Anna Johnson, PE
Dilip Trivedi, Dr.Eng, PE
Kevin Hanengan, PE
Rosalyn Yu, PE

Protecting the San Francisco International Airport from Sea Level Rise

36th International Conference on Coastal Engineering

Baltimore, Maryland

30 – July – 2018

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Site Description and Vulnerability

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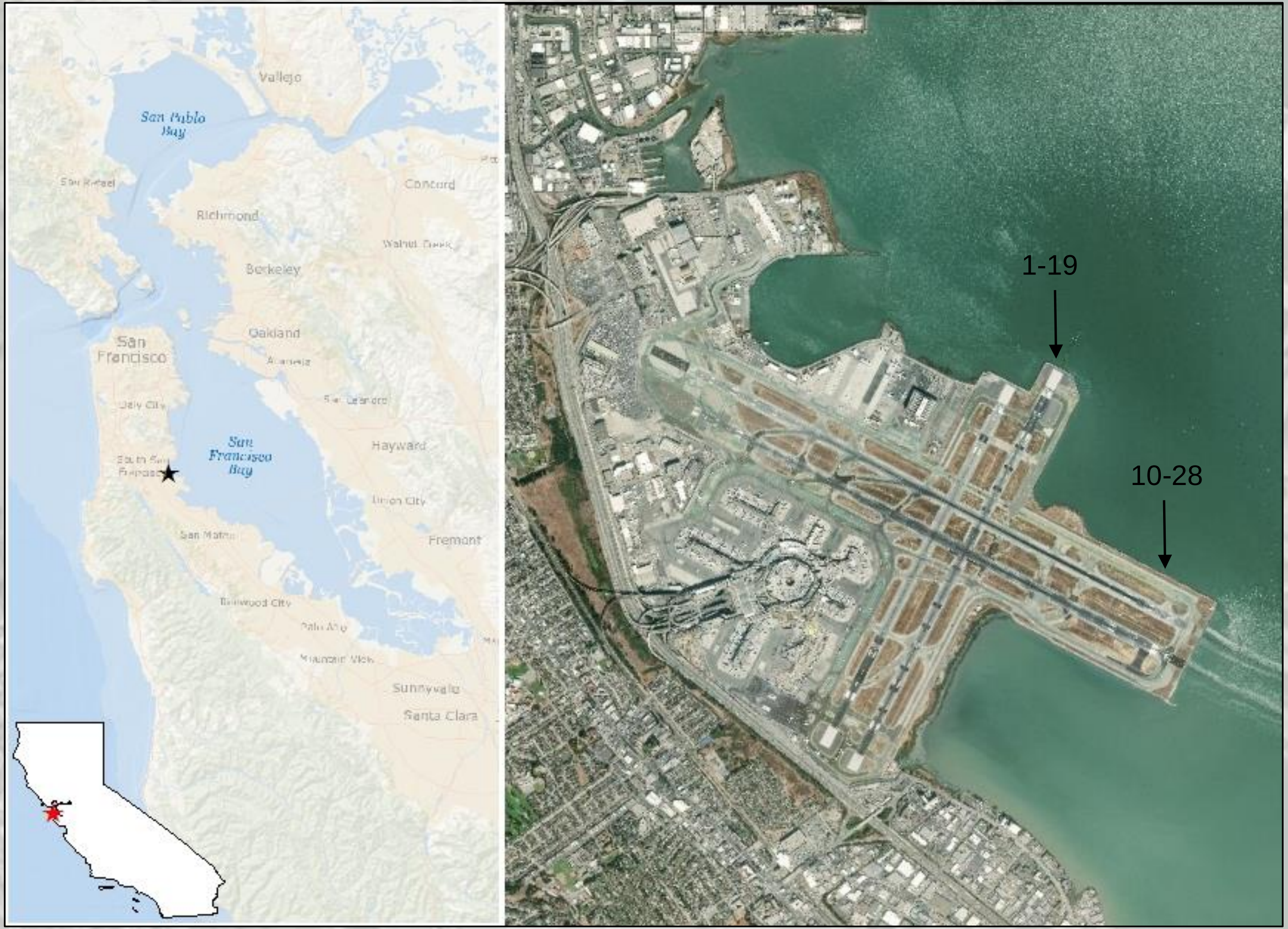
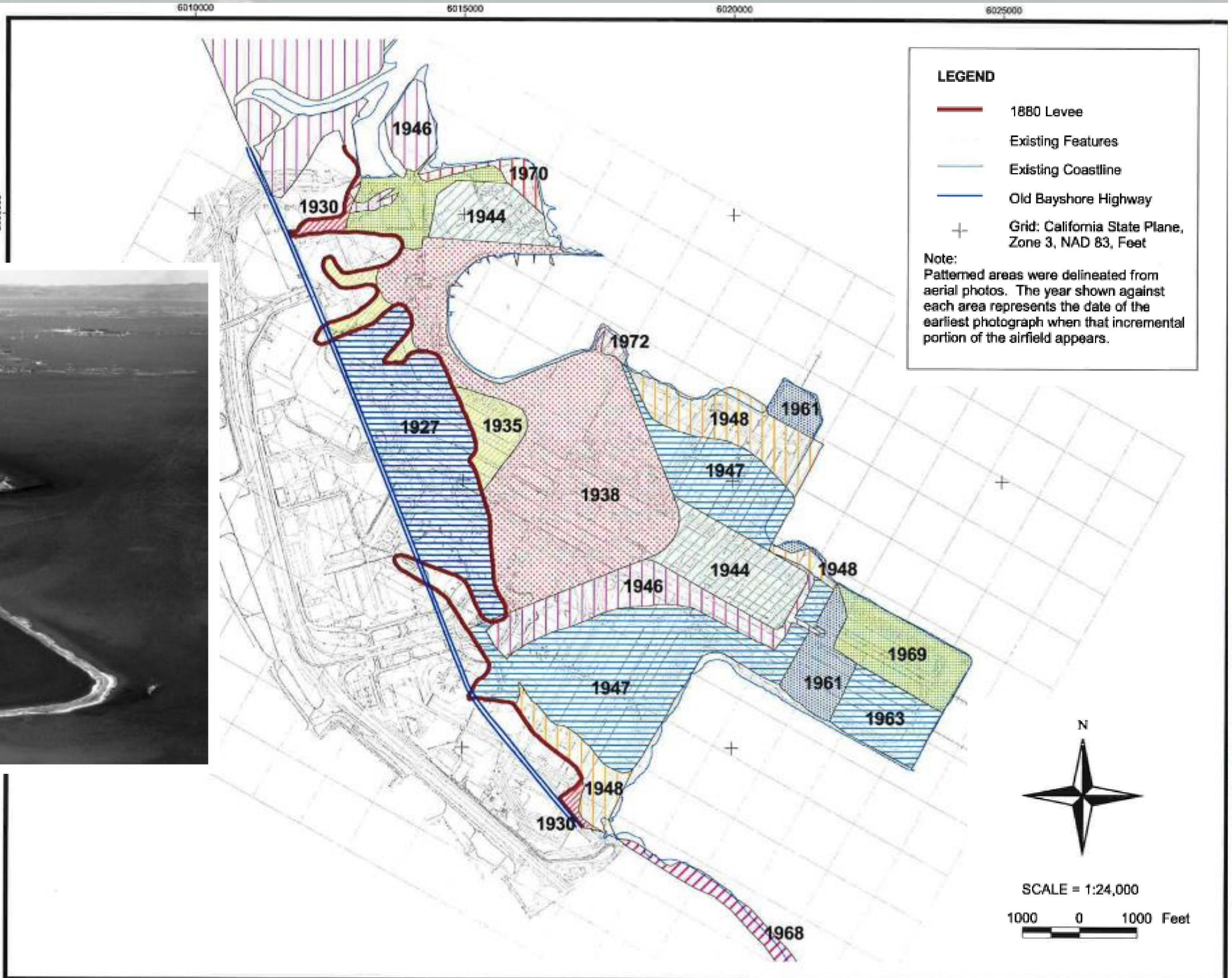
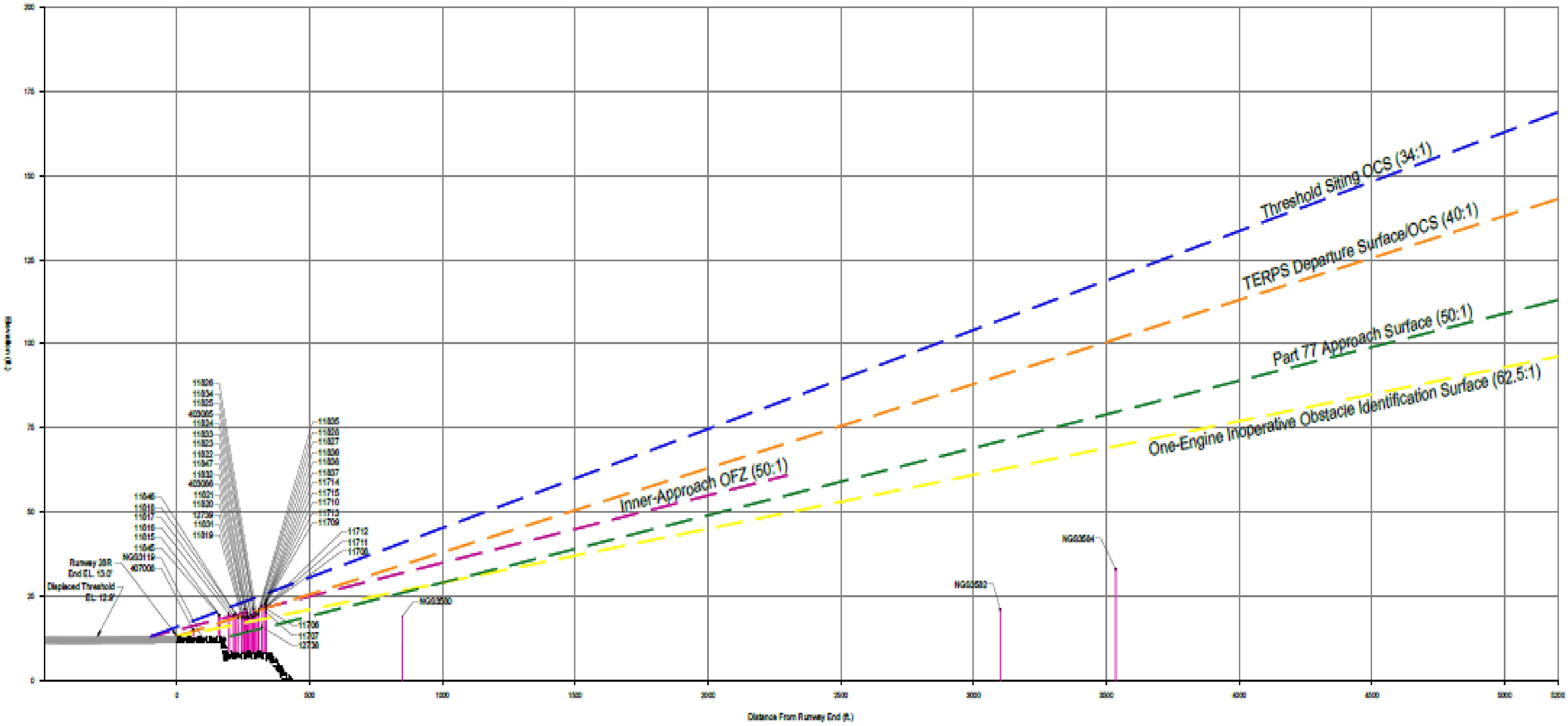


- SFIA has approximately 8 miles of shoreline along San Francisco Bay;
- Protection is needed to prevent flooding;
- Seawalls surround the entire shoreline of SFIA;
- Protection will have to be enhanced to prevent flooding caused by Sea Level Rise.
- The end of the runways are particularly vulnerable due to regulations imposed by the Federal Aviation Administration (FAA) that limits the height of the seawalls.

History


6010000
6015000
6020000
6025000
2060000
LEGEND
1880 Levee
Existing Features
Existing Coastline
Old Bayshore Highway
Grid: California State Plane, Zone 3, NAD 83, Feet
Note:
Patterned areas were delineated from aerial photos. The year shown against each area represents the date of the earliest photograph when that incremental portion of the airfield appears.
1946
1970
1930
1944
1972
1927
1935
1938
1961
1948
1947
1944
1948
1946
1969
1961
1963
1947
1948
1930
1968
N
SCALE = 1:24,000
1000 0 1000 Feet

Runways


Threshold Siting OCS (34:1)
TERPS Departure Surface/OCS (40:1)
Part 77 Approach Surface (50:1)
One-Engine Inoperative Obstacle Identification Surface (62.5:1)
Inner-Approach OFZ (50:1)
Runway 28R
Displaced Threshold

Sea Level Rise + Subsidence

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SAN FRANCISCO - High emissions (RCP 8.5)

	Probability that sea-level rise will meet or exceed… (excludes H++)									
	1 FT.	2 FT.	3 FT.	4 FT.	5 FT.	6 FT.	7 FT.	8 FT.	9 FT.	10 FT.
2030	0.1%									
2040	3.3%									
2050	31%	0.4%								
2060	65%	3%	0.2%	0.1%						
2070	84%	13%	1.2%	0.2%	0.1%					
2080	93%	34%	5%	0.9%	0.3%	0.1%	0.1%			
2090	96%	55%	14%	3%	0.9%	0.3%	0.2%	0.1%	0.1%	
2100	96%	70%	28%	8%	3%	1%	0.5%	0.3%	0.2%	0.1%
2150	100%	96%	79%	52%	28%	15%	8%	4%	3%	2%

SAN FRANCISCO - Low emissions (RCP 2.6)

	Probability that sea-level rise will meet or exceed… (excludes H++)									
	1 FT.	2 FT.	3 FT.	4 FT.	5 FT.	6 FT.	7 FT.	8 FT.	9 FT.	10 FT.
2060	43%	1.4%	0.2%							
2070	62%	4%	0.6%	0.2%	0%					
2080	74%	11%	2%	0.4%	0.2%	0.1%				
2090	80%	20%	3%	1.0%	0.4%	0.2%	0.1%	0.1%		
2100	84%	31%	7%	2%	0.8%	0.4%	0.2%	0.1%	0.1%	
2150	93%	62%	31%	14%	7%	4%	2%	2%	1%	1%

Source: State of California Sea-Level Rise Guidance 2018 Update by the Ocean Protection Council

	Fill Construction			Required Time for Primary Settlement (years)		Estimated Settlement due to Fill Placement (inches)		
Runway End	Fill Thickness (feet)	YBM Thickness (feet)	Approx. Construction Year(s)	50%	90%	Total Primary Settlement	Primary Settlement Remaining	Secondary Settlement Remaining
19	15 - 30	40 - 70	1948, 1961	5 – 15	23 – 55	20 – 50	2 – 5	1 – 2
28	5 - 20	24 – 50	1963, 1969	3 – 8	10 – 36	19 – 31	2	1 – 2

Source: Geotechnical Analysis performed by AGS, Inc.

Coastal Engineering Analysis – Water Levels

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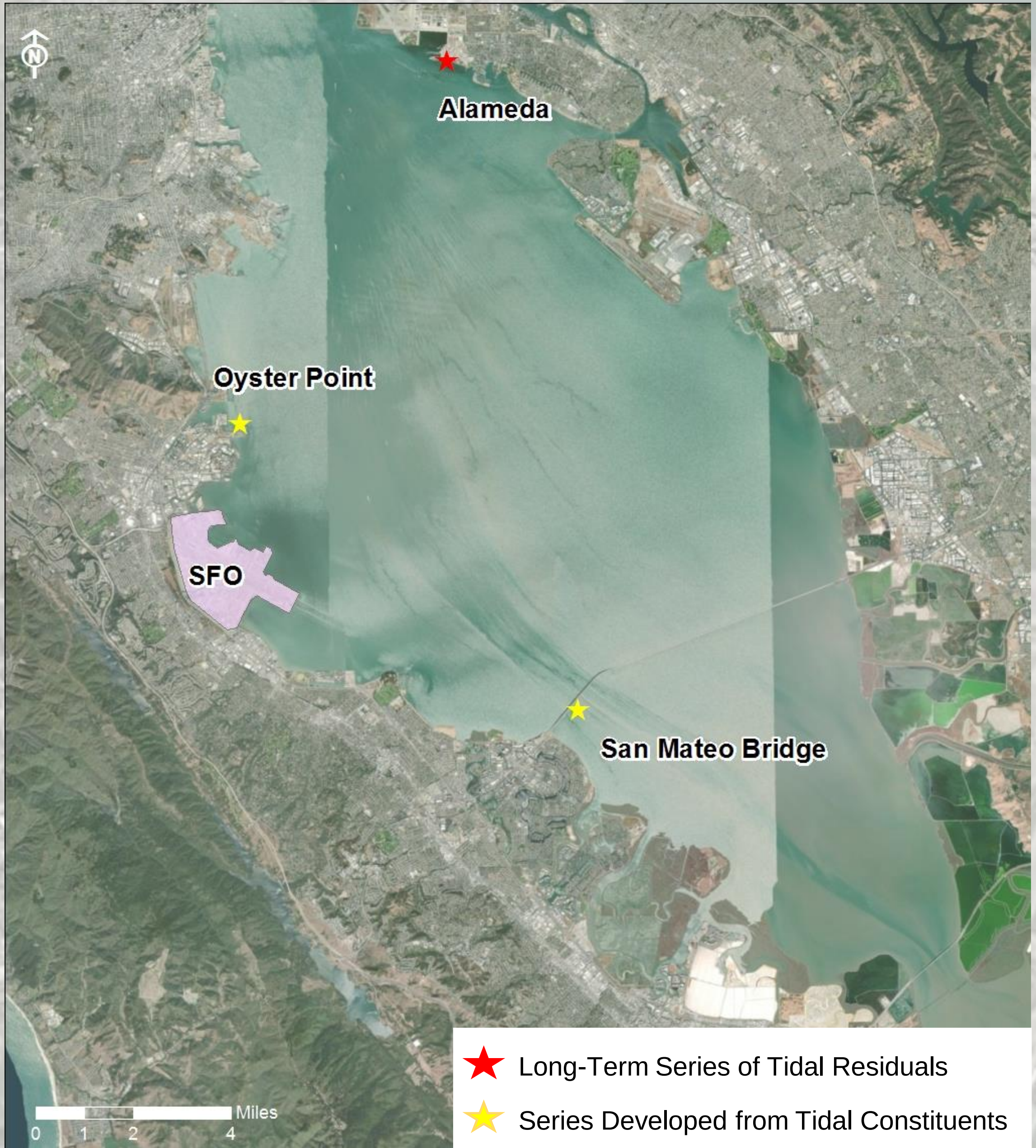
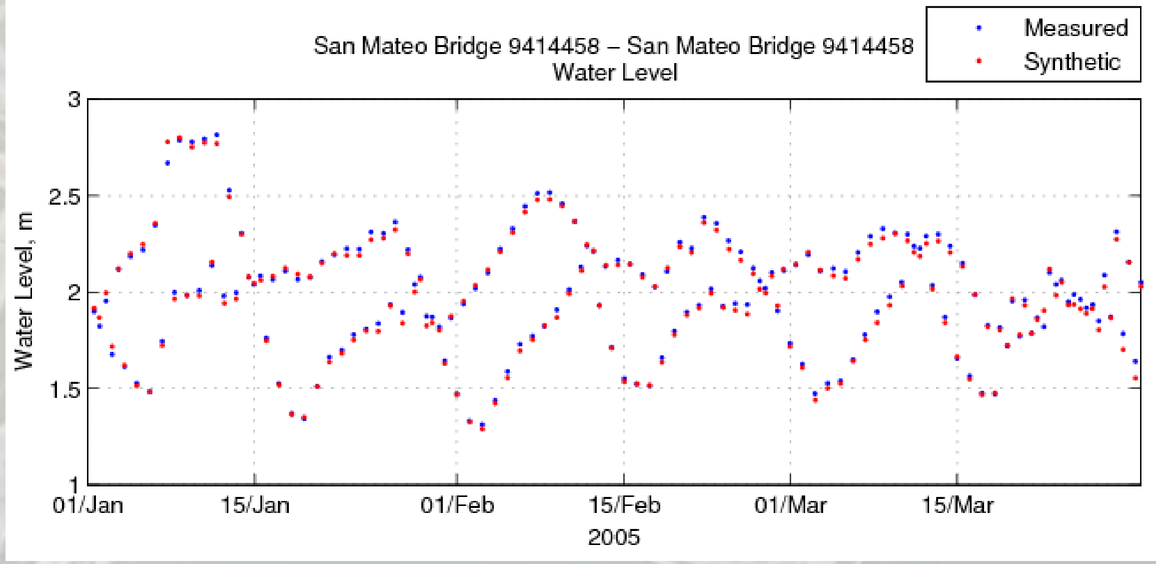


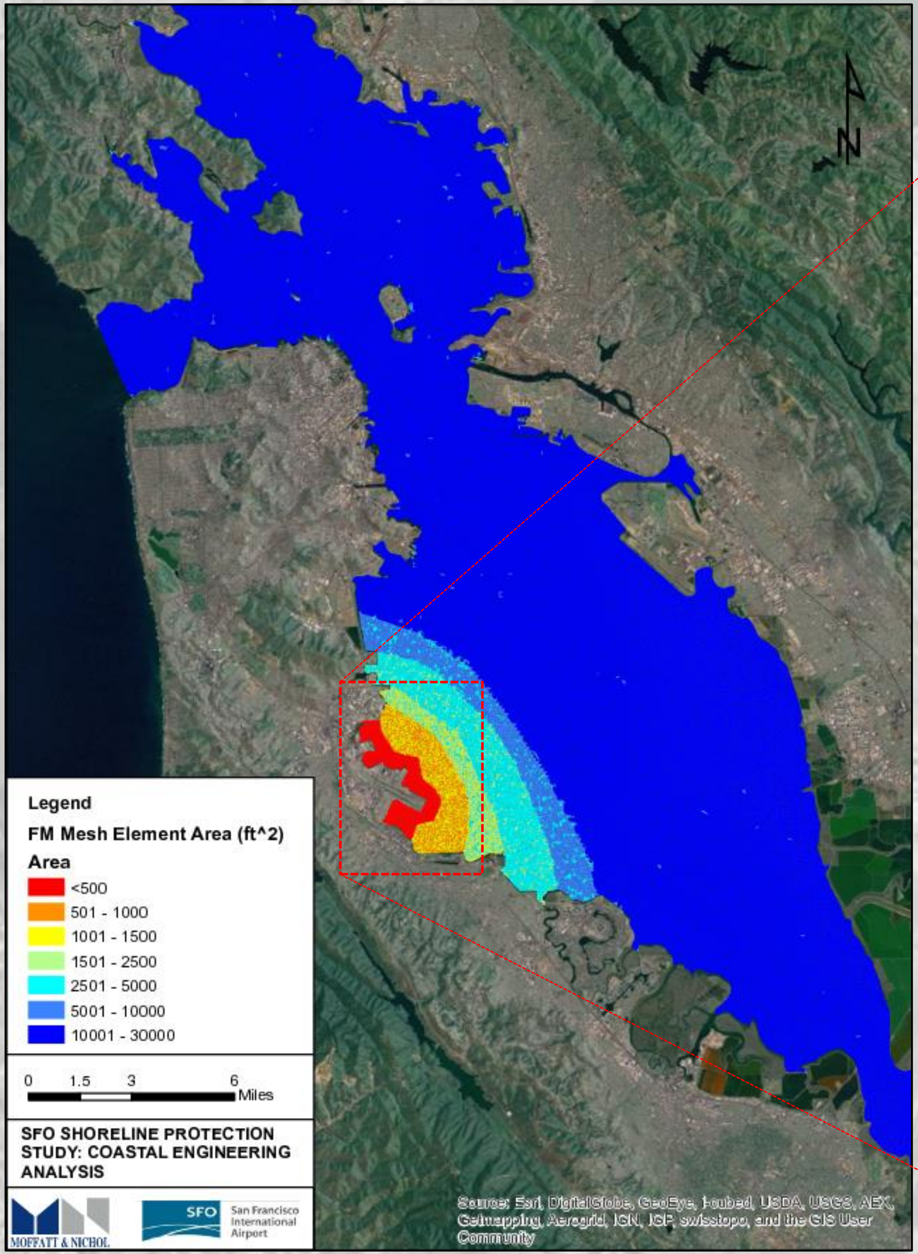
Analysis

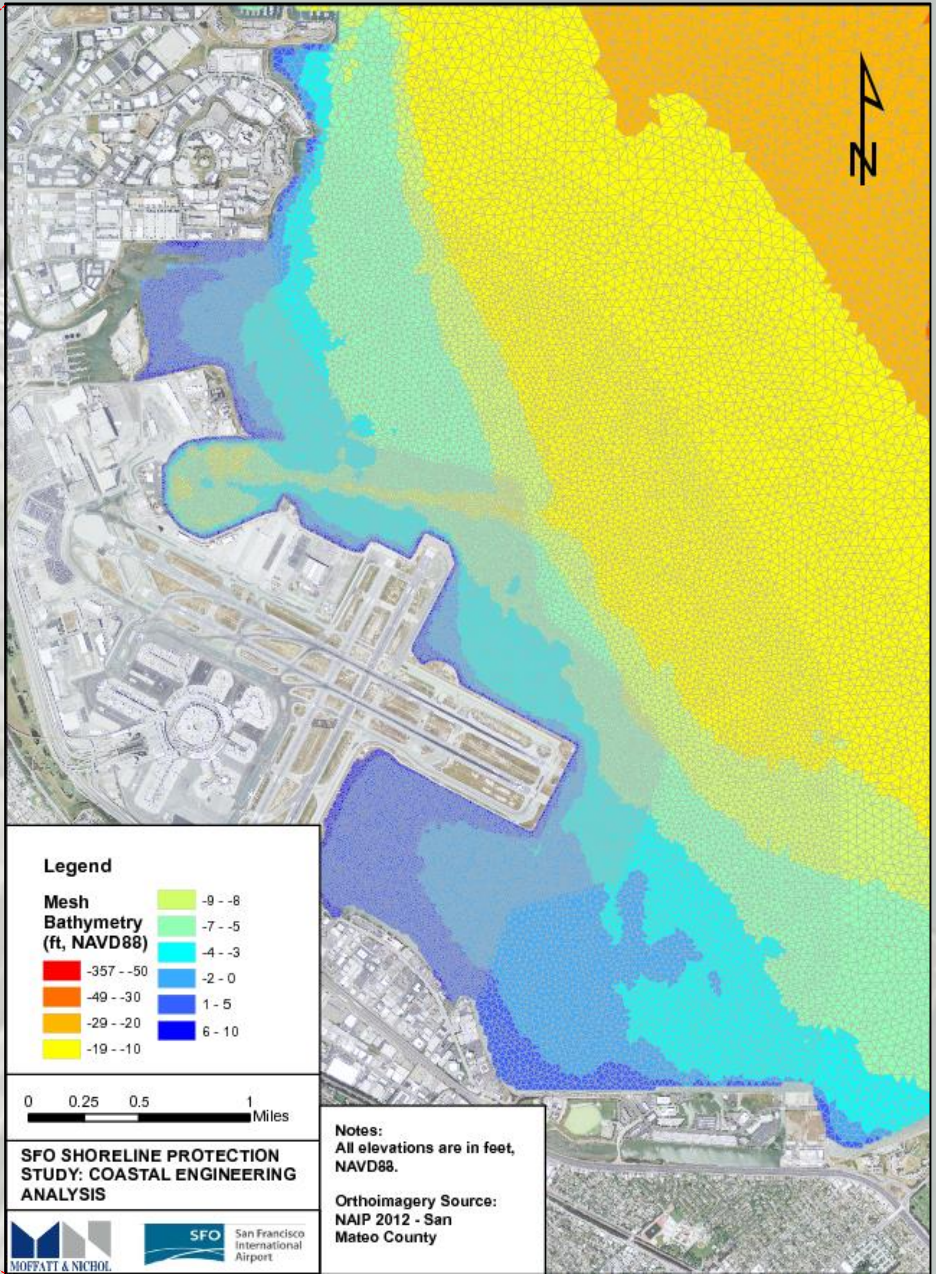
- Extracted Tidal Residuals (difference between Measured and Predicted Water Level Values) from Station at Alameda for period between 1979 and 2013;
- Developed Time Series of Astronomical Tide at Oyster Point and San Mateo Bridge using NOAA Established Tidal Constituents for period between 1979 and 2013;
- Added Tidal Residuals onto the Astronomical Tides at Oyster Point and San Mateo Bridge;
- Verified the Methodology;
- Determine Time Series of Water Levels at SFO by Spatially Interpolating the Time Series between Oyster Point and San Mateo Bridge for the period between 1979 and 2013.



Comparison between Measured and Synthetic High Tides at San Mateo Bridge

Coastal Engineering Analysis – Mesh Generation





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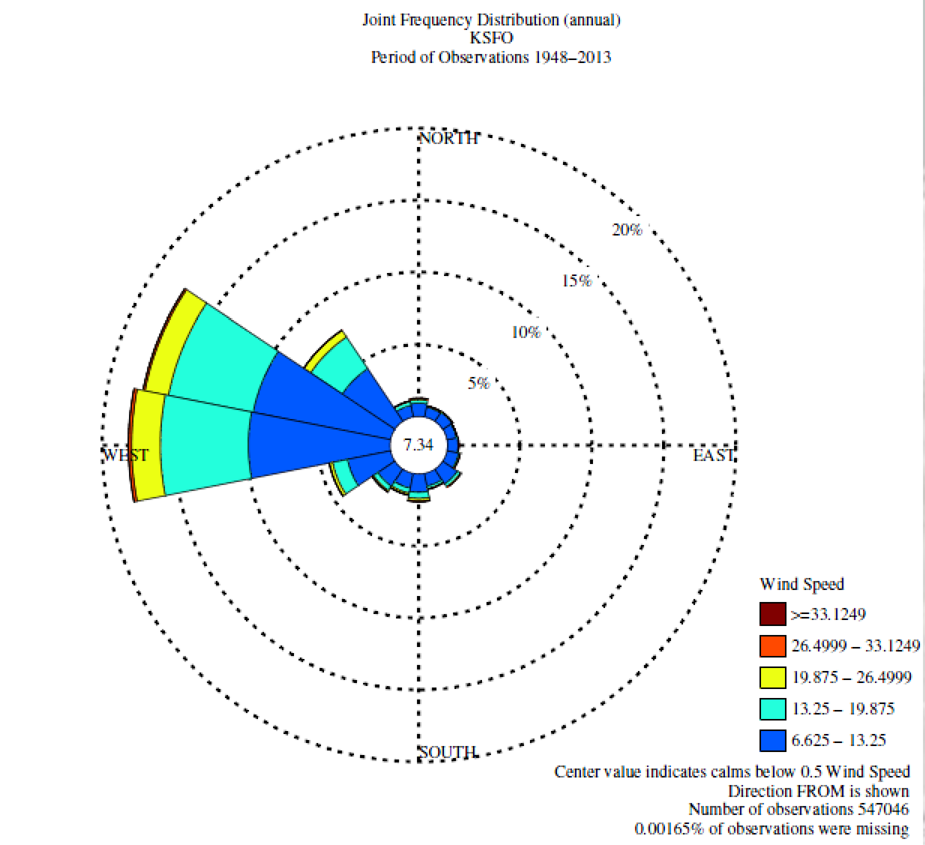
Coastal Engineering Analysis – Wave Analysis



Percentage of Occurrence

Wind Speed	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
Total	10.2	2.49	2.77	2.45	2.44	2.18	3.14	2.78	4.5	3.23	3.69	6.26	21.6	21	9.37	1.87	100
33.12–39.75													0.01				0.04
26.5–33.12	0.01								0.05	0.03	0.01	0.02	0.21	0.13	0.01		0.48
19.87–26.5	0.1	0.02	0.01			0.02	0.05	0.04	0.18	0.13	0.1	0.23	2	1.67	0.56	0.04	5.16
13.25–19.87	0.24	0.07	0.06	0.06	0.04	0.1	0.24	0.19	0.43	0.36	0.38	1.05	6.14	6.02	2.66	0.28	18.3
6.625–13.25	0.93	0.7	0.76	0.66	0.73	0.82	1.24	0.89	1.27	1.04	1.43	3.06	9.88	9.77	4.42	0.82	38.4
0–6.625	8.92	1.69	1.94	1.72	1.67	1.24	1.61	1.65	2.56	1.67	1.78	1.9	3.39	3.38	1.73	0.73	37.6

Wave Analysis Input Data

- Extracted Wind Data from KSFO;
- No Swell Impacts

Wave Modeling Methodology

- Objective: Create a time series of wave parameters for the same duration as the water level data;
- Simulate 1350 steady state runs with combinations of different water levels, wind speeds, and wind directions;
- Linearly interpolate wave parameters for the actual water level, wind speed, and wind direction.

Water Level (m, NAVD88)	Wind Direction (deg N)	Wind Speed (m/s)
0.00	0.0	0.00
3.28	22.5	17.49
4.10	45.0	23.33
4.92	67.5	29.16
5.74	90.0	34.99
6.56	112.5	40.82
7.38	135.0	46.65
8.20	157.5	52.48
9.02	180.0	58.32
9.84	247.5	-
-	315.0	-
-	337.5	-
-	360.0	-

Coastal Engineering Analysis – Wave Analysis

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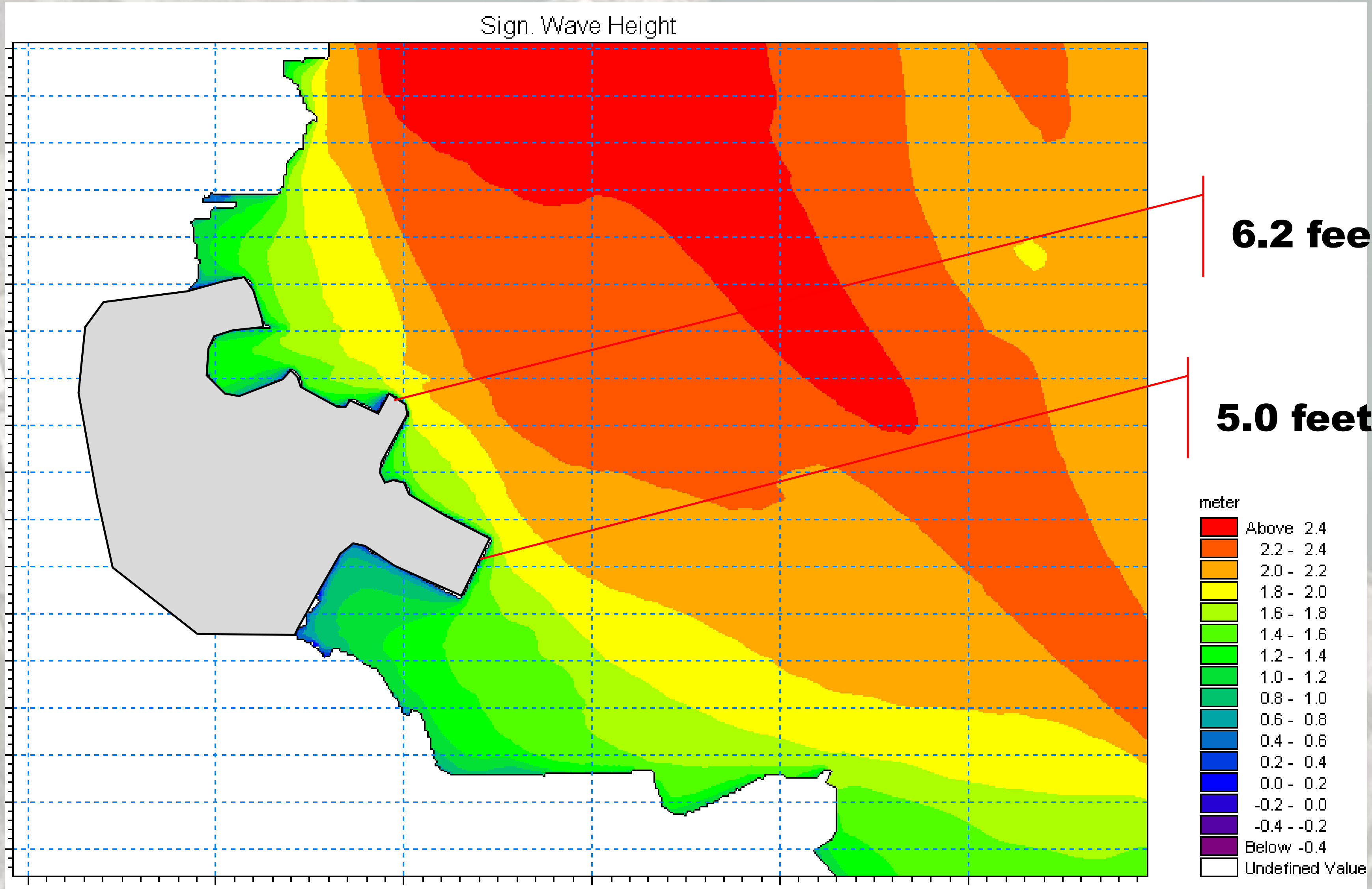
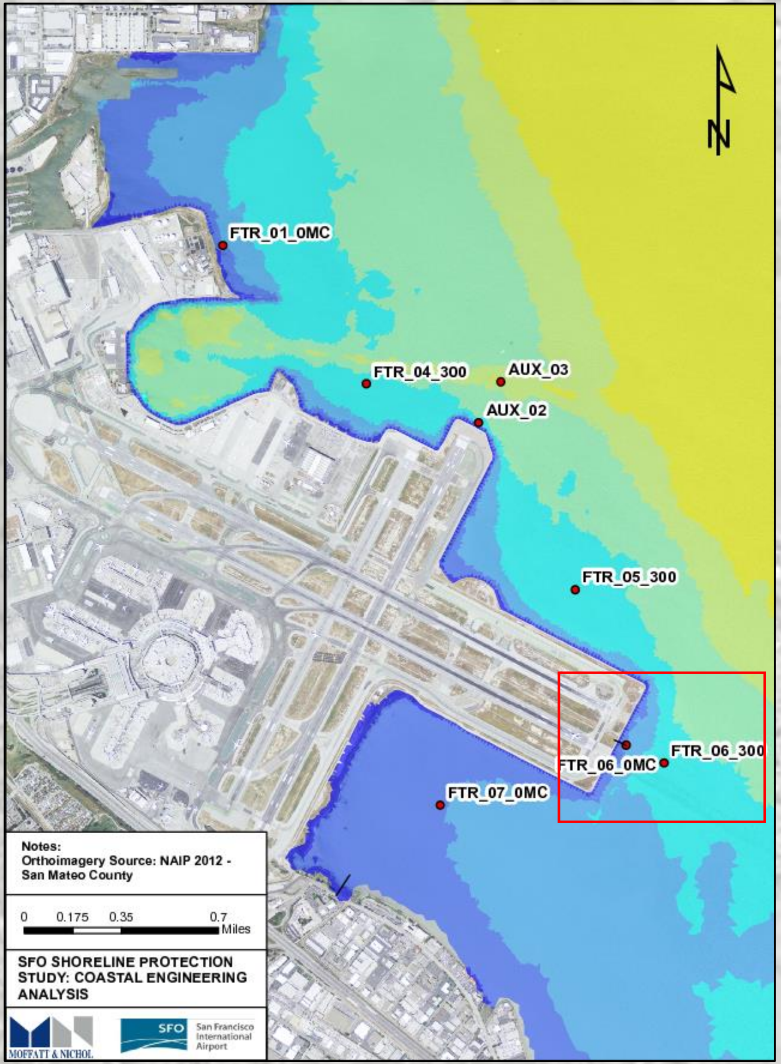
Example Wave Simulation:
Example Wave Model Results – Significant Wave Height for 30 m/s Wind Speed at 90° and 9.8 ft NAVD88 Water Level

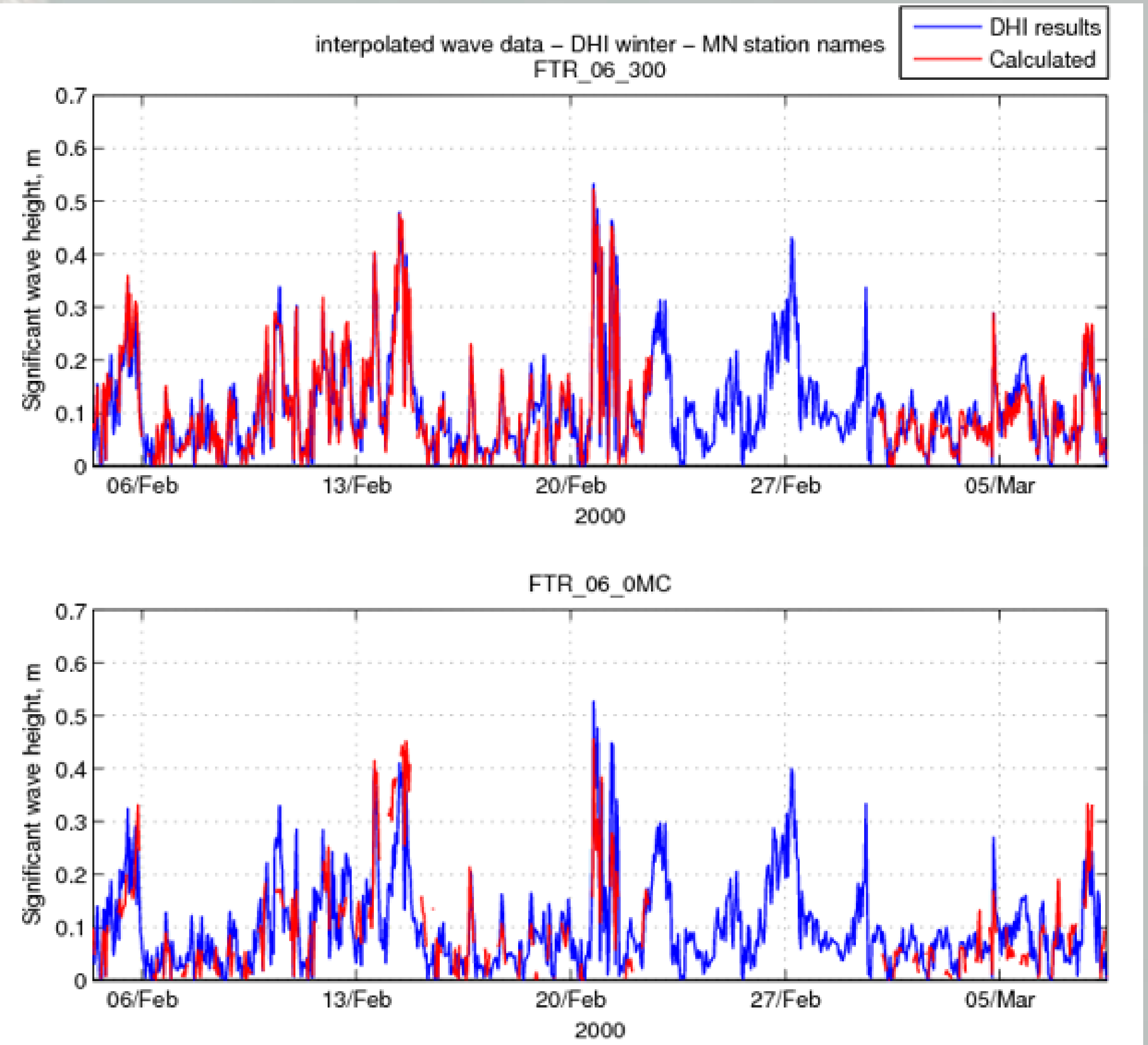


Coastal Engineering Analysis – Model Verification

Wave Calibration Data

- Calibrated with DHI's Mike21-NSW output hourly time series of wind wave significant wave heights simulated to support FEMA's Floodplain Mapping Program.

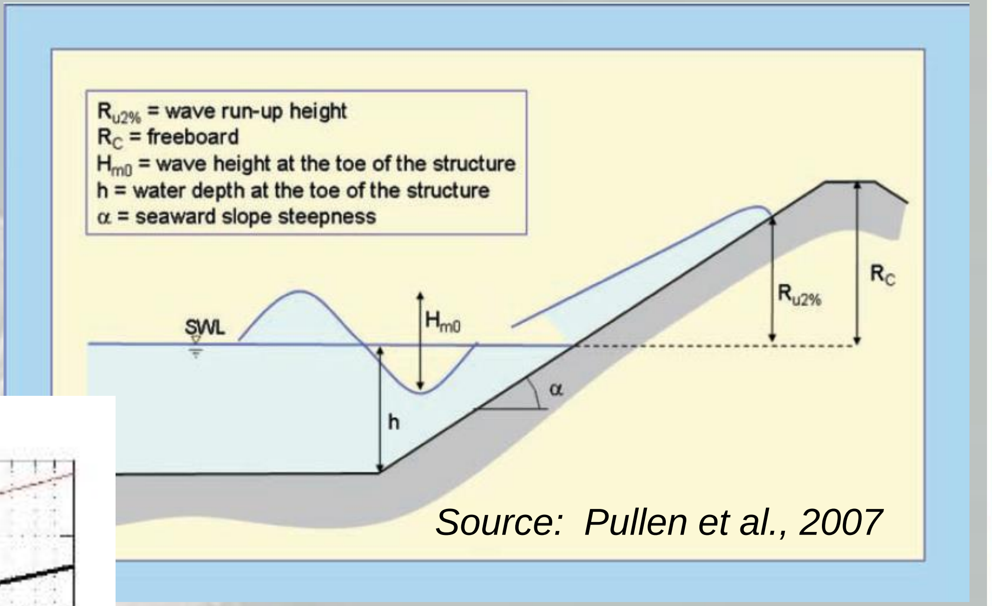




Coastal Engineering Analysis – Total Water Level

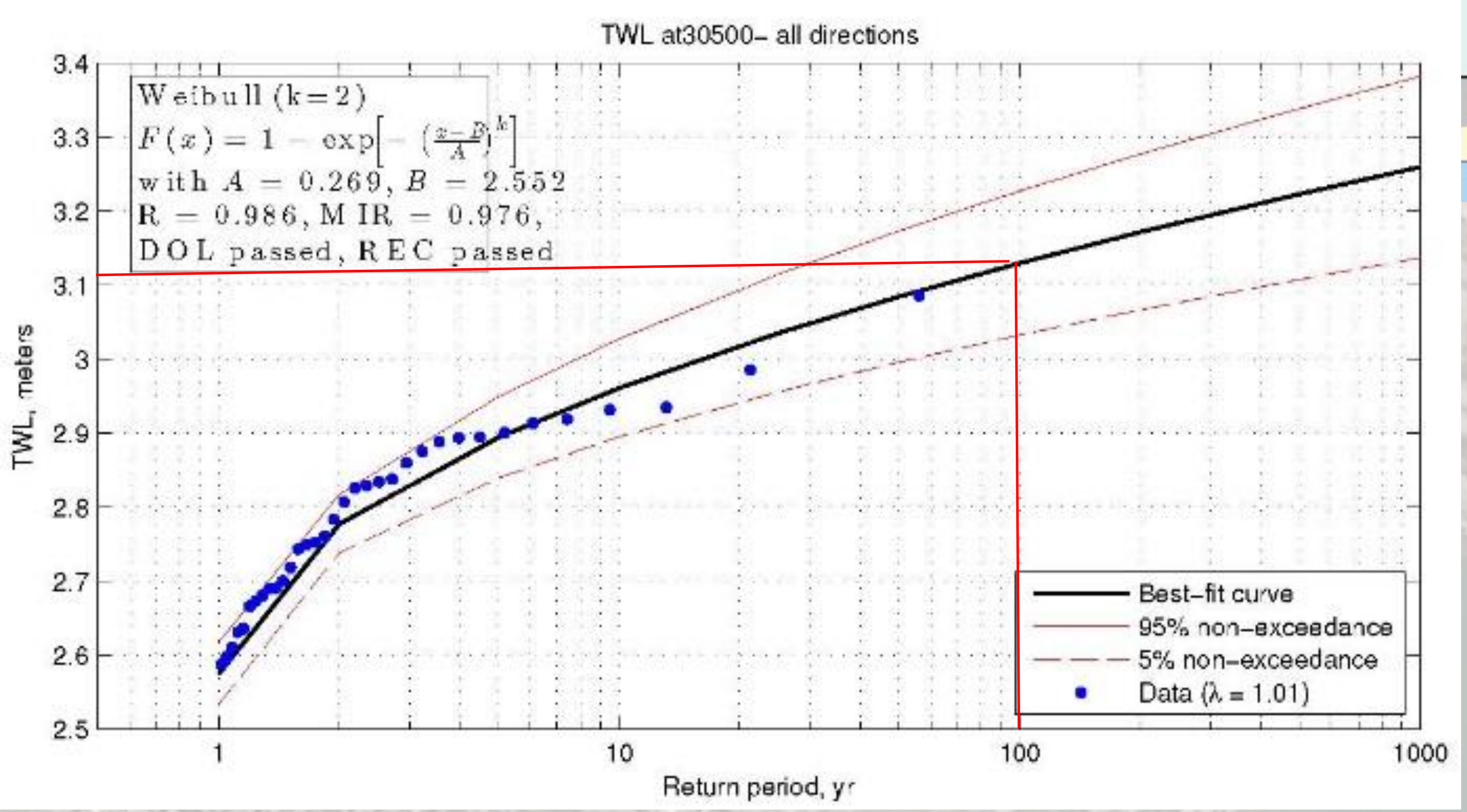
Total Water Level Determination

- TWL = Still Water Level + Wave Runup;
- 2% Runup calculated for each hour in the 34-year time series of water level and wave data.
- EVA conducted on Still Water Level + 2% Runup



Source: Pullen et al., 2007

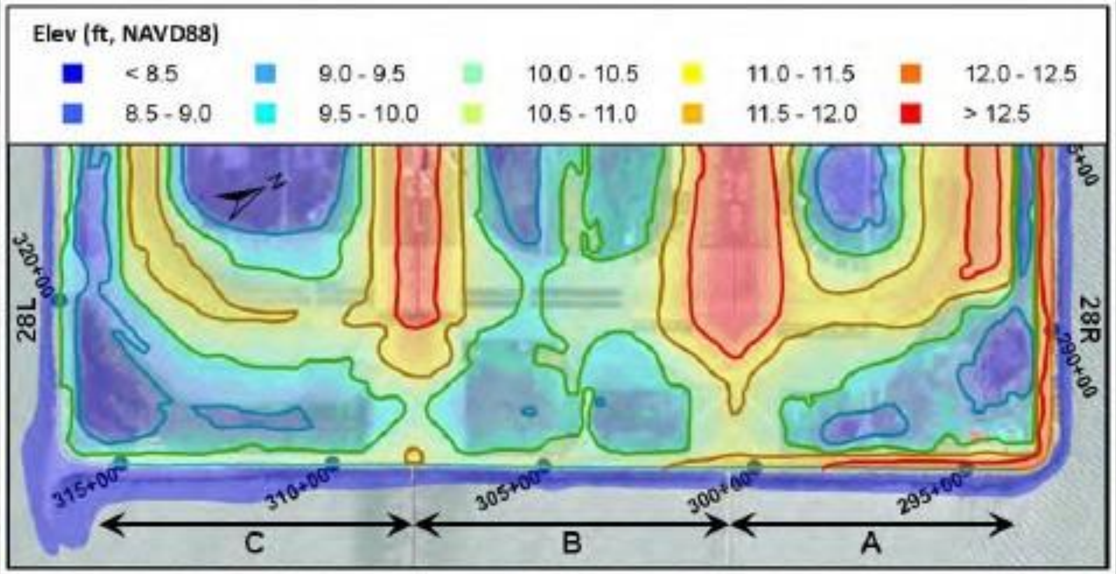
Extreme Value Analysis for TWL at the end of Runway 28 estimates a total water level of 10.2 feet NAVD88

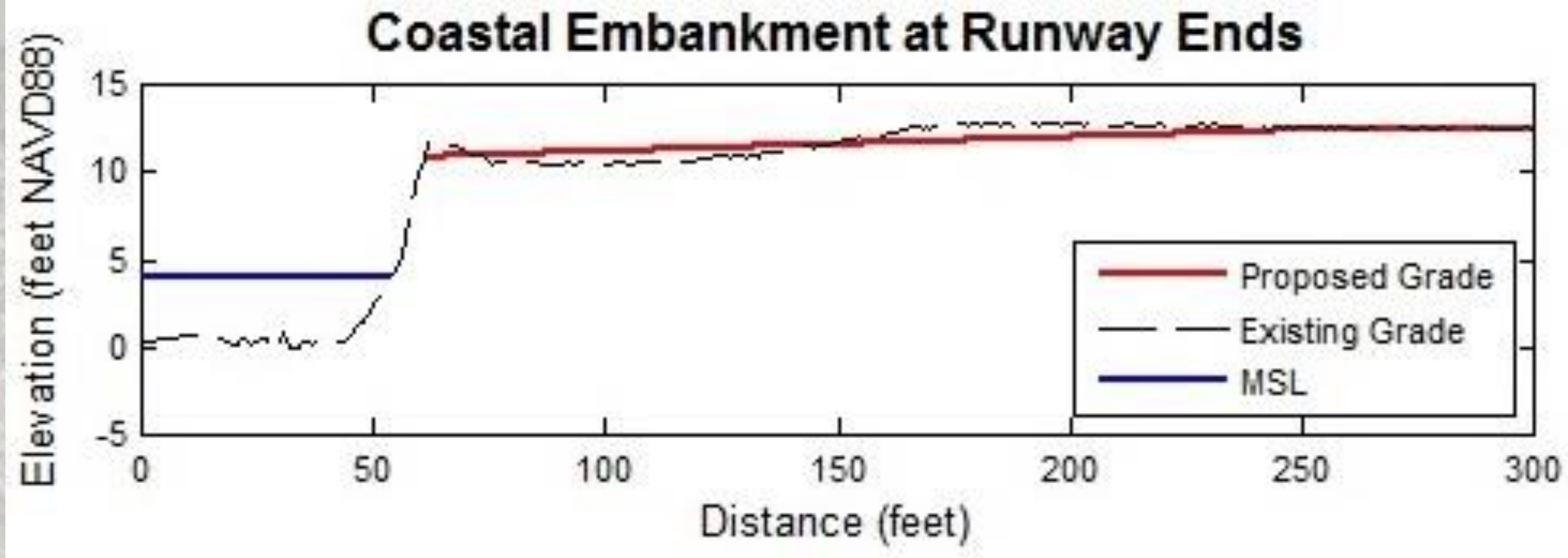


Sea Level Rise Remedial Solutions

Flooding at Runway End
- Ponding from Wave Overtopping
- Expected to Increase with SLR
- Cannot raise elevations of the seawall due to FAA restrictions

Current Elevations at End of Runway 28



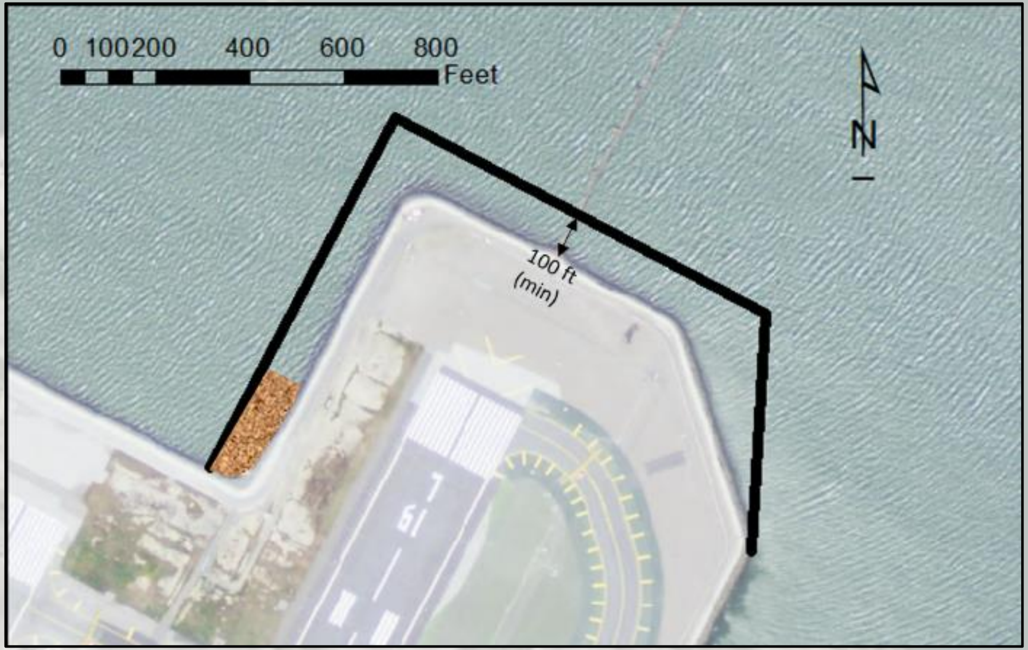


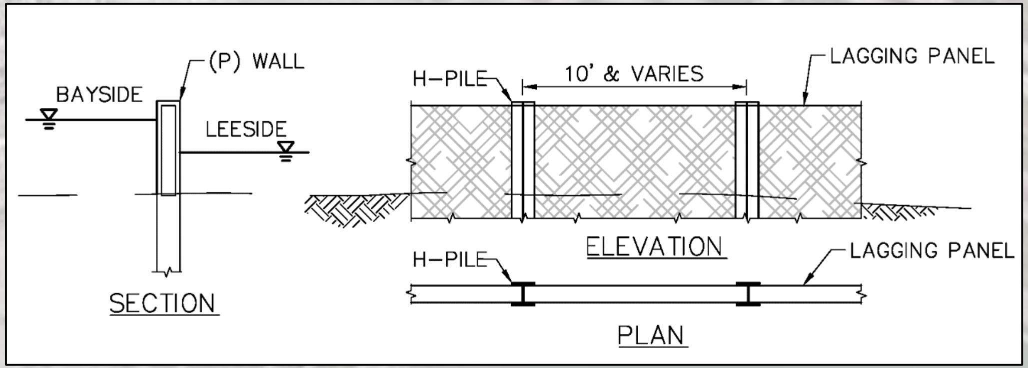
Short- term SLR Proposed Solution
- Still water level not expected to reach top of embankment;
- Major concern is increase wave overtopping;
- Grade the existing area to allow waves to runup and drain back to Bay.

Sea Level Rise Remedial Solutions

Long-Term Sea Level Rise Solution

- Must minimize 'footprint' within San Francisco Bay waters;
- Propose to enclose runway ends with a sheet pile breakwater offset a distance sufficient enough to accommodate the required seawall elevation.





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THANK YOU!

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