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GEOLOGY AND SOILS

INTRODUCTION

This section summarizes geologic and geotechnical aspects of the site as they relate to the OPSP and Phase I Project. The discussion is based on a review of the following documents:

- Gabewell, Inc. with Harding Lawson Associates, 2000, "Final Closure and Post-Closure Maintenance Plan, Oyster Point Landfill, South San Francisco, California". September
- EIP Associates, 2006, "Draft Environmental Impact Report/Environmental Assessment, South San Francisco Ferry Terminal Project". Chapter 3.6. February 14.
- Kleinfelder, 2007, "Feasibility Study and Cost Estimate, Proposed Oyster Point Marina Redevelopment, South San Francisco, California". November 12.
- Treadwell & Rollo, 2009a, "Preliminary Foundation Design Criteria," Memorandum to Steve Shanks, SKS Investments, January 16.
- Treadwell & Rollo, 2009b, "Geotechnical Investigation of the Landfill Cover, Oyster Point Landfill, South San Francisco, California," February 13.
- Treadwell & Rollo, 2009c, "Work Plan for Field Investigation of SUMP 1, Oyster Point Business Park / Oyster Point Landfill, South San Francisco, California." Draft, February 10.
- Treadwell & Rollo, 2009d, "Methene Mitigation Systems: Description and Unit Costs, Oyster Point Landfill / Oyster Point Business Park, South San Francisco, California." Draft, January 29.

REGULATORY SETTING

CITY OF SOUTH SAN FRANCISCO HAZARD MITIGATION PLAN

The City of South San Francisco has adopted the Association of Bay Area Governments Local Hazard Mitigation Plan as the Hazard Mitigation Plan (HMP) for the City by resolution 65-2006, on August 16, 2006. The HMP has been designed to identify the areas where people or structures may have higher vulnerability to earthquakes, flood, wildland fires, and other natural hazards. The plan identifies policies and actions that may be implemented by the City to reduce the potential for loss of life and property damage in these areas based on an analysis of the frequency of earthquakes, floods, wildland fires and landslides in terms of frequency, intensity, location, history, and damage effects. The Plan serves as a guide for decision-makers as they commit resources to reduce the effects of natural hazards.

CITY OF SOUTH SAN FRANCISCO GENERAL PLAN UPDATE EIR

The General Plan Update Health and Safety Element includes a section on Geological and Seismic Hazards. This section identifies geotechnical and geologic impacts to the general City of South San Francisco area. The most recent General Plan update was completed in October 1999.

EAST OF 101 AREA PLAN

The 1999 General Plan update also includes a summary of the East of 101 area plan, providing specific policies for the area located east of U.S. Highway 101.

ALQUIST-PRIOLO EARTHQUAKE FAULT ZONING ACT

The California Alquist-Priolo Earthquake Fault Zoning Act of 1972 requires the mapping and zoning of active faults within the State of California. Under the act, development within zones of active fault displacement is restricted for structures intended for human occupancy. Any development site located within an Earthquake Fault Zone Boundary as delineated on State maps must be studied to determine if an active fault crosses the subject parcel. Setbacks from active faults are required under the Act. There is an Alquist-Priolo Earthquake Fault Zone Map for the South San Francisco Quadrangle, in which the Project site is located.

CALIFORNIA SEISMIC HAZARDS MAPPING ACT

The California Seismic Hazards Mapping Act of 1990 (California Public Resources Code Sections 2690-2699.6) addresses seismic hazards other than surface rupture, such as liquefaction and seismically induced landslides. The Seismic Hazards Mapping Act specifies that the lead agency for a project may withhold development permits until geologic or soils investigations are conducted for specific sites and mitigation measures are incorporated into plans to reduce hazards associated with seismicity and unstable soils. The State of California does not currently have a Seismic Hazard Map for the South San Francisco Quadrangle, in which the Project is located. However, the Seismic Hazard Map Home Page indicates that mapping for the southern part of the South San Francisco Quadrangle is currently under preparation.[1] This map may be completed in the near future.

CALIFORNIA BUILDING CODE (2010)

The California Building Code (CBC) was developed to incorporate modifications to the International Building Code (developed by the International Conference of Building Officials) required by California law and statute and has been adopted by most jurisdictions in California, including the City of South San Francisco, to oversee construction. The CBC defines four Seismic Zones in California, which are ranked according to their seismic hazard potential. Zone 1 has the least seismic potential and Zone 4 has the highest seismic potential. The City of South San Francisco is located in Seismic Zone 4 and thus development is required to comply with all design standards applicable to Seismic Zone 4. The earthquake protection law (California Health and Safety Code section 19100 et seq.) requires that structures be designed to resist stresses produced by lateral forces caused by wind and earthquakes. Specific minimum standards for seismic safety and structural design to meet earthquake protection requirements are set forth in Chapter 16 of the CBC.

[1] http://www.conservation.ca.gov/cgs/shzp/Pages/Index.aspx, January 16, 2008.

GEOLOGIC SETTING AND SEISMICITY

REGIONAL GEOLOGY

The San Francisco Bay Area lies within the Coast Range geomorphic province, a series of discontinuous northwest trending mountain ranges, ridges, and intervening valleys characterized by complex folding and faulting. The general area of Oyster Point is located on the reclaimed baylands along the westerly shores of San Francisco Bay. The bay is underlain by a depressed rock block, which is Cenozoic in age, and is wedged between two uplifted blocks featuring the East Bay Hills on the east and the Coastal Range of the San Francisco Peninsula on the west. This series of blocks is associated with the complex zone of the San Andreas fault system. The San Andreas fault is located in the Coastal Ranges along the western edge of the depressed block, and the Hayward fault (located at the base of the East Bay Hills) forms the east delineation of the depressed block.

During the geologic period known as the Pleistocene Epoch, when the sea level was lowered approximately 300 feet in the Bay Area due to glacial activity, ravines and canyons were created by erosion in the elevated rock blocks. Alluvial debris was washed onto the depressed bedrock areas forming the alluvial cones, alluvial slopes, and a central plane. This central plane was an extension of Santa Clara Valley with an outlet through the Golden Gate gap to an ocean shoreline, which was miles from the present shore.

As the melting of the continental ice sheets raised ocean levels, the valley, which is now San Francisco Bay, was progressively flooded by salt water. During this process, sandy alluvial deltas were built up upon the valley topography in shallow water, while in deeper water the fine-grained soils were deposited as mud. Eventually, the bay water level rose to sufficient height to submerge the alluvial cones at the margin of the valley, together with the intervening low ground and ravine outlets. Bay Mud deposits accumulated to a uniform level, burying the submerged ravines, cones, and deltas to vary depths depending upon the elevation of the original topography. The bay deposits can be summarized as follows:

- Bay mud; unconsolidated and soft, consisting of silty, slightly sandy clays and sandy silts often with organic inclusions.
- Alluvial sands and clays underlying the bay mud.
- Lower bay clay; consolidated and of similar composition to the Bay Mud.
- Sandy soils; medium to fine-grained, compact and angular, underlying the lower bay clay and directly overlying bedrock.
- Bedrock; locally weathered and decomposed, consisting of sandstone, shale, and in places, serpentine and other intrusive rock. Available data indicate that the depth of the rock in the vicinity of Oyster Point ranges from near the ground surface at the western edge of the site to estimated depths of 200 feet or more at the east end of the landfill.

LOCAL GEOLOGY

Oyster Point is located within the historic margins of the San Francisco Bay, which is directly east of the site. According to available geological information (Bonilla, 1971)[2], Oyster Point is underlain by

[2] Bonilla, M.G., 1971, "Preliminary geologic map of the San Francisco South 7.5-minute quadrangle and part of the Hunters Point 7.5-minute quadrangle, California," U.S. Geological Survey Miscellaneous Field Studies Map MF-311; scale 1:24,000.

artificial fill, Bay mud, and sandstone units of the Franciscan formation. Deep channels that have been filled with Bay Mud of varying thicknesses are known to traverse shorelines in the site vicinity and have been described by others as present at the west end of the site (Treadwell & Rollo 2009a). These ancient buried channels are commonly called paleochannels. Available information pertaining to historical shorelines and known fill areas (Nichols & Wright, 1971)[3] indicates that historically the Oyster Point Marina area was developed by filling a low tideland area. The fill appears to have been placed circa 1958 at the west end of Oyster Point, and after 1958 at the east end.

According to a 2000 report for the Post Closure Management of the Oyster Point Landfill prepared by Gabewell with PES Environmental, the lithologic units present within and beneath the closed Oyster Point Landfill consist of a surficial clay/imported fill cap present at thicknesses from 1 to 14 feet, waste beneath the cap present up to 45 feet thick, Bay Mud present beneath the waste up to 90 feet thick, alluvial units beneath the Bay Mud of indeterminate thickness, and Franciscan bedrock that crops out a the western end of the landfill and dips steeply eastward beneath the Bay Mud and alluvium to estimated depths of about 200 feet or more. According to recent subsurface investigations by Treadwell & Rollo (2009) the thickness of the waste layer ranges from a few feet at the landfill perimeter to 35 to 40 feet over most of the site, and up to about 70 feet in some areas.

FAULTING AND SEISMICITY

Geologic and geomorphic structures within the San Francisco Bay Area are dominated by the San Andreas fault (SAF), a right-lateral strike-slip fault that extends from the Gulf of California in Mexico, to Cape Mendocino, on the Coast of Humboldt County in northern California. It forms a portion of the boundary between two independent tectonic plates on the surface of the earth. To the west of the SAF is the Pacific plate, which moves north relative to the North American plate, located east of the fault. In the San Francisco Bay Area, movement across this plate boundary is concentrated on the SAF; however, it is also distributed, to a lesser extent across a number of other faults that include the Hayward, Calaveras, and Concord among others. Together, these faults are referred to as the SAF system. Movement along the SAF system has been ongoing for about the last 25 million years. The northwest trend of the faults within this fault system is largely responsible for the strong northwest structural orientation of geologic and geomorphic features in the San Francisco Bay Area.

The site is situated within the San Francisco Bay Area, which is characterized by numerous active faults and moderate to high seismic activity. Based on the information provided in Hart and Bryant (1997)[4] the site is not located within a State-designated, Earthquake Fault Rupture Hazard Zone where site-specific studies addressing the potential for surface fault rupture are required and no known active faults traverse the site.

Table 9.1 below shows the name, distance, direction, and magnitude of the closest faults to Oyster Point.

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[3] Nichols, D.R., and Wright, N.A., 1971, "Preliminary map of historical margins of marshland, San Francisco Bay, California," U.S. Geological Survey Open-File Report, Basic Data Contribution 9, scale 1:125,000.

[4] Hart, E. W. and W. A. Bryant. 1997. "Fault-Rupture Hazard Zones in California: Alquist-Priolo Earthquake Fault Zoning Act with index to Earthquake Fault Zone Maps." (Special Publication 42) California Division of Mines and Geology. Sacramento, CA.

Table 9.1: Faults in the Vicinity

Fault Name	Distance (km)	Direction	Maximum Moment Magnitude
San Andreas - 1906 Rupture	7.3	Southwest	7.9
San Andreas – Peninsula	7.3	Southwest	7.0
San Gregorio	15.2	West	7.3
Hayward – North	22.6	Northeast	6.9
Hayward – Total	22.6	Northeast	7.1
Hayward – South	23.4	East	6.9
Monte Vista	27.5	Southeast	6.5
Calaveras (North of Calaveras Reservoir)	36.9	Northeast	6.8
Concord - Green Valley	43.5	Northeast	6.9
Healdsburg - Rodgers Creek	47.5	North	7.0
Hayward - South East Extension	48.0	Southeast	6.5

Based on the map of known active faults (ICBO, 1998)[5], the San Andreas fault is the closest fault and is located approximately 7.3 kilometers southwest of Oyster Point. A major seismic event on these or other nearby faults may cause substantial ground shaking at the site.

GEOTECHNICAL DESIGN CONSIDERATIONS

Geotechnical properties of the fill and native soils at the site that will affect the performance of future site improvements are discussed below.

GENERALIZED SUBSURFACE CONDITIONS

The majority of the site is underlain by landfilled solid wastes. The thickness of the landfill varies from about 4 to 70 feet and generally increases toward the center of the site. The landfill waste material consists of a variety of materials including wood, paper, plastic, cardboard, tin, rags, bricks, glass, and various organic debris mixed with varying amounts of soil. The bottom of the landfill is generally above elevation +10 feet (MSL) in the western portion of the site, and as deep as El -20 feet in the eastern portion.

A soil cap varying in thickness from about 1 to 14 feet overlies the landfill areas. The soil cap consists primarily of stiff to very stiff silty and sandy clays of low to moderate plasticity, and medium dense clayey sands, with occasional gravelly clay and silty sand layers.

Throughout most of the site the waste materials are underlain by very soft to soft clays and silty clays (Bay Mud) with organics and shells. The exception to this is at the western margin of the site where the waste fill is underlain by bedrock consisting of weathered claystone, sandstone, and siltstone. The Bay Mud is underlain by bedrock in the western portion of the site and by very stiff to hard clays and dense sands under the remainder of the landfill. Most of the site is underlain by 50 to 90 feet of Bay Mud.

[5] International Conference of Building Officials, 1998. "Maps of Known Active Fault Near-Source Zones in California and Adjacent Portion of Nevada – To be used with the 1997 Uniform Building Code," California Division of Mines and Geology, February.

Groundwater elevations range from about 5 feet to 20 feet above mean lower low water (MLLW). The higher groundwater elevations are found toward the western margin of the site where the topography is higher. The majority of the project site has a groundwater elevation from about 5 to 8 feet above MLLW.

The above is a general description of the soil, rock, waste and groundwater conditions documented in the boring logs encountered in our research. Soil, rock and groundwater conditions can deviate from those encountered at the boring locations. In addition, the subsurface conditions may have changed as a result of settlement, decomposition of waste and/or erosion, and therefore the description herein may not reflect the current subsurface conditions at the site.

SETTLEMENT

A major geotechnical issue for design, construction and maintenance of structures at the site is settlement of the waste material and Bay Mud soils that underlie most of the waste. There are three major settlement mechanisms that are on-going at the site: consolidation settlement of the waste material and the underlying Bay Mud soils, compaction of the waste and biological decomposition shrinkage of the waste.

Both consolidation and compaction of waste are load-induced settlements. Consolidation settlement results from the expulsion of water from void spaces within soil or waste in response to new loads. The Bay Mud soils that underlie the site have been undergoing consolidation settlement in response to the waste and soil fill weight since filling began in the 1950s. Laboratory test data from consolidation tests indicate that consolidation settlement of Bay Mud is on-going throughout the site. Imposition of new loads as part of new site development will lead to additional consolidation settlement of Bay Mud and waste materials below the groundwater level. Consolidation settlements are likely accruing due to the expulsion of both water and air from the waste mass. The magnitude of consolidation settlement in the waste and in the Bay Mud is difficult to estimate. However, since no new significant fill has been placed in over 40 years, it is speculated that much of the consolidation settlement of both the waste and of the underlying Bay Mud has already occurred under current loads.

Compaction settlement results from crushing of the material under a new load. The magnitude of compaction settlement under new loads from new site development is of some concern, especially in the proposed building areas where grade may be raised. However, the magnitude of settlement due to waste compaction is small compared to the magnitude of settlement due to biological decomposition shrinkage, as described below.

We anticipate the major portion of the settlement to be the result of decomposition of the waste. Unlike consolidation and compaction settlements, shrinkage is somewhat independent of the load. Shrinkage is defined as the settlement resulting from the biological conversion of waste with organic solids into methane, carbon dioxide and other decomposition products. The rate and magnitude of settlements resulting from the biological shrinkage of the waste is dependent on several factors including waste thickness, composition, and age of the waste. A large portion of the settlements occur within the first two years following placement with a relatively steady rate occurring after that for an indefinite period of time. Based on our review of published performance information at landfills of similar size and composition to the project site, we expect total shrinkage settlements of between 10 to 15 percent of the initial waste fill height. The thickness of the waste fill at the subject landfill varies between 1.5 and 70 feet at the deepest portion. Considering the age of the landfill and the elapsed time since closure of the landfill, the anticipated settlements are expected to fall between 3 to 6 feet over the next 15 years, for the thickest portion of the landfill at the east side of the site. Since the settlement of the landfill is time dependent and it is uncertain when the decomposition of the waste ceases to occur, it is prudent to assume that the decomposition process occurs indefinitely.

Differential settlements within the waste portion of the site are difficult to predict due to the significant variety of waste material and its substantial thickness. At other landfill sites with waste thickness of approximately 25 to 30 feet, differential settlements of up to about 25 percent of the total settlement have been measured over a horizontal distance of 100 feet for a period of 12 years. Due to the uncertainties associated with settlement at the site and the substantial thickness of the waste, differential settlements could easily exceed 50 percent of the total settlement over a distance of 100 feet in the next 15 years. Consideration must also be given to differential settlement between the waste and non-waste portions (including pile supported structures) of the site. Since the non-waste areas are not expected to undergo significant settlement, the differential settlement will be equal to approximately the total settlement of the waste at the interface location.

Placement of additional fill at the site will result in additional settlement due to consolidation settlement of the Bay Mud soils and the submerged waste and further compaction of waste above groundwater. The magnitude of the new settlement will depend on the thickness of the fill, the lateral extent and the current thickness of the soil cap. For estimating purposes, settlements on the order of 3 to 5 inches for every foot of new fill should be anticipated.

GROUND IMPROVEMENT

Several techniques are sometimes used at landfill sites in an effort to improve ground conditions and reduce settlements. Ground improvement techniques may include dynamic deep compaction or preloading with temporary soil fills. Although these techniques can reduce settlements in waste materials, they do not eliminate them as they do not prevent decomposition. Common ground improvement techniques would not likely improve the Bay Mud properties significantly across much of the site. Accordingly, we do not feel ground improvement methods are particularly feasible at Oyster Point.

Seismic Hazards

The site is in a region of high seismic activity and is expected to be subjected to major shaking during the design life of the project. Seismic hazards commonly investigated for projects in the site vicinity include strong-ground shaking, soil liquefaction, lateral spreading and seismic densification.

Strong Ground Shaking

The San Francisco Bay Area is a seismically active region. The OPSP site and region will likely be subjected to strong to violent seismically induced ground shaking within the design life of the development. The site is located in an area of active regional seismicity near active seismic sources.

According to a recent study completed by the Working Group on California Earthquake Probabilities (WGCEP)[6], which assesses the probability of earthquakes in the San Francisco Bay Area, there is a 62 percent probability that an earthquake of Magnitude 6.7 or greater will strike within the life of the OPSP improvements.

Liquefaction

Soil liquefaction is a condition in which saturated, granular soils undergo a substantial loss of strength and deformation due to pore pressure increase resulting from cyclic stress application induced by

[6] Working Group On California Earthquake Probabilities (WGCEP), 2003, Earthquake Probabilities in the San Francisco Bay Region: 2002–2031, U.S. Geological Survey Open-File Report 03-214.

earthquakes. In the process, the soil acquires mobility sufficient to permit both horizontal and vertical movements if the soil mass is not confined. Soils most susceptible to liquefaction are saturated, loose, clean, uniformly-graded, and fine-grained sand deposits. If liquefaction occurs, foundations resting on or within the liquefiable layer may undergo settlements. This will result in reduction of foundation stiffness and capacity.

Based on the subsurface data obtained from the previous drilled borings at Oyster Point (noted above among the references reviewed), the existing landfill materials, residual soils, Bay Mud, and Franciscan Complex bedrock have a low potential for liquefaction. Therefore, damage due to liquefaction at Oyster Point is considered low. It should be noted that the landfill is contained by soil dikes along the water-side site perimeter. These perimeter dikes are reported to have been constructed of Bay Mud, which has low potential for liquefaction. Prior to new site development, geotechnical studies shall be undertaken to confirm the material types used in the construction of the perimeter dikes to verify the assumed low potential for liquefaction.

Lateral Spreading

Lateral spreading is a consequence of liquefaction, which results in lateral movement toward a slope. Because liquefaction potential is considered to be low at this site, the potential for lateral spreading is also considered to be low. Again, the perimeter dikes shall be evaluated to confirm that they consist of materials with low liquefaction potential.

Seismic Densification

During earthquake shaking, certain soils above the groundwater table may undergo densification, which could result in additional ground-surface settlement. Typically, granular soils above the water table are subject to densification during significant strong ground shaking due to earthquakes. Landfill waste material can behave as a “granular” material. Therefore, the waste material, if subject to a significant earthquake, could result in some settlement. However, based on the age of the landfill, the amount of settlement due to seismic densification is not anticipated to be greater than the future settlements anticipated as a result of the consolidation of the landfill material and underlying Bay mud.

Slope Stability

A principal geotechnical issue in developing final plans for the project is stability of the existing landfill perimeter dikes. Slope stability at the site is controlled primarily by the strength of the materials used in the dike construction and of the Bay Mud on which the dikes are founded. Stability analyses shall include analyses for both static stability and seismic stability under a design magnitude earthquake event. Seismic analyses shall include pseudo-static analyses to estimate permanent slope displacements due to earthquake motions.

IMPACTS AND MITIGATION MEASURES

STANDARDS OF SIGNIFICANCE

According to CEQA Guidelines, exposure of people or structures to major geological hazards is considered a significant adverse impact. The potential geologic, geotechnical, and seismic effects of the proposed OPSP can be considered from two points of view: (1) construction impacts; and, (2) geologic hazards to people or structures. The basic criterion applied to the analysis of construction impacts is whether construction of the OPSP will create unstable geologic conditions that would last beyond the short-term construction period. The analysis of geological hazards is based on the degree to which the site geology could produce hazards to people or structures from earthquakes, ground shaking, ground movement, fault rupture, or other geologic hazards, features or events.

According to CEQA Guidelines, the project would have a significant environmental impact if it were to result in:

1. The exposure of people or structures to potential substantial adverse effects, including the risk of loss, injury or death involving rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault;
2. The exposure of people or structures to potential substantial adverse effects, including the risk of loss, injury or death involving strong seismic ground shaking;
3. The exposure of people or structures to potential substantial adverse effects, including the risk of loss, injury or death involving seismic-related ground failure, including liquefaction and seismic-induced landslides;
4. The exposure of people or structures to potential substantial adverse effects, including the risk of loss, injury or death involving landslides;
5. Development located on a geologic unit or soil that is unstable (or that would become unstable as a result of the OPSP) and which could potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction or collapse;
6. The exposure of people or structures to potential substantial adverse effects, including the risk of loss, injury or death involving volcanic hazards;
7. Development located on expansive soil, creating substantial risks to life and property;
8. The loss of topsoil or development in an area of erodible soils.
9. Development in areas where soils are incapable of adequately supporting the use of septic tanks or alternative wastewater disposal systems where sewers are not available for the disposal of wastewater;
10. The alteration or destruction of a unique geological feature.

SURFACE FAULT RUPTURE

Impact Geo-1: **Surface Fault Rupture.** According to the latest available maps, the OPSP site is not contained within an Alquist-Priolo Earthquake Fault Zone boundary. Published geologic maps of the area show the San Andreas fault (the closest known fault to the site) as lying about 7.3 kilometers (4.5 miles) to the west. The potential impact of surface fault rupture is considered ***less-than-significant.***

EXPOSURE TO STRONG SEISMIC GROUND SHAKING

Impact Geo-2: **Seismic Ground Shaking.** There is a high probability that the proposed development will be subjected to strong to violent ground shaking from an earthquake during its design life. Strong to violent seismic ground shaking is considered a ***potentially significant impact.***

Mitigation Measures

Geo-2a: **Compliance with California Building Code.** OPSP development shall meet requirements of the California Building Code, including the California Building Standards, published by the International Conference of Building Officials, and as modified by the amendments, additions and deletions as adopted by the City of South San Francisco, California. Incorporation of seismic construction standards will reduce the potential for catastrophic effects of ground shaking, such as complete structural failure, but will not completely eliminate the hazard of seismically induced ground shaking.

Geo-2b: **Compliance with a design-level Geotechnical Investigation report prepared by a Registered Geotechnical Engineer and with Structural Design Plans as prepared by a Licensed Professional Engineer.** Proper foundation engineering and construction shall be performed in accordance with the recommendations of a Registered Geotechnical Engineer and a Licensed Professional Engineer. The structural engineering design, with supporting Geotechnical Investigation, shall incorporate seismic parameters compliant with the California Building Code.

Geo-2c: **Obtain a building permit.** The OPSP applicant shall obtain a building permit through the City of South San Francisco Building Division. Plan Review of planned buildings and structures shall be completed by the Building Division for adherence to the seismic design criteria for planned commercial and industrial sites in the East of 101 area of the City of South San Francisco. According to the East of 101 area plan, Geotechnical Safety Element, buildings shall not be subject to catastrophic collapse under foreseeable seismic events, and will allow egress of occupants in the event of damage following a strong earthquake.

Conformity with mitigation measures Geo-2a, -2b and -2c would reduce the impact of strong seismic ground shaking to a level of ***less-than-significant*** through compliance with applicable regulations and a design-level geotechnical investigation. This applies to the entire OPSP, including the Phase I Project.

SEISMICALLY INDUCED GROUND FAILURE, INCLUDING LIQUEFACTION AND GROUND SURFACE SETTLEMENT

Impact Geo-3. **Liquefaction, Densification, and Ground Surface Settlement.** The Association of Bay Area Governments identifies the OPSP area as an area of high hazard for liquefaction. However, based on the subsurface data obtained from the previous drilled borings at Oyster Point (noted above among the references reviewed), the existing landfill materials, residual soils, Bay Mud, and Franciscan Complex bedrock have a low potential for liquefaction. Therefore, damage due to liquefaction at Oyster Point is considered low. It should be noted that the landfill is contained by soil dikes along the water-side site perimeter. These perimeter dikes are reported to have been constructed of Bay Mud, which has low potential for liquefaction. Prior to new site development, geotechnical studies shall be undertaken to confirm the material types used in the construction of the perimeter dikes to verify the assumed low potential for liquefaction. Liquefaction or densification of soils composing or underlying the perimeter dikes could result in settlement and differential settlement of site improvements including buildings, pavements, and utilities and pose a threat to human health. The potential for liquefaction of perimeter dike soils is considered a ***potentially significant impact*****.**

Mitigation Measures

Geo-3a: **Compliance with recommendations of a Geotechnical Investigation and in conformance with Structural Design Plans.** A design-level Geotechnical Investigation shall be prepared for the site under the direction of a California Registered Geotechnical Engineer and shall include analysis for liquefaction potential of the site soils, particularly in the perimeter dikes. Proper foundation engineering and construction shall be performed in accordance with the recommendations of the Geotechnical Investigation. The Geotechnical Investigation shall be reviewed and approved by the City's Geotechnical Consultant and by the City Engineer. A Registered Structural Engineer shall prepare project structural design plans. Structures shall be designed to reduce the effects of anticipated seismic settlements. The Geotechnical Engineer shall review the Structural Design Plans and provide approval for the Geotechnical elements of the plans. The design plans shall identify specific mitigation measures to reduce liquefaction potential, if the potential for liquefaction is found to exist, or other ground failure modes such as lateral spreading, seismic densification or stability of the perimeter dike slopes. Mitigation measures may include ground improvement by methods such as stone columns or jet grouting.

Geo-3b: **Obtain a building permit.** The OPSP applicant shall obtain a building permit through the City of South San Francisco Building Division. Plan Review of planned buildings and structures shall be completed by the Building Division for adherence to the seismic design criteria for planned commercial and industrial sites in the East of 101 area of the City of South San Francisco. According to the East of 101 area plan, Geotechnical Safety Element, buildings should not be subject to catastrophic collapse under foreseeable seismic events, and will allow egress of occupants in the event of damage following a strong earthquake.

Conformity with mitigation measures Geo-3a and 3b would reduce the impact of liquefaction or densification of soils composing or underlying the perimeter dikes to a level of ***less-than-significant***. This applies to the entire OPSP, including the Phase I Project.

Impact Geo-4. **Perimeter Dike Stability.** Based on a review of available subsurface information, the dikes that surround the site are assumed to be constructed primarily of cohesive soils derived from Bay Mud. Slope stability of the perimeter dikes is critical to the integrity of the site. Slope stability of the dikes is controlled primarily by the strength of the materials used in dike construction and of the soils on which the dikes are founded. Prior to new site development, geotechnical studies shall be undertaken to confirm the material types used in the construction of the perimeter dikes to verify that the slopes meet minimum criteria for stability under both static and seismic conditions. Failure of the perimeter dike slopes could result in settlement and differential settlement of site improvements including buildings, pavements, and utilities and pose a threat to human health. In the absence of evidence that demonstrates adequate stability of the perimeter dike slopes under both static and seismic conditions, stability of the perimeter dike slopes is considered a ***potentially significant impact.***

Mitigation Measure

Geo-4: **Compliance with recommendations of a Geotechnical Investigation.** A design-level Geotechnical Investigation shall include an evaluation of static stability and seismic stability under a design magnitude earthquake event. Seismic analyses shall include pseudo-static analyses to estimate permanent slope displacements due to earthquake motions. The Geotechnical Engineer shall prepare recommendations to mitigate potential slope instability, if slope stability problems are identified. Mitigation measures may include ground improvement by methods such as stone columns or jet grouting. Design-level Geotechnical Investigations shall be completed during preliminary and final design stages and will confirm material types used in the construction of the perimeter dikes to verify that the slopes meet minimum criteria for stability under both static and seismic conditions. Knowledge of the stability of the perimeter dikes will guide the selection of any future measures to mitigate any deficiencies identified in the perimeter dike.

Implementation of these mitigation measures will reduce the impact of seismically-induced ground failure and seismic slope stability to a ***less-than-significant*** level. This applies to the entire OPSP, including the Phase I Project.

VARIABLE SUBSURFACE CONDITIONS

Impact Geo-5: **Variable Subsurface Conditions and Selection of Foundation Types and Depths.** Geotechnical considerations for the selection of alternative foundation types for the site include the following:

- The presence of Bay Mud, landfill waste and other area fill over most of the proposed building footprint areas;
- Varying thicknesses of Bay Mud, landfill waste and other fill;
- Sloping bedrock surface; and
- Presence of possible paleochannels in the north/northwest portions of the site.

These variable subsurface conditions will influence the design, performance and constructability of foundation systems for the proposed buildings and are considered a *potentially significant impact*.

Mitigation Measures

Geo-5a: **Deep Foundations**. Because of the magnitude of expected settlement of Bay Mud soils and waste fill materials that would occur under new building loads, the OPSP applicant must consider the use of deep foundations such as driven piles. Specific recommendations for suitable deep foundation alternatives and required penetrations will be provided during the course of a design-level geotechnical investigation and will depend on factors such as the depth and hardness of the underlying clays, sands or bedrock, and the corrosivity of the waste materials and Bay Mud soils. Suitable deep foundation types may include driven precast, prestressed concrete piles or driven closed-end steel pipe piles with the interior of the pile filled with concrete after driving.

Deep foundations shall extend through all waste materials and Bay Mud and be tipped in underlying stiff to hard clays, dense sands or weathered bedrock. Where waste and Bay Mud soils underlie the site, wall and column loads as well as floor slabs shall be founded on deep foundations. Settlement of properly-designed and constructed deep foundation elements is typically less than about one-half inch. The majority of settlement typically occurs during construction as the loads are applied.

Where landfill waste and Bay Mud are not present (possibly at extreme western and northwestern edges of the site) and competent soil or bedrock are present near the ground surface (within about 5 feet of finished grade elevation), shallow foundations such as footings or mats may be appropriate foundation types, as determined during the course of a design-level geotechnical investigation. Where proposed structures straddle a transition zone between these conditions, a combination of shallow and deep foundations may be required. Any transition zones shall be identified during site-specific geotechnical investigations for preliminary and final designs.

Geo-5b: **Predrilling and/or Pile Configuration.** Piles either shall be predrilled through the fill and landfill materials to protect the piles from damage due to unknown materials, to reduce pushing waste material deeper, and to reduce pile alignment problems or shall have a pointed tip configuration. If a drill is used, it should only loosen and break up in-place obstructions that may cause pile damage. During recent subsurface investigations reported by Treadwell & Rollo (2009b) obstructions including concrete rubble was encountered throughout the landfill area, particularly in the northern end of the site. Even with predrilling, precast concrete piles could be damaged during installation at a landfill site such as Oyster Point. For preliminary planning purposes, a precast concrete pile breakage rate during installation of 10 to 15 percent may be considered applicable.

Piles usually have to include pointed tip configurations to avoid pushing landfill waste downward. These configurations are typically readily accommodated by pile driving contractors.

Geo-5c: **Indicator Pile Program.** Prior to specifying the lengths of the production piles, drive indicator piles at the structure sites in order to observe the driving characteristic of the piles and the ability of the driving equipment when a driven pile is used. The driving criteria and pile length of production piles shall also be estimated from the information obtained from driving of the indicator piles. The contractor shall use the same equipment to drive both the indicator and production piles. Indicator pile lengths and locations shall be selected by the Geotechnical Engineer, in conjunction with the Structural Engineer and Contractor after the foundation plan has been finalized.

The indicator pile program will serve to establish information on the following:

- Estimates of production pile lengths;
- Drivability of production piles;
- Performance of pile driving equipment; and
- Variation in driving resistance relative to depth and location of piles.

Implementation of these mitigation measures will reduce the impact of variable subsurface conditions on the construction and performance of foundations to a ***less-than-significant*** level. This applies to the entire OPSP, including the Phase I Project.

Impact Geo-6: **Drag Load on Deep Foundations.** The landfill wastes and the underlying Bay Mud are settling due to consolidation and on-going decomposition-induced settlement of the wastes. Deep foundations (piles) will extend through the waste and Bay Mud layers and into underlying materials that are relatively incompressible. The settlement of the waste and Bay Mud around the piles will tend to move downward relative to the pile. This settlement will accumulate a drag load on the pile element, which will depend on the material layering and thickness, pile length and load on the pile. On-going settlement of Bay Mud soils and waste materials is considered a ***potentially significant impact.***

Mitigation Measure Geo-6: **Account for Drag Load on Deep Foundations.** The Geotechnical Engineer shall account for accumulation of drag load in the structural design of the deep foundations elements (piles).

Implementation of this mitigation measure will reduce the impact of drag load on the performance of deep foundations to a ***less-than-significant*** level. This applies to the entire OPSP, including the Phase I Project.

LANDFILL GAS AT BUILDING-SOIL INTERFACE

Impact Geo-7: **Landfill Gas Entry into Buildings.** Construction of buildings over the landfill cap could allow landfill gas to accumulate beneath building floors and permeate into the building interiors. Landfill gas accumulation inside buildings and at the building-soil interface may adversely affect the health and safety of building occupants. Accumulation of landfill gas beneath and inside structures is a ***potentially significant*** impact.

Mitigation Measure Geo-7: **Incorporate Systems for Landfill Gas Control.** Measures for the control of landfill gas shall be included in building design. Measures for the control of landfill gas typically include a collection system, floor slab shielding and interior alarms.

Implementation of a landfill gas control system will reduce the impact of landfill gas at the building-soil interface to a level of ***less-than-significant***. This applies to the entire OPSP, including the Phase I Project.

SETTLEMENT OF LANDFILL MATERIALS AND BAY MUD

Impact Geo-8: **Landfill Waste Materials and Bay Mud.** Placement of additional fill or other new loads at the site will result in additional site settlement due to consolidation settlement of the Bay Mud soils and the compaction and decomposition induced settlement of submerged waste and waste above groundwater. Due to the generally heterogeneous nature of the landfill, differential settlement of the soil cap will be on-going. This differential settlement can disrupt drainage patterns and cause damage to pavements, underground utilities and soil-supported structures. The magnitude of new settlement in response to additional fill will depend on the thickness of the fill, the lateral extent, and the current thickness of the soil cap. For estimating purposes, settlements on the order of 3 to 5 inches for every foot of new fill should be anticipated. Settlement due to the presence of unstable soil, waste and Bay Mud is a ***potentially significant*** impact.

Mitigation Measures Geo-8a: **Avoid Significant New Loads on Landfill Waste and Bay Mud.** A design-level Geotechnical Investigation shall include exploration to more thoroughly determine the thickness and areal extent of landfill waste and Bay Mud. To avoid inducing additional settlement to the settlement that is already on-going, grading plans shall include as little additional new fill as possible, and significant new structure loads or any structures that are settlement-sensitive shall be founded on deep foundations extended below the Bay Mud, as recommended in the design-level Geotechnical Investigation report.

All grading shall be planned to avoid penetrating the landfill cap and to reduce the amount of long-term settlement in response to new fills. Because the Bay Mud and waste across most of the site are still settling under the weight of existing fill and waste decomposition and will settle more under new fills, additional settlement should be expected, with the creation of localized low-lying surface areas. Existing low areas shall be corrected during site grading to allow for proper drainage. Long-term maintenance planning for the development shall also include provisions for periodic grading to correct drainage problems and improve site grades, as outlined in the Disposition and Development Agreement.

The Geotechnical Engineer will recommend other site-specific recommendations based on the results of the design-level Geotechnical Investigation to mitigate on-going settlement and any additional settlement to be expected in response to new development.

Geo-8b: **Design Building-Soil Interface to Allow Free Movement.** The Structural Engineer shall provide that structures not supported on deep foundations not be structurally tied into pile-supported buildings, except as noted below, and shall be designed to allow free vertical movement between structures.

Articulated ramps on walkways and building entrances at the interface between the pile and soil-supported areas can provide a smooth walkway over moderate differential settlements with some amount of maintenance. As the magnitude of the differential settlement increases, however, these ramps may need to be rebuilt or realigned to account for the larger elevation differential. Similar ramps may also reduce differential settlements between driveways and pile-supported parking lots.

Over time, voids will tend to form beneath pile-supported buildings due to on-going settlement of the landfill. Use of wall skirts around the building perimeter will help to reduce the visual impact of these voids.

Implementation of these mitigation measures will reduce the impact of settlement and differential settlement of landfill materials and Bay Mud soils on the performance of constructed site improvements to a ***less-than-significant*** level. This applies to the entire OPSP, including the Phase I Project.

UNDERGROUND UTILITIES

Impact Geo-9: **Hazardous Conditions During Excavation and Following Construction.** Excavations extending into either the landfill cap or into the waste fill are expected to encounter potentially hazardous conditions including poisonous and explosive gases. This may be true in shallower excavations as well. This is a ***potentially significant*** impact during and following site construction activities.

Mitigation Measures

Geo-9a: **Monitoring and Testing.** Special precautions shall be taken to monitor the safety conditions and to provide for the safety of workers in the area. Additionally, if excavations encounter water, this water shall be tested for contaminants and may have to undergo specialized handling, treatment and/or disposal if it is contaminated. A system to disperse methane during construction shall be installed in or adjacent to the trenches.

Geo-9b: **Locate Underground Utilities in Soil Cap.** To the extent practicable, the utilities shall be constructed in the soil landfill cap to avoid direct contact of the utility lines and construction workers with the waste material. If construction of utilities in the waste material is necessary, proper design and construction precautions shall be taken to protect the system and the workers from the corrosive and hazardous conditions of the waste.

Geo-9c: **Seal Trenches and Underground Structures.** Trenches and underground structures shall be sealed to preclude gas intrusion. Typical types of sealing procedures include providing a low permeability clay cover of 1 foot over the top of the pipe, or the utility trench be lined with a relatively impervious geomembrane. Underground manholes may be shielded from methane intrusion by placement of a membrane around the outside of the structure. To reduce gas migration off-site within the utility trenches, all trenches crossing the transition zone between the landfill and non-landfill portions of the property shall be sealed with a clay plug surrounding the pipe or other approved methods. In addition, plugs shall also be provided at the perimeters of buildings to reduce migration of gas through the utility trenches to beneath the buildings.

Implementation of these mitigation measures will reduce the impact of hazardous conditions due to high landfill gas concentrations during excavation and on the constructed improvements to a ***less-than-significant*** level. This applies to the entire OPSP, including the Phase I Project.

Impact Geo-10: **Damage to Landfill Cap Due to Excavation.** Excavations for buildings, utilities and other underground structures that extend into the landfill cap may result in damage to the landfill cap. This would be a ***potentially significant*** impact on safety during and after construction and on the continued performance of the landfill cap.

Mitigation Measure

Geo-10: **Provide For Continuity of Landfill Cap.** Following planned landfill excavation and landfill cap repair, the project Civil Engineer shall require that excavations for building foundations, utility trenches and other underground structures be configured to maintain continuity of the landfill cap. The specific configuration will depend upon the excavation depth and orientation to underlying wastes. However, a low-permeability layer of soil or a geomembrane properly tied to surrounding cap areas may be required.

Provisions for landfill continuity of the landfill cap following planned landfill excavation and landfill cap repair, designed by a qualified Civil Engineer, will reduce the impact level of excavations into the landfill cap to ***less than significant***. This applies to the entire OPSP in the vicinity of the landfill, including the Phase I Project.

Impact Geo-11: **Stresses at Building Connections.** Underground utilities will be subject to distress at building connection locations due to differential settlement. It is anticipated that the most crucial sections of the utility lines will occur at the interface between the soil supported utility line and the pile supported buildings. At this interface differential settlements of several feet are possible. This would be a ***potentially significant*** impact on the performance of underground utilities.

Mitigation Measure Geo-11: **Common Trenches and Vaults.** Where underground utilities are to be located in landfill areas, consideration shall be given to reducing the number of utilities trenches by locating utilities in common trenches to the extent practicable. In addition, vaulted systems shall be designed and maintained at such interfaces that provide flexible and/or expandable connections to the proposed buildings. In addition, the utility lines beneath buildings shall be suspended from hangers fastened to structural floor slabs.

Implementation of these measures will reduce utility stresses at building connections to levels ***less than significant***. However, even with special design to mitigate the expected differential settlement, extra maintenance and repair will be necessary on the utility lines located in the landfill area. This applies to the entire OPSP, including the Phase I Project.

Impact Geo-12: **Stresses in Utility Line Materials.** Differential settlement will cause distress to the materials used in underground utilities construction. On a landfill site the effects of differential settlement are typically more severe than at a conventional site due to the generally higher levels of settlement that occur. Differential settlement is a ***potentially significant*** impact on the performance of underground utilities.

Mitigation Measure Geo-12: **Flexible Materials and Joints.** Utility lines shall be constructed of flexible pipe such as welded polyethylene to accommodate differential settlement within the waste material and landfill cap. At the border of the landfill, where differential settlements are expected to be large, the utility lines shall be designed to allow for rotation. As with buried utilities on a conventional site, proper bedding and backfilling shall be completed, as specified in a design-level geotechnical investigation report.

Use of flexible materials and joints in underground utilities will reduce distress of the buried utilities to levels ***less than significant***. However, even with special design to mitigate the expected differential settlement, extra maintenance and repair will be necessary on the utility lines located in the landfill area. This applies to the entire OPSP, including the Phase I Project.

Impact Geo-13: **Disruption of Flow Gradient.** Differential settlement will tend to disrupt flow gradients in gravity-flow sewers and storm drains. This is a ***potentially significant*** impact on the performance of these utilities.

Mitigation Measure Geo-13: **Increase Flow Gradient.** The Civil Engineer shall consider increasing the flow gradient in sewers and storm drains so that differential settlements will not disrupt the flow. An alternative is to provide a pumping system that does not rely on gravity flow. Such measures will reduce the impact of reduced flow gradient due to differential settlement to ***less than significant***. This applies to the entire OPSP, including the Phase I Project.

Detailed design of utilities, landfill gas shielding and collection systems, foundation systems and floor slabs will require careful coordination among civil, environmental, structural and geotechnical consultants. Even with careful design and construction, the need for utility maintenance will likely be greater than at a conventional site.

SOIL EROSION

Impact Geo-14: **Soil Erosion.** The OPSP would involve mass grading at a location that drains stormwater to the San Francisco Bay. Demolition of existing structures and pavements could expose underlying landfill cap soils to the elements. Excavation of soil for construction of new buildings and pavement sections would also be performed and temporary stockpiles of loose soil will be created. Soils exposed during site grading would be subject to erosion during storm events. Grading would disturb site soils potentially leading to impacts to the San Francisco Bay. This would be a ***potentially significant*** impact during and following site construction activities.

Mitigation Measure Geo-14: **Storm Water Pollution Prevention Plan.** In accordance with the Clean Water Act and the State Water Resources Control Board (SWRCB), the Applicant shall file a Storm Water Pollution Prevention Plan (SWPPP) prior to the start of construction. The SWPPP shall include specific best management practices to reduce soil erosion. This is required to obtain coverage under the General Permit for Discharges of Storm Water Associated with Construction Activity (Construction General Permit, 99-08-DWQ).

Implementation of a storm water pollution prevention plan (mitigation measure Geo-14) will reduce the impact of soil erosion to a level of ***less-than-significant***. This applies to the entire OPSP, including the Phase I Project.

EXPANSIVE SOILS

Impact Geo-15: **Expansive Soils.** Available existing geotechnical information for the OPSP site does not identify the presence of highly-plastic, near-surface expansive soils. Therefore, at this time the impact of expansive soils with respect to shallow foundations is considered to be ***less-than-significant***. This applies to the entire OPSP, including the Phase I Project.

LANDSLIDES

The OPSP site is a nearly level area with no nearby hills that could fail by landsliding. There is ***no impact*** related to landslides. This applies to the entire OPSP, including the Phase I Project.

VOLCANIC HAZARDS

The OPSP site is not located in an active volcano or volcanic hazard area. There is ***no impact*** related to volcanic hazards. This applies to the entire OPSP, including the Phase I Project.

SEPTIC SYSTEMS

A sewer system is present in the area and septic systems are not required at the site. The OPSP would have ***no impact*** related to septic systems. This applies to the entire OPSP, including the Phase I Project.

UNIQUE GEOLOGICAL FEATURES

No unique geologic features will be impacted by the proposed OPSP. The OPSP would have ***no impact*** related to unique geological features. This applies to the entire OPSP, including the Phase I Project.

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