FINAL DRAFT

June 9, 2016

Point Molate Bay Trail

Coastal Erosion Assessment

Prepared for

Nichols Consulting Engineers

By

A-N West, Inc.
Consulting Civil and Structural Engineers

Scope of Coastal Assessment

The coastal erosion assessment included visiting the site, assessing the rock slope protection, wave and tsunami run-up, future sea level conditions, and the need for any supplemental shore protection for the trail.

The coastal erosion assessment covers Segments A and B as shown on the Exhibit A map. These segments run from the Richmond San Rafael Bridge to the north end of the former Naval Fuel Supply Depot.

The shore protection at the Point Molate Beach Park and the portion of bluff[1] just to the north of the Beach Park, both undergoing noticeable erosion, were excluded and are being dealt with separately from this assessment.

General Description

The coastline comprises headlands with small bays. The main headlands are those at Castro Point and Point Molate.

At the beaches, the foreshore[2] rises from mud at a slope of about 10 horizontal to 1 vertical and is typically covered with rock fragments and sometimes sand. The foreshore is about 50 foot wide in general and is backed by either bluffs, low level banks, or shore protection.

The existing shore protection along the Point Molate trail alignment is varied. Riprap, rock, stone, concrete debris, concrete armor blocks, and timber walls, have been used and this protection has been supplemented over time with riprap. Various rock and concrete materials have been dumped in place without mechanical consolidation. Some areas have not been consolidated by wave action. Accordingly the material is still in a loose condition and unsafe to walk across without care. Only at two locations were approximate measurements of gradation appropriate; where material was of a somewhat uniform gradation.

The bluffs present along most of the shoreline are generally steep. The material is friable and can be eroded by combinations of heating and cooling of the surface, wind and rain, drainage, wave and tidal action. The toe of the bluffs are generally protected with rock protection.

A summary of the condition of shore protection arising from the field investigation is included as Exhibit A.

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[1] Bluff used here refers to a steep bank or cliff up to about 20 feet in height

[2] “Foreshore” used here is the beach between low tide and high tide,

Effects Considered

Future Sea Level Rise

The San Francisco Bay Conservation and Development Commission (BCDC) and the California Coastal Commission have published sea level rise projections and related inundation maps over the past several years. Upper limit values, as published by the National Research Council (NRC) in 2012 are currently being accepted for planning purposes. A sea level rise of 0.97 feet by 2030, 1.99 feet by 2050, and 5.46 feet at the end of this century are used in this report.[3]

Tides

The tidal datum values in feet at nearby NOAA Station ID 9414863 are shown below together with estimated tide levels due to future sea level rise. Values are given in feet relative to NAVD88 (North American Vertical Datum of 1988).

		Present Day	2030	2050	2100
Mean Higher High Water	MHHW	+6.06	+7.03	+8.05	+11.52
Mean High Water	MHW	+5.45	6.42	+7.44	+10.91
Mean Tide Level	MTL	+3.26	+4.23	+4.6	+7.9
Mean Sea Level	MSL	+3.26	+4.23	+5.25	+8.72
Mean Low Water	MLW	+1.12	+2.09	+3.11	+6.58
Mean Lower Low Water	MLLW	0.00	+0.97	+1.99	+5.46

The present published extreme high tide with a one percent exceedance (highest estimated tide) is approximately +9.0 (to within plus or minus 0.5 feet) at Richmond. Such a highest estimated tide would be associated with a storm surge due to sustained high winds in the ocean.

Wind Waves

Locally generated waves from the west and northwest are limited by the low fetch[4] and the protection from the coastal ridge along the ocean. Waves at the entrance to Richmond Harbor channel are reported to be on the order of 3 foot maximum.

The effective fetch for waves from the west and northwest is estimated at 3.9 nautical miles.[5]

[3] The projections of sea level rise are for planning purposes. The projections are uncertain. Tide level gauge readings have been recorded at Fort Point, San Francisco since 1855; the rate of rise from 1940 to 1986 has been assessed at 0.0075 foot/year. There is a wide fluctuation over short periods in measured sea level elevations. The current 5-year running average of values is relatively flat.

[4] “Fetch” is the area in which the seas are generated by a wind having a near constant direction and speed.

[5] I nautical mile = 6,080 feet = 1.15 miles

In the region of Point Molate, the significant wave height due to 50 knot[6] winds[7] sustained over 30 minutes would be 3.5 foot high with a 3.5 second wave period. An associated maximum wave would be about 5.6 feet high. Such waves will break and dissipate energy before reaching a bluff or shore protection[8] at this study location.

The calculated wave height would be affected by storm surge, refraction, shoaling, and shelter from wave barriers. The wave height is low and adjustments have not been estimated. It is believed, by judgment, that their effects on the wave height magnitude offset each other.

Storm surge resulting from sustained storms at the Golden Gate would raise up the water surface.

Refraction, the effects of varying bed contours, could reduce the wave height in curved bays and increase the wave height at headlands.

Shoaling, the reduction in wave height due to the very flat slope of the mud beach approaching the foreshore, occurs and would reduce the magnitude of the wave height.

Sheltering of portions of the shore, provided by old wave barriers and by wharves, would reduce the size of waves.

The effect of sea level rise is to produce higher wind generated waves that would break on the shore protection with resulting greater forces and higher run-up.

The United States Geological Survey (USGS) shows the reduction of wave action from large waves moving into the Golden Gate. Waves of over 8 feet significant[9] wave height at Golden Gate decay to less than 3 feet significant wave height as they approach the vicinity of Point Molate.

Wind and wave estimates for San Francisco Airport have been used to assess wave action at the Richmond Marina and the Outer Harbor. The estimated wave heights are larger than the waves in the vicinity of Point Molate. Refraction will cause a reduction in the size of such waves reaching the Point Molate shoreline to a somewhat similar value as estimated above.

The estimated waves are compared below against the operation and berthing conditions for wharves, piers, and the ferry once in use along this shoreline.

Limiting waves compatible with allowing operations at the open wharves at and near Point Molate would be likely be less than 1.5 feet high. The typical vessels moored at the wharves could ride out at berth in waves of 3.5 feet height with a wave period of 3.5 seconds.

Significant wave heights in San Pablo Bay are believed to be up to 2 feet only.

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[6] 50 knot is a high estimate. The maximum 30 minute sustained wind may be nearer 45 knots.
[7] 1 knot = 1.15 miles per hour = 1.69 ft/s = 0.514 m/s
[8] “Shore protection” is used in this report to refer to a variety of types of protection against erosion by wave, tide and current action.
[9] “Significant wave height” is the average height of the one-third highest waves of a group of waves.

The estimated wave height and period conform well with wave criteria related to past waterfront operations.

Concerns over ferry wake damage generally relate to vessels traveling in close proximity to beaches and wetlands. This is not the condition in the vicinity of Point Molate. The route of ferries from Vallejo to San Francisco is from 1.1 to 1.6 miles from the shoreline. It was noted that only wavelets broke on the beach following the passage of a ferry on a calm day.

In summary, a significant wave height of 3.5 feet and associated significant wave period of 3.5 seconds is suitable for coastal assessment purposes.

Wave Run-up

Wave run-up and overtopping[12] will be of consideration where the trail is low in elevation and close to the shore. The locations where run-up is likely to occur can be indicated on available inundation maps such as that included as Exhibit B. The light blue areas at the shoreline indicate inundation.

Run-up on shore protection depends on rock or concrete block size, slope, and gradation. Considering the variability in the shore protection construction, a single generalized value for estimated run-up height of 1.5 times the maximum wave height acting at the shore protection above the MHW level is proposed. This value may be subject to adjustment for specific sub-segments of the trail, where profile information is available.

The present day maximum run-up due to a depth limited 2.8 feet high wave is estimated to be no more than +9.6 NAVD88.

By year 2050, using a 24 inch projected sea level rise, the wave run-up at a future MHW of +7.4 NAVD88, would result in a run-up elevation of +14.0 NAVD88. This estimate is based on the higher limits of the sea level projection range from Table A-2 of the NRC (2012).

The trail is designed to be no lower than approximately +14.6 NAVD88.[13] Therefore no overtopping of the trail is expected over its likely initial life of 20 to 30 years. Should sea level rise meet the high projections assumed for the end of this century then there would be concern over the vertical distance between trail and water surface. In such a case, the trail could be raised or a protective barrier added as part of a major maintenance or reconstruction project.

Splashing and spray could occur due to winds approaching from the Bay acting together with larger waves at higher tides. Splash and spray nuisance would increase as sea level rises depending on the elevation and set back of the trail. The proposed alignment shows a setback of typically 20 feet or more from the top of bluff and the nuisance is likely to be slight during its initial life.

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[12] The passing of water over the top of a structure as a result of wave run-up.
[13] NCE communication May 13, 2016

Tsunami[14]

Tsunami effects result from generation in the ocean at a great distance from the entrance to San Francisco Bay. The magnitude of a tsunami is reduced as it moves through the Bay to Point Molate to about a third of the height at the Golden Gate.

Tsunami maximum water levels for marine terminal design are published for this area in Chapter 31F "Marine Oil Terminals" of the 2013 California Building Code (2013 CBC).[15]

Another recent source[16] indicates a varying tsunami water surface level of +13 feet reducing to +9 feet NAVD88 along the west side of the Chevron Richmond Refinery.

The tsunami wave heights at the refinery are for a very extreme long term condition and overly conservative for a trail located away from Risk Category III and IV development[17]. The more appropriate recurrence interval related to a coastal trail with low risk category development nearby might be less than 100 years. Values for a 100 year return period are given in this report. The tsunami run-up height at Point Molate for a 100 year return period could be just over a foot above mean high tide.

Records of tsunami related readings in the Bay over the past few decades are consistent with tsunami run-up heights of about a foot or less in the vicinity of Point Molate.

Information on and analysis of tsunamis is presently being gathered by the American Society of Civil Engineer's code committee for inclusion in the next edition of the California Building Code.[18] If there is to be new Risk Category III or IV building development in close proximity to the trail, the Tsunami run-up appropriate for that level of development will likely be that related to a 2,500 year return period (0.0004 annual occurrence rate and a 2 percent probability of occurrence in the next 50 years).[19]

Summary of Water Surface and Run-up Elevations

The higher still water elevations and wave run-up elevations are summarized below.

		Present Day	2030	2050	2100
Highest Wave Run-up Elevation with water surface at MHHW		+9.6	+11.7	+14.0	+19.5
Tsunami run-up with 2,500 year return period		+10.9	+11.8	+12.8	+16.3
Approximate Extreme High Tide at Richmond		+9.0	+10.0	+11.0	+14.5

[14] A long period wave caused by an underwater earthquake or volcanic eruption.
[15] A specific maximum water level is given as 7.5 feet for at the Richmond outer harbor. The value is added to the mean high tide elevation.
[16] Draft report to Chevron by URS
[17] Table 1604.5 of 2013 CBC
[18] The American Society of Civil Engineer's ASCE 7-16 is due to be published shortly.
[19] The 2016 CBC will include more tsunami design criteria than in the past. The adoption of the criteria will be important when potential for future development near to the trail is considered.

		Present Day	2030	2050	2100
Tsunami run-up with 100 year return period with water surface at MHW		+6.6	+7.5	+8.5	+12.0
Mean Higher High Water	MHHW	+6.06	+7.0	+8.1	+11.5
Mean High Water	MHW	+5.45	+6.4	+7.4	+10.9
Mean Tide Level	MTL	+3.26	+4.2	+5.3	+8.7

Values are given relative to NAVD88 (North American Vertical Datum of 1988).

Exhibit B, "Inundation Map" shows inundation for a +11 ft NAVD88 elevation so as to provide a general indication of the effect of inundation along the shoreline.

Condition of Existing Shore Protection

Because of the low magnitude of the wave forces, there has been no cause to engineer the shore protection in the past.

Shore, bank or bluff protection has not been done to any particular engineering standard, but rather done out of expediency. No particular criteria on thickness of rock layers, nature and size of under layers, interlocking or stability of rock, or conformance to a uniform surface has been followed.

Approximate determination of rock size and gradation were made at Location A and Location F on Segment B as indicated on Exhibit A. At both locations, about half of the individual rocks moved when stepping on the surface. In the future, if there is greater wave action, the surface may become more stable due to consolidation by the waves.

Basic revetment stability calculations for these locations indicate that a 3.4 foot wave could be sustained at Location A and that only a 2.2 foot wave could be sustained at Location F. Larger waves have probably occurred at Location F, but perhaps not up to the elevation where the gradation measurements were taken. Larger rocks were present nearer the toe of the shore protection at Location F.

The variability in shore protection at other locations was not amenable to determining the gradation.

No signs of split rock were observed. The rock appear to be durable although not tested by the action of high wave caused impacts. With a large sea level rise and associated increase in wave action, there might be a resulting deterioration of the rock.

Erosion

Fragments from the exposed bluff from point B to E in Segment B as shown on Exhibit A can be seen trapped by the rocks on the foreshore. Remnants of dumped rock protection exist in the bank at the top of the slope to the back of the bluff. Dumped rock protection has moved out beyond the bluff on to the foreshore.

In general, recession of bluffs due to Bay water is related to the height of bluff being acted on by water and waves.

Disintegration of the exposed bluff surface has been reduced with the building up of toe protection. Where bluff protection has been built up behind a line of large rocks to about mean high water to form a berm, the recession has been limited.

With a large sea level rise, more of the bluff surface would be exposed to water and wave action for a greater period. Wind wave heights would increase with deeper water and wave pressures would increase because the existing berm would be less effective in reducing wave energy. The rate of recession would be expected to increase in the future due to sea level rise unless more protection is added.[20]

The trail setback is a consideration when assessing the rate of bluff recession. The set back of the proposed trail alignment is typically 20 foot and more. Based upon comparison of aerial photographs back to 1939, the alignment of the shore protection appears to be relatively stable. Man-made changes related to the old ferry, the construction of the Richmond-San Rafael Bridge, the addition of shore protection, and changes at the former Naval Fuel Supply Depot obscure assessment of shoreline changes.

Estimates of the stability of rock and concrete fragment slope protection against wind wave action indicate that the ability of the rock protection to prevent future erosion is marginal. Deeper water and larger waves would likely degrade the protection and periodic repair could be needed. Monitoring the actual sea level rise would allow a better assessment of sea level rise and potential erosion to be made

Storm water percolating into the soils behind the beach, or from failed storm water pipes could result in soil erosion at a bluff or at the back of the shore protection. Areas graded towards the shore may encourage storm water in saturating and weakening the bluffs or shore protection.

Depending on the soils or rock at bluffs or behind shore protection, there could be movement of Bay water into the soils or rock at high tides resulting in their weakening from the leaching of fine material.

Based on observations of a cut slope in similar local material away from the shore, erosion can occur at times of heavy rainstorms. The action of wind and rain breaks down the weathered face of the slope to form a protective scree. On a beach, such protection is removed by wave action and spread out over the foreshore.

Within the cove at the Point Molate Beach Park, the slope at the approach to the bluff is about 1 vertical to 15 horizontal. For the purposes of evaluating wave action and run-up, it is assumed that the shore protection just to the north of the Beach Park was constructed on a similar slope

The bluff in Segment B appears be receding at a relatively slow rate, since there are approximately 20 feet or more of separation from the proposed trail to the bluff. This is at contrast with active bluff

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[20] Probably at a rate exceeding the relative proportion of height of cliff exposed to wave and water contact.

erosion noted to the south of the shore protection at the north end of Point Molate Beach Park which is excluded from this study.[21]

Should an extreme tsunami occur, greater than the 100 year event, then unstable rocks, loose soil, and unanchored items will be moved out into the Bay and the shore protection weakened against normal wind wave action. Some old ferry mooring wave barrier piles may be damaged and the sheltering effect from wave action reduced. Rock might be broken by the associated impact forces.

Old aerial mapping from 1939 onwards was compared against the aerial mapping for this trail project. The quality and scale of the available mapping does not allow for any quantitative estimates of recession to be made. The man-made changes to the shoreline over the years can be discerned. Other lengths of shoreline appear not to have been greatly changed. It appears reasonable to assume that the trail with the provided setback from the bluff or shore protection will not be impacted unless sea level rise should attain the high projections being used for planning purposes.

Conclusions

The lowest elevation of the trail is to be +14.6 NAVD88. The 2050 projected water surface elevations due to sea level rise with wind wave run-up or an extreme tsunami are below this value by 0.6 foot or more.

Based upon consideration of available historic aerial photography and evaluation of the site from a coastal engineering approach, there appears to be no need for additional shore protection to be included for this trail project at this time.

No significant active bluff recession has been noted in the study area. With the proposed trail set back from the top of the bluff of 20 feet or more, there appears little concern that shoreline erosion will damage the trail during its initial 20 or 30 years of life, unless sea level rise reaches or exceed the higher projection over that period of time.

When major maintenance of the trail becomes due, the trail alignment could be adjusted if necessary after consideration of the actual water surface elevation at that time, an improved projection of future water surface elevation, and a comparison of shoreline recession against the survey for this project.

[21] Active erosion is occurring outside the study area from the end of the riprap at about 100 foot north of the north gate to the Point Molate Beach Park to about 1,000 feet south of north gate to the Point Molate Park.

The stability or potential for movement of the bluffs has not been considered in this study. Such a geotechnical assessment requires some consideration of the geologic background and properties of the soils and rock, and is outside the scope of this assessment.

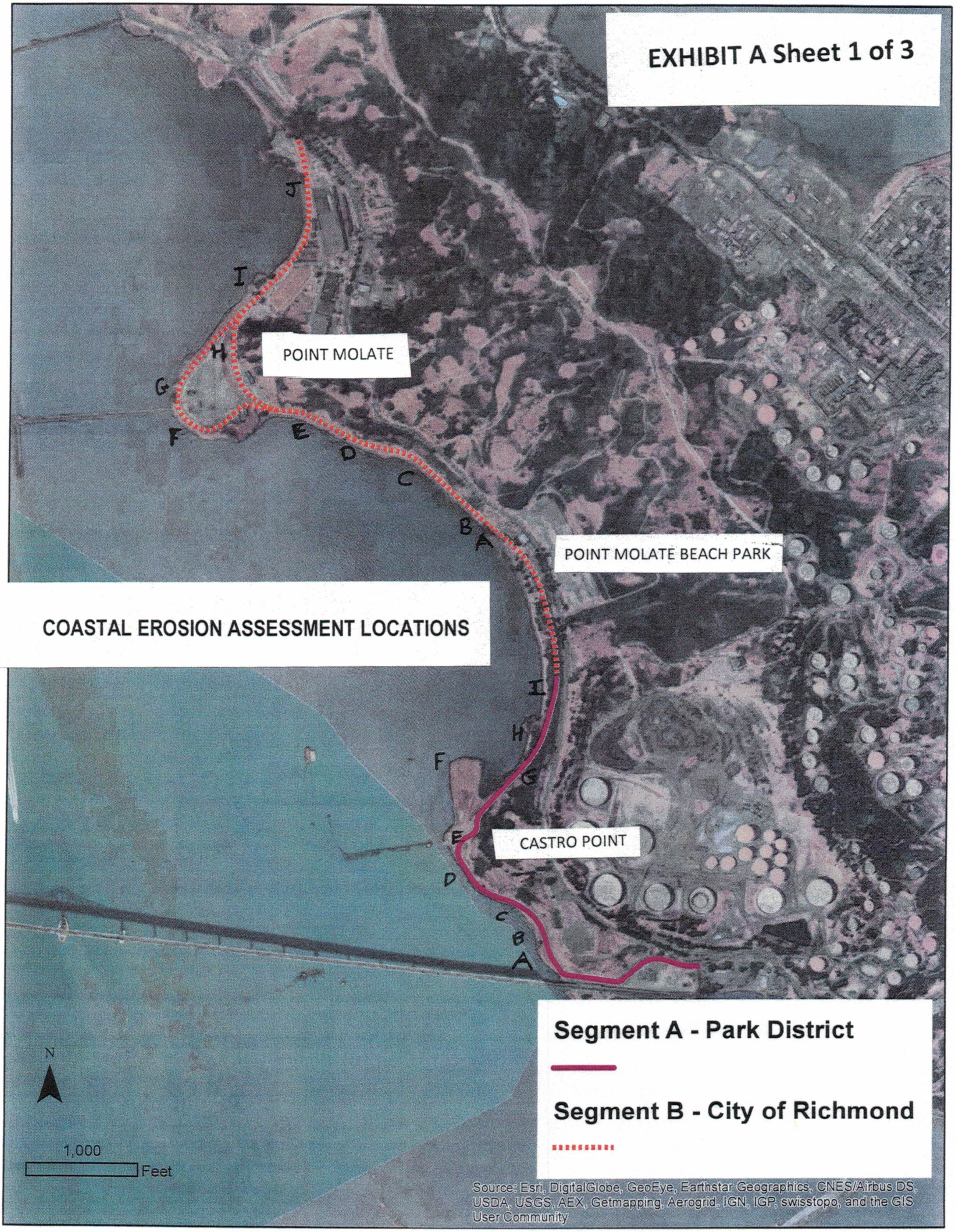


EXHIBIT A Sheet 1 of 3
COASTAL EROSION ASSESSMENT LOCATIONS
POINT MOLATE
POINT MOLATE BEACH PARK
CASTRO POINT
J
I
H
G
F
E
D
C
B
A
Segment A - Park District
Segment B - City of Richmond
N
1,000
Feet
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Pt Molate Beach Description
Segment A

Location	Description	Photos	Historical
A TO B	Rock strewn foreshore slope 10:1 to bluff protected with old pile & conc block debris. Sheltered from S and SW by Chevron Long Wharf	871 872	
B to C	Sand beach foreshore, 60' wide at LW, slope 10:1, bank riprap to MHHW.	873 874 875	
C to D	Rock fragment strewn foreshore, slope 10:1, bank protected with rough placed varied stone, rock, & concrete demo debris up to MHHW. Varied degree of protection. Rock up to 5 ton. Vegetation above MHHW.	876 877	
D to E		877 869	
E	Point Castro. Remnant of old ferry. Wood pile wave barrier, top at +1 MHHW with batter piles. Concrete block riprap raised up to floor elevation of old building. Dock with wreck.	866 867 868 869	Site of former ferry to San Rafael prior to bridge in 1956.
E to F	Old stone and concrete block from demo up to MSL. New concrete block from demo above MSL nearer to Point Castro. Concrete riprap to MHW beyond, with stack of old wood piles in close proximity.	866 865 864 878	Remains of old dock present.
G	Marsh area with mud flat. Recent 24 inch +/- stone protection to the bank in west direction.	863 864 879	
H	Sand beach foreshore, up to 50' wide at LW, slope 12:1. ?photo	861 862	
I	Sand beach foreshore, 50' wide, up to MHHW at 10:1 slope. Flat 40' wide backshore to steep cliff, both vegetated.	881 882 883	
	Point Molate Beach Park.	884	

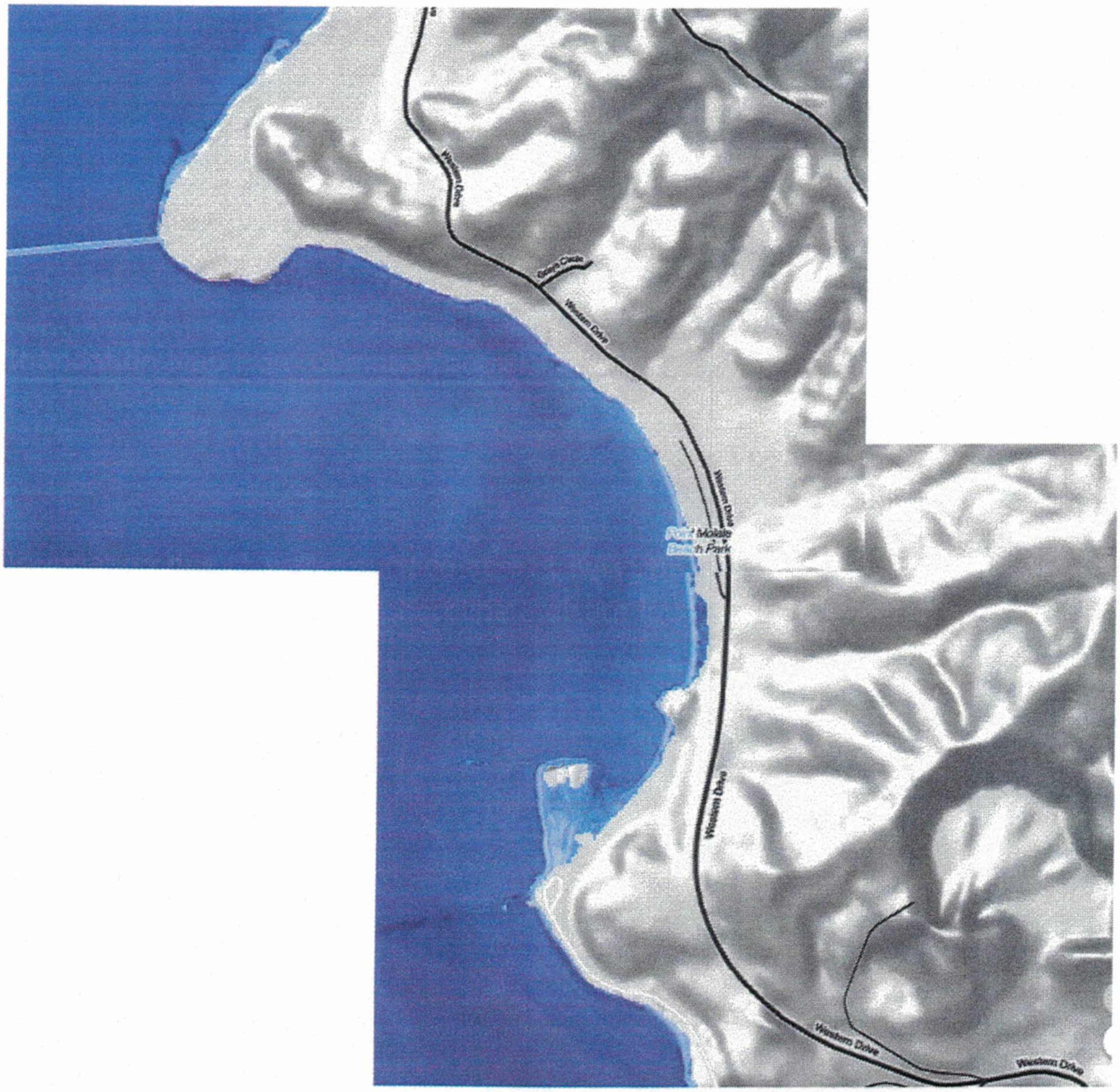
Pt Molate Beach Description
Segment B

Location	Description	Photos	Historical
	Point Molate Beach Park	914 915 916	
A	Sand and rock strewn foreshore at 10:1 slope, steep rock bank, small rock at flatter slope, then 12' vegetated strip to AC pavement.	891	
B	Rock outcrop at foreshore up to MSL. Short rise of rock covered bank. Shallow vegetated bank slope back to AC pavement.	908 909 911 912 913	
C	Exposed cliff with surface. Steep slopes with light rock protection. New concrete demo pieces of 15" down in size. Grass bank at 20:1 up to AC pavement.		
D	rock fragment strewn foreshore. Loose friable rock cliff with some loose rock.		
E	Line of large rocks (5 ton +/-) at toe of cliff with small rock berm against cliff.	892 893	
F	Loose rock and some concrete fragments. Grading	895	
G	24" stone at 2:1 bank protection, loosely placed. Rock fragment strewn foreshore.	907	
H	Rock covered bank and timber pile (18" diameter+/-) wall with long piles stacked 3 high. A various rock, small stone, degraded sacked concrete above wall topped with a 2:1 3' high vegetated bank up to regraded area.	898	
I	Some new rock on top and some concrete blocks on steep rocky slope Loose rock 15" +/- with intermittent timber piles and timber piled wall. Some new concrete cone protection 46" square base & 27" high.	899 900 901 906	
J	Beach with mud flat, foreshore with rock fragments and some sand, 2:1 rock bank and vegetated slope to flat graded and paved areas. Rock 24" to 6" angular.	902 903 904 905	

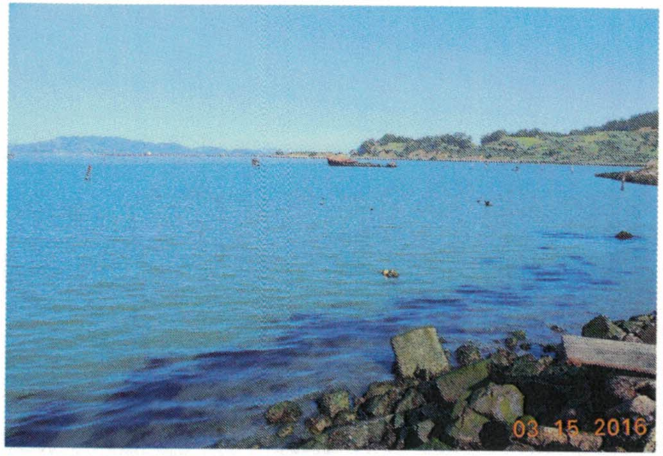
EXHIBIT B

Inundation Map from Climate Central

Inundation due to water surface at +11 NAVD88
The light blue areas at the shoreline indicate inundation



SEGMENT A



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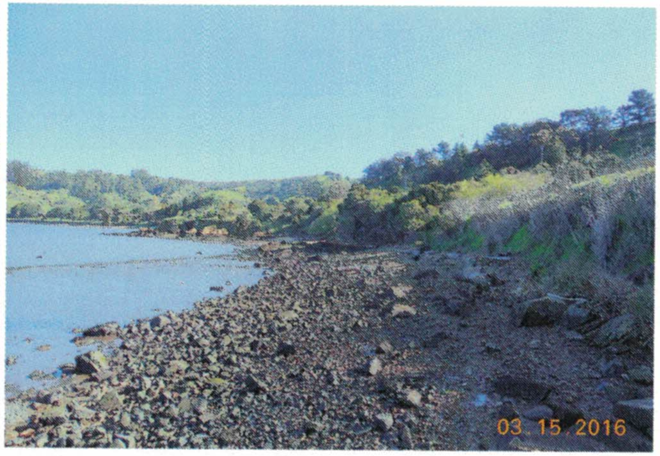

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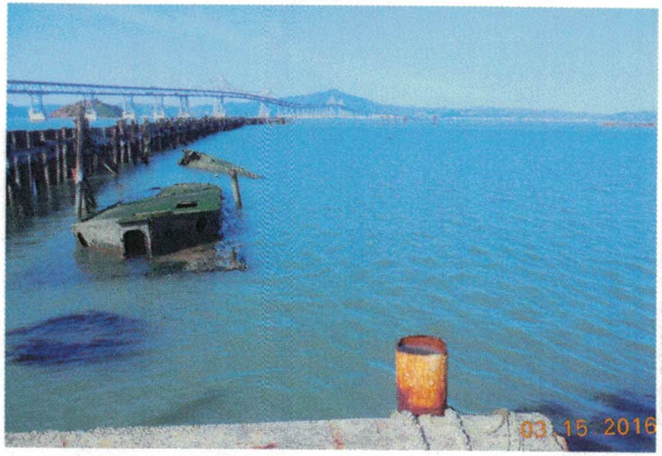

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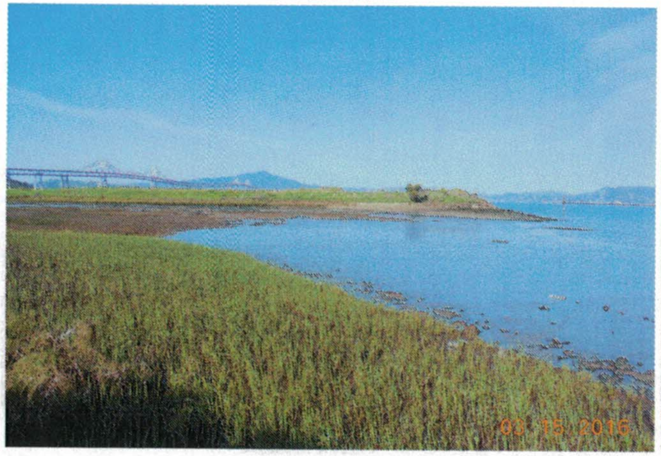
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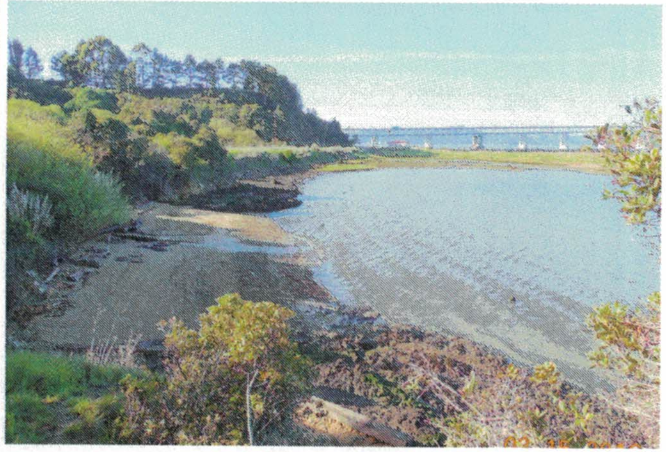
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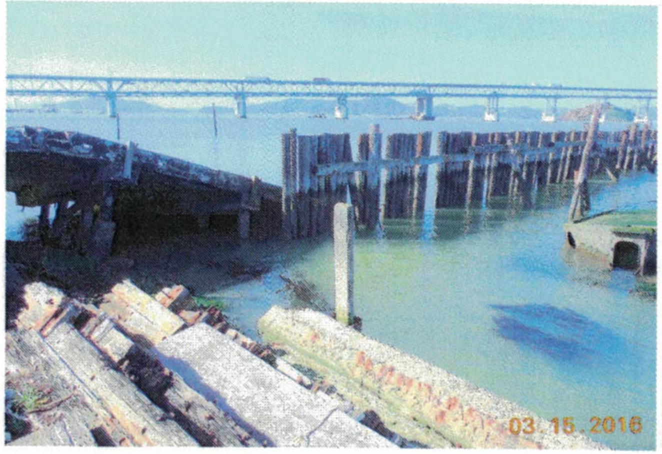

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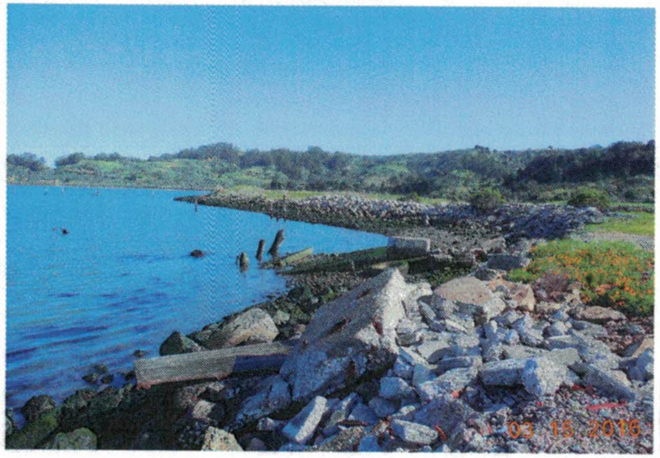
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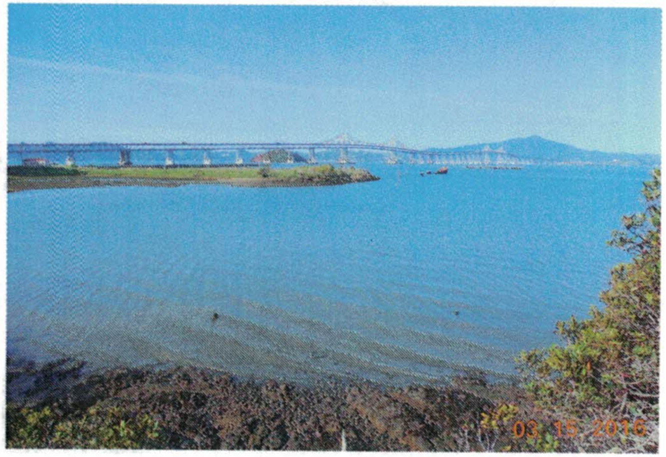
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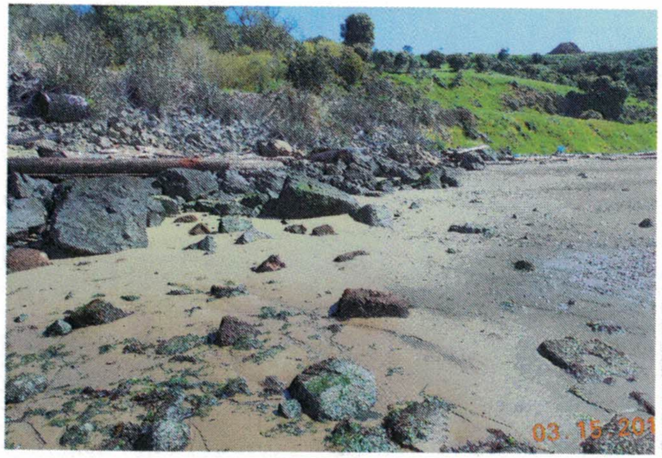
SEGMENT A



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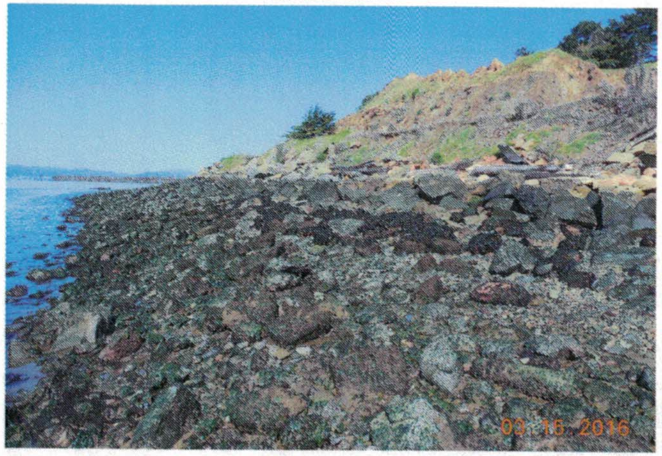

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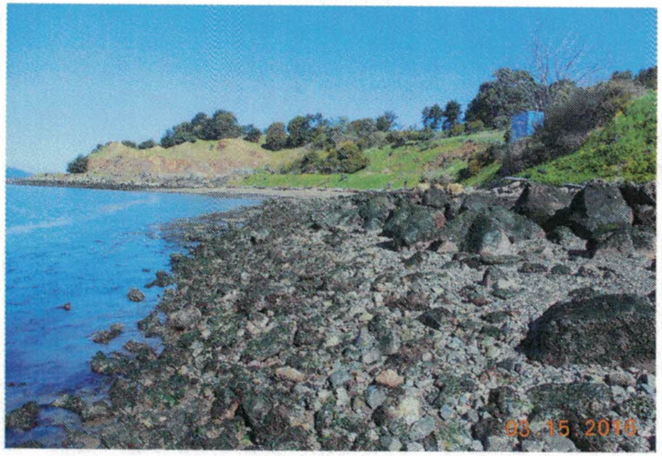

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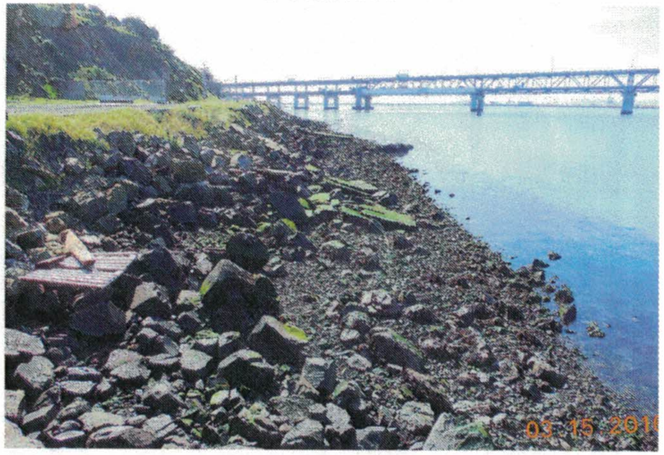

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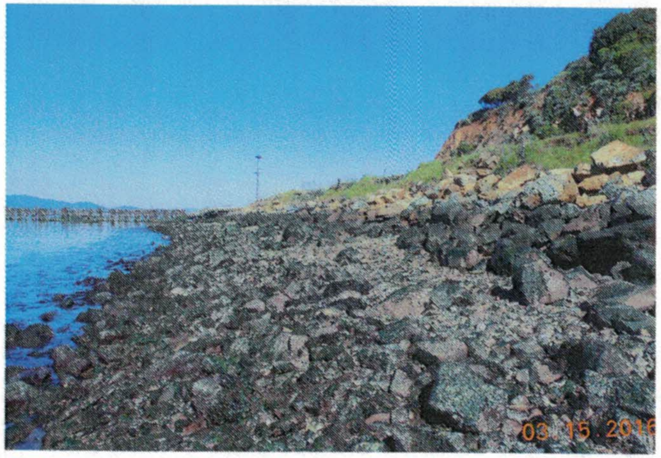

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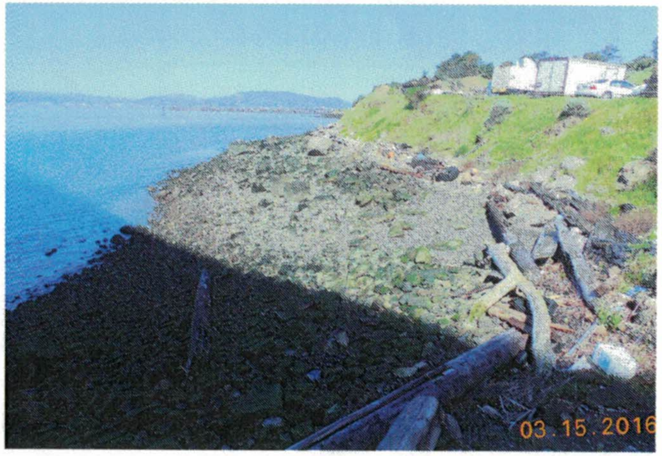

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SEGMENT A

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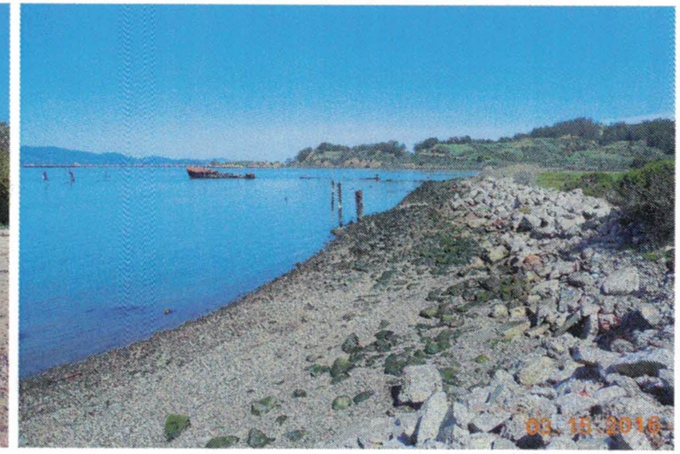

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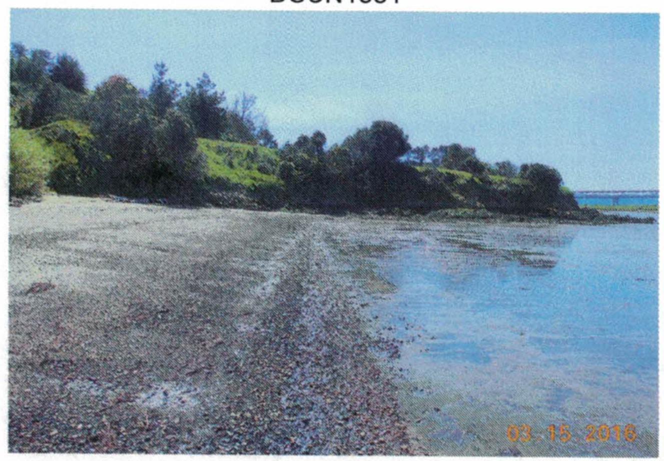

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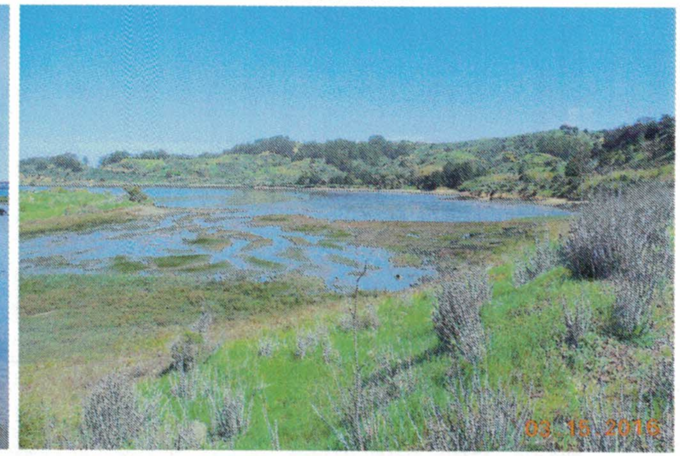

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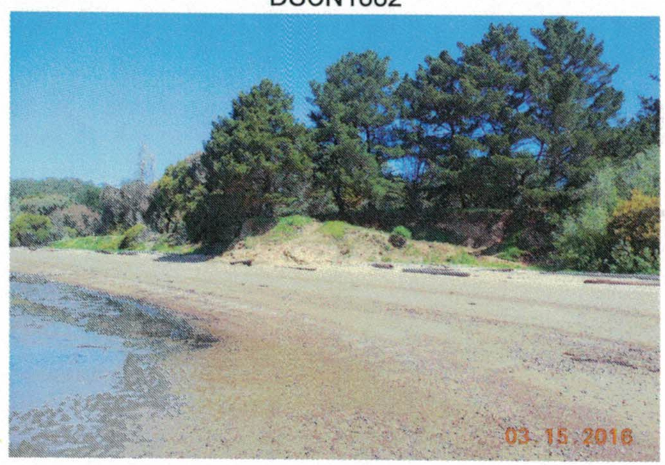

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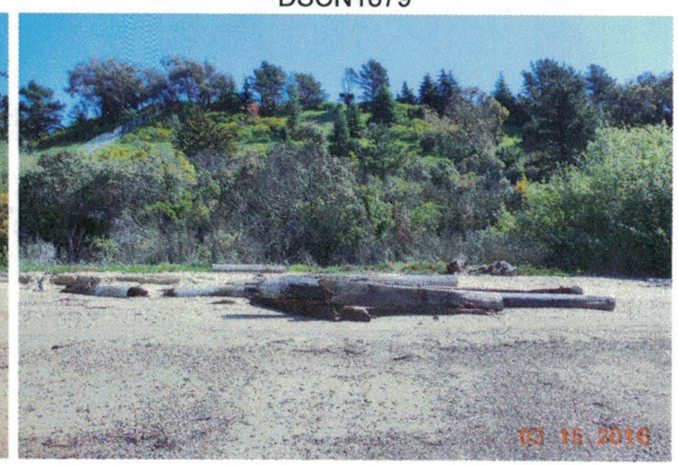
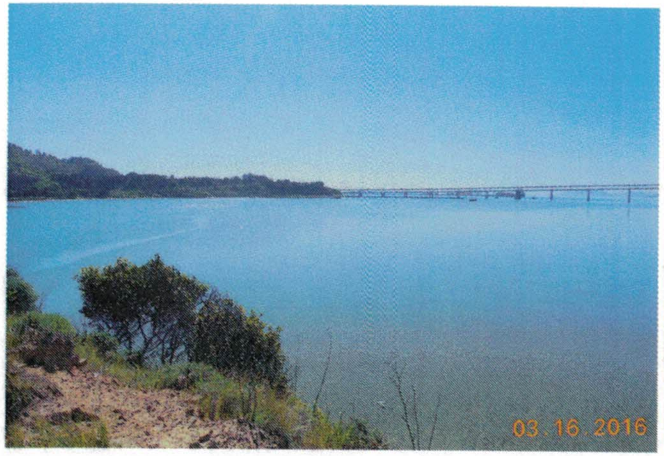


DSCN1880

SEGMENT B



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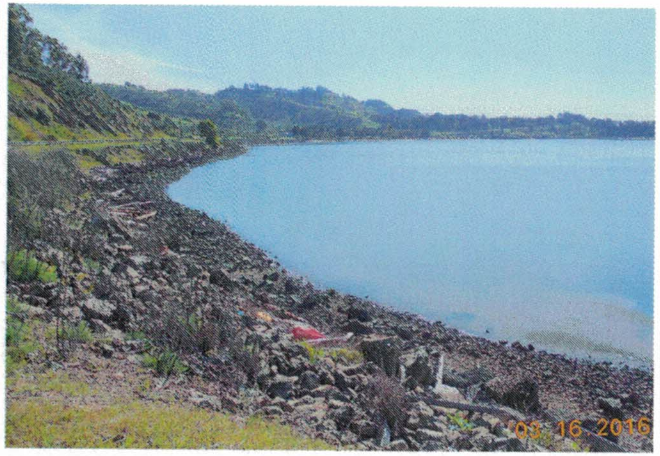

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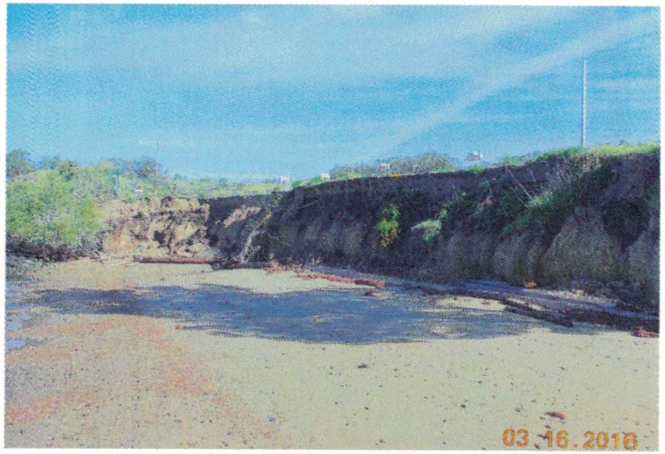

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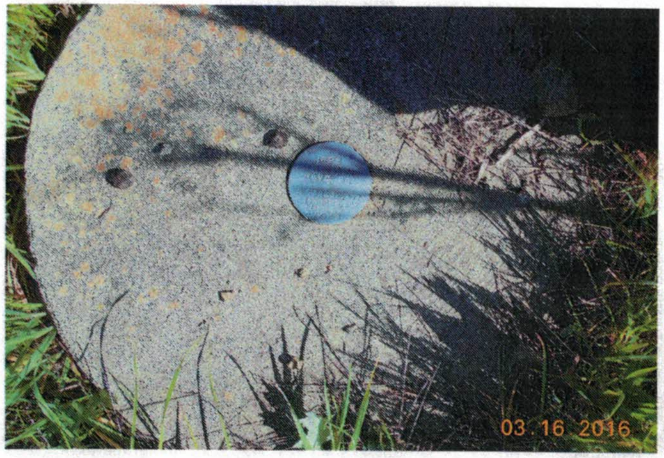

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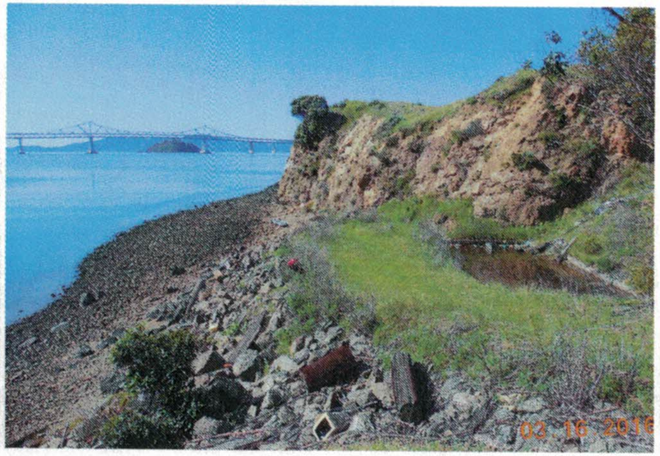

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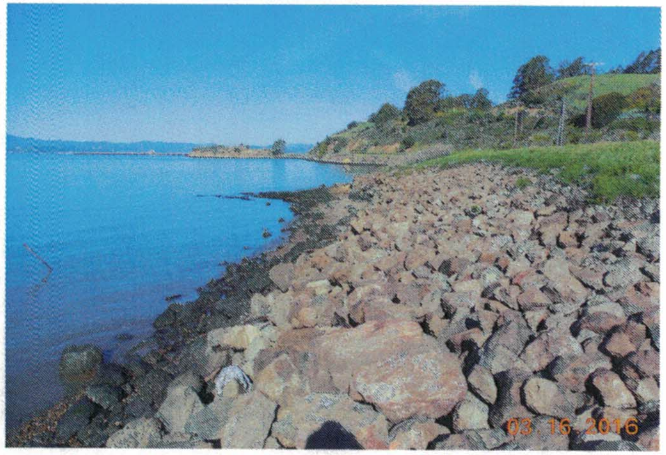

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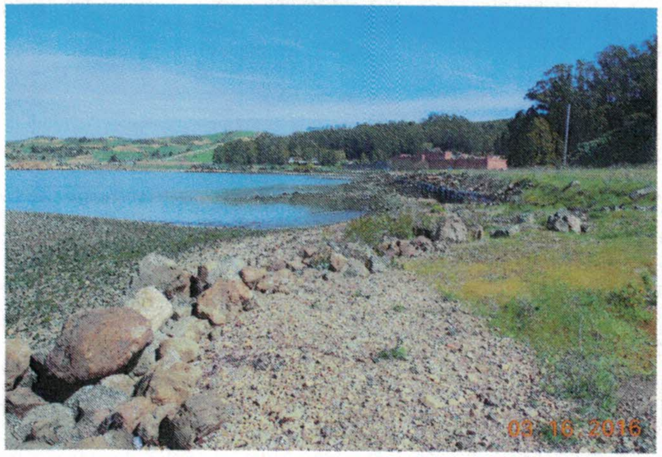

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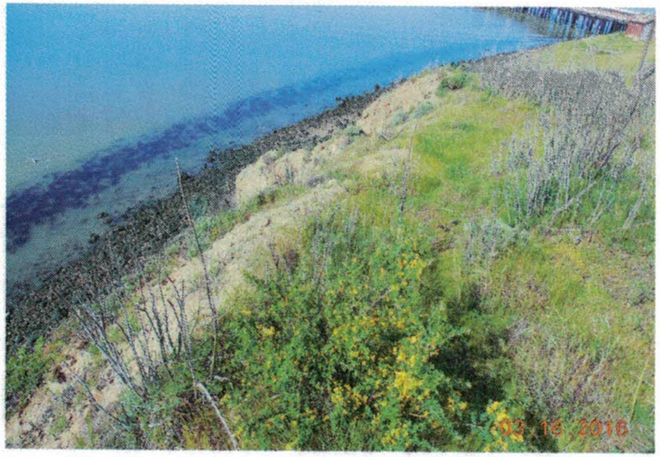

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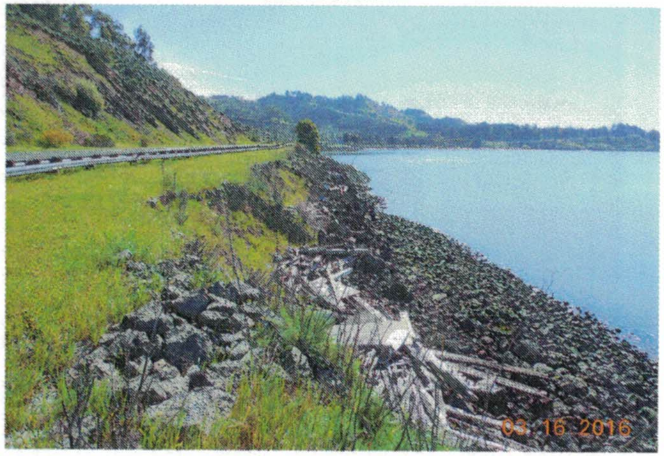

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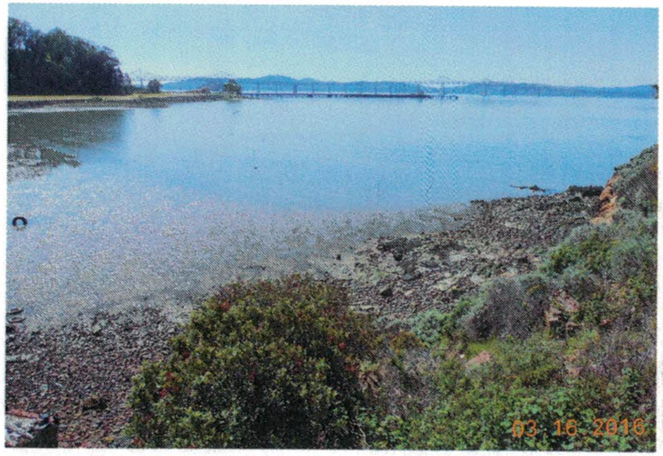
SEGMENT B



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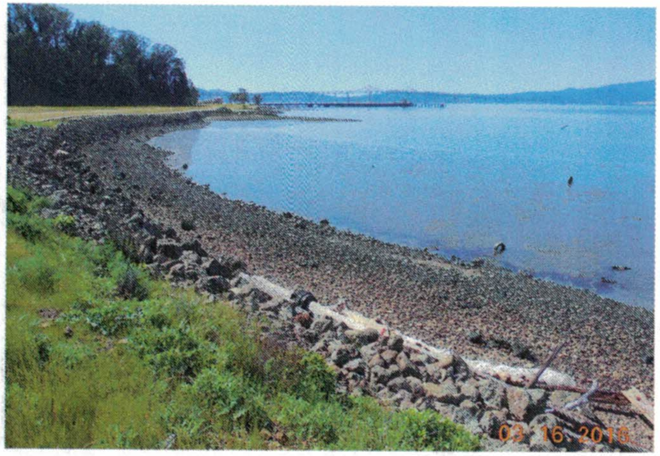

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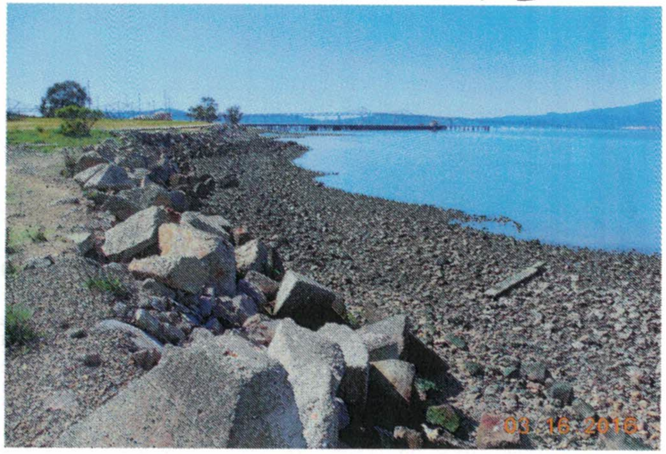

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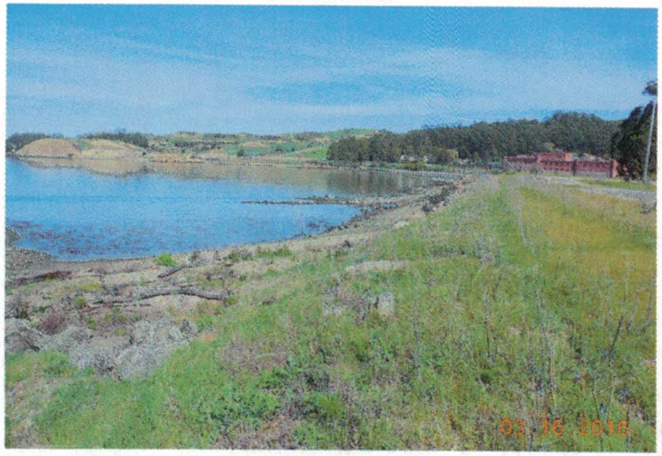

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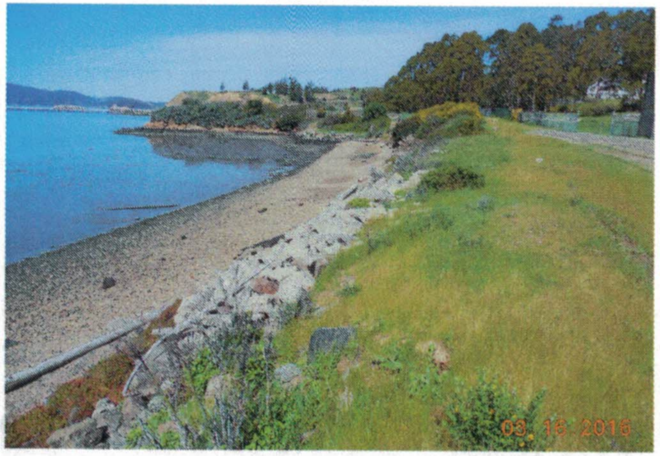

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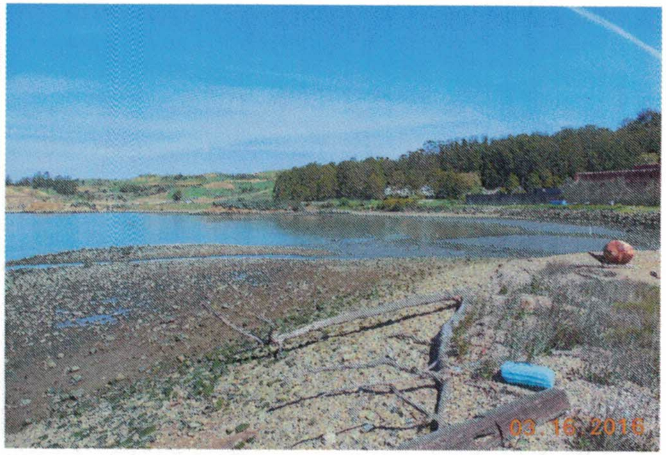

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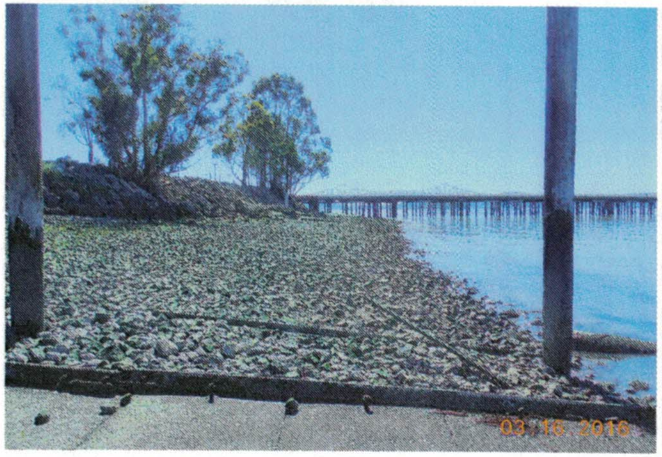

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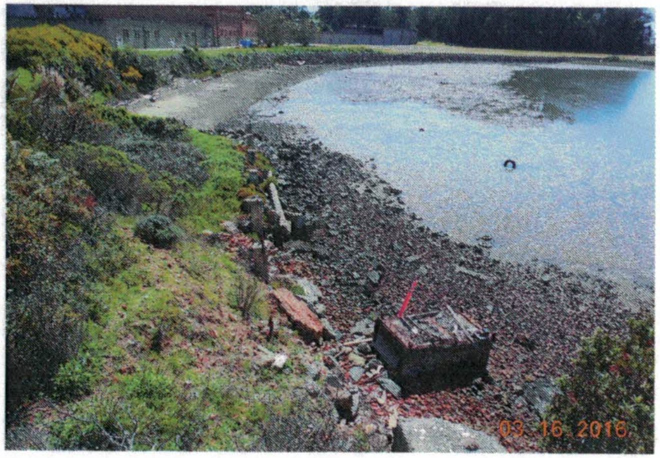

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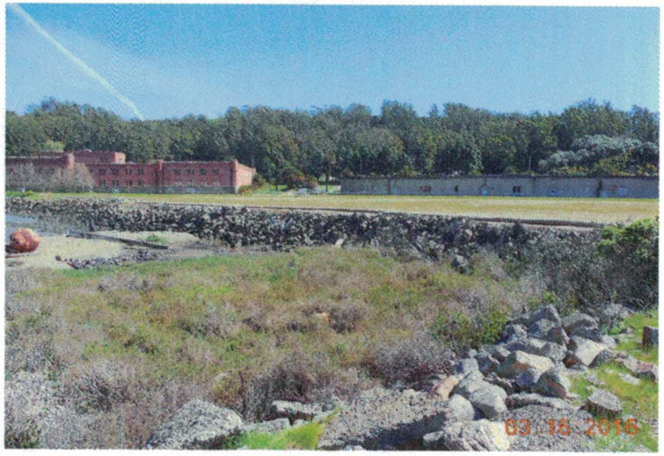
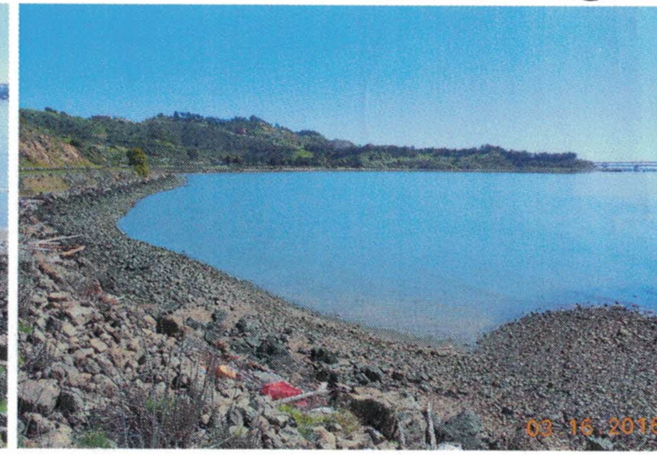


DSCN1901

SEGMENT B



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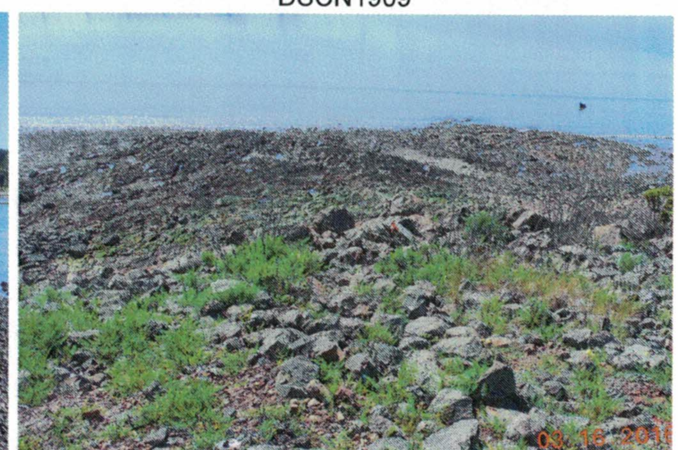

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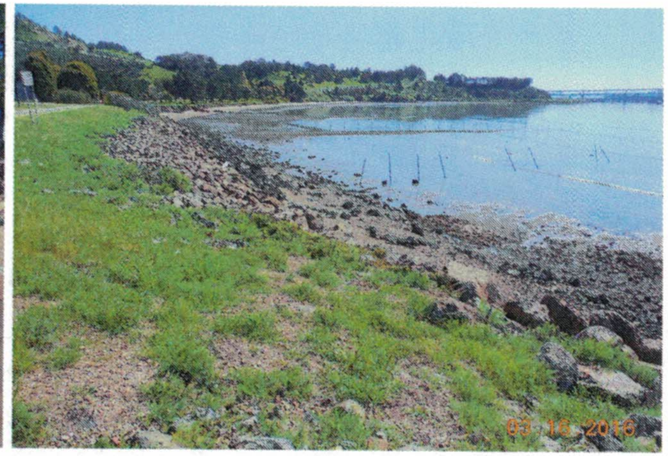

DSCN1911

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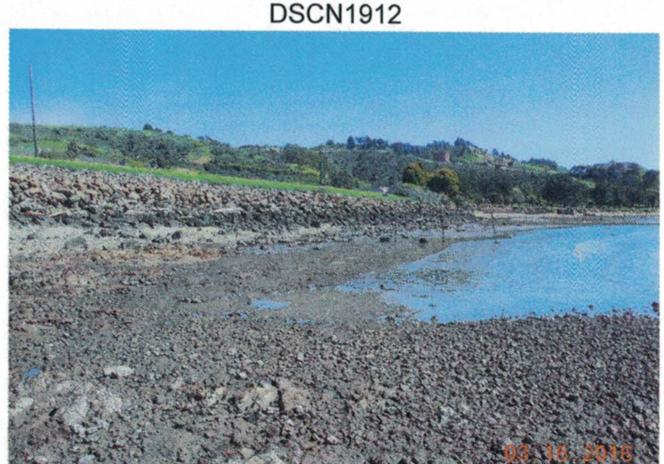

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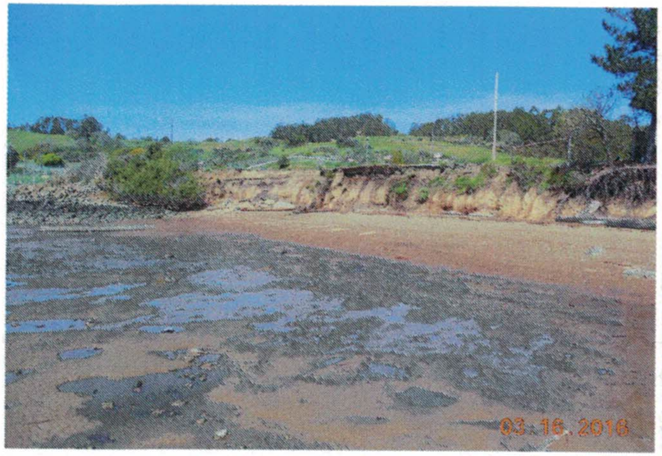

DSCN1914