B. GEOLOGY, SOILS AND SEISMICITY

INTRODUCTION

This section identifies and evaluates issues of geology, soils, and seismicity as they relate to the proposed project. A regional and site-specific geologic context is provided in the setting discussion, along with a description of soil conditions. Hazards related to soils, geologic units, and regional fault systems are also evaluated. Pertinent city, county and state policies and regulations are also summarized to guide the reader. Geologic and seismic hazards associated with the implementation of the proposed project are discussed in the impact analysis.

SETTING

REGIONAL SETTING

The proposed project is located in the east-central portion of San Mateo County along the western edge of the San Francisco Bay, in Redwood City. This region of California is commonly referred to as the Coast Ranges geomorphic province (CGS Note 36, 1997). The Coast Ranges geomorphic province is characterized by a series of northwest trending ridges and valleys subparallel to the San Andreas Fault. The Franciscan Assemblage is the principal rock complex within the Coast Range and is composed of marine sedimentary and volcanic rocks. The Franciscan Assemblage is primarily composed of Jurassic to Cretaceous-age rocks (approximately 65 to 150 million years old) and consists primarily of greenstone (altered volcanic rock), basalt, chert (ancient silica-rich ocean deposits) and sandstone. Lowland areas along the margins of the San Francisco Bay typically consist of unconsolidated alluvial and estuarine deposits.

GEOLOGY AND SOILS

Geology

The project site is located at the toe of the northwest trending Santa Cruz Mountain Range near the mouth of Redwood Creek along the southeastern margin of San Francisco Bay. The site consists of essentially level topography ranging from less than 5 feet to 10 above mean sea level (msl) with a depressional area towards the center of the site (USGS, 1980). The geologic substrate is a product of alluvial deposition from the Santa Cruz Mountains to the west and tidal influx from San Francisco Bay. These lowland deposits consist of fine-textured alluvium (e.g. Bay mud) and more recently deposited artificial fill overlying sedimentary and volcanic rocks of the Franciscan Complex in the San Francisco Bay block (Pampeyan, 1993). These older, underlying rocks are exposed in the southwest portion of Redwood City in the form of sandstone, chert, serpentine, and greenstone (Pampeyan, 1993).

Advance Soil Technology, Inc. performed a preliminary geotechnical investigation for the project site in January of 2001. In an effort to characterize the stratigraphy of the project site, four location-specific exploratory borings were drilled to depths of 100 feet or greater (Advance Soil Technology, Inc. 2001). All four borings encountered similar materials at slightly varying depths. In general, the borings indicate that the surface layer is comprised of brown to reddish-brown, sandy to silty clay fill materials that extend to depths of 5.5 to 11.5 feet below the ground surface. Below this surface layer is a highly expansive gray to bluish-gray silty clay, commonly referred to as Young Bay Mud, extending to depths of between 29 and 38.5 feet below the ground surface. This layer also contains stratified layers of shells and peat and courser materials, such as sand and gravel.

At depths in excess of 30 to 40 feet below the ground surface, a grayish brown silty clay with gray and tan mottling is encountered. This layer is commonly referred to as Old Bay Mud. Old (Lower) Bay Mud is firm when moist, and contains varying amounts of sand and fine gravel. This layer ranges from 60 feet to as much as 280 feet in thickness along the bay margin (Pampeyan, 1993). Both forms of Bay Mud can present a variety of engineering challenges due to inherent low strength, compressibility, and saturated conditions. These challenges are discussed below in the context of geologic hazards.

Soils

The project site is overlain by fill materials that in the northeast section of the property extend to depths of greater than 11 feet below the ground surface (Advance Soil Technology, Inc. 2001). In portions of the site, geotechnical borings encountered a medium brown silty clay in shallow soils. Although described in preliminary geotechnical reports as fill, these materials are similar to the Reyes silty clay, as mapped in the Natural Resources Conservation Service (NRCS) Soil Survey for eastern San Mateo and San Francisco Counties, California (1991). These soils are primarily derived from alluvial deposition along Redwood Creek and inputs of marine sediments from tidal influx. In general, these soils are deep and poorly drained with free groundwater encountered at depths from 2.5 to 5 feet below the ground surface (Advance Soil Technology, Inc. 2001). These soils have a tendency to settle, particularly when underlain by bay muds from which they may have formed. Reyes silty clay soils are classified as hydric and present severe limitations to building site development, because of their high moisture content, ability to flood in shallow excavations, and high shrink-swell potential (NRCS, 2002).

GEOLOGIC HAZARDS

Expansive Soils

Expansive soils are those defined as having a “shrink-swell” behavior.[1] Structural damage to concrete slabs, foundations, and other structures may result over an extended period of time, usually the result of inadequate soil and foundation engineering. Typically, soils that exhibit expansive characteristics are found within the upper five feet of the soil profile, though they may occur at greater depth. Expansion and contraction of soils, depending on the season and the amount of surface water infiltration, may exert enough pressure on structures to result in

[1] Shrink-swell is the cyclic change in volume (expansion and contraction) that occurs in fine-grained clay sediments from the process of wetting and drying.

cracking, settlement, and uplift, thereby resulting in damage to foundations, above-ground structures, paved roads and streets, and concrete slabs. As indicated in the Preliminary Geotechnical Investigation, expansive soils were encountered in all four borings. This issue is discussed further in the impact analysis, below.

Soil Erosion

Soil erosion is the process whereby soil materials become detached and transported downslope either by wind or water. Rates of erosion can vary depending on the soil texture, structure, and amount of organic matter. The corresponding slope length and degree of steepness are also prime factors in determining the potential for soil erosion. Exposed soil surfaces, especially where unnatural slopes are created by cut and fill activities, may also lead to excessive erosion. Excessive soil erosion can eventually lead to damage of building foundations, roadways and dam embankments. Increases in erosion may also result in corresponding increases in sediment loads to local waterways, thereby adversely affecting aquatic habitat. In recognition of the relatively level topography and high content of clay in on-site soils, the erosion potential for soils in the immediate project area is considered low assuming standard erosion control measures are implemented during construction (see the discussion of Impact B.4, below).

Corrosive Soils

Corrosive soils can damage underground utilities including pipelines and cables, and can weaken roadway structures. Soils located along the lowland areas near the bay typically have a higher than normal corrosivity due to their relatively high sodium content. High quantities of sodium increase the susceptibility of steel and concrete structures to the effects of corrosion. As discussed in Chapter III, Project Description, the Cargill Salt Company previously used the subject property for salt production and storage purposes. Given the nature of this prior land use, a generally saline environment exists at the site. Based on this information, onsite soils are considered highly corrosive.

SEISMIC HAZARDS

Seismicity

The San Francisco Bay Area region contains both active and potentially active faults, and is considered a region of high seismic activity.[2] The 1997 Uniform Building Code (UBC) locates the entire eastern Bay Area region, including the project area, within Seismic Risk Zone 4. Areas within Zone 4 are expected to experience maximum magnitudes and damage in the event of an earthquake (Lindeburg, 1998). As a result, future displacement along various active and

2 An *active* fault is defined by the State of California as a fault that has had surface displacement within the Holocene era (approximately the last 11,000 years). A *potentially active* fault is defined as a fault that has shown evidence of surface displacement during the Quaternary era (last 1.6 million years), unless direct geologic evidence demonstrates inactivity for all of the Holocene or longer. This definition does not, of course, mean that faults lacking evidence of surface displacement are necessarily inactive. *Sufficiently active* is also used to describe a fault if there is some evidence that Holocene displacement occurred on one or more of its segments or branches (Hart, 1997).

potentially active fault systems is expected to produce a wide range of ground shaking intensities within the vicinity of the project area.[3]

The maximum (moment) magnitudes (Mw) on Table IV.B-1 represent characteristic earthquakes on each of the active faults within the project region.[4] While the magnitude is a measure of the energy released in an earthquake, intensity is a measure of the ground shaking effects at a particular location. Shaking intensity can vary depending on the overall magnitude, distance to the fault, focus of earthquake energy, and type of geologic material. The Modified Mercalli (MM) intensity scale is commonly used to measure earthquake effects due to ground shaking (refer to Table IV.B-2). The MM values for intensity range from I (earthquake not felt) to XII (damage nearly total). MM intensities ranging from IV to X could cause moderate to significant structural damage.[5]

Regional Faults

According to the Fault Activity Map of California (Jennings, 1994), the faults nearest to the site exhibiting historic displacement (activity within the last 200 years) are the San Andreas (Peninsula Segment), Hayward (southern segment), and Calaveras faults, located approximately 6 miles west, 13 miles northeast, and 20 miles northeast, respectively, of the project site. Other active faults in the region are depicted on Figure IV.B-1 and listed in Table IV.B-1. They include the Concord-Green Valley, Marsh Creek-Greenville and San Gregorio faults. Table IV.B-1 provides the distance and maximum moment magnitudes for faults with the greatest likelihood to produce strong ground shaking in the project area. Potentially active faults in the area include the Stanford fault, San Bruno fault and Palo Alto fault. These faults are older and show evidence of surface displacement within the last 1.6 million years. Due to the age of these faults, these faults are considered less likely than the active faults to trigger an earthquake. However, during a large earthquake, such faults may exhibit some degree of sympathetic movement due to an earthquake on a major active fault.

The California Geological Survey (CGS, formerly known as California Division of Mines and Geology) has determined the probability of earthquake occurrences and their associated peak ground accelerations throughout the State of California. A probabilistic seismic hazard map is a map that shows the hazard from earthquakes that geologists and seismologists agree could occur in California. It is probabilistic in the sense that the analysis takes into consideration the uncertainties in the size and location of earthquakes and the resulting ground motions that can affect a particular site. The maps are typically expressed in terms of probability of exceeding a certain ground motion. Current maps produced by the CGS are based on 10 percent exceedance

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3 Ground shaking can be described in terms of peak acceleration, peak velocity, and displacement of the ground. Areas that are underlain by bedrock tend to experience less ground shaking than those underlain by unconsolidated sediments such as artificial fill.

4 Moment magnitude is related to the physical size of a fault rupture and movement across a fault. Richter magnitude scale reflects the maximum amplitude of a particular type of seismic wave. Moment magnitude provides a physically meaningful measure of the size of a faulting event (CDMG, 1997).

5 The damage level represents the estimated overall level of damage that would occur for various Modified Mercalli intensity levels. The damage, however, would not be uniform. Some buildings would experience substantially more damage than this overall level, and others would experience substantially less damage. Not all buildings perform identically in an earthquake. The age, material, type, method of construction, size, and shape of a building all affect its performance (ABAG, 1998).

TABLE IV.B-1
ACTIVE AND POTENTIALLY ACTIVE EARTHQUAKE FAULTS

Fault	Closest Segment	Last Movement	Fault Type[a]	Maximum Magnitude[b]
San Andreas (Peninsula Segment)	6 miles W	Historic (1989 ruptures)	Active	7.1
San Andreas (North Segment)	12 miles NW	Historic (1906 rupture)	Active	7.9
Hayward	13 miles NE	Prehistoric (1868 rupture) Holocene	Active	7.1
Calaveras (North)	20 miles NE	Historic (1861 rupture) Holocene	Active	7.5
San Gregorio	20 miles SW	Historic Segments 1869–1931	Active	7.3
Marsh Creek-Greenville	31 miles NE	Historic (1980 rupture) Holocene	Active	6.9
Concord-Green Valley	31 miles NE	Historic (1955 rupture) Holocene	Active	6.9
Rogers Creek	47 miles N-NE	Historic Holocene	Active	7.0

NOTE: N/A – Not Available

a See footnote 2.
b The Maximum Moment Magnitude Earthquake is the strongest earthquake that is likely to be generated along a fault zone, based on the geologic character of the fault and earthquake history.

SOURCE: Advance Soil Technology, Inc. 2001 and Jennings et. al., 1994.

in 50 years. This probability level allows engineers to design buildings for larger ground motions than those that geologists and seismologists think would occur during a 50-year interval.[6] This would make buildings safer than if they were only designed for the ground motions that are expected to occur in the next 50 years. Seismic shaking maps are prepared using consensus information on historical earthquakes and faults. These levels of ground shaking are used primarily for formulating building codes and for designing buildings. The maps can also be used for estimating potential economic losses and preparing for emergency response (Peterson, et al., 1999). The peak ground acceleration based on a 10 percent exceedance in 50 years within the vicinity of Redwood City could range between 0.80 g to 0.90 g (Peterson, et al., 1999).

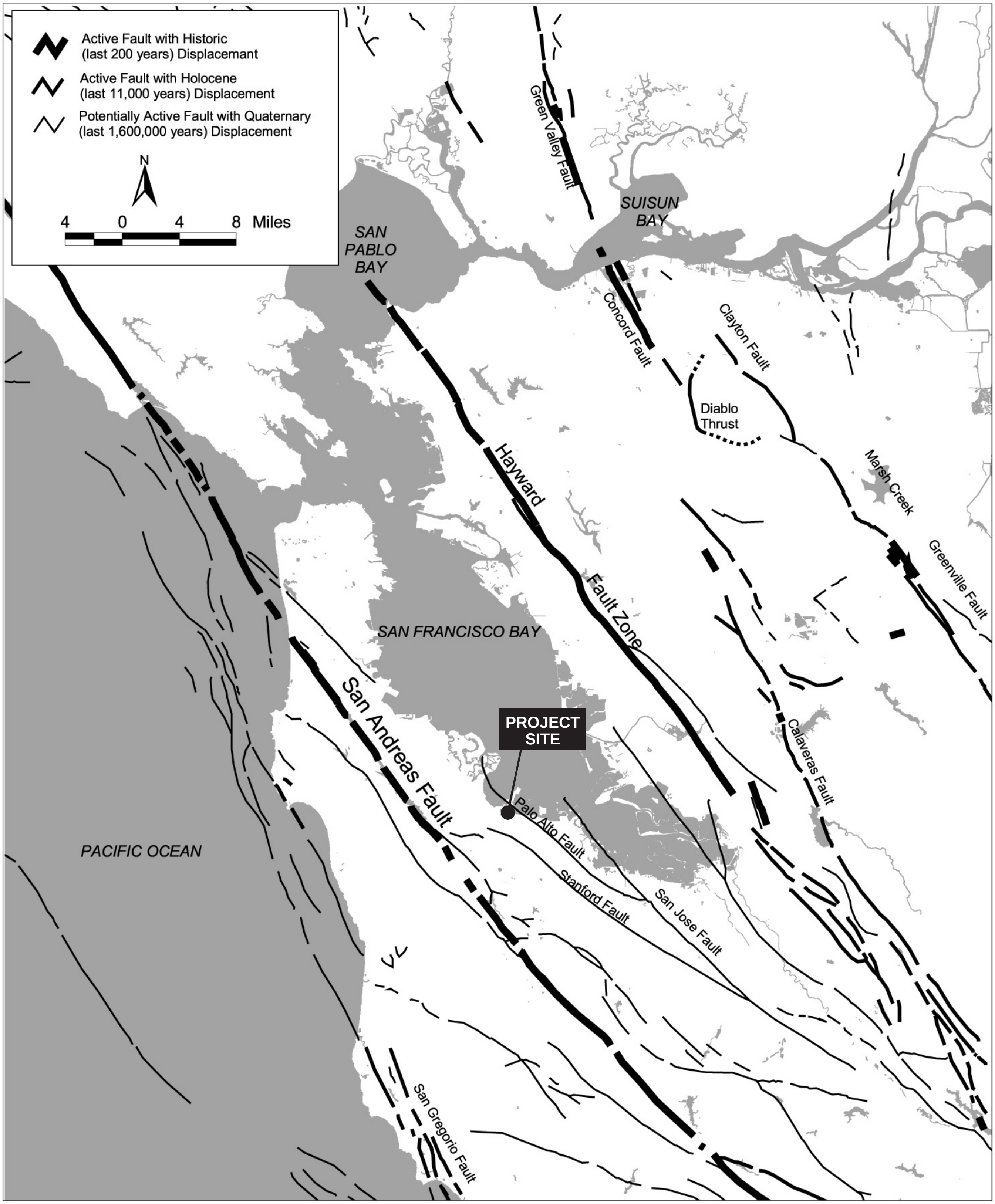
6 For example, the 10 percent probability of exceedance in 50 years maps depict an annual probability of 1 in 475 of being exceeded each year. This level of ground shaking has been used for designing buildings in high seismic areas. The maps for 10 percent probability of exceedance in 50 years show ground motions that geologists and seismologists do not think would be exceeded in the next 50 years. In fact, there is a 90 percent chance that these ground motions would NOT be exceeded.

TABLE IV.B-2
MODIFIED MERCALLI INTENSITY SCALE

Intensity Value	Intensity Description	Average Peak Acceleration[a]
I	Not felt except by a very few persons under especially favorable circumstances.	< 0.0015 g
II	Felt only by a few persons at rest, especially on upper floors on buildings. Delicately suspended objects may swing.	< 0.0015 g
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 similar to a passing of a truck. Duration estimated.	< 0.0015 g
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.	0.015 g-0.02 g
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.	0.03 g-0.04 g
VI	Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.	0.06 g-0.07 g
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.	0.10 g-0.15 g
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.	0.25 g-0.30 g
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.	0.50 g-0.55 g
X	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from riverbanks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks.	> 0.60 g
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.	> 0.60 g
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. Objects are thrown upward into the air.	> 0.60 g

[a] g is gravity = 980 centimeters per second per second

SOURCE: Bolt, Bruce A., *Earthquakes*, W.H. Freeman and Company, New York, 1988.



SOURCE: California Department of Conservation, Geological Survey (After Jennings, 1994)

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Figure IV.B-1
Active and Potentially Active Bay Area Earthquake Faults

Fault Rupture

Under the Alquist-Priolo Earthquake Fault Zoning Act (formerly the Alquist-Priolo Special Studies Act) of 1972 (revised 1994), Fault Rupture Hazard Zones were established by the CGS along “active” faults, or faults along which surface rupture occurred in Holocene time (the last 11,000 years). In the Bay Area, these include the San Andreas, Hayward, Rodgers Creek, Concord-Green Valley, Marsh Creek-Greenville, and San Gregorio faults. As noted in Table IV.B-1, the closest active fault to the project site is the San Andreas, located roughly 6 miles west. Therefore the project site is neither located within, nor crosses, a delineated Alquist-Priolo Fault Rupture Hazard Zone (CGS, 1997) and the potential for fault rupture at the site is considered to be low.

Settlement

Natural settlement typically occurs in unconsolidated deposits, such as artificial fill and Bay Mud, over time as a result of increased foundation loads and vibrations from overlying structures. Natural settlement may affect foundations, slabs and pavements. In addition to natural settlement, earthquake shaking can produce compaction and densification of dry, uniformly graded, granular material that are loose in consistency. The amount of compaction across an area can vary due to differences in soil types, producing differential settlement. Artificial fill may also be susceptible to differential settlement. Differential settlement can affect utilities, foundations, slabs, and pavements. At the project site, artificial fills vary in composition both horizontally and vertically, and ground shaking could cause non-uniform compaction or settlement of soil. Hazards relating to these forms of settlement are discussed further in the impact analysis, below.

Liquefaction

Liquefaction is the sudden temporary loss of shear strength in saturated, loose to medium dense, granular sediments subjected to ground shaking. It generally occurs when seismically induced ground-shaking causes pore water pressure to increase to a point equal to the overburden pressure. The upward flow of water then may turn cohesionless soil into a liquefied condition, thereby reducing foundation bearing strength and causing failure of buildings and other facilities.

The potential for liquefaction depends on the duration and intensity of earthquake shaking, particle size distribution of the soil, density of the soil, and elevation of the groundwater. In recognition of the shallow groundwater table across the project, and the presence of younger alluvial materials, the proposed project could be subjected to the effects of liquefaction. Hazard maps produced by the Association of Bay Area Governments (ABAG) depict liquefaction and lateral spreading hazards for the entire Bay Area in the event of a significant seismic event (ABAG, 2003).[7] According to these maps, the project site is in an area expected to have a moderate to high potential to experience liquefaction. The CGS has not yet investigated the project site and surrounding area for potential designation as a Seismic Hazard Zone (discussed below) for liquefaction. For this reason, this issue is discussed further in the impact analysis.

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7 Lateral spreading is a ground failure associated with liquefaction and generally results from predominantly horizontal displacement of materials toward relatively unsupported free faces.

Landslides

Landslides may occur on slopes of 15 percent or less, however, the probability is greater on steeper slopes that exhibit old landslide features such as scarps, slanted vegetation, and transverse ridges. Landslides typically occur within slide-prone geologic units that contain excessive amounts of water, are located on steep slopes, and where planes of weakness are parallel to the slope angle. However, due to the relatively level surfaces present in the immediate project area, the potential for landslides is considered to be low.

Earthquake-Induced Inundation

Tsunamis (seismic sea waves) are long period waves that are typically caused by underwater disturbances (landslides), volcanic eruptions, or seismic events. Areas that are highly susceptible to tsunami inundation tend to be located in low-lying coastal areas such as tidal flats, marshlands, and former bay margins that have been artificially filled but are still at or near sea level.

San Francisco Bay is considered too small to allow for the development of a tsunami. A tsunami generated in the Pacific would have to turn 90 degrees south towards the southern portion of the bay to affect the project site. It is estimated that any run up caused by such a event would diminish to about 1/10 of the run-up at the Golden Gate (Advance Soil Technology, Inc. 2001). For this reason, such a hazard affecting the project site is considered minimal.

REGULATORY CONTEXT

Alquist-Priolo Earthquake Fault Zoning Act

The Alquist-Priolo Earthquake Fault Zoning Act (formerly the Alquist-Priolo Special Studies Zone Act), signed into law December 1972 (revised in 1994), requires the delineation of zones along active faults in California. The purpose of the Alquist-Priolo Act is to regulate development on or near active fault traces to reduce the hazard of fault rupture and to prohibit the location of most structures for human occupancy across these traces.[8] Although surface fault rupture is not necessarily restricted to areas within an Alquist-Priolo Fault Rupture Hazard Zone, cities and counties must regulate certain development projects within the zones. For example, local permitting agencies must withhold permits until geologic investigations demonstrate that development sites are not threatened by future surface displacement (Hart, 1997). As previously indicated, the project site is not located within a CGS-designated Fault Rupture Hazard Zone.

California Building Code

State law regarding the construction of public buildings and a large percentage of private buildings is contained in the California Building Code. Title 24, Part 2 of the California Building Code deals with geologic and seismic hazards, other than surface faulting. Chapter 23 of the California Building Code deals with general design requirements, and includes regulations for

8 A "structure for human occupancy" is defined by the Alquist-Priolo Act as any structure used or intended for supporting or sheltering any use or occupancy that has an occupancy rate of more than 2,000 person-hours per year.

earthquake-resistant design and construction. The project is located within California Building Code Seismic Zone 4 and is required to follow the most stringent California Building Code design and construction standards. Requirements for excavations, fills, foundations, retaining walls, grading, and earthwork construction are discussed in Chapters 29 and 70 of the California Building Code.

Seismic Hazards Mapping Act

The Seismic Hazards Mapping Act was developed to protect the public from the effects of strong ground shaking, liquefaction, landslides, or other ground failure, and from other hazards caused by earthquakes. This act 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. Before a development permit is granted for a site within a seismic hazard zone, a geotechnical investigation of the site must be conducted and appropriate mitigation measures incorporated into the project design. The CGS has completed seismic hazard mapping for portions of California most susceptible to liquefaction, groundshaking and landslide, including portions of the San Francisco Bay Area. However, a seismic hazard map of the project site and surrounding area has not yet been completed.

Redwood City Municipal Ordinance

Redwood City's Municipal Ordinance outlines stormwater requirements for new development within the City. Specifically, Sections 27A.8, 27A.9, and 27A.15 of the ordinance require the implementation of best management practices to control the volume and rate of stormwater runoff from new developments as appropriate to minimize the discharge and transport of pollutants. All grading and site construction activities are subject to the above requirements. Section 27A.15 is of special importance, since the project site is located adjacent to Redwood Creek. This section specifically requires property owners to not remove healthy bank vegetation beyond that actually necessary for maintenance, nor remove said vegetation in such a manner as to increase the vulnerability of the watercourse to erosion.

The Redwood City Community Services Department also outlines requirements for cathodic protection systems, which protect underground piping systems from corrosion. These systems generally consist of sacrificial anodes fitting pipes. These sacrificial anodes are connected with electrical wire that runs up to the surface and is connected to a source of direct current. The flow of electricity between the pipeline and the electrode is reversed so the sacrificial electrode corrodes instead of the pipeline or storage tank.

IMPACTS AND MITIGATION MEASURES

This impact analysis focuses on potential project impacts related to seismicity, liquefaction, settlement, expansive and corrosive soils, and soil erosion. The evaluation considers project plans, current conditions at the project site, and applicable regulations and guidelines.

APPROACH TO ANALYSIS

The impact analyses provided in this section apply to each phase of the project, since each phase will involve impacts that meet the applied significance criteria. Therefore, where mitigation measures are identified, they must be implemented during each phase of the project in order to reduce the impact to a less than significant level.

SIGNIFICANCE CRITERIA

Consistent with Appendix G of the CEQA Guidelines, development of the proposed project would be considered to result in a significant impact on the environment 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 in 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 potentially active fault (Refer to Division of Mines and Geology Special Publication 42.);
  - strong seismic ground shaking;
  - seismic-related ground failure, including liquefaction; and
  - landslides;
- result in substantial soil erosion or the loss of topsoil to such a level that siltation would cause significant impact on water quality and aquatic habitats;
- be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction or collapse; or
- be located on expansive soil, as defined in Table 18-1-B of the Uniform Building Code (1994), creating substantial risks to life or property.

IMPACT ANALYSIS

Impact B.1: In the event of a major earthquake, seismic ground shaking and associated liquefaction and earthquake-induced settlement could result in structural damage or failure of the proposed facilities. (Potentially Significant)

The project site will likely experience at least one major earthquake (greater than moment magnitude 7) within the next 30 years. The intensity of such an event would depend on the causative fault and the distance to the epicenter, the moment magnitude, and the duration of shaking. A seismic event in the Bay Area could produce ground shaking intensities at the project site ranging from moderate (MM VI) to violent (MM IX). As a comparison, the 1989 Loma Prieta event, with a moment magnitude of 6.9, produced very strong (MM VIII) shaking intensities (ABAG, 2003). Earthquakes of this intensity can cause slight to considerable structural damage.

The project will comply with the UBC and California Building Code, and will incorporate site-specific geotechnical recommendations, as required by the City. Geotechnical investigation and recommendations required for the project shall include an analysis of expected ground motions at the site generated by seismic activity on Bay Area faults and, as required by the UBC, will be incorporated into structural designs for the proposed project.

The project site is currently underlain by artificial fill and Bay Mud. Ground shaking associated with a major seismic event could cause the non-uniform compaction (earthquake-induced differential settlement) of underlying sediments. The proposed project would require placement of engineered fill beneath foundations, walkways, and roadways. These fill materials would require appropriate engineering beneath each structure of the proposed development to avoid earthquake-induced settlement and ground failure in the event of a major seismic event. A geotechnical report prepared by Advance Soil Technology (2001) included recommendations that would mitigate seismic-related hazards and seismic-induced settlement impacts. These recommendations are required by the City of Redwood City to be implemented in the final design of the proposed development. However, the report does not address all areas proposed to be developed. Specifically, the levee along Redwood Creek has not been addressed in a project-related geotechnical investigation. A geotechnical investigation of the levee to determine if the soil material and compaction satisfy the City's levee requirements for seismic-related hazards and seismic-induced settlement should be completed before any grading or construction permits are issued.

Mitigation Measure B.1: To reduce potential levee slope instability hazards along Redwood Creek, the project sponsor shall retain a California-certified geotechnical or civil engineer to conduct a slope stability analysis of levees bordering the project site. The recommendations from this analysis shall be incorporated into the final grading and foundation design and submitted to the City of Redwood City Building and Inspection Services Depart for review and approval before final grading and construction permits are issued. (Identified by this EIR)

Seismic design consistent with current professional engineering and industry standards would be used in construction for resistance to strong ground shaking, especially for lateral forces. The implementation of the seismic design criteria as required by the California Building Code would reduce the potential for structural failure, major structural damage, and reduce the primary effects of ground shaking on structures and infrastructures to an acceptable level of risk. Additional requirements associated with Mitigation Measure B.1 recommended by the Certified Engineering Geologist or Geotechnical Engineer, would also be incorporated into the project. Accurate prediction of seismic events is not possible, nor can site-specific design entirely eliminate the potential for injury and damage that can occur during a seismic event. However, conformance with City geotechnical and building code requirements and incorporation of Mitigation Measure B.1 would reduce potential impacts related to seismic ground shaking to a less than significant level.

Liquefaction hazard maps produced by ABAG indicate that the project site is within an area considered to be at moderate to high risk to experience ground failure in the event of a significant earthquake (magnitude 7.0 or greater). To evaluate the potential for liquefaction, Advance Soil

Technology, Inc. conducted blow counts at varying depths to identify the characteristics of the sub-surface soils on the project site (Advance Soil Technology, Inc. 2001). No loose saturated sand or cohesionless soils were encountered during the exploratory borings and therefore the risk of liquefaction affecting project-related structures is considered less than significant.

Significance after Mitigation: Less than Significant.

Impact B.2: Proposed construction associated with the project could be subjected to hazards related to expansive soils and settlement. (Potentially Significant)

Over time, settlement could occur on the project site as a result of increased foundation loads from overlying structures being placed on semi-consolidated deposits, such as artificial fill and Bay Mud. The entire project site is underlain by nonengineered artificial fill of varying depths and approximately 20 to 30 feet of Bay Mud. Bay Mud is an organic, compressible soil that settles over time as loads are applied. The near-surface soils at the site vary in composition both horizontal and vertically, and existing surface grades vary in elevation throughout the site. Total and differential settlement of site soils could therefore damage proposed foundations, structures, and utility lines.

Differential settlement would occur on the site as a result of varying amounts of fill. The low-lying areas (drainage trench, detention pond) would require additional fill to conform the site grades and would therefore be subject to increased weight and settlement. The high and low spots created for pavement drainage would also settle at different rates due to the increased amount of fills. In addition, the area previously occupied by the salt mound has been surcharged over time and would therefore be likely to undergo less settlement than the surrounding areas.

Settlements could potentially occur from static loads and possibly half of the settlement would take place during construction or shortly thereafter. Differential settlement could occur between column or floor slabs due to variability of underlying soil conditions. Geotechnical investigations on the site also identified surficial soil susceptible to shrink-swell (expansive) behavior. The effects of expansive soils could damage foundations and aboveground structures, paved parking areas, and concrete slabs. Surface structures with foundations constructed in expansive soils would experience expansion and contraction depending on the season and the amount of surface water infiltration. The expansion and contraction could exert enough pressure on the structures to result in cracking, settlement, and uplift.

Preliminary recommendations provided by the project's geotechnical engineer indicate that a pile foundation consisting of driven, precast, and prestressed concrete friction piles would be most appropriate to counteract the effects of settlement (Advance Soil Technology, Inc. 2001). The piles would derive their primary support from stiff clays encountered below the Bay Mud at depth (Advance Soil Technology, Inc. 2001). The City requires that final foundation and site design incorporate consideration of a design-level geotechnical investigation. A standard criterion for conducting a geotechnical investigation is that expansive soils and foundation engineering be adequately addressed by a geotechnical or civil engineer. Recommendations by the project engineer will be included in the final design to be reviewed by the City before any grading or construction permits may be issued.

Mitigation Measure B.2: The project sponsor shall implement the recommendations contained in the preliminary geotechnical investigation. These recommendations include excavating and off-hauling expansive soil and using imported fill material in the upper two feet beneath all finished building pad areas and the upper 18 inches beneath exterior walkways. This fill material shall be tested for suitability and approved by a California Certified Geotechnical Engineer prior to importation to the site. (Proposed as Part of the Project)

All recommendations by the project engineer and geotechnical engineer will be included in the final design and reviewed by City of Redwood City before grading or construction permits are issued. Compliance with City design and review requirements would reduce potential settlement and expansive soil impacts to a less-than-significant level.

Significance after Mitigation: Less than Significant.

Impact B.3: Project-related facilities, including buildings, parking structures, and underground utilities, could be subjected to corrosive soils. (Potentially Significant)

As indicated in the setting discussion, onsite soils naturally contain a relatively high level of salt, due to the tidal influx. Prior salt mining and storage by Cargill have likely resulted in even higher salinity, as indicated by an approximately 5.5 foot-deep salt layer that was encountered at boring location B-4. In addition, the project site is currently used as a final destination for Cargill's bittern production. The bittern arrives at the site in underground steel pipelines near the southeast corner of the site and is loaded onto ships at the existing boat docks along the eastern edge of the site.

Saline soils are highly corrosive to both concrete and steel. The presence of chlorides and sulfates in the salt and other chemicals can attack unprotected steel and steel reinforcement in concrete. This corrosive environment could result in potentially significant impacts to proposed structures and utilities. Mitigation Measures B.3a and B.3b would reduce potential impacts related to corrosive soils to less-than-significant levels.

Mitigation Measure B.3a: The applicant shall implement the geotechnical recommendations contained in the preliminary geotechnical investigation pertaining to corrosive soils, which include removing the existing onsite salt layer or mixing it with native or imported material. Corrosive-resistant concrete shall also be used in all construction for structures that come in contact with the ground. (Proposed as Part of the Project)

Mitigation Measure B.3b: The applicant shall install a cathodic protection system on the project site to protect underground metallic fittings, appurtenances and piping from corrosion. The cathodic protection system shall be designed to be consistent with Redwood

City standards. The Redwood City Engineering and Construction Department shall review the design of the cathodic protection system at the time the applicant submits its construction drawing set for each construction phase. (Identified by this EIR)

Significance after Mitigation: Less than Significant.

Impact B.4: Construction of the proposed project could result in surface soil erosion, thereby increasing sediment loads to Redwood Creek. (Potentially Significant)

Construction-associated grading and excavation has the potential to expose bare soil to precipitation and subsequent entrainment in surface runoff. Construction activities could therefore result in increased erosion and sedimentation to the surface waters of Redwood Creek, adversely affecting water quality and aquatic habitat.

Mitigation Measure B.4: During construction, the applicant shall comply with erosion and sediment control measures in accordance with Redwood City's stormwater management requirements and construction best management practices for the reduction of pollutants in runoff and the State Water Quality Control Board National Pollution Discharge Elimination System (NPDES) requirements, including the development and implementation of a Storm Water Pollution Prevention Plan (SWPPP) incorporating Best Management Practices (BMPs), as identified in Section IV.C, Hydrology and Water Quality. The SWPPP shall identify BMPs for implementation during construction activities, such as detention basins, straw bales, silt fences, check dams, geofabrics, drainage swales, and sandbag dikes. (Proposed as Part of the Project)

Compliance with these requirements together with San Mateo County and Redwood City stormwater management requirements would reduce erosion of disturbed soils during construction activities to less-than-significant levels.

Significance after Mitigation: Less than Significant.

REFERENCES – Geology, Soils and Seismicity

(*The references cited below are available at the Redwood City Community Development Services Department, 1017 Middlefield Road, Redwood City, California, unless specified otherwise below.*)

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