C. GEOLOGY, SOILS AND SEISMICITY

This section assesses, on a program level, the geotechnical conditions potentially affecting buildout of the Draft Specific Plan. The analysis is based on a review of geological and soils maps, published reports on geologic conditions within the project site and its vicinity, and a site reconnaissance. This section includes an assessment of potential impacts from seismically-induced strong ground shaking, landslides, slope failure, lateral slope deformation, differential settlement, and unstable or expansive soils. Mitigation measures for identified significant impacts are provided.

1. Setting

This section describes the existing geologic and seismic conditions of the project site and its vicinity, and associated hazards.

a. Geologic Conditions. The geology, topography, and soils of the project site and the vicinity are described below.

(1) Regional Geology. The project site is located on the northern margin of the Carquinez Strait, which links Suisun Bay and the Sacramento River Delta to San Pablo Bay. The regional geologic setting is the Coast Range Geomorphic Province of California, a relatively geologically young and seismically-active region on the western margin of the North American plate. Within this broadly defined region between the Pacific Ocean to the west and the Central Valley to the east, the topography is characterized by a series of northwest-southeast trending uplands or low mountain ranges and intervening valleys. In general, the Coast Ranges are composed of sedimentary bedrock with layers of recent alluvium filling the intervening valleys.[1] The Carquinez Strait, immediately south of the project site, is a relatively narrow valley cut through an upland area underlain by resistant sedimentary bedrock of the Upper Cretaceous Great Valley Sequence and younger Tertiary sedimentary rocks.[2] The upland is bounded by tidal lowlands at the margins of Suisun Bay (to the east) and at the confluence of the Napa River and San Pablo Bay (to the west).

(2) Site-Specific Geology. The project site, which is located where the foothills of the Coast Range meet the Carquinez Strait shoreline, has a diverse composition of geologic substrates (see Figure IV.C-1, Site Geology). The extreme northern portion of the site, north of Jefferson Street, is underlain by Cretaceous-age bedrock of the Great Valley Sequence, which is characterized by unnamed mudstone, siltstone, shale, sandstone, and conglomerates. This bedrock extends north, across Interstate 780 (I-780) into the Pine Lake district of Benicia.

Jefferson Ridge itself and the extreme southwestern portion of the project site are underlain by Vine Hill Sandstone. The lower-lying area south of Grant Street comprises a band of alluvial fan and fluvial deposits dating from the Holocene. Alluvium and fluvial refer to sediments deposited by the action of a stream or river, or other running water. In the project site, these deposits are medium dense to dense gravely sand or sandy gravel.

In addition to the naturally-occurring geologic materials at the project site, fills have been placed in the extreme southern portion of the project site (and extend southward through Port of Benicia land to the present-day Carquinez Strait shoreline). Fill generally occurs south of the work/live artists' lofts on Tyler Street and therefore is likely only present along the southeastern boundary of the project site.

[1] California Geographic Survey (CGS), 2002. *California Geomorphic Provinces, Note 36.* Revised December 12.

[2] Dibblee, Thomas, 1980. *Geologic Map of the Benicia Quadrangle, California*, USGS Open File Map 80-400.

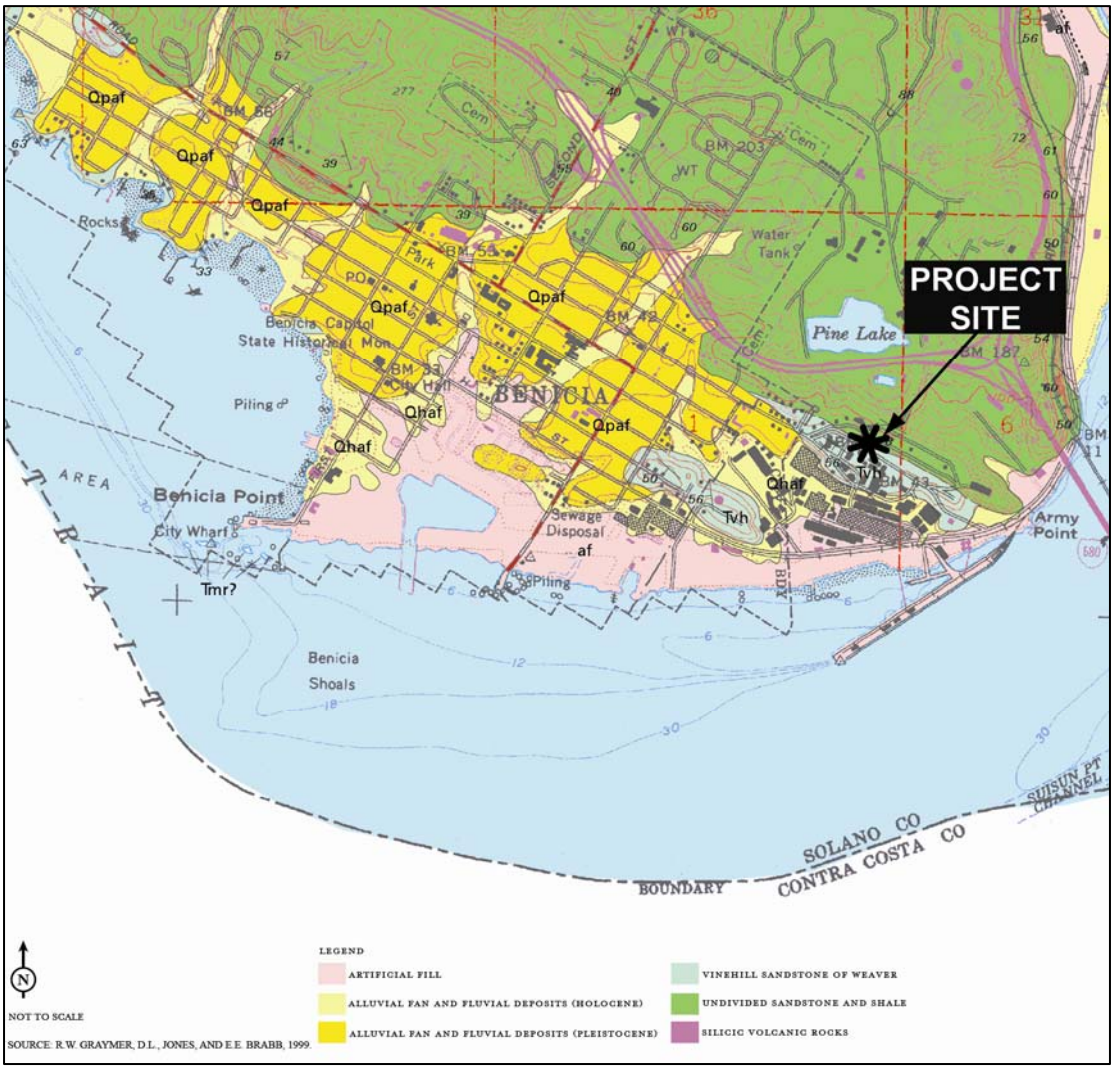


Figure IV.C-1: Site Geology

These fills were placed on low-lying shoreline and wetland areas starting in approximately the 1870s to allow for increased shipping uses. Artificial fill in this area is anticipated to include loose gravel, sand, silt, clay, rock fragments, organic matter, and man-made debris in various combinations. Because most of the fill south of the project site was placed before 1965, it is likely not well compacted and consists simply of dumped materials. Artificial fill occupies the area generally extending from Army Point west to East 5th Street and south of the Southern Pacific Railroad tracks.[3]

Fill has also been placed in other portions of the project site, including around Jefferson Ridge. This fill which is likely the result of historic cut and fill activities, extends generally to 10 feet below the

[3] Graymar, R.W., Jones, D.J., Brabb, EE., 1999. *Geology of the Cordelia and the Northern Part of the Benicia 7.5 Minute Quadrangles, California.* From the Digital Map Database, Open-File Report 99-162.

ground surface in the vicinity of Jefferson Ridge. This fill is softer and more compressible than exposed native soils.[4]

(3) Topography. The project site occupies approximately 50 acres of land that slope downward from the northern portion of the site to the flatlands adjacent to the Carquinez Strait shoreline. The site ranges in elevation from approximately 100 feet above mean sea level (msl) at Jefferson Street to approximately 20 feet above msl in the extreme southwestern portion of the project site. The predominant topographical feature in the project site is Jefferson Ridge, which trends generally in a northwest/southeast direction. South of Grant Street, the site exhibits a slight slope downward to the southwest and the Carquinez Strait shoreline. Slopes at the site range from 9 to 30 percent around Jefferson Ridge, and 2 to 9 percent from Adams Street south to the southern boundary of the project site. No above-ground or underground creeks have been identified on the project site.

(4) Soils and Minerals. Soil is generally defined as the unconsolidated mixture of mineral grains and organic material that covers the land surfaces of the earth. Soils can develop on unconsolidated sediments and weathered bedrock. The characteristics of soil reflect the five major influences on their development: topography, climate, biological activity, parent (source) material, and time.

Most of the soil on the project site is Dibble-Los Osos clay loam (see Figure IV.C-2, Site Soils). The Dibble soil is typically on ridge tops and southern-facing slopes; the Los Osos soil usually occurs on north-facing slopes.[5] These soils are developed in upland areas underlain by sedimentary rock and have a relatively low shrink-swell potential. Small portions of the extreme southwestern portion of the project site are underlain by Reyes silty clay. The Reyes soils are associated with existing or former salt water marshes that are adjacent to bodies of sea water. They are typically found in areas of low slope (less than 2 percent), in elevations ranging from 2 feet below sea level to about 10 feet above sea level. The soils formed in mixed bay and stream alluvium under marsh-type plants such as pickleweed, bulrush, and saltgrass.[6]

The erosion hazard within the site ranges from slight to moderate on gentle slopes (2 to 9 percent) to moderate to high on steep (greater than 30 percent) slopes.[7] The project site is not identified in the Benicia General Plan or the Benicia Mineral Resource Management Study as an area of mineral resource conservation.

b. Seismic Conditions. The following section includes a description of seismic conditions in and around the project site.

(1) Regional Seismicity. The entire San Francisco Bay Area is located within the San Andreas Fault Zone (SAFZ), a complex of active faults forming the boundary between the North American and Pacific lithospheric plates. Movement of the plates relative to one another results in the accumulation of strain along the faults, which is released during earthquakes. Numerous moderate to strong historic earthquakes have been generated in northern California by the SAFZ. The level of

[4] ENGEO, Inc., 2000. *Geotechnical Exploration, Bortolazzo Property, Benicia, California*. May 15.

[5] Ibid.

[6] National Resources Conservation Service, 2007. Soil Data. Website: http://ortho.ftw.nrcs.usda.gov/osd/dat. April 25.

[7] Ibid.

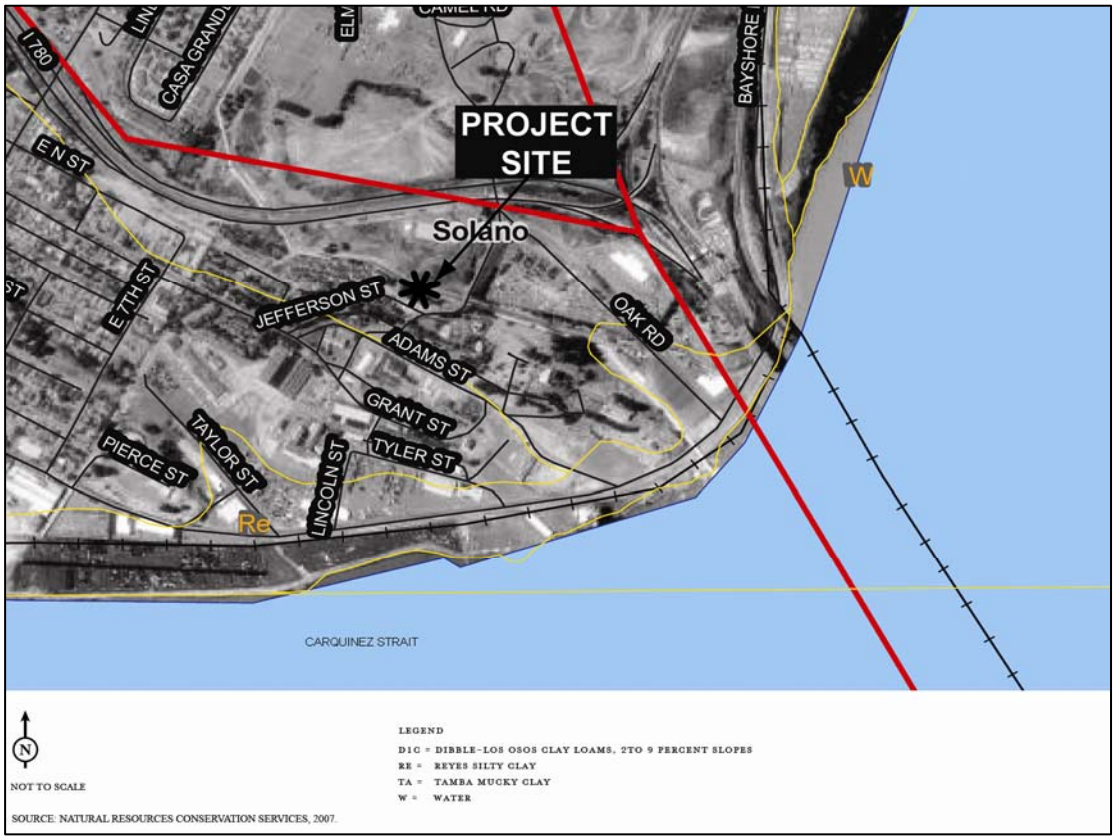
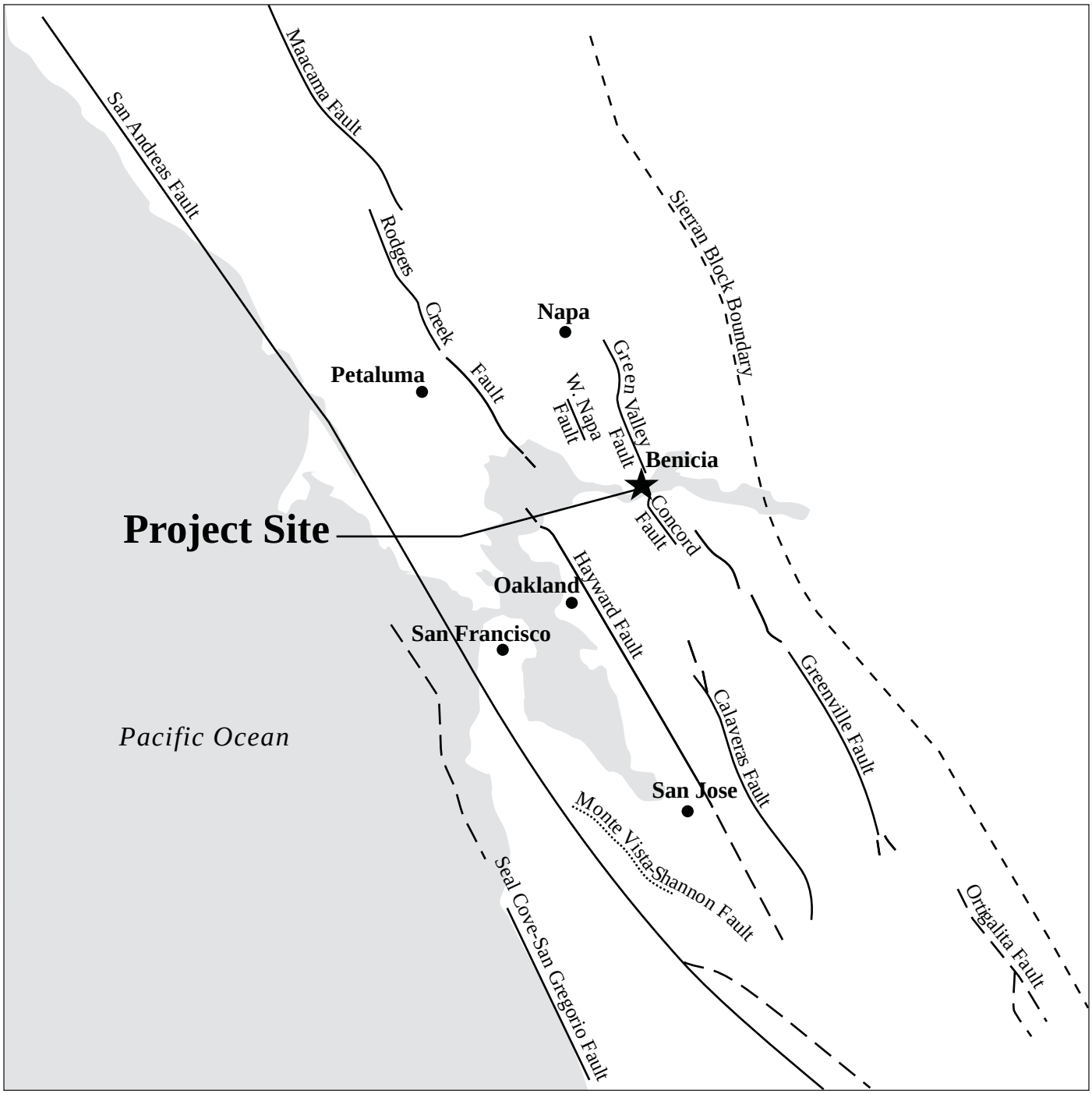


Figure IV.C-2: Site Soils

active seismicity has resulted in classification of the area as seismic risk Zone 4 (the highest risk category) in the California Building Code. The SAFZ includes numerous faults found by the California Geological Survey under the Alquist-Priolo Earthquake Fault Zoning Act (A-PEFZA) to be "active" (i.e., to have evidence of fault rupture in the past 11,000 years). Active faults in the region are shown on Figure IV.C-3).

The U.S. Geological Survey's Working Group on California Earthquake Probabilities estimated that there is a 62 percent probability that one or more Moment Magnitude (M_w) 6.7 [8] or greater earthquakes will occur in the San Francisco Bay Area between 2002 and 2031. The probability of a M_W 6.7 magnitude or greater earthquake occurring along individual faults was estimated to be 21 percent along the San Andreas Fault, 27 percent along the Hayward Fault, 11 percent along the Calaveras Fault, 4 percent along the Concord-Green Valley Fault, 10 percent along the San Gregorio Fault, 3 percent on the Greenville Fault, and 3 percent for the Mt. Diablo Thrust fault. In addition, there is a cumulative 14 percent chance of a background (other earthquake source, either mapped or undiscovered) event occurring. When predictions are expanded to 100 years, it is estimated that about three M_W 6.7 or greater events could occur during that time. Thus the probability of at least one

[8] Moment magnitude (M_W) is now commonly used to characterize seismic events as opposed to Richter Magnitude. Moment magnitude is determined from the physical size (area) of the rupture of the fault plane, the amount of horizontal and/or vertical displacement along the fault plane, and the resistance to rupture of the rock type along the fault.



LSA

FIGURE IV.C-3

Legend

Active Fault - Fault has evidence of surface displacement within the past 11,000 years (dashed where inferred)

Potentially Active Fault - Fault has evidence of surface displacement in the past 1.6 million years, but not within the past 11,000 years

Seismic Source without Surface Rupture

N

0 10 20
MILES

Lower Arsenal Mixed Use Specific Plan EIR

Regional Faults

SOURCE: BASELINE, 2004

I:/CIB0701 lower arsenal/figures/Fig_IVC3.ai (5/11/07)

M_W 6.7 or greater magnitude earthquake rises to near certainty – about 96 percent – when calculated for a 100-year span.[9]

The Coast Range-Sierran Block Boundary (CRSBB) forms the western geomorphic boundary of the Central Valley with the Coast Ranges to the west. This boundary is underlain by a seismically active fold and thrust belt. The CRSBB is generally defined as the range front at the western margin of the Coast Ranges. The project site is basically within this broadly-defined boundary. The CRSBB is currently recognized as a potential seismic source, capable of generating moderate earthquakes within the study area.[10] Recent evaluations of the CRSBB indicate that tectonic compression occurs across the boundary as the Coast Range Block is tectonically pushed beneath the Sierran Block. The result of this active compression is the development of folds and thrust faults within the CRSBB. The faults associated with this zone do not typically propagate to the surface and are, therefore, called "blind thrusts." Because the faults are not expressed at the surface, identification of the locations of the faults cannot, typically, be determined on the basis of geomorphic evidence. However, the compressional zone is considered capable of generating moderate to large earthquakes that could produce strong seismic shaking throughout the region, including the Plan Area. Eleven moderate earthquakes (M_w 5.8 to M_w 6.8) have been documented along the CRSBB zone during the last 150 years, including the 1892 Winters earthquakes.[11] The 1983 Coalinga earthquake (M_w 6.7) is a recent example of an earthquake that occurred on a blind thrust within the CRSBB zone.

(2) Site-Specific Seismicity. The project is not within an Alquist-Priolo Earthquake Fault Zone (A-PEFZA); the project site is approximately 2 miles west of the Green Valley-Concord A-PEFZA fault zone.[12] The Green Valley-Concord fault is a right lateral strike-slip fault with a northwest-southeast axis,[13] and, as noted above, has a 4 percent chance of an M_w 6.7 earthquake occurring between 2002 and 2031. The project site has not yet been mapped as part of the Seismic Hazards Mapping Act. [14]

Other active faults in the vicinity of the project site that could affect proposed development include the San Andreas Fault Zone, and the Hayward, Calaveras, Rodgers Creek, Greenville, Cordelia, and the West Napa faults. These faults are considered active and capable of generating damaging earthquakes based on either historic fault rupture or on geologic evidence that clearly demonstrates faulting during Holocene time (within approximately the last 11,000 years).

Potentially active faults within 20 miles of the project site include the Lake Herman and Sky Valley

[9] United States Geological Survey, 2003. *Earthquake Probabilities in the San Francisco Bay Region: 2002 to 2031 – A Summary of Findings,* Open File Report 03-214.

[10] Wong, I.G., Ely, R.W., and Lollmann, A.C., 1988. Contemporary Seismicity and Tectonics of the Northern and Central Coast Ranges-Sierran Block Boundary Zone, California, Journal of Geophysical Research, V. 93, pp. 7813-7833.

[11] Wakabayashi, J. and Smith, D.L., 1994. Evaluation of Recurrence Intervals, Characteristic Earthquakes, and Slip Rates Associated with Thrusting along the Coast Range-Central Valley Geomorphic Boundary, California, Bulletin of the Seismological Society of America, Vol. 84, No. 6, pp.1960-1970.

[12] California Division of Mines and Geology (CDMG), 1993. *State of California Special Studies Zones, Vine Hill Quadrangle Map.*

[13] Right-lateral: if the trace of the fault were viewed while standing on one side during an event, it would appear that the ground on the other side of the fault moved to the right. Strike-slip: the sides are moving laterally relative to each other with little or no vertical movement.

[14] California Geological Survey (CGS), 2006. *State of California Seismic Hazard Zone Mapping Act of 1991.*

faults (both northeast of the project site), and the Antioch, Southampton, Livermore, Los Positas, and Midway faults. Faults that are considered to be potentially active do not have known Holocene displacement, but are young with respect to geologic time (evidence of activity in the last 2,000,000 years) and are considered to be possible earthquake sources.

c. Seismic and Geologic Hazards. The following section details seismic and other geologic hazards within the project site.

(1) Surface Rupture. Surface rupture occurs when the ground surface is broken due to fault movement during an earthquake. The location of surface rupture generally can be assumed to be along an active or potentially active major fault trace. No known active fault traces cross the project site; therefore, the potential for fault rupture at the project site is low.[15]

(2) Ground Shaking and Peak Acceleration. Ground shaking is a general term referring to all aspects of motion of the earth's surface resulting from an earthquake, and is normally the major cause of damage in seismic events. The extent of ground shaking is controlled by the magnitude and intensity of the earthquake, distance from the epicenter, and local geologic conditions. The Modified Mercalli Intensity Scale (MMI) is the most commonly used scale for measurement of the subjective effects of earthquake intensity (See Table IV.C-1). A related concept, acceleration, is measured as a fraction or percentage of the acceleration under gravity (g).

The closest known active faults are the Concord and Green Valley faults (often referred to as the Concord-Green Valley fault system, since they may represent portions of one continuous fault on either side of the Carquinez Strait) approximately 2 miles east of the project site.[16]

The City of Benicia General Plan indicates that those areas approximately corresponding to Jefferson Ridge would be subject to a moderate level of ground shaking amplification. The remainder of the project site would be subject to a high or very high level of ground shaking amplification.[17] Based on Association of Bay Area Governments (ABAG) studies, the estimated intensity for ground shaking at the project site during an earthquake on the Concord-Green Valley fault system would range from MMM VIII (very strong) on the northern portion of the site to MMI IX (violent) in the central portion of the site (around Adams Street) and MMMI X (very violent) in the southern portion of the site (see Figure IV.C-4, Anticipated Ground Shaking). The result of very violent shaking on the site would be the destruction of most masonry and frame structures, including foundations.[18]

Estimates of peak ground acceleration (how hard the ground shakes at a given location) have been made for the Bay Area based on probabilistic models that account for multiple seismic sources. Under these models, consideration of the probability of expected seismic events is incorporated into the determination of the level of ground shaking at a particular location. The expected peak horizontal acceleration (with a 10 percent chance of being exceeded in the next 50 years) generated by any of the seismic sources potentially affecting the project area, including the project site, is estimated by the

[15] Graymar, R.W., Jones, D.J., Brabb, EE., 1999. *Geology of the Cordelia and the Northern Part of the Benicia 7.5 Minute Quadrangles, California.* From the Digital Map Database, Open-File Report 99-162.

[16] California Geological Survey, 1999. Special Publication 42: Fault Rupture Hazard Zones in California.

[17] Benicia, City of, 1999. *City of Benicia General Plan, Community Health and Safety Maps.* Adopted June 15.

[18] Association of Bay Area Governments, 2007. Shaking Maps. Website: www.abag.ca.gov. April 25.

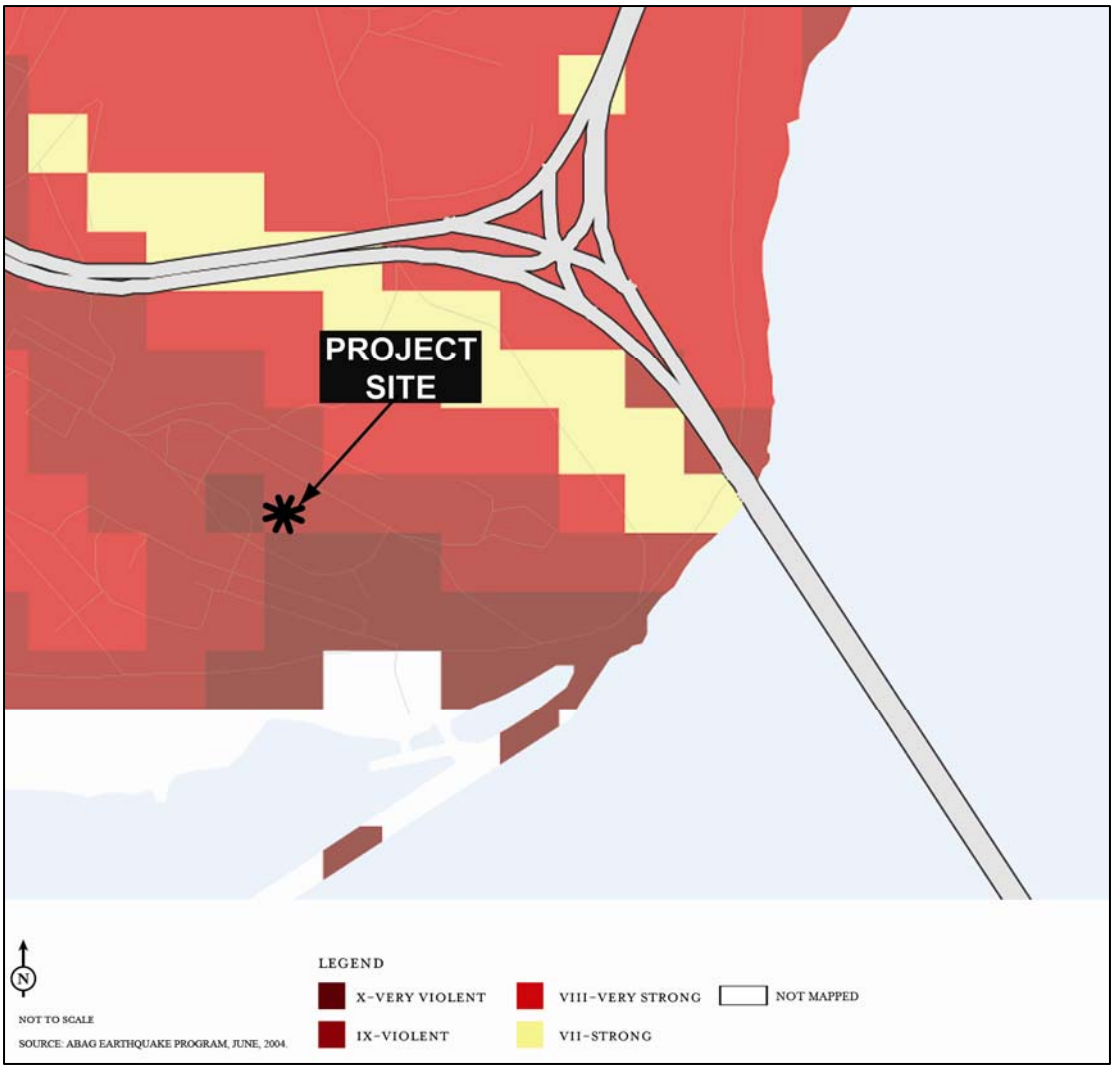


Figure IV.C-4: Anticipated Ground Shaking

California Geological Survey as 0.514 acceleration due to gravity (g).[19] This level of ground acceleration at the project site is a potentially significant hazard.

(3) Liquefaction and Lateral Spreading. Liquefaction is the temporary transformation of loose, saturated granular sediments from a solid state to a liquefied state as a result of seismic ground shaking. In the process, the soil undergoes transient loss of strength, which commonly causes ground displacement or ground failure to occur. Since saturated soils are a necessary condition for liquefaction, soil layers in areas where the groundwater table is near the surface have a higher liquefaction potential than those in which the water table is located at greater depths.

[19] California Geological Survey, 2007. *Probabilistic Seismic Hazards Mapping Ground Motion Page*, Peak Horizontal Ground Acceleration 10% Probability in 50 Years, Firm Rock/Soft Rock/Alluvium Condition. April 25.

Table IV.C-1: Modified Mercalli Intensity Scale

I	Not felt except by a very few under especially favorable circumstances.
II	Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.
III	Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration like passing of truck. Duration estimated.
IV	During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V	Felt by nearly everyone, many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop.
VI	Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.
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 motor cars.
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. Collapse of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving motor cars disturbed.
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.
X	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks.
XI	Few, if any, (masonry) structures remain standing. Bridges destroyed. Board fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.
XII	Damage total. Practically all works of construction are damaged greatly or destroyed. Waves seen on ground surface. Lines of sight and level are distorted.

Source: California Geological Survey, 2002, *How Earthquakes and Their Effects are Measured*: Note 32

According to the City of Benicia General Plan, the portion of the project site generally south of Adams Street is susceptible to potential liquefaction, lateral spreading, and settlement hazards.[20] This mapping is generally consistent with that produced by ABAG. The ABAG liquefaction maps characterize the area south of Grant Street/Polk Street as having a high or very high liquefaction hazard (see Figure IV.C-5, Anticipated Liquefaction). The northern portion of the project site, including Jefferson Ridge and its vicinity, according to the ABAG maps, has a very low susceptibility to liquefaction.[21] The low potential for liquefaction is confirmed by geotechnical investigations that have been conducted in the area.[22]

[20] Benicia, 1999. op. cit.

[21] Association of Bay Area Governments, 2007. Liquefaction Maps. Website: www.abag.ca.gov. April 25.

[22] ENGEO, Inc., 2000. *Geotechnical Exploration, Bortolazzo Property, Benicia, California.* May 15.

Holdrege and Kull, 2006. *Geotechnical Engineering Investigation Report for Grant Street Row Residential Development*. January 29.

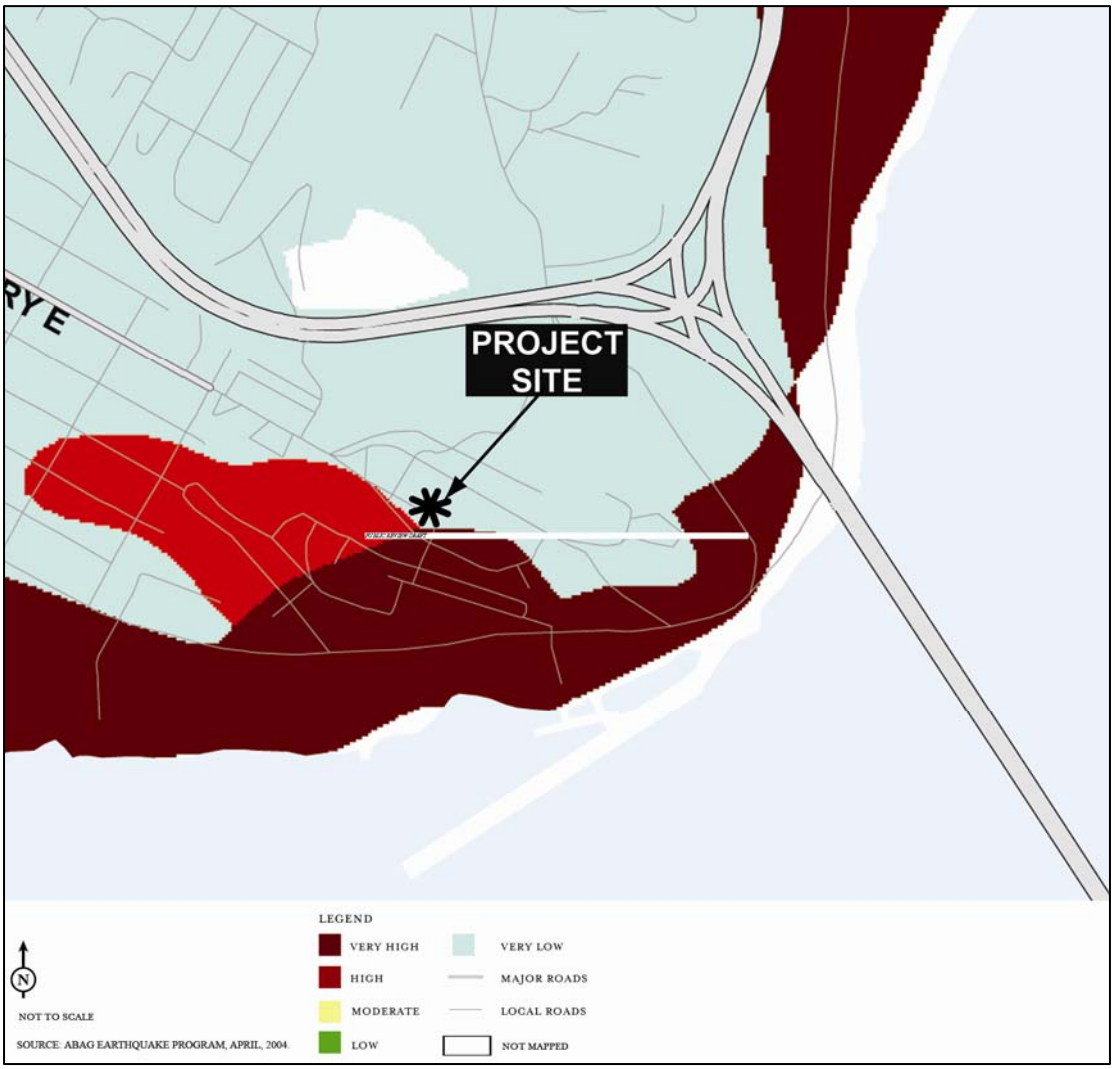


Figure IV.C-5: Anticipated Liquefaction

Lateral spreading is a form of horizontal displacement of soil toward an open channel or other "free" face, such as an excavation boundary. Lateral spreading can result from either the slump of low cohesion unconsolidated material or more commonly by liquefaction of either the soil layer or a subsurface layer underlying soil material on a slope.[23] The lateral spreading hazard tends to mirror the liquefaction hazard for a project, and by definition needs an open channel or "free" face to expand into; this can include temporary excavations resulting from the construction process.

Regional maps provided by ABAG indicate that the area south of Grant Street/Polk Street has a high or very high liquefaction hazard. Therefore, the risk of lateral spreading in this portion of the project site is considered to be high during the construction/excavation period.[24]

[23] Rauch, Alan F., 1997. EPOLLS: An Empirical Method for Predicting Surface Displacements due to Liquefaction-Induced Lateral Spreading in Earthquakes, Ph. D. Dissertation, Virginia Tech, Blacksburg, VA.

[24] ABAG, 2003. op. cit.

(4) Expansive Soils. Expansion and contraction of volume can occur when certain soils undergo alternating cycles of wetting (swelling) and drying (shrinking). During these cycles, the volume of the soil changes markedly. As a consequence of such volume changes, structural damage to buildings and infrastructure may occur if the potentially expansive soils are not considered in project design and during construction.

Many of the soils on the project site, including the Dibble-Los Osos clay loams, are expected to be moderately to highly expansive, and could undergo significant volume changes (swell and compression) when subjected to varying moisture content. Some of the bedrock underlying the site (including the mudstone in the north of the site), is also likely to be expansive.

(5) Slope Stability. Slope failure can occur as either rapid movement of large masses of soil ("landslide") or slow, continuous movement ("creep"). The primary factors influencing the stability of a slope are: 1) the nature of the underlying soil or bedrock, 2) the geometry of the slope (height and steepness), 3) rainfall, and 4) the presence of previous landslide deposits. In addition to these general factors, slope stability is also influenced by human activities, including placement of loads (e.g., buildings and other improvements) and excavation activities. While all slopes respond to the force of gravity by some amount of downslope movement of materials, it is the relatively rapid slope failures that present engineering challenges for developments on slopes.

According to ABAG mapping, the project site has not been highly susceptible to landslides (see Figure IV.C-6, Historic Landslides). The area of the project site generally north of Grant Street, and in the extreme southwestern corner of the project site (near Lincoln and Jackson Streets) has been the location of a few landslides in the past.

The City of Benicia General Plan indicates that the portion of the project site generally north of Jefferson Street is subject to potential landslide and debris flow hazards. The remainder of the project site is relatively flat, and has not been subject to significant landslides. However, the cut and fill, and engineered slopes on the site that have been created in the past may add to landslide hazards in the steeper portions of the site (i.e., around Jefferson Ridge).[25]

(6) Settlement and Differential Settlement. Differential settlement or subsidence could occur if buildings or other improvements were built on low-strength foundation materials (including imported non-engineered fill) or if improvements straddle the boundary between different types of subsurface materials (e.g., a boundary between native material and fill). Although differential settlement generally occurs slowly enough that its effects are not dangerous to inhabitants, it can cause significant building damage over time. Portions of the project site that may contain loose or uncontrolled (non-engineered) fill may be susceptible to differential settlement. Where structures cross boundaries between native bedrock and engineered fill, differential settlement can occur due to differences in density and strength of sub-grade materials. Generally, it is required that building pads be constructed by a process of over-excavation and emplaced engineered fill to achieve stable support for footing- or slab-based foundation systems.

[25] Pike, Richard J., et. al., 2001. *Map and Map Database of Susceptibility to Slope Failure by Sliding and Earthflow in the Oakland Area, Californi*a.

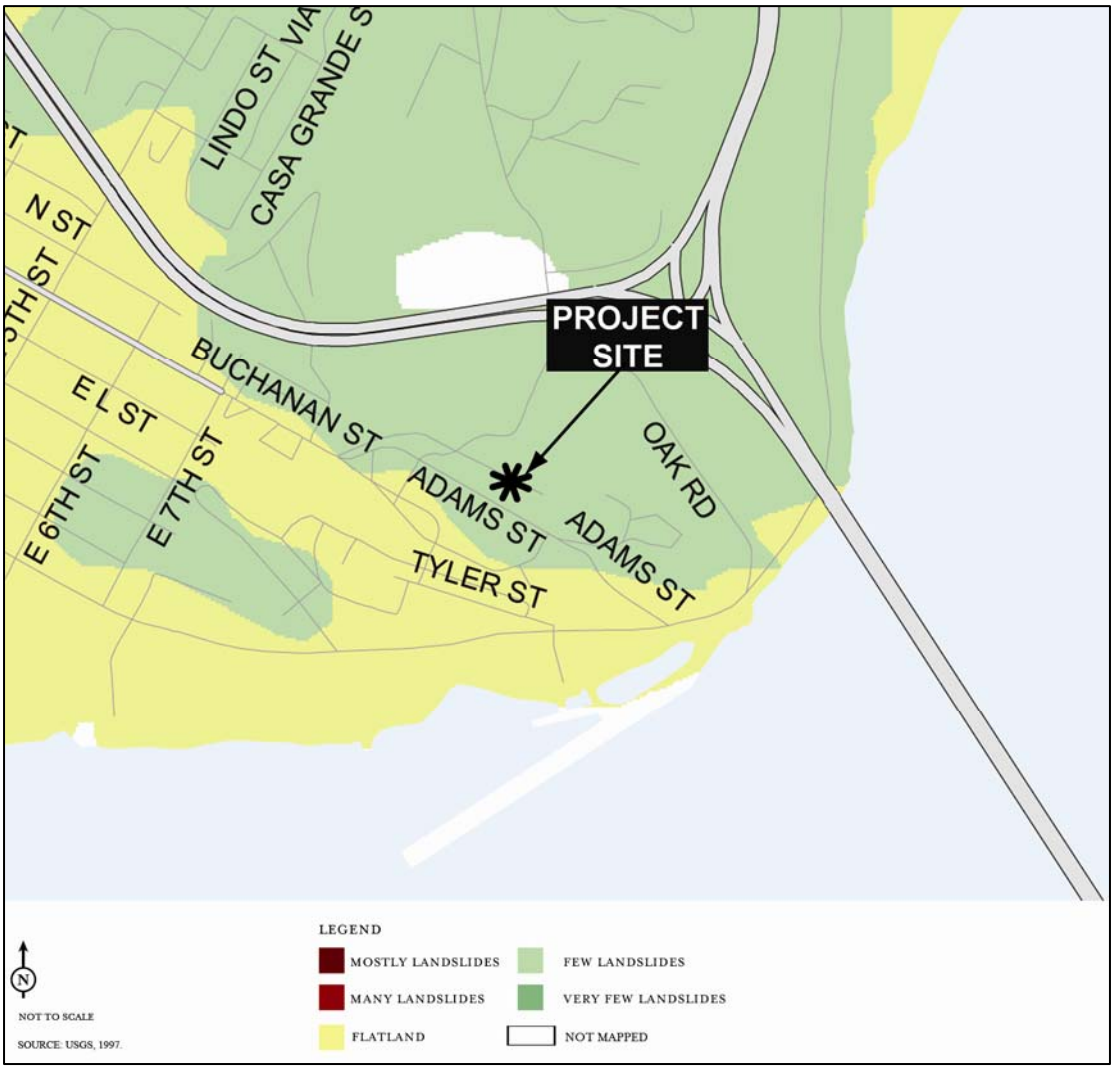


Figure IV.C-6: Historic Landslides

Due to historical uses of the project site, cut and fill may have occurred in select locations, including the location of roadways and building pads. In addition, the extreme southern portion of the site likely contains artificial fill placed over historic salt marshes. All areas of fill may pose settlement hazards.

d. City of Benicia General Plan. The General Plan includes several goals, policies and programs that are related to protecting people and property from potential or known geologic and seismic hazards.

Responses to Hazards

- *Community Hazards Goal 4.11:* Minimize harm from geologic hazards.

- *Community Hazards Program 4.11.A:* Require geotechnical engineering reports to address project site stability and building foundation integrity for projects involving substantial grading.[26]
- *Community Hazards Program 4.11.C:* Require peer review of geotechnical engineering reports if it is determined that City staff does not have the technical expertise to review such reports.
- *Community Hazards Program 4.11.D:* Prepare a planning-level geologic hazards map of the Planning Area as needed.
- *Community Hazards Program 4.11.E:* Update the geologic hazards map as new information becomes available.

2. Draft Specific Plan

The Draft Specific Plan does not contain goals, policies, or actions that apply directly to geology and soils.

3. Impacts and Mitigation Measures

This section analyzes the impacts related to geology, soils, and seismicity that could result from implementation of the Draft Specific Plan. The section begins with criteria of significance which establish the thresholds for determining whether a project impact is significant. The latter part of this section presents the potential geology, soils and seismicity impacts associated with the proposed project. Mitigation Measures are provided as appropriate. Because there is variability in geologic conditions throughout the site, certain impacts and mitigation measures pertain only to certain development zones.

a. Criteria of Significance. The project would have a significant geologic, soils, or seismicity impact if it would:

- 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 issued by the State Geologist for the area or based on other substantial evidence of a known fault? Refer to Division of Mines and Geology Special Publication 42;
  - Strong seismic ground shaking;
  - Seismic-related ground failure, including liquefaction; or
  - Landslides.
- Result in the loss of availability of a known mineral resource that would be of value to the region and the residents of the State; or
- Result in the loss of availability of a locally-important mineral resource recovery site delineated on a local general plan, specific plan or other land use plan.

[26] To grade property or install drainage improvements within the City of Benicia, sponsors must obtain a grading permit. In addition, sponsors need a zoning permit from the City Planning Department. Plans and related information for the proposed grading operation must be submitted to the Engineering Division. Grading work requires the installation of erosion control measures and may require a storm water discharge permit from the State Water Resources Board as determined by the Engineering Division. For major grading work, submittal of a soils (geotechnical) report prepared by a licensed engineer will be required. Submittal of grading plans and the soils report are required with the grading permit application.

b. Less-than-Significant Geology, Soils and Seismicity Impacts. The following discussion describes the less-than-significant impacts associated with implementation of the Draft Specific Plan that are common to the four development zones (Jefferson Ridge Zone, Adams Street Zone, Grant Street Zone, and South of Grant Zone).

(1) Fault Rupture. The development of the proposed project would not be subject to, or contribute to, on- or off-site fault rupture, as there are no known active faults crossing the project site.

(2) Subsidence. The proposed project would not contribute to aquifer related subsidence, because groundwater would not be extracted.

(3) Mineral and Energy Resources. The proposed project would not hinder energy reserve development, because the project site is not located over a known gas, oil or geothermal field.[27] Implementation of the proposed project would not result in the loss of a known mineral resource; as noted in the setting section, the project site is not identified in the Benicia General Plan or the Benicia Mineral Resource Management Study as an area of mineral resource conservation.[28] Potential impacts associated with erosion and loss of topsoil are discussed in Section IV.D, Hydrology and Water Quality of this EIR. Impacts associated with energy use are discussed in Section IV.N, Sustainability and Energy.

c. Significant Geology, Soils and Seismicity Impacts and Mitigation Measures for Specific Zones. The following discussion describes the geology, soils, and seismicity-related impacts by topical area and by zone (where impacts vary by zone).

(1) Seismic Ground Shaking. All structures in the greater San Francisco Bay Area could be affected by ground shaking in the event of an earthquake. The amount of ground shaking depends on the magnitude of the earthquake, the distance from the epicenter, and the type of earth materials in between. Very strong to very violent ground shaking is expected at the project site during an earthquake on the Concord-Green Valley fault. In addition, strong seismic shaking could occur on the site during earthquakes on other regional faults. The expected level of seismic shaking could cause injuries and fatalities and extensive structural and non-structural damage to existing and future buildings within the site; most masonry and frame structures, and some well-built wooden structures would be destroyed.

<u>Impact GEO-1 (All Zones)</u>: Seismically-induced ground shaking in the Specific Plan Area could result in damage to life and/or property at <u>new</u> development sites. (S)

New development within the Specific Plan Area (see Impact and Mitigation Measure GEO-2 for adaptively reused buildings) could be subject to hazards associated with strong seismic ground-shaking. Implementation of the following mitigation measure on proposed development sites would reduce this impact to a less-than-significant level:

> <u>Mitigation Measure GEO-1a (All Zones)</u>: Prior to the issuance of any site-specific grading or building permit in the Specific Plan Area, a final design-level geotechnical investigation report shall be prepared and submitted to the City of Benicia Community Development

[27] CDC, 2000. *Energy Map of California, Third Edition*, Division of Oil, Gas or Geothermal Resources.

[28] EIP Associates, 1990. *Benicia Mineral Resource Management Study*. January.

Department for review and confirmation that the proposed project fully complies with the California Building Code (Seismic Zone 4). The report shall determine the project site's geotechnical conditions and address potential seismic hazards such as seismic shaking. The report shall recommend foundation techniques appropriate to minimize seismic damage. In addition, the geotechnical investigation shall conform to the California Division of Mines and Geology (CDMG) recommendations presented in the *Guidelines for Evaluating Seismic Hazards in California*, CDMG Special Publication 117.

All subsequent parcel-specific development and building plans shall comply with the California Building Code (Seismic Zone 4) requirements, or requirements superceding California Building Code requirements. In addition, future development plans shall comply with the requirements of the final design-level geotechnical investigation report unless superseded by a parcel-specific design-level geotechnical investigation report.

All mitigation measures, design criteria, and specifications set forth in the geotechnical reports shall be fully implemented. (LTS)

Impact GEO-2 (All Zones): Seismically-induced ground shaking in the Specific Plan Area could result in damage to life and/or property in adaptively reused buildings. (S)

The historic buildings within the project site would be retained and adaptively reused as part of Draft Specific Plan implementation (and could be used more intensively than under existing conditions). These buildings were constructed prior to current building codes and the establishment of seismic standards. Select buildings may have been seismically retrofitted, but others may be highly susceptible to earthquake-induced damage.

Implementation of the following mitigation measure in all adaptively reused buildings in the Specific Plan Area site would reduce this impact to a less-than-significant level:

Mitigation Measure GEO-2 (All Zones): Prior to approval of an occupancy permit for redeveloped buildings in the Specific Plan Area, a design-level seismic upgrade report shall be prepared, submitted to the City for review and approval, and the upgrade recommendation(s) shall be fully implemented. Prior to approving the design-level report, the City shall independently review the seismic upgrade report to determine the adequacy of the hazards evaluation and proposed mitigation measures. Such reviews shall be conducted by a structural engineer or registered civil engineer who has competence in the field of seismic hazard evaluation and mitigation. (LTS)

It is acknowledged that seismic hazards cannot be completely eliminated even with site-specific geotechnical investigations and advanced building practices (as provided in the two mitigation measures above). However, exposure to seismic hazards is a generally accepted part of living in the San Francisco Bay Area and therefore the mitigation measures described above reduce the potential hazards associated with seismic activity to a less-than-significant level.

(2) Shrink-Swell Soils and Settlement. The Dibble-Los Osos clay loams, which are present throughout the Specific Plan Area in all four zones, are moderately to highly expansive, and could cause damage to proposed structures. Portions of the bedrock underlying the project site and Reyes silty clay in the extreme southern portion of the project site are also expected to be expansive. In

addition, historic fills on the project site could cause differential settlement, resulting in long-term damage to structures.

Impact GEO-3 (All Zones): Damage to structures or property related to shrink-swell potential of project soils and/or settlements of non-engineered fill could occur. (S)

As previously described, many of the soils underlying the project site have a moderate to high shrink/swell potential. In addition, the project site likely contains artificial fill, which could result in long-term damage to buildings. Fills of different thickness and fills adjacent to cut areas where native soils are exposed at the surface could create the potential for differential settlements. The areas most susceptible to differential settlement are those where thick fills are adjacent to native soils. With new loads placed in areas of net fill, the new loading could trigger settlement. If the settlement is not uniform (i.e., differential settlement), structural damage could occur. Buried utilities may also be subject to differential settlements along their alignments, resulting in damage and potential disruption of utility service.

Implementation of the following two-part mitigation measure would reduce the potential impacts associated with the moderate to high shrink-swell potential and differential settlement to a less-than-significant level.

> Mitigation Measure GEO-3a (All Zones): Prior to the issuance of a site-specific grading permit or the construction of new roadways, sidewalks, and utility lines, a design-level geotechnical investigation shall be prepared by licensed professionals and approved by the City of Benicia Community Development and Public Works Departments. The design-level geotechnical investigation shall include measures to ensure potential damages related to expansive soils and differential settlement are minimized. Mitigation options for expansive soils may range from removal of the problematic soils and replacement, as needed, with properly conditioned and compacted fill, to design and construction of improvements to withstand the forces exerted during the expected shrink-swell cycles and settlements. Recommendations for specific foundation designs which minimize the potential for damage related to settlement shall be presented in the report.
>
> Mitigation Measure GEO-3b (All Zones): Designs of all open space and park areas shall be reviewed and approved by the City of Benicia Community Development Department. The designs of all open space and park areas shall incorporate low water-need plantings to minimize the potential for damage to pavements, utilities, and structures from expansive soils. The use of similar landscaping shall be encouraged at private development parcels by providing information to new tenants regarding the relationship between irrigation and subsequent property damage. A document which describes the potential for damage from expansive soils from over-irrigation and includes solutions such as drought-tolerant plant material and drip irrigation systems shall be prepared by the applicant and provided to all occupants of the Plan Area. (LTS)

(3) Liquefaction and Other Ground Failure/Displacement. According to ABAG maps, the Jefferson Ridge Zone has a low susceptibility to liquefaction. This mapping is consistent with the physical characteristics of Jefferson Ridge, where the water table is not located close to the surface and the underlying soil conditions are not loose, saturated, and granular (characteristics that increase the potential for liquefaction). Therefore, mitigation is not required to reduce liquefaction hazards in

the Jefferson Ridge Zone.

However, liquefaction potential is high or very high in the lower-lying portions of the project site, including the Adams Street Zone, Grant Street Zone, and South of Grant Street Zone. Liquefaction of sediments underlying new development in these zones could cause ground displacement and ground failure, including lateral spreading and flows.

Impact GEO-4 (Adams Street Zone, Grant Street Zone, and South of Grant Street Zone): Damage to structures or property related to liquefaction, ground displacement, and ground failure could occur. (S)

Implementation of the following mitigation measure would reduce impacts associated with liquefaction, ground displacement, and ground failure to a less-than-significant level.

> Mitigation Measure GEO-4 (Adams Street Zone, Grant Street Zone, and South of Grant Street Zone): Prior to the issuance of a site-specific grading permit or the construction of new roadways, sidewalks, and utility lines, a design-level geotechnical investigation shall be prepared by licensed professionals and approved by the City of Benicia Community Development and Public Works Departments. The design-level geotechnical investigation shall include measures to ensure potential damages related to liquefaction, ground displacement, and ground failure are minimized. (LTS)

(4) Landslides. Based on ABAG mapping, the project site (much of which is gently sloping or flat) is not highly susceptible to landslides. However, minor landslides could occur in the steeper portions of the Jefferson Ridge Zone. No mitigation is required to reduce landslide hazards in the Adams Street Zone, Grant Street Zone, and South of Grant Street Zone.

Impact GEO-5 (Jefferson Ridge Zone): Damage to structures or property could occur at the Jefferson Ridge Zone due to existing or induced slope instability resulting in landsliding. (S)

The area in the vicinity of Jefferson Ridge includes relatively steep slopes on which landslides have occurred in the past. Construction of buildings or site improvements within or adjacent to landslides or slopes prone to landsliding could result in damage during new or continued slope movement. The potential for slope failure would increase during the expected very strong to very violent seismic shaking (particularly if the causative earthquake occurs during the rainy season when soils are saturated).

Implementation of the following two-part mitigation measure would reduce potential slope instability impacts to a less-than-significant level:

> Mitigation Measure GEO-5a (Jefferson Ridge Zone): Prior to the issuance of any site-specific grading or building permit, a design-level geotechnical investigation report shall be prepared and submitted to the City of Benicia Community Development Department for review and confirmation that the proposed project fully complies with the California Building Code (Seismic Zone 4). The applicant shall incorporate all recommendations of the final geo-technical investigation report regarding mitigation of slope instability into the project design.
>
> Mitigation Measure GEO-5b (Jefferson Ridge Zone): All grading plans, cut and fill slopes,

compaction procedures, and retaining structures shall be designed by a licensed professional engineer and inspected during construction by a licensed professional engineer (or representative) or Certified Engineering Geologist (or representative). All designs shall be submitted to, and approved by, the City of Benicia prior to implementation. (LTS)