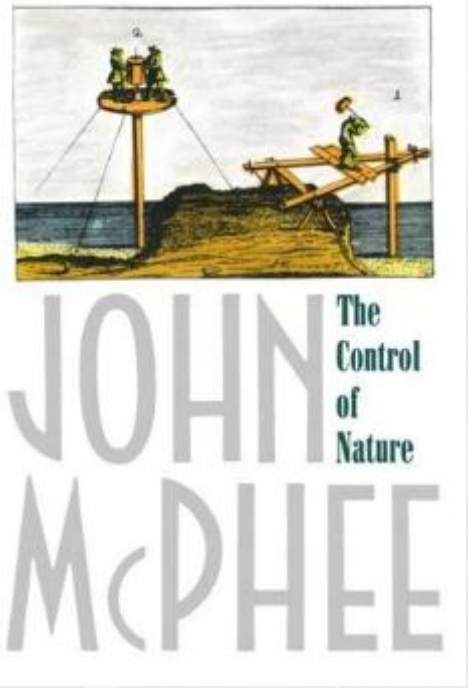
Engineering With Nature to Reduce Wave Energy

Jane Smith and Mary Bryant

Coastal and Hydraulic Laboratory
Engineering Research and Development Center

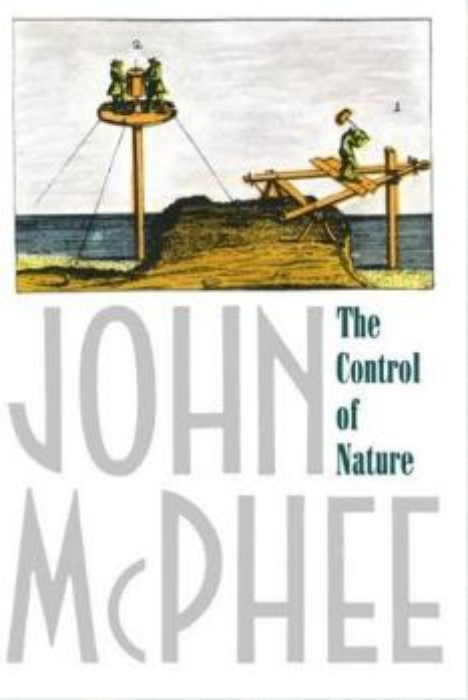
US Army Corps of Engineers
BUILDING STRONG®



The Control of Nature

Attempts to control natural processes:

- **Atchafalaya**
- **Cooling the Lava**
- **Los Angeles Against the Mountains**



The Control of Nature

U. Wyoming Engineer Building: STRIVE ON-THE CONTROL OF NATURE is WON, NOT GIVEN

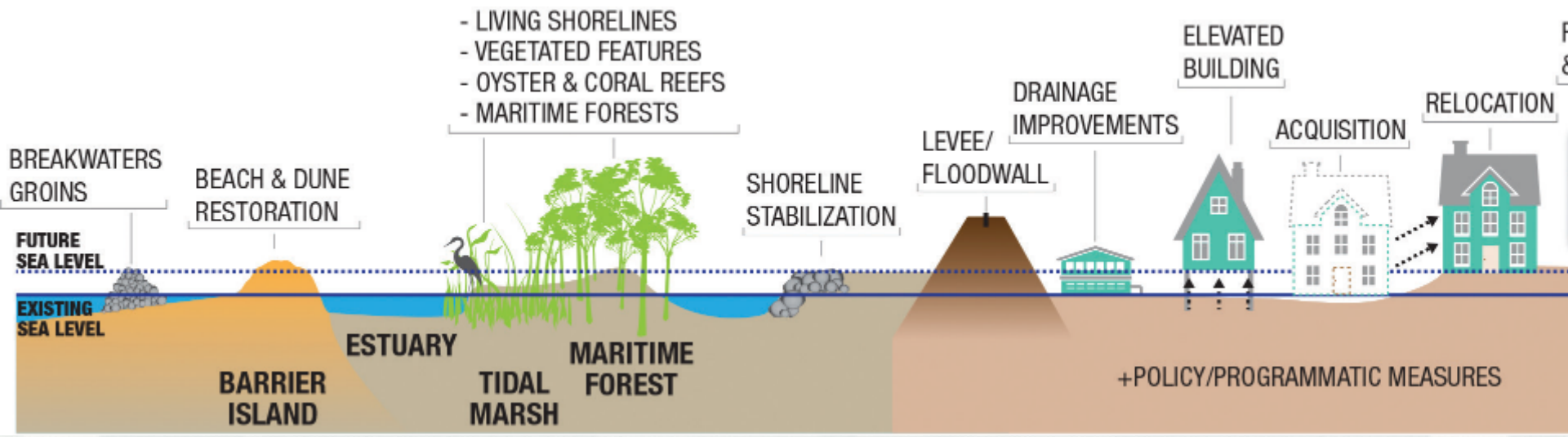
McPhee: "It is a description of people defying nature. They may have no choice"

In the end, nature will always win.

Engineering AGAINST Nature or Engineering WITH Nature?

- Levees
- Beaches and sand dunes
- Wetlands
- Reefs (rock, coral, shells)
- Headlands
- Berms and islands
- Runoff retentions areas

Engineering with Nature Concepts



Wave Dissipation in Wetlands

- Quantify wave attenuation through vegetation
  - Understand and model nearshore processes
  - Evaluate potential for coastal protection

Lab Studies of Waves and Veg

- Flume: 1.5 m deep, 1.5 m wide, 64 m long
- Artificial vegetation: 6.4 mm diameter, 41.5 cm stem length, 200 and 400 stems/m^2 density
- Three water depths: 30.5 cm, 45.7 cm, and 53.3 cm
- Irregular waves: T_p ~ 1.25-2.25 s, H_{m0} ~ 5.0-19.2 cm

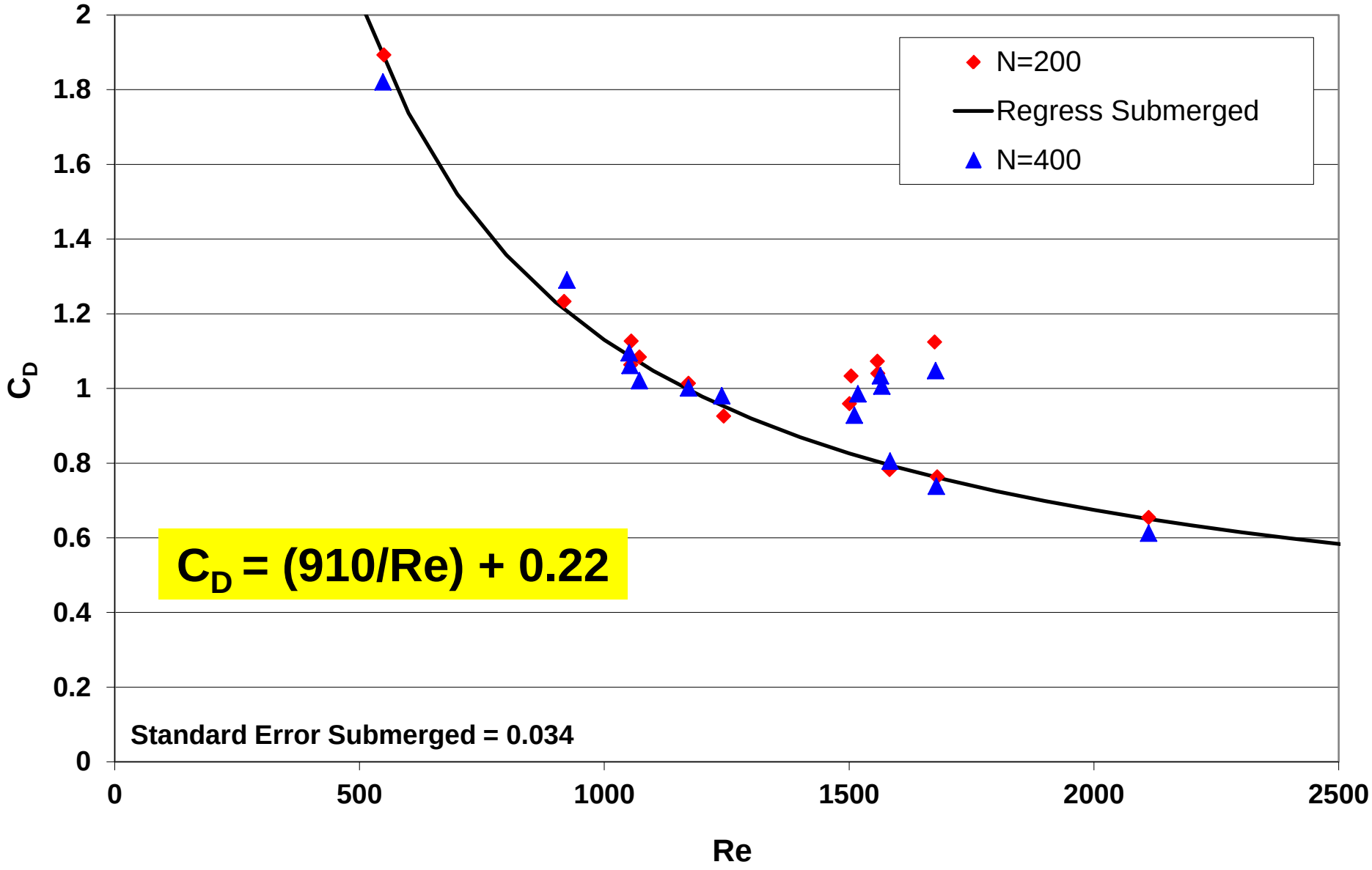
Estimate C_D

- Following Mendez and Losada (2004), Dalrymple et al. (1984)

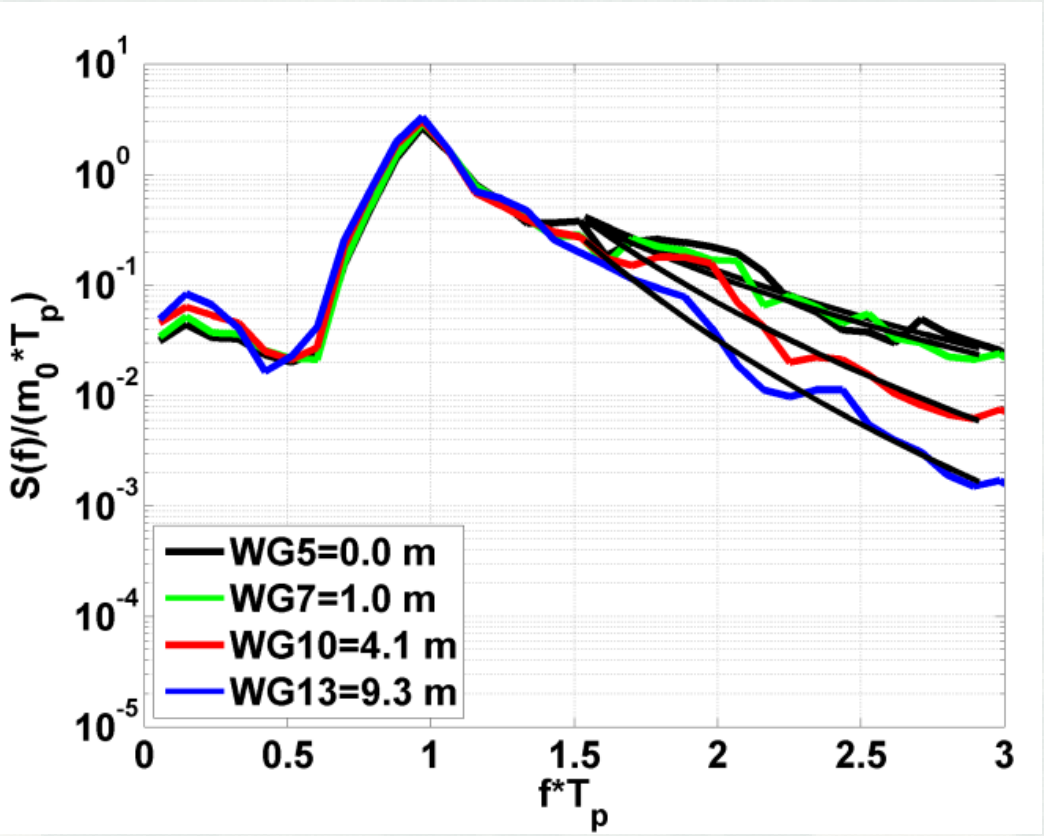
$$D = \frac{g^2}{16\sqrt{\pi}} C_D b_v N \left(\frac{T_p}{L}\right)^3 \frac{sinh^3 k\alpha h + 3\sinh k\alpha h}{3k cosh^3 kh} H_{rms}^3$$

Background tank friction was removed

Estimate C_D


N=200
Regress Submerged
N=400
$C_D = (910/Re) + 0.22$
Standard Error Submerged = 0.034
C_D
Re
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
500
1000
1500
2000
2500

Equilibrium Range

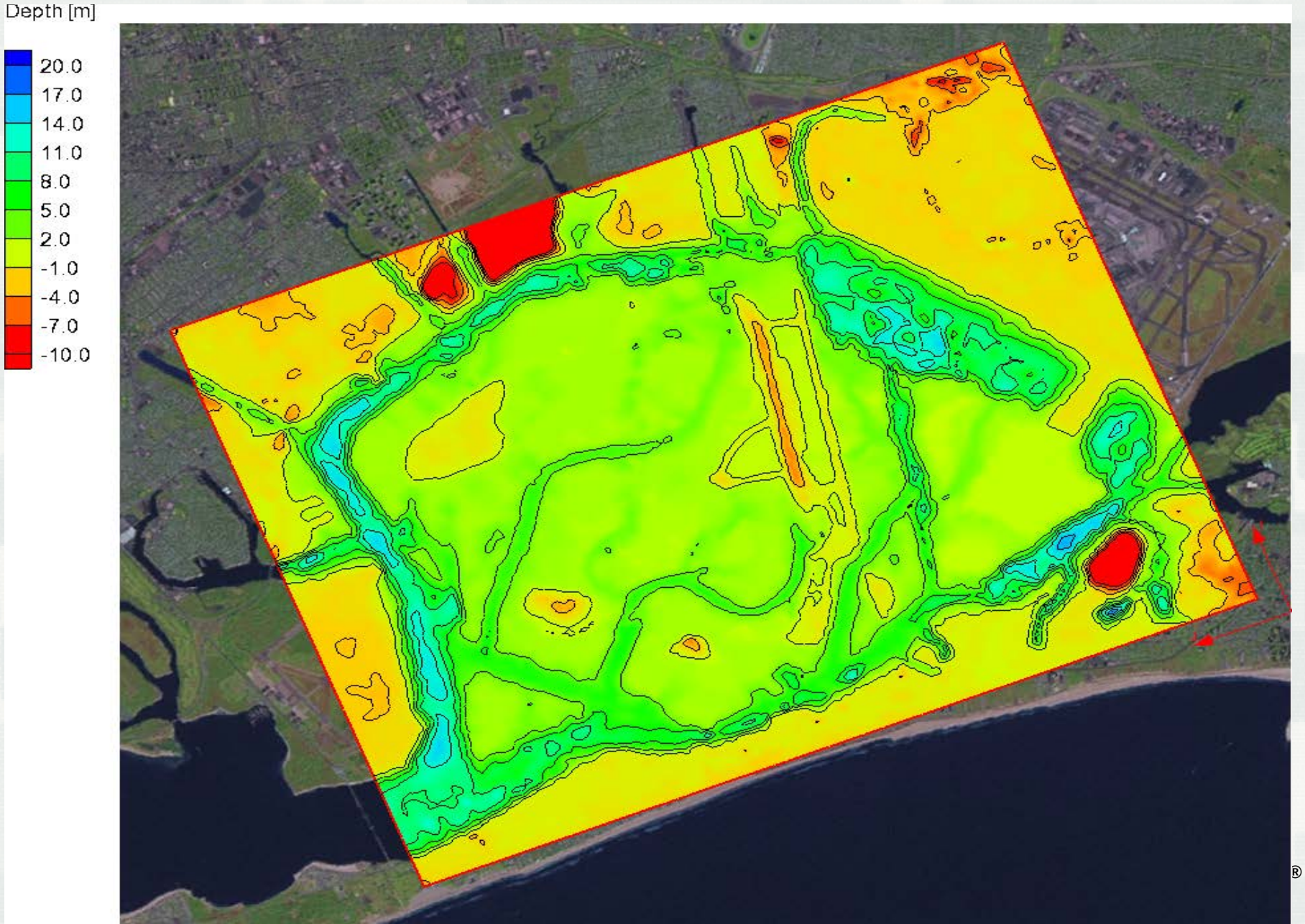


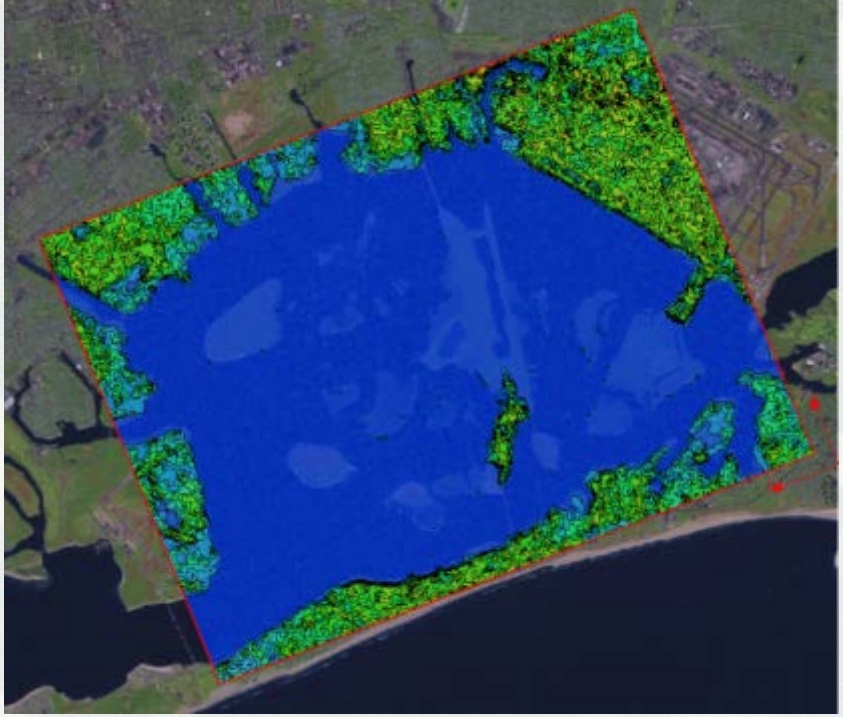
- Deviations of slope of spectral tail
- $1.5f_p$ to $3f_p$
- Preferential dissipation of higher frequencies
- dissipation of higher frequencies dependent on stem density and submergence ratio

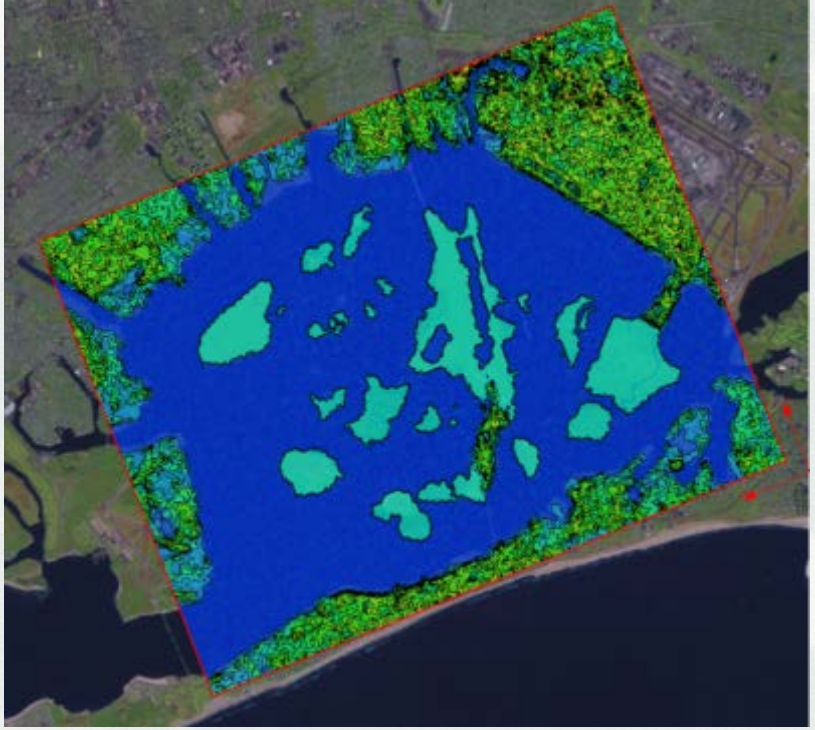
Jamaica Bay, NY, Hypothetical Restoration

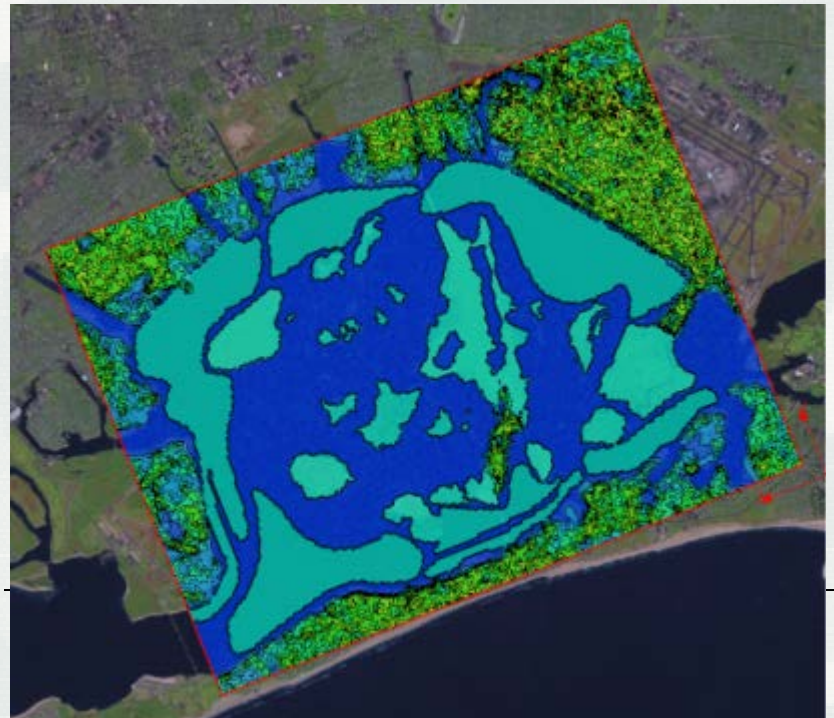
- Four vegetation states
  - No vegetation, existing bathymetry
  - Existing vegetation and bathymetry
  - Moderate vegetation w/ modified bathymetry
  - Extensive vegetation w/ modified bathymetry
- Three wind & water level combinations
  - Winds: 18.5 m/s, 22.1 m/s, 26.0 m/s
  - Water Levels: 1.3 m, 2.0 m, 2.9 m
- *Spartina alterniflora* in the low marsh, *Spartina patens* in the high marsh, & *Phragmites*
- $C_D \sim 0.35$, $N = 400$, $b_v = 0.6$ cm

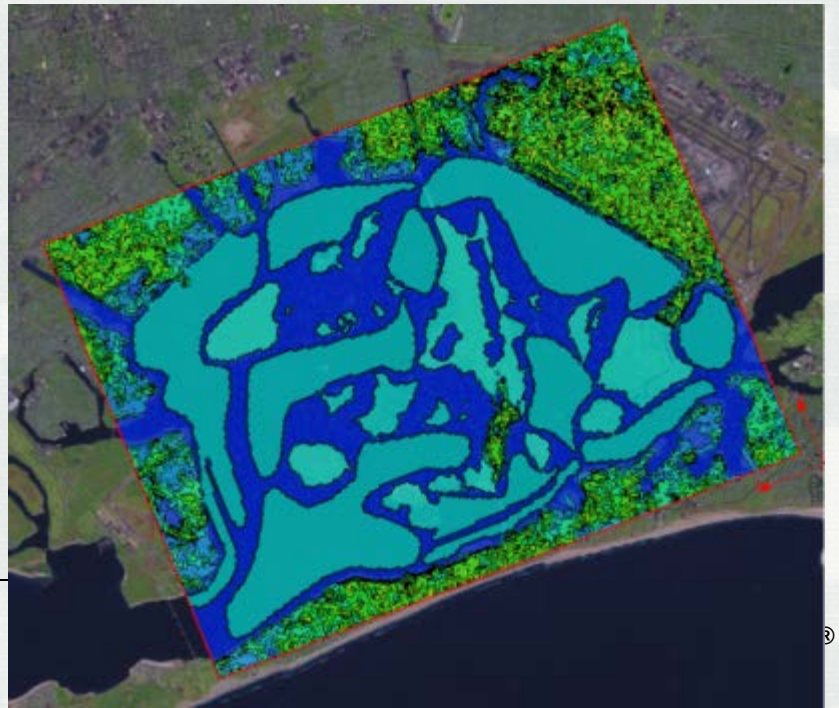
Jamaica Bay Bathymetry



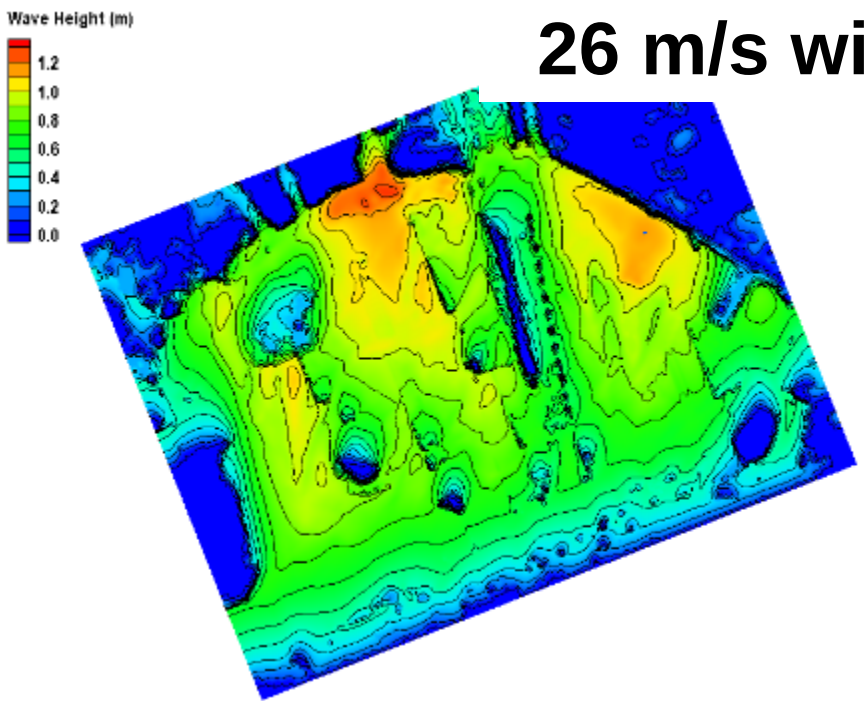


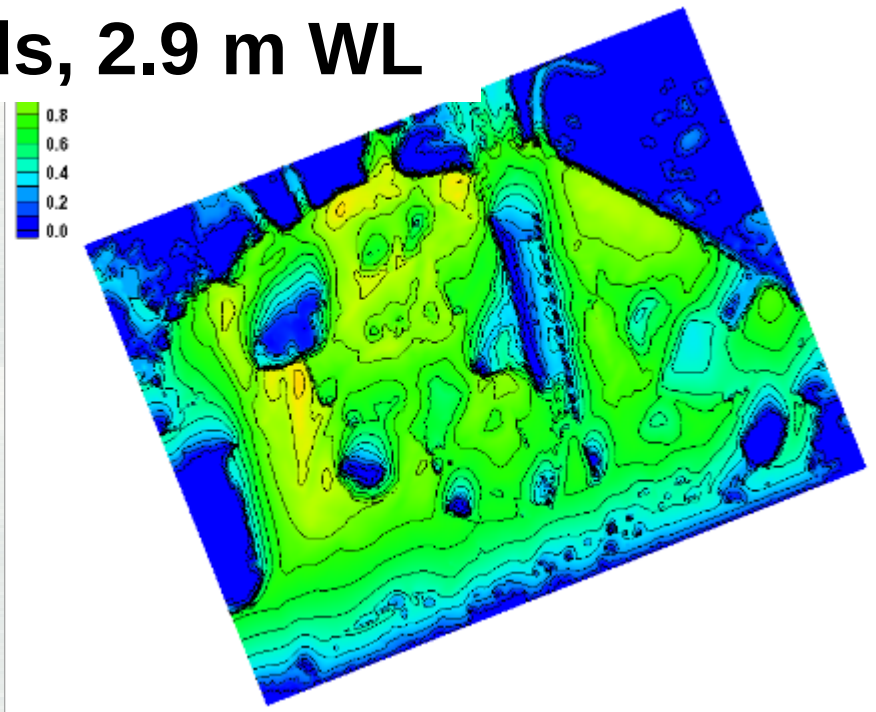


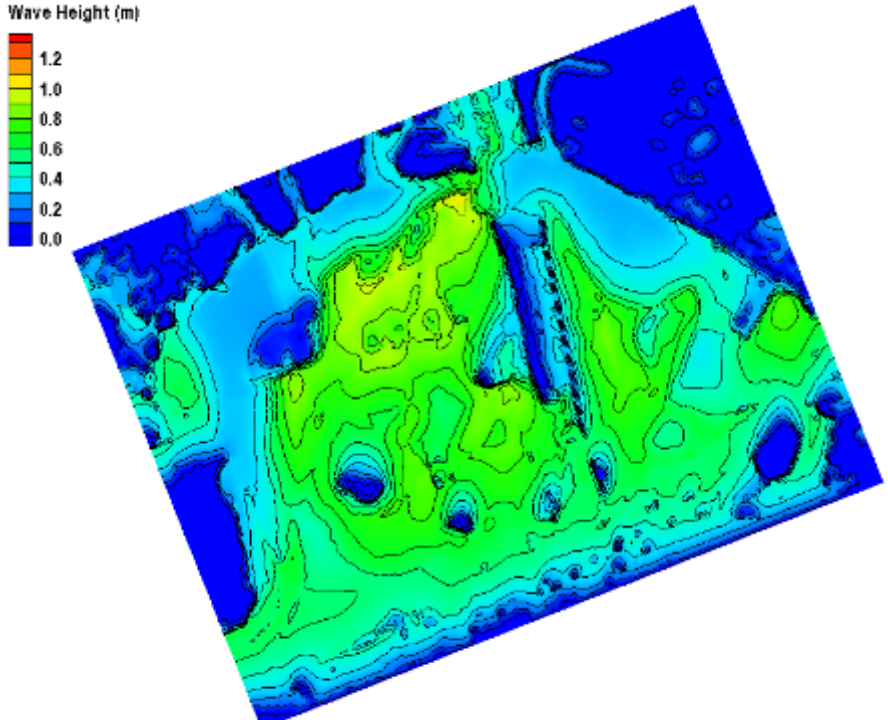


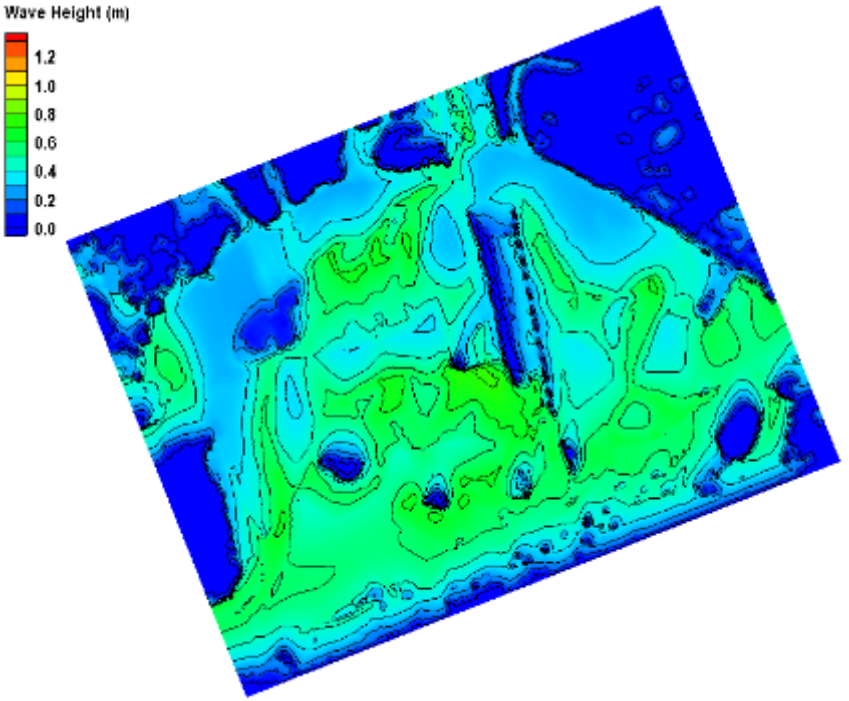


26 m/s winds, 2.9 m WL

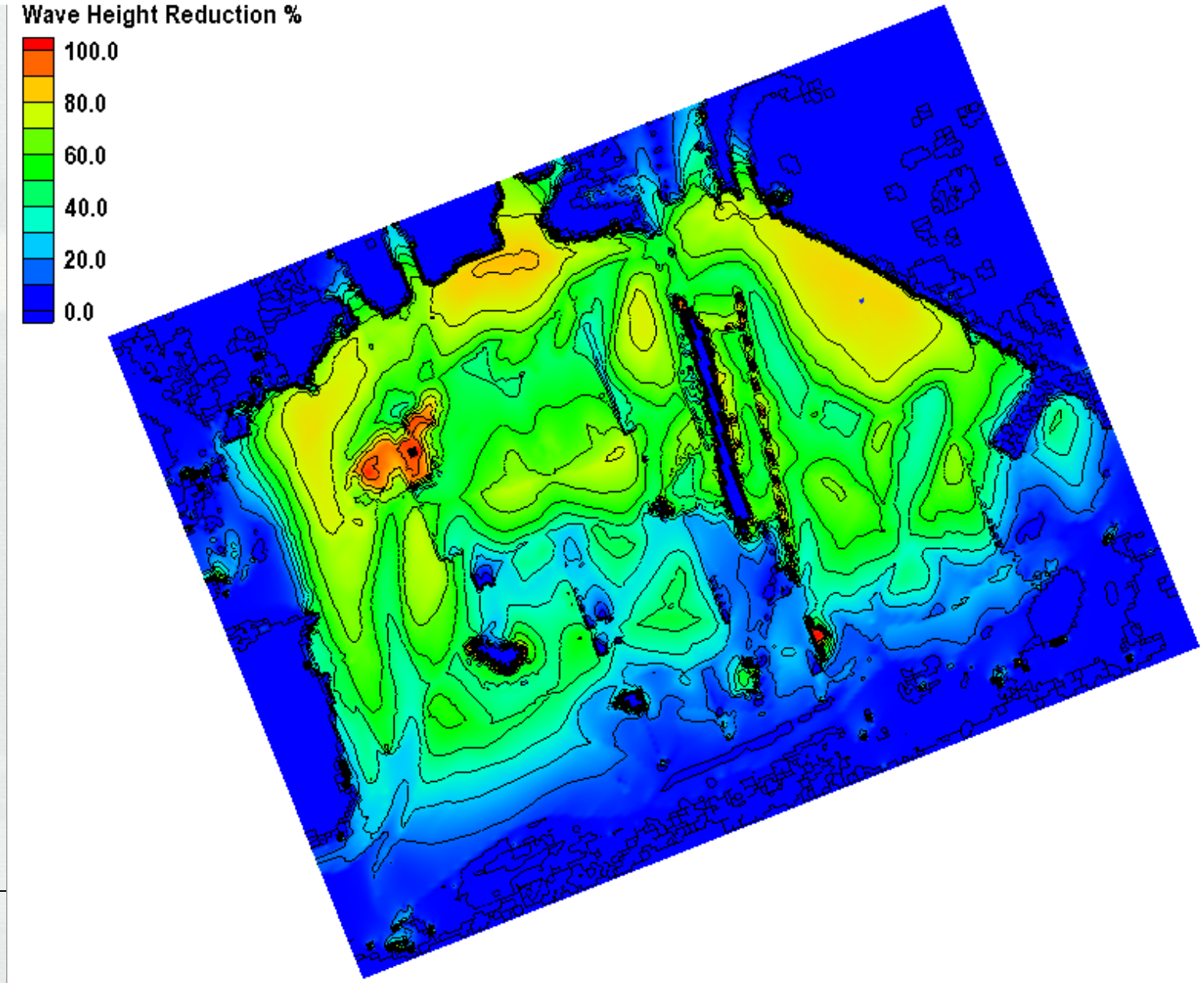








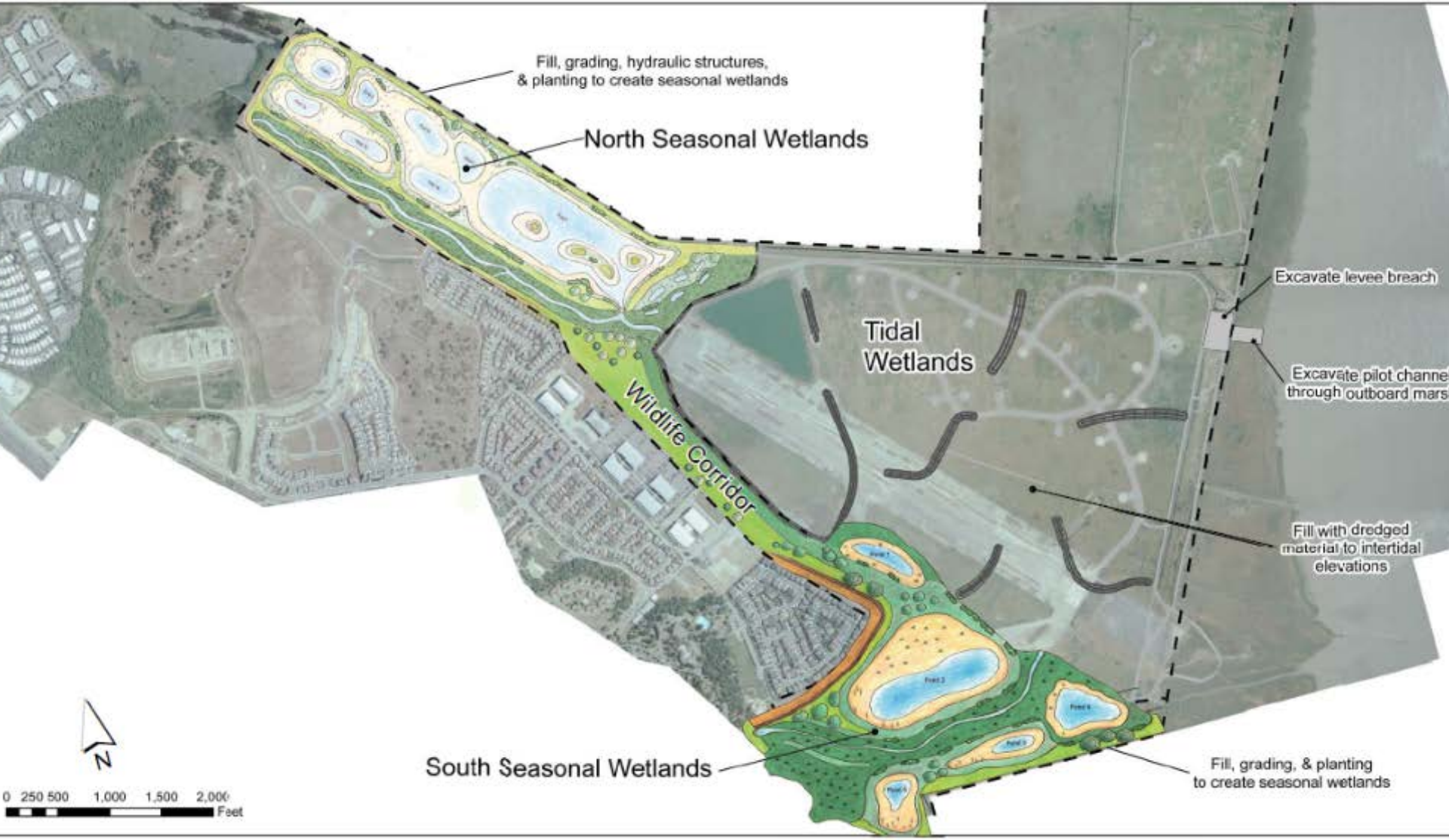
percent reduction in wave height from bare to extensive vegetation coverage



Hamilton Bay Restoration

- Site diked ~100 yr ago, Hamilton Army Airfield
- Significant subsidence
- 650-acre wetland restoration, 20 yrs
- Beneficial use of 5.6 mill yd^3 of dredged material
- Wetland design w/ berms
- U.S. Army Corps of Engineers and the California Coastal Conservancy

Hamilton Bay Restoration

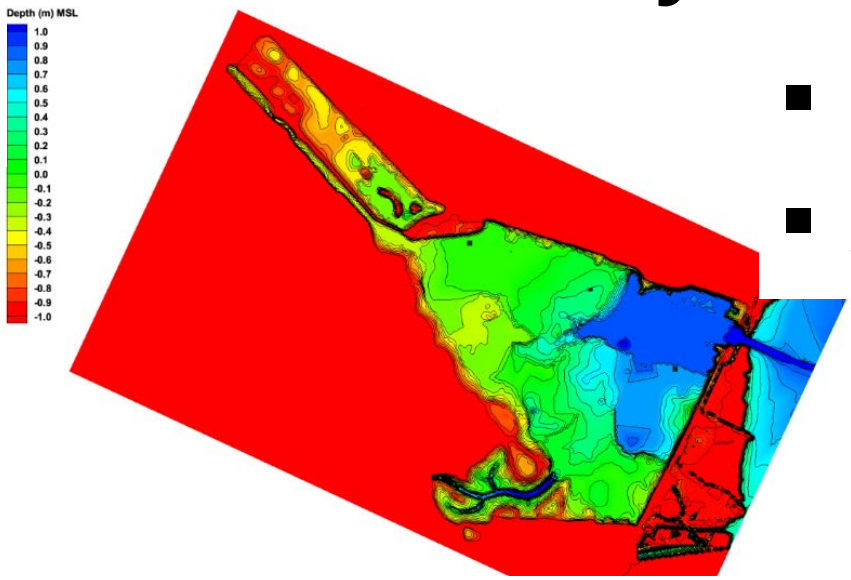


Compare Berms and Mounds for Wave Reduction

- Berm = linear feature
- Mound = circular feature
- Sears Point Restoration breached in Oct 2015
- 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.

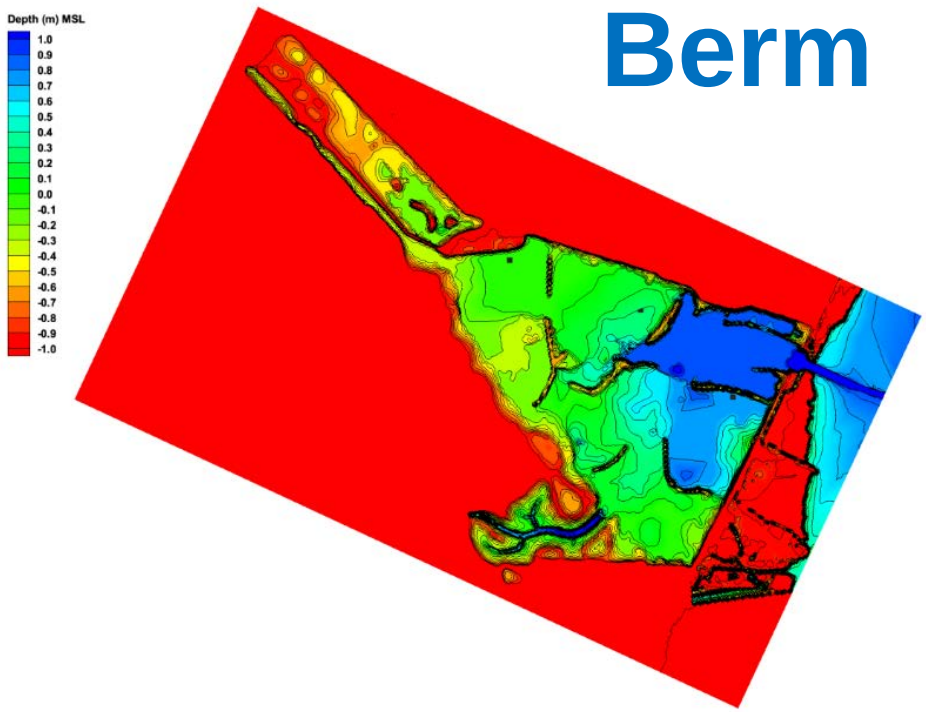
Hamilton Bathymetry

No Berm

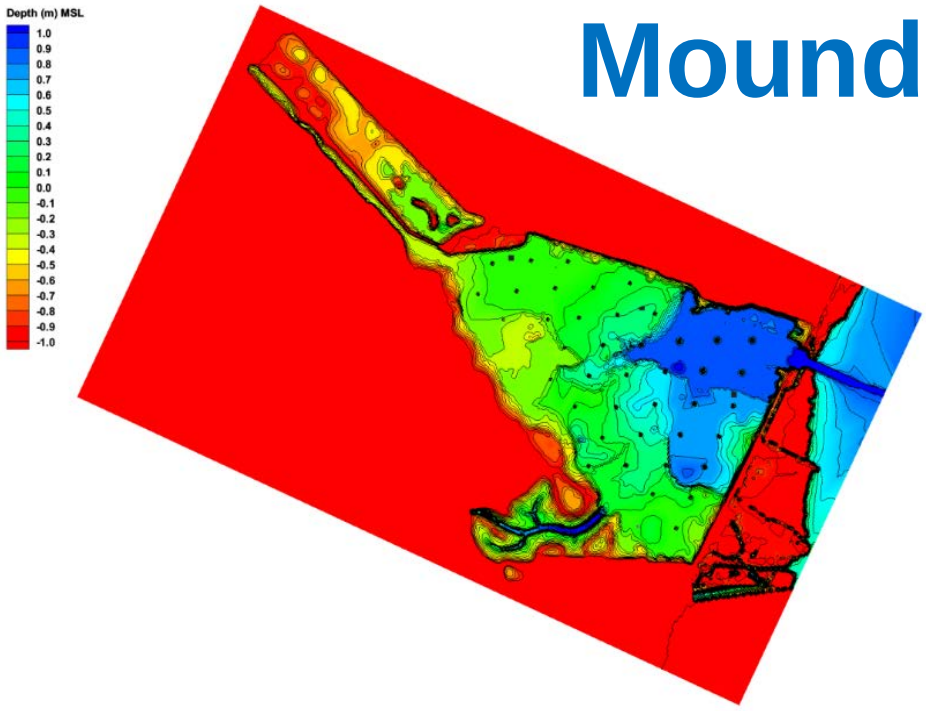


- 3.46 x 2.05 km
- Δ =10 m

Berm



Mound

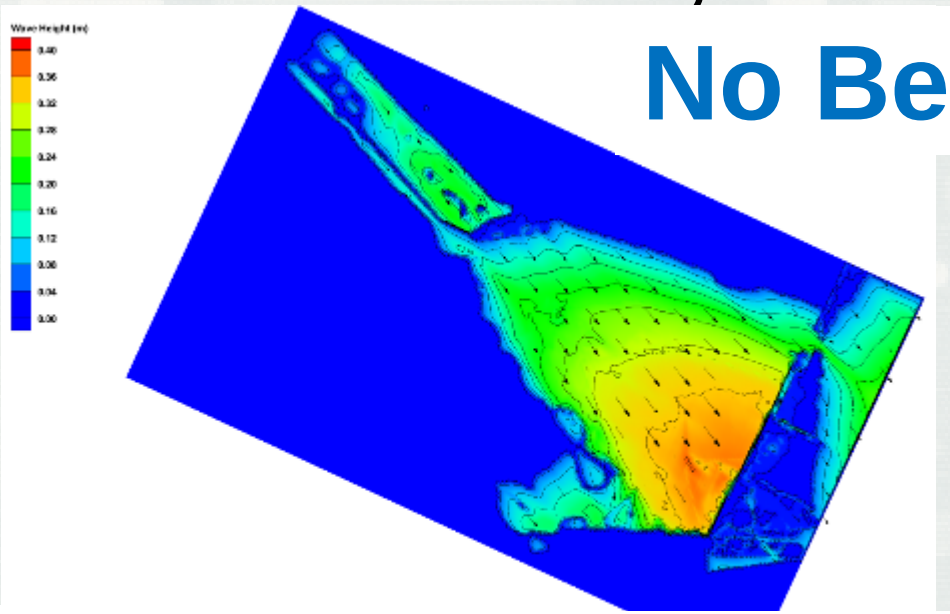


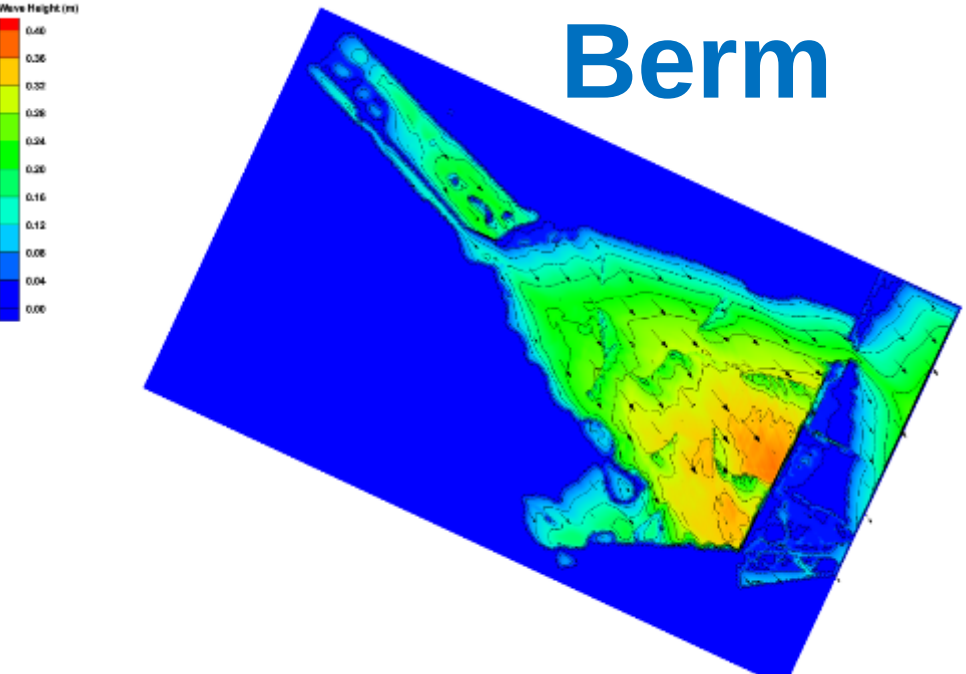
Idealized Simulations

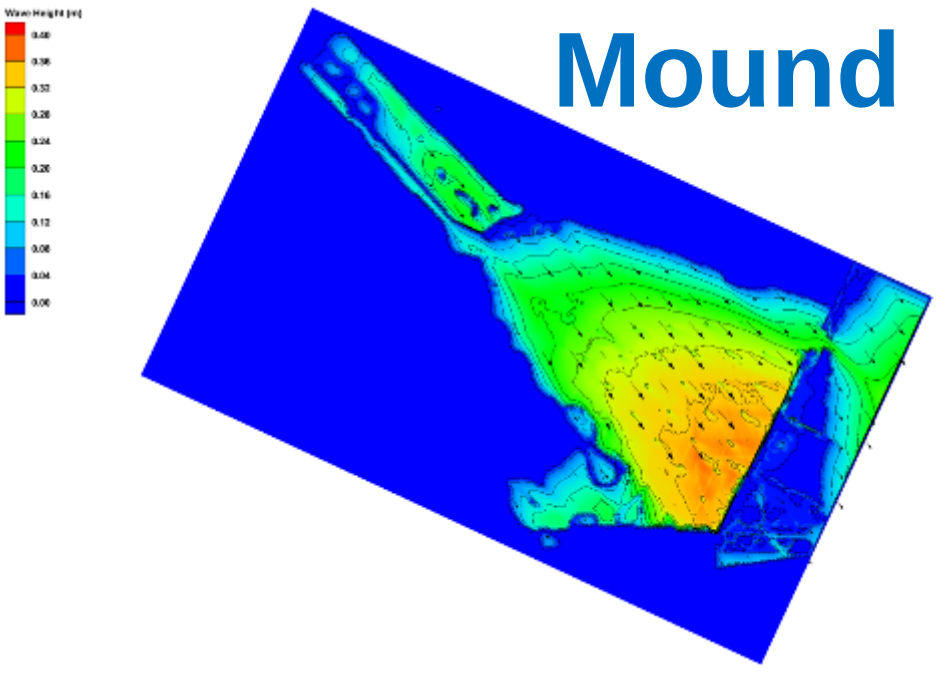
- Winds of 15 and 20 m/s (14-yr wind record)
- Water levels of + 0.5 and +1.0 MSL
- 8 wind directions (N, NE, E, SE, S, SW, W, NW)
- With and without vegetation
  - Pickleweed

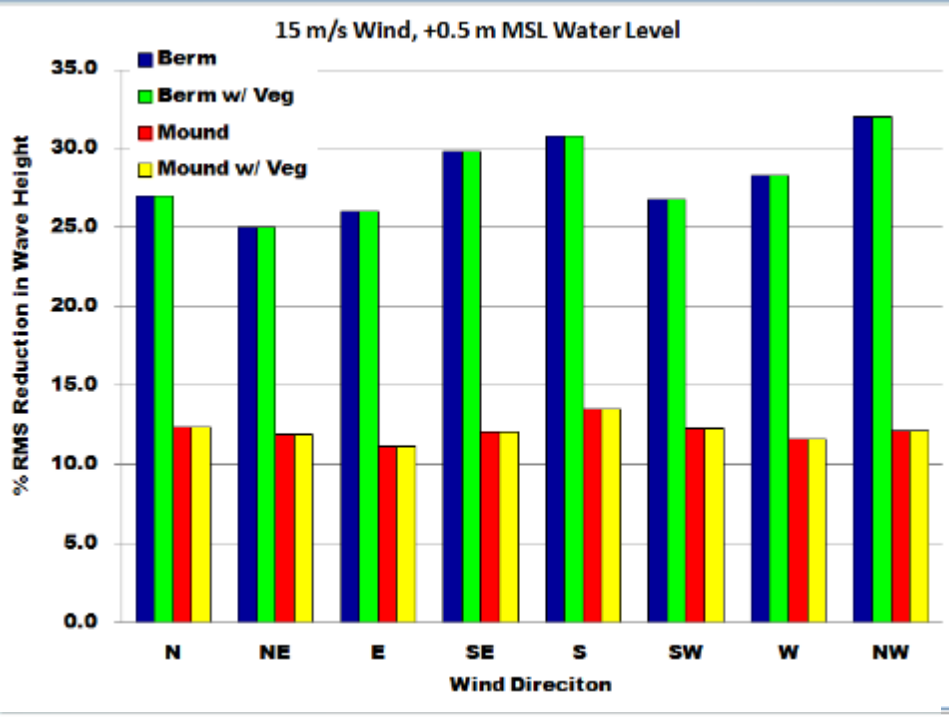
  - depth range of +0.4-0.95 m MSL
  - C_D = 0.1, stem height=0.6 m, density = 300/m^2 diameter = 0.01 m (Northwest Hydraulic Consultants 2011)

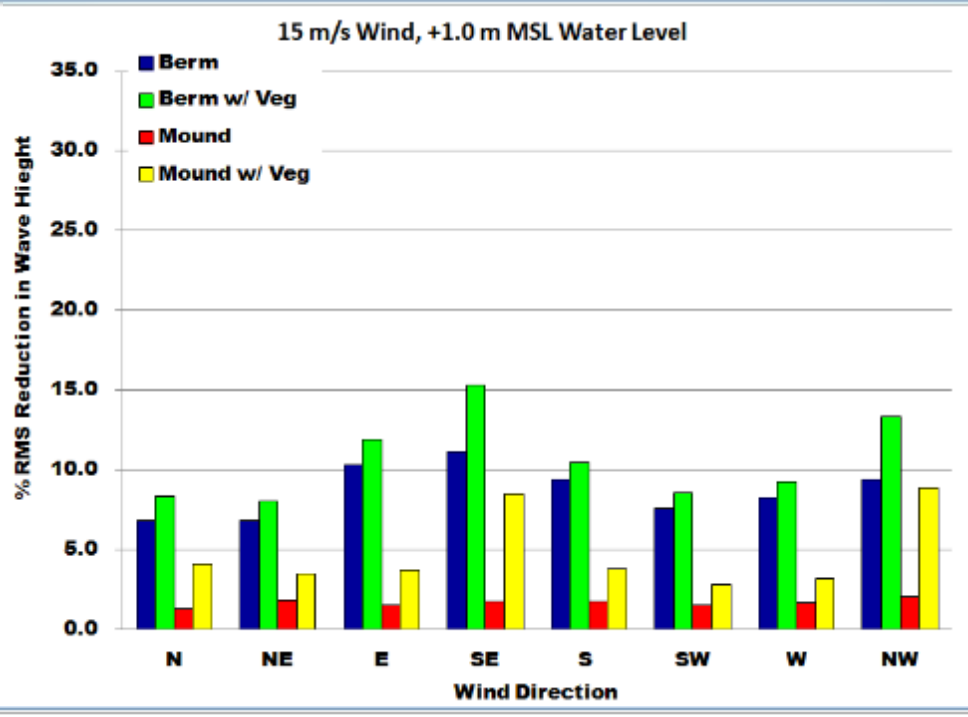
No Berms: 20 m/s NW, +0.5m MSL

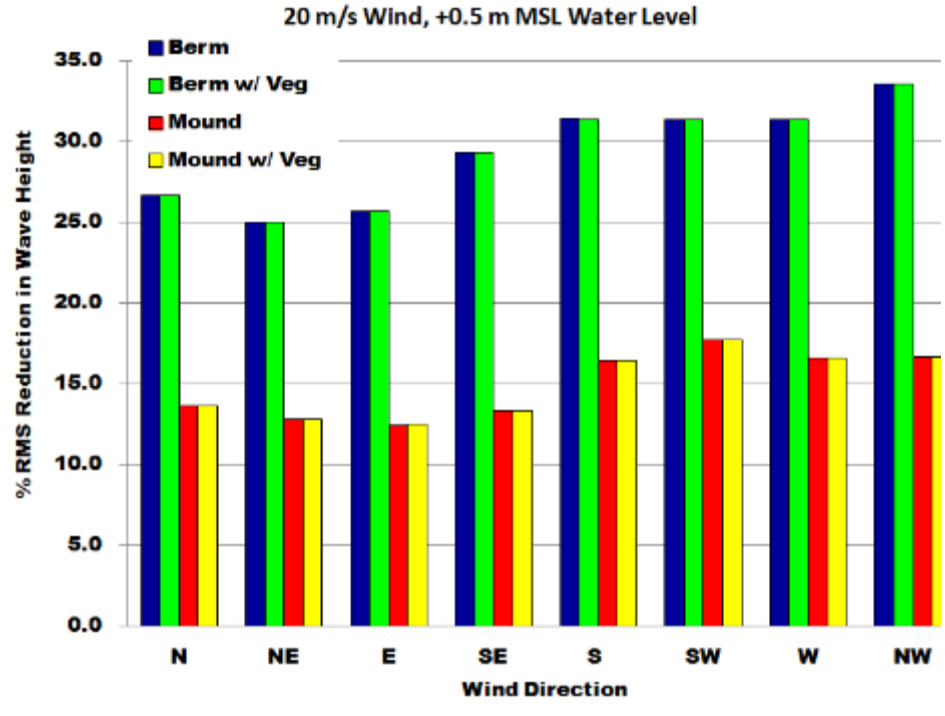


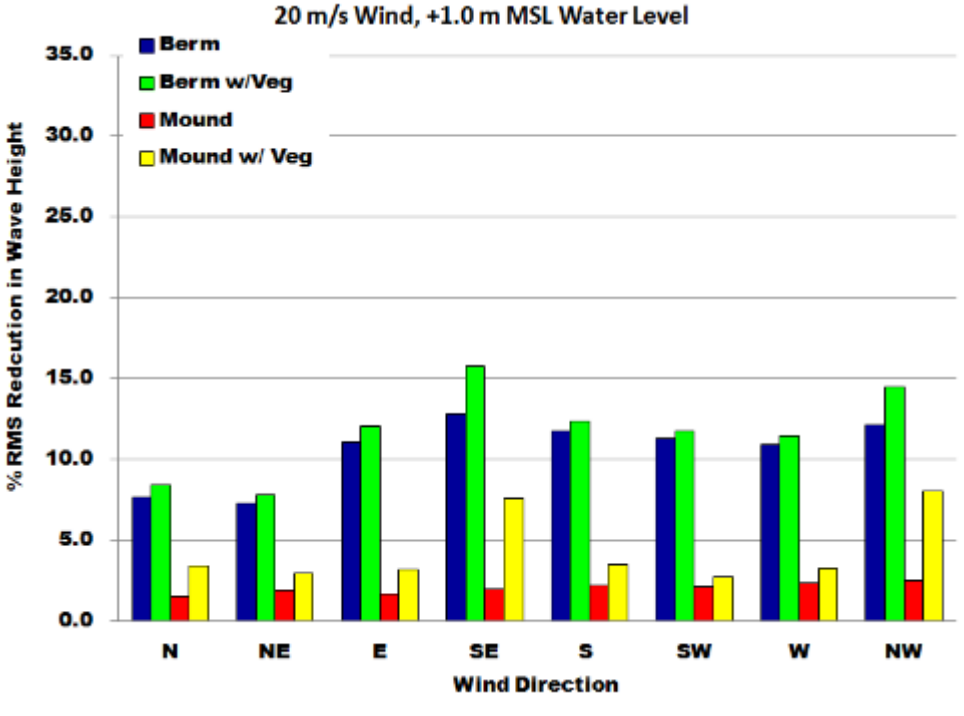





15 m/s Wind, +0.5 m MSL Water Level
Berm
Berm w/ Veg
Mound
Mound w/ Veg
% RMS Reduction in Wave Height
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
N
NE
E
SE
S
SW
W
NW
Wind Direciton


15 m/s Wind, +1.0 m MSL Water Level
Berm
Berm w/ Veg
Mound
Mound w/ Veg
% RMS Reduction in Wave Hieght
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


20 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


20 m/s Wind, +1.0 m MSL Water Level
Berm
Berm w/Veg
Mound
Mound w/ Veg
% RMS Redcution 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

Conclusions

- Lab experiments
  - Good correlation between C_D and Re for submerged vegetation
  - Higher C_D for emergent conditions
- Need to attempt larger validation for broader vegetation types and hydrodynamic conditions
  - Data exists, but need to systematically evaluate C_D
- Application of vegetation in a spectral wave model shows significant reductions in wave heights on project scales
  - Resiliency of the vegetation?
  - Does the benefit justify the cost compared to other methods of shore protection?
  - Will constructed wetlands persist? Climate change…
  - How to quantify physical, ecological and social benefits?