INDIA BASIN WATERFRONT PARKS PROJECT

COASTAL PROCESSES STUDY

SAN FRANCISCO, CALIFORNIA

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September 2015
M&N Job No: 8898 and 8488

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1. INTRODUCTION

A collaborative effort between the San Francisco Recreation and Park Department, the Trust for Public Land, the San Francisco Parks Alliance, and Build Inc. envisions to develop a waterfront parks plan for India Basin. The project location and vicinity are shown in Figure 1 and Figure 2.

The overall project scope of work includes a coastal processes study and identification of potential shoreline improvement concepts. This report provides coastal process background information within India Basin and Lash Lighter Cove to support developing potential shoreline improvement concepts. The level of detail presented herein is intended to be sufficient to develop conceptual level improvements for the shoreline. Specific tasks undertaken include:

- A visual reconnaissance survey of 700 Innes AVE, 900 Innes Ave, India Basin Shoreline Park, the PG&E Shoreline Trail and Heron's Head Park,
- Conduct a coastal processes study to evaluate wind wave, tidal water level conditions,
- Conduct a sedimentation study to estimate historic sedimentation rates and wind driven and tidally driven sediment transport patterns,
- Identify potential shoreline improvement concepts

Figure 1: Location Map

Figure 2: Vicinity Map

2. EXISTING SHORELINE CONDITIONS

A summary of the existing shoreline conditions observed by Moffatt & Nichol staff during field visits on May 12 and June 19, 2015 is provided herein. Plan view maps and photographs taken during the site visits are presented in Appendix A. The following shoreline features, as shown in Figure 3, are used to describe the site:

- Embankment or bluff: a slope which may or may not be vegetated and extends from the intertidal zone up to an elevation above typical tidal influence
- Revetment: engineered rock slope protection which extends from the intertidal zone up to an elevation above typical tidal influence
- Intertidal marsh: a relatively flat intertidal slope which supports, or has adequate elevation to support, marsh habitat
- Foreshore slope: an intertidal slope transiting the comparatively flat mudflat to the intertidal marsh (if present) and relatively steep embankment/bluff/revetment
- Mudflat: comparatively low elevation habitat with minimal slope
- Concrete ramp/slope: a relatively steep slope typically extending above tidal influence
- Bulkhead wall: a vertical or near-vertical edge (typically concrete) that retains a soil embankment and protects the embankment from damage by wave action

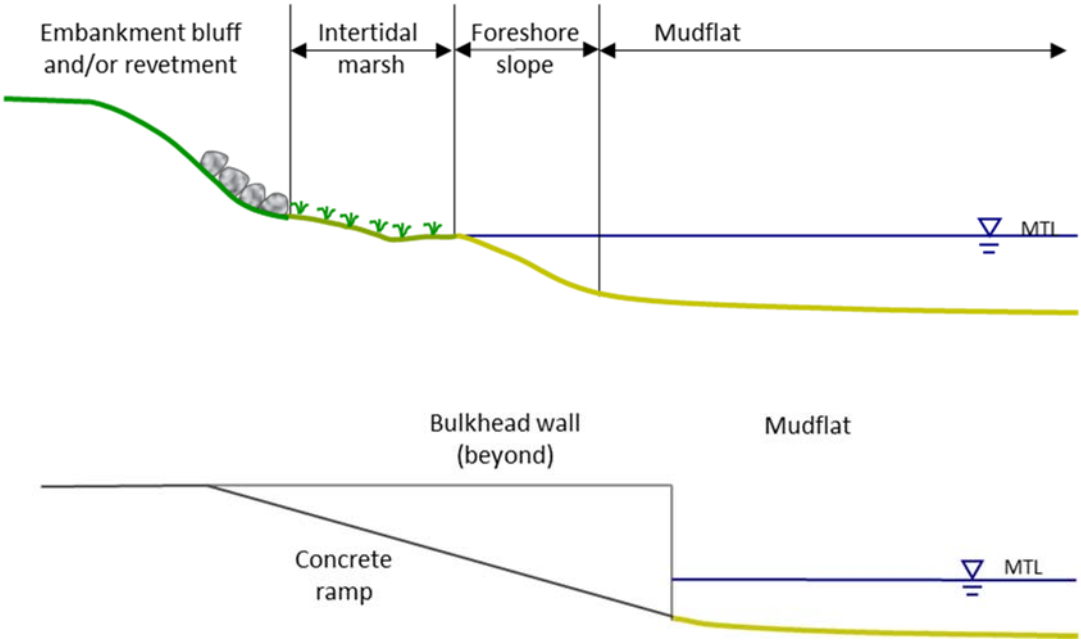

Figure 3: Shoreline Terminology Definition Sketch

The proposed waterfront parks plan for India Basin includes five properties: 700 Innes Avenue, 900 Innes Avenue, India Basin Shoreline Park, PG&E Shoreline Trail and Heron's Head Park. Each property has been divided into several reaches based on shoreline orientation and existing conditions. A sketch indicating the general extent of each reach is provided in Figure 4.

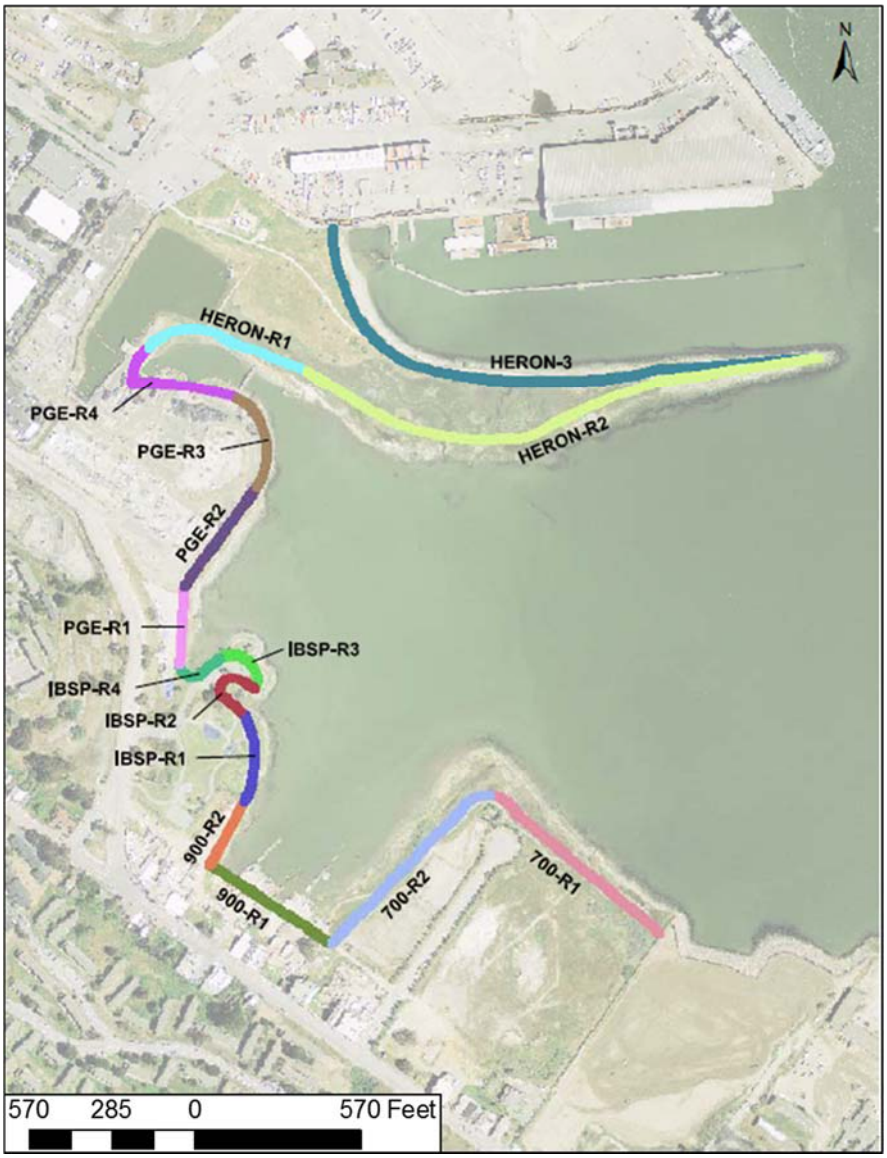

Figure 4: Reach Definition Sketch

2.1 700 Innes Ave & India Basin Open Space

The 700 Innes Ave property is the southern-most property included in the project. The coastal reach of interest extends from the boundary of the Hunters Point Shipyard Northside Park, north to the 900 Innes Avenue property. The property is broken down into 2 reaches as shown in Figure 5.

In general, the shoreline is composed of vegetated bluffs fronted by an intertidal marsh. Offshore of the intertidal marsh (below Mean Tide Level [MTL]) a sloped foreshore extends to mudflats. Top of bank elevations generally range from 15.5 - 19.5 feet NAVD88 with the lower elevations at the southern and northern limits of the reach where it connects to the adjacent properties.

In Reach 700-R1, which faces northeast, there is a layer of rock placed at the toe of the vegetated bluff which provides scour protection. Bayward of the tidal marsh there is a

concrete debris berm which serves as a wave break. The concrete debris berm consists of material which varies in size from approximately 2 feet in diameter up to 6 feet in diameter. The concrete debris berm has locations where the material is sparse and has a lower top elevation compared to adjacent berm heights. The foreshore slope consists of rock and concrete debris below MTL extending to the mudflat with significant plant growth on much of the debris. At the eastern end of the reach there is a low, vegetated sand dune.

Reach 700-R2 is similar to Reach 700-R1 except that the concrete debris berm is not present and the foreshore slope consists of a sandy material. A photo of the typical conditions along the shoreline is provided in Figure 6.

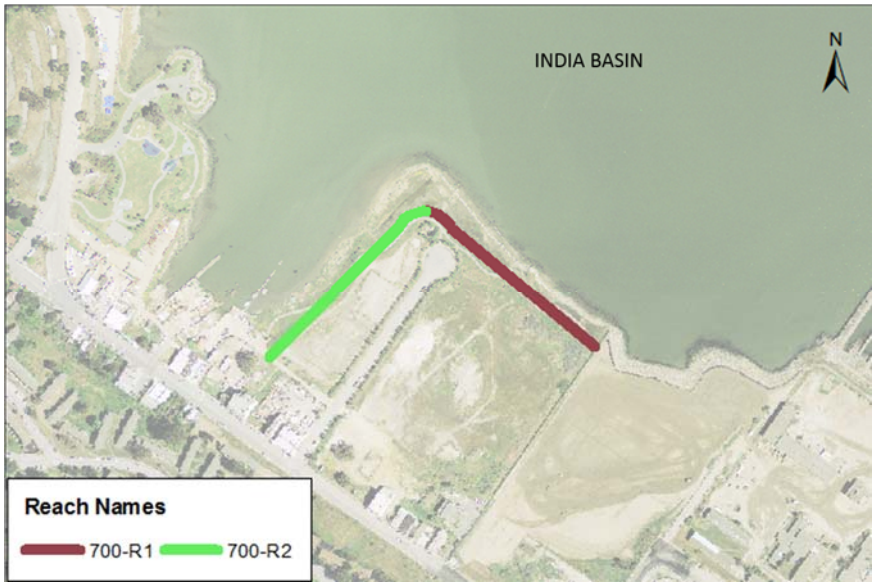

Figure 5: 700 Innes Avenue Reach Definition Sketch

Figure 6: Typical Conditions Along Reach 700-R2 (left) and Reach 700-R1 (right)

2.2 900 INNES AVE

The 900 Innes Ave property extends from 700 Innes Ave at the south to the India Basin Shoreline Park. The property is divided into two reaches as shown in Figure 7. The shoreline is composed of concrete structures (Reach 900-R1) and a vegetated bluff (Reach 900-R2) leading to a mudflat. Top of bank elevations at the concrete structures range from +7 to +9 feet NAVD88 and approximately +17 feet NAVD88 along the vegetated bluff.

In Reach 900-R1, the concrete structures consist of a deck leading to waterfront bulkhead walls and ramps. The deck shows some signs of differential settlement, the bulkhead walls are generally in fair shape with no signs of significant degradation and the concrete ramps are in various states of degradation with much of the ramps spalling, broken or cracked. Remnant piles, of wood and steel, and timber railings run out onto the mudflat.

In Reach 900-R2, the vegetated bluff appears stable as no signs of erosion were evident along the bluff, although along a portion of the bluff large pieces of concrete debris have been placed at the toe. Photos of the typical conditions along the shoreline are shown in Figure 8.

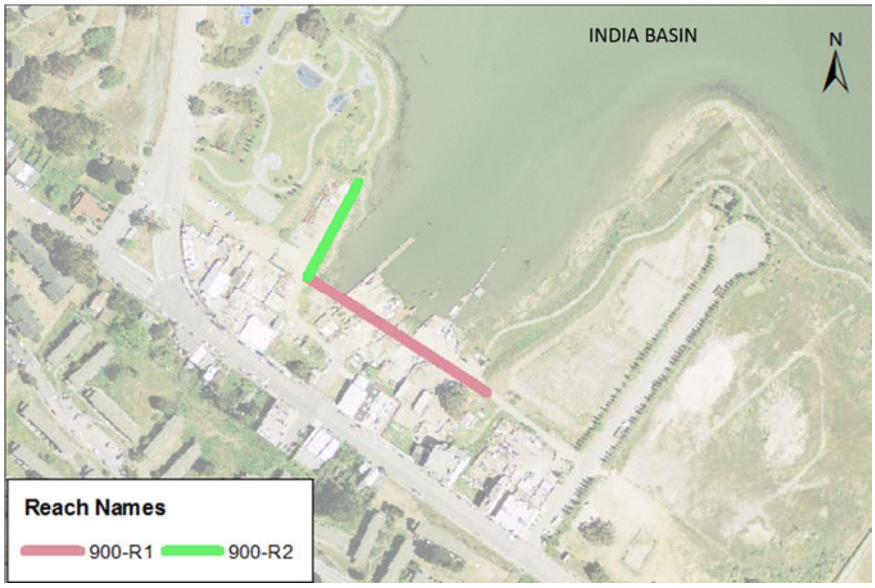

Figure 7: 900 Innes Avenue Reach Definition Sketch

Figure 8: Typical Condtions Along Reach 900-R1 (left) and Reach 900-R2 (right)

2.3 INDIA BASIN SHORELINE PARK

The India Basin Shoreline Park property extends from the 900 Innes Ave site at the south to the PG&E Shoreline Trail at the north. The property is divided into 4 reaches as defined in Figure 9. The shoreline of India Basin Shoreline Park is composed of vegetated berms, with intertidal marshes, and engineered revetments.

The vegetated berm is found in Reach IBSP-R1 and IBSP-R2 and IBSP-R3. In Reach IBSP-R1, the vegetated berm extends along shore approximately 300 feet from the southern limit of the property and is fronted by a foreshore slope with scattered rock and concrete debris leading to the mudflat. The top of the berm varies from approximately +9 to +10 feet NAVD88 and has signs of erosion along most of the length. In reach IBSP-R2 and IBSP-R4, the vegetated berm is fronted by intertidal marshes. The top of the berm ranges in elevation from +10 to +15 feet NAVD88. Photos showing the typical conditions are provided in Figure 10 and Figure 11.

The engineered rock revetment makes up the rest of Reach IBSP-R1 and Reach IBSP-R3. Its top elevation is at +9 to +10 feet NAVD88. The revetment is under laid with filter fabric. In some areas large portions of rock are missing and the filter fabric is exposed. In Reach IBSP-R3 there is a small sandy slope in between two sections of the revetment where storm water from the parking lot discharges to the Bay. Photos showing the typical conditions are provided in Figure 11.

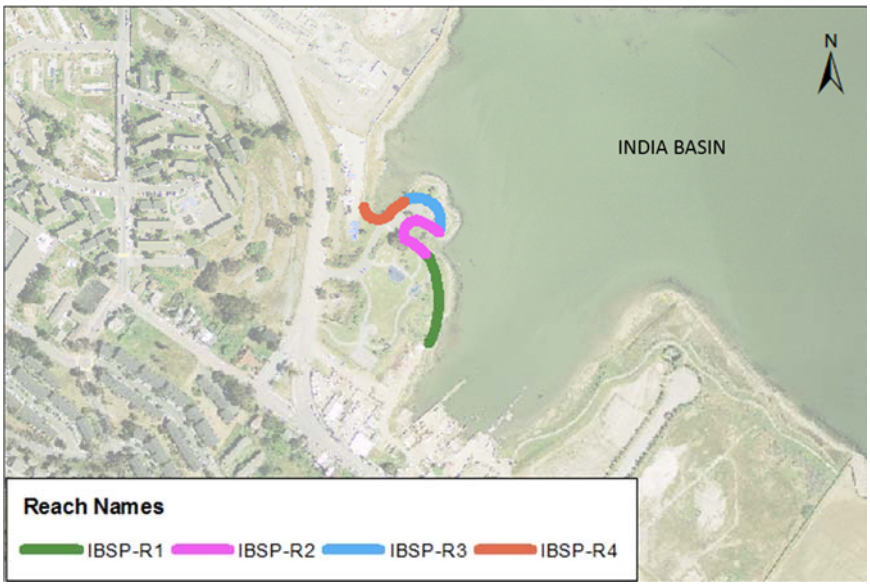

Figure 9: India Basin Shoreline Park Reach Definition Sketch

Figure 10: Typical Conditions Along Reach IBSP-R1 (left) and Reach IBSP-R4 (right)

Figure 11: Typical Condtions Along Reach IBSP-R2 (left) and IBSP-R3 (right)

2.4 PG&E SHORELINE TRAIL

The PG&E Shoreline Trail property extends from the India Basin Shoreline Park at the south to Heron's Head Park at the north. The property is divided into four reaches as shown in Figure 12. This shoreline is characterized by embankments either vegetated or covered in rock and concrete debris. The top of bank along the shoreline ranges in elevation from +12' to +19 feet NAVD88. Erosion of the embankment exists along the majority of this shoreline.

Reaches PGE-R1 and PGE-R3 are composed of the vegetated embankments fronted by sandy beaches and small scattered rock and concrete debris while in Reach PGE-R2 and PGE-R4 the vegetated slopes have large slabs of concrete randomly placed on slope. At the northern end of Reach PGE-R4 there is a stretch of bulkhead wall adjacent to the PG&E power plant site. Photos of the typical shoreline conditions are presented in Figure 13.

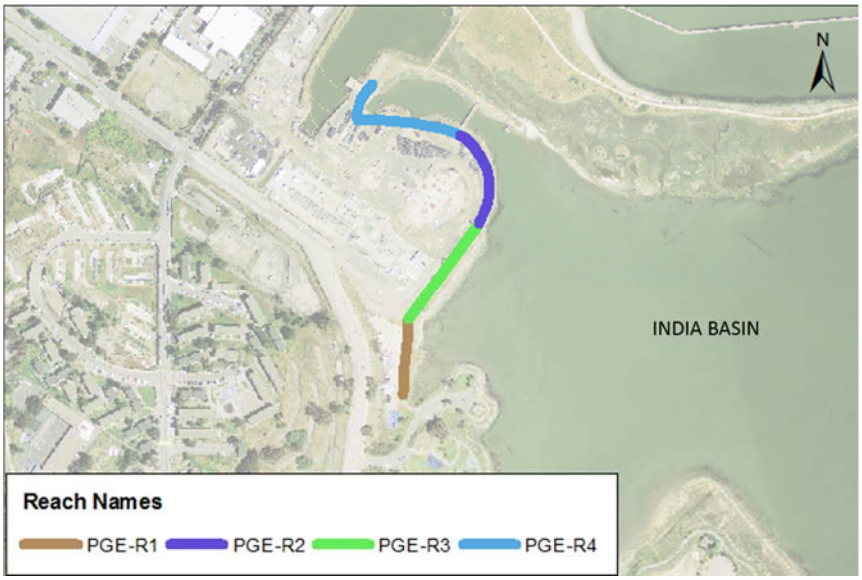

Figure 12: PG&E Shoreline Trail Reach Definition Sketch

Figure 13: Typical Conditions Along Reach PGE-R1, R2 (left) and Reach PGE-R3, R4 (right)

2.5 HERON'S HEAD PARK

Heron's Head Park extends from PG&E Shoreline Trail at the south power to the northern limit of Heron's Head Park at Pier 98. The property is divided in 3 reaches as shown in Figure 14. The shoreline along Heron's Head Park consists of vegetated embankment, tidal marsh and rock revetments. The top of bank along the shoreline ranges in elevation from +10 to +15 feet NAVD88.

Reach Heron-R1 is composed of a vegetated embankment fronted by shell beaches, small rock and concrete debris. Erosion was noted along most of the vegetated embankment. At the western limit of the reach there is a small area of rock revetment which protects and overlook structure. Reach Heron-2 is primarily tidal marsh. Photos of the typical shoreline condition is provided in Figure 15.

At the eastern limit of Reach Heron-R2 and all of Heron-R3 the shoreline is composed of scattered rock on the foreshore slope and rock placed on the upper portion of the shoreline which acts as scour protection. Photos of the typical shoreline condition are provided in Figure 16.

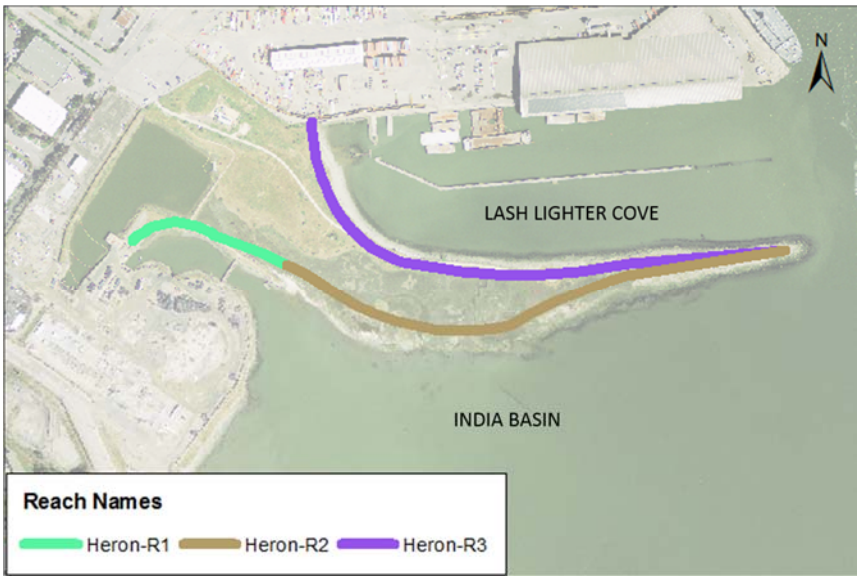

Figure 14: Heron's Head Park Reach Definition Sketch

Figure 15: Typical Condtions Along Reach Heron-R1 and Western Portion of Heron-R2

Figure 16: Typical Condtions Along Reach Heron-R2 (left) and Reach Heron-R3 (right)

3. ENVIRONMENTAL CONDITIONS

3.1 BATHYMETRY AND WATER LEVELS

3.1.1 Tides

Water levels at the project site are dominated by a mixed semi-diurnal tide, which has two unequal highs and lows each day. Tidal datum elevations in the project vicinity were obtained from the National Oceanic and Atmospheric Administration (NOAA) long-term station at Alameda, CA (#9414750). Tidal elevations are summarized in Table 1.

Table 1: Tidal Datums Alameda, CA

	MLLW (feet)	NAVD88 (feet)	CCSF (feet)
City and county of San Francisco Datum (CCSF)	11.4	11.1	0.0
Highest Observed Water Level (12/03/1983)	9.65	9.42	-1.7
Mean Higher High Water	6.59	6.37	-4.8
Mean High Water	5.97	5.75	-5.4
Mean Tide Level	3.55	3.32	-7.8
Mean Low Water	1.13	0.90	-10.2
North American Vertical Datum 1983	0.23	0.00	-11.1
Mean Lower Low Water	0.00	-0.23	-11.4
Lowest Observed Water Level (01/11/2009)	-2.57	-2.80	-13.9

The water levels shown in Table 1 represent the Still Water Level (SWL), which include astronomical tide, storm surge, and tsunamis over the period of observation. It represents a *static water level* that persists for a prolonged period (several minutes to hours at a time). Embankments which are exceeded by the SWL elevation constitute an inundation or large-scale flooding.

3.1.2 Existing Bathymetry

Meridian Surveying conducted a hydrographic survey of India Basin and Lash Lighter Cove between May 12 and May 19, 2015. Figure 17 provides a map of the surveyed bathymetry. Generally, within India Basin, elevations immediately offshore vary between 0 and -3 feet NAVD88, except for the eastern portion of Heron's Head Park which has elevations between -4 and -10 feet NAVD88. Within Lash Lighter Cove elevations immediately offshore generally range between -3 and -4 feet NAVD88.

Within India Basin elevations shallower than -2 feet NAVD88 and flat slopes extend for distances of greater than 200 feet offshore for the majority of the India Basin except along reach 700-R1, IBSP-R3, PGE-R3, and Heron-R-2 in these areas elevations of -2 to -3 feet NAVD88 or deeper are noted within 50-100 feet of the shoreline.

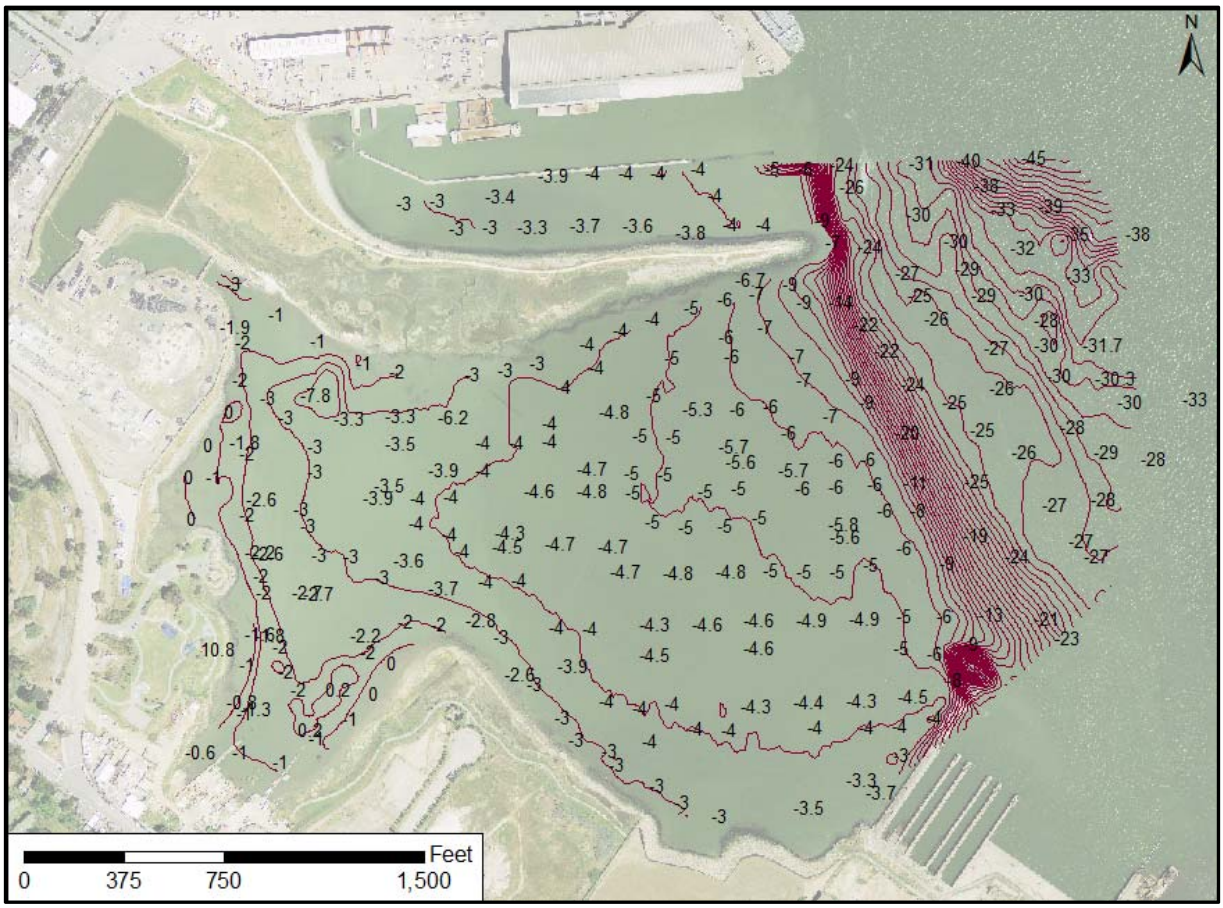

Figure 17: Bathymetric Survey Data 2015 (NAVD88, Feet)

3.1.3 Flood Elevations

FEMA has yet to publish, as of the time of this report, a flood map for the City and County of San Francisco. Preliminary estimates provided by FEMA based on the work of BakerAECOM (2012) indicate that the 100-year Base Flood Elevation (BFE) varies within India Basin and Lash Lighter Cove.

Table 2 provides a breakdown by property and shoreline reach.

Table 2: Preliminary FEMA Flood Elevations

Property	Reach	Preliminary FEMA Flood Elevation (feet, NAVD88)
700 Innes Ave	700-R1	12
	700-R2	10
900 Innes Ave	900-R1	10
	900-R2	
India Basin Shoreline Park	IBSP-R1	10
	IBSP-R2	
	IBSP-R3	
	IBSP-4	

Property	Reach	Preliminary FEMA Flood Elevation (feet, NAVD88)
PG&E Shoreline Trail	PGE-R1	10
	PGE-R2	13
	PGE-R3	
	PGE-R4	10
Heron's Head Park	Heron-R1	10
	Heron-R2	
	Heron-R3	

3.1.4 Sea Level Rise

In March 2013, the Sea-Level Rise Task Force of the Coastal and Ocean Working Group of the California Climate Action Team (CO-CAT) released their State of California Sea-Level Rise Guidance Document based on the National Academy of Sciences (NAS) Report Sea-Level Rise for the Coasts of California, Oregon, and Washington. The NAS document contains sea level rise projections for the years 2030, 2050, and 2100 relative to year 2000. CO-CAT recommends the use of these projections for the planning of waterfront projects and that sea level rise values for planning be selected based on risk tolerance and adaptive capacity. This guidance has been largely adopted by state agencies including the Bay Conservation and Development Commission (BCDC) in formulating their policies for adaptation to sea level rise.

Table 3 summarizes the sea level rise (SLR) projections, including the low and high range values, for the San Francisco Bay area provided in NAS (2012).

Table 3 Sea Level Rise Projections for San Francisco, California (feet)

Time Period	Low	Projected	High
2000-2030	0.14	0.47	0.97
2000-2050	0.40	0.92	1.99
2000-2100	1.39	3.02	5.46

3.2 WIND

Wind data for the India Basin and Lash Lighter Cove area was collected from Alameda, CA, approximately 4.5 miles east of the project site. Wind data measured at Alameda was selected as it is representative of conditions over the central bay. The Alameda wind gage provides hourly observations of wind speed and direction since 1945.

Annual and seasonal wind roses based from Alameda, CA are provided in Figure 18 and Figure 19. The annual wind rose shows that winds are predominately from the west. The seasonal roses show that there is some variation in predominant wind direction throughout the year. The winter and fall wind roses exhibit increased frequency of winds from the north, northeast, southeast and south associated with winter storms while the spring and summer are similar to the annual conditions.

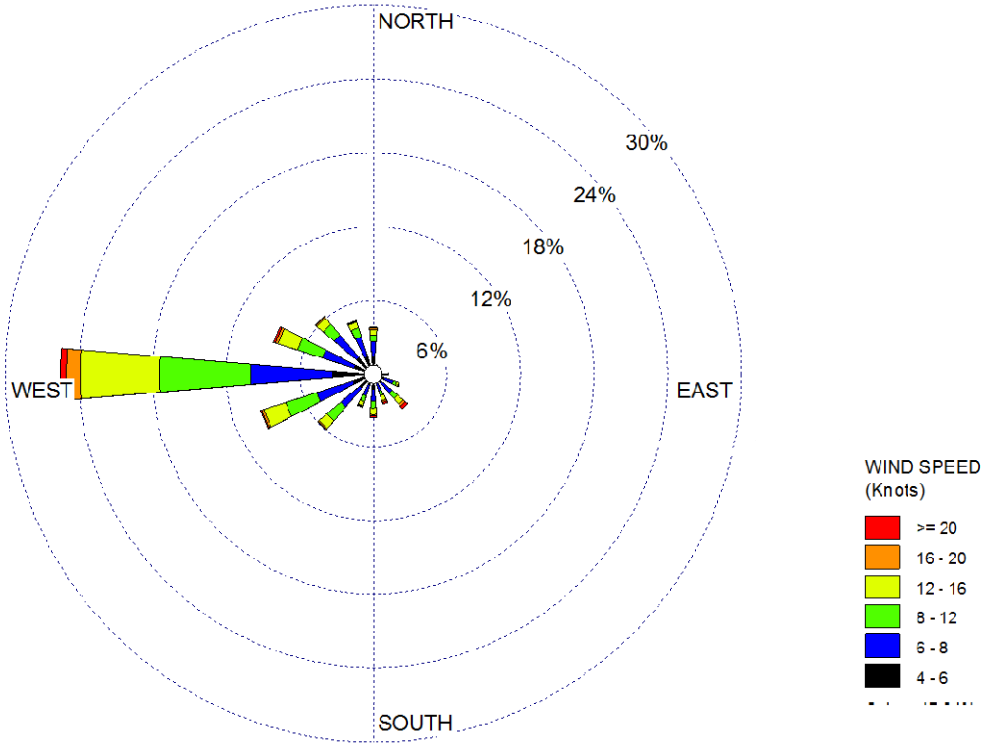

Figure 18: Annual Wind Rose Alameda, CA

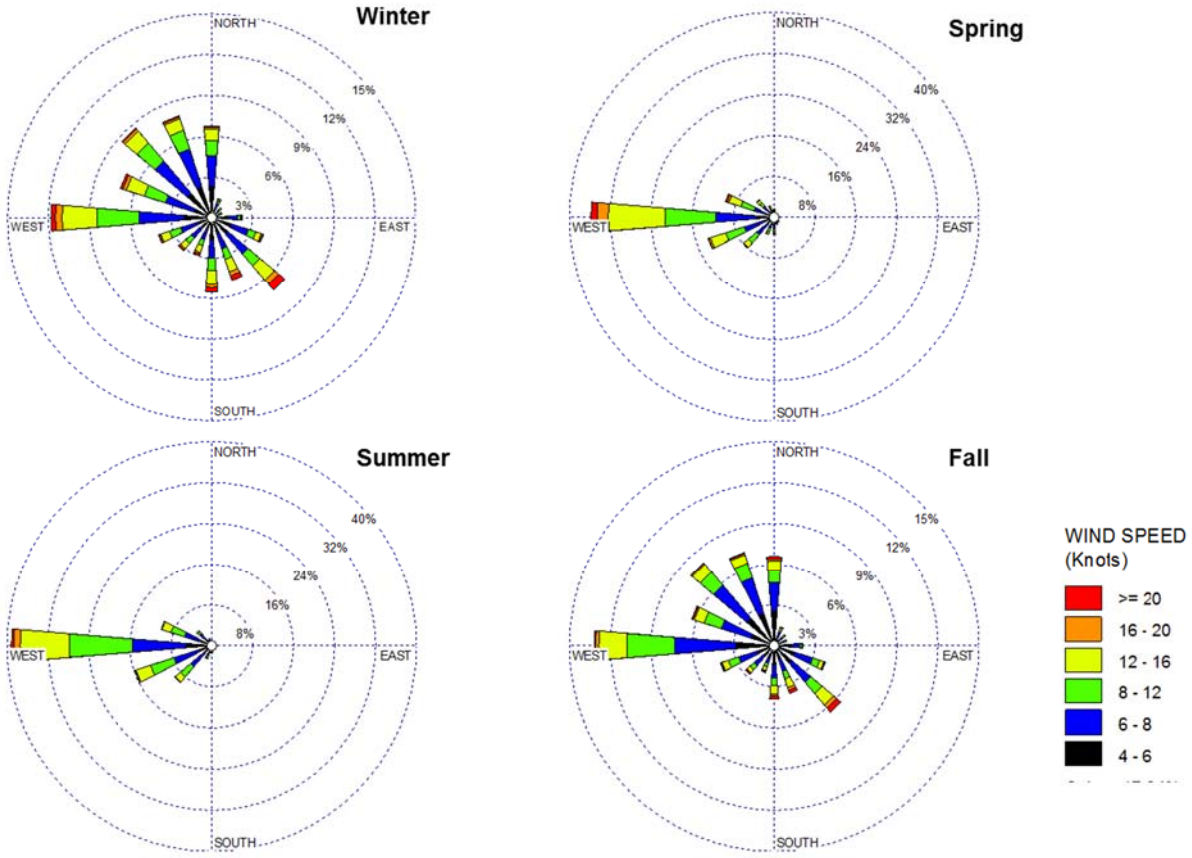

Figure 19: Seasonal Wind Roses Alameda, CA

Prevailing wind conditions give an idea of daily and seasonal conditions, while extreme wind information can be used to determine design conditions for wind waves. For India Basin and Lash Lighter Cove winds from the north through southeast are of primary concern for wind wave development. Extremal analysis was undertaken based on the selection of annual maximum winds for the 68 year record of observations, from 1945 to 2013. The Generalized Extreme Value Distribution using the maximum likelihood approach providing the best fit to the data was selected. Table 4 shows the wind speed return period values at Alameda for the north, northeast, east, and southeast directions.

Table 4: Return Period Wind Speeds (Alameda, 2-min average knots, 1945-2013 period)

Return Period (years)	Wind Speed at 10 m Standard Elevation (knots)			
	N	NE	E	SE
2	23.9	18.2	15.2	28.6
5	28.4	22.5	19.7	34.1
10	31.0	25.0	23.0	37.2
25	33.9	27.7	27.4	40.6
50	35.8	29.5	31.0	42.9
100	37.5	31.1	34.8	45.0

3.3 WIND WAVES

Wind waves within India Basin and Lash Lighter Cove were analyzed using the Mike 21-spectral wave (SW) model. The model simulates both the growth of waves due to wind stress and wave transformation in the nearshore environment due to shoaling, refraction, and diffraction. The model calculates both direction and frequency spectral wave parameters over a flexible mesh computational grid. This allows for the use of high-resolution model bathymetry at the shoreline and in the nearshore areas of the project site while remaining computationally efficient.

The model domain was chosen to cover all areas of the San Francisco Bay where wind generated waves could eventual propagate towards the shoreline of India Basin and Lash Lighter Cove. Figure 20 shows the extent of the model domain, which encompasses all of the Central and South Bay and excludes areas outside of the Golden Gate and north of Point Richmond. Bathymetry for the model was compiled from the NOAA Estuarine Bathymetry data set for the San Francisco Bay, available USGS Lidar Data (USGS 2011) and the recently completed hydrographic survey of India Basin and Lash Lighter Cove by Meridian Surveying. Figure 20 shows the model bathymetry for the entire domain and Figure 21 shows the model bathymetry of India Basin and Lash Lighter Cove.

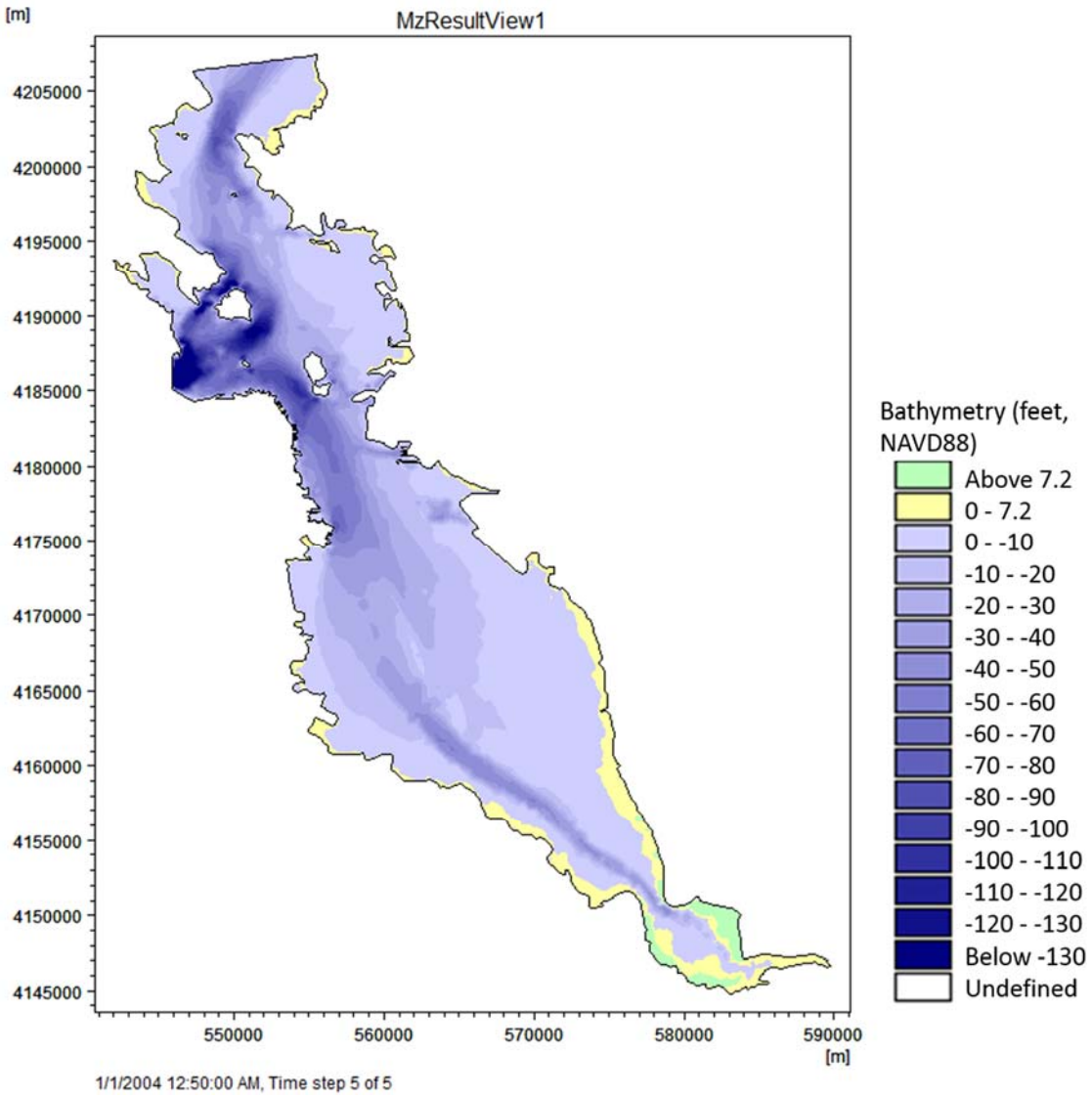

Figure 20: MIKE 21 Spectral Wave Model Mesh Extent

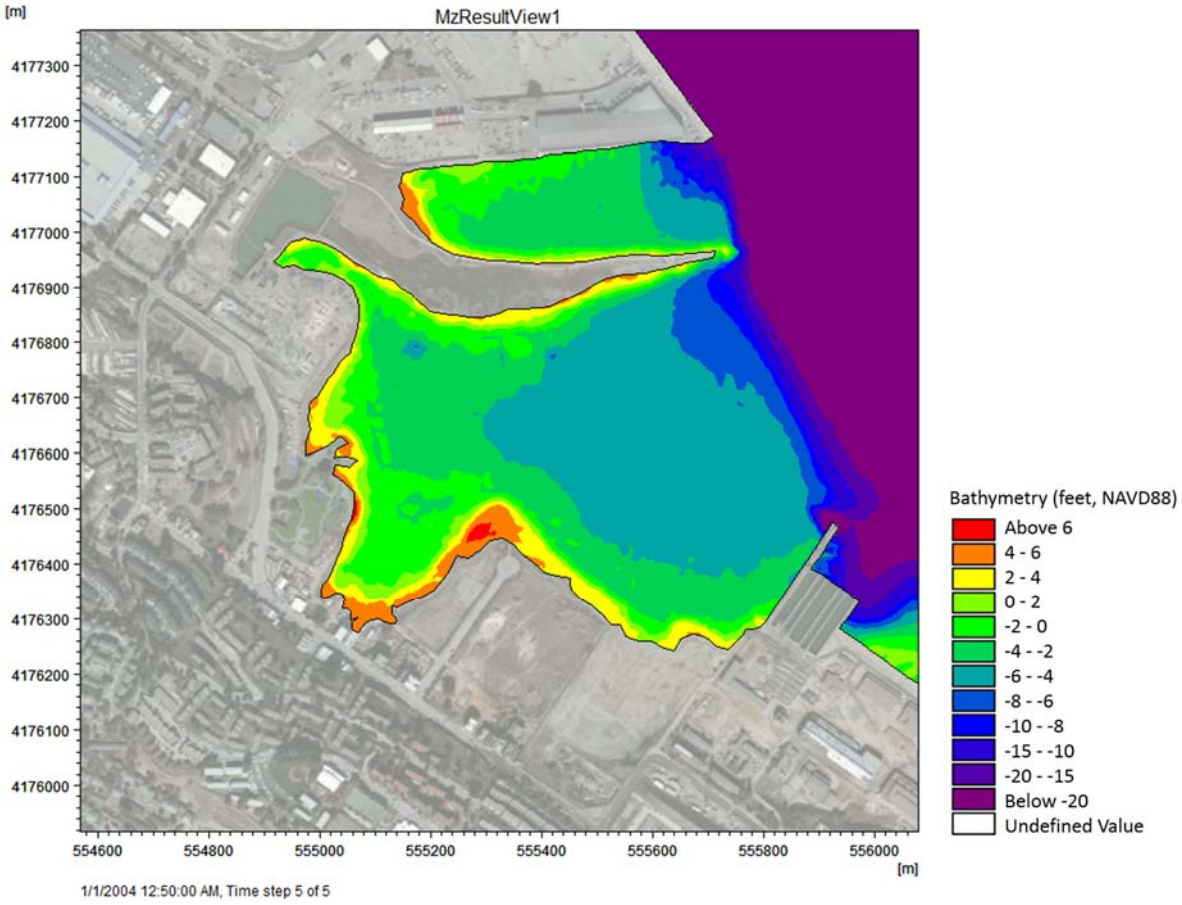

Figure 21: Mike 21 SW Model Project Vicinity Bathymetry

Wind wave analysis was conducted for 2-, 5-, 10-, 25- and 50-year return period wind events for the north, northeast, east and southeast directions. Each model run assumed a water surface elevation of Mean Higher High Water (MHHW). Wind wave results were extracted from the locations presented in Figure 22. Maximum significant wave heights, provided in Table 5, along each shoreline reach were selected to illustrate how the wave heights can vary along the shoreline of India Basin and Lash Lighter Cove. Sample model outputs for the 2-year and 50-year return period events are presented in Figure 23 to Figure 26 for all four directions.

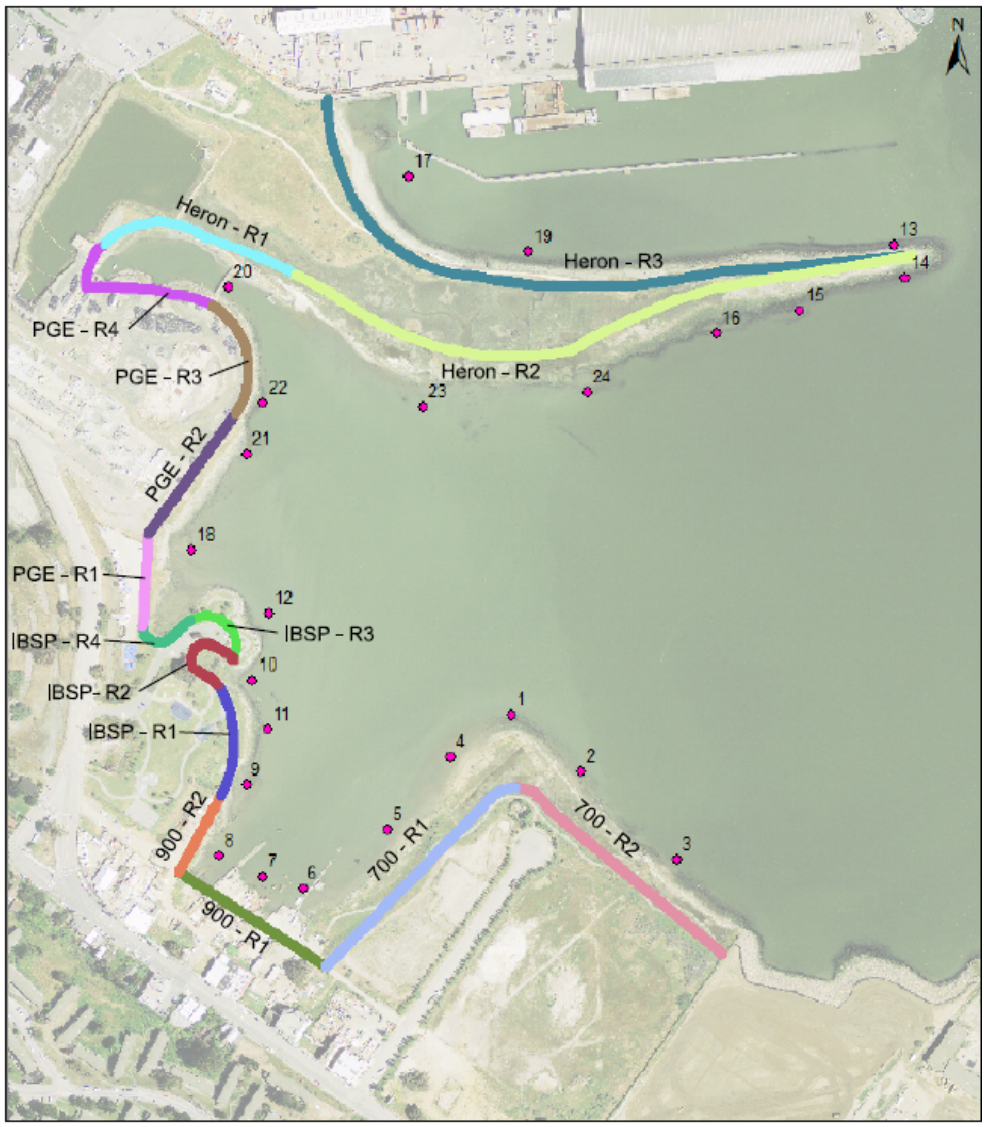

Figure 22: Wind Wave Model Extract Locations

Table 5: Wave Heights at various locations within India Basin and Lash Lighter Cove (feet)

Property	Reach	Wave Height (feet)		
		2-yr	10-yr	50-yr
700 Innes Ave	700-R1	1.3	2.2	2.7
	700-R2	0.6	0.9	1.1
900 Innes Ave	900-R1	0.4	0.7	1.0
	900-R2	0.7	1.2	1.5
India Basin Shoreline Park	IBSP-R1	1.0	1.7	2.1
	IBSP-R2	1.2	1.9	2.3
	IBSP-R3	1.4	2.2	2.7
	IBSP-R4	1.3	2.1	2.5
PG&E Shoreline Trail	PGE-R1	1.3	2.1	2.5
	PGE-R2	1.2	2.0	2.4
	PGE-R3	1.1	1.8	2.3
	PGE-R4	0.9	0.9	1.5
Heron's Head Park	Heron-R1	0.9	0.9	1.5
	Heron-R2	1.2-2.9	2.4-4.5	2.9-5.5
	Heron-R3	2-1.3	3-1.6	3.7-1.9

In general, wave heights within both India Basin and Lash Lighter Cove are significantly reduced compared to waves within the main portion of San Francisco Bay. For the 2-yr return period wave event wave heights along the majority of the India Basin shoreline are around 1 to 1.4 feet in height while for a design level event (50-year return period) wave heights are generally between 2.0 and 2.7 feet. The area offshore of 900 Innes avenue and reach 700-R2 exhibit wave heights less than 1.0 feet for the 2-year event and less than 1.5 feet for the design level event. The shoreline of Heron's Head Park in both India Basin and Lash Lighter Cove is the most exposed portion of shoreline.

For the shoreline of Heron's Head Park within India Basin, Reach Heron-R2, wave heights range from 1.2 to 2.9 feet for the 2-year event while under the design event wave heights range from 2.9 to 5.5 feet, moving from the more protected western portion to the more exposed eastern end. In Lash Lighter Cove, Reach Heron-R3, wave heights range from 1.3 to 2 feet for the 2-year event and 1.9 to 3.7 feet under the design level event, moving from the more protected western portion to the more exposed eastern end.

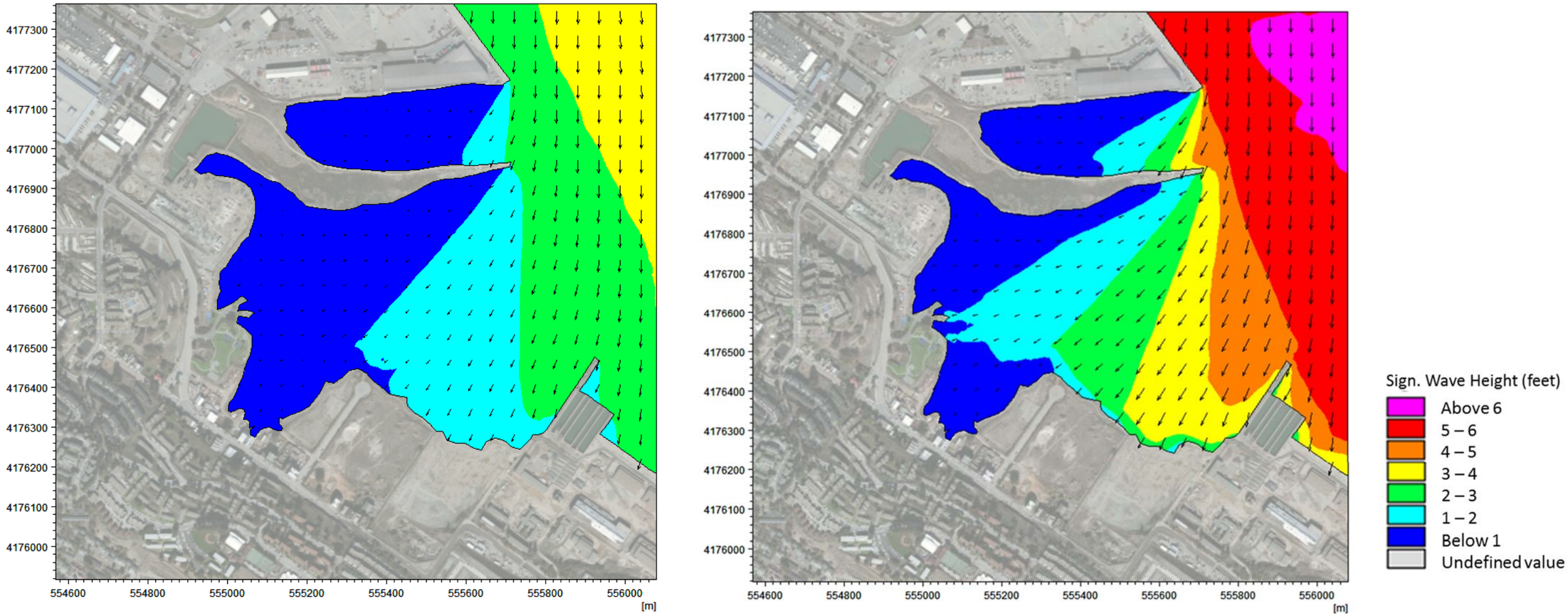

Figure 23: Wind Wave Results North Winds, 2-Year Return Period (left), 50-Year return Period (right)

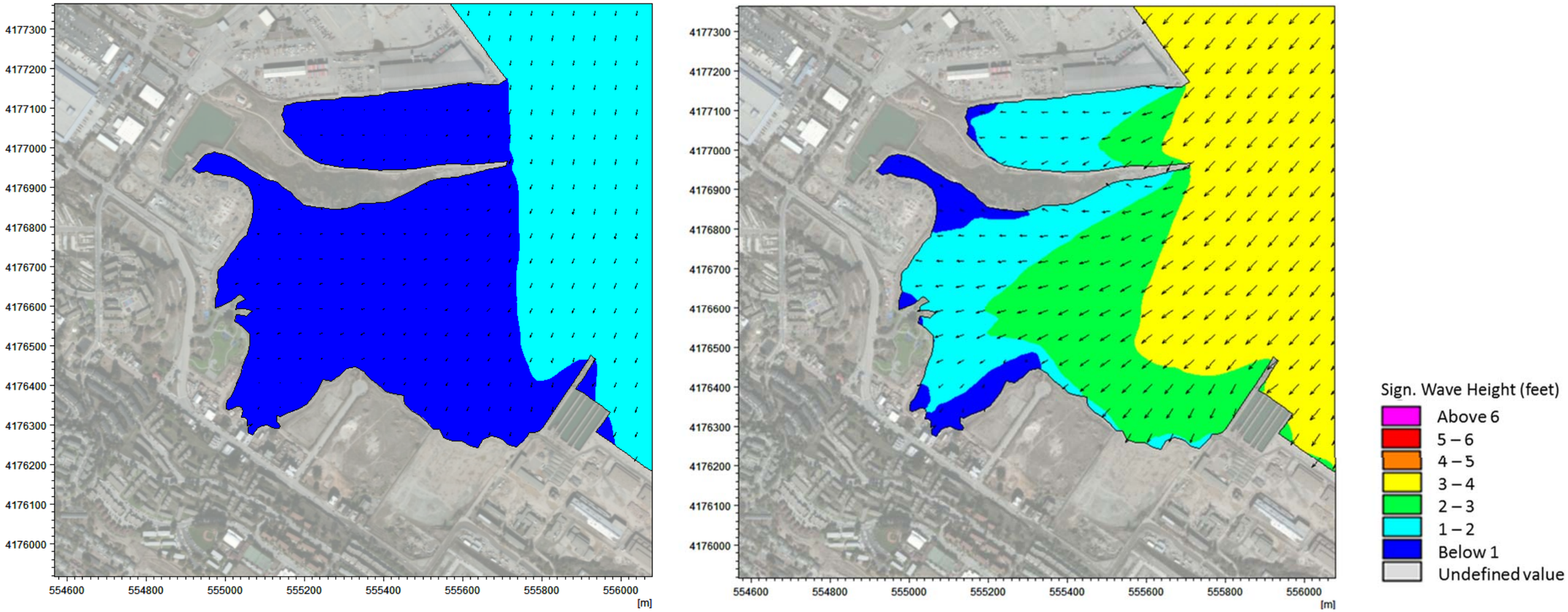

Figure 24: Wind Wave Results Northeast Winds, 2-Year Return Period (left), 50-Year return Period (right)

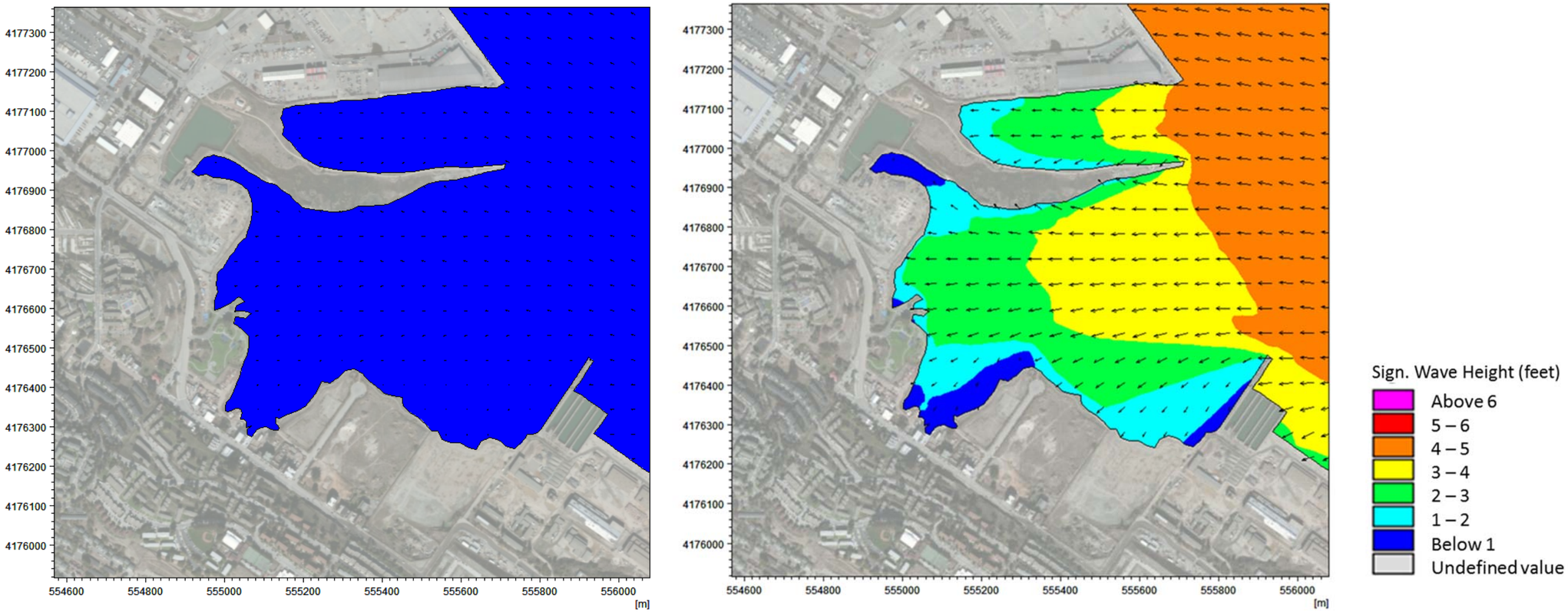

Figure 25: Wind Wave Results East Winds, 2-Year Return Period (left), 50-Year return Period (right)

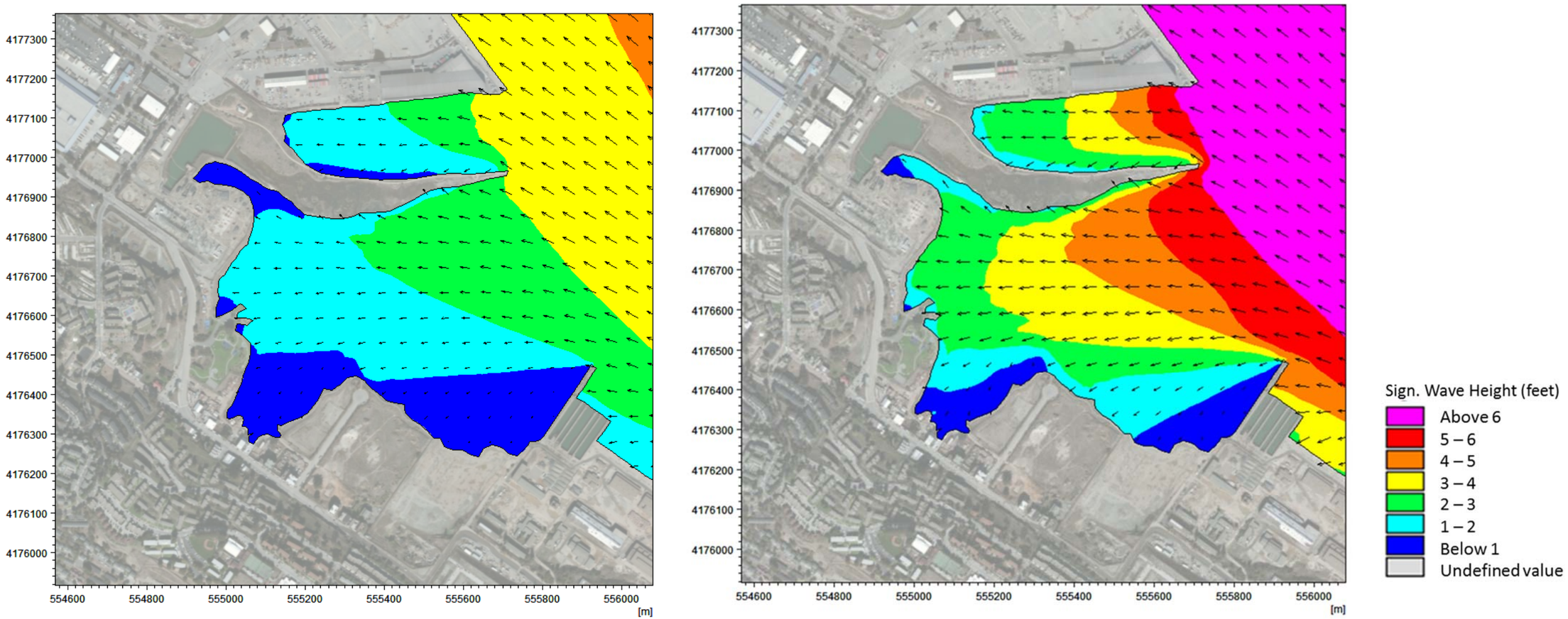

Figure 26: Wind Wave Results Southeast Winds, 2-Year Return Period (left), 50-Year return Period (right)

4. SEDIMENT TRANSPORT

4.1 BATHYMETRIC ANALYSIS

Evaluation of long-term changes within India Basin and Lash Lighter Cove was completed through a comparison of bathymetric surveys. The following bathymetric surveys were utilized in this analysis:

- US Coast and Geodetic hydrographic surveys obtained from NOAA for the years 1942, 1954, 1979, and 1981
- Meridian Surveying hydrographic survey 2015

The 1942, 1954 and 2015 surveys provided good coverage of the entire basin area. The 1979 survey covered the southern half of India Basin while the 1981 survey covered Lash Lighter Cove and the northern half of India Basin. Overtime, significant filling into the bay has taken place to create India Basin and Lash Lighter Cove as they are today. A review of historic aerial photography indicates that the 700 Innes Ave site was constructed through filling of the Bay around 1968 and that filling for the construction of Pier 98 and Heron's Head Park was completed in 1977 (BCDC 1993, PORT 1993, and PORT 1994).

The historic surveys from 1945 and 1954 indicate that the area has historically been shallow. Significant shoaling has occurred well offshore of the present shorelines of 700 Innes Ave, 900 Innes Ave and India Basin Shoreline Park in response to the construction of Pier 98 and Heron's Head Park. The nearshore areas of India Basin Shoreline Park, 900 Innes Ave and Reach 700-R2 of 700 Innes Ave have shoaled 1-2 feet since 1954 and the nearshore area of Reach 700-R1 of 700 Innes Ave has shoaled 3-4 feet.

A comparison of the bathymetric surveys between 1954 and 2015 was used to estimate historic long-term shoaling rates. The 1954 and 2015 surveys were selected as they provided the most complete coverage of the existing basins. The results of this comparison in inches per year are presented in Figure 27. In general, long term shoaling rates in the majority of India Basin range between 0-2 inches/year, while within Lash Lighter Cove long-term shoaling rates range between 2-4 inches/year. The higher shoaling rate in the offshore portion of India Basin represents expansion of the shallow mudflats towards deeper water. Isolated locations which were above present day elevations in 1954 have very slowly eroded over time, light blue locations in Figure 27, to present day elevations of around -1 feet NAVD88.

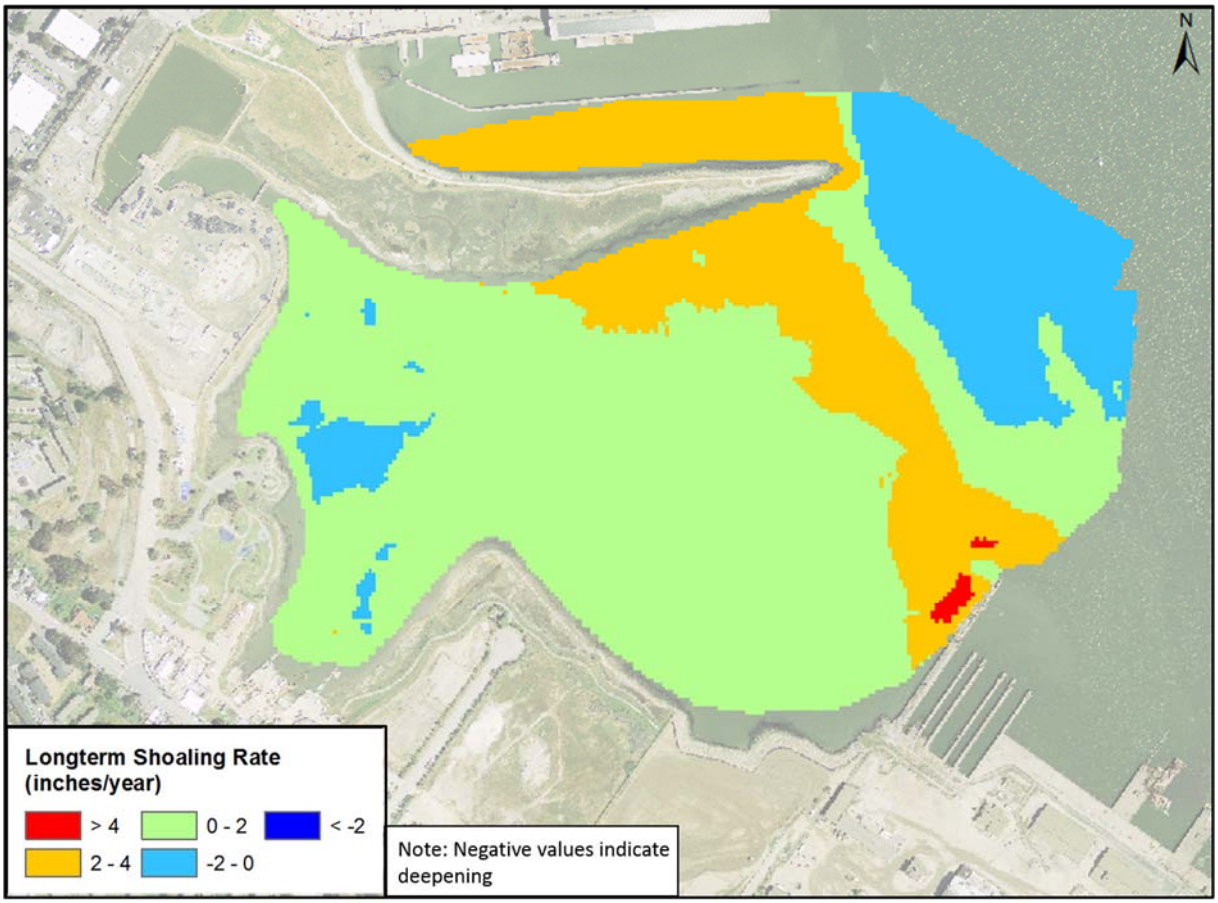

Figure 27: Long-term Shoaling Rates (1954-2015)

A comparison of the 1981/1979 surveys to the 2015 survey provides some information regarding how the basin may respond to increases in elevation as well as deepening. The 1979/1981 surveys show the conditions of the basin just after the end of filling operations at Heron's Head Park and Pier 98. Figure 28 shows the deep areas which have significantly filled in (depositional areas) and the high spots which have significantly eroded, erosional areas, significantly to reach present day elevations. The depositional areas were previously dredged 16 to 18 feet deeper than present day elevations while the erosional areas around Heron's Head Park were 3-6 feet higher.

The depositional areas filled in at a rate of 3-8 inches per year with the deeper locations filling at a higher rate than shallower areas. Erosional areas deepened at a rate of 1-3 inches/year with higher areas eroding faster than location which were closer to adjacent elevations. As these locations were equilibrating to the surrounding depth, the adjacent areas exhibited sedimentation rates similar to the long-term rates discussed earlier.

Future sedimentation in both India Basin and Lash Lighter Cove can be expected to continue at a rate in line with the long-term rates of 0-2 inches/year for the shallow areas and 2-4 inches/year for the deeper portions further offshore, dependent on the availability of sediment. Sediment supply within the San Francisco Bay has greatly reduced in recent decades so future sedimentation rates are likely on the low end of this range.

Increasing depths significantly in India basin for a dredge channel can be anticipated to fill in at a rate of 3-8 inches/year depending on the depth of dredging while significant increases in elevations will likely eroded at a rate of 1-3 inches per year depending on exposure to wave action.

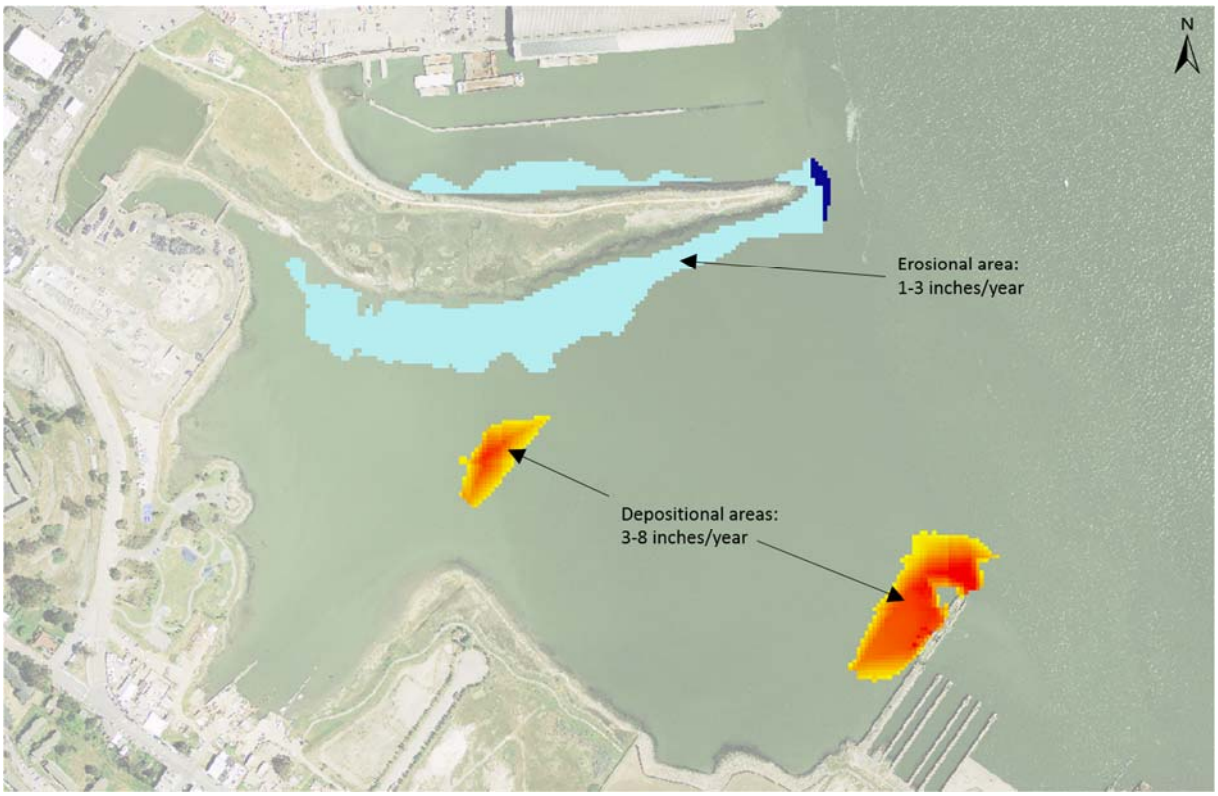

Figure 28: Erosional and Depositional Areas since 1979/1981

4.2 WAVE AND TIDAL CURRENT CLIMATE

4.2.1 Wave Driven Transport Potential

Wave driven transport occurs when breaking waves cause sediment to be suspended into the water column which are then transported by the resultant wave induced currents. The overall direction of this transport is a result of the predominant wave direction and the orientation of the shoreline. Due to the varied shoreline orientation and predominant wave direction within India Basin and Lash Lighter Cove the wave driven transport of sediment will also vary.

The predominant wave direction for the India Basin Shoreline and Lash Lighter Cove are:

- Northeast - 700 Innes Ave, 900 Innes Ave, and the north shoreline of Heron's Head Park(Reach Heron-R3)
- East - India Basin Shoreline Park and the PG&E Shoreline
- Southeast - south shoreline of Heron's Head Park (Reach Heron-R2)

Based on the predominant wave direction and shoreline orientations the overall wave driven sediment transport directions are shown in Figure 29. Generally, wave driven

sediment transport moves available sediment into the northwest corner of Lash Lighter Cove, the basin between Heron's Head Park and the PG&E Shoreline Trail, the cove at the northern limit of India Basin Shoreline Park, and towards 900 Innes Avenue. Reach IBSP-R3 has a mixed transport direction indicated by the dashed line with two arrows. This means that available sediment here can be transported in either direction due to the varied orientation of the shoreline and moderate wave exposure.

These patterns indicate where sediment introduced into India Basin and Lash Lighter Cove is likely to be transported unless measures are taken to stabilize or contain them.

Figure 29: Overall Wave Driven Sediment Transport Patterns

4.2.2 Tidal Current Transport Potential

Tidal current patterns were developed from a Mike 21 Flexible Mesh Hydrodynamic Model. A two week tidal series which covered a spring-neap tidal cycle was simulated. As no calibration data is available for India Basin or Lash Lighter Cove the results were utilized to understand the general directions which tidal currents propagated. A general pattern of tidal ebb and flood currents is presented in Figure 30.

Flood currents are generally shore perpendicular along 900 Innes Ave, India Basin Shoreline Park and PG&E Shoreline Trail while shore parallel for 700 Innes Ave and Heron's Head Park. Ebb Tides are a reversal of the flood currents and have been found to typically be stronger than flood currents in San Francisco Bay. Tidal currents typically carry suspended sediments on flood tide and deposit sediment during high tide when tidal currents are at their weakest.

The shore perpendicular flood currents will likely deposit suspended sediments along the shorelines of 900 Innes Ave, India Basin Shoreline Park, and the PG&E Shoreline Trail. The shore parallel currents along Heron's Head Park and 700 Innes Avenue will transport suspended sediment towards the northwest corner of Lash Lighter Cove, the basin between Heron's Head Park and the PG&E Shoreline Trail and towards 900 Innes Ave.

Figure 30: Flood and Ebb Current Patterns

4.3 BASIN WIDE SEDIMENT TRANSPORT

Under combined wave and tidal current action sediment deposited within India Basin will be transported toward the cove between the PG&E Shoreline Trail and Heron's Head Park, the cove at the northern end of India Basin Shoreline Park, or 900 Innes Ave. Within Lash Lighter Cove deposited sediment will be transported toward the northeast corner of the basin. As a result of these transport processes extensive mudflats have developed at the northern end of India Basin Shoreline Park and 900 Innes Ave while deeper depths are found closer to shore along Reach 700-R2, IBSP-R3 and PGE-R3.

5. SHORELINE IMPROVEMENT OPTIONS

This section discusses the typical coastal processes which various types of shoreline improvements perform best. Shoreline improvement options have been broken down into four general types:

- Beaches
- Hardened Shorelines
- Living Shorelines
- Human powered boat access

Beaches

Beaches can provide many different types of recreational uses and also serve as a flood protection mechanism. The stability and long-term performance of a beach is dependent on the wave environment and wave driven sediment transport along the shoreline. Sea level rise will also impact the long-term use of the beach.

Beaches can function in a variety of wave environments. Typically, desirable areas will have prevailing wave conditions that prevent fine sediments such as muds from settling but design events that are low enough that severe damage is not caused. Wave driven sediment transport plays a significant role in the function of a beach over time. Typically desirable conditions are areas where wave driven sediment transport is in a single direction over long stretches of the shoreline.

Sea level rise over time will cause recession of the beach and movement of sediment offshore. This is can be an important consideration when selecting potential locations for a beach as the movement of this material has the potential to impact other features.

Marshes

For marshes there are many factors which effect their performance, some of the basic conditions include depth, wave environment, sediment transport and response to sea level rise. Marshes which are sometime discussed within in the broader topic of living shorelines can be designed as individual improvements or designed together as a system of improvements, e.g. oyster beds can provide protection to marsh areas from wave action.

Marshes require specific elevations typically above MLLW, a low wave environment and a low sedimentation rate of fine sediment which will allow the marsh to accrete over time in response to sea level rise. Areas where wave driven and tidally driven sediment transport patterns converge from other portions of the shoreline are ideal. If sediments are not available for sedimentation, then marsh areas should have space to retreat in response to sea level rise.

It is worth mentioning that other improvements which fall into the category of living shorelines maybe possible within India Basin and Lash Lighter Cove. However, the factors which impact their performance are related to substrate, water depths, water temperatures, and turbidity and therefore are not discussed further.

Hardened Shorelines

Hardened shorelines, such as rock revetments or bulkheads, serve to stabilize a shoreline from erosion or retain filled areas. While many different types of materials can be used

depending on shoreline slopes, the wave conditions generally drive the usee this type of improvement.

Greater exposure to wave action is typical for hardened shorelines. Hardened shorelines are largely unaffected by sediment transport, unless they project out perpendicular to the shoreline which then creates an impediment to wave driven transport. Sea level rise generally has minor impacts to hardened shorelines, though consideration should be taken in the ability to extend, vertically, the protection provided by the hardened shoreline as sea level rises.

Human Powered Boat Access

Human powered boat access, such as kayak, canoe or standup paddle boarding, are dependent on depths, wave conditions and sediment transport while sea level rise will impact access over time. For the types of boat being considered water depths of at least 2-3 feet are desirable. Wave conditions should be typically low to moderate as launching activities require some protection from wave action. Sedimentation rates need to be low to allow for continued use and access structures, if needed, need to consider direction of wave driven and tidally driven sediment transport as they have the potential to block transport which can effect access as well as the stability of adjacent shorelines.

6. SUMMARY OF FINDINGS

Based on the analysis of coastal processes presented above, various reaches within India Basin and Lash Lighter Cove are considered appropriate for several kinds of improvements: beaches, marshes, hardened structures and human powered boat access. The locations are only based on the coastal process and many other factors will ultimately define the desirability of various improvements throughout India Basin and Lash Lighter Cove.

A brief discussion of the factors that make each reach appropriate for the different shoreline improvements is provided below and maps for each type of improvement are provided in Figure 31 to Figure 34, at the end of this section.

Beaches: These reaches have a moderate wave environment, wave heights ranging from 1-2 feet. This moderate climate allows coarser grained sediment to remain along the shoreline without eroding, while finer materials are removed. Some sort of containment structure, e.g. groin, may be needed prevent coarser grained sediment being transported into adjacent areas where it may not be desirable and reduce the frequency/need for maintenance.

Marshes: These reaches have a low to calm wave environment, 2-year return period wave heights less than 1 feet. Additionally, tidally and wave driven sediment transport processes will naturally bring available sediment to these reaches. Raising of grades will be needed to achieve appropriate elevations for marsh growth.

Human Powered Boat Access: These reaches provide the necessary water depth closest to shore. Some form of access structure, fixed or floating pier, may be necessary depending on if offshore sediments are able to be walked on safely. Dredging of an access channel to other reaches will likely result in rapid filling, 3-8 inches/year, of the channel and frequent maintenance dredging.

Hardened Shorelines: In theory, all reaches could be hardened. However, the reaches indicated are those which have little to no other options for improvement due to the high wave environment, 2-year return period wave heights ranging from 2-3 feet or greater, or very limited space for improvements. In these areas wave runup will be a significant factor for flood protection and sea level rise impacts to public access.

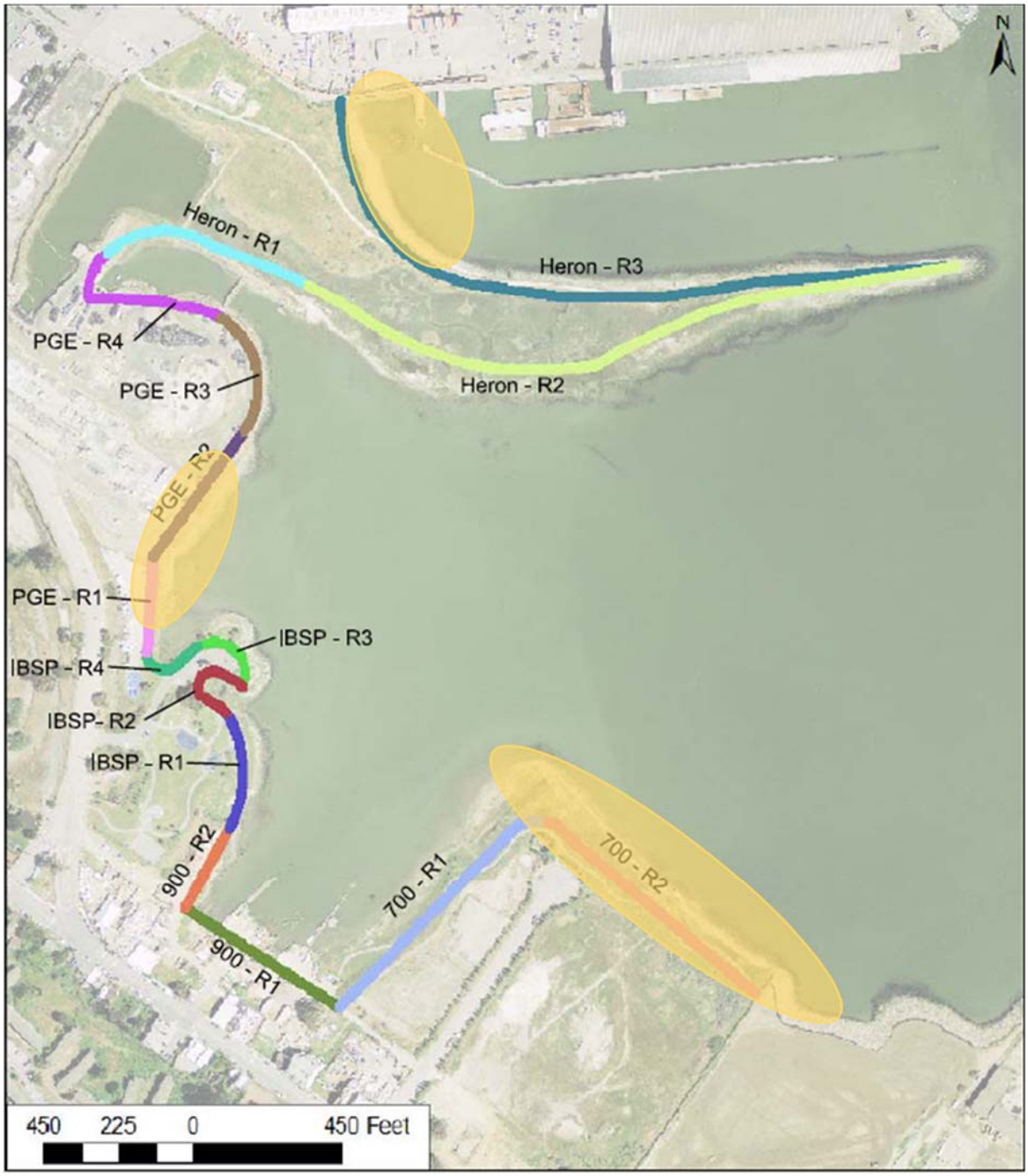

Figure 31: Potential Beach locations

Figure 32: Potential Marsh Locations

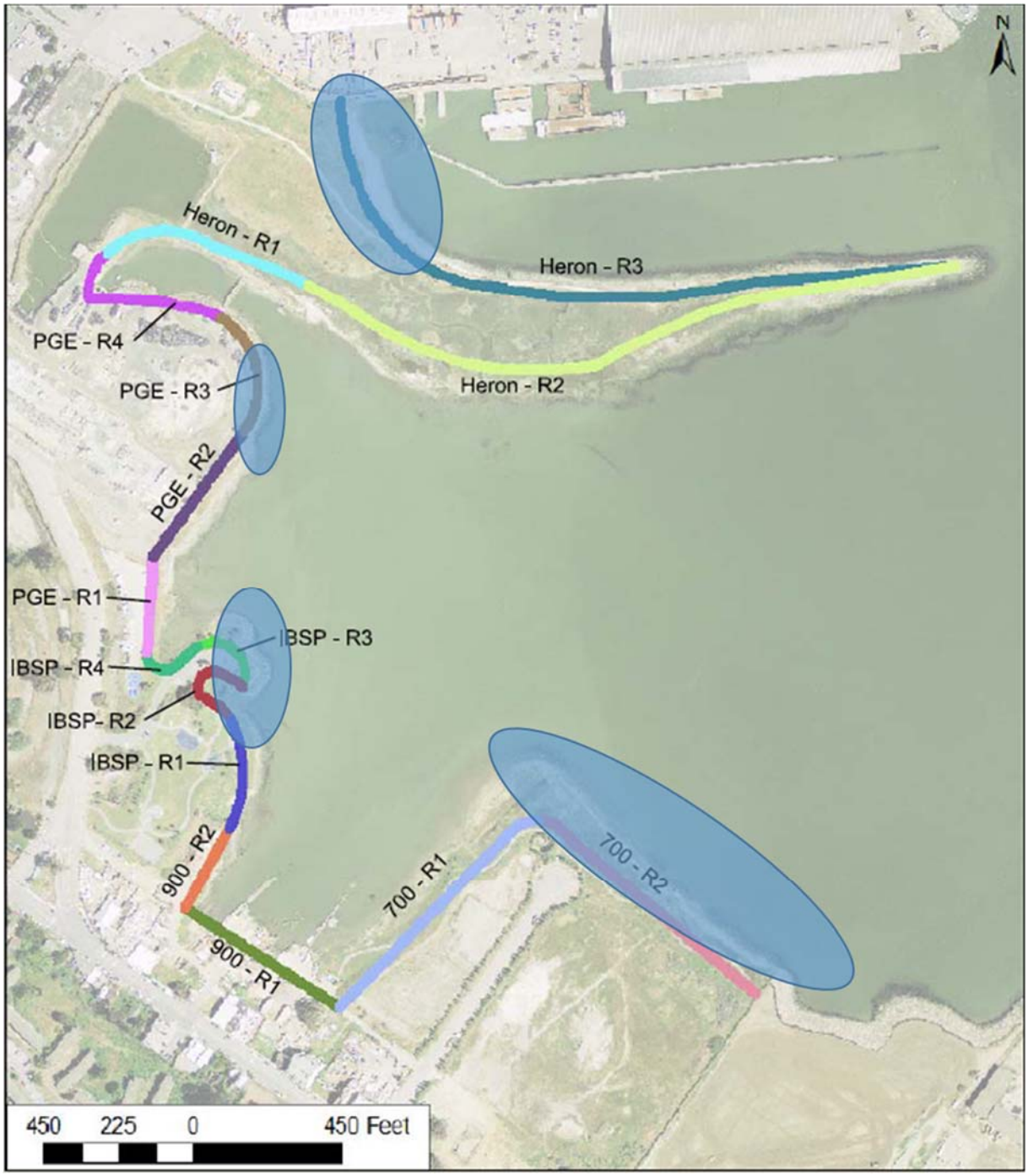

Figure 33: Potential Human Powered Boat Access Location

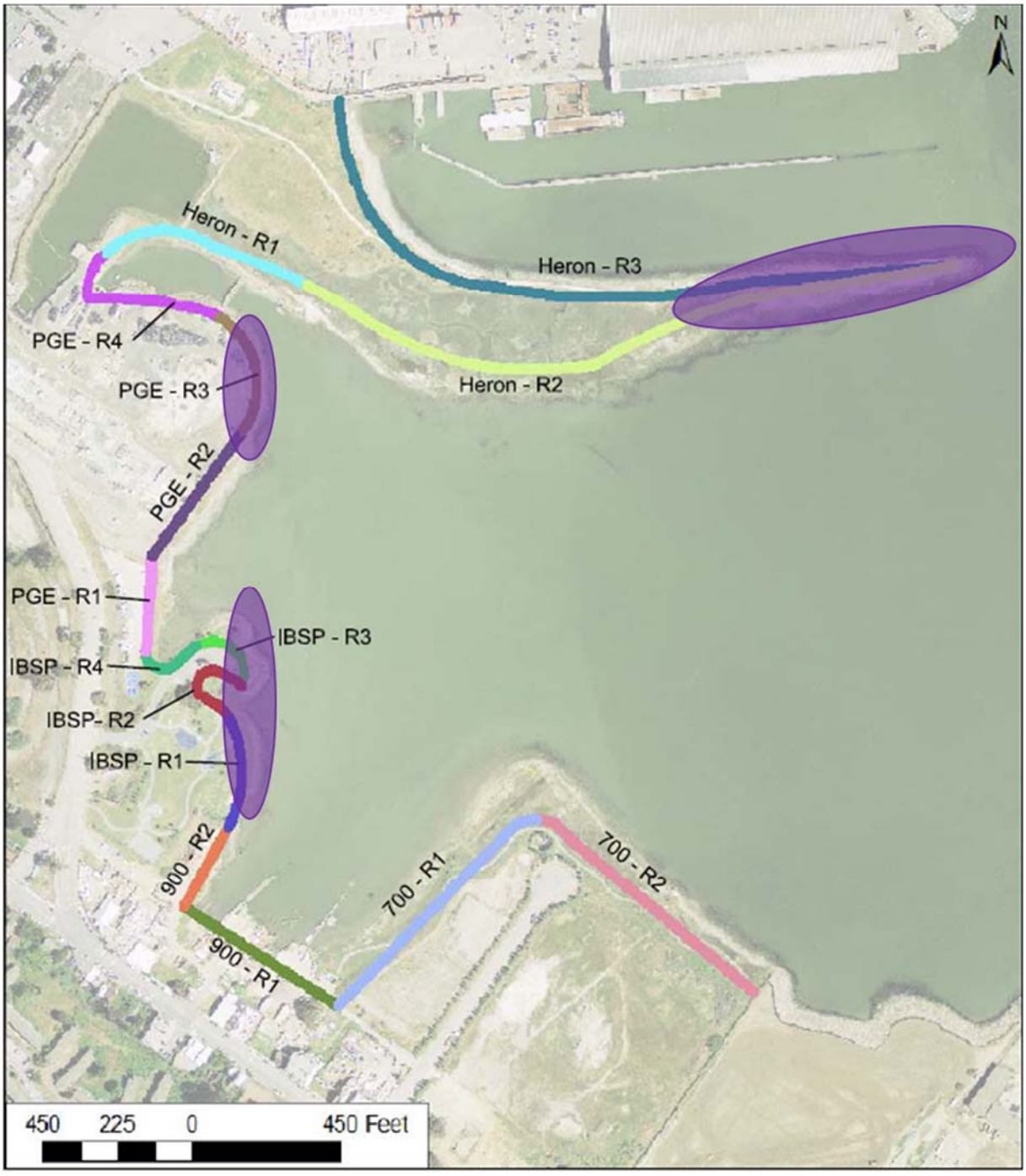

Figure 34: Potential Hardened Shoreline Locations

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APPENDIX A: VISUAL RECONNAISSANCE SURVEY

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India Basin Coastal Processes Study – Appendix A

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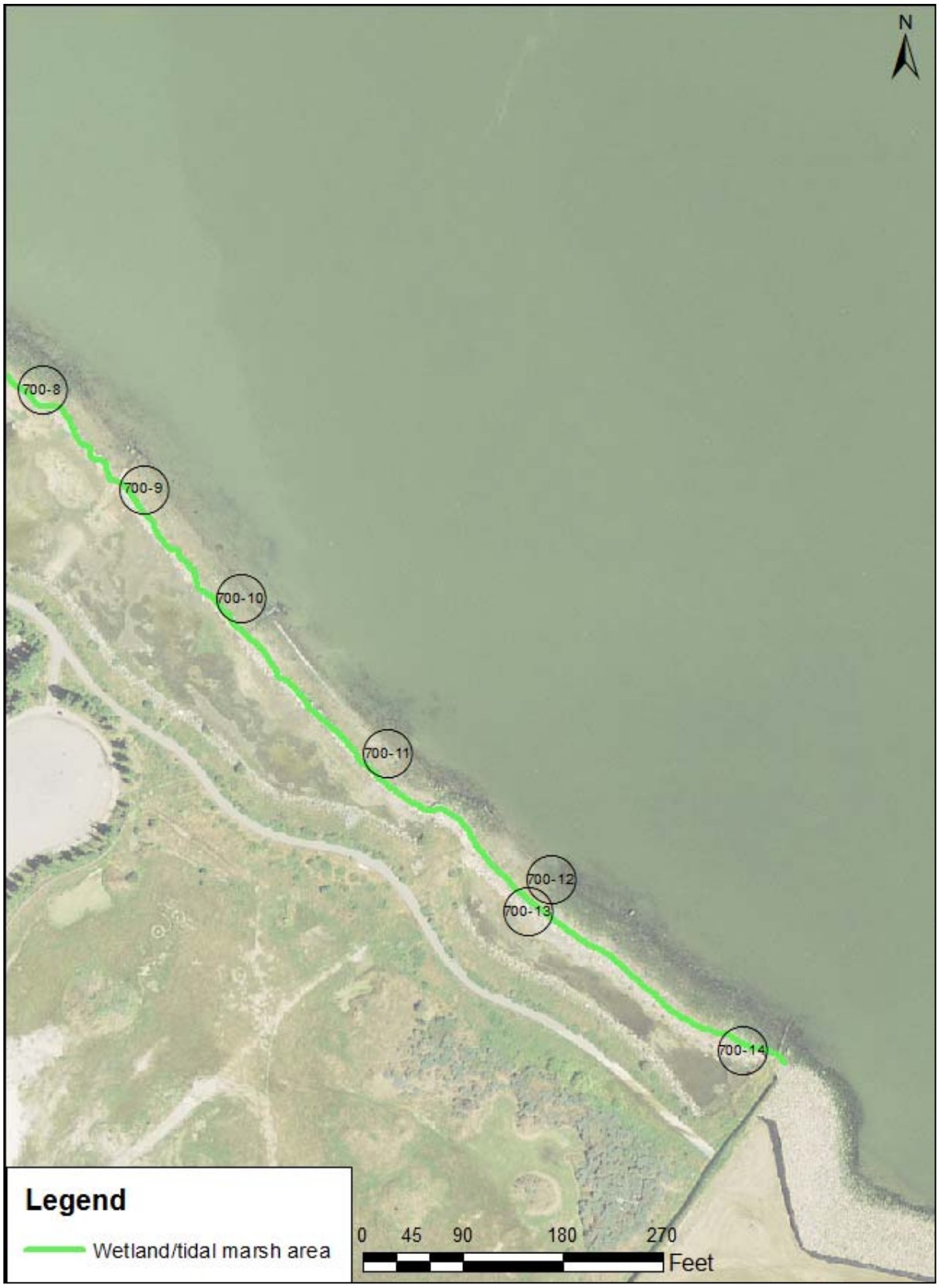

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India Basin Coastal Processes Study – Appendix A

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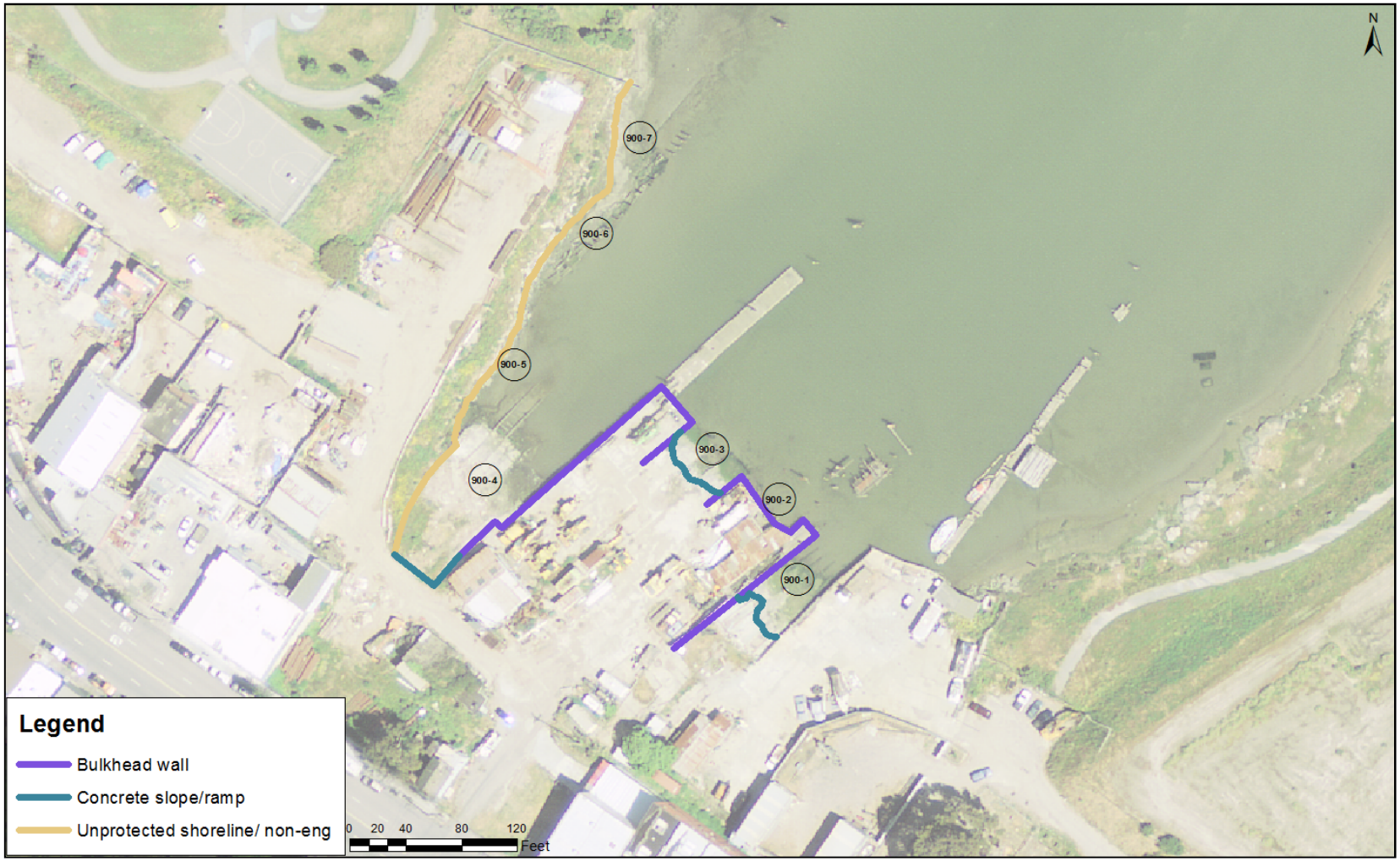

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India Basin Coastal Processes Study – Appendix A

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India Basin Coastal Processes Study – Appendix A

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ISBP-2

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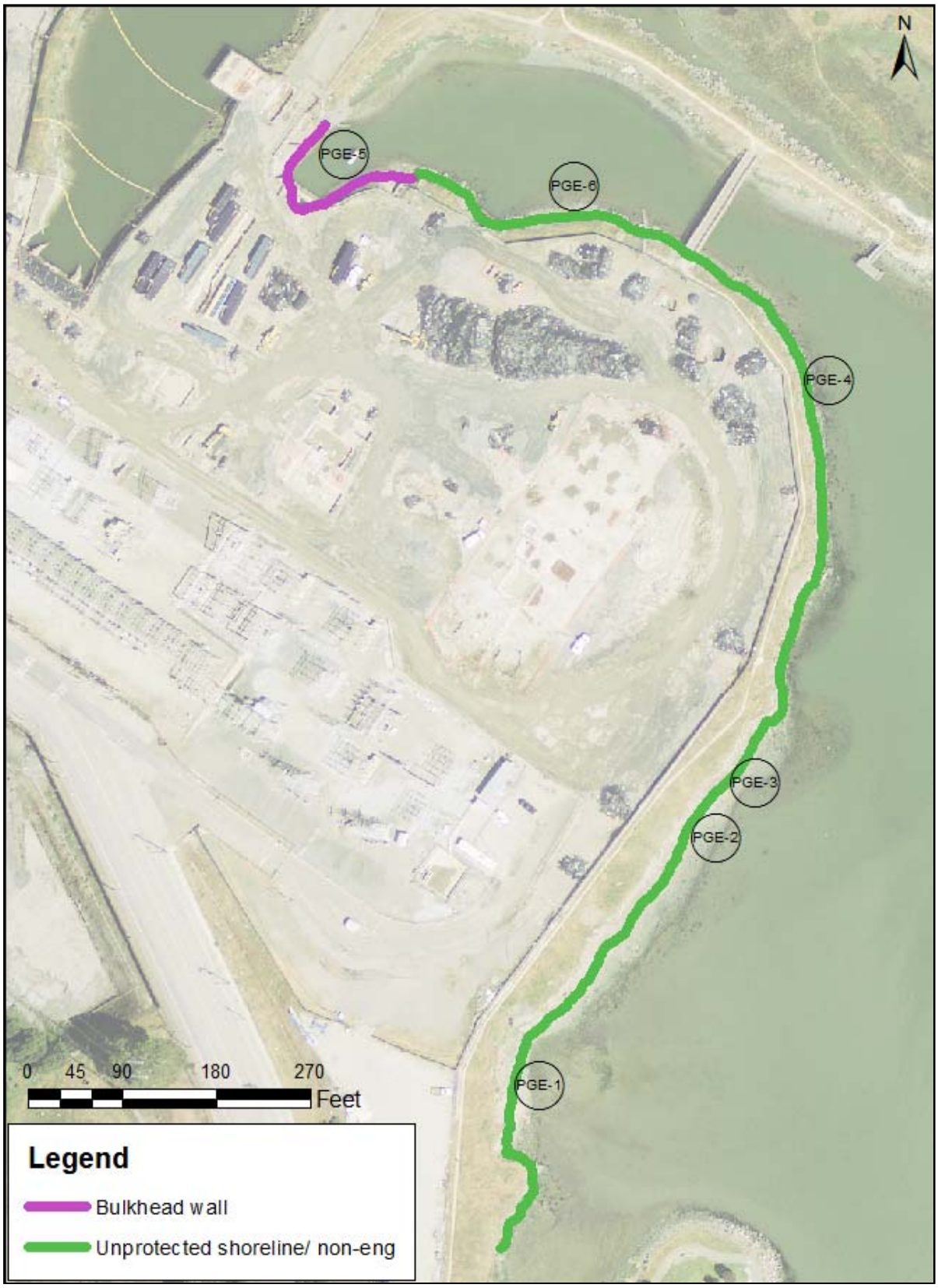

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India Basin Coastal Processes Study – Appendix A

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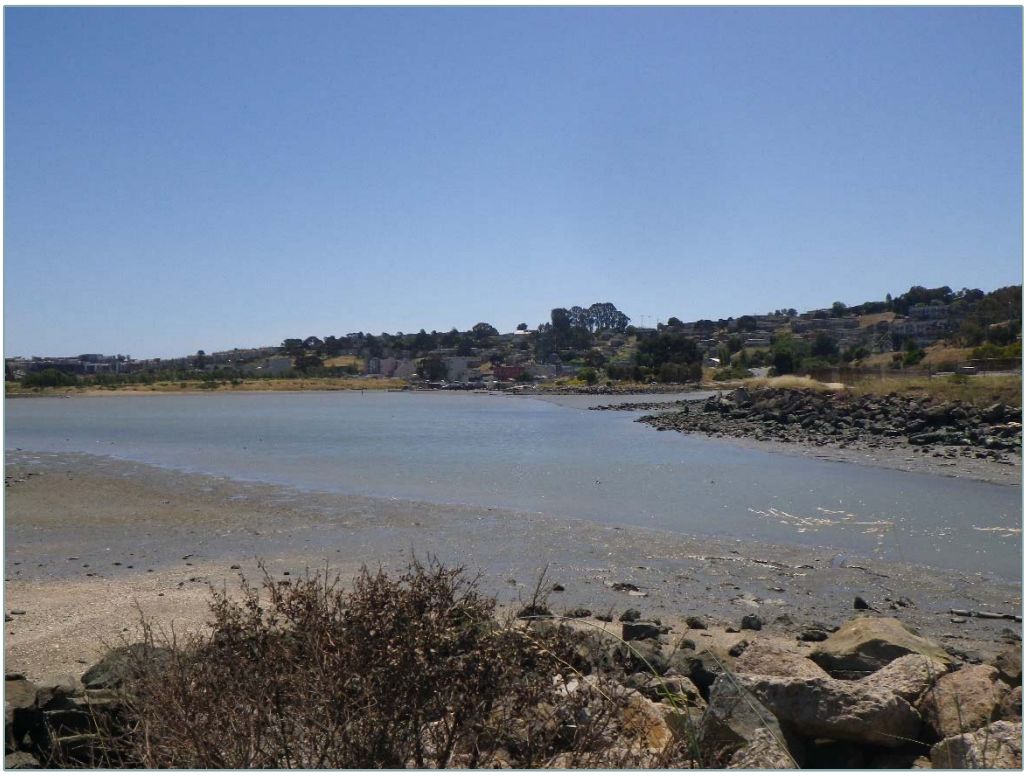

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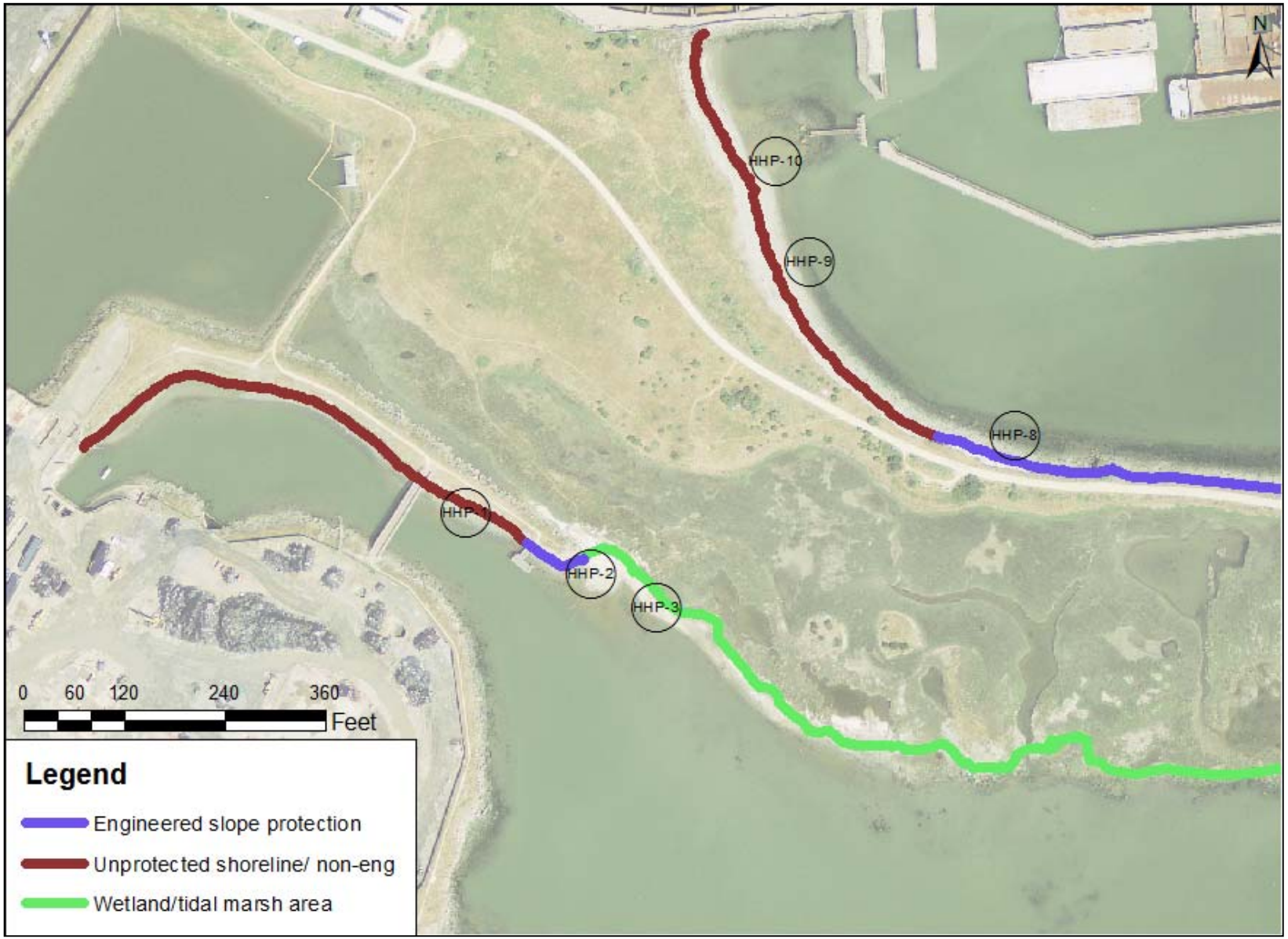

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India Basin Coastal Processes Study – Appendix A

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India Basin Coastal Processes Study – Appendix A

HHP-7

HHP-4

HHP-5

HHP-6