Coastal Hazards and Adaptation in Pacifica, CA

Pacifica Library, Pacifica, California USA
August 16, 2010

Sponsored by **Wild Equity Institute**

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Speaker: Bob Battalio

Professional Civil Engineer (CA,WA,LA,OR)

Coastal Processes training from UC Berkeley, 1985

Principal @ Philip Williams & Assoc., Ltd (PWA), San Francisco www.pwa-ltd.com

Practices Coastal Zone Engineering and Management

Worked on Pacifica Pier Abutment Repair, Pacifica State Beach Renovation, Ocean Beach Littoral Processes Study, CA Sea Level Rise Coastal Erosion Study, FEMA Guidelines for Pacific Coast Flood Studies

President, California Shore and Beach Preservation Association (Non profit)

Pacifica resident since 1989

Lives in Vallemar with wife Bethe and two sons Sam and Jake

Surfer

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OUTLINE

Geographic Setting

Coastal Flood and Erosion Hazards,
Accelerated Sea Level Rise

Management Approaches in Pacifica

Bob Battalio @ Ocean Beach, December 1994. Copyright ©, Martha Jenkins, 1994

Geographic Setting

The northern part of Pacifica coast is geologically uplifted and eroding

The southern part of Pacifica is a series of valleys between headlands

The bluffs and headlands are eroding

Bluff / headland erosion and creek discharge bring sediments that maintain beaches

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Daly City / Pacifica Coast: San Andreas Fault crosses just north of Mussel Rock.

The cliffs are comprised of the Merced Formation, poorly consolidated sedimentary materials formed during the late Pliocene and Pleistocene epochs. The formation was then uplifted in the late Quarternary Period, now up to 750 feet above present sea level.

The Merced formation largely consists of interbedded sandstone and shale. The area is subject to land slides and wave erosion.

Mussel Rock is an outcrop of greenstone, and is part of the Cretaceous Franciscan Complex found on the west side of the San Andreas Fault, in Pacifica.

Circa early 1960's

Source: USGS, on-line

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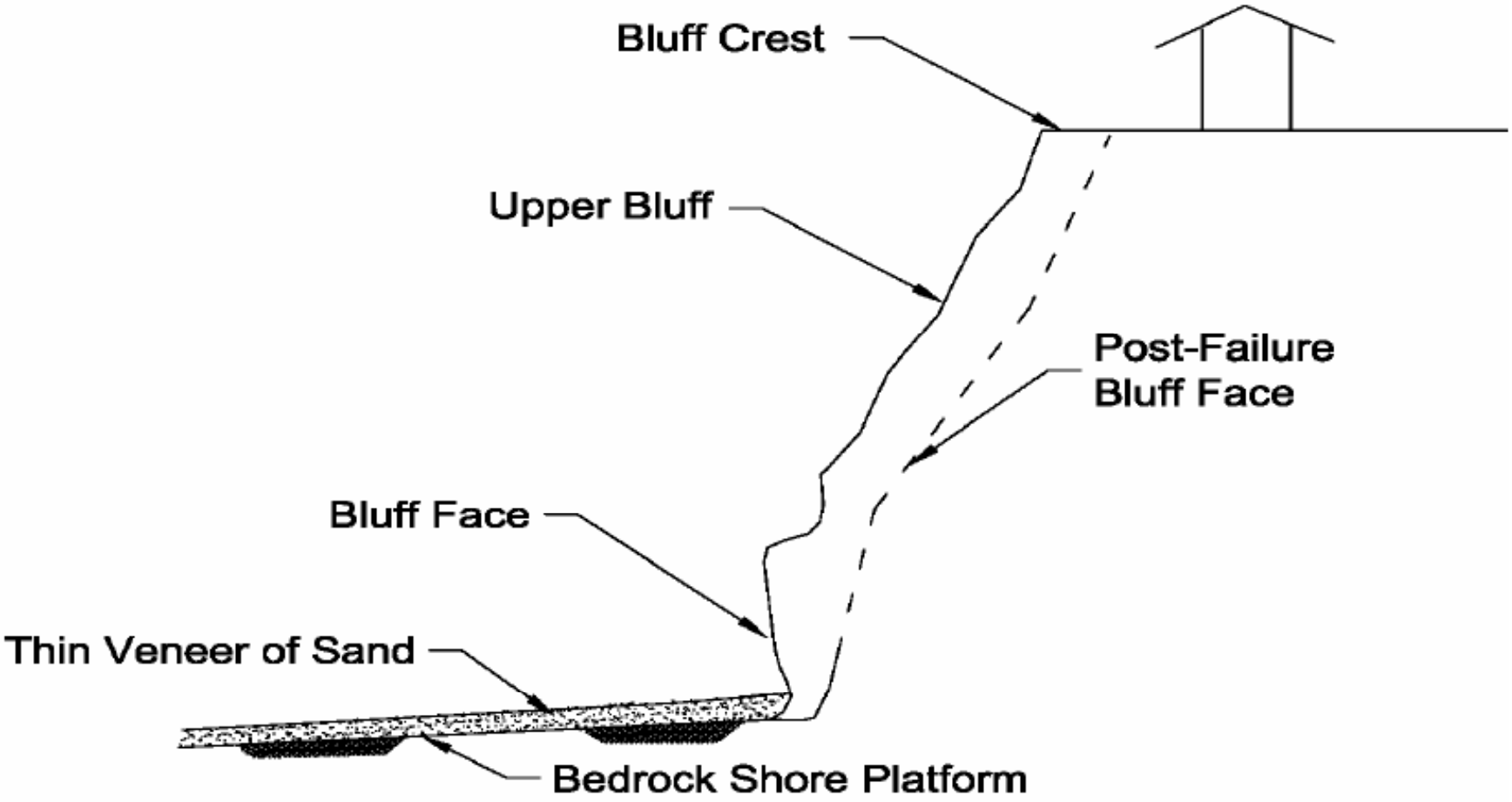

Figure D.4.6-31. Typical Erodible Bluff Profile Fronted by Narrow Sand-capped Beach

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

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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

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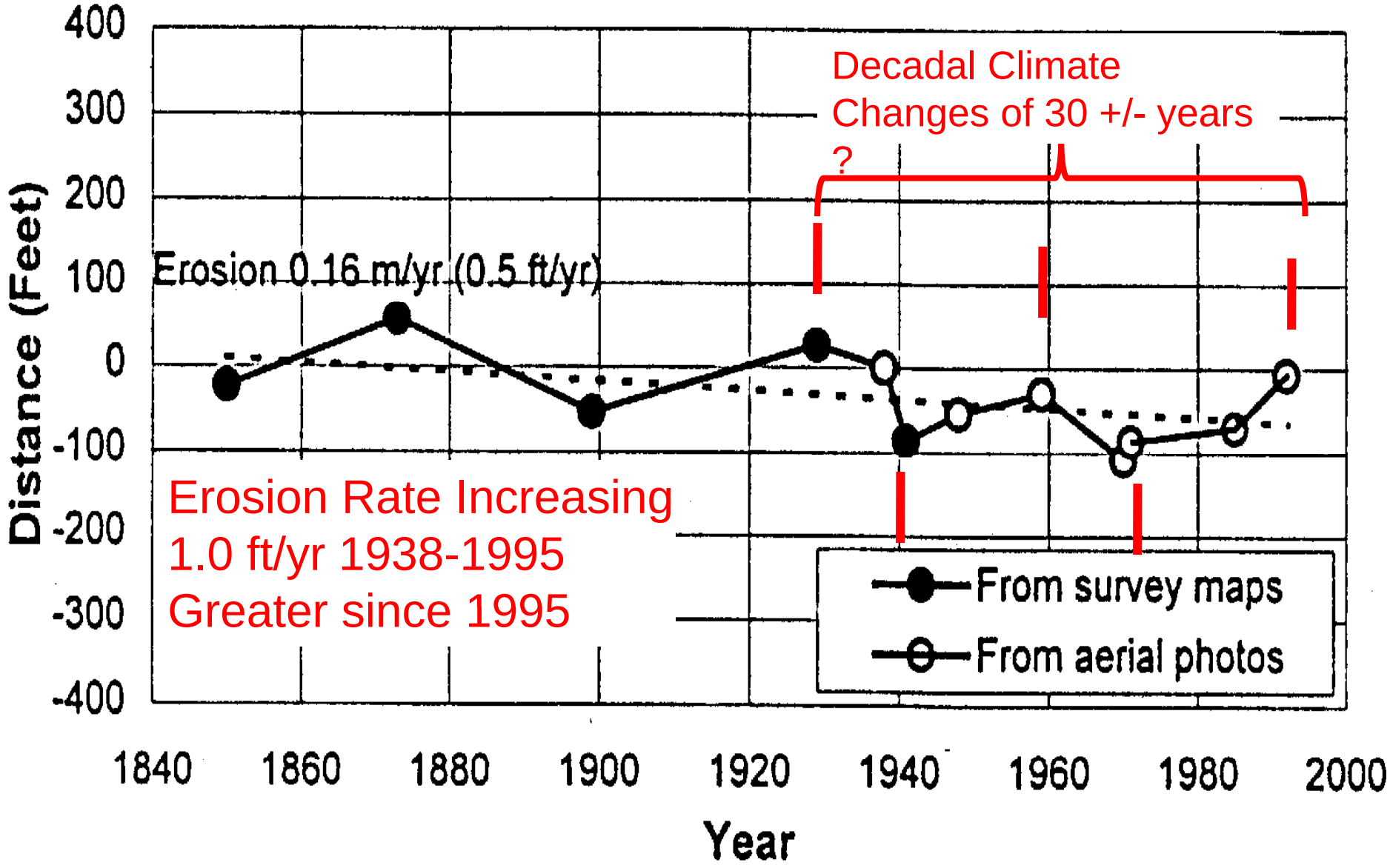

Shoreline Change Data So. Ocean Beach

Source: Battalio, 1996

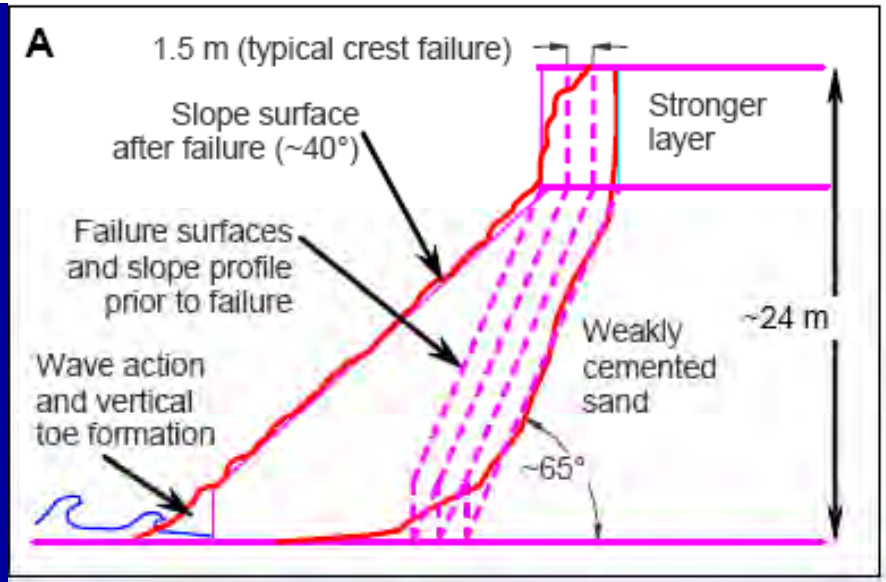

Figure 4. Schematic diagram (A) and photo (B) of weakly cemented coastal cliff failure mode. The failure surface is typically inclined at 65° to the horizontal.

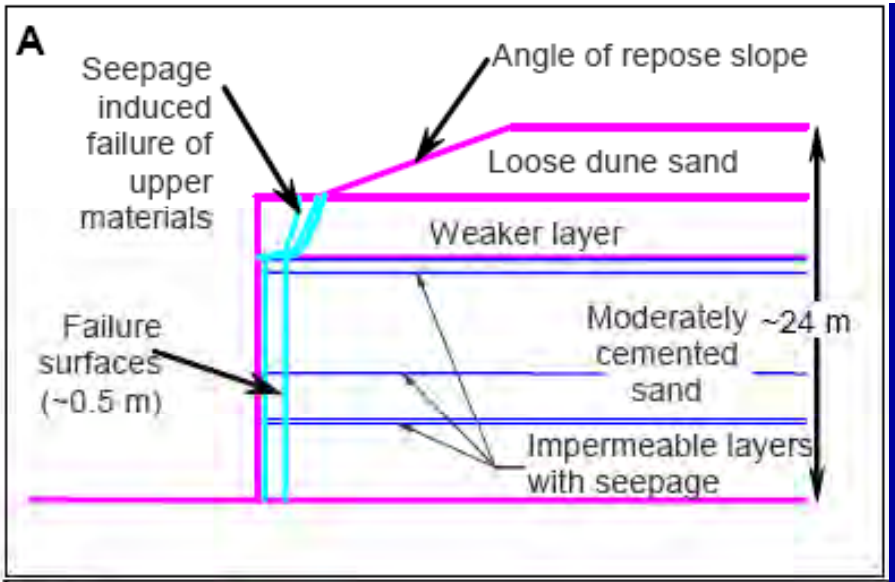

Figure 5. Schematic diagram (A) and photo (B) of moderately cemented coastal cliff failure mode. The failure surface is typically near-vertical.

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

Source: Collins , Kayen and Sitar, 2007

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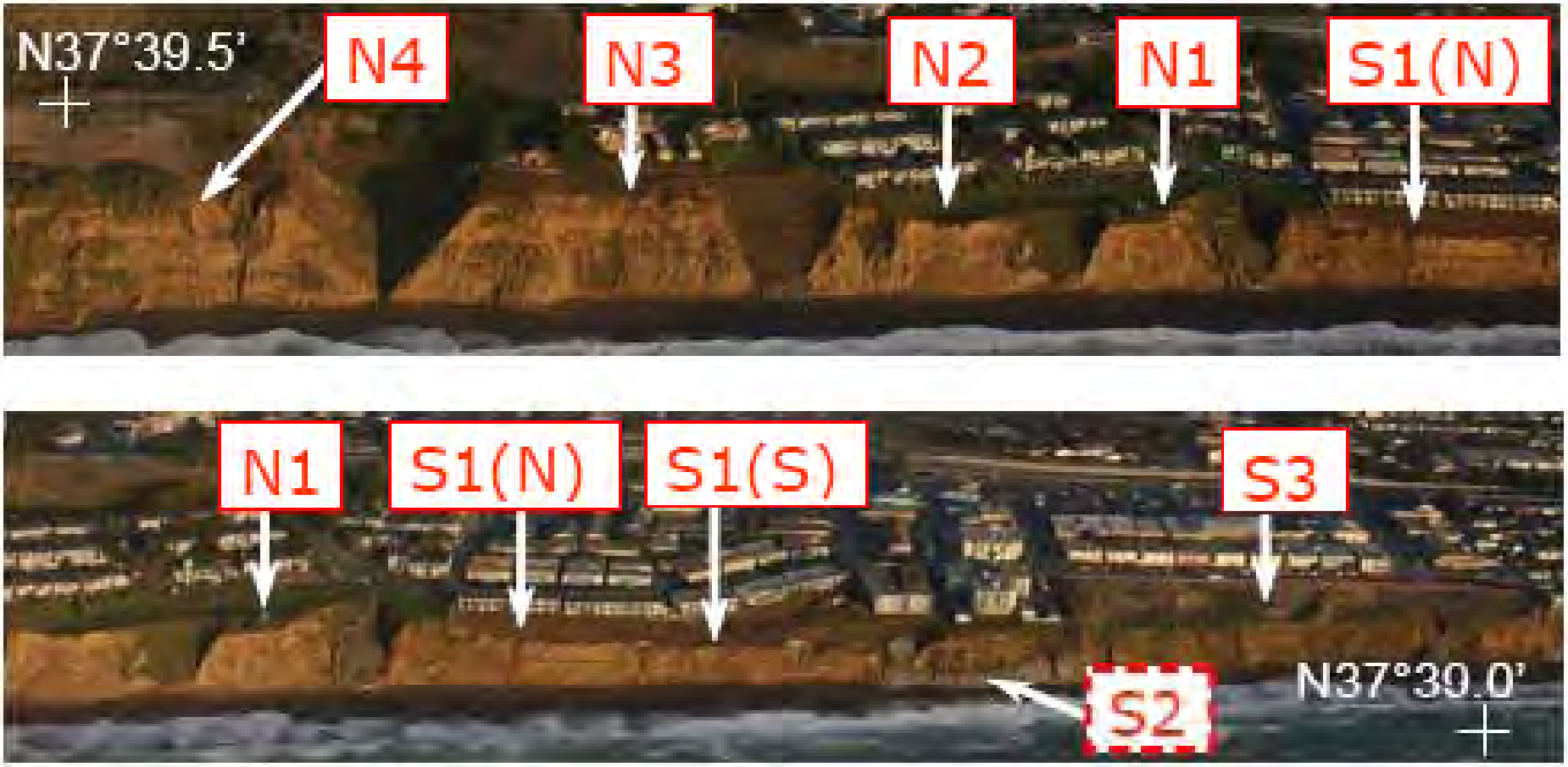

Figure 3. Oblique view of the Pacifica study area showing locations of observed cliffs. Cliff S2 was not observed for failures. Photo courtesy of the California Coastal Records Project.

Source: Collins , Kayen and Sitar, 2007

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Layers and seeps; Manor Bluffs, Pacifica Aug 2010 © Bob Battalio, 2010

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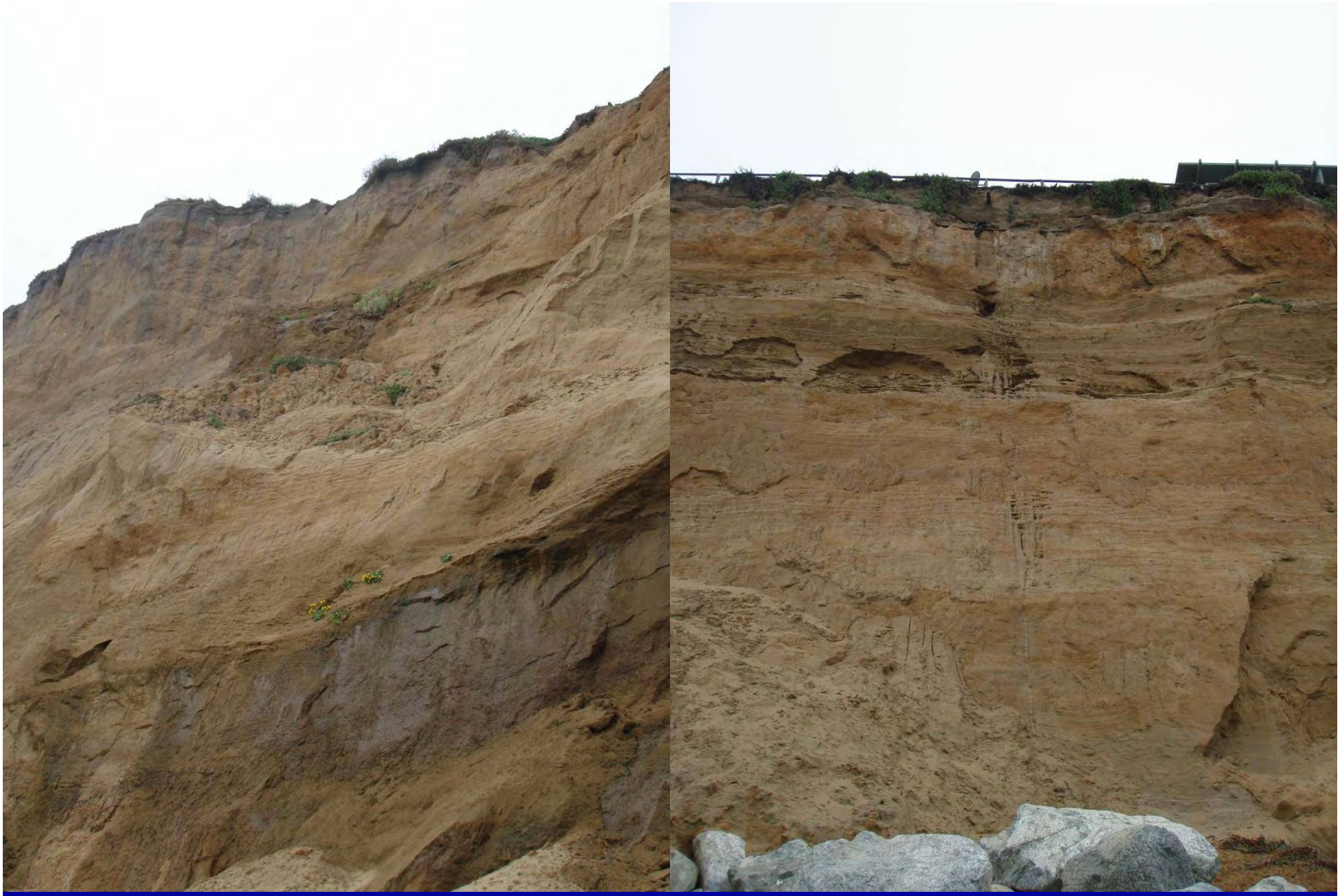

Seeps, rills and piping; Manor Bluffs, Pacifica Aug 2010 © Bob Battalio, 2010

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

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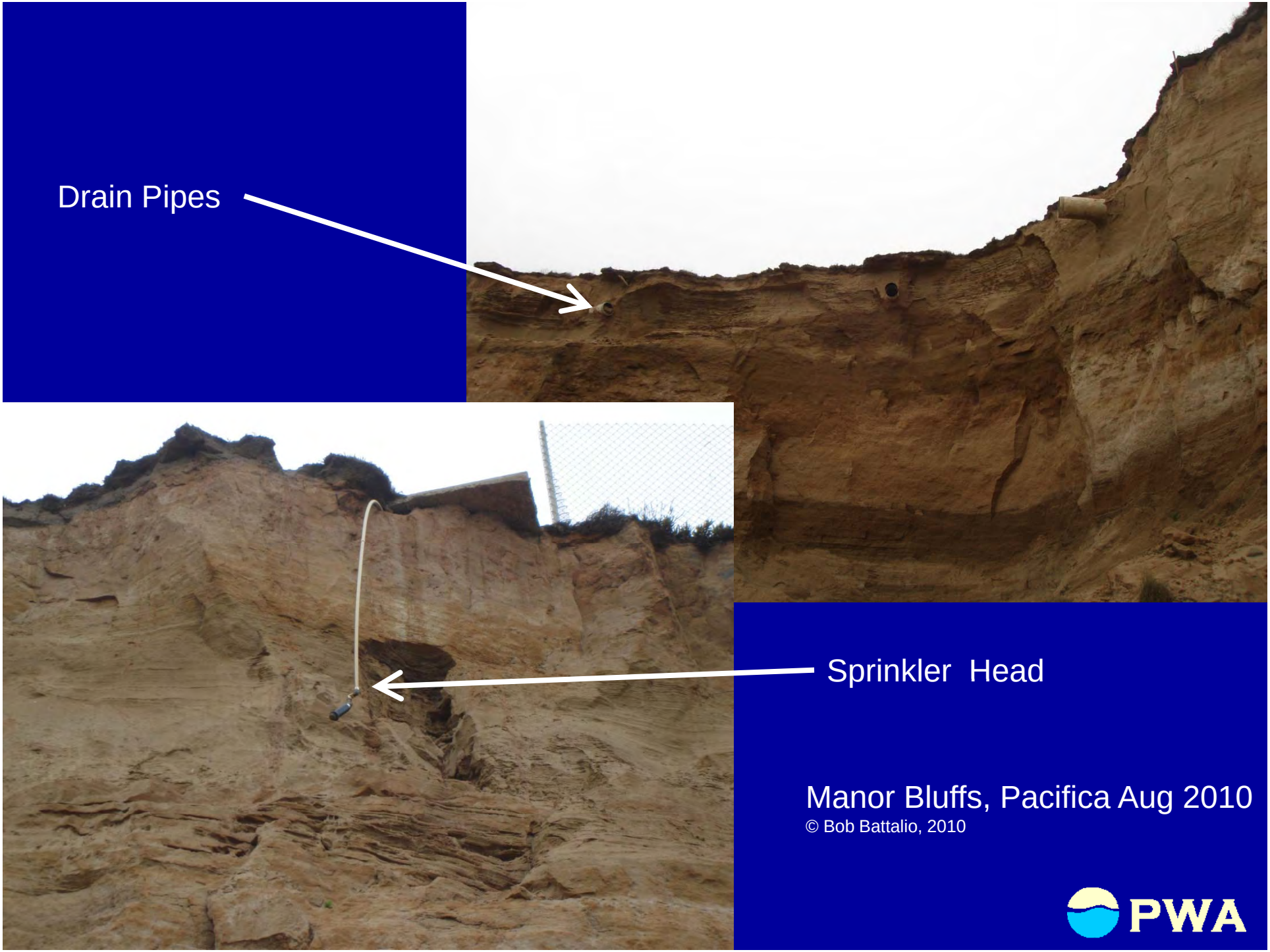
Drain Pipes



Sprinkler Head

Manor Bluffs, Pacifica Aug 2010

© Bob Battalio, 2010

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

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Historic Shorelines and Erosion Rates

(approximate)

USGS

Hapke, C. and Reid, D. 2006. The National Assessment of Shoreline Change: A GIS compilation of vector shorelines and associated shoreline change data for the sandy shorelines of the California Coast. U.S. Geological Survey. USGS Open-File report 2006-1251.

Hapke, C., Reid, D., and Borrelli, M. 2007. The National Assessment of Shoreline Change: A GIS compilation of vector cliff edges and associated cliff erosion data for the California Coast. U.S. Geological Survey. USGS Open-File report 2007-1112.

NAIP Imagery

NAIP imagery is acquired at a one-meter ground sample distance (GSD) with a horizontal accuracy that matches within six meters of photo-identifiable ground control points, which are used during image inspection.

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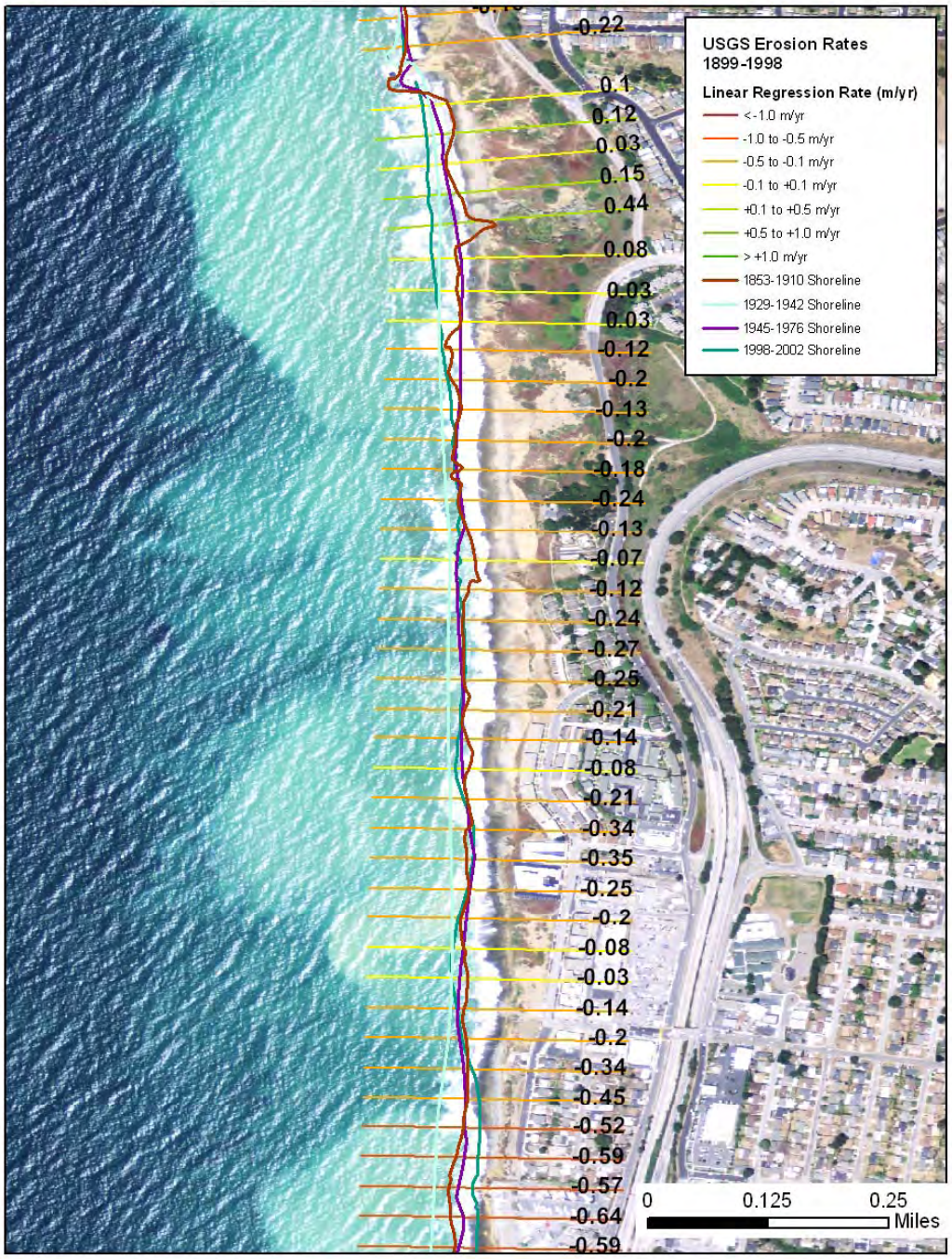
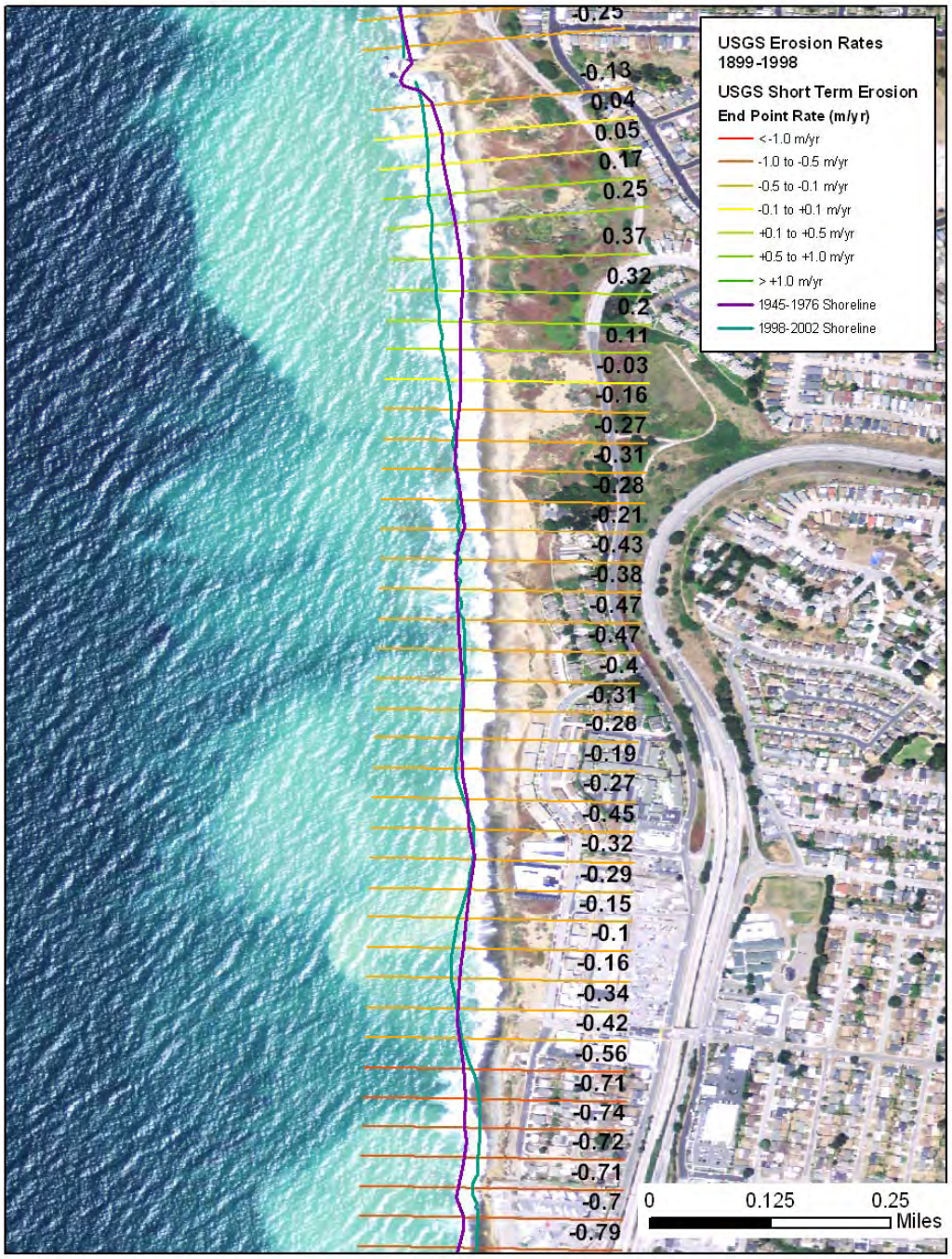
Manor
Long Term
-0.6 m/yr
To
+0.4 m/yr



PWA

Manor
Short Term
-0.8 m/yr
To
+0.4 m/yr



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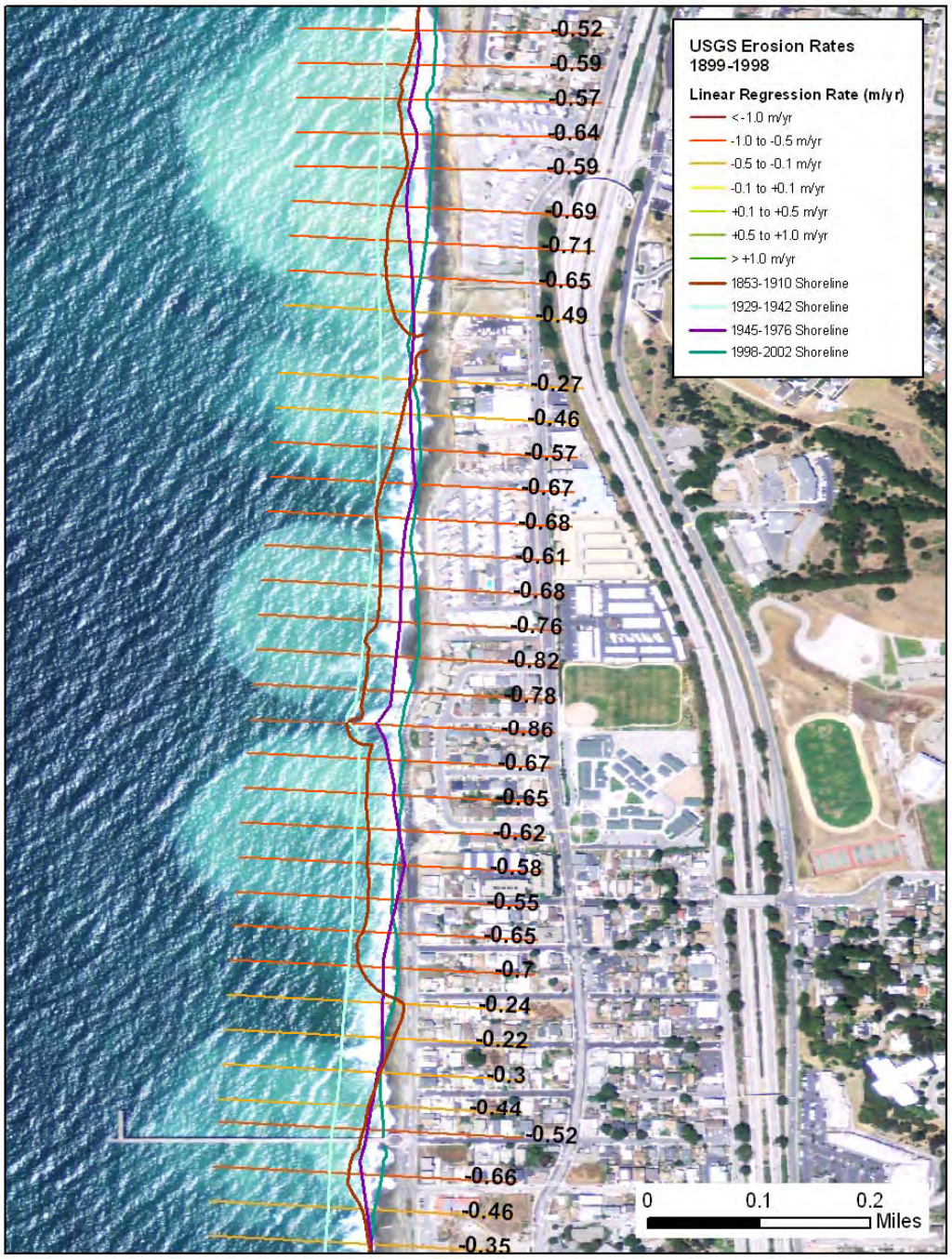
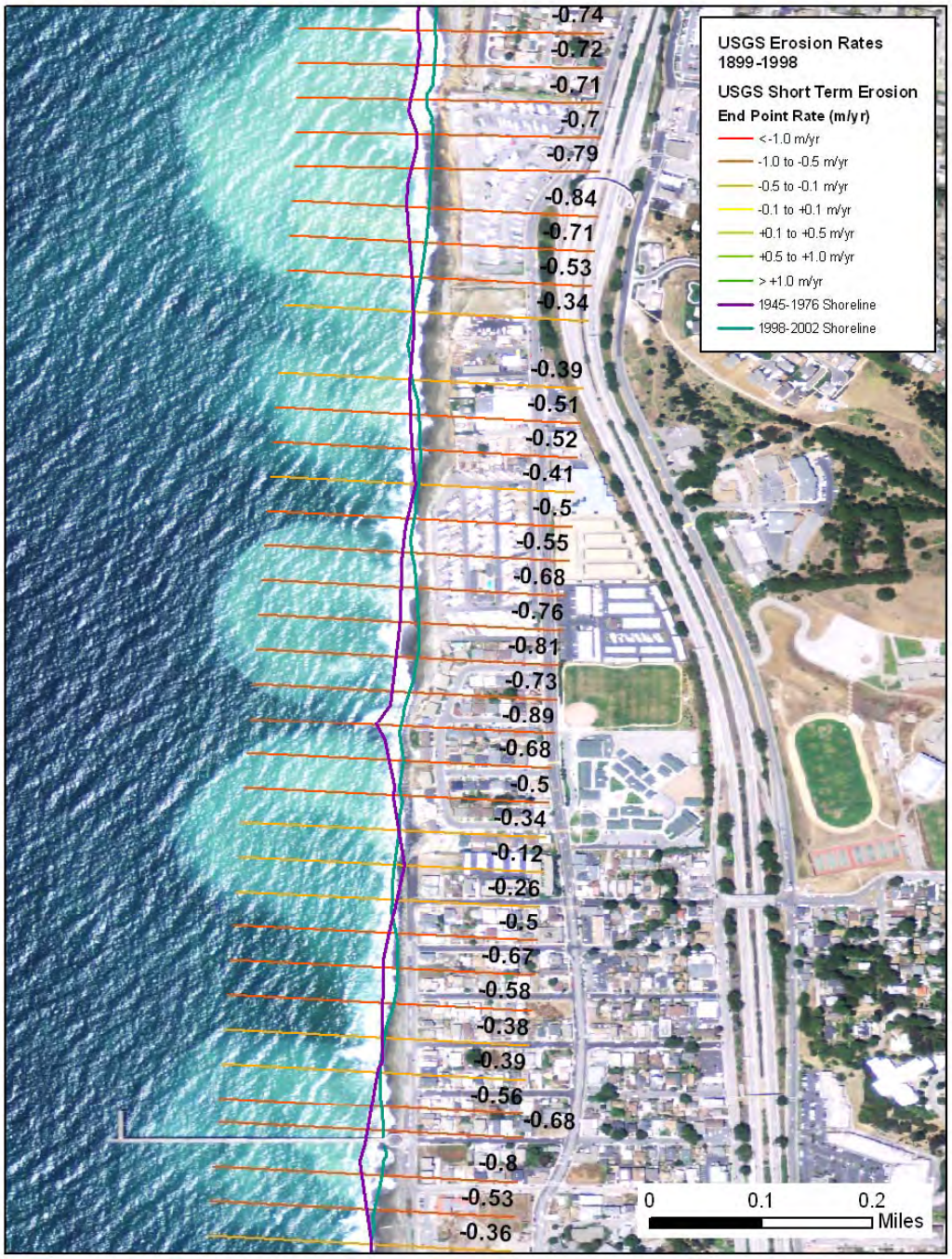
Sharp Park
Long Term
-0.7 m/yr
To
-0.3 m/yr



PWA

Sharp Park
Short Term
-0.8 m/yr
To
-0.1 m/yr



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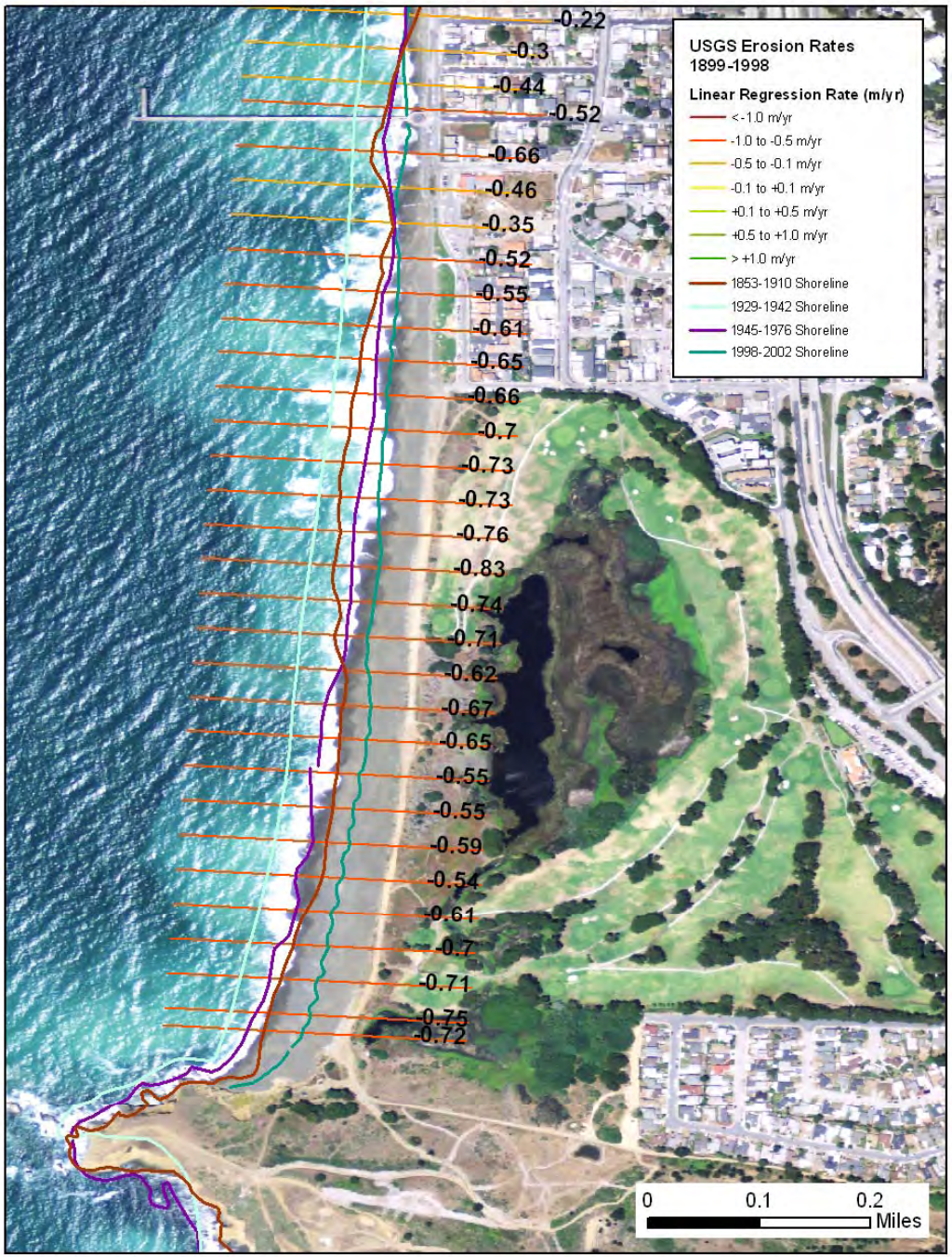
Sharp Park South
Long Term
-0.8 m/yr
To
-0.1 m/yr



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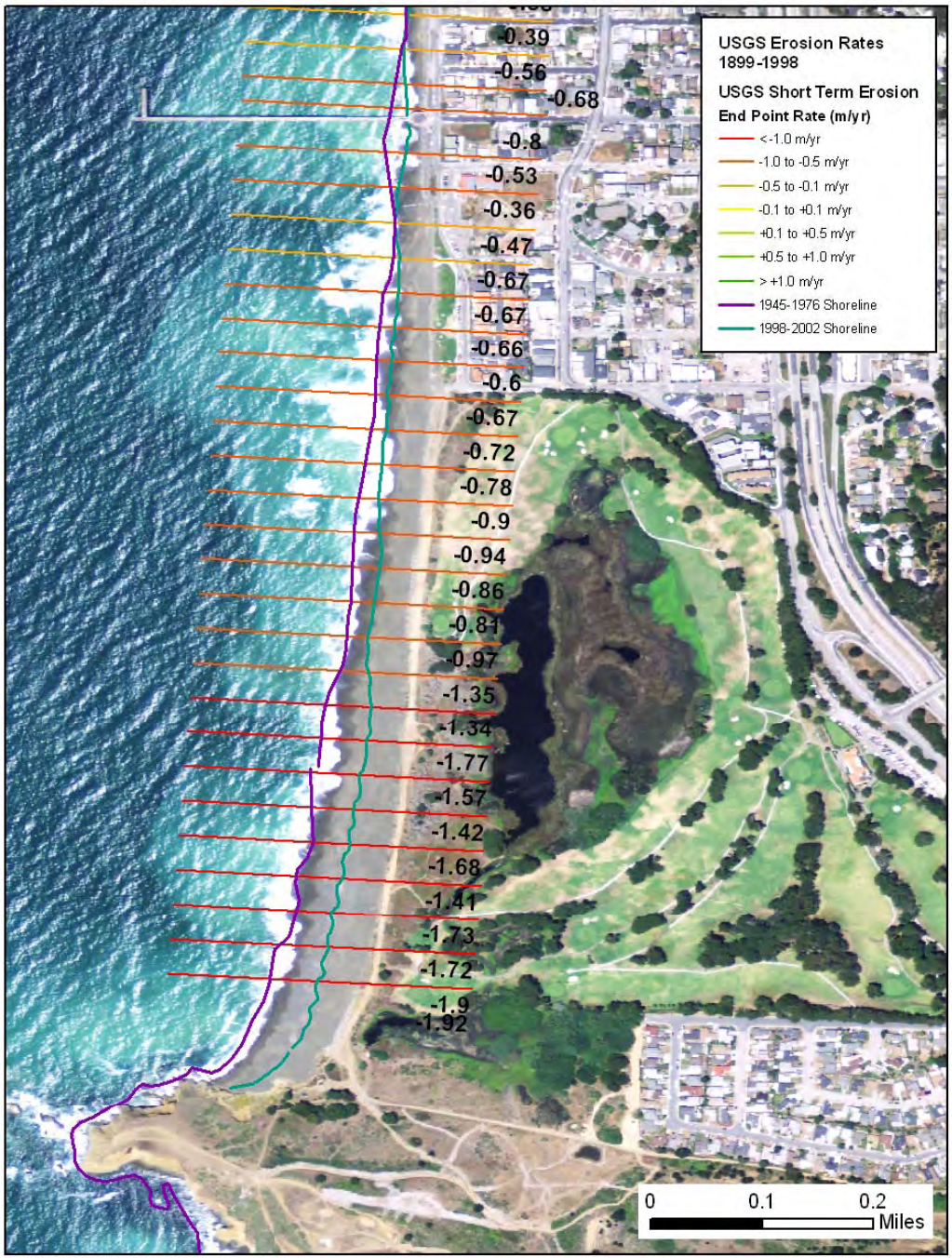
Sharp Park South Short Term -1.9m/yr To -0.4 m/yr



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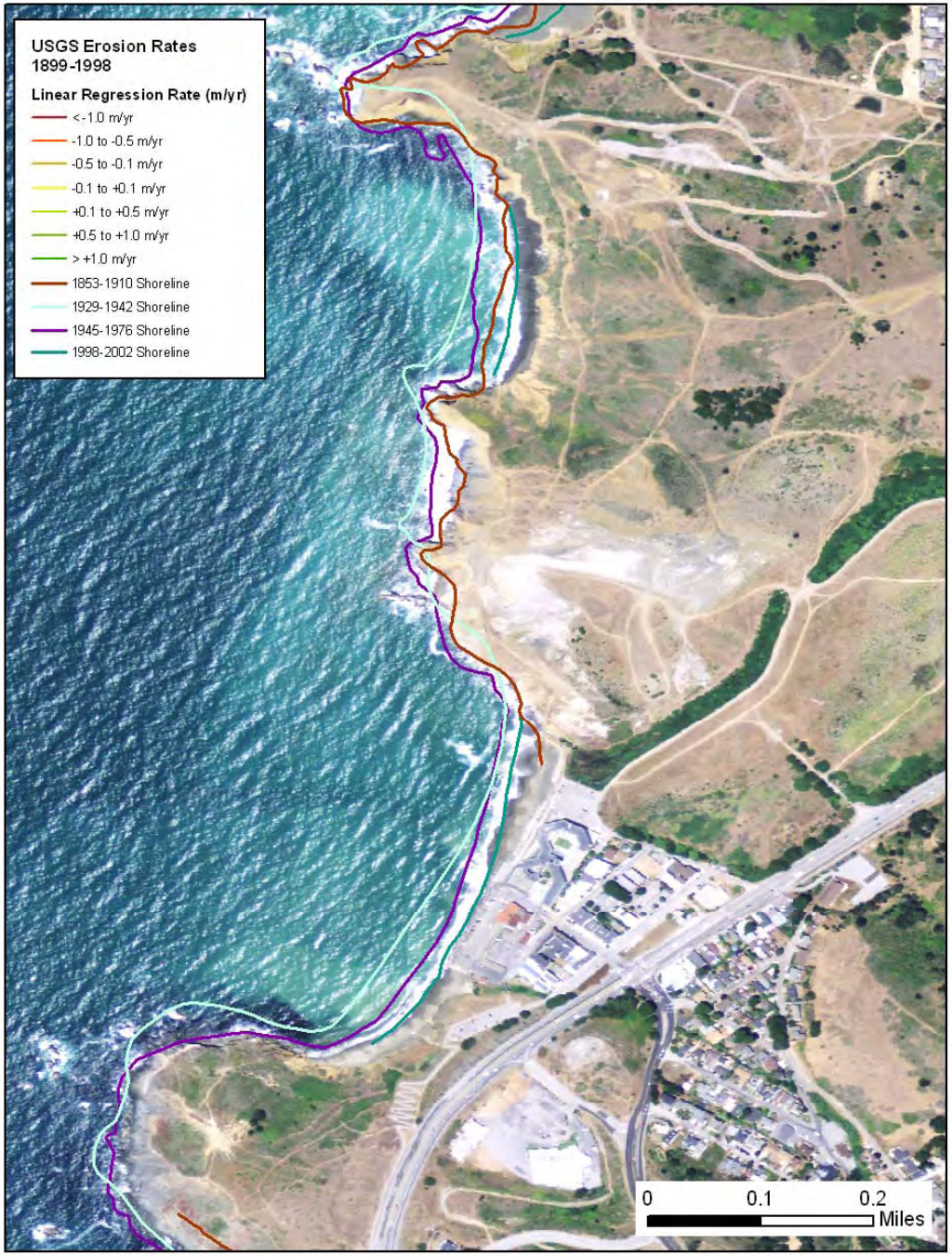
Rockaway Long Term



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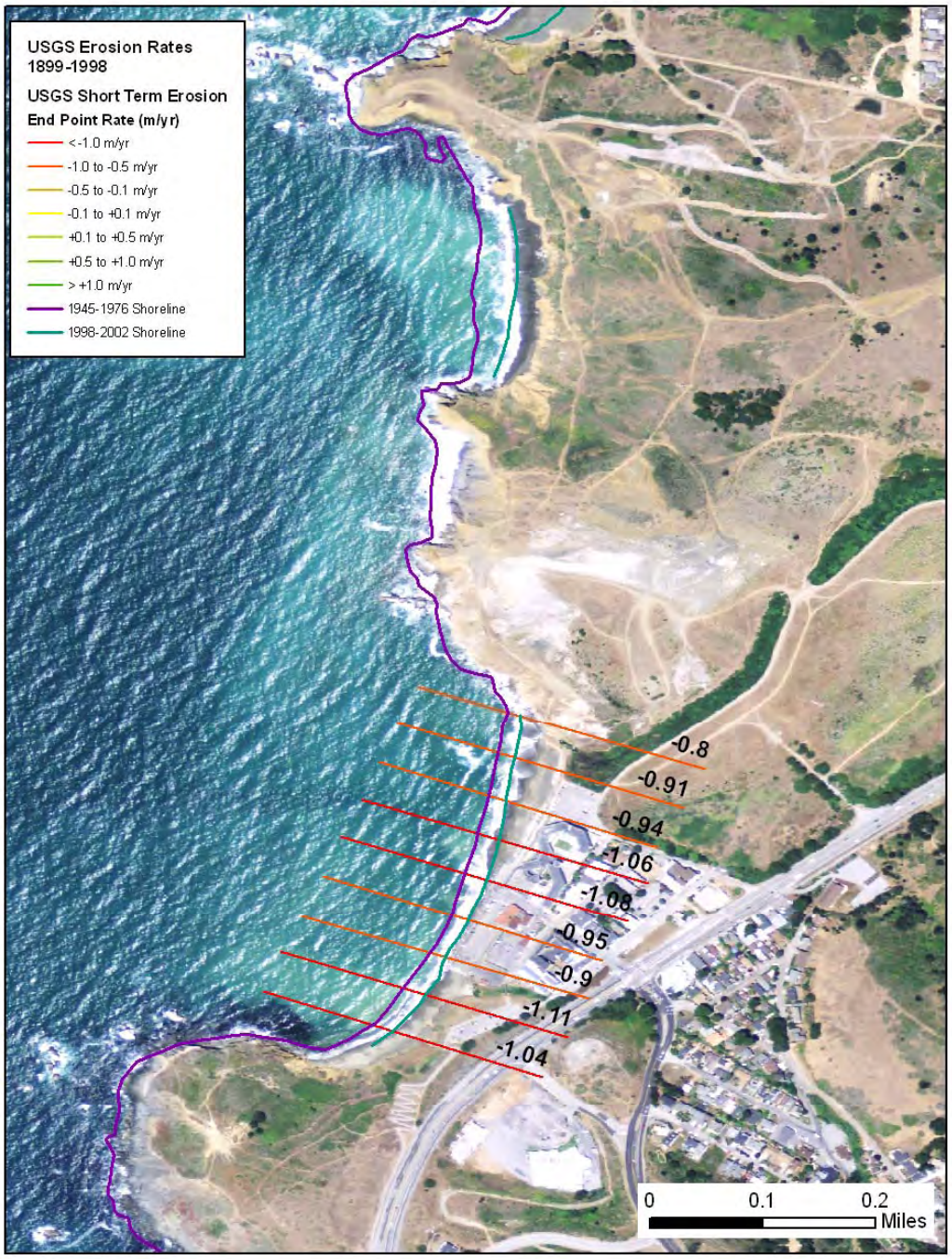
Rockaway
Short Term
About
-1.0 m/yr



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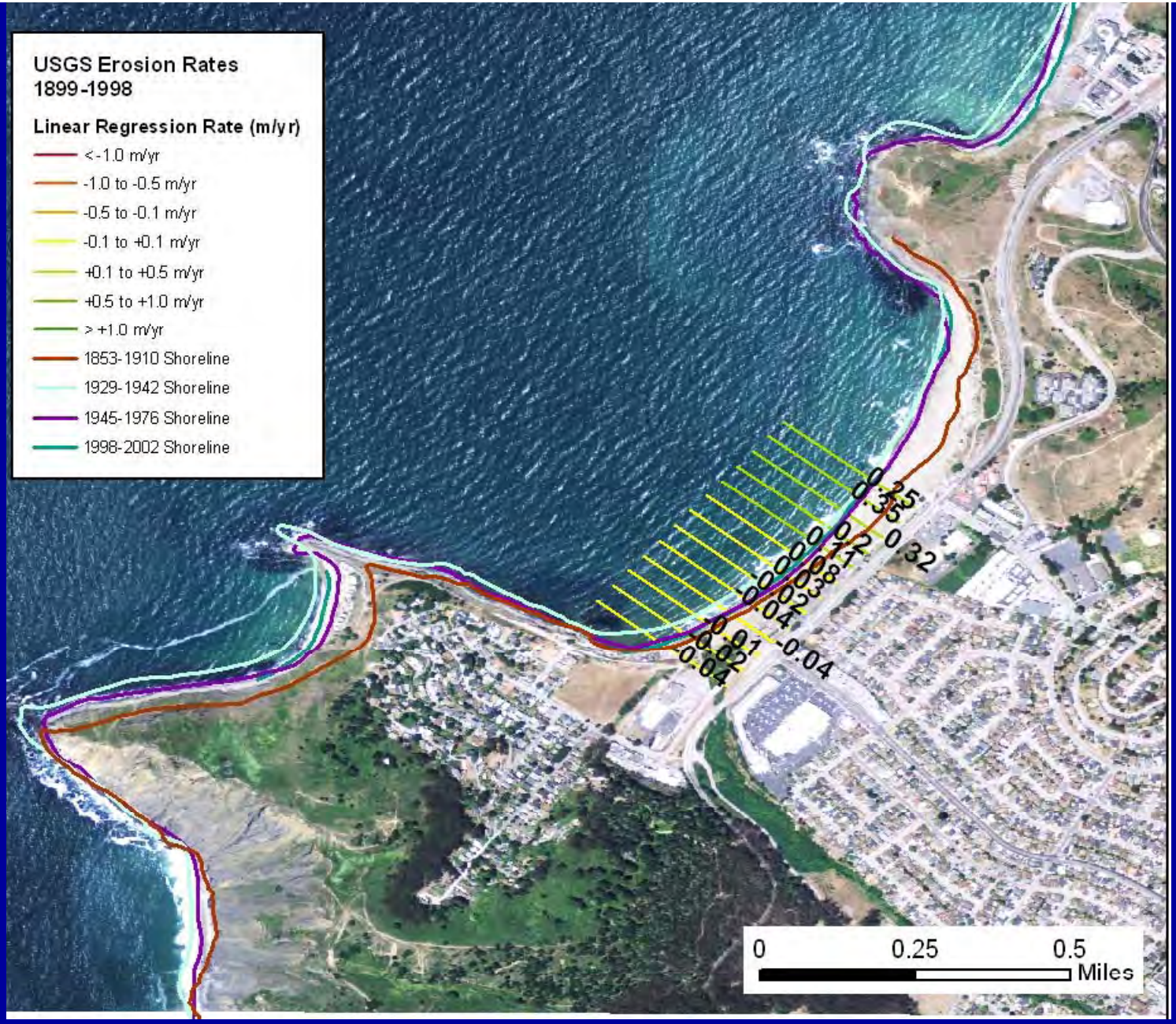

Linda Mar
Long Term
0 m/yr
To
+ 0.4 m/yr

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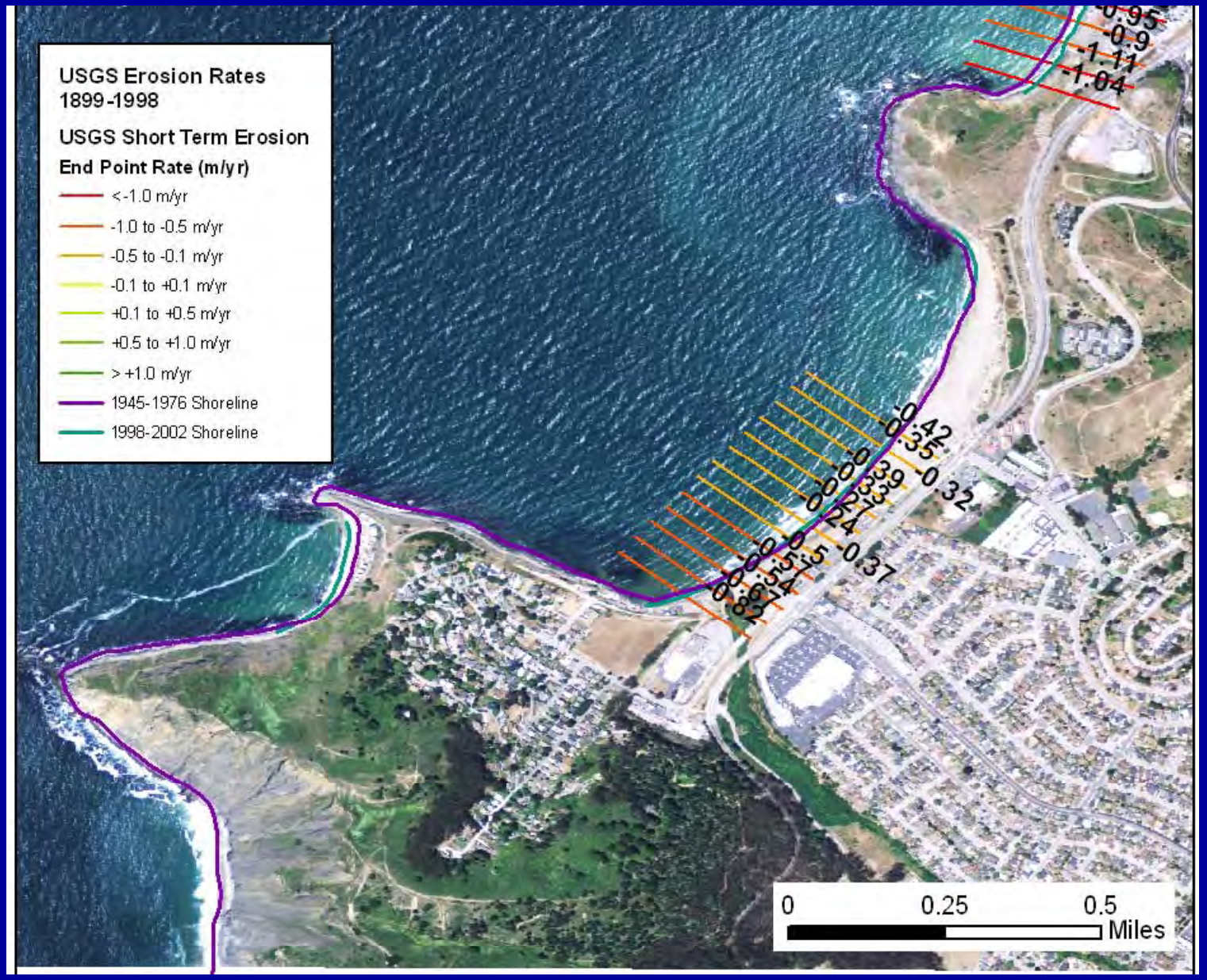

Linda Mar
Short Term
-0.2 m/yr
To
-0.8 m/yr

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Coastal Processes

- Near Shore Surf Zone Profile
- Wave Transformations
- Sand Transport
- Wave Runup and Overtopping

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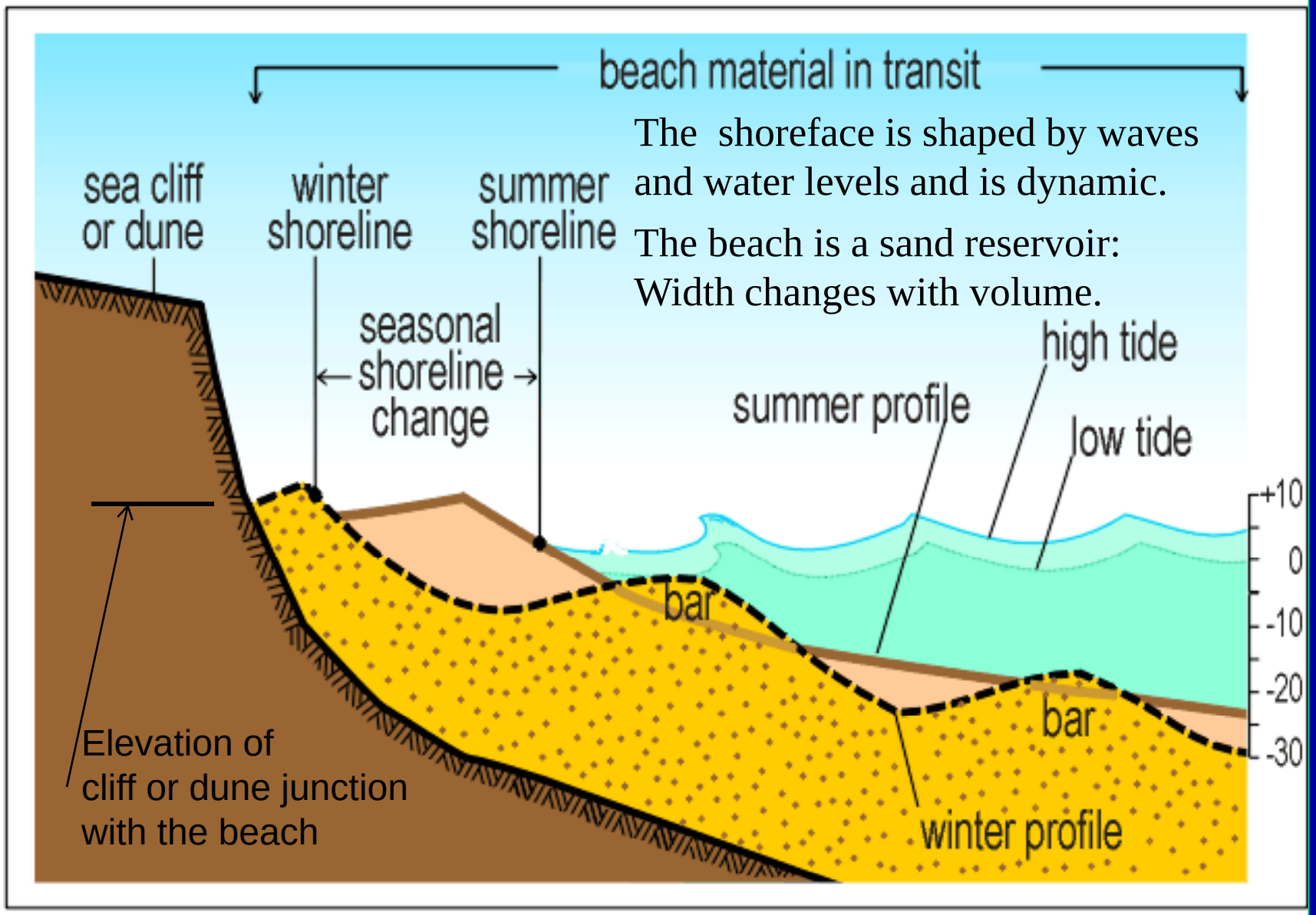

The shoreface is shaped by waves and water levels and is dynamic.

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

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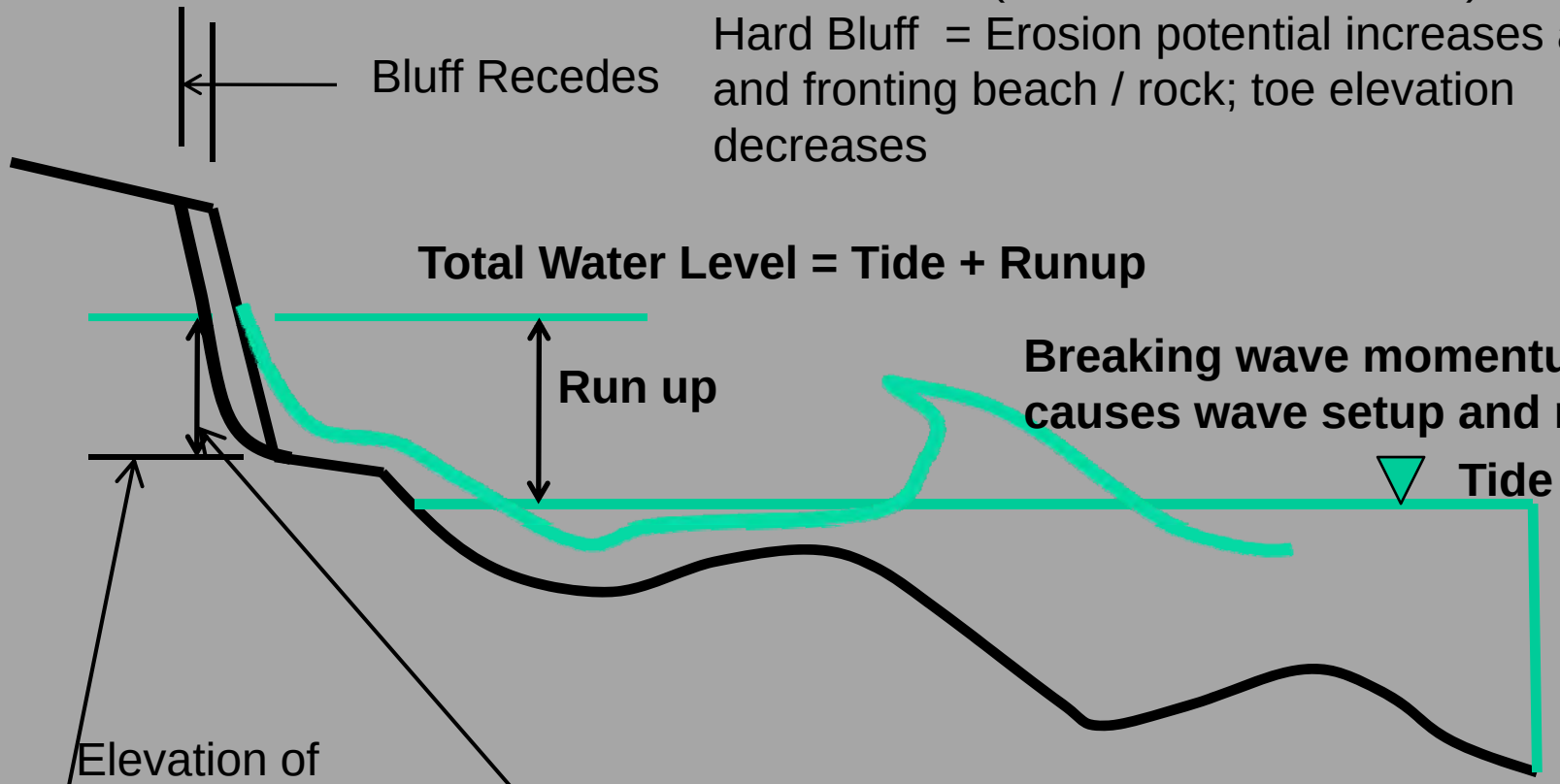
Conceptual Model of Bluff Erosion

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



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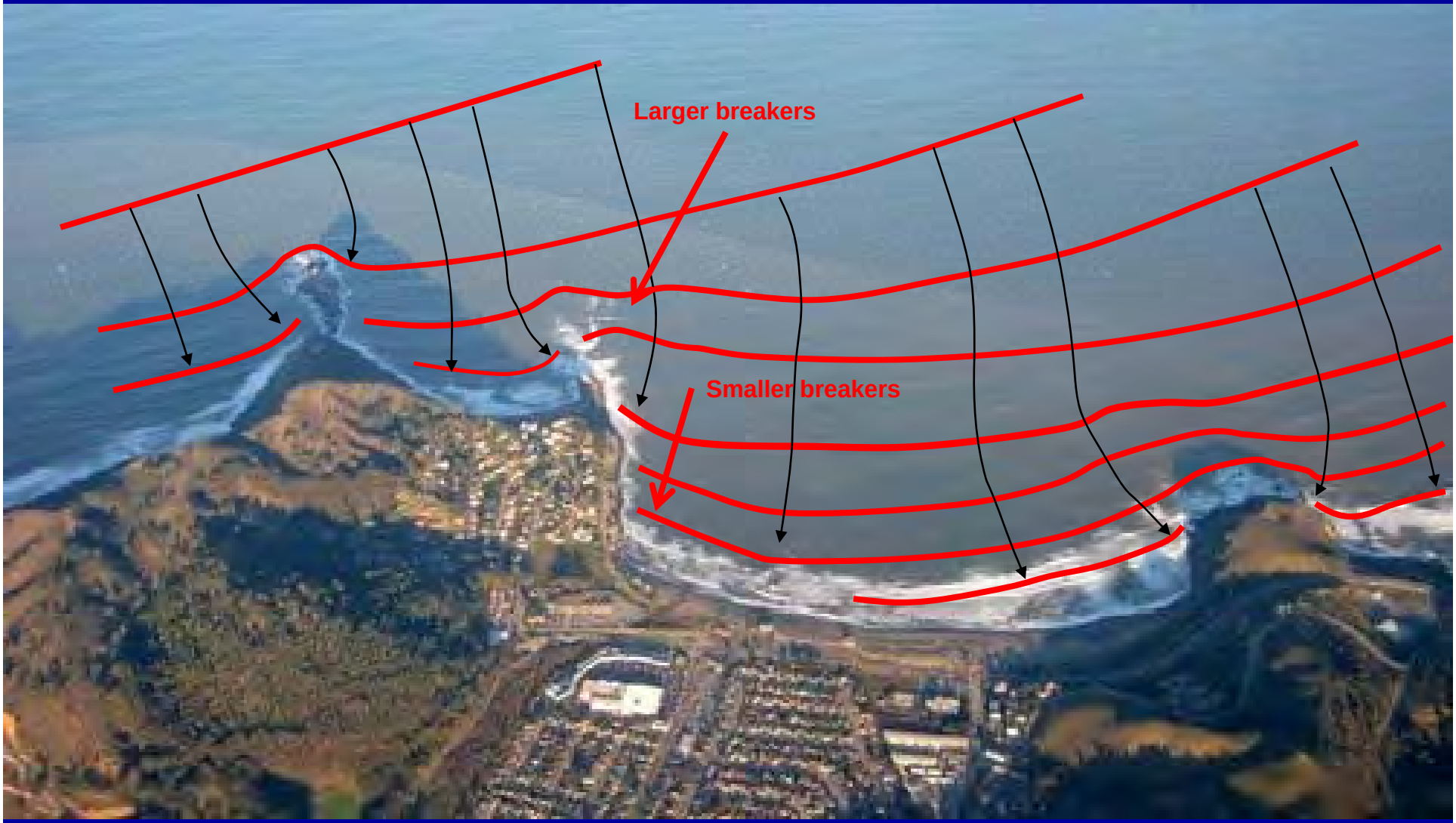
More than a shoreline, the wave-shaped shore zone is on the order of thousands of feet wide and a hundred feet tall !

Example of wave focusing and spreading due to depth refraction



Photos: DEBORAH LATTIMORE

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Golden Gate Littoral Cell

Pacifica Littoral Cell

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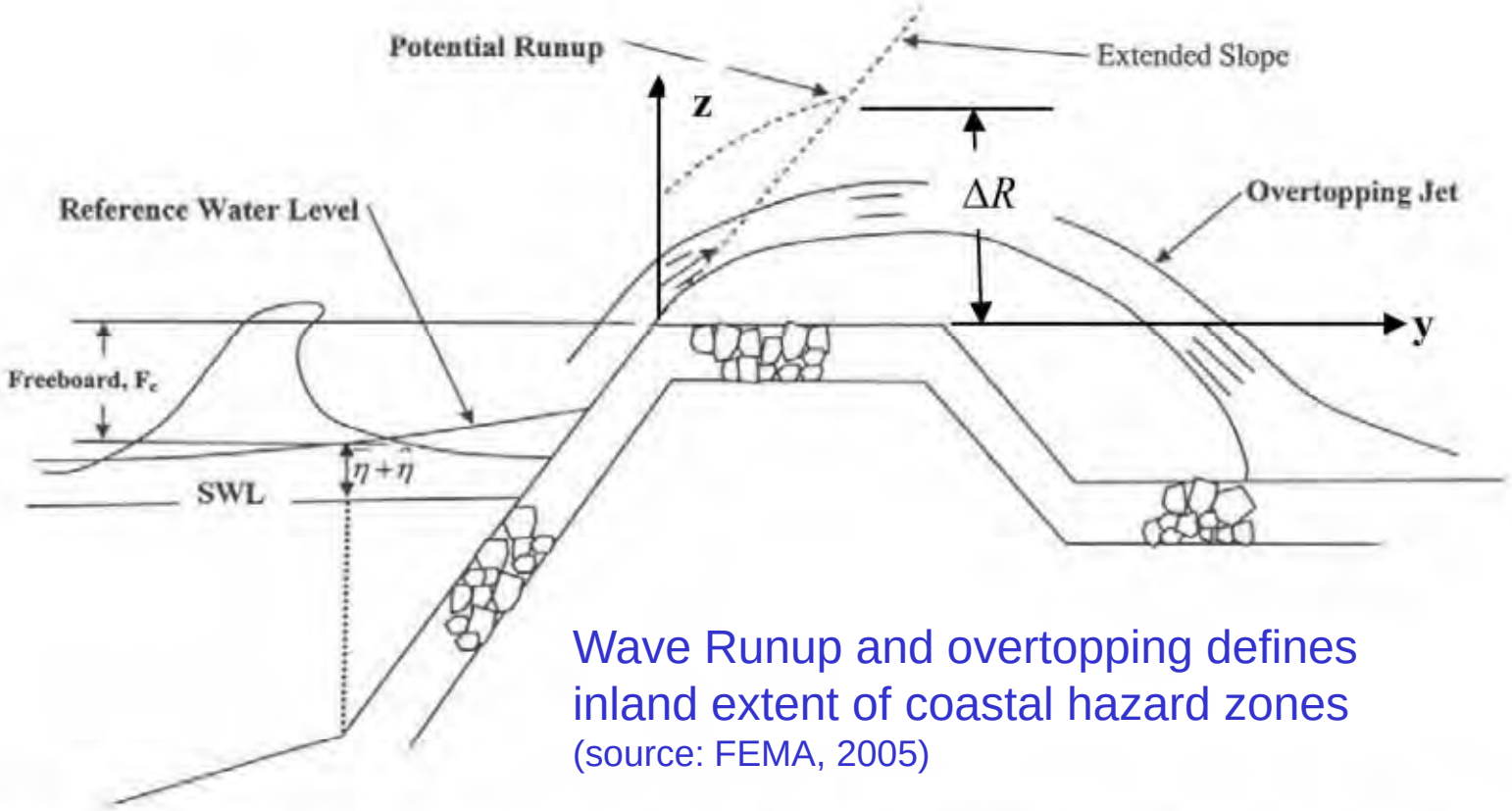

Wave Runup and overtopping defines inland extent of coastal hazard zones
(source: FEMA, 2005)

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

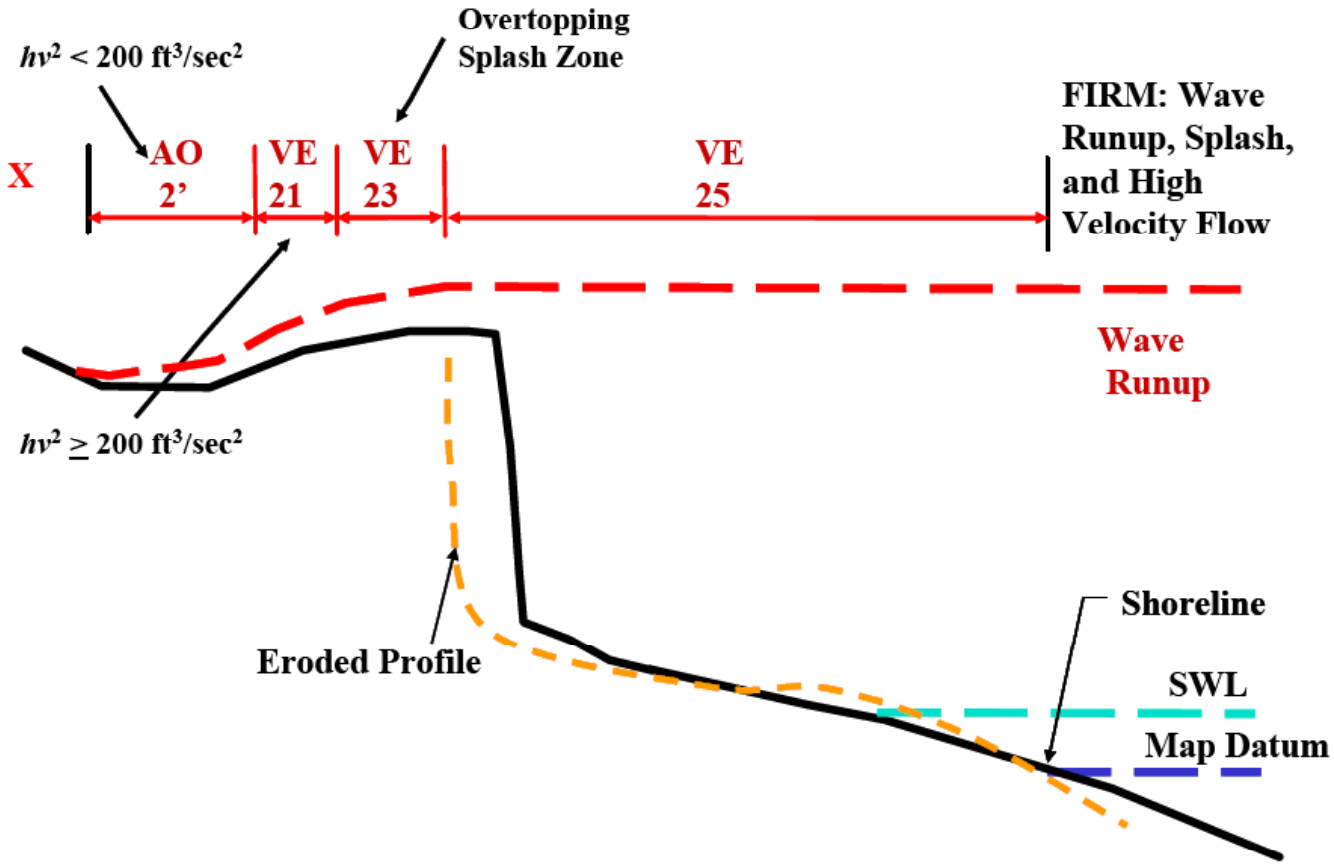

Figure D.4.9-5a. Erodible Low Coastal Bluff with VE Zone Controlled by Wave Runup, Overtopping Splash, and High-velocity Flow

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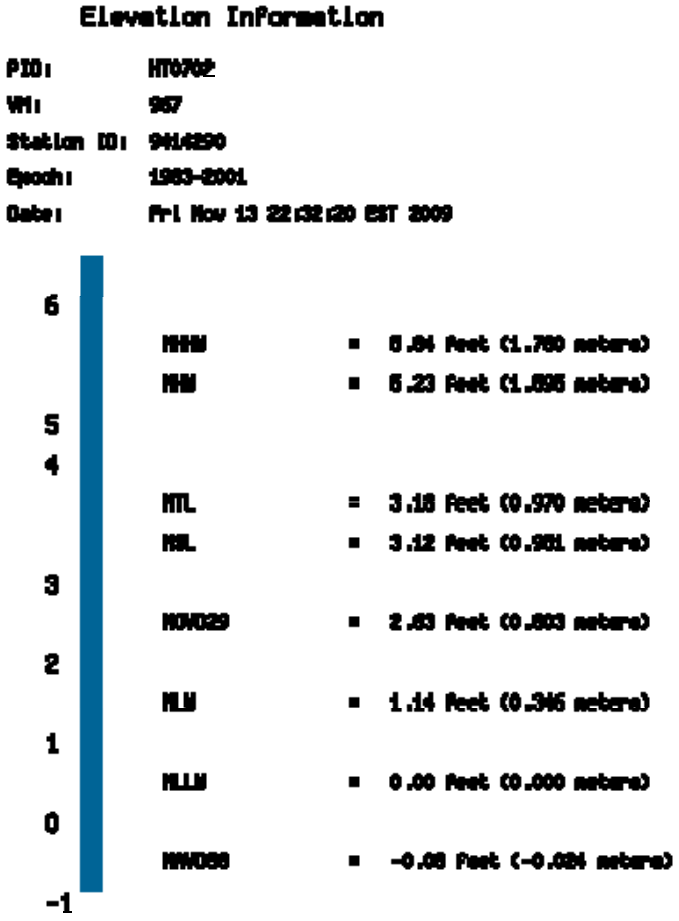
Ocean Tides and Water Levels



Sources: NOAA NOS, PWA and others

EXTREME HIGH WATER LEVELS
APPROXIMATE ESTIMATES
(FEET NAVD)

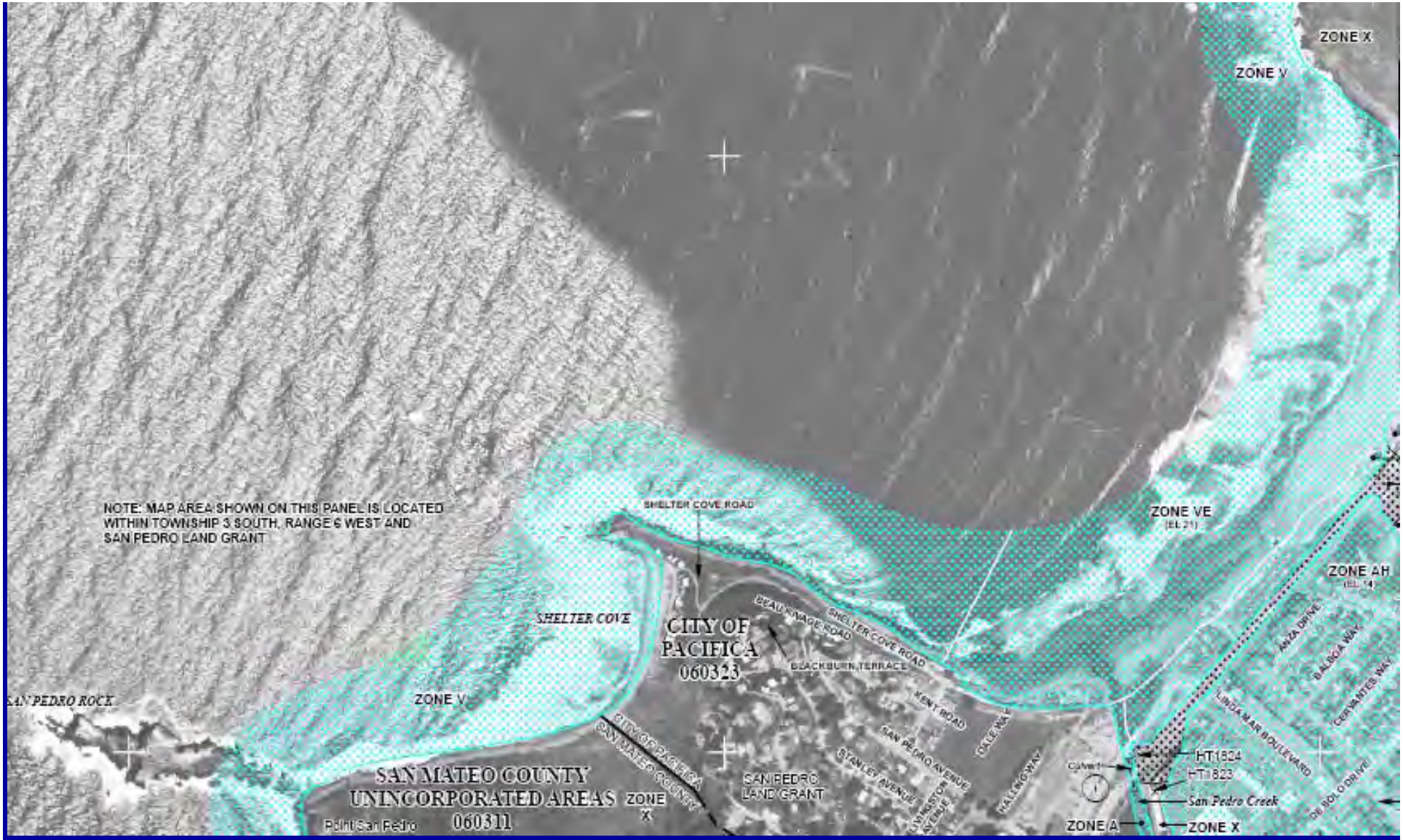
100-year coastal swl	9’ +/-
100-year coastal twl sheltered	TBD
100-year coastal twl exposed	21 to 35’

Notes:
Swl = Still Water Level (not including waves)

Twl = Total Water Level (includes waves)

NGVD is about +2.7 feet NAVD

Values do not include future sea level rise



Existing Federal Emergency Management Agency (FEMA)
Digital Flood Insurance Rate Map (DFIRM)
Based on 1980s conditions and standard of practice
(underestimates existing flood risk)

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New FEMA Maps will show greater flood risk

Since 1980's (when FEMA last mapped flood hazards)

- Large coastal flood events (1982-3, 1997-98, etc.) affect risk calculation
- Sea level has risen
- Shore has eroded / receded
- New Guidelines for Pacific Coast Flood Studies
  - Extreme rather than average runup and overtopping
  - Momentum –Force basis for inland limit of High Velocity Zone
  - Consider erosion during extreme event
  - More accurate consideration of wave setup

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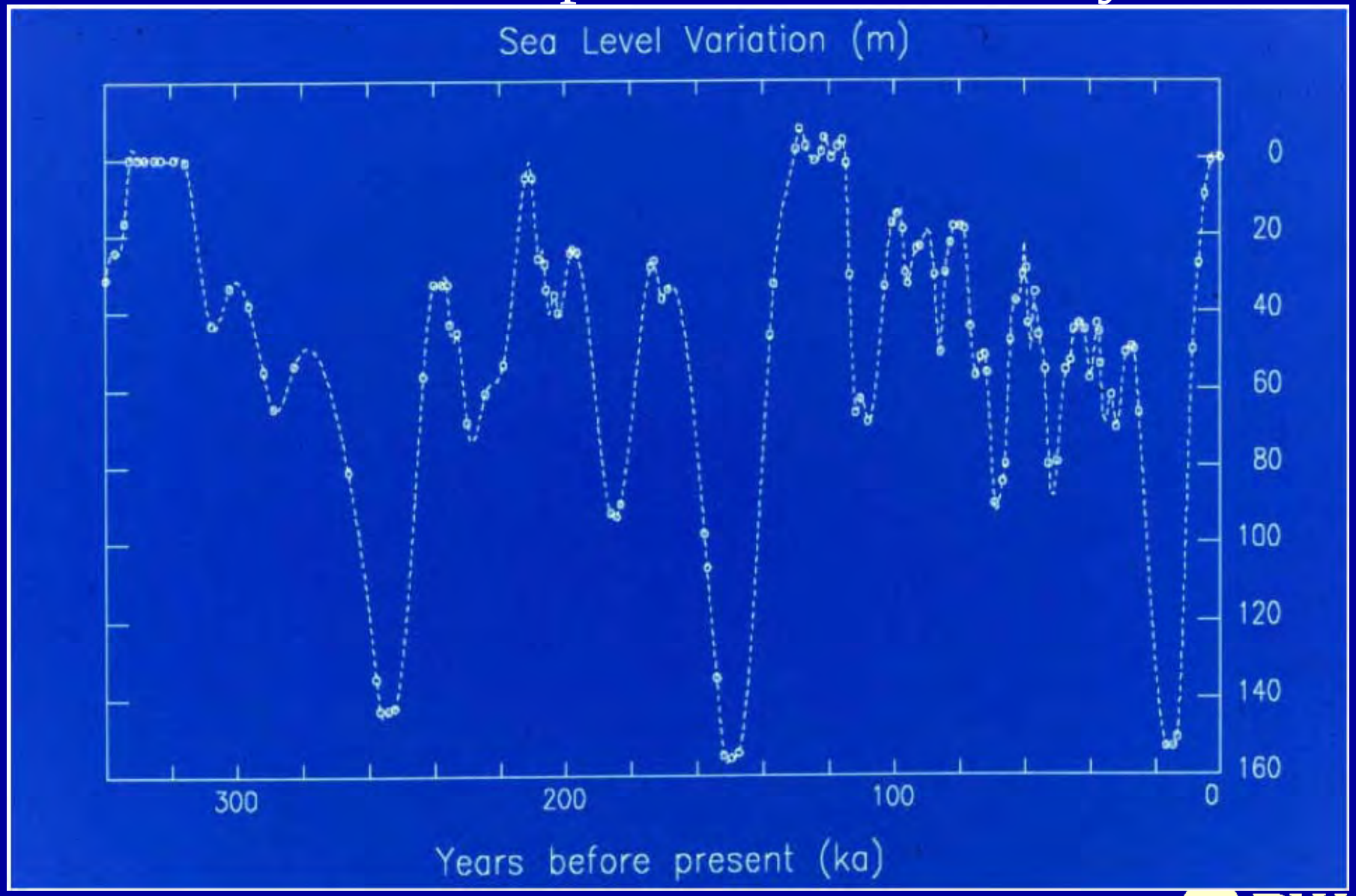
Sea Level Rise

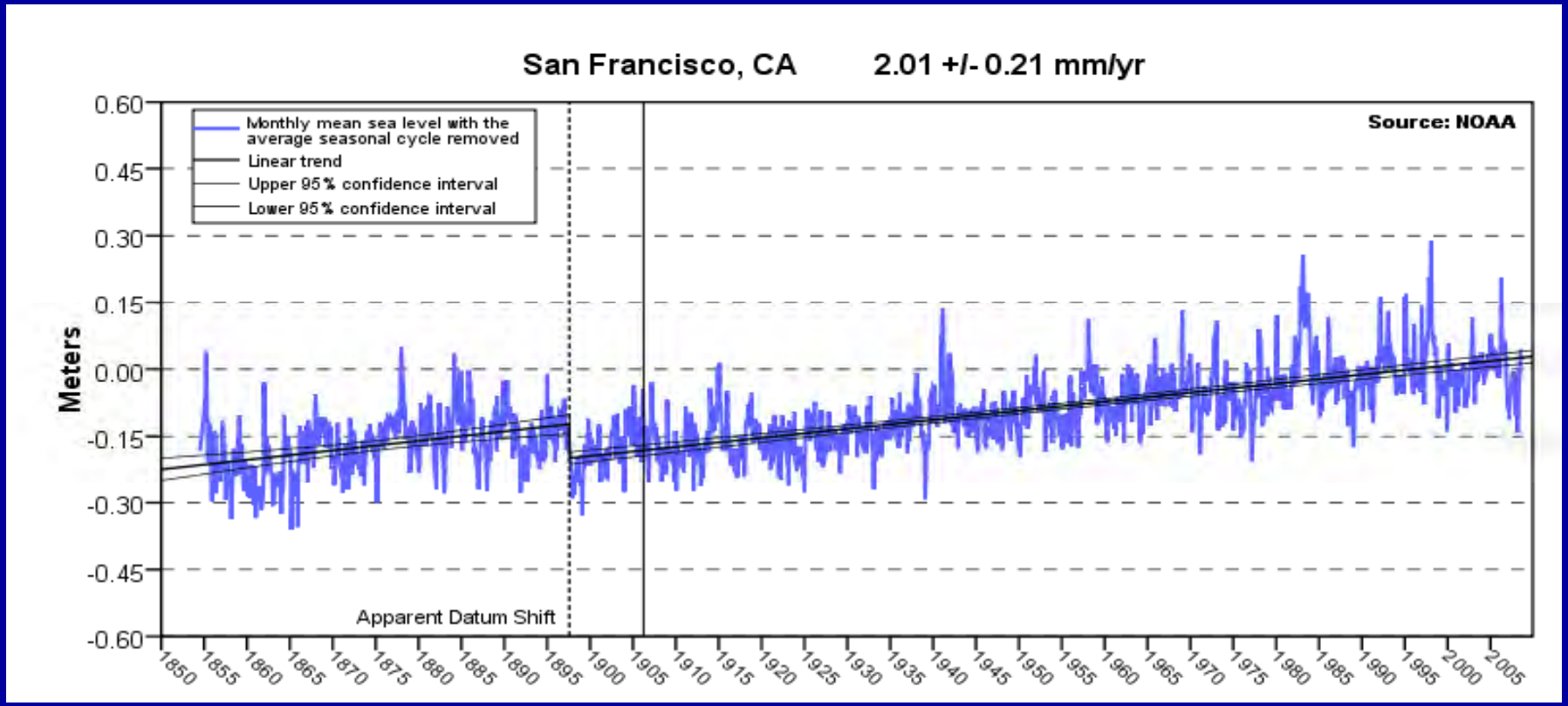
- Long Term
- Recent Historic
- Future
- Implications to Coastal Hazards
  - Flooding
  - Erosion

Sea level - the past 300 thousand years



Sea level rise – the past century

Global average: 7 inches in the 20th century



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Accelerated Sea Level Rise Predictions

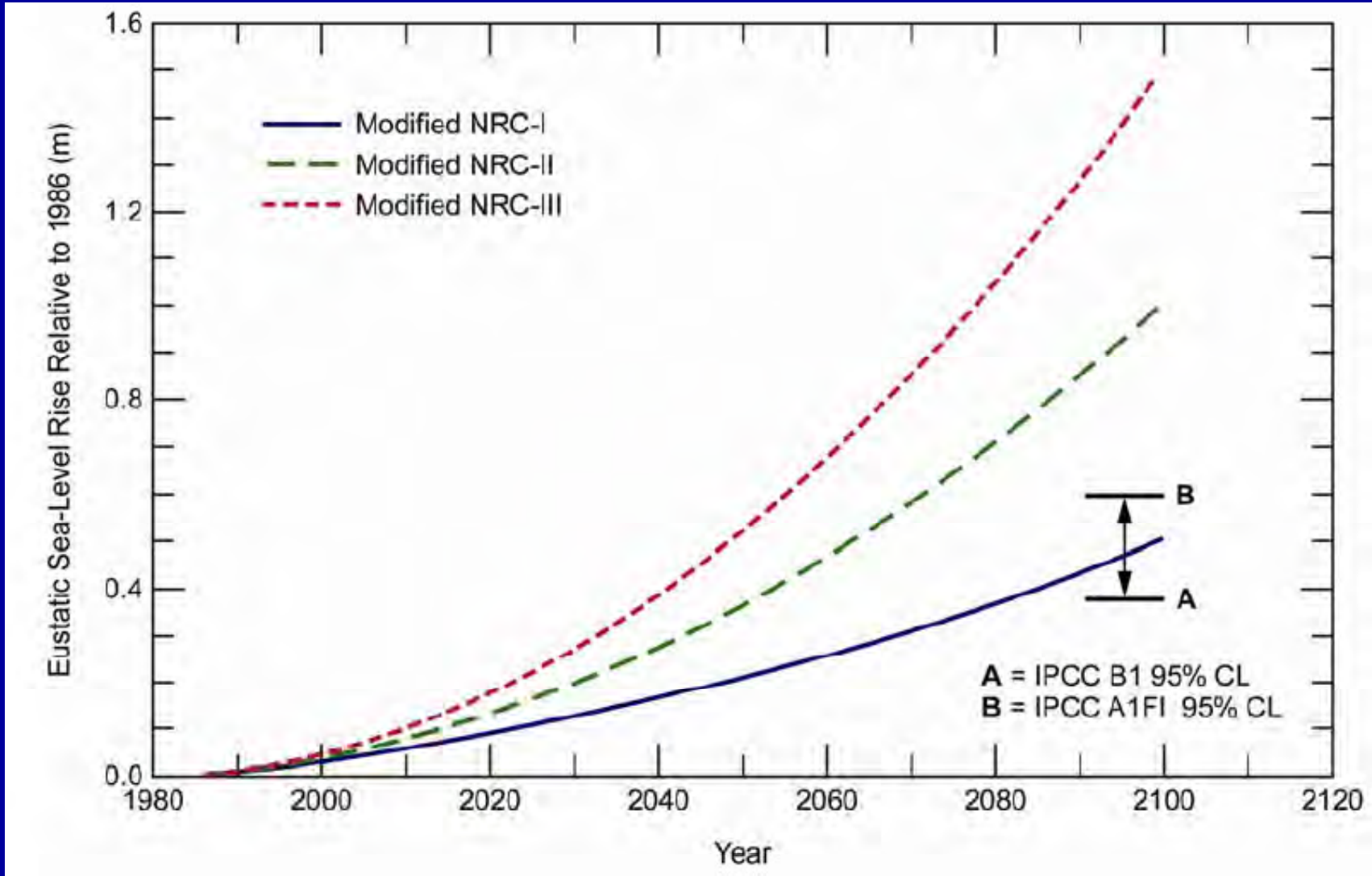

Figure B-11. Modified NRC (1987) eustatic sea-level rise scenarios and the IPCC (2007) scenario estimates for use in predicting future sea-level change.

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Future sea level rise

Delta Vision Blue Ribbon Task Force (2008)

By 2050: 16 in (40 cm)

By 2100: 55 in (140 cm)

Used by BCDC, Coastal Conservancy, USACE, California Climate Change Strategy

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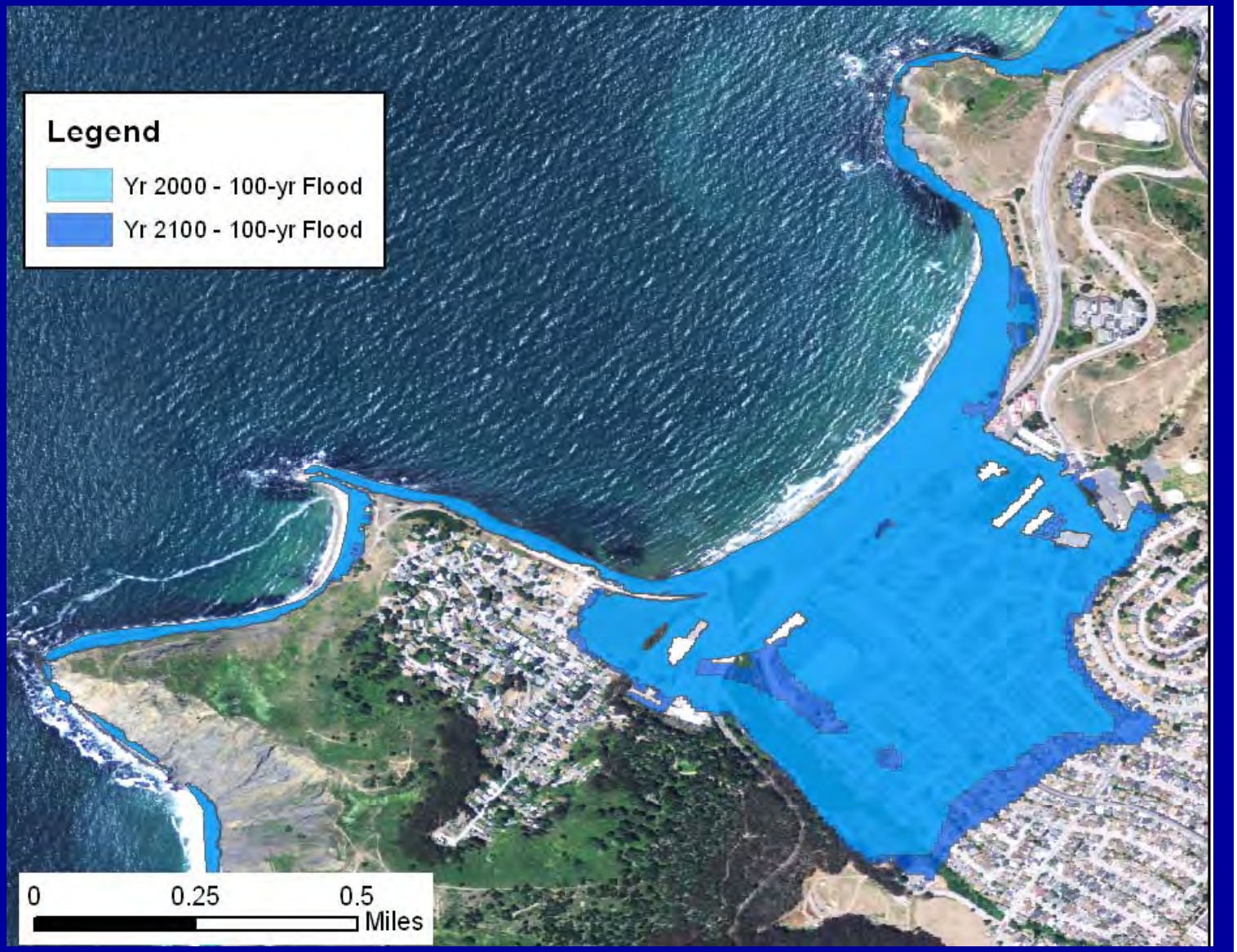
Source: Pacific Institute

http://www.pacinst.org/reports/sea_level_rise/

Note: First order approximate estimate for State-wide vulnerability assessment, not for general or local use



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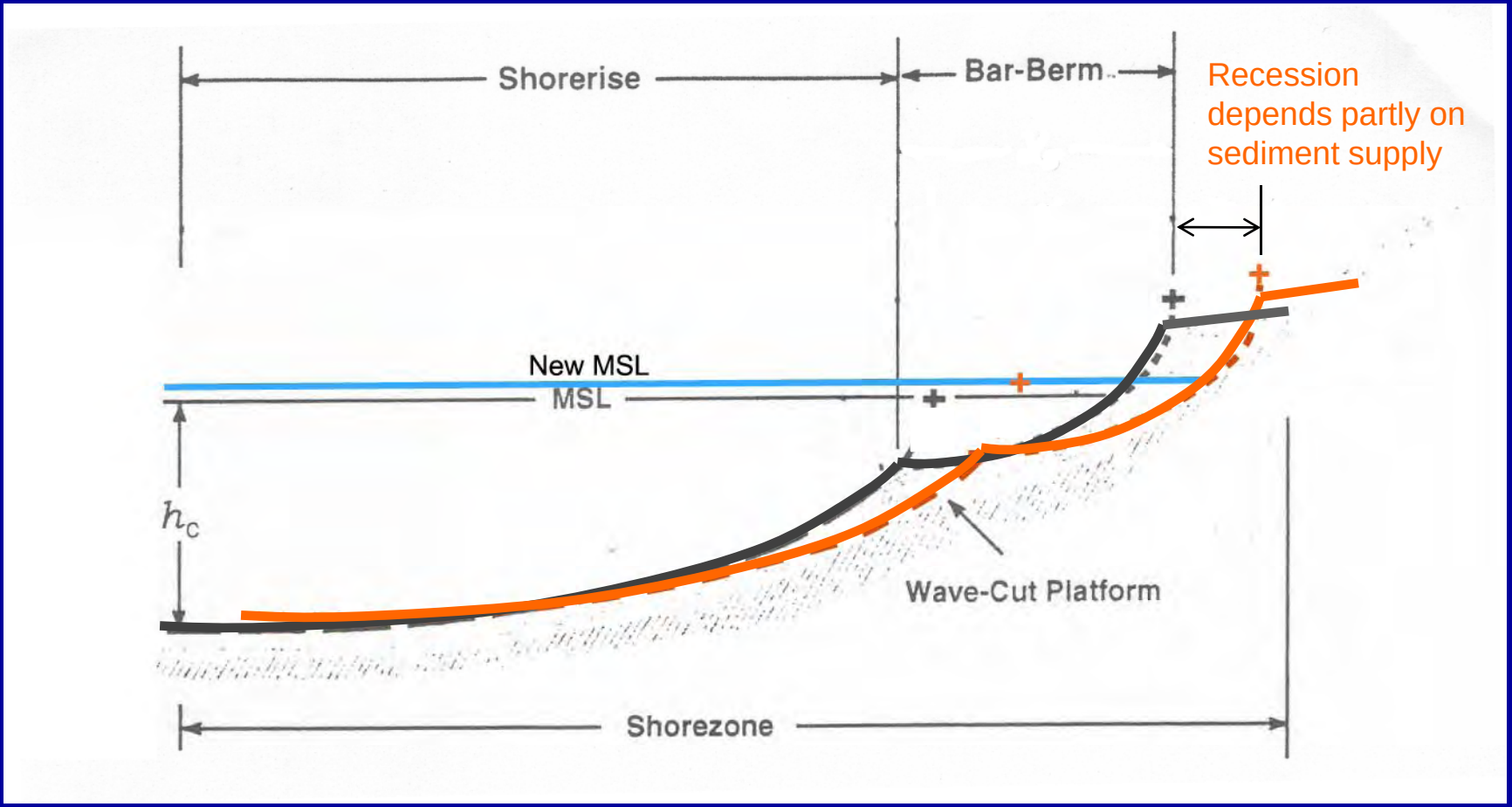
Shore Recession Resulting from Sea Level Rise



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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

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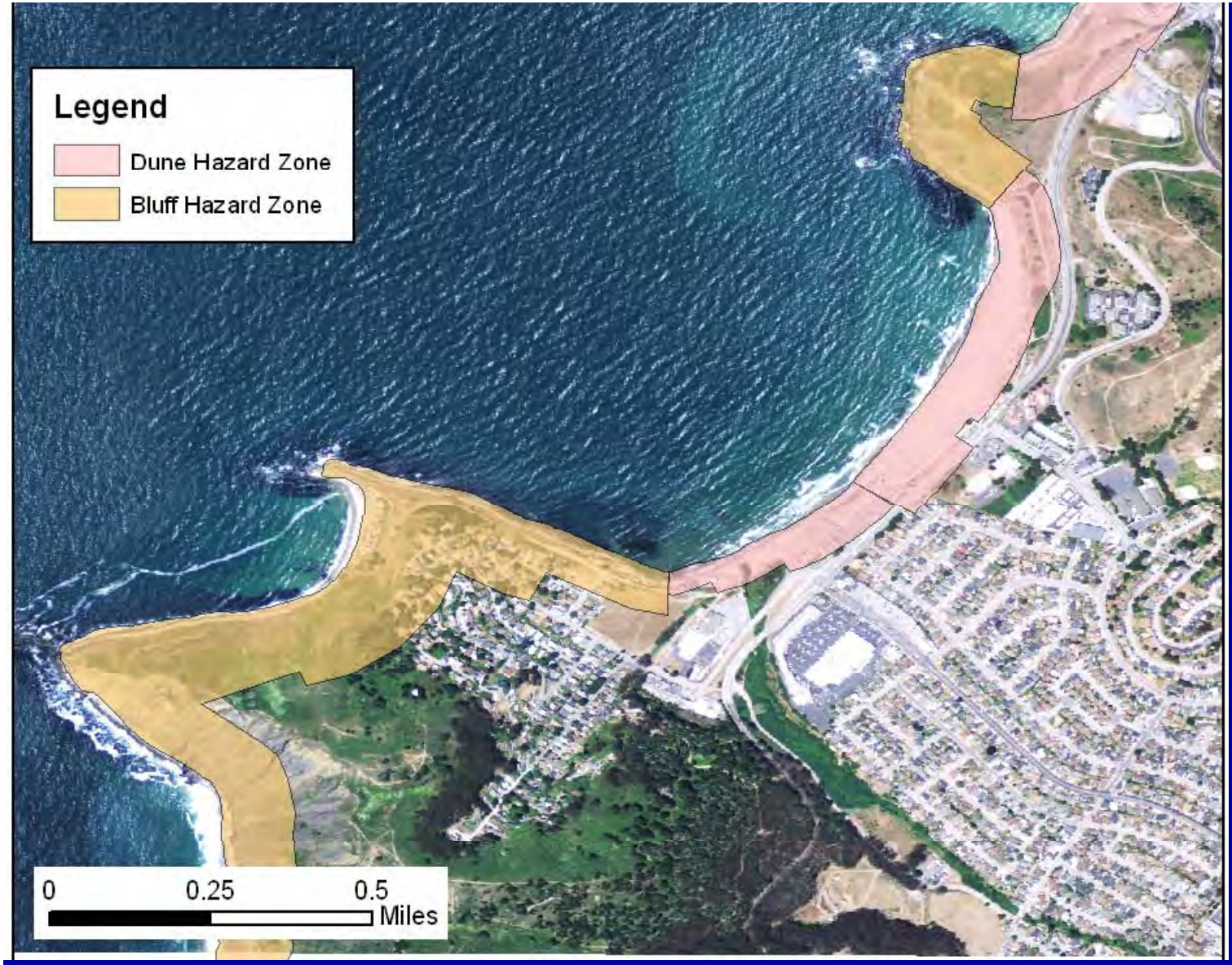

Note: First order approximate estimate for State-wide vulnerability assessment, not for general or local use

Estimated Erosion with Sea Level Rise Source: PWA, 2009
http://www.pwa-ltd.com/about/about_news.html#OPC_Report

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Photographic Tour of Pacifica from North to South with Commentary !

Daly City, Fort Funston, Lake Merced, Ocean Beach

Photos: DEBORAH LATTIMORE

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Sharp Park, Manor, Mussel Point

Photos: DEBORAH LATTIMORE

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Mussel Point, Pacifica Aug 2010 © Bob Battalio, 2010

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

Source: Shore & Beach 7/98

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

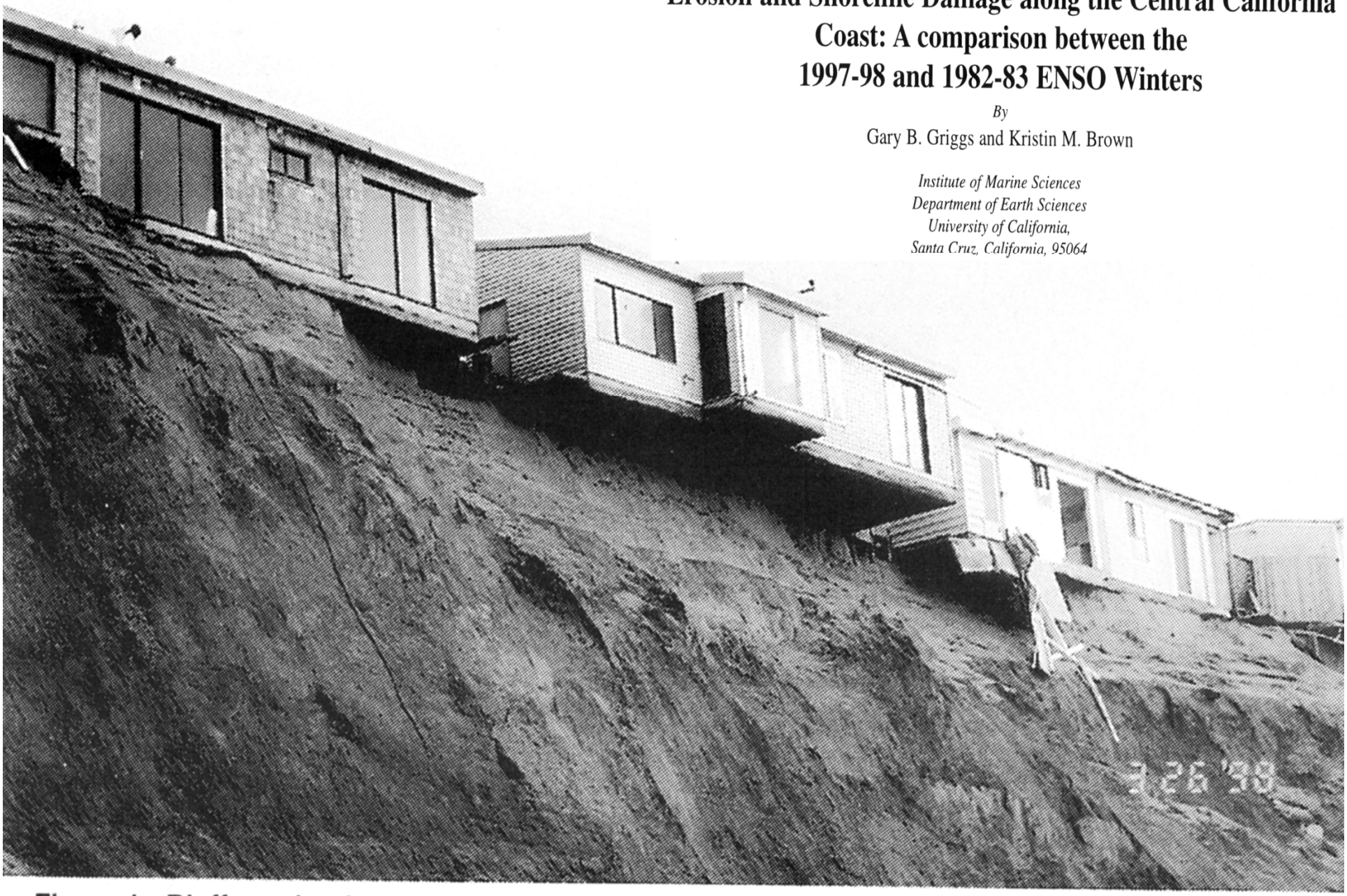
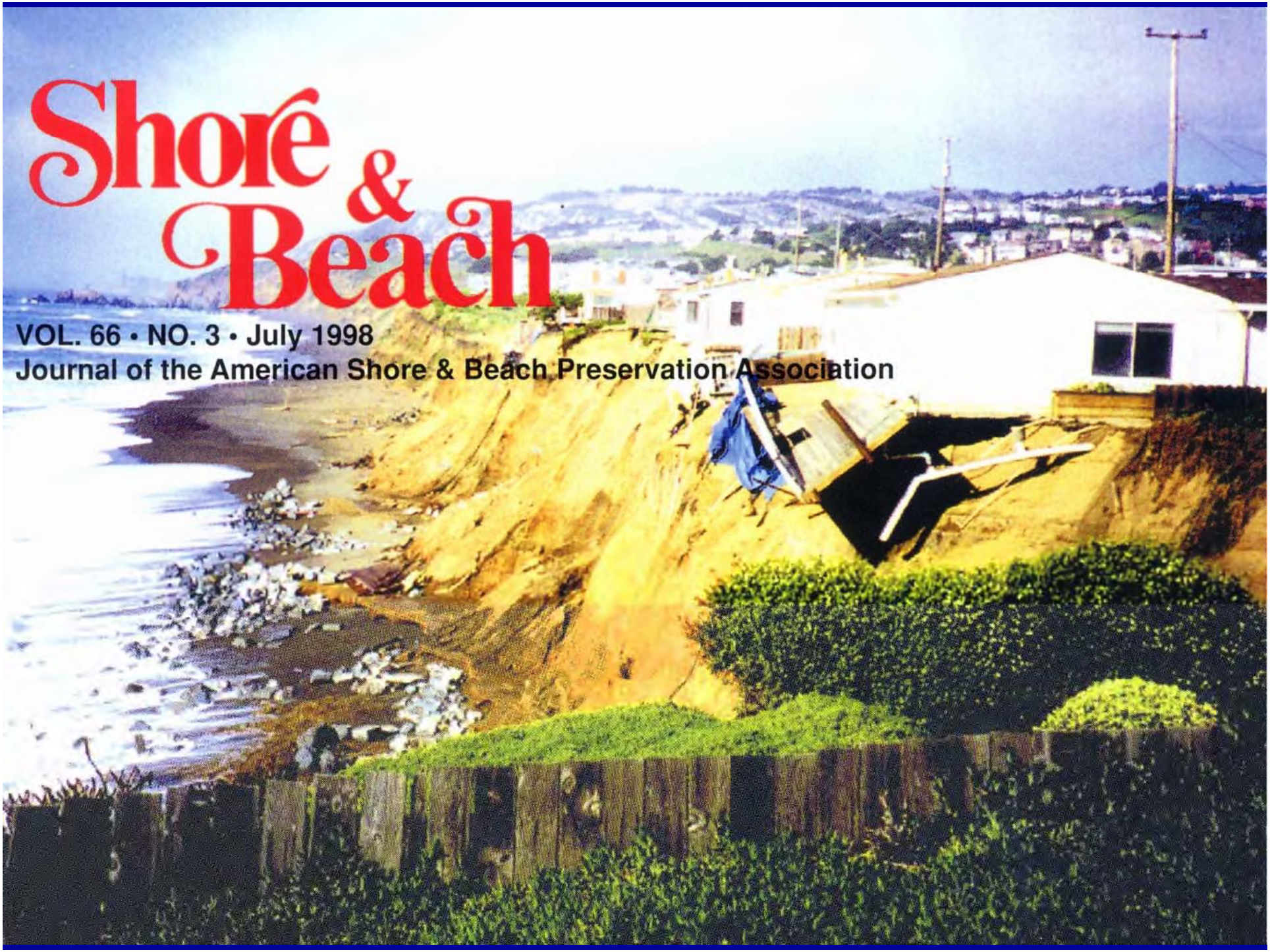


Figure 1. Bluff erosion in Pacifica between January and March 1998 ultimately led to the demolition of ten homes in April (Photo by Monty Hampton, USGS).



Shore & Beach

VOL. 66 • NO. 3 • July 1998
Journal of the American Shore & Beach Preservation Association

Esplanade Seawall

Photographs © Bob Battalio, 2005

Armoring; Manor Bluffs, Pacifica Aug 2010 © Bob Battalio, 2010

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Jan 20, 2010

Photographs © Bob Battalio, 2010

Dec 22, 2009

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Lands End ! Manor Bluffs, Pacifica Aug 2010 © Bob Battalio, 2010

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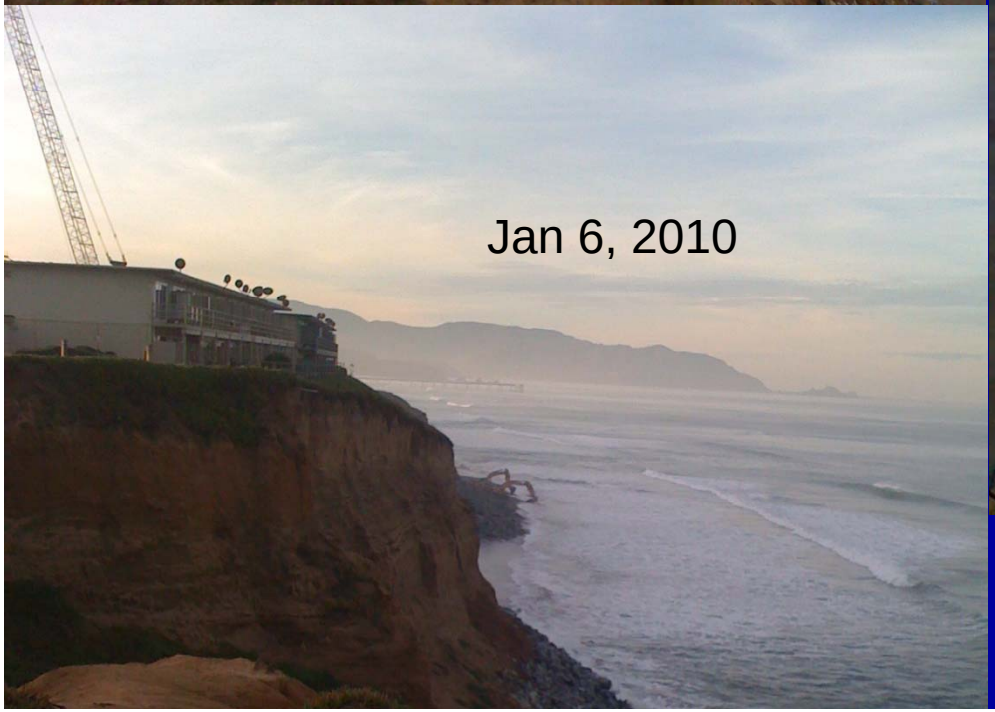

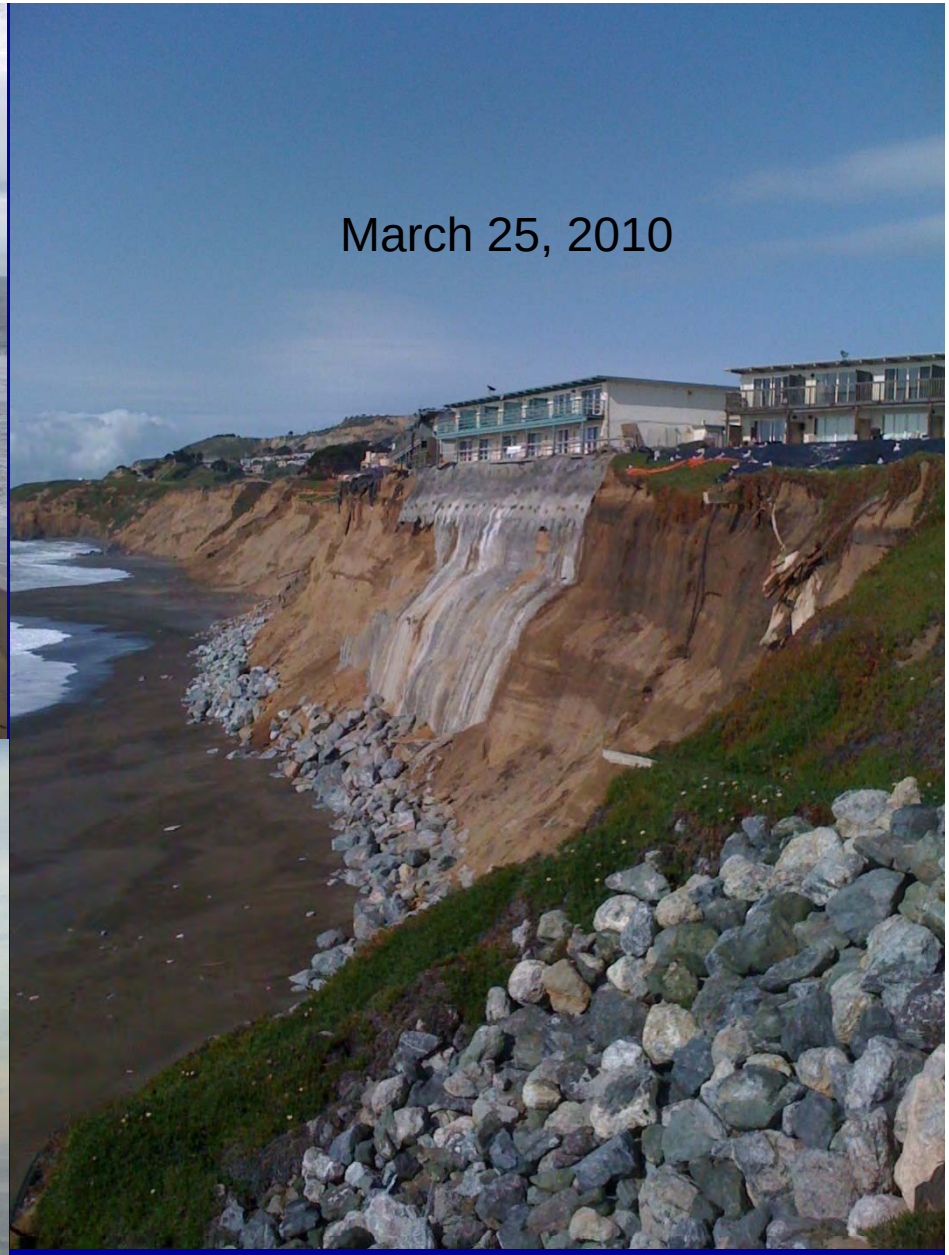

Photographs © Bob Battalio, 2010

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Aug 2010 © Bob Battalio, 2010

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Aug 2010 © Bob Battalio, 2010

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Ocean View !

Aug 2010 © Bob Battalio, 2010

“Shotcrete” Reinforced concrete retaining wall, with color and texture
Aug 2010 © Bob Battalio, 2010

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Photographs © Bob Battalio, 2010

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No dry beach below “The Bluffs at Pacifica,”, Pacifica Aug 2010 © Bob Battalio, 2010

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Sharp Park

Photos: DEBORAH LATTIMORE

California Coastal Records Project ; 1972 Photo

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

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California Coastal Records Project ; 2005 Photo

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

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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.

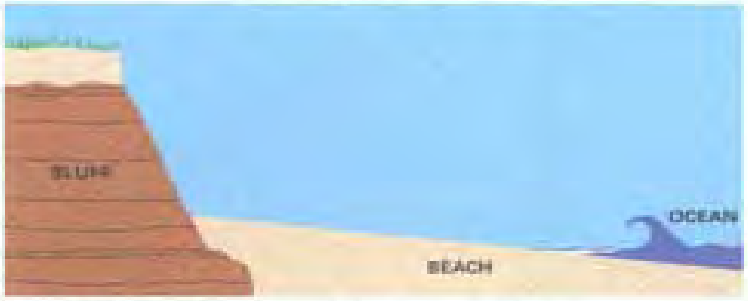
4. Active erosion of near shore.
   - Reduction of sediment supply
   - Increased wave reflection
   - Increased local scour
   - Accelerated currents and sand transport

5. Unnatural Surface

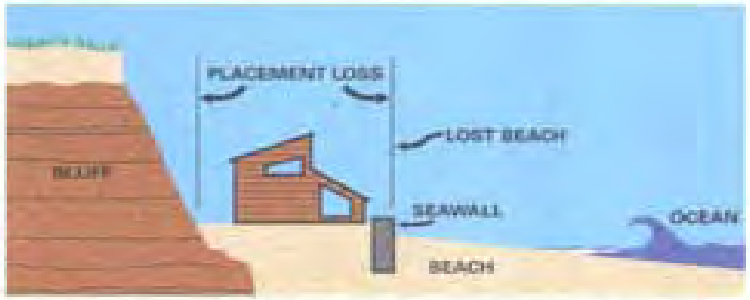
6. Change in appearance

Seawall Impacts: Placement Loss and Passive Erosion

Placement Loss



A. Beach without any coastal shore protection



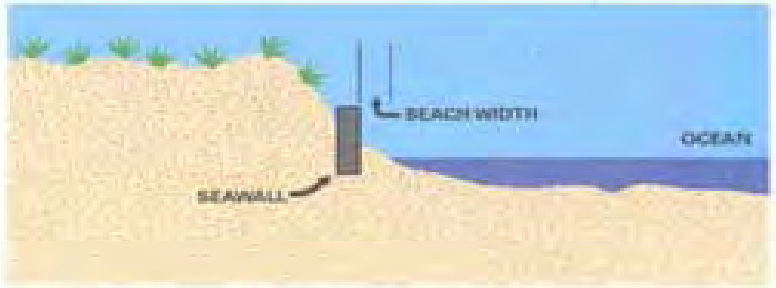
B. Placement loss of beach due to construction of seawall and house

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

PWA

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

2005

Source: California Coastal Records Project

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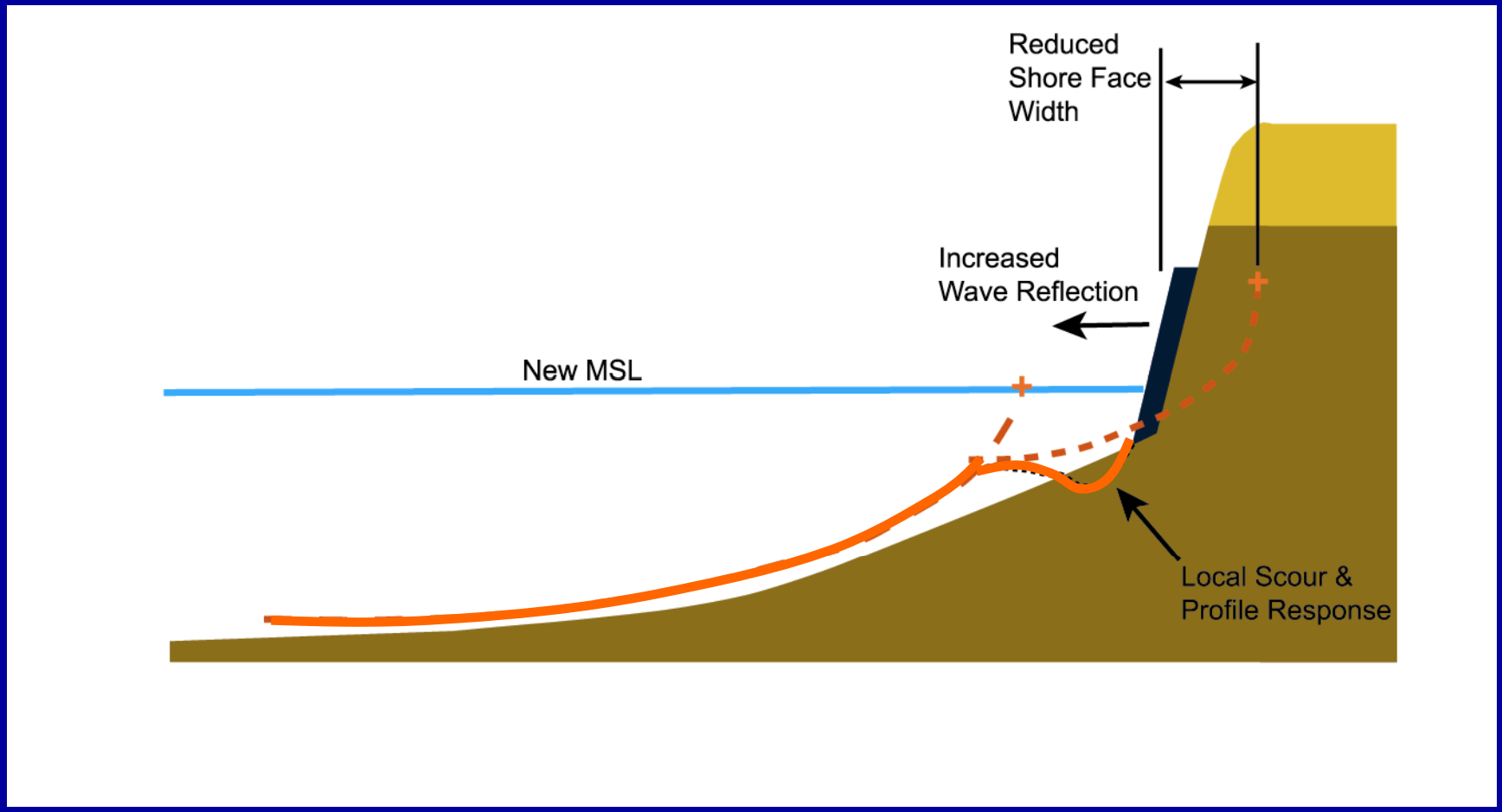
Long Term Shore Morphology Changes With Armoring (Eroding Shore)



Beach Blvd Seawall soon after construction

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

Source: Geomatrix Consultants, Nov, 1987

PWA

Our Children's future ?

Photo copyright Bob Battalio

Beach Blvd Seawall, winter high tide conditions

PWA

Letters to the Editor

Pacifica Tribune, January 18, 2006

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 Pacifica Pier.

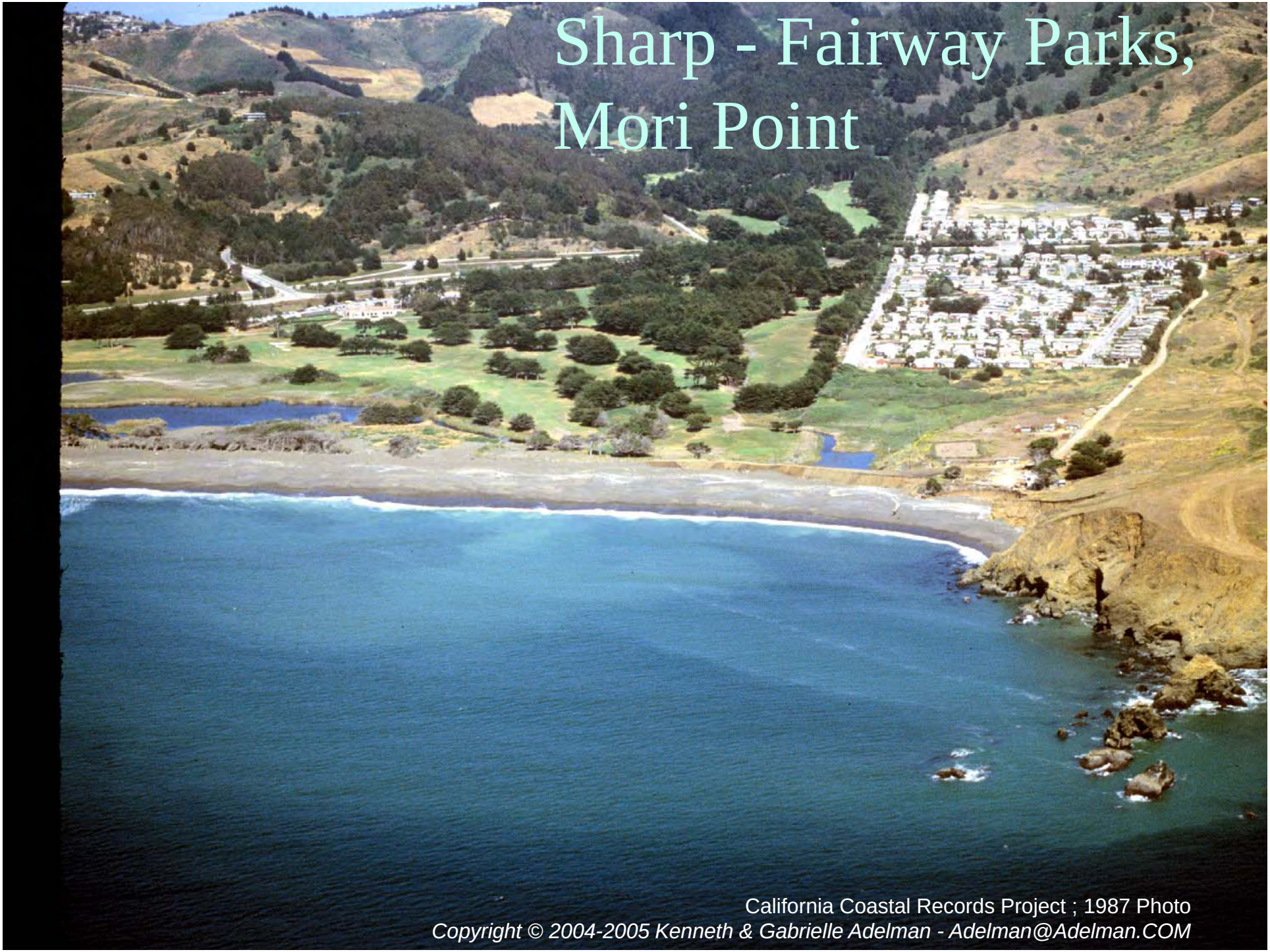
I was under water for several seconds and, when I was finally able to breathe and open my eyes again, was completely stunned to find myself sitting on the floor near the back of someone's garage with my arm hooked through a barbeque pit. I was extremely fortunate to not have sustained major head and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

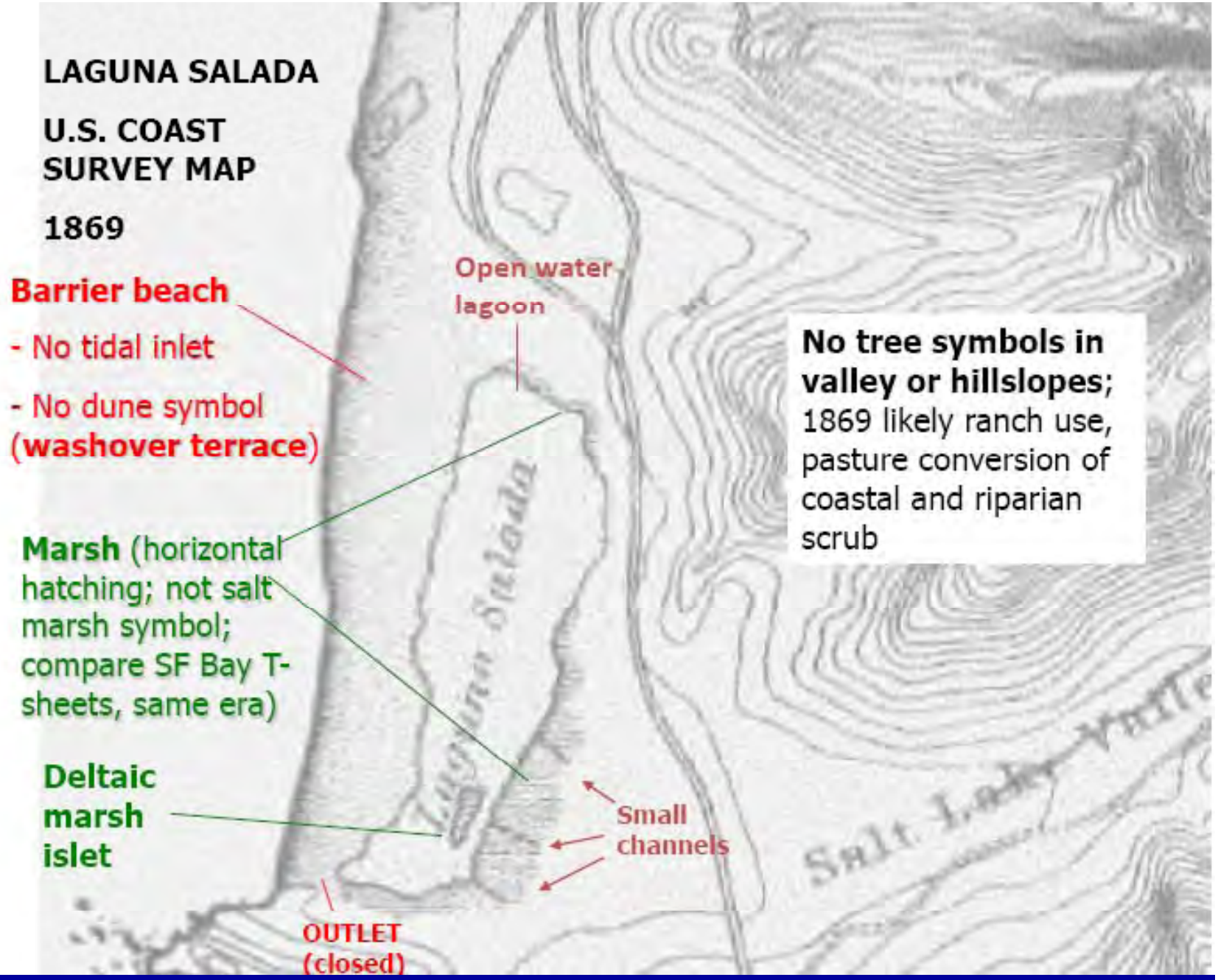
Anjanette Stutes
Sharp Park

PWA



California Coastal Records Project ; 1987 Photo

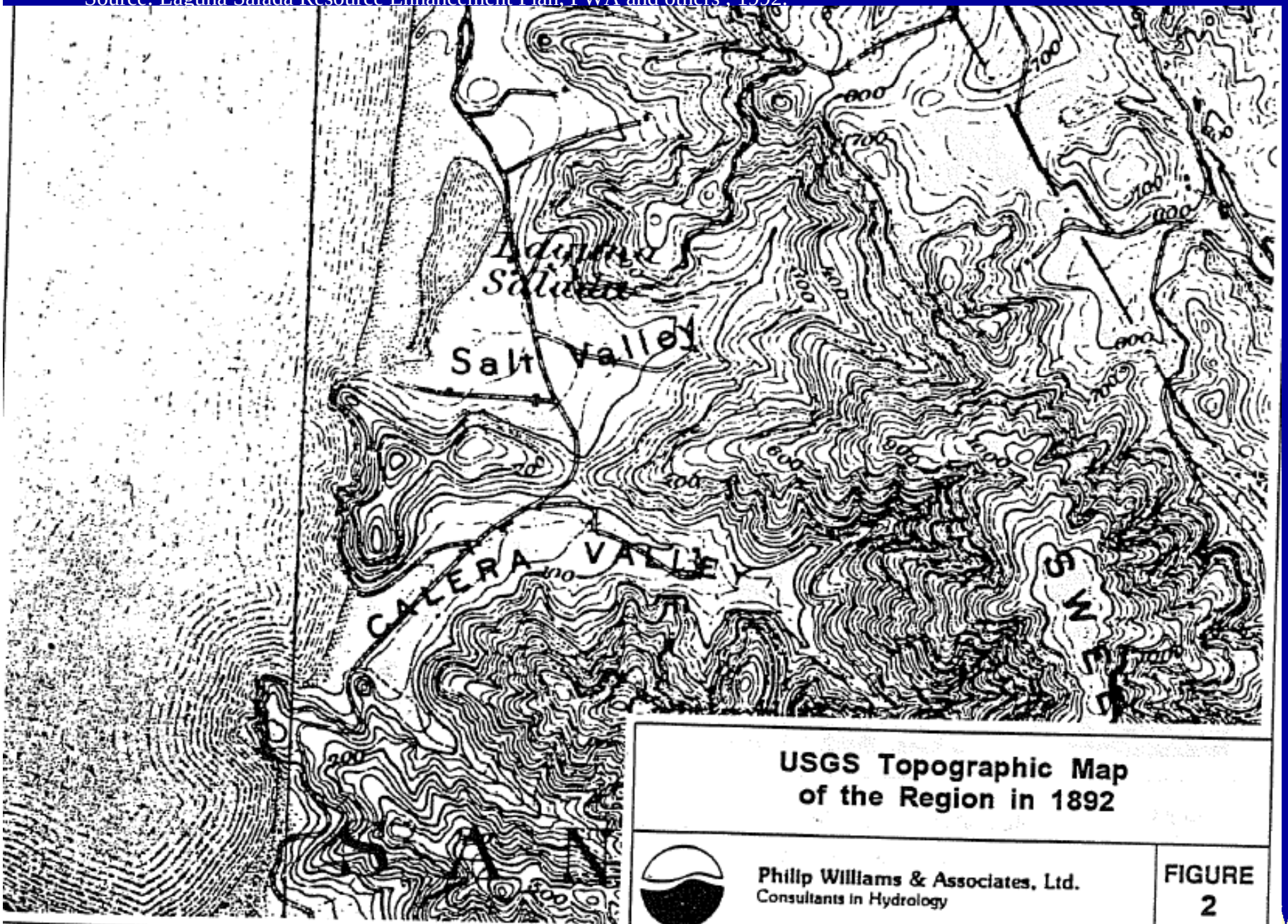
Copyright © 2004-2005 Kenneth & Gabrielle Adelman - Adelman@Adelman.COM



Source: Peter Baye, PhD, 2009 *Laguna Salada Talk*

PWA

Source: Laguna Salada Resource Enhancement Plan, PWA and others , 1992.



USGS Topographic Map of the Region in 1892

Philip Williams & Associates, Ltd.
Consultants in Hydrology

FIGURE 2

Laguna Salada 1928-30

1869 U.S. Coast Survey Map: **LAGUNA SALADA, Pacifica**

1946 aerial photo

- Large wide, low gradient valley (floodplain) at east end of lagoon wetlands; riparian scrub position

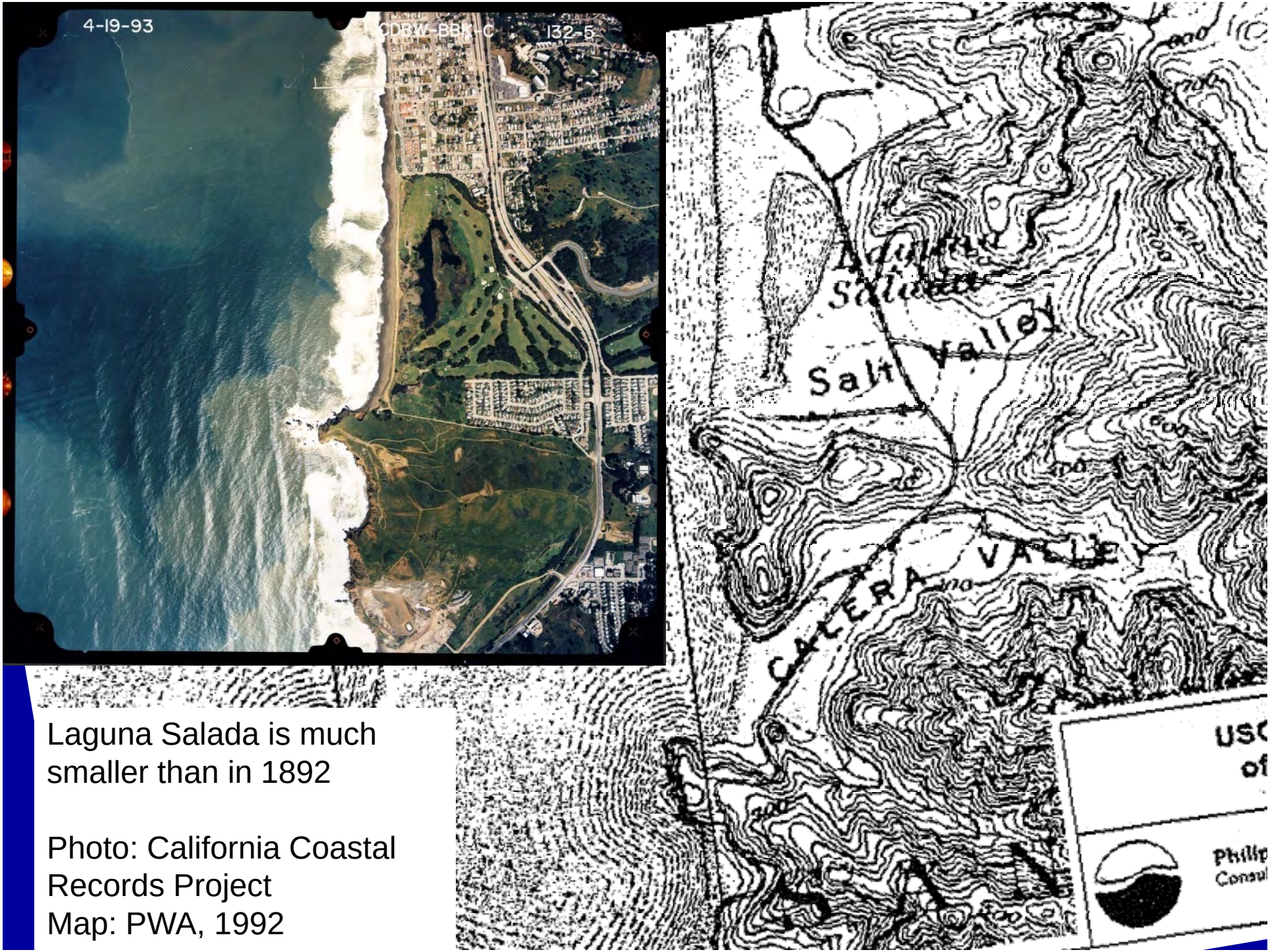
- lagoon mostly open water; narrow fringing marsh

-Golf course fills valley and south lagoon, & landward edge of washover terrace

- lagoon remnant mostly emergent marsh; little open water (drained)

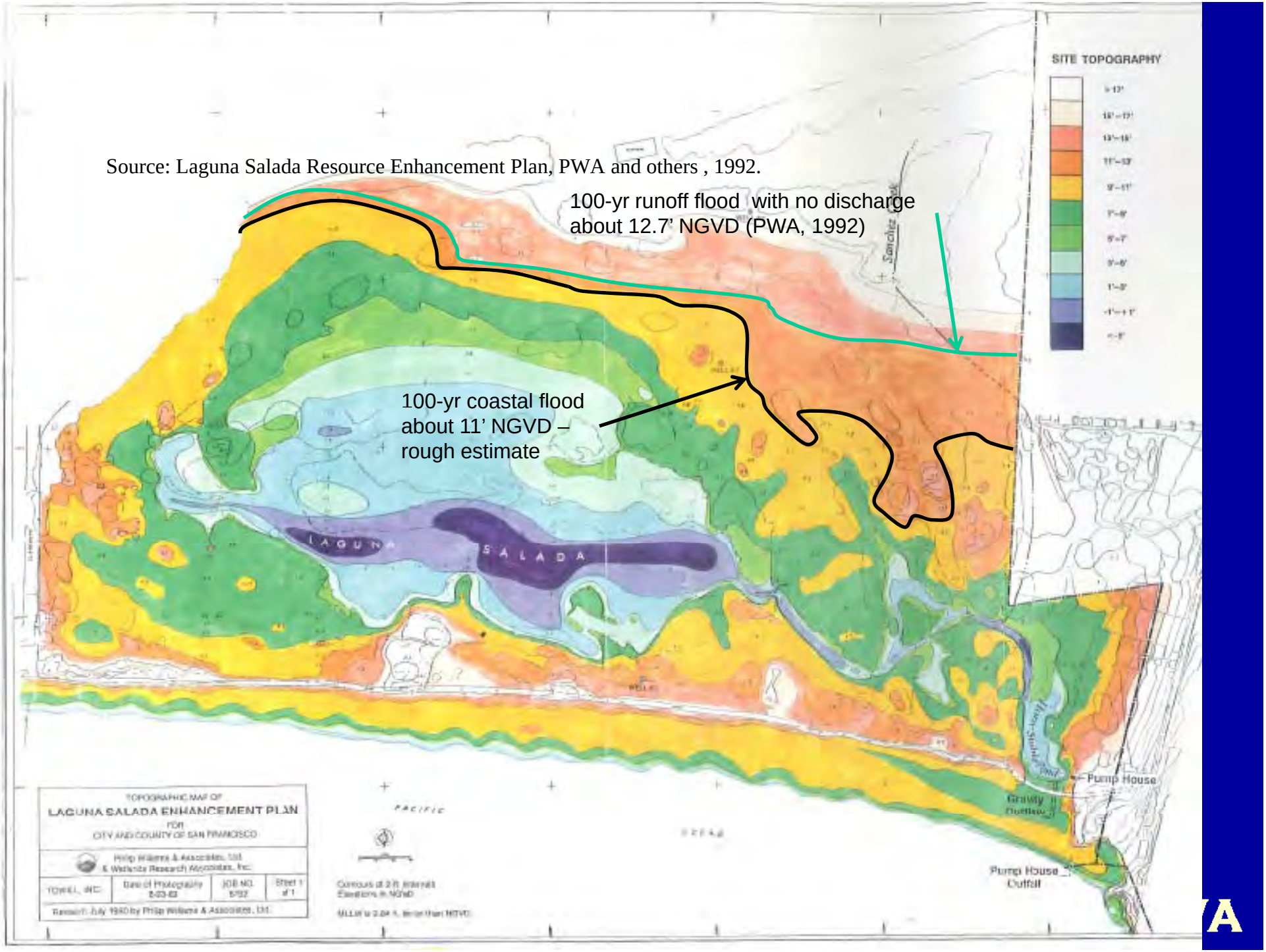
Source: Peter Baye, PhD, 2009 *Laguna Salada Talk*

PWA



Laguna Salada is much smaller than in 1892

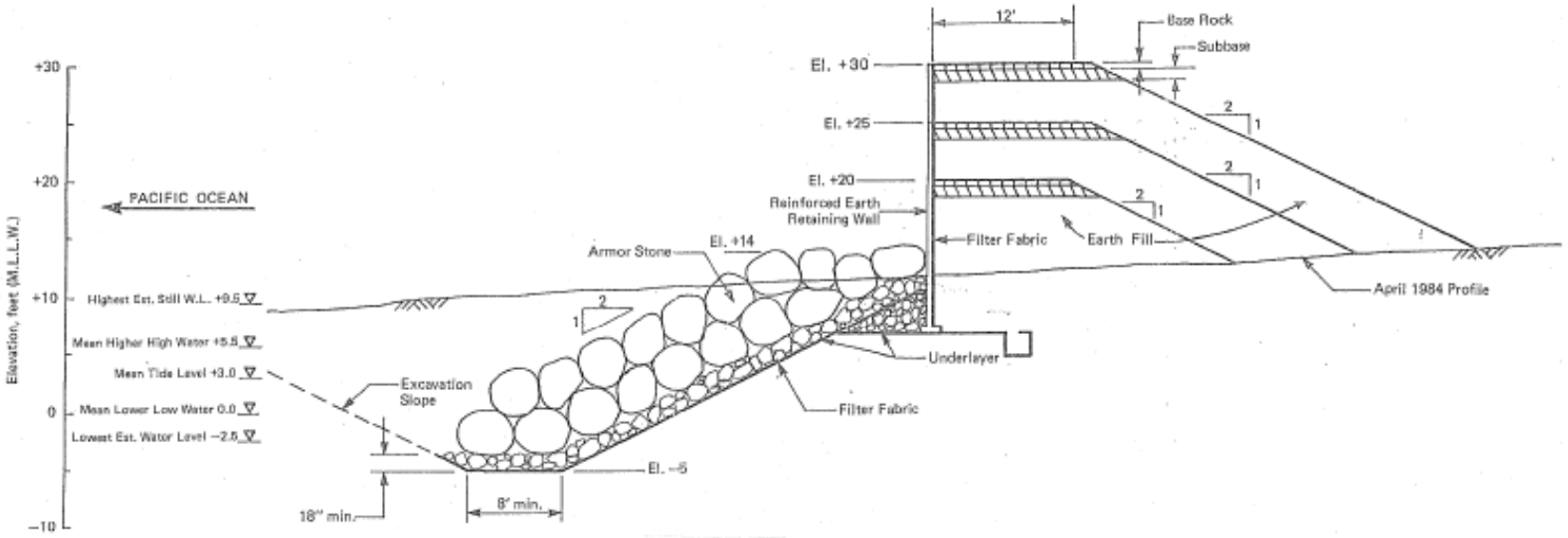
Photo: California Coastal Records Project
Map: PWA, 1992



Source: Laguna Salada Resource Enhancement Plan, PWA and others , 1992.

Proposal to “Hold the Line” at Laguna Salada

One of the alternatives is similar to Beach Blvd seawall which has performed poorly, required extensive maintenance and resulted in loss of beach.



ALTERNATIVE 3

CREST ELEVATION = +20 FEET, + 25 FEET or +30 FEET

NOTES:

1. Profile Based on Topographic Maps “Sharp Park Storm Drainage Reconstruction”, Sheets 1–4, Prepared by Towill Inc., Date of Photography 27 April 1984. Refer to Figure 4 for Approximate Location of Cross-Section.
2. Armor Stone Protection to Consist of Two Layers of 3- to 5-ton Rock from Elevation −5 feet to +14 feet.

0 5 10 20 30 feet

Horizontal and Vertical Scale

PRELIMINARY EMBANKMENT CONFIGURATIONS
ALTERNATIVE 3

Project No. 1086A	SHARP PARK EMBANKMENT Pacifica, California	Figure 11
Geomatrix Consultants		

Source: Geomatrix Consultants, Nov, 1987

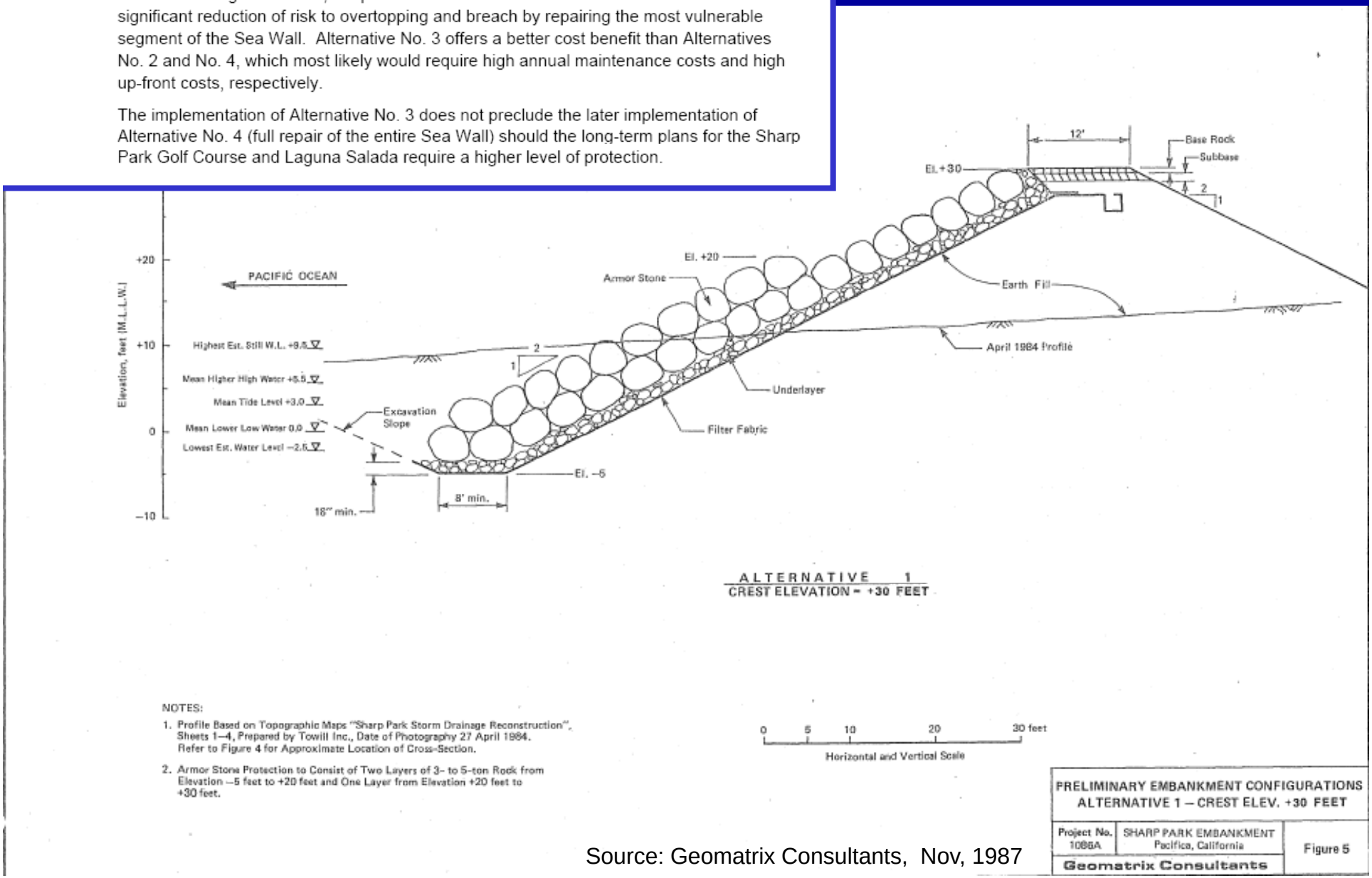
PWA

ARUP, Dec 8, 2009 recommends raising earth embankment to +30' and armoring for about 1,800 feet, similar to this graphic from prior Geomatrix Report, to cost about $6-$7 Million plus about $60, 000 to $70,000 per year in maintenance.

10 Recommended Alternative

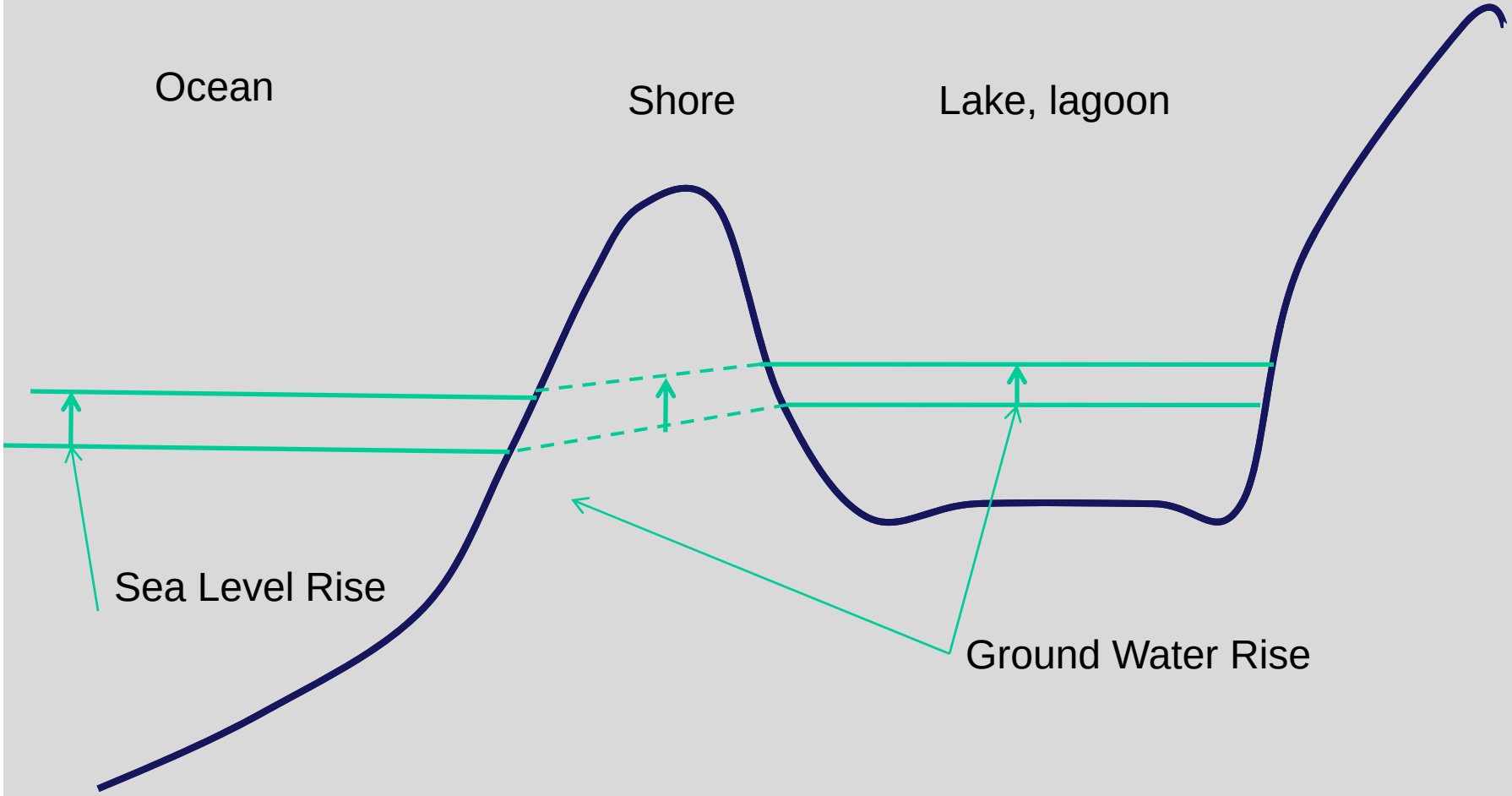
Based on the level of assumed risk, cost-benefit, and current plans for the Sharp Park Golf Course and Laguna Salada, the preferred alternative is No. 3. This alternative offers a significant reduction of risk to overtopping and breach by repairing the most vulnerable segment of the Sea Wall. Alternative No. 3 offers a better cost benefit than Alternatives No. 2 and No. 4, which most likely would require high annual maintenance costs and high up-front costs, respectively.

The implementation of Alternative No. 3 does not preclude the later implementation of Alternative No. 4 (full repair of the entire Sea Wall) should the long-term plans for the Sharp Park Golf Course and Laguna Salada require a higher level of protection.

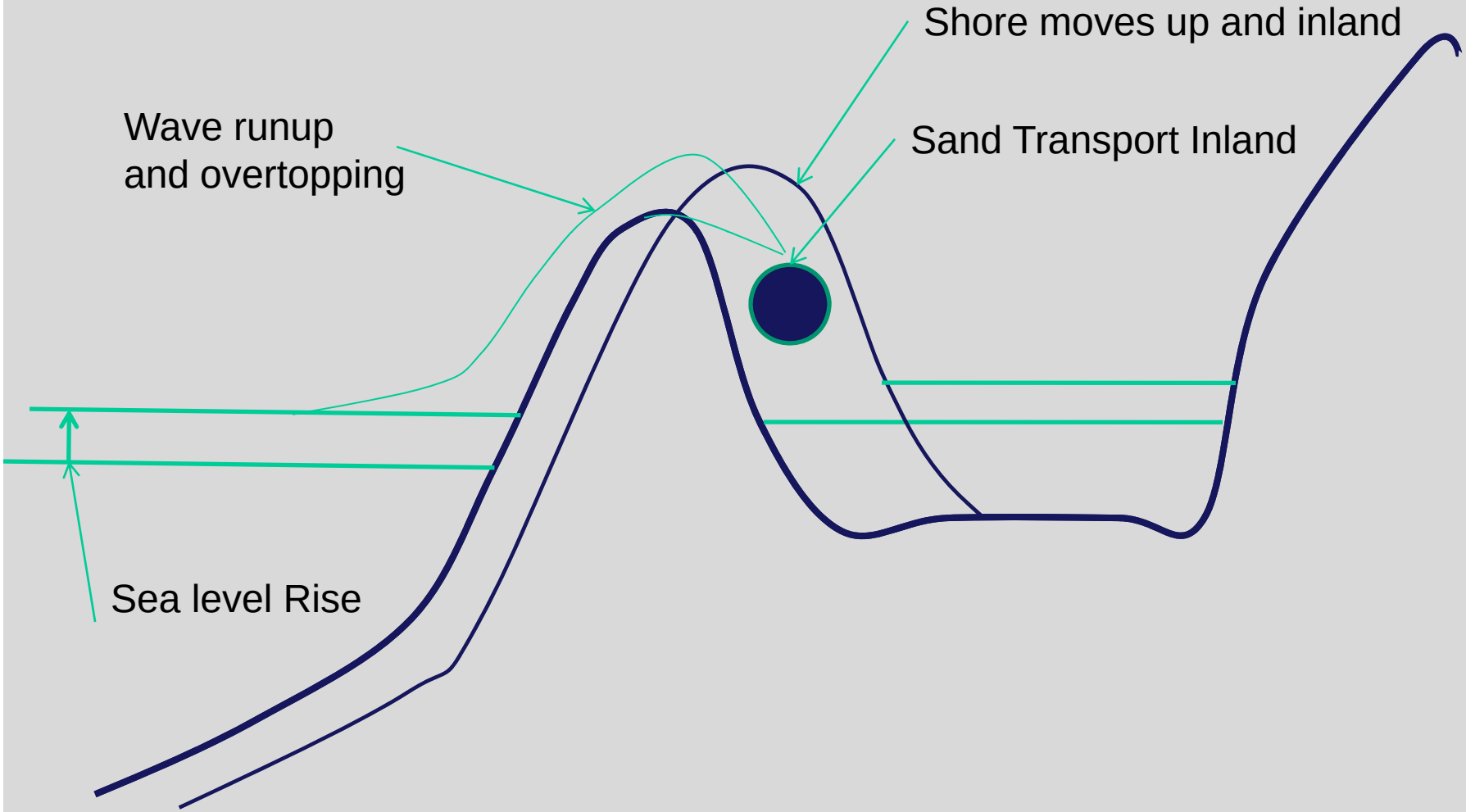


Source: Geomatrix Consultants, Nov, 1987

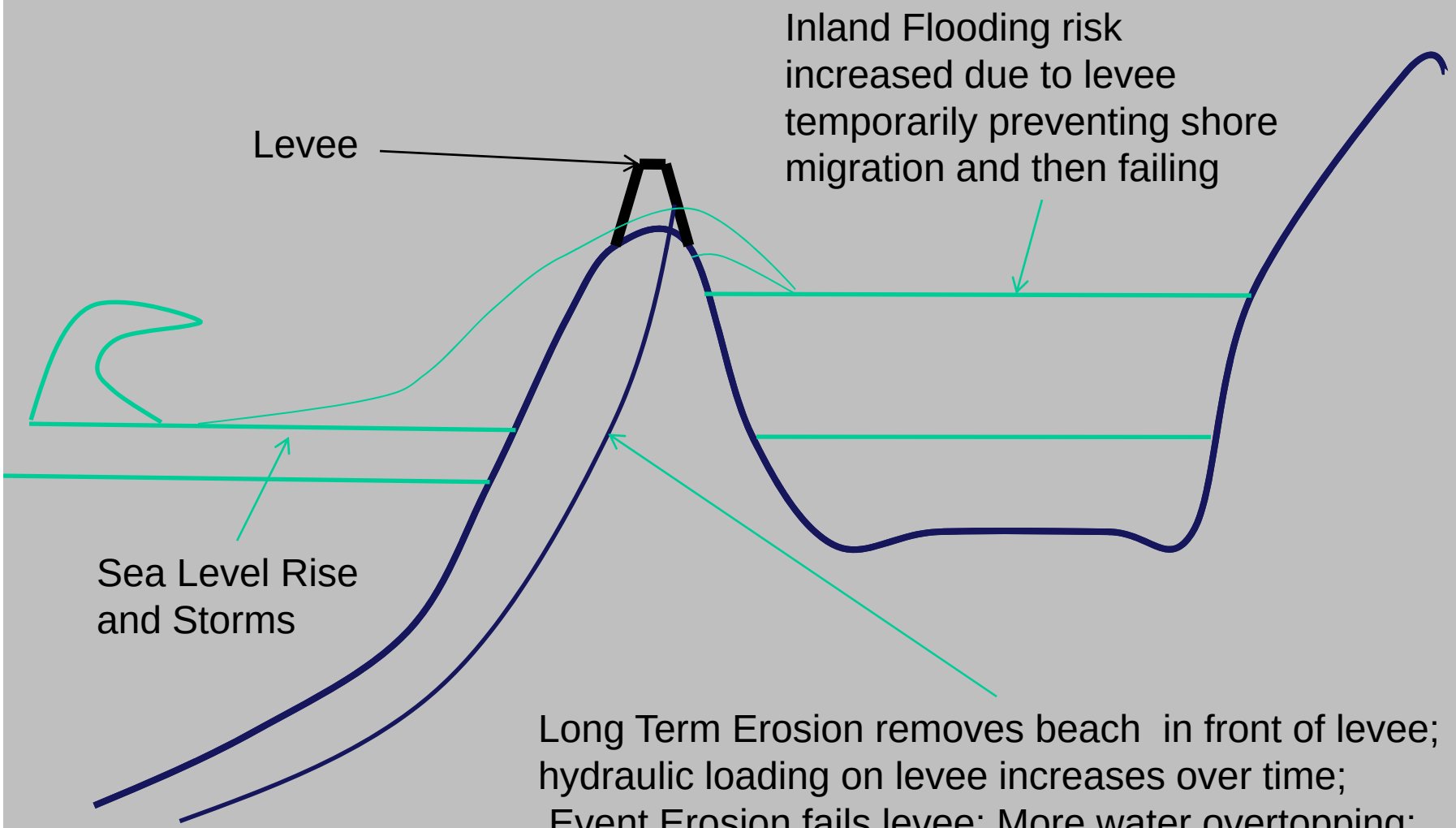
Ground Water Rises with Sea Level Rise



Shore Transgression with Sea Level Rise
Natural shore and wetlands maintained by shifting up and inland



Coastal Levees don't work well over long term; Flood damage risk higher due to poor planning



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Accreted Sediments
Sharp Park
March 18, 2010
Photograph © Bob Battalio 2010


Accreted Sediments
Sharp Park
March 18, 2010
Photograph © Bob Battalio 2010

Rockaway Cove, Hidden Cove, Mori Point

Photos: DEBORAH LATTIMORE

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Montara Mountain, Pedro Point, Shelter Cove, Linda Mar

Photos: DEBORAH LATTIMORE

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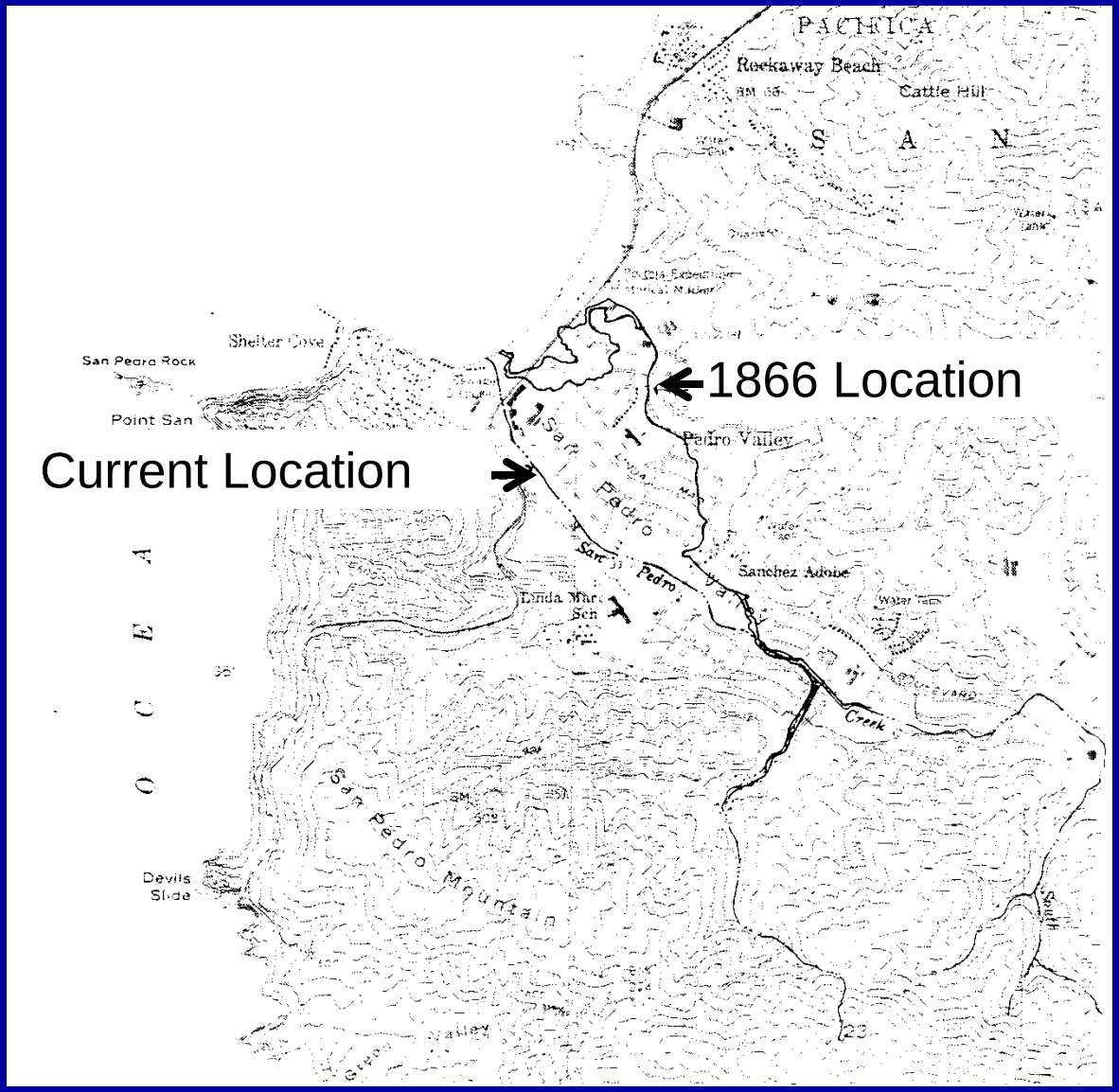
Comparison of 1866 & Current Locations of San Pedro Creek



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

Photograph © Bob Battalio 2005

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1. Pacifica State Beach (Linda Mar), Pacifica

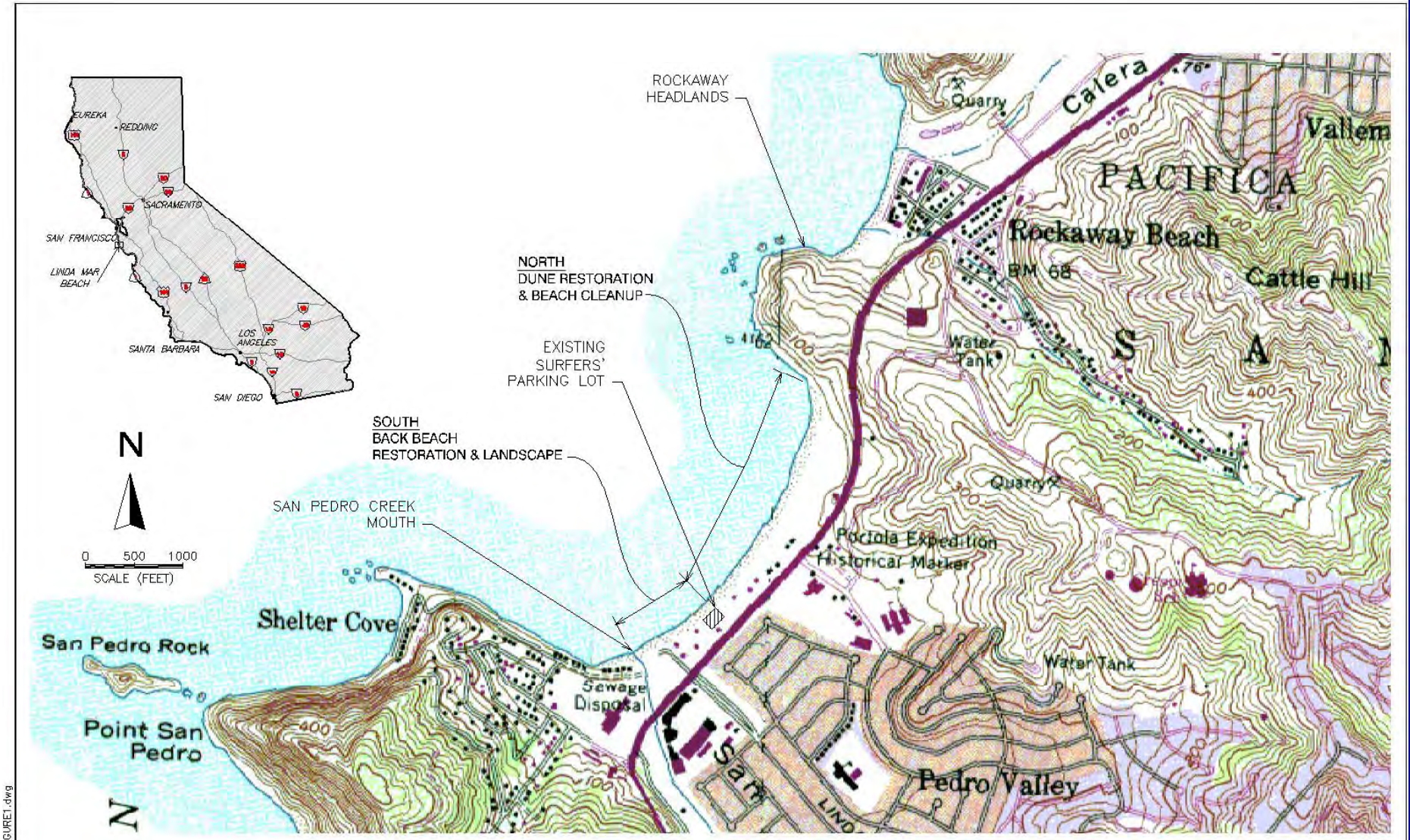

figure 1

ASBPA Best Restored Beaches 2005

Vicitnity Map
Linda Mar Beach

G:\Projects\1547 Pacifica\FIGURE1.dwg

2009

Pacifica State Beach
Managed
Retreat Project

2004

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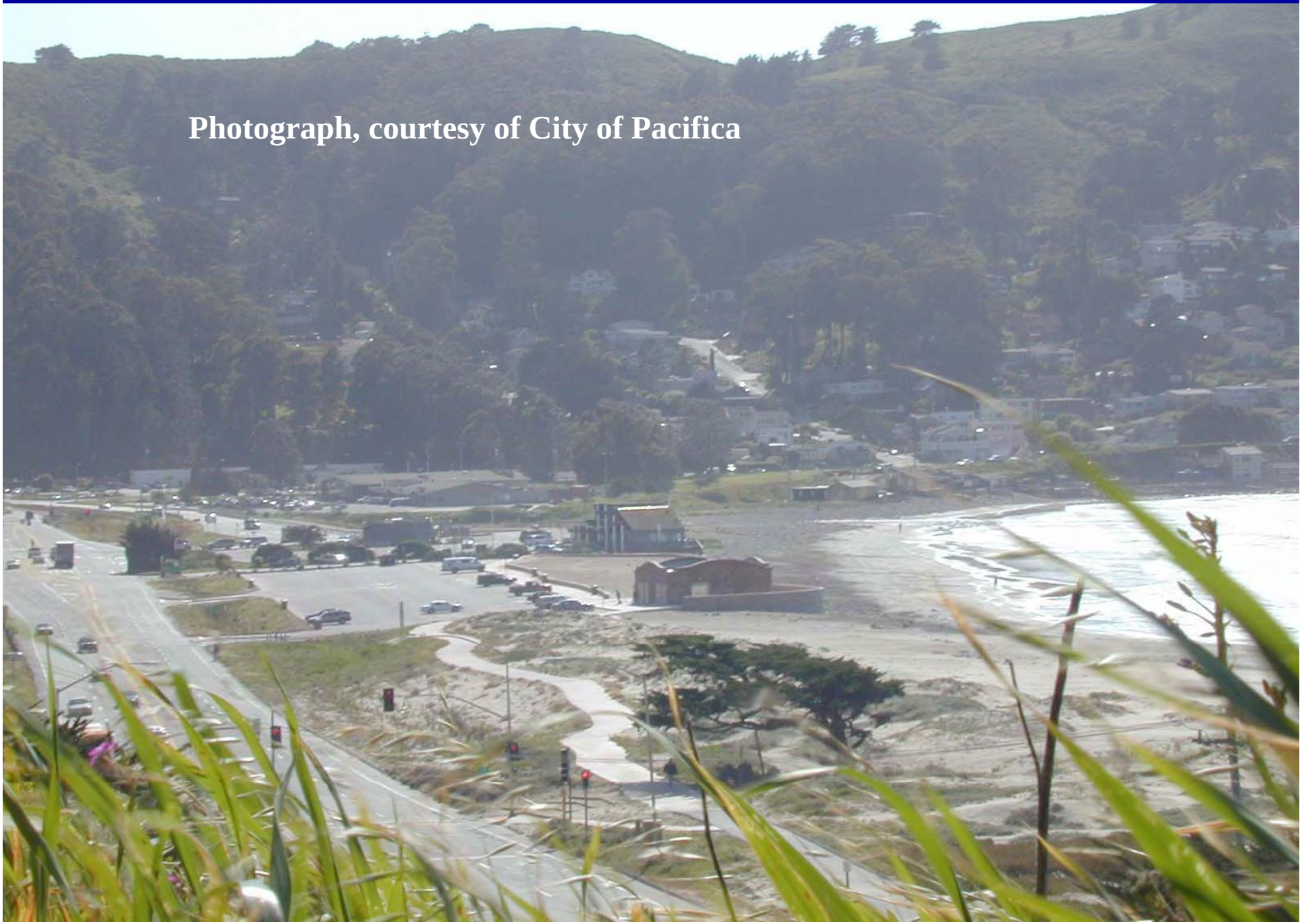
1. Pacifica State Beach, April 15, 2005, Post Construction of Managed Retreat Project



Adaptation Strategy

- Hazard / Vulnerability Assessments
- Management Approaches
- Regional Coastal Zone Management

Hazard Assessments

- Map Coastal Flood and Erosion Hazard Zones
  - Historic changes and sediment budget used as foundation
  - Existing Conditions, hazards with projection of historic trends
  - Future Conditions, hazards projected for range of sea level rise
- Assess Vulnerability
  - Proximity of asset to mapped hazard indicates vulnerability
  - Consider Failure mode(s), severity of consequences, timing
  - Rank Vulnerability Risk in terms of time and severity
  - Develop Action Plan to prioritize and mitigate risks over time
- Assets
  - Property & Infrastructure
  - Ecology
  - Recreation
  - Community

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Implications of Different Management Responses

No Action:

With enough sediment, the shore will move upward as well as landward. No action is required in most undeveloped areas (e.g. Laguna Salada)

Managed Retreat / Realignment:

Allow shore to migrate landward by progressively realigning infrastructure and functions; Maintains ecology, recreation, natural aesthetics at cost of demolition and reconstruction of development over time
(e.g. Linda Mar Beach, Laguna Salada)

Beach Nourishment:

Place sand (gravel, cobble) to temporarily widen the beach. Must be repeated when beach narrows. Potential adverse ecologic effects if rocky habitat buried; potential adverse recreational effects due to a straight, steep and reflective shore. Potential for construction impacts to beach and nearshore. (e.g. Linda Mar Beach, Rockaway)

Armoring:

Protect inland areas by constructing barriers. This will result in a loss of beaches and natural shores near the tide range, degrading ecology and access. Public safety is likely to degrade, and risks of catastrophic damages will increase. (e.g. Rockaway, Sharp Park and Manor)

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Regional Coastal Zone Management

- Use Boundaries Based on Coastal Processes
  - Joint Powers Agencies can integrate multiple municipalities
  - State, Federal, other special districts
- Tap into outside funding
  - State (Coastal Conservancy, Ocean Protection Council, Boating and Waterways, State Parks, Caltrans, DWR)
  - Federal (NOAA, NPS, USACE)
  - Joint (Coastal Sediment Management Workgroup)
- Use Existing Templates / Authorities
  - Local Coastal Plan, General Plans, Climate Action Plan
  - Redevelopment
  - Parks Plans
- Public Participation

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ADAPTION: a slow, usually unconscious modification of individual and social activity…...

ADAPTATION: a form or structure modified to fit a changed environment.

(Selected from Dictionary.com)

California Strategy for Adaptation to Climate Change

http://www.energy.ca.gov/2009publications/CNRA-1000-2009-027/CNRA-1000-2009-027-F-ES.PDF

What is adaptation? Adaptation involves minimizing the impacts of climate change already set in motion. The ultimate goal of adaptation is to enhance society's long-term resilience to imminent climate impacts.

What is a Climate Adaptation Strategy? To prepare for the expected impacts of climate change, California has developed a statewide adaptation strategy in coordination with efforts targeting greenhouse gas mitigation policies.

. Consider project alternatives that avoid significant new development in areas that cannot be adequately protected (planning, permitting, development, and building) from flooding, wildfire and erosion due to climate change. The most risk-averse approach for minimizing the adverse effects of sea level rise and storm activities is to carefully consider new development within areas vulnerable to inundation and erosion. State agencies should generally not plan, develop, or build any new significant structure in a place where that structure will require significant protection from sea level rise, storm surges, or coastal erosion during the expected life of the structure.

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Climate change, like a wave, is a moving frame of reference

Bob Battalio @ Pacifica, Copyright ©, Franco, 2000

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Adaptation, like surfing, is navigating changing conditions

Bob Battalio @ Pacifica, Copyright ©, Franco, 2000

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And extension of a good ride.

Bob Battalio @ Pacifica, Copyright ©, Franco, 2000

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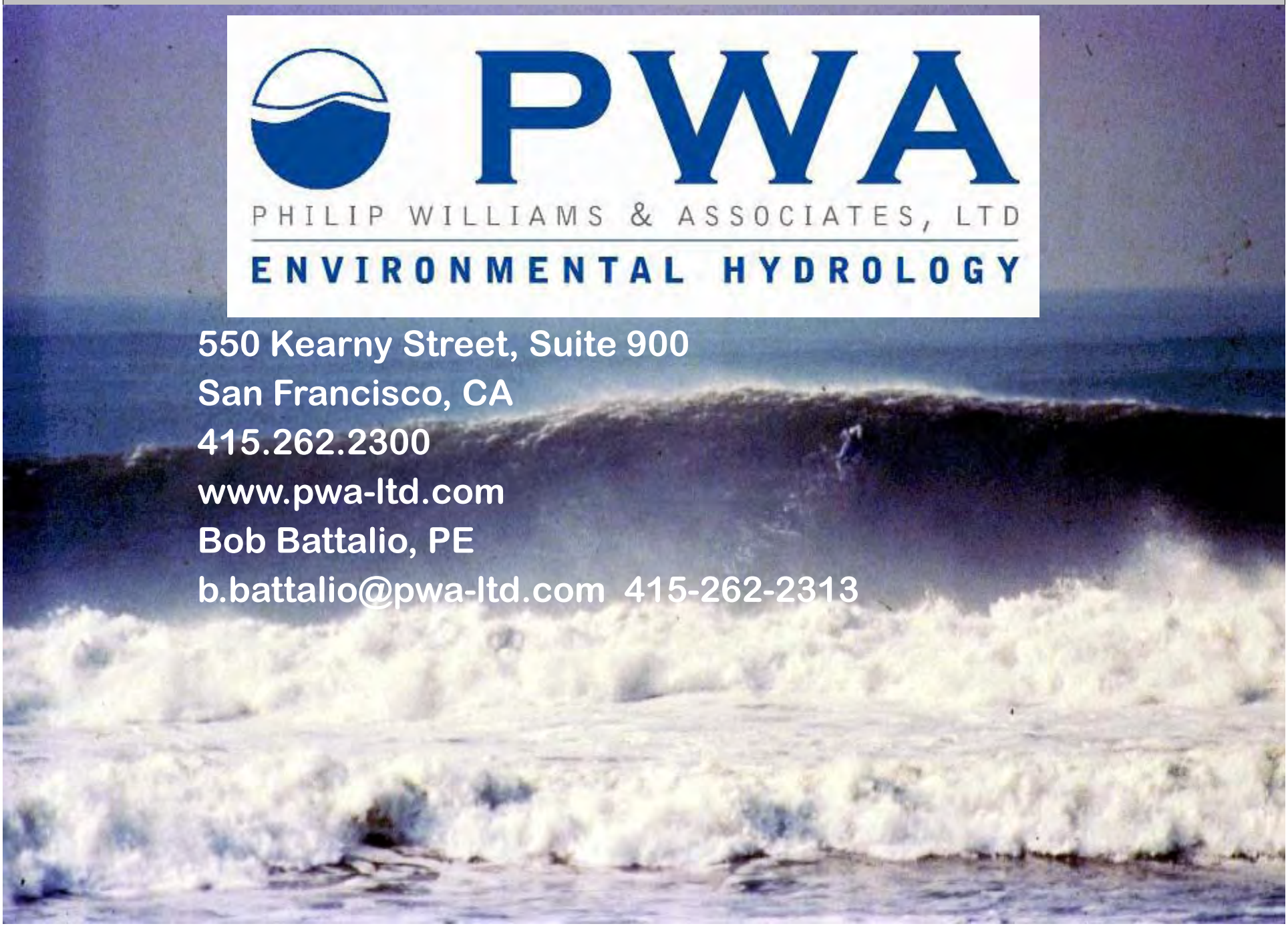

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