Appendix C
Modeling Memo

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MEMORANDUM

To: Dave Hubbard and Matt James, CRC

Cc: Erin Maker, City of Carpinteria, and Dan Gira and Lane Taylor, Wood.

From: Chris Webb and Bryce Corlett, M&N

Date: Revised November 24, 2021

Subject: Carpinteria Living Shoreline Concept and Analysis

M&N Job No.: 11015

Introduction

The Carpinteria Shoreline Management Plan calls for the construction and maintenance of a living shoreline along the City beach between Ash Avenue and Linden Avenue and potentially extending east of Carpinteria Creek along a short reach of Carpinteria State Beach. This feature is intended to provide flood protection over the near-term future during initial sea level rise (SLR) of two feet under ocean storm wave conditions. This memorandum provides information about the concept design of the living shoreline and the beach, and presents results of modeling and analyses of multiple alternatives using the model Xbeach for wave runup and overtopping.

Project Alternatives

Four different alternatives were developed with the City and project team for analyses. The alternatives are listed in Table 1 below. The alternatives are intended to reduce potential flooding of and wave attack damage to the Beach Neighborhood and a portion of Carpinteria State Beach if approved by the State, but not necessarily prevent it entirely. Severe storms could still potentially overtop the beach and dune and enter the neighborhood, although damage from flooding and direct wave attack would be substantially reduced compared to existing conditions. Also, the timeframe for effectiveness of the project is near-term during SLR of up to 2 feet (30 to 50 years, or 2050 to 2070). Therefore, the feature will likely require maintenance and repair over time, with more maintenance required as sea levels rise, reaching a point at which the feature may no longer be as effective during storms in the long-term future (50+ years such as 2070 to 2100). The same living shoreline alternatives are proposed at both the Beach Neighborhood and a portion of Carpinteria State Beach east of Carpinteria Creek.

Table 1: Table

Alternative	Description	Crest Elevation (Feet, NAVD88)
Alternative 1	Existing Winter Dike	+19
Alternative 2	Wider Beach From Nourishment	+12
Alternative 3	Single Ridge Dune with Wider Beach	+16
Alternative 4	Double Ridge Dune with Wider Beach	+16

Description of Alternatives

A brief description of the alternatives is below. The primary reach of this project would extend for approximately 1,440 feet from Ash Avenue to Linden Avenue within areas under City jurisdiction for beach nourishment and dune construction while the maximum reach of the project would also include a short 350 feet long reach, from Carpinteria Creek to near Tarpits Park at Carpinteria State Beach.

Alternative 1 – Existing Winter Dike

The City’s existing practice of erecting a winter dike provides protection to the Beach Neighborhood under existing conditions. It was first developed in 1983 during an extreme El Nino winter of high waves and very high tides. It is overtopped periodically and requires repair after severe storms. The City uses existing beach sand at the seaward edge of the beach to build up the dike to an elevation of +19 feet relative to North American Vertical Datum 1988 (NAVD 88). Dike side slopes are relatively steep at approximately 2:1 or 3:1. The dike ends at Ash and Linden Avenues and can be flanked by high water around the ends. Figure 1 attached shows a cross-section of the existing winter dike on the beach profile. This dike and beach profile configuration were obtained from the U.S. Geological Survey (USGS) from conditions surveyed in February 2014.

Alternative 2 – Wider Beach From Nourishment

The existing beach width from the back of the beach to the seaward edge of the berm (level towel area) is approximately 100 feet wide at Ash Avenue. A wider beach could be created by nourishing the beach with approximately 500,000 cubic yards (cy) of sand. That amount of sand would create a beach that is nearly 250 feet wide from the back of the beach out to the seaward edge of the berm at a maximum elevation of +12 feet NAVD 88. The beach would slope seaward at 5:1 (horizontal:vertical, or H:V) toward the water. This sand volume would be adequate to fully nourish the City beach and provide sufficient material quantity to maintain a protective beach width after beach profile equilibration after construction, and to serve as a natural source for the living shoreline over time.

The beach elevation can vary, but the natural beach elevation from beach profiles in southern California forms at approximately +12 feet NAVD 88. If a beach is installed that is higher than that natural elevation, then a vertical scarp will form from water eroding the profile. Scarps periodically form at beaches that are at +12 feet NAVD 88, but they are relatively low such as 2 to 3 feet high. If the beach is elevated above +12 feet NAVD 88, then the scarps also are higher and can present a hazard to beachgoers.

The wider beach would exist from approximately slightly west of Ash Avenue to Linden Avenue. Beaches can be overtopped even with increased width, and this alternative would reduce the volume of water overtopping the beach but would not prevent it. New sand would be delivered to the site from another location to build this beach. Sand would disperse out of the placement site after placement and leave a narrower beach within one season. The beach width after one season of ocean waves and tides reworking it would be approximately 170 feet from the back of the beach and the beach profile would flatten to approximately 10:1 (H:V). Figure 2 attached shows a cross-section of the proposed wider beach from nourishment on the beach profile.

Alternative 3 – Single Ridge Dune With A Wider Beach

The third option is a type of hybrid between the previous options, with a single ridge dune fronted by a wider beach. The dune would be slightly lower in crest elevation than the existing winter dike, up to +16 feet NAVD 88, and be wider and relatively flatter in grade. A wider beach and new dune system could be created by nourishing the beach with approximately 500,000 cubic yards (cy) of sand. The side slopes could be more like a natural dune such as 4:1 or 5:1 compared to the existing winter dike, and the dune footprint would be 60 feet wide at the base. It would extend from the Sandyland revetment to the far end of Linden Avenue and extend along a short reach of Carpinteria State Beach if approved by the State. Dune habitat consisting of California native southern foredune plant species would be installed on the dune to promote its natural resilience and re-building properties. The dunes would be reinforced with a cobble core and/or within their toe as needed to improve resilience. Access would be provided over the dune at each street end in the form of a ramp that angles up the face of the dune, reaches the crest, and then angles down the other side. An ADA ramp will be installed at the foot of Ash Avenue with very gradual slope and an artificial surface. The crest elevation of the dune would not drop at the location of access points.

The wider beach would exist in front of the dune from Ash Avenue to Linden Avenue. The beach would be up to an elevation of +12 feet NAVD 88 and would be 120 feet wide from the toe of the dune to the seaward edge of the level beach berm after natural sand dispersion occurs post-construction. The beach would slope seaward at 10:1 toward the water. New sand would be delivered to the site from another location to build this beach and the dune. Figure 3 attached shows a cross-section of the proposed wider beach from nourishment on the beach profile.

Alternative 4 – Double Ridge Dune With A Wider Beach

The fourth option is a variation on alternative 3, with a double ridge dune fronted by a wider beach. The dunes would also be lower in crest elevation than the existing winter dike, up to +16 feet NAVD 88, and be wider and relatively flatter in grade. Within the same footprint, there would be two dune peaks rather than one. The concept is based on increasing friction on incoming waves to reduce their energy in an attempt to reduce their runup elevations. The side slopes could be like a natural dune such as 4:1 or 5:1, and the footprint would be 60 feet wide at the base. It would extend the same length, from the Sandyland revetment to Linden Avenue. As with Alternative 3, dune habitat would be installed on the dunes to promote natural resilience and dune re-building, and access would be provided over the dune at each street end. The dunes would be reinforced with a cobble core and/or within their toe as needed to improve resilience.

The wider beach would exist in front of the dune from Ash Avenue to Linden Avenue. The beach would be up to an elevation of +12 feet NAVD 88 and would be 120 feet wide from the toe of the dune to the seaward edge of the level beach berm after natural sand dispersion occurs post-construction. The beach would slope seaward at 10:1 toward the water. New sand would be delivered to the site from another location to build this beach and the dune. Figure 4 attached shows a cross-section of the proposed wider beach from nourishment on the beach profile.

Methods

Alternatives were analyzed for their ability to block water from overtopping the beach and flooding the neighborhood during significant ocean storm conditions. The numerical model Xbeach was used as the primary method of analyses, with results being compared between alternatives to identify which configurations lowered the wave runup elevation the most at the rear end of the beach. Storm conditions considered include the combined storm wave and tidal event that would occur every 10 years, every 20 years, and every 100 years (in two different wave/tide combinations). Date of the beach profile, waves and tides were obtained from the USGS. In addition, these environmental conditions were also run for existing sea level and a sea level rise scenario of two feet.

Xbeach is a widely applied model developed by the U.S. Army Corps of Engineers in collaboration with European scientists at Deltares. The model predicts wave runup and overtopping on the beach and the changes in the beach profile (the cross-sectional elevation of the beach) using input data of beach profile, tidal elevations, ocean wave height and period. The model is useful in predicting the changes in the beach profile and consequent changes in wave runup over the beach. These predictive capabilities are suitable for determining the elevation of wave runup at the living shoreline location at the back of the beach and any residual wave overtopping. It enables relative comparison of the dissipative properties of alternative cross-shore profile configurations of alternative projects. A full description of the Xbeach model and the methods used in analyses is presented in the appendix to this memo.

Analysis of Alternatives

Alternatives were analyzed for the elevation of wave runup at the back of the beach during the four different storm scenarios. More weight was given to the results for more frequent storms such as the 10- and 20-year storm events because this project is intended to function during the near-term of sea level conditions and thus the more frequent storm events. It is assumed the under 100-year storm conditions that significant damage would occur along the shoreline and the living shoreline would need replacement or significant repair.

Results

The four alternatives were compared for results of wave runup elevations at the rear of the beach for the four different wave and tide combinations. Results are shown in Table 1 on the following page for the 10-year and 20-year storms. The data of interest for comparison are presented in the column second from the right, under the heading "2% Water Depth at Crest." That column presents the elevation that the highest 98% of waves during the storm event. If the elevation exceeds the elevation of the dune crest, then water overtops the dune in the form of a whitewater bore. In every instance whitewater overtops the dune, however, the elevation of that water is minimized under the scenario of the single ridge dune with a wider beach.

The order of performance of the alternatives in reducing wave runup elevations is presented from best to worst below:

1. Single ridge dune with a wider beach;
2. Winter dike;
3. Double ridge dune with a wider beach; and
4. Wider beach from nourishment.

Alternative	Sea Level Rise	Recurrence Period			*2% Water Level at Crest*			2% Water Depth at Crest	
		"Storm"	Wave	Water Level	*'white water'*	*'green water"*	*Crest Elev.*	"white water'	"green water"
Winter Dike	2 ft	20 yrs	10 yrs	2 yrs	*22.52*	*N/A*	*19.00*	3.5 ft	0.0 ft
Wider Nourished Beach	2 ft	20 yrs	10 yrs	2 yrs	*17.10*	*N/A*	*12.05*	5.1 ft	0.0 ft
Single Ridge Dune With Wider Beach	2 ft	20 yrs	10 yrs	2 yrs	*18.21*	*N/A*	*16.00*	2.2 ft	0.0 ft
Double Ridge Dune With Wider Beach	2 ft	20 yrs	10 yrs	2 yrs	*19.25*	*N/A*	*16.00*	3.3 ft	0.0 ft
Winter Dike	2 ft	10 yrs	10 yrs	MHW	*21.32*	*N/A*	*19.00*	2.3 ft	0.0 ft
Wider Nourished Beach	2 ft	10 yrs	10 yrs	MHW	*14.58*	*N/A*	*12.05*	2.5 ft	0.0 ft
Single Ridge Dune With Wider Beach	2 ft	10 yrs	10 yrs	MHW	*18.04*	*N/A*	*16.00*	2.0 ft	0.0 ft
Double Ridge Dune With Wider Beach	2 ft	10 yrs	10 yrs	MHW	*18.97*	*N/A*	*16.00*	3.0 ft	0.0 ft
Winter Dike	0 ft	20 yrs	10 yrs	2 yrs	*21.18*	*N/A*	*19.00*	2.2 ft	0.0 ft
Wider Nourished Beach	0 ft	20 yrs	10 yrs	2 yrs	*15.99*	*N/A*	*13.44*	2.6 ft	0.0 ft
Single Ridge Dune With Wider Beach	0 ft	20 yrs	10 yrs	2 yrs	*18.16*	*N/A*	*16.00*	2.2 ft	0.0 ft
Double Ridge Dune With Wider Beach	0 ft	20 yrs	10 yrs	2 yrs	*18.68*	*N/A*	*16.00*	2.7 ft	0.0 ft
Winter Dike	0 ft	10 yrs	10 yrs	MHW	*21.23*	*N/A*	*19.00*	2.2 ft	0.0 ft
Wider Nourished Beach	0 ft	10 yrs	10 yrs	MHW	*16.45*	*N/A*	*13.44*	3.0 ft	0.0 ft
Single Ridge Dune With Wider Beach	0 ft	10 yrs	10 yrs	MHW	*17.88*	*N/A*	*16.00*	1.9 ft	0.0 ft
Double Ridge Dune With Wider Beach	0 ft	10 yrs	10 yrs	MHW	*18.25*	*N/A*	*16.00*	2.3 ft	0.0 ft

Table 1 – Wave Runup Elevations for the 10- and 20-Year Storm at Carpinteria Beach for Four Alternative Living Shorelines, With 0 Feet and 2 Feet of Sea Level Rise

Conclusions

The following conclusions are drawn from this work:

1) The single dune ridge living shoreline with a wider beach is superior to other options from modeling.

2) Overtopping of the beach and living shoreline will still occur.

3) The City may wish to consider retaining the widest and highest possible beach with sand retention. This may be accomplished by the following:

   a) Retention is possible using a structure such as a groin.

   b) A pilot project temporary groin at Linden Avenue at the downcoast end of the neighborhood beach is suggested for consideration.

An example of the proposed project is shown in Figures 5 and 6 attached to this memo.

Recommendations

The following recommendations are provided for consideration:

1. The City may wish to search for a large source of sand offshore in the ocean. Data exist as obtained by the Beach Erosion Authority for Clean Oceans and Nourishment (BEACON Shoreline Management Plan 1989) and by the USGS that should prove helpful. Cursory review of the BEACON data indicate a possible sand source off of Carpinteria, but that sand source may need to be more thoroughly investigated in the field by a vibracoring effort. This type of work is costly and should be done in collaboration with a regional entity such as BEACON in the context of regional sediment management.

2. The City will ultimately need to design a project with the following components:

A. Beach nourishment with a significant volume of approximately 500,000 cubic yards to fill the beach, pre-fill the groin compartment, and allow for overflow of sand from the beach to the downcoast beach to compensate for any potential sand trapping effects of the groin. Sand composed of relatively large grain sizes, at least the same as the existing beach and preferably coarser will increase longevity. However, finer-grained sand should also be considered as it will feed the dune system during wind events by aeolian transport and deposition.

B. Living shoreline with a single dune ridge. Design of this living shoreline is still needed, but conceptually it should be approximately the same cross-sectional area as the concept shown in Figure 3. The dune crest should be variable and naturalized with hummocks and saddles. The concept will need to include accessways at each street end, and a combined boat launch and ADA ramp at Ash Avenue. Habitat design considerations will be provided by the City's ecologist Coastal Restoration Consultants.

C. Pilot project temporary groin at Linden Avenue. This groin may be composed of a sheetpile wall comprised of either steel or fiberglass. It would be driven into the beach by vibrating method and consist of interlocking sheets that fit together to form a lengthy wall. The benefit of a temporary pilot sheetpile groin is that it is removable if determined to cause adverse impacts, and it could be "tuned" or adjusted to optimize its' performance as determined by monitoring. The groin's length and elevation are still to be determined, but example dimensions could be:

1. A length out to a depth of -3 feet NAVD 88 to trap sand close to shore but not entirely block sand from reaching the downcoast beach. Sand would still be able to move around the groin and pass downcoast.

2. A maximum crest elevation on the horizontal beach berm of +12 feet NAVD 88 to enable sand be trapped by the groin, but to still allow sand to pass over the groin under average wave and tide conditions. Sand movement over the landward end of the groin (called the "root") would nourish the downcoast beach and minimize formation of any downcoast embayment. The crest elevation of the groin could gradually drop towards the water to follow the profile of the beach to minimize visual impacts.

3. The orientation of the groin should be perpendicular to shore to maximize the sand trapping effects and to create the longest possible sand deposit upcoast toward Ash Avenue.

4. The location of the groin should remain on City property and thus be located at the end of Linden Avenue at the property boundary adjacent to the State Beach.

5. Monitoring of the performance of the groin should occur after construction with beach profile and beach width measurements being taken monthly to determine its effects.

    a. Beach profiles can be wading profiles out to the depth able to be reached by a person wading from shore at low tide. The locations of beach width and profile measurements should coincide with the upcoast and downcoast sides of the groin within 100 yards of the structure, and then be spaced ¼ mile both up-and downcoast for a distance of approximately 1 mile if possible, or to the tidal inlet of Carpinteria Marsh on the upcoast end and to Carpinteria Creek on the downcoast end.

    b. Beach width measurements can be done by pacing the width of the beach from the base of the dune out to the waterline at low tide once a month at the beach profile locations.

    c. Drone images of the beach planform should also be taken monthly in the first year to record images of the beach, and then quarterly thereafter for up to five years to create a data base of images through all seasons to visually determine beach changes.

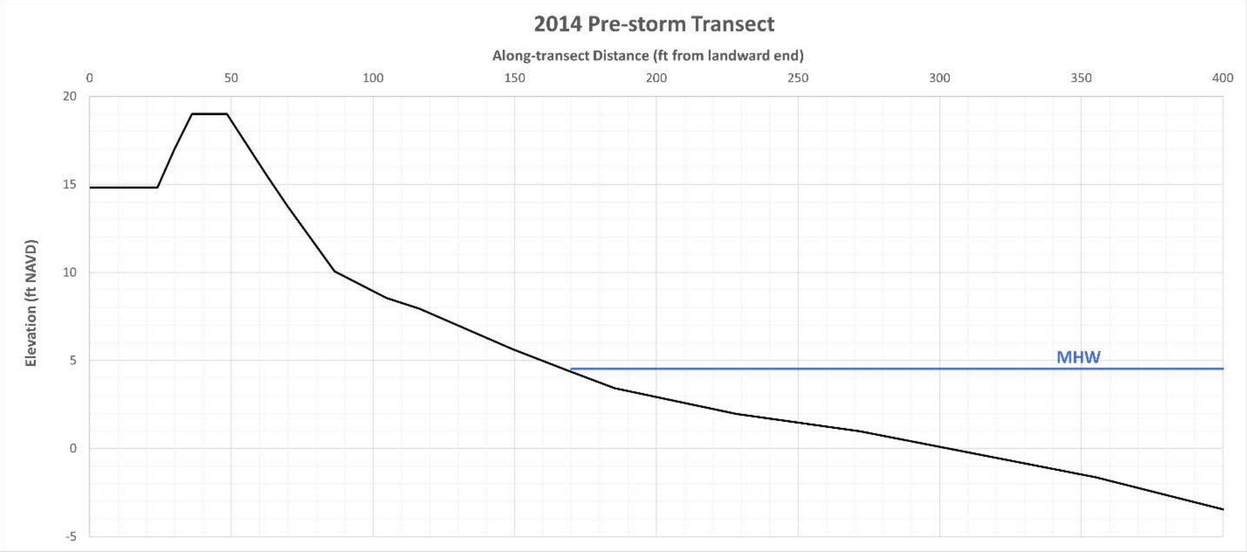
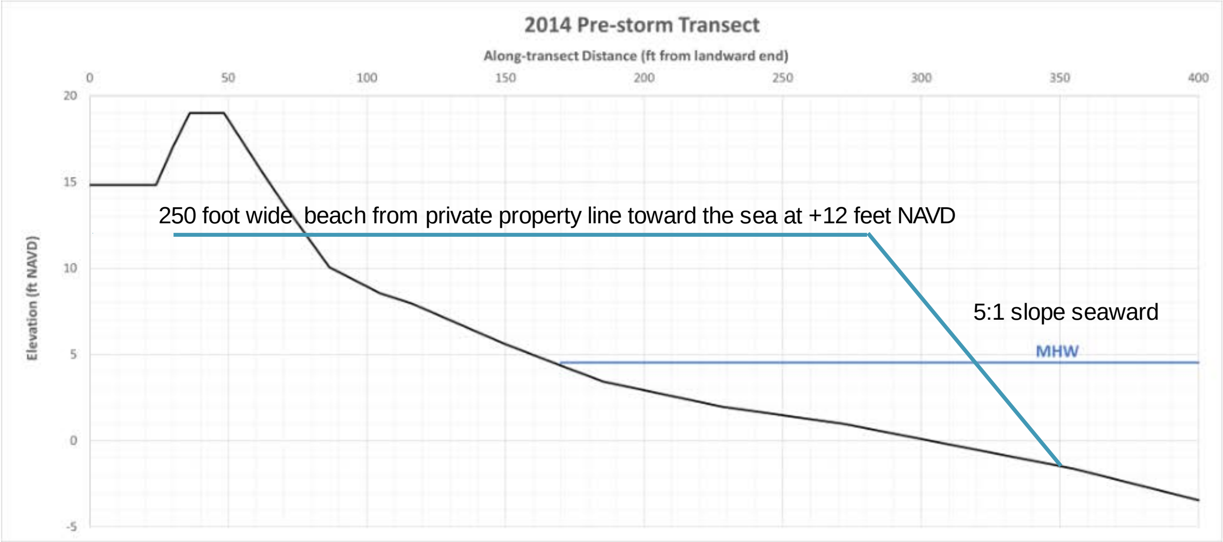


Figure 1 – Winter Dike Profile

Wider Beach by Nourishment – Immediately Post -Construction



Wider Beach by Nourishment After a Winter Season

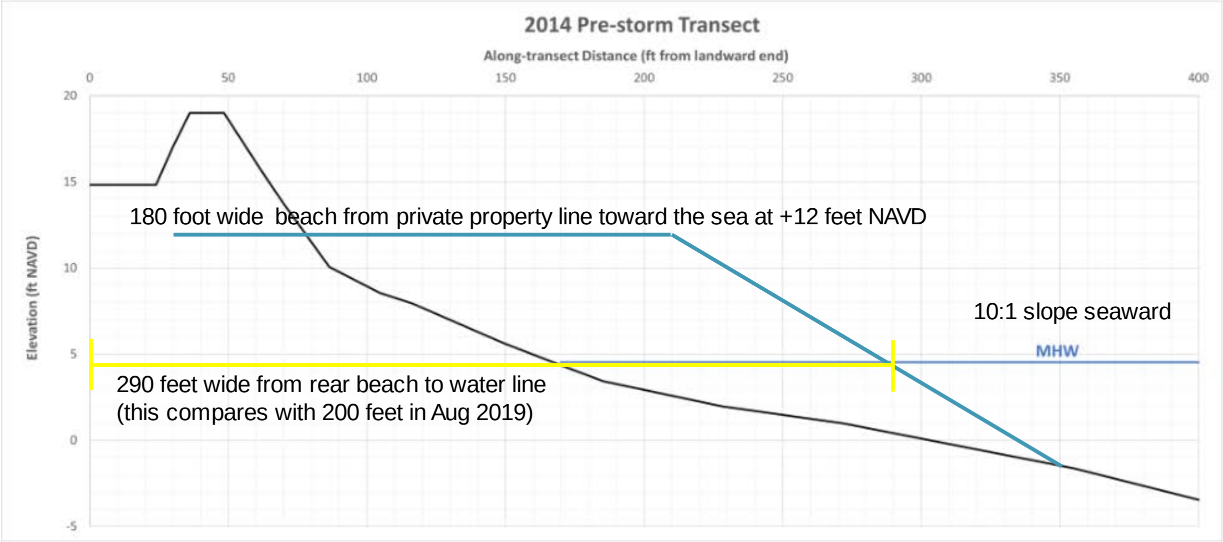


Figure 2 – Profile of a Wider Beach From Nourishment

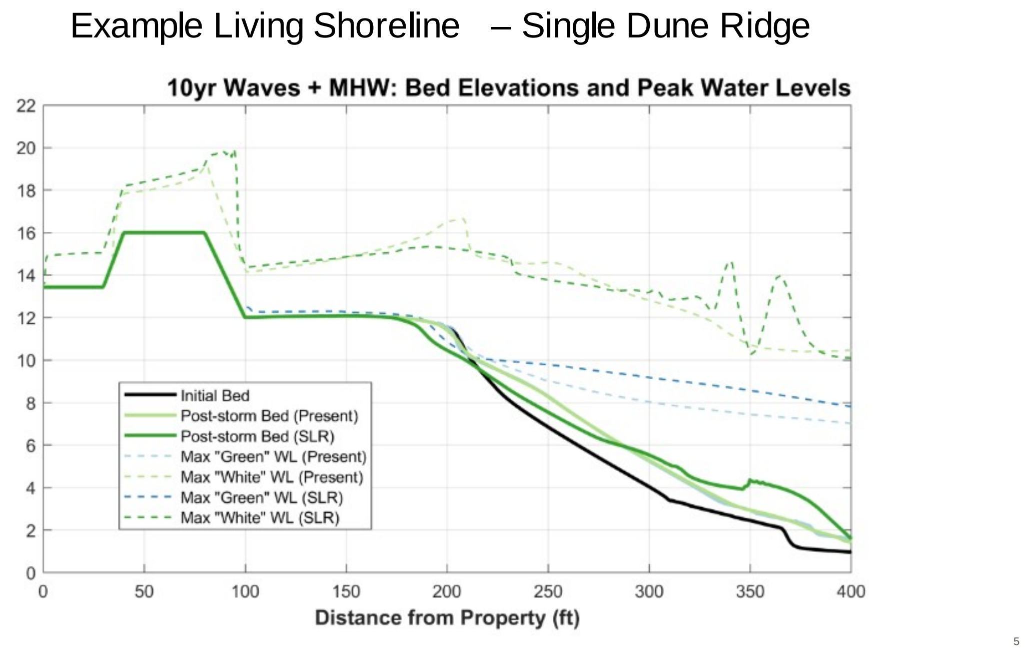


Figure 3 – Profile of the Single Dune Ridge with a Wider Beach

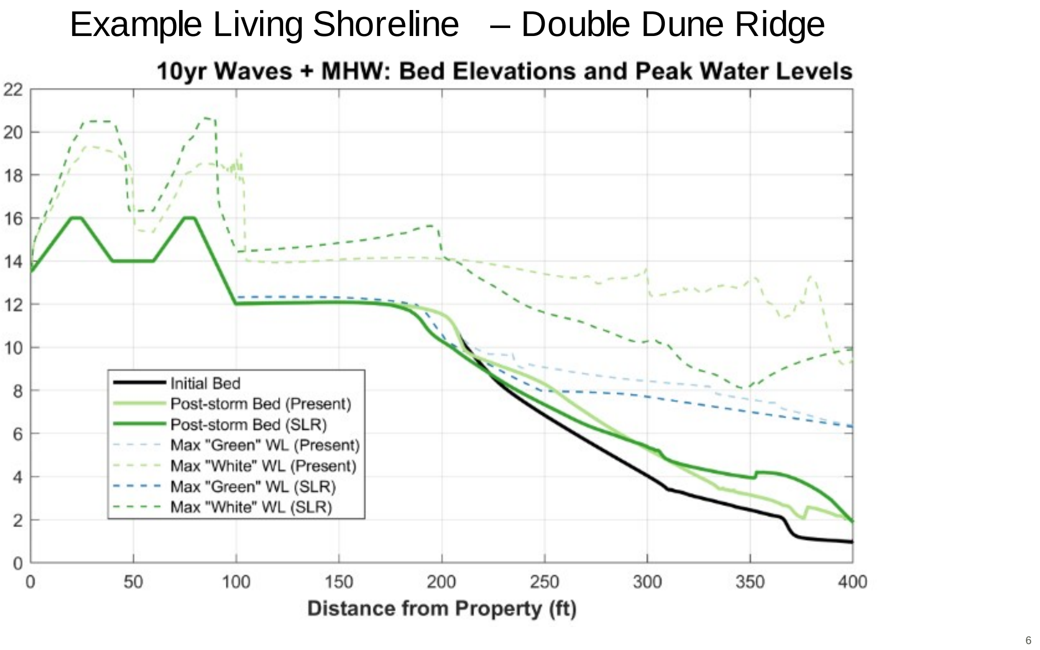


Figure 4 – Profile of the Double Dune Ridge with a Wider Beach

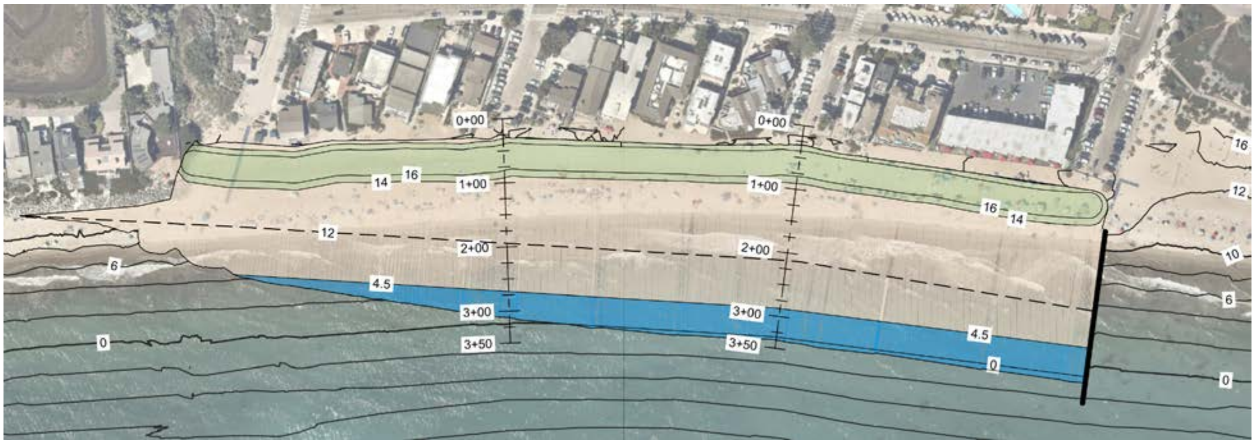


Figure 5 – Temporary Pilot Groin With Wider Beach and Single Ridge Dune

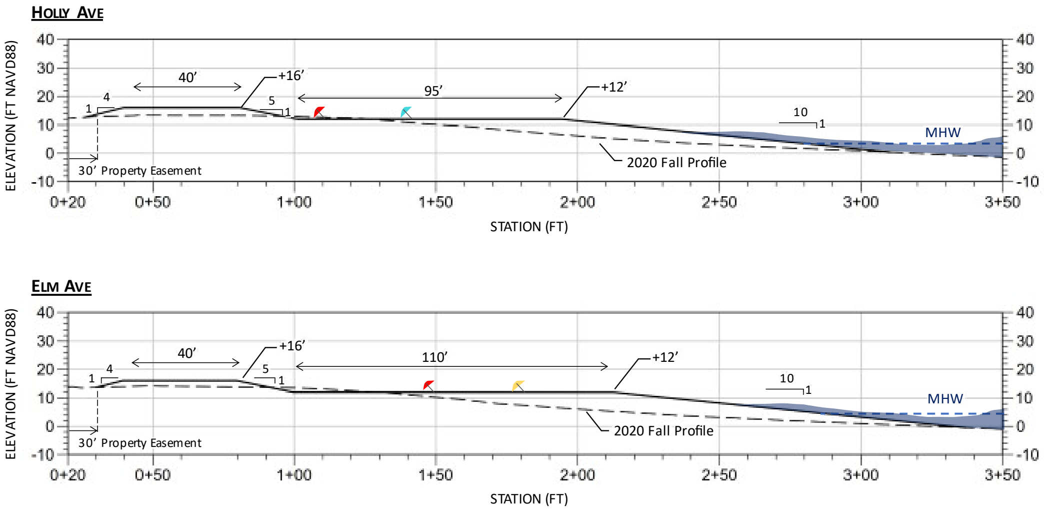


Figure 6 – Typical Section of the Concept with a Temporary Pilot Groin With Wider Beach and Single Ridge Dune

Attachment

Appendix A: Technical Methods

Model Summary

The effects of storm conditions on shore-normal overtopping and erosion along Carpinteria Beach for existing and proposed beach profiles were evaluated with a cross-shore profile using XBeach rev. 5834 (released May 11, 2021)[1]. XBeach is an open-source hydrodynamic and morphodynamic numerical model which was originally developed to simulate the responses of sandy open coasts to storms. Site-specific storm conditions for this project were developed from wave and water level records at or near Carpinteria Beach. The "existing condition" beach profile for this project was developed from a February 2014 USGS beach survey to represent typical winter beach conditions.

Each storm simulation required two model runs to estimate both erosion and overtopping. The first simulated storm-induced erosion by using an erodible bed with the hydrostatic version of XBeach. The final beach profile produced by this simulation was used as a fixed bed with the nonhydrostatic version of XBeach to estimate individual wave runup and overtopping depths at the beach crest. Overtopping depths for each scenario formed the basis of quantitative comparisons between proposed beach profile alternatives, and morphological results formed the basis of qualitative comparisons between alternatives.

Specific descriptions of boundary conditions and ground conditions are provided below.

Boundary Conditions

Water Levels: Water levels applied at the seaward boundary of the model were the combined result of tidal water level variability and storm surge. A 36-hour water level timeseries (e.g., Figure A-1) was constructed from a synthetic tidal timeseries previously developed by Moffatt & Nichol to be representative of tidal variability in Southern California. The synthetic tidal timeseries was modified such that peak wave conditions coincided with mean high water, as determined at the nearest NOAA water level monitoring station (CO-OPS 9411340 at Santa Barbara, CA). Tidal datums at Santa Barbara are presented in Table A-1 for the most recent tidal epoch (1983-2001).

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[1] See https://svn.oss.deltares.nl/repos/xbeach/trunk

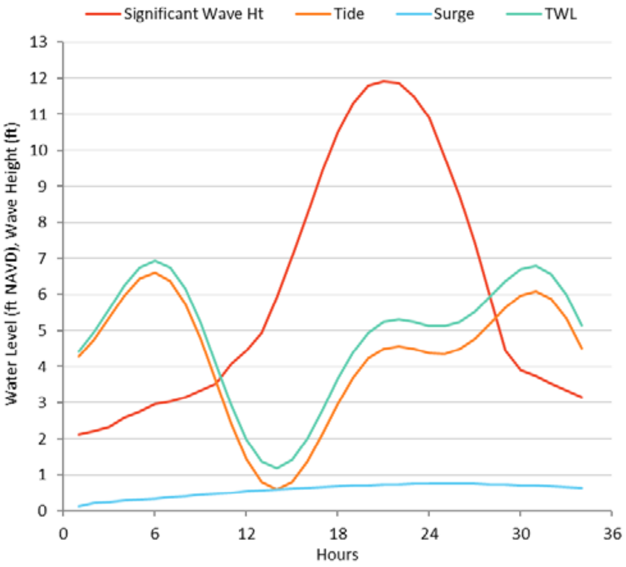

Figure A-1: Example water level and wave conditions for a 100-year storm scenario for Carpinteria Beach, CA.

Table A-2: Tidal datums and two-year water level at NOAA CO-OPS 9411340 (Santa Barbara, CA) for the most recent tidal epoch.

	Abbr.	Elevation (ft NAVD)
Two-year Water Level (*calculated*)	-	7.02 ft
Highest Astronomical Tide *(Dec 2, 1990 16:24)*	HAT	7.08 ft
Mean Higher-High Water	MHHW	5.25 ft
Mean High Water	MHW	4.50 ft
Mean Sea Level	MSL	2.65 ft
Mean Low Water	MLW	0.84 ft
Mean Lower-Low Water	MLLW	-0.14 ft
Lowest Astronomical Tide *(Jan 1, 1987 00:18)*	LAT	-2.15 ft

Storm surges at Carpinteria Beach associated with specific return periods were determined from the ERA-Five storm surge reconstruction from 1979-2019 at Santa Barbara, CA (Tadesse & Wahl, 2021)[2]. The extreme value analysis of the storm surge reconstruction shown in Figure A-2; the storm surge associated with a 100-year return period is approximately +0.75 ft. Within XBeach simulations, the storm surge was varied over time such that the peak surge height coincided with peak wave heights (Figure A-1).

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[2] http://gssr.info/

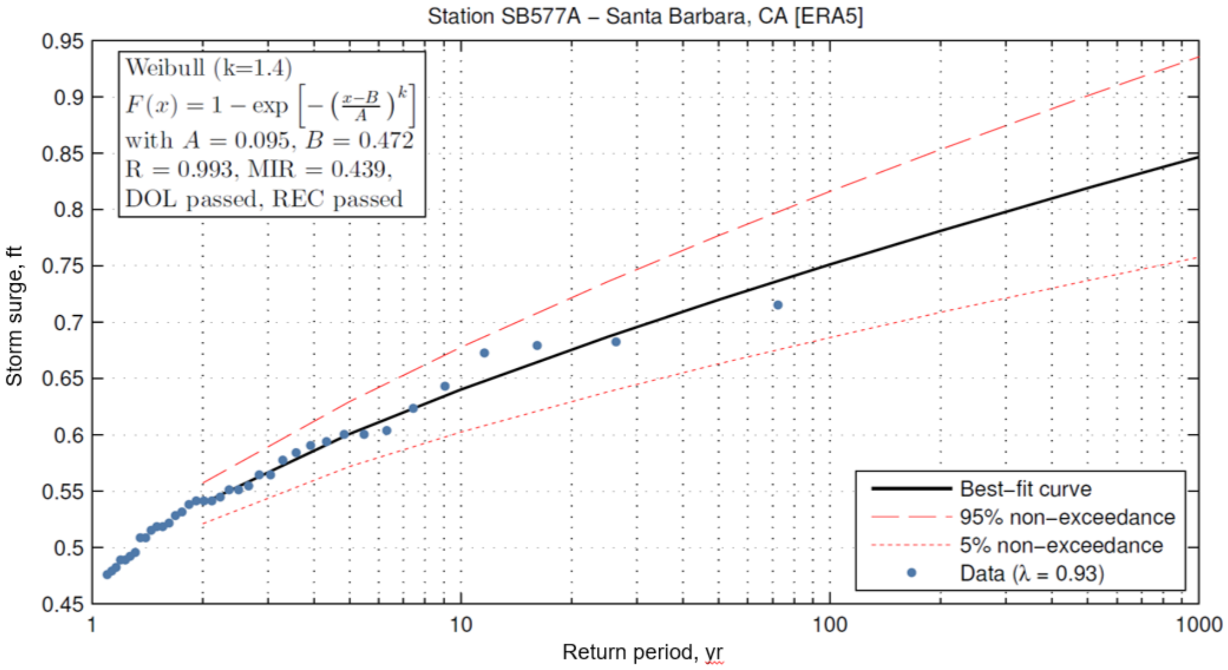

Figure A-2: Storm surge extreme value analysis using reconstructed surge heights at Santa Barbara, CA (Tadesse & Wahl, 2021).

Waves: Nearshore (10 m water depth) significant wave heights for specific return periods were determined from wave data provided by the California coastal wave monitoring and prediction system (MOPS) (O'Reilly, Olfe, Thomas, Seymore, & Guza, 2016) at the nearest location to Elm Avenue (Transect B0054[3]; data available from 2001-2021). The extreme value analysis of wave heights at cross-shore transect B0054 is shown in Figure A-3. In Table A-2, the 100-year MOPS-based wave height is compared with extreme wave heights estimated from the National Data Buoy Center (NDBC) wave data (Buoy 46053) as well as Wave Watch III (WW3) hindcast wave heights (extracted at the location of Buoy 46053); NDBC and WW3 wave height estimates are shoaled and refracted to a depth of 10 meters to be consistent with the MOPS dataset. The MOPS-based extreme wave heights are between estimates of extreme wave heights based on the NDBC wave buoy observations and the WW3 hindcast, which suggests that the MOPS-based extreme wave heights are representative of extreme wave conditions along Carpinteria Beach.

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[3] https://cdip.ucsd.edu/mops/?moplist=Overview&mop=B0054&xitem=historic

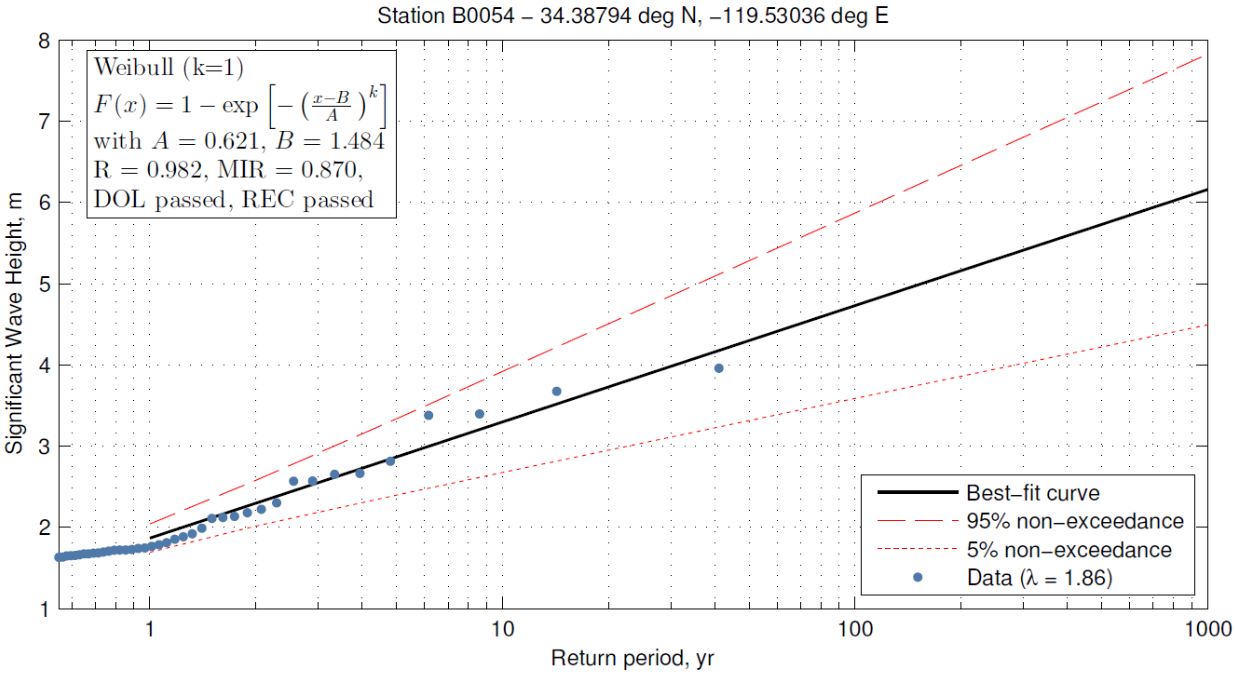

Figure A-3: Extreme value analysis of wave heights at MOPS Transect B0054 (O'Reilly, Olfe, Thomas, Seymore, & Guza, 2016).

Table A-3: 100-year wave heights at 10-meters water depth, estimated for Carpinteria Beach, CA.

Data Source	Significant Wave Height
MOPS Transect B0054	15.5 ft
NDBC Buoy 46053	16.5 ft
WW3 at NDBC Buoy 46053	14.6 ft

Significant wave heights and peak wave periods for discrete return periods are provided in Table A-3 for MOPS Transect B0054. Peak wave periods were estimated as the largest wave period associated with wave heights similar to the estimated extreme wave height. These wave conditions were deshoaled and back-refracted to determine the shore-normal deep water equivalent wave which was used as the offshore boundary condition for the cross-shore profile in XBeach.

Table A-4:Extreme significant wave heights and peak wave periods at 10-meters water depth for MOPS Transect B0054.

Return Period	Significant Wave Height	Peak Wave Period
100 years	15.5 ft	18.2 sec
50 years	14.1 ft	18.2 sec
10 years	10.8 ft	16.7 sec

Storm Conditions: Storms were modeled as specific combinations of wave and water level conditions. Four different storm scenarios were modeled; this includes two 100-year storm scenarios, one 20-year storm scenario, and one 10-year storm scenario (Table A-4). Each scenario had a duration of 36 hours; this included an initial 12-hour ramp-up period of largely tidal water level variability, followed by a 24-hour period containing a wave ramp-up and ramp-down period on top of tidal water level fluctuations (Figure A-1).

Two 100-year storm scenarios were selected to examine the effects of (1) higher waves associated with a 100-year storm, and (2) higher water levels to approximate conditions during observed overtopping of the winter dike. The winter dike has been overtopped twice in recent memory: once during a storm on January 30, 2010, and once during a series of storms in late February/early March 2014 (E. Maker, Pers. Comm., 2021). Both instances of overtopping were associated with higher water levels and relatively small waves. The two-year water level at Santa Barbara, CA (7.0 ft NAVD), was found to approximate the higher water associated with both overtopping events (6.9-7.4 ft NAVD). An event combining a 2-year return period for the water level and a 50-year return period for the wave height is expected to have a return period of approximately 100 years, though the exact return period may be less due to the effects of wave heights on water levels.

Two storm scenarios were also developed to represent storms with shorter (10-year and 20-year) return periods. The 20-year storm scenario used the two-year water level as the higher water level was found to typically cause more erosion and similar wave overtopping depths.

Table A-5: Wave and water level combinations for modeled storm conditions.

Storm	Waves	Water Level at Peak Storm
100-year	100-year	Mean High Water
100-year	50-year	2-year Water Level
20-year	10-year	2-year Water Level
10-year	10-year	Mean High Water

Ground Conditions

Beach Profile: Initial ground surface elevations for a representative "winter" shore-normal beach profile were constructed from a February 24, 2014, beach survey provided by USGS (D. Hoover, Pers. Comm., 2021; Figure A-4), as well as publicly available[4] 2015 USACE topo-bathy LiDAR data and a regional 1978 NOAA offshore survey. The composite profile extended offshore from the seaward property line at the end of Elm Avenue in Carpinteria, CA, to a depth of approximately 80 ft NAVD. For numerical stability, the composite profile was further extended to a depth of roughly 1700 feet before use in XBeach. In addition, the crest height of the 2014 winter dike was reduced to 19 ft NAVD to reflect the typical crest height along Carpinteria Beach. This profile was used as the foundation of beach profile alternatives.

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[4] See https://coast.noaa.gov/dataviewer/#/lidar/search/-13303845.663777854,4072999.602632562,-13296173.297063729,4079582.741693623

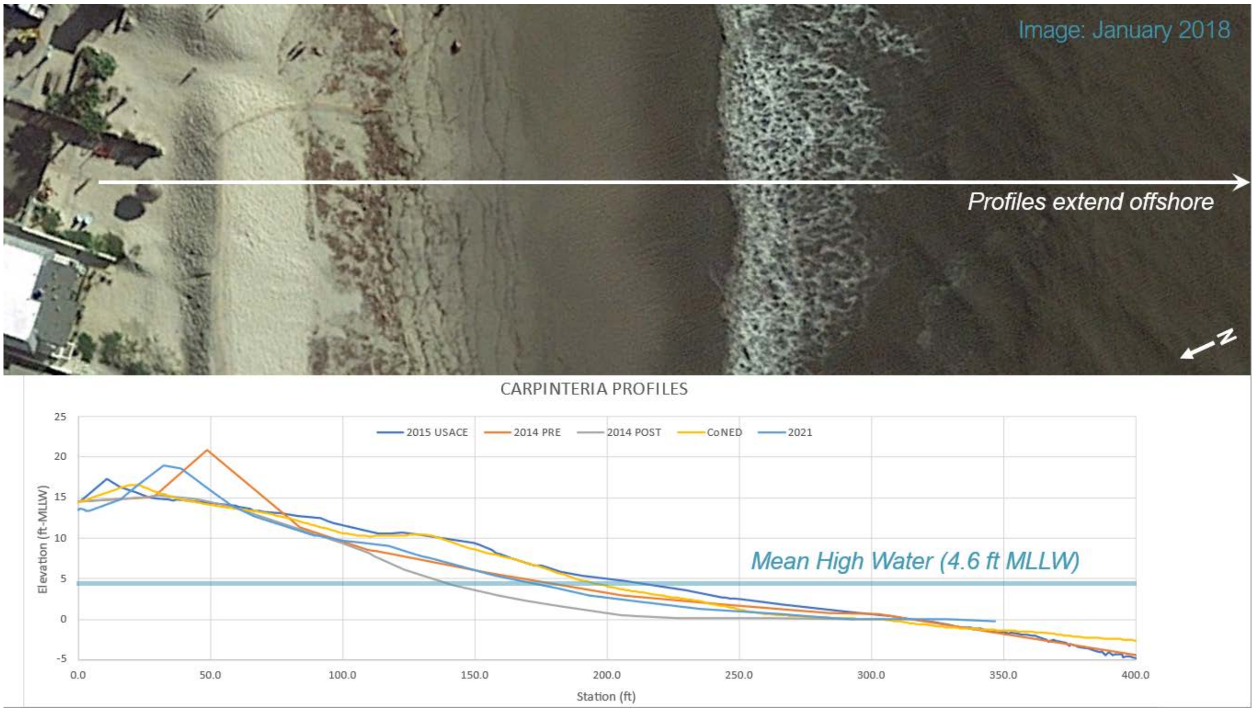

Figure A-4: Beach profiles of Carpinteria Beach, CA; the profile used for modeling is shown as "2014 Pre" to emphasize that the profile occurred prior to the large storms in February-March 2014. Profiles are based on USGS data unless otherwise indicated.

Grain Size: Grain sizes for the winter dike shore profile were based on a composite sample for Ash Avenue collected in 2015 to support BEACON (Table A-5). The model of the winter dike used grain sizes associated with 90% passing (0.377 mm), 50% passing (0.215 mm), and 15% passing (0.135 mm). Grain sizes for the beach profile alternatives were assumed to be slightly larger than native sand. Models of beach profile alternatives used grain sizes of 0.50 mm (90% passing), 0.35 mm (50% passing), and 0.22 mm (15% passing).

Table A-6: Percent passing associated with native beach sand collected at Ash Avenue in 2015 to support BEACON.

Sieve size (mm)	Percent Passing
9.5	100.00
4.76	99.68
2.38	99.40
2	99.23
1.19	98.92
0.59	98.27
0.42	94.80
0.3	81.48
0.25	66.60
0.149	18.20
0.074	0.62

Works Cited

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