An Assessment of the Impacts of Sea Level Rise to the California Coast

Photo by D. Revell – 2/23/08

California Coastal Records Project

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Outline

- Background
- Project Objectives
- Overview of Methods
- Results
- Policy Recommendations
- Limitations

Project Objectives

Map Flood and Erosion Hazards

Identify vulnerable infrastructure and some costs of adaptation

Photo by D. Revell

Project funded by the California Energy Commission's Public Interest Energy Research Program, CalTrans, and the California Ocean Protection Council

Future decisions will be tough…

Beaches or Armoring

General Approach - Vulnerability

- Adopt CA climate scenarios developed for CEC projects.
- Expand 1990 Pacific Institute Study of SF Bay to outer coast
- Develop maps of flood and erosion hazards for CA coast.
- Identify and quantify populations and infrastructure at

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ost of some protective responses.

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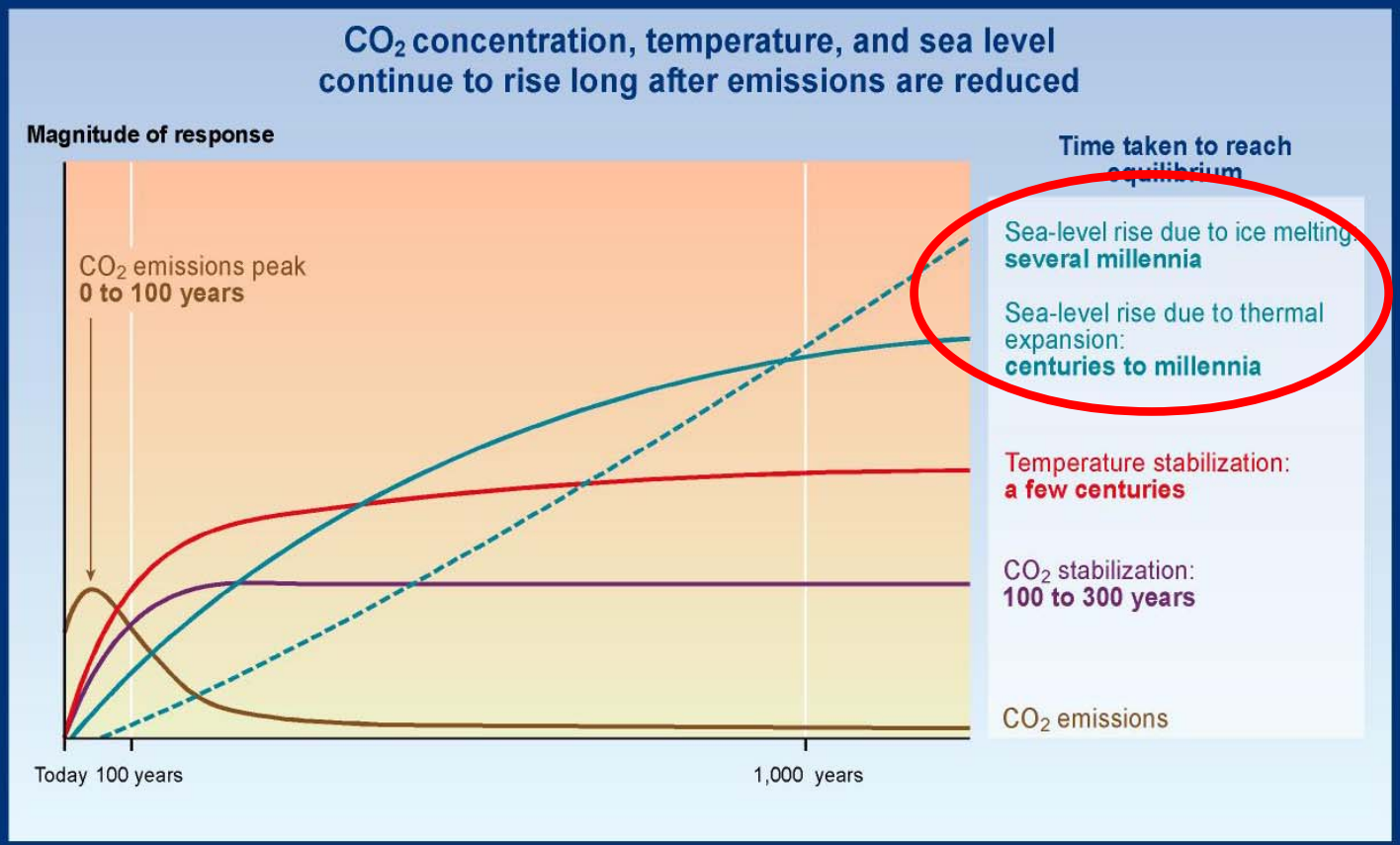
Time Scales of Climate Change Impacts



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INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

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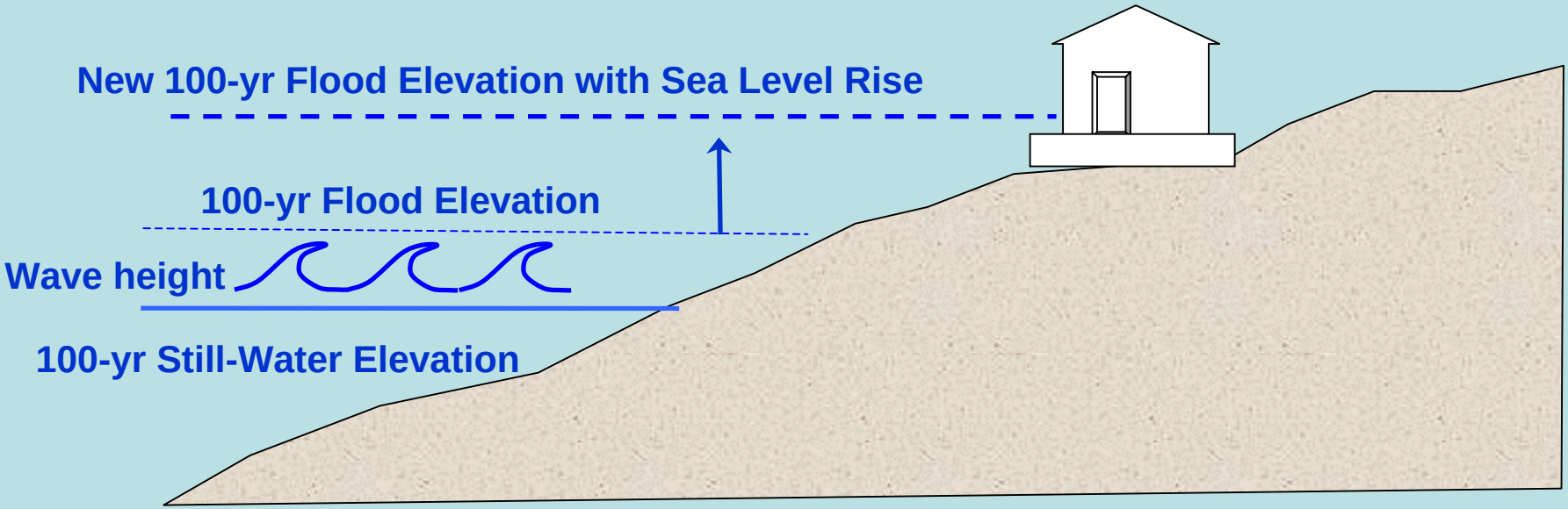
Mapping Flood Hazards



- Review all existing FEMA Flood Insurance Studies
- Extract Coastal Base Flood Elevations into GIS
- Add Sea level rise scenarios to BFE elevations
- Map inundation using terrain datasets

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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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Study Area

Oregon Border to Santa Barbara Harbor

So. Cal – Current ongoing studies

USGS, Scripps, CEC

Likely mgt. responses

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Backshore Types

- Dune/Inlet
- Cliff/ Bluff
- Landslide
- Armored

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GIS data:

Shoreline Inventory, Geology, Armoring, Landslides, LIDAR, Bathymetry, Sandy Shoreline change rates, Cliff Erosion rates.

Non GIS references:

Griggs et al Living with the Changing California Coast

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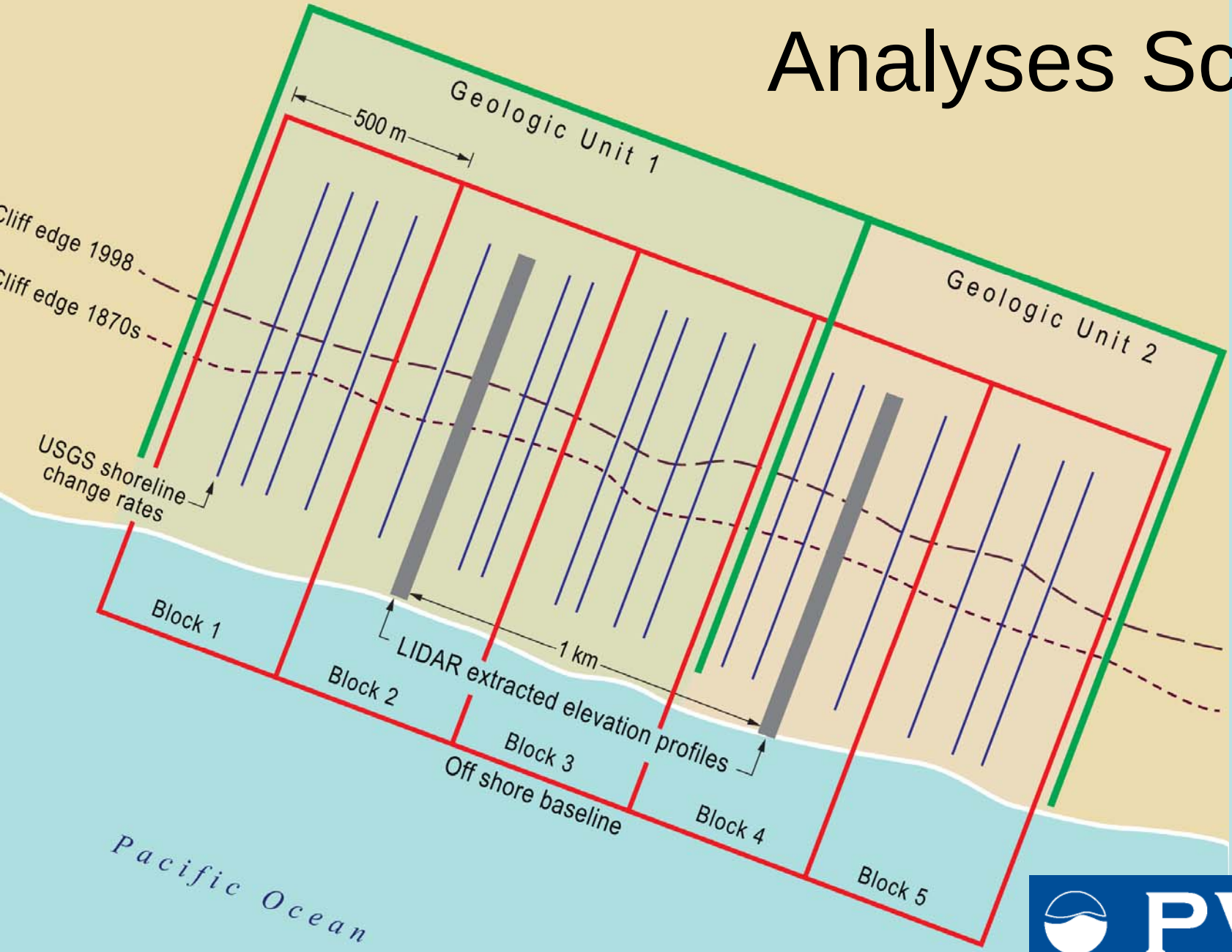
Analyses Scale



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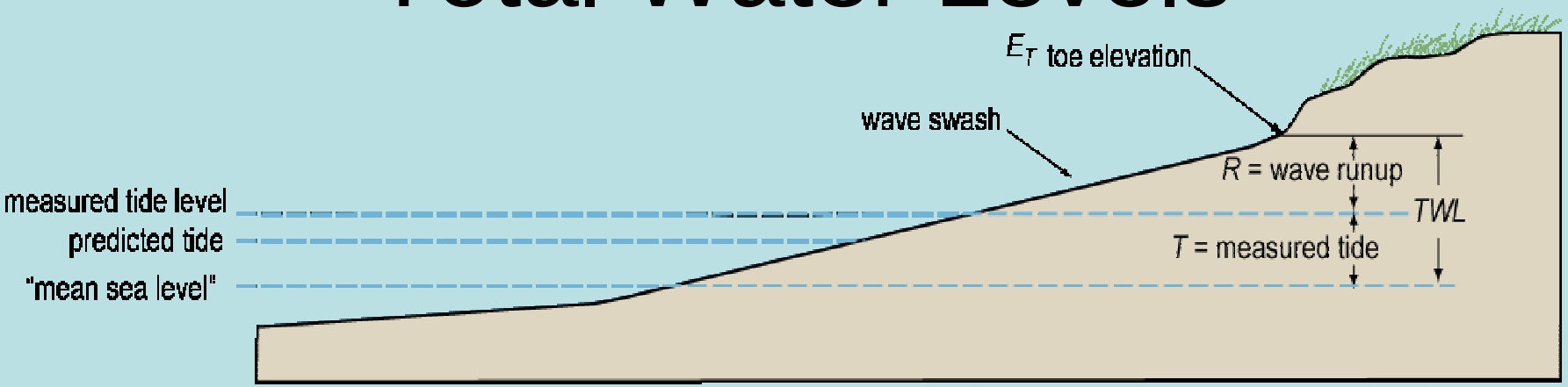
Total Water Levels



Total Water Level, TWL = "measured" Tides, **(T)** + Wave Runup, **(R)**

T = Sea level rise scenarios (Cayan et al), 100 years at 3 hour tides coupled waves and storm effects (ENSO, surge) for 2 scenarios

2 locations – SF, Crescent City

R = Wave run-up - Deepwater waves (Cayan et al) for three sites – Pt. Conception, San Francisco, Crescent City

- CDIP models to transform waves at 140 nearshore locations at 10m
- Calculated wave run-up (Stockdon et al 2006).

Generated excedance curves for each subdivided geologic unit (500m) using individual slopes and toe elevations

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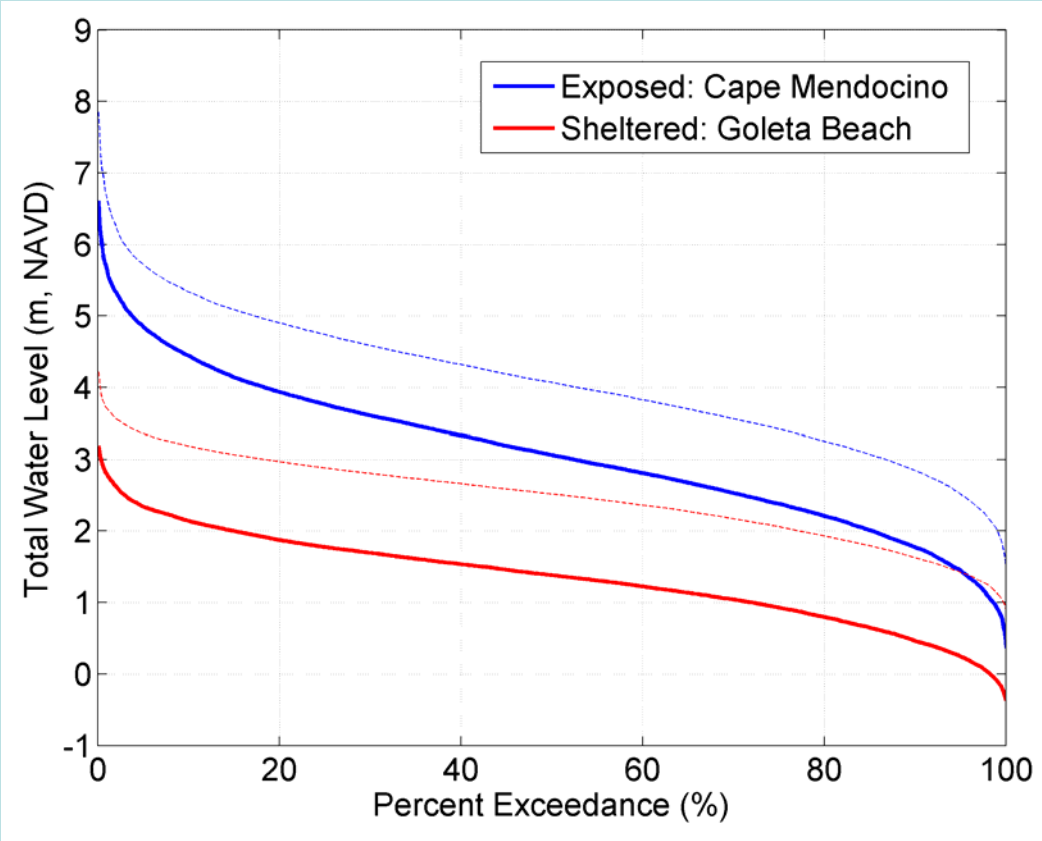
Total Water Levels



- Combined SLR and Wave Run-up
- Generate excedance curves for each block using individual slopes and toe elevations

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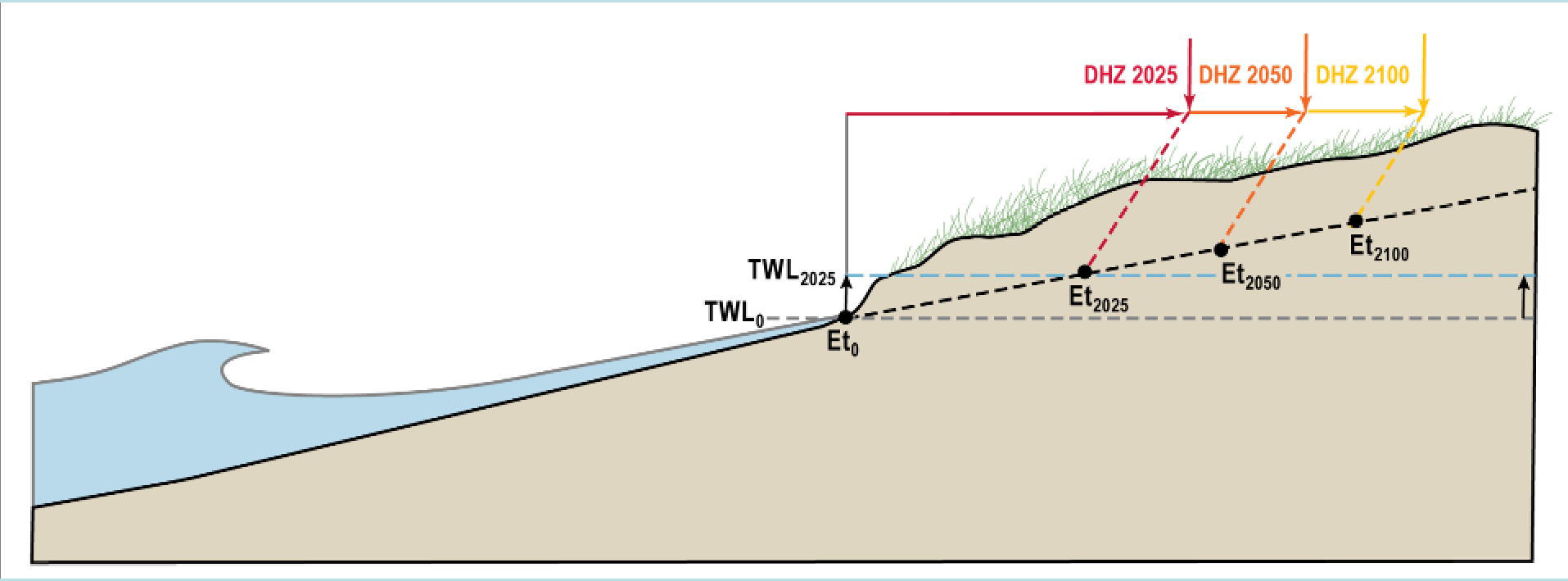
Dune Erosion Model



- 3 components –
  - Changes in TWL from SLR combined with shoreface slope
  - Historic shoreline trends (USGS)
  - Impact of a “100 year storm event”

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Dune Hazard Zones

Air Photo from 2005

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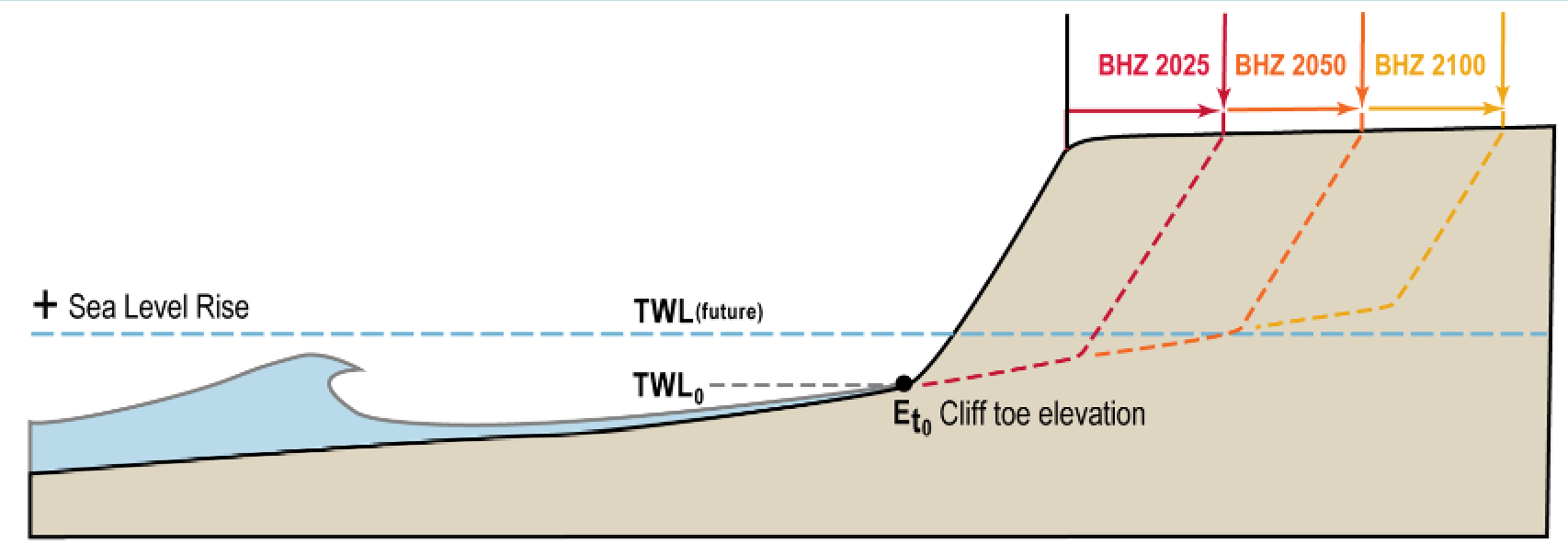
Cliff Erosion Model



- Acceleration of historic erosion rates (Rh)
- 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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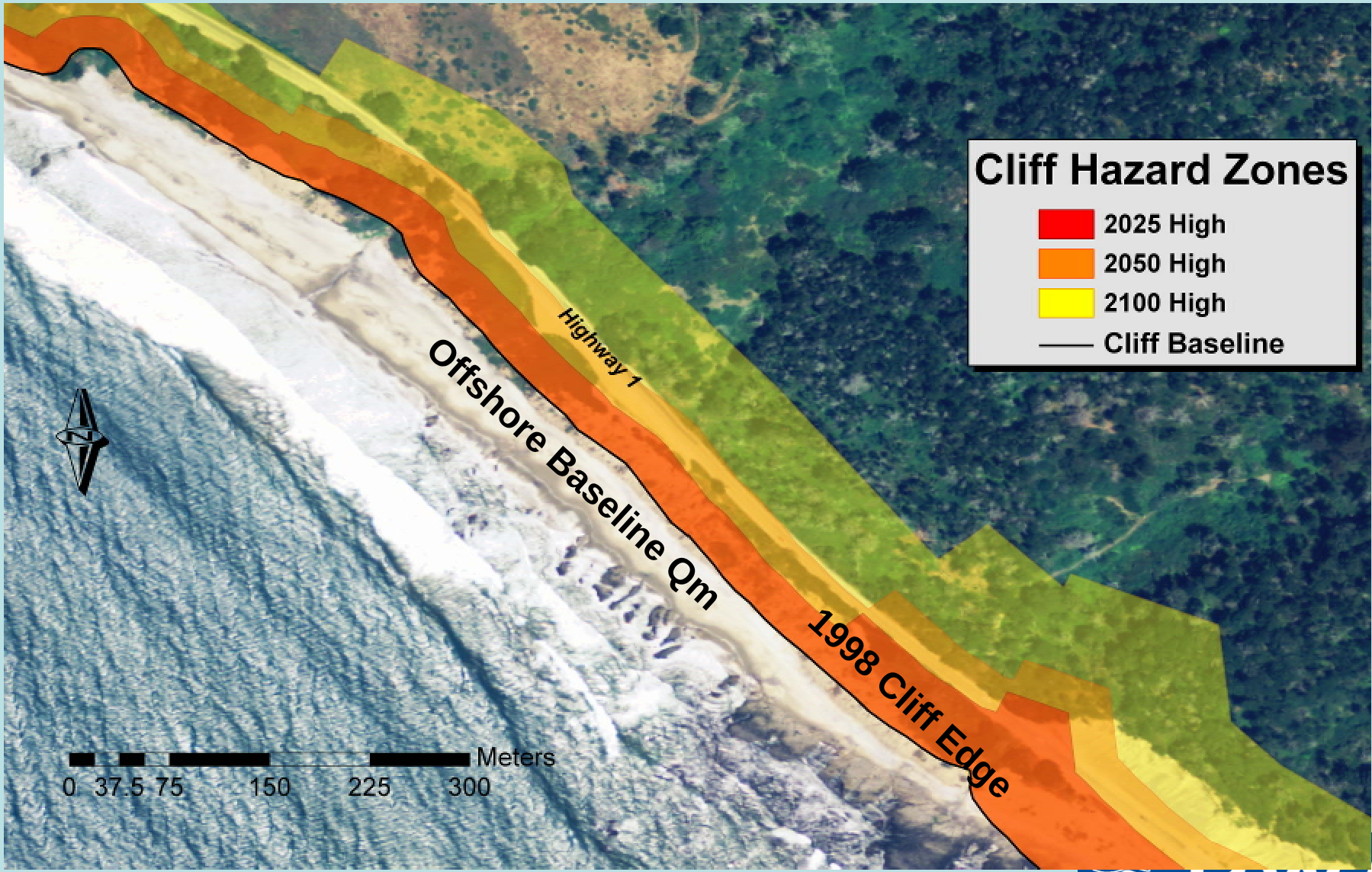
Cliff Hazard Zones



Air Photo from 2005

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Results - Dunes

- 300 km or 185 miles
- Majority of Norcal “accreting”
- Reversal in sign seen between 2050 and 2100

Hazard Zone Low - High	Mean Erosion Distance (m)	Max Erosion Distances (m)
2025	115 - 116	530 - 535
2050	119 - 128	535 - 545
2100	132 - 175	540 - 600

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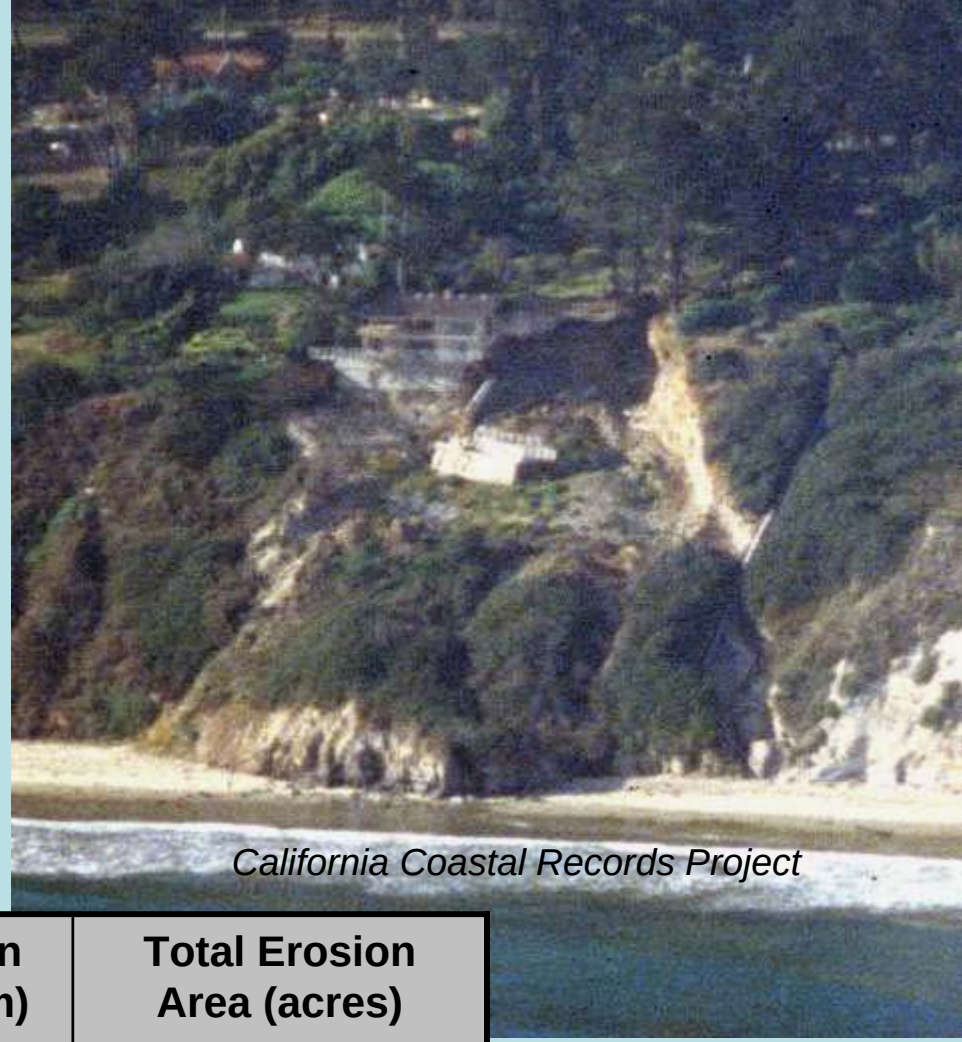
Results - Cliffs

- 1,140 km or 710 miles
- Geology exerts strong influence
- Wave exposure and toe elevation important



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Hazard Zone Low - High	Mean Erosion Distance (m)	Max Erosion Distance (m)	Total Erosion Area (acres)
2025	8 - 9	64 - 65	1,415 – 1,425
2050	24 - 25	170 – 175	5,250 – 5,375
2100	60 - 65	395 - 570	13,335 – 15,085

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Results – Total Erosion

County	Total erosion miles^2 (km^2)
Del Norte	4.5 (11.7)
Humboldt	6.1 (15.8)
Mendocino	8.3 (21.5)
Sonoma	2.2 (5.7)
Marin	4.7 (12.2)
San Francisco	0.5 (1.4)
San Mateo	3.2 (8.3)
Santa Cruz	1.8 (4.7)
Monterey	4.4 (11.4)
San Luis Obispo	2.9 (7.5)
Santa Barbara	2.6 (6.7)
TOTAL	41 (213.8)

*Does not include So. Cal

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Study Products

- Methodology and model for evaluating coastal erosion resulting from slr
- GIS hazard zones of two scenarios at 3 planning horizons
- Flood elevations for the entire coast
- Estimates of future erosion rates
- Erosion rates by geologic unit

Photo by D. Revell – 2/23/08

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Erosion Method - Limitations

- Input Data Sets Accuracy
- Potential erosion **not** actual
- Single Climate Model Output
  - not an ensemble
  - no calibration of erosion rates with existing TWL data
- Single wave time series
  - no trends in wave climate
  - Waves transformed to 10m
- GIS buffering algorithms
- LIDAR
  - Post El Nino conditions are indicative of 2008

- Simplified geometric response
  - Equilibrium profile application
  - Assumed increase in erosion rates is linear
  - Feedback mechanisms ignored
- Shoreline Change Rates
  - Impact of 1998 Lidar uncertain
  - LT rates may not be indicative of current trends

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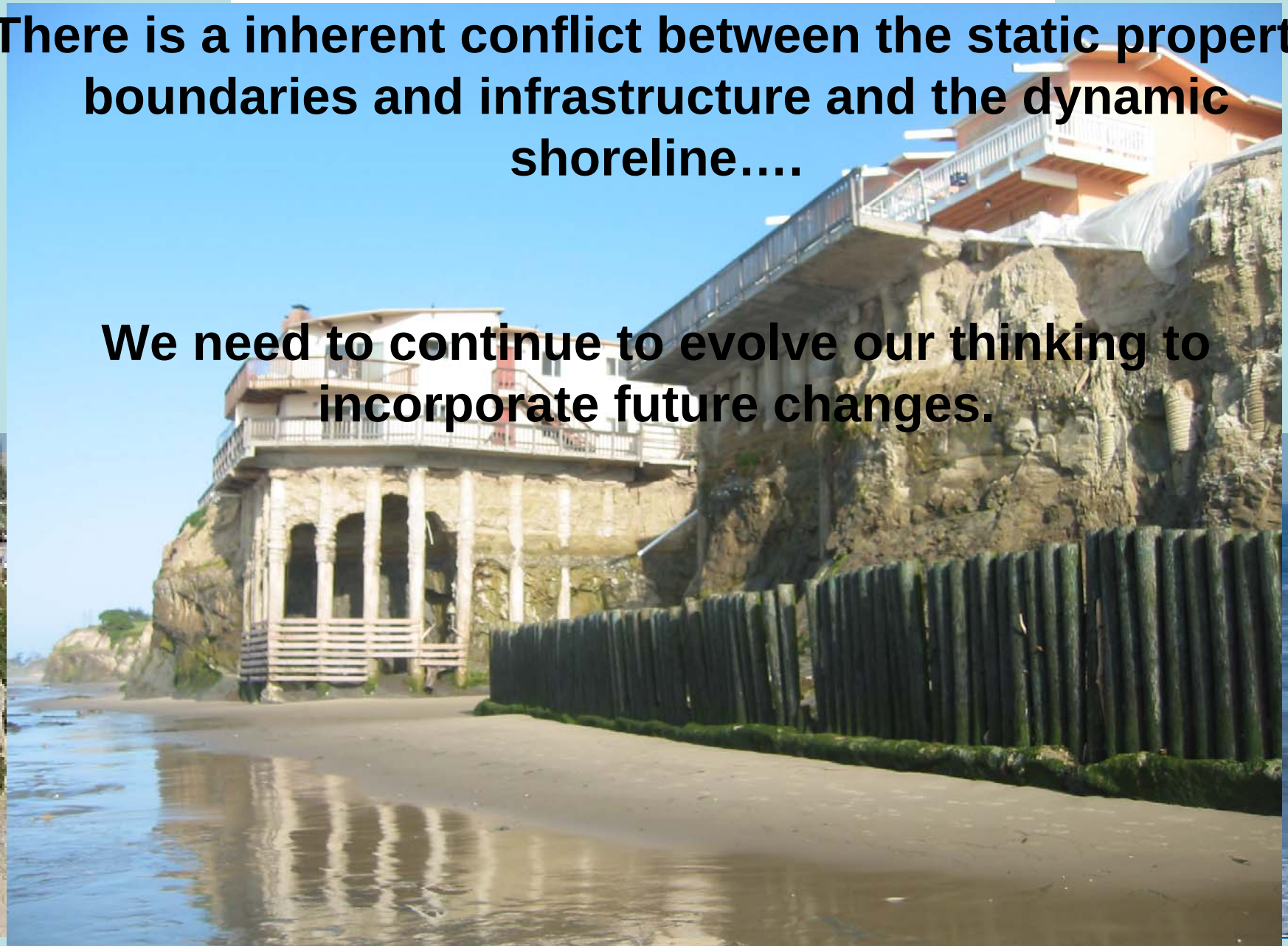
Policy and Management Recommendations - General

1. **Integrate future sea level rise and accelerating erosion into coastal policies –LCP, LUP revisions.**
2. **Limit scales of development in areas at risk from slr – setbacks, size of development, uses**
3. **Preserve adjacent uplands to keep options open.**
4. **Maintain historic ecological linkages between oceans, beaches, dunes, and wetlands – MLPA, RSM.**
5. **Cost-benefit analyses should explicitly evaluate the social, recreational and environmental**

Policy and Management Recommendations - Specific

1. **Direct staff to investigate standard methods to incorporate sea level rise into permit decision making**
2. **Adopt policies to implement avoidance of future erosion hazards- e.g. managed retreat, rolling easements**
3. **Clarify the definition of "existing development" so that new development and redevelopment preclude future shoreline armoring – e.g. OR, NC, TX**
4. **Have future seawalls bonded to have upfront costs for removal, maintenance at end of**

C ta



There is a inherent conflict between the static property boundaries and infrastructure and the dynamic shoreline….

We need to continue to evolve our thinking to incorporate future changes.

Acknowledgements

- **Ocean Protection Council** – Chris Blackburn
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THANK YOU!!!

Future Research Needs

Data needs

- New LIDAR flight – top of bluffs, 10m contour; bathy would be fantastic.
- Long term monitoring program – sand levels, toe elevation, coastal evolution, storm impacts, wave climate, rock hardness, failure cycles
  - "Coastal Observation System"
- Ensemble of GCM outputs
- Human Uses and levels of activity
- Levee and coastal structure evaluation
- Habitat ecological and physical linkages important for erosion reduction
- More detailed localized and regional studies
- Additional research on vulnerable subpopulations

Methods

- Higher resolution geology and geomorphology
- Refine shoreline change rates at higher temporal scales
- Focused studies with improved resolution data sets
- Evaluation of alternative erosion models
- Evaluate changes to fluvial flooding from elevated sea levels

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