

22 June 2015

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The Trust for Public Land  
101 Montgomery Street, Suite 900  
San Francisco, California 94104

**Subject: Preliminary Study  
Geotechnical and Environmental Issues  
New Park Concept Plan  
900 Innes  
India Basin  
San Francisco, California  
Langan Project No.: 731651501**

Dear Ms. Strickland:

This letter presents the results of our preliminary study regarding geotechnical and environmental issues associated with the development of the 900 Innes Avenue Park in San Francisco, California as shown on Figure 1. The 900 Innes Avenue Park is part of the India Basin Waterfront Parks Vision Plan, which includes about 60 acres of public and privately owned vacant land to be developed into new publicly accessible parkland and open space. We performed a preliminary geotechnical investigation for the adjacent India Basin Development project that includes India Basin Open Space (southernmost section of the India Basin Waterfront Parks Vision Plan), and presented our findings and conclusions in a report dated 4 September 2014.

## **PROJECT DESCRIPTION**

The project site is north of the India Basin Open Space park area, east of Innes Street, and south of the proposed India Basin Shoreline Park as shown on Figure 2. The 2.4-acre site includes 1.8 acres of land. The proposed 900 Inness Avenue Park includes extending a segment of the Bay Trail along the edge of the shoreline, a continuous bike/pedestrian lane, and recreational areas including beach areas and dog parks. In addition, a driveway is proposed for boat transfer / drop off, and for emergency vehicles. Additional improvements may include the construction of a one-story, light, boat building; alternatively, the existing historic shipwright's cottage, adjacent to Innes Avenue may be retrofitted. New utilities will be installed for lighting and irrigation. Site grading may require placing 3 to 5 feet of fill.

Wetlands may be created along the shoreline. Sedimentation and coastal process along the coastline are being evaluated by Moffat and Nichols.

## **SITE AND SUBSURFACE CONDITIONS**

Site grades within the 900 Innes Avenue Park area vary from Elevation 10 feet near the edge of the shoreline to Elevation 30 feet adjacent to Innes Avenue. The site is partially paved, with two docks, two boat launches and an access road. The site includes an abandoned one-story family unit, two storage buildings, and a partially collapsed covered pier. The historic Shipwright's cottage is adjacent to Innes Avenue.

Published maps, aerial photos, and the results of available subsurface information indicate the majority of the site is east of the edge of the historic San Francisco Bay shoreline. The approximate location of the historic shoreline is shown in the attached Site Plan, Figure 2. The shoreline was filled between 1938 and 1968.

The portion of the site east of the old shoreline is likely underlain by 10 to 15 feet of sandy fill; 10 to 20 feet of soft, compressible clay referred to as Bay Mud and loose sand; medium dense sand; Old Bay Clay; and bedrock. The thicknesses of fill, Bay Mud, sand and Old Bay Clay, likely increase towards the Bay. The portion of the site west of the old shoreline is likely covered by 10 to 15 feet of fill, underlain by loose to dense sand to depths of at least 30 feet below existing site grades. Groundwater at the site is within the upper ten feet of the fill and can likely rise to the ground surface, near the shoreline.

The site, historically used as ship building and repair, and referred to as Donco Industries, was most recently investigated in 2013 for contamination, in coordination with EPA and the San Francisco Department of Health. The Phase I/II Investigation Targeted Brownfield Assessment Final Report by Weston Solutions, dated September 2013, indicates a release of petroleum hydrocarbons, PCBs, PAHs, and metals occurred at the site. Weston Solutions concludes the contamination is likely related to historical site activities (ship repair services), and current site activities (construction equipment and heavy machinery storage). They further indicate site development for recreational use may require the construction of a barrier, and/or excavation and disposal of contaminated soils, and and/or containment of contaminated soil. Each cleanup alternative will require subsequent confirmation and delineation sampling of the impacted areas.

## **REGIONAL SEISMICITY AND FAULTING**

Regional faulting and seismic hazards at the project site are discussed in this section.

### **Regional Faulting**

The major active faults in the area are the San Andreas, San Gregorio, Hayward, and Calaveras Faults. These and other faults of the region are shown on Figure 3. For each of the active faults within 50 kilometers of the site, the distance from the site and estimated mean

characteristic Moment magnitude<sup>1</sup> [2007 Working Group on California Earthquake Probabilities (WGCEP) (2007) and Cao et al. (2003)] are summarized in Table 1.

**TABLE 1**  
**Regional Faults and Seismicity**

<b>Fault Segment</b>	<b>Approx. Distance from fault (km)</b>	<b>Direction from Site</b>	<b>Mean Characteristic Moment Magnitude</b>
N. San Andreas – Peninsula	11.3	West	7.23
N. San Andreas (1906 event)	11	West	8.05
Total Hayward	18	Northeast	7.00
Total Hayward-Rodgers Creek	18	Northeast	7.33
N. San Andreas – North Coast	18	West	7.51
San Gregorio Connected	19	West	7.50
Total Calaveras	34	East	7.03
Mount Diablo Thrust	34	East	6.70
Monet Vista – Shannon	35	Southeast	6.50
Green Valley Connected	39	East	6.80
Rodgers Creek	40	North	7.07
Point Reyes	47	West	6.90
West Napa	50	North	6.70

Figure 3 also shows the earthquake epicenters for events with magnitude greater than 5.0 from January 1800 through August 2014. Since 1800, four major earthquakes have been recorded on the San Andreas Fault. In 1836 an earthquake with an estimated maximum intensity of VII on the Modified Mercalli (MM) scale (Figure 4) occurred east of Monterey Bay on the San Andreas Fault (Toppozada and Borchardt 1998). The estimated Moment magnitude,  $M_w$ , for this earthquake is about 6.25. In 1838, an earthquake occurred with an estimated intensity of about VIII-IX (MM), corresponding to a  $M_w$  of about 7.5. The San Francisco Earthquake of 1906 caused the most significant damage in the history of the Bay Area in terms of loss of lives and property damage. This earthquake created a surface rupture along the San Andreas Fault

<sup>1</sup> Moment magnitude is an energy-based scale and provides a physically meaningful measure of the size of a faulting event. Moment magnitude is directly related to average slip and fault rupture area.

from Shelter Cove to San Juan Bautista approximately 470 kilometers in length. It had a maximum intensity of XI (MM), a  $M_w$  of about 7.9, and was felt 560 kilometers away in Oregon, Nevada, and Los Angeles. The Loma Prieta Earthquake occurred on 17 October 1989, in the Santa Cruz Mountains with a  $M_w$  of 6.9, approximately 89 km from the site. In 1868 an earthquake with an estimated maximum intensity of X on the MM scale occurred on the southern segment (between San Leandro and Fremont) of the Hayward Fault. The estimated  $M_w$  for the earthquake is 7.0. In 1861, an earthquake of unknown magnitude (probably a  $M_w$  of about 6.5) was reported on the Calaveras Fault. The most recent significant earthquake on this fault was the 1984 Morgan Hill earthquake ( $M_w = 6.2$ ).

The most recent earthquake to affect the Bay Area occurred on 24 August 2014 and was located on the West Napa fault, approximately 50 kilometers northeast of the site, with a  $M_w$  of 6.0.

The 2007 WGCEP at the U.S. Geologic Survey (USGS) predicted a 63 percent chance of a magnitude 6.7 or greater earthquake occurring in the San Francisco Bay Area in 30 years. More specific estimates of the probabilities for different faults in the Bay Area are presented in Table 2.

**TABLE 2**  
**WGCEP (2007) Estimates of 30-Year Probability**  
**of a Magnitude 6.7 or Greater Earthquake**

<b>Fault</b>	<b>Probability (percent)</b>
Hayward-Rodgers Creek	31
N. San Andreas	21
Calaveras	7
San Gregorio	6
Concord-Green Valley	3
Greenville	3
Mount Diablo Thrust	1

### **Fault Rupture**

Historically, ground surface displacements closely follow the traces of geologically young faults. The site is not within an Earthquake Fault Zone, as defined by the Alquist-Priolo Earthquake Fault Zoning Act, and no known active or potentially active faults exist on the site. In a

seismically active area, a remote possibility exists for future faulting in areas where no faults previously existed; however, we conclude the risk of surface faulting and consequent secondary ground failure is very low.

## Seismic Hazards

During a major earthquake on a segment of one of the nearby faults, strong to very strong shaking is expected to occur at the project site. Strong shaking during an earthquake can result in ground failure such as that associated with soil liquefaction<sup>2</sup>, lateral spreading<sup>3</sup>, and differential compaction<sup>4</sup>.

When a saturated soil with little to no cohesion liquefies during a major earthquake, it experiences a temporary loss of strength as a result of a transient rise in pore water pressure generated by strong ground motion. Flow failure, lateral spreading, differential settlement, loss of bearing, ground fissures, and sand boils are evidence of excess pore pressure generation and liquefaction. The site is within a designated liquefaction hazard zone as designated by the California Geological Survey (CGS) seismic hazard zone map for the area titled *State of California Seismic Hazard Zones, City and County of San Francisco, Official Map*, dated 17 November 2001 (Figure 5).

Loose to medium dense sandy fill and native sand below the high groundwater level may liquefy during a major earthquake on a nearby active fault. We anticipate several inches of vertical, earthquake-induced ground settlement could occur within the project site. The anticipated settlement is expected to be erratic and vary significantly across the site.

Densification of the fill above the design groundwater level may result in a few inches of ground settlement; however, several inches of densification settlement could occur locally in the fill.

Site grades along the Bay margin have been significantly modified to current elevations by man-made improvements, primarily by excavation and fill activities. Considering the surface of the fill and Bay Mud, are sloping, and likely presence of continuous, potentially liquefiable loose to medium dense sand below the groundwater level, we conclude lateral movement of the fill

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<sup>2</sup> Liquefaction is a transformation of soil from a solid to a liquefied state during which saturated soil temporarily loses strength resulting from the buildup of excess pore water pressure, especially during earthquake-induced cyclic loading. Soil susceptible to liquefaction includes loose to medium dense sand and gravel, low-plasticity silt, and some low-plasticity clay deposits.

<sup>3</sup> Lateral spreading is a phenomenon in which surficial soil displaces along a shear zone that has formed within an underlying liquefied layer. Upon reaching mobilization, the surficial blocks are transported downslope or in the direction of a free face by earthquake and gravitational forces.

<sup>4</sup> Differential compaction is a phenomenon in which non-saturated, cohesionless soil is densified by earthquake vibrations, causing differential settlement.

towards the bay will likely occur during a major earthquake on a nearby active fault. During a major earthquake on a nearby active fault, we anticipate lateral ground displacement on the order of several inches might occur. We anticipate the direction of the lateral ground displacement will likely be towards the east/ northeast (towards the bay).

## **PRELIMINARY DISCUSSION AND CONCLUSIONS**

On the basis of the available subsurface information and our understanding of the proposed development, we conclude the project is feasible from a geotechnical standpoint. The main geotechnical issues at the project site are:

- presence of uncontrolled fill across the site
- presence of hazardous substances within the fill
- anticipated ground displacements within the fill and native sand during a major earthquake on a nearby active fault
- presence of weak, compressible Bay Mud beneath the fill east of the old shoreline and Bay Mud consolidation under new building loads and new fill placement

During a major earthquake on a nearby active fault we anticipate ground displacements (vertical and lateral) within the fill may be on the order of several inches. Differential, earthquake-induced, vertical ground settlement might be on the order of four inches over a horizontal distance of 50 feet. Earthquake-induced ground settlement could affect the performance of the proposed Bay Trail, bike/pedestrian path, access road and utilities. Repairs will likely be required after a major earthquake on a nearby active fault.

We anticipate that in general, consolidation of the Bay Mud and Old Bay Clay under the weight of the existing fill is nearly complete. However, the onsite fill was placed without mechanical effort /compaction. Structures / proposed improvements over the existing fill will be subjected to excessive ground settlements induced by earthquake, new fill and building loads; in addition, differential settlement within the fill may be abrupt and erratic.

Placement of new fill will likely initiate consolidation of the Bay Mud. Bay Mud consolidation will result in large ground settlement that should be considered in the design of utilities, site grading, and other site improvements.

The anticipated earthquake-induced ground settlement and settlement from new fill should be accommodated in the design of the emergence access road and utilities, as need. The magnitude of the ground settlement should be evaluated during a design level geotechnical investigation.

Considering the presence of contaminants in the fill, site development for recreational use may require the construction of a barrier, and/or excavation and disposal of contaminated soils, and and/or containment of contaminated soil. Each cleanup alternative will require subsequent confirmation and delineation sampling of the impacted areas.

Lightweight, one-story structures may be supported on a stiffened mat foundation provided the mat is designed for the large anticipated differential ground settlement. Alternatively, lightweight structures may be supported on deep foundations.

The stability of the shoreline should be evaluated during the design level phase of the proposed improvements. If the anticipated ground movement is not acceptable, mitigation measures should be implemented, as needed.

## **PRELIMINARY RECOMMENDATIONS**

Our preliminary recommendations for site preparation and grading, foundation design, floor slabs, and seismic design are presented in this section of the report.

### **Site Preparation and Grading**

This section presents preliminary earthwork recommendations for site preparation and grading.

#### Site Clearing

Site demolition should include the removal of pavement, utility lines, and other below-grade elements that will interfere with the proposed construction. Excavations in fill for foundations and site utilities may encounter concrete elements and debris. Breaking up obstructions using jack hammers or hoe rams into small pieces may be required to facilitate offsite removal. Where utilities that are removed extend off site, they should be capped or plugged with grout.

Onsite fill will likely require special handling during site grading. Soil management measures to be implemented during construction should be addressed in the project Site Mitigation Plan.

Where concrete rubble is present, pieces larger than four inches in greatest dimension should be removed. Stripped pavement materials can be used as backfill provided they are crushed to less than four inches in greatest dimension and mixed with soil to prevent nesting. The weight of the asphalt and concrete fragments should not comprise more than 30 percent of the mixture. Existing concrete elements can be used as fill provided they are crushed to less than three inches in maximum dimension and properly mixed with onsite soil.

### Subgrade Preparation

In areas to receive site improvements, including flatwork, the exposed soil subgrade should be scarified to a depth of at least eight inches, moisture-conditioned to above the optimum moisture content and compacted to at least 95 percent relative compaction<sup>5</sup>. The soil subgrade should be kept moist until it is covered by fill or other improvements.

### Fill Placement and Compaction

Placement of more than three feet of new fill will result in large ground settlement that should be considered in the design of utilities, site grading, and other site improvements.

Fill should consist of onsite soil or imported soil that is non-corrosive, free of organic matter or other deleterious material, contains no rocks or lumps larger than four inches in greatest dimension, has a liquid limit of less than 40 and a plasticity index lower than 12, and is approved by the Geotechnical Engineer.

Fill should be placed in horizontal lifts not exceeding eight inches in loose thickness, moisture-conditioned to near the optimum moisture content, and compacted to at least 90 percent relative compaction. Fill thicker than five feet or clean sand or gravel (soil with less than 10 percent fines by weight) used as fill should be compacted to at least 95 percent relative compaction.

The Geotechnical Engineer should approve all sources of fill at least three days before use at the site. The grading contractor should provide analytical test results or other suitable environmental documentation indicating the imported fill is free of hazardous materials at least three days before use at the site. If this data is not available, up to two weeks should be allowed to perform analytical testing on the proposed import material. A bulk sample of approved fill should be provided to the geotechnical engineer at least three working days before use at the site so a compaction curve can be prepared.

### Utilities and Utility Trenches

Excavations for utility trenches can be readily made with a backhoe; however, unexpected obstructions may make some of the trenching operations difficult. All trenches should conform to the current CAL-OSHA requirements.

Backfill for utility trenches and other excavations is also considered fill, and it should be compacted according to the recommendations presented in Section 8.1.3. If imported clean sand or gravel is used as backfill, however, it should be compacted to at least 95 percent

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<sup>5</sup> Relative compaction refers to the in-place dry density of soil expressed as a percentage of the maximum dry density of the same material, as determined by the latest ASTM D1557 laboratory compaction procedure.

relative compaction. Jetting of trench backfill should not be permitted. Special care should be taken when backfilling utility trenches in pavement areas. Poor compaction may cause excessive settlements, resulting in damage at the ground surface.

Utilities should be designed to accommodate 6 to 12 inches of vertical settlement where they enter the new buildings. If lateral soil movement is not mitigated, utility connections should also accommodate six inches of lateral soil movement.

### **Lightweight Structures on Stiffened Mat Foundations**

Lightweight, one-story structures may be supported on a stiffened mat foundation provided the mat is designed for a differential settlement of four inches over a horizontal distance of 50 feet. Considering the variability of onsite fill and lack of documentation of fill compaction, we conclude during a major earthquake on a nearby active fault the actual ground differential settlement may be on the order of four inches over a horizontal distance of 50 feet. Alternatively, structures may be supported on deep foundations.

### **Ground Building Slabs**

If there are any areas where floor moisture is undesirable, the floor should be moisture-proofed. To reduce water vapor transmission through the floor slabs, we recommend installing a capillary moisture break and a water vapor retarder over the soil subgrade and beneath new floor slabs. A capillary moisture break consists of at least four inches of clean, free-draining gravel or crushed rock. The vapor retarder should meet the requirements for Class C vapor retarders stated in ASTM E1745-97. The vapor retarder should be placed in accordance with the requirements of ASTM E1643-98. These requirements include overlapping seams by six inches, taping seams, and sealing penetrations in the vapor retarder. The vapor retarder should be covered with two inches of sand to aid in curing the concrete and to protect the vapor retarder during slab construction. The particle size of the gravel/crushed rock and sand should meet the gradation requirements presented in Table 3.

**TABLE 3**  
**Gradation Requirements for Capillary Moisture Break**

<b>Sieve Size</b>	<b>Percentage Passing Sieve</b>
<i>Gravel or Crushed Rock</i>	
1 inch	90 – 100
3/4 inch	30 – 100
1/2 inch	5 – 25
3/8 inch	0 – 6
<i>Sand</i>	
No. 4	100
No. 200	0 – 5

The sand overlying the membrane should be dry at the time concrete is placed. Excess water trapped in the sand could eventually be transmitted as vapor through the slab. If the sand becomes wet, concrete should not be placed until the sand has been dried or replaced.

Concrete mixes with high water/cement (w/c) ratios result in excess water in the concrete, which increases the cure time and results in excessive vapor transmission through the slab. Therefore, concrete for the floor slab should have a low water/cement (w/c) ratio – less than 0.5. If approved by the project structural engineer, the sand can be eliminated and the concrete can be placed directly over the vapor retarder, provided the w/c ratio of the concrete does not exceed 0.45 and water is not added in the field. If necessary, workability should be increased by adding plasticizers. In addition, the slab should be properly cured.

Before the floor covering is placed, the contractor should check that the concrete surface and the moisture emission levels (if emission testing is required) meet the manufacturer's requirements.

### **Corrosion Protection**

Concrete elements with a maximum water cement ratio of 0.55 (including grade beams and slabs), supported on onsite soil should be Type I or Type II concrete. Concrete elements in contact with Bay Mud should use Type V concrete. Additional corrosion testing should be performed during the design level investigation for each building.

Any utilities extending into Bay Mud should be corrosion protected. Below ground concrete structures and steel piles will require protection from corrosion. A site corrosivity evaluation should be performed by a corrosivity specialist to develop long-term corrosion control for the selected foundation system and proposed construction materials for the underground site utilities.

### Seismic Design

Seismic parameters for design of buildings at the site will depend where on the site the buildings will be constructed. Our preliminary conclusion is the Site Class could range from  $S_D$  (less than 10 feet of Bay Mud) to  $S_E$  (more than 10 feet of Bay Mud).

Maximum Considered Earthquake (MCE) mapped short ( $S_s$ ) and one second ( $S_1$ ) spectral values for the project site are 1.50g and 0.616g, respectively. Limits of building areas with less than ten feet of Bay Mud (Site Class D) and more than 10 feet of Bay Mud (Site Class E) can be estimated using the Bay Mud thickness contours presented on Figure 9. Values of  $F_a$ ,  $F_v$ ,  $S_{MS}$ ,  $S_{M1}$ ,  $S_{DS}$ , and  $S_{D1}$ , for Site Class D, and E per 2013 CBC / ASCE 7-10 are presented in Table 4. The actual Site Class for each building should be confirmed during the design level investigation.

**TABLE 4**  
**Recommended Site Coefficients and**  
**Mapped Response Acceleration Parameters**

	<b>Site Class D (West of Hudson Avenue)</b>	<b>Site Class E (East of Hudson Avenue)</b>
$F_a$	1.00	0.90
$F_v$	1.50	2.40
$S_{MS}$	1.50	1.35
$S_{M1}$	0.92	1.48
$S_{DS}$	1.00	0.90
$S_{D1}$	0.62	0.99

If the design level investigation indicates a continuous liquefiable soil layer is present beneath new buildings, the Site Class is F, and a site specific response spectra will be required if the building period is greater than 0.5 second.

## LIMITATIONS

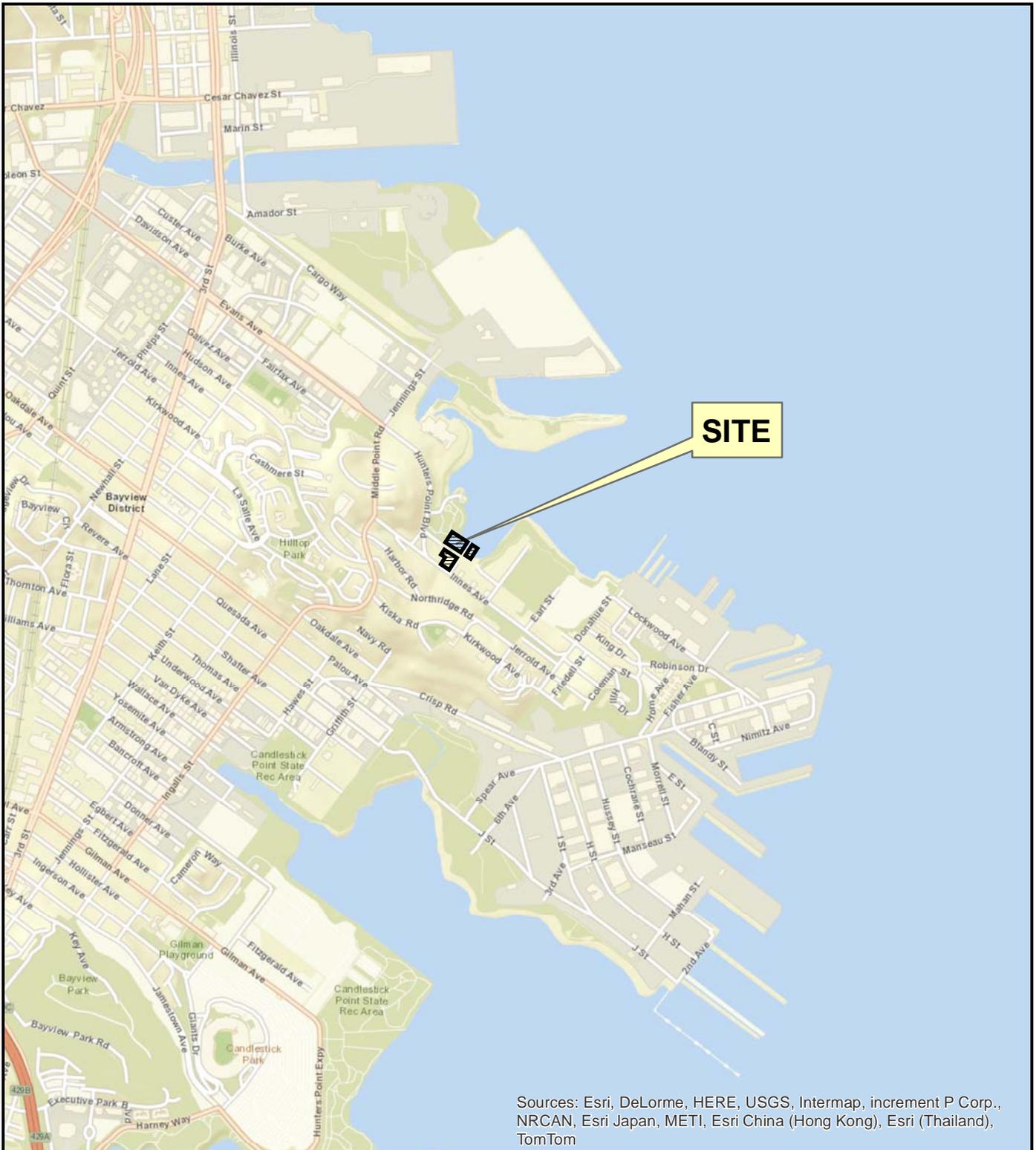
The conclusions and recommendations presented in this report are preliminary and may be used to estimate costs for preliminary schematic drawings; however during final design, detailed geotechnical investigation(s) should be performed for the proposed improvements. The design level geotechnical investigations should include field investigations and laboratory testing, as needed; engineering analyses should be performed for the final design and the results should be used to further evaluate subsurface conditions and to develop geotechnical design parameters for soil improvement, foundations, and other geotechnical aspects of the design specific to this site.

Sincerely,  
**Langan Treadwell Rollo**

Maria Flessas, G.E. #2502  
Principal

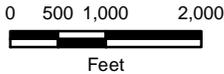
731651501.01\_MGF\_Feasibility Study 900 Innes Avenue

Attachments: Figure 1 – Site Location Map  
Figure 2 – Site Plan  
Figure 3 – Map of Major Faults and Earthquake Epicenters  
in the San Francisco Bay Area  
Figure 4 – Modified Mercalli Scale  
Figure 5 – Liquefaction Hazard Zone Map



Sources: Esri, DeLorme, HERE, USGS, Intermap, increment P Corp., NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom

World street basemap is provided through Langan's Esri ArcGIS software licensing and ArcGIS online. Credits: Sources: Esri, DeLorme, NAVTEQ, USGS, Intermap, IPC, NRCAN.



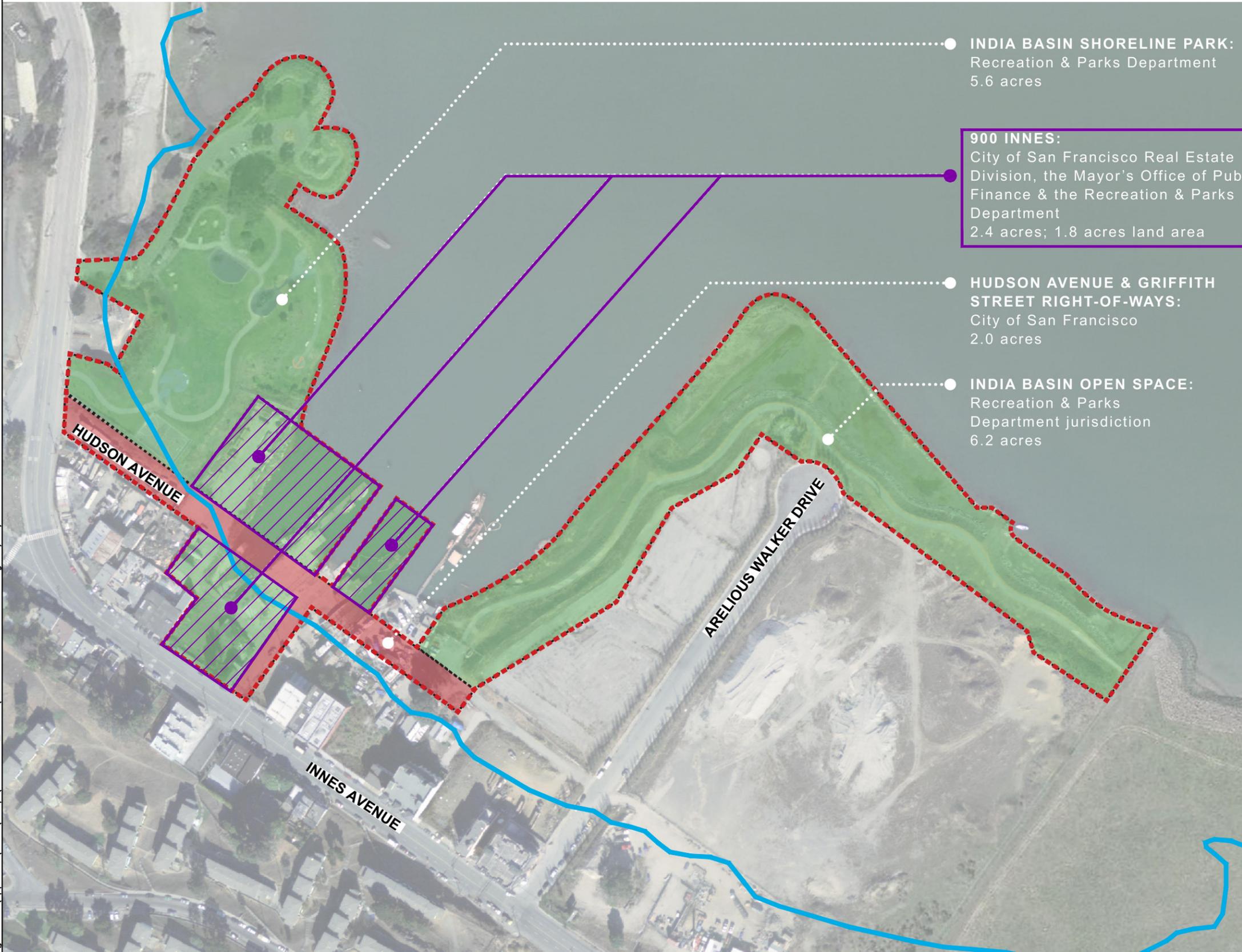
**900 INNES  
INDIA BASIN**  
San Francisco, California

**SITE LOCATION MAP**

**LANGAN TREADWELL ROLLO**

Date 06/18/15	Project No. 731651501	Figure 1
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- **INDIA BASIN SHORELINE PARK:**  
Recreation & Parks Department  
5.6 acres
- **900 INNES:**  
City of San Francisco Real Estate  
Division, the Mayor's Office of Pub  
Finance & the Recreation & Parks  
Department  
2.4 acres; 1.8 acres land area
- **HUDSON AVENUE & GRIFFITH  
STREET RIGHT-OF-WAYS:**  
City of San Francisco  
2.0 acres
- **INDIA BASIN OPEN SPACE:**  
Recreation & Parks  
Department jurisdiction  
6.2 acres

**EXPLANATION**

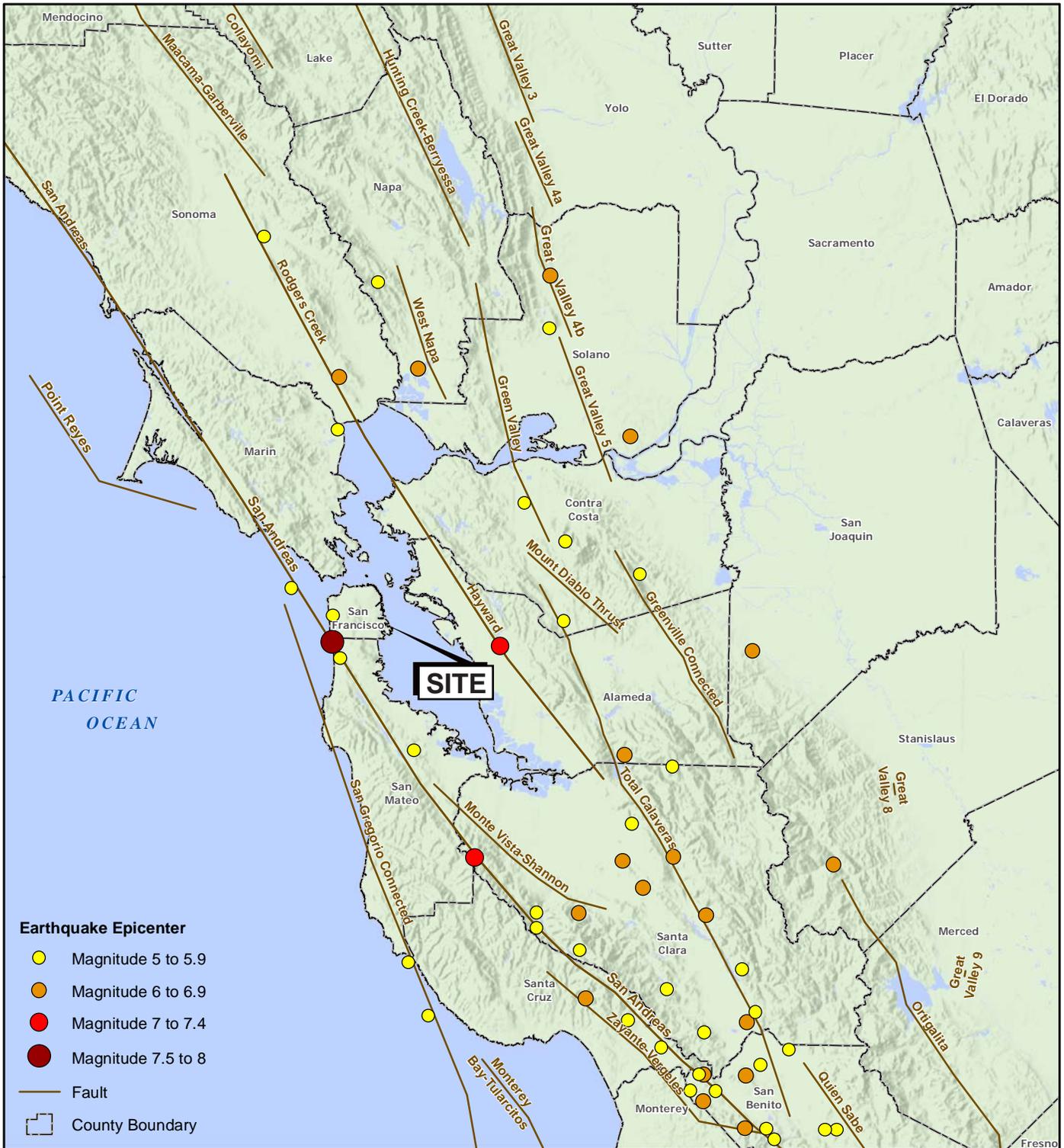
-  Approximate location of Historic Shoreline
-  Project Areas
-  Right-of-ways
-  900 Innes



0 200 Feet  
Approximate scale

<b>900 INNES INDIA BASIN</b> San Francisco, California		
<b>SITE PLAN</b>		
Date 06/18/15	Project No. 731651501	Figure 2
<b>LANGAN TREADWELL ROLLO</b>		

Reference: Base map from a drawing titled "2, Existing Conditions, Existing Site Aerial," by Bionic, undated.



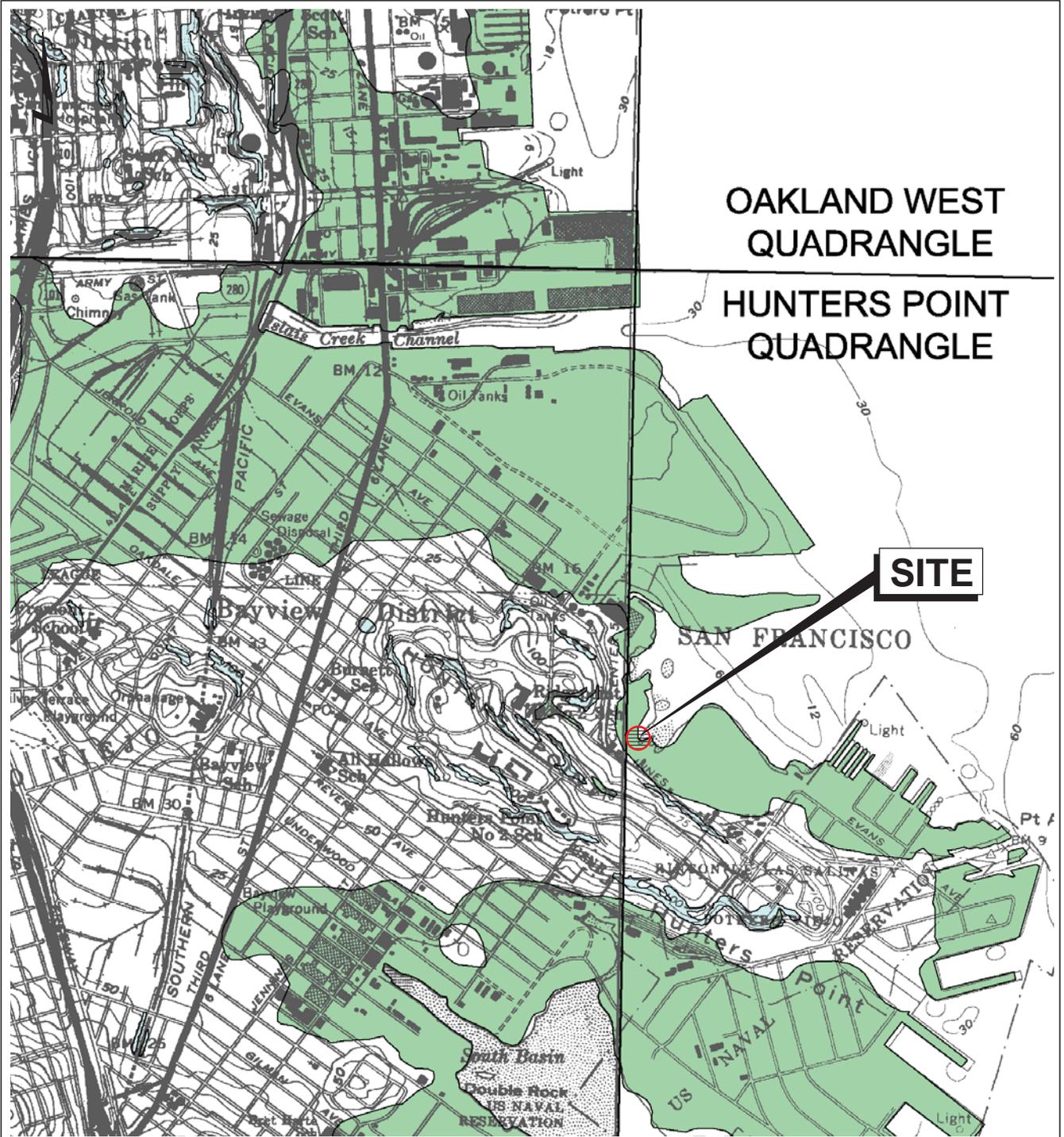
- Notes:**
1. Quaternary fault data displayed are based on a generalized version of U.S. Geological Survey (USGS) Quaternary Fault and fold database, 2010. For cartographic purposes only.
  2. The Earthquake Epicenter (Magnitude) data is provided by the USGS and is current through 08/24/2014.
  3. Basemap hillshade and County boundaries provided by USGS and California Department of Transportation.
  4. Map displayed in California State Coordinate System, California (Teale) Albers, North American Datum of 1983 (NAD83), Meters.



<b>900 INNES INDIA BASIN</b> San Francisco, California	<b>MAP OF MAJOR FAULTS AND EARTHQUAKE EPICENTERS IN THE SAN FRANCISCO BAY AREA</b>		
<b>LANGAN TREADWELL ROLLO</b>	Date 06/18/15	Project No.731651501	Figure 3

- I **Not felt by people, except under especially favorable circumstances. However, dizziness or nausea may be experienced.**  
Sometimes birds and animals are uneasy or disturbed. Trees, structures, liquids, bodies of water may sway gently, and doors may swing very slowly.
- II **Felt indoors by a few people, especially on upper floors of multi-story buildings, and by sensitive or nervous persons.**  
As in Grade I, birds and animals are disturbed, and trees, structures, liquids and bodies of water may sway. Hanging objects swing, especially if they are delicately suspended.
- III **Felt indoors by several people, usually as a rapid vibration that may not be recognized as an earthquake at first. Vibration is similar to that of a light, or lightly loaded trucks, or heavy trucks some distance away. Duration may be estimated in some cases.**  
Movements may be appreciable on upper levels of tall structures. Standing motor cars may rock slightly.
- IV **Felt indoors by many, outdoors by a few. Awakens a few individuals, particularly light sleepers, but frightens no one except those apprehensive from previous experience. Vibration like that due to passing of heavy, or heavily loaded trucks. Sensation like a heavy body striking building, or the falling of heavy objects inside.**  
Dishes, windows and doors rattle; glassware and crockery clink and clash. Walls and house frames creak, especially if intensity is in the upper range of this grade. Hanging objects often swing. Liquids in open vessels are disturbed slightly. Stationary automobiles rock noticeably.
- V **Felt indoors by practically everyone, outdoors by most people. Direction can often be estimated by those outdoors. Awakens many, or most sleepers. Frightens a few people, with slight excitement; some persons run outdoors.**  
Buildings tremble throughout. Dishes and glassware break to some extent. Windows crack in some cases, but not generally. Vases and small or unstable objects overturn in many instances, and a few fall. Hanging objects and doors swing generally or considerably. Pictures knock against walls, or swing out of place. Doors and shutters open or close abruptly. Pendulum clocks stop, or run fast or slow. Small objects move, and furnishings may shift to a slight extent. Small amounts of liquids spill from well-filled open containers. Trees and bushes shake slightly.
- VI **Felt by everyone, indoors and outdoors. Awakens all sleepers. Frightens many people; general excitement, and some persons run outdoors.**  
Persons move unsteadily. Trees and bushes shake slightly to moderately. Liquids are set in strong motion. Small bells in churches and schools ring. Poorly built buildings may be damaged. Plaster falls in small amounts. Other plaster cracks somewhat. Many dishes and glasses, and a few windows break. Knickknacks, books and pictures fall. Furniture overturns in many instances. Heavy furnishings move.
- VII **Frightens everyone. General alarm, and everyone runs outdoors.**  
People find it difficult to stand. Persons driving cars notice shaking. Trees and bushes shake moderately to strongly. Waves form on ponds, lakes and streams. Water is muddied. Gravel or sand stream banks cave in. Large church bells ring. Suspended objects quiver. Damage is negligible in buildings of good design and construction; slight to moderate in well-built ordinary buildings; considerable in poorly built or badly designed buildings, adobe houses, old walls (especially where laid up without mortar), spires, etc. Plaster and some stucco fall. Many windows and some furniture break. Loosened brickwork and tiles shake down. Weak chimneys break at the roofline. Cornices fall from towers and high buildings. Bricks and stones are dislodged. Heavy furniture overturns. Concrete irrigation ditches are considerably damaged.
- VIII **General fright, and alarm approaches panic.**  
Persons driving cars are disturbed. Trees shake strongly, and branches and trunks break off (especially palm trees). Sand and mud erupts in small amounts. Flow of springs and wells is temporarily and sometimes permanently changed. Dry wells renew flow. Temperatures of spring and well waters varies. Damage slight in brick structures built especially to withstand earthquakes; considerable in ordinary substantial buildings, with some partial collapse; heavy in some wooden houses, with some tumbling down. Panel walls break away in frame structures. Decayed pilings break off. Walls fall. Solid stone walls crack and break seriously. Wet grounds and steep slopes crack to some extent. Chimneys, columns, monuments and factory stacks and towers twist and fall. Very heavy furniture moves conspicuously or overturns.
- IX **Panic is general.**  
Ground cracks conspicuously. Damage is considerable in masonry structures built especially to withstand earthquakes; great in other masonry buildings - some collapse in large part. Some wood frame houses built especially to withstand earthquakes are thrown out of plumb, others are shifted wholly off foundations. Reservoirs are seriously damaged and underground pipes sometimes break.
- X **Panic is general.**  
Ground, especially when loose and wet, cracks up to widths of several inches; fissures up to a yard in width run parallel to canal and stream banks. Landsliding is considerable from river banks and steep coasts. Sand and mud shifts horizontally on beaches and flat land. Water level changes in wells. Water is thrown on banks of canals, lakes, rivers, etc. Dams, dikes, embankments are seriously damaged. Well-built wooden structures and bridges are severely damaged, and some collapse. Dangerous cracks develop in excellent brick walls. Most masonry and frame structures, and their foundations are destroyed. Railroad rails bend slightly. Pipe lines buried in earth tear apart or are crushed endwise. Open cracks and broad wavy folds open in cement pavements and asphalt road surfaces.
- XI **Panic is general.**  
Disturbances in ground are many and widespread, varying with the ground material. Broad fissures, earth slumps, and land slips develop in soft, wet ground. Water charged with sand and mud is ejected in large amounts. Sea waves of significant magnitude may develop. Damage is severe to wood frame structures, especially near shock centers, great to dams, dikes and embankments, even at long distances. Few if any masonry structures remain standing. Supporting piers or pillars of large, well-built bridges are wrecked. Wooden bridges that "give" are less affected. Railroad rails bend greatly and some thrust endwise. Pipe lines buried in earth are put completely out of service.
- XII **Panic is general.**  
Damage is total, and practically all works of construction are damaged greatly or destroyed. Disturbances in the ground are great and varied, and numerous shearing cracks develop. Landslides, rock falls, and slumps in river banks are numerous and extensive. Large rock masses are wrenched loose and torn off. Fault slips develop in firm rock, and horizontal and vertical offset displacements are notable. Water channels, both surface and underground, are disturbed and modified greatly. Lakes are dammed, new waterfalls are produced, rivers are deflected, etc. Surface waves are seen on ground surfaces. Lines of sight and level are distorted. Objects are thrown upward into the air.

<b>900 INNES INDIA BASIN</b> San Francisco, California	<b>MODIFIED MERCALLI INTENSITY SCALE</b>		
<b>LANGAN TREADWELL ROLLO</b>	Date 06/18/15	Project No. 731651501	Figure 4



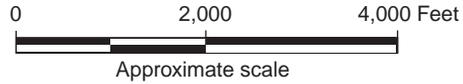
OAKLAND WEST  
QUADRANGLE

HUNTERS POINT  
QUADRANGLE

**SITE**

**EXPLANATION**

- Liquefaction;** Areas where historic occurrence of liquefaction, or local topographic, geological, geotechnical, and subsurface water conditions indicate a potential for permanent ground displacements.
- Earthquake-Induced Landslides;** Areas where previous occurrence of landslide movement, or local topographic, geological, geotechnical, and subsurface water conditions indicate a potential for permanent ground displacements.



Reference:  
State of California "Seismic Hazard Zones"  
City and County of San Francisco  
Released on November 17, 2001

**900 INNES  
INDIA BASIN**  
San Francisco, California

**LIQUEFACTION HAZARD ZONE MAP**

**LANGAN TREADWELL ROLLO**

Date 06/18/15    Project No. 731651501    Figure 5