3.4 Geology, Soils, and Seismicity

This section of the Draft Environmental Impact Statement/Report (EIS/R) describes the existing geology and soils resources within the project area for Phase 2 of the South Bay Salt Pond (SBSP) Restoration Project at Eden Landing. The Phase 2 project area incorporates temporary construction-related disturbance areas, as well as the long term operational footprint of the project. It then analyzes whether the project implementation would cause a substantial adverse effect on geology and soils resources and to what extent the existing geologic and soil conditions could affect long term operation of the project. The information presented is based on a review of existing geology and soils resources within the project area and other pertinent federal, state and local regulations. The analysis of the project's potential impacts to geology and soil resources is presented for each alternative described in Chapter 2, Alternatives. The program-level mitigation measures described in Chapter 2, Alternatives, would be implemented as part of this project. Therefore, this section only identifies additional mitigation measures as needed.

3.4.1 Physical Setting

Methodology

The development of the baseline conditions, significance criteria, and impact analysis in this section is commensurate to and reliant on the analysis conducted in the 2007 South Bay Salt Pond (SBSP) Restoration Project Final Environmental Impact Statement/Report (2007 Final EIS/R). The baseline condition specific to the Phase 2 project area at the southern half of Eden Landing is based on an assessment of the current conditions within and surrounding the project site.

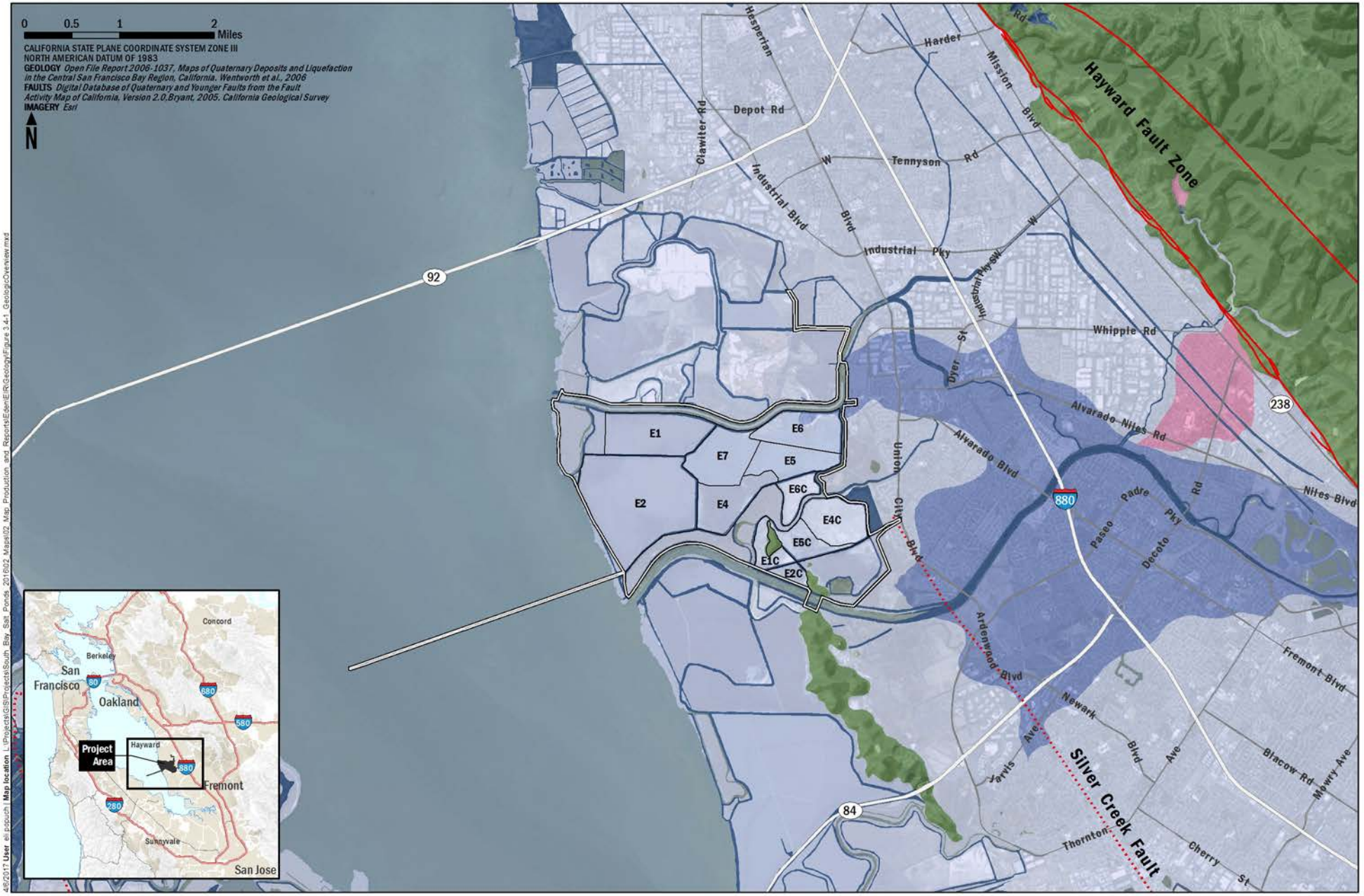
Geologic, seismic, and soil characteristics for the South San Francisco Bay (South Bay) were evaluated using existing published data and other publicly available sources summarized in the 2007 Final EIS/R. The sources and references for that evaluation include maps of general geologic distribution, faults, soils, liquefaction susceptibility, and other characteristics.

Regional and Project Setting

The regional setting for the SBSP Restoration Project as a whole was presented in Chapter 3.5 of the 2007 Final EIS/R. The following excerpts present an overview of key geologic, seismic, soils, and hazards concepts identified as a result of that document in relation to this program. A discussion of these concepts and how they relate to the existing conditions within the Phase 2 project area at the southern half of Eden Landing is provided below.

Geology

The San Francisco Bay (or Bay) Region is located along the boundary between the Pacific and North American plates, two large crustal plates that are separated by the north-northwest-trending San Andreas Fault, within the California Coast Ranges Geomorphic Province. A map showing an overview of geology in the San Francisco Bay Area from the United States Geological Survey (USGS) is shown on Figure 3.4–1 (Wentworth 1997).



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South Bay Salt Pond Restoration Project

Figure 3.4-1

General Geological Overview

The geomorphology of the region includes parts of three prominent, northwest-trending geologic/geomorphic features, which include, from west to east, the Santa Cruz Mountains, the Santa Clara Valley, and the Diablo Range. The Santa Clara Valley forms part of an elongated structural block (the San Francisco Bay block) within the central Coast Ranges that contains San Francisco Bay and its surrounding alluvial margins. This structural block is bounded by the San Andreas Fault to the southwest and the Hayward-Calaveras Fault zone to the northeast.

The oldest rocks in the region belong to the Franciscan Complex of Jurassic to Cretaceous age (205 to 65 million years ago [Ma]). These rocks are intensely deformed (i.e., folded, faulted, and fractured) due to ancient tectonic processes and, to a lesser extent, from more recent tectonic processes associated with the San Andreas Fault system. Franciscan rocks generally comprise the "basement" of the Coast Ranges northeast of the San Andreas Fault; Cretaceous granitic rocks, known as the Salinian block, comprise the basement of the ranges located southwest of the San Andreas Fault. A sequence of Tertiary (65 to 1.8 Ma) marine and non-marine sedimentary rocks unconformably overlies the granitic and Franciscan basement rocks in the region.

During the Plio-Pleistocene (5 Ma to 11,000 years ago [ka]) epochs, sediments eroded from the uplifting Diablo Range and the Santa Cruz Mountains formed broad alluvial fan complexes along the margins of the Santa Clara Valley. The 5-Ma to 300,000-year-old (Plio-Pleistocene) Santa Clara Formation, which consists of a sequence of fluvial and lacustrine sediments, was deposited unconformably on the older Tertiary and Franciscan rocks along the margins of the Santa Clara Valley during this time and has subsequently folded, faulted, and eroded. The Santa Clara Formation is unconformably overlain by younger Quaternary and Holocene (11 ka to present) alluvial and fluvial deposits (stream channel, overbank, and flood basin environments), which interfinger to the north with estuarine muds of San Francisco Bay (Helley et al. 1979).

The South Bay and the Phase 2 project area is part of a north-northwest-trending subsiding basin that is filled primarily with Quaternary alluvium (stream) deposits eroded from the surrounding margins and estuarine sources (Bay mud). The Sangamon and Holocene Bay muds are separated by the Quaternary alluvium and eolian (wind-blown) sand deposits. Alluvium deposits consist of sediments eroded from the surrounding Santa Cruz Mountains and Diablo Range uplands. These alluvial sediments were transported and deposited by streams and include a mixture of sands, gravels, silts, and clays with highly variable permeability. In contrast, the fine-grained Bay muds have very low permeability. The youngest Holocene Bay muds underlie almost the entire original Bay (Atwater et al. 1977; Helley et al. 1979). Figure 3.4-2 shows Bay mud thickness in the South Bay area (McDonald et al. 1978). Estuarine (Bay) muds were deposited in San Francisco Bay during high sea level periods of the Sangamon (70,000 to 130,000 years ago) and the Holocene (less than 11,000 years ago) (Atwater et al. 1977).

Due to movement on the San Andreas and related faults including the Hayward and Calaveras Faults, as well as the previous geologic history, a wide variety of igneous, metamorphic, and sedimentary rocks are present. The north-northwest-trending faults and sediment-filled Southern San Francisco Bay are clearly visible.

Soils

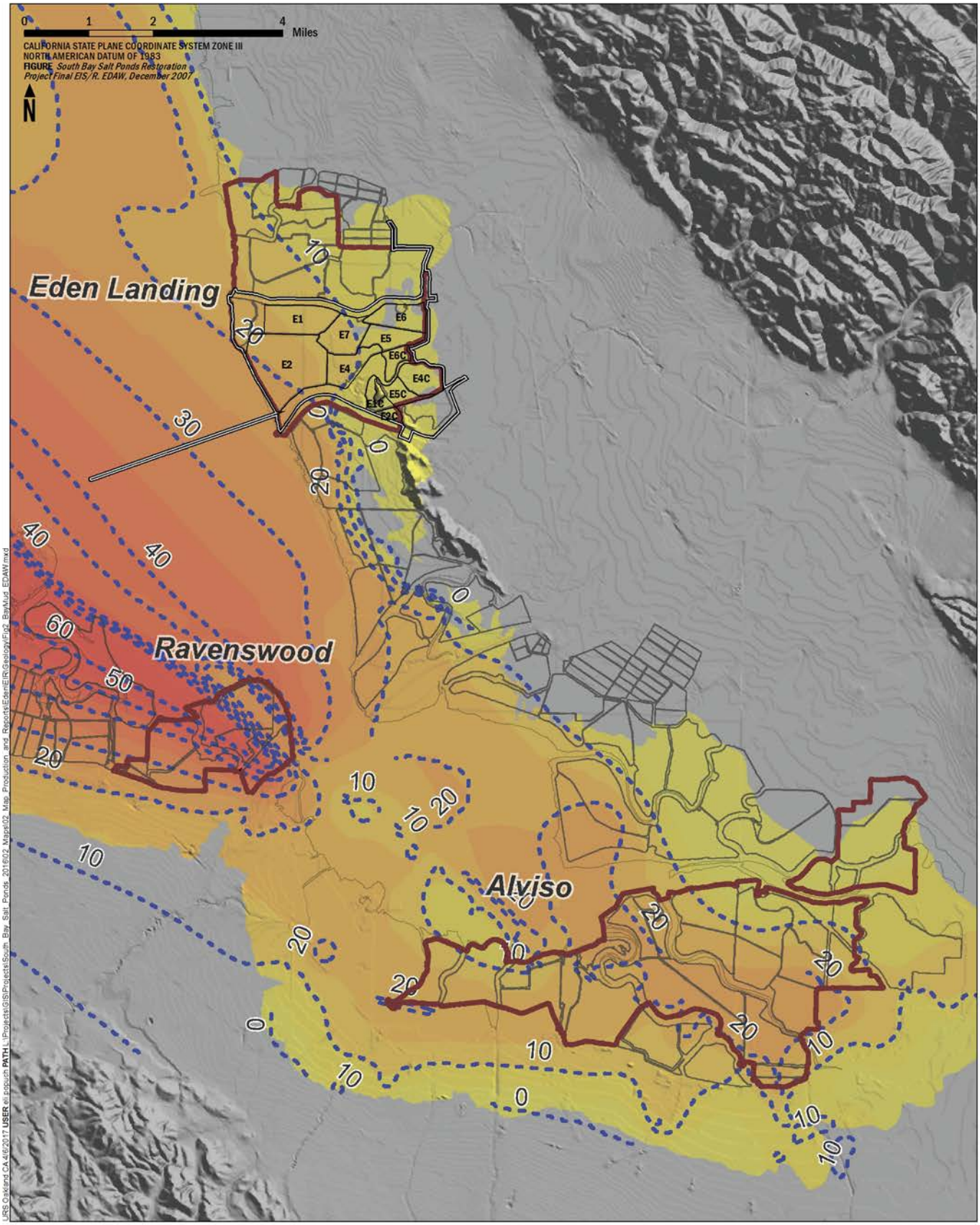
According to soil surveys published by the United States Department of Agriculture (USDA) Soil Conservation Service, soils along the Bay on the San Francisco Peninsula generally consist of those typically found on bottom lands, and can vary from very poorly drained to well-drained. Soils along the

east side of the South Bay, and specifically in the vicinity of the Phase 2 project area, is primarily comprised of very poorly drained clays (USDA Soil Conservation Service and University of California Agricultural Experiment Station 1981) (Figure 3.4-3).

Soils in the Eden Landing Phase 2 project area are primarily Reyes-Clay soils (USDA Soil Conservation Service and University of California Agricultural Experiment Station 1981). These soils consist of very poorly drained clays located on tidal flats or urban land, and are otherwise known as Bay muds.

Faults

The San Francisco Bay Region is located within a very broad zone of right-lateral transpression (strike-slip faulting and compression) marking a tectonic boundary zone dominated by strike-slip faulting associated with the San Andreas Fault system. The major active components of the San Andreas Fault system that occur in the South Bay Region include the proper or main trace of the San Andreas, Hayward, and Calaveras Faults. The Eden Landing Phase 2 project area is approximately 3.3 miles (5.3 kilometers [km]) from the trace of the Hayward Fault and 11.7 miles (18.7 km) east of the San Andreas Fault. The northern terminus of the potentially active Silver Creek Fault is mapped less than 1 mile from the eastern boundary of the pond complex (Figure 3.4-1).



LEGEND

- 10 ft Bay Mud Contour
- Pond Complex Boundary
- Eden Landing Phase 2 Project Area

Bay Mud thickness (ft)

0 10 20 30 40 50 60

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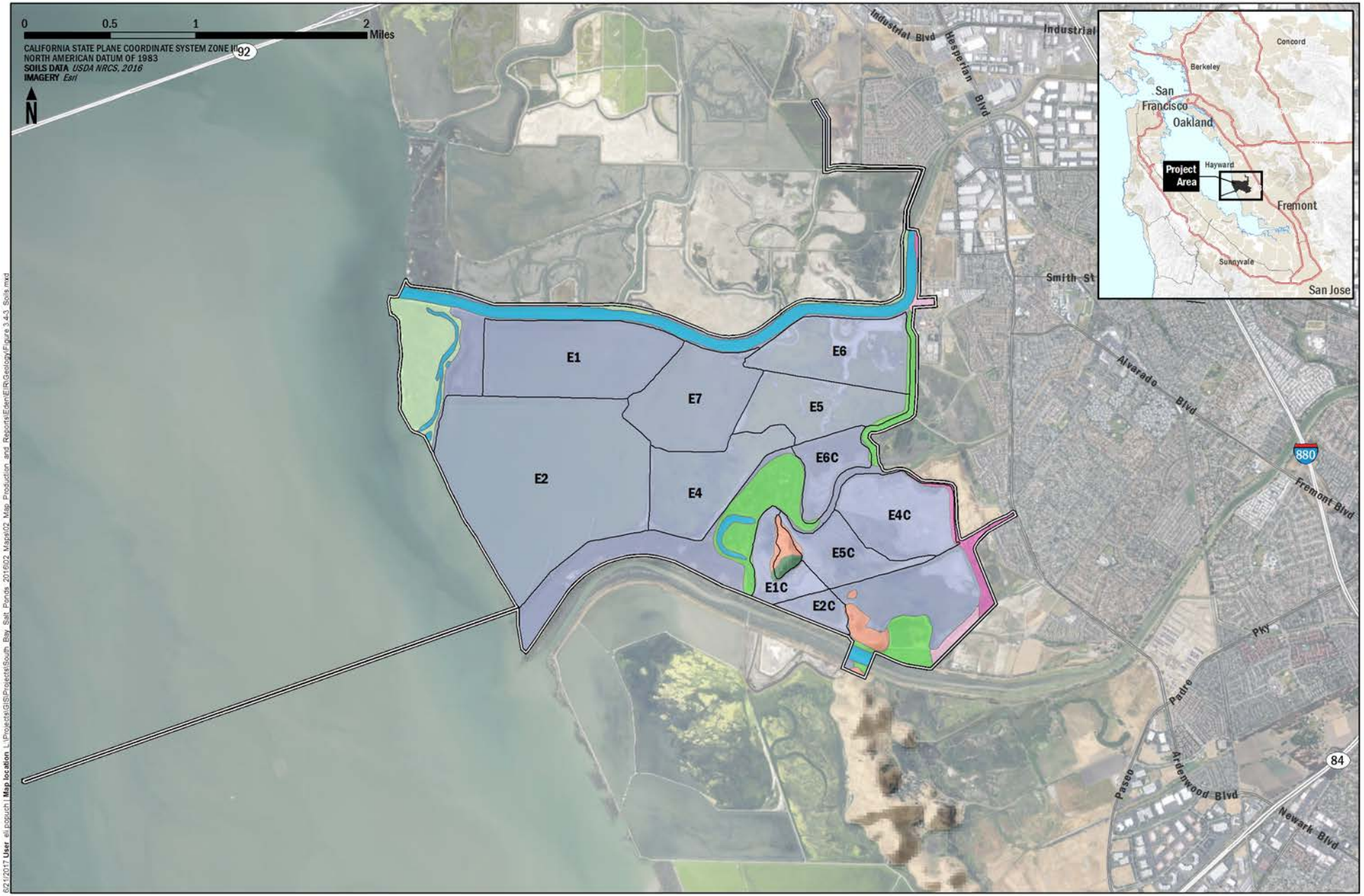
South Bay Salt Pond Restoration Project

Figure 3.4-2
Bay Mud Thickness, South Bay



LEGEND

NRCS Detailed Soils

- Contra Costa Clay Loam, 30 to 50 Percent Slopes
- Omni silty clay loam, drained
- Reyes clay
- Reyes Clay, Drained
- Reyes Clay, Ponded
- Sycamore Silt Loam, Drained
- Vallecitos-Rock Outcrop Complex, 30 to 50 Percent Slopes
- Water
- Eden Landing Phase 2 Project Area
- Southern Eden Landing Ponds

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South Bay Salt Pond Restoration Project

Figure 3.4-3

Soils

Seismicity and Seismic Hazards

The San Francisco Bay Region is considered to be one of the more seismically active regions in the world, based on its record of historic earthquakes and its position along the San Andreas Fault system. The San Andreas Fault system consists of several major right-lateral strike-slip faults in the region that define the boundary zone between the Pacific and North American tectonic plates. Numerous damaging earthquakes have occurred along the San Andreas Fault and its associated fault system in historical time.

Seismic or earthquake hazards are generated by the release of underground stress along a fault line and can cause ground shaking, surface fault rupture, tsunami/seiche generation, liquefaction, and earthquake-induced landsliding within the region, and the Phase 2 project area.

Surface Fault Rupture

Surface fault rupture, which is a manifestation of the fault displacement at the ground surface, usually is associated with moderate- to large-magnitude earthquakes (magnitudes of about 6 or larger). Generally, primary surface fault rupture occurs on active faults having mappable traces or zones at the ground surface. Potential surface fault rupture hazards exist along the known active faults in the greater San Francisco Bay Region. Faults that have been identified by the California Geologic Survey as potential surface rupture hazards in proximity to the Phase 2 project area include the San Andreas and Hayward Faults. These faults show historic (last 200 years) displacement associated with mapped surface rupture or surface creep.

Ground Shaking

Ground shaking takes the form of complex vibratory motion in both the horizontal and vertical directions. The amplitude, duration, and frequency content of ground shaking experienced at a specific site in an individual earthquake are highly dependent on several factors, including the magnitude of the earthquake, the fault rupture characteristics, the distance of the fault rupture from the site, and the types and distributions of soils beneath the site. Large-magnitude earthquakes produce stronger ground shaking than small-magnitude events. Sites close to the zone of fault rupture typically experience stronger motion than similar sites located farther away. Site soils can amplify ground motion in certain frequency ranges and can dampen ground motion within other frequency ranges. Soft soils sites, such as the Holocene Bay Mud and Quaternary alluvium, eolian deposits, and older Pleistocene Bay mud could amplify ground motions in the long period range compared to stiff or firm soils sites. This would affect structures having long, natural periods of vibration, such as bridges and tall buildings. Such soft soil substrate is present in the Eden Landing Phase 2 project area.

Liquefaction and Related Ground Failures

Liquefaction is a soil behavior phenomenon in which a soil located below the groundwater surface loses a substantial amount of strength due to high excess pore-water pressure generated and accumulated during strong earthquake ground shaking. During earthquake ground shaking, induced cyclic shear creates a tendency in most soils to change volume by rearrangement of the soil-particle structure. The potential for excess pore-water pressure generation and strength loss associated with this volume change tendency is highly dependent on the density of the soil, with greater potential in looser soils like those surrounding South Bay including the Eden Landing Phase 2 project area.

The severity of the liquefaction hazard depends on: density of the saturated granular soils, depth and thickness of potentially liquefiable layers, magnitude and duration of the ground shaking, and distance to the nearby free face or ground slope. Generally, looser deposits have the potential to densify more as a result of ground shaking and are subject to larger volumetric changes. Generally thicker deposits would accumulate more volumetric change than thinner deposits.

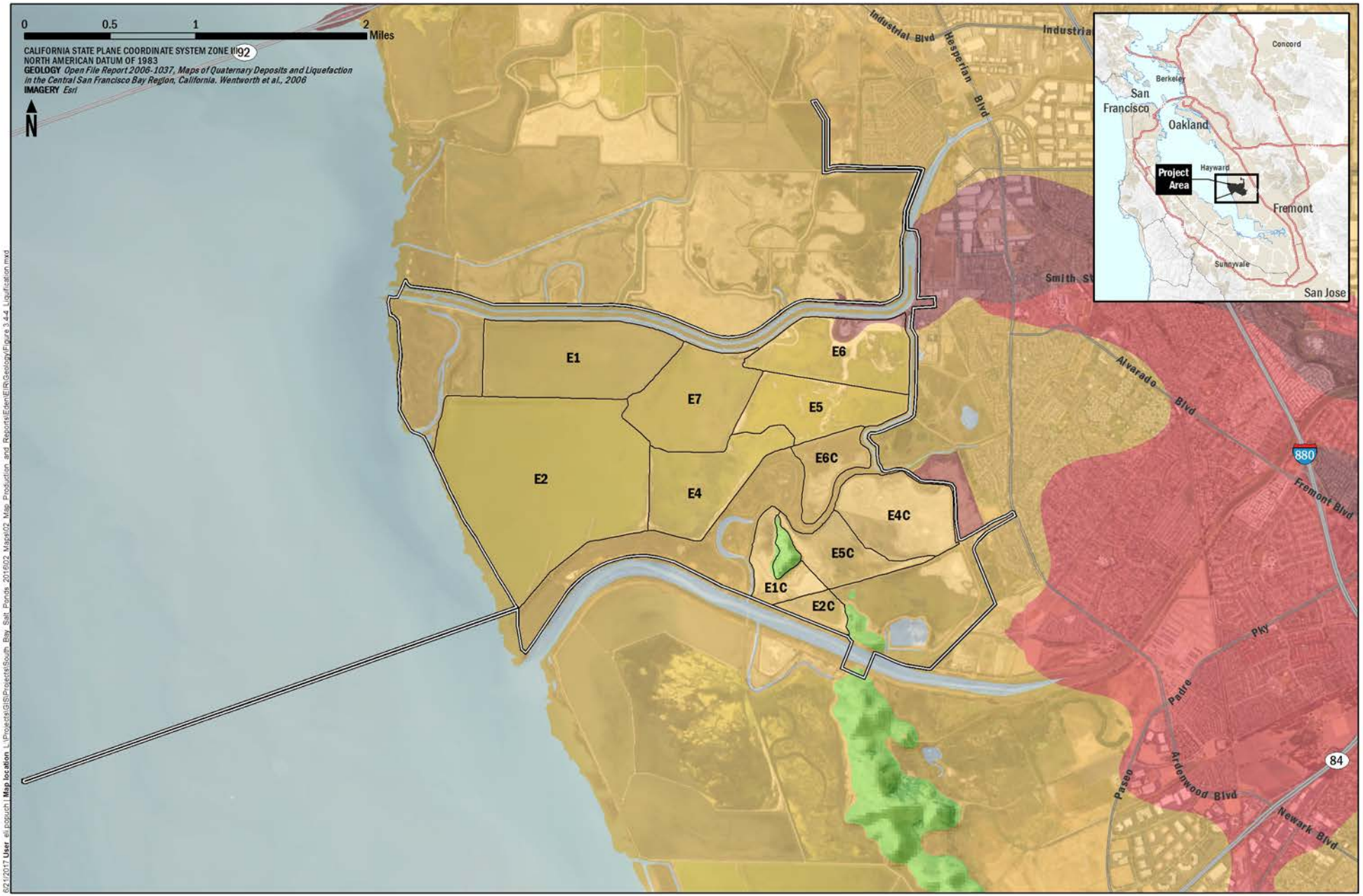
Figure 3.4-4 shows liquefaction susceptibility based on subsurface conditions, including soil type, soil thickness, and depth to groundwater. Locations of observed ground effects (lateral spreading, sand boil, or settlement) from historic earthquakes (1989 Loma Prieta, 1906 San Francisco, and others) are also shown. The majority of the Phase 2 project area has a "Moderate" susceptibility for liquefaction, with a small portion of Pond E6C within the Inland Ponds having a "Very High" susceptibility (Witter et al. 2006). This area of "Very High Susceptibility" traverses the northern levee along Pond E6C where the existing Bay Trail spur runs.

Landslides and Earthquake Triggered Landslides

Landsliding is a general term used to describe the gravity-driven downslope movement of weathered earth materials. Landsliding is frequently used to describe rapid forms of flow, slide, or fall, where a mass of rock or weathered debris moves downhill along discrete shear surfaces. Water generally plays an important role in landsliding by oversteepening slopes through surface erosion, by generating seepage pressures through groundwater flow, and by adding weight to a soil mass when it is saturated. Other factors that influence landsliding are: (1) strength of the rock/soil material; (2) degree/depth of weathering; (3) slope angle; (4) the orientation and density of rock structures, such as bedding, joint, and fault planes; and (5) grading activities. Inertial forces from earthquake ground shaking can also reduce the stability of a slope and cause sliding or falling of soil or rock. Landslides may also be triggered by earthquakes and ground shaking.

Subsidence

Within the Eden Landing Phase 2 project area, Bay mud is a very soft, highly compressible material that can cause settlement and ground subsidence. The potential for settlement is correlated to the thickness of the material that underlies a given location. Within southern Eden Landing, the thickness of Bay mud varies from about zero to 25 feet. Therefore, a new earthen or structural load constructed in an area that contains a significant thickness of Bay mud can cause consolidation of Bay mud, which would cause ground settlement that would result in lower ground surface elevations over time.



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South Bay Salt Pond Restoration Project

Figure 3.4-4

Liquefaction

3.4.2 Regulatory Setting

Federal

Flood risk assessments and some flood-protection projects are conducted by federal agencies, including Federal Emergency Management Agency (FEMA) and United States Army Corps of Engineers (USACE). Flood risk management actions and levee integrity will be influenced by geology, soils, and seismicity in the Eden Landing Phase 2 area. Applicable regulations and potential impacts to flood risk management are discussed in Section 3.2, Hydrology, Flood Management, and Infrastructure.

State

State regulations that govern geotechnical and geological aspects of Eden Landing Phase 2 project area include the Alquist-Priolo Earthquake Fault Zoning Act and Seismic Hazards Mapping Act. The California Building Code (CBC) would apply if a significant, permanent structure is constructed; however, none is proposed. The two primary regulations governing soils and geology are discussed below.

Alquist-Priolo Earthquake Fault Zone Act

Alquist-Priolo Earthquake Fault Zones are regulatory zones that encompass surface traces of active faults that have a potential for future surface fault rupture. To be located within an Earthquake Fault Zone means that an active fault is present within the zone, and the fault may pose a risk of surface fault rupture to existing or future structures. If property is not developed, a fault study may be required before the parcel can be subdivided or before most structures can be permitted. If a property within a Fault Zone is developed, the Alquist-Priolo Earthquake Fault Zone Act requires that all real estate transactions within the zone be disclosed by the seller to prospective buyers.

The law requires the State Geologist to establish regulatory zones (known as Earthquake Fault Zones) around the surface traces of active faults and to issue appropriate maps. (“Earthquake Fault Zones” were called “Special Studies Zones” prior to January 1, 1994.) The maps are distributed to all affected state agencies, counties, and cities for their use in planning and controlling new or renewed construction. Local agencies must regulate most type of development within Earthquake Fault Zones. For purposes of the Act, a project is defined as all land divisions and includes most structures for human occupancy. Single-family wood-frame and steel-frame dwellings up to two stories that are not part of a development of four units or more are exempt from the provisions of the Act. However, local agencies can be more restrictive than state law requires.

Before a project can be permitted, counties and cities must require a geologic investigation to demonstrate whether a proposed project will be constructed across active faults. An evaluation and written report of a specific site must be prepared by a licensed geologist. If an active fault is found, a structure for human occupancy cannot be placed over the trace of the fault and must be set back from the fault (generally 50 feet).

Seismic Hazards Mapping Act

The Seismic Hazards Mapping Act addresses seismic hazards such as strong ground shaking, soil liquefaction, and earthquake-related landslides. This act requires the State of California to identify and map areas that are at risk for these and other related hazards. Counties and cities are also required to regulate development in the mapped seismic hazard zones.

Permit review is the primary method of regulating local development under the Seismic Hazards Mapping Act. Counties and cities cannot issue development permits in these hazard zones until site-specific soils and/or geology investigations are carried out and measures to reduce potential damage are incorporated in the development plans.

The design of all structures (i.e., building and non-building structures) is required to comply with the Uniform Building Code (UBC)[1] and the CBC, which are the applicable building codes. Construction activities are overseen by the immediate local jurisdiction and regulated through a multi-stage permitting process. Projects within city limits typically require permit review by the city, while projects in unincorporated areas require a county permit. Grading and building permits require a site-specific geotechnical evaluation by a state-certified engineering geologist and/or geotechnical engineer. The geotechnical evaluation provides a geological basis from which to develop appropriate construction designs. A typical geotechnical evaluation usually includes an assessment of bedrock and quaternary geology, geologic structure, and soils, and a history of excavation and fill placement. The evaluation may also address the requirements of the Alquist-Priolo Act and the Seismic Hazards Mapping Act when appropriate.

3.4.3 Environmental Impacts and Mitigation Measures

Overview

This section describes environmental impacts and mitigation measures related to geology, soils, and seismicity. It includes a discussion of the criteria used to determine the significance of impacts. Potential impacts are characterized by evaluating direct, indirect, short-term (temporary), and long-term effects. Impact evaluations for the Action Alternatives are assessed based on the existing conditions described in Section 3.4.1, not the conditions that would occur under the No Action Alternative. This approach follows the requirements of CEQA, and what was done for the 2007 Final EIS/R. In this case, the No Action Alternative represents no change from current management direction or level of management intensity, as provided in the Adaptive Management Plan (AMP), the California Department of Fish and Wildlife's (CDFW's) Eden Landing Ecological Reserve (ELER, or Reserve) Restoration and Management Plan and the *Eden Landing Ecological Reserve System E2 and E2C Operation Plan* (Operations Plan), is consistent with the National Environmental Policy Act (NEPA) impact discussion. Mitigation measures are recommended, as necessary, to reduce significant impacts.

Significance Criteria

For the purposes of this Draft EIS/R, implementation of project alternatives at the Phase 2 project area within the Eden Landing pond complex would have a significant effect if it would:

- Be located on a site with geologic features that pose a substantial hazard to property and/or human life (e.g., an active fault, an active landslide); or
- Expose people or property to major geologic hazards that cannot be avoided or reduced through the use of standard engineering design and seismic safety techniques; or
- Cause substantial erosion or siltation.

[1] Published by the International Conference of Building Officials, the UBC is a widely adopted model building code in the United States. The CBC incorporates by reference the UBC, with necessary California amendments.

The first two of these significance criteria are addressed in the impacts discussed below, which are a function of the geographic location of the Phase 2 ponds and underlying geologic features (e.g., faults, Bay muds). The third bulleted significance criterion above is addressed partly herein and partly in Section 3.2, Hydrology, Flood Management, and Infrastructure. The Phase 2 Alternatives proposed at southern Eden Landing would not cause substantial erosion or siltation of top soils, so no further discussion of that topic is necessary here. The potential erosion caused by altering existing drainage patterns in the mudflats and sloughs is discussed in Section 3.2, Hydrology, Flood Management, and Infrastructure, and the biological and ecological effects of mudflat or marsh erosion are discussed in Section 3.5, Biological Resources.

As explained in Section 3.1.2, while both Council on Environmental Quality Regulations for Implementing NEPA and the CEQA Guidelines were considered during the impact analysis, impacts identified in this EIS/R are characterized using CEQA terminology.

Program-level Evaluation Summary

The 2007 Final EIS/R evaluated the potential geologic, soils, and seismic hazards that could affect the three long-term restoration alternatives. At the program level, the decision was made to select Programmatic Alternative C and implement Phase 1 actions. Therefore, a summary of the impacts for Alternative C from the 2007 Final EIS/R is provided below.

Potential effects from settlement and subsidence (including effects on levees and subsurface utility and surface rail crossings), liquefaction, lateral spreading, and ground and levee faults from fault rupture were found to be less than significant under Alternative C. This is because new and/or improved flood risk management levees would be designed, constructed, and maintained to address settlement, liquefaction, lateral spreading, and ground failure from a fault rupture. These facilities would be designed to account for the location of existing underground utilities and surface rail lines.

Risk from tsunami and/or seiche were found to be less than significant because Alternative C would not include habitable structures, and warning systems would allow for evacuation of the shoreline in such an event so inundation by tsunamis would not be expected to expose people to potential injury or death. Because impacts from Alternative C were found to be less than significant, no mitigation measures specific to geology and soils conditions are carried forward to Eden Landing Phase 2 from the 2007 Final EIS/R.

Project-Level Evaluation

Phase 2 Impact 3.4-1: Potential effects from settlement due to consolidation of Bay mud.

Alternative Eden A (No Action). Under Alternative Eden A (the No Action Alternative), no new activities would be implemented as part of the Phase 2 project. The CDFW would continue maintaining and operating the ponds as part of the ELER and according to the Operations Plan and the activities described in the AMP and in accordance with current CDFW practices.

The Eden Landing Phase 2 project area is underlain by Bay mud of varying thickness. Implementation of Alternative Eden A would allow existing features within the Phase 2 project area, including levees, pond bottoms, and recreational trail alignments to continue to settle at their current rate. Under this No Action

Alternative, no new structures or weight would be added that would expedite settlement caused by underlying Bay mud.

Under Alternative Eden A, CDFW would commit minimal effort to maintaining the majority of existing salt pond levees within the Phase 2 project area. Per CDFW's Restoration and Management Plan (California Department of Fish and Game [CDFG] 1999), existing levees along Ponds E4C, E5, E6C and E6 would be maintained for flood risk management, and maintenance of other levees and access roads coordinated with Alameda County Flood Control and Water Conservation District (ACFCWCD) and utilities such as Pacific Gas and Electric (PG&E) to ensure access to, and maintenance of existing assets is retained. Other periodic maintenance by CDFW would involve cleaning tide gates and weirs, and operating the water control system to maintain salinity levels, and control invasive species (CDFG 1999) through managed connections to Old Alameda Creek (OAC) and Alameda Creek Flood Control Channel (ACFCC). Beyond these efforts, all non-priority levees within the Phase 2 project area would settle over time, and due to wave action, unintentional breeching, and levee overtopping become increasingly prone to complete failure. However, because high priority flood risk management levees would be maintained, the potential effects from settlement due to consolidation of Bay mud would not increase overall hazards associated with dissolution and settlement of levees internal to the Phase 2 project area. As such, potential impacts associated with implementation of Alternative Eden A would overall, be less than significant and pose no new risks.

Alternative Eden A Level of Significance: Less than Significant

Alternative Eden B. Alternative Eden B includes a mix of project components that are intended to increase hydrologic connectivity of the project area via OAC and ACFCC. This increased connectivity, particularly through the northern portion of the Bay and Inland Ponds is intended to facilitate transition of the project area to tidal marsh over time. There would also be additional trails placed on improved levees. Project components such as breaching levees and the excavation of pilot channels would not increase settlement rates because they would not add additional weight to areas underlain by Bay mud. However, the construction and operation of footbridges and water control structures, along with the construction of dredge material infrastructure and the import of dredge material to raise pond bottom elevations and construct habitat transition zones, and the import of upland fill material to create islands, construct habitat transition zones, and improve levees for habitat separation and flood risk management, could increase localized background settlement rates over time.

Levees intended for habitat separation, flood risk management, and public access would be designed and constructed to account for settlement and consolidation caused by underlying Bay mud. The improved backside levee at the Inland and Southern Ponds, along with the associated habitat transition zone, would be designed to withstand seismic events to the extent practicable. Also, levees and other features would be initially overbuilt to account for localized settlement. The long-term settlement resulting from the increased weight associated with these levees and other features would be offset by required maintenance to ensure that minimum levee elevations for flood risk management are retained. Due to design considerations and ongoing maintenance of proposed flood risk management infrastructure associated with the project, the potential effects from settlement due to consolidation of Bay mud would not increase hazards associated with settlement. Therefore, implementation of Alternative Eden B would be less than significant, and pose no new risks.

Alternative Eden B Level of Significance: Less than Significant

Alternative Eden C. Alternative Eden C includes a mix of project features that would transition the Bay Ponds to tidal marsh and convert the Inland and Southern Ponds to enhanced managed ponds. The tidal marsh vs. managed pond areas would be separated by a proposed improved mid-complex levee between the Bay and Inland Ponds, which extends south through the J-Ponds to the ACFCC. Similar features described in Alternative Eden B would be constructed as part of Alternative Eden C including footbridges, viewing platforms, water control structures, habitat transition zones, islands, improved levees for habitat separation and flood risk management, and improved pond bottom elevations in the Bay Ponds. There would also be additional trails placed on improved levees above and beyond those in Alternative Eden B. New structures and import of dredge material and upland fill material could increase background settlement rates in these localized areas over time. While the components described are similar, the major difference between Alternative Eden B and C would occur in the proposed location of improved levees, the habitat transition zone, and the number and location of proposed water control structures, and the placement location for dredge materials. As with Alternative Eden B, these improvements – particularly the imported dredge material, the habitat transition zone, and the improved mid-complex levee – would add additional fill material to areas underlain by Bay mud. This could potentially increase the rate of settlement. However, the dredge material, habitat transition zones, and levee improvements are intended to function in coordination with the many other aspects of the Phase 2 project improvements, and as a whole, the Phase 2 project improvements are intended raise the elevation of the deeply subsided pond bottoms. Also, the levees and other features would be initially overbuilt to account for localized settlement. The long-term settlement resulting from the increased weight associated with these levees and other features would be offset by required maintenance to ensure that minimum levee elevations for flood risk management are retained. Therefore, on balance, the proposed actions associated with Alternative Eden C would work to offset the long term impacts of settlement and consolidation, and would not create impacts to people or property. Impacts resulting from potential settlement due to consolidation of Bay mud are therefore less than significant.

Alternative Eden C Level of Significance: Less than Significant

Alternative Eden D. Under Alternative Eden D, dredge materials would be placed in the Bay and Inland Ponds, the Bay Ponds would be restored to tidal marsh, and the Inland Ponds and Southern Ponds would be temporarily retained as managed ponds and enhanced with water intakes, water control structures, and habitat features intended to add complexity and ecological value. Coastal flood risk management would primarily be provided by a combination of an enhanced mid-complex levee and improvements to the backside levee along the eastern edge of the Inland and Southern Ponds. Once tidal marsh habitat forms in the Bay Ponds, fully tidal flows could be restored to the Inland and Southern Ponds as the backside levee at the Inland and Southern Ponds would provide the flood risk management. A significant habitat transition zone would be constructed behind the bay-facing levee, and a temporary (rather than permanent) mid-complex levee would separate the Bay and Inland Ponds. There would be similar trails and public access feature options as in Alternative Eden B.

Imported dredge materials and associated infrastructure, levee improvements for habitat separation and flood risk management purposes, construction of water control structures and habitat transition zones, and adding recreational facilities under Alternative Eden D would impose added weight on the underlying Bay mud, thereby potentially accelerating existing background rates of settlement. However, improved flood risk management and habitat separation levees (and related improvements) would be designed and constructed to compensate for settlement and consolidation over time. The long-term settlement resulting from the increased weight associated with these levees and other features would be offset by required

maintenance to ensure minimum levee elevations for flood risk management are retained. Also, the levees and other features would be initially overbuilt to account for localized settlement.

Construction of the habitat transition zone along the western edge of the Bay Ponds would prevent scouring of lands within the Bay Ponds and assist in facilitating its transition to tidal marsh. The potential accelerated settlement and consolidation caused by the addition of material along the bay-facing levee, and improved levees at the backside of the project area would be offset by required maintenance to ensure minimum levee elevations for flood risk management are retained. Further, construction of the habitat transition zones, temporary, and improved flood risk management levees would not create impacts to people or structures. This would prevent potential effects on people and property resulting from potentially accelerated rates of subsidence. Impacts resulting from potential settlement due to consolidation of Bay mud under Alternative Eden D are therefore less than significant.

Alternative Eden D Level of Significance: Less than Significant

Phase 2 Impact 3.4-2: Potential effects from liquefaction of soils and lateral spreading.

Alternative Eden A (No Action). Based on existing data, the project area is within an area of moderate liquefaction susceptibility. Under Alternative Eden A, CDFW would commit minimal effort to maintaining the majority of existing salt pond levees within the Phase 2 project area. Per CDFW's Restoration and Management Plan (CDFG 1999), existing levees along Ponds E4C, E5, E6C and E6 would be maintained for flood risk management, and maintenance of other levees and access roads (such as those to utilities) would be coordinated with ACFCWCD and PG&E, as applicable, to ensure that access to, and maintenance of existing assets is retained.

Liquefaction may cause portions of existing levees to settle below minimum elevations, allowing them to be overtopped. In areas where liquefaction causes failure and deformation of levee slopes, levees may be breached. Corresponding ponds and adjacent areas may be flooded as a result, but these conditions exist now. Alternative Eden A would not create a new opportunity to expose people to damage resulting from liquefaction or lateral spreading. As such, impacts resulting from the selection of Alternative Eden A would be less than significant.

Alternative Eden A Level of Significance: Less than Significant

Alternative Eden B. Alternative Eden B is intended to restore the entirety of southern Eden Landing to tidal marsh in a single project implementation stage. The eastern, backside levees would be improved to provide the necessary degree of flood risk management. Following this, habitat enhancements including habitat transition zones, islands made from remnant levees, channel excavation, and levee lowering would be implemented. Two sections of internal levee improvements would also be made along the J-ponds and other ACFCWCD-owned channels. Public access trails and a viewing platform would be placed on improved levees.

Project components such as breaching levees and excavation of pilot channels, construction and operation of proposed features such as water control structures, islands, mounds, and improved levees for habitat separation, may be impacted by liquefaction due to the presence of underlying Bay mud and soft compressible soils. However, if these features were impacted by liquefaction or lateral spreading caused by ground shaking, they would be repaired, as needed.

The addition of proposed walking trails, viewing platforms and footbridges would enable greater public access to portions of the project area but are not considered components that would place the general public a significant risk should they be impacted by liquefaction or lateral spreading during a ground shaking event. It would not expose people or property to major geologic hazards. Alternative Eden B does not include construction of any buildings or habitable structures that could be subject to liquefaction from seismic-related ground failure.

Based on the above, liquefaction of soils, and therefore lateral spreading within the project area, could cause deformation of levee slopes, affect habitat transition zones, and cause failure of trail routes, footbridges and viewpoints. However, the project would not expose people to unnecessary flood hazards resulting from liquefaction or lateral spreading and therefore potential effects from lateral spreading and liquefaction are considered less than significant.

Alternative Eden B Level of Significance: Less than Significant

Alternative Eden C. Alternative Eden C includes a mix of project features that would transition the Bay Ponds to tidal marsh, and the Inland and Southern Ponds to managed ponds. The tidal marsh habitat vs. managed pond areas would be separated by a proposed improved mid-complex levee between the Bay and Inland Ponds, which would extend south through the J-Ponds to the ACFCC. Similar project features described in Alternative Eden B would be constructed as part of Alternative Eden C with differences in location. Most notably, the proposed improved mid-complex levee, habitat transition zone, and the number and location of proposed water control structures would be different, but would also be designed with liquefaction and lateral spread potential, and would be repaired if destroyed as a result of lateral spread or liquefaction.

Additional public access trails beyond those in Alternative Eden B, larger pedestrian and bicycle bridges over the ACFCC and OAC to connect these trails, and two viewing platforms would be placed on improved levees. The pedestrian bridges notwithstanding, Alternative Eden C does not include construction of any buildings or habitable structures that could be subject to liquefaction from seismic-related ground failure. The addition of proposed walking trails, viewing platforms and footbridges would enable greater public access to portions of the project area but are not considered components that would place the general public a significant risk should they be impacted by liquefaction or lateral spreading during a ground shaking event. It would not expose people or property to major geologic hazards

Based on the above, Alternative Eden C would not introduce unnecessary exposure of people and property to flood hazards resulting from liquefaction or lateral spreading. As such, impacts resulting from the selection of Alternative Eden C would be less than significant.

Alternative Eden C Level of Significance: Less than Significant

Alternative Eden D. Under Alternative Eden D, the Bay Ponds would be restored to tidal marsh, and the Inland and Southern Ponds would be temporarily retained as managed ponds and enhanced with water intakes, water control structures, and other habitat improvement features intended to add complexity and ecological value to these managed ponds. Coastal flood risk management would primarily be provided by a combination of an enhanced mid-complex levee and improvements to the backside levee along the eastern edge of the Inland and Southern Ponds. Once the tidal marsh habitat forms in the Bay Ponds, fully tidal flows could be restored to the Inland and Southern Ponds as the backside levee at the Inland and Southern Ponds would provide the flood risk management. A significant habitat transition zone would be

constructed behind the bay-facing levee, and a temporary mid-complex levee would separate the Bay and Inland Ponds.

Public access to features such as trails and view platforms could increase public exposure to liquefaction and impacts resulting from lateral spreading. As with Alternatives B and C, the addition of proposed walking trails, viewing platforms and footbridges would enable greater public access to portions of the project area. However, these are not considered components that would significantly place the general public at risk should they be impacted by liquefaction or lateral spreading during a ground shaking event. It would not expose people or property to major geologic hazards. Alternative Eden D does not include construction of any buildings or habitable structures that could be subject to liquefaction from seismic-related ground failure.

Based on the above, Alternative Eden D would not introduce features that would cause unnecessary exposure of people and property to flood hazards resulting from liquefaction or lateral spreading. As such, impacts resulting from the selection of Alternative Eden D would be less than significant.

Alternative Eden D Level of Significance: Less than Significant

Phase 2 Impact 3.4-3: Potential for ground and levee failure from fault rupture.

Alternative Eden A (No Action). Under Alternative Eden A, CDFW would commit minimal effort to maintaining the majority of existing salt pond levees within the Phase 2 project area. Per CDFW's Restoration and Management Plan (CDFG 1999), existing levees along Ponds E4C, E5, E6C and E6 would be maintained for flood risk management.

No active or potentially active faults are mapped within the Eden Landing Phase 2 project area; however the concealed quaternary Silver Creek Fault is located less than 1 mile east of the Southern Ponds. Ground shaking during an earthquake caused by rupture of this fault or others in the region could cause existing and proposed levees within the project area to fail and collapse. Because flood risk management levees would be repaired and maintained, potential impacts to people and property due to an earthquake induced rupture of the Silver Creek Fault would be less than significant.

Alternative Eden A Level of Significance: Less than Significant

Alternative Eden B. Alternative Eden B would restore the entirety of southern Eden Landing to tidal marsh in a single project implementation stage. The eastern, backside levees would be improved to provide the necessary degree of flood risk management. Following this, habitat enhancements including habitat transition zones, islands made from remnant levees, channel excavation, and levee lowering would be implemented.

No active or potentially active faults are mapped within the Eden Landing Phase 2 project area; however the concealed quaternary Silver Creek Fault is located less than 1 mile east of the project area. Proposed flood risk management levees and other structures constructed as part of Alternative Eden B would be designed to account for ground shaking during an earthquake to prevent failure from fault rupture. Should failure or fault rupture occur, however, flood risk management levees and other features associated with Alternative Eden B would be repaired, as needed. As such, potential impacts to people and property due to an earthquake induced rupture of the Silver Creek Fault would be less than significant under Alternative Eden B.

Alternative Eden B Level of Significance: Less than Significant

Alternative Eden C. Alternative Eden C would retain the Inland and Southern Ponds as managed ponds and add a number of water control structures to allow the depth and salinity of these ponds to be actively managed for a range of different pond-dependent wildlife. The Bay Ponds would be restored to tidal marsh, as in Alternative Eden B, and a mid-complex levee would largely be built on top of existing internal levees. This alternative would feature a similar range of habitat enhancements as Alternative Eden B but in different locations. The Bay Trail is planned for the same routes as Alternative Eden B, but Alternative Eden C would add an additional set of trails on either side of the OAC and a bridge over the OAC to connect them. These trails would form a spur trail to the site of the Alvarado Salt Works, and a viewing platform there. Another large bridge would be built over the ACFCC to extend the Bay Trail spine further and beyond the ELER boundary itself.

No active or potentially active faults are mapped within the Eden Landing Phase 2 project area; however the concealed quaternary Silver Creek Fault is located less than one mile east of the Southern Ponds. Proposed levees and recreational trails constructed as part of Alternative Eden C would be designed to account for ground shaking during an earthquake to prevent failure from fault rupture. While the general public is anticipated to use public trails and occupy viewing areas, these resources would not put the general public at risk of life or property to major geologic hazards. Additionally, should failure or fault rupture occur, flood risk management levees and other features associated with Alternative Eden C would be repaired, as needed. As such, potential impacts to people and property due to an earthquake induced rupture of the Silver Creek Fault or other faults in the region would be less than significant under Alternative Eden C.

Alternative Eden C Level of Significance: Less than Significant

Alternative Eden D. Alternative Eden D is a staged implementation of the tidal marsh restoration outlined in Alternative Eden B. It would make use of a mid-complex levee, as in Alternative Eden C, but that levee would be temporary. This separation of the Bay Ponds from the others would allow those large outer ponds to first be restored to tidal marsh, after which, the mid-complex levee would be removed, and the Inland and Southern Ponds then restored to tidal marsh. Water control structures would be added to the Inland and Southern Ponds for use during the years in which they would be operated as managed ponds and then removed to allow tidal flows. The trail and associated viewing platform would be similar to those in Alternative Eden B.

No active or potentially active faults are mapped within the Eden Landing Phase 2 project area; however, the concealed quaternary Silver Creek Fault is located less than 1 mile east of the Southern Ponds. Proposed flood risk management levees and recreational trails constructed as part of Alternative Eden D would be designed to account for ground shaking during an earthquake to prevent failure from fault rupture. While the general public is anticipated to use public trails and occupy viewing areas, these resources would not put the general public at risk. Additionally, should failure or fault rupture occur, flood risk management levees and other features associated with Alternative Eden D would be repaired, as needed. As such, potential impacts to people and property due to an earthquake induced rupture of the Silver Creek Fault or other faults in the region would be less than significant under Alternative Eden D.

Alternative Eden D Level of Significance: Less than Significant

Phase 2 Impact 3.4-4: Potential effects from consolidation of Bay mud on existing subsurface utility crossings and surface rail crossings.

Alternative Eden A (No Action). Under Alternative Eden A (the No Action Alternative), no new activities would be implemented as part of the Phase 2 project. The CDFW would continue maintaining and operating the ponds as part of the ELER and according to the Operations Plan and the activities described in the AMP and in accordance with current CDFW practices.

The Phase 2 project area contains no surface rail crossings or subsurface utility crossings. The existing above ground PG&E distribution line running along the north side of Ponds E1, E7 and E6, along with the distribution line bisecting Pond E2C and running along the south side of E5C and E4C would remain active and be unaffected by long-term operation because these levees would be maintained.

Because there are no rail lines or subsurface utilities within the project area, impacts to subsurface utility crossings and surface rail crossings as a result of continued consolidation and the ensuing impacts of consolidating Bay mud would be less than significant under Alternative Eden A.

Alternative Eden A Level of Significance: Less than Significant

Alternative Eden B. Alternative Eden B would restore the entirety of southern Eden Landing to tidal marsh in a single project implementation stage. Dredge materials would be placed in the Bay and Inland Ponds to raise pond bottom elevations. The eastern, backside levees would be improved to provide the necessary degree of flood risk management. Following this, habitat enhancements including habitat transition zones, islands made from remnant levees, channel excavation, and levee lowering would be implemented. Two sections of internal levee improvements would also be made along the J-ponds and other ACFCWCD-owned channels.

The Phase 2 project area contains no surface rail crossings or subsurface utility crossings within the southern Eden Landing ponds or in the portion of the Bay between the offloading facility and Pond E2. The existing above ground PG&E distribution line running along the north side of Ponds E1, E7 and E6 would be removed, but the above ground distribution line bisecting Pond E2C and running along the south side of E5C and E4C would remain active and be unaffected by long-term operation because these levees would be maintained.

Because there are no rail lines or subsurface utilities within the project area, impacts to subsurface utility crossings and surface rail crossings as a result of continued consolidation and the ensuing impacts of consolidating Bay mud would be less than significant under Alternative Eden B.

Alternative Eden B Level of Significance: Less than Significant

Alternative Eden C. Implementation of Alternative Eden C would retain the Inland Ponds and the Southern Ponds as managed ponds and add a number of water control structures to allow the depth and salinity of these ponds to be actively managed for a range of different pond-dependent wildlife. Dredge materials would be placed in the Bay Ponds to raise pond bottom elevations and the Bay Ponds would be restored to tidal marsh, as in Alternative Eden B, through the use of a mid-complex levee that would largely be built on top of the existing internal levees.

The Phase 2 project area contains no surface rail crossings or subsurface utility crossings within the southern Eden Landing ponds or in the portion of the Bay between the offloading facility and Pond E2. The existing above ground PG&E distribution line running along the north side of Ponds E1, E7 and E6

would be removed, but the above ground distribution line bisecting Pond E2C and running along the south side of E5C and E4C would remain active and be unaffected by long-term operation because these levees would be maintained.

Because there are no rail lines or subsurface utilities within the project area, impacts to subsurface utility crossings and surface rail crossings as a result of continued consolidation and the ensuing impacts of consolidating Bay mud would be less than significant under Alternative Eden C.

Alternative Eden C Level of Significance: Less than Significant

Alternative Eden D. Alternative Eden D is a staged implementation of the tidal marsh restoration outlined in Alternative Eden B. It would make use of a mid-complex levee, as in Alternative Eden C, but that levee would be temporary. This separation of the Bay Ponds from the others would allow those large outer ponds to first be restored to tidal marsh, after which, the mid-complex levee would be removed, and the Inland and Southern Ponds then restored to tidal marsh. Water control structures would be added to the Inland and Southern Ponds for use during the years in which they would be operated as managed ponds and then removed to allow tidal flows. The trail and associated viewing platform would be similar to those in Alternative Eden B.

The Phase 2 project area contains no surface rail crossings or subsurface utility crossings within the southern Eden Landing ponds or in the portion of the Bay between the offloading facility and Pond E2. The existing above ground PG&E distribution line running along the north side of Ponds E1, E7 and E6 would be removed, but the above ground distribution line bisecting Pond E2C and running along the south side of E5C and E4C would remain active and be unaffected by long-term operation because these levees would be maintained.

Because there are no rail lines or subsurface utilities within the project area, impacts to subsurface utility crossings and surface rail crossings as a result of continued consolidation and the ensuing impacts of consolidating Bay mud would be less than significant under Alternative Eden D.

Alternative Eden D Level of Significance: Less than Significant

Impact Summary

Phase 2 impacts and levels of significance are summarized in Table 3.4-1. The levels of significance are those remaining after implementation of program-level mitigation measures, project-level design features, and the AMP and other Refuge management documents and practices. The geology and soils analysis required no project-level mitigation measures in order to reduce the impacts to a level that was less than significant.

Table 3.4-1 Phase 2 Summary of Impacts – Geology and Soils

IMPACT	ALTERNATIVE EDEN A	ALTERNATIVE EDEN B	ALTERNATIVE EDEN C	ALTERNATIVE EDEN D
Phase 2 Impact 3.4-1: Potential effects from settlement due to consolidation of Bay mud.	LTS	LTS	LTS	LTS
Phase 2 Impact 3.4-2: Potential effects from liquefaction of soils and lateral spreading.	LTS	LTS	LTS	LTS
Phase 2 Impact 3.4-3: Potential for ground and levee failure from fault rupture.	LTS	LTS	LTS	LTS
Phase 2 Impact 3.4-4: Potential effects from consolidation of Bay mud on existing subsurface utility crossings and surface rail crossings.	LTS	LTS	LTS	LTS

Notes:
Alternative Eden A is the No Action Alternative (No Project Alternative under CEQA).
LTS = Less than Significant

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