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August 26, 2010
Project No. SL07154-2

Pacifica Companies for the City of Grover Beach
c/o Allison Rolfe
1785 Hancock Street, Suite 100
San Diego, California 92110

SUBJECT: **Seawave Runup Analysis**
Proposed Grover Beach Lodge
Grover Beach, San Luis Obispo County, California

Dear Ms. Rolfe:

1.0 Introduction

GeoSolutions, Inc. has performed a seawave run-up analysis for the proposed Grover Beach Lodge project located on a portion of West Grand Avenue in the City of Grover Beach, California. Plate 1 is a Site Plan for the property. In addition, a tsunami inundation map is provided that presents the tsunami inundation potential for the project. Plate 2 depicts the tsunami inundation map.

2.0 Stillwater, Tidal, and Global Warming Elevations

The topography for the site was provided by EDA Design Professionals using City of Grover Beach Data which has a benchmark termed GTA-2. There is a two-foot (2) conversion that is added to the GTA-2 elevation data to convert the data to NGVD29 data (National Geodetic Vertical Datum, see attached sheet for datum addition information). For the purpose of this study, elevation data discussed within this letter will be converted to NGVD29 data unless specified. Plate 1 depicts the topographic map that maintains the City of Grover Beach datum (it is understood that elevation data is difficult to read on this map however, it is the only map provided to the undersigned). Existing elevation at the site was utilized for this study.

One of the low elevation points depicted on the site topographic map is approximately 7 feet (GTA-2 elevation). When a conversion factor is added to the GTA-2 data, the low elevation point is approximately 9 feet (NGVD29 datum).

Stillwater elevation is the undisturbed water level or surface of the water if all wave and wind action were to cease (U.S. Army Corps of Engineers, 2002). The geologic and marine parameters for the stillwater analysis were based on 1982-1983 storm conditions on the

California coast. According to National Oceanic and Atmospheric Administration (NOAA), the 1982-1983 storm conditions were the strongest and most devastating of the 20th century. To estimate the 100-year stillwater elevation for this analysis, a MLLW (mean-lower low water) tidal datum was used. The following tidal elevations were obtained from a NOAA station datum at Port San Luis, California (see attached Tidal Datum Elevations). The PID number used for Port San Luis was FV0898. The tidal elevation used for this analysis was MHHW (mean higher high water) which is 5.32 feet (MLLW daturm). This NOAA station also indicated that during an epoch from 1983 to 2001 the maximum water level that occurred above MHHW was 2.33 feet (1/18/1973, see attached data sheet). Sea level changes have been anticipated for the next 100 years. Data presented within USGS Coastal Vulnerability Assessment for Santa Barbara, CA (USGS Open File Report 2005-1057, see attached), anticipate a rate of 3.22 +/- 0.99 mm/yr, based on 27 years of data. For a 100-year period the relative sea level change would be approximately 32 cm or approximately 1 foot of elevation change.

Incorporating the above given data, the 100-year stillwater elevation would be:

> 5.32 feet (which is MHHW) + 2.33 feet (maximum water level, above MHHW) + 1 foot (sea level change) which equals 8.65 feet (MLLW).

Since this report utilizes a NGVD 29 data, a conversion from MLLW datum to NGVD 29 datum is utilized. The conversion from 8.65 MLLW to NGVD 29 data is 3.01 feet (subtract 3.01 feet from 8.65 MLLW to get to 5.64 feet NGVD29 stillwater elevation). A low site elevation is approximately 9 feet and a high elevation is approximately 21 feet (both NGVD 29 datum).

The mean high high water level, coupled with a maximum water level and global warming factor is 5.64 feet (NGVD29 datum) which is the still water level calculated for the site. Since the approximate low elevation at the property is 9 feet (NGVD29 datum), the property is approximately 3.3 feet above the mean high high tide with a maximum water level and global warming factor.

3.0 Wave Conditions

Wave and tidal conditions at the site were established based upon parameters included in the "Bank and Shore Protection in California Highway Practice" manual issued by the State of California, Department of Transportation (1960). Additional information is included in the Assessment of 1982-83 Winter Storms Damage, Malibu Coastline" (Denison and Robertson, 1985). In January, 1983, wave heights from 6 to 10 feet with 4- to 6- second periods were recorded and were considered to be the most severe of that winter. Larger waves would break father from shore, reducing wave energy during run-up. Storm surge is estimated at 2.0 feet (Department of Navy, 1984, see attached data sheet).

4.0 Wave Runup

Wave runup is the maximum vertical extent of wave uprush (height R) on a beach or structure above the still water level (Swenson, 1997). Determination of the wave runup height using procedures in FEMA (2003) is based upon the largest wave which would break on the beach in

the vicinity of the property. This analysis utilized a 10-foot breaking wave (H_o) with a 6 second period (T) and a beach slope angle of 1:10 (horizontal:vertical) with a smooth slope (without a seawall structure). G is a gravity function. An attached graph (from FEMA, 2003 reproduced from Shore Protection Manual 1984) depicts the wave runup guidance. A similar graph by Sorenson can be utilized for wave runup and is included in Appendix A.

Cot of slope (1/10) = 5.7
$H_o/gT^2 = 10/32.2\ ft/sec^2\ (6)^2 = 0.0086$
The graph from Sorenson gives a value of $R/H_o = 0.75$.
R = 0.75/10 = 7.5 feet.

A wave runup of approximately 7.5 feet can be added to the 5.64 foot still water level calculated in section 2.0 of this report.

5.64 + 7.5 feet = 13.14 feet which is the approximate level of the storm runup level for the site (NGVD29 datum). This value is greater than the low elevations of the property. However, from topographic maps submitted to our office, the dune area between the proposed Lodge and beach area maintains a low elevation of approximately 20 feet (NGVD29 datum).

The State of California has provided maps that depict the tsunami inundation for the Oceano vicinity. The tsunami inundation map depicts the site as within a tsunami inundation zone. Plate 2 depicts the tsunami inundation map. The site is within the 100-year flood zone (FEMA, 1997).

5.0 RECOMMENDATION

The project civil engineer is recommended to evaluate the potential for flooding at the project.

We appreciate the opportunity to provide you with professional services. If you should have any questions regarding this report, please contact the undersigned at (805) 543-8539.

Sincerely,
GeoSolutions, Inc.

PROFESSIONAL GEOLOGIST
JOHN M.D. KAMMER
NO. 2118
CERTIFIED
ENGINEERING
GEOLOGIST
STATE OF CALIFORNIA

John Kammer, C.E.G. 2118
Principal

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EDA Design Professionals, Topographic Map, February 19, 2002.

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FEMA, April, 2003, Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix D.

Sorensen, R.M., 1997, Basic Coastal Engineering, Chapman and Hall, New York.

Swenson, Mike, 1997, University of Wisconsin-Madison, Coastal Geomorphology, Sorenson, , http://homepages.cae.wisc.edu/~chinwu/GLE401/web/Mike/Wave%20runup.htm.

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U.S. Army Corps of Engineers, 2002, Coastal Engineering Manual, Engineer Manual 1110-2-1100, Washington, D.C., Appendix A,

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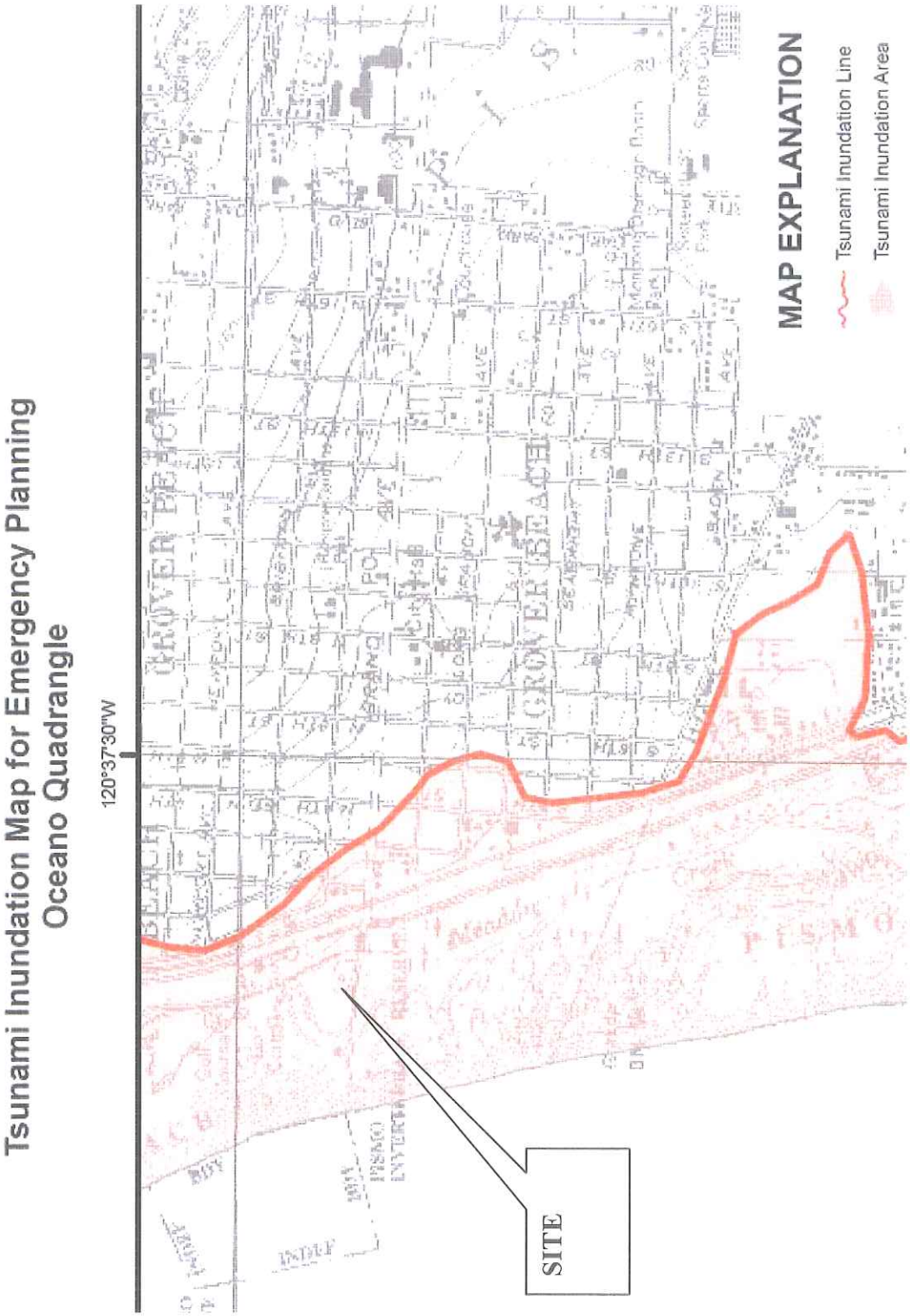
SITE PLAN

GROVER BEACH LODGE
WEST OF HIGHWAY 1 AND NORTH OF GRANDE AVENUE
GROVER BEACH, CALIFORNIA

PLATE
1

PROJECT NO:
SL07154-2



http://www.conservation.ca.gov/cgs/geologic_hazards/Tsunami/Inundation_Maps/SanLuisObispo/Documents/Tsunami_Inundation_Oceano_Quad_SLO.pdf

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SITE PLAN

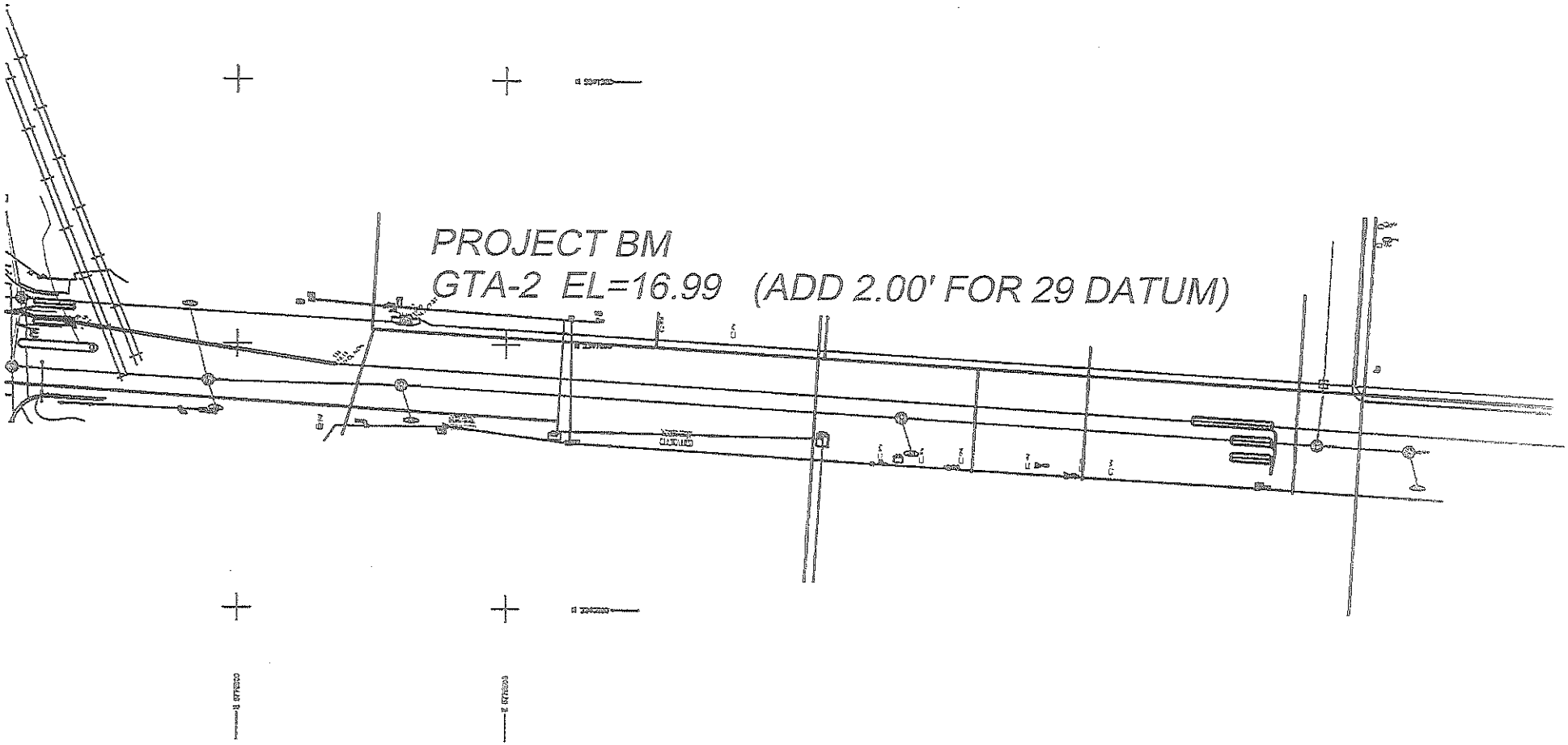
TSUNAMI INUNDATION MAPFOR EMERGENCY PLANNING
OCEANO QUADRANGLE - GROVER BEACH LODGE
WEST OF HIGHWAY 1 AND NORTH OF GRANDE AVENUE
GROVER BEACH, CALIFORNIA

PLATE
2

PROJECT NO:
SL07154-2

APPENDIX A

Ancillary Data


PROJECT BM
GTA-2 EL=16.99 (ADD 2.00' FOR 29 DATUM)

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service

Station ID: 9412110
Name: PORT SAN LUIS, PACIFIC OCEAN
CALIFORNIA
NOAA Chart: 18704
USGS Quad: PORT SAN LUIS

PUBLICATION DATE: 04/21/2003

Latitude: 35° 10.6' N
Longitude: 120° 45.6' W

T I D A L D A T U M S

Tidal datums at PORT SAN LUIS, PACIFIC OCEAN based on:

LENGTH OF SERIES: 19 Years
TIME PERIOD: January 1983 - December 2001
TIDAL EPOCH: 1983-2001
CONTROL TIDE STATION:

Elevations of tidal datums referred to Mean Lower Low Water (MLLW), in METERS:

HIGHEST OBSERVED WATER LEVEL (01/18/1973)	=	2.331
MEAN HIGHER HIGH WATER (MHHW)	=	1.623
MEAN HIGH WATER (MHW)	=	1.408
MEAN TIDE LEVEL (MTL)	=	0.863
MEAN SEA LEVEL (MSL)	=	0.853
MEAN LOW WATER (MLW)	=	0.317
NORTH AMERICAN VERTICAL DATUM-1988 (NAVD)	=	0.024
MEAN LOWER LOW WATER (MLLW)	=	0.000
LOWEST OBSERVED WATER LEVEL (01/07/1951)	=	-0.732

National Geodetic Vertical Datum (NGVD 29)

Bench Mark Elevation Information In METERS above:

Stamping or Designation	MLLW	MHW
6 1936	4.395	2.987
NO 16 1973	2.839	1.431
TIDAL BM 18 1975	3.555	2.147
TIDAL BM 20 1975	10.146	8.738
2110 A 1982	4.628	3.220
2110 D 1982	3.416	2.008
NO 15 1971 RESET 1983	4.825	3.417
MAR 3 LS 3354	4.814	3.406
2110 E 2000	9.786	8.378

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service

Station ID:	9412110	PUBLICATION DATE:	04/21/2003
Name:	PORT SAN LUIS, PACIFIC OCEAN CALIFORNIA		
NOAA Chart:	18704	Latitude:	35° 10.6' N
USGS Quad:	PORT SAN LUIS	Longitude:	120° 45.6' W

D E F I N I T I O N S

Mean Sea Level (MSL) is a tidal datum determined over a 19-year National Tidal Datum Epoch. It pertains to local mean sea level and should not be confused with the fixed datums of North American Vertical Datum of 1988 (NAVD 88).

NGVD 29 is a fixed datum adopted as a national standard geodetic reference for heights but is now considered superseded. NGVD 29 is sometimes referred to as Sea Level Datum of 1929 or as Mean Sea Level on some early issues of Geological Survey Topographic Quads. NGVD 29 was originally derived from a general adjustment of the first-order leveling networks of the U.S. and Canada after holding mean sea level observed at 26 long term tide stations as fixed. Numerous local and wide-spread adjustments have been made since establishment in 1929. Bench mark elevations relative to NGVD 29 are available from the National Geodetic Survey (NGS) data base via the World Wide Web at National Geodetic Survey.

NAVD 88 is a fixed datum derived from a simultaneous, least squares, minimum constraint adjustment of Canadian/Mexican/United States leveling observations. Local mean sea level observed at Father Point/Rimouski, Canada was held fixed as the single initial constraint. NAVD 88 replaces NGVD 29 as the national standard geodetic reference for heights. Bench mark elevations relative to NAVD 88 are available from NGS through the World Wide Web at National Geodetic Survey.

NGVD 29 and NAVD 88 are fixed geodetic datums whose elevation relationships to local MSL and other tidal datums may not be consistent from one location to another.

The Vertical Mark Number (VM#) and PID# shown on the bench mark sheet are unique identifiers for bench marks in the tidal and geodetic databases, respectively. Each bench mark in either database has a single, unique VM# and/or PID# assigned. Where both VM# and PID# are indicated, both tidal and geodetic elevations are available for the bench mark listed.

The NAVD 88 elevation is shown on the Elevations of Tidal Datums Table Referred to MLLW only when two or more of the bench marks listed have NAVD 88 elevations. The NAVD 88 elevation relationship shown in the table is derived from an average of several bench mark elevations relative to tide station datum. As a result of this averaging, NAVD 88 bench mark elevations computed indirectly from the tidal datums elevation table may differ slightly from NAVD 88 elevations listed for each bench mark in the NGS database.

Elevation Information

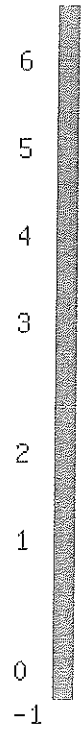
PID: FV0898

VM: 945

Station ID: 9412110

Epoch: 1983-2001

Date: Wed Jul 28 19:23:51 EDT 2010



MHHW	=	5.32 feet (1.623 meters)
MHW	=	4.62 feet (1.408 meters)
NGVD29	=	3.01 feet (0.916 meters)
MTL	=	2.83 feet (0.863 meters)
MSL	=	2.80 feet (0.853 meters)
MLW	=	1.04 feet (0.317 meters)
NAVD88	=	0.08 feet (0.024 meters)
MLLW	=	0.00 feet (0.000 meters)

The NAVD 88 and the NGVD 29 elevations related to MLLW were computed from Bench Mark, 941 2110 TIDAL 6, at the station.

Displayed tidal datums are Mean Higher High Water(MHHW), Mean High Water (MHW), Mean Tide Level(MTL), Mean Sea Level (MSL), Mean Low Water(MLW), and Mean Lower Low Water(MLLW) referenced on 1983-2001 Epoch.

Coastal Vulnerability Assessment of Channel Islands National Park to Sea-Level Rise, USGS Open-File Report 2005-1057

Map of Coastal Vulnerability

Tide
Abstract
Introduction
Data Ranking System
Channel Islands National Park
Methodology
Geologic Variables
Physical Process Variables
Calculating the Vulnerability Index
Results
Discussion
Conclusions
References

Physical Process Variables

The **relative sea-level** change variable is derived from the change in annual mean water elevation over time as measured at tide gauge stations along the coast. The rate of sea-level rise for Santa Barbara, CA (closest to the northern Channel Islands) is 3.22 +/- 0.99 mm/yr based on 27 years of data, and the rate of rise for Newport Beach, CA (closest to Santa Barbara Island) is 2.22 +/- 0.53 (Zervas, 2001). This variable inherently includes both eustatic sea-level rise as well as regional sea-level rise due to isostatic and tectonic adjustments of the land surface. Relative sea-level change data are a historical record, and thus portray only the recent sea-level trend (< 150 years). Relative sea-level rise for Channel Islands falls within the low vulnerability category for Santa Barbara Island and moderate vulnerability for the northern Channel Islands based on water elevation data at Newport Beach and Santa Barbara, respectively (Figure 11). There were no sea-level rise data available for locations within the Channel Islands; therefore mainland approximations were used. Sea-level rise rates for the Channel Islands may be different than the values from Santa Barbara and Newport Beach; however these values are expected to be a close approximation of sea-level rise rate within the Channel Islands. For information on tectonics and land surface adjustments within the Channel Islands readers are directed to Sorlien (1994).

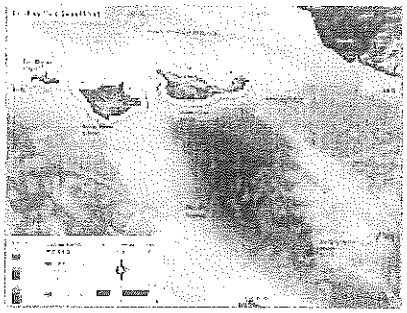


Figure 11. Rate of relative sea-level rise for Channel Islands National Park.

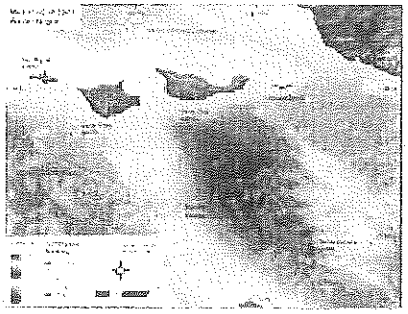


Figure 12. Mean significant wave heights for Channel Islands National Park.

Mean significant wave height is used here as a proxy for wave energy which drives the coastal sediment budget. Wave energy is directly related to the square of wave height;

$$E = 1/8\ \rho g H^2$$

where E is energy density, H is wave height, ρ is water density and g is acceleration due to gravity. Thus, the ability to mobilize and transport coastal sediments is a function of wave height squared. In this report, we use hindcast nearshore mean significant wave height data for the period 1976-95 obtained from the U.S. Army Corps of Engineers Wave Information Study (WIS) (see references in Hubertz and others, 1996). The model wave heights were compared to historical measured wave height data obtained from the NOAA National Data Buoy Center to ensure that model values were representative of the study area. Mean wave heights for the Channel Islands vary between 2 meters (moderate vulnerability) at San Miguel and western Santa Rosa to just less than 1 meter (very low vulnerability) at Anacapa (Figure 12).

Tidal range is linked to both permanent and episodic inundation hazards. Tide range data were obtained from NOAA/NOS published benchmarks from Bechers Bay on Santa Rosa Island. Mean tidal range was 1.05 m, therefore the Channel Islands were classified as high vulnerability (1.0 - 2.0 meters) with respect to tidal range (Figure 13).

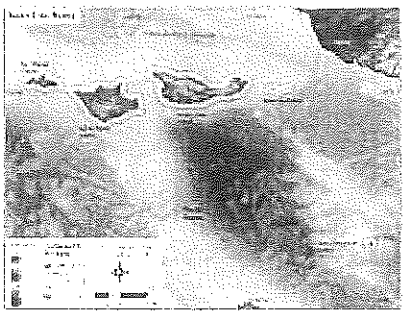


Figure 13. Mean Tidal Range for Channel Islands National Park.

U.S. Department of the Interior, U.S. Geological Survey
URL: http://pubs.usgs.gov/of/2005/1057/html/ppvariables.htm
Maintained by Publishing Services
Last modified: 10:15:39 Wed 06 Jul 2005
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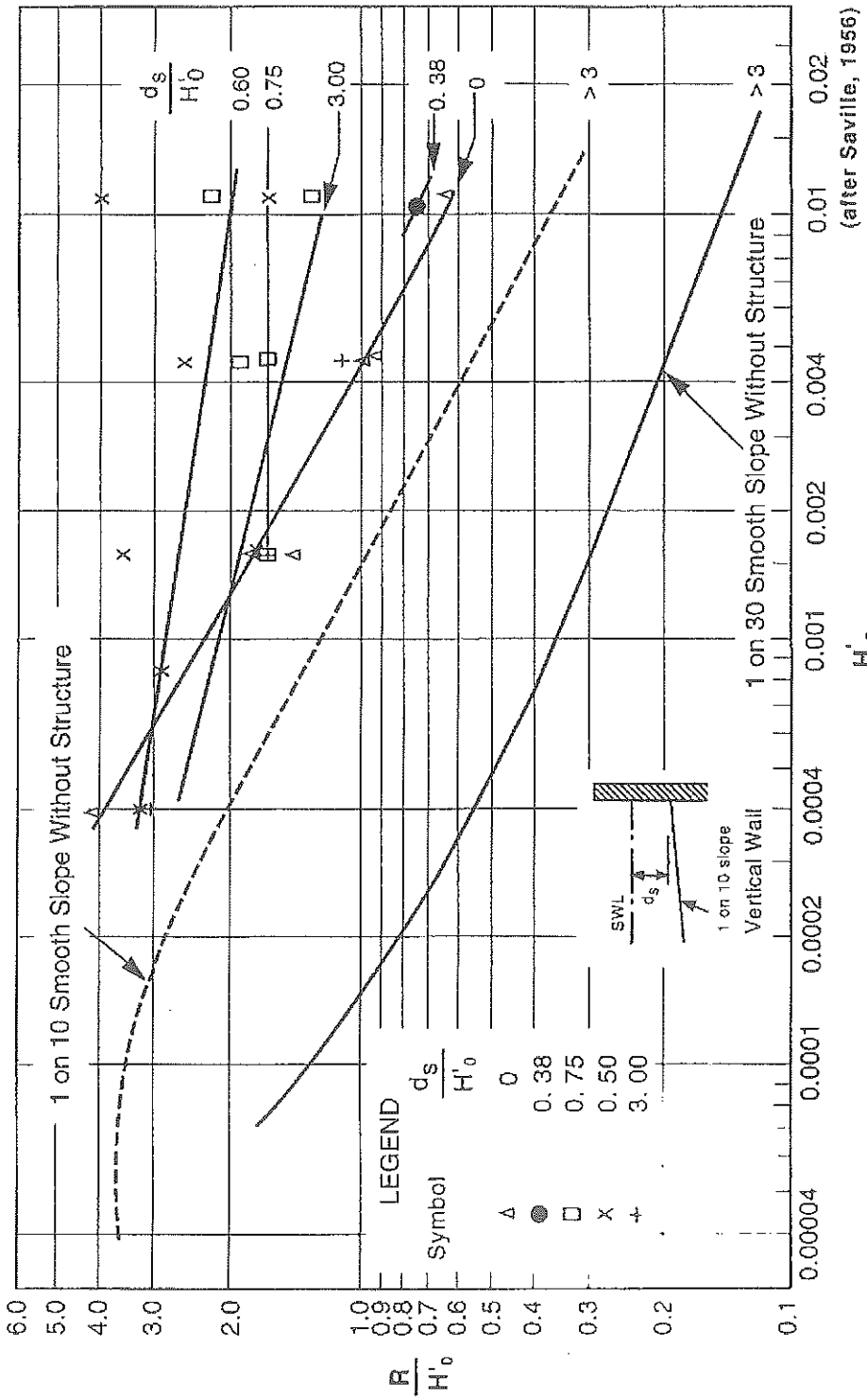
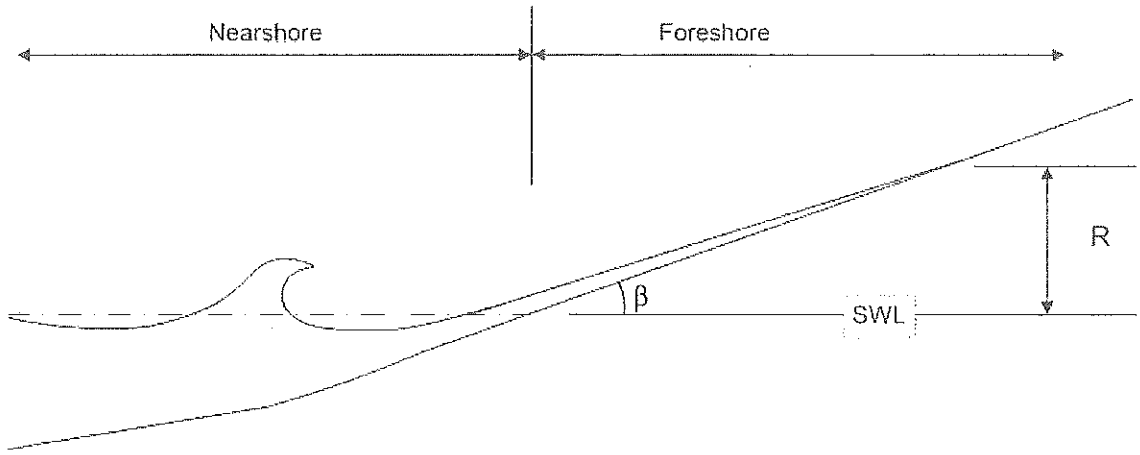


Figure D-14. Wave Runup Guidance from Vertical Wall, From *Shore Protection Manual* (USACE, 1984)

Wave Runup

Definition

Wave runup is the maximum vertical extent of wave uprush on a beach or structure above the still water level (SWL) (Sorensen, 1997). This definition is depicted in the figure below.



Definition of wave runup (R). SWL indicates still water level.

Wave runup is an important process in causing and or promoting bluff erosion. Wave runup may cause erosion by directly impacting the bluff, dislodging material, and redistributing it to the foreshore and nearshore. Wave runup promotes bluff erosion by carrying failed bluff material away from the toe of the bluff, regardless of what caused failure and erosion of the bluff. For example, a small slump due to elevated groundwater levels may carry material to the bluff toe. If this material remained at the toe, it would act to stabilize the bluff. However, if wave runup removes the material, then the bluff is less stable and more prone to direct wave attack.

Two different wave runup values were investigated in this study: mean and two percent wave runup. Mean runup is simply the average runup (R) of all waves observed. The two percent wave runup ($R_{2\%}$) is the runup that only two percent of the wave runup values observed will reach or exceed.

Wave Runup Prediction Formulas

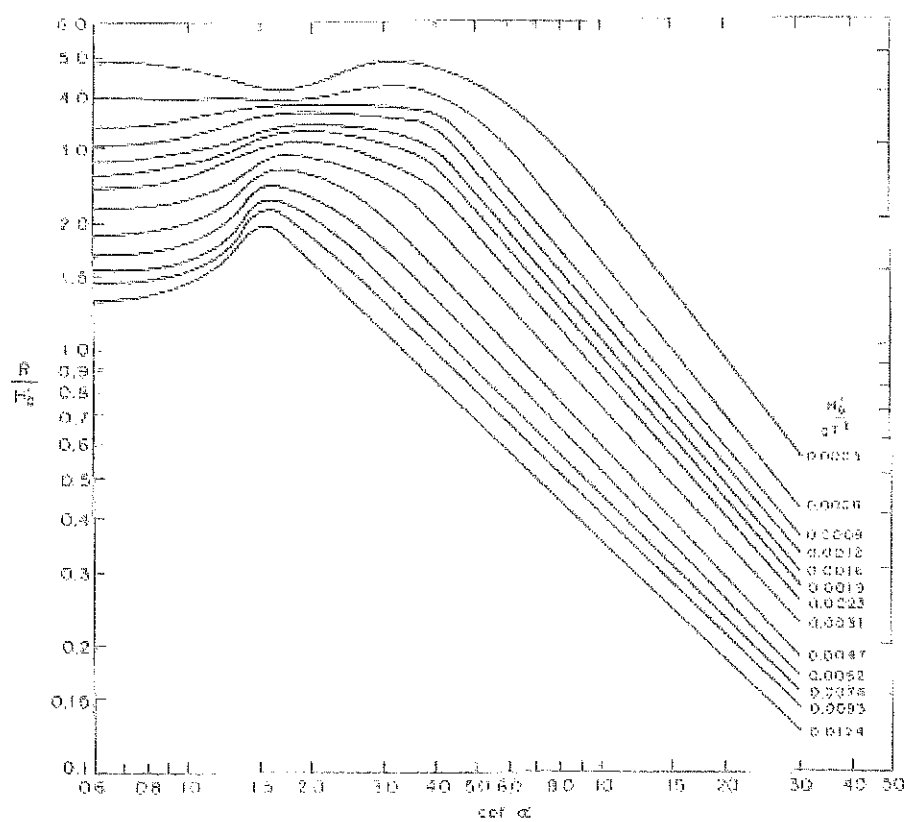
Five different formulas for predicting wave runup were investigated in this study. The following table provides the wave runup equations used in this study with some comments on the different formulas.

General equations and variables defined for wave runup formulas.

WR predictinon equations investigated for this study

Method	Source	Slopes	Waves	Setting	Equations	Comments
Hunt	Hunt, 1959; Battjes, 1974	Smooth, impermeable, continuous	Regular	Laboratory	$\frac{R}{H_o} = \xi$	$0.1 < \xi < 0.3$
CERC	CERC Shore Protection Manual, 1984	Smooth, impermeable, continuous	Regular	Laboratory	Chart solution, see figure below	$\frac{d_s}{H_o} \approx 2.0$
Mase	Mase, 1989	Smooth, impermeable, continuous, gentle: $\theta = 1.9° - 11.3°$	Irregular	Laboratory	$\frac{R}{H_o} = a\xi^b$ $R_{2\%}: \ a = 1.86, \ b = 0.71$	$0.007 \le \frac{H_o}{\ } \le 0.07$

		θ = 1.5° - 11.0°				
Nielsen and Hanslow	Nielsen and Hanslow, 1991	Natural sand beaches with θ = 1.5° - 10.8° and Mean grain size = 0.18 - 0.8 mm	Irregular	Field	$\overline{R}: \ a = 0.88, \ b = 0.69$ $R = cL_{zwm}$ $R_{2\%}: \ c = 1.98$ $\overline{R}: \ c = 0.89$ $L_{zwm} = 0.6(H_{orms}L_o)^{0.5} \tan\beta_F$ for $\tan\beta_F \geq 0.10$ $L_{zwm} = 0.05(H_{orms}L_o)^{0.5}$ for $\tan\beta_F < 0.10$	
Ahrens and Seelig	Ahrens and Seelig, 1996	Sand and gravel beaches	Irregular	Laboratory and Field	$\frac{R_{2\%}}{H_{so}} = \frac{4.1}{N_o}\sqrt{\frac{d_{sw}}{d_{sr}}}$ $N_o = \frac{H_{so}}{w_{sr}T}$ $w_{sr} = 14.5(d_{sr})^{1.1}$	d in mm, w_{sr} in cm/s w_{sr} for fresh water and $0.15 \leq d_{sr} \leq 0.85$ mm



CERC wave runup chart solution, reproduced from Sorensen (1997).

Table 3-6. Highest and lowest water levels (concluded).

Location	Observation Period	Mean Range meters (feet)	Highest Water Levels Above Mean High Water meters (feet)			Lowest Water Levels Below Low Water meters (feet)		
			Average Yearly Highest	Extreme High	Date of Record	Average Yearly Lowest	Extreme Low	Date of Record
PACIFIC COAST[2]								
San Diego, Calif.	1906-70	1.73 (5.7)	0.55 (1.8)	0.79 (2.6)	20 Dec 68 29 Dec 59	0.61 (2.0)	0.85 (2.8)	17 Dec 33 17 Dec 37
La Jolla, Calif.	1925-53 1956-70	1.58 (5.2)	0.55 (1.8)	0.73 (2.4)	20 Dec 68	0.58 (1.9)	0.79 (2.6)	17 Dec 33
Los Angeles, Calif.	1924-70	1.65 (5.4)	0.55 (1.8)	0.70 (2.3)	19 and 20 Dec 68	0.55 (1.8)	0.79 (2.6)	26 Dec 32 17 Dec 33
Santa Monica, Calif.	1933-70	1.65 (5.4)	0.55 (1.8)	0.64 (2.1)	27 Dec 36 17 and 18 Jul 51	0.55 (1.8)	0.82 (2.7)	17 Dec 33
San Francisco, Calif.	1898-1970	1.73 (5.7)	0.46 (1.5)	0.70 (2.3)	24 Dec 40 19 Jan 69 9 Jan 70	0.64 (2.1)	0.82 (2.7)	26 Dec 32 17 Dec 33
Crescent City, Calif.	1933-46 1950-70	2.10 (6.9)	0.73 (2.4)	0.94 (3.1)	4 Feb 58	0.73 (2.4)	0.88 (2.9)	22 May 55
Astoria, Oreg.	1925-70	2.53 (8.3)	0.79 (2.6)	1.16 (3.8)	17 Dec 33	0.58 (1.9)	0.85 (2.8)	16 Jan 30
Neah Bay, Wash.	1935-70	2.50 (8.2)	0.88 (2.9)	1.25 (4.1)	30 Nov 51	0.94 (3.1)	1.16 (3.8)	29 Nov 36
Seattle, Wash.	1899-1970	3.44 (11.3)	0.67 (2.2)	1.01 (3.3)	6 Feb 04 5 Dec 67	1.19 (3.9)	1.43 (4.7)	4 Jan 16 20 Jun 51
Friday Harbor, Wash.	1934-70	2.35 (7.7)	0.70 (2.3)	0.98 (3.2)	30 Dec 52	0.98 (3.2)	1.22 (4.0)	7 Jan 47
Ketchikan, Alaska	1919-70	4.66 (15.3)	1.34 (4.4)	1.80 (5.9)	2 Dec 67	1.37 (4.5)	1.58 (5.2)	8 Dec 19 16 Jan 57 30 Dec 59
Juneau, Alaska	1936-41 1944-70	5.00 (16.4)	1.52 (5.0)	1.92 (6.3)	2 Nov 48	1.37 (4.5)	1.73 (5.7)	16 Jan 57
Skagway, Alaska	1945-62	5.09 (16.7)	1.49 (4.9)	2.04 (6.7)	22 Oct 45	1.52 (5.0)	1.83 (6.0)	16 Jan 57
Sitka, Alaska	1938-70	3.02 (9.9)	1.04 (3.4)	1.43 (4.7)	2 Nov 48	0.98 (3.2)	1.16 (3.8)	19 Jun 51 16 Jan 57
Yakutat, Alaska	1940-70	3.08 (10.1)	1.13 (3.7)	1.46 (4.8)	2 Nov 48	0.94 (3.1)	1.19 (3.9)	29 Dec 51 16 Jan 57
Seward, Alaska	1925-38	3.23 (10.6)	1.04 (3.4)	1.25 (4.1)	13 Oct 27	1.07 (3.5)	1.28 (4.2)	14 Jan 30
Kodiak Island, Alaska Womens Bay	1949-63	2.68 (8.8)	0.85 (2.8)	1.13 (3.7)	21 Nov 49	0.88 (2.9)	1.10 (3.6)	15 and 16 Jan 57
Unalaska Island, Alaska Dutch Harbor	1934-39 1946-70	1.13 (3.7)	0.61 (2.0)	0.88 (2.9)	14 and 15 Jan 38	0.61 (2.0)	0.82 (2.7)	13 Nov 50
Adak Island, Alaska Sweeper Cove	1943-70	1.13 (3.7)1	0.55 (1.8)	0.82 (2.7)	28 Dec 66	0.70 (2.3)	1.01 (3.3)	11 Nov 50
Attu Island, Alaska Massacre Bay	1943-69	1.01 (3.3)	0.49 (1.6)	0.73 (2.4)	6 Jan 66	0.52 (1.7)	0.73 (2.4)	12 and 13 Nov 50

[2] Tsunami levels not included.

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