

MEMORANDUM

To: Dave Charobee; Katherine Buck – (City of Redondo Beach)

From: Jerry Holcomb, PE – (Moffatt & Nichol)

Date: May 8, 2025

Subject: Redondo Harbor Boat Launch Ramp – Coastal Criteria and Hazards Analysis

M&N Job No.: 232677

1 Introduction

Local residents and community leaders have agreed upon the development of a public boat launch within King Harbor. King Harbor is in the City of Redondo Beach, CA, approximately 10 miles northwest of the Port of Los Angeles and Port of Long Beach (Figure 1). King Harbor accommodates three marina basins, named Basin 1, Basin 2 and Basin 3 from north to south. The proposed public boat launch locations (three alternative locations) are within the red box (shown in Figure 1) between the Seaside Lagoon rock groin and the entrance of Basin 3. The new public boat launch will allow access to the open ocean and provide recreational and commercial opportunities for community members.

This memorandum uses publicly available data, field collected data, and modelling results to: 1) provide coastal design criteria and environmental conditions within the Project site, 2) summarize coastal hazards at the Project site including future sea level rise (SLR), and recommend SLR adaptation measures.



Figure 1. Project Location and Features.

2 Metocean Conditions

2.1 Water Levels

2.1.1 Tides and tidal datum

The tides in Redondo Beach are semi-diurnal with pronounced diurnal inequalities (i.e., two high and low tides each within a 24.6-hour period with varying elevations); otherwise known as mixed tides. Water levels were taken from NOAA station 9410840 which is located off Santa Monica Pier, 13 miles north of the project site. This tide gauge has been recording tidal elevations since 1974. The tidal datums have been developed by the National Oceanic and Atmospheric Administration (NOAA) based on the 1983-2001 tidal epoch. The tidal datums at the Santa Monica Station are recommended to be used in this project and are presented in Table 1 below.

Table 1. Tidal Datums at NOAA Tide Station 9410840, Santa Monica, CA.

Abbreviation	Description	Water Elevation (ft, MLLW)	Water Elevation (ft, NAVD88)
HOWL	Highest Observed Water Level	+8.50	+8.31
HAT	Highest Astronomical Tide	+7.27	+7.08
MHHW	Mean Higher High Water	+5.43	+5.24
MHW	Mean High Water	+4.69	+4.50
MSL	Mean Sea Level	+2.79	+2.60
MLW	Mean Low Water	+0.93	+0.74
NAVD88	North American Vertical Datum of 1988	+0.19	+0.00
MLLW	Mean Lower Low Water	+0.00	-0.19
LAT	Lowest Astronomical Tide	-1.97	-2.16
LOWL	Lowest Observed Water Level	-2.84	-3.03

2.1.2 SLR Probability & Timing

Sea level rise (SLR) science has evolved with a better understanding of both global and local physical processes. Future SLR projections are developed based on the current best scientific understanding of these processes using advanced global, regional, and local modeling techniques. The Ocean Protection Council (OPC) and California Coastal Commission (CCC) both published updated SLR guidance documents in 2024. Each report provides SLR scenarios and values for various coastal regions in California. The regional SLR projections for Santa Monica in CCC's *Sea Level Rise Policy Guidance: Interpretive Guidelines for Addressing Sea Level Rise in Local Coastal Programs and Coastal Development Permits* report (California Coastal Commission, 2024) was chosen to be used. The OPC's *State of California Sea Level Rise Guidance: 2024 Science & Policy Update* report provided SLR projections for the greater Los Angeles area (OPC, 2024). The difference in values for the selected SLR scenarios between the Santa Monica and Los Angeles Stations is 0.1 ft.



Sea level scenarios are offered in five different categories: Low, Intermediate-Low, Intermediate, Intermediate-High, and High. The selection of SLR scenario is dependent on the level of risk the community is willing to accept. Both OPC and CCC recommend evaluating Intermediate, Intermediate-High, and High scenarios for infrastructure projects.

2.1.2.1 Selected SLR Scenarios

A 50- and 75-year service life was considered when selecting the SLR scenario to be used for analysis within this study. The projected timing of evaluated SLR scenarios is presented in Table 2. As seen in the table, a range of time horizons is projected for each SLR value depending on the level of risk aversion. Projections are summarized according to the possible timelines of their occurrence as follows based on the 2024 CCC Guidance:

1. SLR of 1.7 ft (0.52 m) is representative of a time horizon range from 2050-2080.
2. SLR of 2.9 ft (0.88 m) is representative of a time horizon range from 2070-2100.

The 75-year service life was chosen for the analysis; 2.9 ft of SLR is predicted to occur by 2100 based on the Intermediate scenario.

Table 2. Probability and Potential Timing Associated with Selected SLR Scenarios in Santa Monica (California Coastal Commission, 2024).

SLR Scenario Probability*	Intermediate 5 percent	Intermediate – High 0.1 percent	High <0.1 percent
1.7 ft	2080	2060 - 2070	2050 - 2060
2.9 ft	2100	2080	2070 - 2080

Note: *Probability assuming 3°C of warming in 2100.

2.1.3 Extreme Water Levels

Extreme water levels for a range of return periods were published by NOAA on the Santa Monica tide gauge (Station 9410840). Table 3 Presents the extreme water levels based on Santa Monica tide gauge results to be used for the project. The values for the 1-year, 2-year, 10-year, and 100-year return periods were provided by NOAA while the remaining were interpreted from the annual exceedance probability curves shown in Figure 2 and Table 3.

Table 3. Extreme Water Levels at Project Site.

Return Period	Stillwater Elevation (ft, MLLW)
100-Year	8.0
50-Year	7.8
25-Year	7.7
10-Year	7.6
5-Year	7.4
2-Year	7.3
1-Year	7.0

Note: The extreme water levels are based on NOAA Tide Gauge at Santa Monica.



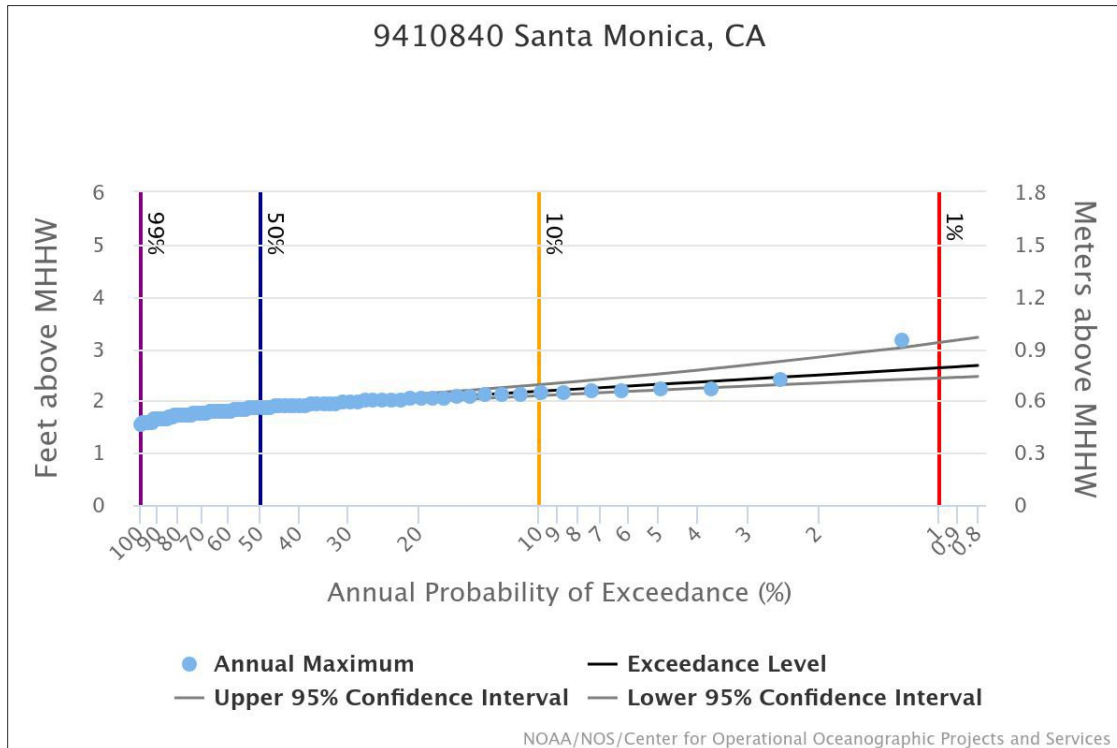


Figure 2. Annual Exceedance Probability Curves - High Water Levels.

2.2 Currents

The currents during operational conditions are mainly driven by tidal flows. With the rise and fall of tides, the currents within the harbor change directions and are called flood and ebb currents. Wave-induced currents contribute to the currents at the boat launch ramps too. Extreme currents are likely to occur during tsunamis when long-period waves are caused by underwater disturbances such as earthquakes across deep ocean and inundating the coast.

2.3 Wind

2.3.1 Operational Wind Condition

Wind data was summarized from 80-year measurements (1944-2025) at Los Angeles International Airport which is located approximately 7 miles north of Kings Harbor. Los Angeles International Airport is the nearest airport that has wind measurements available for public use. Daily wind speeds were recorded as hourly, 2-minute wind speeds at a location 33 feet (10 meters) above the ground. The data was used to create a wind rose shown in Figure 3. Winds are dominant from the west to west-southwest direction and 60 percent of them are below 10 knots. The strong winds between 18 to 26 knots are coming from the west. Figure 3 also shows the percentage of occurrence for different wind directions and speeds.



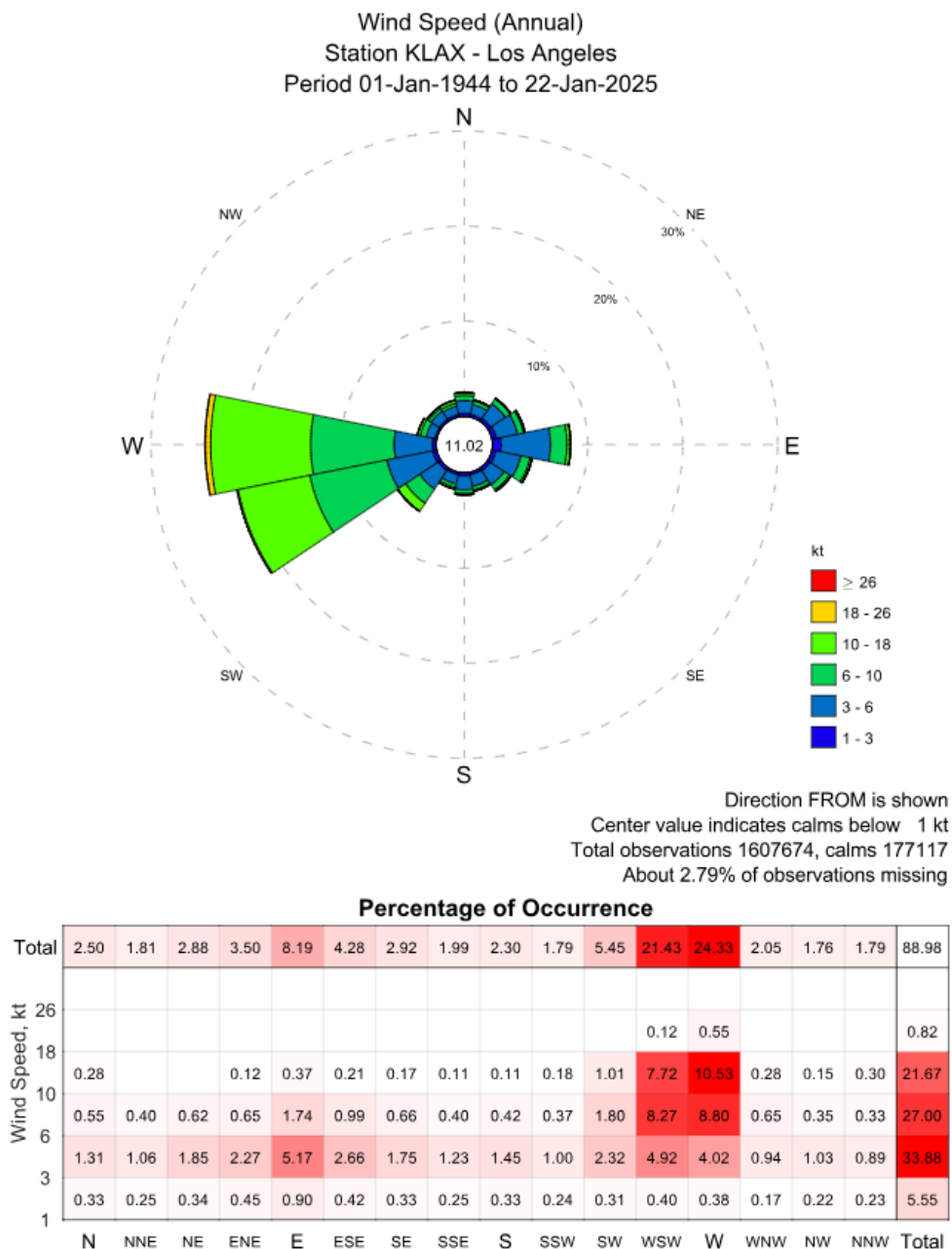


Figure 3. Annual Wind Rose and Joint Probability Table From Los Angeles International Airport (1944-2025).

2.3.2 Extreme Wind Condition

A statistical analysis was performed on the wind measurements taken from the Los Angeles International Airport to determine extreme wind conditions. The return period wind speeds were recorded within an 'all direction' category. The extreme wind return period distribution plot is shown in Figure 4 with a summary presented in Table 4.



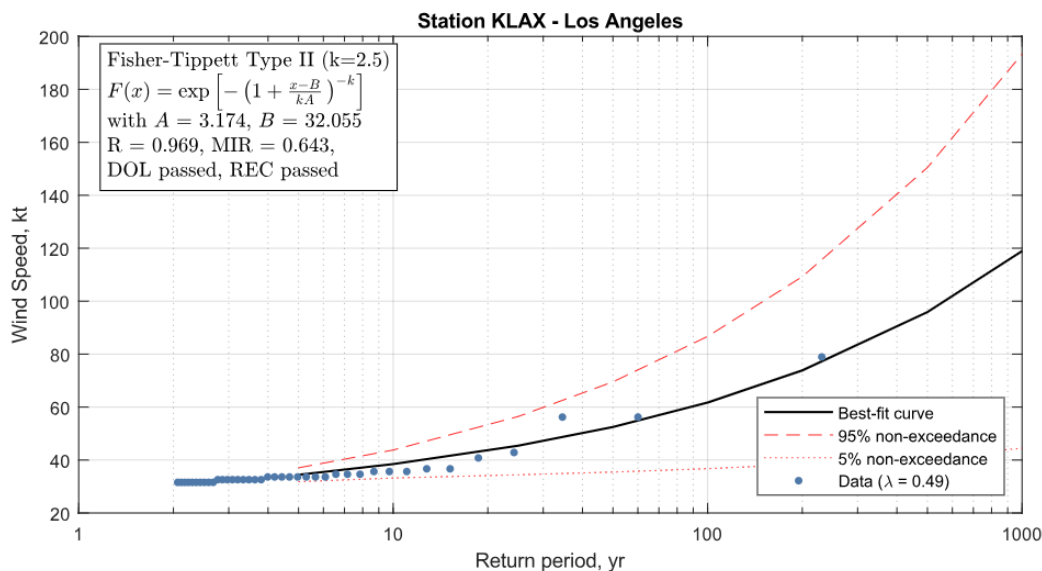


Figure 4. Extreme Wind Return Period Distribution Plot at Los Angeles International Airport (1944-2025).

Table 4. Extreme Wind Speeds at Los Angeles International Airport (1944-2025).

Return Period	2-min Wind Speed (knots)	30-sec Wind Speed (knots)
100-Year	61.7	69.9
50-Year	52.5	59.5
25-Year	45.4	51.4
10-Year	38.5	43.6
5-Year	34.4	39.0
1-Year	31.2	35.3

2.4 Offshore Waves

2.4.1 NDBC Buoy

NOAA's National Data Buoy Center (NDBC) deploys moored buoys that are used to collect meteorological and oceanic data. Buoy Station 46221 has collected offshore wave data from 2008 to the present day and is located approximately 14 miles offshore from the project site as seen in Figure 5. Figure 6 includes the wave rose at NDBC Station 46221. Waves are predominantly seen from the west and south-southwest directions. The significant wave heights of 1 percent, 10 percent, and 50 percent exceedance are 8.4 ft, 4.9 ft and 3.1 ft, respectively. The joint probability table for significant wave height and peak wave period is presented in Figure 7. More than 44 percent of the waves have a peak wave period between 13 to 16 seconds. 6.3 percent of the waves have a peak wave period longer than 18 seconds. The longer the wave period, the more energetic the wave is.



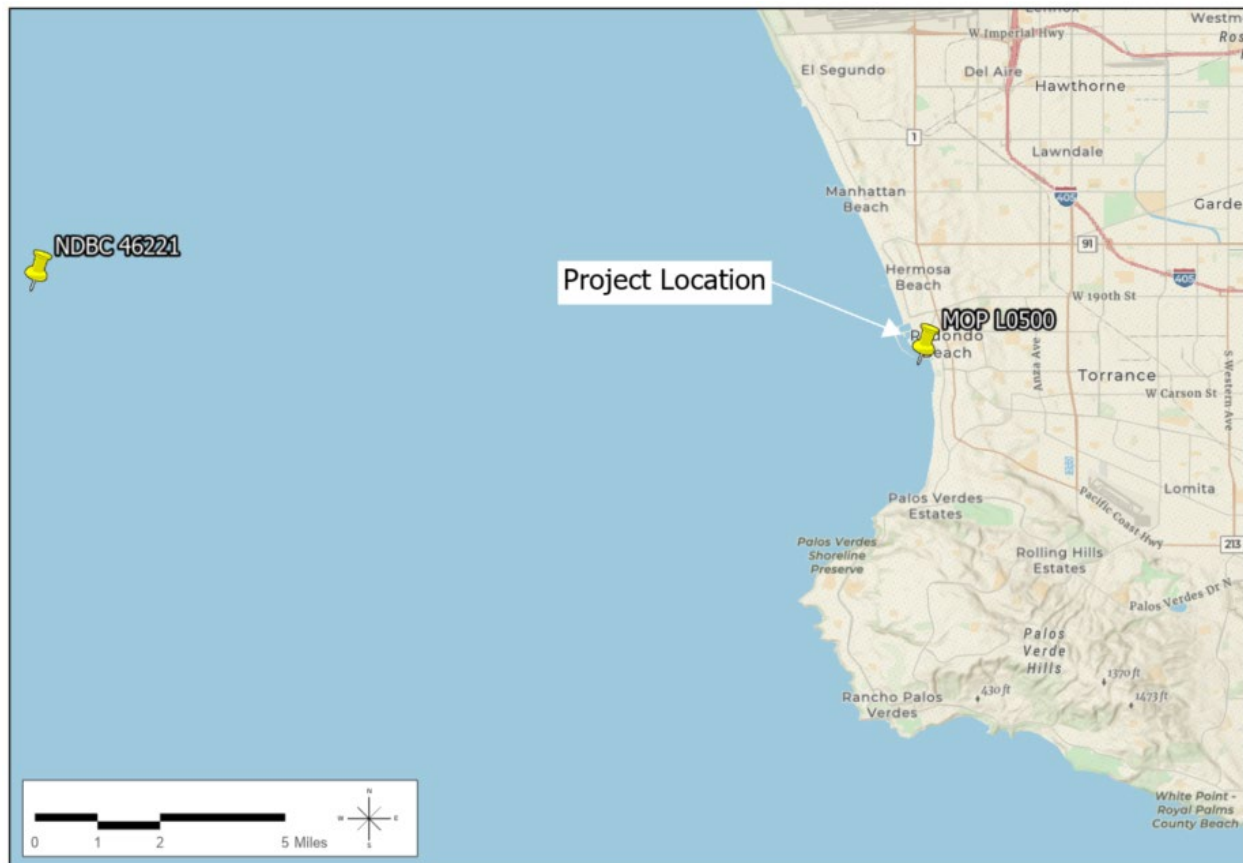


Figure 5. Location of NDBC and L0500 Buoys Relative to Project.



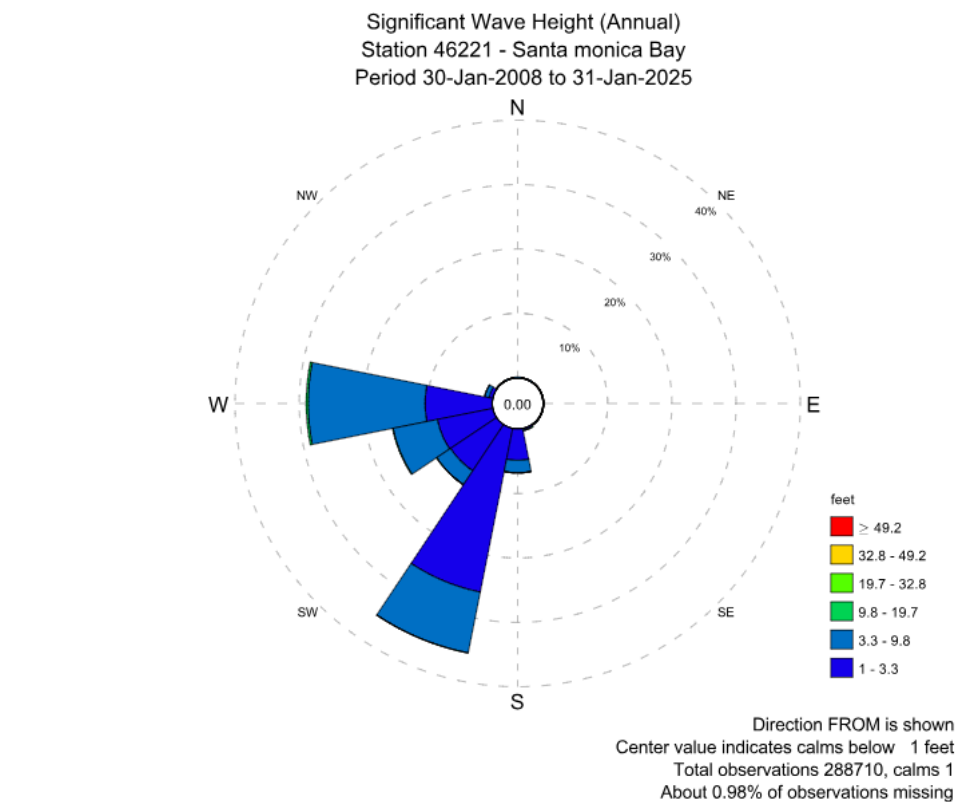


Figure 6. Wave Rose Plot at NDBC Station 46221.

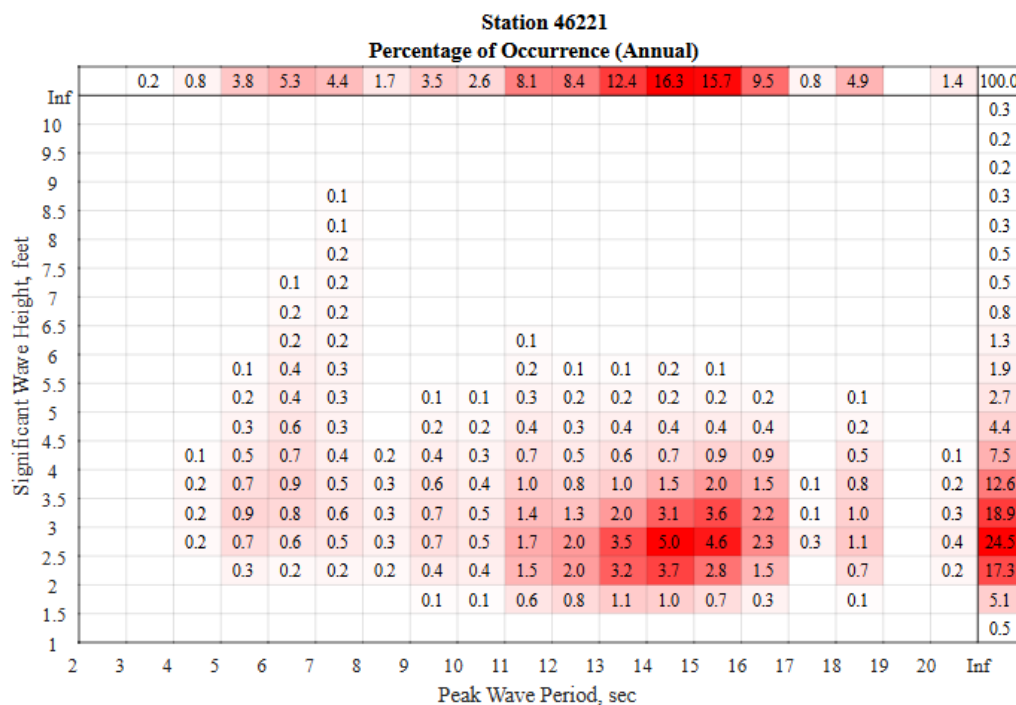


Figure 7. Joint Probability of Wave Hight and Period at NDBC Station 46221.



2.4.2 CDIP MOP L0500

The Coastal Data Information Program (CDIP) provides monitor-based wave hindcast and nowcast along the California coast, called the Monitoring and Prediction (MOP) system. The offshore wave conditions for modeling were developed based on wave data at Station L0500 from MOP from January 2000 to January 2025. Figure 5 presents the location of the MOP station, which is at the entrance of King Harbor with a depth of 33 feet (10 meters). Figure 8 includes the wave rose plot and joint probability table at Station L0500. The dominant waves at the entrance come from the southwest, perpendicular to the orientation of King Harbor's breakwater. More than 60 percent of the waves since 2000 at L0500 are less than 3.3 ft.

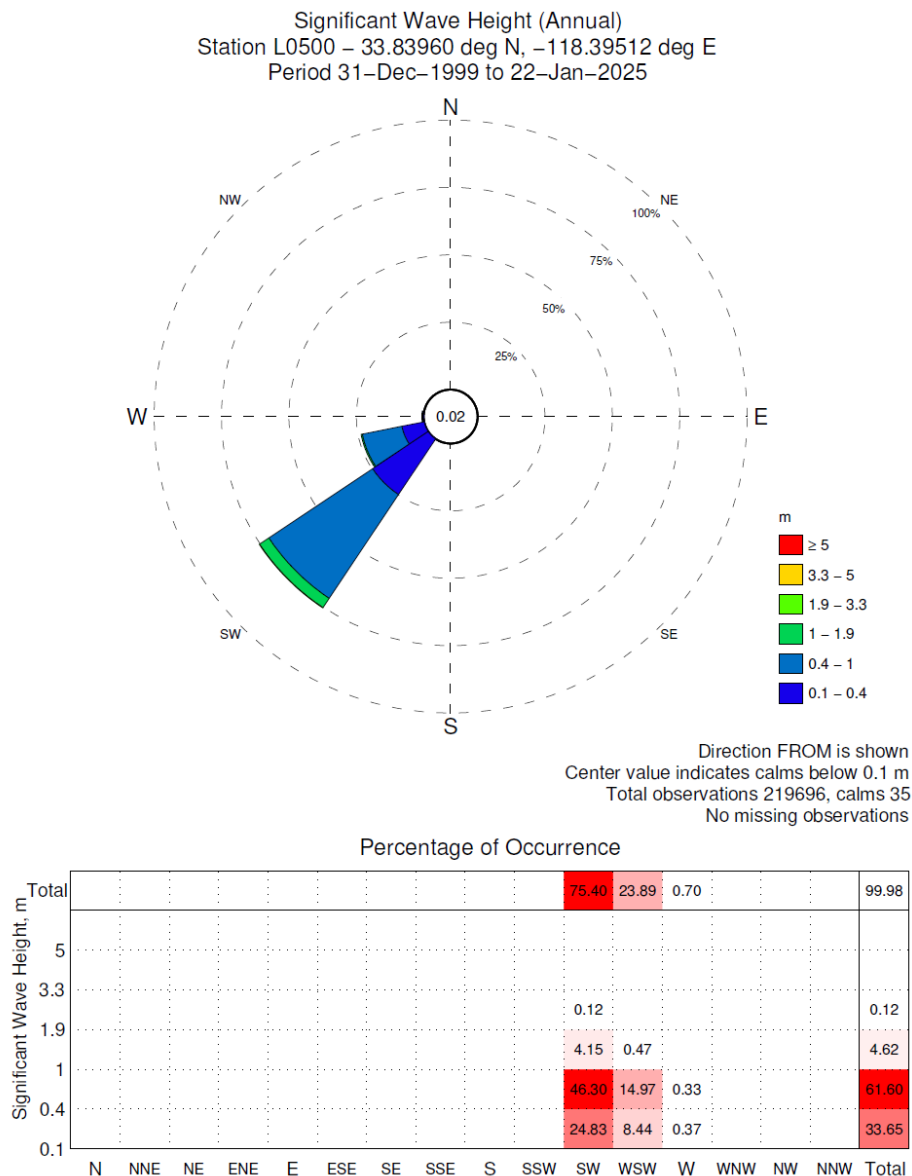


Figure 8. Wave Rose and Joint Probability Table at MOP Station L0500.



Historically, El Nino years in the 1980s had large wave events with elevated water levels and caused damage along the California coast. Therefore, additional wave events and high water level events obtained from FEMA's FIRM IDS studies¹ at the harbor entrance were added to the MOP data. An extreme value analysis of waves at the King Harbor entrance was conducted. The resulting extreme wave conditions by return periods are listed in Table 5. The associated peak wave periods are recommended as 16 to 18 seconds based on the measurements at the offshore NDBC buoy and gauges inside the harbor (see Section 2.4.1 and Section 3). These wave conditions were applied in the wave model as boundary conditions and discussed in Section 4.3.

Table 5: Extreme Offshore Wave Conditions – at King Harbor Entrance.

Return Period (year)	Significant Wave Height (ft)	Peak Wave Period ¹ (s)
1	6.7	16
2	7.1	16
5	7.8	16
10	8.4	16
25	9.3	16
50	10.3	18
100	11.4	18

Note: ¹ The peak wave periods were conservatively determined based on measurements at NDBC buoys and wave gauges in the harbor.

3 Wave Data Collection

Two RBR pressure gauges with wave measurement capabilities (RBR solo³ D | wave16) were deployed on November 7th, 2024 within King Harbor to capture the wave climate. The gauge locations can be seen in Figure 9. The gauges were attached to the center bar of PVC frames filled with sand that were gently lowered to rest on the seafloor. A picture of the PVC frame can be seen in Figure 10. Locations were selected to be representative of wave information across the area, based on their proximity to design alternatives.

¹ BakerAECOM (2015). FEMA Region IX California Coastal Analysis and Mapping Project Intermediate Data Submittal #3, Nearshore Hydraulics, LA County, California, Appendix 4.





Figure 9. Locations of RBR Wave Gauges within King Harbor.



Figure 10. PVC Frame Used to Mount the RBR Wave Gauges.

The wave gauges were set to collect burst measurements at a speed of 2 Hz for 512 samples, every 10 minutes. Data from the gauges were analyzed and presented below for the 2-month period (November 7th 2024 to January 10th, 2025) that they were deployed. Figure 11 and Figure 12 show significant wave height (feet) and peak wave period (seconds) plotted over time for Locations 1 & 2.

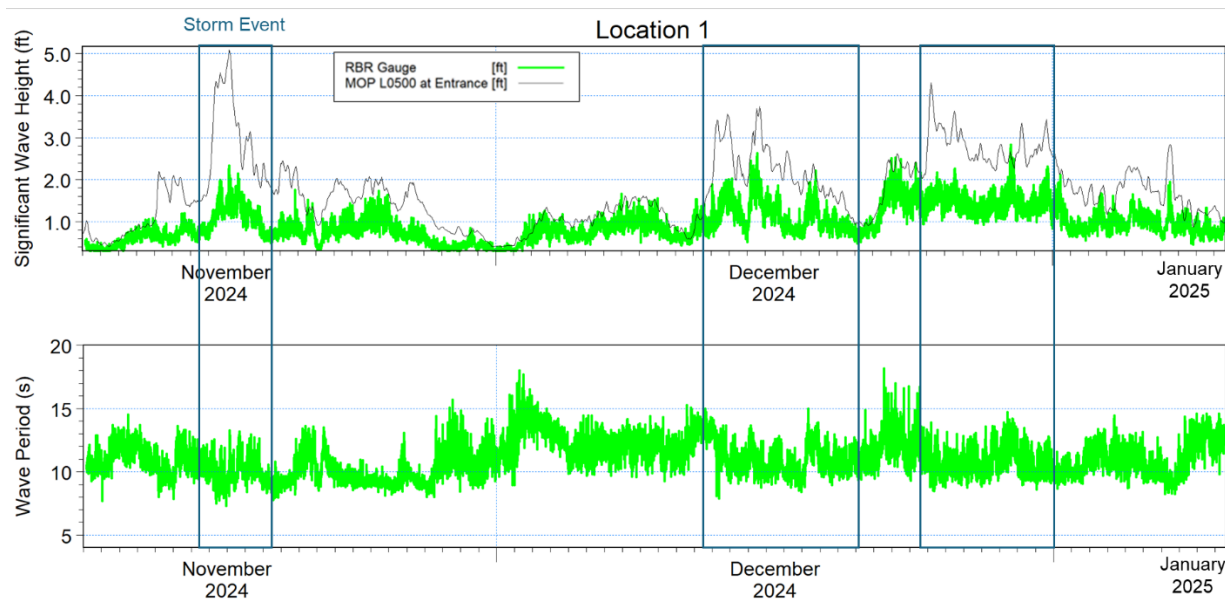


Figure 11. Timeseries of Significant Wave Height and Significant Wave Period for Location 1.

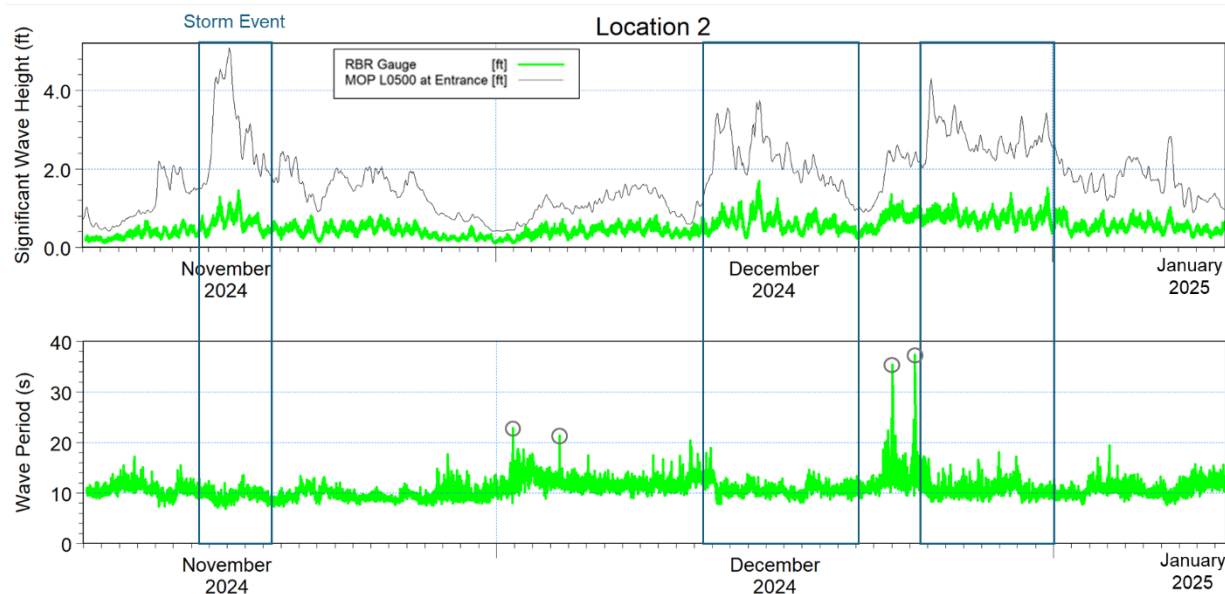


Figure 12. Timeseries of Significant Wave Height and Significant Wave Period for Location 2.



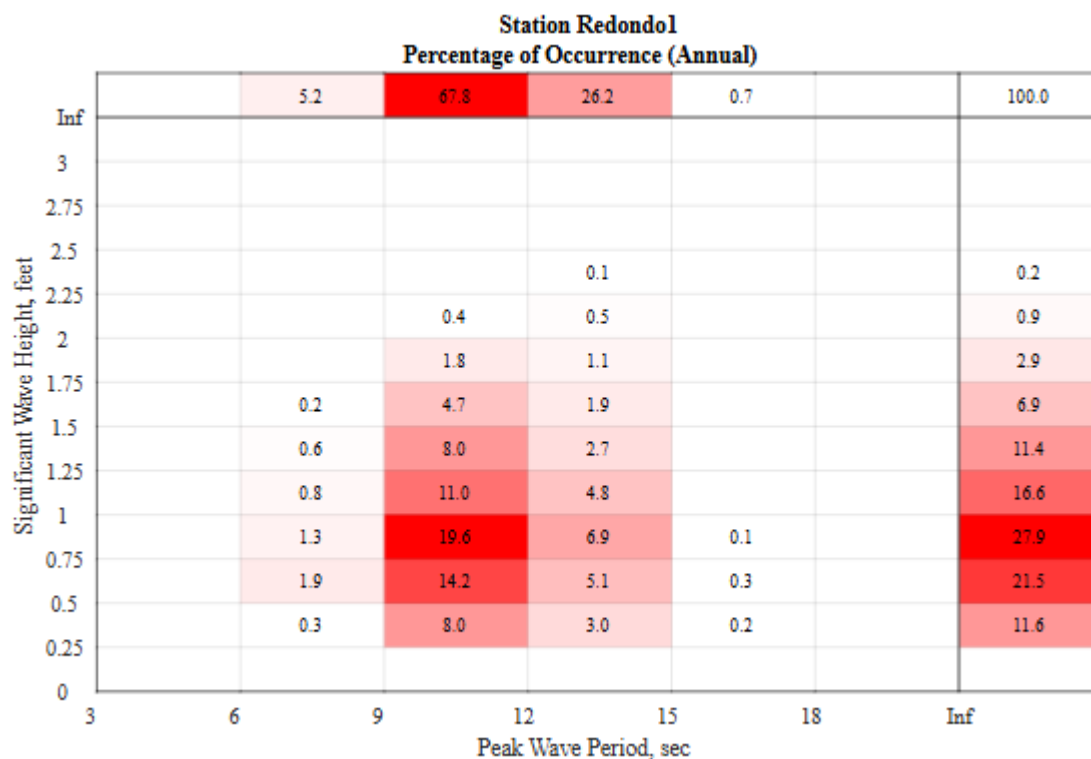


Figure 13. Joint Probability Table for Location 1.

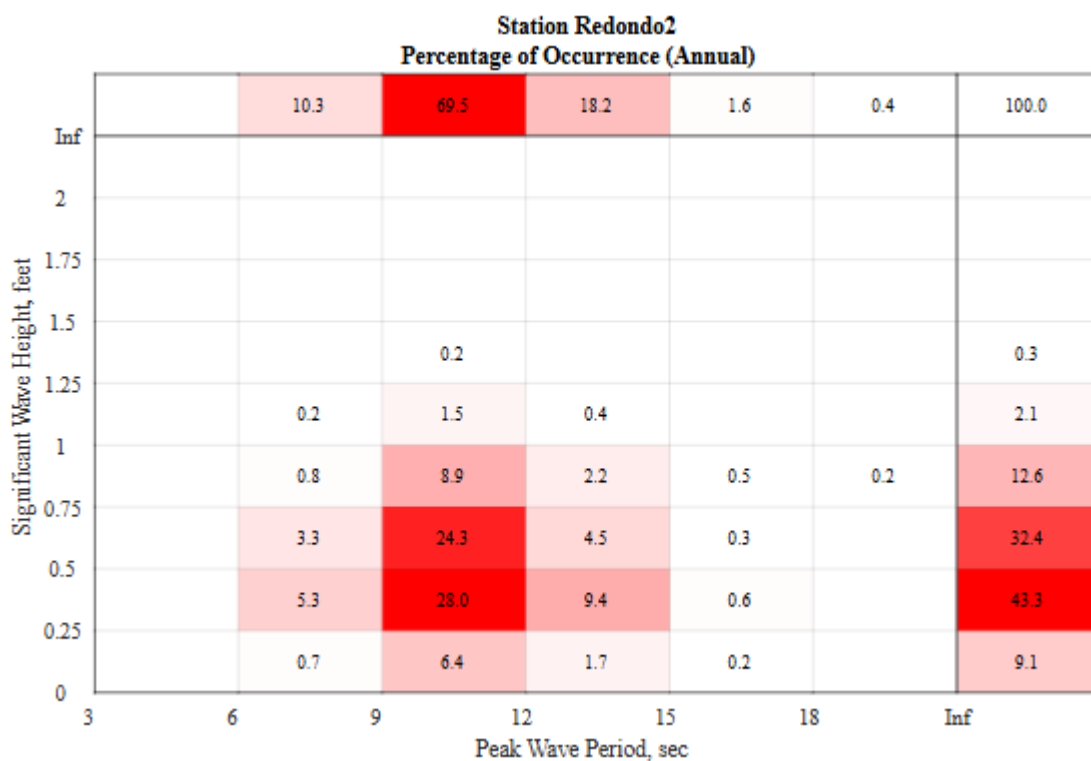


Figure 14. Joint Probability Table for Location 2.



The measured approximate 2-month data show that significant wave heights do not exceed 3 ft at Location 1 and 1.7 ft at Location 2. The significant wave period at Location 1 ranges from 7 seconds to 18 seconds, consistent with what has been seen at the offshore NDBC buoy. However, there are occurrences of wave periods longer than 20 seconds observed at Location 2, marked in grey circles in Figure 12. These long periods could be an indication of seiche problems within the harbor or data noise from instruments. Additional modeling in the future final design once a preferred alternative is chosen could help to identify whether potential seiche problems exist or not. Storm events captured by both gages are highlighted in blue boxes in Figure 11 and Figure 12. The MOP wave time series at the harbor entrance (L0500) are also plotted in these two figures. A good correlation between the MOP and RBR measurements is observed, especially during storm events. Figure 13 and Figure 14 summarize the joint probability of wave height and period for Locations 1 & 2. The most frequent wave period for both locations is between 9 to 12 seconds, with 68 percent to 70 percent of the waves, corresponding to the wind waves. The frequent swell wave periods are from 12 to 15 seconds, with 18 percent to 26 percent occurrence.

The data show that the wave heights at Location 1 were consistently higher than that recorded at Location 2. This is likely due to the gauges' proximity to the breakwater. The breakwater provides protection from offshore waves for Location 2. Small waves less than 1 ft are not of operational concern but waves greater than 2 ft will disrupt the operation.

4 Site-specific Wave Modeling

MIKE21 Wave model Flexible Mesh (FM) from Danmark Hydraulics Institute (DHI) was used to develop the wave conditions at the proposed boat launch sites. MIKE21 Wave FM is a newly released phase-resolving wave model formulated in the time domain. It replaces the traditional MIKE21 Boussinesq Wave (BW) model and can accurately model wave diffraction and refraction. MIKE21 Wave FM model solves the same governing equations as the MIKE21 BW model but uses unstructured flexible meshes that require less computational time.

The modeling approach of wave conditions at the boat launch sites can be summarized as the following:

- Develop operational and extreme wave conditions at the entrance of the harbor using as model input data
- Develop 2D MIKE21 Wave FM model for the Redondo King Harbor
- Calibrate the MIKE21 Wave FM model with measured waves
- Simulate the design and operational wave conditions with the calibrated wave model and provide waves at the boat ramps.

4.1 Model Mesh and Bathymetry

A flexible mesh with varied element sizes was developed for Redondo King Harbor. Figure 15 illustrates the model domain that covers the entire harbor. Bathymetry contours from the previous 2016 main channel dredging study were used to develop model bathymetry. The vertical datum is set to MLLW. The deepest point within the domain is at the harbor entrance, at an elevation of -42 ft MLLW. The three marina basins have depths between 10 to 20 ft below MLLW.

The flexible mesh has a resolution of 10 to 15 ft over the entire domain. Finer elements are applied in shallow areas with steep slopes.



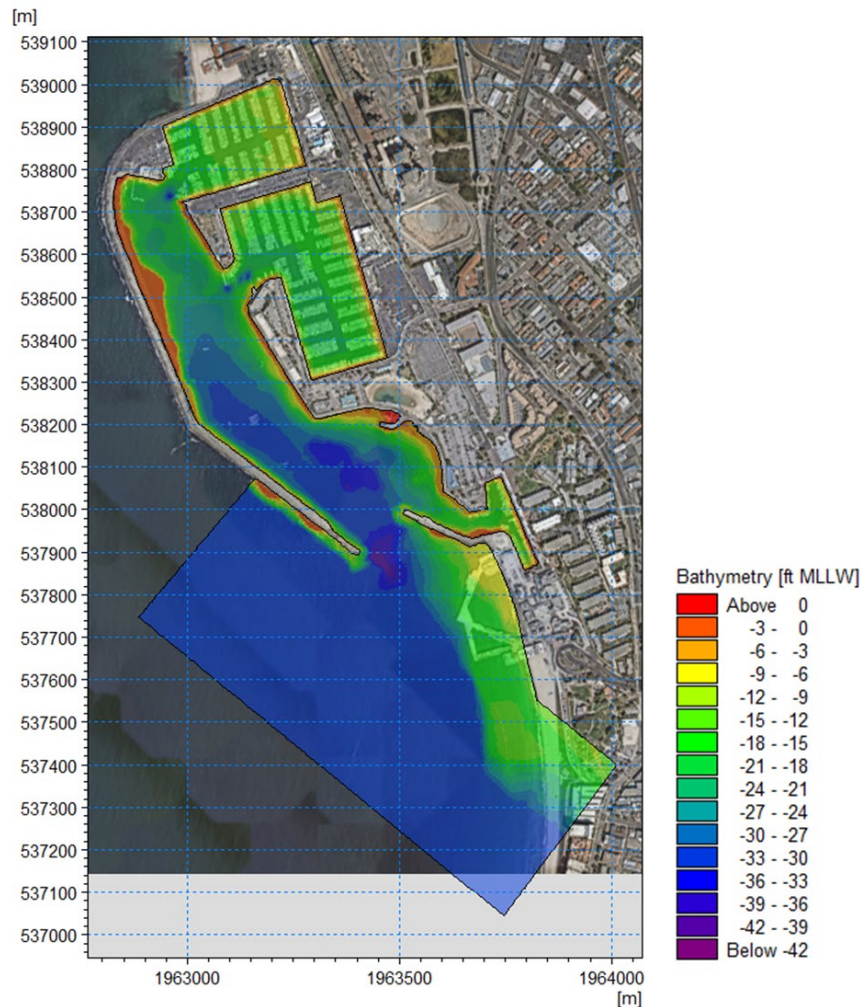


Figure 15. Model Domain and Bathymetry of the Existing Harbor.

4.2 Model Calibration

Two RBR wave gauges were deployed inside the harbor measuring waves in the winter season. The measured waves discussed in Section 3 are used to calibrate and verify the MIKE21 wave FM model. The model calibration focused on three events captured during the deployment period, covering a wave period from 13.3 seconds to 7.1 seconds. These three events are within the three highlighted with blue box storm periods illustrated in Figure 11 and Figure 12. Such a range of wave periods covers both swell and wind wave events. However, this wave study is focused on swell waves with longer wave periods as it will control the boat ramp design. The wave direction at the entrance is from the southwest with very small variations.

During the model calibration, the porosity layers in the model were initially determined by the types of shoreline and then adjusted to achieve the best fit with the measured waves during these events. The porosity values within the harbor were set between 0.2 to 0.45 after model calibration. Table 6 summarizes the measured and modeled significant wave heights at the two wave gauges, named Location 1 and Location 2, respectively. The modeled wave heights in Event 1 and Event 2 match very well with the measured wave heights, showing less than 0.1 ft difference. The modeled waves are slightly higher than measured, indicating relatively conservative estimates. In Event 3, the model over-estimates



the wave height at Location 1 (Gauge “Pier”), and underestimates it at Location 2 (Gauge “Channel”). This is related to the missing winds in the model, as this is a wind-induced wave event with a 7-second period. Overall, the MIKE21 Wave FM model is deemed sufficiently accurate for computing swell waves within King Harbor.

Table 6. Model Calibration Results at RBR Wave Gauges.

Parameter	Event 1	Event 2	Event 3
Event Time (GMT)	12/28/2024 11:00 AM	11/17/2024 8:00 AM	11/15/2024 6:00 PM
Offshore Sign. Wave Height ¹	2.5 ft	3.1 ft	4.4 ft
Offshore Peak Wave Period	13.3 s	10 s	7.1 s
Offshore Incoming Wave Direction (from)	228°N	227°N	235°N
Stillwater Level	3.6 ft MLLW	5.7 ft MLLW	4.4 ft MLLW
Measured Sign. Wave Height at RBR Location 1	1.08 ft	1.33 ft	1.25 ft
Modeled Sign. Wave Height at RBR Location 1	1.15 ft	1.43 ft	1.38 ft
Measured Sign. Wave Height at RBR Location 2	0.78 ft	0.64 ft	0.86 ft
Modeled Sign. Wave Height at RBR Location 2	0.85 ft	0.67 ft	0.46 ft

Note: ¹ Offshore wave conditions at the harbor entrance where MOP L0500 is located.

The model was also verified with USACE’s model study for Redondo Beach King Harbor improvements in 1990². With an entrance wave of 11.5 ft, 15 seconds and Stillwater level at 7.0 ft MLLW, the study reported a maximum wave height of 4.3 ft at Gage 12. Figure 16 depicts the location of Gage 12 from USACE’s 1990 study. The MIKE21 Wave FM model simulated the same entrance wave conditions from the model boundary and compared the maximum wave height obtained at the RBR Location 2 (Gauge “Channel”) with that at Gage 12. The current MIKE21 model predicts a maximum wave height of 4.2ft at “Channel”, close to 4.3ft estimated at Gage 12 by USACE.

² Robert R. Bottin, Jr. and Rochard E. Kent. (1990) Redondo Beach King Harbor, California Development of Design Data for Harbor Improvements, Coastal Model Investigation, Final Report, USACE Technical Report CERC-90-6, May 1990.



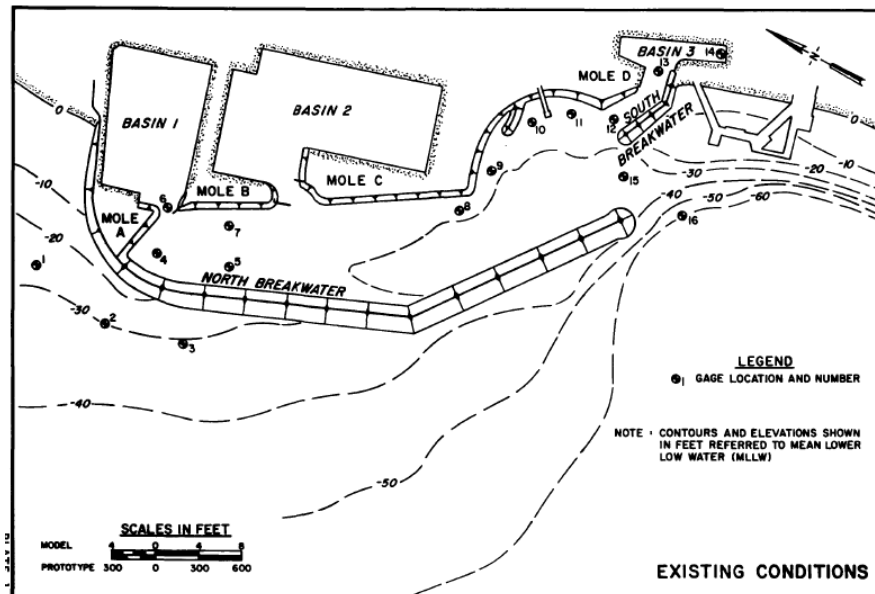


Figure 16. Gage Location in USACE 1990 Study.

4.3 Modeled Scenarios and Boundary Conditions

Three proposed alternatives named Alternative 1, Alternative 2 and Alternative 5 were studied. Figure 17 through Figure 19 present the boat launch ramp locations of these three alternatives. Alternative 1 has the boat launch ramp at the entrance of Basin 3 marina. Its location is the one furthest from the King Harbor entrance among the three, meaning the least wave disturbance. Alternative 2 is located in the harbor turning basin. Alternative 5 is close to the previously demolished sport fishing pier, south of the Seaside Lagoon rock groin. An L-shape sheet pile wall is proposed next to the boat launch in Alternative 5 to provide extra wave protection. This sheet pile wall was not included in the 2D wave model for this concept level modeling study.



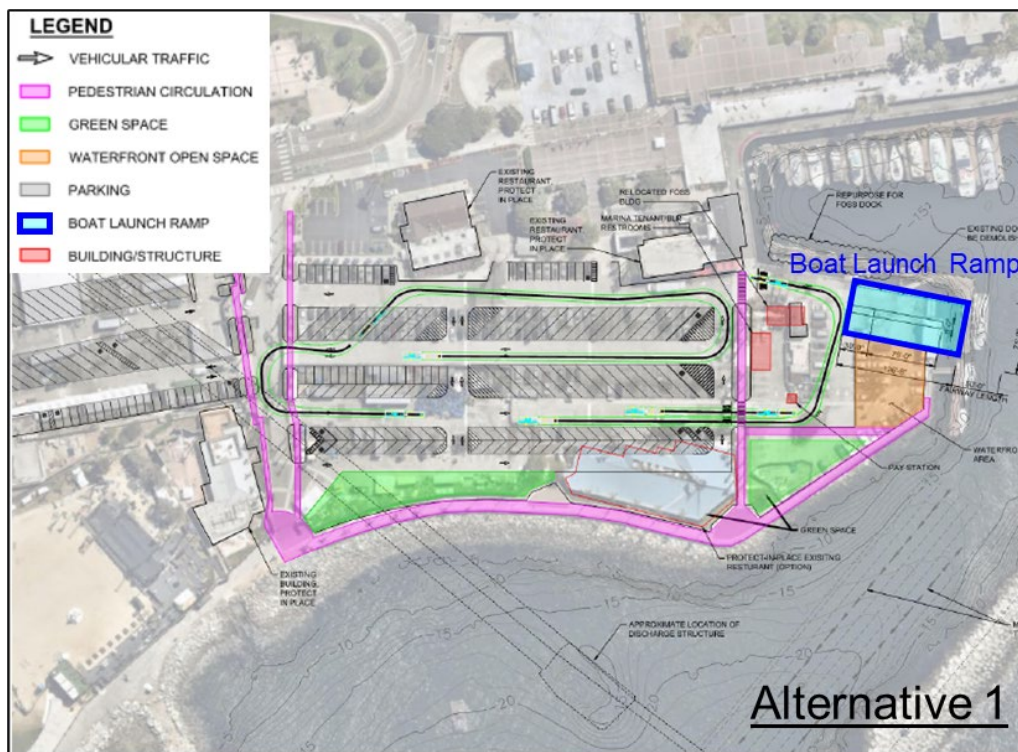


Figure 17. Boat Launch Ramp Placement – Alternative 1 (dated December 18, 2024).

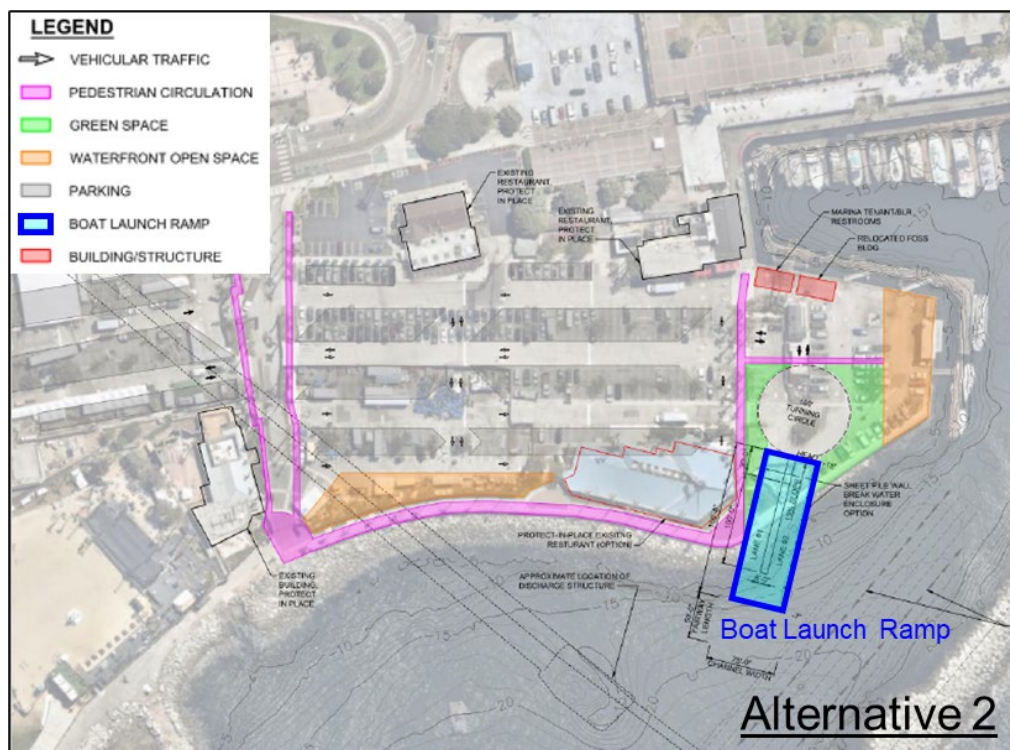


Figure 18. Boat Launch Ramp Placement – Alternative 2 (dated December 18, 2024).



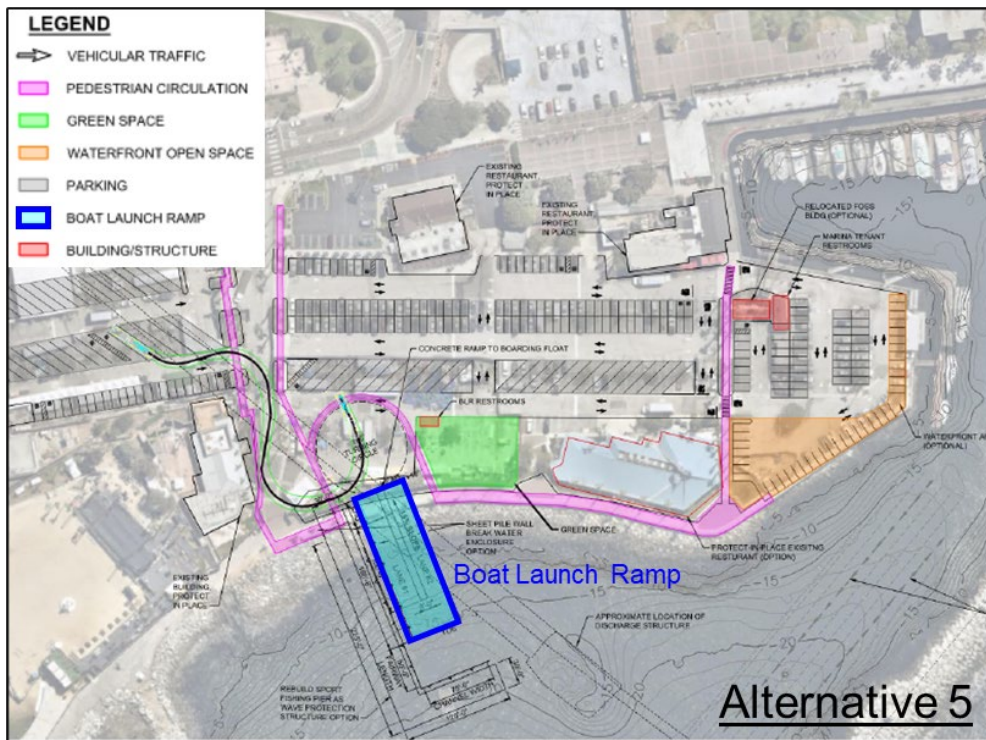


Figure 19. Boat Launch Ramp Placement – Alternative 5 (Note: The graphic shows a rebuilt pier and potential sheet pile wall wave attenuator, but the wave modeling assumed no pier or wave attenuator) (dated December 18, 2024).

To provide design waves and understand boat ramp operational limits, a series of model scenarios were conducted and listed in Table 7. The wave conditions applied at the boundary were developed based on Scripps' CDIP MOP database at Station L0500 at the King Harbor entrance. Peak wave periods of 16 and 18 seconds were used. Details on the offshore waves are discussed in Section 2.4. The 1-year extreme water level at the Santa Monica tide gauge was applied with the extreme waves under various return periods. A SLR condition was also modeled to address future coastal hazards. More discussions on coastal hazards are included in Section 5.

Table 7. Model Scenarios and Boundary Conditions.

Purpose	Return periods	Stillwater Level	Wave Condition at Boundary ³	
			Sign. Wave Height (ft)	Peak Wave Period (s)
Operation Conditions	1-year	7.0 ft MLLW ¹	6.7 ft	16 s
	2-year	7.0 ft MLLW	7.1 ft	16 s
	5-year	7.0 ft MLLW	7.8 ft	16 s
	10-year	7.0 ft MLLW	8.4 ft	16 s
	25-year	7.0 ft MLLW	9.3 ft	16 s
	50-year	7.0 ft MLLW	10.3 ft	18 s
Design Wave Conditions; Coastal Hazard Analysis	100-year	7.0 ft MLLW	11.4 ft	18 s
	100-year	9.9 ft MLLW ²	11.4 ft	18 s

Note:

¹ 1-year extreme Stillwater level based on NOAA tide gauge at Santa Monica (ID 9410840).

² 1-year Stillwater level with +2.9 ft SLR by 2080 (see discussion in Section 2.1.2).

³ The mean wave direction at the boundary for all scenarios was set to 230°N, based on MOP L0500 data.

4.4 Model Results

As shown in Figure 20, four output locations were selected to extract modeled waves at the proposed boat launch ramps. Their associated depths are also included in Figure 20. Note that two locations are selected for Alternative 5. Alt5-1 is at the boat launch ramp and assumes no sheet pile wall. Alt5-2 is at the seaward side of the potential sheet pile wall.



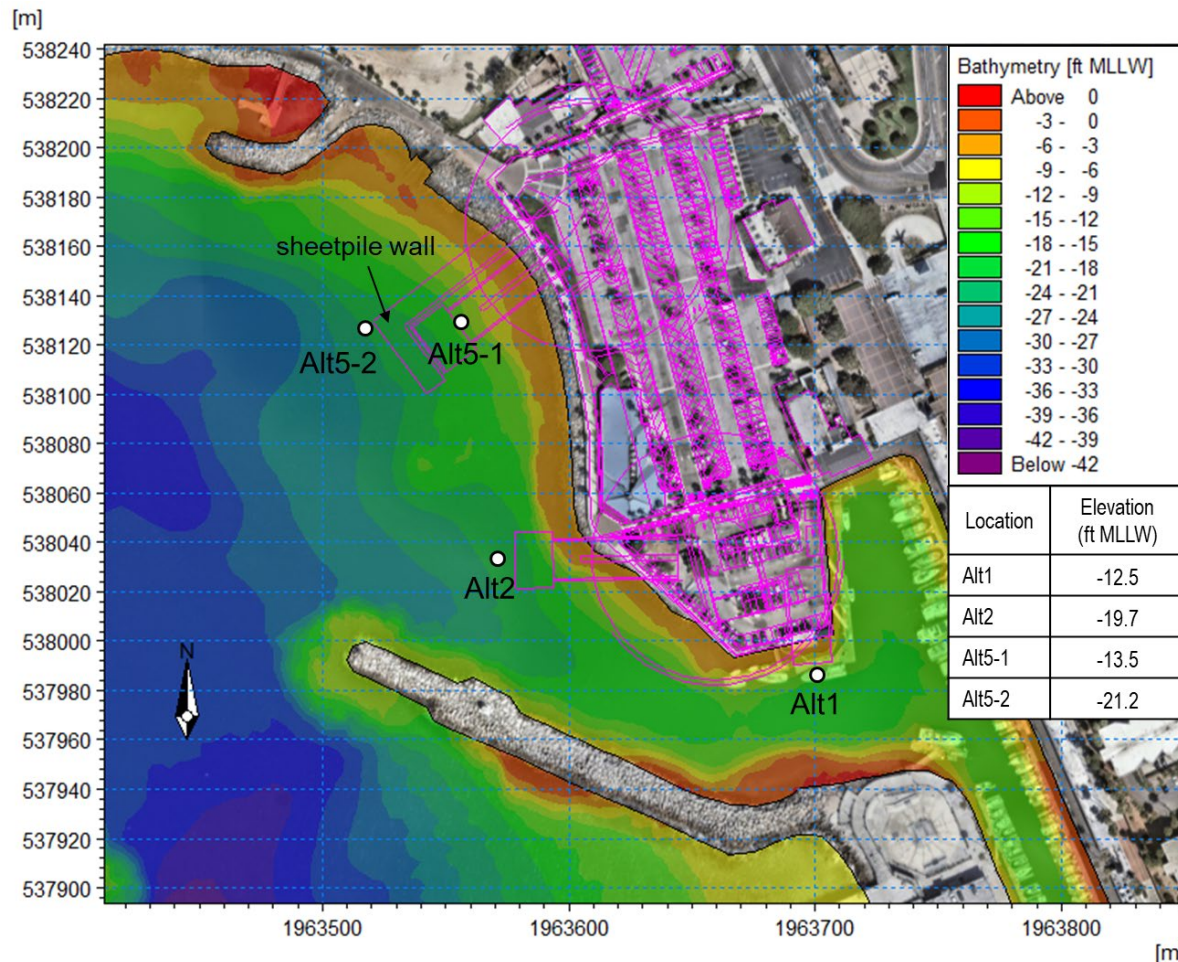


Figure 20. Extraction Locations for Three Alternatives (Note: Although rebuilt pier and sheet pile wall are shown in this graphic at the Alternative 5 location, the pier and wave attenuator were not included in the wave modeling).

4.4.1 100-year Design Waves

The modeled 100-year wave conditions at the four output locations are listed in Table 8. With 2.9 ft SLR, the predicted 100-year significant wave heights at these locations are generally 0.1 to 0.3 ft higher than the ones without SLR. Alternative 1 has the smallest waves among the three alternatives as it is most sheltered from the harbor entrance. The 100-year significant wave height at Alt1 is 2.3 ft with current sea level and reaches 2.5 ft with 2.9 ft SLR. Alt5-2 shows the highest waves among the four locations, reaching 4 ft without SLR and 4.3 ft with 2.9 ft SLR. Waves at Alt5-1 will be much lower than modeled if the location is protected by the proposed sheet pile.



Table 8: 100-year Waves at Boat Launch Ramp.

Scenario	Significant Wave Height ¹ (ft)				Peak Wave Period (s)
	Alt1	Alt2	Alt5-1	Alt5-2	
100-year Wave, 1-year Water Level	2.3	2.7	3.5	4.0	18
100yr Waves, 1-year Water Level with SLR by 2080	2.5	3.0	3.6	4.3	18

Note: ¹ The wave height locations are shown in Figure 20.

4.4.2 Operational Wave Conditions

Wave events with shorter return periods were simulated to understand the potential limits for boat ramp operations. Table 9 tabulates the modeled wave conditions at the four boat ramp extraction locations under wave height of 1-year, 2-year, 5-year, 10-year, 25-year, 50-year and 100-year return periods. All modeling runs assumed a 16 second wave period. Note that the results listed in Table 9 do not include SLR impact.

Using a 2-ft significant wave height as an operation criterion at the boat launch ramp, Alternative 1 will experience unfavorable wave heights exceeding 2 ft under a return period of 50 years or longer. Alternative 2 will exceed this operational criterion under a return period of 25 years or longer. Alternative 5 will have more frequent downtime, as the 1-year wave height is already 1.9 ft at Alt5-1 and 2.3 ft at Alt5-2. The results of Alternative 5 also support the recommendation of adding a sheet pile wall structure at the boat ramp to provide wave protection.

Table 9. Wave Conditions at Boat Launch Ramp by Return Periods.

Return Period (yr)	Significant Wave Height (ft)			
	Alt1	Alt2	Alt5-1	Alt5-2
1	1.2	1.5	1.9	2.3
2	1.3	1.6	2.0	2.4
5	1.4	1.7	2.2	2.6
10	1.5	1.8	2.4	2.9
25	1.9	2.2	2.9	3.4
50	2.1	2.5	3.2	3.8
100	2.3	2.7	3.5	4.0



5 Coastal Hazards Analysis

5.1 Shoreline Erosion Hazards

The existing shoreline at the project site, as shown in Figure 21, has engineered shore protection structures such as a seawall, bulkhead and rock revetment along the majority of its perimeter. There is no existing sandy shoreline that can experience erosion; therefore, shoreline erosion is not applicable and is not considered a hazard in this analysis.



Figure 21. Project site seawall (A and B) and bulkhead (C) from different views (photos taken in fall of 2024)



5.2 Flood Hazards

Flood hazards at the site (flooding of the areas surrounding the launch ramp) may be caused by high still water levels (SWL) and/or wave runup (Figure 22). SWLs fluctuate with tidal variability, storm surge, and changes in mean sea level. Elevated SWLs typically cause inundation over the course of hours or longer. Wave runup, on the other hand, is generated by waves above the SWL acting on the shoreline or coastal structures and typically causes intermittent flooding over the course of minutes. Note that wave runup typically reaches much higher elevations than the SWL, as the forward momentum associated with the wave propels water up and onshore into the project site, i.e. up the launch ramp.

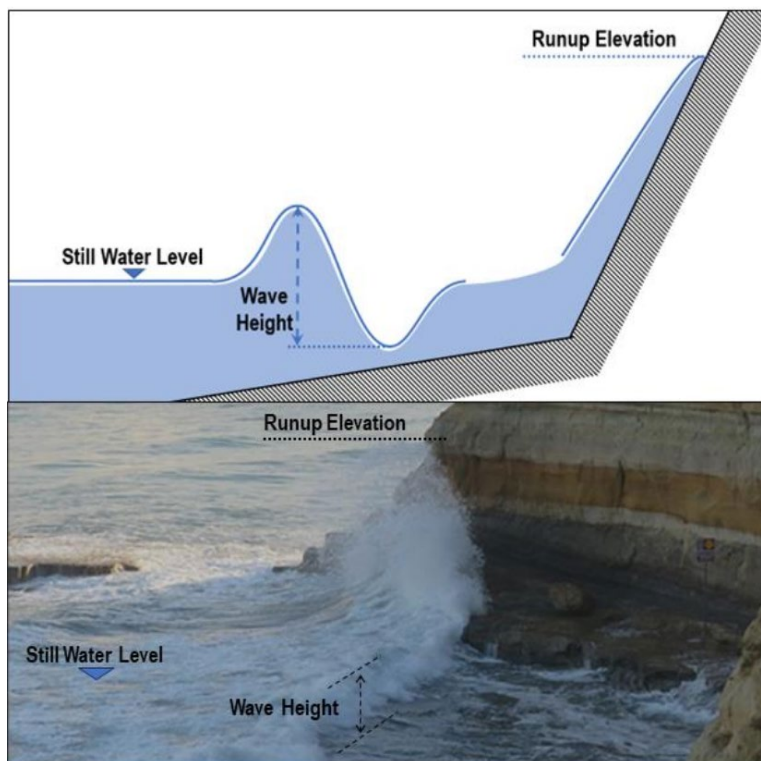


Figure 22. Flood Hazard Definitions.

5.2.1 Still Water Flooding

SWL can be defined as the water surface elevation in the absence of local variation due to waves, at present and projected SLR conditions. For the latter, we used a SLR of 2.9 ft, which is associated with the intermediate-high scenario, with a 0.1 percent exceedance probability, in 2080 (see section 2.1.2.1). Table 3 shows the range of present SWLs at the project site for different return periods.

The 100-year return period SWL, anomalous high-water conditions caused by atmospheric patterns (such as El Niño) and/or astronomical components, i.e., the present SWL of 8.0 ft MLLW compares relatively well to the historical highest observed water level at 8.5 ft MLLW. Extreme 100-yr SWLs at the project site are +8.0 and +10.9 ft MLLW under Present and 2080 SLR conditions, respectively.

Based on the 2016 USGS LiDAR (Dewberry, 2016) shown in Figure 23 (no other current topographic survey data was available for this analysis), the ground elevations within the project shoreline range from approximately +9 to +13 ft MLLW. Based on the Mole D Splash Wall record drawings (DMJM, 1990), the top of seawall (TOSW) is at +17 ft MLLW, and its top of footing (TOF) is at +12.5 ft MLLW. Therefore, under the Present and 2080 sea levels, the seawall footing does not flood under the 100-year SWL. The



backlands of Alternatives 2 and 5, with top of ramp elevations of +18 ft MLLW, and Alternative 1, with top of ramp of +12 ft MLLW, would also not flood with these extreme 100-yr SWLs for Present or 2080 SWLs. However, it is worth noting there is an opening in the existing seawall at the location of Alternative 5, and the seawall does not extend to the Alternative 1 location where the ground elevation is at approximately +9.5 ft MLLW.

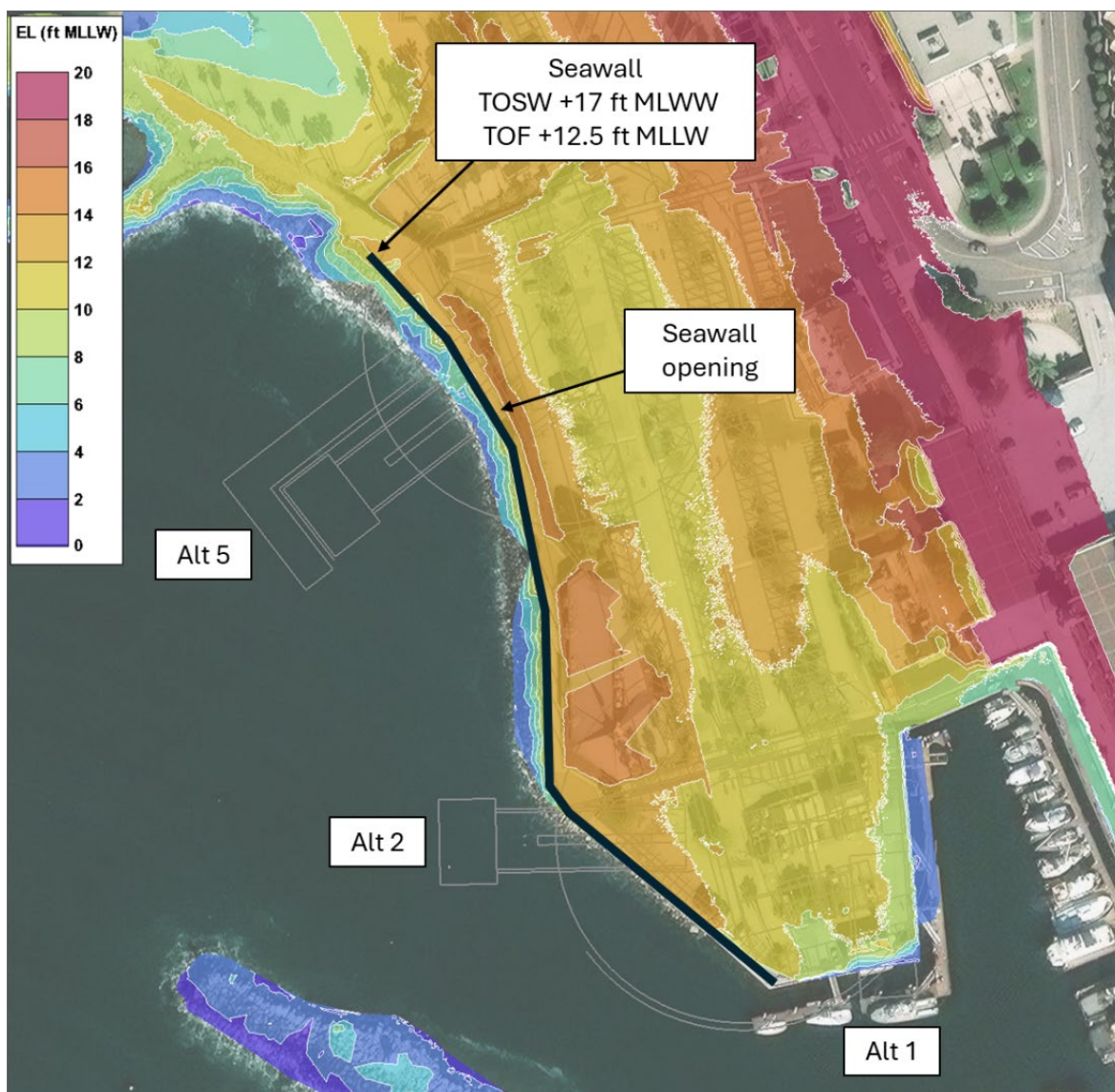


Figure 23. Existing Surface Elevation at the Project Site. Based on USGS LiDAR (2016), alternatives 1, 2, and 5 shown in grey, and approximate seawall extents shown in black.

5.2.2 Total Water Level Flooding

Total Water Level (TWL) is defined as the water elevation that results from the combination of the SWL, wave setup, and wave-induced runup. This section analyzes the results of present and future TWL flooding predictions from three separate sources: (1) USGS CoSMoS, (2) FEMA FIRM, and (3) Moffatt & Nichol (M&N) wave runup analysis.



5.2.2.1 USGS CoSMoS

CoSMoS (USGS, 2021) has the capability to map detailed predictions of coastal flooding based on existing and future climate scenarios for Southern California (Barnard, 2018). The modeling system incorporates state-of-the-art physical process models to enable the prediction of currents, wave height, wave runup, and total water levels. Coastal flooding predictions simulate the effects of erosion, wave runup, and overtopping during storm events. Flooding extents are calculated and mapped at profiles spaced about 330 ft apart along the shoreline.

The projected water levels used in the flood mapping consider future shoreline changes, tides, sea level anomalies such as El Niño, storm surge, and SLR. Future wave conditions used in the model are based on forecasted conditions out to the year 2100. Future storm event scenarios for typical conditions, 1-, 20-, and 100-year return periods are available for SLR scenarios from 0 to 6.6 ft. The CoSMoS SLR scenario closest to the 2.9 ft previously described in sections 5.2.1 and 2.1.2.1 is 3.3 ft; see Figure 24.

The CoSMoS data shows the TWL not reaching the project site under the present SLR, and in agreement with the 100-year SWL no flood condition, because it can be inferred that the present 100-year wave runup does not reach the existing ground elevations. However, a significant portion of the parking lot in the southern end of the project by Alternative 1 is projected to be affected in 2080 by wave runup since the seawall does not extend this location; Alternatives 2 and 5 are protected from 2080 runup because of the existing seawall.

5.2.2.2 FEMA FIRMs

The National Flood Hazard Layer (NFHL) is a geospatial database that contains current effective flood hazard data. The FEMA Flood Insurance Rate Maps (FIRM) provide the 100-yr Base Flood Elevations (BFE), which include 100-year wave runup elevations for present-day (only) sea levels at coastal locations based on calculations at discrete analysis transects.

The FIRM at the project site is shown in Figure 25. Two separate flood zones, delimited by the jetty, can be observed at the project site:

- Zone VE at EL +21 NAVD88: No flooding of the project area (including Alternative 5 location) because the existing seawall and its curvature may prevent wave uprush from reaching the area.
- Zone AE EL +8 NAVD88: No flooding of the project area because waves are presumed to not penetrate into this zone, including Alternatives 2 and 5 locations, i.e. no wave uprush is included in the FEMA analysis. However, M&N wave monitoring and modeling results do indicate wave presence in this zone.



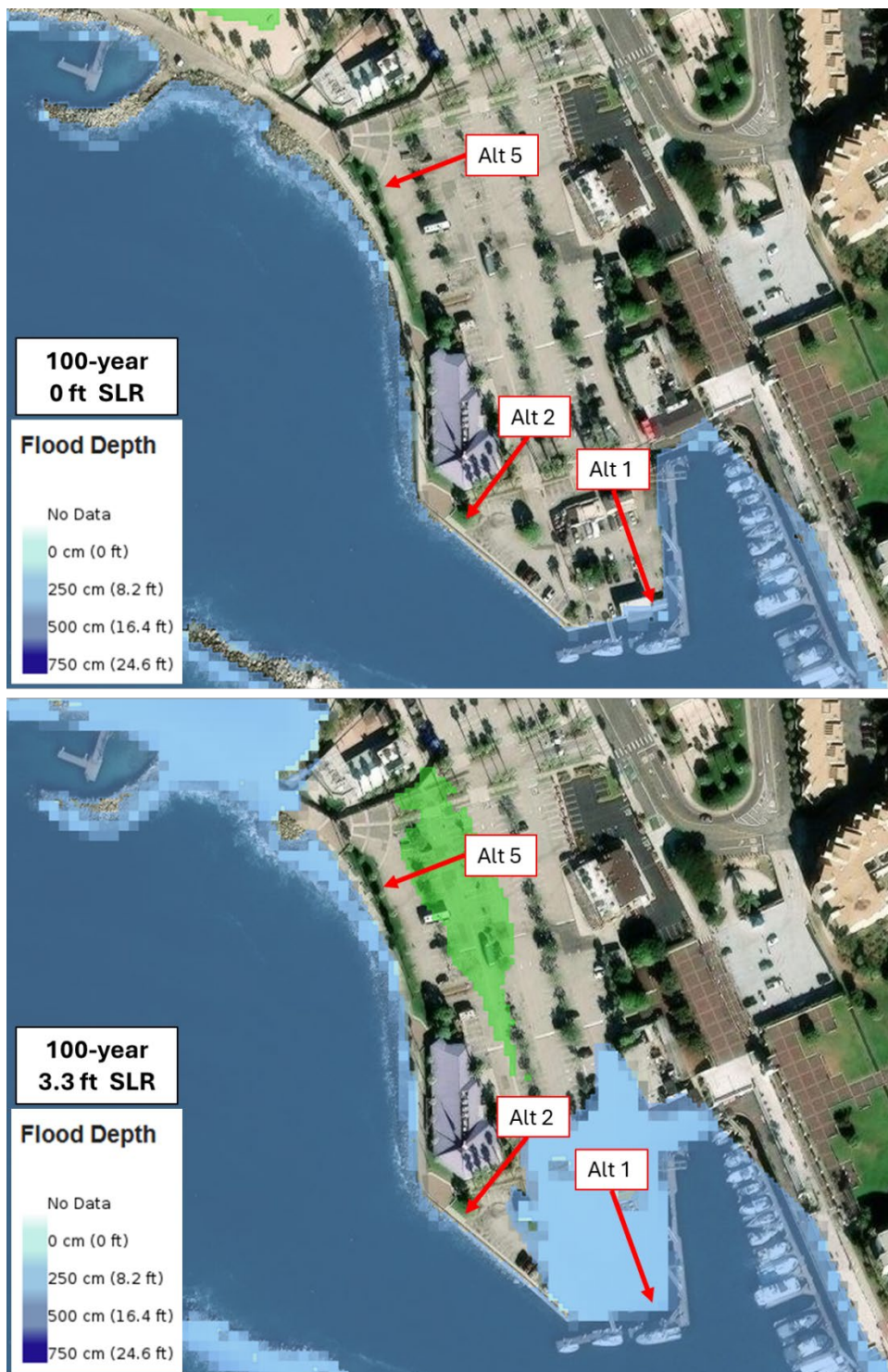


Figure 24. CoSMoS 100-yr-event Flooding Extents Under Existing Conditions (no SLR) (top) and 3.3 ft of SLR (bottom).





Figure 25. FEMA FIRM at Project Site (City of Redondo Beach).

5.2.2.3 M&N Wave Runup Analysis

M&N conducted a wave runup analysis following the methods described by (FEMA, 2005) where the TWL was calculated using the Technical Advisory Committee for Water Retaining Structures approach, known as TAW.

To determine a conservative estimate of the maximum extent of present and future flood hazards from SLR and storm-related flooding, the extreme storm criteria employed in this M&N analysis consisted of the following environmental conditions:

- 100-year-return waves (wave height and wave period)
- 1-year SWL and present-day sea level conditions
- 1-year SWL and 2.9 ft of future SLR

The geometry assumed for each alternative is shown in Table 10 and the runup results are shown in Table 11. The wave runup results for Alternatives 1, 2, and 5, under future SLR exceed the proposed top of ramp elevations, i.e. water will run up to the top (landward) edge of the ramp under the 100-year-return wave conditions. For present sea level, wave runup for Alternatives 1 and 2 does not exceed the top of ramp elevations, but does for Alternative 5 .



Table 10. Boat Launch Ramp Design Geometry Used in Wave Runup Calculations.

Design Parameter	Alt 1	Alt 2	Alt 5
Top of Ramp Elevation (ft MLLW)	+12	+18	+18
Bottom of Ramp Elevation (ft MLLW)	-7*	-7*	-7*
Existing Bottom Elevation (ft MLLW)	-9.5*	-16*	-16*
Ramp Slope (percent)	15	15	15
Notes	Wave direction is at an angle to the ramp	Wave direction is at an angle to the ramp	Wave direction is parallel to the ramp
* For both alternatives, the existing harbor bottom is deeper than the proposed bottom of ramp, indicating the need for a transition structure at the bottom of the ramp.			

Table 11. Wave Runup Results under 100-year waves and 1-year SWL, with and without SLR.

	Alt 1, 0 ft SLR	Alt 1, 2.9 ft SLR	Alt 2, 0 ft SLR	Alt 2, 2.9 ft SLR	Alt 5, 0 ft SLR	Alt 5, 2.9 ft SLR
SWL (ft MLLW)	7	9.9	7	9.9	7	9.9
Hs (ft)	2.3	2.5	2.7	3.0	3.5	3.6
Tp (sec)	18	18	18	18	18	18
TWL, Runup Elevation (ft MLLW)	11.8	15.1	16.1	20.0	19.0	22.2
Top of Ramp	12	12	18	18	18	18
Overtopping occurs?	No	Yes	No	Yes	Yes	Yes

When comparing the wave runup results for the different alternatives, given the same SLR and wave period, the bigger wave height and parallel alignment of the wave direction and boat ramp lead to a larger runup for Alternative 5. To illustrate the results with the proposed geometry, cross-sections have been plotted in Figure 26, Figure 27, and Figure 28, leading to the following observations:

- Alternative 1:
 - More sheltered to waves, resulting in no overtopping of the ramp under the present 100-year wave event;
 - Need for operational restrictions for both current and future SLR under extreme wave conditions but less frequently than for Alternatives 2 and 5; and
 - Under 2080 SLR (+2.9 ft), wave runup exceeds the top of ramp indicating the need for adaptation measures such as raising the top of the ramp in the future.



- Alternative 2:
 - More exposed to waves coming through the harbor entrance than for Alternative 1, but lower waves than at the Alternative 5 location, with no overtopping of the ramp under the present 100-year-return wave event;
 - Need for operational restrictions for both current and future SLR under extreme wave conditions but less frequently than for Alternative 5; and
 - Under both present and 2080 (+2.9 ft) SLR conditions, the wave runup exceeds the top of ramp which results in the need for measures such as:
 - Installing an in-water sheet pile wall seaward of the ramp to reduce the wave size/wave penetration. A sheet pile has not been included in the numerical model, but it is assumed that it will minimize wave penetration and therefore significantly lower wave runup. With future SWL of 9.9 ft MLLW; the top of ramp could be lowered from +18 to +12 ft MLLW to accommodate future SLR SWL flooding and a small amount of wave runup. However, the Alternative 2 location with a top ramp at +12 ft MLLW would make an opening in the seawall making the backland area more vulnerable to flooding.
- Alternative 5:
 - Need for operational restrictions for both current and future SLR under specific wave conditions; and
 - Under both present and 2080 SLR conditions, the wave runup exceeds the top of ramp which results in the need for measures similar to Alternative 2.

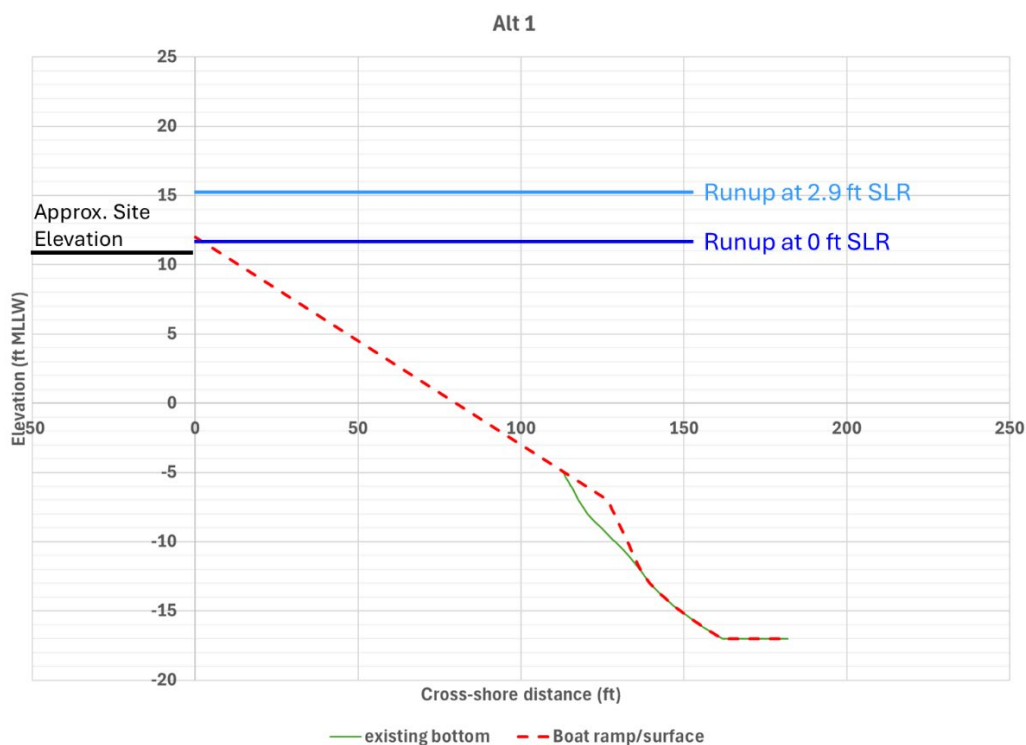


Figure 26. Alternative 1 Preliminary Boat Ramp Design Cross-section with Wave Runup Results.



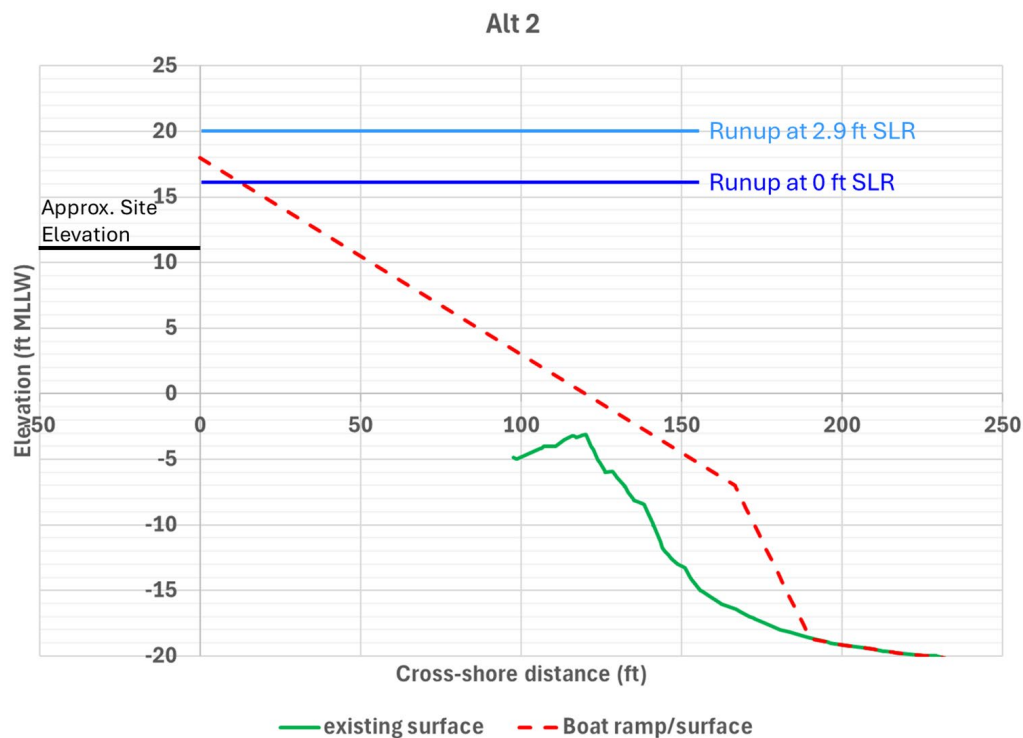


Figure 27. Alternative 2 Preliminary Boat Ramp Design Cross-section with Wave Runup Results.

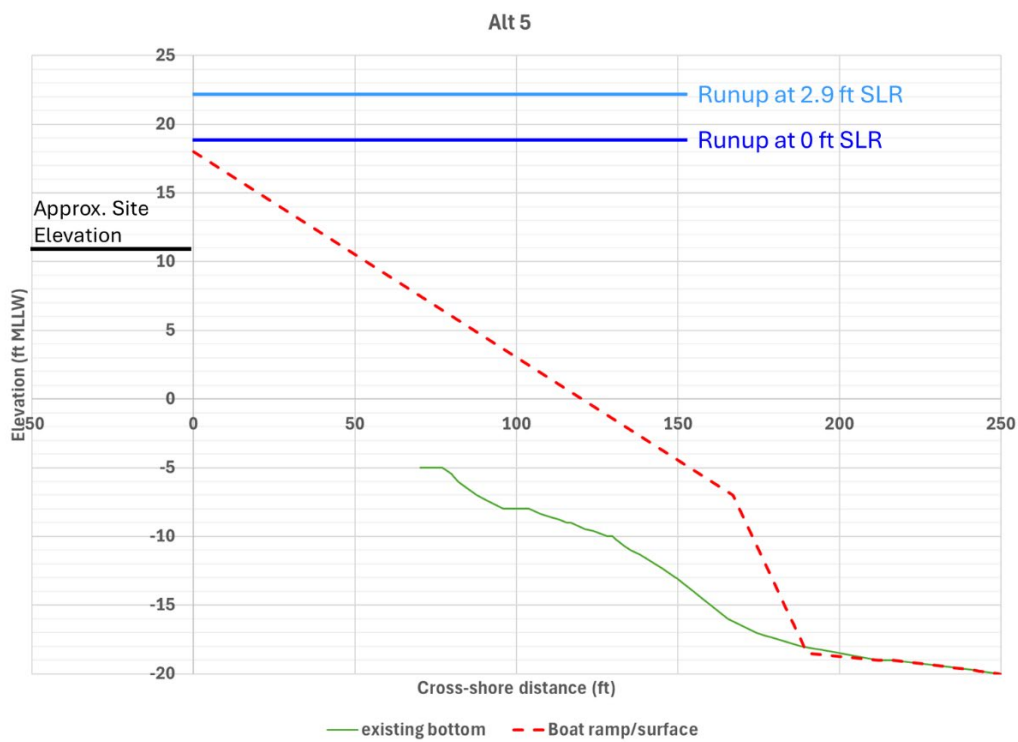


Figure 28. Alternative 5 Preliminary Boat Ramp Design Cross-section with Wave Runup Results.



It is worth noting that the M&N wave runup calculations include the proposed boat ramp geometry, while the FEMA and CoSMoS models are based on existing site conditions. Therefore, the FEMA and CoSMoS data can be used to assess the flooding extent of the current project site (parking lot, existing structures, etc.) but not with the proposed boat ramp. In addition, the wave model results indicate that an 18 second wave penetrates the marina and reaches the Alternative 1 location, while FEMA does not consider the wave impact at the Alternative 1 location. Thus, for the present and future wave runup associated with the proposed boat ramp, the M&N calculations are considered more applicable and accurate.

In addition, the California Department of Boating and Waterways (DBAW) grant requires a 20-year-SLR (2050) design condition, which is 0.9 ft for the intermediate-high condition. As shown in Table 8, only a 0.2 ft wave height difference is observed between the present and 2080 SLR wave results; therefore, the 2080 SLR results presented in this report are comparable to the DBAW 2050 requirements.

5.3 Limitations

Both FEMA and CoSMoS models were developed on a coarse model grid on a regional scale that do not consider shoreline complexities at a local level. Coastal flooding maps presented in this section should be interpreted to generally identify the potential extent of present and future coastal flooding and highlight areas that are most susceptible to flooding at the project site.

6 Coastal Hazards Adaptation Measures

Based on the results of the wave runup analyses, adaptation measures to address coastal hazards are needed for all alternatives. Three potential measures are discussed below.

6.1 Boat Ramp Operational Restrictions

Using a 2-ft significant wave height limit as the boat ramp operation criterion as described in section 4.4.2, for the present sea level, this 2-ft wave height has the following exceedance probabilities:

- Alternative 1: 2 percent probability of annual exceedance (50-year event);
- Alternative 2: 4 percent probability of annual exceedance (25-year event), and
- Alternative 5: 50 percent probability of annual exceedance (1-year event).

Launch ramp closure would be necessary during these exceedance periods, and the analysis indicates Alternative 5 would have a higher frequency of these closure periods. It should be noted that these operational restrictions are based on the premise that wave runup can occur on the ramp during boat launch operations.

6.2 Raising Top of Ramp to Accommodate Wave Runup

In order to avoid overtopping and flooding of the backland areas, the tops of the ramps would need to be raised to accommodate the wave runup levels shown in Table 11:

- Alternative 1: an additional 3.1 ft to accommodate 2.9 ft of SLR (from +12 ft to +15.1 ft MLLW).
- Alternative 2: an additional 2.0 ft to accommodate 2.9 ft of SLR (from +18 ft to +20 ft MLLW).
- Alternative 5: an additional 1 ft for the present sea level and 4.2 ft to accommodate 2.9 ft of SLR (from +18 ft to +19 and +22.2 ft MLLW, respectively), which is likely not practical.

These top of ramp elevations assume that the neighboring shoreline perimeter will also be raised to avoid wave overtopping. Because the proposed top of ramp elevations are higher than the existing ground, grading to match the existing ground elevations would be needed in the present and for future SLR.



6.3 Sheet Pile Wall Installation

The results of the Alternatives 2 and 5 wave runup analysis indicate the need for installing a sheet pile wall at these boat ramp locations to provide wave protection. It is assumed that the sheet pile wall would block incoming waves, resulting in minimal wave penetration, with mainly SWL flood hazard to be considered. The sheet pile would need to be designed to facilitate navigation in and out of the ramp. The installation of the sheet pile would likely allow for lowering of the top of ramp elevation for Alternatives 2 and 5; a 12 ft MLLW top of ramp elevation would accommodate the Present and 2080 sea levels with a small amount of wave runup.

7 Discussion, Summary, and Conclusions

Redondo Beach residents and community leaders have agreed upon the development of a public boat launch within King Harbor. The new public boat launch will allow access to the open ocean and provide recreational and commercial opportunities for community members.

Wave gauges were deployed in the harbor during a 2-month period; the collected data was used to evaluate the waves at the site and to calibrate the wave model. The numerical wave model provided operational and design wave conditions. The design wave was the 100-year-return wave with a 1-year-return SWL. The wave model results were used to determine wave runup flood hazards, for present and future SLR of up to 2.9 ft. The most critical factors in the analysis were found to be:

- Proposed top of ramp elevations of +12 and +18 ft MLLW.
- Significant wave height of 2 ft as the operational criterion.
- Wave runup above the top of the ramp.

A comparison of Alternatives 1, 2, and 5 is presented in Table 12.

Based on the results and analysis presented herein, Alternative 1 is the preferred alternative because it:

- has the least amount of wave runup
- would not require installation of a sheet pile wall
- requires the smallest amount of backland fill to match the top of ramp elevation
- has the lowest frequency of operational restrictions based on wave height.

Alternatives 2 and 5 would require installation of an in-water sheet pile wall to reduce wave runup and regulatory agencies approval of the wall is likely to be challenging. Therefore, Alternatives 2 and 5 are not recommended.



Table 12. Comparison of Design Alternatives.

	No Project	Alternative 1	Alternative 2	Alternative 5
Description	No boat ramp	• New boat ramp at south-end of harbor • Top of ramp +12 ft MLLW • Ramp slope 15 percent • Bottom of ramp -7 ft MLLW • Existing bottom elevation -9.5 ft MLLW	• New boat ramp near restaurant • Top of ramp +18 ft MLLW • Ramp slope 15 percent • Bottom of ramp -7 ft MLLW • Existing bottom elevation -16 ft MLLW	• New boat ramp near old Sport fishing Pier • Top of ramp +18 ft MLLW • Ramp slope 15 percent • Bottom of ramp -7 ft MLLW • Existing bottom elevation -16 ft MLLW
Key Pros	No negative effects on existing structures	• Runup does not reach top of ramp for present-day conditions • Location more sheltered from waves • Top of ramp elevation closer to existing ground elevation	• Runup does not reach top of ramp for present-day conditions • Shorter navigation route from ocean to ramp location	• Shorter navigation route from ocean to ramp location
Key Cons	No new or enhanced access to boating	• 1 ft of fill may be required to match the proposed +12 ft MLLW top of ramp elevation • Operational limits are required	• Without wave protection with a sheet pile wall, approx. 7 ft of fill of the backlands would be required to match the +18 ft MLLW top of ramp elevation. • Installation of in-water sheet pile wall likely required, which would impact boater navigation and may not be permissible • Operational limits are required	• Without wave protection with a sheet pile wall, approx. 7 ft of fill of the backlands would be required to match the +18 ft MLLW top of ramp elevation. • Installation of in-water sheet pile wall likely required, which would impact boater navigation and may not be permissible • Operational limits are required
Coastal Hazards	• No impact to shoreline erosion • No impact to flooding	• Project does not impact shoreline erosion • Wave runup elevation exceeds top of ramp with future SLR	• Project does not impact shoreline erosion • Wave runup elevation exceeds top of ramp with future SLR	• Project does not impact shoreline erosion • Wave runup elevation exceeds top of ramp for present day and future SLR
Operational Restrictions	Not applicable	• 2 percent probability of annual exceedance of 2 ft wave limitation	• 4 percent probability of annual exceedance of 2 ft wave limitation	• 50 percent probability of annual exceedance of 2 ft wave limitation



	No Project	Alternative 1	Alternative 2	Alternative 5
Adaptation Measures	Not applicable	For 2080 SLR, raising top of ramp to accommodate for total water levels would be needed.	- For present and 2080 SLR, +20 ft top of ramp elevation is needed to accommodate total water levels - Or installing sheet pile wall in front of boat ramp to reduce wave size/penetration	- For present and 2080 SLR, +20 ft top of ramp elevation is needed to accommodate total water levels - Or installing sheet pile wall in front of boat ramp to reduce wave size/penetration.
Preferred Alternative	No	Yes	No	No



8 References

- Barnard. (2018). *Coastal Storm Modeling System (CoSMoS) for Southern California, v3.0 Phase 2. ver. 1g ed.* USGS.
- California Coastal Commission. (2024). *Sea Level Rise Policy Guidance: Interpretive Guidelines for Addressing Sea Level Rise in Local Coastal Programs and Coastal Development Permits.*
- California Ocean Protection Council. (2024). *Draft: State of California Sea Level Rise Guidance: 2024 Science and Policy Update.*
- Dewberry. (2016). *West Coast El Nino 2016 B16 LiDAR.* Tampa, FL: USGS.
- DMJM. (1990). *Mole D Splash Wall.* City of Redondo Beach.
- FEMA. (2005). *final Draft Guidelines for Coastal Flood Hazard Analysis and Mapping for the Pacific Coast of the United States.* FEMA.
- IPCC. (2019). *The Ocean and Cryosphere in a Changing Climate.*
- OPC. (2024). *State of California Sea Level Rise Guidance: 2024 Science & Policy Update.*
- USGS. (2021). *Our Coast Our Future Hazard Map.* Retrieved from <https://ourcoastourfuture.org/hazard-map/>

