

Engineering With Nature: Coastal Protection

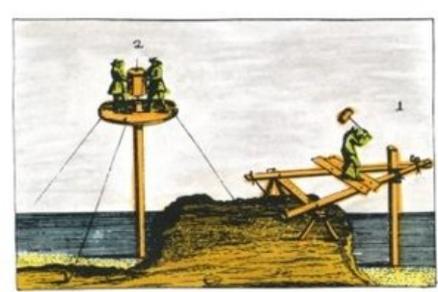
Jane McKee Smith

**Coastal and Hydraulic Laboratory
Engineering Research and
Development Center**



**US Army Corps of Engineers
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JOHN
McPHEE

The
Control
of
Nature

The Control of Nature

Attempts to control natural processes:

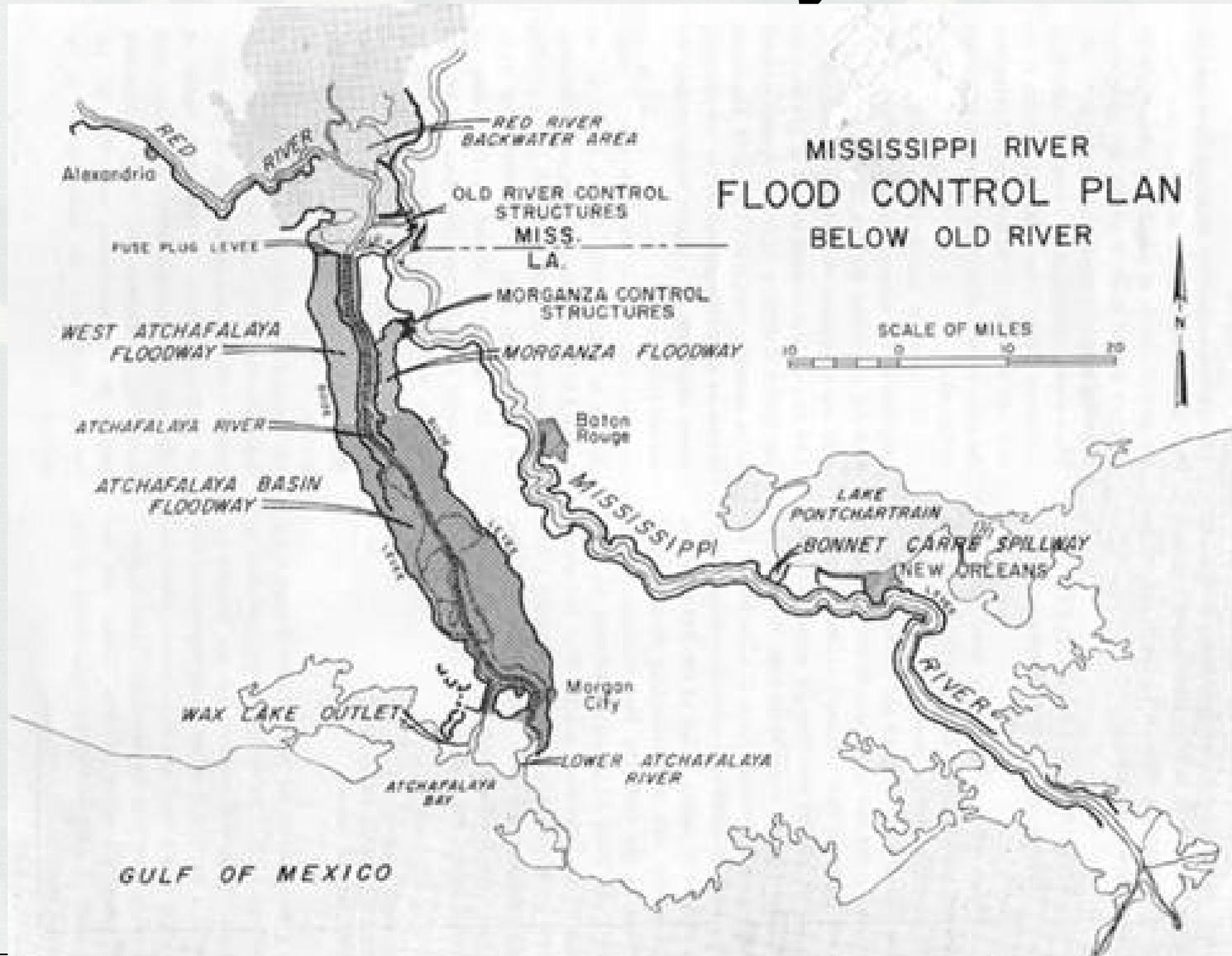
- Atchafalaya
- Cooling the Lava
- Los Angeles Against the Mountains





About 2,000 miles (3,219 km) across

Atchafalaya

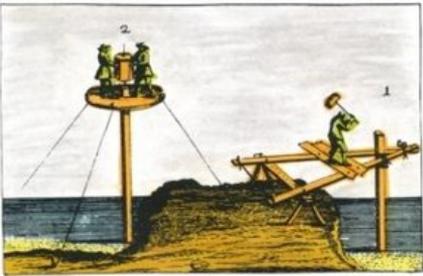




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The Control of Nature

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



JOHN
McPHEE

The
Control
of
Nature

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

In the end, nature will always win.

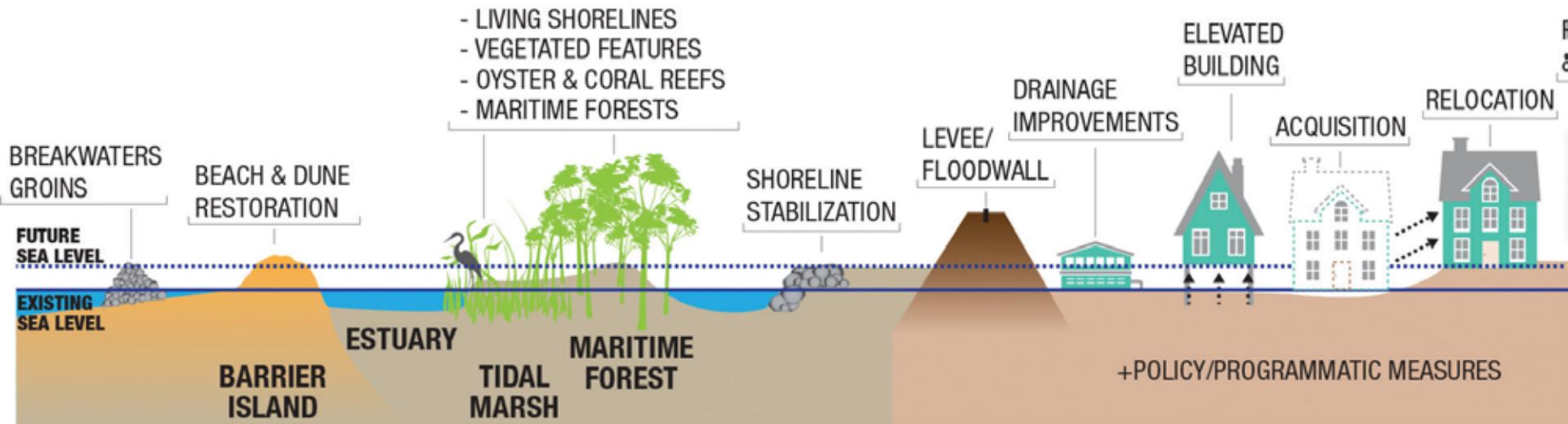


Engineering AGAINST Nature or Engineering WITH Nature?

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

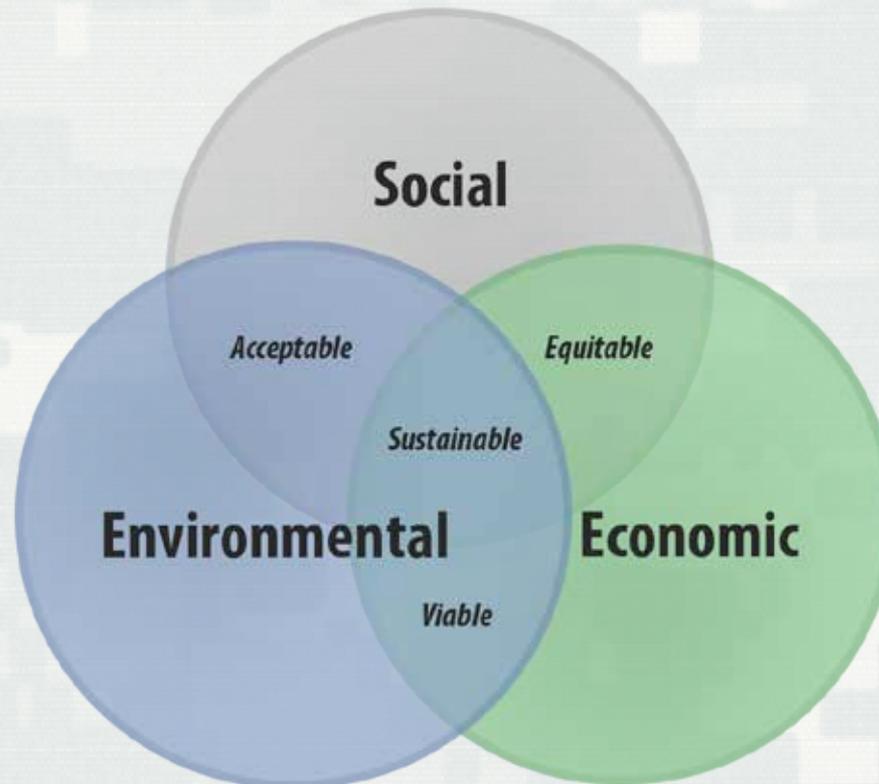






Engineering With Nature...

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



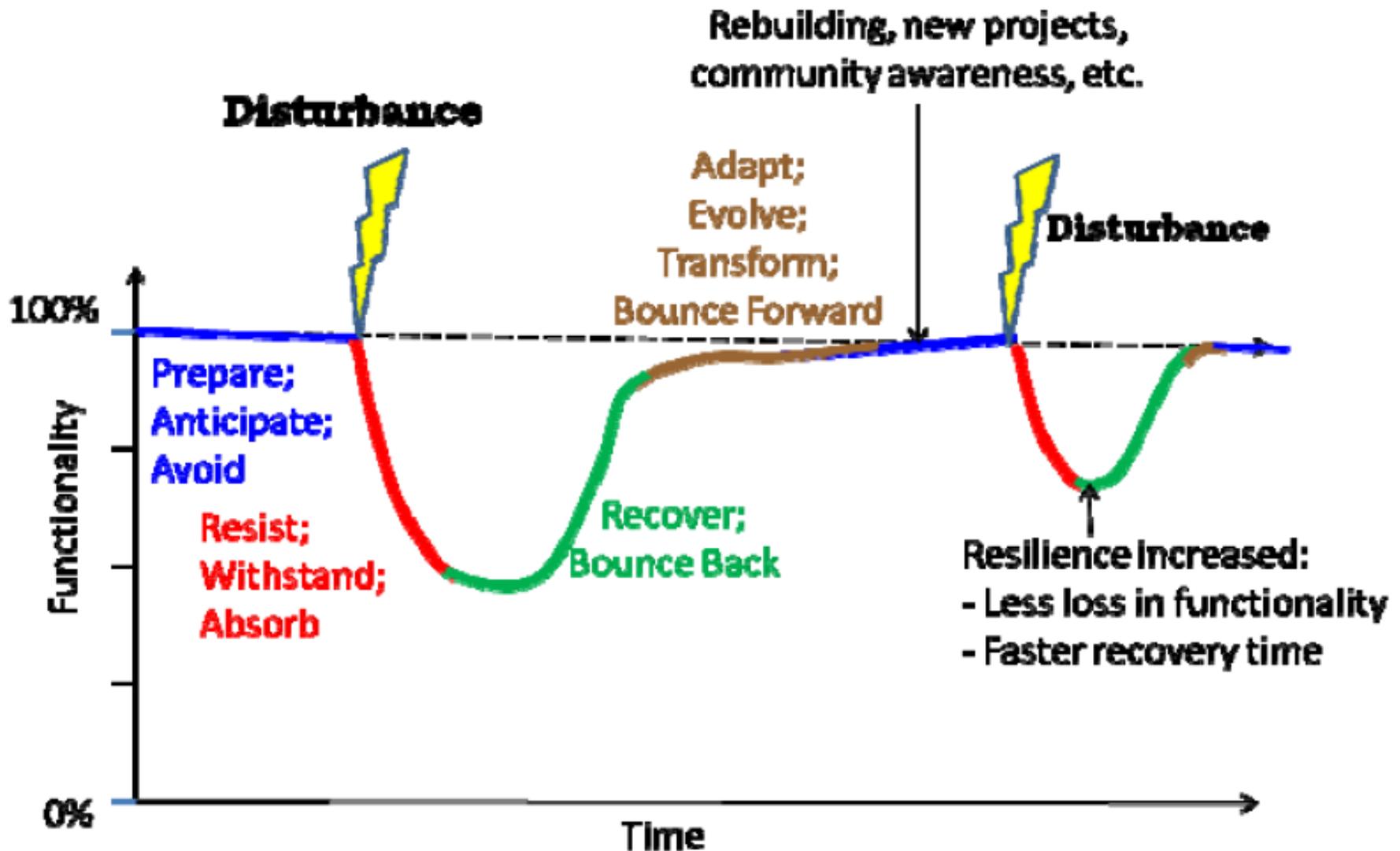
Engineering With Nature...

Key Elements:

- § Science and engineering that produces operational efficiencies
- § Using natural process to maximum benefit
- § Broaden and extend the benefits provided by projects
- § Science-based collaborative processes to organize and focus interests, stakeholders, and partners



Community Resilience



Wave Dissipation by Wetlands

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



Data Sets

§ Number of published datasets

Asano et al. (1992)
Augustin et al. (2009)
Bradley and Houser
(2009)
Cavallaro et al. (2010)
Cooper (2005)
Dubi (1995)
Dubi and Tørum (1996)
Fonseca et al. (1992)
Jadhav et al. (2013)
Knutson et al. (1982)
Koftis et al. (2013)

Lima et al. (2006)
Løvås and Tørum (2000)
Lövstedt and Larson (2010)
Lowe et al. (2007)
Manca et al. (2012)
Massel et al. (1999)
Mazda et al. (2006)
Möller et al. (1999)
Möller and Spencer (2002)
Mullarney and Henderson
(2010)

Paul and Amos (2011)
Quartel et al. (2007)
Sánchez-González et al.
(2011)
Stratigaki et al. (2011)
Tschirky et al. (2000)
Vo-Luong and Massel (2008)
Wayne (1976)
Wu et al. (2011)
Yoon et al. (2011)
Ysebaert et al. (2011)

§ But few for *Spartina alterniflora*, few emergent, and limited range of waves and water levels



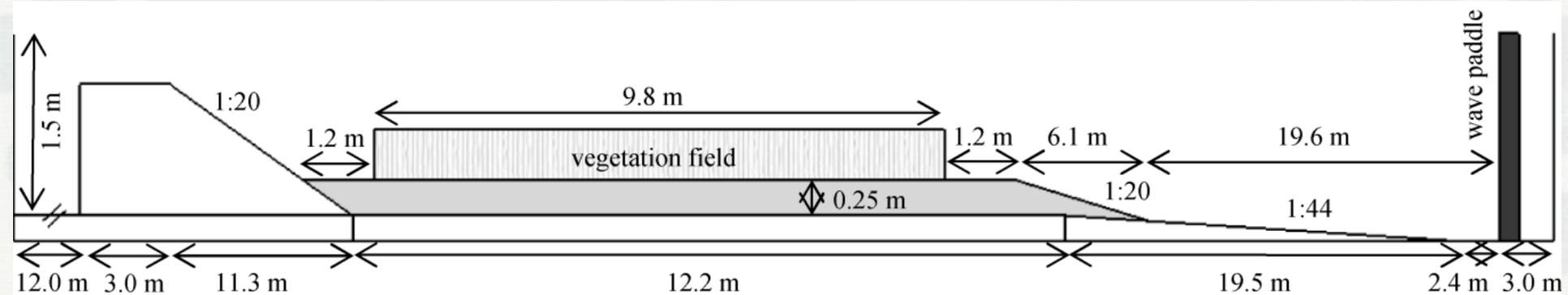
Laboratory Test

§ 1.5 m-wide wave flume

- ▶ 64.1 m long, 1.5 m deep
- ▶ equipped with a piston wavemaker

§ constructed a plywood false bottom

- ▶ 1:20 leading slope
- ▶ 9.8 m vegetation field



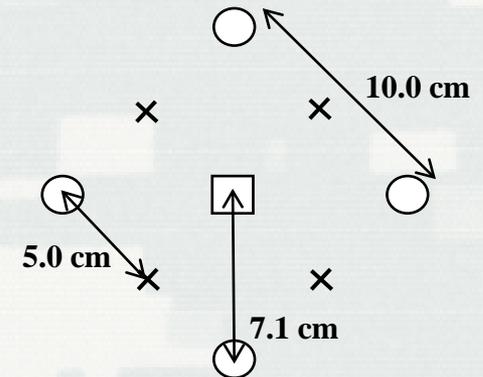
Idealized Vegetation

Three requirements

- ▶ similar geometry to a stem
- ▶ flexible under wave action
- ▶ remain upright to model emergent conditions

§ polyolefin tubing

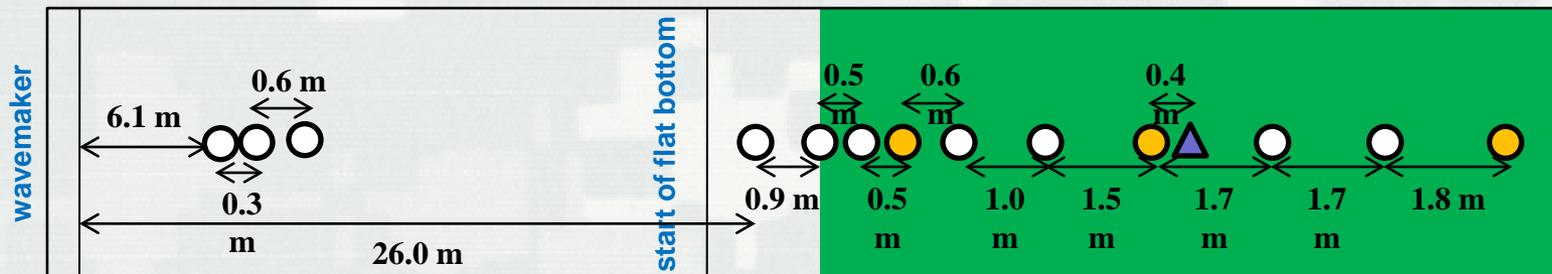
- ▶ benefits:
 - readily available
 - modulus of elasticity and diameter close to values reported in literature
- ▶ 6.4 mm diameter
- ▶ 41.5 cm stem length
- ▶ densities of 100, 200, and 400 stems/m²
 - correspond to element spacing of 10.0 cm, 7.1 cm, and 5.0 cm



Instrumentation



- § 13 single-wire capacitance wave gauges
 - ▶ offshore Goda array
 - ▶ 9 in vegetation field (changing spatial resolution)
 - ▶ sampling rate: 25 Hz
- § 3 ADVs paired with wave gauges
 - ▶ sampling rate: 25 Hz
- § 1 high-resolution ADCP
 - ▶ sampling rate: 4 Hz
- § waves generated for 8 minutes



Idealized Vegetation



200 stems/m²



400 stems/m²



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Water Levels and Waves

§ Three water depths (h): 30.5 cm, 45.7 cm, 53.3 cm

- ▶ correspond to l_s/h ratios of 1.0 (emergent), 0.91, 0.78

§ Irregular waves

- ▶ $T_p \sim 1.25$ s to 2.25 s
- ▶ $H_{m0} \sim$ ranging from 5.0 cm to 19.2 cm

§ Double peak spectra with $T = 1.25$ s and 2.0 s



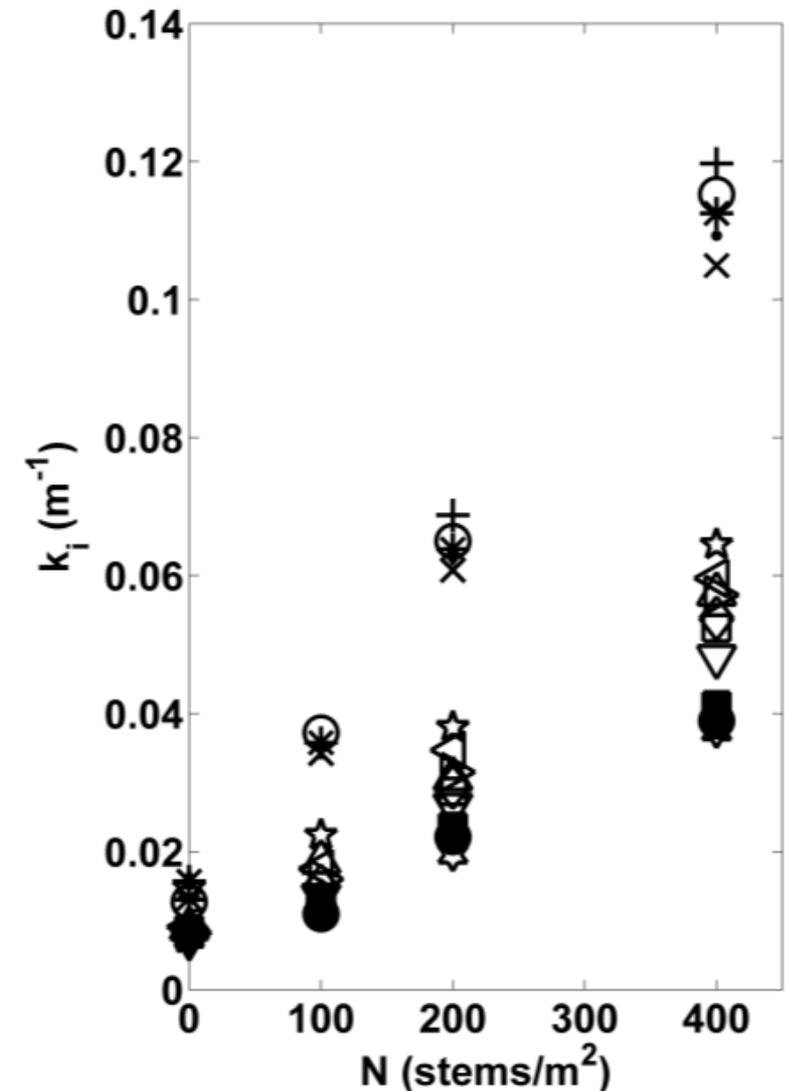


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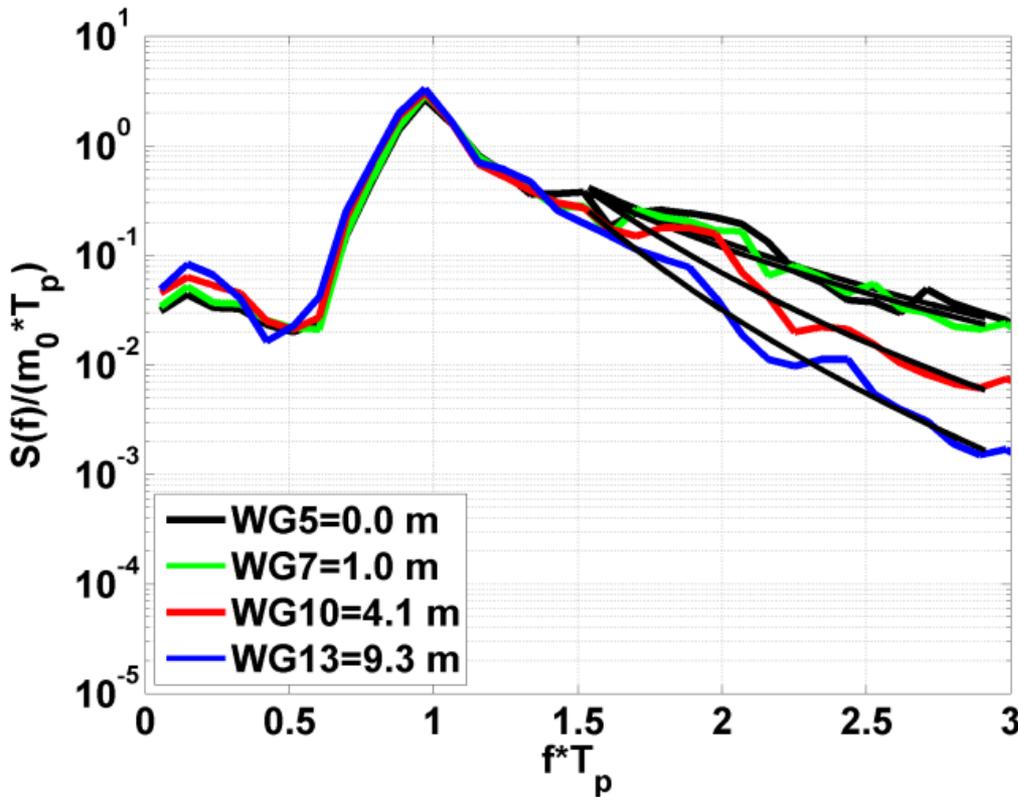
Trends in Wave Attenuation

§ Wave attenuation was found to:

- ▶ increase with stem density
- ▶ increase with submergence ratio
- ▶ slightly increase with incident wave height
- ▶ marginally decrease with longer waves during emergent conditions



Equilibrium Range

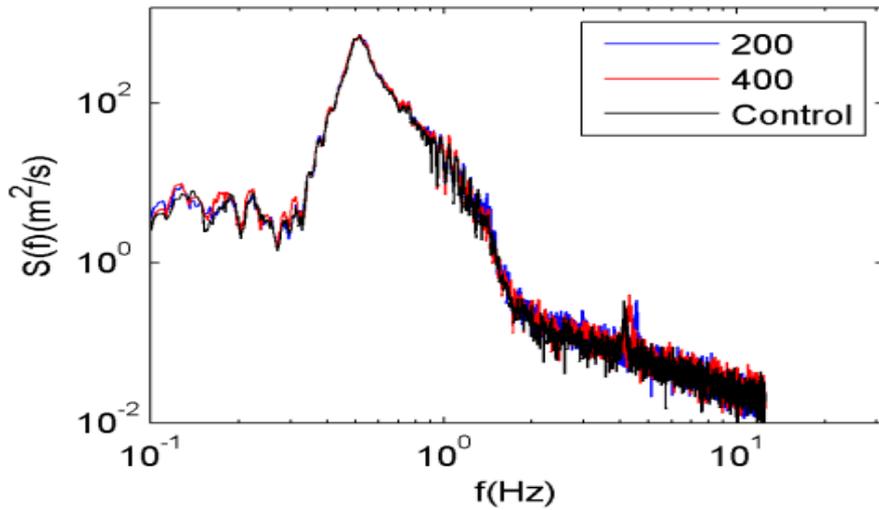


- § Deviations of slope of spectral tail
- § $1.5f_p$ to $3f_p$
- § Preferential dissipation of higher frequencies
- § dissipation of higher frequencies dependent on stem density and submergence ratio

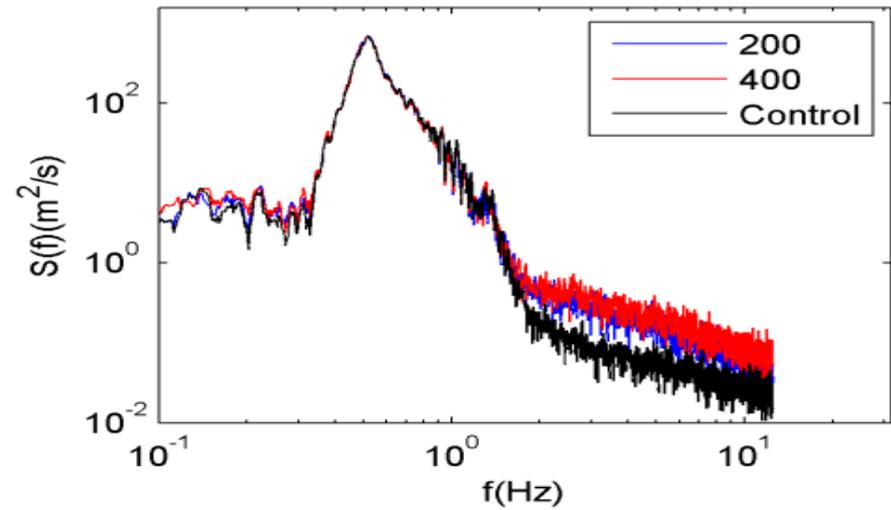


Velocity Spectra

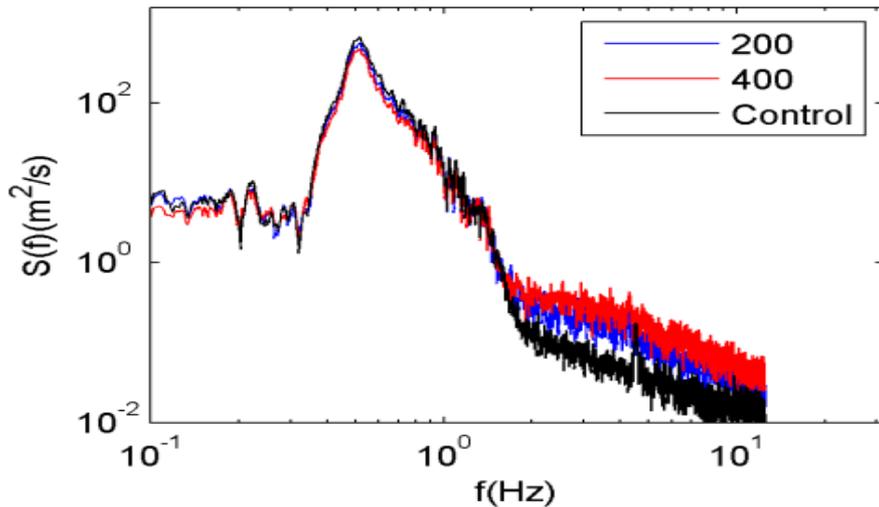
x = 0.0 m



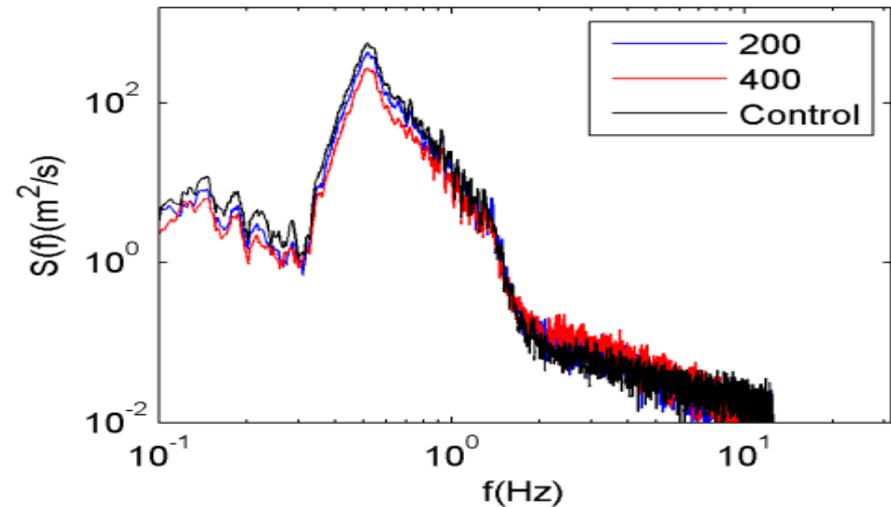
x = 1.0 m



x = 4.1 m



x = 9.3 m



Estimate C_D

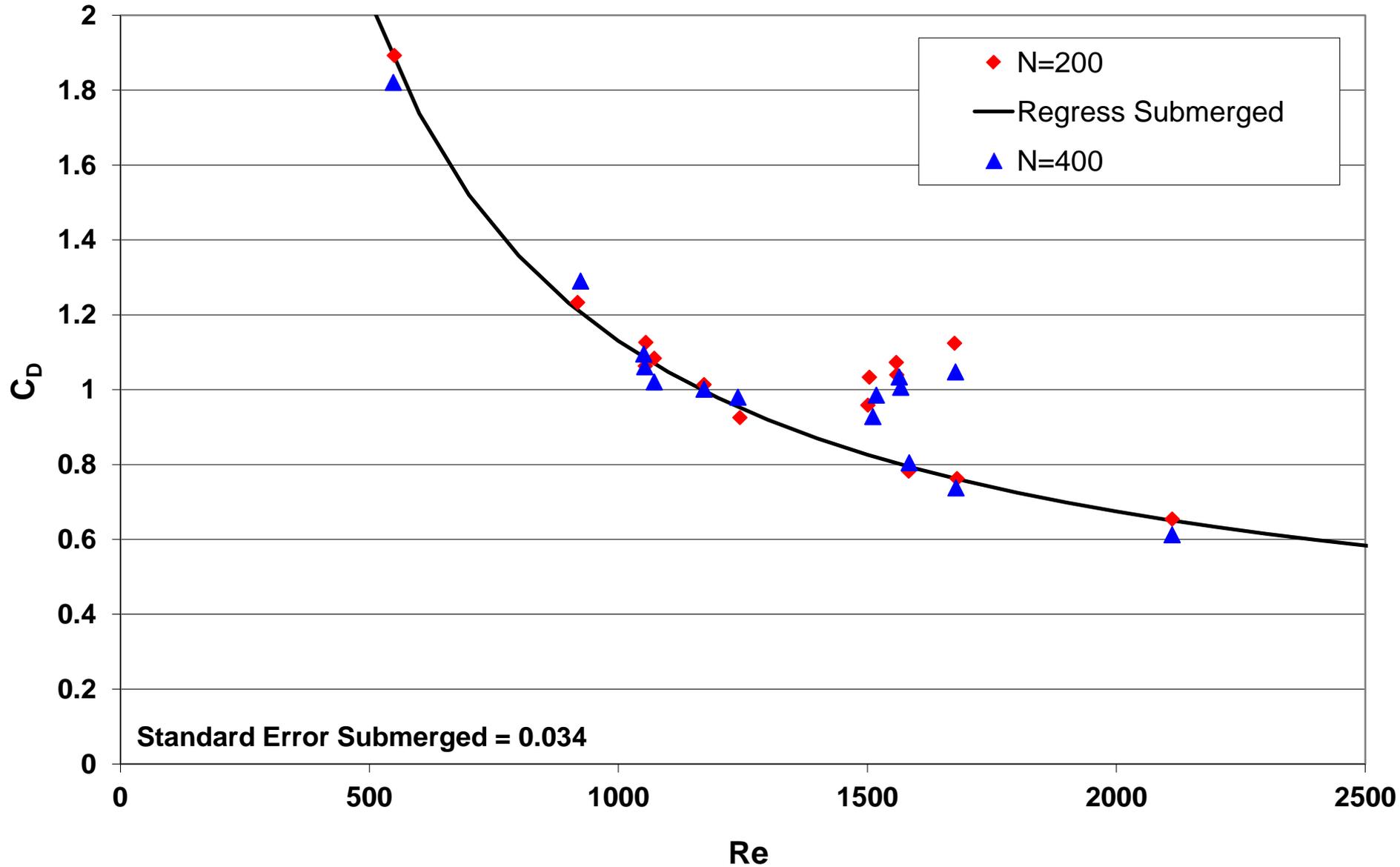
§ Following Mendez and Losada (2004),
Dalrymple et al. (1984)

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

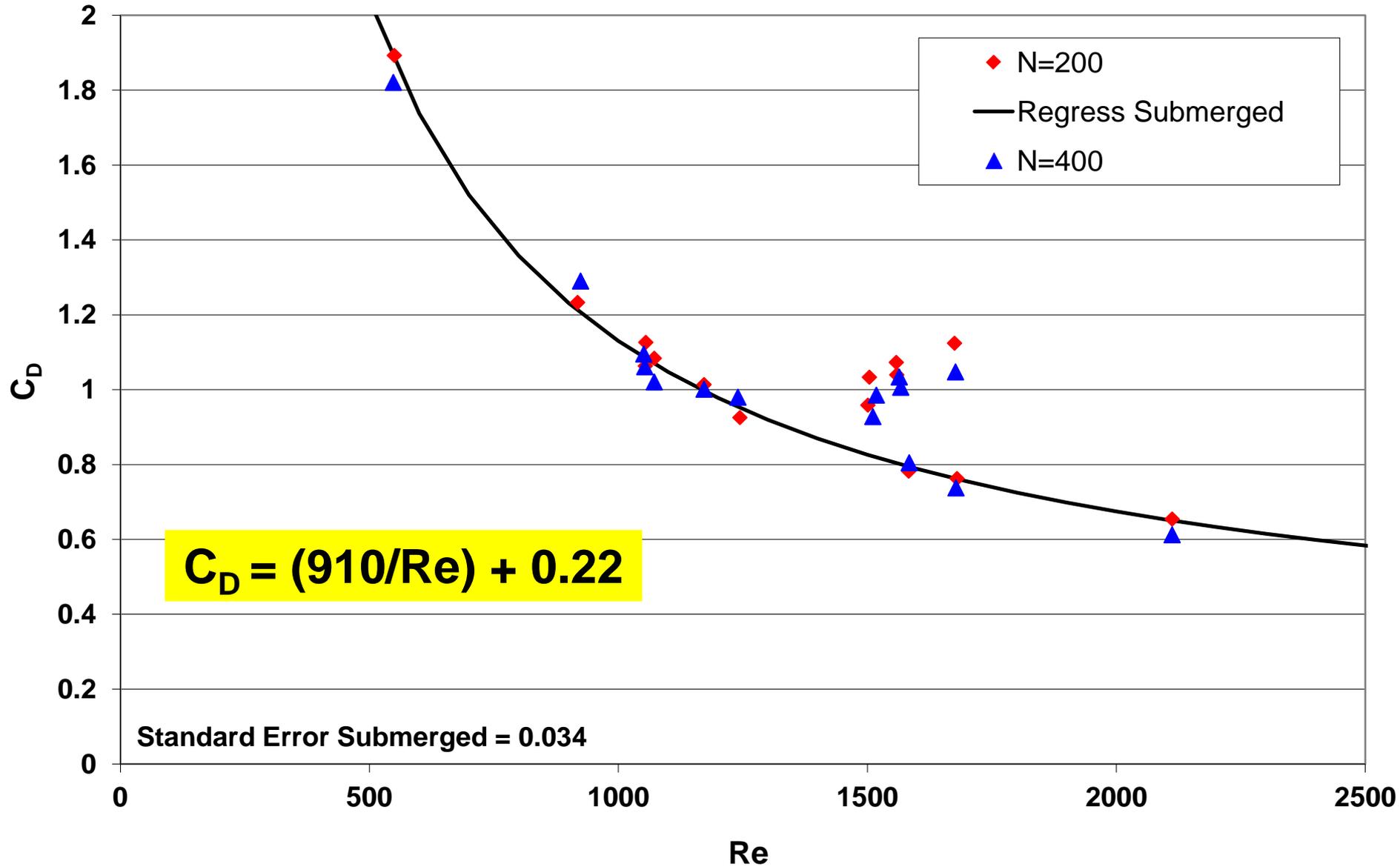
Background tank friction was removed



Estimate C_D

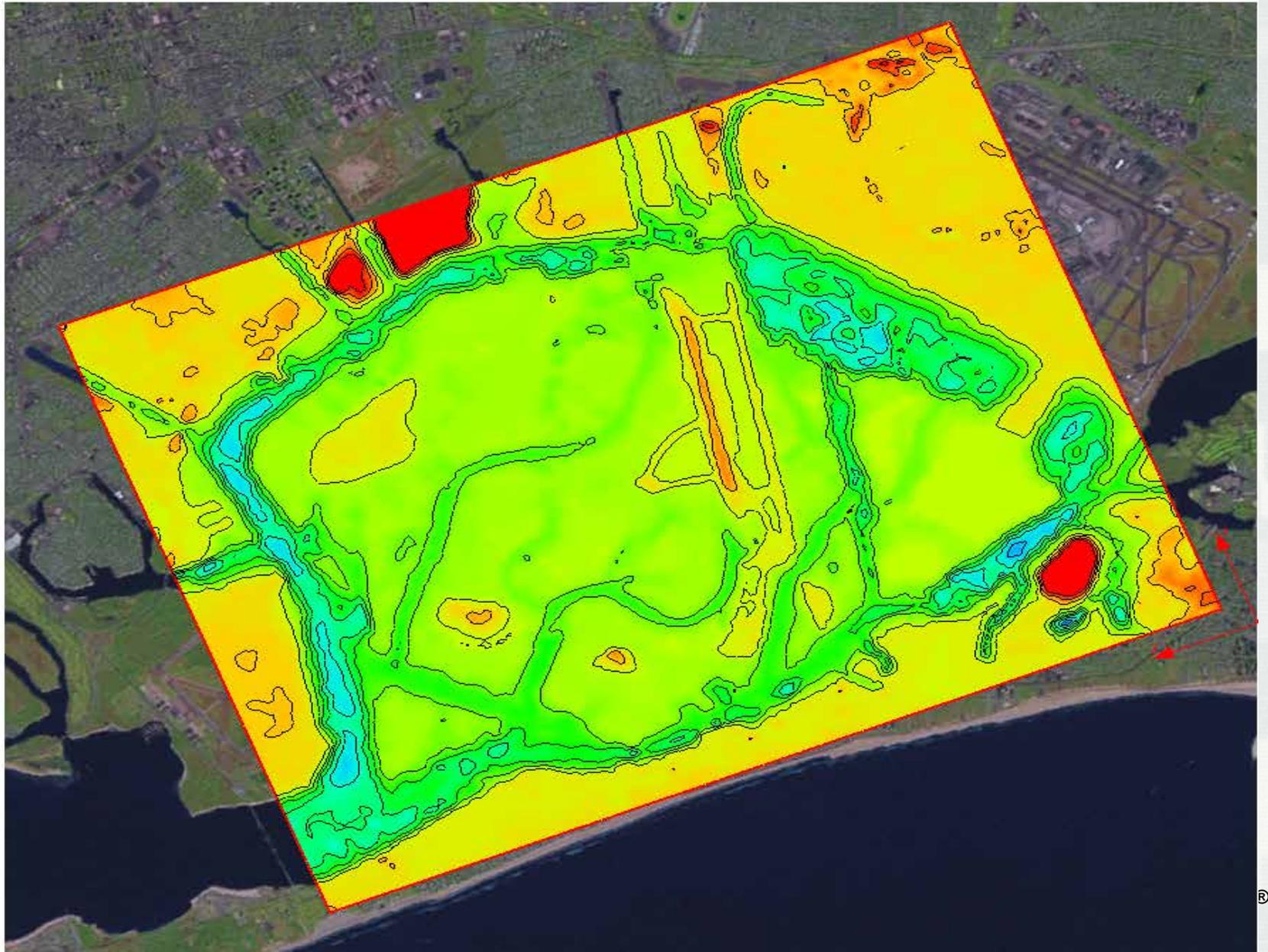
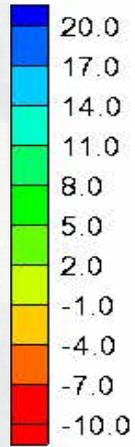


Estimate C_D



Vegetation Implemented STWAVE

Depth [m]



Simulations

§ Three wind & water level combinations

- ▶ 18.5 m/s winds, 1.3 m WL
- ▶ 22.1 m/s winds, 2.0 m WL
- ▶ 26.0 m/s winds, 2.9 m WL

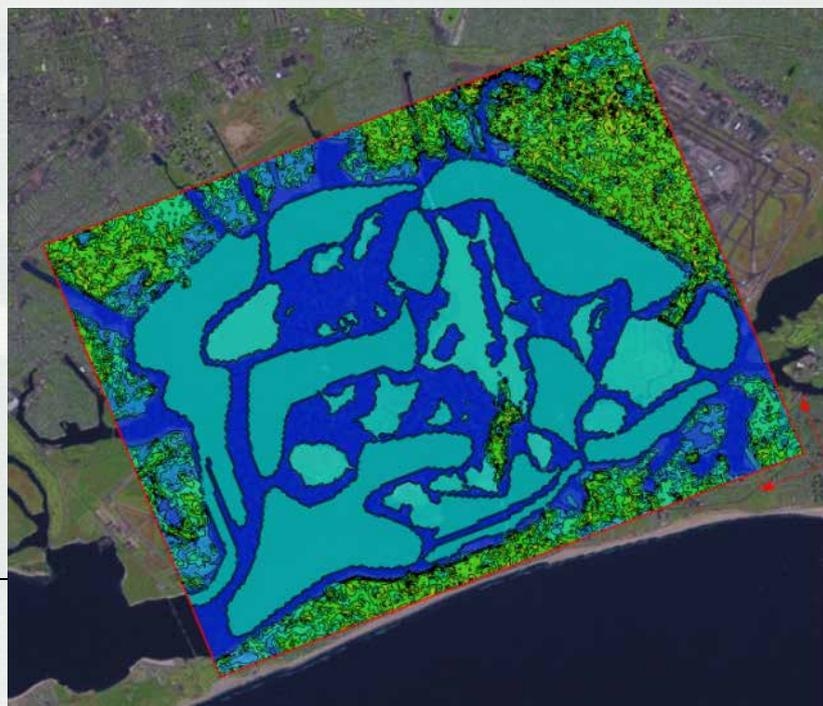
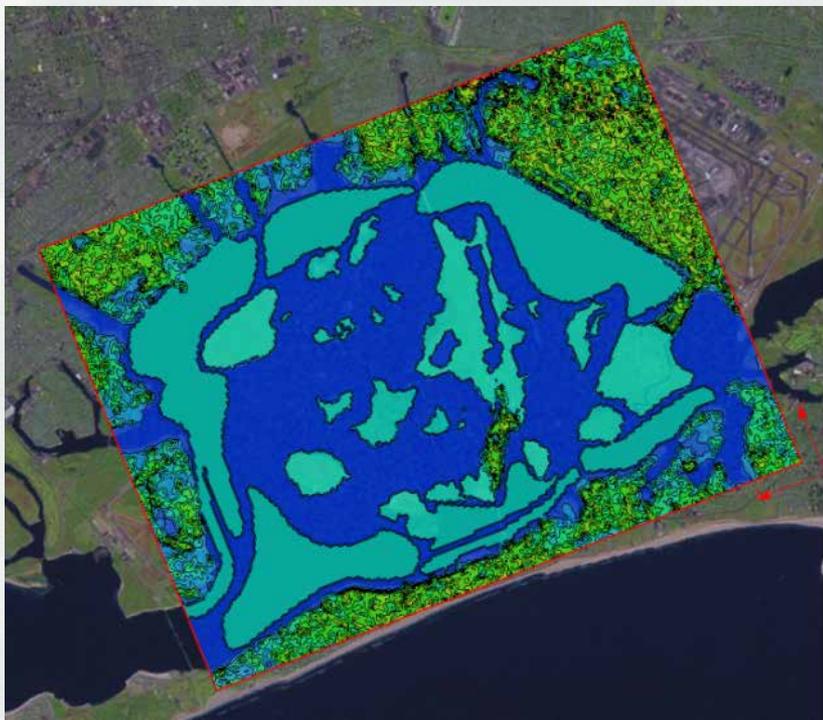
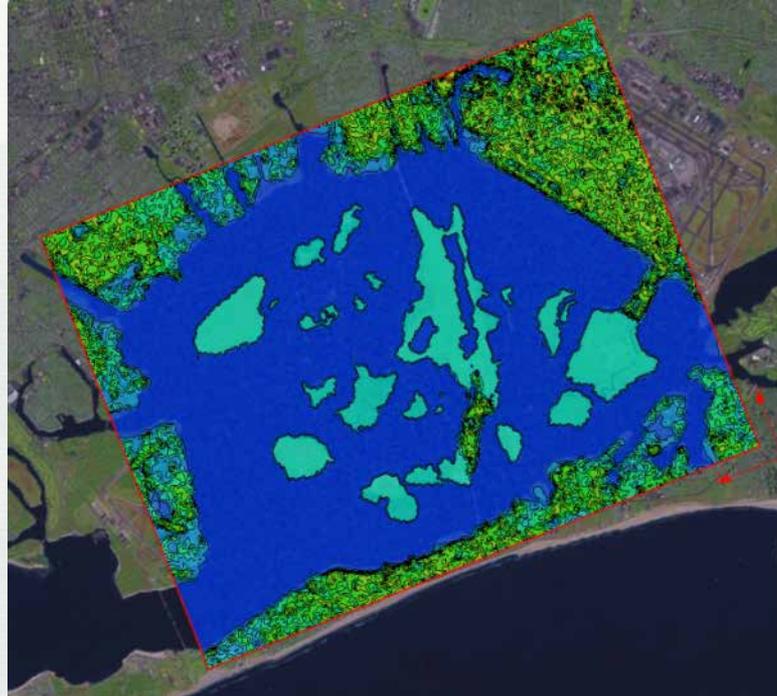
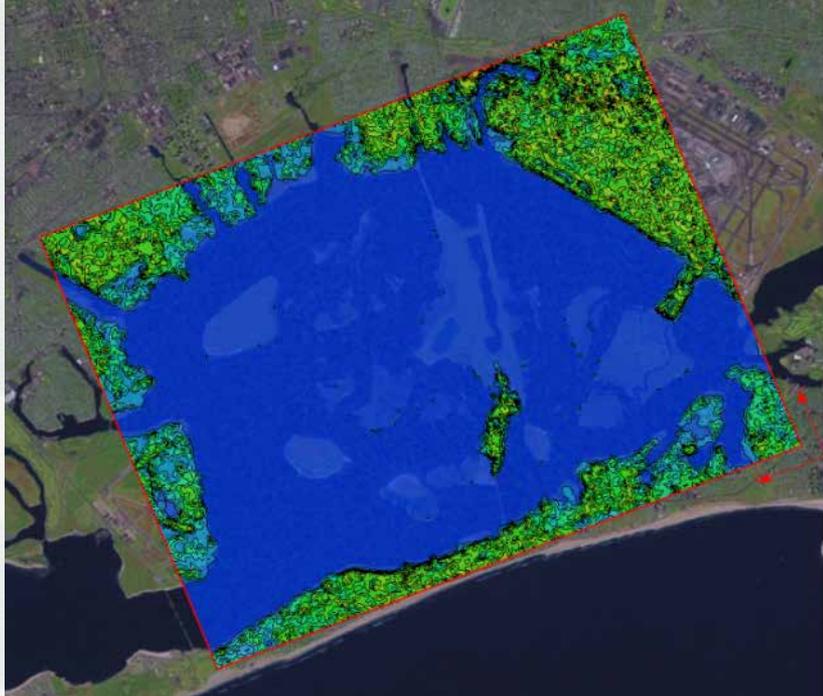
§ Four vegetation states

- ▶ No vegetation, existing bathymetry
- ▶ Existing vegetation and bathymetry
- ▶ Moderate vegetation w/ modified bathymetry
- ▶ Extensive vegetation w/ modified bathymetry

§ *Spartina alterniflora* in the low marsh, *Spartina patens* in the high marsh, & *Phragmites*

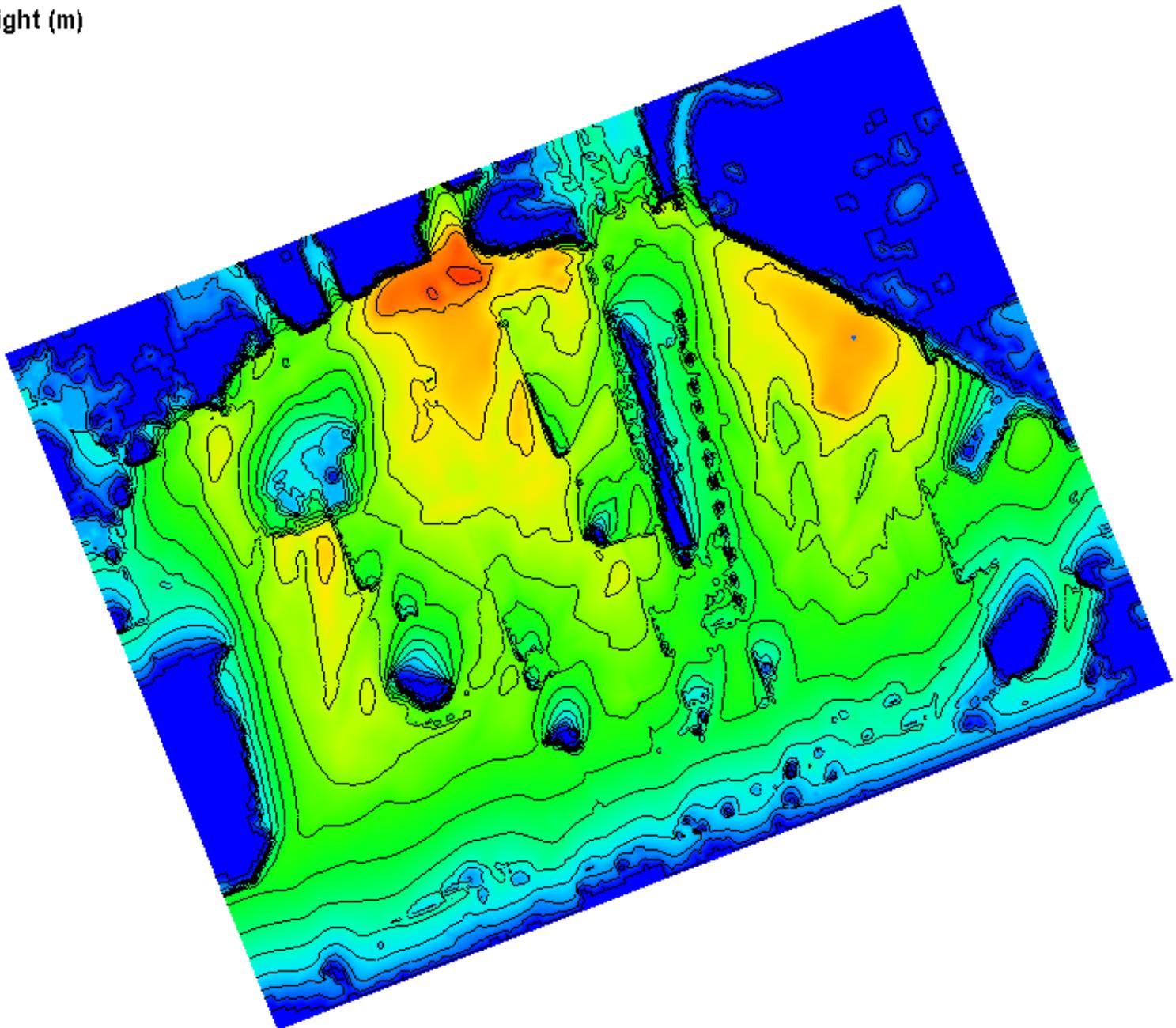
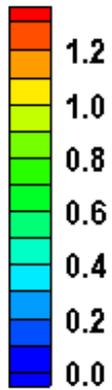
§ $C_D \sim 0.35$, $N = 400$, $b_v = 0.6$ cm





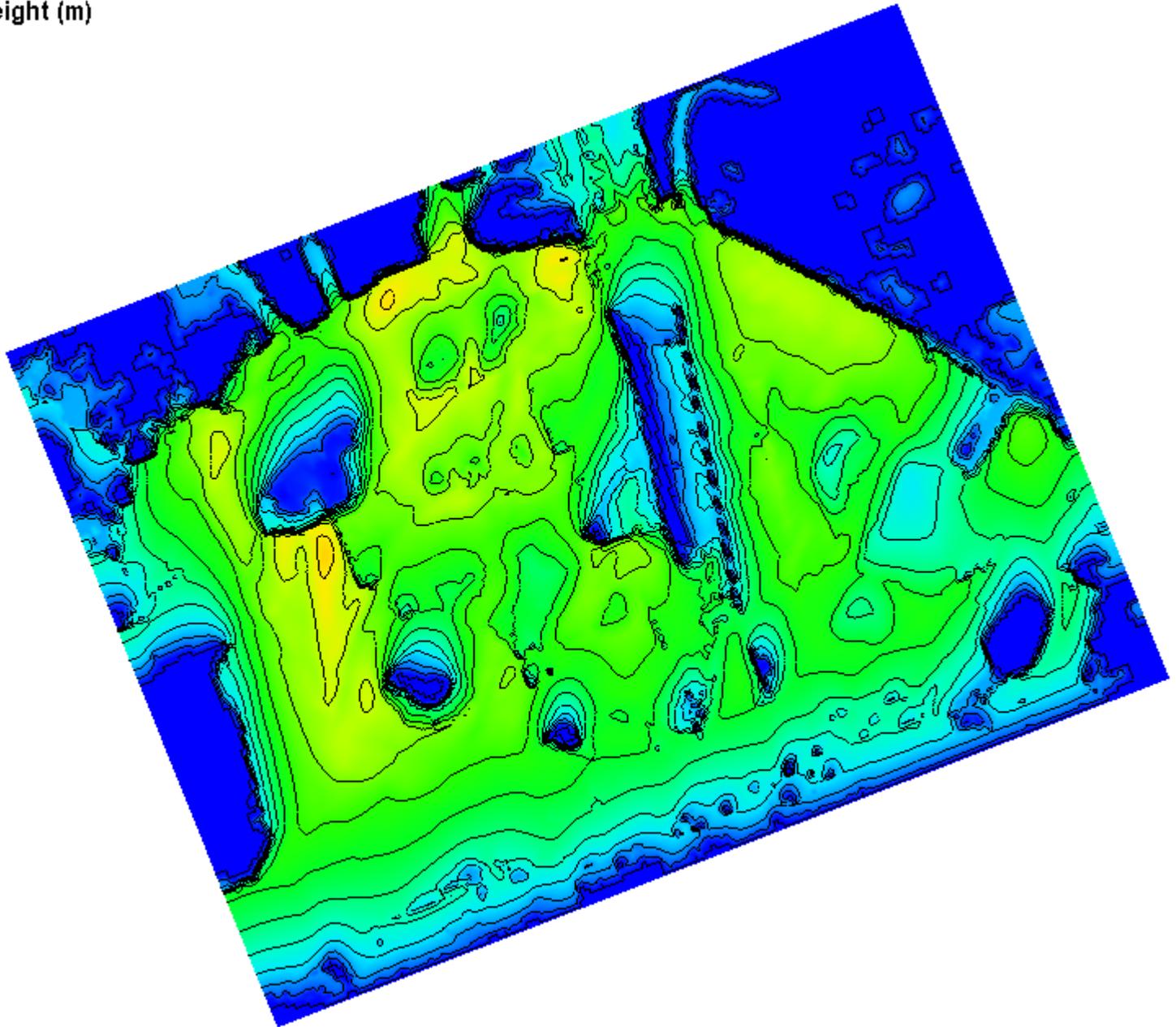
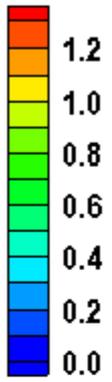
26 m/s winds, 2.9 m WL, no vegetation

Wave Height (m)



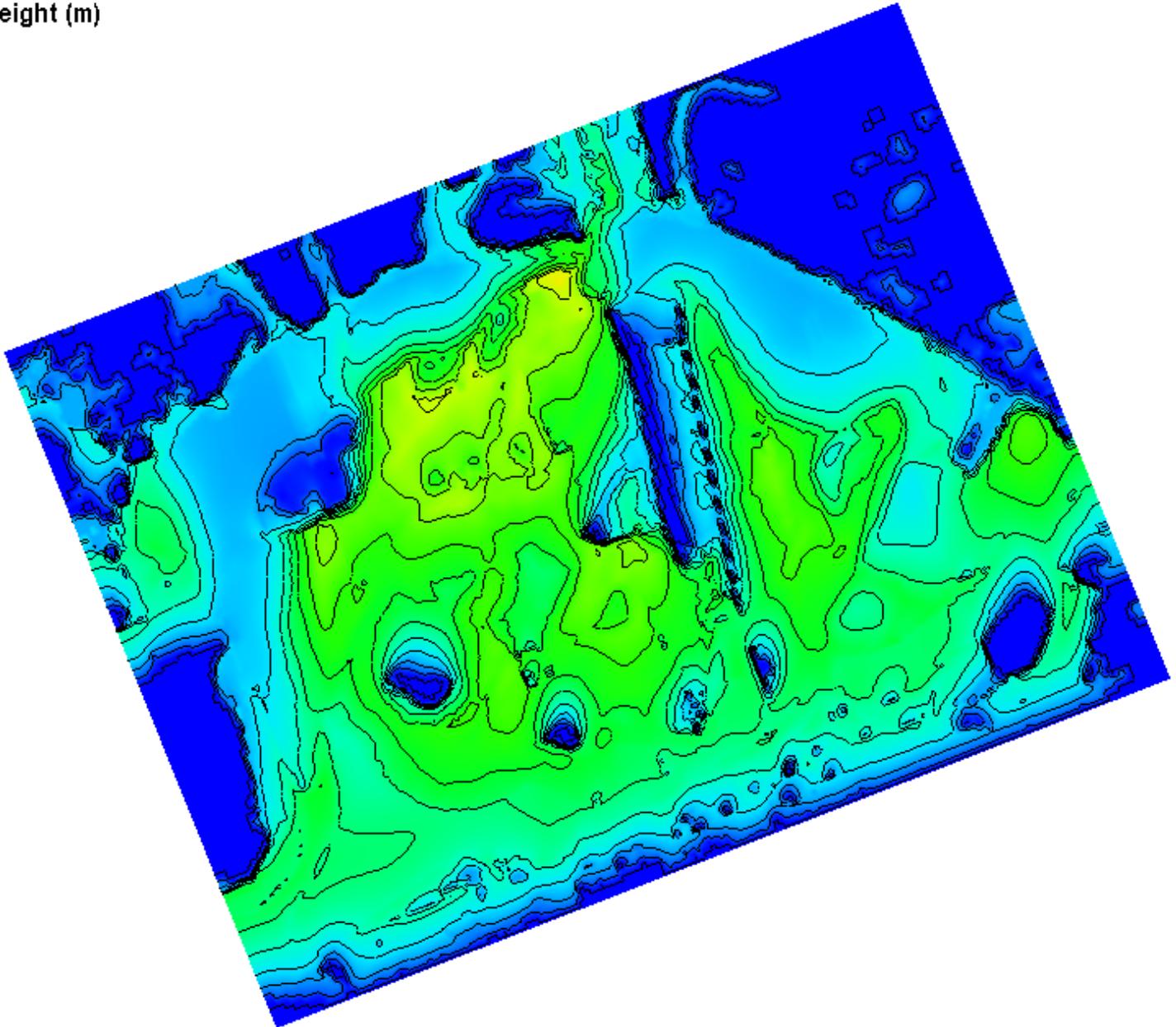
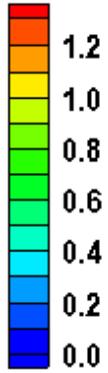
26 m/s winds, 2.9 m WL, existing vegetation

Wave Height (m)



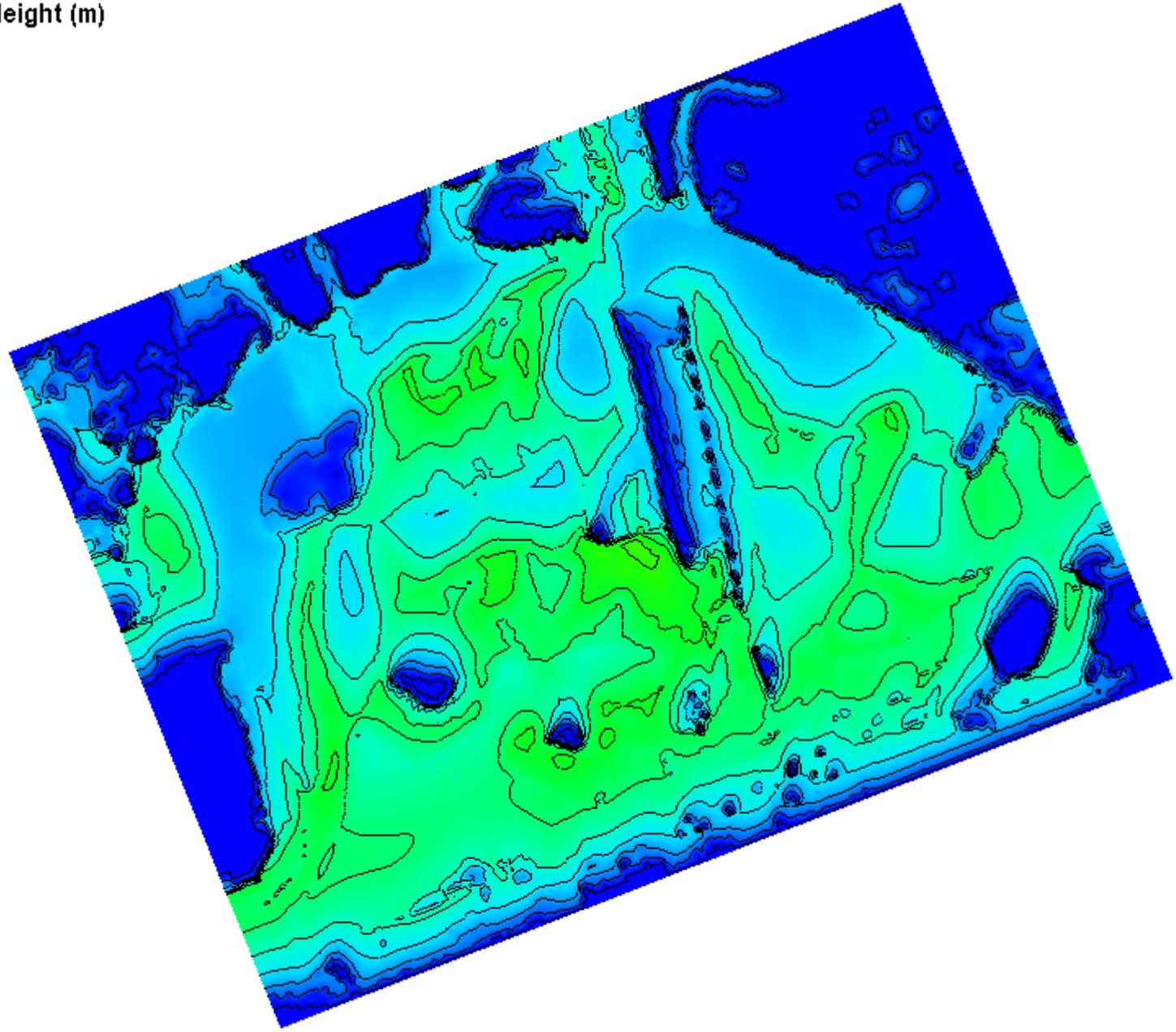
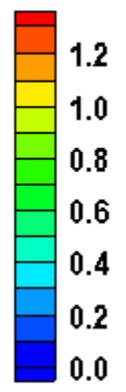
26 m/s winds, 2.9 m WL, moderate vegetation

Wave Height (m)



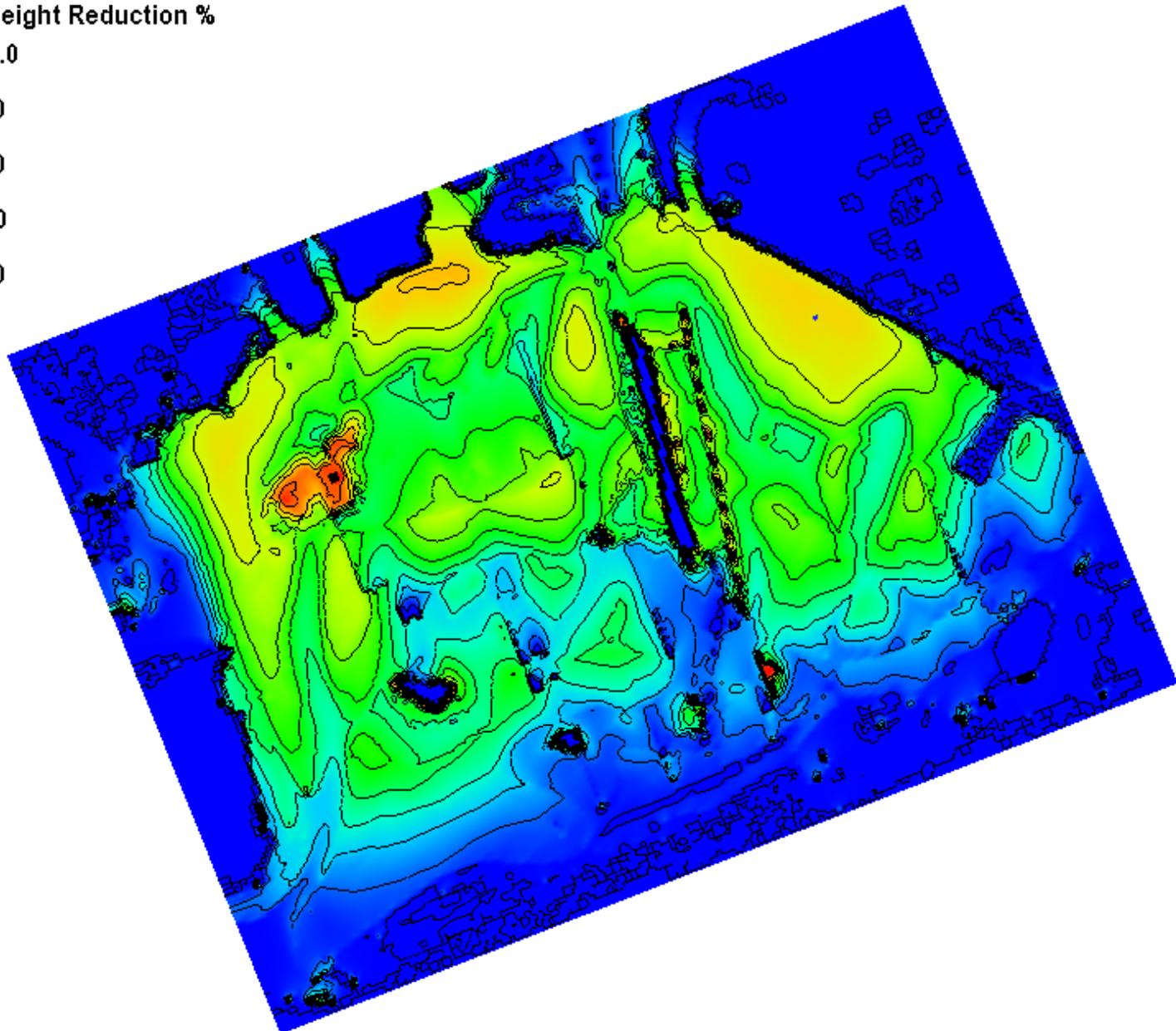
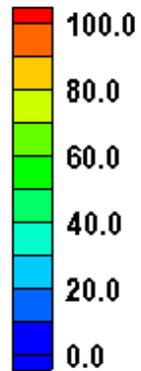
26 m/s winds, 2.9 m WL, extensive vegetation

Wave Height (m)



percent reduction in wave height from bare to extensive vegetation coverage

Wave Height Reduction %



Results

§ Lab data

- ▶ Shows expected trends with vegetation parameters
- ▶ 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 no one has tried to systematically to evaluate C_D

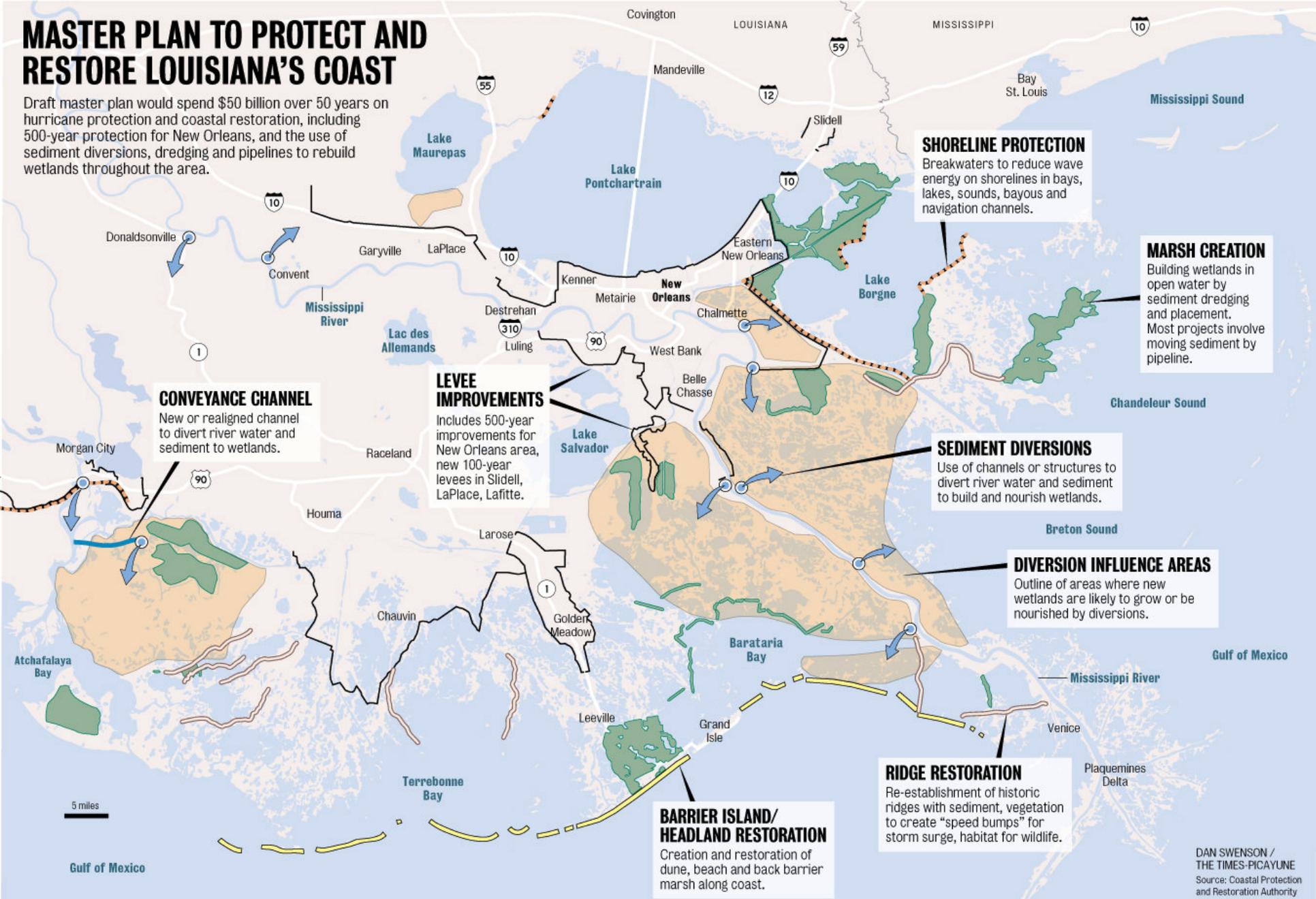
§ Application of vegetation in a spectral wave model shows very significant reductions in wave heights on project scales

- ▶ Resiliency of the vegetation?
- ▶ Does the benefit justify the cost compared to other methods of shore protection?
- ▶ Will constructed wetlands persist?



MASTER PLAN TO PROTECT AND RESTORE LOUISIANA'S COAST

Draft master plan would spend \$50 billion over 50 years on hurricane protection and coastal restoration, including 500-year protection for New Orleans, and the use of sediment diversions, dredging and pipelines to rebuild wetlands throughout the area.



SHORELINE PROTECTION
Breakwaters to reduce wave energy on shorelines in bays, lakes, sounds, bayous and navigation channels.

MARSH CREATION
Building wetlands in open water by sediment dredging and placement. Most projects involve moving sediment by pipeline.

CONVEYANCE CHANNEL
New or realigned channel to divert river water and sediment to wetlands.

LEVEE IMPROVEMENTS
Includes 500-year improvements for New Orleans area, new 100-year levees in Slidell, LaPlace, Lafayette.

SEDIMENT DIVERSIONS
Use of channels or structures to divert river water and sediment to build and nourish wetlands.

DIVERSION INFLUENCE AREAS
Outline of areas where new wetlands are likely to grow or be nourished by diversions.

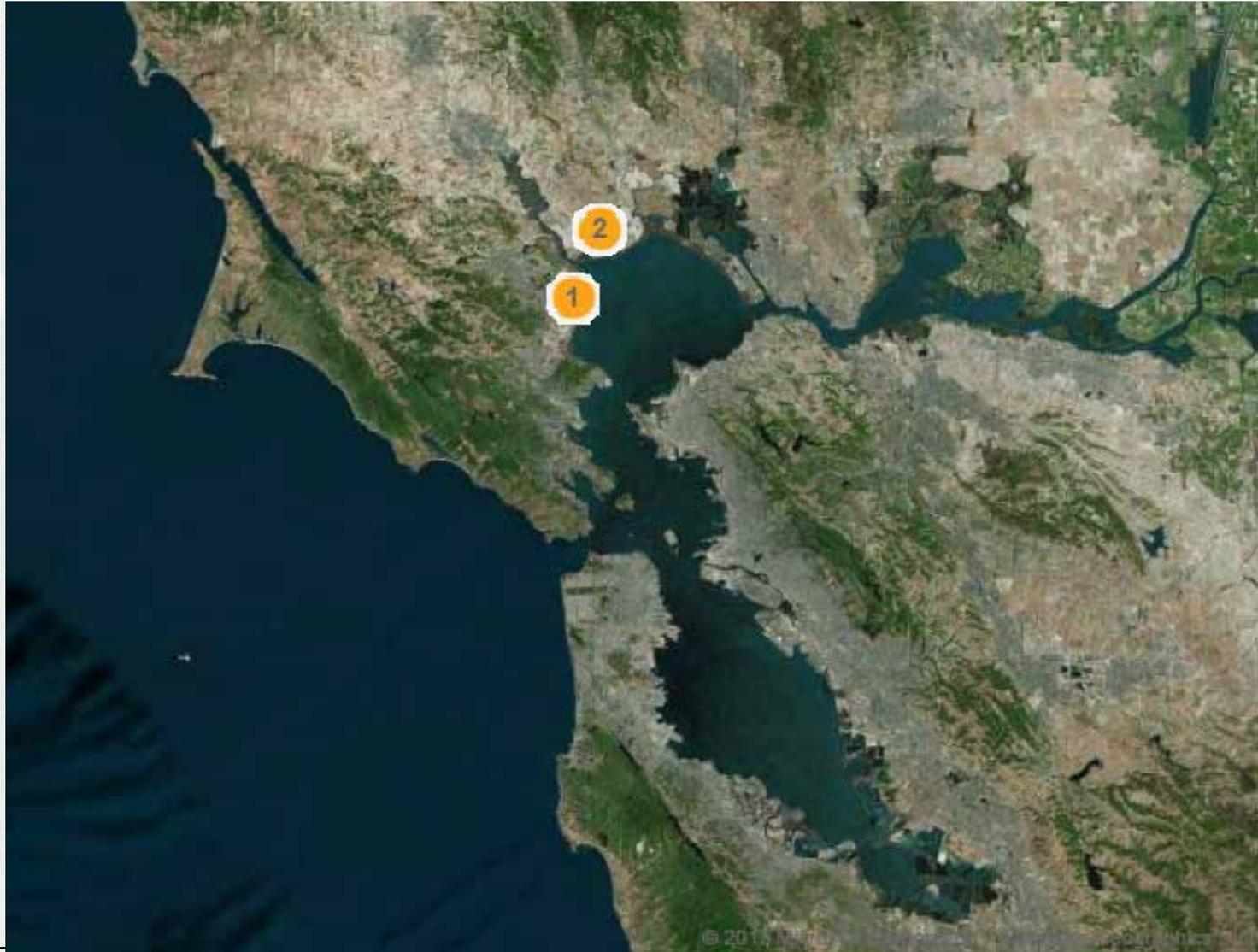
RIDGE RESTORATION
Re-establishment of historic ridges with sediment, vegetation to create "speed bumps" for storm surge, habitat for wildlife.

BARRIER ISLAND/ HEADLAND RESTORATION
Creation and restoration of dune, beach and back barrier marsh along coast.

KEY: — Levees ↻ Diversions ◻ Diversion influence areas ◻ Marsh creation - - - Shoreline protection - - - Ridge restoration - - - Barrier island restoration - - - Conveyance channel

DAN SWENSON / THE TIMES-PICAYUNE
Source: Coastal Protection and Restoration Authority

San Francisco Bay



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Engineer Research & Development Center

§ In Vicksburg, Mississippi

- ▶ Coastal and Hydraulics Laboratory
- ▶ Environmental Laboratory
- ▶ Geotechnical and Structures Laboratory
- ▶ Information Technology Laboratory



§ In Alexandria, Virginia: Geospatial Research Laboratory

§ In Champaign, Illinois: Construction Engineering Research Laboratory

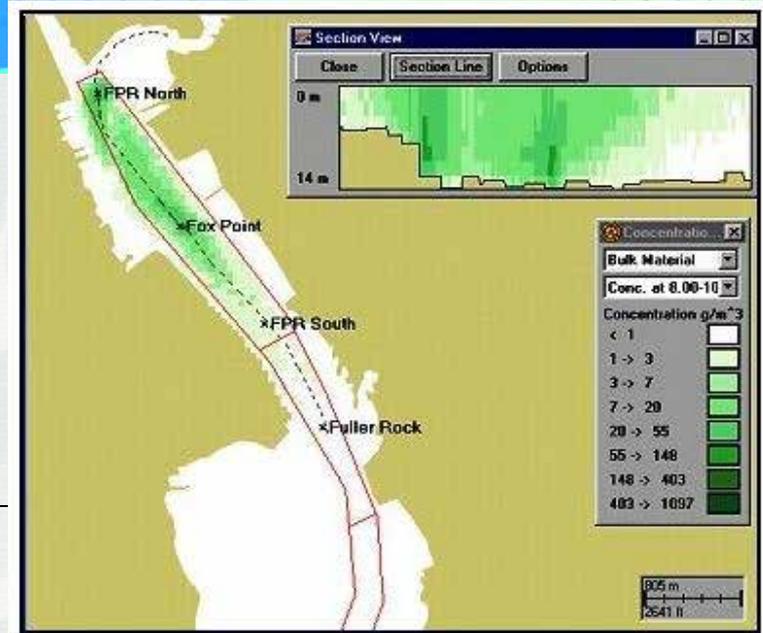
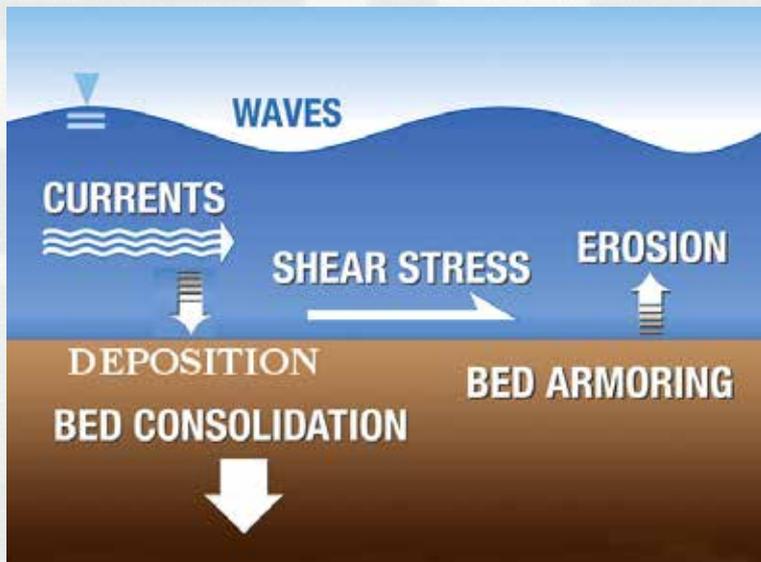
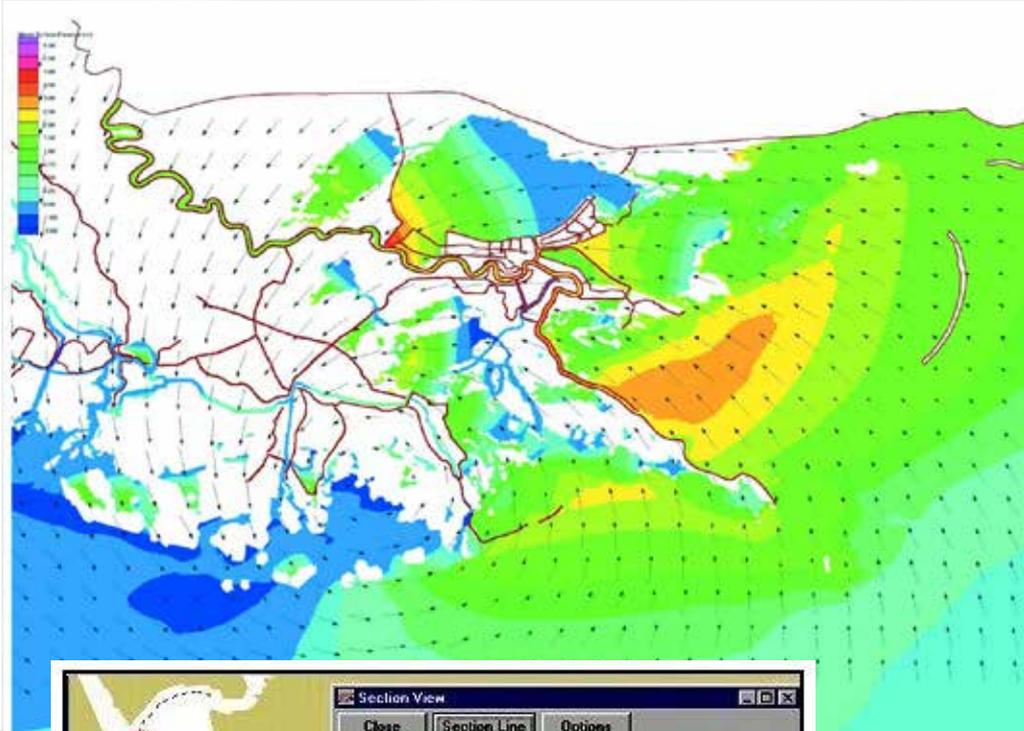
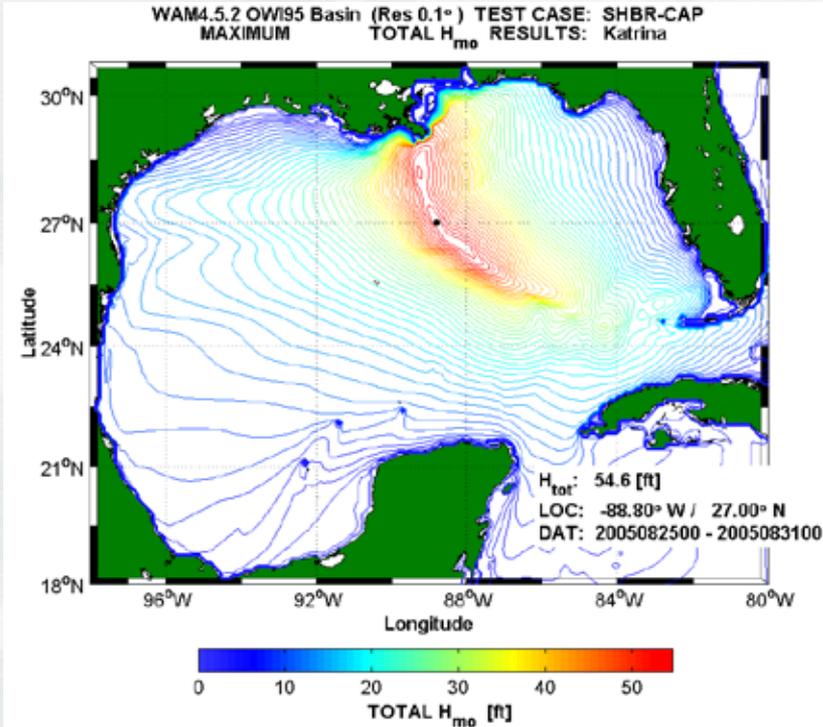
§ In Hanover, New Hampshire: Cold Regions Research and Engineering Laboratory



Coastal Processes at CHL



Coastal Processes



Coastal Processes

