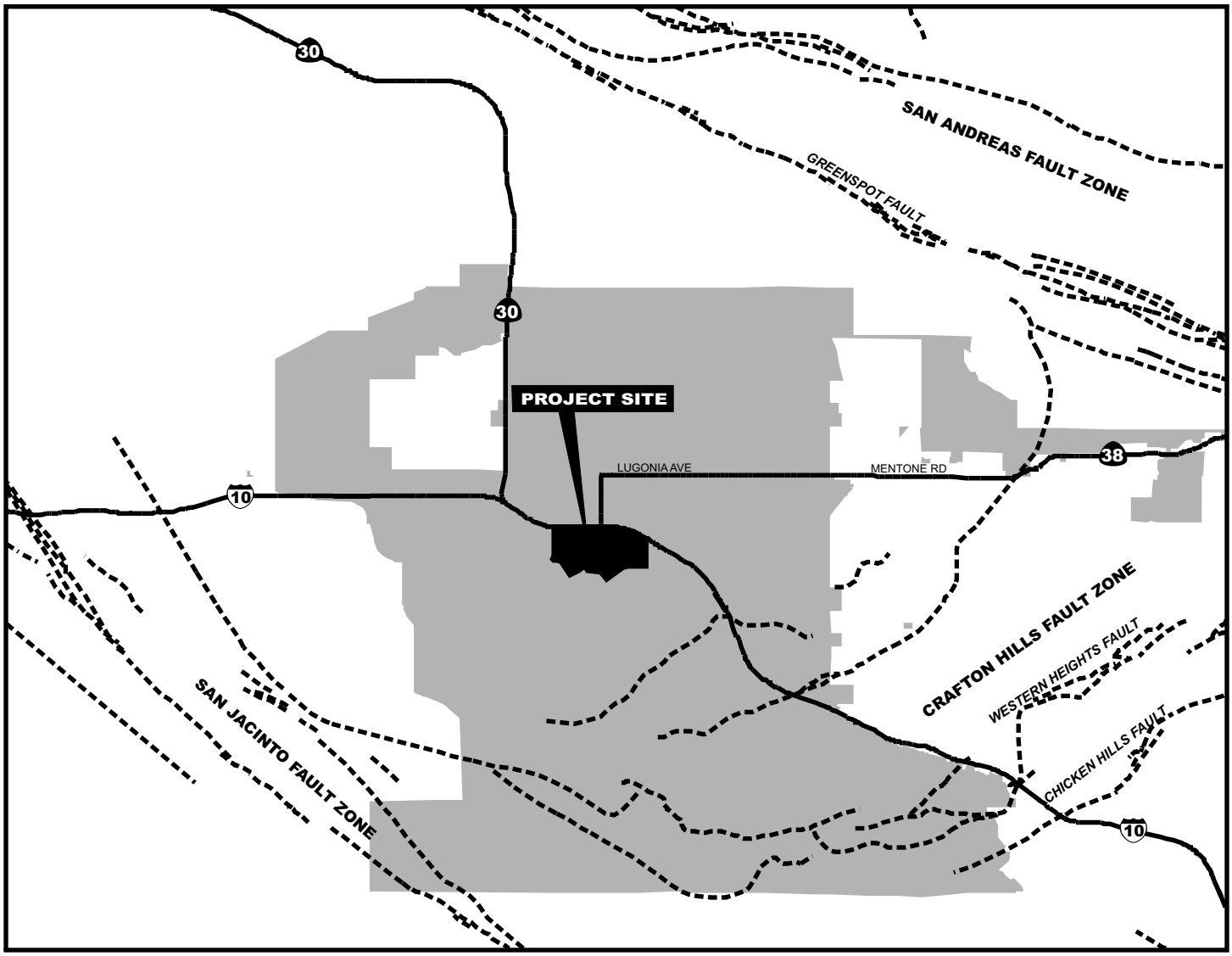
[6]California Geological Survey, *Alquist-Priolo Earthquake Fault Zones* (2005), available at: http://www.consrv.ca.gov /CGS/ rghm/ap/index.htm, accessed November 3, 2009.

[7]U.S. Geological Survey, *The San Andreas Fault*, Sandra S. Schulz and Robert E. Wallace, 1997, available at: http://pubs.usgs.gov/gip/earthq3/safaultgip.html, accessed: November 5, 2009.

[8]California Department of Conservation, California Geological Survey, *California Geomorphic Provinces, Note 36*, 2002, available at: http://www.consrv.ca.gov/CGS/information/publications/cgs_notes/note_36/note_36.pdf, accessed: November 10, 2009.

[9]U.S. Geological Survey and California Geological Survey, 2006, *Quaternary Fault and Fold Database for the United States*, available at: http://earthquake.usgs.gov/regional/qfaults/, accessed November 5, 2009.

[10]City of Redlands, *General Plan Master Environmental Assessment/Final Environmental Impact Report*, 1995.



LEGEND:

Proposed Specific Plan Area

City of Redlands

Faults

SOURCE: United States Geological Survey, 2010.

N

APPROX. SCALE

0 0.8 1.6 MILES

FIGURE 4.5-1

REGIONAL FAULTS

The Alquist-Priolo Act was passed as a direct result of the 1971 San Fernando Earthquake. The primary purpose of the Alquist-Priolo Act is to mitigate the hazards associated with fault rupture by "preventing construction of buildings used for human occupancy on the surface trace of active faults."[11] The Alquist-Priolo Act has been revised eleven times, most recently in 2007, to reflect changes and additions of affected cities. A review of the Alquist-Priolo earthquake Fault Zones Map was conducted to determine if the project site is located within a fault zone. There are two active faults near the project site that result in the classification of the area as affected by the Alquist-Priolo Fault Zone (APFZ) . The San Jacinto Fault is the closest in proximity to the project site, and is located 3.7 miles to the southwest. The San Andreas Fault is located 4.5 miles to the northeast of the project site. The San Andreas Fault system is a system of abutting northwest and southeast plates which extend from 100 miles northwest of San Francisco, southeast to the northern border of the Salton Sea. Other nearby potentially active faults include the Western Heights Fault, the Chicken Hills Fault, and the Greenspot Fault. The Western Hills Fault, located five miles to the southeast of the project site, and the Chicken Hills Fault, 6.7 miles to the southeast, are part of the Crafton Hills Fault Zone. The Greenspot Fault, located 4.8 miles to the northeast of the project site, is part of the San Andreas Fault Zone. Projects in areas affected by an APFZ have their building permits withheld until geologic investigations demonstrate that the area is not threatened by displacement from future faulting.[12]

Ground Shaking. Ground shaking is a type of earthquake-induced movement that can cause more widespread damage than all other types of movements because it tends to affect a larger geographical area. The City of Redlands area, including the project site is underlain by alluvium, which is porous and easily moved during seismic activity. In addition, the San Andreas and San Jacinto active fault zones are capable of generating strong ground shaking during an associated earthquake. Both the San Andreas and San Jacinto fault zones are right-lateral strike-slip faults and have probable magnitudes of 6.8 to 8.0 and 6.5 to 7.5 (Richter), respectively.[13]

Liquefaction. Liquefaction, essentially the transformation of soil from a solid to a liquid state, results in lateral spreading, ground settlement, sand boils, and soil falls. Liquefaction typically occurs in areas with a high groundwater table and low density, fine sandy soils. Liquefaction also occurs with high-density ground motion. New construction or buildings proposed to be altered within the City of Redlands which are located on soil that may be subject to liquefaction must meet specific structural requirements. High groundwater levels increase the probability of liquefaction during seismic activity. The northernmost portion of the City of Redlands is located in a "high" liquefaction risk zone. However, the project site is not known to be located within a liquefaction risk zone.[14]

Landslides. Landslides are a type of slope instability that can occur as a direct result of earthquake shaking. The County of San Bernardino General Plan Natural Hazards Element states that, because the San Andreas Fault zone bisects the San Bernardino Mountains, along with the somewhat steep slopes exhibited by the mountains, there is potential for landslides in areas adjacent to the mountains to pose substantial risks to lives and property. The base of the San Bernardino Mountains is located approximately five miles from the project site.

Seiche and Tsunami Hazards. Seiches are waves that rock back and forth in enclosed bodies of water such as lakes, reservoirs, bays and harbors. The project site is not located adjacent to any enclosed bodies of water and is located approximately 50 miles east of the Pacific Ocean, 18 miles southwest of the Bear

[11] *Ibid.*

[12] Division of Mines and Geology, *Special Publication 42, Interim Revision*, 2007.

[13] Southern California Earthquake Data Center, U.S. Geological Survey, California Institute of Technology (CalTech), and University of California at San Diego, 2007, available at: http://www.data.scec.org/index.html, accessed: November 10, 2009.

[14] U.S. Geological Survey & City of Redlands, *General Plan Master Environmental Assessment/Final Environmental Impact Report*, 1995.

Valley Dam and reservoir, 8 miles southwest of the Seven Oaks Dam, 4.6 miles south of the East Highland Reservoir, and 13.4 miles south of Lake Arrowhead and Lake Papoose. No other bodies of water are in the vicinity of the project site.

A tsunami is a spontaneous water wave that occurs when hundreds to more than a thousand square miles of submerged continental shelf or slope is rapidly displaced vertically during a large earthquake or submarine slide. The potential for an earthquake-induced tsunami to occur in the project site is remote due to the distance from the ocean.

REGULATORY FRAMEWORK

Alquist-Priolo Earthquake Fault Zoning Act. The Alquist-Priolo Earthquake Fault Zoning Act (Alquist-Priolo Act) provides policies and criteria to assist cities, counties, and State agencies in the development of structures for human occupancy across the trace of active faults. The Alquist-Priolo Act was intended to provide the citizens of the State with increased safety and to minimize the loss of life during and immediately following earthquakes by facilitating seismic retrofitting to strengthen buildings, including historical buildings, against ground shaking.

Seismic Hazards Mapping Act. In order to address the effects of strong ground shaking, liquefaction, landslides, and other ground failures due to seismic events, the State of California passed the Seismic Hazards Mapping Act of 1990. Under the Seismic Hazards Mapping Act, the State Geologist is required to delineate "seismic hazard zones." Cities and counties must regulate certain development projects within these zones until the geologic and soil conditions of the Specific Plan area are investigated and appropriate mitigation measures, if any, are incorporated into development plans. The State Mining and Geology Board provides additional regulations and policies to assist municipalities in preparing the Safety Element of their General Plan and encourage land use management policies and regulations to reduce and mitigate those hazards to protect public health and safety. Under Public Resources Code Section 2697, cities and counties shall require, prior to the approval of a project located in a seismic hazard zone, a geotechnical report defining and delineating any seismic hazard. Each city or county shall submit one copy of each geotechnical report, including mitigation measures, to the State Geologist within 30 days of its approval.

California Building Code. The California Building Code (CBC) Title 24 is a compilation of building standards, including seismic safety standards for new buildings. CBC standards are based on building standards that have been adopted by state agencies without change from a national model code; building standards based on a national model code that have been changed to address particular California conditions; and building standards authorized by the California legislature but not covered by the national model code. Given the State's susceptibility to seismic events, the seismic standards within the CBC are among the strictest in the world. The CBC applies to all occupancies in California, except where stricter standards have been adopted by local agencies.

THRESHOLDS OF SIGNIFICANCE

The proposed project would result in a significant impact related to geology and seismicity if it would:

- Result in substantial soil erosion or the loss of topsoil;
- Be located on expansive soil, as defined in Table 18-1-B of the Uniform Building Code (1994), creating substantial risks to life or property;
- Be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction or collapse; and/or

- Expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:
  - Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issues by the State Geologist for the area or based on other substantial evidence of a known fault
  - Strong seismic ground shaking
  - Seismic-related ground failure, including liquefaction
  - Landslides

IMPACTS

Geologic Materials and Soils

Soil Erosion/Loss of Topsoil. Approximately 65 percent of the project site consists of Hanford Association soils, 25 percent is Tujunga Association soils, 7 percent is Ramona Association soils, and 3 percent is Greenfield Association soils.[15] As mentioned earlier, these soils are well-drained, have faster infiltration rates, higher levels of organic matter and improved soil structure. These are soil composition factors which result in greater resistance to soil erosion. In addition to soil composition, climate and slope are factors in creating a potential for soil erosion. The proposed project is in a flat, highly urbanized area, with an extensive drainage system and impervious surfaces. The project site is not subject to high levels of wind or rain, factors that may contribute to soil erosion.

During the construction of individual projects, the potential exists for runoff and fugitive dust, resulting in a small, temporary, loss of topsoil. However, this loss would not be considered substantial with the implementation of Best Management Practices (BMPs), required as part of the National Pollutant Discharge Elimination System (NPDES) permit and application of South Coast Air Quality Management District (SCAQMD) Rule 403. The project site generally consists of impervious surface and implementation of the proposed project would not be expected to result in a substantial change from these conditions. The construction of individual projects could improve the existing drainage system as BMPs would be required and would not contribute to a substantial loss of topsoil during operation. Therefore, the proposed project would result in less-than-significant impacts related to soil erosion or loss of topsoil.

Expansive/Unstable Soil. All of the soils located on the project site are well-drained, high absorbing soils, with minimal, if any flooding potential or runoff, although Ramona Association soils have some slight potential for expansiveness. Ramona Association soils are located in the southwestern part of the project site below State Street from Center Street to Grand Street. Compliance with safety and building standards and regulations enacted by the State and the City of Redlands will act to prevent damage and any other possible impacts of this type of soil behavior on the project site. These standards and regulations would be adhered to as part of the design and development associated with the proposed project. The project is not anticipated to result in substantial risks to life or property from expansive soils or result in unprotected construction on unstable soil that could be at risk from subsidence, spreading or collapse. Therefore, the proposed project would result in less-than-significant impacts related to expansive or unstable soil.

[15]U.S. Dept. of Agriculture, *Web Soil Survey*, can be viewed at http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx, Accessed November 2, 2009.

Seismicity

Fault Rupture. The project site is located within an area classified as being affected by an Alquist-Priolo Earthquake Fault Zone (APFZ). As discussed above, earthquake faulting systems are present throughout Southern California, and the State and the City have implemented building codes to assure that new construction developments are seismically resistant. Compliance with these mandatory building codes during the design and construction of the projects associated with the proposed project would be mandatory. Therefore, the proposed project would result in less-than-significant impacts related to fault rupture.

Ground Shaking. As with all properties in the seismically-active Southern California region, the project site is susceptible to strong seismic ground shaking. However, as with any new development in the State of California, building design and construction would be required to conform to the current seismic design provisions of the CBC. The 2007 CBC incorporates the latest seismic design standards for structural loads and materials, as well as provisions from the National Earthquake Hazards Reduction Program to mitigate losses from an earthquake and provide for the latest in earthquake safety. Construction of the proposed project would be required to adhere to the seismic safety requirements contained in the Redlands Building Code, and the proposed buildings would be designed to resist ground shaking through modern construction techniques. In addition, the proposed project would comply with the California Department of Conservation, Division of Mines and Geology (CDMG) Special Publications 117, Guidelines for Evaluating and Mitigating Seismic Hazards in California (1997), which provides guidance for the evaluation and mitigation of earthquake-related hazards. The proposed project would not cause or accelerate geologic hazards, which would result in substantial damage to structures or infrastructure, or expose people to substantial risk of injury impacts from strong seismic ground shaking. Therefore, without mitigation, the proposed project would result in a significant impact related to ground shaking.

Liquefaction. The project site is not located in an area mapped for liquefaction potential. Groundwater monitoring wells near the project site have measured water depths greater than 100 feet below ground surface.[16]. There would be no potential for ground displacement. Therefore, no impacts related to liquefaction would occur.

Landslides. The project site is located five miles to the nearest hillside area; and would not be affected by any potential landslides. Therefore, no impacts related to landslides would occur.[17]

Seiche and Tsunami Hazard. There are two reservoirs/dams located in the Santa Bernardino Mountains, northeast of the project site. The Seven Oaks and Bear Valley dams are situated at eight miles and eighteen miles northeast of the project site, respectively. The likelihood of damage occurring in the project site as a result of an earthquake-induced seiche occurring at one or both of these reservoirs is low due to the distance from the project site. The Pacific Ocean is located approximately 50 miles west of the project site. The potential for an earthquake-induced tsunami to occur in the project site is remote due to the distance from the ocean. Therefore, no impacts related to a seiche or tsunami hazard would occur.

MITIGATION MEASURES

The City of Redlands shall ensure the following mitigation measures are implemented as appropriate for individual development projects associated as part of the proposed project.

[16]California Department of Water Resources, *Ground Water Level Data 2008*, Available at: http://wdl.water.ca.gov/gw/hyd/rpt_hydrograph_data_CF.cfm?wellNumber=01S03W23A003S, accessed June 7, 2010.

[17]The Reynolds Group, *Phase I Environmental Site Assessment*, September 2004 and January 2004.

GS1 Prior to approval of final plans for individual projects associated with the Downtown General Plan and Specific Plan No. 45 Amendments, the applicant of each project shall develop and submit for approval by the City a site-specific geotechnical study prepared by a registered geotechnical engineer to ensure that all applicable building codes and design specifications are incorporated into the plans. The geotechnical study shall identify design requirements for structures and foundations to maintain structural integrity to the maximum extent under probable earthquake conditions as determined by the study, including but not limited to, strong seismic ground shaking including the potential for liquefaction.

GS2 Structures built for individual projects associated with the Downtown General Plan and Specific Plan No. 45 Amendments shall comply with the most current seismic building code standards. This mitigation measure will confirm that the construction of dwelling units and infrastructure meet State safety requirements.

LEVEL OF IMPACT AFTER MITIGATION

Soil Erosion/Loss of Topsoil

Impacts related to soil erosion and loss of topsoil were determined to be less than significant without mitigation.

Expansive/Unstable Soil

Impacts related to expansive or unstable soil were determined to be less than significant without mitigation.

Fault Rupture

Impacts related to fault rupture were determined to be less than significant without mitigation.

Ground Shaking

Impacts related to ground shaking were determined to be significant without mitigation. Therefore, mitigation Measures **GS1** and **GS2** would reduce the impacts to less than significant.

Liquefaction

Impacts related to liquefaction were determined to be less than significant without mitigation.

Landslides

Impacts related to landslides were determined to be less than significant without mitigation.

Seiche and Tsunami Hazard

Impacts related to a seiche or tsunami hazard were determined to be less than significant without mitigation.

CUMULATIVE IMPACTS

Geotechnical hazards are site-specific, and there is little, if any, cumulative geological relationship between the proposed project and the related projects. Nevertheless, cumulative development in the area would increase the overall population, thus, increasing the risk of exposure to seismically-induced hazards. As with the proposed project, related projects and other future development projects would be subject to the same local, regional, State, and federal regulations pertaining to geology and soils, including CBC and Building Code requirements. Therefore, with adherence to such regulations, cumulative impacts with regard to geology and soils would be less than significant.