FINAL REPORT

Los Angeles County
Department of Beaches and Harbors

Seasonal Sand Berm Protection Program

April 2016

NOBLE CONSULTANTS | GEC

Final Report

Los Angeles County

Seasonal Sand Berm Protection Program

Prepared For:

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County of Los Angeles

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1 INTRODUCTION

The Los Angeles County shoreline is a unique urban setting that is one of the most valuable, if not the most valuable, coastal resources in the State. Its regional beaches, many miles of which have been artificially enhanced and stabilized over the 20th Century, provide recreation and enjoyment for millions of visitors annually. In addition, the beaches generate significant revenue, and provide a natural buffer against storm waves and tides that protects the extensive inland development and infrastructure.

Winter coastal storms with high tides, surf, and beach erosion have been the primary concern for the Los Angeles County shoreline. For this reason, the Department of Beaches and Harbors (DBH) has built and maintained 17 winter sand berms for approximately 30 years at Zuma, Venice, Dockweiler, and Hermosa beaches as a preventive measure to help protect public beach facilities from coastal flood damage. The program represents a modest effort to effectively protect the valuable facilities and carry out the Department's mission to maintain the County's beaches and protect the facilities that allow the maximum public use of them. This purpose will undoubtedly become even more important in the years ahead as climate changes, sea level rises, and public demand for beach use continues to grow.

The purpose of this analysis is to review the Department's winter sand berm protection program in more depth to assess its effectiveness and value to protect the public beach facilities, and to recommend improvements in geometry and placement to maximize the storm damage reduction benefit. The scope of services include the following tasks:

1. Meet with DBH staff to review the County's berm construction history, typical construction details, maintenance practice, and anecdotal evidence of past performance.
2. Develop the representative beach profile, stillwater level, and wave characteristics that shall be input to the wave uprush analysis. Typical winter beach profile scenarios, storm wave heights and periods shall be formulated using Coast of California Storm Tidal Waves Study (CCSTWS) data. Probable stillwater level shall be estimated from the combined parameters of astronomical tide, El Niño effects, and wave setup associated with winter storm occurrence.
3. Perform wave uprush analysis at four beach sites to evaluate the required sand dune crest elevation for storm protection.
4. Prepare a memorandum report that summarizes the findings and recommendations of the study; meet with DBH staff to discuss the results of our study.

2 BACKGROUND

2.1 Hermosa, Dockweiler, and Venice Beaches

The County has been constructing berms for winter storm wave protection on Hermosa Beach, Dockweiler Beach, and Venice Beach since approximately the 1970's (CCC, 2006). The beaches, where the berms have been constructed, are developed with public facilities such as parking lots, restrooms, pedestrian beach access ways, lifeguard headquarters, maintenance facilities, and associated utilities and infrastructure. In April 2003, California Coastal Commission (CCC) approved a request for after-the-fact approval of construction of the berms, which had already constructed in the previous Novembers (CDP No 5-02-385). Based on the 2011 permit approval of CCC, the winter sand berms on these beaches measure approximately 15 feet high and vary in length from approximately 235 feet to 1,343 feet. The locations of the winter berms that have been historically constructed on these three beaches are shown in Figure 1 through Figure 3.

2.2 Zuma Beach

The County of Los Angeles Department of Beaches and Harbors (LADBH, 2013) proposed to construct ten approximately 15 foot high, 20 foot wide seasonal sand berms. Based on the Coastal Development Permit (LADBH, 2013) application that the County submitted to the California Coastal Commission, six of the proposed sand berms would be 215 feet long, three would be 300 feet long, and one would be 250 feet long The locations of these proposed berms are show in Figure 4.

2.3 Storm Damage Protection

In general, the temporary sand berms are built in November of each year in order to be in place during the winter storm season to provide a measure of storm damage protection for the public beach facilities. Using a fleet of bulldozers, the berms are generally built to crest elevations of approximately 12 to 15 feet above existing beach level. Depending upon the length of the berm, it can take anywhere from several days to one week to build each one. The intent is to provide a natural buffer against direct wave attack and sheet flow runup that would otherwise destroy pavement, seriously damage the advanced sewage treatment facilities at the public restrooms, and compromise buildings and utilities. Depending upon the existing beach width at the time of construction, the berms are setback landward as far as possible to avoid exposure during normal tides. However, because of the limited beach width that is available and the need to provide for emergency vehicle access behind the berms at all times, the sand mounds are offset seaward from each public improvement anywhere from 30 to 100 feet.

3 STUDY SITES

Four winter sand berm sites were included in this analysis, one for each of the four beach sites. The wave uprush analysis was conducted based on the beach profiles and the wave characteristics formulated in the Coast of California Storm and Tidal Waves Study (CCSTWS). CCSTWS for Los Angeles region (NCI, 2010) is a comprehensive effort geared towards the understanding, assessment, evaluation and analysis of the coastal processes along the Los Angeles coastline. Historical beach profiles, which have been collected by the County since the 1930's and augmented with recent comprehensive beach profile surveys, were compiled and analyzed in CCSTWS. Table 1 lists the four beach profile stations that were selected in this analysis to represent the typical beach condition at the four winter sand berm sites, respectively.

The nearshore wave conditions were computed in CCSTWS for 240 stations along the Los Angeles County coastline. The four wave stations that are located at or adjacent to the winter sand berm sites are listed in Table 1. The wave characteristics at these stations were used to represent the wave conditions for the winter berm sites.

Table 1. Representative CCSTWS Beach Profiles and Wave Stations

Site	Beach profile station	Wave station
Hermosa Beach	215+00	74
Dockweiler Beach	44+00	104
Venice Beach	248+00	135
Zuma Beach	90+00	263

4 BEACH PROFILES

The four representative beach profiles, which were surveyed in May 2005, are shown in Figure 5 through Figure 8 for the four winter sand berm sites, respectively. The May 2005 survey is the most comprehensive beach profile survey in recent years. The nearshore beach slope is approximately 40 (horizontal) to 1 (vertical) or flatter for Hermosa, Dockweiler, and Venice beaches, and is approximately 20 to 1 for Zuma Beach. The front (seaward-side) slopes of the natural sand berms are approximately 10:1 or flatter.

A preliminary measurement of the winter sand berms was made for Hermosa and Dockweiler beaches, and are shown in Figure 5 and Figure 6 together with the surveyed beach profiles. The front slopes of these berms were measured to vary between 3:1 to 4:1. This is consistent with the design slope of 4:1. The winter sand berms for Venice and Zuma beaches were assumed to have the design front slope of 4:1, as shown in Figure 7 and Figure 8.

5 OCEANOGRAPHIC CONDITIONS

5.1 Still Water Level

The still water level along the Los Angeles County shoreline is mainly controlled by the astronomical tide, with additional contributions of El Niño effects and storm surges that are associated with winter storm occurrence. Two tidal gauges have been installed by the National Oceanic and Atmospheric Administration (NOAA) that are close to the project sites. One is NOAA gauge Station 9410840 at Santa Monica and the other is Station 9410660 at Los Angeles Outer Harbor. The tidal datums for the 1983-2001 epoch are listed in Table 2.

Table 2. Tidal Datum at Santa Monica and at Los Angeles Outer Harbor

Tidal datum	Elevation (ft, MLLW)	
	Santa Monica (NOAA 9410840)	LA Outer Harbor (NOAA 9410660)
Highest Measured Water Level	8.50 (11/30/1982)	7.82 (01/27/1983)
Mean Higher High Water (MHHW)	5.42	5.49
Mean High Water (MHW)	4.69	4.75
Mean Tide Level (MTL)	2.81	2.85
Mean Sea Level (MSL)	2.79	2.82
National Geodetic Vertical Datum-1929 (NGVD29)	2.63	2.63
Mean Low Water (MLW)	0.93	0.94
North America Vertical Datum-1988 (NAVD88)	0.20	0.20
Mean Lower Low Water (MLLW)	0.00	0.00
Lowest Measured Water Level	-2.84 (12/17/1933)	-2.73 (12/17/1933)

Source: NOAA Tidal Bench Marks

While the water level measurement started in 1995 for the Santa Monica Station, the Los Angeles Station has a much longer period of data record that started from 1923. Therefore, the data collected at Los Angeles Station was used in this analysis. It is noted that the measured water level data includes not only the astronomical tide, but also the contributions of El Niño effects and storm surges during the winter storm events. Therefore, the water level data measured at the Los Angeles Station was used to represent the still water level condition for the four berm sites. The hourly water level data between 1970 and 2005, which is consistent with the time span of the CCSTWS wave data, was used in this analysis.

5.2 Waves

Wind waves and swells along the Los Angeles County shoreline are produced primarily by six basic meteorological patterns: extratropical storm swells in the northern hemisphere (north or northwest swell); wind swells generated by northwest winds in the outer coastal waters (wind swell); westerly (west sea) and southeasterly (southeast sea) local seas; storm swells of tropical storms or hurricanes off the Mexican coast; and southerly swells originating in the southern hemisphere (southerly swell).

The nearshore wave conditions along the Los Angeles shoreline were computed in CCSTWS study (NCI, 2010) using O'Reilly's spectral back-refraction model. This model transforms the deepwater wave conditions, which were hindcasted with the Global Reanalysis of Ocean Waves (GROW) model, to the nearshore region. The wave transformation processes in the model included island sheltering, wave shoaling and wave refraction. The nearshore wave conditions were computed for every three hours (8 times per day) between 1970 through 2005 for 240 stations with water depths of approximately 10 meters.

The four wave stations that were used for the four beach sites are listed in Table 1. As examples, Figure 9 through Figure 12 show the wave periods, nearshore significant wave heights and the corresponding deepwater wave heights during the 1982-83 winter season for the four sites, respectively.

6 WAVE RUNUP ANALYSIS

6.1 CEM Runup Method

Because of the random nature of ocean waves, the wave conditions and resulting wave runups vary during a wave event. The wave runup used in this analysis is the 10% wave runup that is defined as the average of the highest 10% of the runups during a wave event. The 10% wave runup, $R_{10\%}$, was computed in this analysis using the following equation recommended in Coastal Engineering Manual (USACE, 2003), or CEM:

$$\frac{R_{10\%}}{H_0} = 1.70\xi_0^{\ 0.71}$$

where H_0 is the significant deepwater wave height, and ξ_0 is the Iribarren number, or the surf similarity parameter that is defined as

$$\xi_0 = \tan\beta\left(\frac{H_0}{L_0}\right)^{-1/2}$$

in which $\tan\beta$ is the averaged beach slope from the wave breaking point to the wave runup limit, and L_0 is the deepwater wave length. The deepwater wave length L_0 is

$$L_0 = gT^2 / 2\pi$$

where g is the gravitational acceleration and T is the peak wave period.

6.2 Computed Wave Runups

The 10% wave runup was computed for every three hours with the CEM method, using the 3-hourly wave condition (deepwater wave heights and wave lengths) with the corresponding maximum (hourly) still water levels within each of the 3-hour intervals. It is noted that the average beach slope $\tan\beta$ used for wave runup calculation depends on the location of the wave runup limit on the beach or berm, which is a function of the wave runup itself. Thus, an iteration procedure was applied in the wave runup computation until the solution converges.

The 3-hourly wave runups and wave runup elevations were computed for 36 years from 1970 to 2005, the same period as the CCSTWS wave data coverage. The wave runup elevation is the sum of the computed wave runup value plus the still water level. Both the with winter sand berm (with-berm) condition and the without winter sand berm (without-berm) condition were included in the analysis. As examples, Figure 13 through Figure 16 show the still water levels, computed 10% wave runups, and the corresponding wave runup elevations during the 1982-83 winter season for the four beach with winter sand berms, respectively.

The monthly and annual maximum wave runup elevations were determined based on the 3-hourly results. Figure 17 through Figure 20 show the monthly maximum wave runup elevations for the four sites, respectively. Figure 21 through Figure 24 show the annual maximum runup elevations. It is noted that the wave runup elevations for the with-berm scenario are generally higher than those for without-berm scenario. This is because the side slope of the winter sand berm (approximately 4H:1V) is steeper than the natural berm and front beach. A steeper slope results in higher wave runup on the slope.

The annual maximum wave runup elevations on the winter sand berm between 1970 and 2005 vary between 16 to 27 feet MLLW for Hermosa Beach, 15 to 25 feet MLLW for Dockweiler

Beach, 12 to 22 feet MLLW for Venice Beach, and 12 to 23 feet MLLW for Zuma Beach. The highest wave runup elevation occurred in March 1983 when extremely high waves with long wave periods coincided with high tides.

6.3 Return Frequency Analysis for Wave Runup Elevations

A statistical analysis was conducted based on the 36-year annual maximum wave runup elevations to determine the runup elevations for different recurrent frequencies. Figure 25 through Figure 28 show the return frequency (annual chance) curve for runup elevations for the four beach sites, respectively, for the without-berm scenario. Figure 29 through Figure 32 show the results for the with-berm scenario. Both the data and the Weibull curve that best fits the data are shown in these figures. The runup elevations for various return periods are summarized in Table 3 for the without-berm condition, and in Table 4 for the with-berm condition. The return period, also known as a recurrence interval (year), is an estimate of how often a particular event might occur. The probability is often expressed in number of years. It is noted that the wave runup at Zuma Beach and Venice Beach is lower than the other two beaches. This is because the nearshore waves at Zuma Beach and Venice Beach are lower than the other two beaches, as shown in Figure 9 through Figure 12.

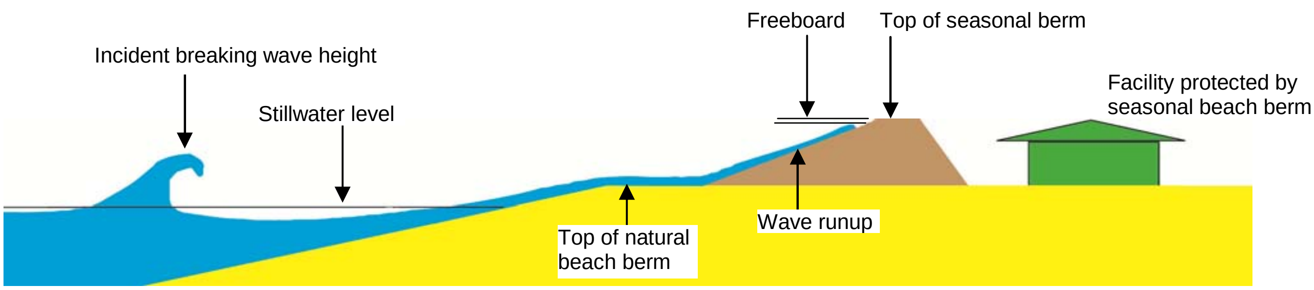
Table 3. Wave Runup Elevations on the Natural Beach for Various Return Frequencies (Without Seasonal Berms)

Return period (Year)	10% Wave runup elevation (ft, MLLW)			
	Hermosa	Dockweiler	Venice	Zuma
1	14.5	13.9	11.9	12.3
2	17.1	17.0	13.2	13.4
5	19.2	18.7	14.9	14.7
10	20.6	19.6	16.1	15.8
25	22.2	20.7	17.8	17.1
50	23.4	21.4	19.0	18.2
100	24.5	22.0	20.3	19.2

Table 4. Wave Runup Elevations for Various Return Frequencies (With Seasonal Berms)

Return period (Year)	10% Wave runup elevation (ft, MLLW)			
	Hermosa	Dockweiler	Venice	Zuma
1	15.5	13.7	12.0	12.1
2	18.7	18.4	13.6	13.8
5	21.4	20.8	15.7	15.9
10	23.2	22.2	17.3	17.6
25	25.3	23.7	19.4	19.8
50	26.8	24.8	21.0	21.4
100	28.1	25.7	22.6	23.1

The coastal flood protection levels in terms of the return frequencies of coastal flood events are summarized in Table 5 for various seasonal sand berm heights. The height of the seasonal berm is defined as the height between crest of the winter seasonal beach berm and the seaward edge of the natural beach berm. The elevations for the seaward edge of the natural beach berms, which were determined based on the 2005 surveyed beach profiles, are also listed in Table 5. A definition sketch of the geometry is illustrated below.



The minimum seasonal berm height required to provide a 50-year coastal flood protection is 13.6 feet for Hermosa Beach, 13.2 feet for Dockweiler Beach, 9.9 feet for Venice Beach, and 10.3 feet for Zuma Beach.

Table 5. Coastal Flood Protection Levels for Various Seasonal Berm Heights

Return period (Year)	Seasonal berm height (above seaward edge of natural beach berm)			
	Hermosa	Dockweiler	Venice	Zuma
1	2.3	2.1	0.9	1.0
2	5.5	6.8	2.5	2.7
5	8.2	9.2	4.6	4.8
10	10.0	10.6	6.2	6.5
25	12.1	12.1	8.3	8.7
50	13.6	13.2	9.9	10.3
100	14.9	14.1	11.5	12.0

Note: elevations for the seaward edge of the natural beach berms are approximately:
13 ft, MLLW -- Hermosa Beach; 12 ft, MLLW -- Dockweiler Beach
11 ft, MLLW -- Venice Beach; 11 ft, MLLW -- Zuma Beach

It is noted that the wave runup used in this analysis is the 10% wave runup that is defined as the average of the highest 10% of the runups during a wave event. Therefore, wave runup higher than the computed 10% runup may occur a few times during a particularly wave event.

7 RECOMMENDATION OF WINTER SAND BERM

We believe that the County's seasonal berm program is a relatively low cost and simple strategy that can be employed to provide effective storm damage protection against the majority of coastal storm scenarios that can be expected to threaten the public beach infrastructure annually. Wave runup analysis indicates that the temporary sand mounds can buffer the beach facilities from storm events that have return periods of 25 to 50 years. The exact level of protection that any of the seasonal berms can provide is a function of its proximity to the water's edge, the duration of the storm, and the extent of beach erosion that may undermine the berm. The County regularly maintains each seasonal berm throughout the winter season to repair sloughed sections. However, the seasonal berms will likely be unable to provide protection for very severe storms events similar to the 1983 sequence that was characterized by prolong periods of high tides, wave attack, and severe beach erosion. As the storm severity increases, the ability of the sand berm to fully protect a particular site will depend upon the County's ability to restore and maintain the full section.

To address severe storm survivability, we recommend that a minimum freeboard of 2 feet be added to the computed wave runup elevations and the corresponding berm heights to take into account the uncertainty of the wave runup analysis and the potential storm-induced erosion of the sand berm that is not included in this analysis. The freeboard is defined as the vertical distance between the crest of the winter sand berm and the computed wave runup elevation as shown in the definition sketch on Page 8. Storm waves may erode away part of the sand berm and thus may lower the crest of sand berm during extreme storm events. For that reason, we recommend that each berm be constructed as high as possible and as far landward as existing conditions allow during time of construction. At a minimum, the following crest elevations and berm heights are recommended for the winter sand berms that correspond to a 50-year wave runup risk level:

– Hermosa Beach: minimum crest elevation = 29 feet MLLW, or berm height = 16 feet
– Dockweiler Beach: minimum crest elevation = 27 feet, or berm height = 16 feet
– Venice Beach: minimum crest elevation = 23 feet MLLW, or berm height = 12 feet
– Zuma Beach: minimum crest elevation = 24 feet MLLW, or berm height = 13 feet

If a higher wave runup risk is selected e.g. 25-year, the seasonal berms may be built to lower crest elevations per the Table 5 criteria plus the recommended two-foot freeboard allowance.

The recommended seasonal berm length is a function of the length of the landward facilities and infrastructure that is to be protected. We recommend that at a minimum, individual berm lengths should be extended at least fifty feet upcoast and downcoast beyond the corresponding end of each improvement to be protected. The total berm length should then be rounded up to a total distance that is a multiple of fifty-foot increments. In this manner each berm length may be computed as follows:

		50-foot minimum upcoast extension
	+	Length of facility to be protected
	+	50-foot minimum downcoast extension
Total berm length	=	(round up to nearest 50-foot increment)

We also recommend that the winter sand berms be constructed as shoreward as possible. This will not only reduce the averaged slope for wave runup and thus lower the wave runup elevation on the berms, but also alleviate the storm-induced erosion of the sand berms during extreme storm events.

8 REFERENCES

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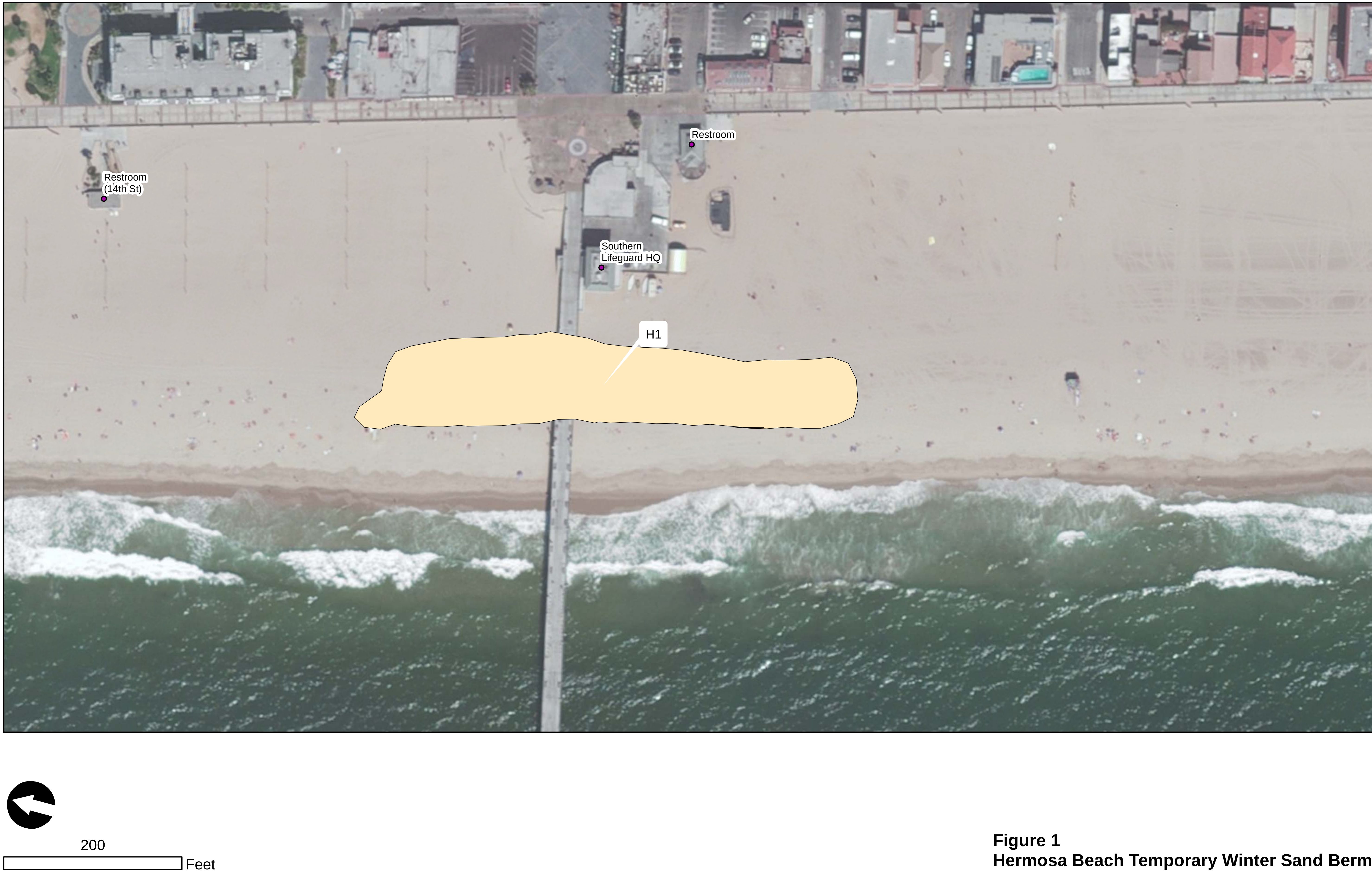

Figure 1
Hermosa Beach Temporary Winter Sand Berms

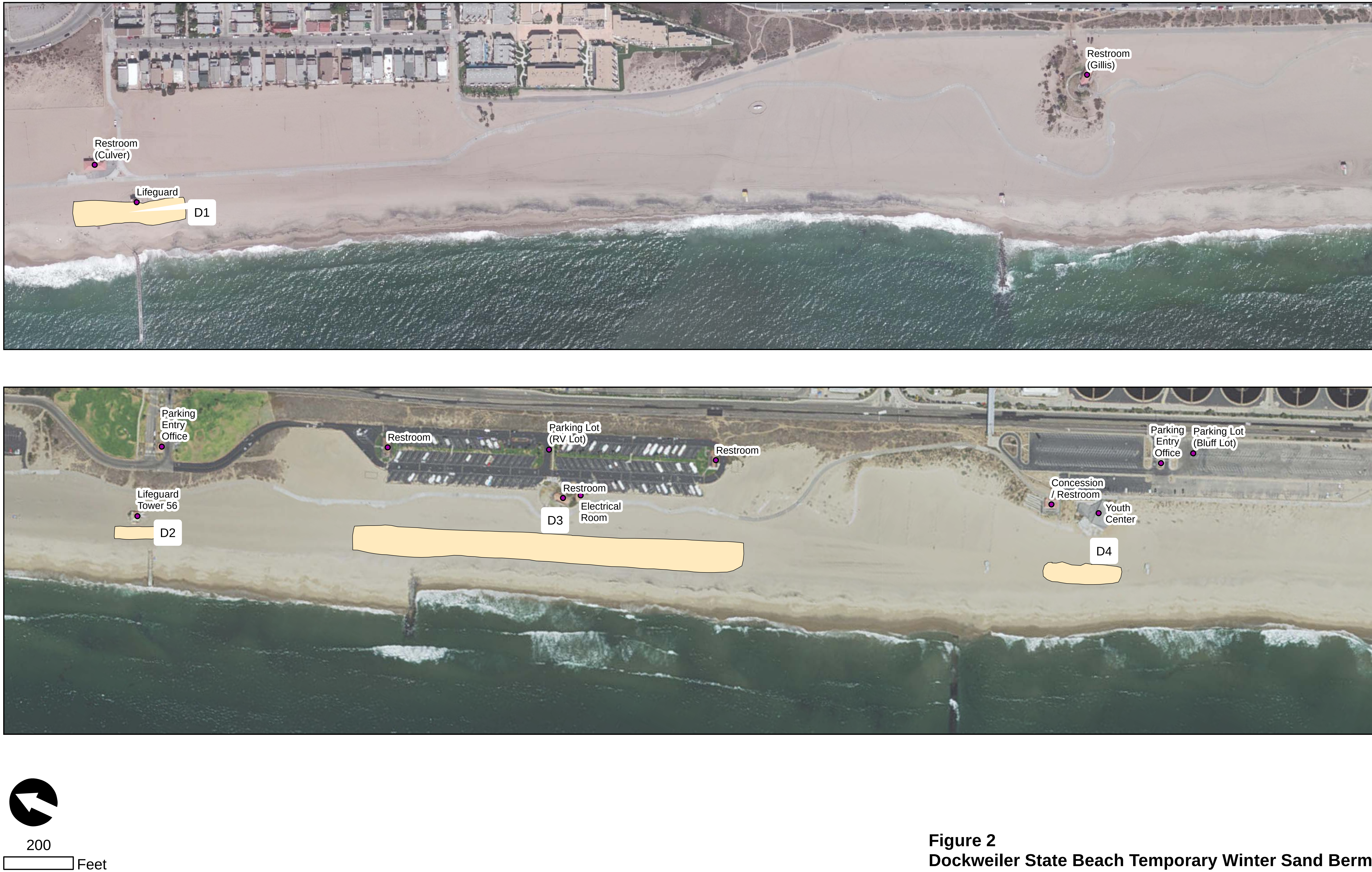

Figure 2
Dockweiler State Beach Temporary Winter Sand Berms

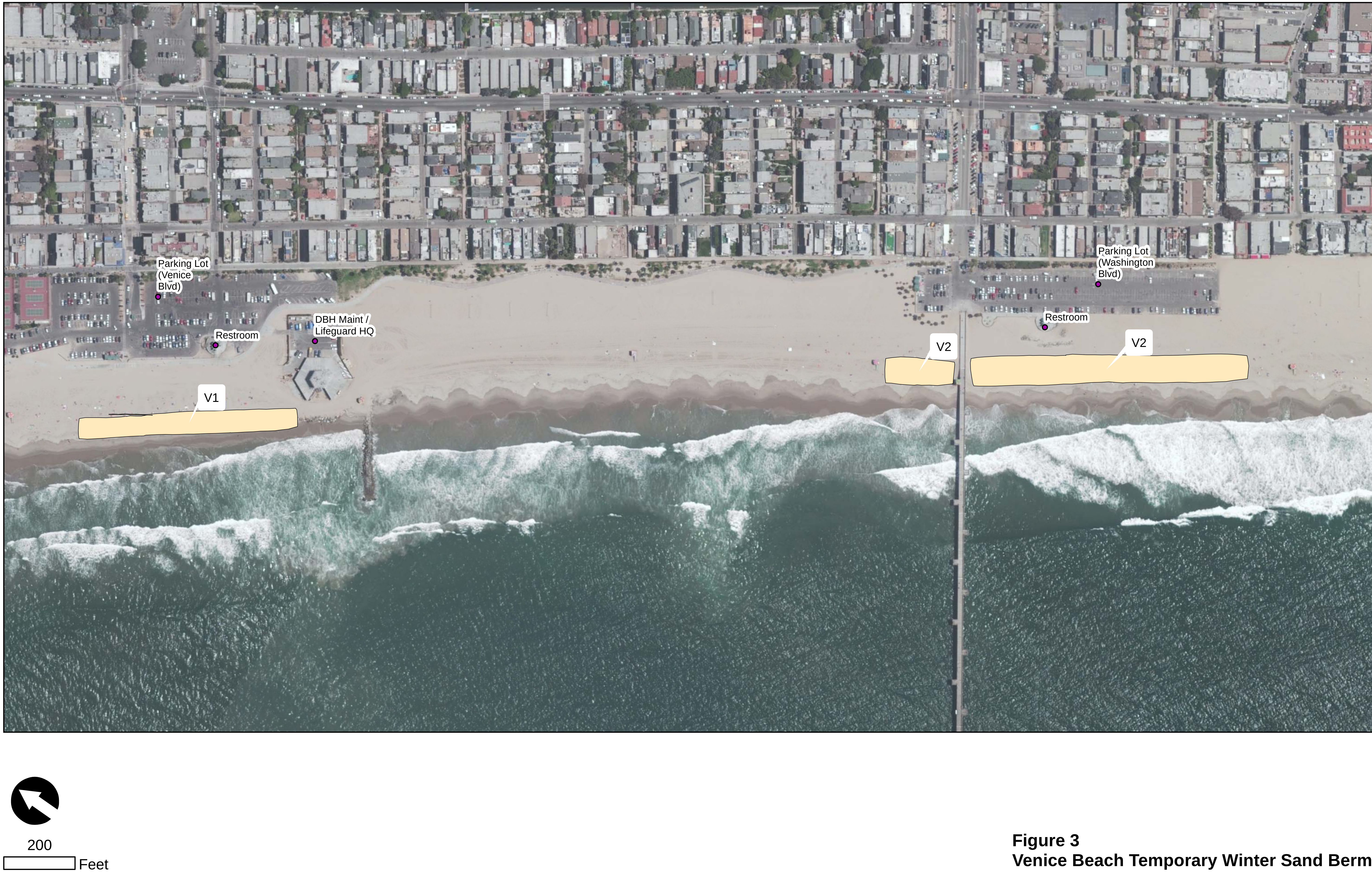

Figure 3
Venice Beach Temporary Winter Sand Berms

200

Figure 4
Zuma County Beach Temporary Winter Sand Berms

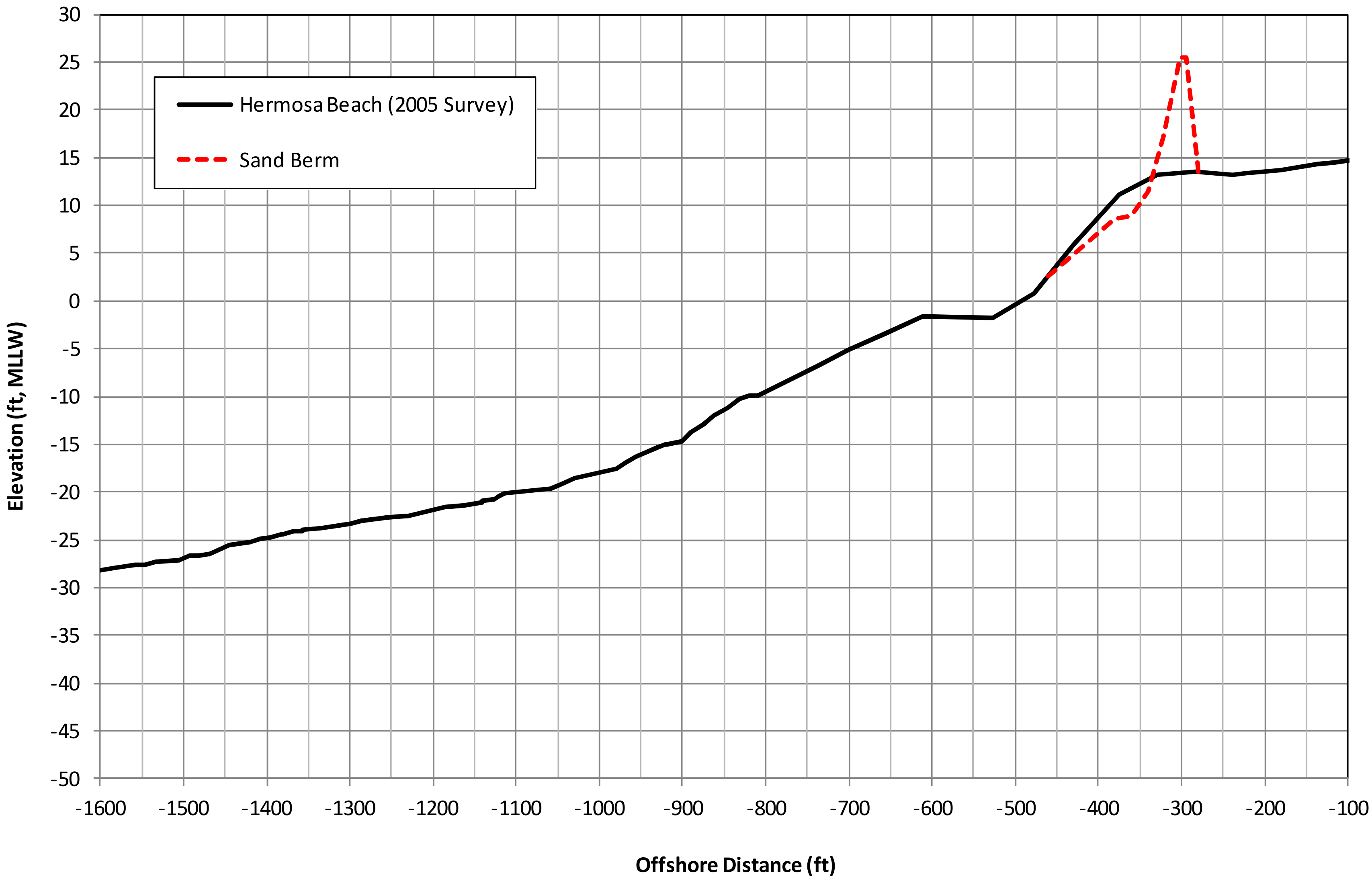

Figure 5. Representative Beach Profile for Hermosa Beach

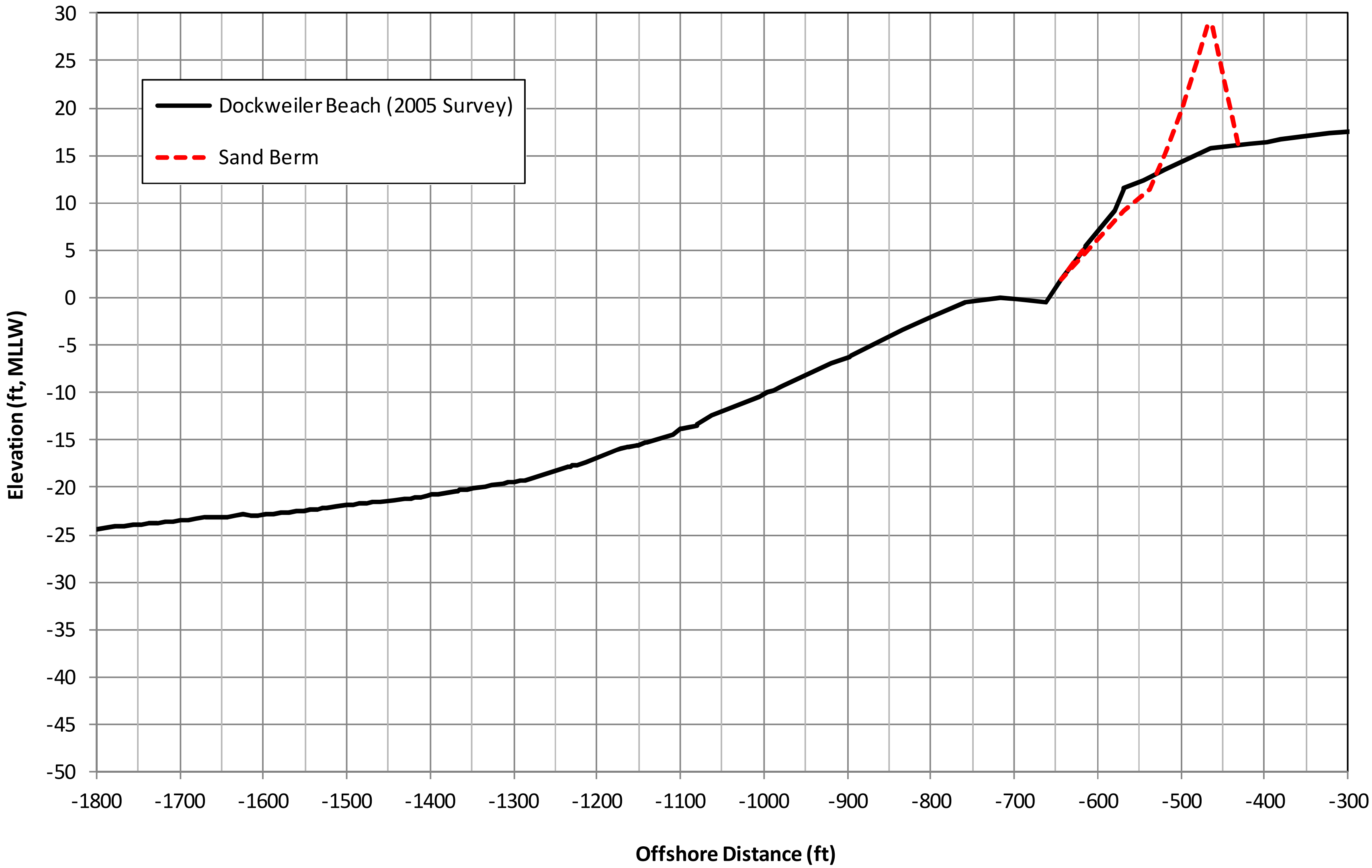

Figure 6. Representative Beach Profile for Dockweiler Beach

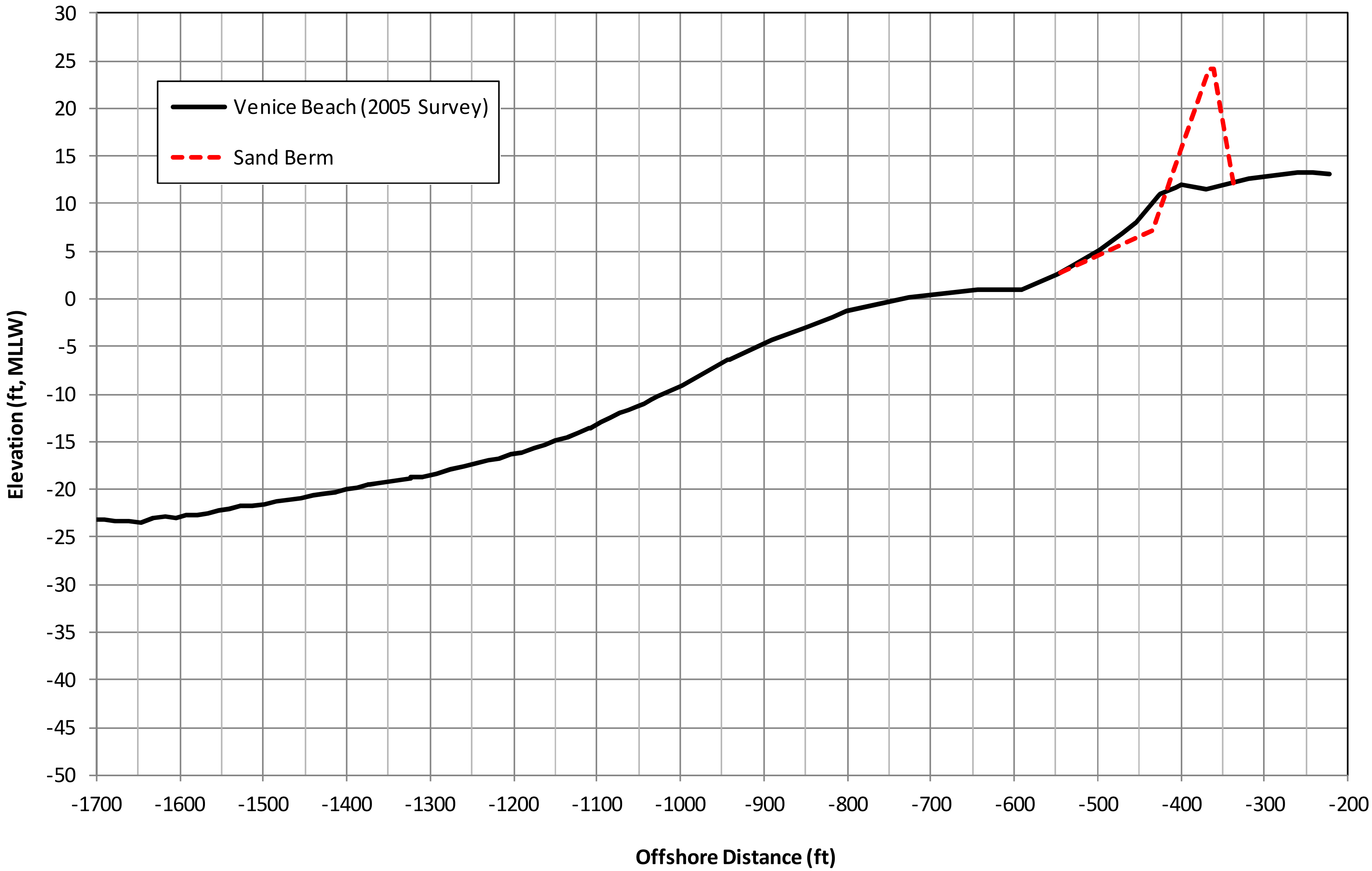

Figure 7. Representative Beach Profile for Venice Beach

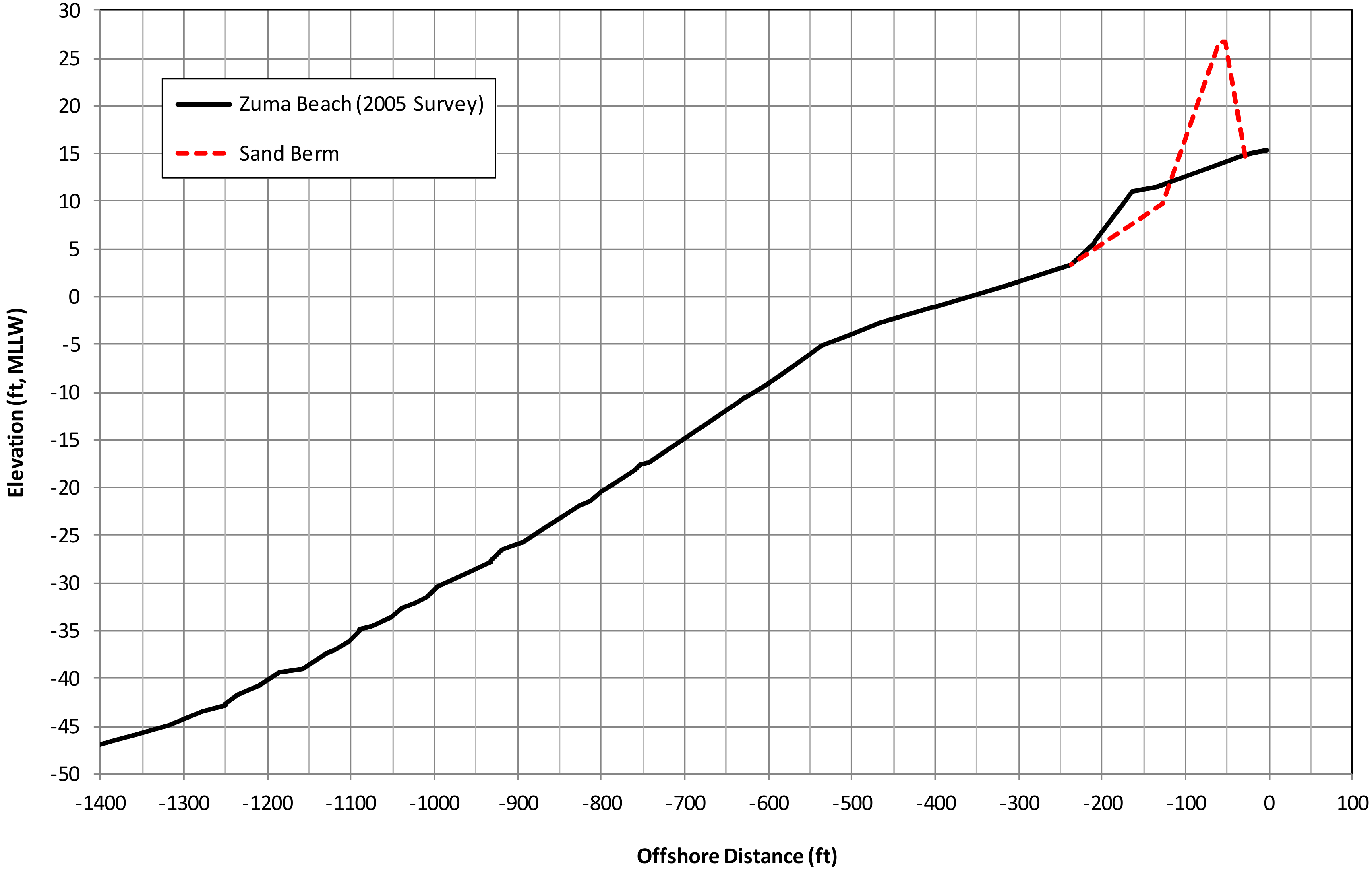

Figure 8. Representative Beach Profile for Zuma Beach

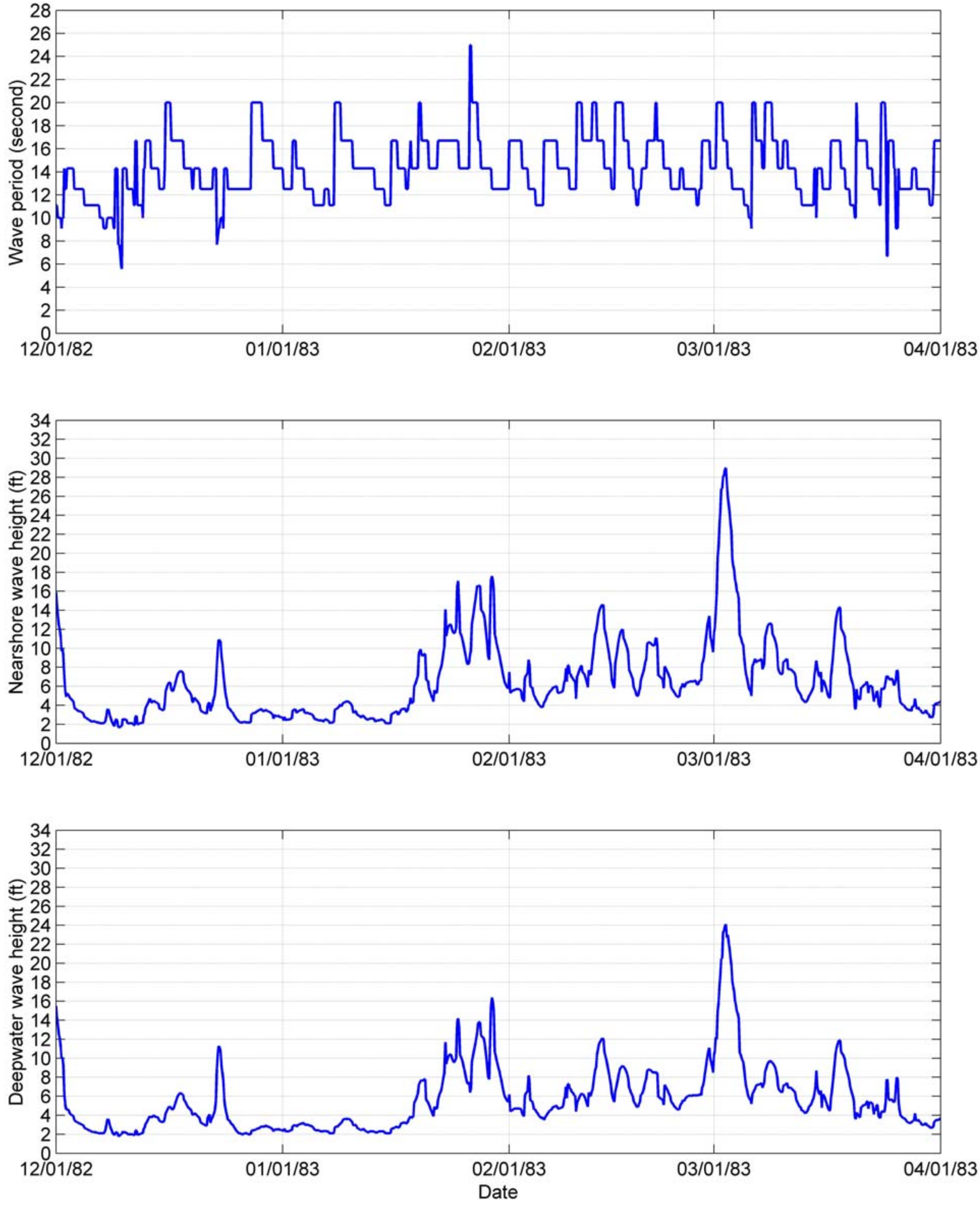

Figure 9. Time Series of Wave Periods and Significant Wave Heights at Hermosa Beach (1982-83 Winter Season)

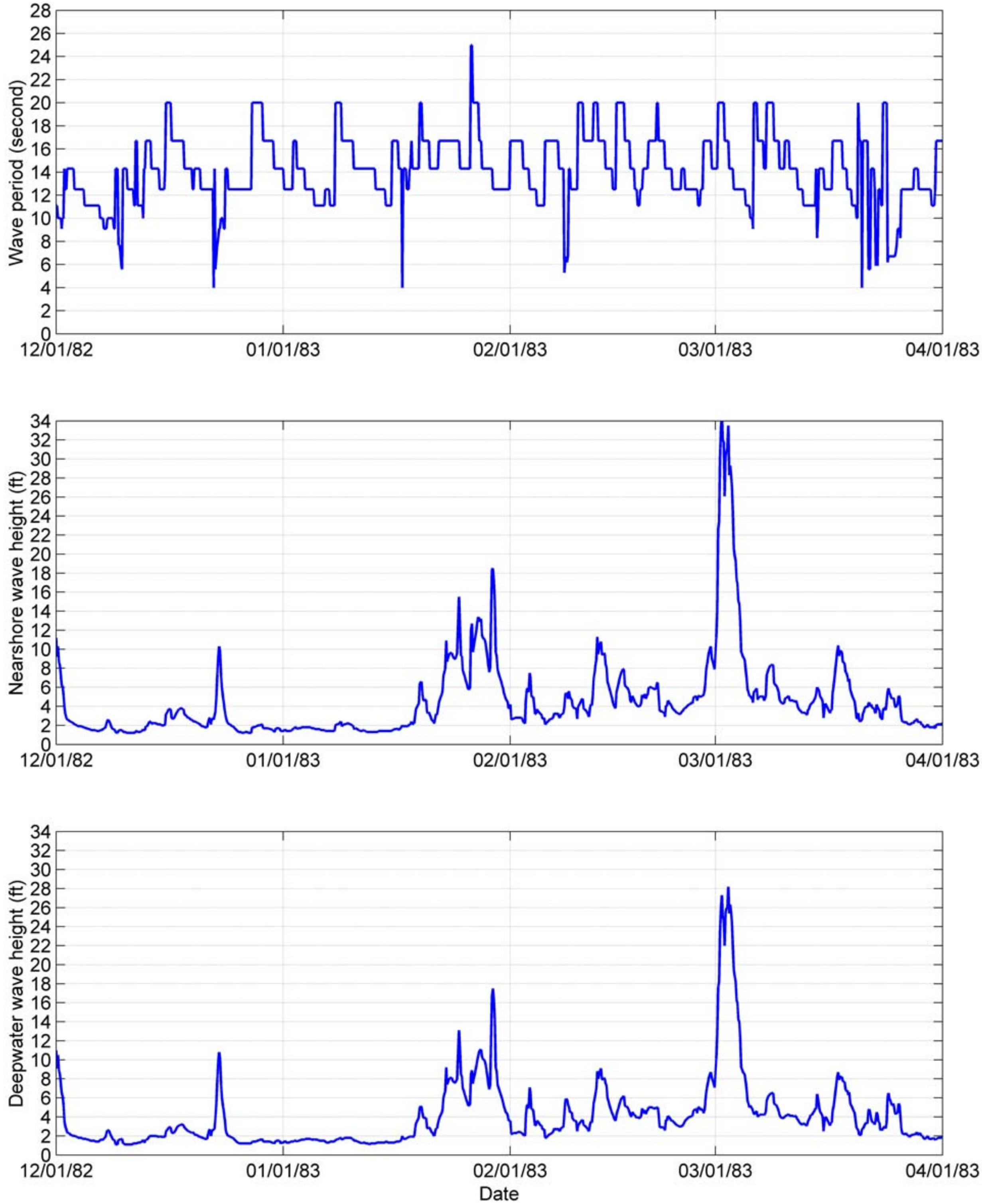

Figure 10. Time Series of Wave Periods and Significant Wave Heights at Dockweiler Beach (1982-83 Winter Season)

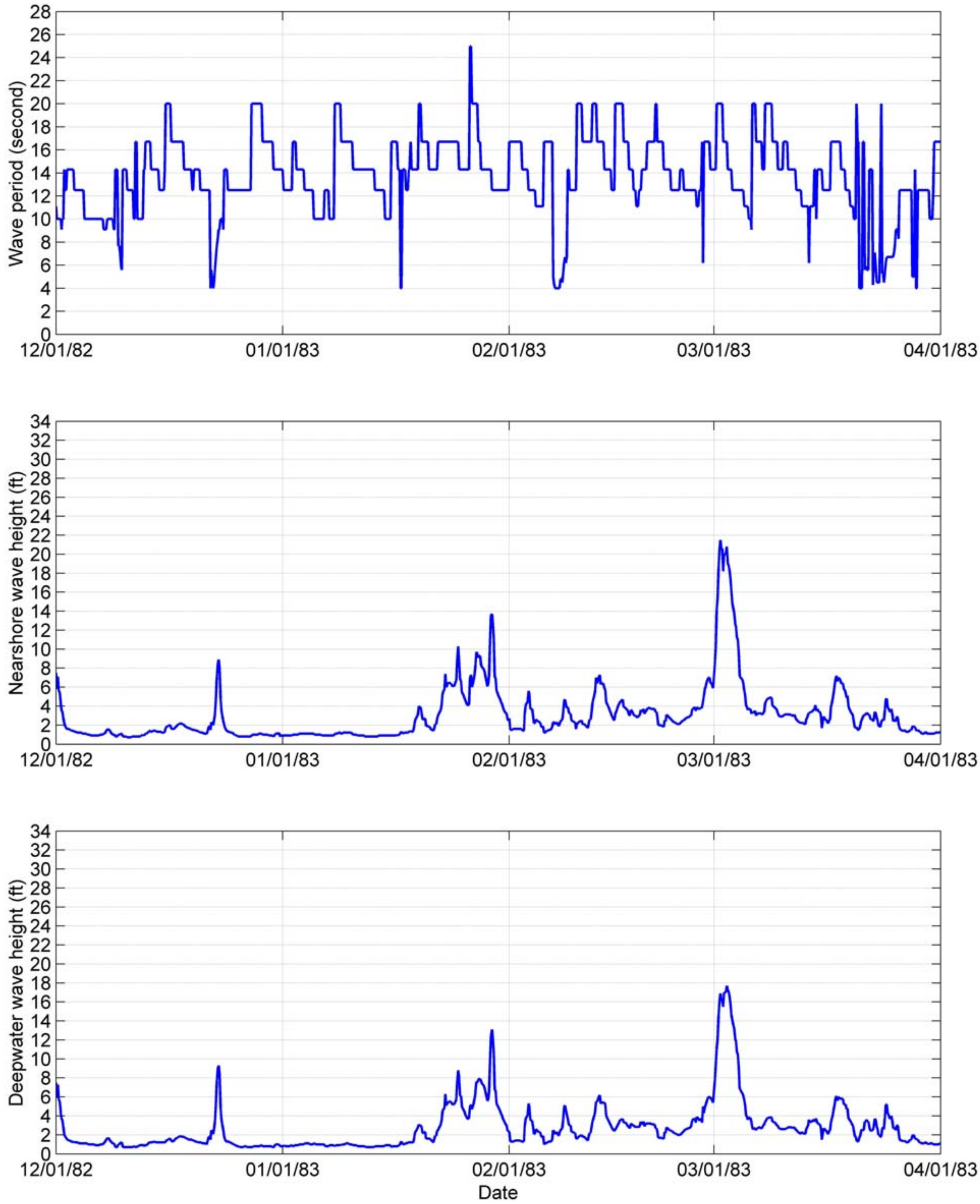

Figure 11. Time Series of Wave Periods and Significant Wave Heights at Venice Beach (1982-83 Winter Season)

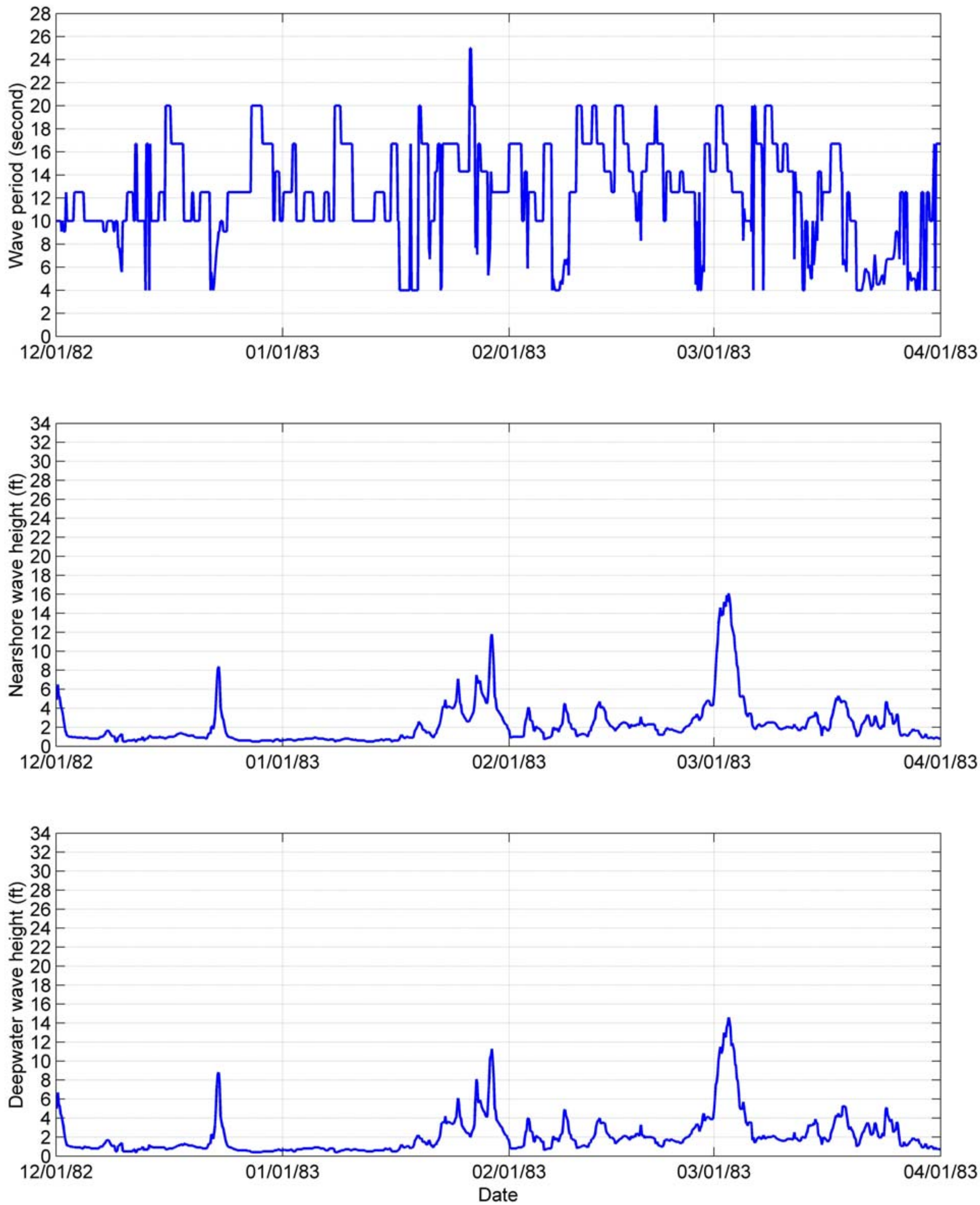

Figure 12. Time Series of Wave Periods and Significant Wave Heights at Zuma Beach (1982-83 Winter Season)

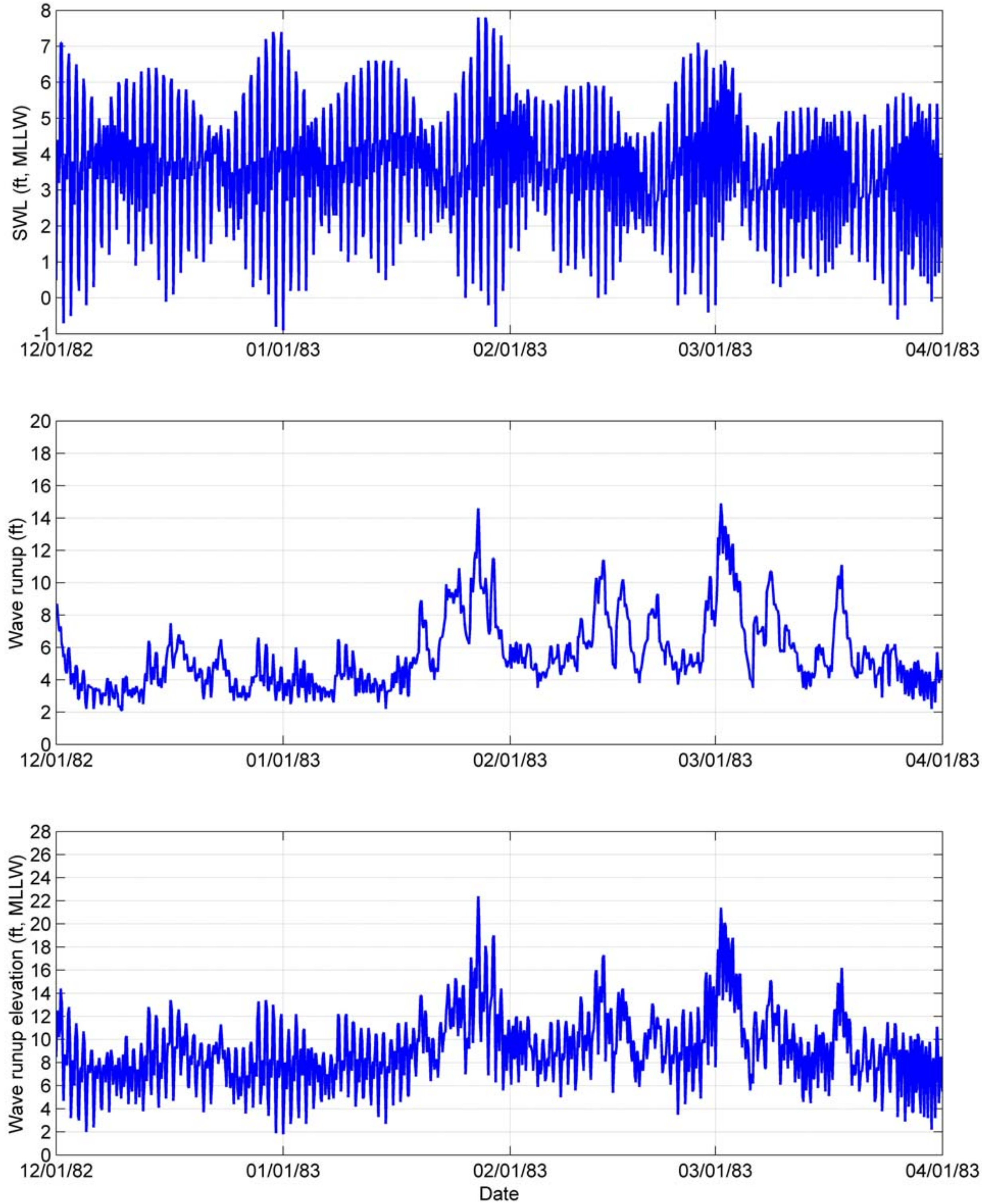

Figure 13. Time Series of Still Water Levels and 10% Wave Runups at Hermosa Beach (With-Berm, 1982-83 Winter Season)

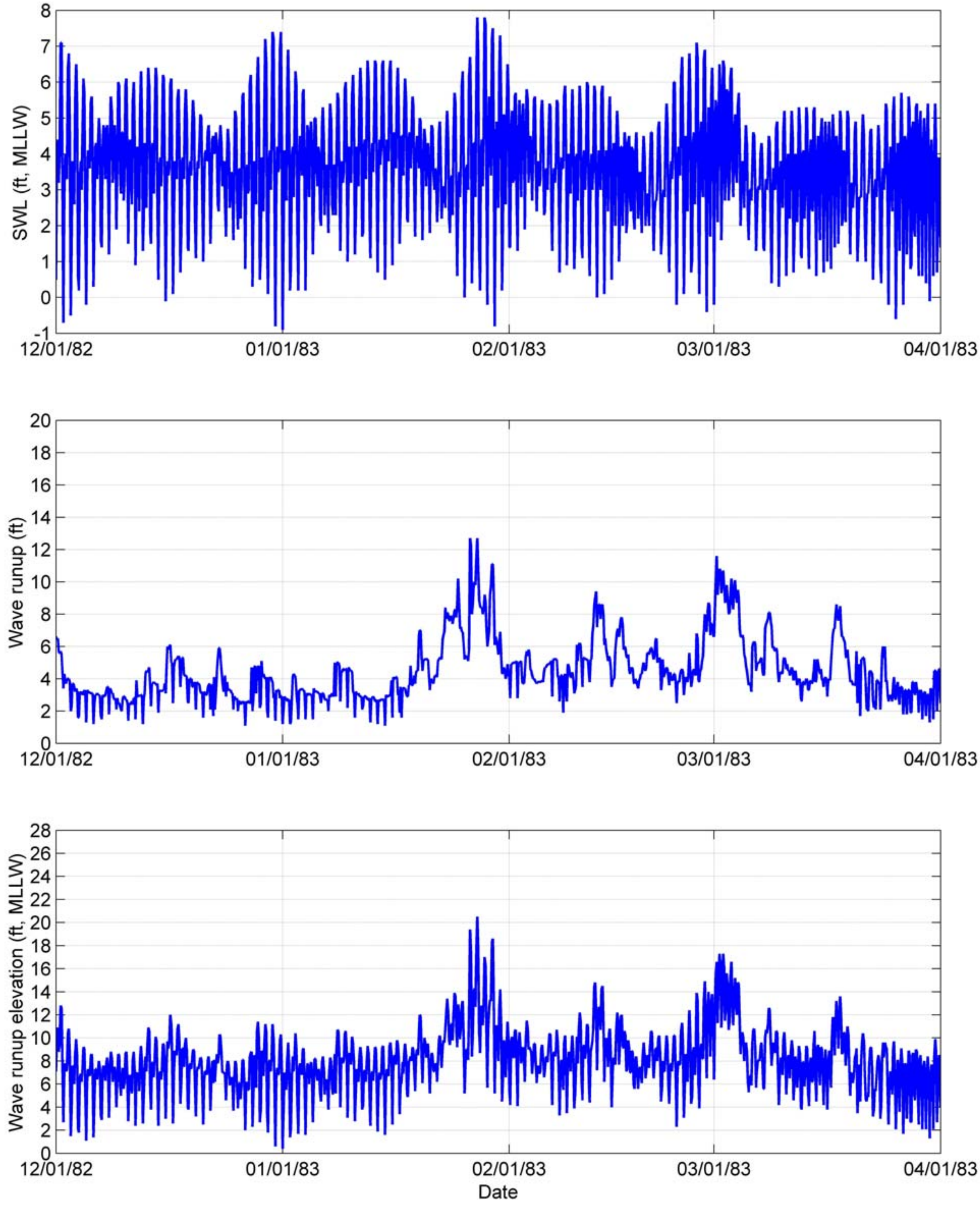

Figure 14. Time Series of Still Water Levels and 10% Wave Runups at Dockweiler Beach (With-Berm, 1982-83 Winter Season)

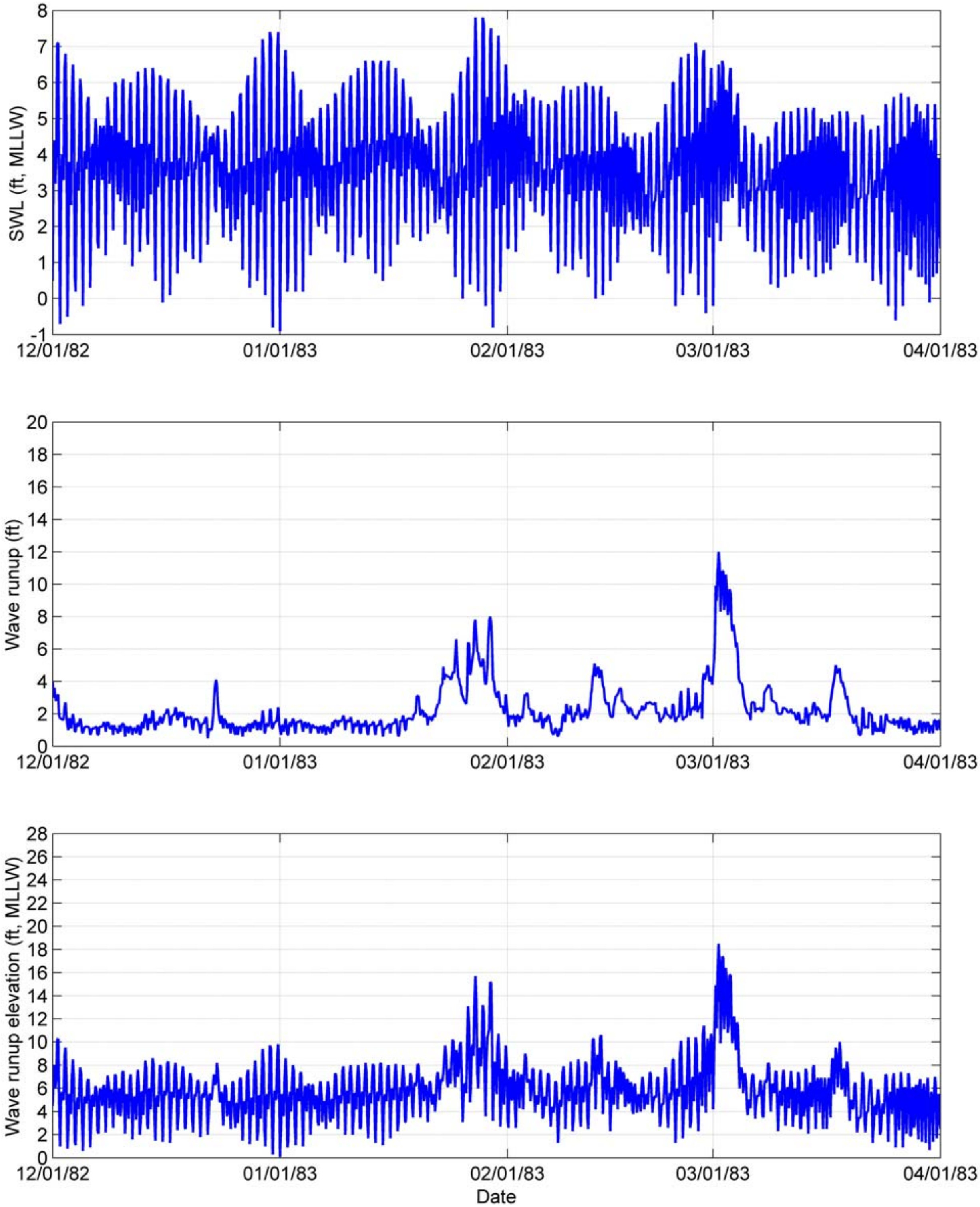

Figure 15. Time Series of Still Water Levels and 10% Wave Runups at Venice Beach (With-Berm, 1982-83 Winter Season)

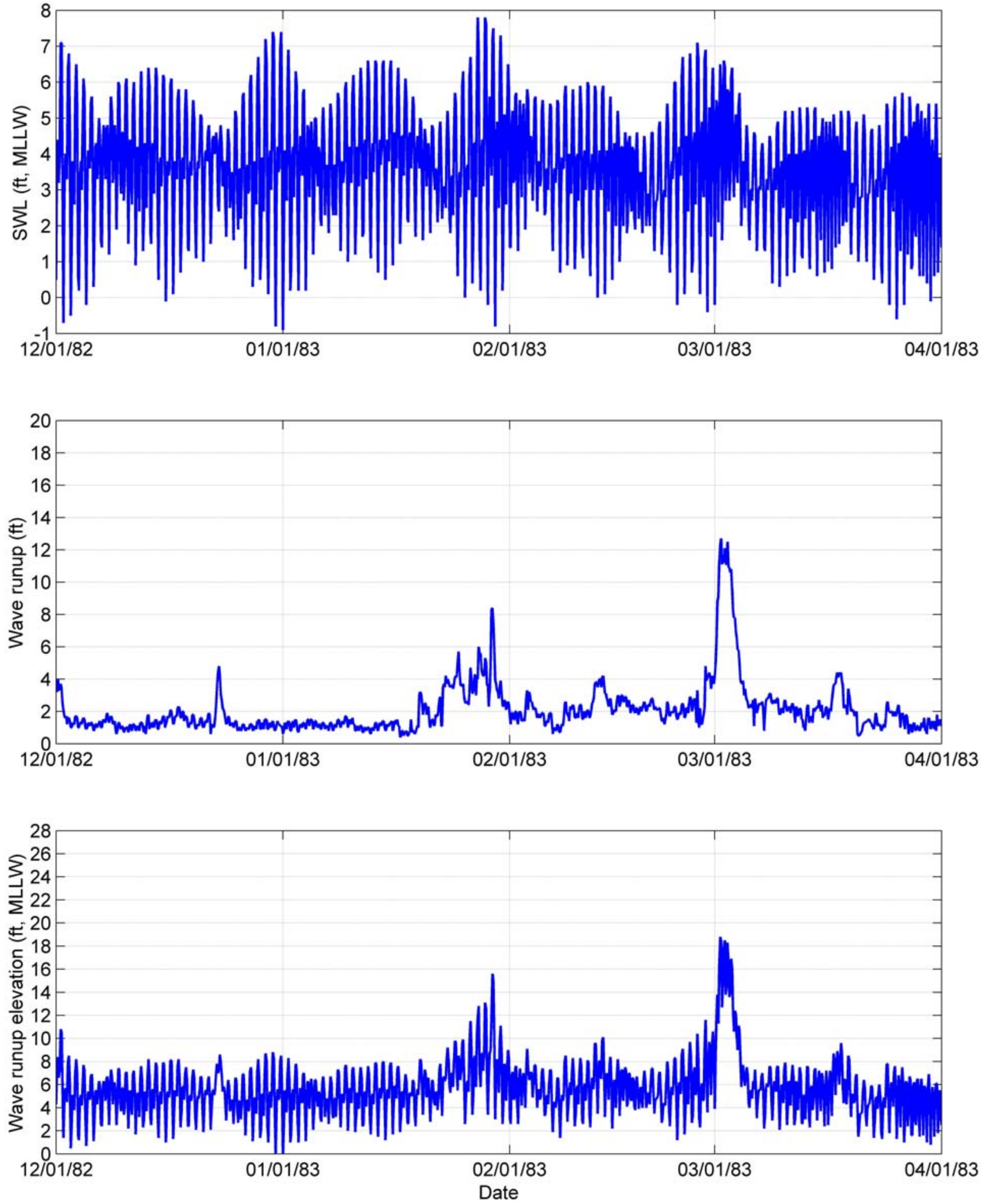

Figure 16. Time Series of Still Water Levels and 10% Wave Runups at Zuma Beach (With-Berm, 1982-83 Winter Season)

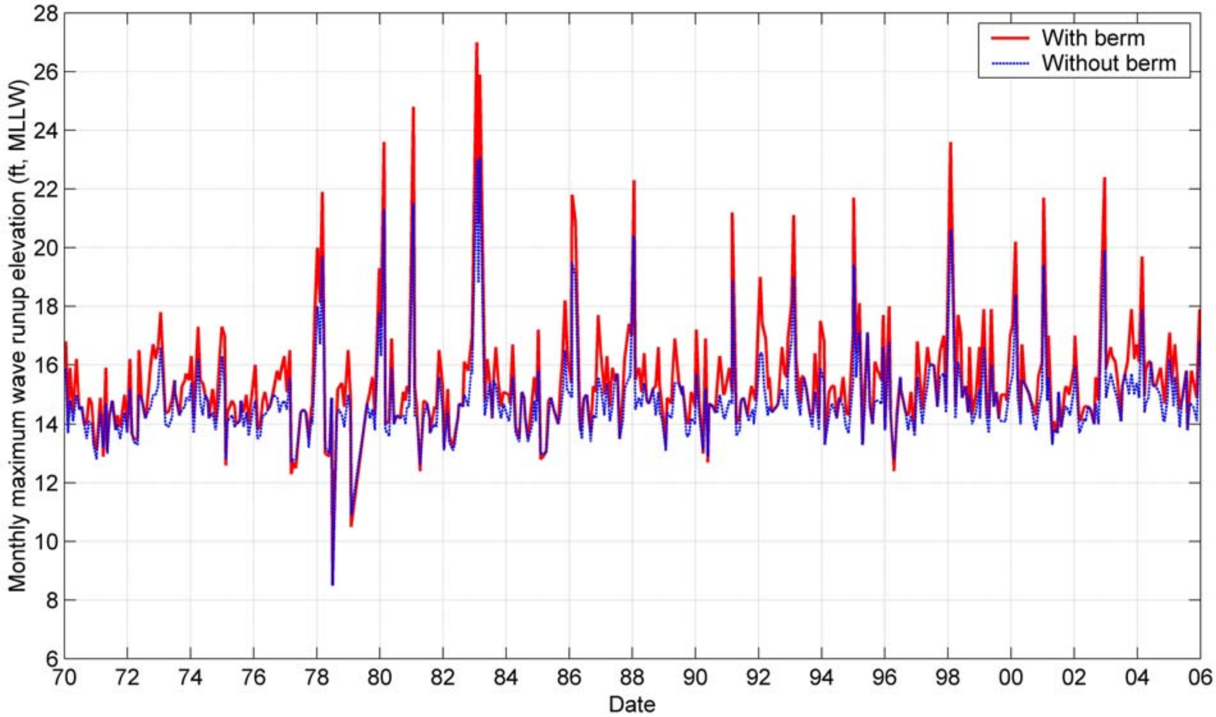

Figure 17. Monthly Maximum 10% Wave Runup Elevations at Hermosa Beach

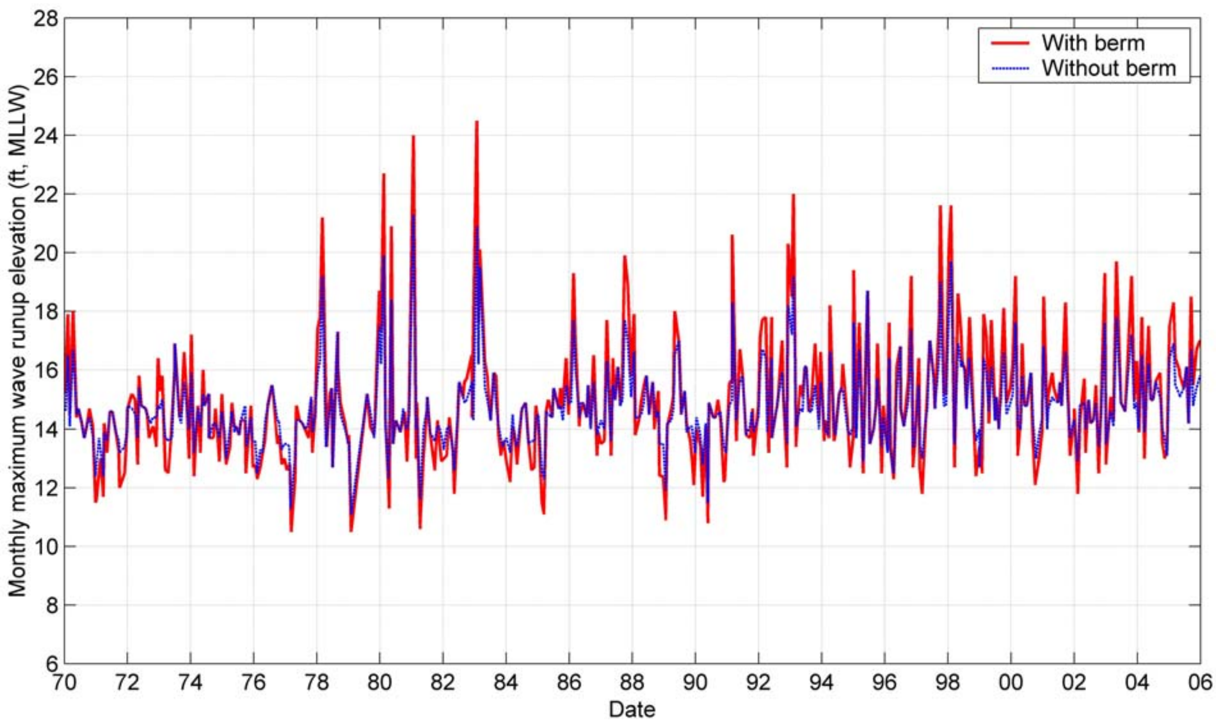

Figure 18. Monthly Maximum 10% Wave Runup Elevations at Dockweiler Beach

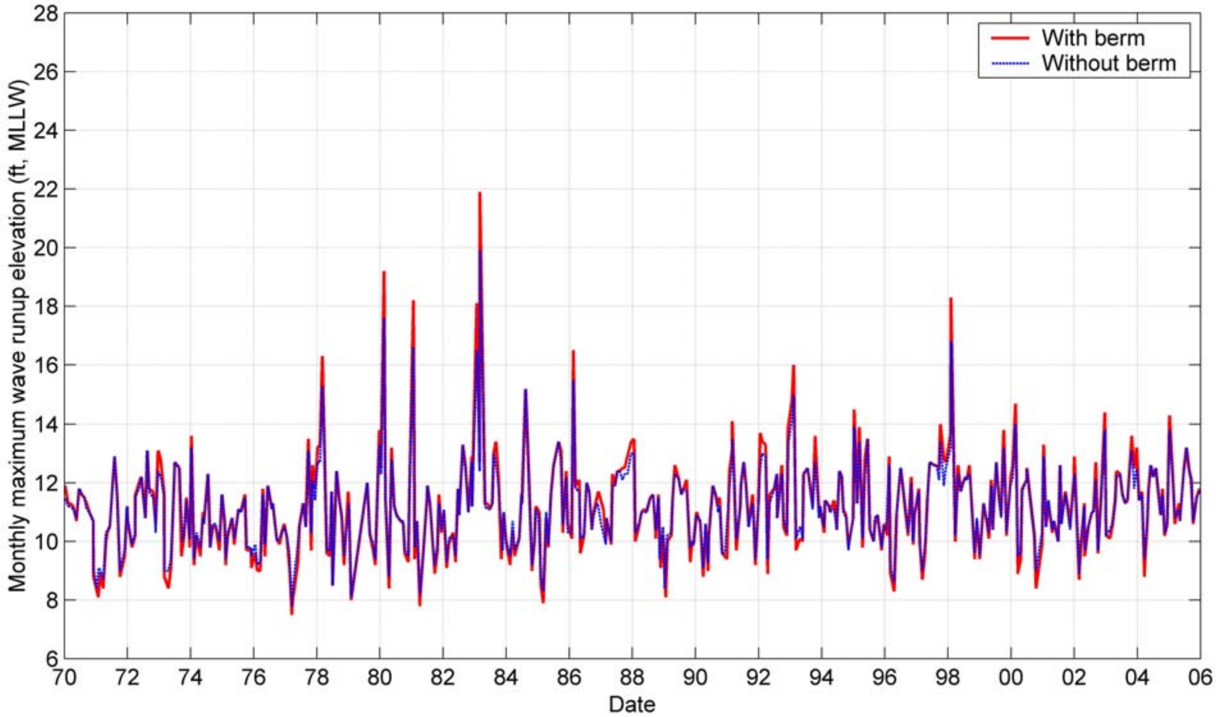

Figure 19. Monthly Maximum 10% Wave Runup Elevations at Venice Beach

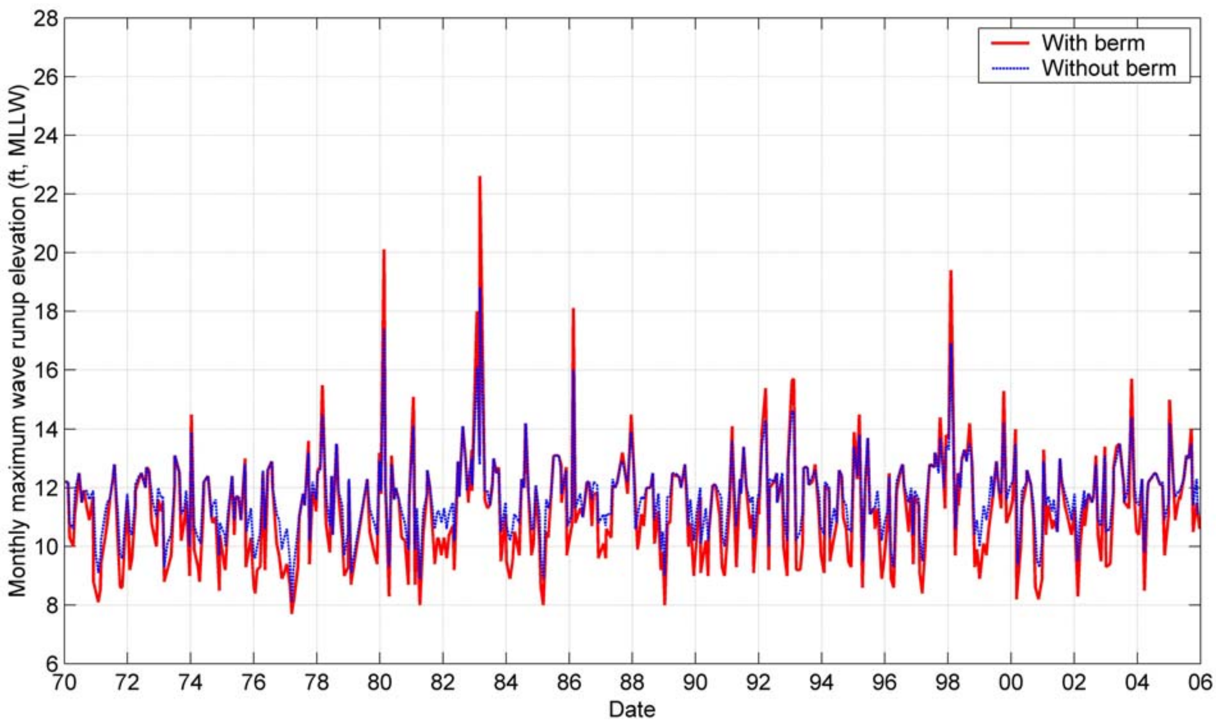

Figure 20. Monthly Maximum 10% Wave Runup Elevations at Zuma Beach

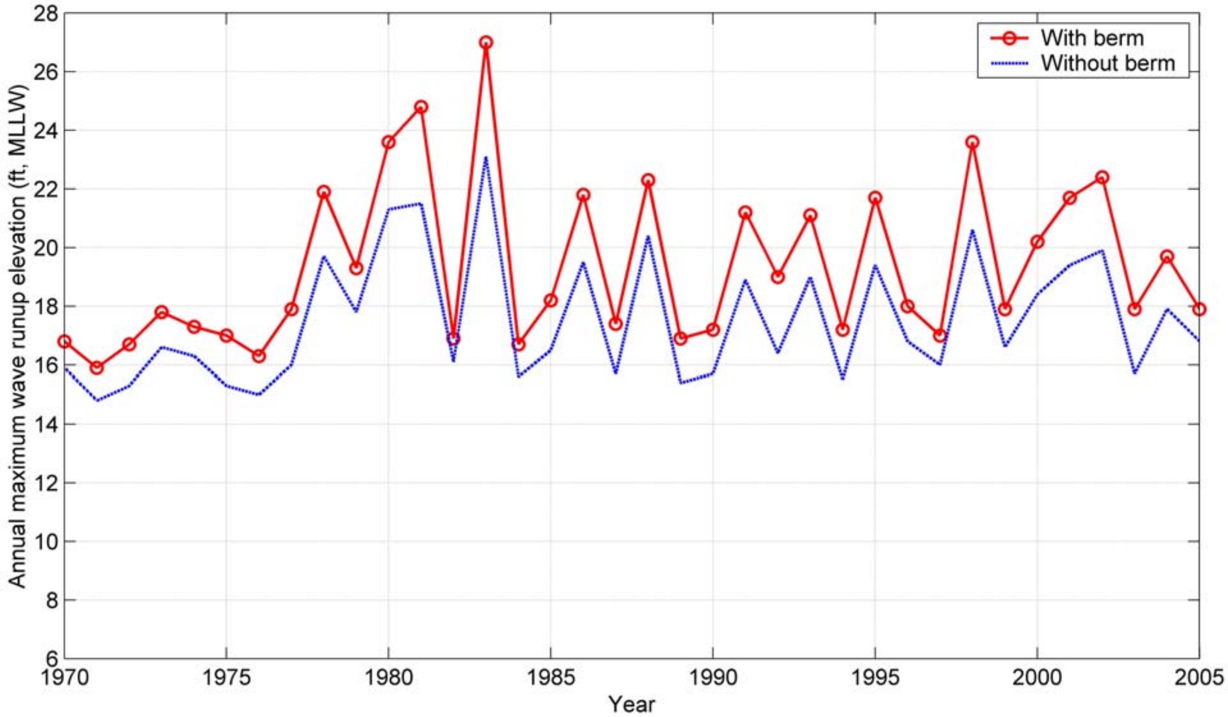

Figure 21. Annual Maximum 10% Wave Runup Elevations at Hermosa Beach

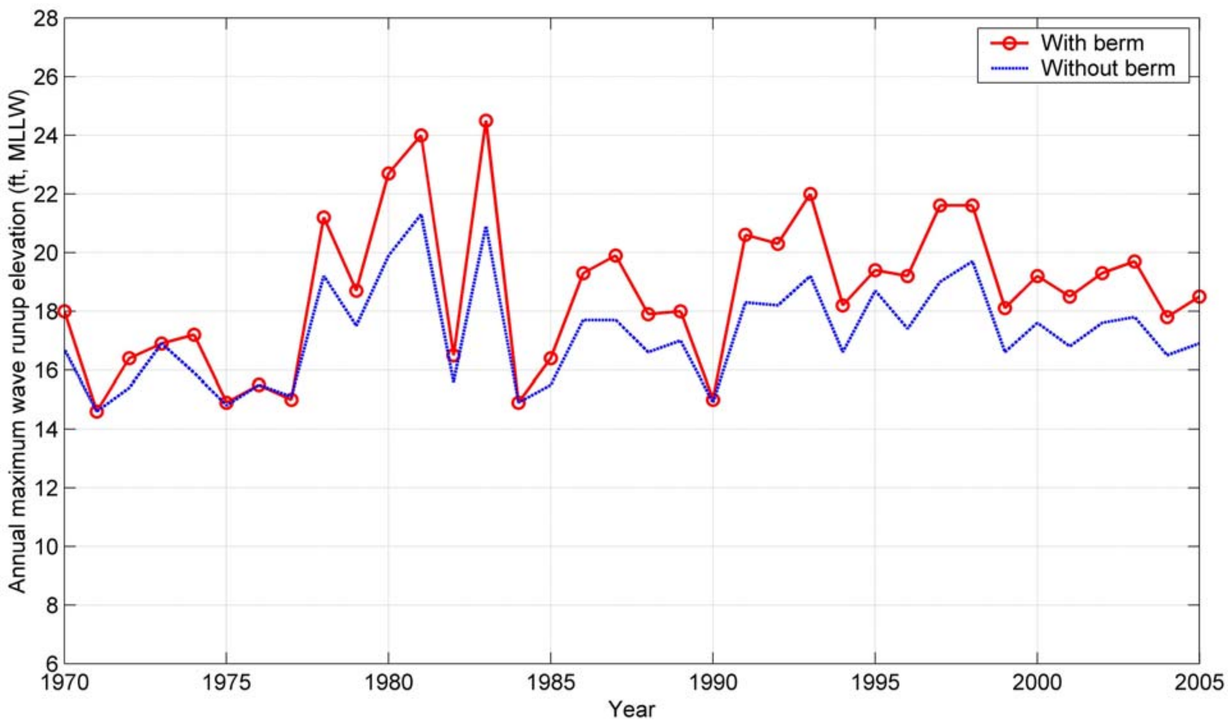

Figure 22. Annual Maximum 10% Wave Runup Elevations at Dockweiler Beach

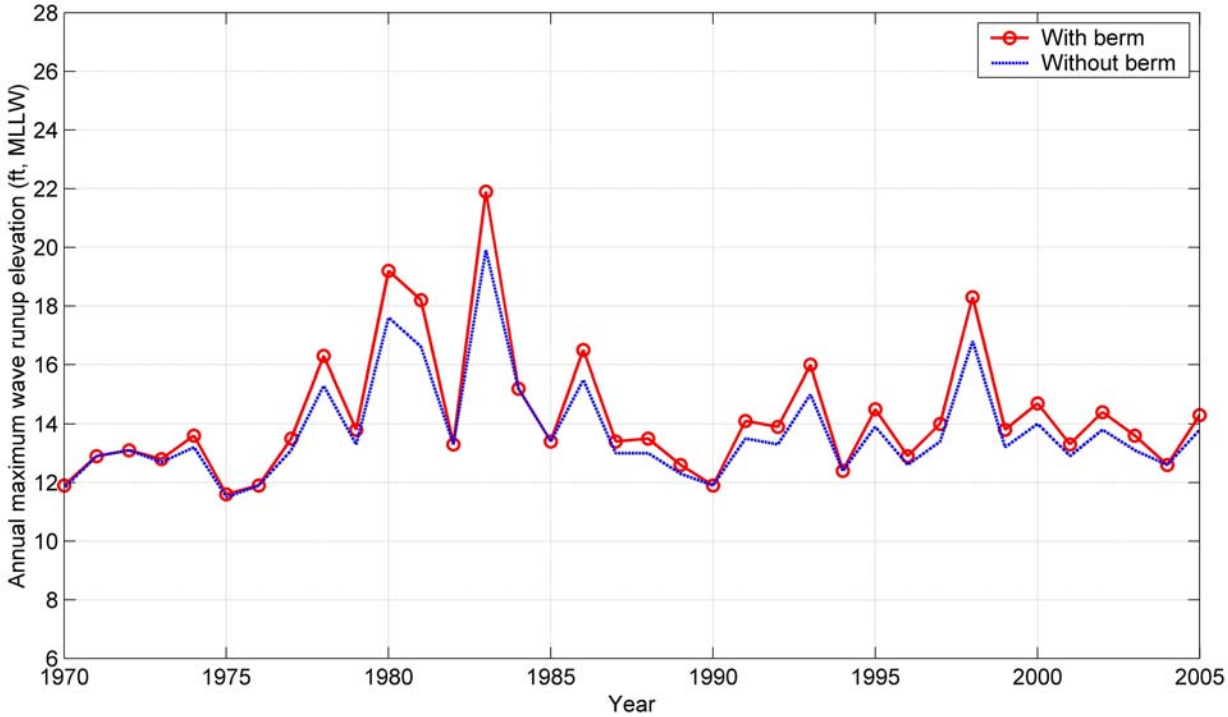

Figure 23. Annual Maximum 10% Wave Runup Elevations at Venice Beach

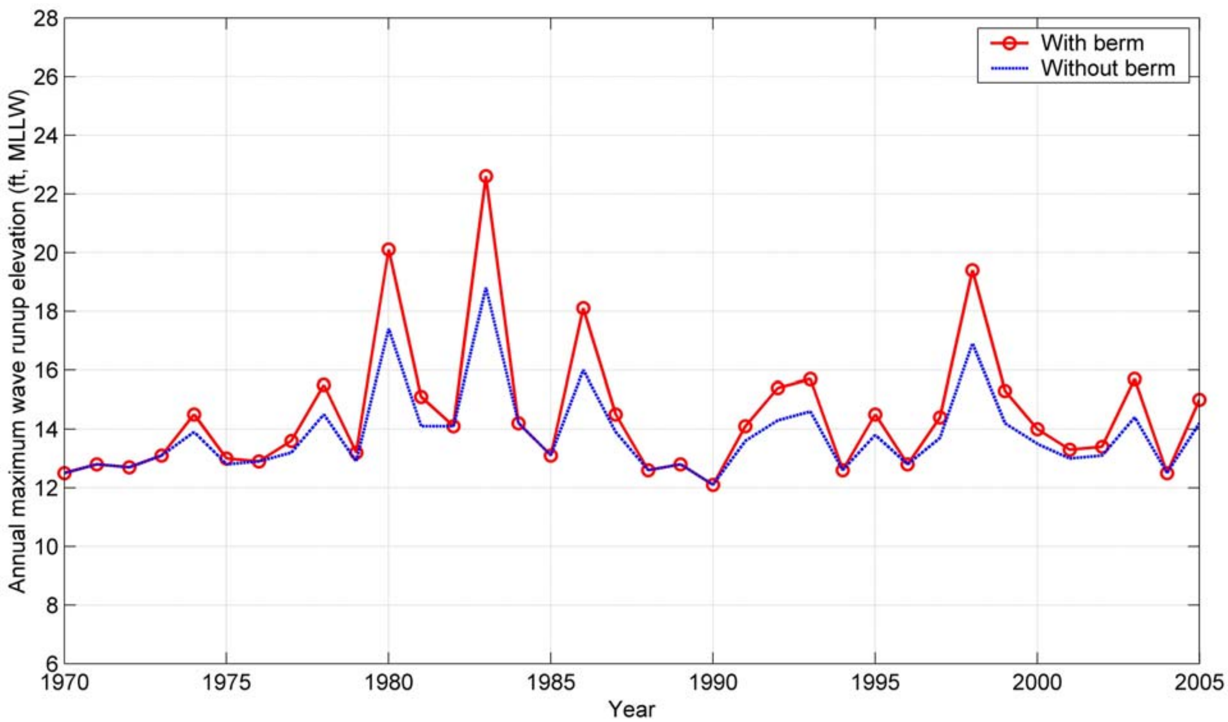

Figure 24. Annual Maximum 10% Wave Runup Elevations at Zuma Beach

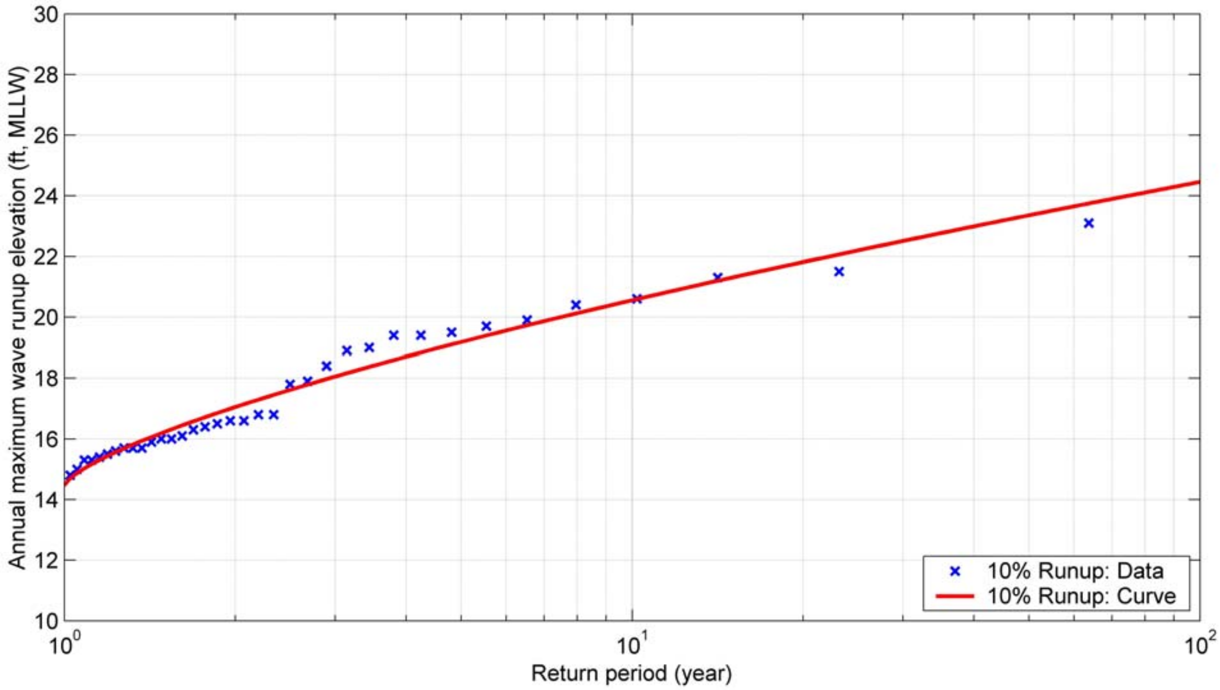

Figure 25. Annual Occurrence Frequency of Wave Runup Elevations at Hermosa Beach (Without Berm)

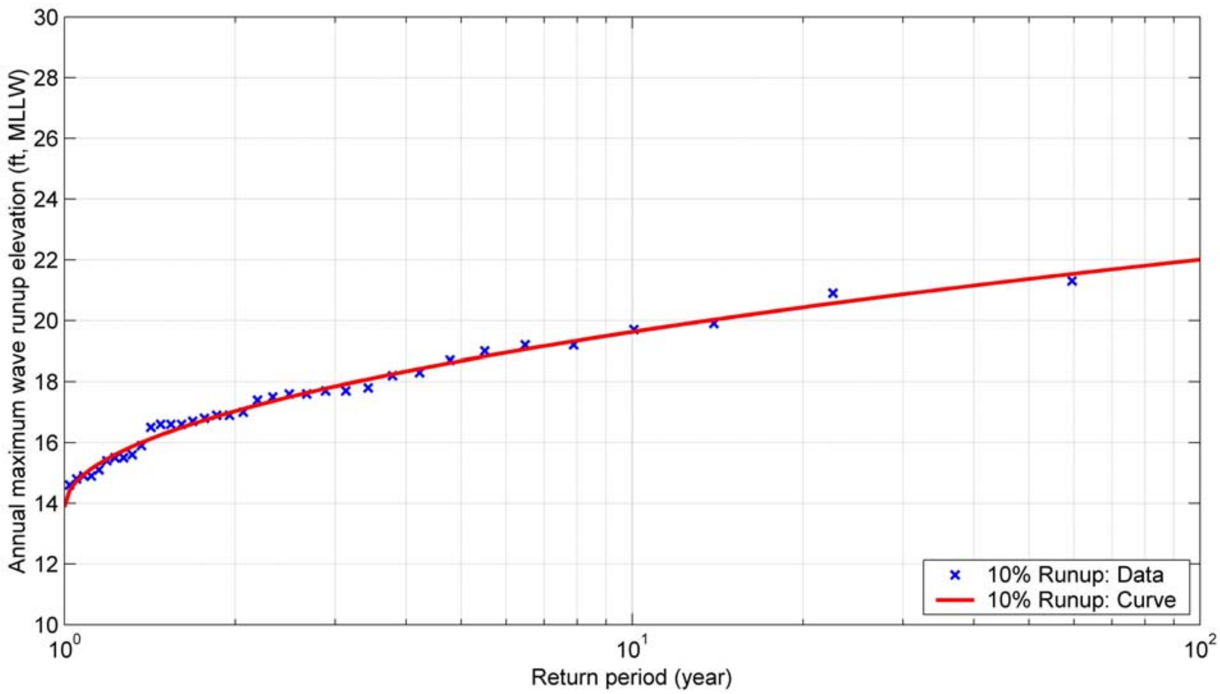

Figure 26. Annual Occurrence Frequency of Wave Runup Elevations at Dockweiler Beach (Without Berm)

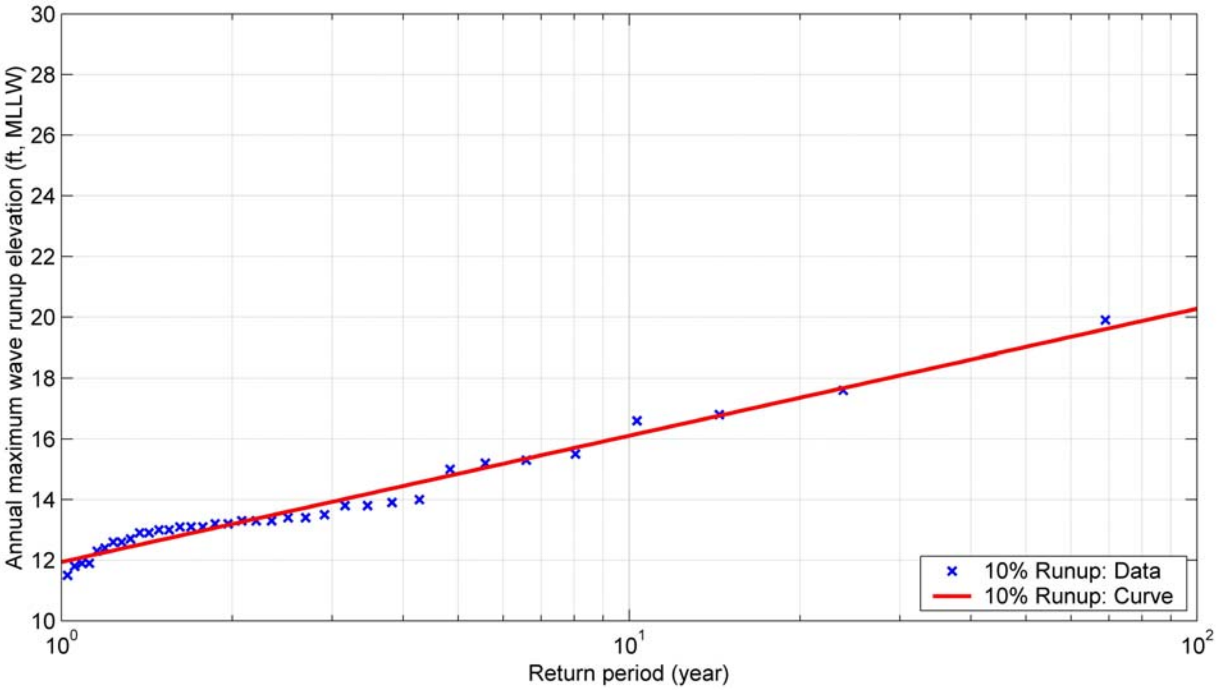

Figure 27. Annual Occurrence Frequency of Wave Runup Elevations at Venice Beach (Without Berm)

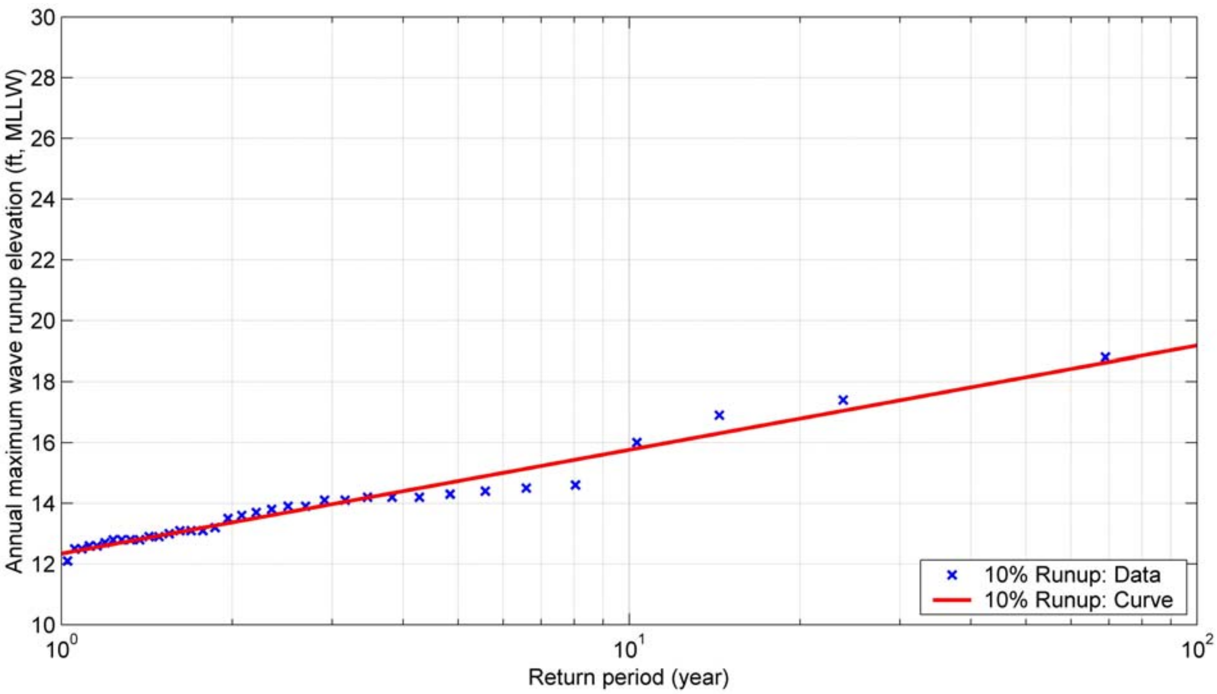

Figure 28. Annual Occurrence Frequency of Wave Runup Elevations at Zuma Beach (Without Berm)

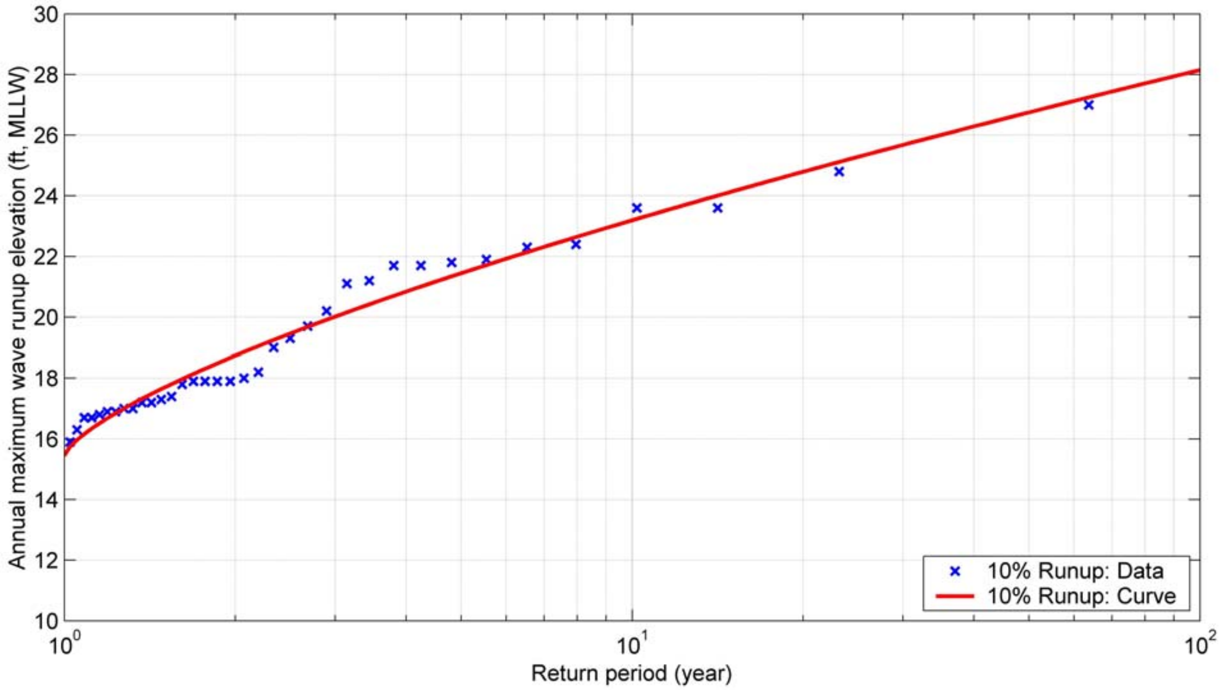

Figure 29. Annual Occurrence Frequency of Wave Runup Elevations at Hermosa Beach (With Berm)

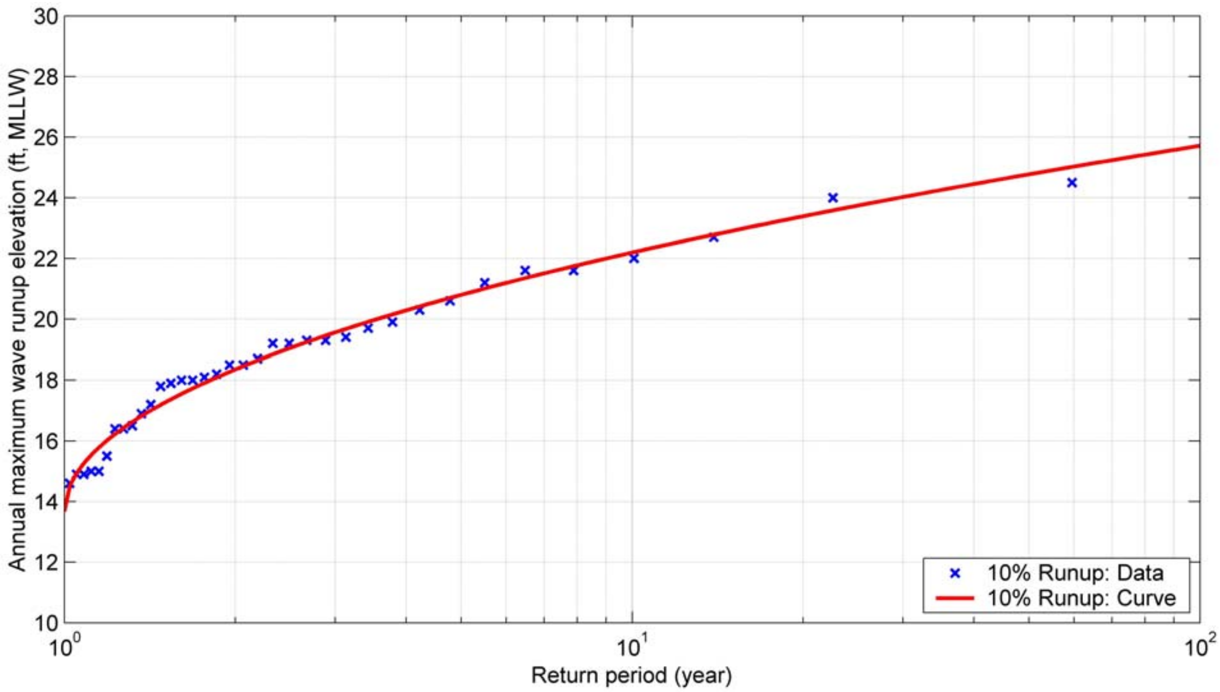

Figure 30. Annual Occurrence Frequency of Wave Runup Elevations at Dockweiler Beach (With Berm)

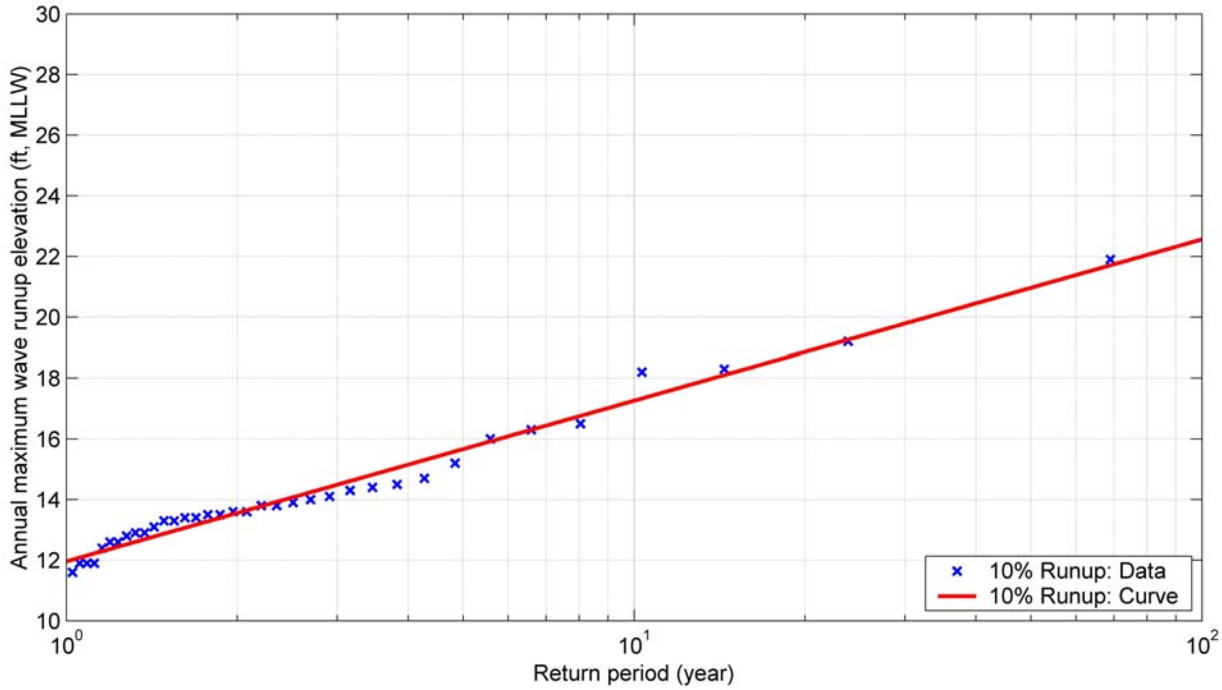

Figure 31. Annual Occurrence Frequency of Wave Runup Elevations at Venice Beach (With Berm)

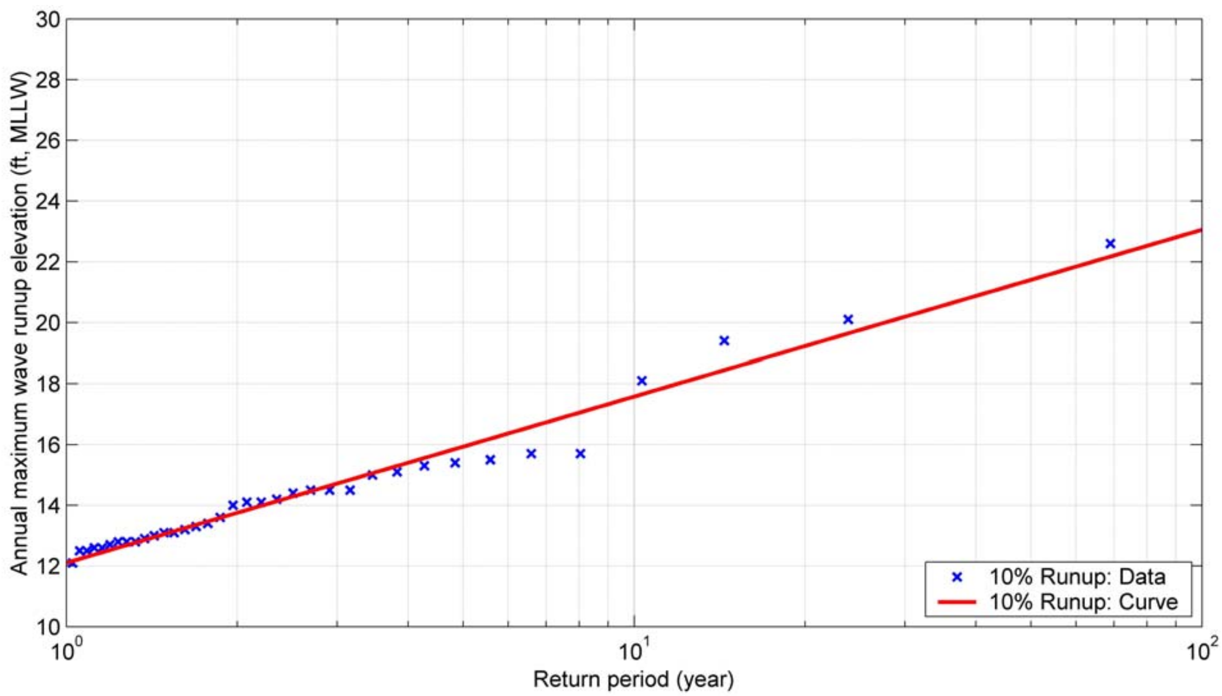

Figure 32. Annual Occurrence Frequency of Wave Runup Elevations at Zuma Beach (With Berm)