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

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**Engineering Research and
Development Center**
For California DredgeFest 2016





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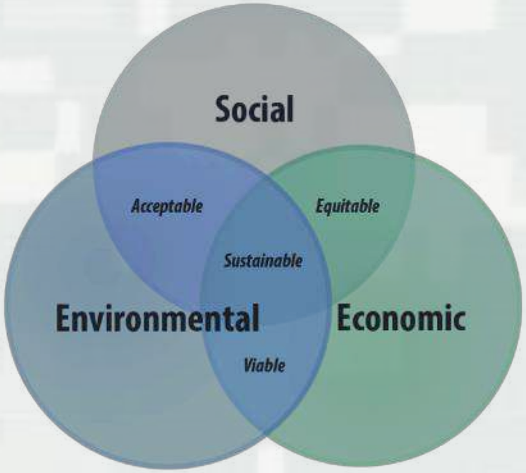
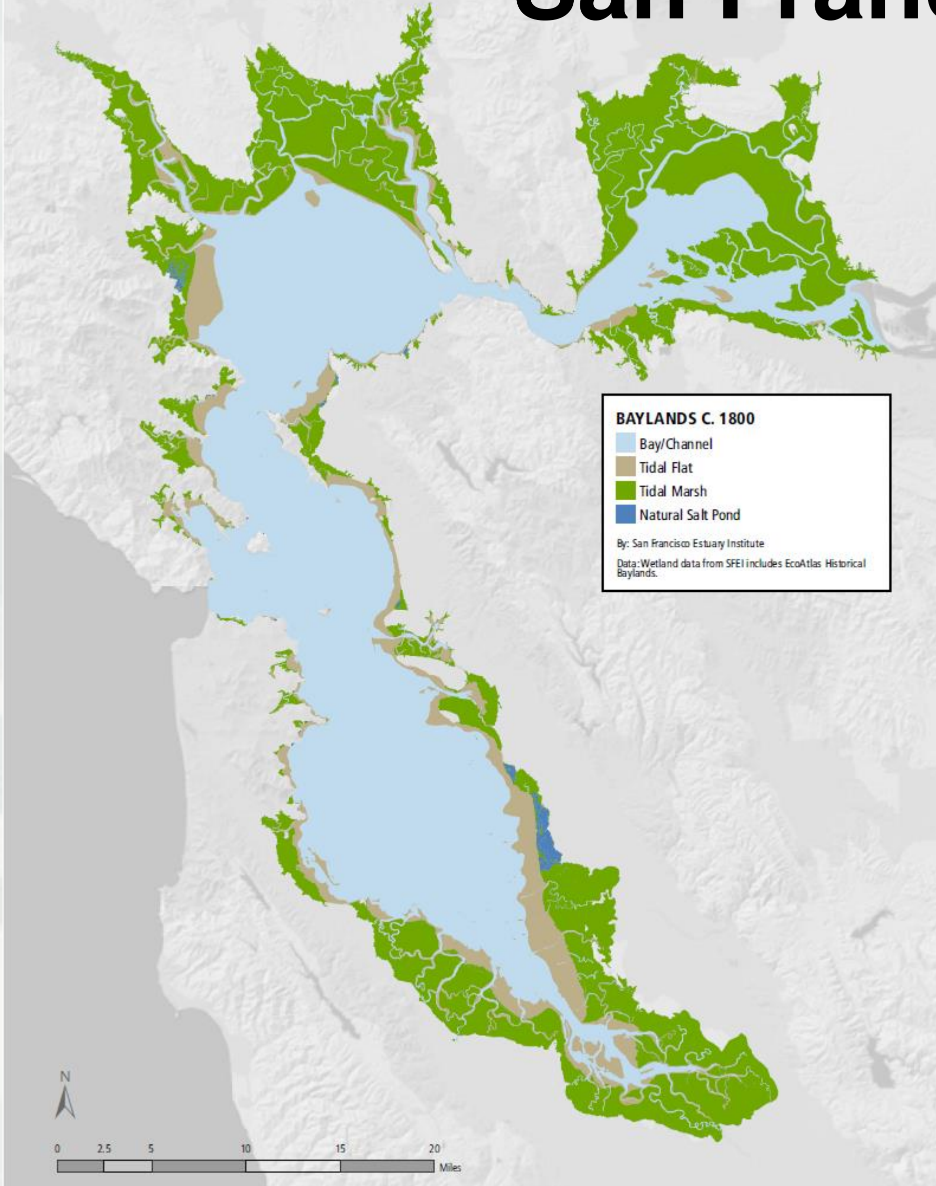
Engineering With Nature…

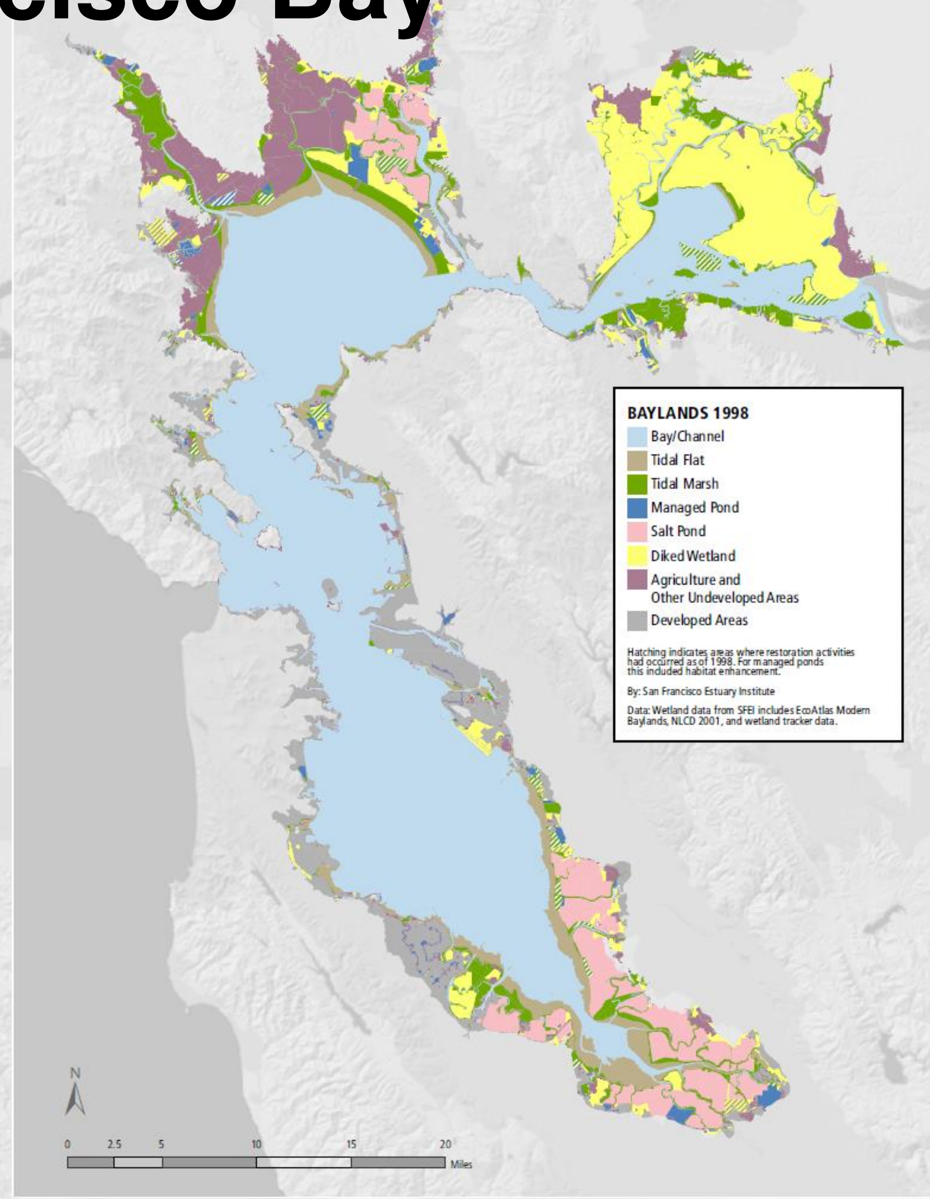
…the intentional alignment of natural and engineering processes to efficiently and sustainably deliver economic, environmental and social benefits through collaborative processes.



- Using natural process to maximum benefit

San Francisco Bay





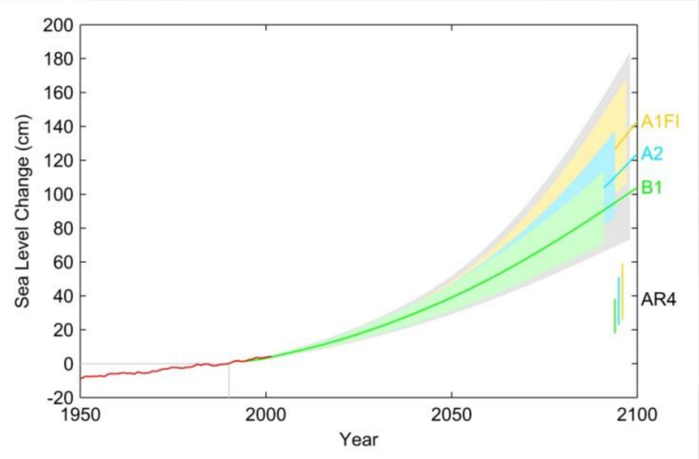
From Baylands Ecosystem Habitat Goals
Science Update 2015

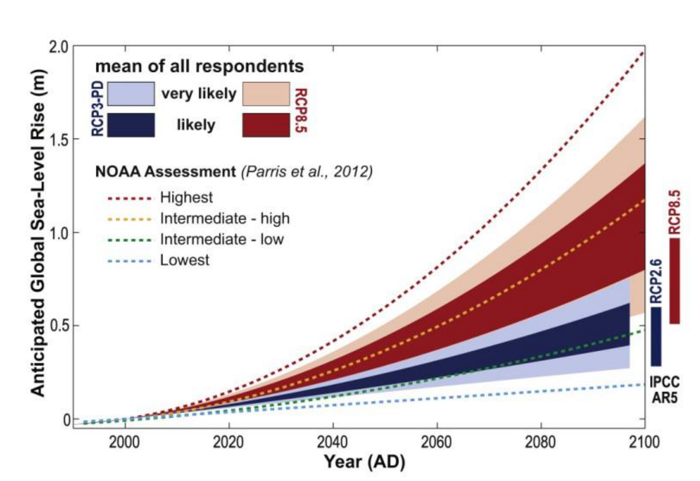
San Francisco Bay

- 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





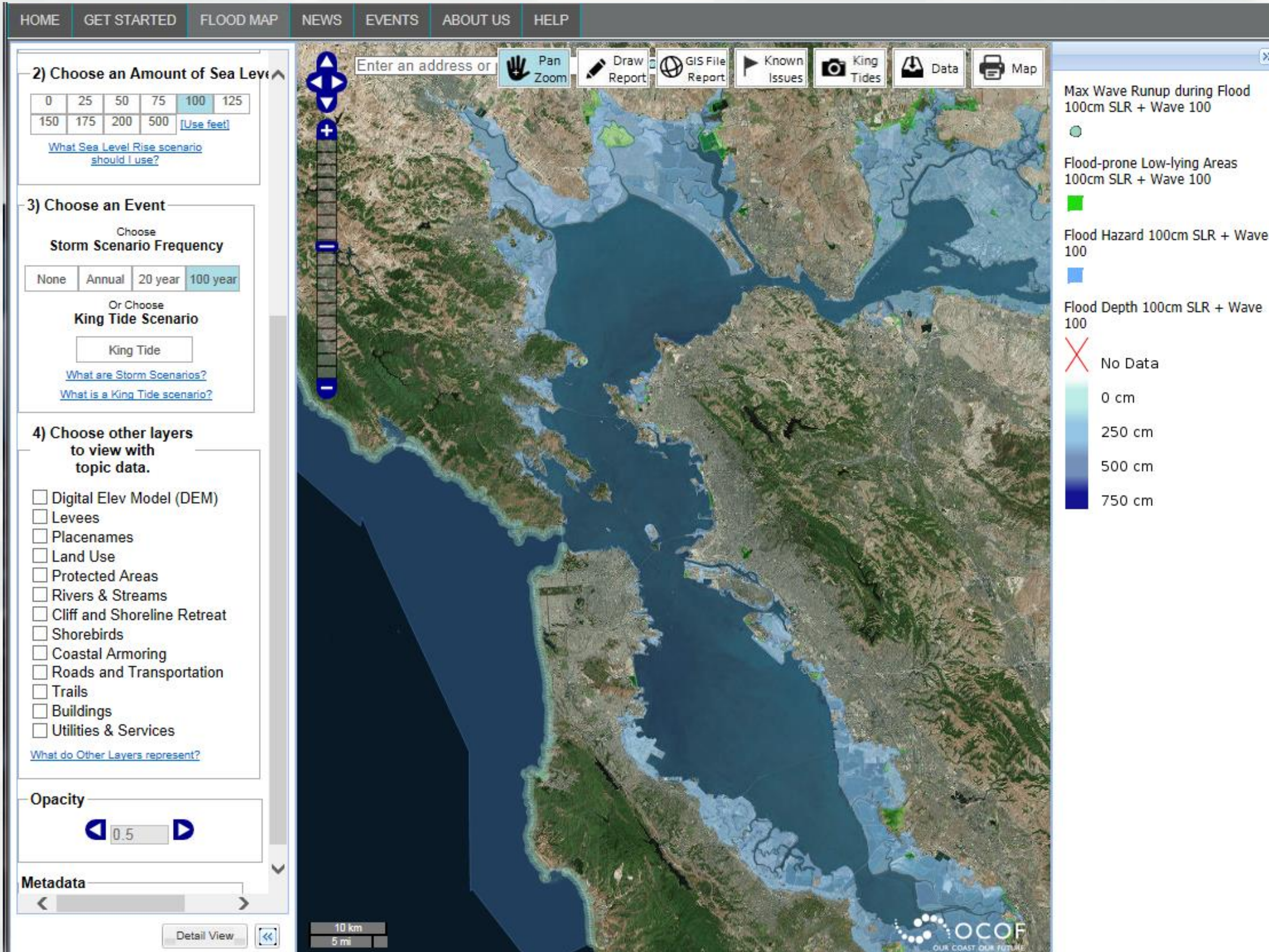
Compiled by USGS

Projections for San Francisco Area

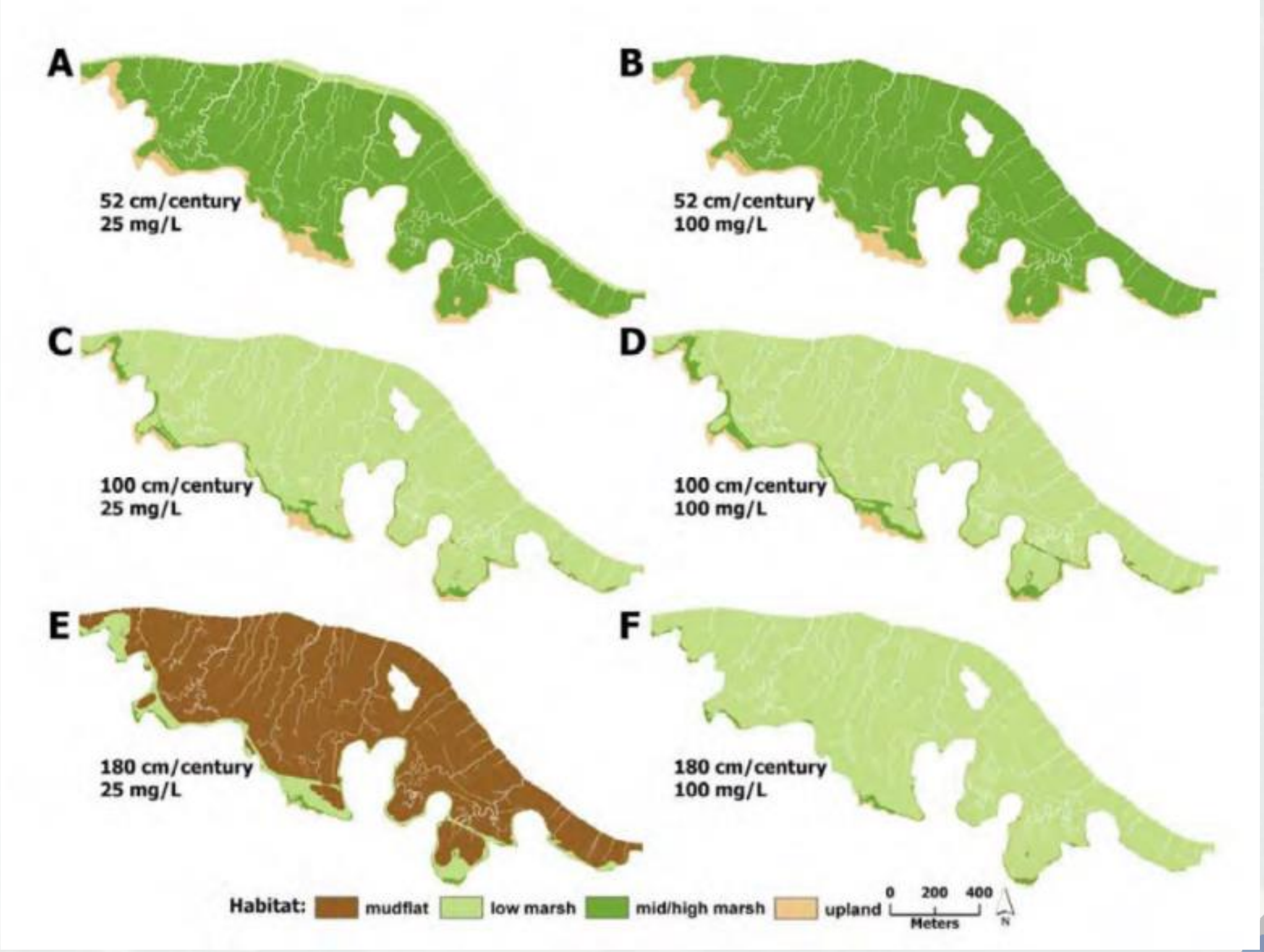
- **SLR for San Francisco (NRC, 2012)**
  - 28 cm of sea level rise by 2050 (range 12-61 cm)
  - 92 cm of sea level rise by 2100 (range 42-166 cm)
- **Storms for California**
  - No significant changes in wave height
  - Extreme events approach from ~10-15 degrees further south
- **El Niño for 21st Century**
  - 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)

Compiled by USGS

EWN


HOME
GET STARTED
FLOOD MAP
NEWS
EVENTS
ABOUT US
HELP
2) Choose an Amount of Sea Leve
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
Pan Zoom
Draw Report
GIS File Report
Known Issues
King Tides
Data
Map
10 km
5 mi
OCOF
OUR COAST OUR FUTURE
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

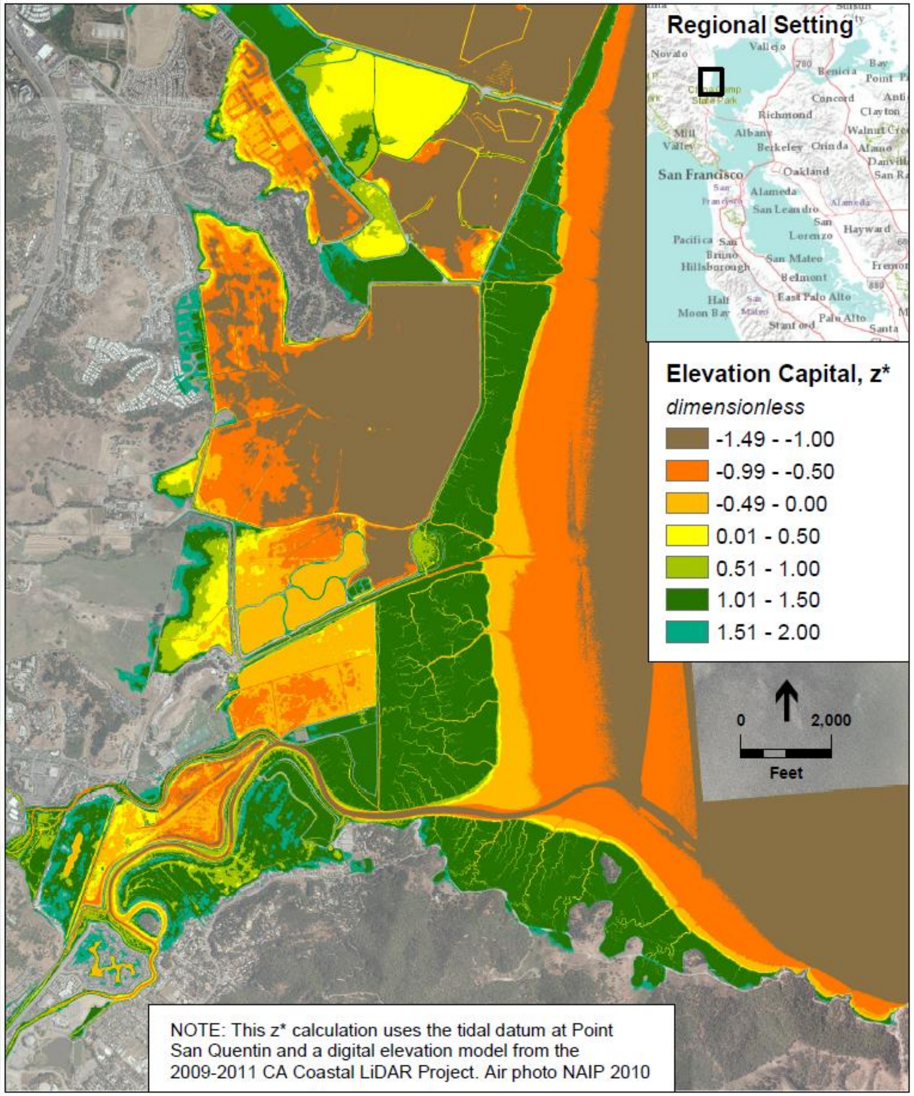


From Schile et al. (2014)

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.**

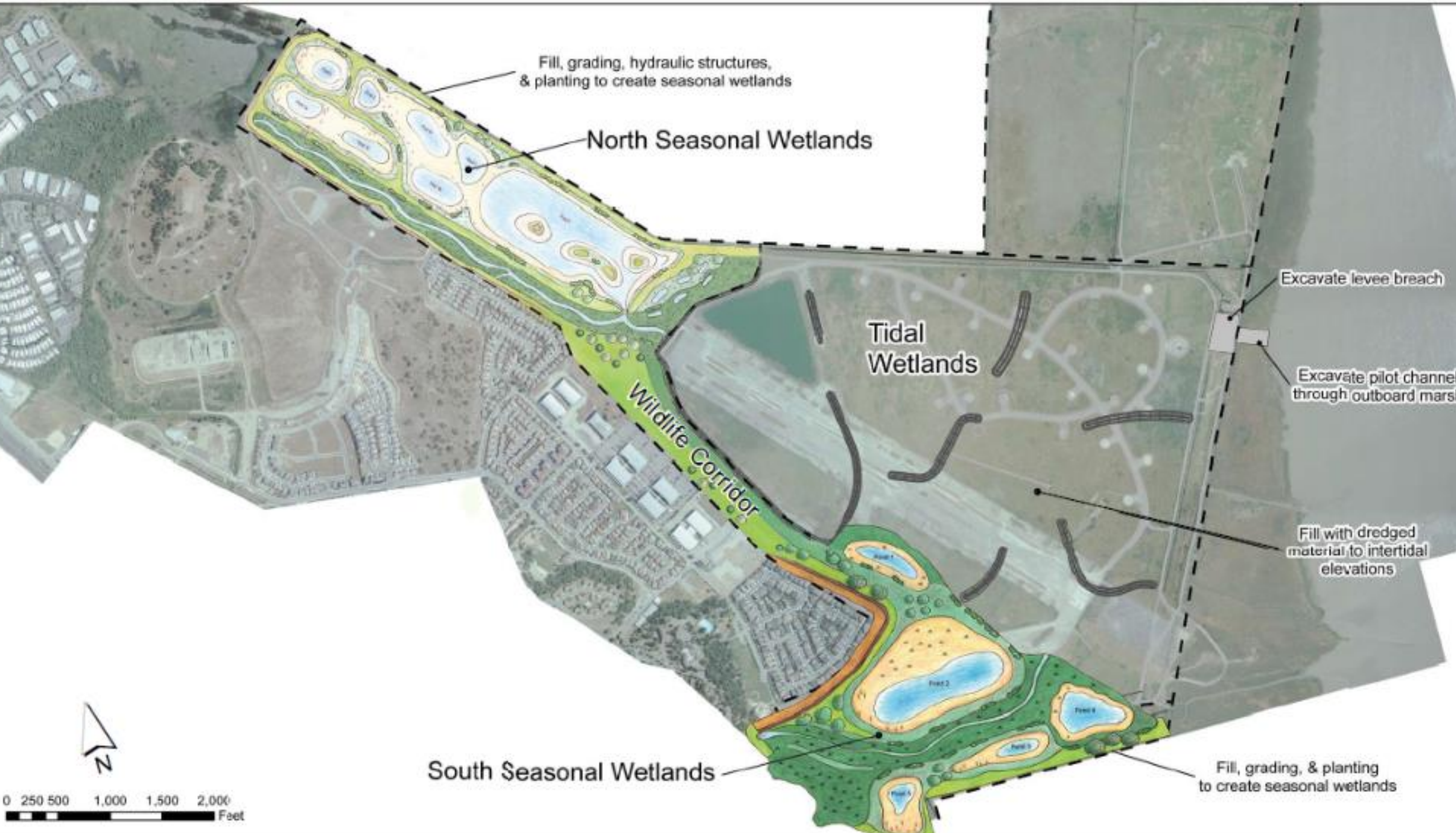
<u>In order to restore these diked baylands, sediment needs to be brought in or encouraged to accrete.</u>



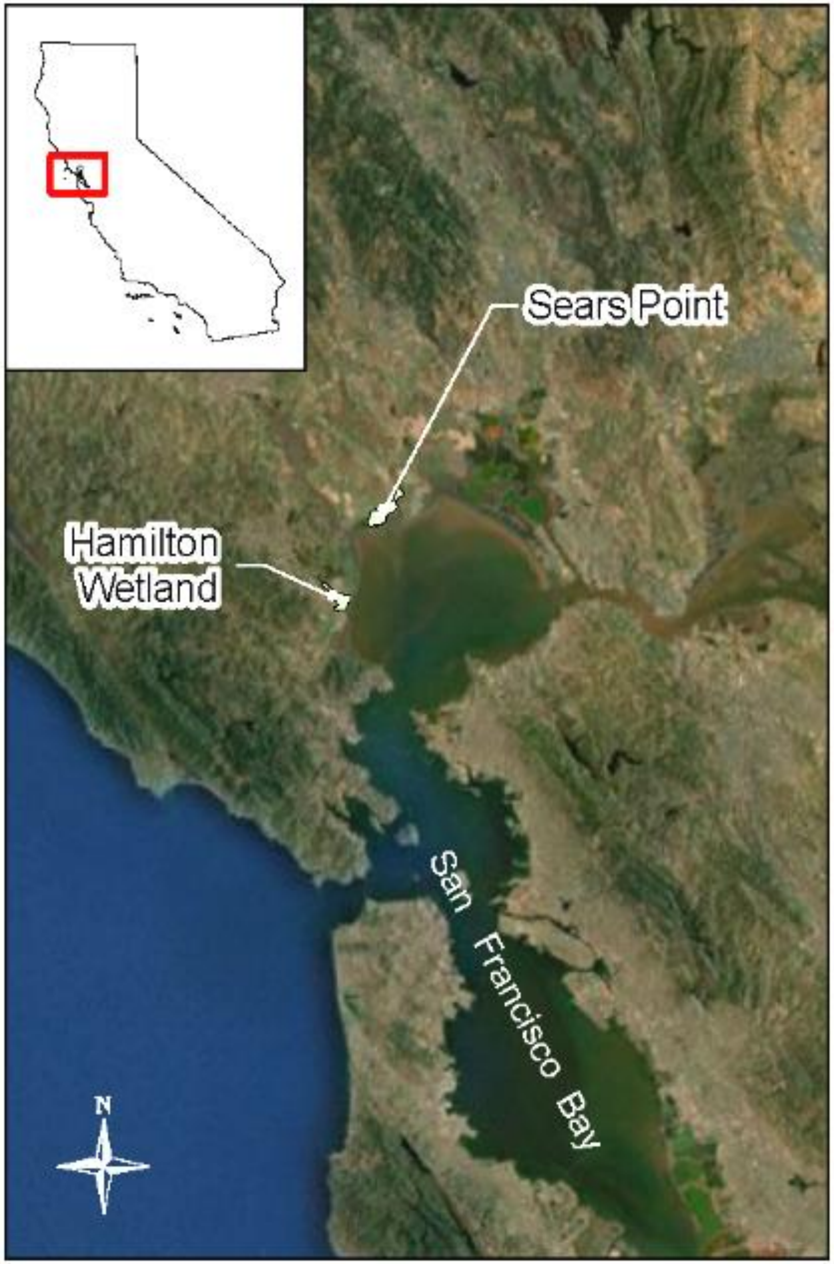
Hamilton Bay Restoration

- Site diked ~100 yr ago, Hamilton Army Airfield
- Significant subsidence
- 650-acre wetland restoration, 20 yrs
- Beneficial use of 24.4 mill yd^3 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

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.

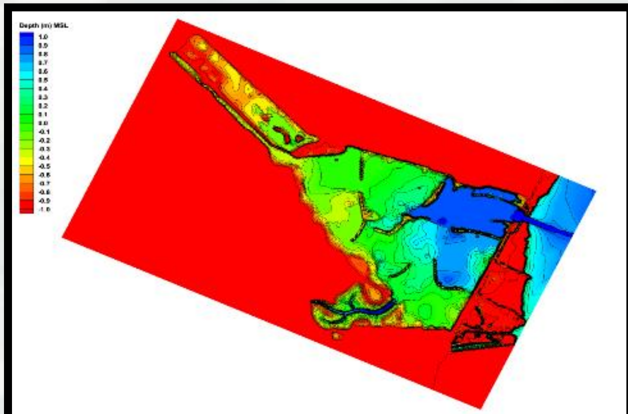
Hamilton Field Data Collection

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

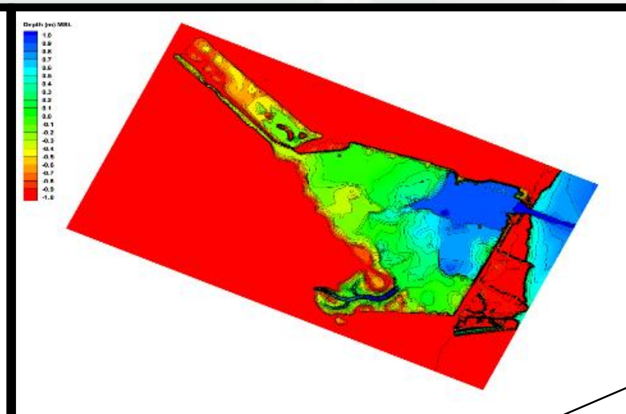
STWAVE

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

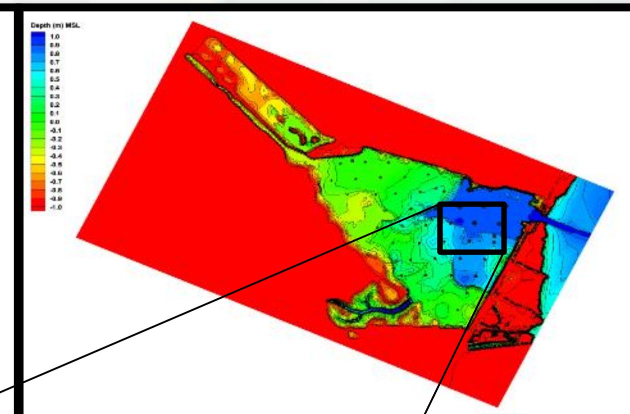
Bathymetry of Hamilton Model under Different Scenario Runs



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

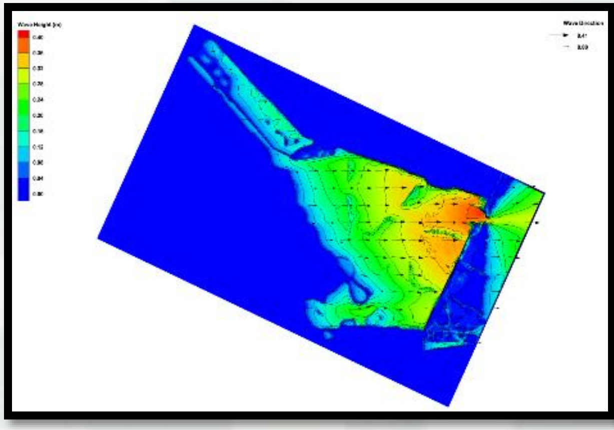
Date	H_{mo} mean error	H_{mo} rms error	T_m mean error	T_m RMS error
Feb 2015	0.013 m	0.028 m	0.21 sec	0.23 sec
Apr 2015	-0.0024 m	0.053 m	0.19 sec	0.25 sec

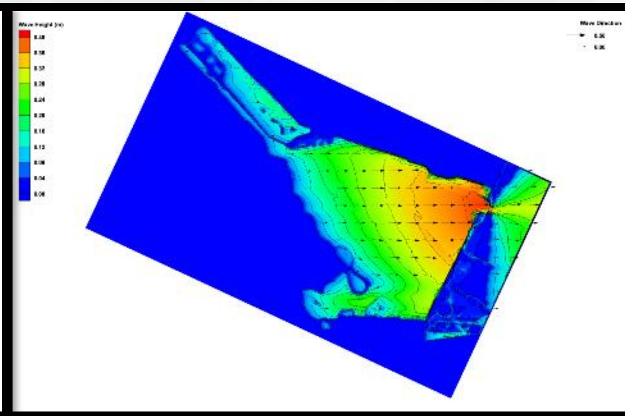
Idealized Simulations

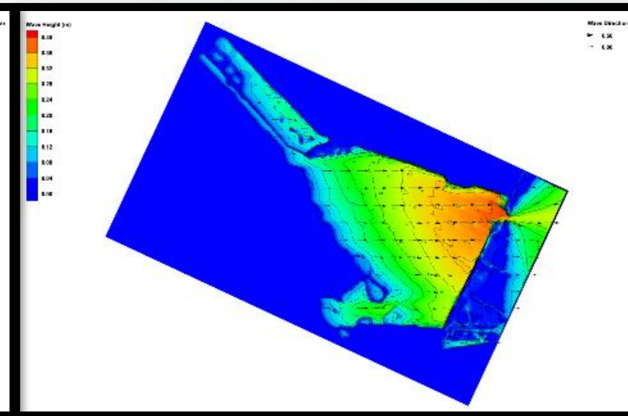
- Winds of 15 and 20 m/s (14-yr wind record at Richmond, CA)
- Water levels of + 0.5 and +1.0 MSL
- 8 wind directions (N, NE, E, SE, S, SW, W, NW)
- With and without vegetation
  - Pickleweed
  - Within depth range of +0.4-0.95 m MSL
  - C_D = 0.1, stem height=0.6 m, density = 300/m^2 diameter = 0.01 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

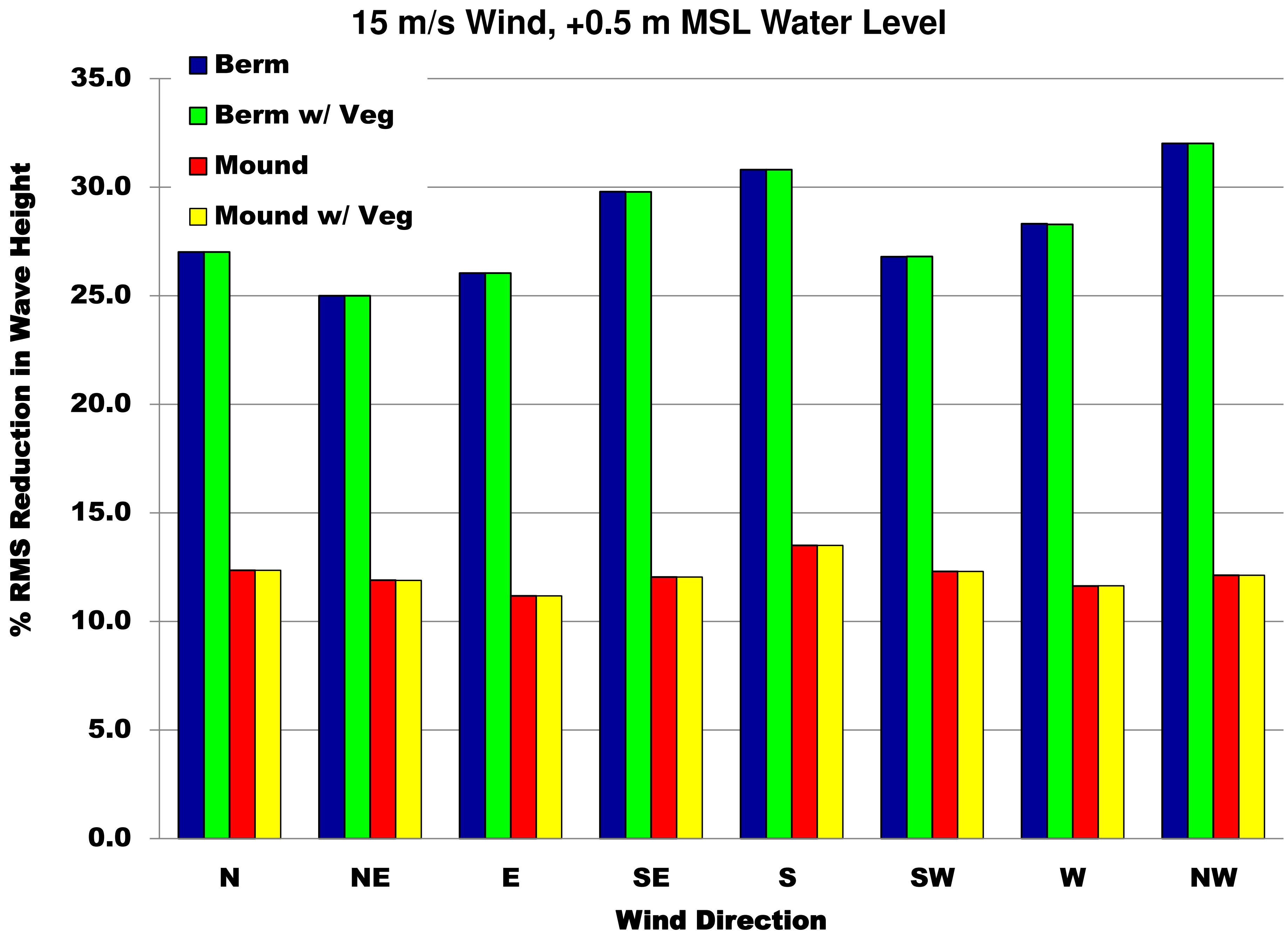


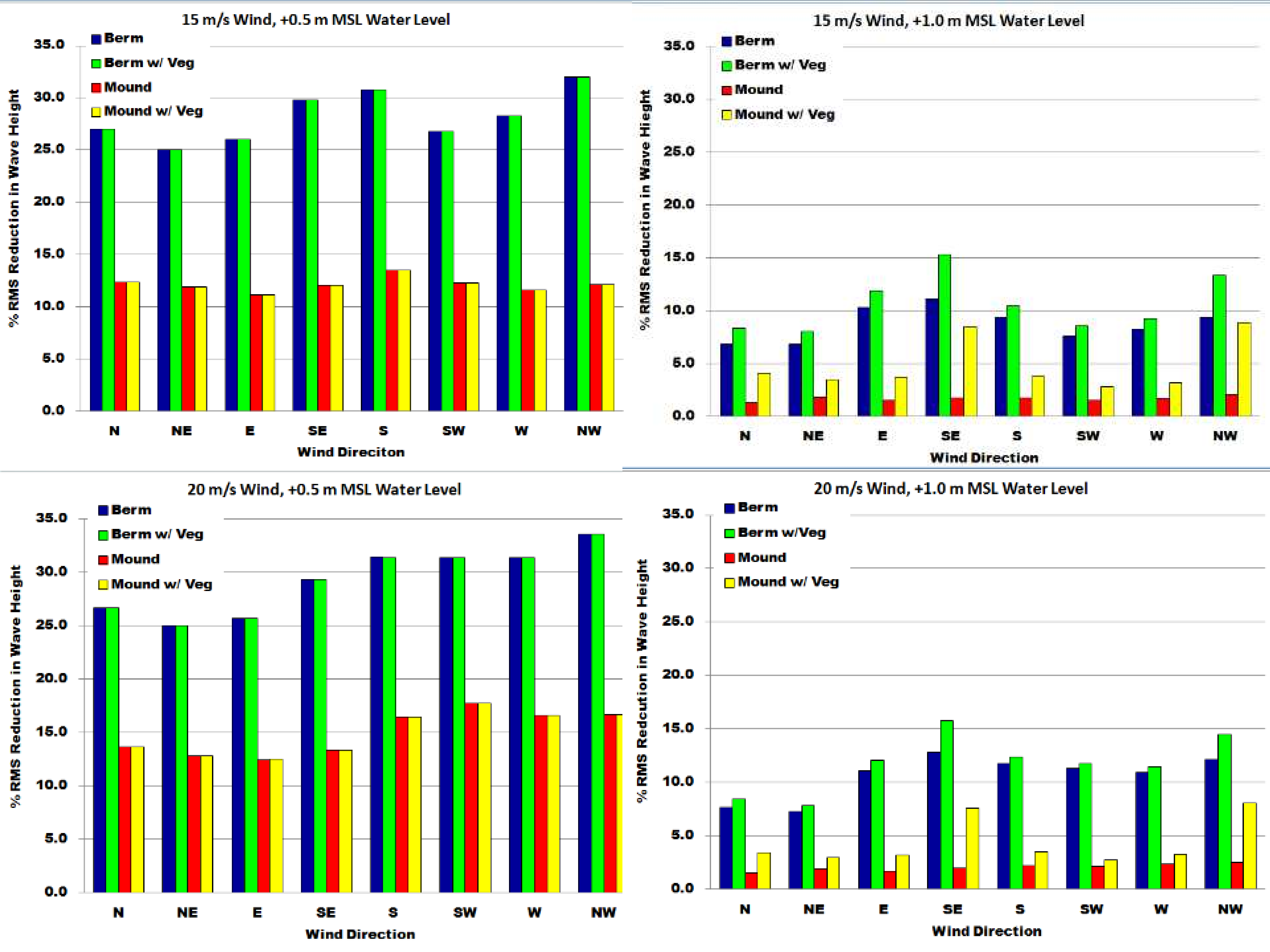




Linear Berms (As-Built) | **No Berms (Control)** | **Mounds (ala Sears Pt.)**

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
Berm
Berm w/ Veg
Mound
Mound w/ Veg
% RMS Reduction in Wave Height
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
N
NE
E
SE
S
SW
W
NW
Wind Direction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0.0
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NE
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S
SW
W
NW
Wind Direction

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.