I. GEOLOGY, SOILS AND SEISMICITY

This section describes the existing geologic setting, including soils and seismicity, for the Measure DD Project and its component sites. This section also assesses potential impacts from strong ground shaking, fault rupture, liquefaction, slope failure, lateral slope deformation, differential settlement and unstable or expansive soils. Mitigation measures for the identified significant impacts are provided, as appropriate.

1. Setting

This section discusses the methods used for analyzing geological conditions of the Measure DD Project area. The existing geologic conditions for each of the four groups of project components are described, as well as governmental regulations related to geology affecting the project components.

a. Methods. The project area's geologic setting described below is based on a site reconnaissance, published and unpublished regional and local area geologic reports and maps, and available site-specific technical reports.

b. Existing Geologic Conditions. The Measure DD group areas are located within the Coast Ranges Geomorphic Province, a geologically young and seismically-active region on the western margin of the North American plate. In general, the uplands of the Coast Ranges are composed of sedimentary and metamorphic bedrock and the intervening valleys are filled with layers of recent alluvium.[1] The flat area of the East Bay west of the Hayward Fault is a gently sloping alluvial plain. The sediments of the alluvial plain were eroded from the relatively young East Bay Hills. These flats have been expanded along the margins of San Francisco Bay, particularly along the Alameda and Oakland shoreline, by the addition of artificial fill over unconsolidated Young Bay Mud (Bay Mud).[2]

(1) Lake Merritt and Lake Merritt Channel (Group 1). The Lake Merritt and Lake Merritt Channel group includes recreational, building, roadway, and water quality improvements. Proposed roadway improvements include clear-span bridges to replace the current structures at 10th and 12th Streets where the Lake Merritt Channel is culverted. Also proposed is a redesign of the Lake Merritt flood control facility at 7th Street to improve tidal exchange and to allow recreational access between Lake Merritt and San Francisco Bay. Extensive reconfiguration of roadways and parking areas around the perimeter of Lake Merritt is also planned, as are repairs to buildings, retaining walls and overlook structures. Existing geologic conditions of the Lake Merritt and Lake Merritt Channel group area are described below.

Geology. In general, areas of less than 10 feet elevation mean sea level (msl) adjacent the shoreline of Lake Merritt and along the Lake Merritt channel are artificial fill over Bay Mud. Where slopes rise above this level, both west of Lake Merritt and southeast of the Lake Merritt Channel, the near surface deposits are mapped as Merritt Sand (beach and dune sand) likely of Pleistocene age (more than 10,000 and less than 1.8 million years old). To the east and north of the Lake, and beyond

[1] California Geological Survey, 2002, *California Geomorphic Provinces, Note 36.*

[2] Sloan, Doris, 2006, *Geology of the San Francisco Bay Region*, University of California Press.

the artificial fill, are gentle hills composed of a medium grained alluvium of about the same age as the Merritt Sand.[3]

A site-specific soil investigation conducted for a construction project in the Lake Merritt Channel at 7th Street indicated surface materials consist of up to 24 feet of poorly compacted fill composed of sandy clay, rock fragments, concrete rubble and debris. Underlying the fill is a medium dense sand or sandy gravel and Bay Mud to a depth of approximately 59 feet. Underlying the Bay Mud is intermittent layers of loose to medium dense clayey sands and dense green sands to about 74 feet, and under that very stiff sandy clay and clay.[4]

A site-specific geotechnical investigation done in support of the 12th Street Reconstruction component notes that, in general, the 15 test borings performed encountered five to seven feet of clayey, gravelly sand fill over alluvial and estuarine (Bay Mud) deposits. The Bay Mud is saturated, low density, compressible, and sometimes expansive in nature. Deeper layers consisted of generally stiff to very stiff clays with discontinuous layers of dense sand.[5]

Topography. The components of the Lake Merritt and Lake Merritt Channel group are located along the edges of Lake Merritt and the Lake Merritt Channel. This area is characterized by flat to gently rolling topography and existing ground surface elevations from sea level to about 25 feet msl (at the southwest corner of Snow Park).[6] Several culverted creeks and storm drain collectors empty into the Lake or Channel; however, no open creek or stream channels cross the project site.

Soils. Surface soils of this portion of the project are mapped by the Natural Resource Conservation Service[7] as Urban Land. The Urban Land category is a description for man-made materials and land consisting of heterogeneous fills of (generally) unknown origin usually already developed and covered by paving and structures. Urban land is further categorized as named variants. The three variants in the project area around Lake Merritt and the Channel are Urban land-Baywood, -Tierra, and -Danville complexes. The Soil Survey does not assign capability classification values for describing engineering constraints for the Urban Land types; however, the soil survey provides general characteristics for the sub-types. Urban land-Baywood complex is noted to have rapid permeability, low shrink-swell potential and normal strength. Urban land-Tierra and -Danville complexes are noted to have slow permeability, moderate to high shrink-swell potential and low strength.

(2) Waterfront Trail (Group 2). The Oakland Waterfront Trail is part of the San Francisco Bay Trail. Properties along the Oakland Estuary waterfront designated for parkland or trail development within Measure DD would be acquired and remediated, as needed. The work may include demolition, refurbishment or replacement of structures as well as trail construction and

[3] Helley, E.J., LaJoie, K.R., 1979, *Flatlands Deposits of the San Francisco Bay Region, California – Their Geology and Engineering Properties, and Importance to Comprehensive Planning*, USGS Professional Paper 943.

[4] Woodward, Clyde, Sherard & Associates, 1967, Soils Investigation for the Proposed Lake Merritt Seventh Street Pumping and Control Station, Oakland, California, Project # S11195.

[5] Geo/Resources Consultants, Inc., 2006, Geotechnical Investigation 12th Street Reconstruction Project, Oakland, California, April, Report No. 2046-100

[6] USGS, 1959 revised 1980, *Oakland West Quadrangle Topographic Map.*

[7] USDA, Soil Conservation Service, 1981, *Soil Survey of Alameda County, California, Western Part.* March.

restoration of shoreline edges to tidal wetlands. The trail and park parcels for the proposed Oakland Waterfront Trail components are located along the eastern shore of the Oakland Estuary. Existing geologic conditions in the vicinity of the Waterfront Trail components are described below.

Geology. With the exception of an area between approximately the 29th Street and High Street Bridges, the geology of the Oakland Estuary shoreline consists of artificial fill over Bay Mud. The near-surface materials of the area between the bridges noted above is classified as Merritt Sand, a relatively young, poorly consolidated beach and dune sand[8] and/or alluvial fan deposits.[9] The tidal canal in this area is a dredged man-made link connecting Brooklyn Basin with San Leandro Bay[10] and was cut through the alluvial deposit/Merritt Sand connection to what is now the Island of Alameda in 1902.[11]

A conceptual level geotechnical study for the trail crossings at Park, Fruitvale and High Streets notes that the subsurface foundation soils in this area likely consist of stiff to very stiff layers of clay and sand.[12]

The geotechnical evaluation conducted for the 66th Avenue Gateway project component notes exploratory borings at the site encountered both natural and artificial materials in the subsurface. In general, artificial fill to depths down to 20 feet overlaid alternating layers of Bay Mud and alluvium. There were localized areas of asphalt concrete with dense sub-base materials encountered near the surface.[13]

At the Cryer Park site three test borings were drilled to a depth of 20 feet. Artificial fill materials, consisting of stiff to very stiff silty clay, medium dense clayey sand, and some wood debris were encountered to a depth of four feet. Underlying the fill, highly plastic clay (Bay Mud) was encountered to depths of up to about ten feet. Beyond this to the terminal depth of the borings was very stiff clay.[14]

Topography. The components of the Oakland Waterfront Trail group are located along 6.6 miles of the eastern shore of the Oakland Estuary and Tidal Canal, an area with flat topography and an existing ground surface elevation from sea level to about eight feet msl.[15] Engineered channels,

[8] Helley, E.J., LaJoie, K.R., 1979, op. cit.

[9] Graymar, R.W., 2000, *Geologic Map and Map Database of the Oakland Metropolitan Area, Alameda, Contra Costa, and San Francisco Counties, California,* USGS Misc. Field Studies MF-2342, V. 1.0.

[10] Sowers, Janet M., William Lettis & Associates, Inc., 1993, revised 1995 & 2000, *Creek & Watershed Map of Oakland and Berkeley,* Oakland Museum of California.

[11] City of Alameda Website, *A Brief History of Alameda,* accessed 2-10-07: http://www.ci.alameda.ca.us/community/

[12] Kleinfelder, Inc., 2005, Letter: Conceptual-Level Geotechnical Study, Proposed Oakland Waterfront Trail, File No. 58402.

[13] Ninyo & Moore, 2005, *Geotechnical Evaluation 66th Avenue Gateway Project, Oakland, Ca.,* Project No. 401058001, April 14.

[14] Kleinfelder, Inc., 2006, *Geotechnical Study, Proposed Cryer Site Park, Embarcadero and Dennison Streets, Oakland, CA,* File No. 64087, January 11.

[15] USGS, 1959 revised 1980, op. cit.

culverted creeks, storm drain collectors and small creeks cross the project site and empty into the Estuary and Channel.

Soils. Surface soils of this portion of the project are mapped by the Natural Resource Conservation Service[16] as Urban Land. The Urban Land category is a description for man-made materials and land, usually already developed and covered by paving and structures, and consisting of heterogeneous fills of (generally) unknown origin.

(3) Recreational Facilities (Group 3). The two components within this group are the renovation of the historic Studio One Art Center, located in North Oakland and the construction of an East Oakland Sports Complex. Existing geologic conditions of and around these facilities are described below.

Studio One Art Center. The building is in the process of being extensively refurbished, including seismic retrofitting with completion of improvements anticipated in 2007.

Geology. The geology of this component site consists of Holocene age alluvial fan deposits layered over Pleistocene age alluvial deposits. In general, these deposits are moderately coarse and poorly sorted. They increase in consolidation and strength with depth. Maximum thickness of these layers is unknown, but the layer is a minimum of 150 feet, tapering thinner towards the east to the foothills and the Hayward Fault.[17]

Topography. This component is located in an area with a gently rolling topography at an elevation of about 110 feet above mean sea level (msl).[18] No open creek or stream channels cross the project site.

Soils. Surface soils of the project site are mapped by the Natural Resource Conservation Service as Urban Land – Danville complex, a mix of about sixty percent Urban Land and thirty percent Danville with the remainder being Botella loam, Clear Lake clay and Tierra loam.[19] Danville soil is a deep soil with slow permeability, high shrink-swell potential and low strength. The Soil Survey does not assign capability classification values for describing engineering constraints for the Urban Land – Danville complex type.

East Oakland Sports Complex. This component is in the conceptual design phase, and site-specific geotechnical information was not available.

Geology. The geology of this component site consists of Holocene age braided natural levee and alluvial basin deposits layered over Pleistocene age alluvial deposits. In general, these deposits are moderately coarse and poorly sorted. They increase in consolidation and strength with depth.

[16] USDA, Soil Conservation Service, 1981, op. cit.

[17] Helley, E.J., LaJoie, K.R., 1979, op. cit.

[18] USGS, 1959 revised 1980, op. cit

[19] Natural Resources Conservation Services (NRCS), 2006. *Soil Survey Of Alameda County, California, Western Part.* Source of Map: Natural Resources Conservation Service Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov

Maximum thickness of these layers is unknown, but the layer is a minimum of 150 feet, tapering thinner towards the foothills to the east.[20]

Topography. The project site is nearly flat, rising gently from an elevation of about ten feet above mean sea level (msl) at the western extreme to about 14 feet msl to the east.[21] No open creek or stream channels appear to cross the project site.

Soils. Surface soils of the project site are mapped by the Natural Resource Conservation Service as Clear Lake Clay, zero to two percent slope.[22] Typically this is a very deep poorly drained soil formed in alluvium in basins. This soil type has a high shrink-swell potential, low strength, and generally exists in areas with a high water table; depth to water is frequently only four to five feet.

(4) City-wide Creeks (Group 4). Oakland's watershed has fifteen main creeks with over thirty tributaries that comprise over 40 miles of open creeks. The creek components are spread throughout the City of Oakland.

Geology. San Francisco Bay is a drowned river valley atop the tectonically derived Bay Block.[23] The Bay Block lies between the Hayward and San Andreas Faults, and is tilted and sunken to the east. Beyond the Hayward Fault the East Bay Block is elevated relative to the Bay Block. The western face of the East Bay Block constitutes the Berkeley and Oakland Hills. Erosion from these East Bay Hills spread west towards the San Francisco Bay in alluvial fans. The individual creek components of the City-wide Creeks portion of Measure DD are located on both sides of the Hayward Fault and continue to carry sediment down from the still rising East Bay Hills toward the Bay.[24]

Topography. The topography of the City of Oakland is varied. Primarily, it consists of the broad shallow slopes of the alluvial plains starting at San Francisco Bay and the Oakland Estuary with elevations of sea level up to approximately 120 to 200 feet msl at the base of the foothills. Continuing east, the gently rolling uplands areas rise into foothills, and then, generally east of the Hayward Fault, into more and more steep terrain of the East Bay Hills, rising to elevations near the eastern border of the City of Oakland of approximately 1440 feet msl.[25]

Soils. The generalized soil map for western Alameda County depicts two primary soil types for the areas where the creek components are located. The upland terraces, with relatively modest slopes, are Tierra-Urban Land. Tierra soils formed from alluvium are level to moderately steep and moderately well drained loams. The erosion hazard tends to mirror the slope, with steep areas being highly prone to erosion.

[20] Graymer, R.W., 2000, op. cit.

[21] USGS, 1959 revised 1980, op. cit.

[22] NRCS, 2006. op. cit.

[23] The outer shell of the Earth is comprised of large tectonically derived plates. In the SF Bay area, where the Pacific Plate moves north past the North American Plate along the San Andreas Fault System, several large 'blocks', their edges defined by the lesser faults of the San Andreas Fault System, have accumulated. A frequently confused term 'terrane', defines packets of rock by type or source, and may cross block boundaries.

[24] Sloan, Doris, 2006, op. cit.

[25] USGS, 1959 revised 1980, op. cit.

The upland areas of the foothills are soils of the Xeropsamments-Maymen-Millshom series. These soils form from sedimentary rock and occur in steep to very steep foothills; soil quality tends to be poor, while well- to excessively-drained, and with various textures. The soils are prone to erosion, and the depth to the underlying bedrock is shallow.

c. Existing Seismic Conditions. Regional and site specific seismicity are discussed below.

(1) Regional Seismicity. The entire San Francisco Bay Area is located within the San Andreas Fault Zone (SAFZ), a complex of active faults forming the boundary between the North American and Pacific lithospheric plates. Movement of the plates relative to one another results in the accumulation of strain along the faults, which is released during earthquakes. Numerous moderate to strong historic earthquakes have been generated in northern California by the SAFZ. The level of active seismicity results in classification of the area as seismic risk Zone 4 (the highest risk category) in the California Building Code. The SAFZ includes numerous faults found by the California Geological Survey under the Alquist-Priolo Earthquake Fault Zoning Act (A-PEFZA) to be "active" (i.e., to have evidence of fault rupture in the past 11,000 years). Regional active faults are shown on Figure IV.I-1.

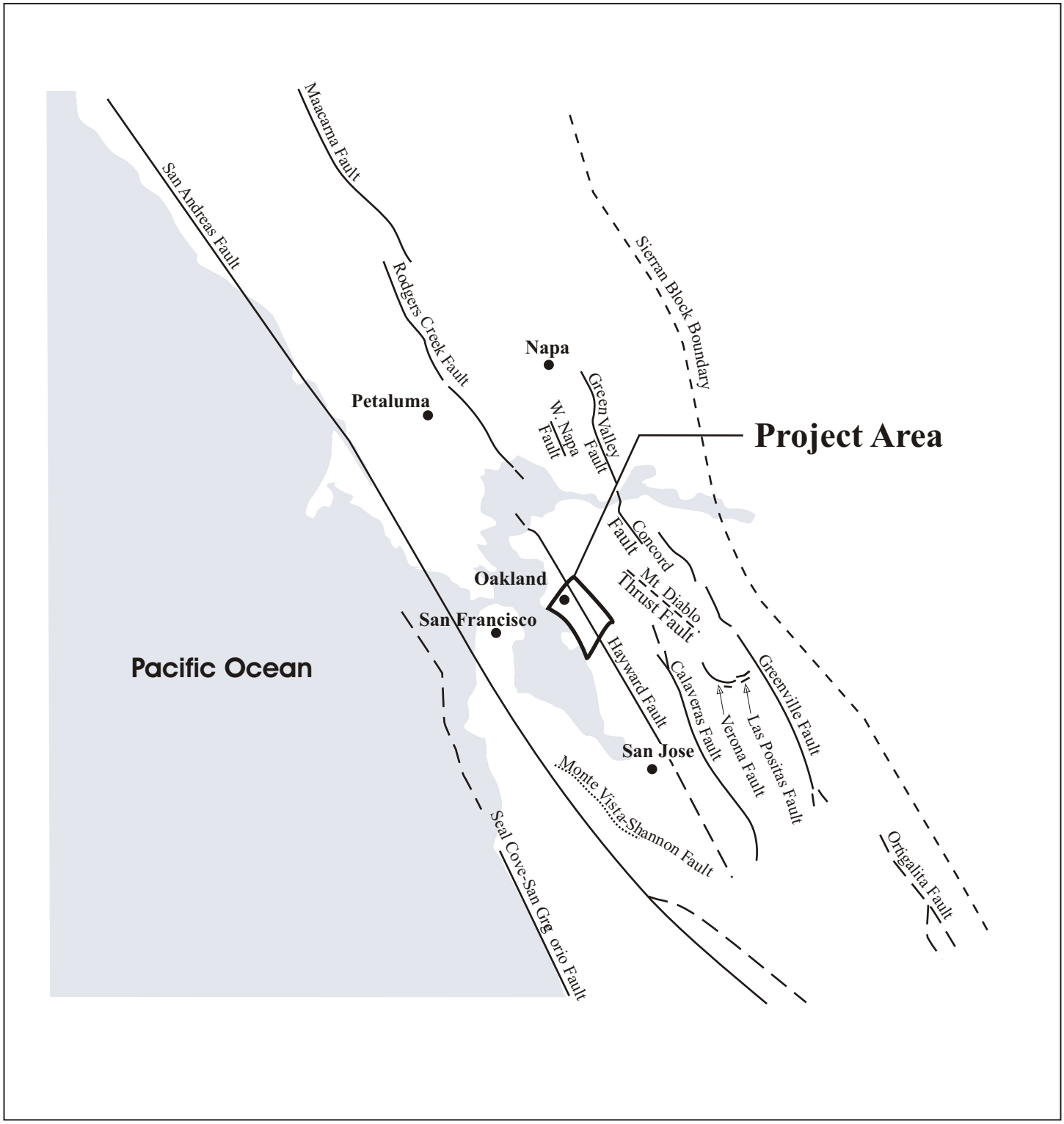
The U.S. Geological Survey's Working Group on California Earthquake Probabilities estimated that there is a 62 percent probability that one or more Moment Magnitude (M_w) 6.7 [26] or greater earthquakes will occur in the San Francisco Bay Area between 2002 and 2031. The probability of a M_W 6.7 magnitude or greater earthquake occurring along individual faults was estimated to be 21 percent along the San Andreas Fault, 27 percent along the Hayward Fault, 11 percent along the Calaveras Fault, four percent along the Concord-Green Valley Fault, ten percent along the San Gregorio Fault, three percent on the Greenville Fault, and three percent for the Mt. Diablo Thrust Fault. In addition, there is a cumulative 14 percent chance of a background (other earthquake source, either mapped or undiscovered) event occurring. When predictions are expanded to 100 years it was estimated that about three M_W6.7 or greater events could occur during that time. Thus the probability of at least one M_W6.7 or greater magnitude earthquake rises to the near certainty of about 96 percent when calculated for a 100-year span.[27]

(2) Project Area Seismicity. A major seismic event in the San Francisco Bay area will have an impact over a broad area. Although the components of Measure DD are discontinuous in location, because of the nature of a major seismic event, they can be considered together in discussing specific seismic concerns affecting them. The Lake Merritt and Lake Merritt Channel, Oakland Waterfront Trail, Recreational Facilities, and City-wide Creeks groups will be subject to the following seismic threats and hazards.

With the exception of the upper reaches of a few of the watercourses of the City-wide Creeks program, none of the components of Measure DD intersect an Alquist-Priolo Earthquake Fault Zone; the nearest A-PEFZ is that of the Hayward Fault, which is located in the East Bay hills. The Hayward

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

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



LSA

LEGEND

- ACTIVE FAULT – FAULT HAS EVIDENCE OF SURFACE DISPLACEMENT WITHIN THE PAST 11,000 YEARS (DASHED WHERE INFERRED)
- POTENTIALLY ACTIVE FAULT – FAULT HAS EVIDENCE OF SURFACE DISPLACEMENT IN THE PAST 1.6 MILLION YEARS, BUT NOT WITHIN THE PAST 11,000 YEARS
- SEISMIC SOURCE WITHOUT SURFACE RUPTURE

N

0 10 20
MILES

FIGURE IV.I-1

Oakland Measure DD
Regional Faults

SOURCE: BASELINE ENVIRONMENTAL, 2007.

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fault is a right lateral strike-slip fault with a northwest-southeast axis,[28] and, as noted above, has a 27 percent chance of an M_w6.7 earthquake occurring between 2002 and 2031. Within the City of Oakland, the fault is approximately parallel and beneath State Route 13; then continues south near the route of Interstate 580. With the exception of a few creek watercourses noted above, all the project components are between 1.5 and 3.9 miles southwest of the Hayward A-PEFZA fault zone.[29]

Virtually all the shoreline land and areas of artificial fill around Lake Merritt and the Lake Merritt Channel, the Oakland Estuary and inland as far as artificial fill extends, are mapped by the California Geologic Survey under the terms of California Seismic Hazards Mapping Act to be subject to liquefaction hazards. In addition, the upland areas of Oakland, particularly east of the Hayward Fault are largely mapped as subject to landslide hazards. [30, 31] Most of the components of Measure DD, particularly the components including built structures such as bridges and buildings, are located in areas mapped by the State of California as being subject to one of these hazards.

d. Seismic and Geologic Hazards. Seismic and geological hazards applicable to the project area are discussed below.

(1) Surface Rupture. Surface rupture occurs when the ground surface is broken due to fault movement during an earthquake. The location of surface rupture generally can be assumed to be along an active or potentially active major fault trace. The City-wide Creeks group (though specific plans are not yet developed) includes components on Palo Seco Creek, Lion Creek and Arroyo Viejo Creek. These creeks components, and possibly other plans yet to be defined, cross the Hayward Fault Zone and some of the creek components may subject to the potential for fault rupture.

(2) Ground Shaking. Ground shaking is a general term referring to all aspects of motion of the earth's surface resulting from an earthquake, and is normally the major cause of damage in seismic events. The extent of ground shaking is controlled by the magnitude and intensity of the earthquake, distance from the epicenter, and local geologic conditions. The Modified Mercalli Intensity Scale (MMI) is the most commonly used scale for measurement of the subjective effects of earthquake intensity (shown in Table IV.I-1). A related concept, Peak Ground Acceleration, is measured as a fraction or percentage of gravity (*g*).[32]

The closest active fault to the project site is the Hayward Fault. The north and south Hayward faults together are considered capable of generating about an M_w 6.9 earthquake. An earthquake of this

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

[29] California Division of Mines and Geology (CDMG), 1982, *State of California Special Studies Zones, Oakland West Quadrangle Map.*

[30] California Geological Survey, 2003, *State of California Seismic Hazard Zones, Oakland East7.5-Minute Quadrangle Map.*

[31] California Geological Survey, 2003, *State of California Seismic Hazard Zones, Oakland West 7.5-Minute Quadrangle Map.*

[32] The acceleration due to gravity, denoted *g* (also gee) is a unit of acceleration defined as approximately 32 ft/s^2, which is the acceleration due to gravity on the Earth's surface at sea level.

Table IV.I-1: Modified Mercalli Scale[a]

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

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

magnitude would generate violent to very violent seismic shaking (MMI IX-X) throughout the City of Oakland.[33]

(3) Peak Ground Acceleration. Estimates of the peak ground acceleration have been made for the Bay Area based on probabilistic models that account for multiple seismic sources. Under these

[33] ABAG Earthquake Program, 2004. *Earthquake Shaking Scenario Map*, http://www.abag.ca.gov.

models, consideration of the probability of expected seismic events is incorporated into the determination of the level of ground shaking at a particular location. The expected peak horizontal acceleration (with a ten percent chance of being exceeded in the next 50 years) generated by any of the seismic sources potentially affecting the project area, is estimated by the California Geological Survey as 0.65 adjacent the Oakland Estuary, and approximately 0.80 in the immediate vicinity of the Hayward Fault.[34]

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

As mentioned above, based on mapping conducted for the State of California Seismic Hazards Act, the project area adjacent the Oakland Estuary, Lake Merritt Channel and most of Lake Merritt shoreline is mapped as a liquefaction hazard area by California Geological Survey as is the area of the East Oakland Sport Complex component. The Studio One component is not in a mapped liquefaction hazard area.

Lateral spreading is a form of horizontal displacement of soil toward an open channel or other "free" face, such as an excavation boundary. Lateral spreading can result from either the slump of low-cohesion unconsolidated material or more commonly by liquefaction of either the soil layer or a subsurface layer underlying soil material on a slope.[35] The lateral spreading hazard will tend to mirror the liquefaction hazard for a site, but needs an open channel or "free" face to expand into; this can include temporary excavations resulting from a construction activity.

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

Those project areas that are mapped as Urban Land are comprised of surface soils made up of un-engineered fill. Urban Land (man-made fill) can be composed of varying amounts of natural soil materials, construction debris, dredging materials, municipal solid waste and other fill.[36] Urban Land variants, such as Urban Land - Danville complex are rated as moderate to highly expansive.[37] The NRCS does not assign engineering properties to soils of the Urban Land classification as they are

[34] California Geological Survey, 2005, *Probabilistic Seismic Hazards Mapping Ground Motion Page*, accessed 2/11/2007, www.consrv.ca.gov/cgs/rghm/pshamap/pshamain.html

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

[36] Scheyer, J.M., and K.W. Hipple. 2005. Urban Soil Primer. United States Department of Agriculture, Natural Resources Conservation Service, National Soil Survey Center, Lincoln, Nebraska (http://soils.usda.gov/use).

[37] NRCS, 2006. op. cit.

variable in content and characteristics; however, expansive soils are frequently a component of Urban Land fill.

(6) Slope Stability. Slope failure can occur as either rapid movement of large masses of soil ("landslide") or slow, continuous movement ("creep"). The primary factors influencing the stability of a slope are: 1) the nature of the underlying soil or bedrock; 2) the geometry of the slope (height and steepness); 3) rainfall; and 4) the presence of previous landslide deposits.

Regional mapping shows that the project area of the Oakland Estuary, Lake Merritt Channel and Lake Merritt shoreline mapped as Category 1A; Unstable, defined as "areas of zero to five percent slope that include tidelands, marshlands, and swamplands that are underlain by moist, unconsolidated muds." The exception to this would be those areas between approximately the 29th and High Street Bridges, and the sites for both the East Oakland Sports Complex and the Studio One Art Center, which are mapped as Category 1; stable, defined as "areas of zero to five percent slope that are not underlain by landslide deposits." Finally, the upland areas where the components of the City-wide Creeks group are located in the East Bay Hills are a mosaic of category 3, 4 and 5 lands; and classified as marginally stable to unstable. Unstable areas are those that are underlain by, or adjacent to, landslide deposits.[38]

(7) Settlement and Differential Settlement. Differential settlement or subsidence could occur if buildings or other improvements were built on low-strength foundation materials (including imported non-engineered fill) or if improvements straddle the boundary between different types of subsurface materials (e.g., a boundary between native material and fill). Although differential settlement generally occurs slowly enough that its effects are not dangerous to inhabitants, it can cause significant building damage over time. Portions of the project site that may contain loose or uncontrolled (non-engineered) fill may be susceptible to differential settlement.

e. Regulatory Context. The regulatory context for geological conditions is described in the following paragraphs.

(1) Alquist-Priolo Earthquake Fault Zoning Act. The Alquist-Priolo Special Studies Fault Zoning Act was signed into law December 22, 1972, and went into effect March 7, 1973. The Act, codified in the Public Resources Code as Division 2, Chapter 7.5, has been amended eleven times. The purpose of this Act is to prohibit the location of most structures for human occupancy across the traces of active faults and to thereby mitigate the hazard of fault rupture (Section 2621.5). The Act was renamed the Alquist-Priolo Earthquake Fault Zoning Act effective January 1, 1994. Under the Act, the State Geologist is required to delineate "Earthquake Fault Zones" along known active faults in California. Cities and counties affected by the zones must regulate certain development "projects" within the zones. They must withhold development permits for sites within the zones until geologic investigations demonstrate that the sites are not threatened by surface displacement from future faulting. The California State Mining and Geology Board provides additional regulations (Policies and Criteria) to guide cities and counties in their implementation of the law (California Code of Regulations, Title 14, Div. 2). The program provides up to date information of the location of active faults that can be used to evaluate other seismic hazards (other than rupture).

[38] Nilson, Tor H., and Wright, Robert H., 1979. *Relative Slope Stability and Land-use Planning In The San Francisco Bay Region, California,* USGS Professional Paper 944, USGS & HUD, Washington D.C.

(2) Seismic Hazards Mapping Act. The State of California Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, California Geological Survey to delineate seismic hazard zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic hazard zone maps in their land-use planning and permitting processes. They must withhold development permits for a site within a zone until the geologic and soil conditions of the project site are investigated and appropriate mitigation measures, if needed, are incorporated into development plans. The Act also requires sellers (and their agents) of real property within a mapped hazard zone to disclose at the time of sale that the property lies within such a zone. Evaluation and mitigation of seismic hazards are to be conducted under guidelines adopted by the California State Mining and Geology Board.[39]

(3) CCR, Title 24 - California Building Standards Code. California Code of Regulations (CCR), Title 24, also known as the California Building Standards Code, is a compilation of building standards for structures for which a building permit is sought. Of the various sections of Title 24, Part 2 comprises the California Building Code (CBC) and incorporates the general standards for the design and construction of buildings, including seismic safety.

(4) City of Oakland Municipal Code. Some applicable chapters regarding geology include:

- Chapter 15.04, Oakland Amendments to the California Model Building Codes. This chapter of the Oakland Municipal Code shall be known as the "Oakland Amendments of the 2001 edition of the California Building Standards Code, Part 2 (California Building Code), Part 4 (California Mechanical Code), and Part 5 (California Plumbing Code), and the 2004 edition of the California Building Standards Code, Part 3 (California Electrical Code)."
- Chapter 15.04.780, Section 3304 - Grading, Excavation and Fills. The Grading Ordinance requires a permit for projects that exceed certain criteria. Subsection 3304.2 defines the terms under which a grading permit will be required.
- Chapter 15.20, Geologic Reports. This chapter mitigates the hazard due to fault rupture by limiting the placement of structures for human occupancy across the trace of active faults. This chapter applies to any new structures, major additions or alterations to any existing structures, replacements of existing structures and subdivisions located wholly or partly within the Special Studies Zone. The City requires a geologic report defining and delineating any fault hazard prior to the approval of a project, and requires that no structures for human occupancy shall be permitted to be placed: 1) across an active fault trace; 2) within fifty (50) feet of any active fault trace unless the geologic investigation can demonstrate that the site is not underlain by active branches of the fault.

(5) City of Oakland General Plan Policies. The following policies and action items from the Safety Element of the City of Oakland General Plan[40] specifically address soils, geology and/or seismic hazards and are applicable to the proposed project.

- Policy GE-1: Develop and continue to enforce and carry out regulations and programs to reduce seismic hazards and hazards from seismically triggered phenomena.
- Policy GE-2: Continue to enforce ordinances and implement programs that seek specifically to reduce the landslide and erosion hazards.

[39] California Geological Survey, 2003, Seismic Hazard Zone Report for the Oakland East 7.5-Minute Quadrangle, Alameda County, Ca.

[40] City of Oakland, 1994, *General Plan Safety Element*, accessed 2-11-07 http://www.oaklandnet.com/-government/SE/Chapter3.pdf

- Policy GE-3: Continue, enhance or develop regulations and programs designed to minimize seismically related structural hazards from new and existing buildings.
- Policy GE-4: Work to reduce potential damage from earthquakes to "lifeline" utility and transportation systems.
- Policy CO-1.1: Soil loss in new development. Regulate development in a manner which protects soil from degradation and misuse or other activities which significantly reduce its ability to support plant and animal life. Design all construction to ensure that soil is well secured so that unnecessary erosion, siltation of streams, and sedimentation of water bodies does not occur.
- Policy CO-1.2: Soil contamination hazards. Minimize hazards associated with soil contamination through the appropriate storage and disposal of toxic substances, monitoring of dredging activities, and clean up of contaminates sites. In this regard, require soil testing for development of any site (or dedication of any parkland or community garden) where contamination is suspected due to prior activities on the site.
- Policy CO-2.2: Unstable geologic features. Retain geologic features known to be unstable, including serpentine rock, areas of known landsliding, and fault lines, as open space. Where feasible, allow such lands to be used for low-intensity recreational activities.
- Policy CO-2.3: Development on filled soils. Require development on filled soils to make special provisions to safeguard against subsidence and seismic hazards.

(6) City of Oakland's Standard and Uniformly Applied Conditions of Approval.

The City of Oakland's Standard and Uniformly Applied Conditions of Approval that would apply to the proposed project are listed below. Implementation of these Conditions of Approval would ensure that a project's potential geology impacts would be reduced.

Condition 24: Erosion and Sedimentation Control (When no grading permit is required). *Ongoing throughout demolition grading, and /or construction activities.* Pursuant to Chapter 13.16 of the Oakland Municipal Code, the project applicant shall implement Best Management Practices (BMPs) to reduce erosion, sedimentation, and water quality impacts during construction to the maximum extent practicable. At a minimum, the project applicant shall provide filter materials deemed acceptable to the City at nearby catch basins to prevent any debris and dirt from flowing into the City's storm drain system and creeks.

Condition 43: Erosion and Sedimentation Control Plan. *Prior to any grading activities.*

a) The project applicant shall obtain a grading permit if required by the Oakland Grading Regulations pursuant to Section 15.04.780 of the Oakland Municipal Code. The grading permit application shall include an erosion and sedimentation control plan. The erosion and sedimentation control plan shall include all necessary measures to be taken to prevent excessive stormwater runoff or carrying by stormwater runoff of solid materials on to lands of adjacent property owners, public streets, or to creeks as a result of conditions created by grading operations. The plan shall include, but not be limited to, such measures as short-term erosion control planting, waterproof slope covering, check dams, interceptor ditches, benches, storm drains, dissipation structures, diversion dikes, retarding berms and barriers, devices to trap, store and filter out sediment, and stormwater retention basins. Off-site work by the project applicant may be necessary. The project applicant shall obtain permission or easements necessary for off-site work. There shall be a clear notation that the plan is subject to changes as changing conditions occur. Calculations of anticipated stormwater runoff and sediment volumes shall be included, if required by the Director of Development or designee. The plan shall specify that, after construction is complete, the project applicant shall ensure that the storm drain system shall be inspected and that the project applicant shall clear the system of any debris or sediment.

Ongoing throughout grading and construction activities.

b) The project applicant shall implement the approved erosion and sedimentation plan. No grading shall occur during the wet weather season (October 15 through April 15) unless specifically authorized in writing by the Building Services Division.

Condition 48: Geotechnical Report.

a) A site-specific, design level, Landslide or Liquefaction geotechnical investigation for each construction site within the project area shall be required as part if this project. Specifically:

Each investigation shall include an analysis of expected ground motions at the site from identified faults. The analyses shall be accordance with applicable City ordinances and polices, and consistent with the most recent version of the California Building Code, which requires structural design that can accommodate ground accelerations expected from identified faults.

The investigations shall determine final design parameters for the walls, foundations, foundation slabs, surrounding related improvements, and infrastructure (utilities, roadways, parking lots, and sidewalks).

The investigations shall be reviewed and approved by a registered geotechnical engineer. All recommendations by the project engineer, geotechnical engineer, will be included in the final design, as approved by the City of Oakland.

The geotechnical report shall include a map prepared by a land surveyor or civil engineer that shows all field work and location of the "No Build" zone. The map shall include a statement that the locations and limitations of the geologic features are accurate representations of said features as they exist on the ground, were placed on this map by the surveyor, the civil engineer or under their supervision, and are accurate to the best of their knowledge.

Recommendations that are applicable to foundation design, earthwork, and site preparation that were prepared prior to or during the projects design phase, shall be incorporated in the project.

A peer review is required for the Geotechnical Report. Personnel reviewing the geologic report shall approve the report, reject it, or withhold approval pending the submission by the applicant or subdivider of further geologic and engineering studies to more adequately define active fault traces.

Final seismic considerations for the site shall be submitted to and approved by the City of Oakland Building Services Division prior to commencement of the project.

b) Tentative Tract or Parcel Map approvals shall require, but not be limited to approval of the Geotechnical Report.

2. Impacts and Mitigation Measures

This section analyzes the impacts related to geology, soils and seismicity that could result from implementation of the Measure DD Project. The section begins with criteria of significance, which establish the thresholds for determining whether a project impact is significant. The latter part of this section presents the potential geologic, soils and seismic impacts associated with the proposed project. Mitigation measures are provided, as appropriate.

a. Criteria of Significance. The project would have a significant impact on the environment if it would:

1) Expose people or structures to substantial 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 or Seismic Hazards Map issued by the State Geologist for the area or based on other substantial evidence of a known fault (refer to Division of Mines and Geology Special Publications 42 and 117 and PRC §2690 et. seq.);

   b) Strong seismic ground shaking;

   c) Seismic-related ground failure, including liquefaction, lateral spreading, subsidence, collapse; or

   d) Landslides.

2) Result in substantial soil erosion or loss of topsoil, creating substantial risks to life, property, or creeks/waterways;

3) Be located on expansive soil, as defined in Table 18-1-B of the Uniform Building Code (1994, as it may be revised), creating substantial risks to life or property;

4) Be located above a well, pit, swamp, mound, tank vault, or unmarked sewer line, creating substantial risks to life or property;

5) Be located above landfills for which there is no approved closure and post-closure plan, or unknown fill soils, creating substantial risks to life or property; or

6) 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 wastewater.

The level of geology impacts is discussed in the following section and summarized in Table IV.I-2.

b. Impacts and Mitigation Measures Applicable to All Project Groups. Impacts related to geology, soils, and seismicity that may result from the implementation of Measure DD would essentially be the same for each of the four project groups. These impacts are described below for each criterion of significance listed above.

(1a) Fault Rupture. None of the Measure DD Project components propose to place habitable structures over or within 50 feet of a known active or potentially active earthquake fault. The Lake Merritt, Waterfront Trail, or Recreational Facilities are not located adjacent to any known active or potentially active faults. The activities of the City-wide Creeks group involve creek restoration activities such as riparian habitat restoration, bank stabilization, public education displays, erosion control and reintroduction of native wildlife, but not habitable structures. Creek restoration and related projects would not be particularly susceptible to damage associated with fault rupture. Implementation of Measure DD would not expose people or structures to substantial risk associated with rupture of a known fault. This potential impact would be less than significant.

(1b) Strong Seismic Ground Shaking. All structures in the Bay Area could potentially be affected by ground shaking during an earthquake. The amount of ground shaking depends on the magnitude of the earthquake, the distance from the epicenter, and the type of earth materials in between. Violent to very violent (MMI IX-X) ground shaking is expected at the project site during expected earthquakes on the Hayward and other regional faults. This level of seismic shaking could cause extensive structural damage to buildings, trails and bridges of the project. Most older masonry and frame structures would likely be destroyed, window glass broken, underground pipes broken, and conspicuous cracks may appear in the ground, curbs and pavement. Nonstructural effects during and following the event may include difficulty or inability to stand, general panic, and temporary loss of utilities service.

Some project components include buildings to be occupied by humans for recreational uses, such as the Boathouse, Pavilion and restaurant; however no residential structures are proposed as part of Measure DD. The California Building Code designates the project area and vicinity as Zone 4, the highest risk category. All components of Measure DD requiring the issuance of Building Permits will be subject to the California Building Code and subject to the most stringent level of seismic safety engineering. Prior to the issuance of any site-specific grading or building permits, a design-level geotechnical investigation (Condition 48) would be required by the City and prepared by a licensed professional and submitted to the City of Oakland Building Services Center for review and

Table IV.I-2: Summary of Potential Impacts – Geology, Soils and Seismicity

	Project Group[a]			
Would the Project:	**Group 1 Lake Merritt**	**Group 2 Waterfront Trail**	**Group 3 Recreational Facilities**	**Group 4 City-wide Creeks**
1) Expose people/structures				
a) to a known earthquake fault?	==	==	==	O
b) to seismic ground shaking?	O	O	O	O
c) to seismic-related ground failure?	O	O	O	O
d) to landslides?	==	==	==	O
2) Result in soil erosion?	See Section IV.H, Hydrology and Water Quality			
3) Be located on expansive soil?	O	O	O	O
4) Be located above a well, pit, swamp, mound, tank vault, or unmarked sewer line?	O	O	O	O
5) Be located above a landfill?	NA	NA	NA	NA
6) Be above to support septic tanks/alternative wastewater disposal systems.?	NA	NA	NA	NA

[a] The Lake Merritt and Waterfront Trail groups are analyzed at the project level. The Recreational Facilities and City-wide Creeks groups are analyzed at the program level. The level of impact and the proposed mitigation measure, if any, are identified as follows:

== No impact
O Less-than-Significant or Less-than-Significant with standard Conditions of Approval
O Reduced to Less-than-Significant after recommended mitigation
● Significant
NA Not Applicable
GEO-1, etc. identifies the mitigation measure, if any, that addresses the impact and reduces it to a level that is less than significant.

Source: LSA Associates, 2007

confirmation that the proposed development fully complies with the California Building Code (Seismic Zone 4). The report would determine the project site's geotechnical conditions and address potential seismic hazards, such as liquefaction. The report would identify building techniques appropriate to minimizing seismic damage. In addition, the geotechnical investigation must conform to the California Division of Mines and Geology (CDMG)[41] recommendations presented in the *Guidelines for Evaluating Seismic Hazards in California*, CDMG Special Publication 117. All earthquake and seismic shaking mitigation measures, design criteria, and specifications set forth in

[41] The California Division of Mines and Geology adopted the name California Geological Survey in 2002, however, older copies of this guide have the original organizational name.

the geotechnical and soils report will be followed during the design and construction of structures proposed under Measure DD. These criteria are required by the City's Standard Condition of Approval 48: Geotechnical Report.
It is acknowledged that seismic hazards associated with any development in the San Francisco Bay

Area cannot be completely eliminated even with site-specific geotechnical investigation and advanced building practices. Exposure to seismic hazards is a generally accepted part of living in the San Francisco Bay Area. However, this potential impact would be less than significant with implementation of the City's standard condition of approval is included as part of the project.

(1c) Seismic-related ground failure, including liquefaction, lateral spreading, subsidence, collapse. The components of the Lake Merritt and Lake Merritt Channel, Waterfront Trail, and Recreational Facilities groups are within a mapped liquefaction hazard zone based on the State of California Seismic Hazards Mapping Act. Development permits for sites within such a zone require a design-level geotechnical investigation, to be prepared by a licensed professional, and approved by the City of Oakland Building Services Department, to evaluate geologic and soil conditions of the project sites, and component design shall incorporate all appropriate mitigation measures, if any, into development plans, as described in Condition of Approval 48: Geotechnical Report, described above. Evaluation and mitigation of seismic hazards are to be conducted under guidelines adopted by the California State Mining and Geology Board (SMGB).[42] Inclusion of the recommended earth preparation, foundations systems and mitigation measures reduces the potential hazards associated with seismic related ground failure to a less-than-significant level.

(1d) Landslides. Only the City-wide Creeks group would have components located in areas of unstable soils potentially at risk for landslide hazard. The activities associated with these components would improve conditions related to soil and slope stability by the revegetation of riparian habitats, increasing permeability and decreasing runoff velocities by removing hardscaping, improving creek channel conditions, stabilizing banks, creek bed alignment and grading improvements, removal or repair of culverts and/or reestablishment of open creek channels. Components subject to the potential "creep" of unstable soils are addressed below as part of the discussion of settlement and differential settlement. This potential impact would be less than significant.

(2) Erosion. Potential impacts associated with erosion and loss of topsoil are discussed in the Hydrology and Water Quality section of this Draft EIR.

(3) Expansive Soils and Differential Settlement. Under the proposed Measure DD, many of the individual components would require that the surface materials be graded in preparation for improvements such as buildings, bridges, trails and roadways. Native soils may exhibit high shrink/swell characteristics in response to the amount of moisture present. Grading and excavation of the project site in preparation for construction of structures and utilities would result in areas of cut and fill. Engineered fill, existing non-engineered fill, and native undisturbed soil would be subject to varying rates of expansion, compaction and settlement. Structures built over discontinuous materials of varying densities and levels of compaction may be subject to stress or damage due to differential settlement. Structures built on Urban Land or Bay Mud may be subject to differential settlement or

[42] California Geological Survey, 2003, op. cit.

failures of underlying layers, particularly if the structural loads are unevenly distributed across the site, or if the site is sloped, or adjacent to a shoreline. In the event an open face, such as a shoreline or ditch is present, or unstable soils underlie a slope, new loads could trigger "creep" whereby the earth slumps relatively slowly towards the unconfined space. Structural damage, warping, and cracking of pavements and other infrastructure, and rupture of utility lines may occur if potentially expansive/unstable soils were not considered during design and construction of improvements.

With the exception of some of the City-wide Creeks group components (which are relatively small in scale and would not include extensive earthworks) and the existing structures of the Studio One Art Center, the components of Measure DD, in complying with the State of California Seismic Hazards Mapping Act and/or the City of Oakland's Grading Ordinance, will require a design-level geotechnical investigation. These investigations will be prepared by a licensed professional and approved by the City of Oakland Building Services Department and will evaluate geologic and soil conditions of the project sites as required by Standard Condition of Approval 48: Geotechnical Report, described above. Mitigation measures, design criteria, and specifications set forth in the design-level geotechnical investigation will be followed and incorporated into the project to reduce impacts associated with shrink-swell soils and settlement to a less-than-significant level.

(4) Well, pit, swamp, mound, tank vault, or unmarked sewer line. The current uses of component sites are well documented. In some areas, such as the 12th and 10th Street bridges, extensive grading and removal of old vaults and culverts are an integral part of the improvement project. The various components of the four groups of the Measure DD project are being developed by the City of Oakland and under guidance and planning resulting from engineering studies and multiple environmental investigations. There is no indication of wells, pits, swamps, mounds, tanks vaults or unmarked sewer lines at any of the other component sites. Should these hazards be discovered during grading or construction of any component, the City's Grading Permit requirements and Standard Conditions of Approval 24 and 43 would reduce this impact to a less-than-significant level. Any abandoned structures discovered during excavation will be fully removed and/or engineered fill will be introduced to eliminate any subsurface voids. This potential impact would be less than significant because the City's condition of approval is included as part of the project.

(5) Be located above landfills for which there is no approved closure and post-closure plan, or unknown fill soils, creating substantial risks to life or property. There are no landfill operations at or near any Measure DD components. Review of the California Department of Toxic Substances Envirostor Website[43] does not indicate any landfill sites under closure proceedings in the area of any project components. Unknown fill soils are addressed above as part of the discussion of settlement and differential settlement. There would be no impact associated with this criterion for any project group.

(6) Soils Incapable of Adequately Supporting the use of Septic Tanks. The proposed project is located within the City of Oakland and will use city services for potable water delivery and wastewater disposal; septic systems are not proposed. None of the project components call for the installation or use of alternative wastewater disposal systems. There would be no impact associated with this criterion for any project group.

[43] California Department of Toxic Substances, 2007, Envirostor Mapping Tool, accessed 2-15-07 at www.envirostor.dtsc.ca.gov/public/

c. Impacts and Mitigation Measures Unique to Specific Project Components. There are no component-specific impacts associated with geology, soils or seismicity.