

Evaluation of Berm Shape for Wave Energy Reduction in Restored Tidal Wetlands in San Francisco Bay

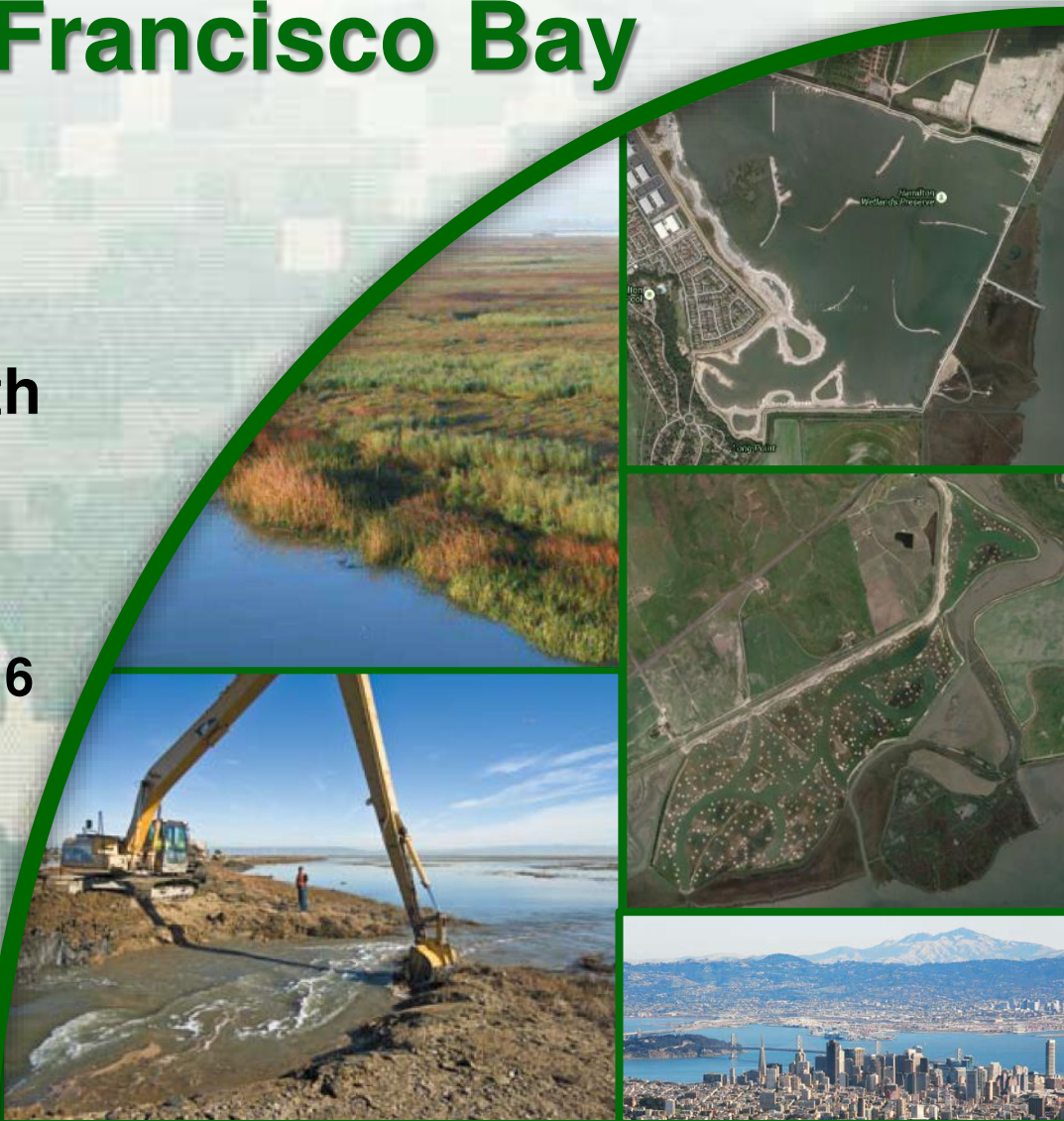
Elizabeth Murray,
Jane McKee Smith,
Thad Pratt, & Jarrell Smith

Engineering Research and
Development Center
For California DredgeFest 2016



®

US Army Corps of Engineers
BUILDING STRONG®

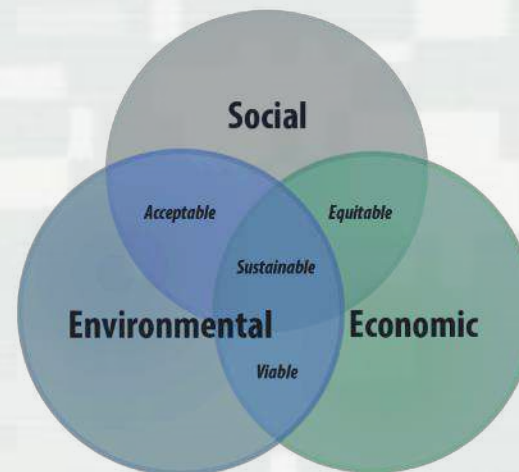


The U.S. Army Engineer Research and Development Center (ERDC)

- Coastal and Hydraulics Laboratory (CHL)
- Environmental Laboratory (EL)
- Geotechnical and Structures Laboratory (GSL)
- Information Technology Laboratory (ITL)
- Geospatial Research Laboratory (GRL)
- Construction Engineering Research Laboratory (CERL)
- Cold Regions Research and Engineering Laboratory (CRREL)

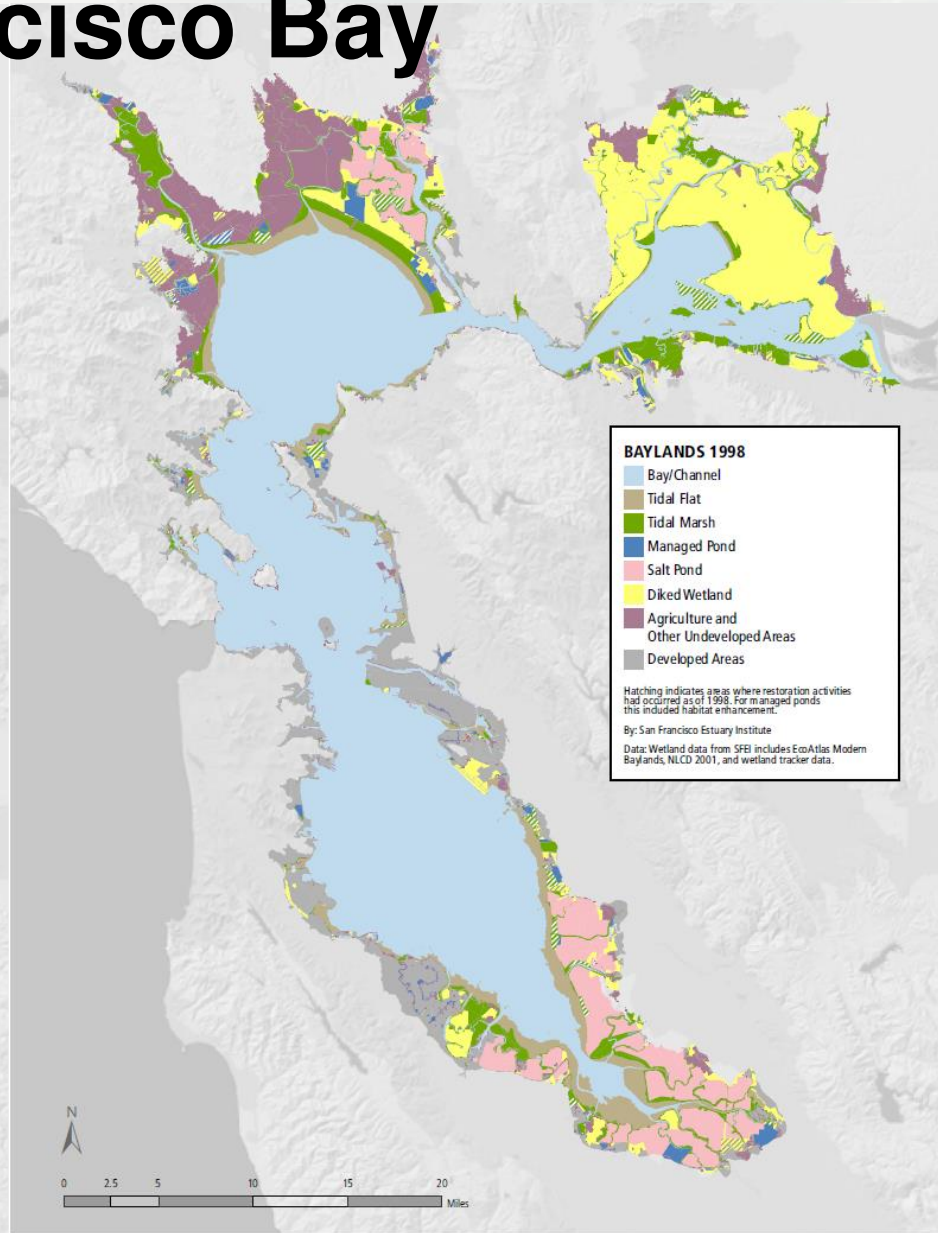
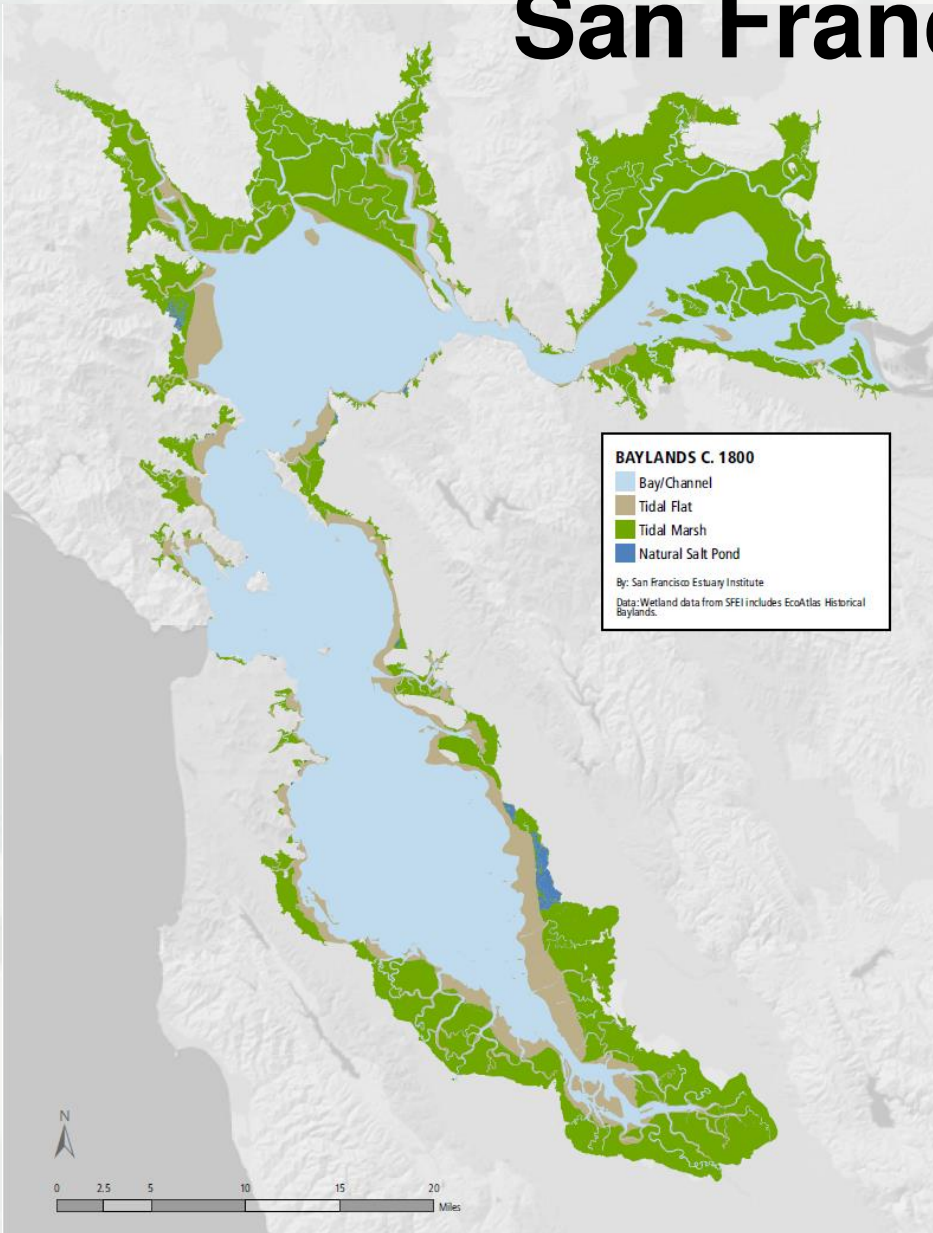
Engineering With Nature...

...the intentional alignment of natural and engineering processes to efficiently and sustainably deliver economic, environmental and social benefits through collaborative processes.



- Using natural process to maximum benefit

San Francisco Bay



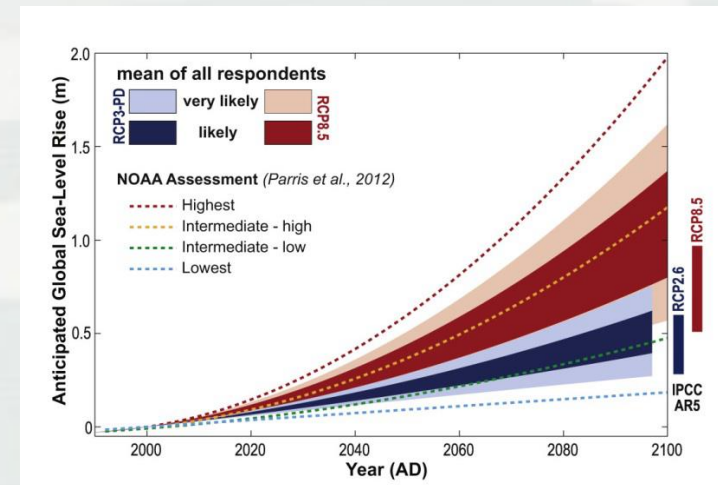
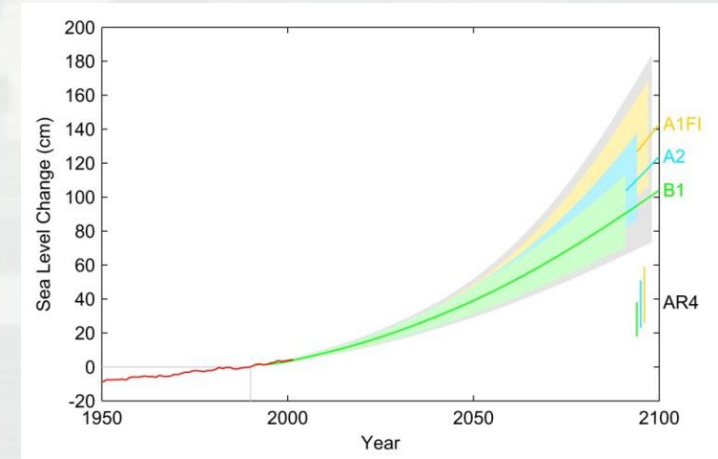
San Francisco Bay



- 90% of tidal wetlands filled
- Reduced habitat
- Endangered plant & animal species
- Removed buffer for rising sea level

Global Sea Level Projections (by 2100)

- **0.5 to 1.9 m** Rahmstorf (*Science*, 2007)/ Vermeer and Rahmstorf (*PNAS*, 2009)
 - ▶ relates sea level rise to mean surface temperature
- **0.8 to 2 m** Pfeffer et al. (*Science*, 2008)
 - ▶ constrained by observations of ice sheet dynamics
- **5 m** Hansen (*Environ. Res. Lett.*, 2007)
 - ▶ non-linearity, amplifying polar feedbacks- 'albedo flip'
 - ▶ New paper in *Atmospheric Chemistry and Physics*
- **0.26 to 0.82 m** Intergovernmental Panel on Climate Change (*IPCC*, 2014)
 - ▶ ice sheet contributions from Greenland (7 m stored) and Antarctica (60 m + stored) conservatively included (excluded in AR4: IPCC, 2007)
- **0.4 to 1.2 m** Horton et al. (*QSR*, 2014)
 - ▶ expert assessment of median range



Projections for San Francisco Area

- **SLR for San Francisco (NRC, 2012)**
 - ▶ 28 cm of sea level rise by 2050 (range 12-61 cm)
 - ▶ 92 cm of sea level rise by 2100 (range 42-166 cm)
- **Storms for California**
 - ▶ No significant changes in wave height
 - ▶ Extreme events approach from ~10-15 degrees further south
- **El Niño for 21st Century**
 - ▶ More frequent extreme events
 - ▶ Doubling of winter erosion
 - ▶ Wave energy increase by 30%
- **Net effect**
 - ▶ Today's 100-year coastal water level event is projected to occur every 1-5 years by 2050 for much of California
 - ▶ Greatest impacts on low-lying coastal areas (e.g., Stinson Beach, San Francisco Bay)



2) Choose an Amount of Sea Level Rise

0	25	50	75	100	125
150	175	200	500	[Use feet]	

[What Sea Level Rise scenario should I use?](#)

3) Choose an Event

Choose Storm Scenario Frequency

None	Annual	20 year	100 year
------	--------	---------	----------

Or Choose King Tide Scenario

King Tide

[What are Storm Scenarios?](#)

[What is a King Tide scenario?](#)

4) Choose other layers to view with topic data.

- Digital Elev Model (DEM)
- Levees
- Placenames
- Land Use
- Protected Areas
- Rivers & Streams
- Cliff and Shoreline Retreat
- Shorebirds
- Coastal Armoring
- Roads and Transportation
- Trails
- Buildings
- Utilities & Services

[What do Other Layers represent?](#)

Opacity

◀ 0.5 ▶

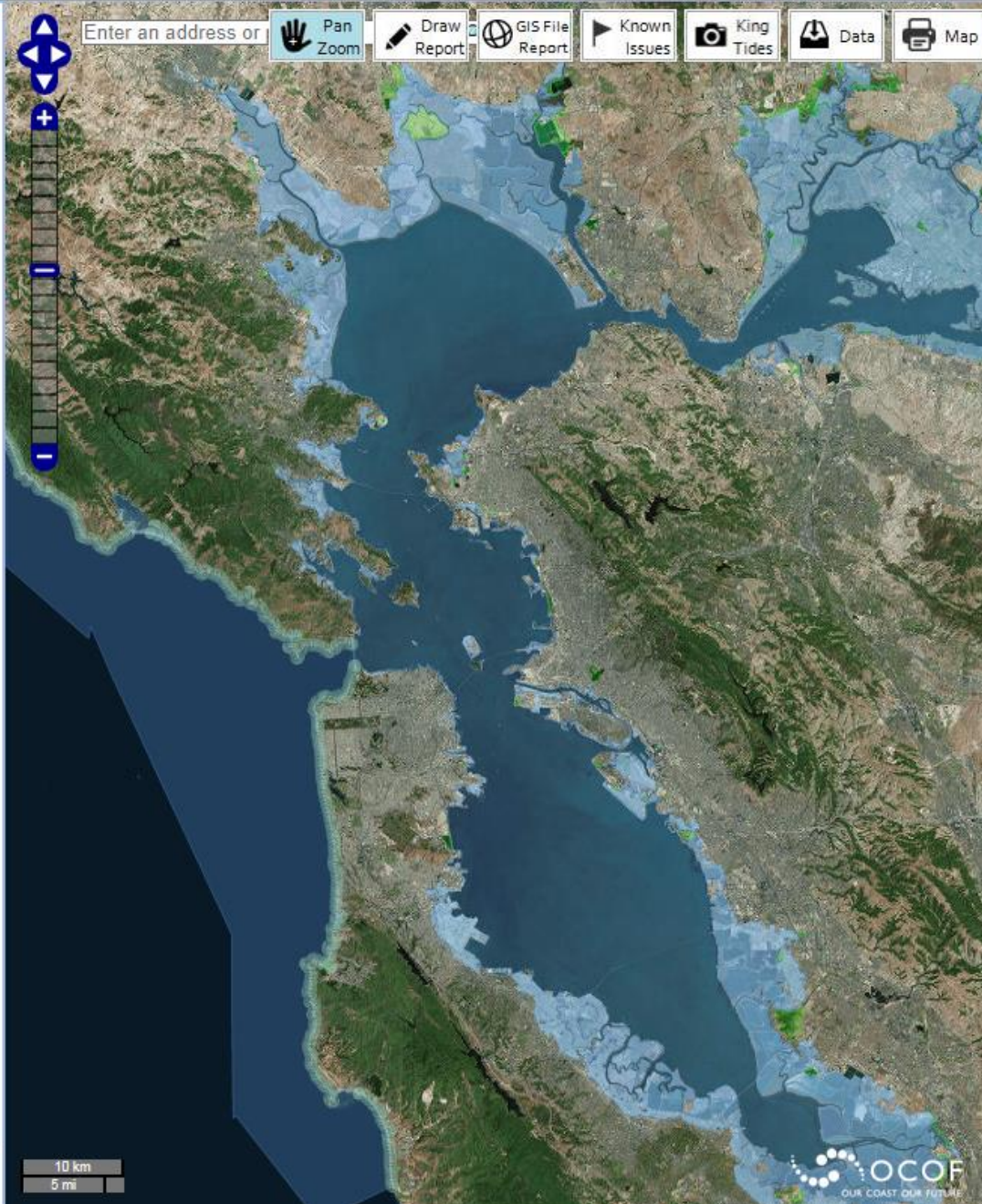
Metadata

◀ ▶

Detail View



Enter an address or



Max Wave Runup during Flood 100cm SLR + Wave 100

Flood-prone Low-lying Areas 100cm SLR + Wave 100

Flood Hazard 100cm SLR + Wave 100

Flood Depth 100cm SLR + Wave 100

✗ No Data

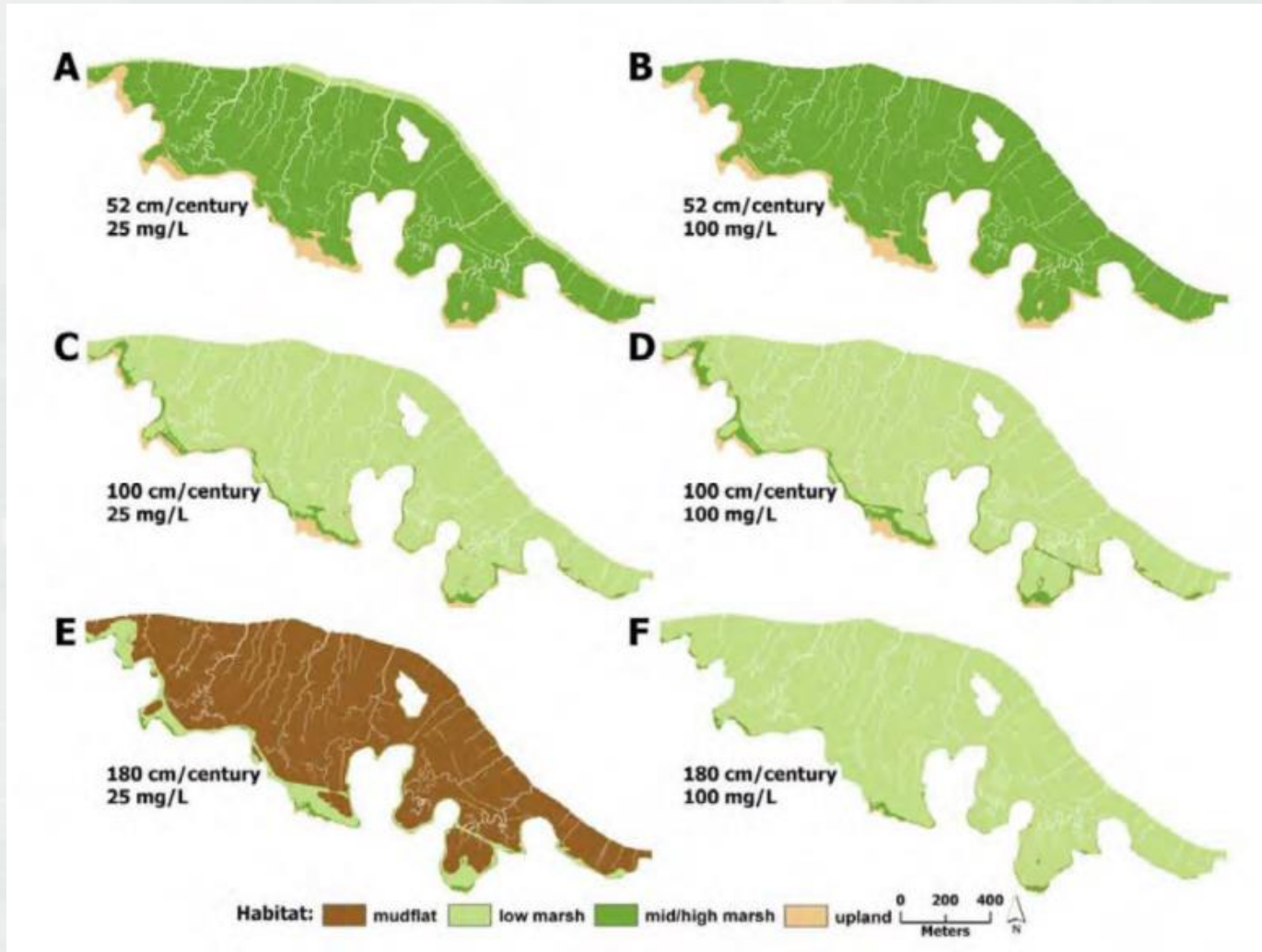
0 cm

250 cm

500 cm

750 cm

Modeling Suggests that Existing Marshes Won't Keep Up with SLR Without Sediment Influx

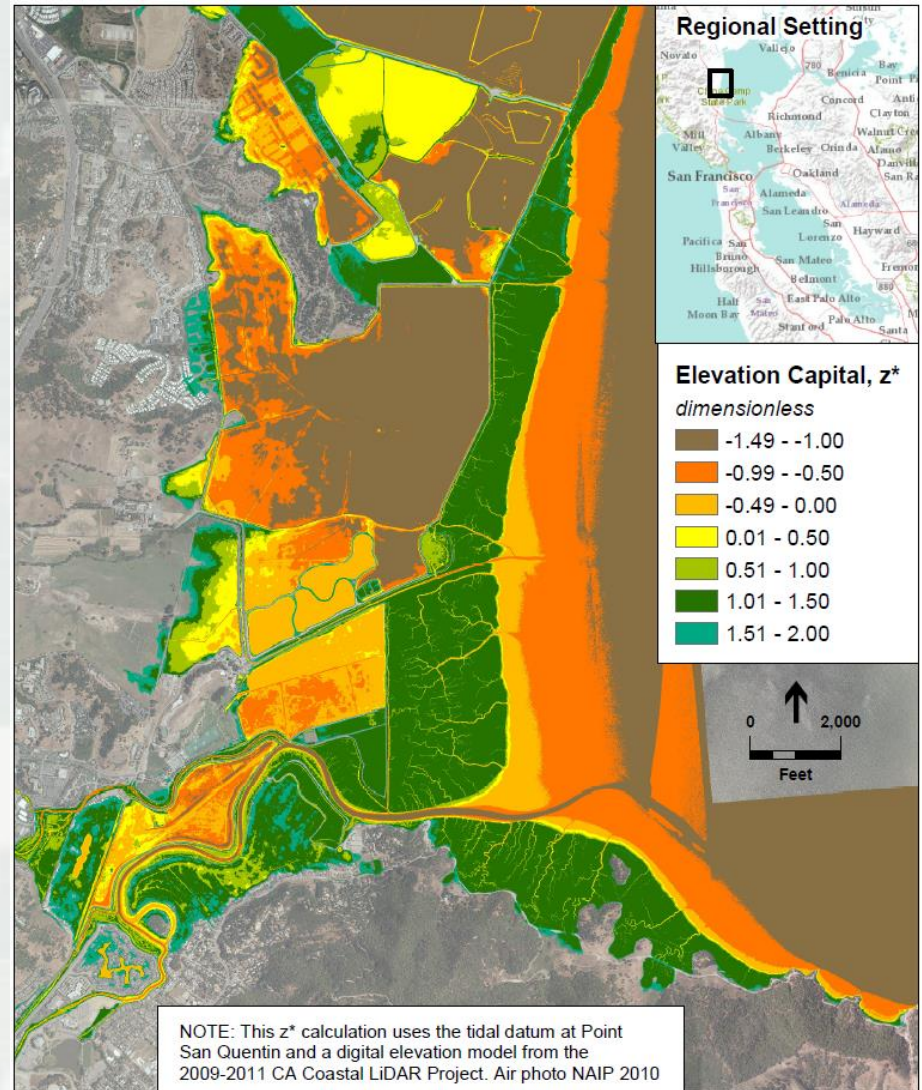


From Schile et al. (2014)

Diked Baylands Have Subsided 1-2m

- Compare absolute elevation of a marsh with the local water levels and tide range.
- Dark green are marsh elevations.
- Yellow, orange and brown are below marsh elevation.

In order to restore these diked baylands, sediment needs to be brought in or encouraged to accrete.

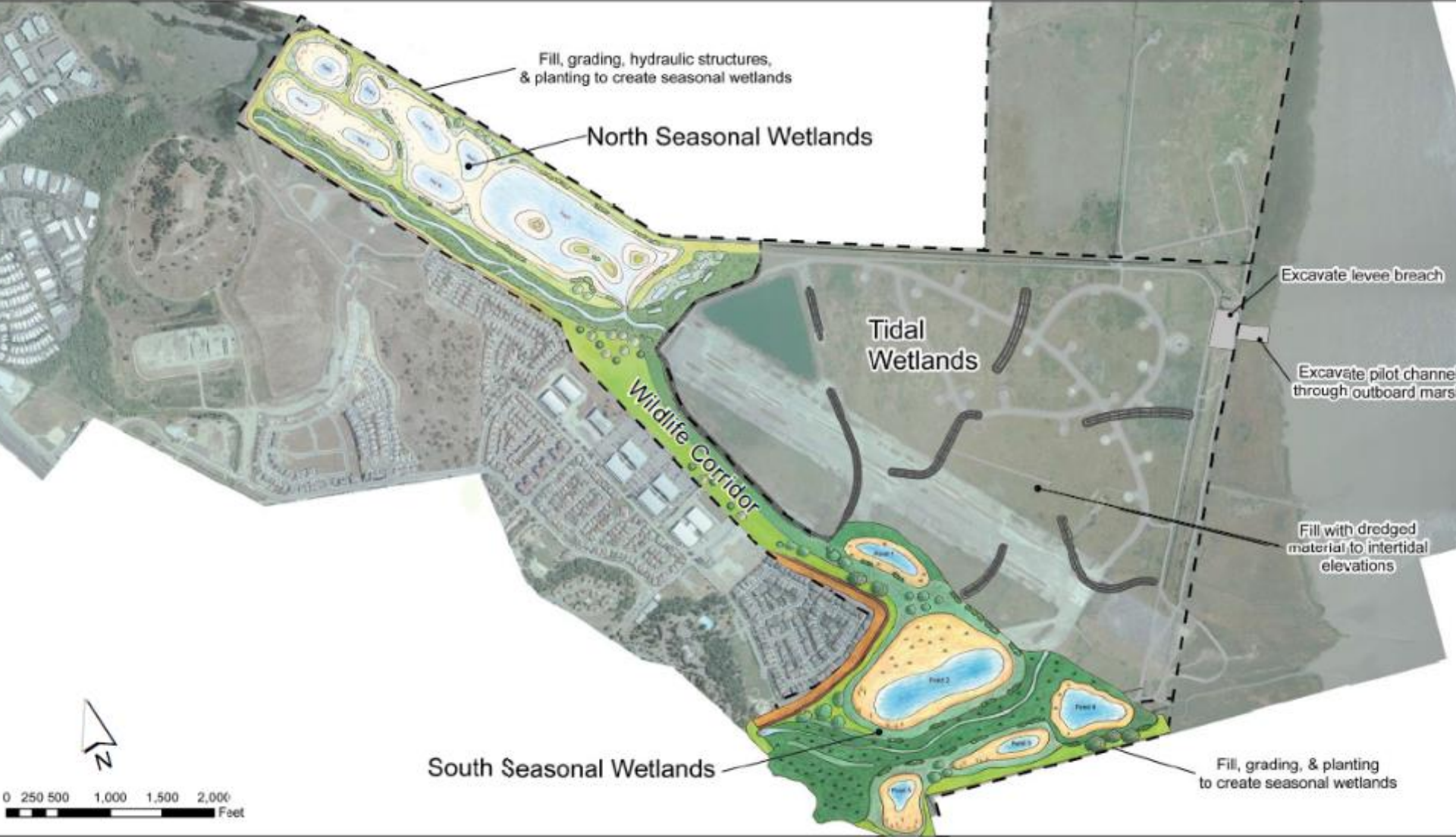


Hamilton Bay Restoration

- Site diked ~100 yr ago, Hamilton Army Airfield
- Significant subsidence
- 650-acre wetland restoration, 20 yrs
- Beneficial use of 24.4 mill yd³ of dredged material
- Wetland design w/ berms
- U.S. Army Corps of Engineers and the California Coastal Conservancy



Hamilton Bay Restoration



Sears Point Restoration



- Similar environment to Hamilton
- 955 acre tidal wetland restoration
- Wetland design w/ mounds
- Sonoma Land Trust and Ducks Unlimited

Sears Point Restoration



Imagery Date: 4/1/2015 38°07'54.00" N 122°27'12.78" W

Compare Berms and Mounds for Wave Reduction

- Berm = linear feature
- Mound = circular feature
- Sears Point behind schedule for breaching
- So...
 - ▶ Simulated Hamilton in a wave model with berms
 - ▶ Removed berms and ran same wave conditions
 - ▶ Add mounds of ~ same volume, sized similar to mounds at Sears Point.

Hamilton Field Data Collection

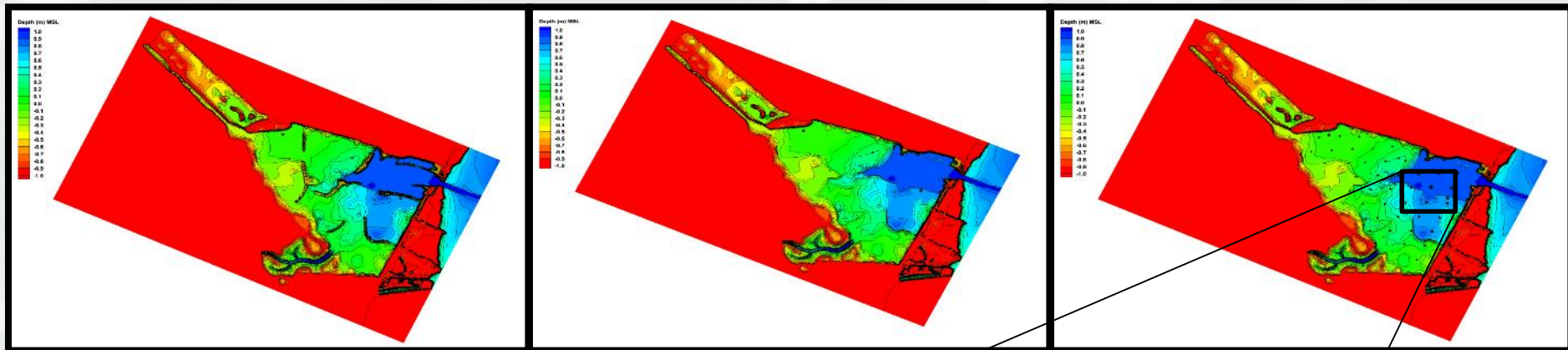
- Waves (wave staffs)
- Water Levels
- Currents
- Salinity
- Conductivity
- Temperature
- Wind Speed and Direction
- Sedimentation



STWAVE

- Phase-averaged, spectra wave model (growth, transformation, and dissipation)
- Wave-vegetation interaction based on Mendez and Losada (2004)
- Wave-current interaction neglected in simulations

Bathymetry of Hamilton Model under Different Scenario Runs



Linear Berms (As-Built)

No Berms (Control)

Mounds (ala Sears Pt.)

*Model mounds
based on
LiDAR of Sears
Point Mounds*



Validation

- Two Storms
 - ▶ Feb 2015
 - 9 m/s NW
 - ▶ April 2015
 - 10 m/s SW



Date	H_{mo} mean error	H_{mo} rms error	T_m mean error	T_m RMS error
Feb 2015	0.013 m	0.028 m	0.21 sec	0.23 sec
Apr 2015	-0.0024 m	0.053 m	0.19 sec	0.25 sec

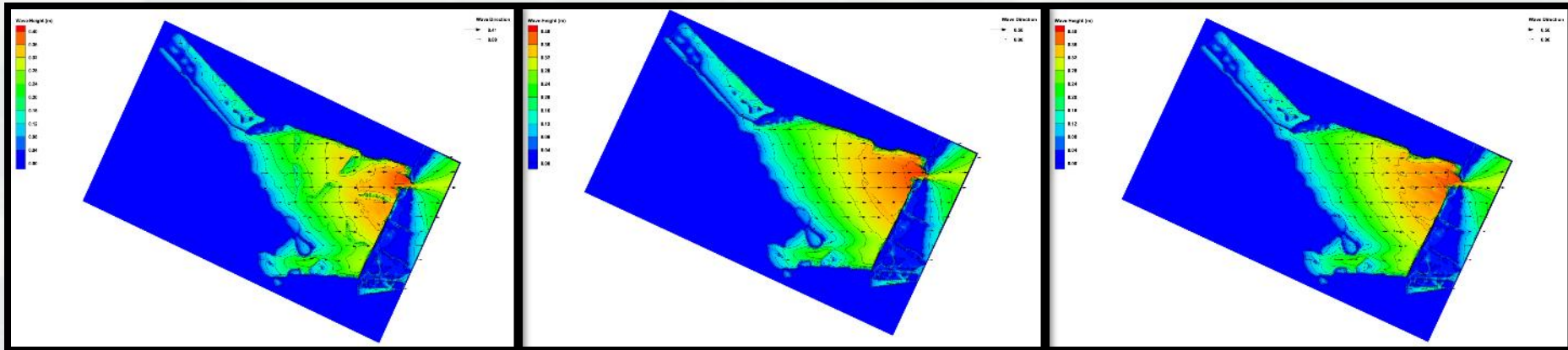
Idealized Simulations

- Winds of 15 and 20 m/s (14-yr wind record at Richmond, CA)
- Water levels of + 0.5 and +1.0 MSL
- 8 wind directions (N, NE, E, SE, S, SW, W, NW)
- With and without vegetation
 - ▶ Pickleweed
 - ▶ Within depth range of +0.4-0.95 m MSL
 - ▶ $C_D = 0.1$, stem height=0.6 m, density = 300/m² diameter = 0.01 m (Northwest Hydraulic Consultants 2011)



Wave Height of Hamilton Model under Different Scenario Runs

Wave heights for 20 m/s wind from W, 0.5 m (MSL) tide, no vegetation



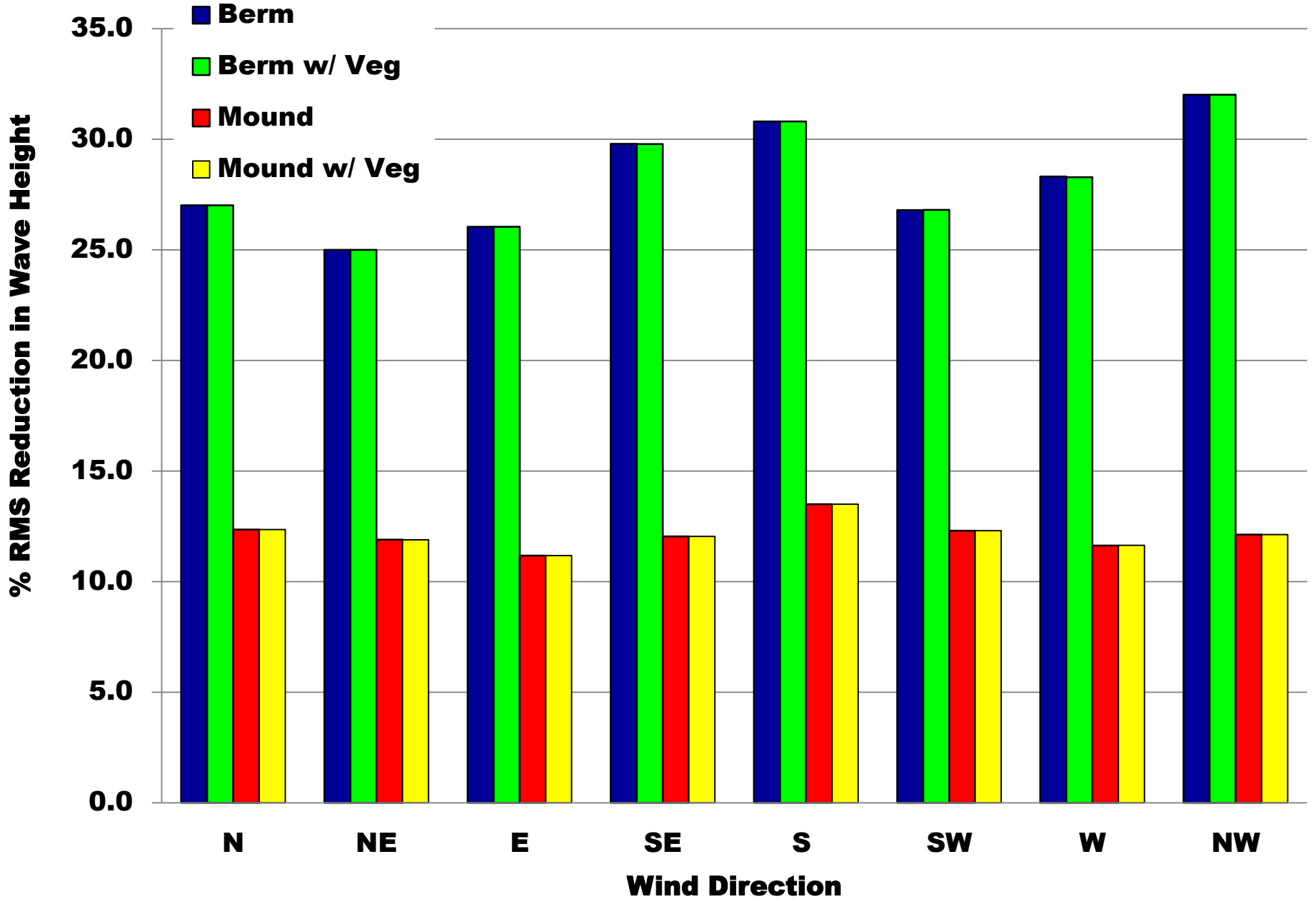
Linear Berms (As-Built)

No Berms (Control)

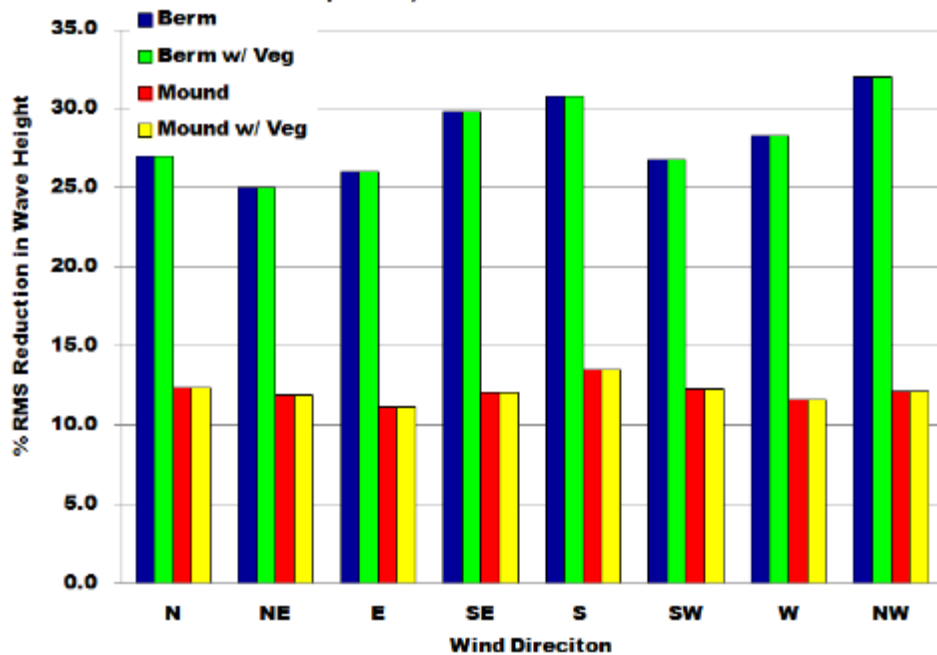
Mounds (ala Sears Pt.)

Other scenarios: different wind directions, wave at entrance, vegetation based on parameters for Pickleweed and *Spartina foliosa*, determined for wave attenuation research at Corte Madera, a nearby salt marsh in San Francisco Bay.

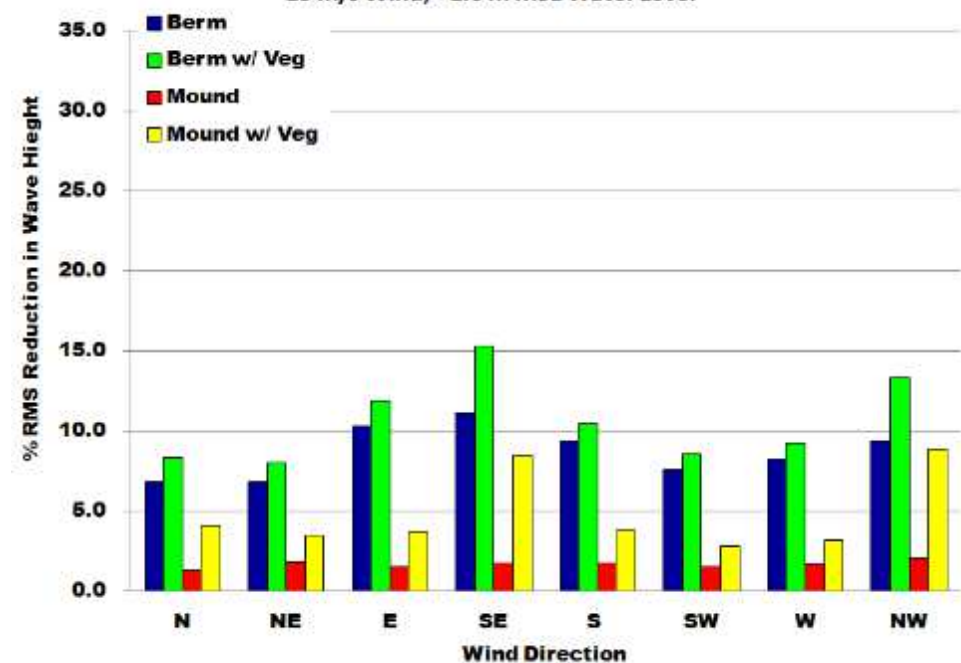
15 m/s Wind, +0.5 m MSL Water Level



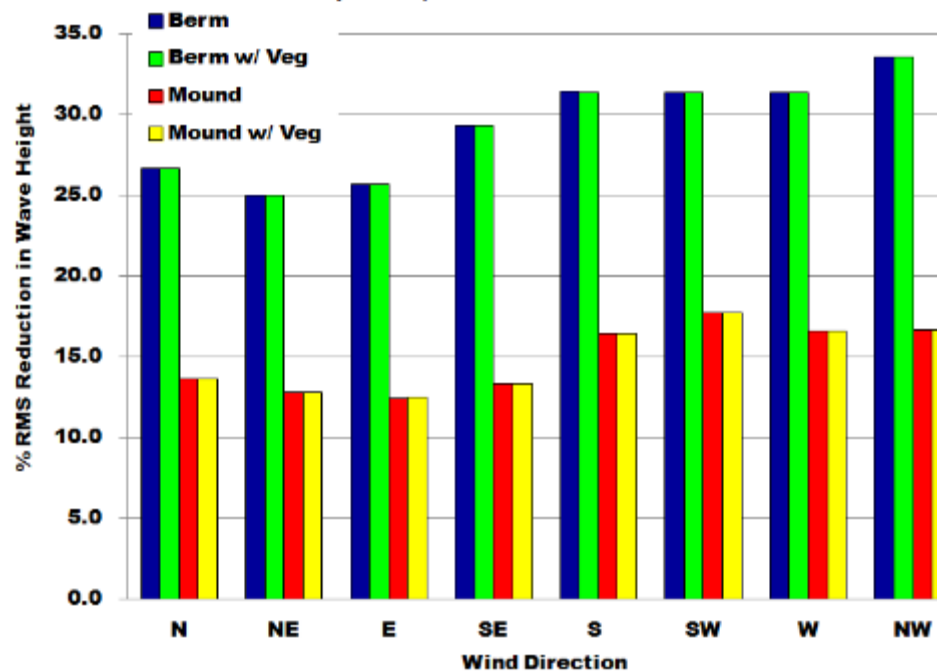
15 m/s Wind, +0.5 m MSL Water Level



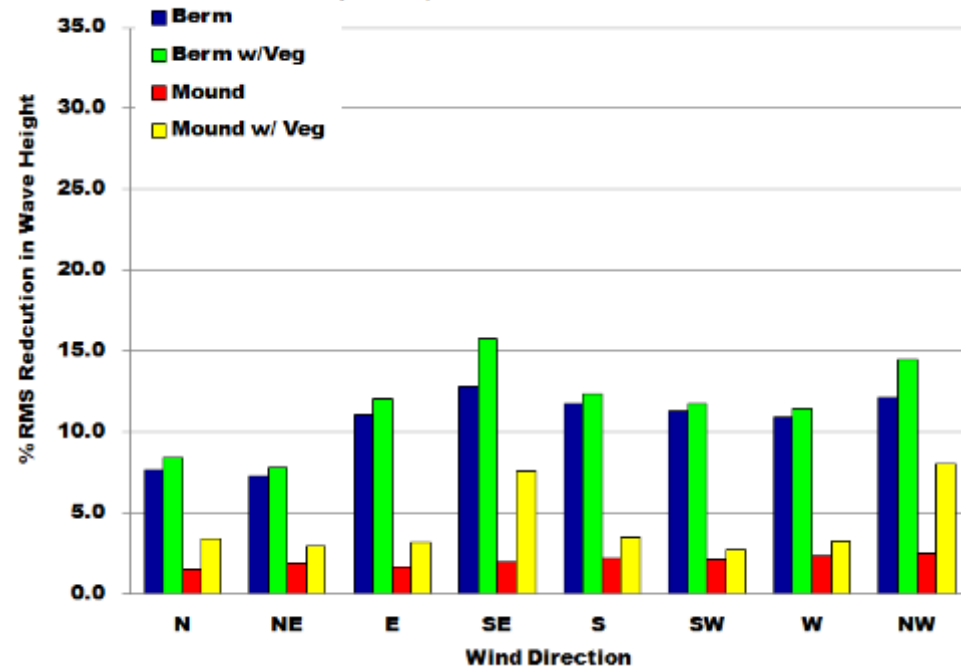
15 m/s Wind, +1.0 m MSL Water Level



20 m/s Wind, +0.5 m MSL Water Level



20 m/s Wind, +1.0 m MSL Water Level



Summary

- As modeled at Hamilton, linear berms produced a greater reduction in wave height than circular mounds:
 - ▶ 25-32% at 0.5m MSL Berms
 - ▶ 11-14% at 0.5m MSL Mounds
- Wave height attenuation by berms AND mounds decreases significantly once they are submerged (75% reduction 1m v. 0.5m MSL)
- Vegetation increases wave height reductions (when vegetation is submerged), vegetation impact greater for circular mounds

Next Steps

- Sears Point is being monitored now.
- Building wave model and running similar simulations this summer.
- Sears Point has different configuration, placement in bay, and depth, which may affect results.
- Will also compare channel evolution to see if we can detect difference in mounds versus berms.