

# Coastal Erosion Processes and Mitigation Measures

**San Francisco Littoral Cell, Pacifica Sub Cell**

**Bob Battalio, PE  
Principal Engineer, ESA PWA**

**November 14, 2012  
City of Pacifica**



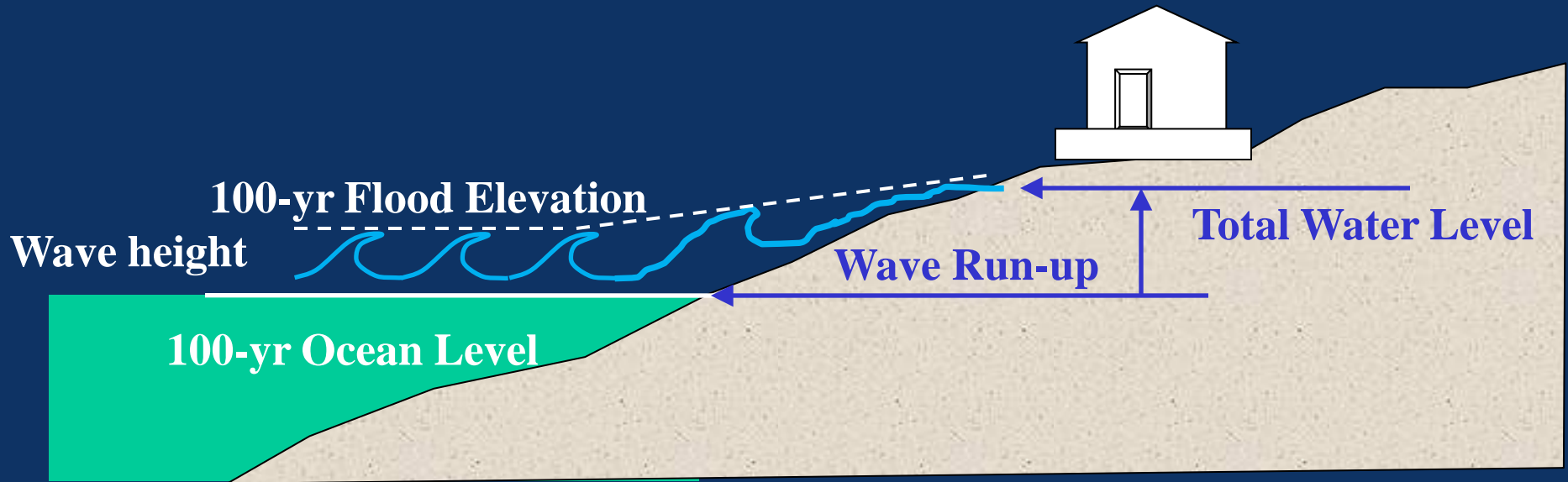
# OUTLINE

- 1. Wave Driven Shore Processes**
- 2. Coastal Armoring**
- 3. Sea Level Rise Effects**
- 4. Beach Nourishment**
- 5. Managed Retreat and Realignment**
- 6. Quick Tour through the shore**

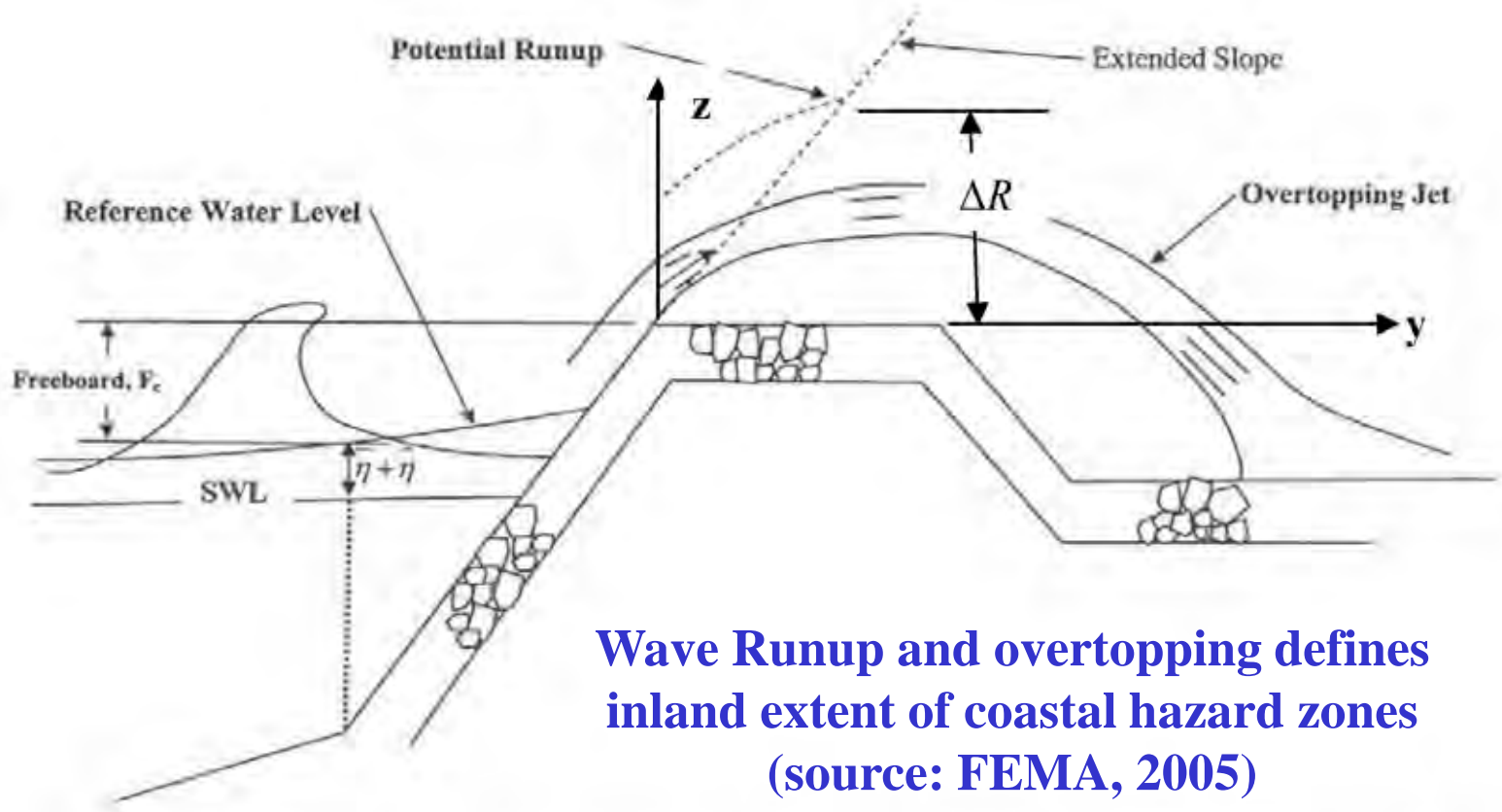
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# Coastal Flood Hazard Maps



**“100-yr” = the extreme that has a 1% chance of being exceeded in a year and has about 67% risk of being exceeded in 100 years**



**Figure D.4.5-13. Parameters Available for Mapping BFEs and Flood Hazard Zones**

**Table D.4.5-6. Overtopping Parameters Used in Hazard Zone Mapping**

Parameter	Variable	Units
Total potential runup elevation	$R$	ft
Mean overtopping rate	$q$	cfs/ft
Landward extent of green water and splash overtopping	$y_{G,Outer}$	ft
Depth of overtopping water at a distance $y$ landward of crest	$h(y)$	ft

# OVERTOPPING

Sharp Park Seawall, Pacifica, CA – Jan 11, 2001

Photos © Bob Battalio 2001



# Example Flood Hazard Mapping

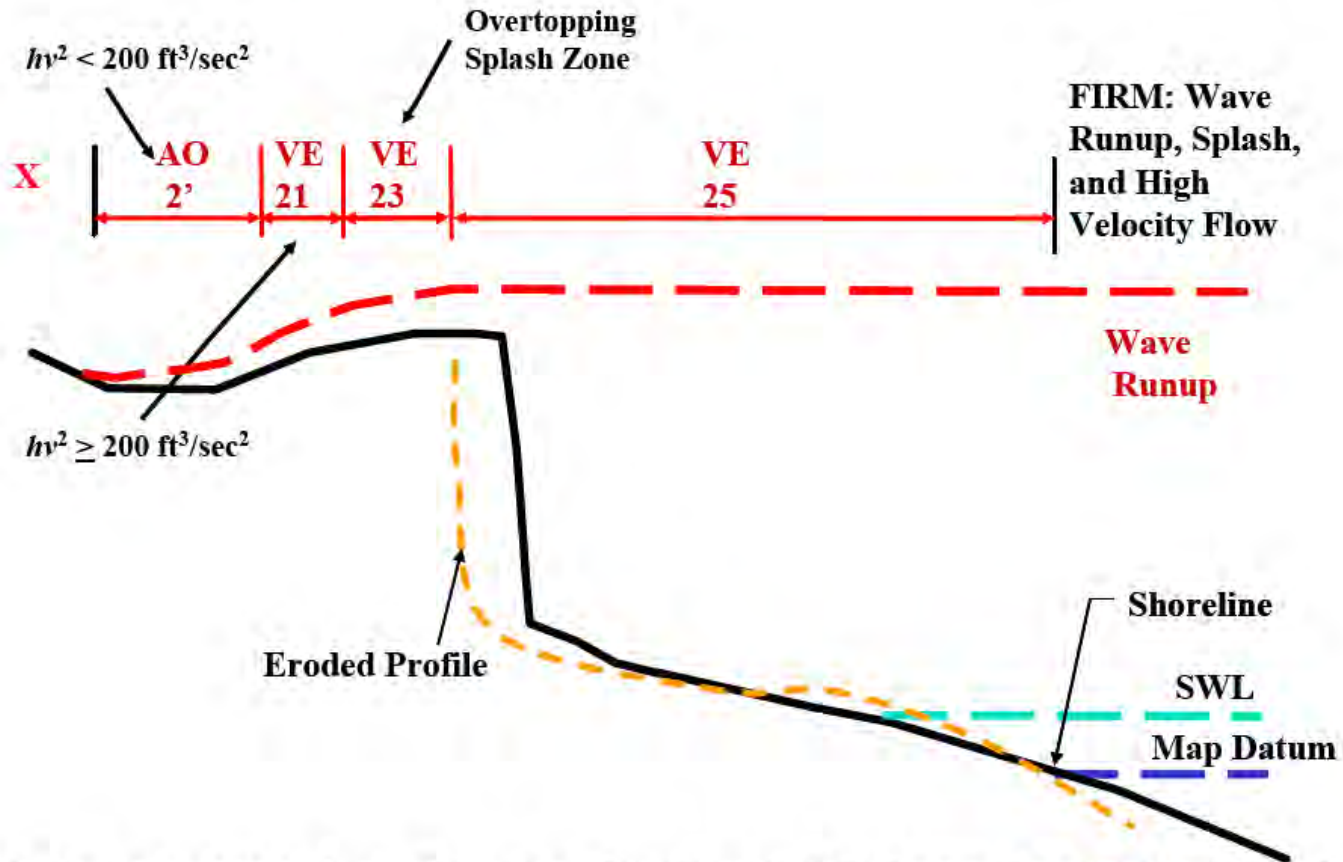


Figure D.4.9-5a. Erodible Low Coastal Bluff with VE Zone Controlled by Wave Runup, Overtopping Splash, and High-velocity Flow

# Sharp Park



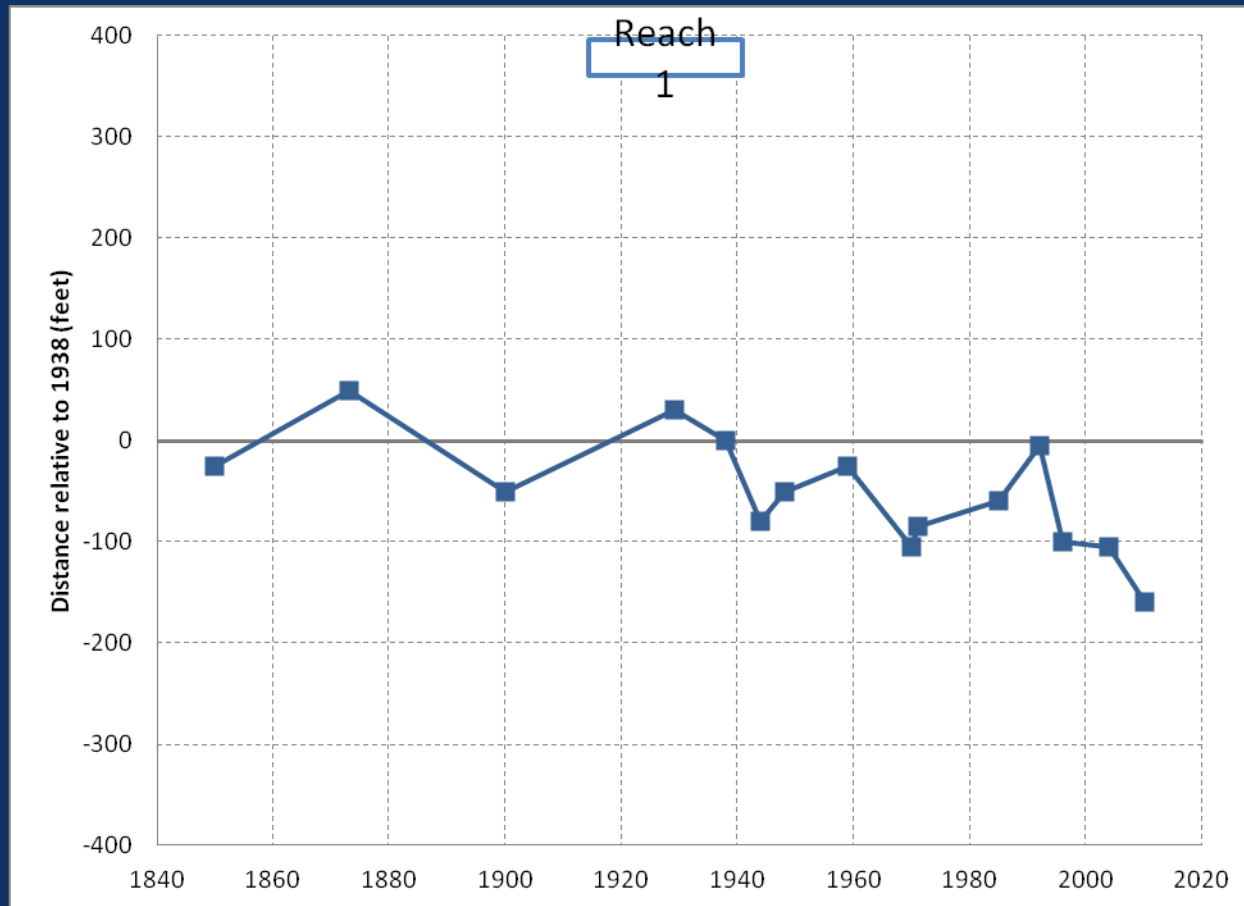
# +30' NAVD



Match line



# Historic Coastal Erosion



Historic shore position change time series for Fort Funston and southern portion of South Ocean Beach. Derived from Sources: ESA 2005, Battalio & Trivedi, 1996; January 2010 location added from January 28, 2010 survey.

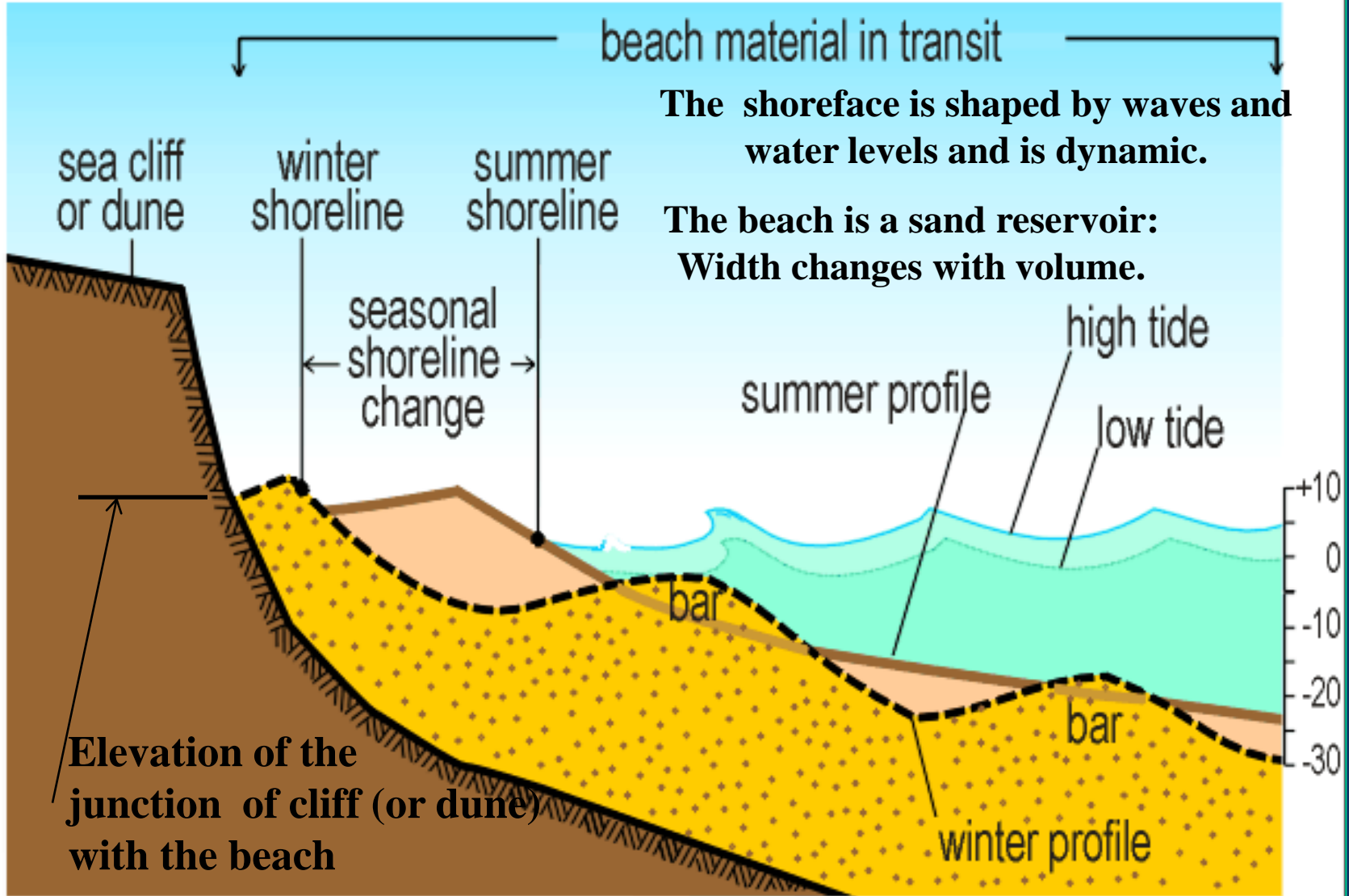
# Uplifted and Eroding

## Example – Daly City, CA

- Narrow beach backed by ~150 ft bluffs
- Merced Formation (fine to medium grained sand, weakly consolidated)
- Prone to large slumps and landslides
- Long-term erosion rate of 1.3-1.6 ft/yr
- Future erosion predicted to be 1.8-4.5 ft/yr, 3 ft/yr recommended for infrastructure setback



Source: PWA, 2008



beach material in transit

**The shoreface is shaped by waves and water levels and is dynamic.**

**The beach is a sand reservoir:  
Width changes with volume.**

**Elevation of the junction of cliff (or dune) with the beach**

# Conceptual Model of Bluff Erosion

**Soft Bluff = Bluff recedes rapidly, little change in toe elevation (relative to water levels)**

**Hard Bluff = Erosion potential increases at toe and fronting beach / rock; toe elevation decreases**

**Bluff Recedes**

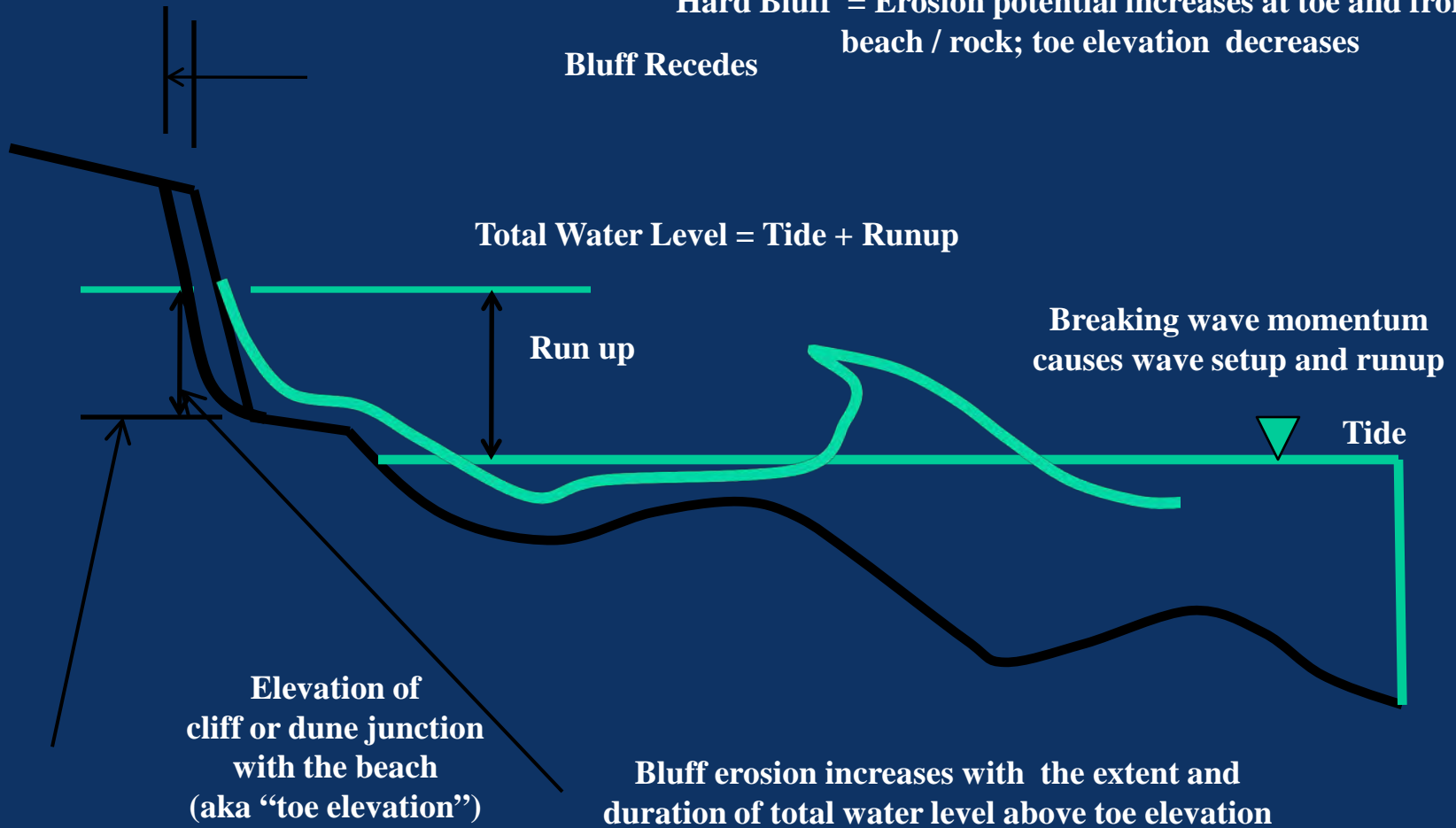




Figure 3. Oblique view of the Pacifica study area showing locations of observed cliffs. Cliff S2 was not observed for failures. Photo courtesy of the California Coastal Records Project.

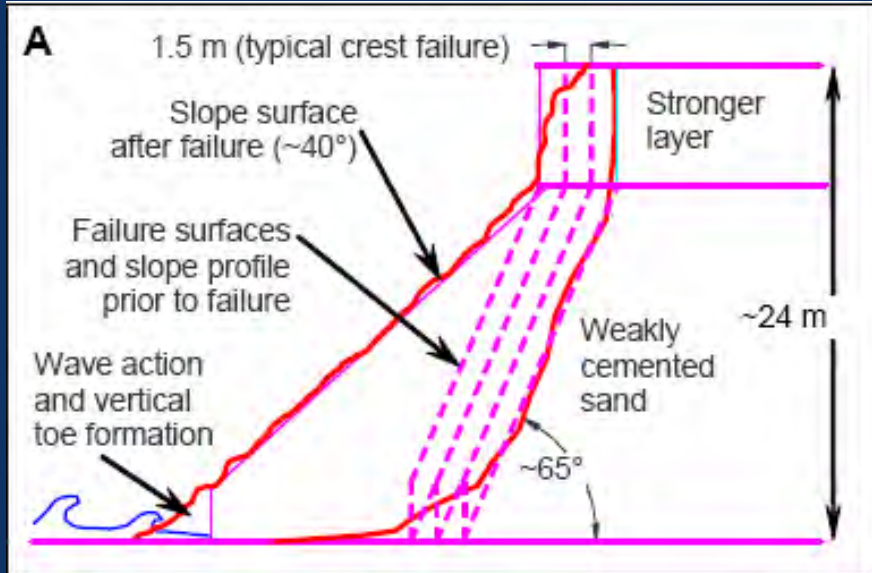


Figure 4. Schematic diagram (A) and photo (B) of weakly cemented coastal cliff failure mode. The failure surface is typically inclined at  $65^\circ$  to the horizontal.

andslides and Climate Change, Proc. Int. Conf. on Landslides and Climate Change, Isle of Wight, UK, May 2007, pp 175-184.

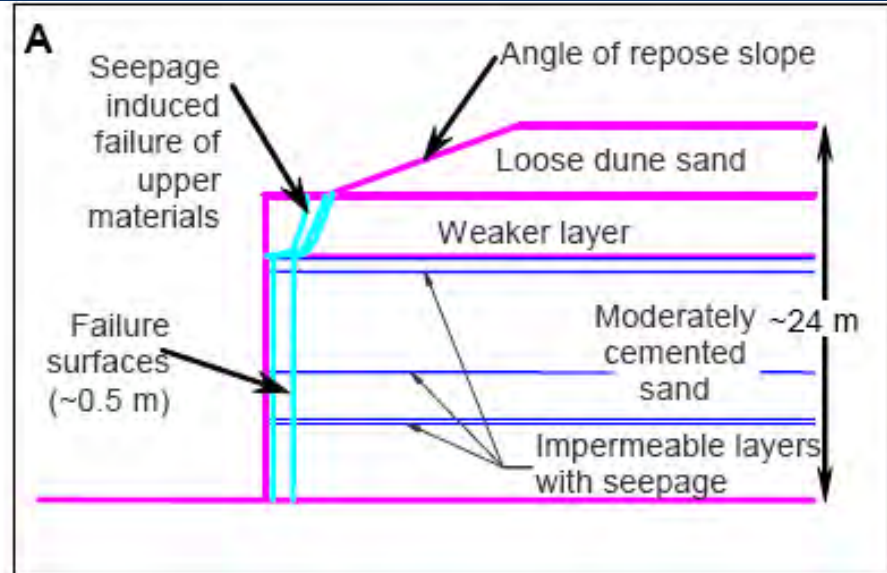
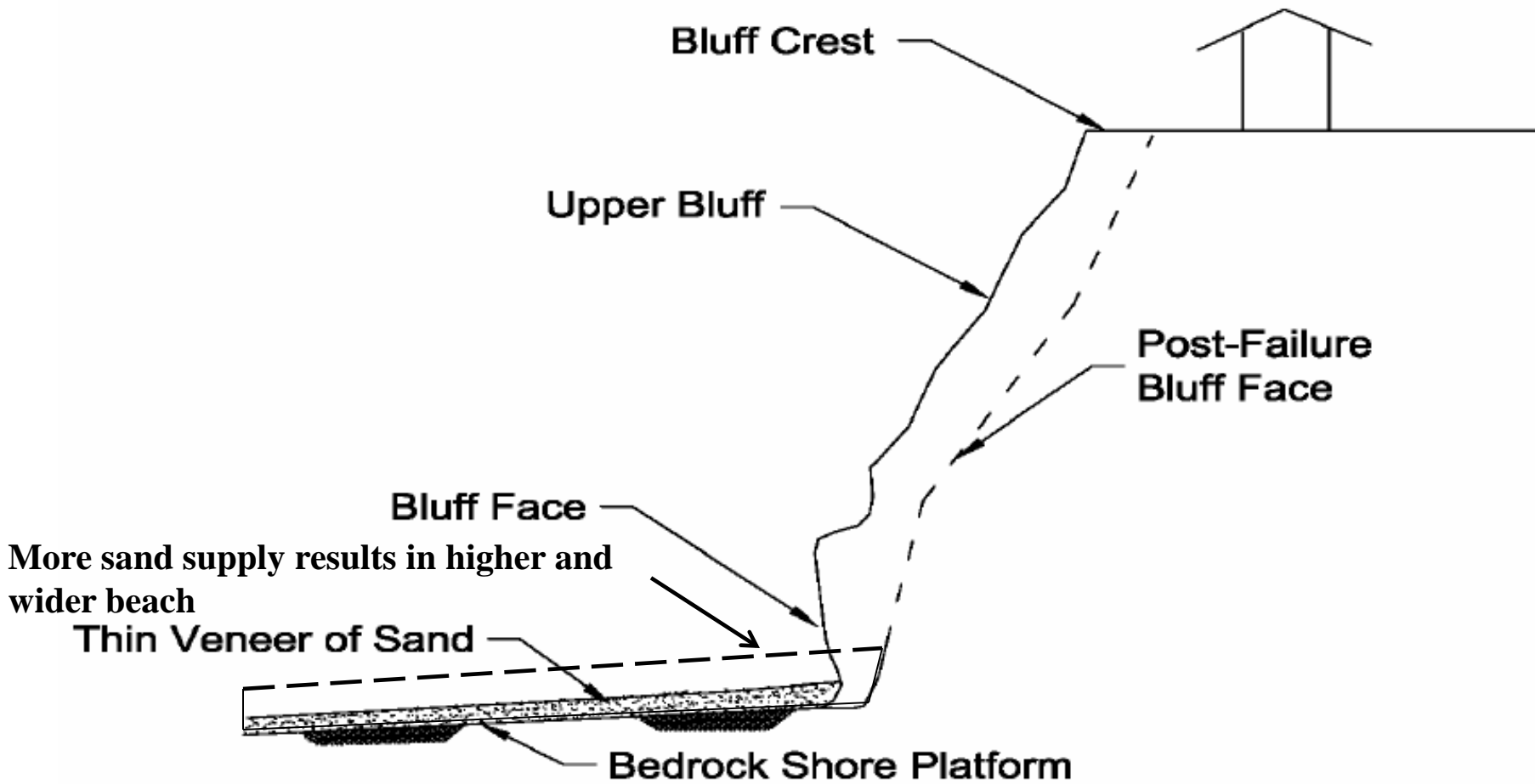


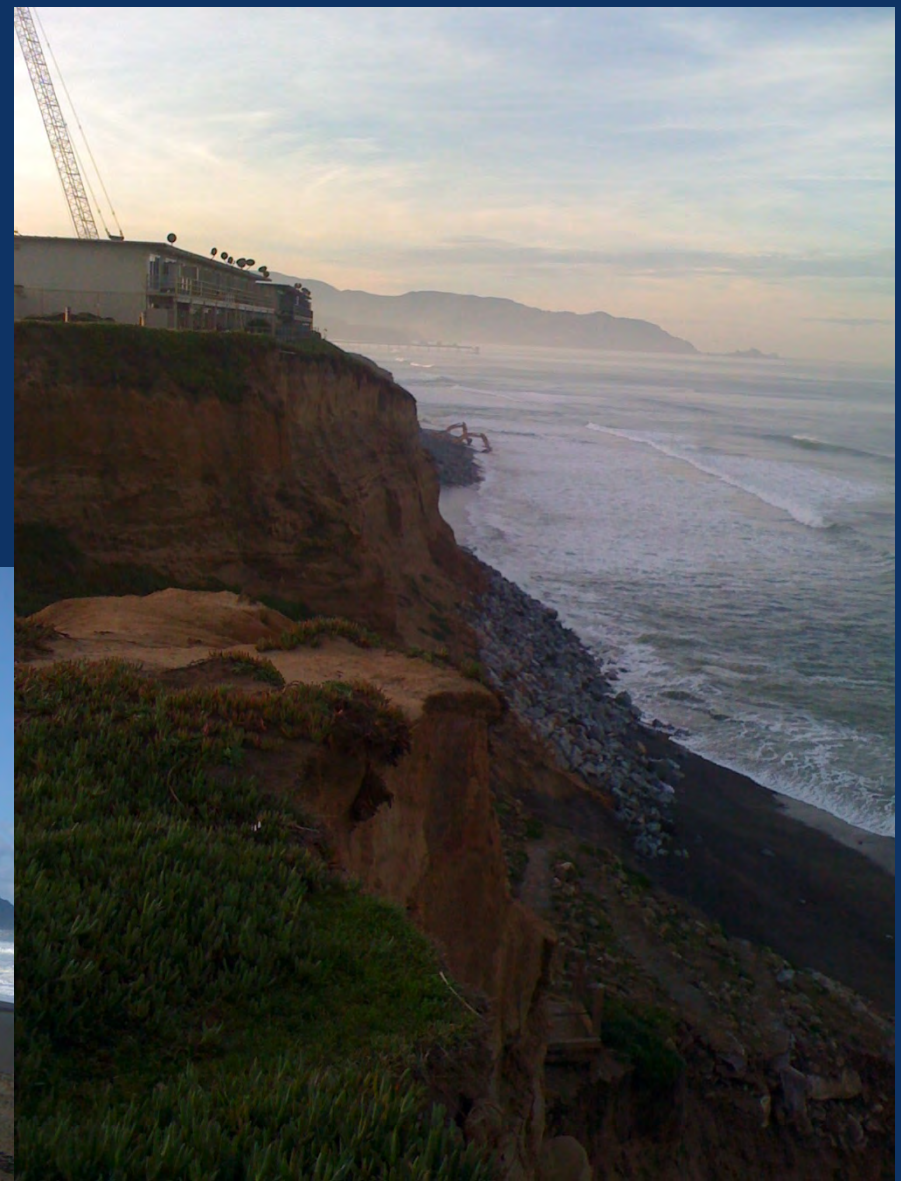
Figure 5. Schematic diagram (A) and photo (B) of moderately cemented coastal cliff failure mode. The failure surface is typically near-vertical.



**Figure D.4.6-31. Typical Erodible Bluff Profile Fronted by Narrow Sand-capped Beach**

Source: FEMA, Guidelines for Pacific Coast Flood Studies, 2005

**In January, 2010, emergency seawall construction was underway in Manor while the beach accreted in south Sharp Park during large long period westerly swells !**






# Accreted Sediments Sharp Park

## Winter 2010

Photograph © Bob Battalio 2010







**Accreted  
Sediments  
Sharp  
Park  
March 18,  
2010**

Photograph © Bob Battalio 2010

# Sand transport and beach width

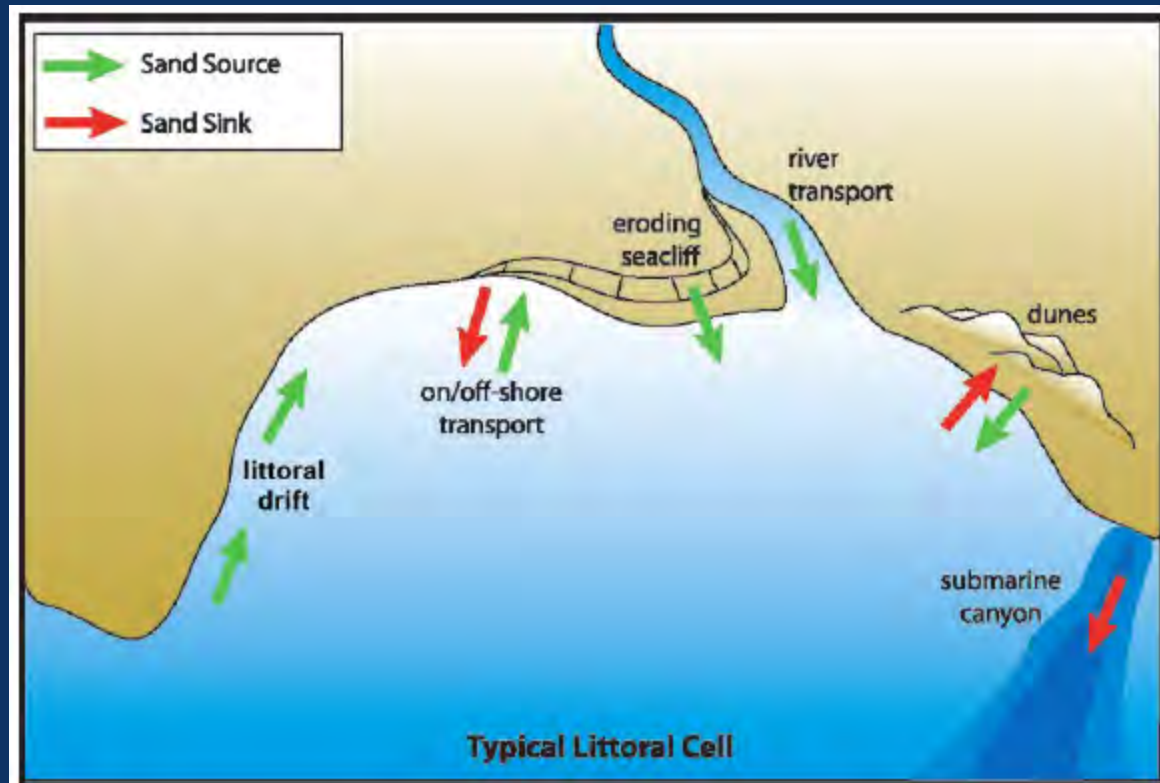


Fig 1.6: Schematic of the principal components that commonly are involved in a sand budget for littoral cells in California (modified from Komar 1996)



**Golden Gate  
Cell**

**San Francisco**

**Ocean Beach**

**SAF**

**Daly City**

**Mussel Point**

**Pacifica  
Cell**

Source: Collins,  
Kayen and Sitar,  
2007

**Study area  
~1.5 km**

**Pacifica**

**Pacific  
Ocean**



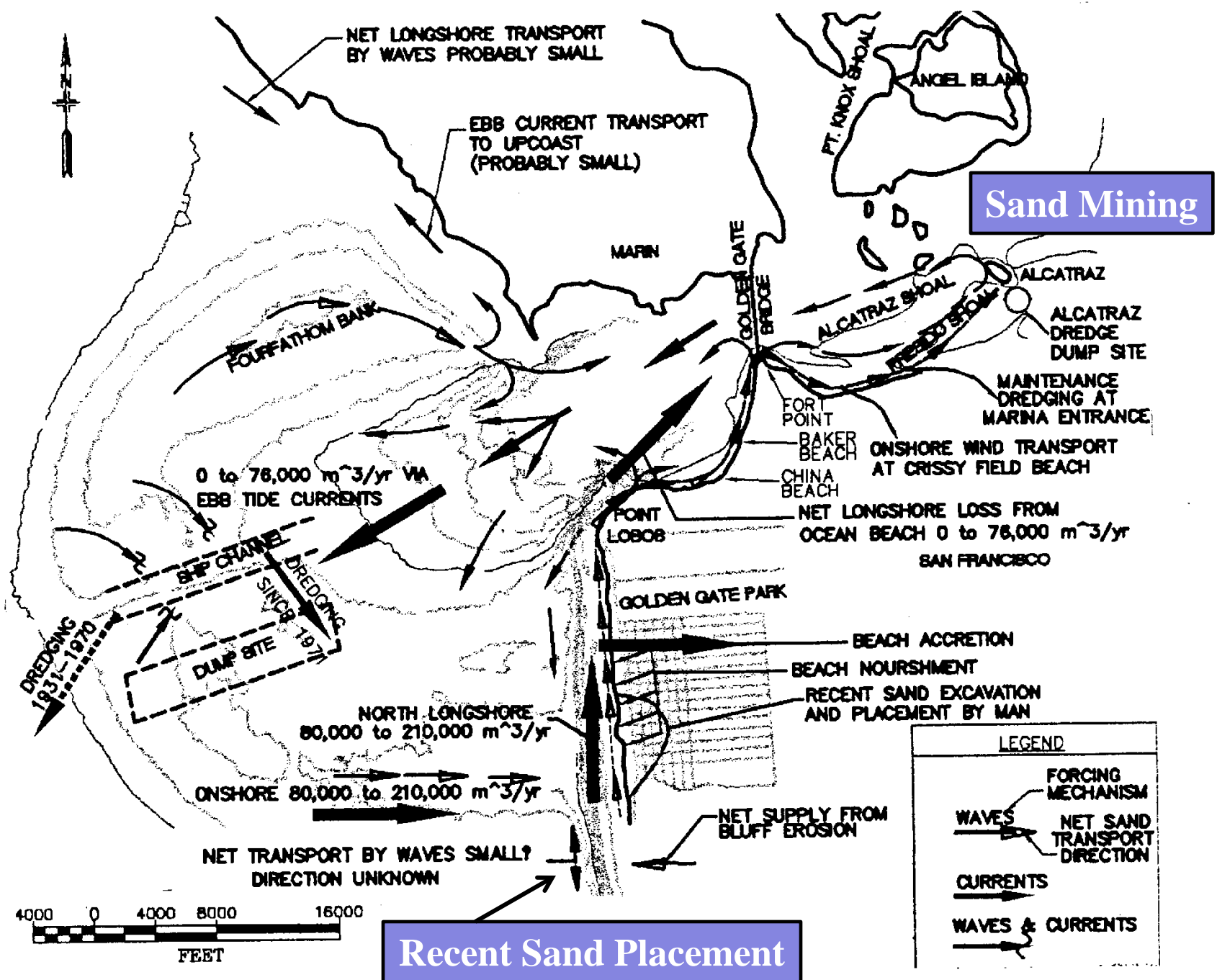
**Golden Gate  
Littoral  
Sub Cell**

**Pacifica  
Littoral  
Sub Cell**



**BUT, coarse  
sediment supplied  
by headland  
erosion in Pacifica  
migrates onshore**

**The San Francisco Littoral Cell includes several subcells;  
This study address coarse sediment on the Pacific Coast**

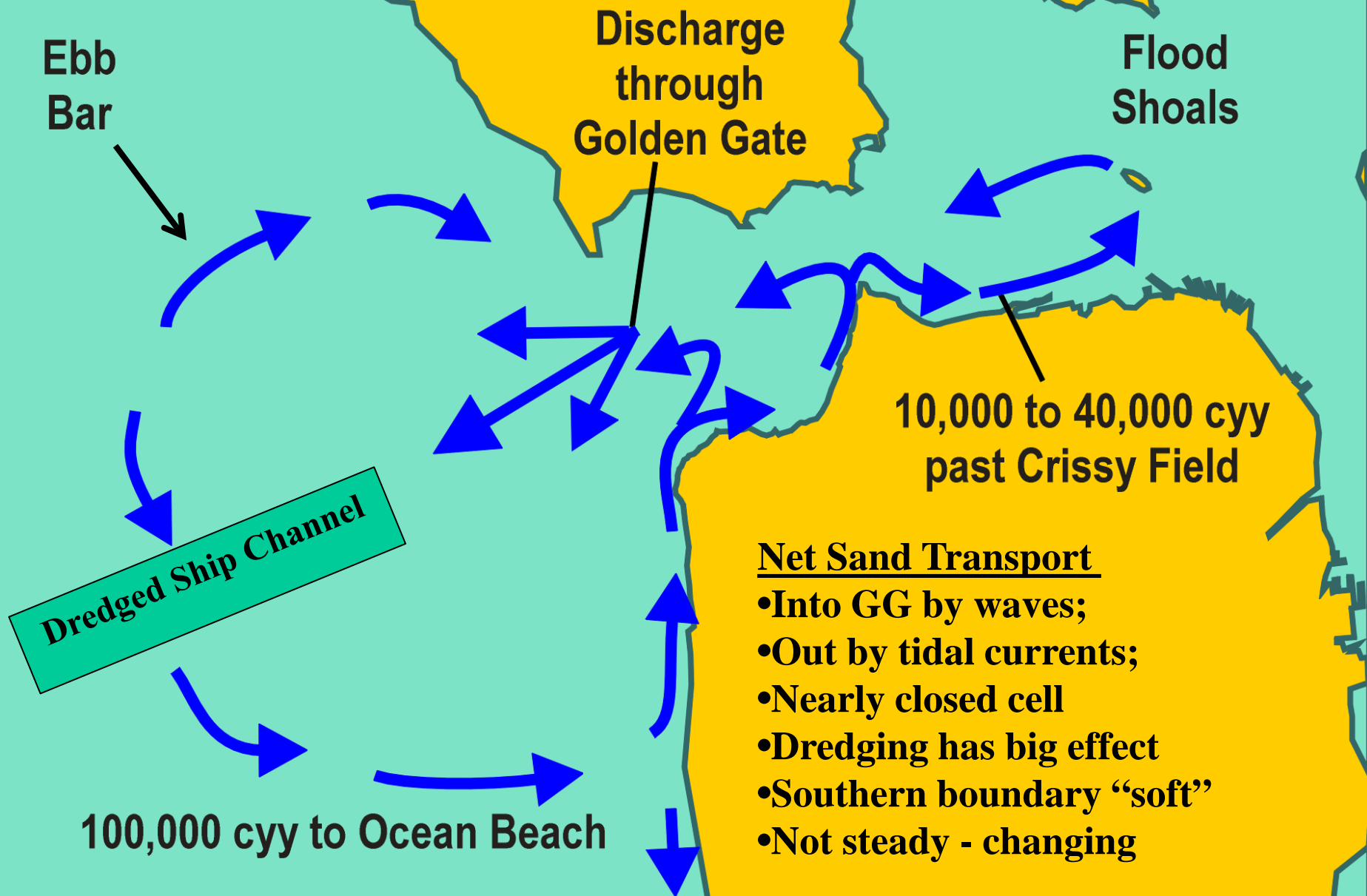


**Sand Mining**

**Recent Sand Placement**

Residual Sediment Transport at Ocean Beach

# Golden Gate Littoral Cell







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## **Potential Seawall Effects on Eroding Shore**

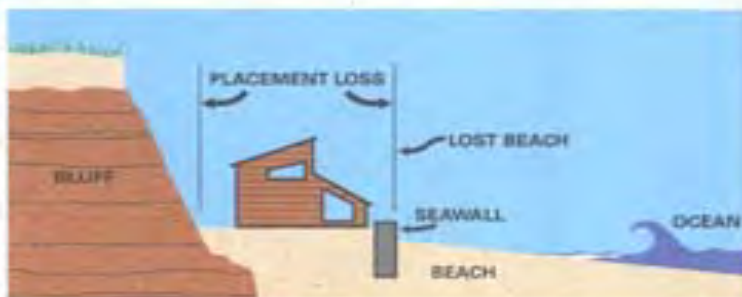
- 1. Reduction of erosion behind the structure.**
- 2. Placement losses of near shore area.**
- 3. Passive erosion of near shore.**
- 4. Active erosion of near shore.**
  - Reduction of sediment supply**
  - Increased wave reflection**
  - Increased local scour**
  - Accelerated currents and sand transport**
- 5. Unnatural Surface**
- 6. Change in appearance**

## Seawall Impacts: Placement Loss and Passive Erosion

### Placement Loss



A. Beach without any coastal shore protection



B. Placement loss of beach due to construction of seawall and house



C. Placement loss of beach due to construction of a rip-rap seawall

### Passive Erosion



A. Initial shoreline showing beach width



B. Shoreline after sea level rise & associated dune or bluff erosion, although the shoreline has moved landward, the beach width remains the same



C. Shoreline after sea level rise where seawall has fixed shoreline position, note reduced beach width

# Coastal Armoring Effects

Shoreline armoring on an eroding shore results in loss of intertidal landform such as beaches.

Example: Officer's Club, Fort Ord, Monterey Bay, CA showing beach recovery after armoring removed and back beach erosion.



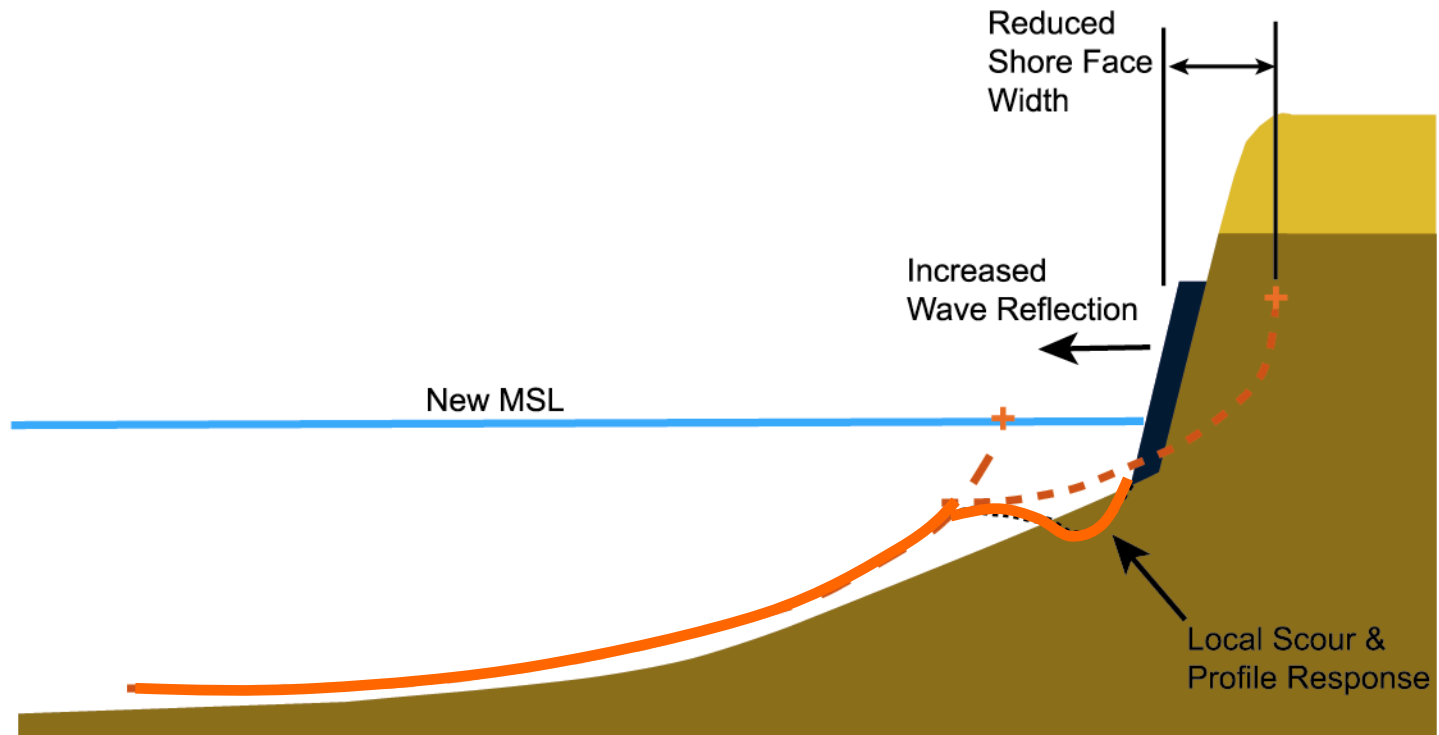
2002

Source: California Coastal Records Project



2005

# Long Term Shore Morphology Changes With Armoring (Eroding Shore)



## Beach Blvd Seawall soon after construction



Photograph 6. Recently constructed reinforced earth seawall with armor stone toe protection. This wall extends along Beach Boulevard north of the Fishing Pier in Pacifica (August 1985).

# Our Children's future ?



Photo copyright Bob Battalio

Beach Blvd Seawall, winter high tide conditions











## Wave Warning

### Editor:

I would like to take a moment to reiterate the warning about watching the waves along the sea wall. On 1/2/06 while standing on Beach Boulevard, I was hit by a massive wave that blew over the sea wall near the Pacific Pier.

I was under water for several seconds and, when I was finally able to breathe and open my eyes again, was completely stunned to find myself sitting on the floor near the back of someone's garage with my arm hooked through a barbeque pit. I was extremely fortunate to not have sustained major head and neck injuries, been impaled on something, crushed against the bumper of a car, or killed.

Thinking back on the two days prior to this incident when I watched people

with their young children enjoying the beauty of our ocean during high tide at this location, I shake with fear.

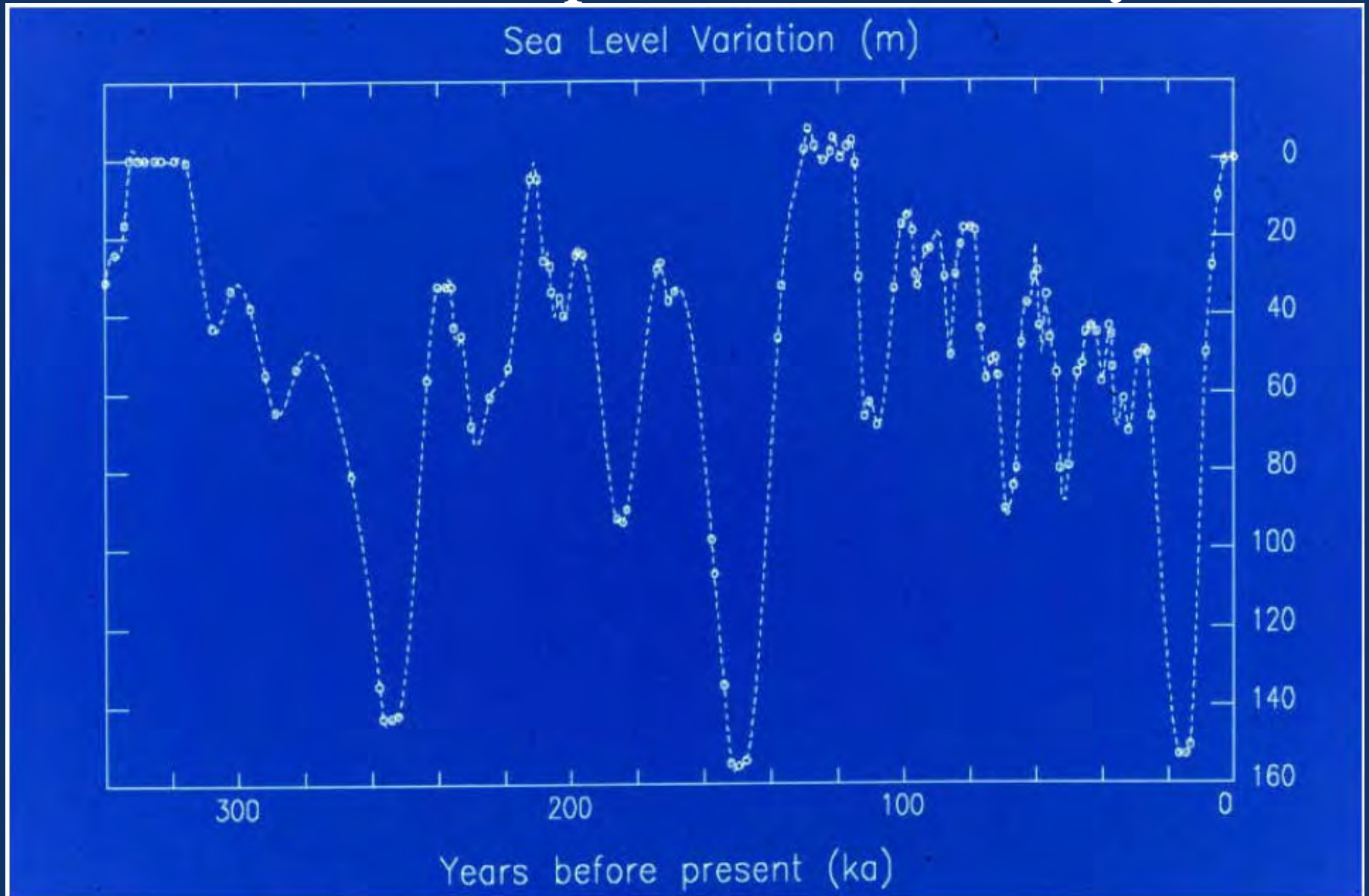
PLEASE be mindful of the powerful force behind that beauty and take extreme caution with your children and yourselves. Had it been a child in my shoes that day, I'm certain they would not have fared the situation as well as I did. I wasn't taken away in an ambulance but have had several visits to my doctor and now, two weeks later, still have residual pain because of my injuries. I would also like to take this opportunity to send a great big thanks to the gentlemen that came running after me and assisted me out of the garage. I really appreciate your help. Hopefully you won't be repeating this sort of rescue with others any time soon. THANK YOU!

Anjanette Stutes  
Sharp Park

# OUTLINE

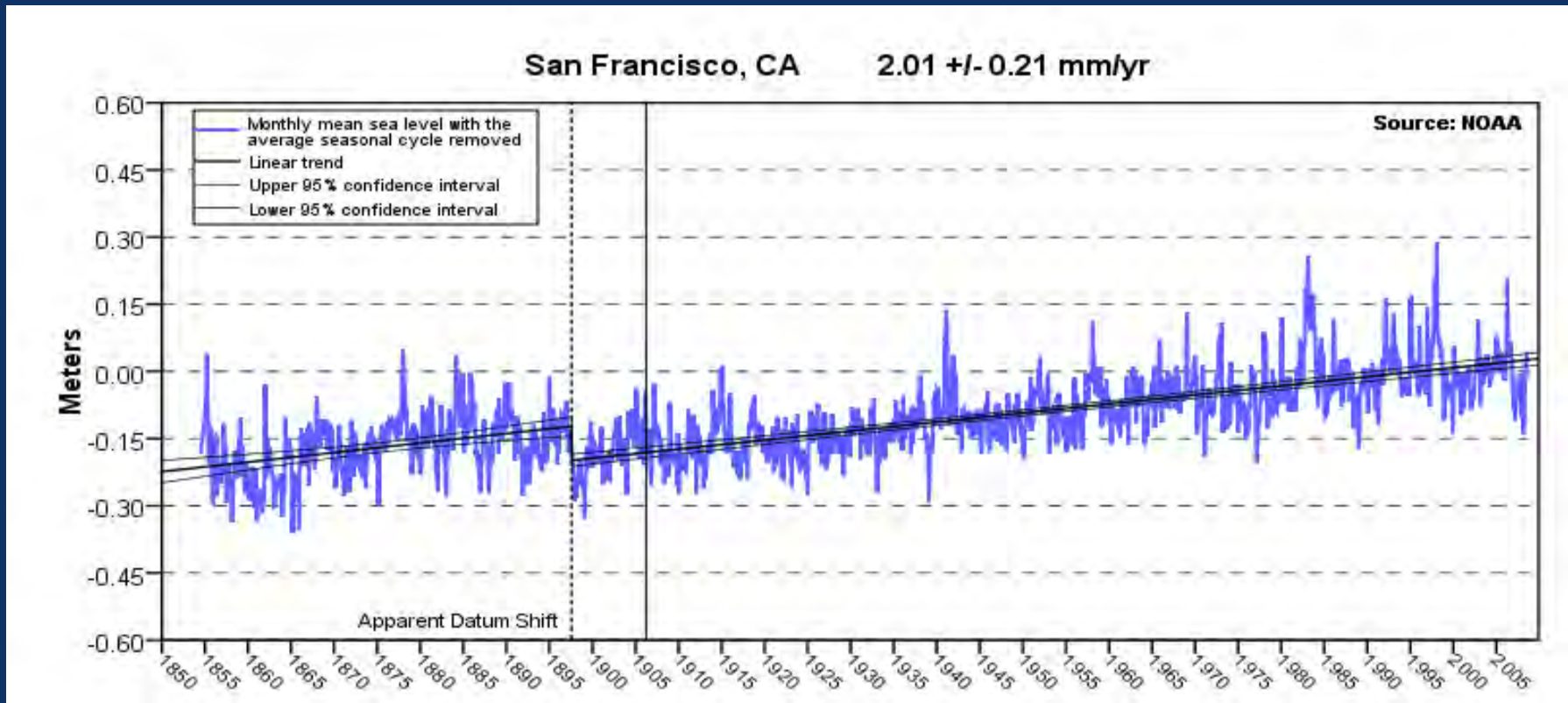
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# Sea level - the past 300 thousand years



# Sea level rise – the past century

Global average: 7 inches in the 20<sup>th</sup> century



# Accelerated Sea Level Rise Predictions

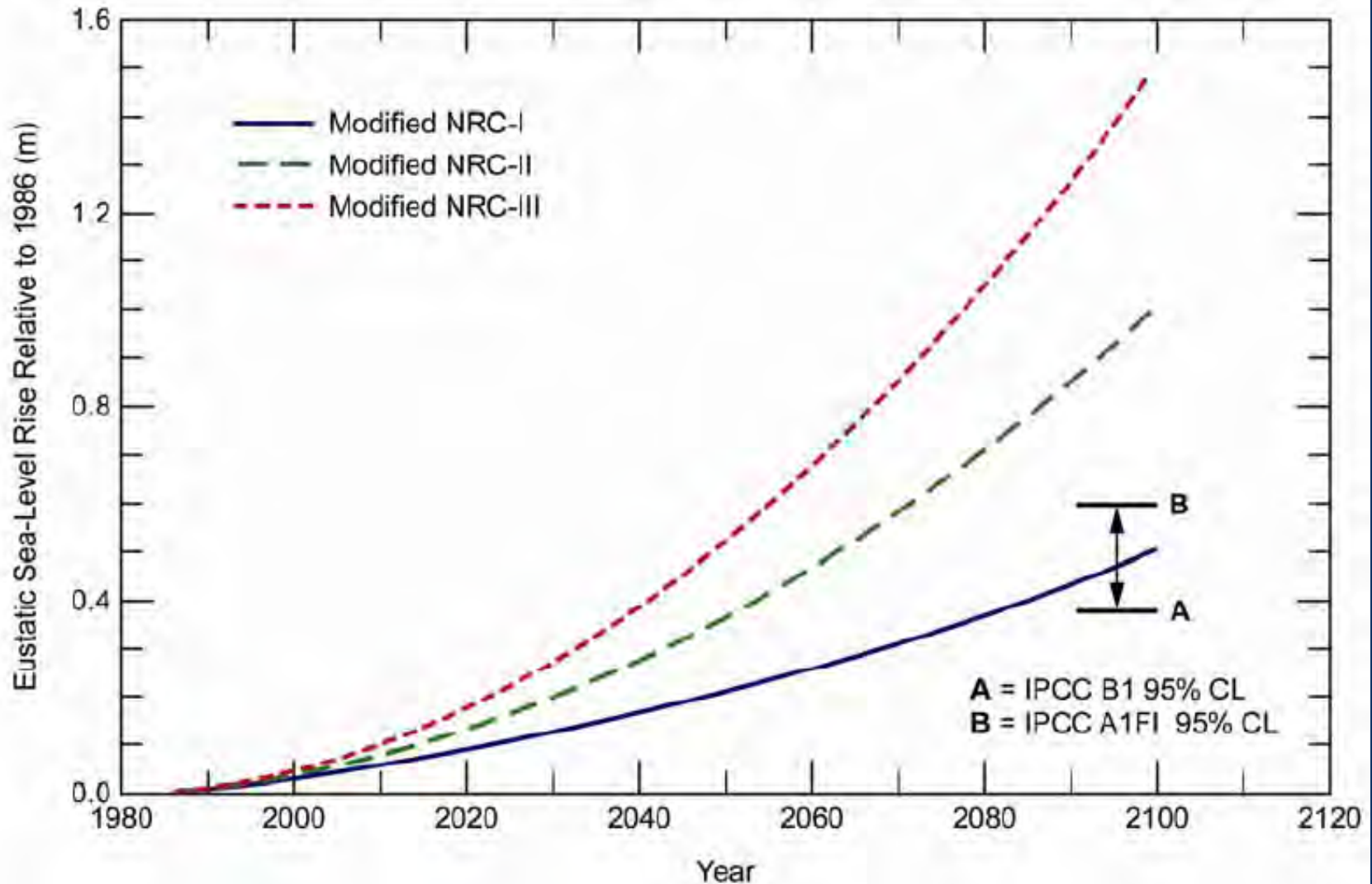


Figure B-11. Modified NRC (1987) eustatic sea-level rise scenarios and the IPCC (2007) scenario estimates for use in predicting future sea-level change.



# Risk - Mapping Erosion Hazards

## Total Water Levels

- Sea Level Rise
- Tides
- Wave Run-up
- Storm Surge
- El Ninos

Exceeds



Elevation of the  
Toe of Cliff or Dune

Causes



## Erosion Response

- Backshore Type
- Geology
- Failure Mechanism
- Shoreline Change



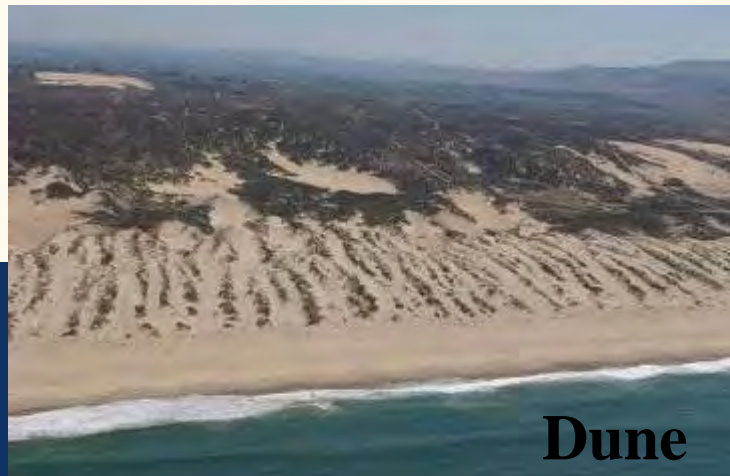
## Climate Change

- Sea Level Rise
- Wave Climate

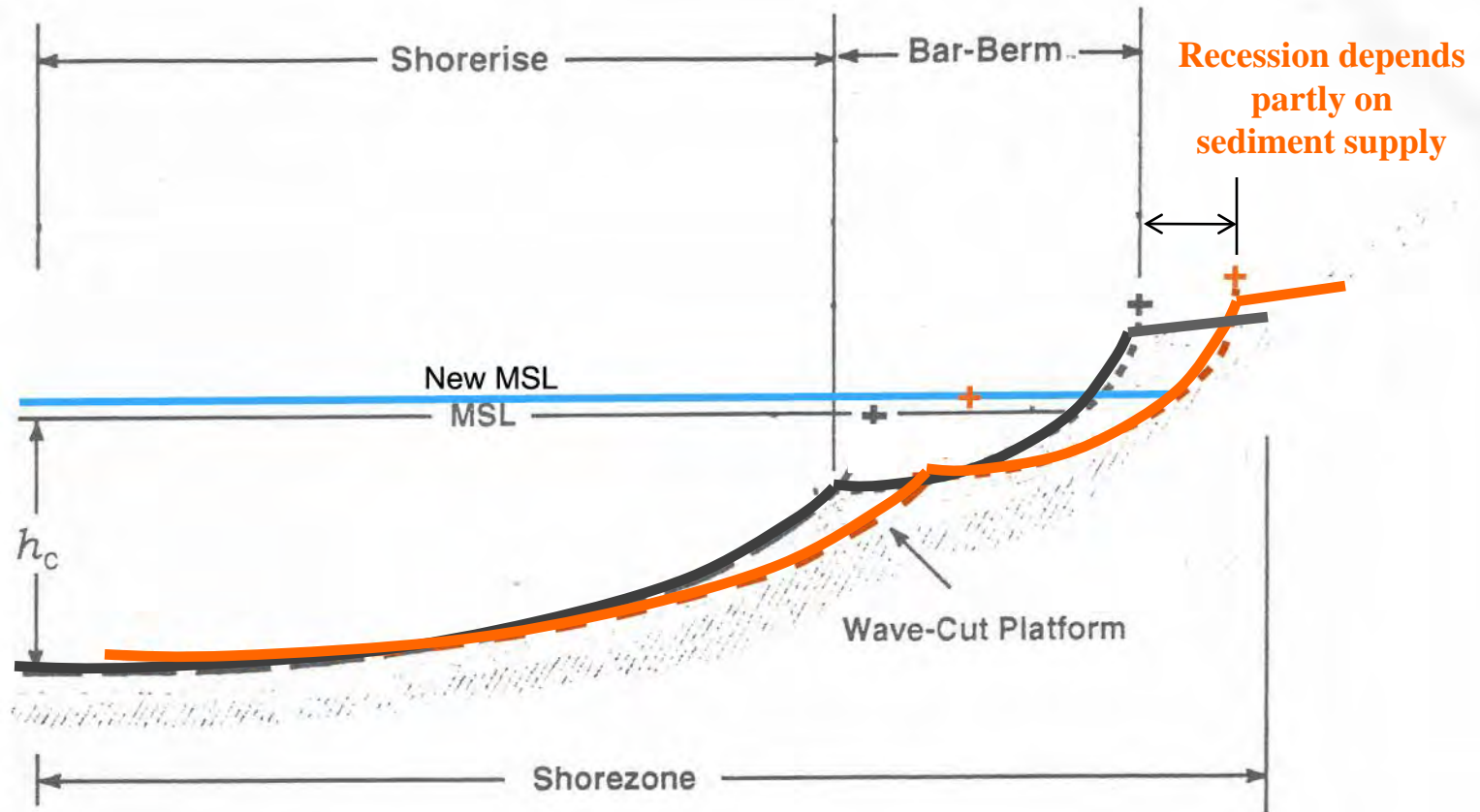


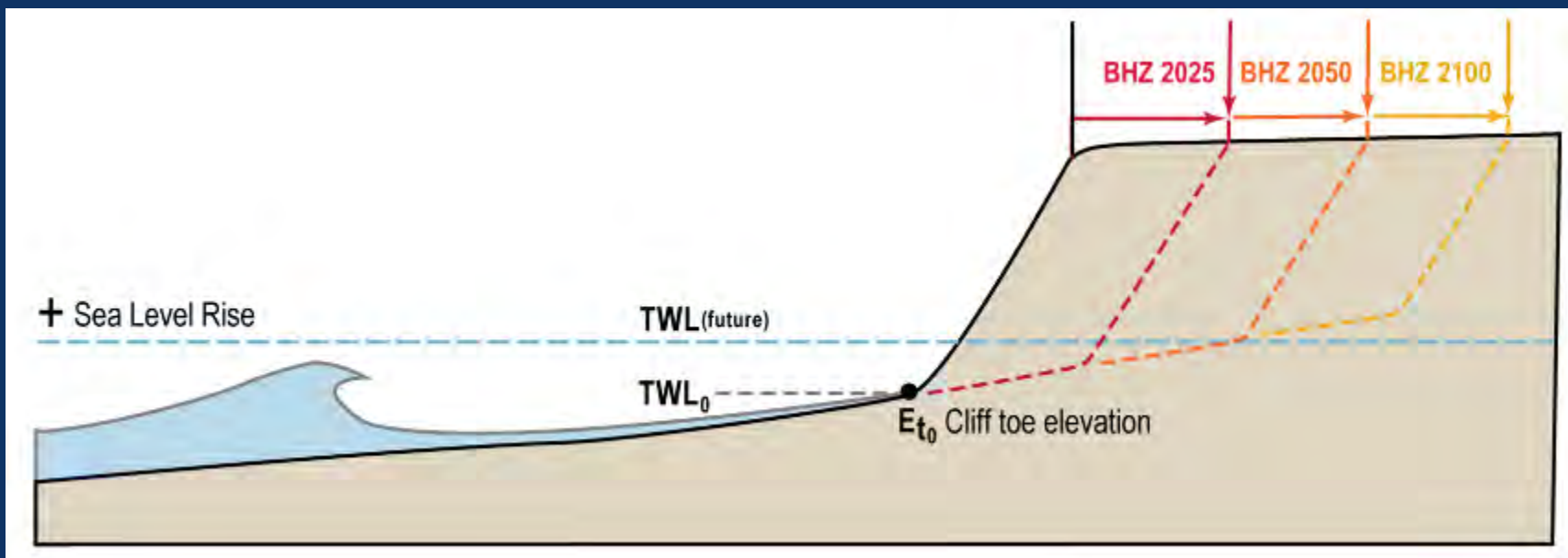
## Shore Change

- Accelerated Erosion
- Inland Migration of Shore
- Loss of Upland



# Shore Recession Resulting from Sea Level Rise



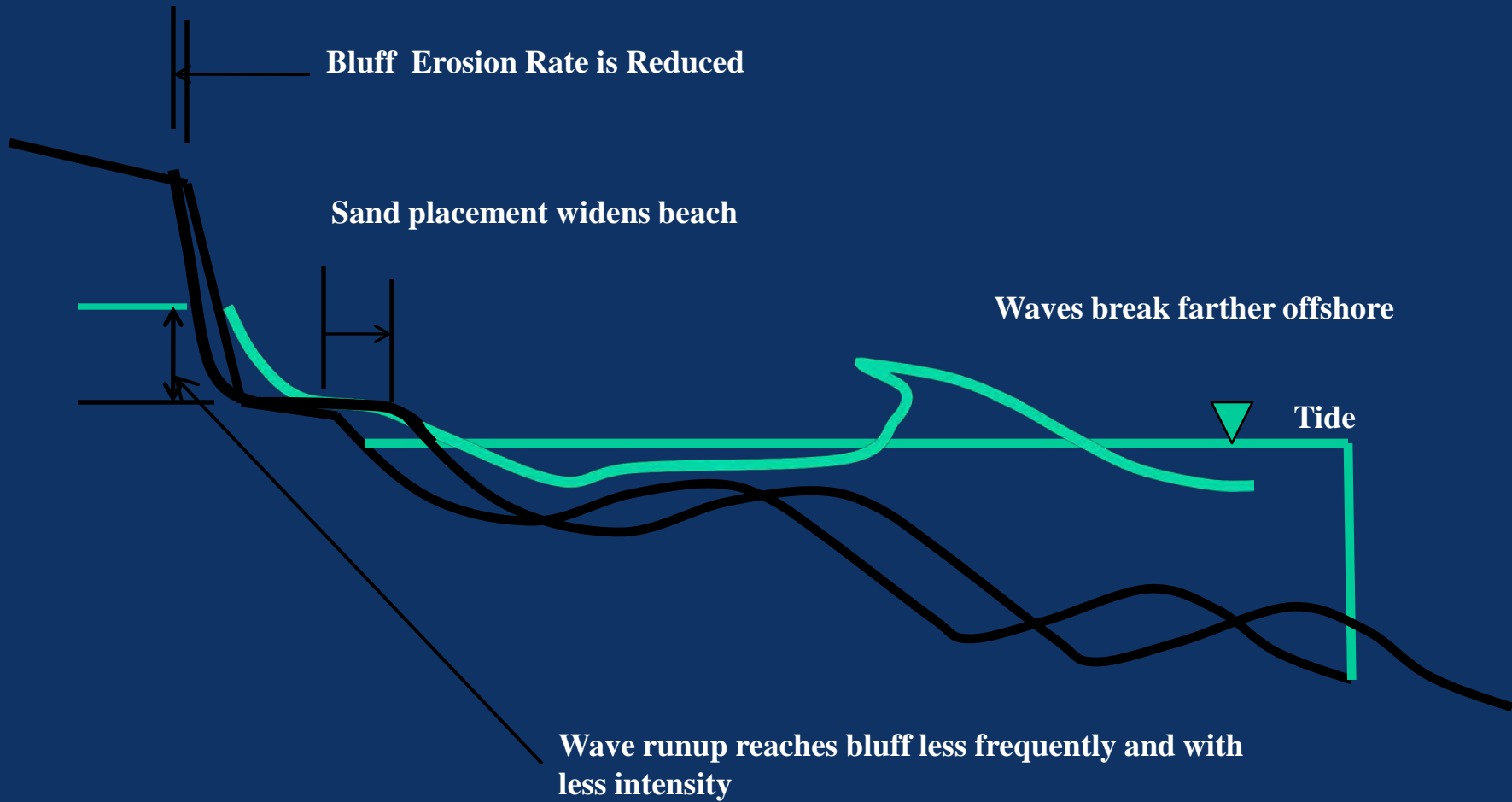


- Acceleration of historic erosion rates ( $R_h$ )
- Prorated based on % increase in TWL exceeding the elevation of the toe of the beach/cliff junction
- Include geologic unit standard deviation x planning horizon to account for alongshore variability

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# Conceptual Model of Beach Nourishment



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# 1. Pacifica State Beach (Linda Mar), Pacifica

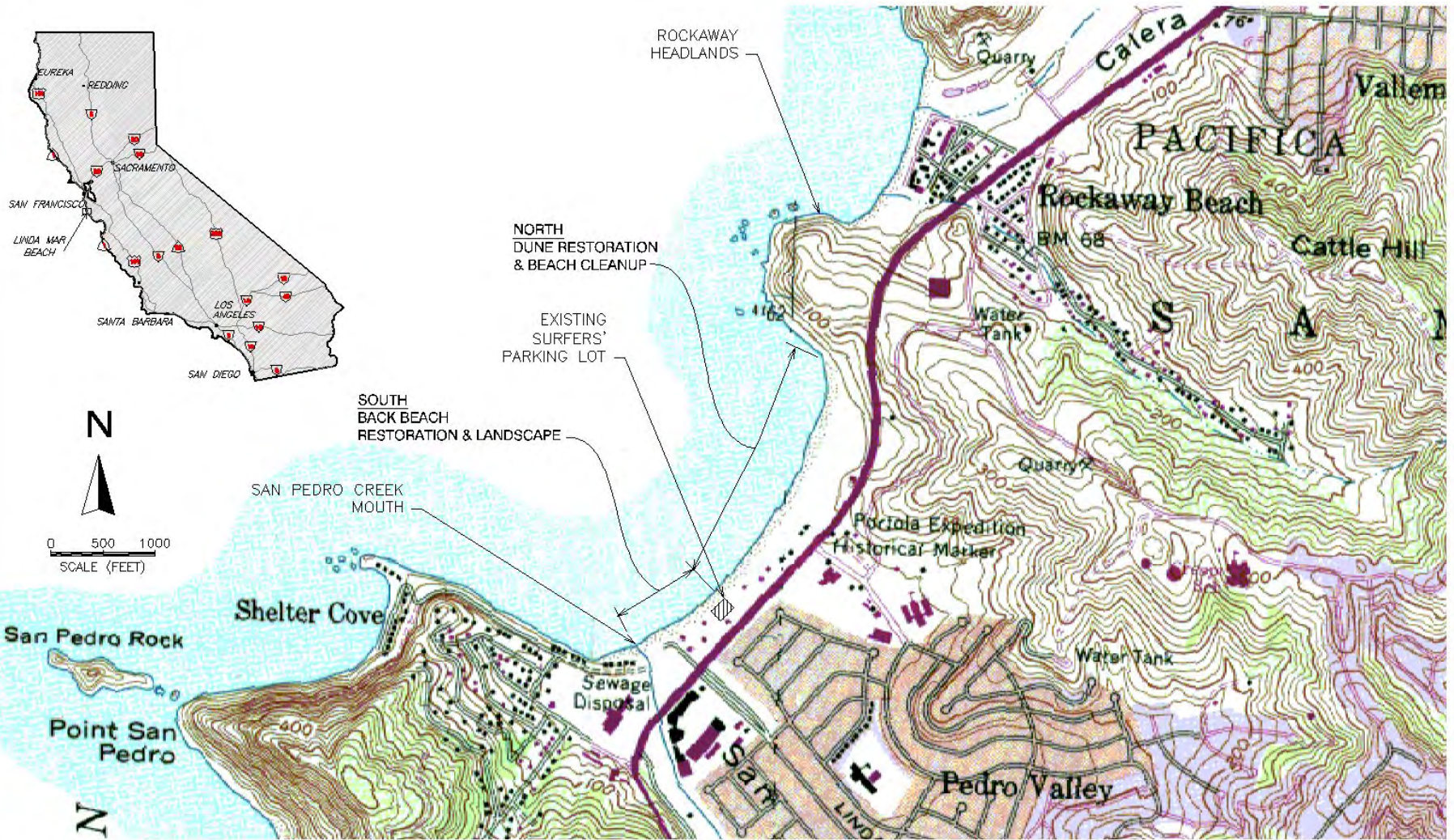


figure 1

## ASBPA Best Restored Beaches 2005

Vicinity Map  
Linda Mar Beach

0:\Projects\1547\_Pacifica\FIGURE1.dwg

2009

**Pacifica State Beach  
Managed  
Retreat Project**

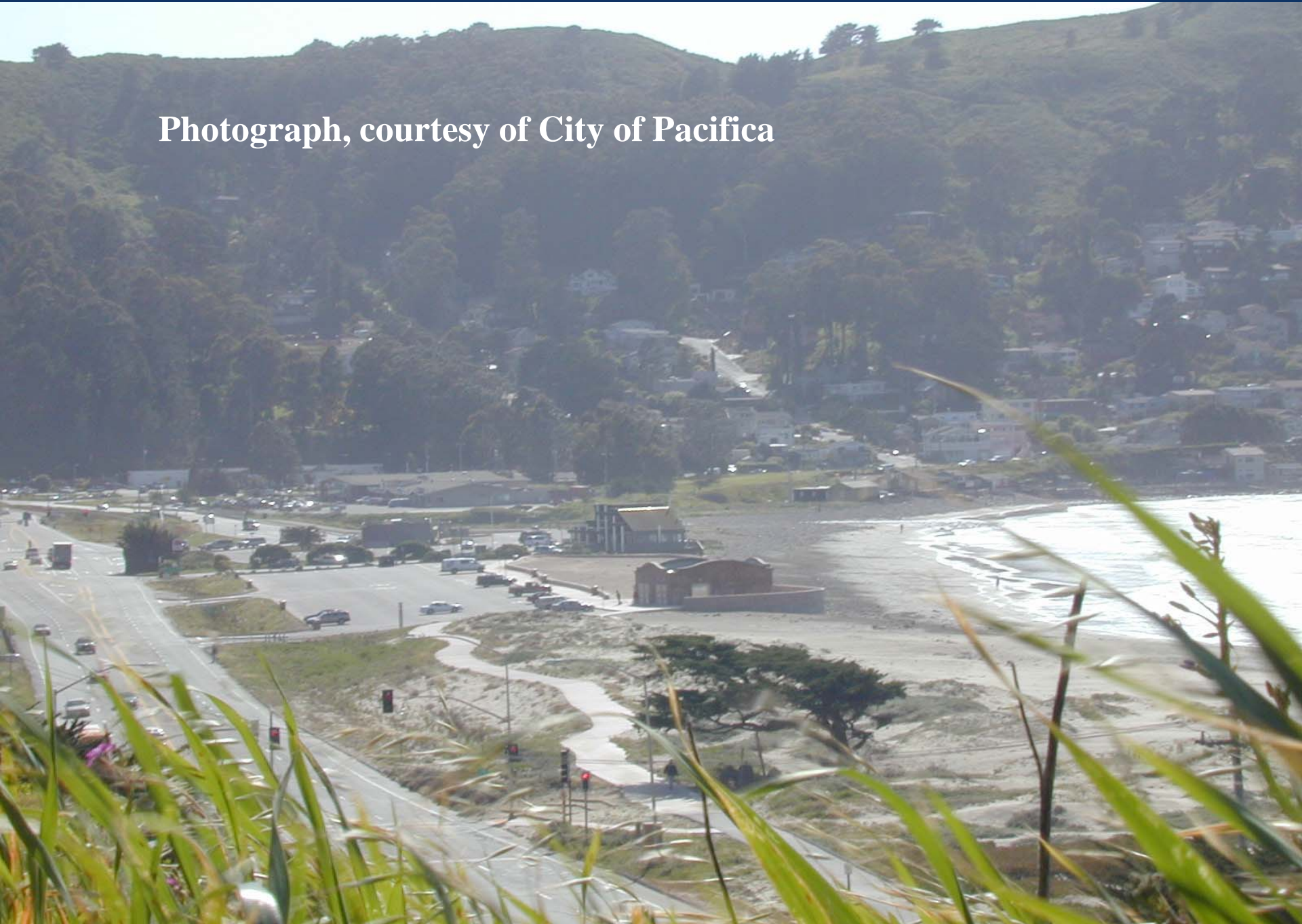


2004



# 1. Pacifica State Beach, April 15, 2005, Post Construction of Managed Retreat Project

Photograph, courtesy of City of Pacifica





**09-8270-11\_San\_Pedro/ San  
Pedro creek and wetland  
restoration area**

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# Daly City, Fort Funston, Lake Merced, Ocean Beach



**Photos: DEBORAH LATTIMORE**



# Fort Funston and municipal sewer outfalls













Circa early 1960's



**09-8173-11\_Thornton\_Beach/  
Former paved highway, slumped  
and undercut by coastal erosion  
and failed cliffs, Thornton Beach,  
Daly City, CA  
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**09-8186,7-11\_Northridge\_Bluff/ Northridge Bluff slide area, from Korean church parking lot, Daly City, CA  
Do Not Reproduce: © Bobbe' Christopherson, All Rights Reserved.**





**Landslide at Daly City, North of Mussel Rock**

# Top of the Cliff in Daly City



Chronicle / Kendra Luck



Chronicle / Kendra Luck



**09-8206-11\_Mussel\_Rock/ Mussel Rock  
slide area, concret foundation pillars  
are all that remain of a home destroyed  
by a massive slide, Daly City, CA**

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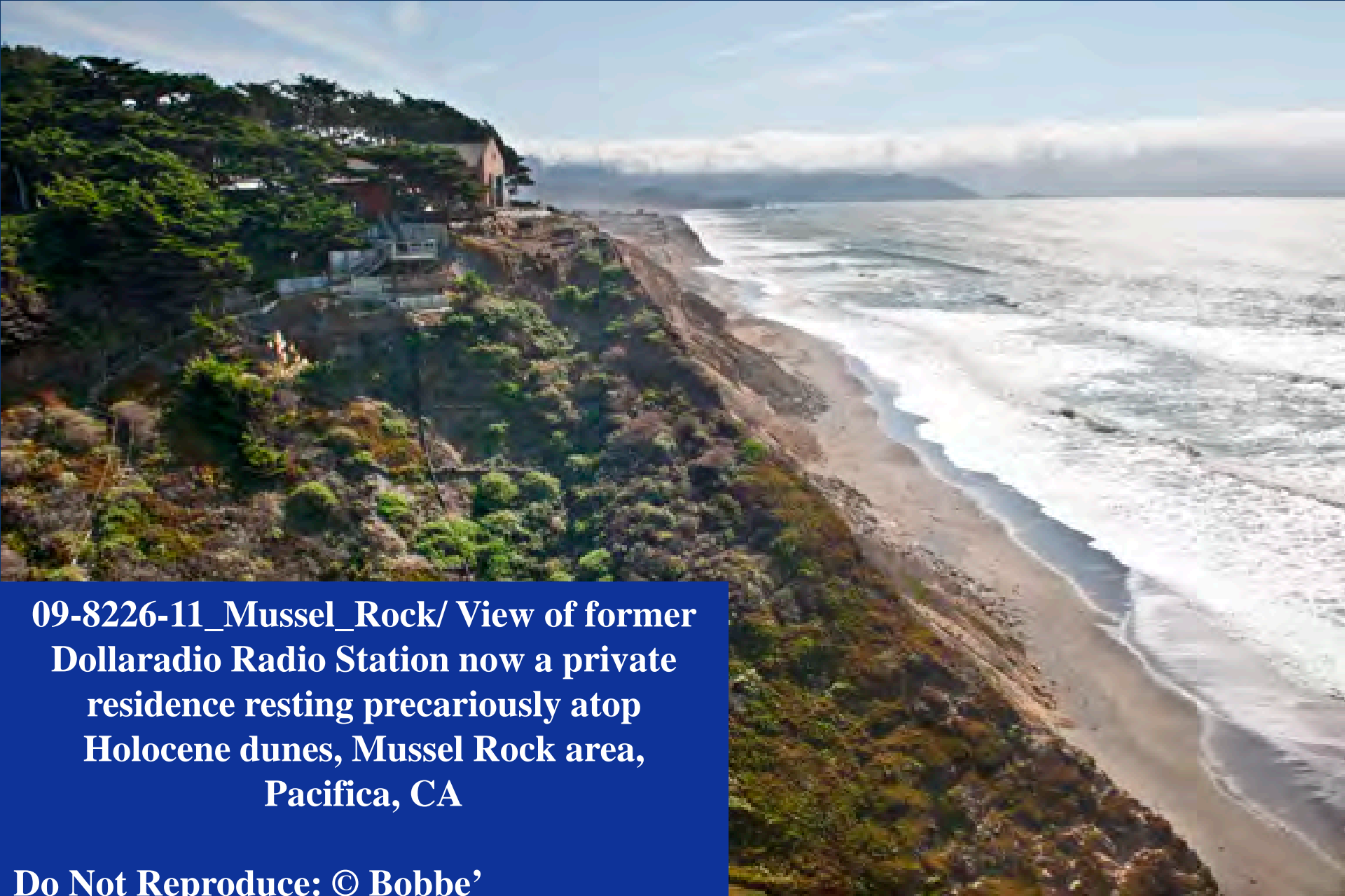
# Sharp Park, Manor, Mussel Point



Photos: DEBORAH LATTIMORE





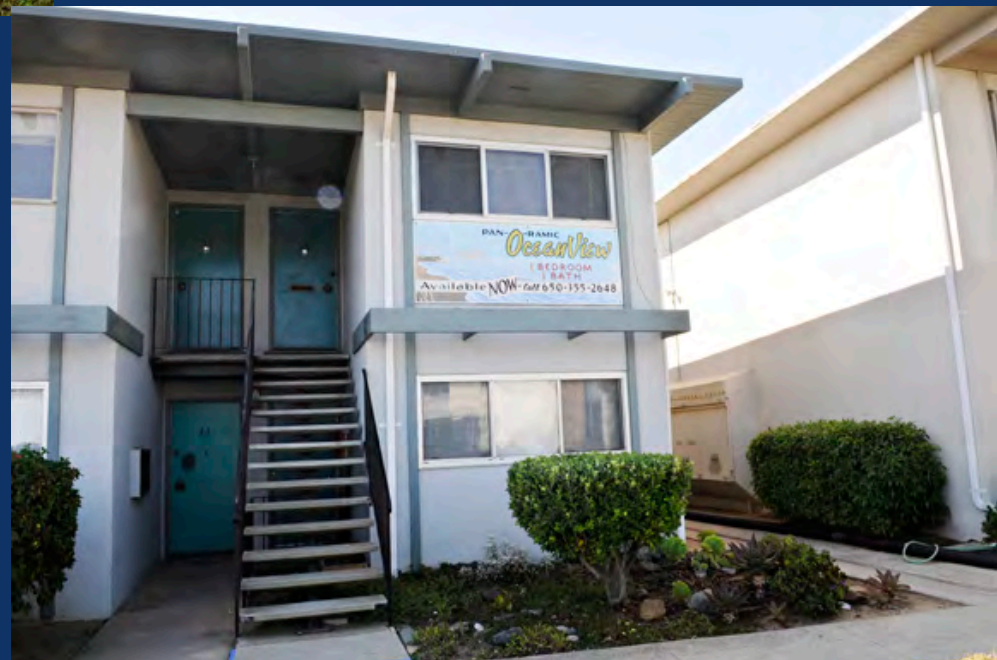


**09-8226-11\_Mussel\_Rock/ View of former  
Dollaradio Radio Station now a private  
residence resting precariously atop  
Holocene dunes, Mussel Rock area,  
Pacifica, CA**

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**09-8242-11\_OceanViewApts/ Sept.  
2011, Pacifica, CA  
Do Not Reproduce: © Bobbe'  
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Layers and seeps; Manor Bluffs, Pacifica Aug 2010 © Bob Battalio, 2010

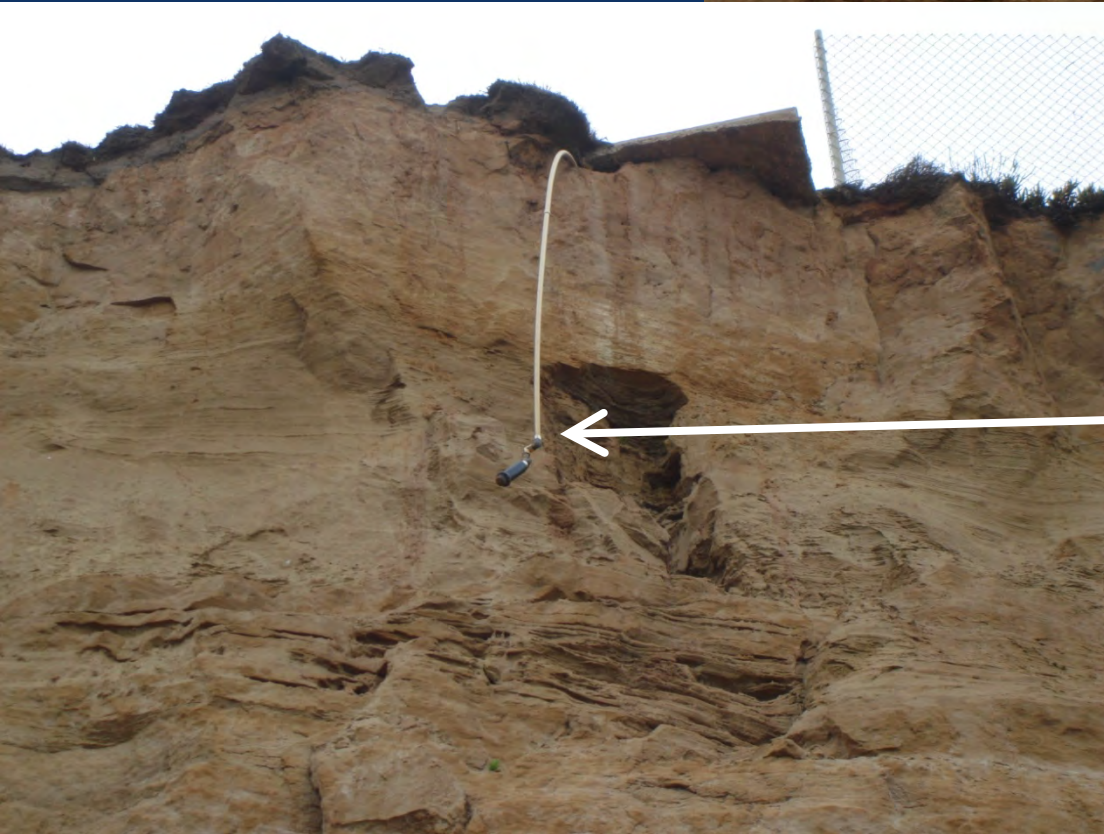


Seeps, rills and piping; Manor Bluffs, Pacifica Aug 2010 © Bob Battalio, 2010



Piping ! Manor Bluffs, Pacifica Aug 2010 © Bob Battalio, 2010

**Drain Pipes**



**Sprinkler Head**

**Manor Bluffs, Pacifica**

**Aug 2010** © Bob Battalio, 2010







Talus cone; Manor Bluffs, Pacifica Aug 2010 © Bob Battalio, 2010



**Bluff sand compared to beach sand, Manor, Pacifica Aug 2010** © Bob Battalio, 2010



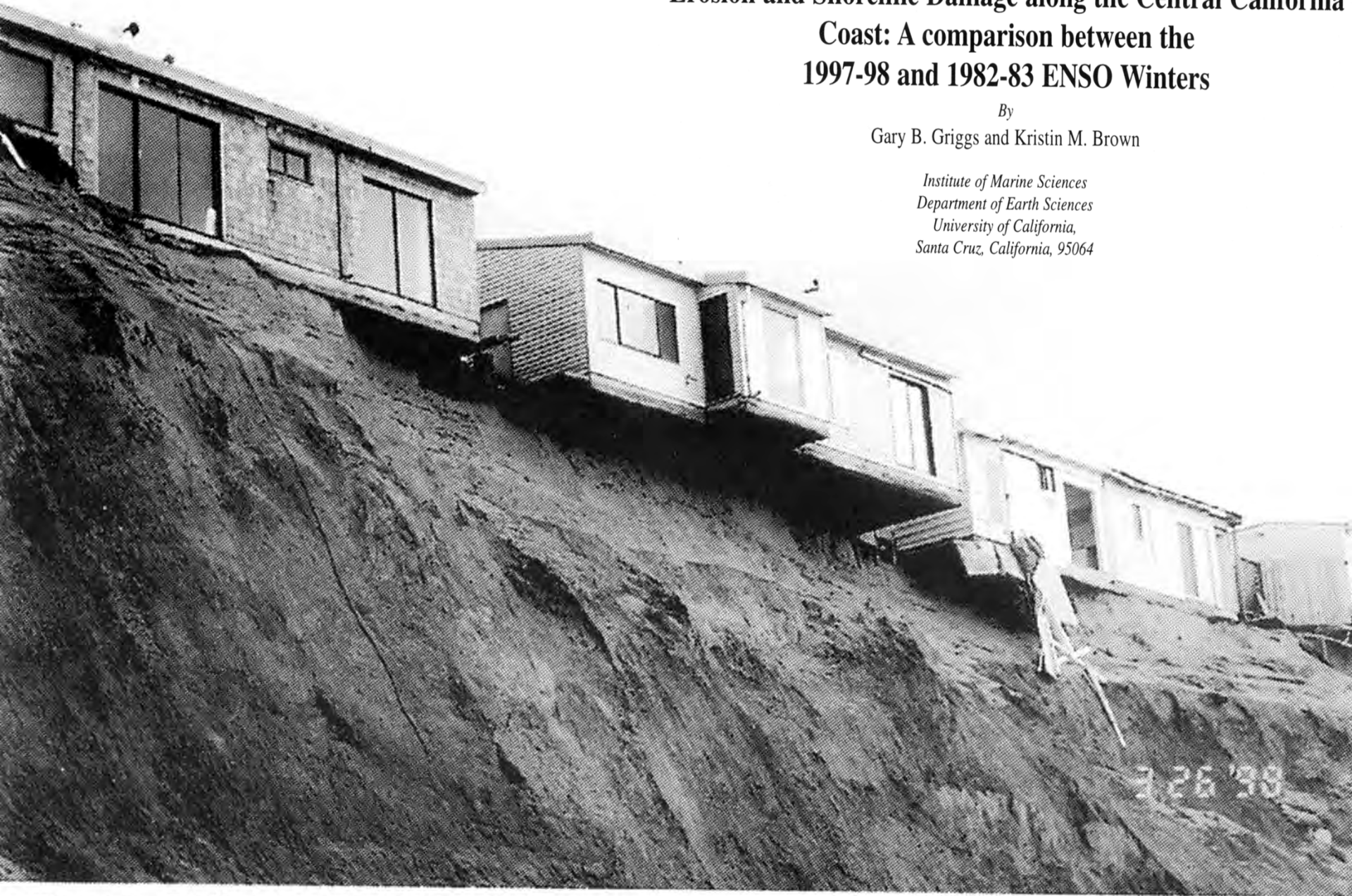
**Figure 2. Pacifica bluffs in October 1983, following the last major El Niño event on the California coast, when a rock revetment was constructed.**

# Erosion and Shoreline Damage along the Central California Coast: A comparison between the 1997-98 and 1982-83 ENSO Winters

By

Gary B. Griggs and Kristin M. Brown

*Institute of Marine Sciences  
Department of Earth Sciences  
University of California,  
Santa Cruz, California, 95064*

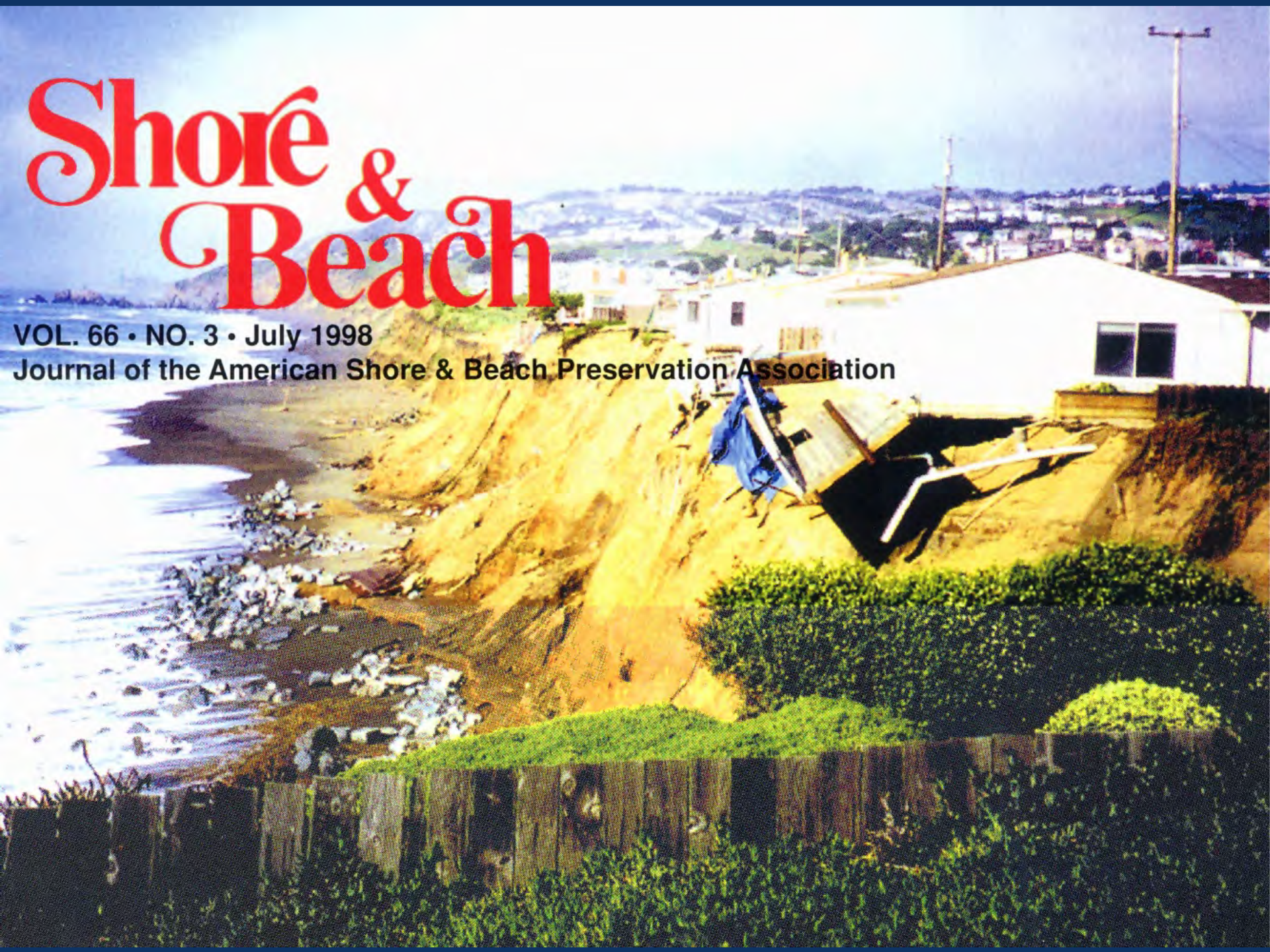


**Figure 1. Bluff erosion in Pacifica between January and March 1998 ultimately led to the demolition of ten homes in April (Photo by Monty Hampton, USGS).**

# Shore & Beach

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Journal of the American Shore & Beach Preservation Association



# Esplanade Seawall



# Sharp Park



**Photos: DEBORAH LATTIMORE**









California Coastal Records Project ; 1972 Photo

Copyright © 2004-2005 Kenneth & Gabrielle Adelman - Adelman@Adelman.COM





California Coastal Records Project ; 2005 Photo

Copyright © 2004-2005 Kenneth & Gabrielle Adelman - Adelman@Adelman.COM



# Sharp - Fairway Parks, Mori Point



# 2004

California Coastal Records Project ; 2004 Photo  
*Copyright © 2004-2005 Kenneth & Gabrielle Adelman -  
Adelman@Adelman.COM*



# Rockaway Cove, Hidden Cove, Mori Point



Photos: DEBORAH LATTIMORE

**Rockaway Beach,  
south end  
August 30, 2011**



# Montara Mountain, Pedro Point, Shelter Cove, Linda Mar



Photos: DEBORAH LATTIMORE



# Linda Mar – Pt San Pedro - cobble substrate with sand cover



**Thank You !**

