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HUNTINGTON BEACH BLUFFS STABILIZATION

Alternatives and Coastal Hazards Analyses

FINAL REPORT

Produced For City of Huntington Beach

Date: 10/19/2022

Document Verification

Client	City of Huntington Beach
Project name	Huntington Beach Bluffs Stabilization Project
Document title	Alternatives and Coastal Hazards Analyses
Document sub-title	-
Status	Final Report
Date	10/19/2022
Project number	212289-02
File reference	-

Revision	Description	Issued by	Date	Checked
00	Report	Garvey	8/28/22	Webb 8/29/22
01	Report	Garvey	8/31/22	Webb 8/31/22
02	Report			Matheus 10/10/22
03	Report	Butler, Garvey	10/18/22	Webb 10/18-19/22

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1. Project Overview

1.1. Project Area

The City of Huntington Beach Bluff Top Park is a valued coastal resource, providing low-cost public access amenities including bike and pedestrian paths, restrooms, public parking and open space to residents and visitors. The blufftop area comprises a relatively narrow strip of land between Pacific Coast Highway and coastal bluffs from Goldenwest Street to approximately 4,000 feet northwest of Seapoint Street (Figure 1-1). The bluffs range in height from 20-30 feet above the sandy beach, and approximately 40 feet above sea level.

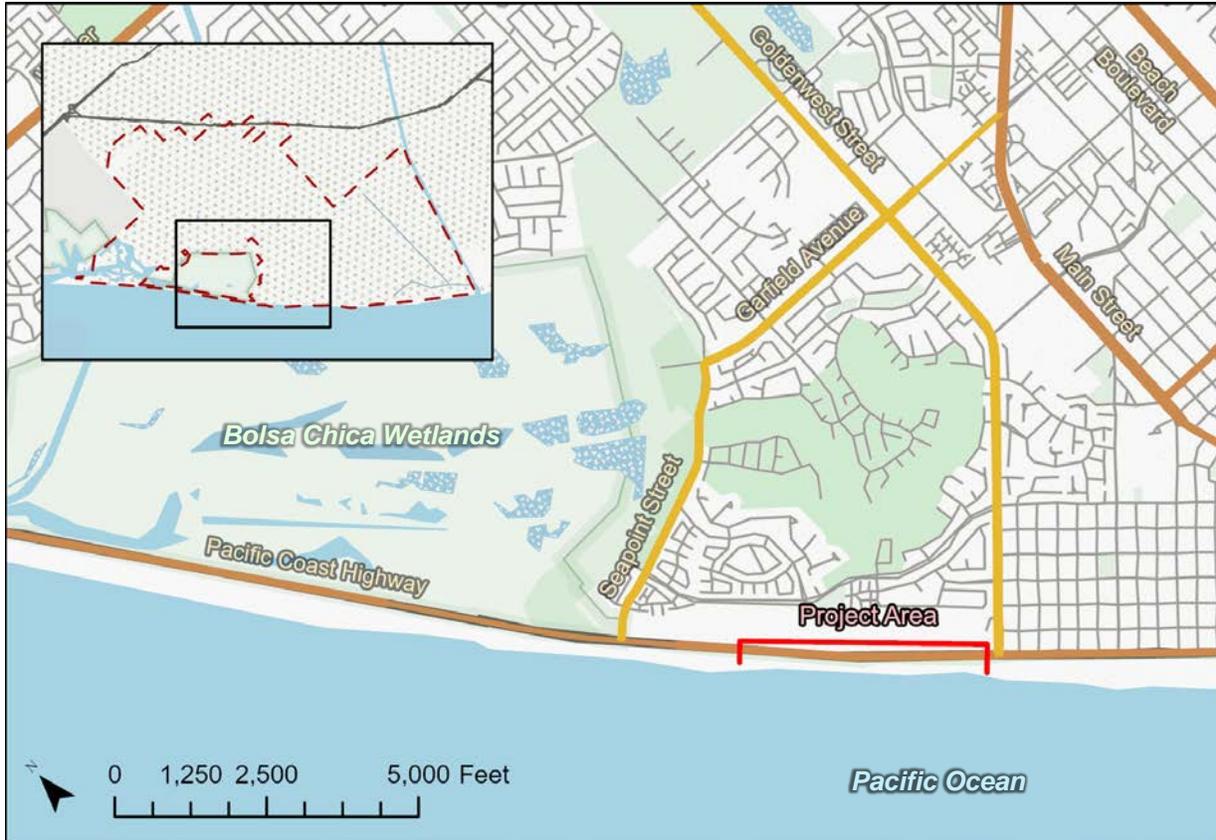


FIGURE 1-1: PROJECT AREA

Over the years this valuable public asset has been subject to ongoing coastal erosion. This erosion is likely caused by the relative alignment of the bluffs, which protrude seaward in planform from the adjacent shoreline forming a subtle headland shape that is less effective at retaining a wide beach than adjacent shoreline areas. Historic subsidence associated with oil extraction activities may also have contributed to the long-term trend of erosion along the bluffs.

Much of the base of the bluffs are protected by relic concrete rubble and stone placed to provide shore protection for historic oil extraction operations. There are seven areas (shown in Figure 1-2) where bluff erosion has been particularly accelerated; these locations are categorized by a loss of armor stone at the base of the bluff. The erosion has formed small “embayments” in the bluff, where the bluff toe has retreated beyond the adjacent reaches.

Two of these eroded areas are particularly close to existing infrastructure. The first area is adjacent to the public restroom (and so named “RESTROOM” location) and the second area is adjacent to the shared bike and pedestrian path along the south parking lot (and so named “SOUTH LOT” location). Figure 1-3 and Figure 1-4 show the conditions of these two areas as of April 27, 2021.





FIGURE 1-2: BLUFF EROSION AREAS



FIGURE 1-3: RESTROOM EROSION AREA



FIGURE 1-4: SOUTH LOT EROSION AREA



1.2. Proposed Project Description

The proposed solution for these two areas is to stabilize the bluffs utilizing natural solutions with minimum impact to the sandy beach to the greatest extent practical. The proposed repair concepts (Figure 1-5 and Figure 1-6) are similar at both locations and consist of:

- Salvage and re-use of remnant rock and rubble material to remove it from the active beach area and placement of it against the bluff toe to resist further erosion;
- Import of 2-ton armor stones if insufficient amount of large-sized salvaged rock exists;
- Sand cover of the bluff toe rock (potential sand source is the beach at the toe of the bluffs or the landward portion of the city beach south of Goldenwest Street); and
- Installation of dune vegetation or seeding, as possible, within the sand along the bluff toe.

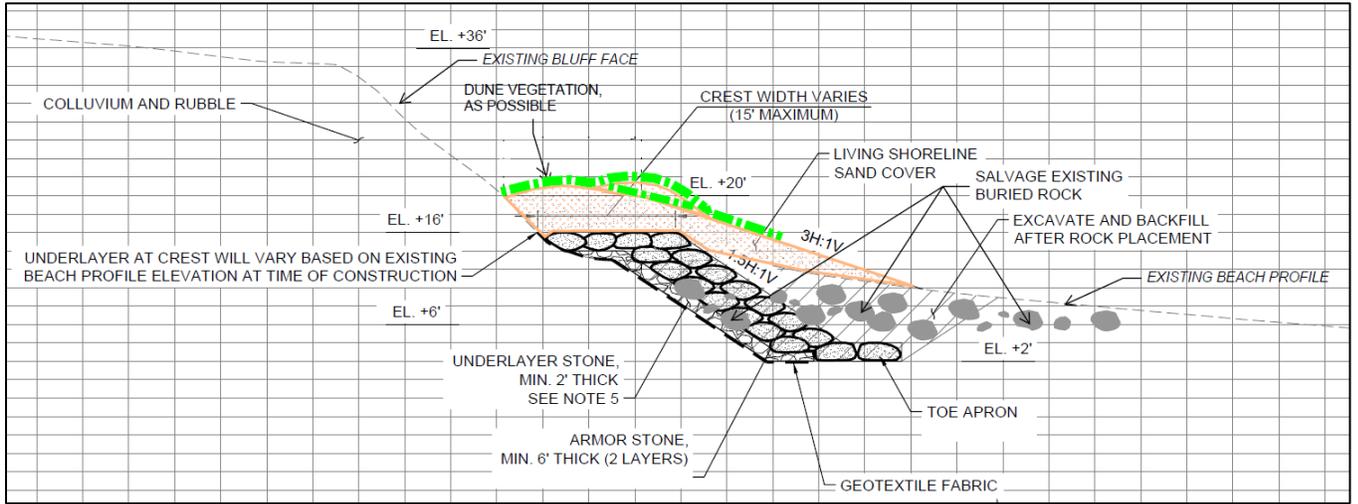


FIGURE 1-5: CONCEPTUAL PROPOSED STABILIZATION DESIGN – RESTROOM LOCATION

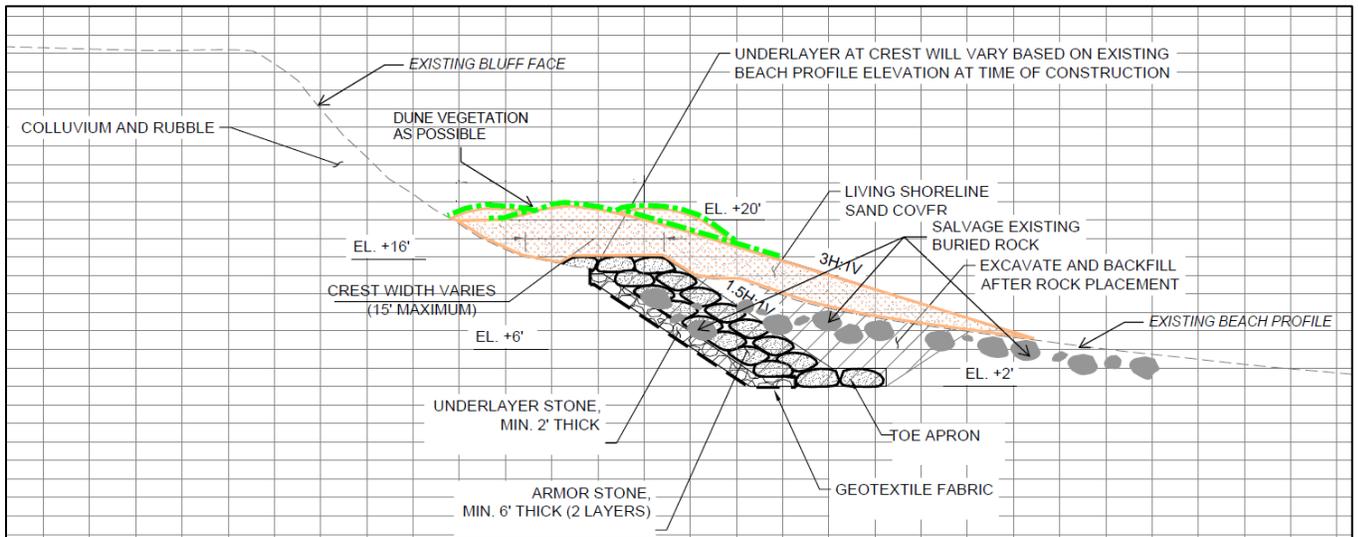


FIGURE 1-6: CONCEPTUAL PROPOSED STABILIZATION DESIGN – SOUTH LOT LOCATION



The shoreline lengths of the stabilization at the Restroom and South Lot locations are approximately 170 and 75 linear feet, respectively.

The proposed approach:

- Is resilient for future sea level rise;
- Minimizes impacts to the sandy beach footprint and is landward of the current high tide line;
- Improves the beach by relocating rock from under the beach and consolidating existing rock landward from its existing footprint to the bluff toe;
- Is a hybrid living shoreline solution of soft and hard protection methods – sand and dune vegetation coupled with buried rock as last line of defense for protection;
- Improves public access along the shoreline;
- Improves safety for beach and path users;
- Increases public health and community wellness; and
- Increases tourism and recreation.

Construction would likely occur in two phases as funding is available and would take approximately 2 to 3 months. The Restroom Site would be constructed first followed by the South Lot site. The majority of the construction work would occur from the beach. Construction equipment would not need to go into the water based on the current wide beach condition. If the beach is significantly narrower at the time of construction (which is not anticipated), the construction may have to be timed to work during low tide hours to avoid in-water work. Although public access to the beach would be maintained during the construction period, construction activities would be limited to weekdays only and outside of the summer season (Memorial Day to Labor Day) to minimize disruption to public access.

The revetment footprint would be excavated and a geosynthetic fabric placed along the bottom of the excavation. On top of the fabric would be placed an approximately 2-foot-thick under layer consisting of smaller (less than 1-ton) stone. This rock would be overlain by an approximately 6-foot-thick layer of 1-2-ton stone using rock salvaged from under the beach seaward of the bluff toe. If there is insufficient quantity of salvageable larger rock, then possibly up to 4,000 tons of 2-ton armor stone may need to be imported. Import the rock to the project site would be no more than 30 truck trips per day, which equates to approximately 10 days of rock import activities assuming standard large 14-ton capacity dump trucks. A sand cover would be placed over the rock and the sand surface could then either be seeded or vegetated or left to be naturally colonized with dune vegetation.

As with any City construction project, measures will be taken to ensure construction-related impacts are mitigated to the maximum extent practicable. This includes dust, noise, erosion, and traffic control, public access, and preventing debris from entering the ocean. Construction Best Management Practices would include avoiding construction work and equipment storage in the tidal zone, avoiding construction equipment maintenance and fueling on the sandy beach, placement of temporary fencing and flaggers to protect public safety, and use of watering trucks as needed for dust control on the ramp to/from the beach. Since the construction work area is less than 1 acre, a SWPPP would not be required but appropriate construction BMPs will be required per the project plans and specifications. All Contractors will be required to comply with the “Occupational Safety and Health Regulations” of the U.S. Department of Labor and the State of California Department of Industrial Relations’ “Construction Safety Orders”.

Access to the beach will be maintained during construction and signage will be placed to route beach users around construction zones. Staging limits and site access routes are provided in Figure 1-7 below. Potential staging areas are approximately ~7,000 square feet and are situated in locations that do not impact pedestrian beach access or public parking. During non-working hours, these staging / laydown and construction areas will be fenced or barricaded to prevent unauthorized entry.





FIGURE 1-7 POTENTIAL CONTRACTOR STAGING AND SITE ACCESS



2. Alternatives Comparison

2.1. No Action

2.1.1. Overview

The “no action” alternative involves no additional action to address coastal hazards within the project area, leaving existing bluffs in their current eroded condition.

2.1.2. Coastal Hazard Risk Reduction

- No reduction in erosion hazards within the project area.

2.1.3. Auxiliary Benefits

- No potential disruption to beach access and recreation during construction activities.
- Maintains existing sediment transport patterns.

2.1.4. Potential Impacts to Coastal Resources

- Loss of coastal access pathways and potential danger to pedestrians along the bluff top within the project area due to ongoing erosion impacts.
- Loss of public parking and restroom facility caused by bluff and shoreline erosion.
- Rock would remain buried underneath the beach and may be exposed during times of a narrower beach.

2.2. Full Armoring

2.2.1. Overview

The “full armoring” alternative consists of both a hybrid armoring approach at the base of the bluff toe and additional armoring of the bluff face. The hybrid armoring measure consists of a buried rock revetment covered in sand and dune vegetation. Armoring of the bluff face is achieved through the installation of a shotcrete wall with tie-back anchors and drilled piers. This alternative is illustrated in Figure 2-1.

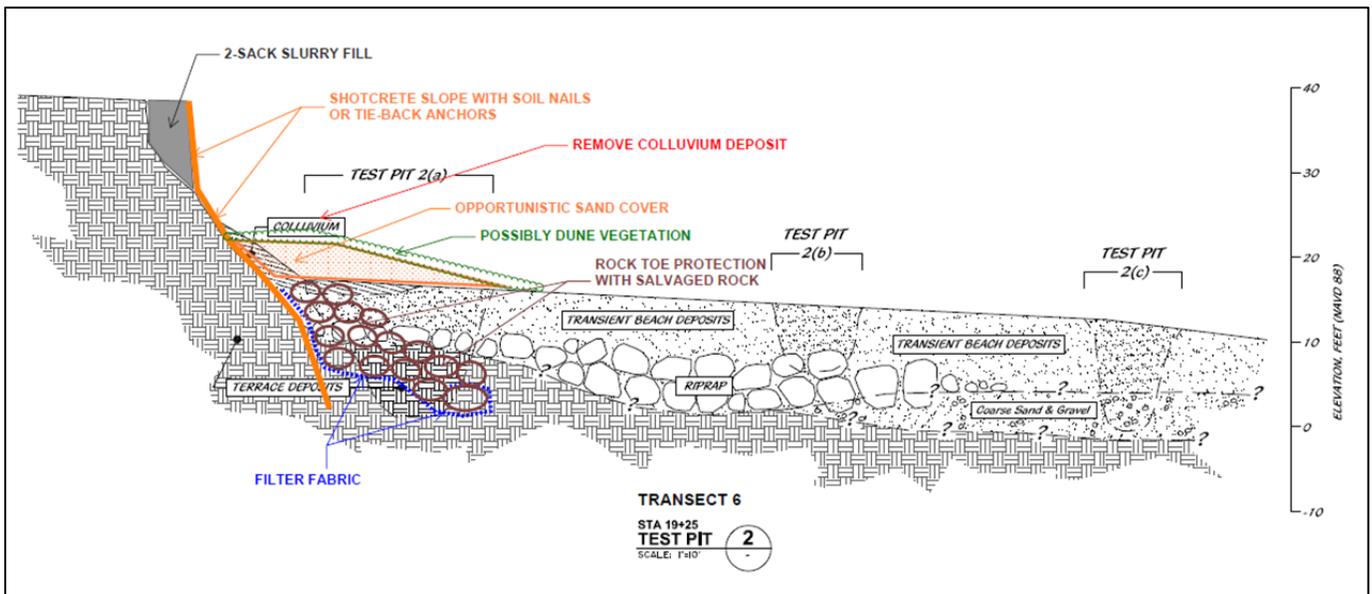


FIGURE 2-1: ALTERNATIVE CONCEPT – FULL ARMORING



2.2.2. Coastal Hazard Risk Reduction

- Rock revetment protects toe of bluff from wave attack erosion.
- Bluff armoring prevents further erosion of bluff face and bluff top.
- Placement of sand over the revetment dissipates wave energy fronting the bluff face and reduces beach loss by replacing eroded material.

2.2.3. Auxiliary Benefits

- Improves the beach recreational area by relocating and consolidating existing rock landward from its existing footprint underneath the beach.
- Armoring of bluff face provides robust long-term protection for future sea level rise.
- Slurry fill of eroded areas restores bluff-top area for recreational uses, e.g., public walkway.
- Sand cover and vegetated dune provide habitat enhancement.

2.2.4. Potential Impacts to Coastal Resources

- No significant alterations to beach access. The proposed revetment will be located landward of the existing rock and rubble protection which currently lines the project area and protrudes further seaward on either side of the proposed bluff stabilization.
- No significant impact to alongshore sediment transport. The proposed rock revetment will be located landward of existing bluff-toe rock and rubble protection on its upcoast and downcoast ends, i.e., the revetment will not trap sediment moving along the shoreline, even when the beach is in an eroded condition.
- Presence of a revetment impounds sediment landward of the revetment structure, removing it as a source for the littoral cell. This impact is offset by removing current stone and rubble from the active beach area and restoring a more natural beach profile response to seasonal and storm induced shoreline erosion. Further, the revetment will be located along the toe of the bluff and is not significantly impounding beach sand.
- Armoring of the bluff face impounds sediment landward of the structure, removing sediment from the system that would otherwise feed into beach areas fronting the protective structure. Although bluff material is finer than beach sand, there could be some contribution of sediment from the bluff which contains sediment with beach sand grain size.
- Although an aesthetic natural-looking sculpting of the shotcrete application on the bluff face could be completed and the current bluff face contains old pipes, concrete and other debris, the installation of the bluff shotcrete would alter the natural character of coastal access and recreation areas.



2.3. Hybrid Protection and Managed Retreat

2.3.1. Overview

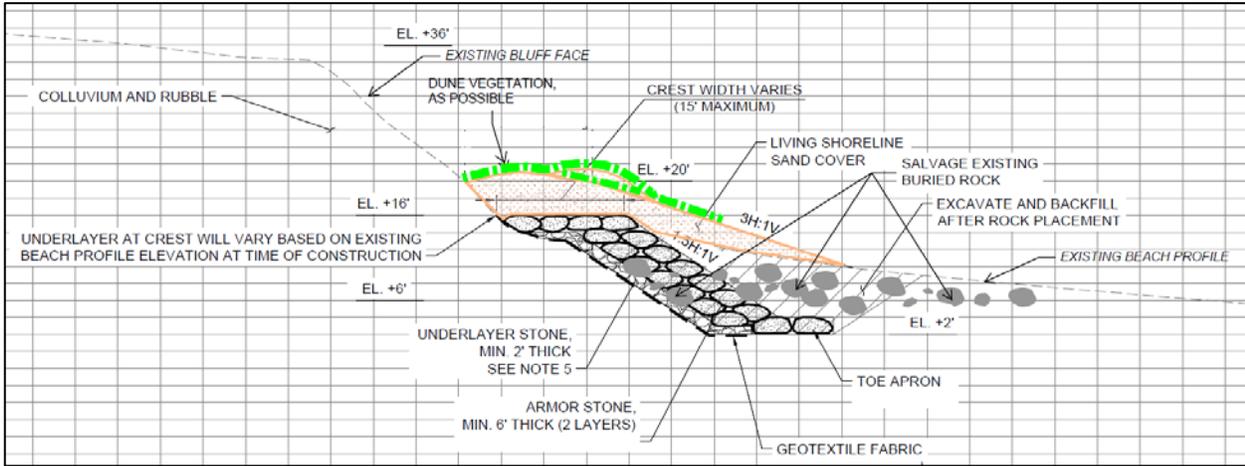


FIGURE 2-2 CONCEPTUAL HYBRID PROTECTION AND MANAGED ALTERNATIVE – RESTROOM LOCATION

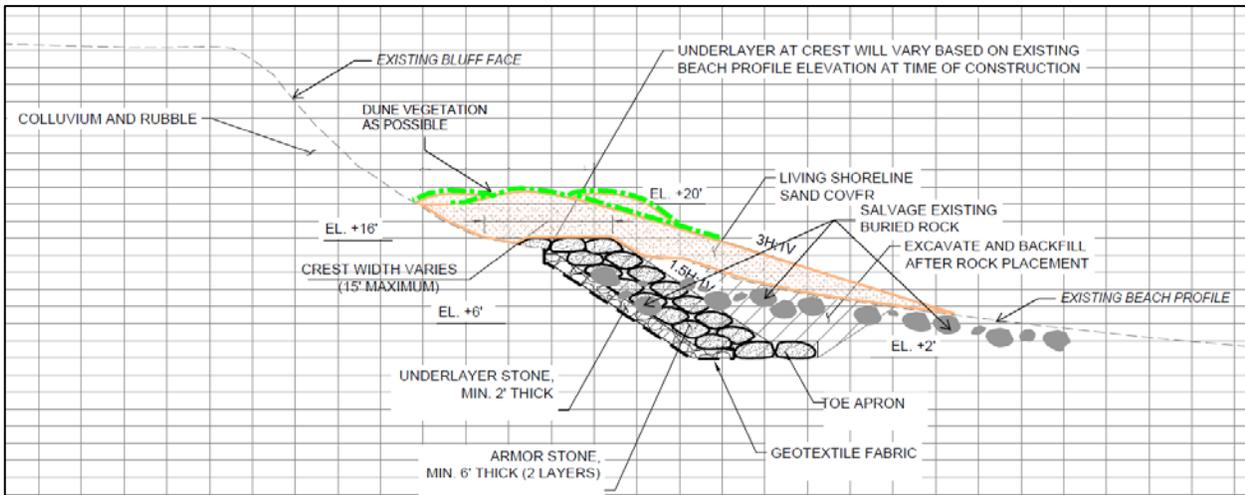


FIGURE 2-3 CONCEPTUAL HYBRID PROTECTION AND MANAGED RETREAT ALTERNATIVE – SOUTH LOT LOCATION

The “hybrid protection and managed retreat” alternative consists of a hybrid approach of protecting the base of the bluff and relocating bluff-top facilities and amenities to avoid erosion hazard areas. The bluff toe protection measure consists of a buried rock revetment covered in sand and dune vegetation. This alternative is illustrated in Figure 2-2 and Figure 2-3 above. Landward relocation of the bluff-top pedestrian pathway has already occurred.

2.3.2. Coastal Hazard Risk Reduction Benefits

- Rock revetment protects toe of bluff from wave attack erosion.
- Placement of sand over the rock further dissipates wave energy fronting the bluff face and reduces beach loss.
- Pathway relocation moves public access amenities away from hazard areas.



2.3.3. Auxiliary Benefits

- Improves the beach recreational area by relocating and consolidating existing rock landward from its existing footprint under the beach.
- Sand cover and vegetated dune provide habitat enhancement.
- Relocating lateral access pathways, where feasible, allows for continued use over time.
- Allows for flexibility for future actions over time to accommodate sea level rise.

2.3.4. Potential Impacts to Coastal Resources

- No significant alterations to beach access. Proposed revetment will be located landward of the existing rock and rubble protection which currently lines the project area and protrudes further seaward on either side of the proposed bluff stabilization.
- No significant impact to alongshore sediment transport. The proposed rock revetment will be located landward of existing bluff-toe rock and rubble protection on its upcoast and downcoast ends, i.e., the revetment will not trap sediment moving along the shoreline, even when the beach is in an eroded condition.
- Presence of a revetment impounds sediment landward of the revetment structure, removing it as a source for the littoral cell. This impact is offset by removing current stone and rubble from the active beach area and restoring a more natural beach profile response to seasonal and storm induced shoreline erosion. Further, the revetment will be located along the toe of the bluff and is not significantly impounding beach sand.
- Relocation of pedestrian pathways away from the bluff edge may reduce scenic views offered by the existing path. This impact may be mitigated by adding overlooks at locations where the bluff is stable.

2.4. Discussion

The hybrid protection and managed retreat is the preferred approach as it:

- Provides needed mitigation of erosion hazards, in order to continue to provide safe and enjoyable public recreation use and access on the bluff top and sandy beach;
- Improves the beach recreational area by relocating and consolidating existing rock landward from its existing footprint under the beach;
- Minimizes impacts to the sandy beach footprint;
- Provides habitat enhancement;
- Is compatible with existing protection along the bluff toe;
- Allows for continued supply of sediment from bluff face;
- Allows for flexibility for future actions over time to accommodate sea level rise;
- Is a good balance of risk reduction and potential impacts to coastal resources; and
- Is a cost-effective solution.



3. Coastal Analyses

3.1. Mean High Tide Line

All project features as currently proposed will be located landward of the Mean High Water (MHW) (Mean High Water) line. Tidal water level variability at the site is estimated from the nearest active tidal water level monitoring station, located at the entrance of the Port of Los Angeles (NOAA CO-OPS Station 9410660). Tidal datums for the current tidal epoch (1983-2001) are provided in Table 3-1, showing the MHW elevation at +4.55 ft (NOAA 2022). All elevations are given relative to the NAVD88 vertical datum, which is used as the vertical datum for the project.

TABLE 3-1 TIDAL DATUMS AT NOAA CO-OPS STATION 9410660: PORT OF LOS ANGELES, CA

Abbreviation	Description	Water Surface Elevation
		ft NAVD88
HOWL	Highest Observed Water Level (1/10/05)	+7.72
HAT	Highest Astronomical Tide	+7.14
MHHW	Mean Higher High Water	+5.29
MHW	Mean High Water (Mean High Tide)	+4.55
MSL	Mean Sea Level	+2.62
MLW	Mean Low Water	+0.74
NAVD88	North American Vertical Datum of 1988	0.00
MLLW	Mean Lower Low Water	-0.20
LAT	Lowest Astronomical Tide	-2.18
LOWL	Lowest Observed Water Level (12/17/33)	-2.93

Source: NOAA CO-OPS Station 9410660 (Los Angeles), NOAA 2022, accessed 21 July 2022, < <https://tidesandcurrents.noaa.gov/datums.html>>

Proposed project footprints are illustrated in Figure 3-1 and Figure 3-2, showing that project features for the Restroom and South Lot sites are located landward of the +10 ft NAVD88 and +6 ft NAVD88 contours respectively. It should also be noted that the rock salvage area is also located landward of the MHW line, as illustrated in Figure 3-3 and Figure 3-4.





FIGURE 3-1: PROJECT FOOTPRINT AT RESTROOM LOCATION (ROCK REVETMENT FOOTPRINT IS WITHIN DUNE FOOTPRINT SHOWN). ALL PROJECT FEATURES LOCATED LANDWARD OF MHW LINE.



FIGURE 3-2: PROJECT FOOTPRINT AT SOUTH LOT LOCATION. (ROCK REVETMENT FOOTPRINT IS WITHIN DUNE FOOTPRINT SHOWN). ALL PROJECT FEATURES LOCATED LANDWARD OF MHW LINE.



FIGURE 3-3: ROCK SALVAGE FOOTPRINT AT RESTROOM LOCATION. ALL PROJECT FEATURES LOCATED LANDWARD OF MHW LINE.



FIGURE 3-4: ROCK SALVAGE FOOTPRINT AT SOUTH LOT LOCATION. ALL PROJECT FEATURES LOCATED LANDWARD OF MHW LINE



3.2. Wave Uprush and Sea Level Rise

To cover the range of conditions experienced in Huntington Beach, wave run-up analyses were conducted on three beach profiles: (1) existing conditions (relatively wide beach), (2) a narrower (intermediate) beach width, and (3) a completely scoured beach width. Each profile was analyzed for both existing sea level and future sea level rise (SLR) scenarios of 3.3 and 6.6 feet (1 and 2 meters, respectively) to assess potential project vulnerabilities to coastal hazards. Minor approximations with regards to the exact timing and probability of the two selected SLR scenarios were made as needed to align with risk aversion designations in 2018 California Ocean Protection Council SLR guidance for the project, provided below:

1. 3.3 feet (1.0 meter) of SLR is representative of the Medium-High Risk Aversion projection for 2070 and the Low Risk Aversion projection for 2100.
2. 6.6 feet (2.0 meters) of SLR is representative of the Medium-High Risk Aversion projection for 2100. The Low Risk Aversion projection does not reach this level until 2150.

Analyses also considered a range of probable wave periods, still water levels (SWL), and beach conditions. Analyses were done to bracket the possible range of low- and high-end values of wave run-up, as determined by the condition of the beach profile and corresponding wave events at the project site.

Runup elevations were calculated following the FEMA (2018) framework for wave runup evaluation and incorporated methodologies described by Stockdon (2006), the DIM Method (FEMA 2005), and the TAW Method (Van der Meer 2002). The framework that FEMA uses to delineate which methods are most appropriate for calculating wave runup is significantly influenced by how each respective methodology defines and assesses the shallow foreshore. For example, the Stockdon and DIM methods are typically more appropriate for evaluation of natural beaches with shallower slopes, whereas the TAW method is characteristically more appropriate for armored beaches and/or structure-backed beaches as it accounts for various reduction factors such as: roughness, porosity, oblique wave incidence, and berm influence. Because of this incongruity, FEMA ultimately recommends the use of the most conservative wave runup elevation and as such, the analysis focused on each scenario's associated total water level (TWL) as a measure of the maximum *potential* runup elevation for a given profile, set of wave conditions, and associated water levels.

In general, total water levels (TWLs) associated with wave runup increase with wave period, still water level (SWL), and SLR. TWLs are generally higher for shore profiles with shallower slopes near the water line, whereas steeper beach slopes and/or rougher surfaces typically yield lower TWLs. At present-day sea levels, the SWL is located at shore elevations associated with relatively shallow slopes for the scoured and wide beach scenarios.

The results of the wave runup analyses for all scenarios are provided in Table 3-2 through Table 3-4. Both the 100-year storm and highest observed water level (HOWL) (1997-98 El Nino Southern California event) were evaluated to capture the most conservative range of potential runup elevations and are provided as SWL in the tables below.



TABLE 3-2 RUNUP RESULTS FOR PRESENT-DAY SEA LEVELS

SLR	SWL (ft)	Peak Wave Period (s)	Existing Condition: Scoured Beach		Proposed Project: Scoured Beach		Proposed Project: Intermediate Beach		Proposed Project: Wide Beach	
			Method	TWL (ft NAVD88)	Method	TWL (ft NAVD88)	Method	TWL (ft NAVD88)	Method	TWL (ft NAVD88)
0	5.8	15	S	16.9	S	16.1	T	19.4	S	16.3
		16	S	17.4	S	16.6	T	20.1	S	16.9
		17	S	18.0	S	17.1	T	20.9	S	17.4
		18	S	18.5	S	17.6	T	21.7	S	17.9
	7.4	15	S	18.4	S	17.6	T	21.8	S	17.9
		16	S	19.0	S	18.2	T	22.7	S	18.4
		17	S	19.5	S	18.7	T	23.5	S	19.0
		18	S	20.1	S	19.2	T	24.4	S	19.5

Note: Methods are indicated as follows: "S" for Stockdon et al. (2006), "D" for DIM (FEMA 2005), and "T" for TAW (van der Meer 2002)

TABLE 3-3 RUNUP RESULTS WITH +3.3-FEET (1.0-METER) SLR

SLR	SWL (ft)	Peak Wave Period (s)	Existing Condition: Scoured Beach		Proposed Project: Scoured Beach		Proposed Project: Intermediate Beach		Proposed Project: Wide Beach	
			Method	TWL (ft NAVD88)	Method	TWL (ft NAVD88)	Method	TWL (ft NAVD88)	Method	TWL (ft NAVD88)
3.3 feet (1 meter)	9.1	15	T	16.1	D	14.5	T	24.6	S	19.6
		16	T	16.1	D	14.5	T	25.5	S	20.1
		17	T	16.2	D	14.5	T	26.4	S	20.7
		18	T	16.2	D	14.6	T	27.4	S	21.2
	10.7	15	T	21.5	D	16.2	T	27.0	S	21.1
		16	T	21.5	D	16.2	T	27.9	S	21.7
		17	T	21.6	D	16.3	T	28.9	S	22.2
		18	T	21.7	D	16.3	T	29.9	S	22.7

Note: Methods are indicated as follows: "S" for Stockdon et al. (2006), "D" for DIM (FEMA 2005), and "T" for TAW (van der Meer 2002)

TABLE 3-4 RUNUP RESULTS WITH +6.6-FEET (+2.0-METERS) SLR

SLR	SWL (ft)	Peak Wave Period (s)	Existing Condition: Scoured Beach		Proposed Project: Scoured Beach		Proposed Project: Intermediate Beach		Proposed Project: Wide Beach	
			Method	TWL (ft NAVD88)	Method	TWL (ft NAVD88)	Method	TWL (ft NAVD88)	Method	TWL (ft NAVD88)
6.6 feet (2 meters)	12.4	15	T	27.6	D	18.1	T	29.4	S	22.9
		16	T	27.7	D	18.1	T	30.5	S	23.4
		17	T	27.8	D	18.1	T	31.6	S	23.9
		18	T	27.9	D	18.1	T	32.6	S	24.5
	13.9	15	T	32.4	D	19.6	T	31.5	S	24.4
		16	T	32.5	D	19.6	T	32.6	S	25.0
		17	T	32.6	D	19.7	T	33.8	S	25.5
		18	T	32.7	D	19.7	T	34.9	S	26.0

Note: Methods are indicated as follows: "S" for Stockdon et al. (2006), "D" for DIM (FEMA 2005), and "T" for TAW (van der Meer 2002)



The rock revetment can be expected to substantially reduce wave runup associated with extreme events. Also, additional reductions in TWL at present-day sea levels could occur if the toe of the revetment were located lower than the present-day still water level. From the runup result tables above, the TWL associated with present-day runup for the intermediate and wide beach scenarios exhibit generally similar or lower runup elevations than those from both future SLR scenarios.

Each of the wave runup estimation methods have limitations in regard to defining the slope and shore profile. The Stockdon method typically yields higher wave runup elevations than the DIM and TAW methods, and wave runup is typically higher for profiles with shallower slopes. Together, this causes some of the estimates for wave runup at present-day sea levels for a scoured beach condition to be higher than those estimated for the 3.3 feet SLR scenario. The results for present-day sea levels are thus conservative and reflect the influence of the foreshore rather than the effect of the back beach revetment/bluff. These differences in wave runup estimates among analytical equations are part of the reason that FEMA uses the most conservative estimate for a given condition. FEMA also uses the most extreme wave runup elevations calculated for a 50-year time series to develop the extreme runup elevation that is ultimately mapped.

Overall, the analyses results reveal that:

1. Wave runup during a 100-year event will not exceed the 40-foot NAVD88 crest of the Huntington Beach bluffs at the site for any tested shore profile with SLR less than or equal to +6.6 feet (2 meters);
2. The proposed rock revetment placed at the toe of the Huntington Beach bluffs will consistently lower wave runup elevations relative to the lowest scoured beach condition (1998 El Nino); and
3. Wave runup elevations associated with the various bluff stabilization alternatives are consistently lower for the wider beach than for the intermediate beach without a project; both produce wave runup elevations higher than the exposed rock revetment condition due to the shallow foreshore slopes assumed for these scenarios.

This analysis suggests that the proposed bluff stabilization design will reduce wave runup at the face of the bluff during the most extreme (i.e., eroded) beach conditions and wave events and thus minimize further bluff retreat at the Restroom and South Lot embayments.



4. Long-term Adaptation Plan

Adaptation of the bluffs stabilization project can take a variety of forms depending on the severity and timing of future hazard impacts as well as resources available to implement adaptation measures. The following section outlines potential adaptation measures, phasing sequences, and trigger types for the proposed project including actions that can be taken in the near future. Adaptation measures, phasing, and triggers within this section represent proposed options for consideration and guidance and are not intended as prescriptive solutions. Future implementation of any adaptation measure should be based on project-specific evaluations that account for the feasibility and impacts of potential alternatives, any prior or planned adaptation actions, and any updates to coastal hazard projections. Potential adaptation phasing strategies for the project are presented in Table 4-1.

TABLE 4-1: POTENTIAL ADAPTATION TRIGGERS AND PROPOSED PHASING FOR THE BLUFFS STABILIZATION PROJECT.

Time Horizon	Adaptation Trigger	Adaptation Measures ¹
Near-Term	N/A	<ul style="list-style-type: none"> • Utilize regional sediment management opportunities (e.g., Bolsa Chica inlet clearing). • Align any beach nourishment required as part of project implementation with local or regional sediment management plans. • Develop or enhance existing beach width monitoring programs to track project performance and inform any future renourishment efforts.
Medium-Term	<ul style="list-style-type: none"> • Significant reduction in beach width fronting project areas. • Infrequent exposure of buried revetment structure. 	<ul style="list-style-type: none"> • Enhance sediment management practices to maintain beach width fronting project area. • Develop plans for realignment of bluff-top facilities and amenities to reduce potential for impacts during extreme episodic erosion events.
Long-Term	<ul style="list-style-type: none"> • Frequent exposure of buried rock revetment. • Flanking of buried rock revetment. • Accelerated erosion of bluff face seaward of buried rock revetment 	<ul style="list-style-type: none"> • Continue to maintain beach width fronting project areas through enhanced sediment management augmented with additional nourishment as is feasible. • Realign bluff-top facilities and amenities as is necessary to remove them from erosion hazard areas. • Consider additional bluff-face stabilization measures in areas where the capacity for landward retreat is limited.

1. Measures listed for each progressive time horizon or adaptation trigger may be necessary only if previously implemented measures become insufficient based on project performance and hazard monitoring.



5. References

- California Ocean Protection Council (OPC). (2018). State of California Sea-Level Rise Guidance: 2018 Update.
- FEMA. (2005). Final Draft Guidelines for Coastal Flood Hazard Analysis and Mapping for the Pacific Coast of the United States, Washington, DC. January 2005.
- Federal Emergency Management Agency (FEMA) (2018). Updated Guidance for Flood Risk Analysis and Mapping: Coastal Wave Runup and Overtopping. First Publication, Guidance Document 89. FEMA, Washington, DC., February 2018.
- NOAA (2022). Tides and Currents Online Database. Accessed 21 July 2022, <<https://tidesandcurrents.noaa.gov/datums.html?datum=NAVD88&units=0&epoch=0&id=9410660&name=Los+Angeles&state=CA>>Stockdon, H.F., R.A. Holman, P.A. Howd, and A.H. Sallenger. (2006). Empirical parameterization of setup, swash, and runup. Coastal Engineering. 53, Elsevier, 573-588.

