11. SOILS AND GEOLOGY

This EIR chapter describes existing geologic and soil conditions at the project site and immediate vicinity, identifies associated potential geotechnical impacts related to development of the proposed project, and sets forth measures designed to mitigate identified significant adverse impacts. Data sources used to complete these descriptions include a preliminary geotechnical investigation of the Marina Shores Village project site performed for the applicant by Treadwell & Rollo, Environmental and Geotechnical Consultants, dated June 21, 2001; the assessment of project hydrologic implications completed for this EIR by Clearwater Hydrology (see chapter 9); a wetlands investigation and a biological assessment performed for the applicant by the Huffman-Broadway Group, both dated February 2002; published reference materials produced by the Department of the Interior, U.S. Geological Survey (USGS); environmental documents prepared for previous development projects on the site (e.g., the Peninsula Marina and Office Park) and in the immediate vicinity (e.g., the "Villas at Bair Island" and the Bair Island Marina); and the Redwood City Strategic General Plan.

The Treadwell & Rollo preliminary geotechnical investigation, much of which is presented in this EIR chapter, describes the limitations and preliminary nature of its conclusions by stating, *"The conclusions presented in this report are preliminary and intended to address general geotechnical conditions of the site. The report has not been prepared to meet the need of design professionals, contractors, or any other parties in preparation of final design or construction documents. Final conclusions and recommendations will be presented after the proposed future studies have been performed and the data collected has been analyzed."* [1] These future study needs are further described in section 11.3 herein (Impacts and Mitigation Measures).

11.1 SETTING

11.1.1 Regional Geologic Setting

[1]Treadwell & Rollo. *Preliminary Geotechnical Investigation, Bair Island Project* (Project No. 3147.01), June 21, 2001, p. 15.

The project site is within a broad structural trough of the California Coast Ranges that extends from an area south of Hollister northward beyond San Pablo Bay. This structural depression, which contains San Francisco Bay, has been subsiding and filling with alluvium during the past five to eight million years. At the site, bedrock of the Franciscan Assemblage underlies the alluvial deposits at a depth of approximately 400 feet. The most recent underlying deposit is soft Bay mud, which has been deposited in the last 10,000 years.[2]

The approximately 46.45-acre project site is located on flat-lying, estuarine sediments along the southwest shoreline of San Francisco Bay. The site is generally bounded by Redwood Creek on the north and east; Smith Slough and the Bair Island National Wildlife Refuge on the northwest and west; townhouses, auto retail, and offices on the west; and Redwood Creek (with a marina of live-aboard vessels and an aquatic club) and U.S. 101 on the south. Redwood Creek and Smith Slough are tributaries to San Francisco Bay.

The project site is comprised of two noncontiguous properties: the Peninsula Marina property, which is currently comprised of approximately 33.24 acres, including 14.1 acres of water area; and the Pete's Harbor property, which currently encompasses approximately 13.21 acres, including 2.9 acres of water.

11.1.2 Site Topography and Drainage

(a) Site Drainage. Stormwater runoff from the Peninsula Marina property discharges to Redwood Creek, either directly via overland flow or by the storm drain system serving the existing commercial complex and parking area. Review of storm drain plat maps on file with the City Department of Public Works confirmed that the storm drain system on the Peninsula Marina property has no link with the Bair Island Road storm drain system. Field observations indicated that all runoff from the Pete's Harbor property flows overland and discharges directly into either the inner harbor, Smith Slough, or Redwood Creek.

The adjacent Bair Island Road system conveys runoff generated over the roadway and parcels flanking it on the north to a 6,400 gallon-per-minute (gpm) stormwater pumping station that is maintained by the City. The pumping station is located immediately south of the junction of Bair Island Road and East Bayshore Road. Drainage from the project site has no connection to or effect on this pumping system.

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[2]Bay Area Geotechnical Group (BAGG). *Report of Geotechnical Investigation for Bair Island Marina, 700 Bair Island Road, Redwood City, California*, February 9, 1998, p. 8.

<u>(b) Site Topography</u>. The project site is relatively flat; existing ground surface elevations range from approximately 105 to 110 feet (or +5.0 feet to +10.0 feet NGVD).[3] The site and surrounding area were originally tidal marshlands with meandering sloughs. During the early 1900s, the area was diked and filled. The upper soil dried over time, and a crust formed on the surface. Between approximately 1950 and 1964, salt evaporation ponds were developed in the surrounding area by constructing interior levees.[4]

The peninsula upon which Peninsula Marina and Pete's Harbor are built was filled in stages, with Pete's Harbor dredged (marina) and filled (parking lots) over two decades from the early 1960s through the mid-1980s. The 1973 revised USGS 7.5-minute topographic maps for the Redwood Point and Palo Alto quadrangles indicated that the Peninsula Marina site had been filled; however, the marina was not shown on the map. According to aerial photo evidence, the marina dredging and construction took place sometime between 1975 and 1979.[5]

11.1.3 Site Soils

<u>(a) USSCS Soil Survey</u>. The project site has undergone human disturbance, including filling, vegetation removal, soil compaction, altered runoff conditions, and road and building construction. The tidal condition of the adjacent reach of Redwood Creek results in a relatively stable and shallow on-site groundwater elevation; mid-winter groundwater elevations could rise somewhat closer to the ground surface. Due to the presence of nearly impervious Bay mud and the tidal zone beneath and adjacent to the project parcels, the perched groundwater underlying the site does not represent a significant groundwater resource. A review of the U.S. Soil Conservation Service (SCS) Soil Survey map for San Mateo County Eastern Part and San Francisco indicates the presence of one soil series on the project site: *urban land--orthents, reclaimed complex, 0 to 2 percent slopes*. In the project vicinity, this soil series is located in areas that were once part of San Francisco Bay and adjacent tidal flats. *Urban land* soils generally consist of deep, poorly drained fill. The soil texture varies greatly, and is typically composed of native soil, gravel, broken cement and asphalt, Bay mud, and solid waste. Field

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[3]All elevations are referenced to City of Redwood City Datum, which is equal to National Geodetic Vertical Datum (NGVD) plus 100 feet. Treadwell & Rollo.

[4]Treadwell & Rollo, p. 3.

[5]Mark Peppercorn, Glenborough-Pauls, LLC, personal communication, May 2002.

investigation has confirmed that the SCS soils mapping is generally accurate throughout the project site.[6]

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[6]The Huffman-Broadway Group, Inc., 2002. *Biological Assessment: Marina Shores Village Project*, *Redwood City, California*. Larkspur, California. Prepared for Glenborough-Pauls, LLC, February 2002, pp. 9-10.

(b) Site-Specific Investigation. To evaluate subsurface conditions, five exploratory borings and five cone penetration tests (CPTs) were performed in May 2001 by Treadwell & Rollo, environmental and geotechnical consultants for the applicant.[7] The on-site test borings indicate that the project site is covered by approximately 5 to 9.5 feet of sandy and clayey fill. The fill generally is underlain by about 15 to 22 feet of weak, compressible marine clay known as Bay mud, except at the south end of the site, where the Bay mud decreases to approximately 8 feet in thickness. Interlayered stiff clay and thin lenses of medium-dense sand are present below the Bay mud to the maximum explored depth of approximately 100 feet.

Soil samples obtained during the field investigation were re-examined in a laboratory to confirm field classifications. Representative samples were tested to measure moisture content, dry density, fines content, shear strength, and compressibility. Tests for pH, sulfate, chloride, and resistivity were performed on a sample of the fill and a sample of the Bay mud recovered from the test borings in order to provide preliminary indications of the potential for chemical conditions in the soil to adversely affect concrete and steel. The results of these tests in relation to proposed construction of the Marina Shores Village Project are discussed in upcoming section 11.3 (Impacts and Mitigation Measures).

(c) Vegetation. Vegetation on the project site is limited to some ornamental landscaping around the perimeter of the commercial buildings, the Uccelli residence, and the fill slope flanking the east side of Bear Island Road, and a narrow band of salt marsh vegetation (e.g., pickleweed and salt grass) along the west bank of Redwood Creek.

(d) Groundwater. The levels of measured groundwater in the borings and CPTs ranged from approximately 3 to 6.5 feet below ground surface. These levels can fluctuate depending on rainfall and seasonal conditions.

11.1.4 Seismicity

(a) Earthquake Fault Locations. No active or probable active fault traverses the project site.[8] The major active faults in the project vicinity include the following: the San Andreas

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[7]Treadwell & Rollo. Much of the following information has been extracted from the previously cited Treadwell & Rollo report, which includes additional, more technical data. The report is available for review at the City of Redwood City Planning Department.

[8]Department of the Interior, United States Geological Survey. Map MF-355: *Active Faults, Probable Active Faults, and Associated Fracture Zones, San Mateo County, California*. Compiled by Robert D. Brown, Jr., 1972.

(approximately 7.5 miles southwest of the project site), San Gregorio (approximately 22 miles west of the site), Hayward (approximately 22 miles northeast of the site), and Calaveras (approximately 32 miles northeast of the site).

Because there are no faults on the project site or on adjacent properties, there is no known risk of surface rupture during an earthquake, and development of the site is not restricted by the presence of an Alquist-Priolo Special Studies Zone (see subsection 11.2.4 below).

<u>(b) Earthquake Probability</u>. In 1999, the Working Group on California Earthquake Probabilities (WGCEP) at the U.S. Geological Survey (USGS) predicted a 70 percent probability of a magnitude 6.7 or greater earthquake occurring in the San Francisco Bay Area by the year 2030, with the following estimates of probability for particular faults: Hayward-Rogers Creek--32 percent; San Andreas--21 percent; Calaveras--18 percent; San Gregorio--10 percent; and Mount Diablo--4 percent.

<u>(c) Earthquake Hazards</u>. Hazards that can result from an earthquake include surface rupture, landsliding, violent ground shaking, differential settlement, liquefaction, and lateral spreading.

(1) Potential for Surface Rupture. Surface rupture occurs along active fault traces, or at locations where compressed and distorted soils break open to relieve earthquake-induced stress. Structures and other improvements built across the actual trace or line of such fractures are generally destroyed. As noted above, no active or probable active fault has been identified on the project site.

(2) Potential for Landsliding. Landsliding entails sudden slope failures. Because the project site and its surroundings are essentially level, landsliding is not considered a significant hazard.

(3) Potential for Ground Shaking. Ground shaking is caused by the seismic waves that radiate out from an earthquake's epicenter. The severity of ground shaking at a particular location is primarily determined by distance from the epicenter of the earthquake and by the local soil profile. Loose, unconsolidated sedimentary deposits can transform the relatively high frequency (back and forth) motion of underlying bedrock into lower frequency but higher amplitude motion at the surface. The stability of unconsolidated soils versus bedrock is illustrated by published records from the 1989 Loma Prieta Earthquake. Surface motion measured in the bedrock of San Francisco Bay's Yerba Buena Island was only 38 percent as strong as that measured on the surface of fill material used to create Treasure Island, less than one mile away.[9]

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[9]California Department of Conservation, Division of Mines and Geology, Office of Strong Motion Studies. Report OSMS 89-06: *California Strong Motion Instrumentation Program, Strong Motion Records from the Santa Cruz Mountains (Loma Prieta) California Earthquake of 17 October 1989*.

Ground shaking can result in the differential settlement of unconsolidated soils in response to unequal surface loading. Movement of the ground causes an additional compaction of the soil that is proportional to the soil's pre-existing density and to the magnitude of imposed surface loads. These conditions often result in unequal settlement, which can cause the failure of poorly stabilized cut-and-fill embankments and of foundations that cannot span areas of discontinuous support.

The project site is expected to experience strong ground shaking during a major earthquake on any of the nearby faults. Ground motions may be amplified (depending on the frequency content of the motion) as was the case during the Loma Prieta Earthquake at some Bay mud sites.[10]

(4) Potential for Liquefaction and Lateral Spreading. Liquefaction and lateral spreading are similar losses of foundation support that occur in saturated (submerged) granular soils, most notably loose, clean, saturated, uniformly graded, fine-grained sand. Under liquefaction, saturated, cohesionless soil experiences a temporary loss of strength due to build-up of excess pore water pressure, especially during cyclic loadings such as those induced by earthquakes.

Beneath the project site, there are some layers below the Bay mud which may liquefy and result in seismically induced ground settlement at the surface. Based on the preliminary investigation by Treadwell & Rollo (p. 12), these layers do not appear to be continuous, and therefore, other earthquake-induced ground failures such as lurching and landsliding have a low potential of occurrence. However, Treadwell & Rollo estimates that some settlement due to liquefaction could occur at the site.

11.2 PERTINENT PLANS AND POLICIES

11.2.1 Redwood City Strategic General Plan Policies

The Redwood City Strategic General Plan *Safety Element* (adopted in 1990) incorporates the countywide *Seismic* and *Safety Elements* prepared by San Mateo County with the cooperation of Redwood City. The *Safety Element* contains the following geotechnical objective and policy pertinent to consideration of the potential environmental impacts of the proposed project:

- *Protect the community from the hazards of soil erosion, weak and expansive soils, and geologic instability.* (Safety Objective 1, page 12-3)

- *Identify structural types and land uses highly sensitive to earthquake activity, and abate or modify them to achieve acceptable levels of risk.* (Safety Policy S-12, page 12-3)

11.2.2 San Francisco Bay Conservation and Development Commission (BCDC)

[10] Treadwell & Rollo, p. 12.

The San Francisco Bay Conservation and Development Commission (BCDC) has permit jurisdiction over tidal areas of the Bay, which include Redwood Creek to its confluence with Smith Slough, Smith Slough itself, and a shoreline band along these watercourses, consisting of the upland area 100 feet inland from and parallel to the line of highest tidal action of the Bay. Portions of the project site on the northern and western edges of the Pete's Harbor property fall within this 100-foot band of BCDC jurisdiction (see Figure 8.1, in chapter 8, Biological Resources, of this EIR).

Work within the Bay or the 100-foot shoreline band, including Bay filling, dredging, and shoreline development, requires a BCDC permit.[11] In particular, BCDC is authorized to issue or deny permits for any filling of San Francisco Bay. Section 66605 of the McAteer-Petris Act allows BCDC to authorize Bay fill only for water-oriented uses, and minor fill to improve shoreline appearance or public access. Also, the McAteer-Petris Act requires that fill should be authorized only if: (a) there is no feasible upland location, (b) the fill is the minimum amount necessary, (c) the fill minimizes harmful effects to the Bay, and (d) the public benefits clearly exceed its detriments.

The proposed project would require a BCDC permit for those proposed shoreline modifications and development components that fall within the 100-foot band from Smith Slough. The locations of the proposed reduction and reconfiguration of Peninsula Marina and Inner Pete's Harbor are outside the 100-foot band and are therefore not subject to BCDC jurisdiction.[12]

11.2.3 Uniform Building Code

The construction of all buildings within Redwood City is regulated by the Uniform Building Code (UBC, 1997). The UBC has been formulated to ensure that buildings constructed in conformance with its earthquake design provisions can safely withstand the effects of earthquake-induced ground shaking. As a result, it is not expected that newly constructed buildings in Redwood City will collapse or otherwise fail structurally during a major earthquake, although they may sustain substantial damage.

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[11]San Francisco Bay Conservation and Development Commission. San Francisco Bay Plan, July 2001, p. 5 and Plan Map 6 (Central Bay South). Also, Huffman-Broadway, pp. 7-8.

[12]Steve McAdam, Deputy Director, San Francisco Bay Conservation and Development Commission, phone communication, December 6, 2001. Also, Huffman-Broadway, p. 8.

11.3 IMPACTS AND MITIGATION MEASURES

11.3.1 Significance Criteria

Based on the CEQA Guidelines, the project would be expected to have a significant soils and geology impact if it would:[13]

(1) Expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:

 (a) 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 (Division of Mines and Geology Special Publication 42);

 (b) strong seismic ground shaking;

 (c) seismic-related ground failure, including liquefaction; or

 (d) landslides;

(2) Result in substantial soil erosion or the loss of topsoil;

(3) 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;

(4) Be located on expansive soil, as defined by Table 18-1-B of the Uniform Building Code, creating substantial risks to life or property;

(5) Have soils incapable of adequately supporting the use of septic tanks or alternative wastewater disposal systems where sewers are not available for the disposal of waste water; or

(6) Conflict with any applicable plan, policy, or regulation adopted by the City of Redwood City for the purpose of avoiding or mitigating an adverse soils or geotechnical impact.

11.3.2 Future Study and Subsequent Mitigation

Before the specific terms of required mitigation can be developed for the geotechnical aspects of the project, additional, more detailed studies must be performed to address specific concerns.

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[13] CEQA Guidelines, Appendix G, items VI(a-e) and IX(b).

Geotechnical mitigation requirements identified in subsequent sections of this chapter include completion of additional, more detailed studies to address specific concerns as the project design is refined. With regard to such any mitigation recommendations that have been described in this EIR chapter which require future additional determinations, the CEQA Guidelines and recent court decisions indicate that mitigation measures must be mandated which will alter the significant impacts of the project. In particular, EIR mitigation measures must ensure that the project would be implemented in a manner that renders insignificant or minimizes potentially significant soil and geology impacts of the project. There is substantial, reasonable, historic information to support the conclusion that the specific subsequent geotechnical/geologic investigations, inspections, and specific formulations required to meet the standards identified in this EIR would adequately mitigate related impacts to less-than-significant levels. The City of Redwood City routinely requires such geotechnical/geologic investigations and specifications at phases of development review that follow EIR certification.

The techniques and standards for geotechnical mitigation are widely known and accepted, but individual measures for particular projects are typically, and most efficiently, specified at a detailed level of design which cannot be expected at this stage for a project of the scale of the proposed Marina Shores Village.

A significant record exists demonstrating the effectiveness of such post-EIR-certification design and engineering requirements in mitigating the potential soil and geologic impacts of concern identified in this EIR. Under the City's grading permit and building permit provisions, requirements, and regulations, the project cannot be given final approval without project compliance with geotechnical/geologic requirements. These requirements and related City inspection and verification procedures prior to project occupancy provide reasonable assurances that the project would incorporate the design and engineering refinements necessary to reduce the degree of impact to less-than-significant levels by either avoiding identified soil and geologic impact areas altogether (i.e., basic project design changes), or by rectifying the impact through conventional engineering and construction procedures (e.g., suitable pile-supported foundation system, surcharging, over-excavating/geotextiling/backfilling) identified throughout the post-EIR investigation and monitoring process.

11.3.3 Project Grading Impacts

Impact 11-1: Geotechnical Hazards Associated with Project Grading. The interaction of existing geotechnical conditions on the project site with the proposed grading, dredging, and surface modifications--and their combined effect on surface settlement, seismic hazards, and soil erosion--have the potential to result in significant adverse effects. The applicant's preliminary geotechnical investigation (Treadwell & Rollo, June 21, 2001) made an initial assessment of these conditions, but a design-level geotechnical investigation would be needed to adequately address all grading, dredging, and stabilization activities on the site. Without such a study--and without the associated supervision of an engineering geologist or geotechnical engineer during project grading, dredging, and construction--the safety and long-term stability of project improvements could not be assured. These possible geotechnical hazards represent a ***potentially significant impact*** (see criteria 1 through 6 in subsection 11.3.1, "Significance Criteria," above).

The project site would be graded to prepare the proposed development areas for construction. All existing buildings, structures, marina improvements, paving, hardscape, and other on-site improvements would be demolished and removed. Demolition debris would be removed by truck and/or barge.

Site grading would be designed to provide surface drainage to an underground drainage system. Finished grades along the shoreline would be elevated to approximately 110 feet (i.e., three feet above the 100-year flood elevation of approximately 107 feet), in accordance with City of Redwood City flood control standards. First-floor habitable space would be set at an elevation of approximately 108 feet (i.e., one foot above the 100-year flood elevation). The bottom floor of the proposed parking structures would be just above the groundwater elevation.

Soils excavated to construct the parking structures would be used as on-site fill, as would the soils removed for underground drainage improvements. A new flushing channel to connect the reconfigured Peninsula Marina with Redwood Creek would be excavated; soils excavated for the channel would also be used as on-site fill.

The existing Inner Pete's Harbor and former Peninsula Marina would be reduced in size and reconfigured (see subsection 3.4.6 in chapter 3, Project Description, herein). The project applicant proposes driving permanent steel sheet piles along the new edges of the marinas, with excavated on-site material and imported fill used to backfill the sheet piles.

Mitigation 11-1: As recommended by the applicant-commissioned Treadwell & Rollo preliminary geotechnical investigation, require the applicant to retain a registered engineering geologist or geotechnical engineer to prepare *detailed, design-level geotechnical investigations* to guide the design of all project grading, dredging, and stabilization activities. The *detailed, design-level geotechnical investigations* shall be performed for each of the structures proposed for the project site. Subsurface conditions shall be explored and laboratory tests conducted on selected soil samples to establish strength parameters for foundation design and perimeter slope stability, and for corrosivity potential of the fill and Bay mud on foundation elements and buried utilities. Specific recommendations shall be developed for foundation support for each building, slab-on-grade floors, pavements, bulkheads, and slope inclinations for permanent slopes. The *detailed, design-level geotechnical investigations* shall include subsurface investigation to further identify the thickness and the consolidation characteristics of the Bay mud underlying the project site. Recommendations from the investigation shall be incorporated into project grading, dredging, and construction plans to the satisfaction of the City Engineer.

The *detailed, design-level investigations*, relevant recommendations, and all associated project grading, dredging, filling, and foundation plans, shall be subject to review and approval by an independent engineering geologist or geotechnical engineer retained by the City Engineer at applicant expense. In addition, the project civil engineer shall certify that all relevant provisions of the investigation have been incorporated into the grading, dredging, and construction plans. All earthwork and site preparation shall be performed under the direct supervision of a registered engineering geologist or geotechnical engineer. Implementation of these measures would reduce these potential impacts to a ***less-than-significant level***.

The *detailed, design-level geotechnical investigations* shall include, but not necessarily be limited to:

- A subsurface investigation to further identify the thickness and the consolidation characteristics of the Bay mud underlying the project site;
- Estimates of potential settlements for the ground- and pile-supported structures, as well as for downdrag loads;
- Detailed geotechnical investigations for each structure proposed for the project site;
- Subsurface explorations and laboratory tests on selected soil samples to establish strength parameters for foundation design and perimeter slope stability, and for corrosivity potential of the fill and Bay mud on foundation elements and buried utilities; and
- Specific recommendations for foundation support for each building, slab-on-grade floors, pavements, bulkheads, and slope inclinations for permanent slopes.

11.3.4 Foundations and Settlement Impacts

Impact 11-2: Total and Differential Settlement. The presence of weak, compressible Bay mud underlying the on-site fill is the most significant factor influencing the selection of a foundation system for the proposed project. The project's structural loads would be too great to be supported on conventional shallow foundations bottomed in fill or weak Bay mud. Shallow foundations would potentially experience excessive total and differential settlements. These possible effects represent a ***potentially significant impact*** (see criterion 3 in subsection 11.3.1, "Significance Criteria," above).

The existing Inner Pete's Harbor and former Peninsula Marina would be reduced in size and reconfigured (see subsection 3.4.6 in chapter 3, Project Description, herein). The project applicant proposes driving permanent steel sheet piles along the new edges of the marinas, with excavated on-site material and imported fill used to backfill the sheet piles.

The project site is underlain by approximately 15 to 22 feet of compressible Bay mud, except at the south end of the site, where the Bay mud decreases to approximately 8 feet in thickness. Most of the settlement due to consolidation of the Bay mud under the weight of the existing fill has already occurred; however, placement of additional fill for site grading would cause additional settlements. Treadwell & Rollo has calculated a preliminary estimate of approximately 3 to 4 inches of subsidence per foot of new fill over 10 to 20 years in non-marina areas.[14]

Although the Bay mud thickness is less in the existing and former marinas, the proposed fill thickness and resulting settlements due to dredging activities for reducing and reconfiguring the marinas could be substantial. Actual settlement would depend on the consolidation history and thickness of Bay mud and thickness of fill placed at any given location.

Acknowledging that the proposed project development on fill over Bay mud would produce settlement and would be subject to earthquake-induced liquefaction, the applicant anticipates that building foundations would be pile-supported, and exterior slabs and ramps would be hinged to the pile-supported building foundations to accommodate differential settlement.

Mitigation 11-2: The *detailed, design-level geotechnical investigations* required under *Mitigation 11-1* shall include laboratory analyses of all dredged material and all materials proposed for use as fill. These analyses shall be sufficient to adequately estimate the rate and total amount of fill consolidation following compaction, and the resulting likelihood of differential settlement, especially in the areas of the reduced and reconfigured marinas. Design of all fills shall incorporate the results of these analyses to minimize the destructive effects of future settlement, and the investigation shall set forth guidelines that address, at a minimum, the composition of fill materials, methods of fill placement, the required degree of fill compaction, and the layout of the subsurface drainage systems needed to adequately dewater the fill. In addition, all improvements to be constructed on top of or within fills shall be designed in accordance with the recommendations of the *detailed, design-level geotechnical investigations*. Once a final grading plan has been prepared and building loads determined, estimates of potential settlements for the ground- and pile-supported structures, as well as for downdrag loads, shall be provided. Following completion of fills, settlement shall be monitored and improvement plans shall be modified as necessary (see details below).

[14] Treadwell & Rollo, p. 10.

(continued)

Mitigation 11-2 (continued):

The results of the *analyses of dredged material* shall be included in any request or application for disposal or reuse of dredged material.

All recommendations contained in and derived from the *detailed, design-level geotechnical investigations* shall be incorporated into the conditions of approval for each structure or construction phase, with implementation enforced by the City throughout the construction period. In general, these recommendations are expected to include, but not be limited to, the following provisions:

- Support all project buildings on driven piles. At this preliminary point in the geotechnical analysis, Treadwell & Rollo recommends precast, prestressed concrete piles with 100-ton capacity (12 inch) and 125-ton capacity (14 inch) at lengths of 75 to 90 feet and 80 to 95 feet, respectively. Perform pile load tests to evaluate the ultimate capacity and required length of the piles.

- If settlements are found to be excessive, consider a surcharge program to reduce the effects of settlement, especially when filling in portions of the existing and former marinas.

- Design ground floor slabs to span between the pile caps and/or grade beams. Fill should not be relied upon for support.

- Use flexible connections for utilities entering buildings in order to protect against breakage caused by differential settlement.

- Hinge exterior slabs and ramps attached to buildings in order to protect against breakage caused by differential settlement between the buildings and the outside ground.

- If settlements are found to be excessive, especially when filling in portions of the existing and former marinas, consider a *surcharge program* to reduce the effects of settlement. Surcharging consists of placing excess fill in areas where settlements are a concern and leaving it in place a sufficient amount of time to partially pre-consolidate the underlying compressible soil.

Implementation of these measures would reduce this potential impact to a ***less-than-significant level***.

(a) Assessment of Underlying Soils and Fills. The *design-level geotechnical investigation* shall assess the strength, stability, and degree of compaction of existing soils and fills on which additional fill is to be placed or on which project improvements are to be constructed. If it is determined that these materials would undergo unacceptable levels of compaction and/or settlement following construction, they shall be removed and replaced as engineered fill. If some of these materials are found to be unsuitable for use as fill material in a concentrated form, they should be thoroughly mixed with acceptable material to provide a suitable composite.

(b) Building Foundations. The proposed buildings should be supported on driven piles that gain support through friction in the stiff clay and dense sand layers underlying the Bay mud. Furthermore, Treadwell & Rollo recommends precast, prestressed concrete piles as the most appropriate pile type for the proposed project. Based on subsurface information from the site, 100- and 125-ton capacities are considered feasible for 12- and 14-inch square piles, respectively, with the 12-inch piles being approximately 75 to 90 feet in length, and the 14-inch piles being 80 to 95 feet in length.[15]

The capacities of the piles do not include the effects of negative friction (i.e., downdrag loads) that would occur as the Bay mud consolidates under the weight of the existing and/or new fill on the project site. The magnitude of the downdrag load would depend on the thickness of the Bay mud and fill and, consequently, would vary across the site. Treadwell & Rollo estimates that the downdrag loads may range between 10 and 15 tons; the actual load can be computed once a project grading plan is available. Pile load tests could be performed to evaluate the ultimate capacity and required length of the piles.[16]

Lateral load resistance can be mobilized by the individual piles in combination with other foundation elements embedded below the ground surface. Lateral pile resistance will depend on the stiffness of the pile, the strength of the surrounding soil, allowable deflection of the pile top, and the moment induced in the pile.

Due to the potential for settlement of the ground surface, Treadwell & Rollo recommends that ground floor slabs be designed to span between the pile caps and/or grade beams. Fill should not be relied upon for support. Although the ground surface might settle away from the slabs, the slabs would initially be in contact with the ground. In time, voids might develop. These voids could be filled by grouting.[17]

[15]Treadwell & Rollo, pp. 9-10.

[16]Treadwell & Rollo, p. 10.

[17]Ibid.

Future settlement from placement of additional fill may reduce the ability of the pile foundation system to resist lateral loads; therefore, special consideration should be given to deepening pile caps and grade beams, as well as installing other elements (e.g., a stiff perimeter "skirt") to supplement the lateral resistance capacity of the foundation.

Pile foundations would transfer building loads below the weak Bay mud to stronger and less compressible soil. However, some minor settlement (less than one inch) of the pile foundations would be caused by compression of the stiff clay supporting the piles. Such settlements could be evaluated when building loads and pile configurations are known.[18]

Flexible connections should be used for utilities entering the buildings. Also, exterior slabs and ramps attached to buildings should be hinged to tolerate differential settlement between the buildings and outside ground.[19]

Differential settlement across buried sloughs might occur, depending upon the amount of new fill placed. Treadwell & Rollo expects such differential settlement to be relatively small and tolerable for pile-supported structures.[20]

(c) Settlement Monitoring. Settlement of all fills shall be monitored following their completion to confirm that actual settlement rates and the associated estimates of total, long-term settlement do not exceed those predicted in the geotechnical investigation. If higher settlement rates are observed, the design of all improvements that may be affected by excessive settlement shall be reviewed by the project geotechnical and structural engineers, as well as by the City Engineer, and appropriate modifications shall be made before these improvements are constructed.

11.3.5 Seismic Impacts

Impact 11-3: Ground Shaking. Development of the proposed project would place new residences and businesses in a subregion that is expected to experience severe earthquake-induced ground shaking during the useful life of the project improvements. This ground movement could also cause differential settlement of poorly consolidated soils (including Bay mud) and induce ground failure within alluvial soils that are prone to liquefaction (including some layers below Bay mud).

[18] Treadwell & Rollo, p. 11.

[19] Ibid.

[20] Ibid.

These possible responses to anticipated seismic activity represent a ***potentially significant impact*** (see criterion 1 in subsection 11.3.1, "Significance Criteria," above).

Beneath the project site, there are some layers below the Bay mud which may liquefy and result in seismically induced ground settlement at the surface. Based on the preliminary investigation by Treadwell & Rollo (p. 12), these layers do not appear to be continuous, and therefore, other earthquake-induced ground failures such as lurching and landsliding have a low potential of occurrence. However, Treadwell & Rollo estimates that some settlement due to liquefaction could occur at the site (approximately one inch) and concludes that these hazards should be further evaluated during the specific project design phase. Because the project buildings are expected to be pile-supported, liquefaction-induced settlement should not affect the structures; however, settlement may affect flatwork, such as sidewalks and asphalt pavements.

Mitigation 11-3: Require that the *detailed, design-level geotechnical investigations* recommended under *Mitigations 11-1* and *11-2* include analysis of project site seismic stability, evaluation of liquefaction potential, and soil response characteristics with respect to ground acceleration.

The *detailed, design-level geotechnical investigations* should include the following:

- Seismic stability analysis of the existing on-site soil, including fill, Bay mud, and underlying alluvial deposits;
- Evaluation of liquefaction potential through the performance of additional borings, cone penetration tests, and/or equivalent methods; and
- Determination of parcel-specific soil response characteristics and maximum credible ground acceleration for an earthquake recurrence interval specified by the City of Redwood City.

Recommendations from the investigations, including appropriate soil stabilization and foundation construction techniques, minimum setbacks around potentially unstable areas, and criteria for the compaction and treatment of on-site fills, shall be incorporated into the project grading and foundation plans. In general, these recommendations are expected to include, but not be limited to, the following provisions:

- Require all construction to comply with the Uniform Building Code (UBC, 1997) for Seismic Zone Factor 4 and Soil Profile Type S_E. Base all project designs on estimates of peak and maximum repeatable earthquake-induced ground surface accelerations expected to occur on the project site, as calculated by the project geotechnical investigations.

- Slope or shore excavations in order to minimize ground movements. Typically, when excavation extends into Bay mud, 4:1 or flatter slopes are required to reduce movements.

Implementation of these measures--combined with conformance with standard Uniform Building Code, City of Redwood City, and other applicable regulations--would reduce the potential effects of ground shaking to a ***less-than-significant level***.

Impacts Due to Surface Failure/Fault Rupture. No active or probably active fault has been identified on the project site. The potential for surface failure or fault rupture is low, and potential impacts are ***less-than-significant***.

Mitigation. No significant impact has been identified; no mitigation is required.

11.3.6 Groundwater Impacts

Impact 11-4: Encountering Groundwater in Bay Mud During Excavation. Excavation for the proposed project's below-grade installations, such as utilities, might be difficult due to the high groundwater and relatively shallow depth of the weak Bay mud. This condition represents a ***potentially significant impact*** (see criterion 3 in subsection 11.3.1, "Significance Criteria," above).

Mitigation 11-4: Require that the *detailed, design-level geotechnical investigations* recommended under *Mitigations 11-1* and *11-2* include analyses of groundwater and Bay mud within the limits of all foundation and utility construction. The analyses shall make recommendations regarding dewatering techniques, slope and shoring requirements for excavations, buffer zones for construction equipment near slope edges, the potential for requiring light grading equipment, subgrade remediation techniques, and the use of excavated fill. Project grading and construction plans shall incorporate the results and recommendations of these analyses. In general, these recommendations are expected to include, but not be limited to, the following provisions:

- Soil excavated from below the water level would be saturated and would require drying before it can be used as fill. Continuous dewatering of excavations might be required.

- The sides of the excavations should be sloped or shored to minimize ground movements; steep cuts are not possible in Bay mud unless shoring is used.

Typically, when excavation extends into Bay mud, 4:1 or flatter slopes are required to reduce movements.[21]

(continued)

Mitigation 11-4 (continued):

- Keep construction equipment away from the edges of slopes in order to reduce vibration degradation. Consider light grading equipment to avoid creating ruts in the subgrade, a situation that might require pumping. Remediate rutted subgrade areas by over-excavating the soft area to a depth of 18 to 24 inches, placing a geotextile at the bottom of the over-excavation, and backfilling with suitable granular material.

- Do not use excavated Bay mud as fill beneath structures or pavement. When placing substantial fill directly on top of Bay mud, such as in the proposed reduced and reconfigured marinas, the fill might need to be placed in thin, uniformly thick lifts to prevent "mud waves" from forming. Mud waves can damage structural elements already installed, particularly piles and underground utilities.

- The project civil engineer shall certify that all relevant provisions of the *detailed, design-level geotechnical investigations* have been incorporated into the grading, dredging, and construction plans.

- All earthwork and site preparation shall be performed under the direct supervision of a certified engineering geologist or geotechnical engineer.

Implementation of these measures would reduce this impact to a ***less-than-significant level***.

11.3.7 Soil and Groundwater Corrosivity Impacts

Impact 11-5: Corrosive Soils. The soil on the project site is classified as "severely corrosive" to iron, steel, metal, and concrete. This condition could result in long-term damage to building foundations and underground utility systems, a possibility that represents a ***potentially significant impact*** (see criterion 1 in subsection 11.3.1, "Significance Criteria," above).

[21] Treadwell & Rollo, p. 13.

ASTM (American Society for Testing and Materials) techniques were used to measure soil pH and electrical conductivity, and to determine the concentrations of chloride and sulfate ions in the project site soil. Based on the resistivity measurements, the soil can be classified as "severely corrosive."[22]

Redox potentials on-site indicate potentially "slightly corrosive" soils resulting from anaerobic soil conditions.

The chloride ion concentrations are sufficient to attack concrete and reinforcing steel embedded in concrete mortar coating. The sulfate ion concentrations are sufficient to damage reinforced concrete structures and cement-mortar-coated steel. The pH of the soils, ranging from 6.7 to 8.0, does not present corrosion problems for buried iron, steel, mortar-coated steel, or reinforced concrete structures. Buried metal and cement structures in contact with earth surfaces should be appropriately protected.

Mitigation 11-5: Require that the *detailed, design-level geotechnical investigations* recommended under *Mitigations 11-1* and *11-2* include an evaluation of corrosive soils within the limits of all foundation and utility construction. Wherever corrosive soils are found in sufficient concentrations, recommendations shall be made to protect iron, steel, metal, and concrete from long-term deterioration caused by contact with corrosive on-site soils. In general, these recommendations are expected to include, but not be limited to, the following provisions:

- Protect buried iron, steel, cast iron, ductile iron, galvanized steel, and dielectric coated steel or iron (including all buried metallic pressure piping) against corrosion from soil.

- Protect buried metal and cement structures in contact with earth surfaces from chloride ion concentrations.

- Use sulfate-resistant concrete mix for all concrete in contact with the ground, including piles, pile caps, and grade beams.

- Consult a corrosion expert during the project's detailed design phase to help design the most effective corrosion protection.

Implementation of this measure would reduce this potential to a ***less-than-significant level***.

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[22]Treadwell & Rollo, p. 14 and appendix C (Corrosivity Test Results, CERCO Analytical, Inc., June 13, 2001).

11.3.8 Soil Erosion and Sedimentation Impacts

Impact 11-6: Soil Erosion and Sedimentation. Project development would disturb the site's natural topography and vegetative cover, leaving soils exposed to wind and water erosion during the construction period. Eroded soils would be washed either directly into Redwood Creek, Smith Slough, or the marinas, or into on-site drainage facilities, which drain into these same water bodies. Resulting sedimentation could affect the flows of Redwood Creek and Smith Slough, increasing flooding potential and maintenance problems. In addition, suspended sediment would degrade water quality in the creek, slough, and marinas by increasing turbidity. These possible effects of soil erosion represent a ***potentially significant impact*** (see criterion 2 in subsection 11.3.1, "Significance Criteria," above).

Mitigation 11-6: Require that the applicant prepare an *erosion control plan* subject to City approval and consistent with the required project Stormwater Pollution Prevention Plan (SWPPP) (see *Mitigation 9-1*). Implement the plan during construction. Erosion during all phases of construction shall be controlled through the use of erosion and soil transport control facilities. These shall include the use of catch basins and filter fabrics, and the direction of stormwater runoff away from disturbed areas. The plan shall also provide for long-term stabilization and maintenance of remaining exposed soils after construction is completed. Areas disturbed by construction shall be either covered with impervious surfaces (e.g., buildings and pavement) or fully stabilized with landscaping and/or native vegetation. All revegetated areas shall be irrigated and maintained as necessary to ensure the long-term survival of the vegetation.

Implementation of this measure would reduce this potential impact to a ***less-than-significant level***.

The recommended development of an erosion control plan is more thoroughly discussed in chapter 9 (Hydrology and Water Quality) of this EIR.