Appendix K-1

Coastal Hazard and Sea Level Rise Vulnerability Assessment (May 8, 2025)

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MEMORANDUM

To: City of Oceanside

From: Moffatt & Nichol

Date: May 8, 2025

Subject: Oceanside Beachfront – Coastal Hazard and Sea Level Rise Vulnerability Assessment

M&N Job No.: 230196

1 Introduction

The City of Oceanside, California, is currently undertaking a long-term, phased enhancement of its highly valued public beachfront area. Moffatt & Nichol (M&N) has been contracted to provide engineering services, including schematic design and CEQA support, for Phase II of this beachfront improvement project. As illustrated in Figure 1 and Figure 2, Phase II of this project includes three discrete project sites: the Junior Seau Beach Community Center (JSBCC), the Junior Seau Pier Amphitheater and Bandshell, and the Beachfront Park and Recreation Center (Betty's Lot). This phase excludes Phase I Pier View Way Bridge project elements.

According to the project Basis of Design (Johnson Favaro, 2024), the plan for the JSBCC is to renovate the existing single-story building, parking lot, and plaza. No structural work is anticipated except an exterior elevated steel mechanical platform at the northeast corner of the building. Improvements to the Amphitheater and Bandshell include proposed reconstruction of a new amphitheater, bandshell, and plaza level seating over the existing site with new access ramps from N. Pacific Street. The plan for Betty's lot includes construction of a terraced beachfront park with multipurpose outdoor courts and a Recreation Center, constructed over one level of at-grade structured parking. The project requires the reconstruction of The Strand and portions of the existing sidewalk. A 1.5 ft-tall concrete bench wall is proposed along the seaward side of The Strand along the Amphitheater site. The proposed gradings and finished floor elevations from design drawings were utilized in this assessment (Johnson Favaro, 2024). Figure 2 shows the 100% schematic design for Phase II project elements.

To support the coastal development permit (CDP) application and inform the project renovation and reconstruction design, the coastal hazards and sea level rise (SLR) vulnerability are analyzed in this study. The detailed analyses presented herein included the following:

- Review of the project site's coastal setting.
- Review of the latest California SLR guidance and selection of appropriate SLR scenarios for the project.
- Review of USGS Coastal Storm Modeling System (CoSMoS) results and FEMA Flood Insurance Rate Maps (FIRM).
- A site-specific wave runup analysis, using data from the FEMA California Coastal Analysis and Mapping Project/Open Pacific Coast (CCAMP/OPC) study and the latest topographic survey conducted by NV5 (NV5, 2024) for this project.
- Development of site-specific flood projection maps under the selected SLR scenarios.
- Evaluation of SLR-related vulnerabilities at the project site, including coastal flooding, erosion, currents, groundwater changes, and tsunami risks,

Figure 1: Oceanside Beachfront Projects Phase II, Image courtesy Johnosn Favro Feasibility Study Presentation

Figure 2: Oceanside Beachfront Improvement Projects Phase II – 100% Schematic Design (Johnson Favaro, 2024)

2 Coastal Settings

The following sections describe the coastal settings of the project site as relevant to the evaluation of potential flooding risks. The discussion focuses on astronomical tides and nearshore waves, which are key components of coastal flooding.

2.1 Tides

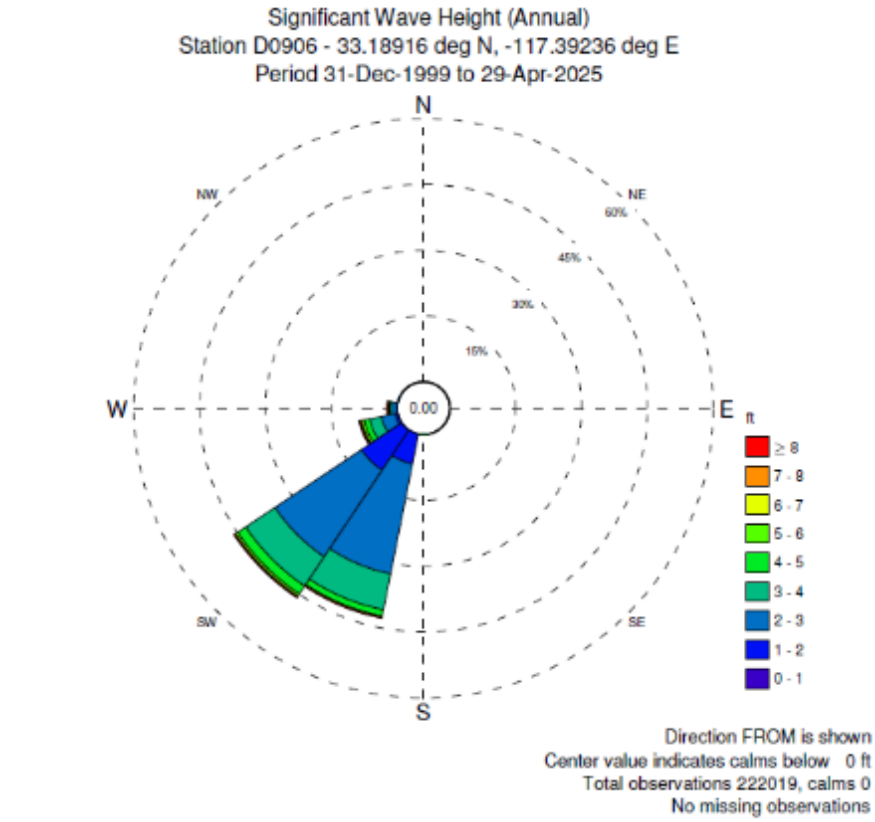
Tides on the Southern California coast have a semi-diurnal pattern, with two high tides and two low tides every day. The nearest tide gauge to the Oceanside Beachfront is the National Oceanic and Atmospheric Administration (NOAA), La Jolla tide gauge (ID#9410230). Table 1 lists tidal datums published at this station for the 1983-2001 epoch, referenced to the North American Vertical Datum of 1988 (NAVD88). The tidal range between Mean Higher High Water (MHHW) and Mean Lower Low Water (MLLW) is 5.32 feet (ft). The historically observed highest water level is 7.62 ft NAVD88, which occurred on November 25, 2015.

Table 1: Tidal Datums at La Jolla (NOAA ID#9410230, 1983-2001 Epoch)

Description	Datum	Elevation (ft NAVD88)
Highest Observed Water Level (11/25/2015)	HOWL	7.62
Highest Astronomical Tide	HAT	7.01
Mean Higher-High Water	MHHW	5.13
Mean High Water	MHW	4.41
Mean Sea Level	MSL	2.54
Mean Low Water	MLW	0.71
North American Vertical Datum of 1988	NAVD88	0.00
Mean Lower-Low Water	MLLW	-0.19
Lowest Astronomical Tide	LAT	-2.20
Lowest Observed Water Level (12/17/1933)	LOWL	-3.06

2.2 Nearshore Waves

The Coastal Data Information Program (CDIP) provides observation-driven wave hindcast and nowcast model data along the California coast through its Monitoring and Prediction (MOP) system. Data from January 2000 to April 2025 at MOP Station D0906, located at the Oceanside Pier at a 33-ft (10-m) water depth (33.1892N -117.3924W), was used to characterize typical nearshore wave conditions. The wave rose plot and joint probability table provided in Figure 3 show that waves are predominantly southwesterly and are typically (72% of the time based on MOP Station D0906 data) less than 3 ft. The peak wave period histogram in Figure 4 shows that 70% of the waves have a peak period between 12 to 16 seconds. An extreme value analysis of waves at the Oceanside Pier was also conducted using the same data. The resulting extreme wave conditions for various return periods are listed in Table 2. The 1-year and 100-year offshore significant wave heights are 8.8 ft and 14.6 ft, respectively.



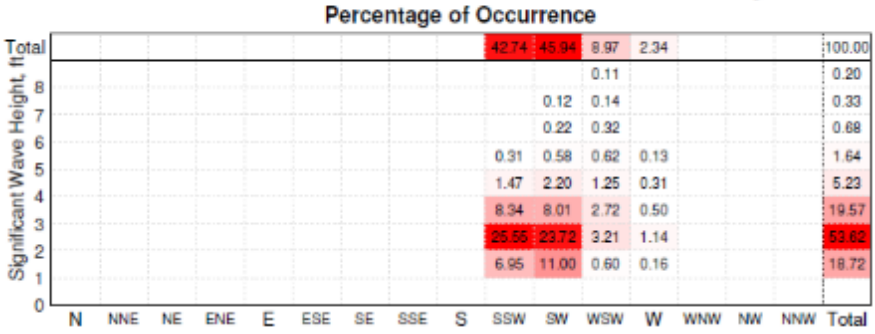


Figure 3:Wave Rose and Joint Probability Table at MOP Station D0906

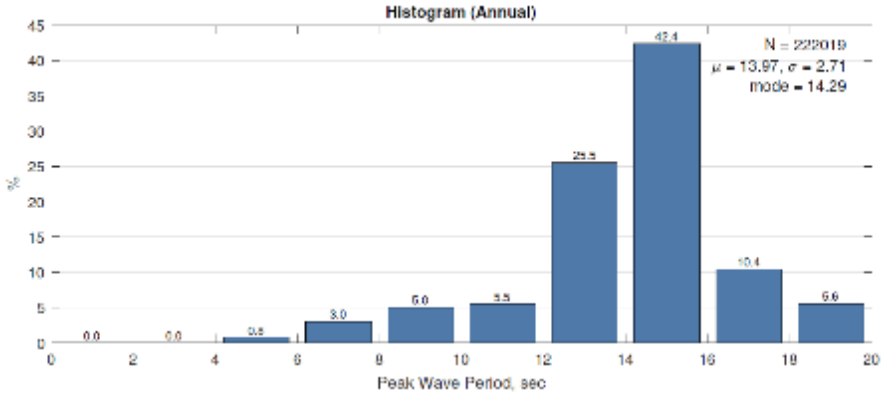


Figure 4:Histogram of Peak Wave Periods at MOP Station D0906 (2000/01-2025/04)

Table 2: Extreme Nearshore Wave Conditions at Oceanside Pier (MOP D0906, 33ft-depth)

Return Period (year)	Significant Wave Height (ft)
1	8.8
5	10.8
10	11.7
50	13.7
100	14.6

3 Sea Level Rise Projections

Per input from Johnson Favaro, the Community Center, which is undergoing a partial, non-structural renovation, has a design life of 35 years. The design life of the other two sites, the Amphitheater Bandshell and Betty's Lot, is 50 years (Johnson Favaro, 2025). With an expected project completion year of 2035, the selected SLR scenarios were projected to the year 2070 for the Community Center and 2085 for Amphitheater Bandshell and Betty's Lot, corresponding with the end of their respective service lives.

Table 3 lists the SLR projections at La Jolla (closest station to the project site), published in the 2024 OPC SLR guidance (Ocean Protection Council, 2024) which has been adopted in the latest California Coastal Commission (CCC) SLR Policy Guidance. Table 3 does not provide a specific SLR projection for 2085, thus, the SLR projections were interpolated from 2080 and 2090 projections (highlighted in blue box). Per CCC 2024 SLR Guidance, CCC recommends using intermediate and intermediate-high scenarios for planning and design of most commercial structures. The following SLR scenarios have been selected for coastal hazards analysis of the beachfront improvements to capture potential hazards at the end of the project design life under intermediate and intermediate-high scenarios.

- Junior Seau Beach Community Center:
    - A 1.4 ft SLR scenario is used to illustrate any potential hazards at the end of the 35-year project design life under the intermediate scenario.
    - A 2.3 ft SLR scenario represents potential hazards at the end of the 35-year project design life under the intermediate-high scenario.
- Junior Seau Pier Amphitheater and Bandshell, and Beachfront Park and Recreation Center (Betty's Lot):
    - A 2.1 ft SLR scenario is used to illustrate any potential hazards at the end of the 50-year project design life under the intermediate scenario.
    - A 3.5 ft SLR scenario represents potential hazards at the end of the 50-year project design life under the intermediate-high scenario.

The SLR scenarios selected for the three discrete sites and their projected time horizons are summarized in Table 4. The evaluation of the two selected SLR scenarios (intermediate and intermediate-high) will provide a good overall picture of the site's coastal vulnerability within their design life span.

Table 3: Projected SLR at La Jolla (Ocean Protection Council, 2024)

YEAR	LOW	INT-LOW	INTERMEDIATE	INT-HIGH	HIGH
2020	0.2	0.2	0.3	0.3	0.3
2030	0.3	0.4	0.4	0.4	0.5
2040	0.4	0.5	0.6	0.7	0.8
2050	0.5	0.7	0.8	1.0	1.3
(35-year design life) 2060	0.6	0.8	1.1	1.6	2.0
2070 → 2070	0.7	1.0	1.4	2.3	3.0
2080	0.8	1.2	1.8	3.1	4.1
2085 → (50-year design life) 2090	0.9	1.4	2.4	3.9	5.3
2100	0.9	1.6	3.1	4.8	6.6
2110	1.0	1.8	3.8	5.7	7.9
2120	1.1	2.0	4.4	6.4	9.0
2130	1.2	2.2	4.9	7.1	9.9
2140	1.2	2.4	5.5	7.6	10.9
2150	1.3	2.6	6.0	8.2	11.8

Table 4: Estimated Project Completion, Design Life and Proposed SLR Projections

Project Component	Estimated Completion Year	Design Life	Year SLR Projection
Community Center	2035	35 years	By 2070: 1.4' (intermediate) By 2070: 2.3' (int-high)
Amphitheater and Bandshell Betty's Lot	2035	50 years	By 2085: 2.1' (intermediate)[1] By 2085: 3.5' (int-high)[1]

4 Coastal Hazards and Sea Level Rise Vulnerability Analysis

The coastal hazards and SLR vulnerability analysis considers potential impacts from the following hazards that are relevant to the Oceanside Beachfront Project Phase II: 1) coastal flooding caused by extreme water levels and wave runup assessed based on a 100-year storm event, 2) currents during typical and extreme storm conditions, 3) coastal erosion, 4) tsunamis inundation, and 5) groundwater impacts. Potential hazards for both existing and proposed conditions under existing and future SLR scenarios were assessed.

4.1 Coastal Flooding

4.1.1 Existing Sources of 100-year Extreme Water Levels

4.1.1.1 FEMA FIRM

Figure 5 presents the FEMA FIRM (panel 06073C0734J with effective date of December 20, 2019) zoomed in to the project site, showing a coastal VE zone with a base flood elevation (BFE) of 16 ft NAVD88. FEMA's BFE, also known as the 100-year flood elevation without SLR, defines the water elevation with a one percent chance of exceedance in any given year. The proposed improvement sites are on the edge of the mapped VE zone. The FEMA coastal Transect #17 passing through Betty's Lot is the closest transect to the project site. Neither SLR nor proposed project re-grading is considered in FEMA's BFE analysis.

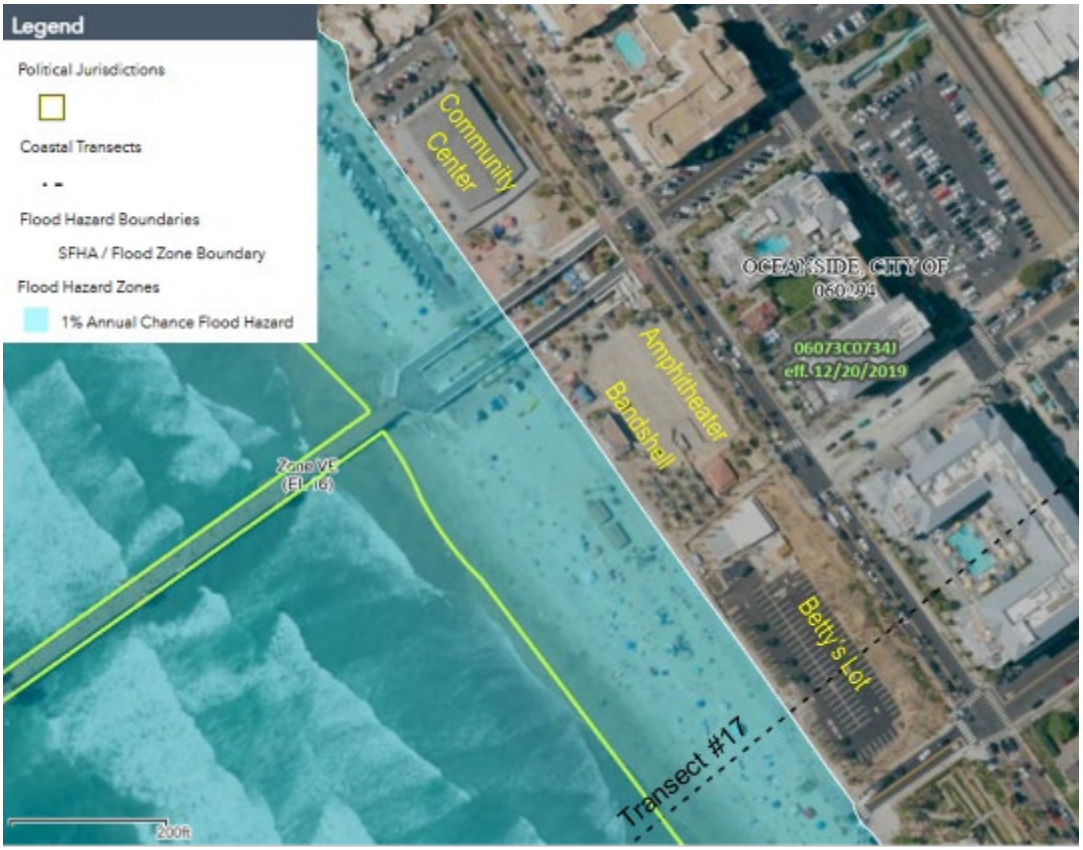


Figure 5: Excerpt of FEMA FIRM Panel 06073C0734J, Effective 12/20/2019.

4.1.1.2 CoSMoS

The CoSMoS model, developed by the United States Geological Survey (USGS), provides estimates of coastal flooding due to future SLR and coastal storms along the California coast (Barnard, 2018). It integrates projections of SLR with models simulating tides, waves, and storm surges to estimate coastal hazards under various scenarios. For this study, modeled 100-year flood elevations, including relative SLR, storm surge, seasonal effects, and wave runup were extracted from the CoSMoS database as provided in Table 5. As CoSMoS results are only available in 0.25 m (0.8 ft) SLR increments, 0.5 m (1.6 ft), 0.75 m (2.5 ft) and 1.0 m (3.3 ft) SLR scenarios were chosen as the closest available representation of the target SLR projections (presented in Table 4). Table 5 lists the predicted 100-year coastal flooding elevations from the CoSMoS hazard map database at the seaward extent of each study site. The community center has a higher flood elevation relative to the other two sites under the same SLR scenario. Under a 3.3 ft SLR scenario, the 100-year flood elevation at the Community Center reaches 15.4 ft NAVD88, resulting in partial inundation of the site. CoSMoS projections do not, however, incorporate proposed project re-grading.

Table 5: CoSMoS Predicted Flood Elevations[1] under 100-year Coastal Storm at Various SLR Intervals (in ft NAVD88)

SLR Scenario	Community Center	Amphitheater and Bandshell	Betty's Lot
No SLR	11.0	9.8	9.0
+0.5 m (+1.6 ft) SLR[2]	14.1	12.6	11.7
+0.75 m (+2.5 ft) SLR[2]	14.8	13.1	12.1
+1.0 m (+3.3 ft) SLR[2]	15.4	13.4	12.5

4.1.2 Site-specific Wave Runup Analysis

As discussed in Section 4.1.1, FEMA FIRM information is only representative of existing sea level conditions and does not incorporate proposed project elements. The CoSMoS model does simulate SLR impacts but does not consider any proposed project elements. Hence, a site-specific wave runup analysis is required to account for the proposed project re-grading and future SLR. This section discusses the site-specific wave runup calculation inputs, methodology, and the resulting 100-year flood elevations at each Phase II site.

4.1.2.1 Analysis Transects

Figure 6 illustrates the three representative transects selected in this wave runup analysis, together with the nearby FEMA FIRM panel Transect #17. One transect is selected for each of the three sites.

The most recent topographic survey of the project area, conducted in August 2024, provided the data representing existing topographic conditions. The proposed finished ground elevations were then incorporated into each profile to reflect post project topography. Bathymetric profile data from FEMA Transect #17, supplemented with available NOAA digital elevation model data, was merged with the topographic data to create the complete transect profile shown in Figure 7. It is notable that the proposed grading is confined to the grading zones as indicated by the shaded grey areas in Figure 7. This grading results in slight alterations to the existing site topography, with elevation differences generally less than 0.5 ft within most seaward grading zones. The lowest grading elevation is 13 ft NAVD88 (occurs at the Amphitheater) which is 6 ft above the HOT of 6.72 ft NAVD88. It is thus expected that the proposed grading will have a relatively small impact on the wave runup process, which occurs mainly on the foreshore slope between MSL and HOT.

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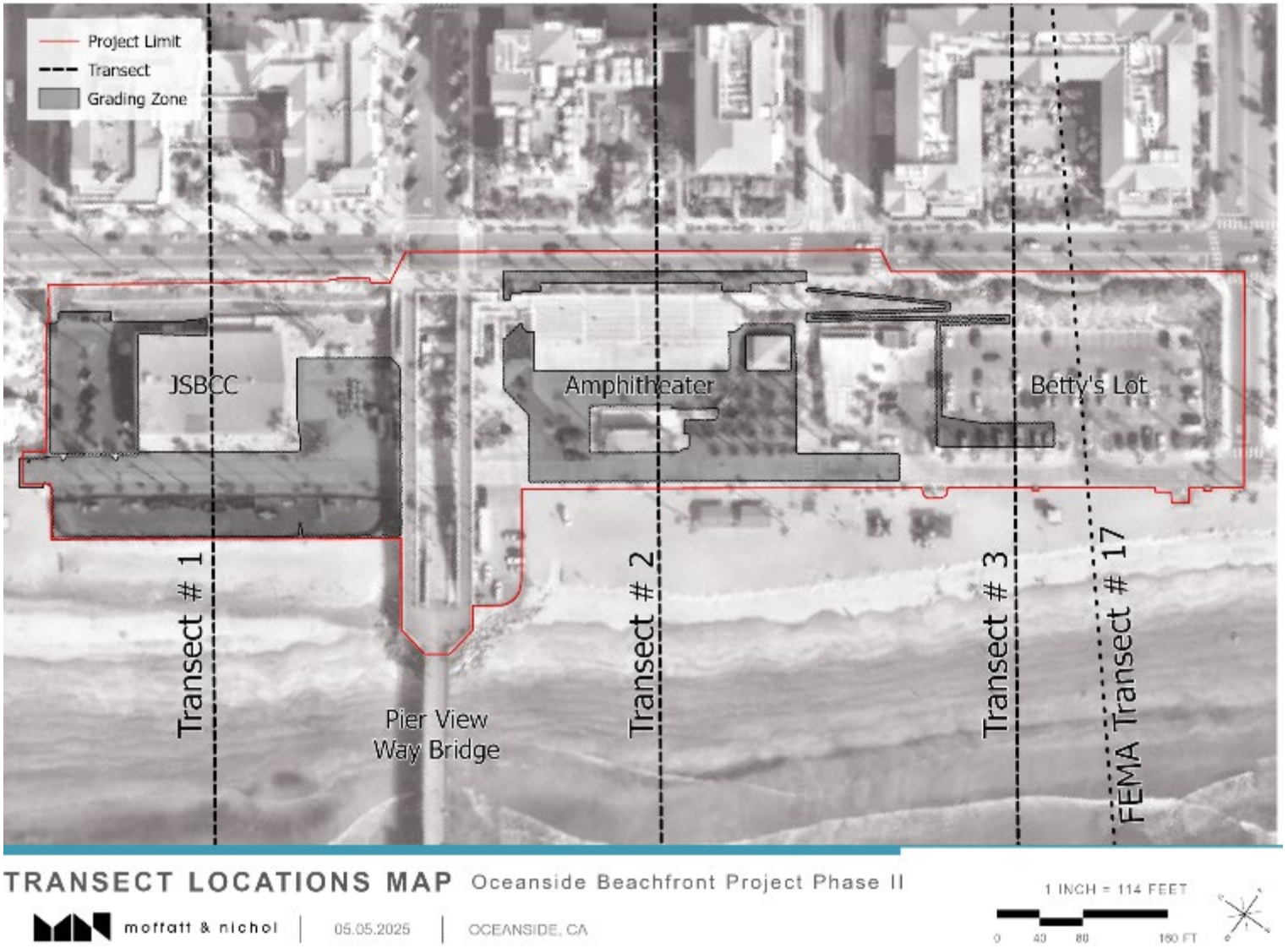

Figure 6: Oceanside Beachfront Project Phase II Transect Locations

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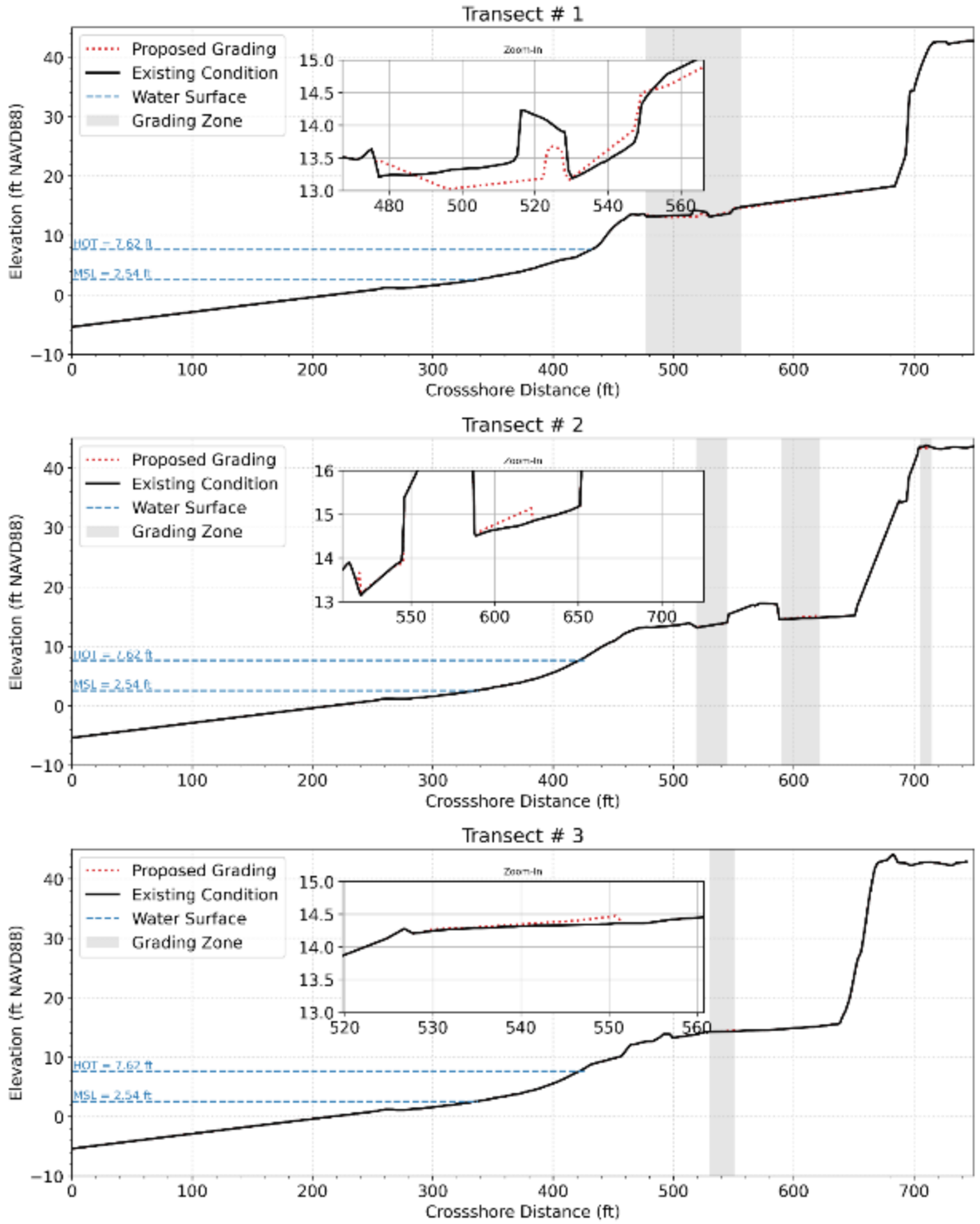

Figure 7:Elevation Profile Plots at the Three Analysis Transects

Proposed grading only results in small difference in grading zones, and overlaps with existing conditions elsewhere

4.1.2.2 Methodology

Runup analysis employed methodologies documented in CCAMP/OPC Intermediate Data Submittal Reports (BakerAECOM, 2016) prepared for the recent FEMA mapping analysis in San Diego County. Figure 8 depicts a flowchart of the technical approach adopted here. Nearshore wave parameters and water levels at the 49 ft (15 m) depth contour for 155 selected peak events, available from the FEMA CCAMP/OPC study at the nearest FEMA Transect (#17), were utilized. The wave setup, runup, and overtopping of these peak events were re-analyzed using the site-specific nearshore bathymetric and topographic conditions at the three representative transects, incorporating relevant SLR design scenarios. The site-specific analysis conducted by M&N can be summarized in the following steps:

- Construct transect elevation profiles at three transects passing the three project sites for both the existing and proposed conditions
- Extract extreme wave event parameters at FEMA Transect #17 to be used in 1-D wave setup and runup analysis.
- Calculate total wave levels (including stillwater elevation, wave setup and runup) for the extreme events at the three transects under three SLR design scenarios (Table 4).
- Conduct extreme value analysis to determine the 100-year flood elevations at each site for all scenarios.

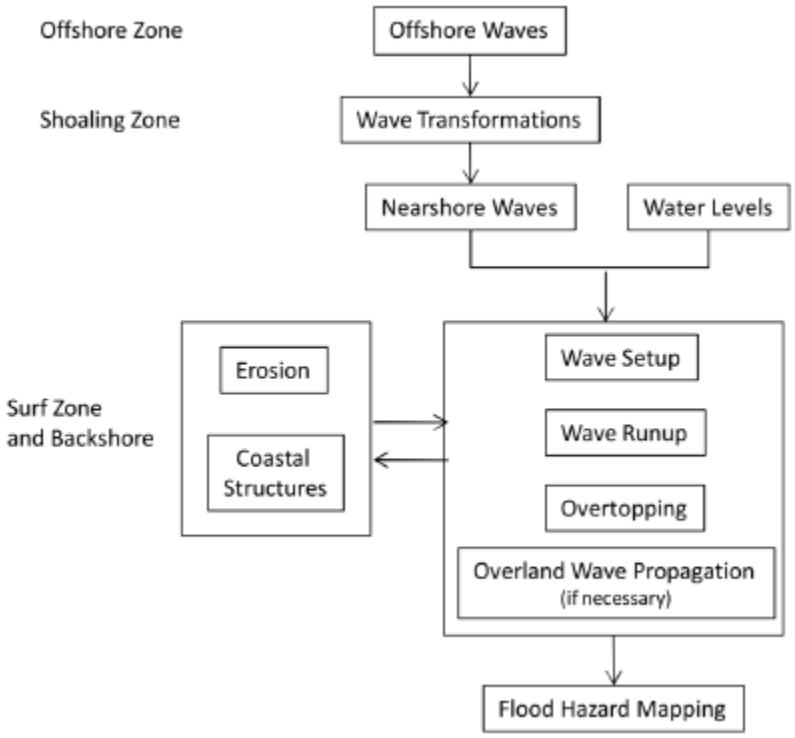

Figure 8: Summary of Technical Approach Adapted from Pacific Guidelines (BakerAECOM, 2016)

Per FEMA CCAMP/OPC guidelines, all three transects were considered as mild slope sandy beach without foreshore bluff or structure. The bluff behind the Community Center and the proposed bench wall are located at an elevation high enough that are not exposed to direct wave runup. For all scenarios, the foreshore slope was calculated as the average slope along elevation profile between MSL and HOT. For SLR scenarios, we assume the transect profile remains the same and MSL and HOT increase with SLR. Table 6 summaries the

slopes for each transect and different SLR scenarios. Given that the maximum foreshore slope is less than 0.11, the Stockdon approach was used for wave runup analysis for all scenarios. Notably, the proposed grading will not affect the foreshore slope, as the grading zone is outside the area considered in the foreshore slope calculation. Hence, the slope results are the same for the current condition and proposed grading.

The proposed 1.5-ft high bench wall helps to reduce the overtopping only when the Total Water Level (TWL) is below its crest (approximately +15 to +15.5 ft NAVD88). When the wall crest is inundated, the relatively short wall offers minimal resistance to runup from long period waves (12 to 16 seconds), characteristics of more extreme events. Therefore, the calculations presented here, ignoring the bench wall along The Strand, provide a reasonably conservative estimate for the TWLs.

Table 6: Foreshore Slopes by Transects Determined Between MSL and HOT [1]

SLR Scenario	**Transect # 1**	
Present (No SLR)	0.05	
1.4 ft SLR	0.08	
2.1 ft SLR	0.09	
SLR Scenario	**Transect # 2**	**Transect # 3**
Present (No SLR)	0.06	0.06
2.3 ft SLR	0.10	0.08
3.5 ft SLR	0.11	0.09

TWL's at each transect were calculated for all 155 wave events. Subsequently, an extreme value analysis of the TWL results was conducted using a Generalized Pareto Distribution (GPD), following the methodology outlined in the FEMA CCAMP/OPC study (BakerAECOM, 2016), to determine 100-year TWL values at each transect. The 100-year TWLs obtained from the extreme value analysis were then used to generate the coastal flood hazard maps presented in Section 4.1.3.

4.1.2.3 Results

The site-specific 100-year TWLs computed at three transects for each design SLR scenario are provided in Table 7, and visualized with corresponding transects as shown in Figure 9 through Figure 11. For transects # 2 (Amphitheater and Bandshell) and # 3 (Betty's Lot), the existing condition (no SLR) scenario resulted in a 100-year TWL of 15.6ft NAVD88, closely aligning with the FEMA BFE of 16 ft NAVD88. Under the higher design SLR scenario, the TWL at transects #2 and #3 increased to 23.4 ft and 22.1 ft NAVD88, respectively. Transect # 1 has a milder foreshore slope, resulting in a slightly lower existing condition 100-year TWL of 14.8 ft NAVD88. Under the higher design SLR scenario the TWL at transect #1 increased to 20.7 ft NAVD88. Notably, proposed project grading does not affect runup calculations as it occurs above the HOT foreshore extents, resulting in equivalent TWLs under both existing and proposed conditions for all SLR scenarios.

Table 7: 100-year Total Water Levels and Associated SLR Scenarios at the Analysis Transects

SLR Scenario	Transect # 1	
Present (No SLR)	14.8	
1.4 ft SLR	18.1	
2.1 ft SLR	20.7	
SLR Scenario	**Transect # 2**	**Transect # 3**
Present (No SLR)	15.6	15.6
2.3 ft SLR	20.9	19.6
3.5 ft SLR	23.4	22.1

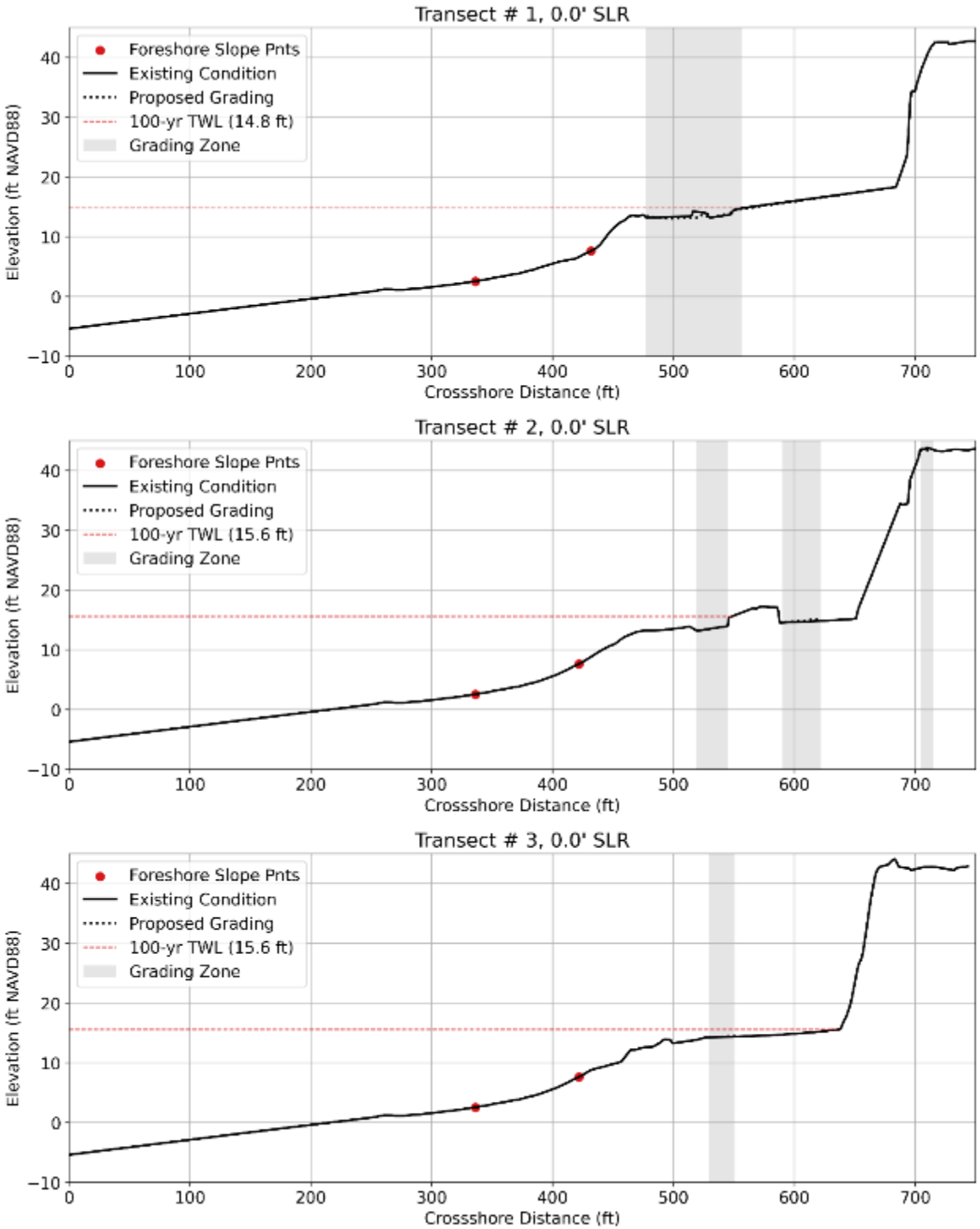

Figure 9. Transect Profiles with 100-year TWL for No SLR Scenario
Proposed grading only brings in a small difference in grading zones, and overlaps with existing conditions elsewhere

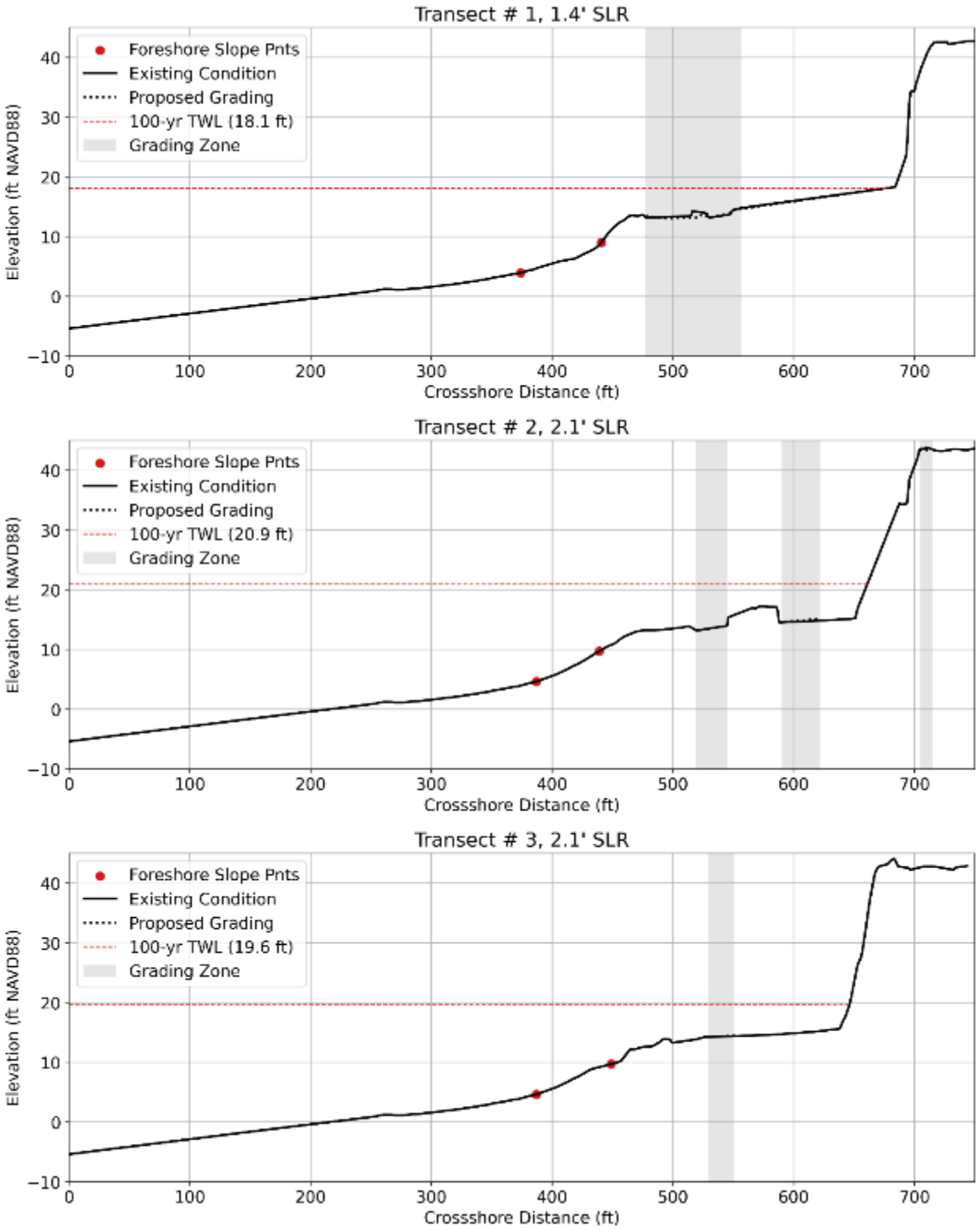

Figure 10. Transect Profiles with 100-year TWL for SLR Scenario # 1
Proposed grading only brings in a small difference in grading zones, and overlaps with existing conditions elsewhere

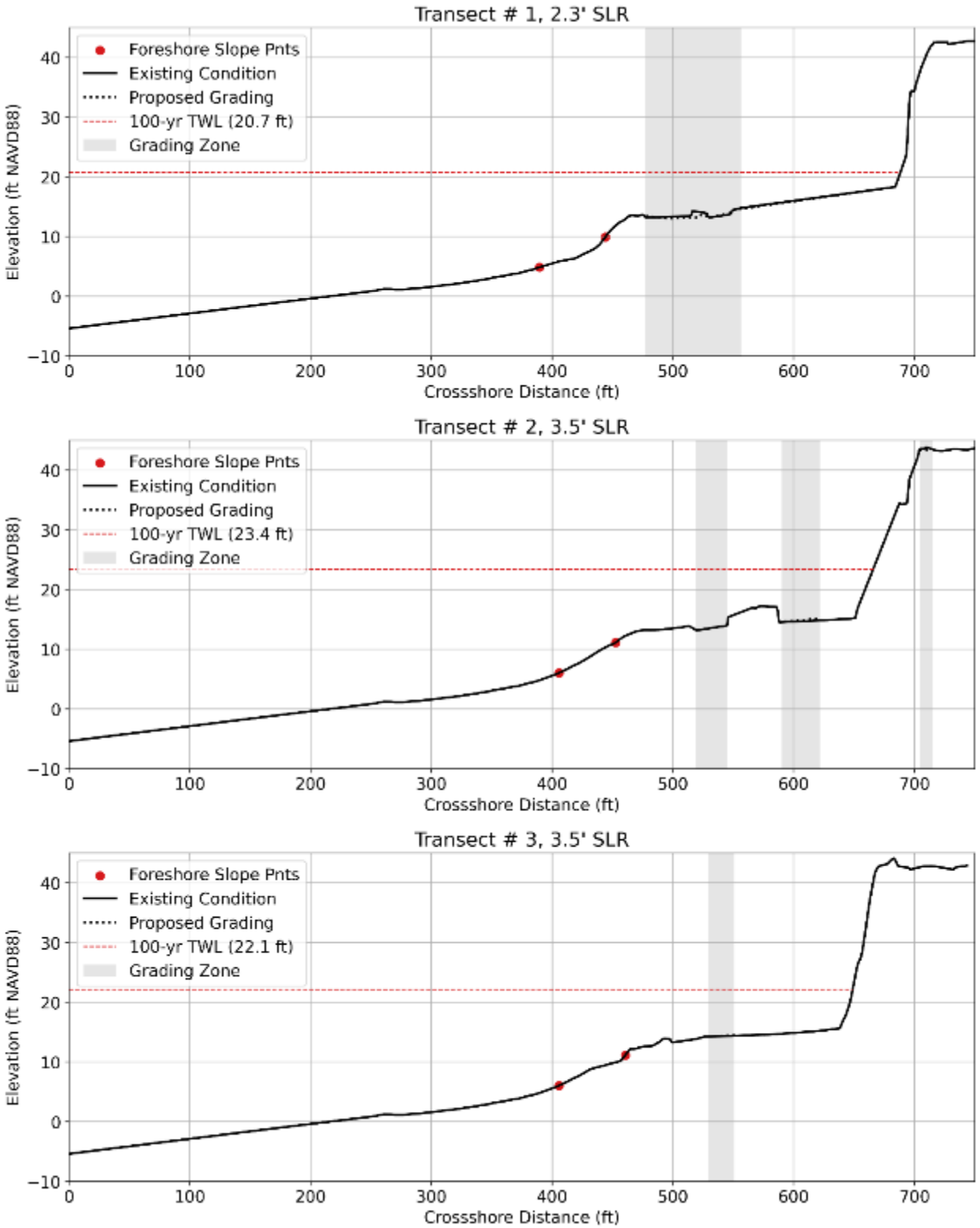

Figure 11. Transect Profiles with 100-year TWL for SLR Scenario # 2
Proposed grading only brings in a small difference in grading zones, and overlaps with existing conditions elsewhere

4.1.3 Coastal Flooding Hazard Maps

Following FEMA mapping guidance, the coastal flooding was based on the elevation of subtracting 3 ft from the TWLs during 100-year storm event. (FEMA, 2005). A conservative "bathtub" approach was used to extend the flood areas landward.

The project area was divided into two segments (Northern and Southern segments) separated by the Pier View Bridge. The Northern segment of the flooding hazard map used the 100-year TWL derived at Transect # 1, and the Southern segment conservatively uses the higher 100-year TWL between Transects # 2 and # 3. Note the difference between the two transects is about 1 ft. Different design SLR values were considered for each segment, given the difference in design life at each location (Section 3). The site-specific runup analysis and hazard maps for the Pier View Way Bridge itself were documented in a separate Phase I memorandum from M&N.

Without SLR, coastal flood hazard zones only occur at the edge of the project sites (Figure 12). Under SLR scenarios, lower regions in each of the three project sites are below the extreme TWL, falling into the coastal hazard zone (Figure 13 & Figure 14). The flood hazard area shaded in red reflects a lower ground elevation due to re-grading, contributing to a minor enlargement of the flood hazard zones under the proposed condition. Although the re-grading to a lower elevation was not fully reflected in the transect profile in Figure 7, the elevation change is small, and does not impact wave runup analysis. Under the lower SLR scenario, the coastal flood hazard zone starts to reach the backshore bluff. The bluff limits further expansion of the hazard zone under the higher SLR scenario. It is important to note that the coastal flooding hazard maps reflect inundation based on ground elevation, not structures. Coastal flood hazards for proposed structures, determined by comparing the proposed finish floor elevation with extreme TWLs listed in Table 7, are summarized under different SLR scenarios in Table 8.

Table 8: Potential Flood Hazard for Proposed Beachfront Projects Phase II

Design Element	**Proposed Floor Finish Elevation (NAVD88)**	**No SLR**	**1.4 ft SLR**	**2.1 ft SLR**
JSBCC	15.14	No[1]	Yes[1]	Yes
Design Element	**Proposed Floor Finish Elevation (NAVD88)**	**No SLR**	**2.3 ft SLR**	**3.5 ft SLR**
Amphitheater Seating	16.0	No	Yes	Yes
Amphitheater Bandshell	17.24	No	Yes	Yes
Betty's Lot	14.0 to 15.9[2]	No	Yes	Yes

Note:

[3] No – no flood risk at the structure under the 100-year flood event. Yes – the structure is likely flooded under the 100-year flood event.

[4] The deck top elevation of the occupied second floor is at 28.25 ft NAVD88. With a deck thickness of 6.5 ft, the deck is likely exposed to uplift wave force under the 3.5ft SLR scenario.

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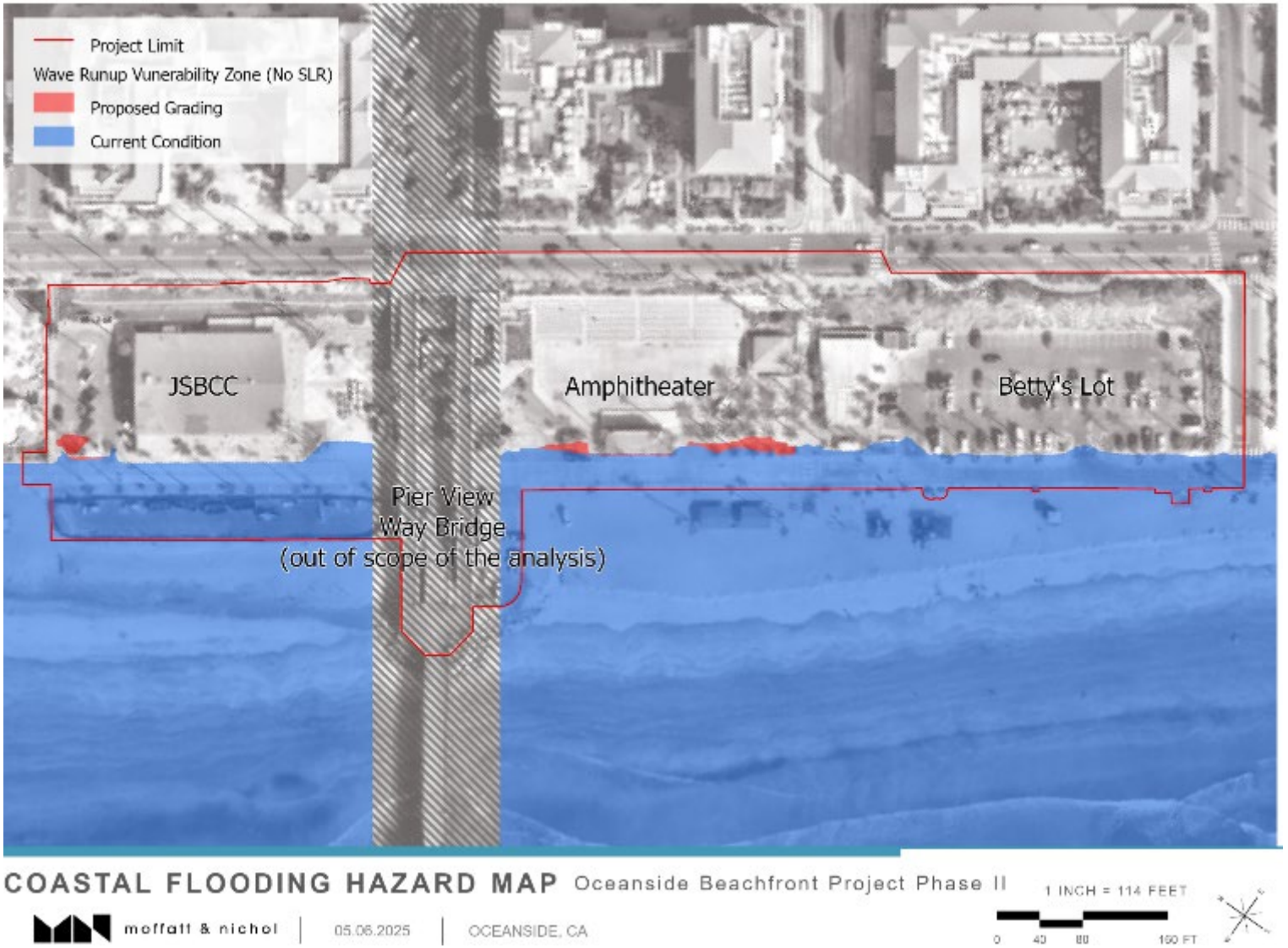

Figure 12. Coastal Flooding Hazard Under 100-year No SLR Scenario
(Blue shade: hazard zone with current ground elevation; Red shade: hazard zone with proposed grading)

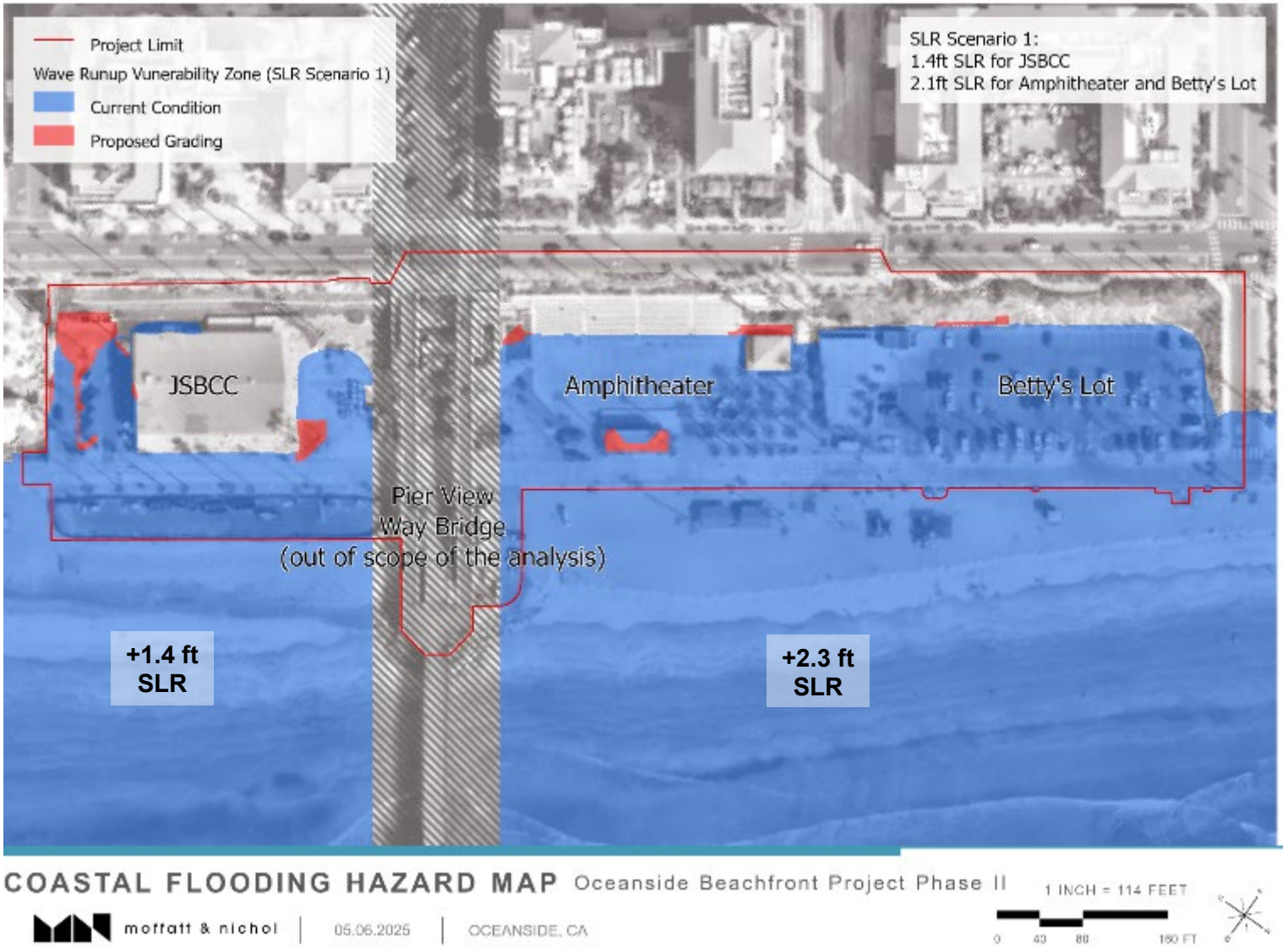

Figure 13. Coastal Flooding Hazard Map Under 100-year Low SLR Scenario
(Blue shade: hazard zone with current ground elevation; Red shade: hazard zone with proposed grading)

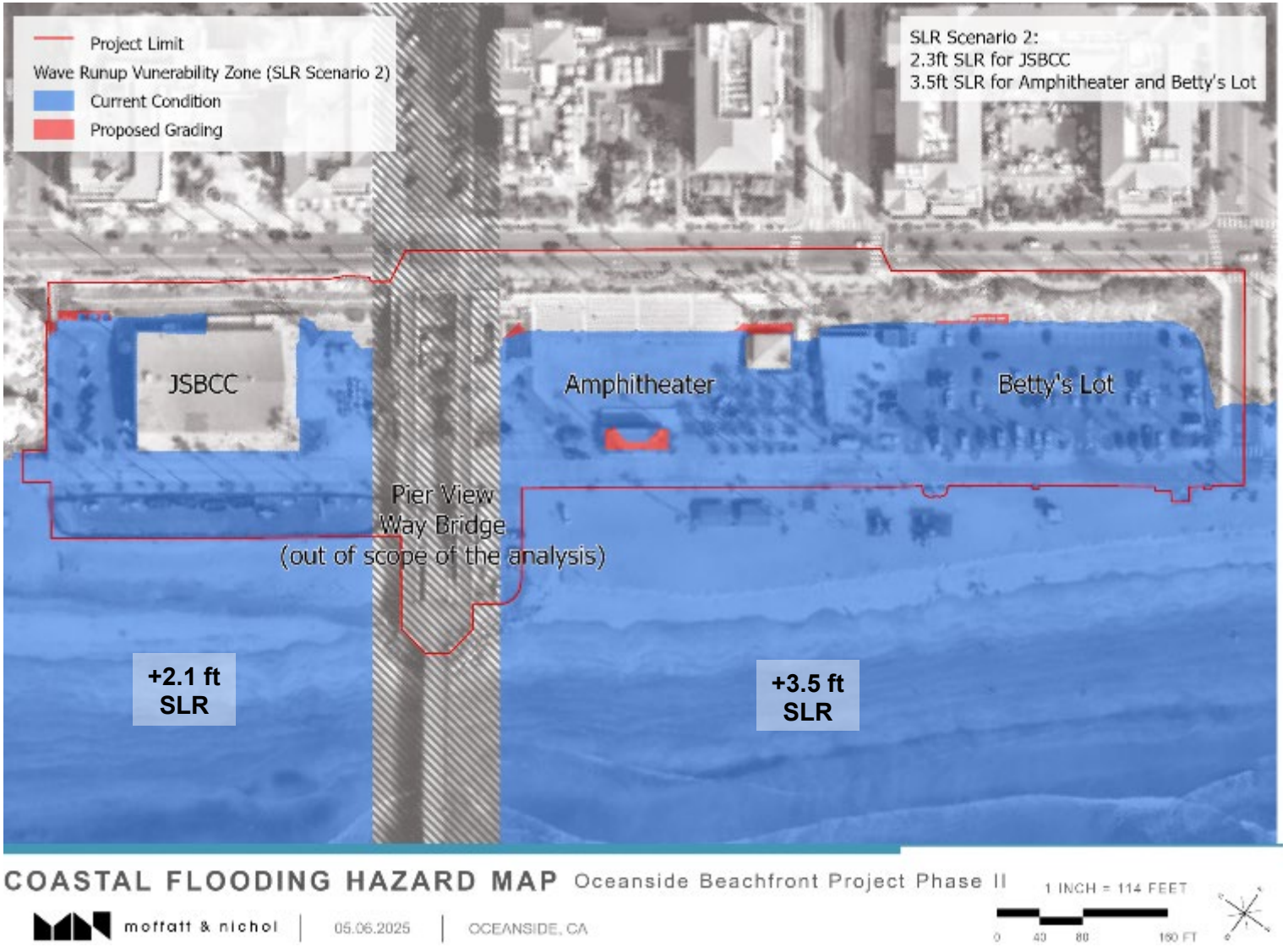

Figure 14. Coastal Flooding Hazard Map Under 100-year High SLR Scenario
(Blue shade: hazard zone with current ground elevation; Red shade: hazard zone with proposed grading)

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4.2 Currents

The USGS CoSMoS model provides estimates of maximum depth-averaged current velocities along the California coastline under various SLR scenarios and storm conditions. Table 9 summarizes maximum current velocities extracted at locations at the beachfront on the analysis transects discussed in Section 4.1.2.1 for both existing and design SLR scenarios, comparing typical (non-storm) and 100-year storm conditions. Notably, predicted maximum currents under typical conditions exceed 2 ft/s, indicating a dynamic environment for sediment transport and potential scour risks. Figure 15 illustrates the maximum predicted velocity magnitudes at the Oceanside Beachfront under 100-year storm condition with 1.0 m (3.3 ft) SLR. The existing Community Center is expected to be flooded under this condition. The typical maximum velocities are less than 1 m/s (3.3 ft/s) except within the wave breaking zone where they reach 1 to 2 m/s (3.3 to 6.6 ft/s).

CoSMoS does not reflect the impact due to the proposed gradings at the beachfront sites. However, the proposed gradings all occur above elevation of 13 ft NAVD88. With such high elevations, current velocities and long-shore sediment process are not expected to be impacted by the proposed project.

Table 9: Maximum Depth-averaged Current Velocity[1] at Oceanside Beachfront Phase II Project (CoSMoS)

SLR Scenario	Max Current Velocity – Tides, No Storm (ft/s)	Max Current Velocity – 100-year Storm (ft/s)
	Community Center	Community Center
No SLR	2.8	0.8
1.6 ft (0.5 m) SLR [1]	5.0	2.9
2.5 ft (0.75 m) SLR [3]	2.1	1.3

SLR Scenario	Max Current Velocity – Tides, No Storm (ft/s)		Max Current Velocity – 100-year Storm (ft/s)	
	Amphitheater & Bandshell	Betty's Lot	Amphitheater & Bandshell	Betty's Lot
2.5 ft (0.75 m) SLR [3]	3.6	3.6	1.6	1.7
3.3 ft (1.0 m) SLR [3]	3.7	3.7	1.7	1.7

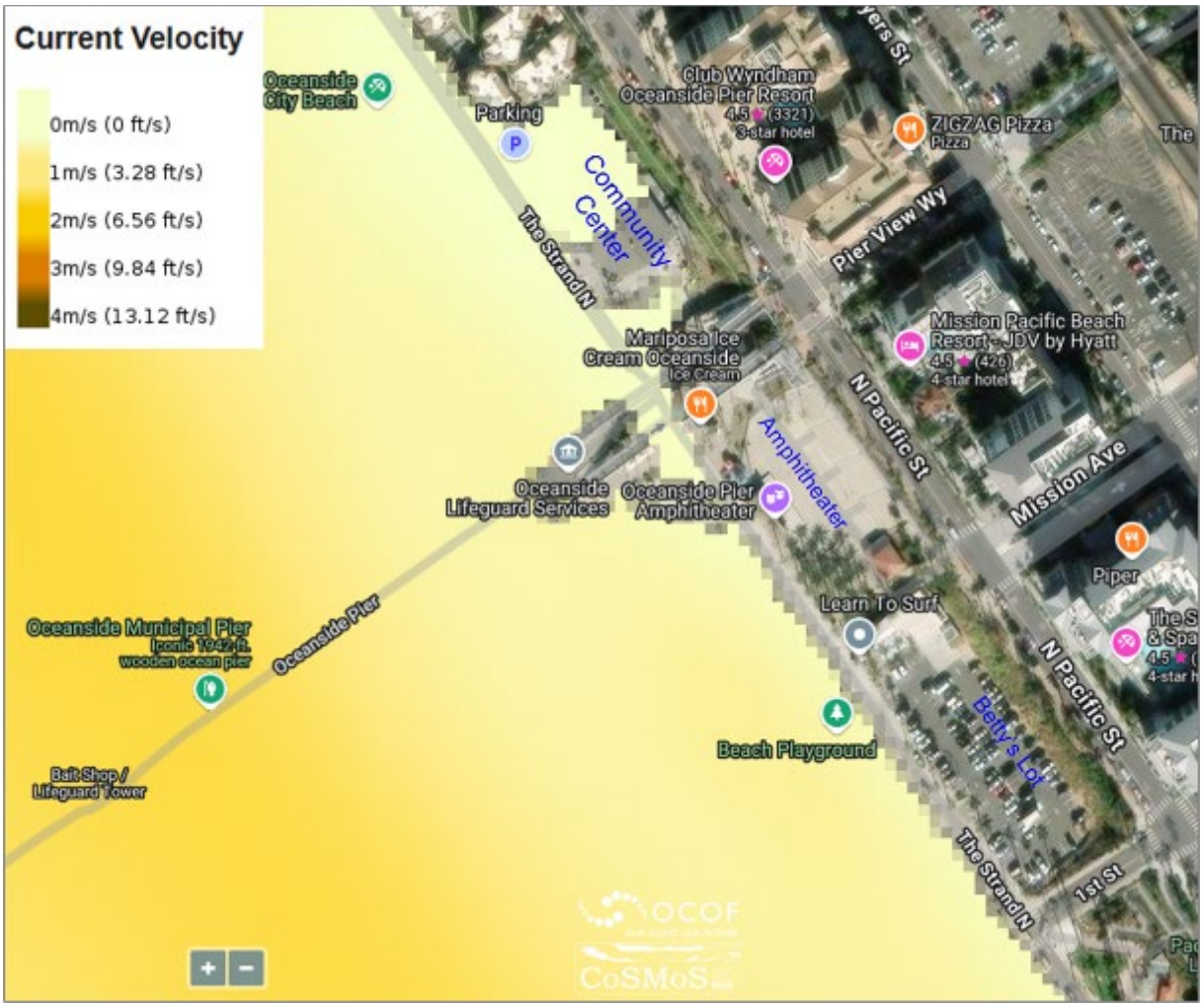

Figure 15: Maximum Current Velocity during 100-year Storm with +1.0 m SLR at Oceanside Beachfront (CoSMoS, 2025)

4.3 Erosion

Historical beach profiles near the Oceanside beachfront site reveal seasonal coastal erosion. SLR is expected to exacerbate this by exposing the beaches to larger waves and higher water levels. As a result, long-term shoreline retreat, with the shoreline moving inland, is expected to occur. Figure 16 illustrates the MSL shoreline position along the project site beachfront under existing and future design SLR scenarios projected by CoSMoS. With +0.5 m (1.6 ft) SLR, the MSL shoreline moves inland, close to The Strand. With +1.0 m (3.3 ft) SLR, the MSL line is further inland, extending past The Strand and into the property boundaries of Amphitheater Bandshell and Betty's Lot. If we consider the more realistic "Hold the Line" option, the extent of erosion is limited to existing infrastructure (in the case here is The Strand, highlighted with yellow dash line in Figure 16). The shoreline retreat will be stopped at the seaward side of The Strand. The actual proposed grading of the beachfront improvements involves no modifications to the seaward side of The Strand. Consequently, the proposed project is not expected to alter the alongshore sediment transport within the sediment littoral cell, and the project itself is not expected to impact coastal erosion.

Figure 16: Shoreline Positions at Oceanside Beachfront under +0.0 m, +0.5 m and +1.0 m SLR (CoSMoS, 2025)

4.4 Tsunami

Southern California faces potential tsunami risks, primarily due to distant sources such as the Aleutian Trench. As illustrated in Figure 17, the proposed beachfront improvement sites fall within the Tsunami Design Zone defined by the ASCE 7-22 Tsunami Geodatabase. Separately, the California Geological Survey and the California Governor's Office of Emergency Services (Cal OES) have produced stateside tsunami inundation and hazard area maps for San Diego County, based on a 1000-year return period event (California Geological Survey, 2019). Figure 18 reveals that Cal OES hazard areas overlap ASCE 7-22 hazard boundaries, indicating that the three sites—Community Center, Amphitheater & Bandshell, and Betty's Lot—are exposed to tsunami inundation. Although the project is located within the tsunami hazard zone identified by both the ASCE database and state maps, its footprint is too small to be expected to alter the overall tsunami risk. Therefore, the project is not anticipated to impact the tsunami risk of the adjacent areas. Tsunami warning signs are recommended.

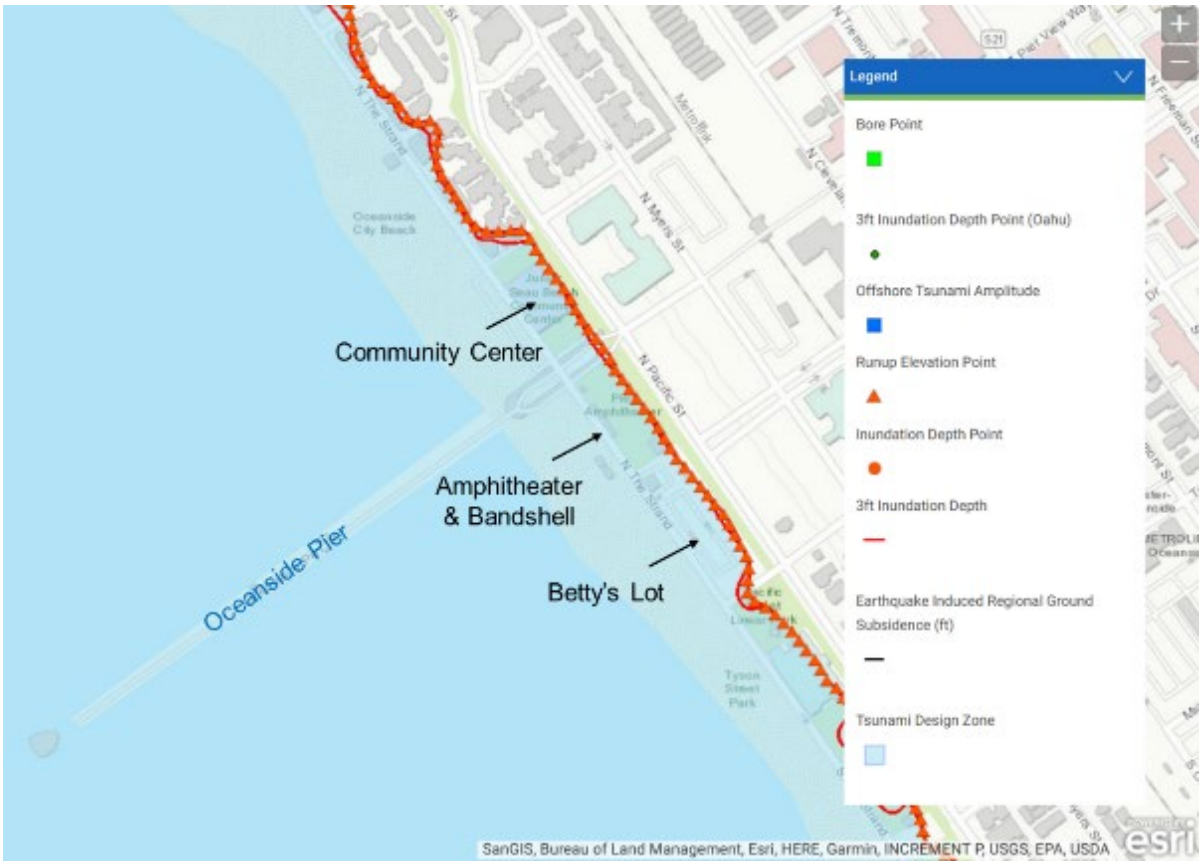

Figure 17: Tsunami Design Zone and Inundation Depth for Existing Beachfront Under a 2475-year Tsunami Event (ASCE, 2025)

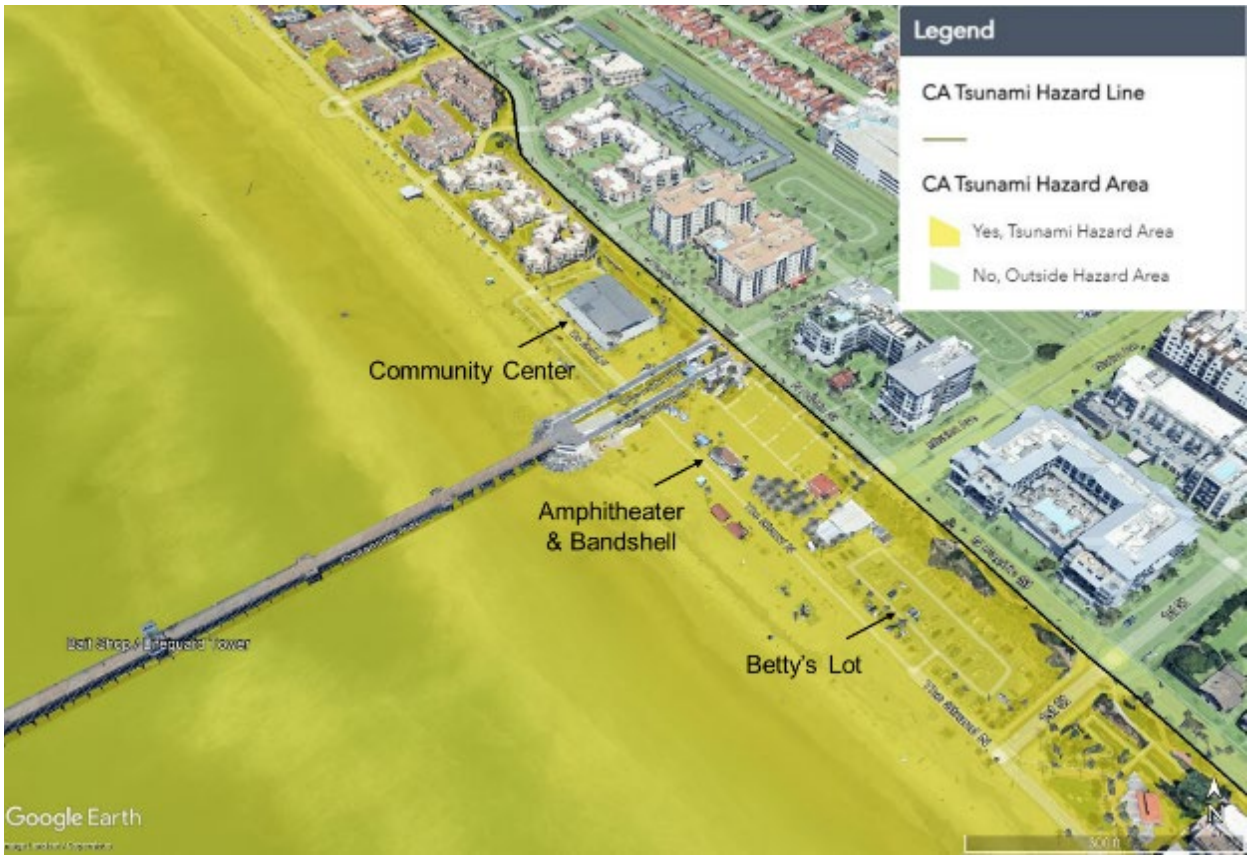

Figure 18: Tsunami Hazard Area Map at Oceanside Beachfront (California Geological Survey, 2019)

4.5 Groundwater

Figure 19 demonstrates how rising sea levels elevate groundwater tables in coastal regions, thereby increasing the risks of flooding and saltwater intrusion into freshwater supplies. To explore these dynamics, the USGS CoSMoS-Groundwater model—built on the MODFLOW software—simulates changes in water table elevations and groundwater flow across coastal California under various sea-level rise scenarios (Befus, Hoover, Barnard, & Erikson, 2020). Given that local factors can significantly influence groundwater hazards—factors that regional models might not fully capture—the CoSMoS outputs are best used as an initial screening tool to identify potential risk areas.

Figure 20 and Figure 21 show CoSMoS model groundwater table depths at the Oceanside Beachfront project site under existing conditions (no SLR) and the 1.0 m (3.3 ft) design SLR scenario, respectively. The CoSMoS model uses surface water level at MHHW as the boundary condition and provides modeling results at 0.25 m SLR increments. The 1.0 m (3.3 ft) SLR in CoSMoS is the most representative set of the highest 3.5 ft design SLR scenario selected for this study. With the 1.0 m SLR, the depth to groundwater under the existing topography reduces from 2 to 5 m (6.6 to 16.4 ft) to 1 to 2 m (3.3 to 6.6 ft) at the beachfront where the structures are located. The zone with 2 to 5 m (6.6 to 16.4 ft) depth to groundwater shrinks with SLR. The proposed grading change at the most seaward grading zone is less than 1 ft at the Community Center and 0.5

ft at the other sites, thus will not result in any negative impacts to groundwater depth. In addition, no groundwater emergence is anticipated during the service lives of the proposed structures.

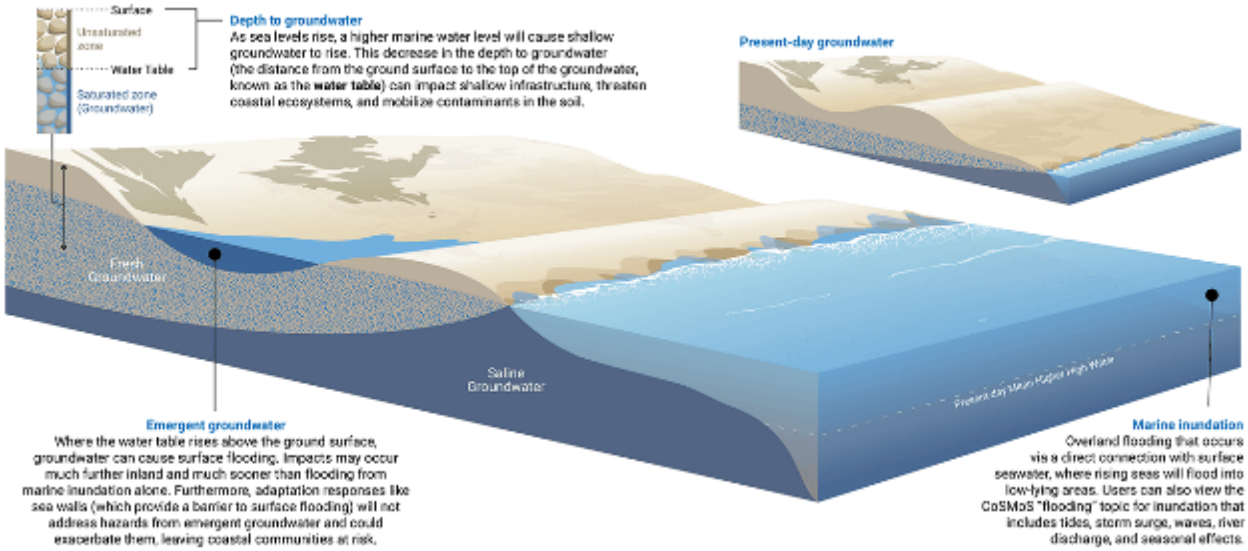

Figure 19: Illustration of Groundwater Level Changes due to SLR (Barnard, 2018)

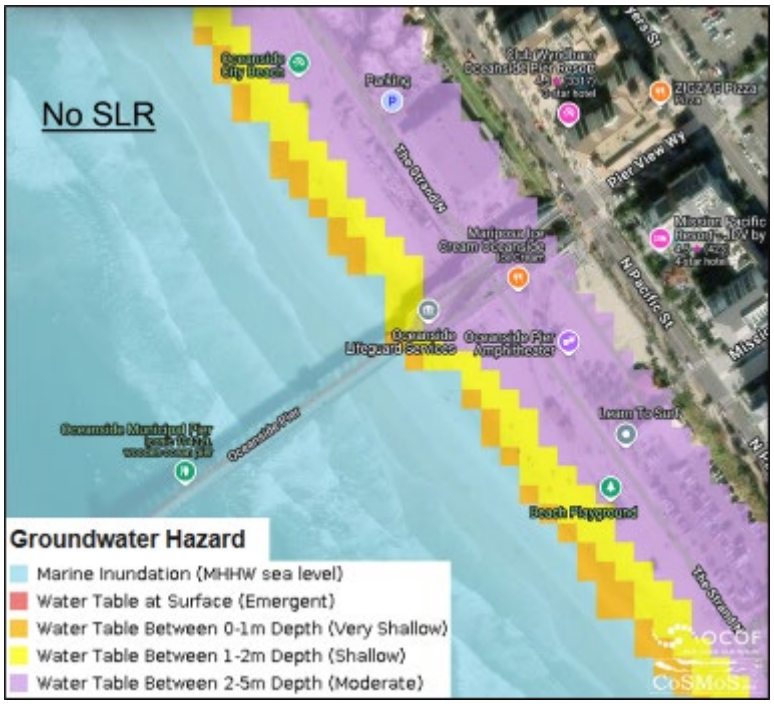

Figure 20: CoSMoS Groundwater Hazard Map under No SLR Condition

Figure 21: CoSMoS Groundwater Hazard Map under +1.0 m (3.3 ft) SLR Condition

5 Conclusions and Recommendations

This study assessed coastal hazards and SLR vulnerability for Phase II of the proposed Oceanside Beachfront Project. This project phase includes improvements at three sites: the Junior Seau Beach Community Center, the Junior Seau Pier Amphitheater and Bandshell, and the Beachfront Park and Recreation Center (Betty's Lot). The assessment included reviewing available public information on coastal flooding, conducting a site-specific wave runup analysis, and evaluating potential effects from other coastal hazards. The evaluation of these hazards and potential impacts focused on the following proposed project features at each site:

- Junior Seau Beach Community Center: New grading in the parking lot and plaza; no elevation changes to the building.
- Junior Seau Pier Amphitheater and Bandshell: New construction of Bandshell and Amphitheater; new gradings on adjacent The Strand.
- Beachfront Recreation Center (Betty's Lot): New single story parking garage reflected in grading changes within the lot.

This analysis provides an evaluation of coastal hazards at the current Beachfront Project Phase II sites due to future SLRs. The primary hazards assessed included coastal flooding, currents, erosion, tsunami inundation, and groundwater changes. A summary of coastal hazards and potential project impacts identified by the study is provided below.

Coastal Hazards

The coastal hazard risks are generally expected to increase with SLR. Under future conditions, elevated water levels will cause waves to break closer to shore, resulting in a higher wave runup on the beachfront. This change can also amplify other risks, including those from tsunamis, groundwater fluctuations, and erosion. Key findings for the assessed coastal hazards are summarized as follows:

- Coastal Flooding: A site-specific runup analysis was conducted to assess coastal flooding hazards at all three project sites. Table 10 summarizes the 100-year TWLs under the selected design SLR scenarios. TWLs for both existing and proposed side conditions are the same since the proposed change does not impact the wave runup. Under existing conditions (no SLR), the 100-year TWL is 15 ft NAVD88 at the community Center and 16 ft NAVD88 at sites south of the Pier View Way Bridge. All three sites are outside the flood zone with the current sea level, per the coastal flood hazard map shown in Section 4.1.3. With SLR, the vulnerability to flood risk at the project sites increases. The lower regions in the three project sites are predicted to be flooded during a 100-year event. Minimum changes in the flood extent are observed between the two SLR scenarios (intermediate scenario vs. intermediate-high scenario).

Table 10: 100-year TWLs (in ft NAVD88) at Oceanside Beachfront Projects Phase II

Sea Level Rise	**Community Center**	
Present (No SLR)	15	
+1.4 ft	18	
+2.3 ft	21	
Sea Level Rise	**Amphitheater & Bandshell**	**Betty's Lot**
Present (No SLR)	16	16
+2.1 ft	21	20
+3.5 ft	23	22

- Coastal Erosion: Under existing conditions (no SLR), the Phase II shoreline adjacent to the project sites already demonstrate seasonal coastal erosion, although the changes are dynamic rather than continuous. With SLR, the shoreline position will retreat. However, assuming The Strand will act as "Hold the Line" infrastructure/barrier, the erosion will stop at the seaward side of The Strand, which leave the Projects Phase II sites outside the erosion impact zone.
- Currents: The predicted maximum currents from USGS CoSMoS indicated potential for erosion.
- Tsunami: The Beachfront Phase II Project sites are located within the tsunami hazard zone, exposed to risks of tsunami inundation and runup. Tsunami warning signs are recommended.
- Groundwater: Groundwater emergence is not expected, but rising groundwater level with SLR presents a potential hazard to underground utilities if present and will reduce soil bearing capacity.

Impact Assessment

The proposed project includes grading modifications within the parking and plaza area adjacent to the Community Center, the construction of new Bandshell and Amphitheater and a new garage building in Betty's Lot. All proposed grading changes are planned for locations above 13 ft NAVD88 (which is more than 6 ft above HOT), meaning they do not modify the foreshore slope (the slope between MSL and HOT) that governs wave runup (as described in Section 4.1.2.1 across all three transects). As a result, the 100-year TWLs remain unchanged for both existing and proposed site conditions.

Since the proposed site modifications are limited to the area above the HOT level, M&N has concluded the following key points regarding the proposed project impact:

- The proposed Project Phase II is not expected to affect coastal flooding at the sites.
- No impacts to erosion, longshore transport, tsunami inundation, or groundwater are expected due to the proposed project.
- With grading modifications limited to less than 1 ft within the most seaward grading zones, the coastal impacts to surrounding areas are negligible.

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