G. GEOLOGY, SOILS, AND SEISMICITY

This chapter describes the existing geologic conditions, including geologic and seismic hazards, for the Larkspur SMART Station Area Plan (Plan) area, summarizes the applicable regulatory framework, identifies potential significant impacts regarding geology, soils, and seismicity for development within the Plan area, and provides mitigation measures to reduce these impacts to a less-than-significant level.

1. Geologic Setting

The geology, topography, soils and mineral resources within the Plan area are described below, as well as potential seismic and geologic hazards. Information for this section is drawn from regional geologic reports and maps from the United States Geological Survey (USGS), the California Geological Survey (CGS), the Natural Resources Conservation Service (NRCS), and other public sources.

a. Geology. The Plan area is located within the Central Coast Ranges geomorphic province, which is characterized by northwest-southeast trending valleys and ridges. The geology underlying most of the Plan area consists of folded, faulted, sheared, and altered sedimentary, igneous, and metamorphic rock (mélange) of the Jurassic-Cretaceous age Franciscan complex.[1] The portion of the Plan area adjacent to and south of Corte Madera Creek consists of man-made fill overlying Bay Mud, marine, and marsh deposits.[2] Typical fill thickness underlying the Ferry Terminal, south of Sir Francis Drake Boulevard, is approximately 6 feet. The fill consists of Creek channel dredging spoils placed in 1924 which were overlaid by dry fill placed intermittently until 1960, with major fill operations occurring in the late 1940s and late 1950s.[3]

b. Topography. The Plan area topography varies, with the area adjacent to and south of Corte Madera Creek relatively level at an elevation of less than 25 feet above NGVD,[4] and the northern portion of the Plan area containing relatively steep hillsides (greater than 15 degrees) and ridges at elevations ranging from approximately 150 to 400 feet above NGVD.[5] The northeastern portion of the Plan area, north of Larkspur Landing Circle, also includes man-made hill slopes created by pre-1948 quarrying. The portions of the Plan area with steep slopes are potentially subject to landslide hazards, triggered by earthquakes or severe storm events, as discussed below.

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

[1] United States Geological Survey, 2000. *Geologic Map and Map Database of Parts of Marin, San Francisco, Alameda, Contra Costa, and Sonoma Counties, California*, Report MF-2337, Version 1.0.

[2] Ibid.

[3] Larkspur, City of, 1973. *Larkspur Ferry EIR*. Pages 11-12.

[4] National Geodetic Vertical Datum of 1988, which is roughly equivalent to mean sea level.

[5] United States Geological Survey, 2012. San Rafael Quadrangle 7.5' series Topographic Map.

A summary of soil survey data from the NRCS is presented below in Table IV.G-1. This data indicates that slightly more than 40 percent of surface soils consist of man-made fill, and another 9 percent are former quarry pits. Most of the remaining surface soils are mapped as Tocaloma-McMullin and Tocaloma-Saurin complexes (Tocaloma series). Tocaloma series soils consist of moderately deep, well-drained, fine-grained soils. In the Plan area, they are located on relatively steep slopes (from 15 to 50 degrees). These soils present low corrosivity to steel, with low linear extensibility, and generally present minimal potential for shrink-swell damage to structures. The potential geologic hazards associated with the soils within the Plan area are discussed below.

Table IV.G-1: Soils in the Plan Area

Soil Association/Name	Slope (degrees)	Approximate Acreage within the Study Area (percentage)	Linear Extensibility (shrink-swell)	Corrosivity (uncoated steel)
Blucher-Cole complex	2 to 5	1.2	Low	High
Los Osos-Urban land-Bonnydoon	15 to 30	3.0	Moderate	N/A
Pits, quarries	N/A	9.3	N/A	N/A
Saurin-Bonnydoon complex	15 to 30	1.1	Moderate	Moderate
Tocaloma-McMullin	30 to 50	32.8	Low	Low
Tocaloma-Saurin	15 to 30	12.2	Low	Low
Xerothents, fill	0 to 9	40.5	N/A	N/A

Source: United States Department of Agriculture, 2013. *Web Soil Survey*. Website: websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx (accessed January 15).

d. Mineral Resources. Although the northeastern portion of the Plan area was used for aggregate mining prior to 1948, no part of the Plan area is designated as a mineral resource site under the State Mining and Reclamation Act of 1975 (SMARA).[6] Based on the requirements of SMARA, this suggests that there are no mineral deposits present in the Plan area that are suitable as marketable commodities with a threshold gross selling price of at least $5 million in 1978 dollars. There are no natural gas, oil, or geothermal resources identified as being located in or adjacent to the Plan area.[7,8]

e. Seismic Conditions. The Plan area is located in the seismically active San Francisco Bay Area. The main feature generating the seismic activity in the region is the tectonic plate boundary between the North American and Pacific plates. Locally, this boundary is referred to as the San Andreas Fault Zone (SAFZ) and includes numerous active faults found by the CGS under the Alquist-Priolo Earthquake Fault Zoning Act to be "active" (i.e., to have evidence of fault rupture in the past 11,000 years). Some of the major active faults near the Plan area within the SAFZ include the San Andreas, Hayward, San Gregorio, and Rogers Creek faults. In a fact sheet published in 2003, the USGS estimated that there was a 62 percent probability that between 2003 and 2032, a 6.7 or greater magnitude earthquake will occur in the San Francisco Bay Region. The probability of a 6.7 magnitude or greater earthquake occurring along individual faults was estimated to be 21 percent along the San

[6] Marin County, 2005. *Geology, Mineral Resources and Hazardous Materials Technical Background Report*. Appendix K-1 of the Marin Countywide Plan, Updated November.

[7] California Department of Conservation, 2000. *Energy Map of California, Map S-2*, 3rd Edition.

[8] California Department of Conservation, 2001. *Oil, Gas, and Geothermal Fields in California, Map S-1*.

Andreas Fault, 27 percent along the Hayward-Rodgers Creek Fault, and 10 percent along the San Gregorio Fault. Figure IV.G-1 shows the Fault Activity Map for the San Francisco Bay Region.

Geologic and soil conditions in an area can influence the shaking effects of an earthquake. The Association of Bay Area Governments (ABAG) earthquake hazard mapping indicates a Magnitude 7.9 event on the San Andreas Fault (similar to the 1906 earthquake) would result in strong to violent (MMI VI/IX) shaking in the Plan area. Effects of ground shaking could be magnified by seismic-related liquefaction and landslides. Based on ABAG/USGS mapping, the soils in the Plan area range from a low hazard for liquefaction susceptibility in the hills to very highly susceptible in the filled areas adjacent to and south of Corte Madera Creek, as shown in Figure IV.G-1. Earthquake induced slope stability may also be an issue in portions of the Plan area with steep slopes. The Marin County Countywide Plan maps historic landslides, as well as debris zones, that could be sources for landslides in the Plan area.

f. Seismic and Geologic Hazards. This section describes the hazards associated with the geologic conditions and the potential for seismic events in the Plan area.

(1) Fault Rupture Damage. Surface rupture occurs when the ground surface is broken due to fault movement during an earthquake. Faults in the Plan area vicinity identified by the CGS are shown in Figure IV.G-1. The location of surface rupture generally can be assumed to be along an active major fault trace.

The nearest active faults to the Plan area are the San Andreas Fault, located approximately 7 miles to the southwest, and the Hayward fault, located approximately 9 miles to the east (shown in Figure IV.G-1). The maximum expected earthquakes for these faults is estimated to be magnitude (M_w) 7.9 and 7.1, respectively.[9] No known active faults or fault-rupture hazard zones are present within the Plan area, and the fault rupture hazard is therefore considered to be very low.[10]

(2) Seismic Shaking. Seismic shaking (or 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. Magnitude is a measure of the energy released by an earthquake; it is assessed by seismographs that measure the amplitude of seismic waves. Intensity is a subjective measure of the perceptible effects of seismic energy at a given point and varies with 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 and is further described in Table IV.G-2. Intensity can also be quantitatively measured using accelerometers (strong motion seismographs) that record ground acceleration at a specific location, a measure of force applied to a structure under seismic shaking. Acceleration is measured as a fraction or percentage of the acceleration under gravity (g). In addition

[9] California Department of Conservation, 1996. Division of Mines and Geology. *Probabilistic Seismic Hazard Assessment for the State of California, Open-File Report 96-08*.

[10] California Geological Survey, 2010. *Alquist-Priolo Earthquake Fault Zone Maps*. Website: www.quake.ca.gov/gmaps/ap/ap_maps.htm (accessed January 15, 2013). December.

to the San Andreas and Hayward Faults, noted above, other regional faults are capable of producing ground shaking in the Plan area.

Estimates of the peak ground acceleration have been made by the State for the 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 Plan area is estimated by the California Geological Survey at about 0.466g on firm rock areas and about 0.482g[11] on fill or alluvium.[12] This level of ground shaking is a potentially significant hazard.

Table IV.G-2: Modified Mercalli Scale

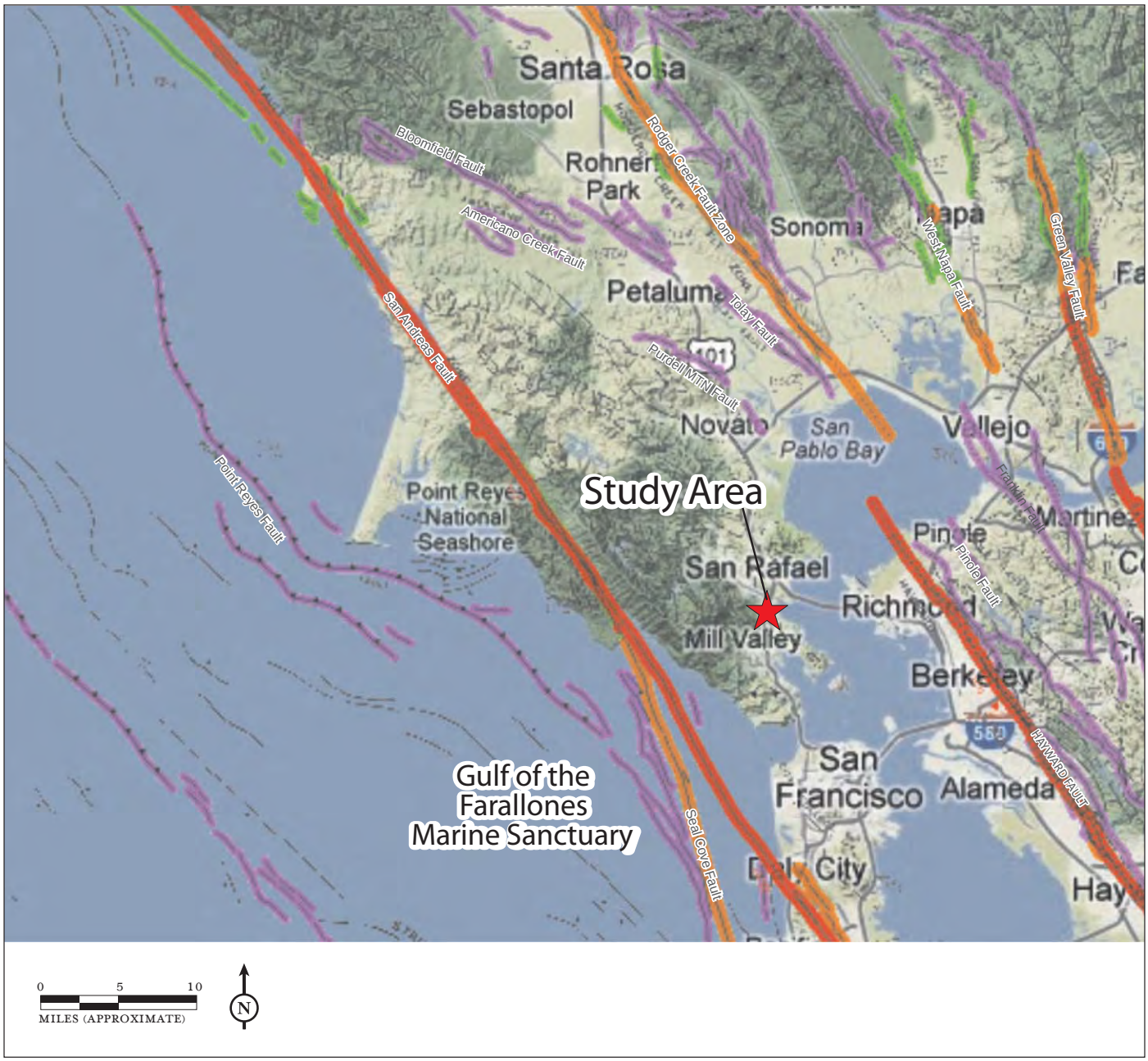
M[a]	Category	Definition
	I	Not felt except by a very few under especially favorable circumstances.
3	II	Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.
	III	Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration like passing of truck. Duration estimated.
4	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 awaken. 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.
5	VI	Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.
6	VII	Everybody runs outdoors. Damage negligible in building 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. Fall 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.
7	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.
8	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. Broad 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.

[a] Richter magnitude correlation.

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

[11] Measured as a fraction or percentage of the acceleration compared to gravity (g).

[12] California Geological Survey, 2012. *Probabilistic Seismic Hazards Mapping Ground Motion Page*. Website: www.consrv.ca.gov/cgs/rghm/pshamap/pshamain.html (accessed January 15, 2013).



LSA

FIGURE IV.G-1

EXPLANATION

Fault traces on land are indicated by solid lines where well located, by dashed lines where approximately located or inferred, and by dotted lines where concealed by younger rocks or by lakes or bays. Fault traced are queried where continuation or existence is uncertain.

Fault Classification Color Code (Indicating Recency of Movement)

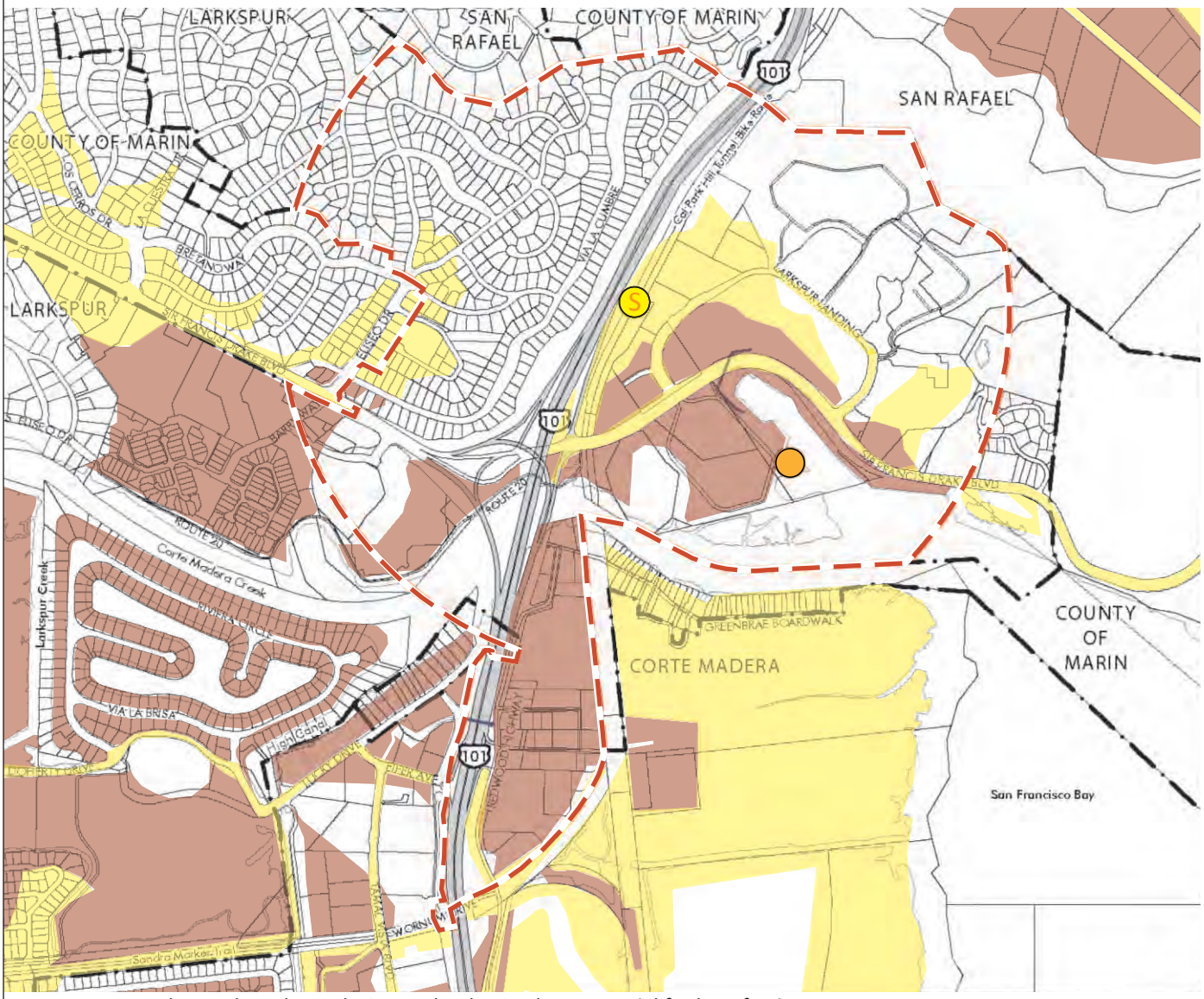
- Fault along which historic (last 200 years) displacement has occurred
- Holocene fault displacement (during past 11,700 years) without historic record
- Late Quaternary fault displacement (during past 700,000 years)
- Quaternary fault (age undifferentiated)
- Pre-Quaternary fault (older than 1.6 million years) or fault without recognized Quaternary displacement

City of Larkspur SMART Station Area Plan EIR

Fault Activity Map

SOURCES: BASELINE, 2013; CALIFORNIA DEPARTMENT OF CONSERVATION, CALIFORNIA GEOLOGICAL SURVEY, 2010, GEOLOGIC DATA MAP NO. 6, 2010 FAULT ACTIVITY MAP OF CALIFORNIA. WEBSITE ACCESSED AT HTTP://WWW.QUAKE.CA.GOV/GMAPS/FAM/FAULTACTIVITYMAP.HTML.

I:\BMD1201 Larkspur SMART\figures\EIR\Fig_IVG1.ai (5/28/13)



Note: Unmapped areas have been designated as having low potential for liquefaction.

LSA

High Liquefaction Susceptibility

Moderate Liquefaction Susceptibility

Study Area Boundary

City Boundary

Smart Station Location

Larkspur Ferry Terminal

FIGURE IV.G-2

City of Larkspur SMART Station Area Plan EIR

Liquefaction Hazard Areas

SOURCES: CITY OF LARKSPUR; ABAG., 2013.

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(3) Liquefaction. Liquefaction is the rapid transformation of saturated, loose, fine-grained sediment to a fluid-like state because of earthquake 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 higher liquefaction potential than those in which the water table is located at greater depths. Liquefaction potential increases in the vicinity of the San Francisco Bay and locally near creeks, such as Corte Madera Creek in the Plan area, where loose granular sediments have accumulated as a result of stream processes. The potential for liquefaction also depends on soil conditions and groundwater levels, which may fluctuate. Liquefaction has resulted in substantial loss of life, injury, and damage to property. In addition, liquefaction increases the hazard of fires because of explosions induced when underground gas lines break, and because the breakage of water mains substantially reduces fire suppression capability. In general, where there is any potential for liquefaction, site-specific studies are needed to determine the extent of the hazard if development were to occur.

Lateral spreading is a form of horizontal displacement of soil toward an open channel or other "free" face, such as an excavation boundary. Ground shaking, especially when inducing liquefaction, may cause lateral spreading toward unsupported slopes. Areas most prone to lateral spreading are those that consist of fill material that has been improperly engineered, that have steep, unstable banks, and that have high groundwater tables. Damage caused by liquefaction and lateral spreading is generally most severe when liquefaction occurs within 15 to 20 feet of the ground surface. Much of the Plan area near and south of Corte Madera Creek has been mapped as having moderate or very high susceptibility to liquefaction, as shown in Figure IV.G-2.[13]

(4) Landsliding. The strong ground motions that occur during earthquakes are capable of inducing landslides, generally where unstable slope conditions already exist. In addition, heavy precipitation events can induce mudflows or debris flows in areas where soils on a hillslope or in a stream channel becomes saturated and unstable.

(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. Landslides are commonly triggered by unusually high rainfall and the resulting soil saturation, by earthquakes, or a combination of these conditions. Slopes greater than 15 degrees are located in the northwest portion of the Plan area, and steep, man-made slopes from historic quarrying operations are located in the northern portion of the Plan area.

(6) Expansive Soils. Expansion and contraction of volume can occur when expansive 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 building and infrastructure may occur if the potentially expansive soils were not considered in

[13] Association of Bay Area Governments, 2013. *Liquefaction Susceptibility Map*. Website: gis.abag.ca.gov/website/liquefactionsusceptibility/index.html (accessed January 15, 2013).

building design and during construction. Native soils in the Plan area range from low to moderate shrink-swell potential, as shown in Table IV.G-1. Moderate to high shrink-swell potential soils are classified as expansive soils and construction on these soils may require appropriate engineering to avoid structural damage.

(7) Subsidence. Subsidence is the lowering of the land-surface elevation. The mechanism for subsidence is generally related to groundwater pumping and subsequent consolidation of loose aquifer sediments. The primary hazards associated with subsidence are increased flooding hazards and damage to underground utilities. Other effects of subsidence include changes in the gradients of stormwater and sanitary sewer drainage systems in which the flow is gravity-driven. The Plan area is largely developed and water is provided by the Marin Municipal Water District.[14] There are no significant agricultural or industrial activities that result in the substantial pumping withdrawal of water from the underlying aquifer that would contribute to subsidence in the Plan area.

(8) Settlement and Differential Settlement. Differential settlement or subsidence could occur if buildings or other improvements were built on low-strength foundation materials (including imported 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 Plan area that contain loose or uncontrolled (non-engineered) fill may be susceptible to differential settlement.

2. Regulatory Framework

This section describes the applicable federal, State and local regulations that pertain to the Plan area.

a. Federal Regulations – National Earthquake Hazards Reduction Program. The National Earthquake Hazards Reduction Program (NEHRP) was established by the U.S. Congress when it passed the Earthquake Hazards Reduction Act of 1977, Public Law (PL) 95–124. In establishing NEHRP, Congress recognized that earthquake-related losses could be reduced through improved design and construction methods and practices, land use controls and redevelopment, prediction techniques and early-warning systems, coordinated emergency preparedness plans, and public education and involvement programs. The four basic NEHRP goals remain unchanged:

- Develop effective practices and policies for earthquake loss reduction and accelerate their implementation.
- Improve techniques for reducing earthquake vulnerabilities of facilities and systems.
- Improve earthquake hazards identification and risk assessment methods, and their use.
- Improve the understanding of earthquakes and their effects.

Several key federal agencies contribute to earthquake mitigation efforts. There are four primary NEHRP agencies:

[14] Marin Municipal Water District, 2012. *Service Area Boundary Map*. Website: www.marinwater.org/documents/mmwd_service_area.pdf (accessed January 15, 2013). March.

- National Institute of Standards and Technology (NIST) of the Department of Commerce
- National Science Foundation (NSF)
- United States Geological Survey (USGS) of the Department of the Interior
- Federal Emergency Management Agency (FEMA) of the Department of Homeland Security

Implementation of NEHRP priorities is accomplished primarily through original research, publications, and recommendations to assist and guide State, regional, and local agencies in the development of plans and policies to promote safety and emergency planning.

b. State Regulations. State regulations described below include the California Building Code, Alquist-Priolo Earthquake Fault Zoning Act, Seismic Hazards Mapping Act, regulations pertaining to oil, gas, and geothermal wells, and the Surface Mining and Reclamation Act of 1975.

(1) California Building Code. The 2009 International Building Code (IBC) is published by the International Conference of Building Officials (ICBO), and is the widely adopted model building code in the United States. The 2010 California Building Code (CBC) is another name for the body of regulations known as the California Code of Regulations (CCR), Title 24, Part 2, which is a portion of the California Building Standards Code (CBSC). The CBC incorporates by reference the IBC requirements with necessary California amendments. Title 24 is assigned to the California Building Standards Commission, which, by law, is responsible for coordinating all building standards. Under State law, all building standards must be centralized in Title 24 or they are not enforceable.

Compliance with the 2010 CBC requires that (with very limited exceptions) structures for human occupancy be designed and constructed to resist the effects of earthquake motions. The Seismic Design Category for a structure is determined in accordance with either: CBC Section 1613 – Earthquake Loads; or American Society of Civil Engineers (ASCE) Standard No. 7-05, Minimum Design Loads for Buildings and Other Structures. In brief, based on the engineering properties and soil-type of soils at a proposed site, the site is assigned a Site Class ranging from A to F. The Site Class is then combined with Spectral Response (ground acceleration induced by earthquake) information for the location to arrive at a Seismic Design Category ranging from A to D; D being the most severe conditions. The classification of a specific site and related calculations must be determined by a qualified person and are site-specific.

(2) Alquist-Priolo Earthquake Fault Zoning Act (A-PEFZA). Surface rupture is the most easily avoided seismic hazard. The A-PEFZA was passed in December 1972 to mitigate the hazard of surface faulting to structures for human occupancy. The Plan area is not located within an A-PEFZA designated fault zone.[15]

(3) Seismic Hazards Mapping Act (SHMA). In 1990, following the 1989 Loma Prieta earthquake, the California Legislature enacted the SHMA to protect the public from the effects of strong ground shaking, liquefaction, landslides and other seismic hazards. The SHMA established a state-wide mapping program to identify areas subject to violent shaking and ground failure; the

[15] California Geological Survey, 2010, op. cit.

program is intended to assist cities and counties in protecting public health and safety. The SHMA requires the State Geologist to delineate various seismic hazard zones and requires cities, counties, and other local permitting agencies to regulate certain development projects within these zones. As a result, the CGS is mapping SHMA Zones and has completed seismic hazard mapping for the portions of California most susceptible to liquefaction, ground shaking, and landslides: primarily the San Francisco Bay area and Los Angeles basin. The Plan area and vicinity are not planned to be mapped in conformance with the SHMA.[16]

(4) Oil, Gas, and Geothermal Wells Regulations. The California Department of Conservation's Division of Oil, Gas, and Geothermal Resources oversee the drilling, operation, maintenance, and plugging and abandonment of oil, natural gas, and geothermal wells.[17] The regulatory program emphasizes the development of oil, natural gas, and geothermal resources in the state through sound engineering practices that protect the environment, prevent pollution, and ensure public safety. Available State mapping does not indicate any oil, gas or geothermal resources or exploration in the Plan area.[18,19]

(5) Surface Mining and Reclamation Act of 1975 (SMARA). The principal legislation addressing mineral resources in California is the state Surface Mining and Reclamation Act of 1975 (SMARA) (Public Resources Code Sections 2710–2719), which was enacted in response to land use conflicts between urban growth and essential mineral production. SMARA specifies that lead agencies require financial assurances of each mining operation to ensure reclamation is performed in accordance with the approved reclamation plan. The financial assurances may take the form of surety bonds, irrevocable letters of credit, trust funds, or similar mechanism. No minerals or aggregate resources of statewide importance are located in the vicinity of the Plan area.[20]

c. City of Larkspur General Plan. The City's December 1990 General Plan contains the following applicable policies and action programs regarding geology, soils, and seismicity:

Health and Safety Element

Goal 5: Reduce risks of personal injury and property damage associated with seismic activity.

- Policy j: Establish acceptable levels of risk and life safety standards, and see that buildings are built to, or brought up to, those standards.
    - Action Program [13]: Require that all unreinforced masonry buildings are seismically upgraded to protect against loss of life.
    - Action Program [16]: As soon as legally permissible, adopt new versions of the Uniform Building Code which contain updated seismic requirements.

[16] California Geological Survey, 2013. *Seismic Hazard Zone Mapping, Northern California*. Website: gmw.consrv.ca.gov/shmp/html/pdf_maps_no.html (accessed January 15, 2013).

[17] Resources Agency, 2007. *Publication No. PRC04: California Code of Regulations*, Title 14, Division, 2, Chapters 2-4. Division of Gas, Oil and Geothermal Resources, March.

[18] California Department of Conservation, 2000, op. cit.

[19] California Department of Conservation, 2001, op. cit.

[20] Marin County, 2005, op. cit.

- Action Program [17]: Require geotechnical engineering investigations for (a) buildings proposed to be constructed in "high" seismic hazard areas potentially subject to severe ground shaking and ground failure (Bay mud, stream and landslide deposits) as shown on Figure 7-3 [Seismic Hazards], and (b) critical structures or structures made of materials other than wood frame.

Goal 6: Limit the exposure of existing and future structures to risk from landslides, debris flows and subsidence, and minimize the potential for damage.

- Policy l: Provide property owners with information to assist them in addressing their risk from landslides and debris flows.
  - Action Program [22]: For development in hillside areas, establish, by ordinance, standards for foundations and retaining walls that meet or exceed the current state of the art in structural and civil engineering practice. The standards shall include:
    (a) A retaining wall that provides support for the footings of a structure must have the same life expectancy as that of the supported structure.
    (b) A series of stepped or terraced retaining walls should be designed and approved by a qualified engineer even when the height of the individual walls is less than the standard that requires review.
    (c) A soils engineer or engineering geologist will be required to provide field supervision of the drilling and concrete pouring operations for pier foundations to insure the exclusion of loose debris from the pier holes, insure adequate pier depth, and confirm soil conditions.
    (d) Foundation plans for hillside structures utilizing pier foundations in soil depths of six feet or greater shall be designed to structural and soils engineering calculations based upon passive pressures and shall demonstrate to the satisfaction of the City that the pier will satisfactorily resist shearing.
- Policy m: Ensure that new development in hillside areas takes place only in areas that are relatively free from the threat of landslide and other forms of ground failure.
  - Action Program [23]: Require approval of a use permit for building additions or new development in areas with an average percent of slope equal to or greater than 25 percent.
  - Action Program [24]: Employ the following standards for assessing the acceptability of new construction in hillside areas and those adjacent areas with a potential risk from landslides and debris flows.
    (a) Areas subject to recent slope movement or within the paths of debris flows are not suitable for the development of occupied structures. Further disruption of these high risk areas will only be permitted by the City for roads, utilities, and other similar facilities after intensive geologic studies have determined that mitigation measures are practical and their costs warranted.
    (b) Generally, parcels with an average slope of 65 percent or greater (or that portion of a parcel with a slope of this magnitude) that show evidence of having been formed by landslide processes in the past are not suited for the development of occupied structures.
    (c) Sites underlain by deep-seated landslides and landslide debris deposits may only be developed with occupied structures if detailed geotechnical investigations demonstrate that any soils creep and future deep seated slide processes will, in the City's opinion, be satisfactorily mitigated.
    (d) High energy flow paths are not suitable for the development of occupied structures. These flow paths are steep seasonal drainages that have been a path for debris flows in the past.

(e) The development of new occupied structures within debris flow dissipation areas, which are those areas in the vicinity of the mouths of high energy flow paths, will be permitted only if adequate mitigation measures are provided.

- Action Program [25]: Require site-specific geologic and geotechnical reports for new construction in hillside areas and areas subject to settlement or subsidence.
- Action Program [26]: Adopt standards for geologic and geotechnical reports that outline the type and extent of investigation required for various stages of the development process, for various geologic and soils conditions, and for the type of land use and structure proposed.

  (a) Proposed development should include detailed plans for drainage facilities. These plans should incorporate a hydrologic and, where appropriate, a geomorphic evaluation of existing drainage courses and City drainage facilities that will be impacted by the project. The evaluation should demonstrate the adequacy of these systems. After adequacy is demonstrated, the drainage facilities should be connected to City storm drains.

  (b) In hillside areas and at the mouths of seasonal and intermittent streams, a geologic report should be required as a part of the site development review process for all structures proposed for human occupancy and situated where geologic hazards may directly or indirectly influence the design, location, and safety of the structure. A geotechnical report should be required where soil engineering and/or geologic conditions may affect the design, location, and safety of a structure proposed for human habitation.

d. City of Larkspur Municipal Code. Chapter 18.34 of the Larkspur Municipal Code contains regulations designed to reduce potential geologic hazards for slope and hillside development. These regulations apply to properties with an average slope of 10 percent or greater and require grading controls, more restrictive building height and setback requirements, and preservation of at least 35 percent of natural and permeable areas (25 percent plus the average slope percentage). Additional requirements apply if structures are proposed near ridgelines, require greater than 150 cubic yards of cut or fill, or propose greater than 25 cubic yards of cut or fill on properties with an average slope of 25 percent or greater.

3. Impacts and Mitigation Measures

This section provides an assessment of the potential adverse impacts of the Station Area Plan related to geology, soils, and seismicity. It establishes the thresholds of significance for impacts and then evaluates the Plan. Where potentially significant impacts are identified, mitigation measures are recommended.

a. Criteria of Significance. Implementation of the Station Area Plan would have a significant impact on geology and soils if it results in:

- Exposure of a significant number of 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;
  - strong seismic ground shaking;
  - seismic-related ground failure, including liquefaction; and/or
  - landslides;

- Substantial soil erosion or the loss of topsoil;
- Development located on a geologic unit or soil that is unstable or that would become unstable as a result of the project and which could potentially result in on- or offsite landslide, lateral spreading, subsidence, liquefaction, or collapse;
- Development located on expansive soil, creating substantial risks to life and property; or
- Development in areas where soils are incapable of adequately supporting the use of septic tanks or alternative wastewater disposal systems where sewers are not available for the disposal of wastewater.

b. Impacts Analysis. The growth and changes to land use (commercial, industrial and residential) resulting from implementation of the Station Area Plan could result in increased development and population in the Plan area. Implementation of the Station Area Plan would therefore result in additional people and structures being exposed to geohazards, including seismic risks, liquefaction, slope instability, soil settlement or compaction, and adverse soil conditions (e.g., expansive soils, corrosive soils). Some of these geohazards, particularly those related to seismic shaking, could result in injuries and/or fatalities; all of the geohazards discussed could result in damage to structures and property. The following section provides an evaluation and analysis for the potential impacts of the Station Area Plan for each of the criteria of significance listed above.

(1) Seismic Hazards. Major regional faults located in the Plan vicinity are capable of producing very strong to violent ground shaking in the Plan area, and a major seismic event is likely during the operational lifetime of development and redevelopment projects implemented under the Station Area Plan. Strong to violent seismic shaking could cause serious structural damage to buildings not engineered and constructed to comply with the current CBC, and could cause extensive non-structural[21] damage to buildings in the Plan area.

<u>Impact GEO-1</u>: Implementation of the Station Area Plan could result in substantial risk related to geologic or seismic hazards. (S)

Existing federal and State programs, including NEHRP, the A-PEFZA, the SHMA and the CBC, are designed to provide current information detailing seismic hazards, impose regulatory requirements regarding geotechnical and soils investigations, provide limitations on the locations of structures for human habitation, impose requirements for hazard notices to potential users, and establish structural standards for requirements for buildings and grading projects. City General Plan policies require geotechnical investigations for areas with high seismic hazards and/or non-wood frame structures (Action Policy 17) and in hillside areas (Action Policies 25 and 26).

These existing programs and policies would serve to reduce risk associated with seismic hazards. However, to address all significant impacts related to seismic hazards within the Plan area, site-specific geotechnical reports should be prepared for all development under the Station Area Plan. Implementation of the following mitigation measure would ensure that impacts related to geologic and seismic impacts from new development would be less than significant.

[21] Nonstructural building elements include, but are not limited to: glass, fixtures, furnishings, and other contents, equipment, and utilities (gas, high-temperature water, steam, fire-protection water, etc.).

Mitigation Measure GEO-1: The following language shall be included as a Condition of Approval for new projects associated with implementation of the Station Area Plan:

- Prior to the issuance of any grading or construction permits for development projects under the Plan, a design-level geotechnical investigation shall be prepared by a licensed professional and will be included in permit applications to the City Building Department for review and approval. The investigation shall determine the development's geotechnical conditions, including seismic shaking hazard and measures to address these hazards. In addition, the following guidance for the design-level geotechnical investigation shall be addressed:
    - Analysis presented in the geotechnical investigation shall conform to the California Division of Mines and Geology recommendations presented in the Guidelines for Evaluating Seismic Hazards in California. Briefly, the guidelines recommend that the investigation include: a site screening evaluation; evaluation of on- and off-site geologic hazards; quantitative evaluation of hazard potential; detailed field investigation; estimation of ground-motion parameters; evaluation of landslide, liquefaction, lateral-spreading and ground-displacement hazards; and recommendations to reduce identified hazards.
    - Design review for the project shall include evaluation of fixtures, furnishings, and fasteners with the intent of minimizing collateral injuries to building occupants from falling fixtures or furnishings during the course of a violent seismic event.
    - The investigation shall describe the proposed project's geotechnical conditions and address potential geohazards, including subsidence, collapse, soil expansion, corrosion, and differential settlement. The investigation shall identify engineering techniques appropriate to minimize potential geohazard damage.

  All design measures, recommendations, design criteria, and specifications set forth in the design-level geotechnical investigation shall be implemented as a condition of permit approval. (LTS)

(2) Substantial Soil Erosion or the Loss of Top Soil. Development or redevelopment under the Plan would include construction activities that would expose soils and could potentially result in substantial erosion. Soil erosion could result in effects to stormwater quality and affect the quality of receiving waters. Following development, no exposure of soils or erosion would be anticipated.

As discussed in Section IV.H, Hydrology and Water Quality, the State Board adopted an NPDES General Permit for Stormwater Discharges Associated with Construction and Land Disturbance Activities, Order No. 2009-0009-DWQ, NPDES No. CAS000002, as amended in 2011 (Construction General Permit). To obtain coverage under the Construction General Permit, a project applicant must submit various documents, including a Notice of Intent and a SWPPP. Activities subject to the Construction General Permit include clearing, grading, and disturbances to the ground, such as grubbing or excavation.

The purpose of the SWPPP is to identify the sources of sediment and other pollutants that could affect the quality of stormwater discharges and to describe and ensure the implementation of BMPs to reduce or eliminate sediment and other pollutants in stormwater as well as non-stormwater discharges resulting from construction activity.

Compliance with the Construction General Permit would reduce erosion and topsoil impacts from the Plan to a less-than significant impact and no further mitigation would be required.

(3) Unstable Geologic Unit or Soil. This section discusses potential impacts of the Station Area Plan related to landslides, lateral spreading, subsidence, liquefaction, or collapse.

Landslide. Landslides induced by earthquakes or heavy precipitation events have the potential to occur in development and redevelopment sites within the Plan area. As shown on Table IV.G-1, approximately half of the Plan area is in areas with slopes greater than 15 degrees, and over 30 percent of the Plan area has slopes greater than 30 degrees. Implementation of Mitigation Measure GEO-1 would reduce the potential impacts related to landslides to a less-than-significant level through the requirement for geotechnical investigations; these investigations must include recommendations from a licensed professional regarding mitigating potential landslide hazards. No further mitigation would be required.

Lateral Spreading and Liquefaction. The Plan area is underlain by materials that have low to very high liquefaction potential. Lateral spreading toward unsupported slopes can be caused by ground shaking and resulting liquefaction. Implementation of Mitigation Measure GEO-1 would reduce this potential impact related to liquefaction and lateral spreading to a less-than-significant level by requiring geotechnical investigations to identify geological hazards for new development and by requiring that the recommendations from a licensed professional be implemented to reduce the identified geological hazard; therefore, no further mitigation would be required.

Subsidence. The Marin Municipal Water District provides water to the project area, so groundwater extraction would not be expected as part of development under the Station Area Plan. Therefore, subsidence would be a less-than-significant impact and no further mitigation would be required.

Collapse. Collapse of soil or rock can occur either at former (or active) mine sites (where mining tunnels can collapse), when soils are subject to addition of water or excessive loading, or failure of trench walls (due to steep slopes). There are no current mining sites in the Plan area, though some gravel mining has historically taken place in the Plan area. Soil collapse from addition of water or loads generally occurs in areas underlain by young alluvial fan sediments, debris flow (a type of landslide) sediments, or windblown sands. Collapsing soil conditions are identified as a geological hazard and would be evaluated during a geotechnical investigation of new development or redevelopment. Implementation of Mitigation Measure GEO-1, which requires geotechnical investigations to identify and mitigate geologic hazards in site design, would reduce this potential impact to a less-than-significant level and no further mitigation would be required.

(4) Expansive Soil. The Plan area includes soils that have been identified as having a low to moderate shrink/swell potential as well as low to high corrosion potential. Structural damage of buildings or rupture of utilities may occur if the potentially expansive and corrosive soils were not considered in the design and construction of development in the Plan area. Implementation of Mitigation Measure GEO-1 would reduce this potential impact related to expansive soils to a less-than-significant level by requiring geotechnical investigations to identify geological hazards for new development and by requiring that the recommendations from a licensed professional be implemented to reduce the identified geological hazard; therefore, no further mitigation would be required.

(5) Septic Tanks. The Plan area is serviced by a sanitary sewer system operated by the Ross Valley Sanitary District. Therefore, there are no impacts related to septic tanks or other alternative wastewater disposal systems and no mitigation is required.

c. Cumulative Impacts of the Station Area Plan. Impacts related to geologic hazards are generally site specific, rather than cumulative in nature, because each project area has unique geologic considerations that would be subject to uniform site development and construction standards. Therefore, the potential for cumulative impacts is limited. Impacts associated with potential geologic hazards related to soil or other conditions occur at individual building sites. These effects are site-specific, and impacts would not be compounded by additional development. The mitigation measure described above would reduce impacts from geologic hazards to a less-than-significant level. Therefore, implementation of the Station Area Plan would not result in a cumulatively considerable contribution to geologic hazards, and the cumulative impact would be less than significant.