Engineering With Nature: Coastal Protection

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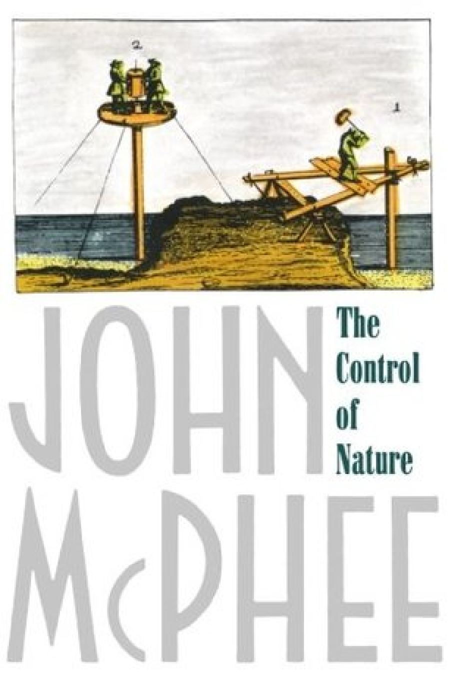
Coastal and Hydraulic Laboratory
Engineering Research and
Development Center

US Army Corps of Engineers
BUILDING STRONG®



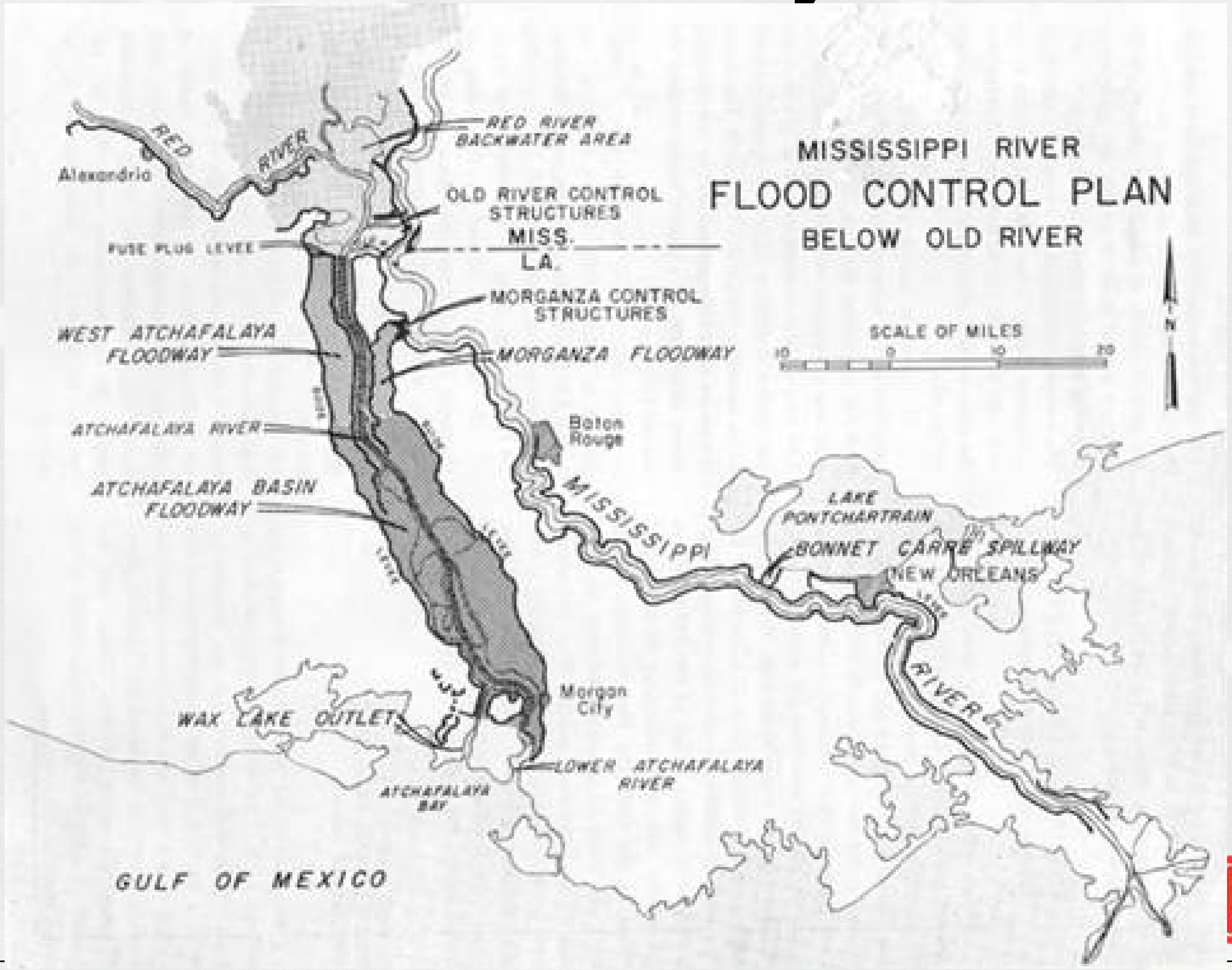
The Control of Nature

Attempts to control natural processes:

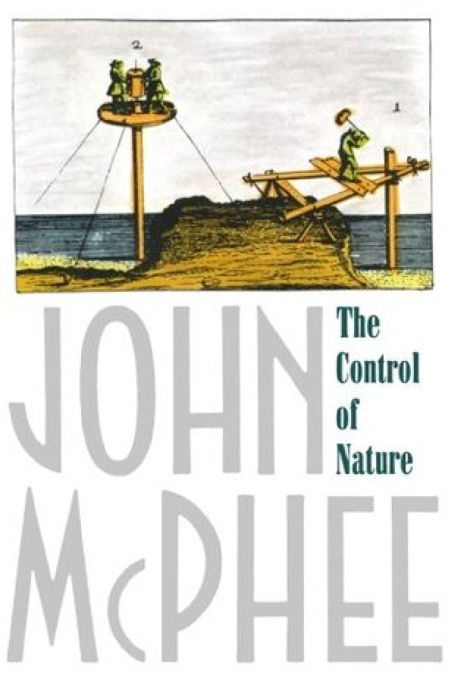
- Atchafalaya
- Cooling the Lava
- Los Angeles Against the Mountains

ALBERTA
SASKATCHEWAN
MONTANA
NORTH DAKOTA
MINNESOTA
SOUTH DAKOTA
WYOMING
NEBRASKA
IOWA
WISCONSIN
MICHIGAN
NEW YORK
PENNSYLVANIA
OHIO
INDIANA
ILLINOIS
WEST VIRGINIA
VIRGINIA
COLORADO
KANSAS
MISSOURI
KENTUCKY
OKLAHOMA
ARKANSAS
TENNESSEE
NORTH CAROLINA
SOUTH CAROLINA
NEW MEXICO
TEXAS
ALABAMA
GEORGIA
MISSISSIPPI
LOUISIANA
Milk
Missouri
Yellowstone
Little Missouri
Grand
Tongue
Bighorn
Wind
Cheyenne
Niobrara
James
Big Sioux
Minnesota
Mississippi
Wisconsin
Des Moines
Iowa
North Platte
South Platte
Platte
Loup
Republican
Smoky Hill
Kansas
Osage
Arkansas
Neosho
Canadian
Red
White
Black
Ouachita
Yazoo
Atchafalaya
Illinois
Kaskaskia
Kankakee
Wabash
Ohio
Scioto
Green
Kentucky
Kanawha
Allegheny
Monongahela
Holston
New
Cumberland
Tennessee
Billings
Minneapolis
Omaha
Lincoln
Des Moines
Chicago
Peoria
Springfield
Denver
Kansas City
Topeka
St. Louis
Indianapolis
Columbus
Cincinnati
Pittsburgh
Evansville
Lexington
Tulsa
Oklahoma City
Memphis
Baton Rouge
New Orleans
About 2,000 miles (3,219 km) across

Atchafalaya




Old River Control Structure



The Control of Nature

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

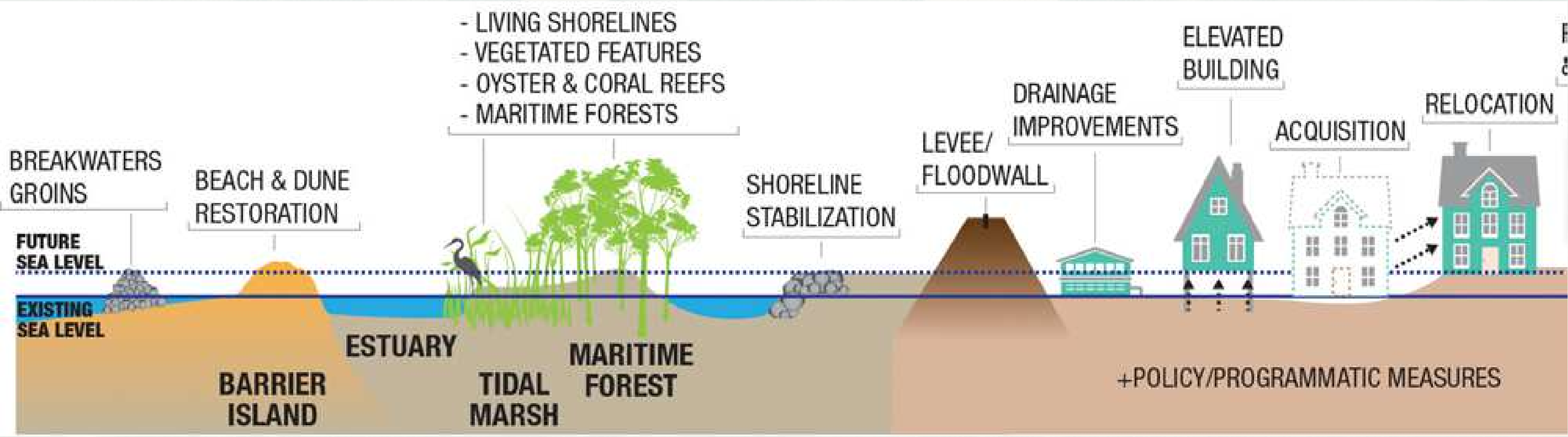
McPhee: “It is a description of people defying nature. They may have no choice”

In the end, nature will always win.

Engineering AGAINST Nature
or
Engineering WITH Nature?

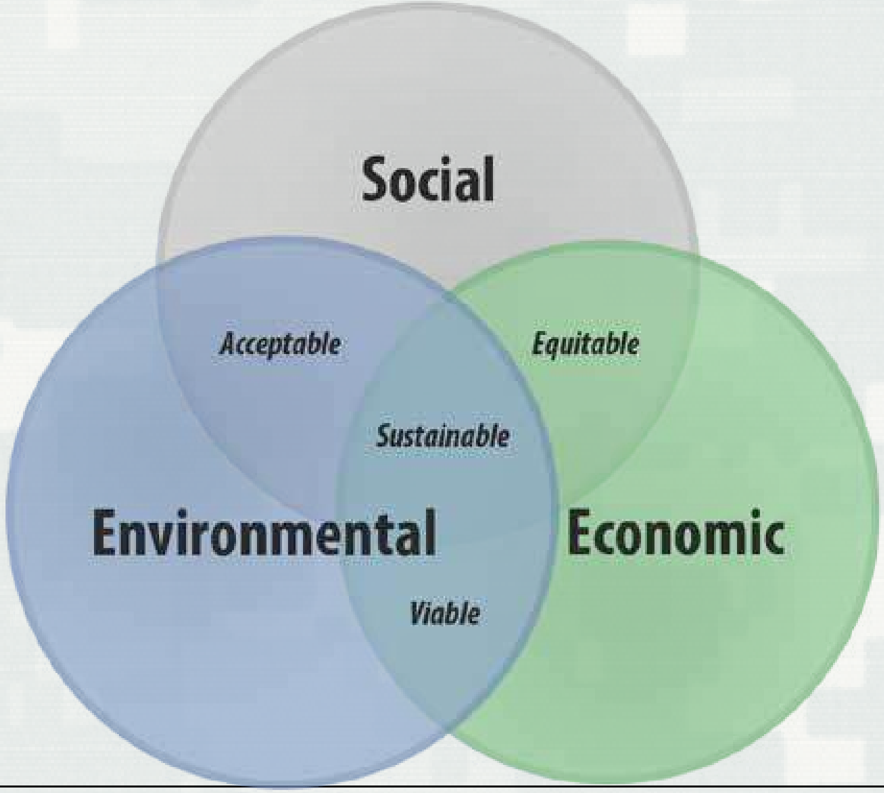
- Levees
- Beaches and sand dunes
- Wetlands
- Reefs (rock, coral, shells)
- Headlands
- Berms and islands
- Runoff retentions areas




- LIVING SHORELINES
- VEGETATED FEATURES
- OYSTER & CORAL REEFS
- MARITIME FORESTS
ELEVATED BUILDING
DRAINAGE IMPROVEMENTS
RELOCATION
ACQUISITION
LEVEE/ FLOODWALL
BREAKWATERS GROINS
BEACH & DUNE RESTORATION
SHORELINE STABILIZATION
FUTURE SEA LEVEL
EXISTING SEA LEVEL
ESTUARY
MARITIME FOREST
BARRIER ISLAND
TIDAL MARSH
+POLICY/PROGRAMMATIC MEASURES

Engineering With Nature…

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

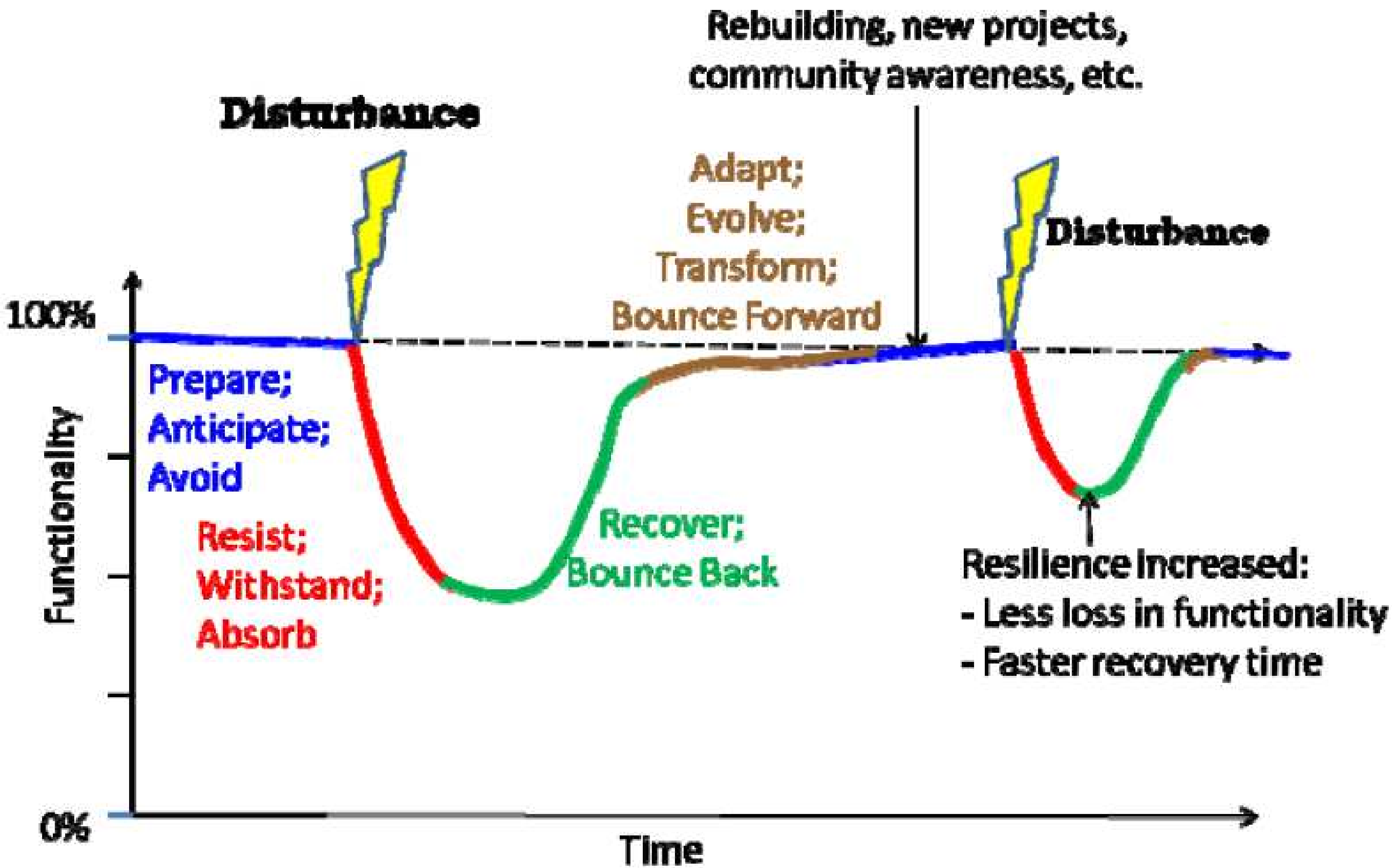


Engineering With Nature…

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)

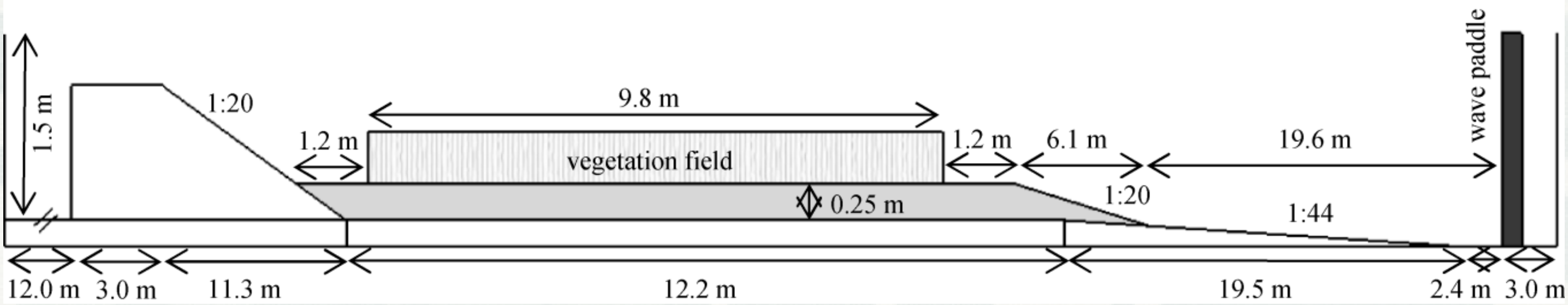
Lima et al. (2006)
Løvås and Tørum (2000)
Lövstedt and Larson (2010)
Lowe et al. (2007)
Manca et al. (2012)
Massel et al. (1999)
Mazda et al. (2006)
Möller et al. (1999)
Möller and Spencer (2002)
Mullarney and Henderson (2010)

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)

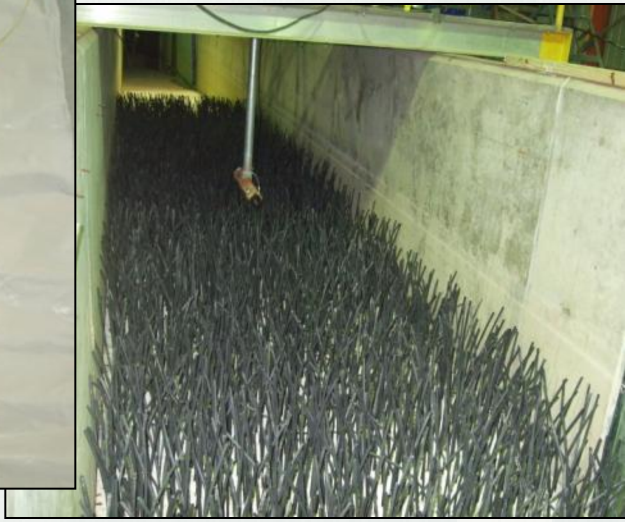
§ But few for *Spartina alterniflora,* few emergent, and limited range of waves and water levels

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

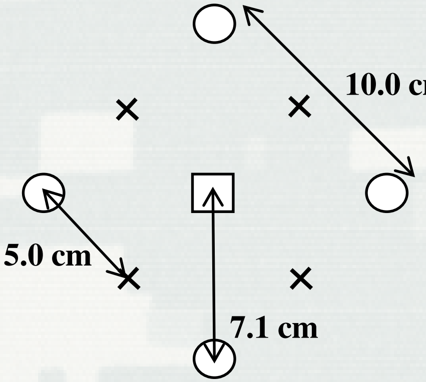


Three requirements

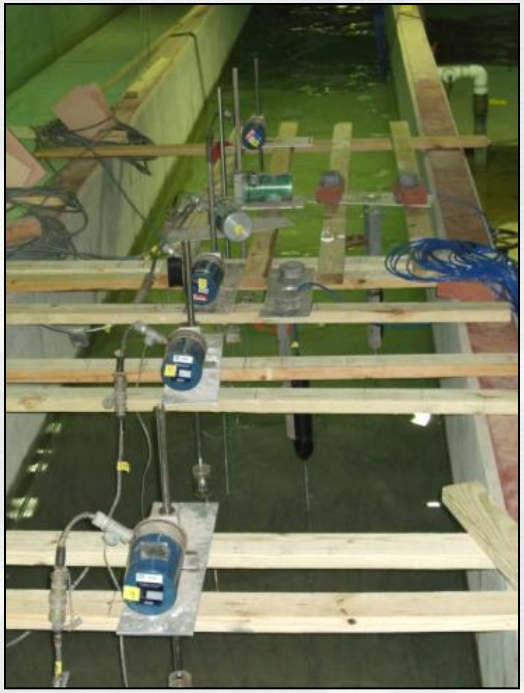
- similar geometry to a stem
- flexible under wave action
- remain upright to model emergent conditions

§ polyolefin tubing

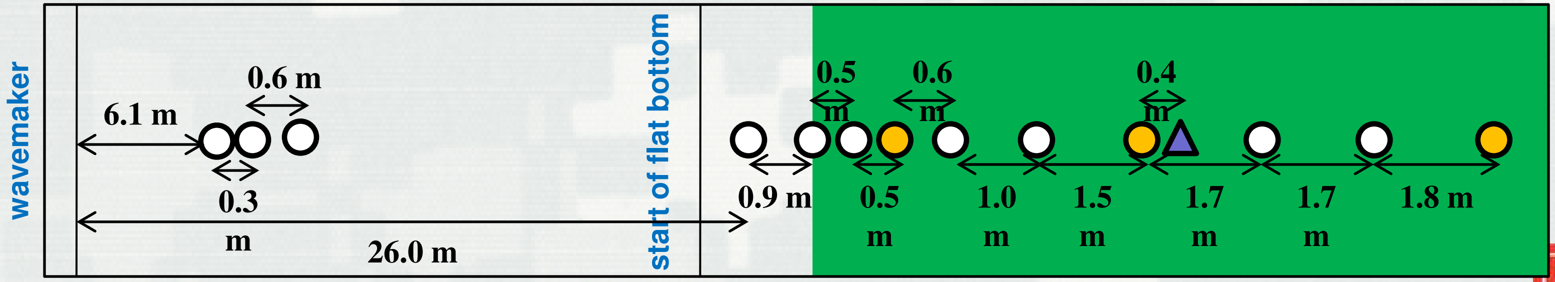
- benefits:
  - readily available
  - modulus of elasticity and diameter close to values reported in literature
- 6.4 mm diameter
- 41.5 cm stem length
- densities of 100, 200, and 400 stems/m^2
  - correspond to element spacing of 10.0 cm, 7.1 cm, and 5.0 cm



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



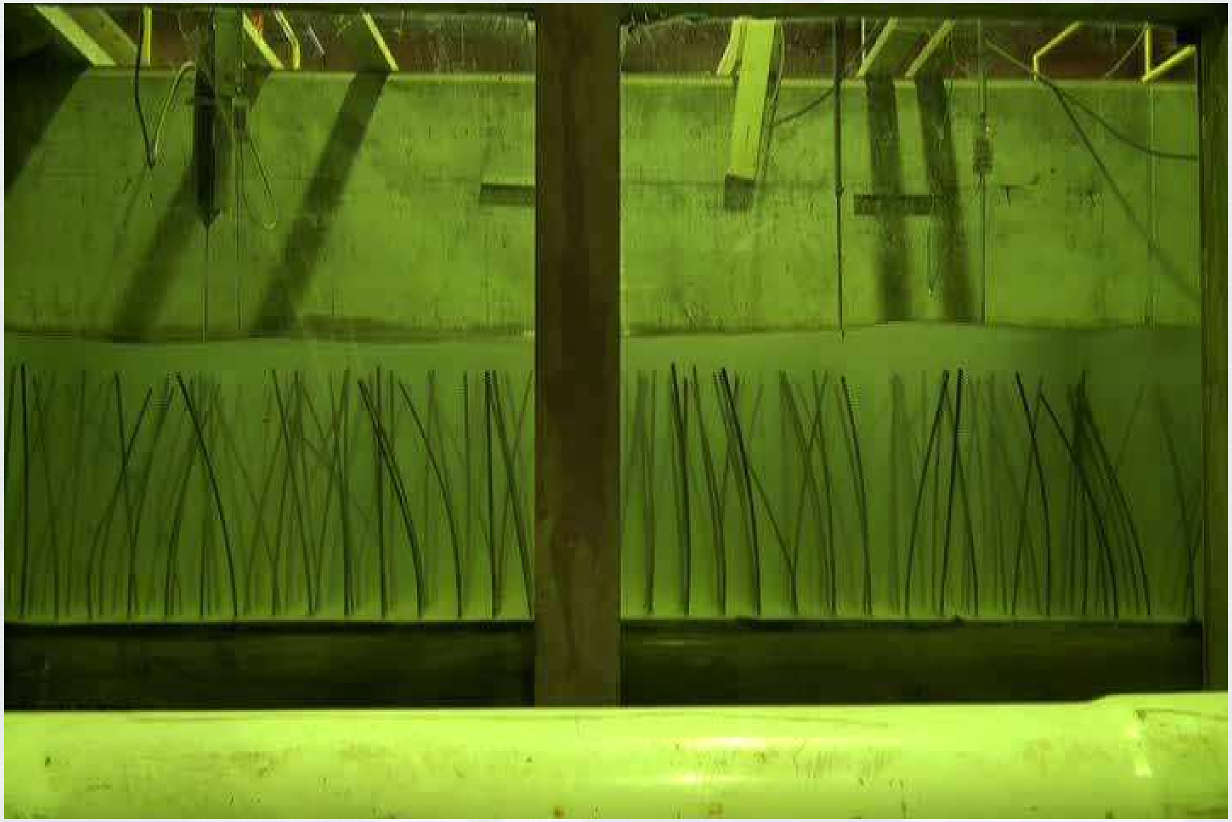
Idealized Vegetation

200 stems/m²

400 stems/m²

Water Levels and Waves

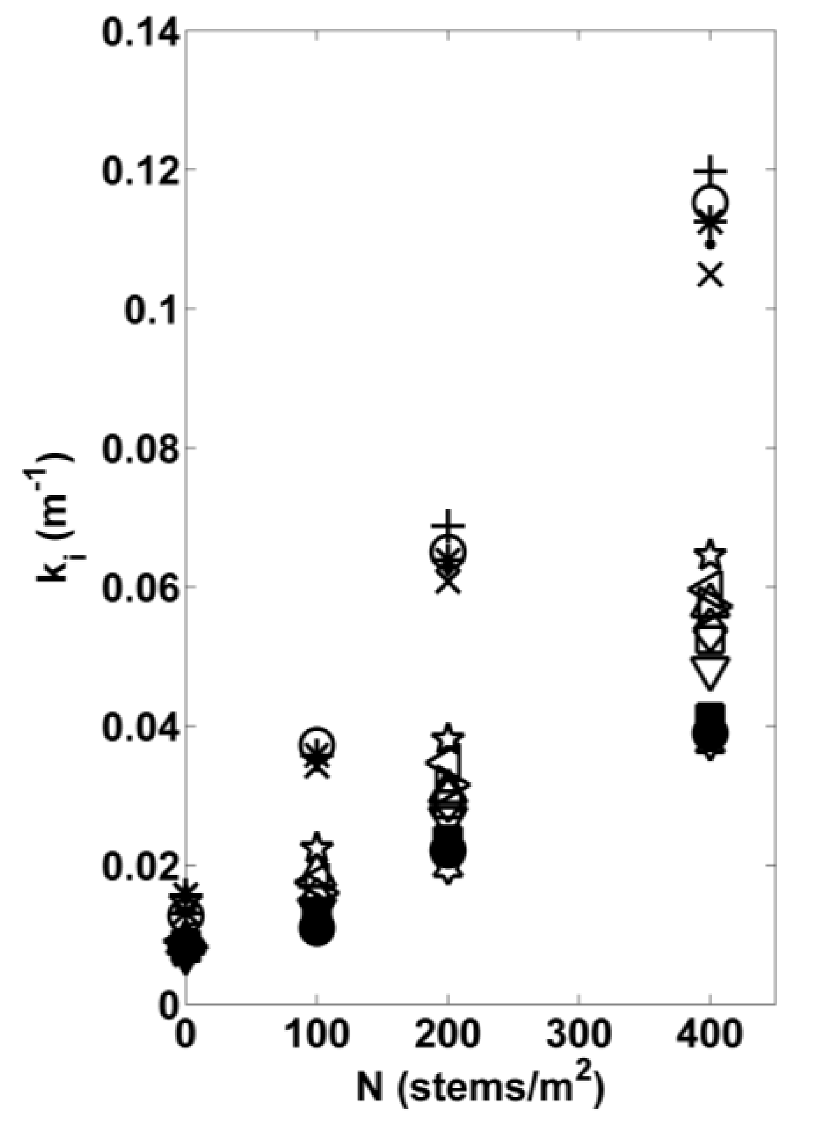
- Three water depths (h): 30.5 cm, 45.7 cm, 53.3 cm
  - correspond to l_s/h ratios of 1.0 (emergent), 0.91, 0.78
- Irregular waves
  - T_p ~ 1.25 s to 2.25 s
  - H_{m0} ~ ranging from 5.0 cm to 19.2 cm
- Double peak spectra with T = 1.25 s and 2.0 s



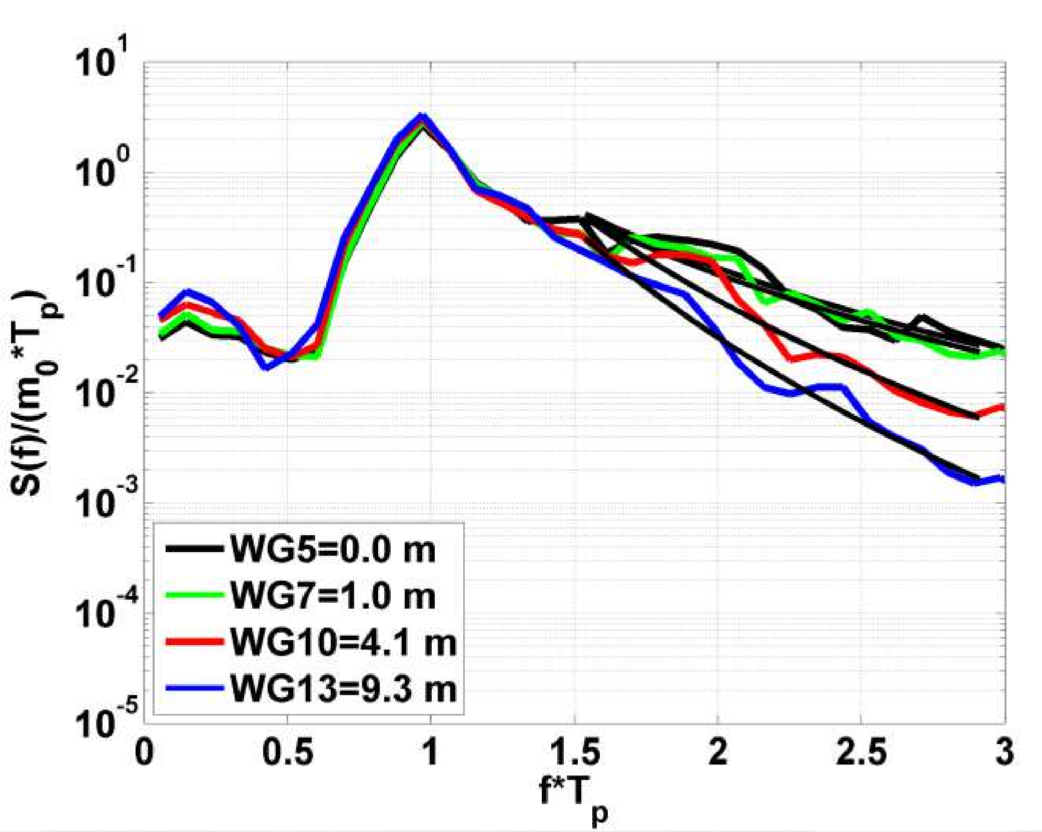
Trends in Wave Attenuation

§ 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

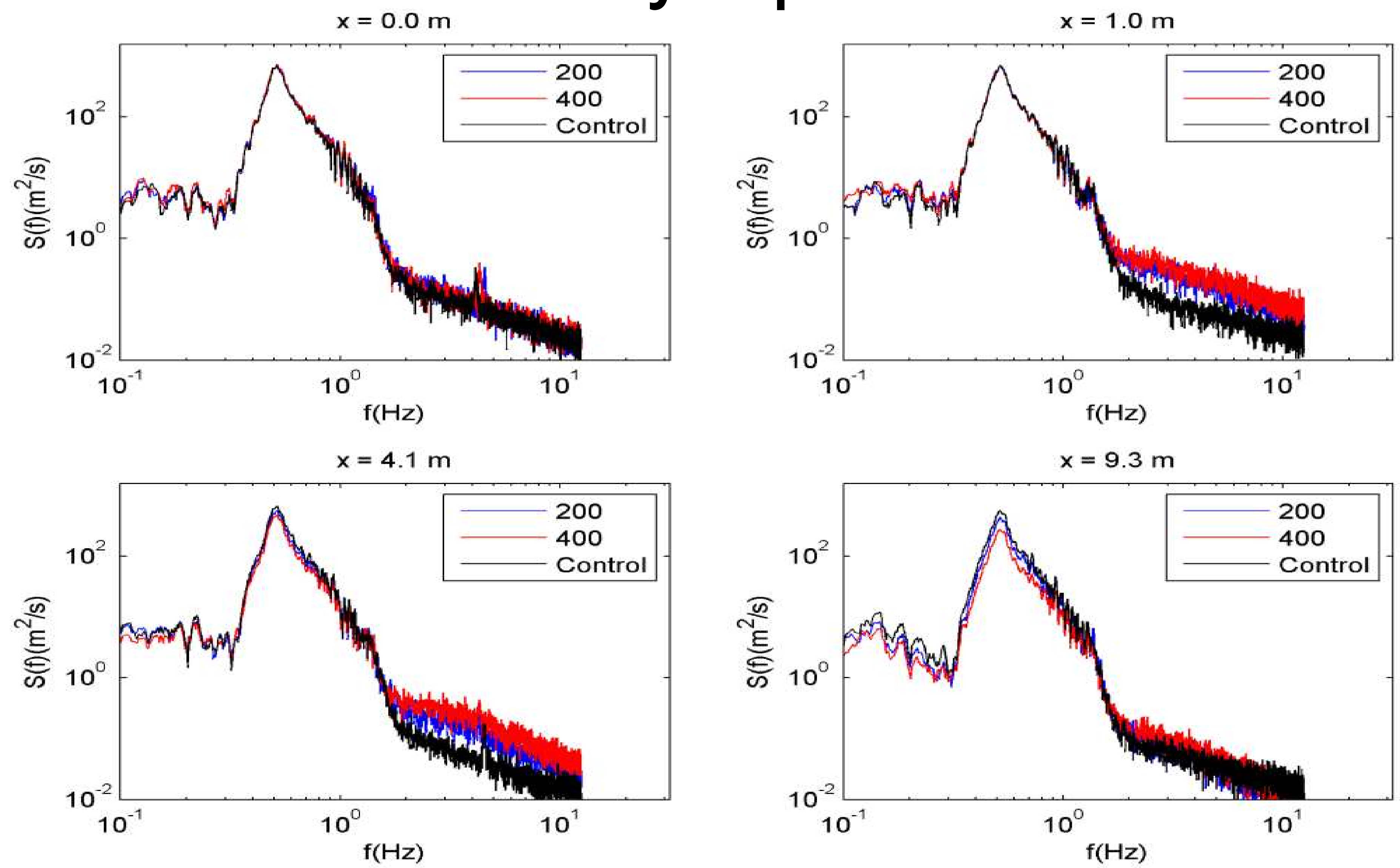


Equilibrium Range



- 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



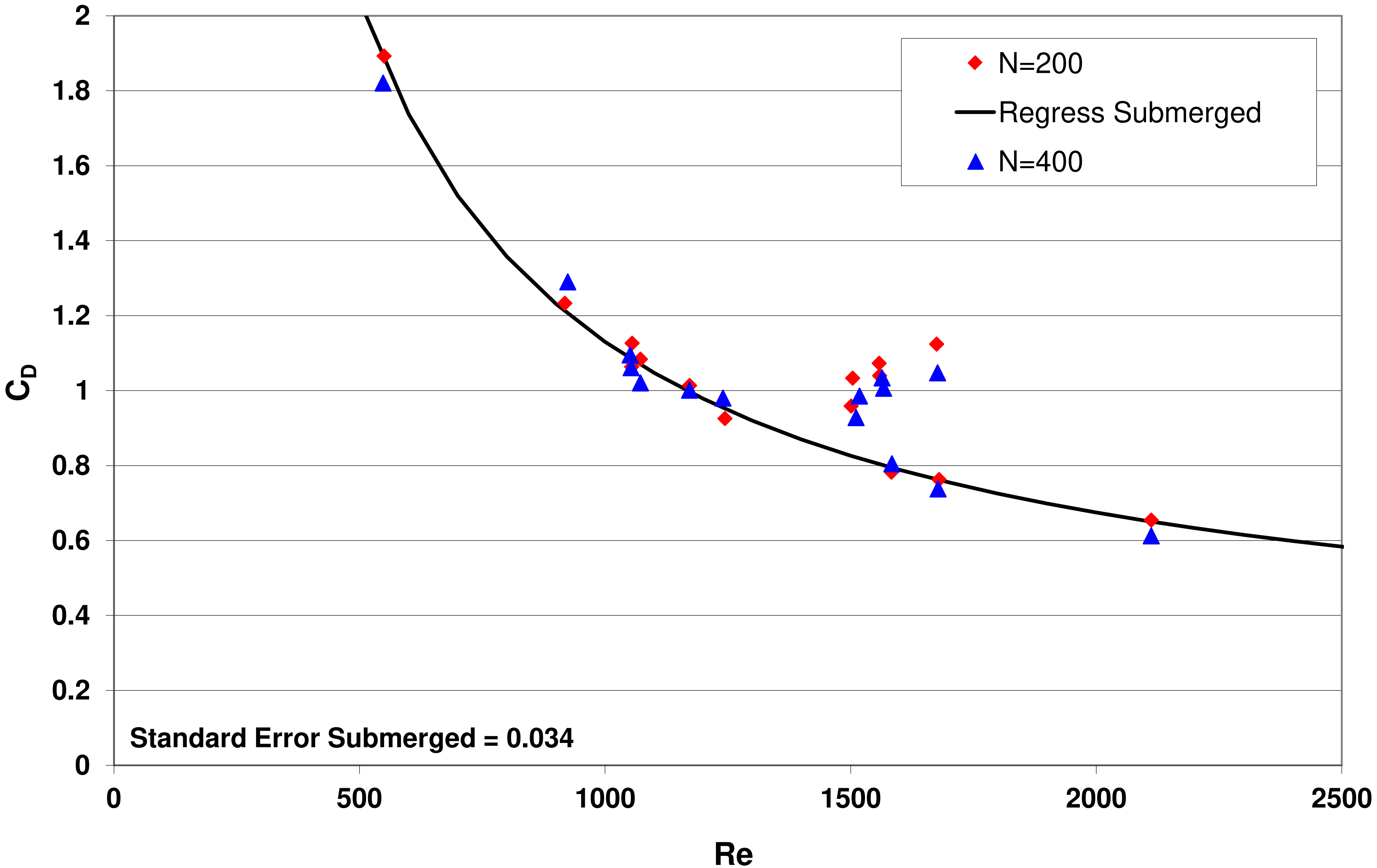
Estimate C_D

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

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

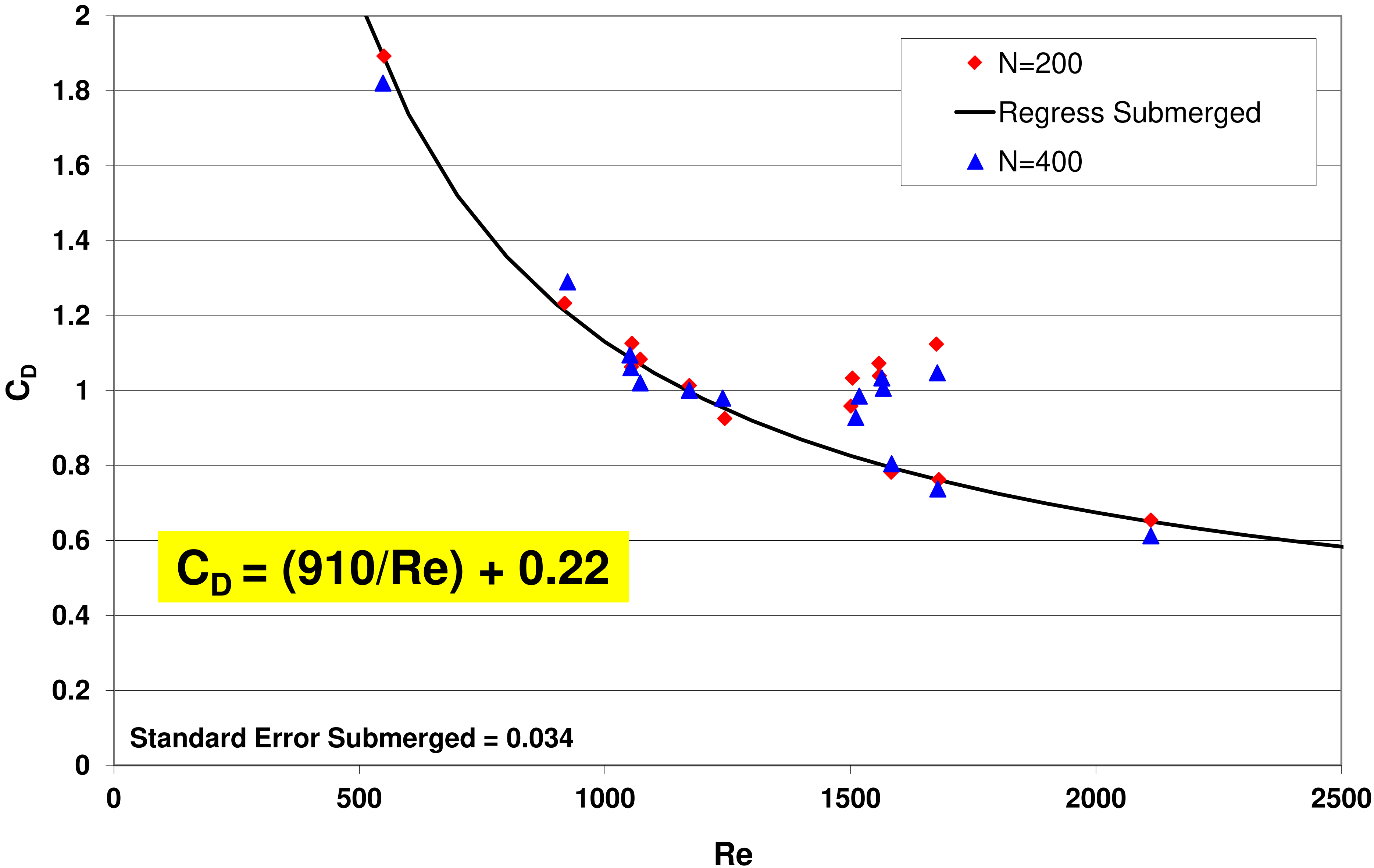
Background tank friction was removed

Estimate C_D



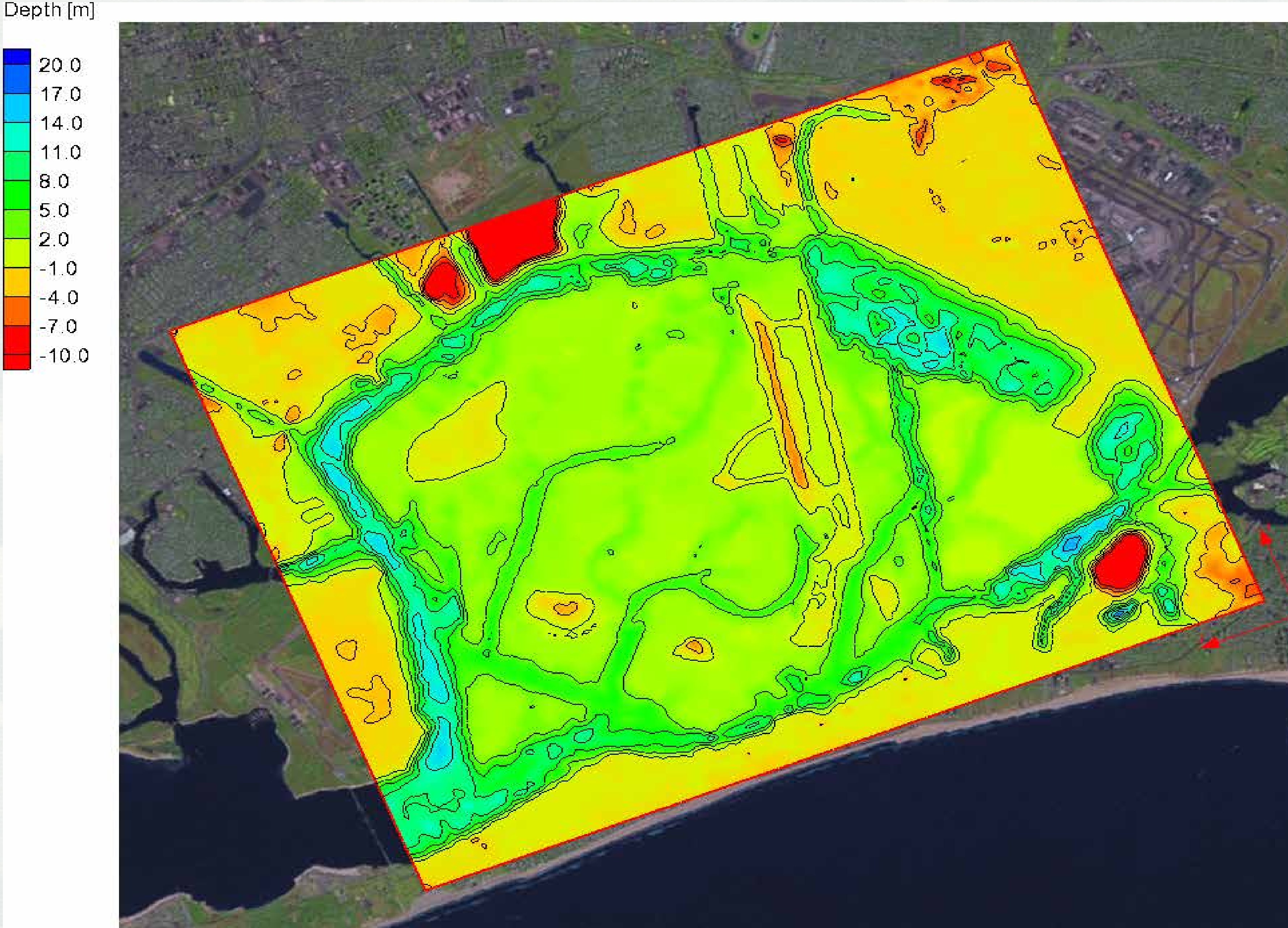
N=200
Regress Submerged
N=400
C_D
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
500
1000
1500
2000
2500
Re
Standard Error Submerged = 0.034

Estimate C_D



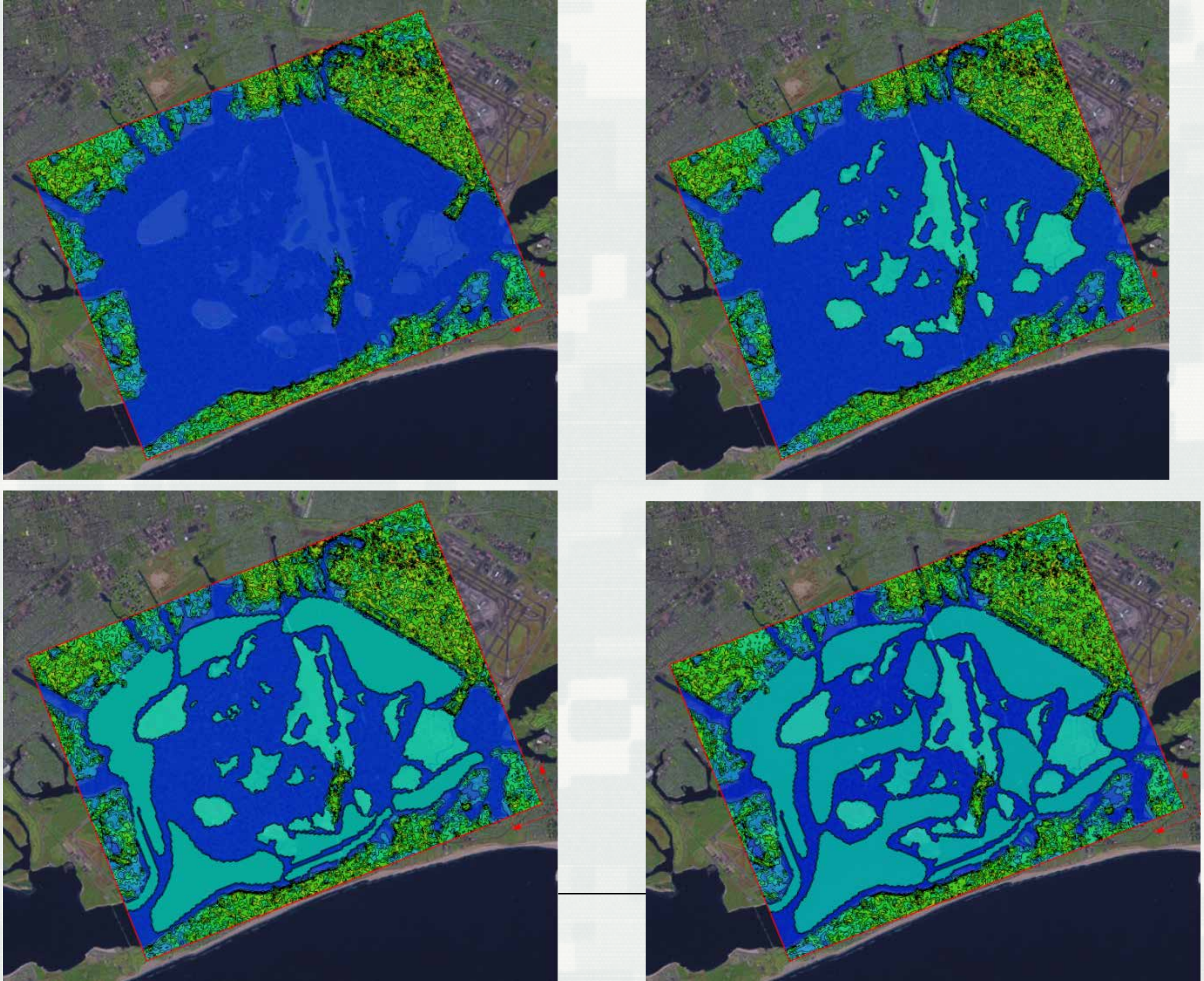
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
C_D
N=200
Regress Submerged
N=400
$C_D = (910/Re) + 0.22$
Standard Error Submerged = 0.034
0
500
1000
1500
2000
2500
Re

Vegetation Implemented STWAVE

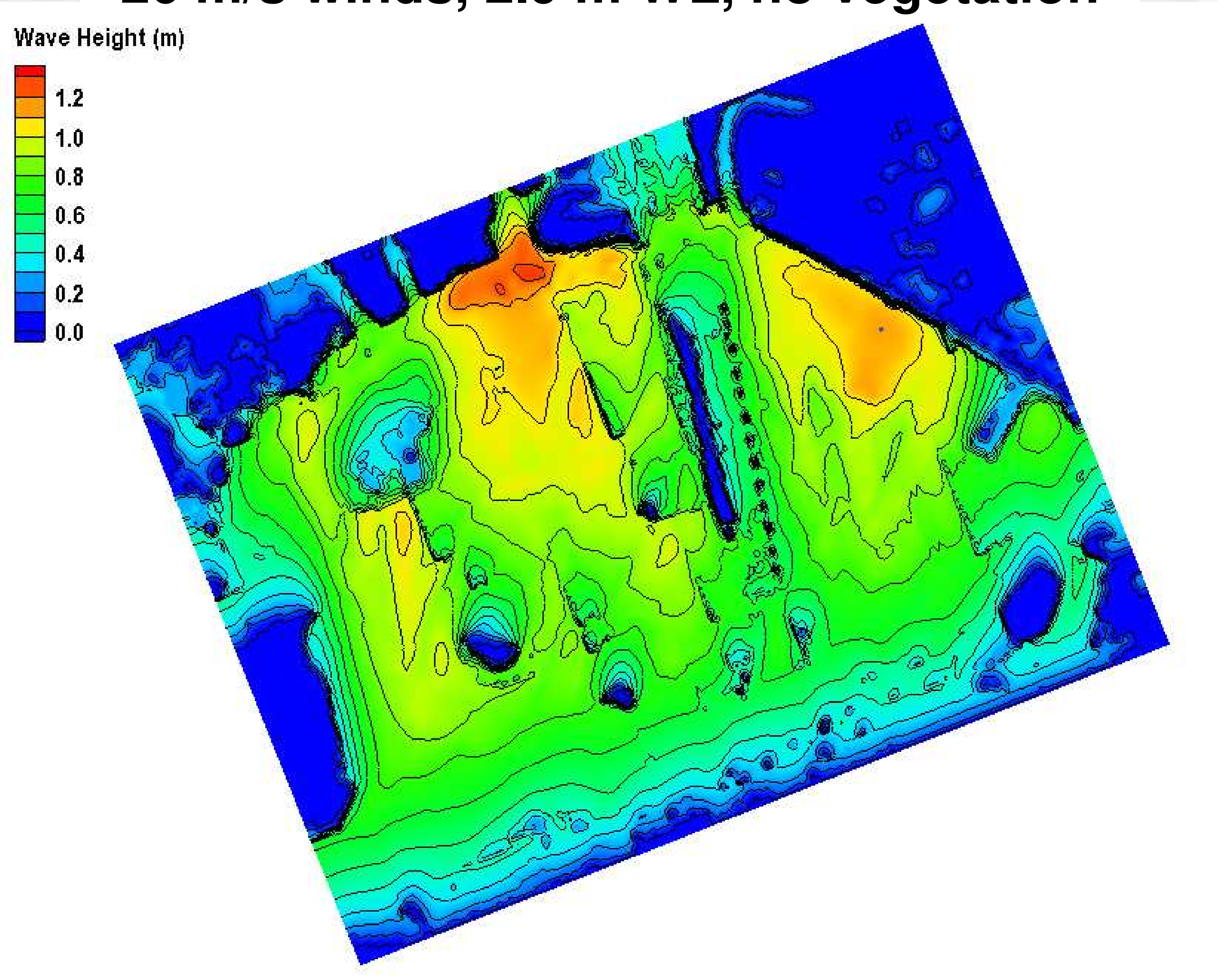


Simulations

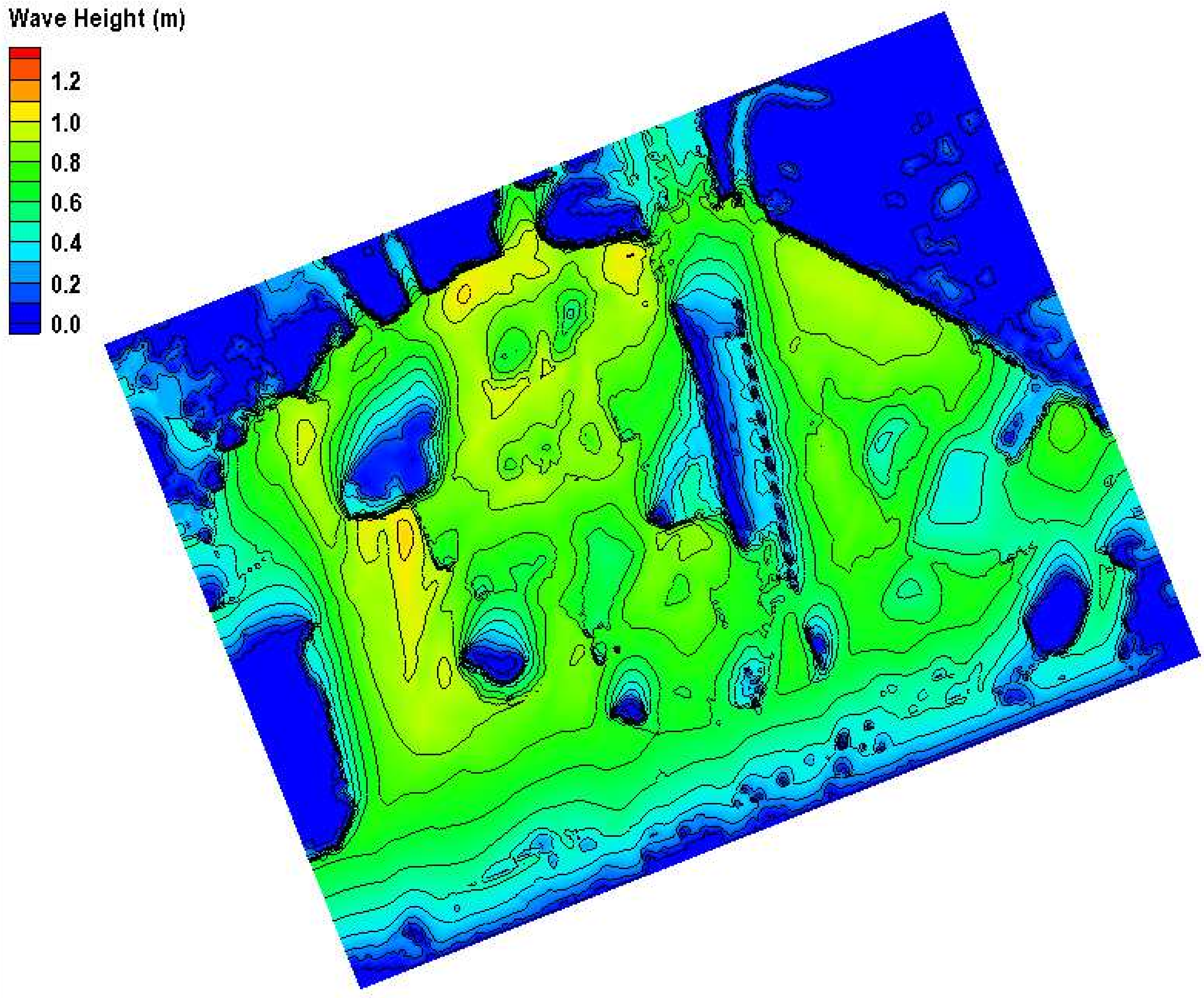
- Three wind & water level combinations
  - 18.5 m/s winds, 1.3 m WL
  - 22.1 m/s winds, 2.0 m WL
  - 26.0 m/s winds, 2.9 m WL
- Four vegetation states
  - No vegetation, existing bathymetry
  - Existing vegetation and bathymetry
  - Moderate vegetation w/ modified bathymetry
  - Extensive vegetation 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



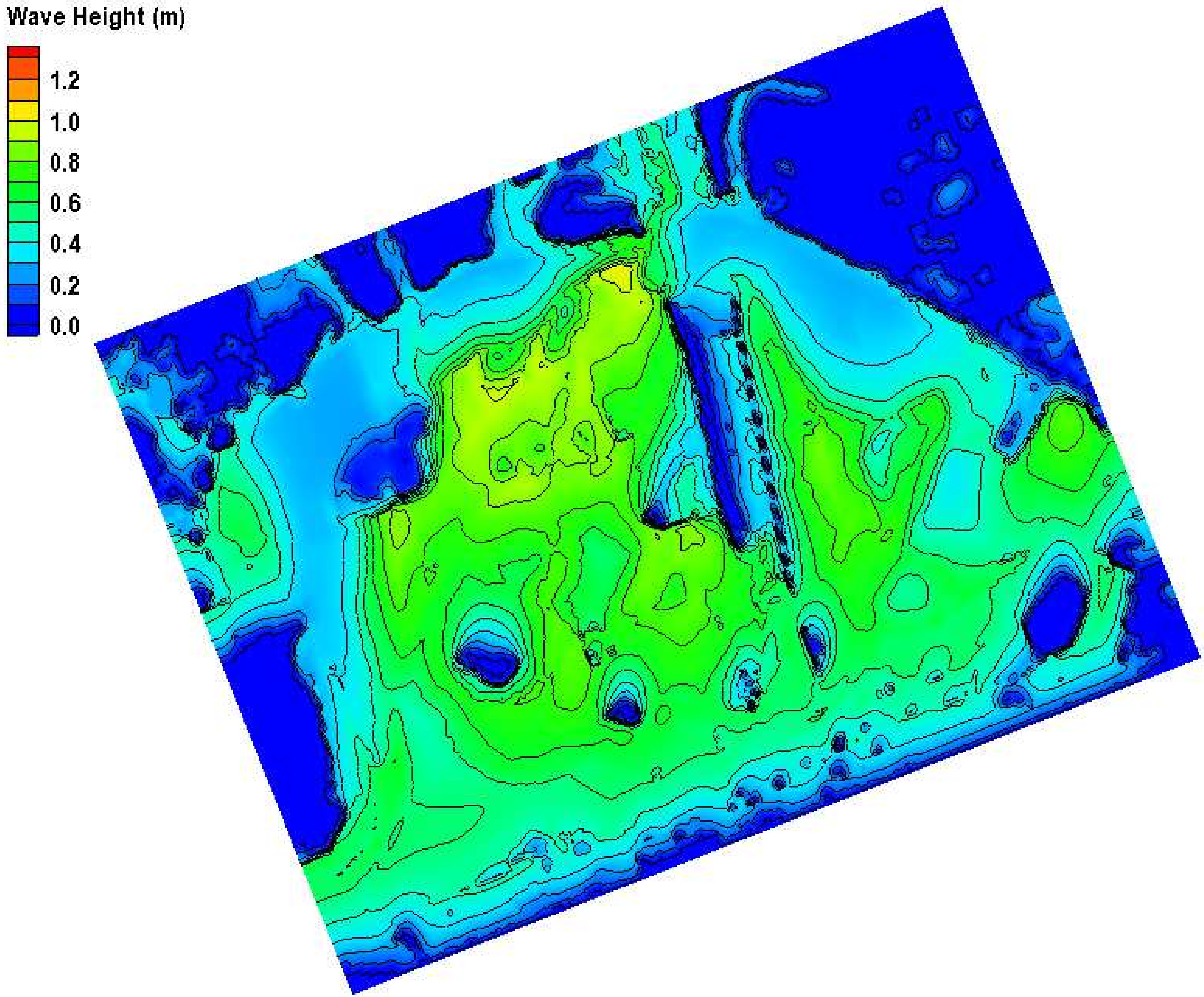
26 m/s winds, 2.9 m WL, no vegetation



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

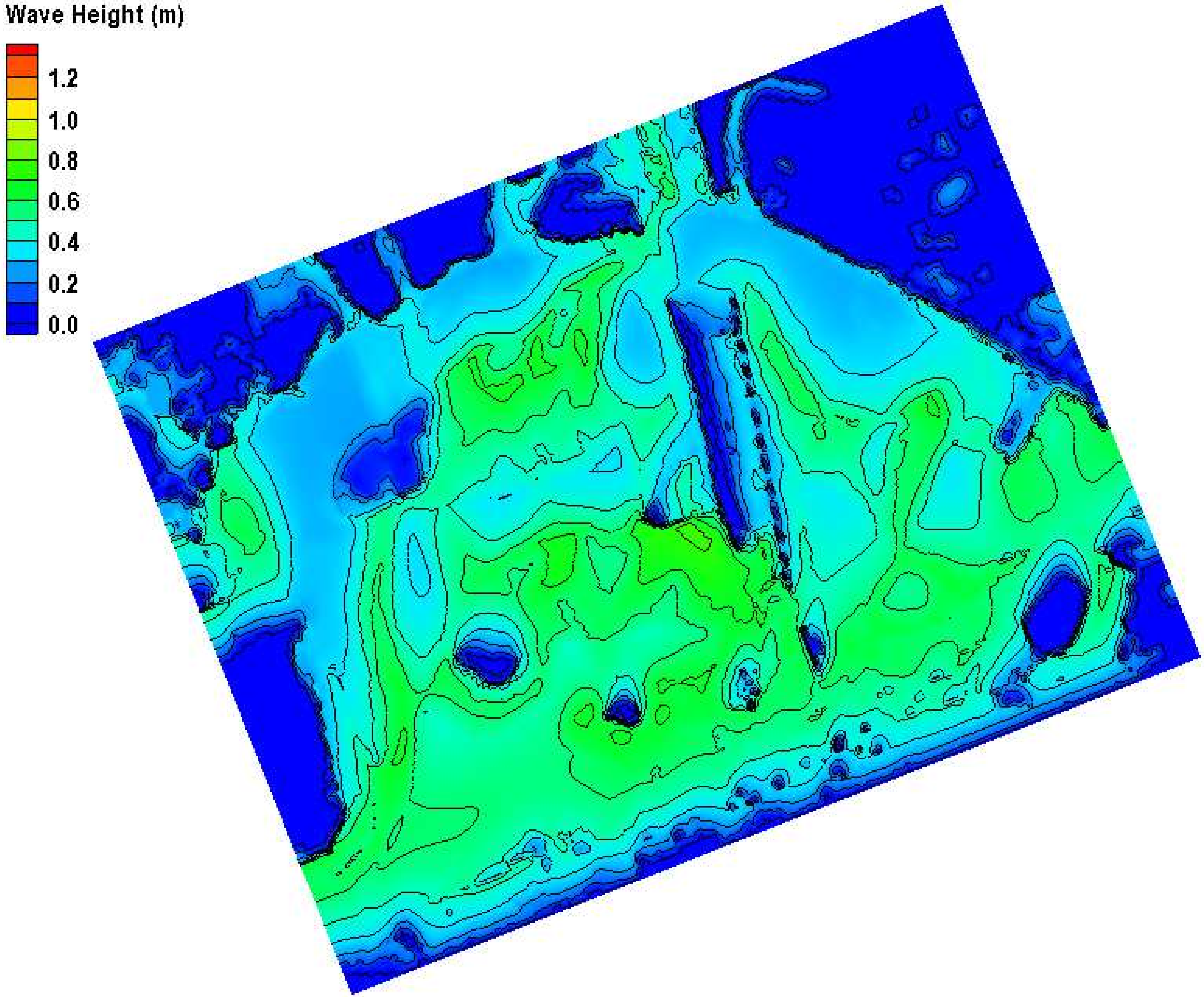


26 m/s winds, 2.9 m WL, moderate vegetation

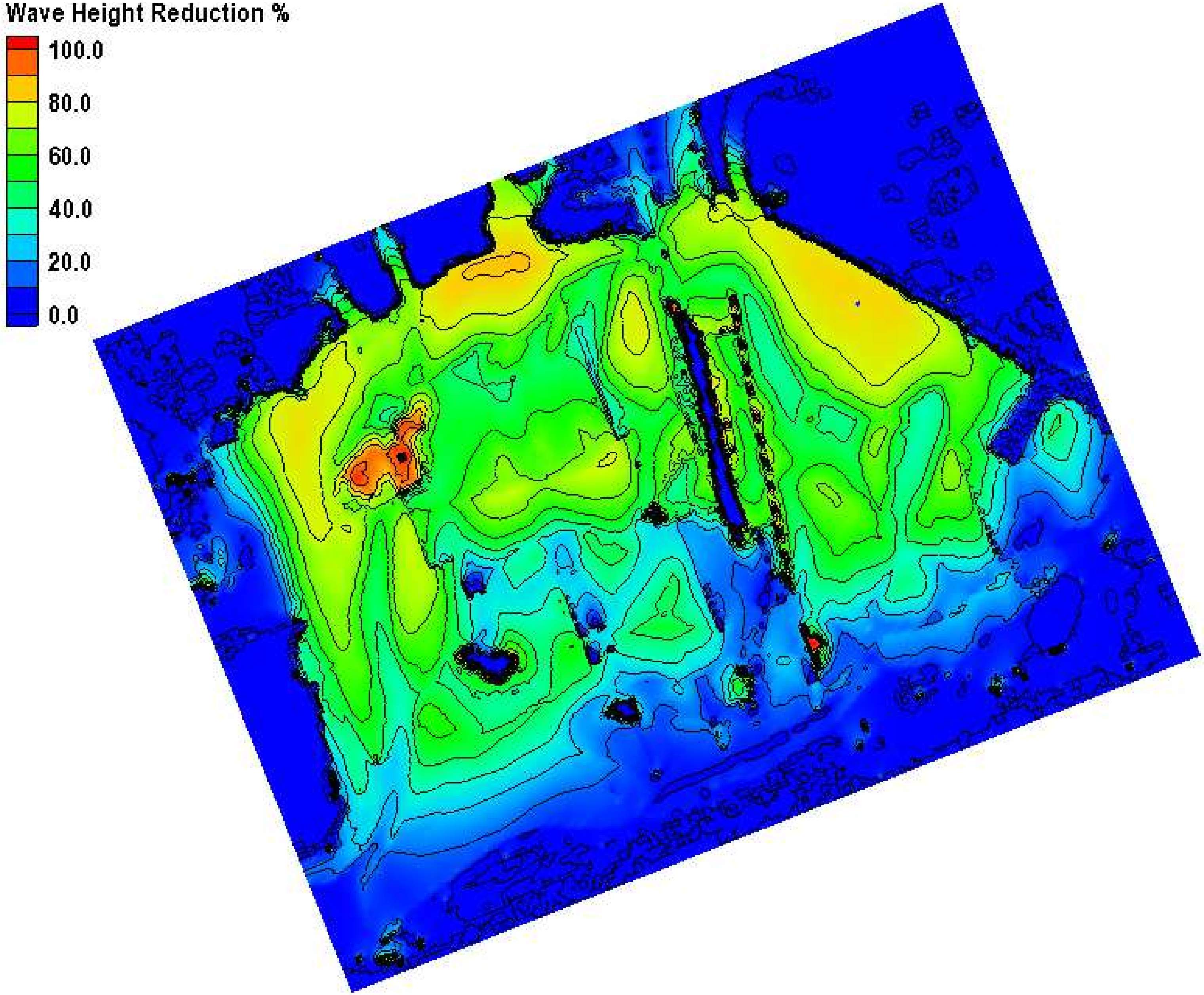


ONG®

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



percent reduction in wave height from bare to extensive vegetation coverage

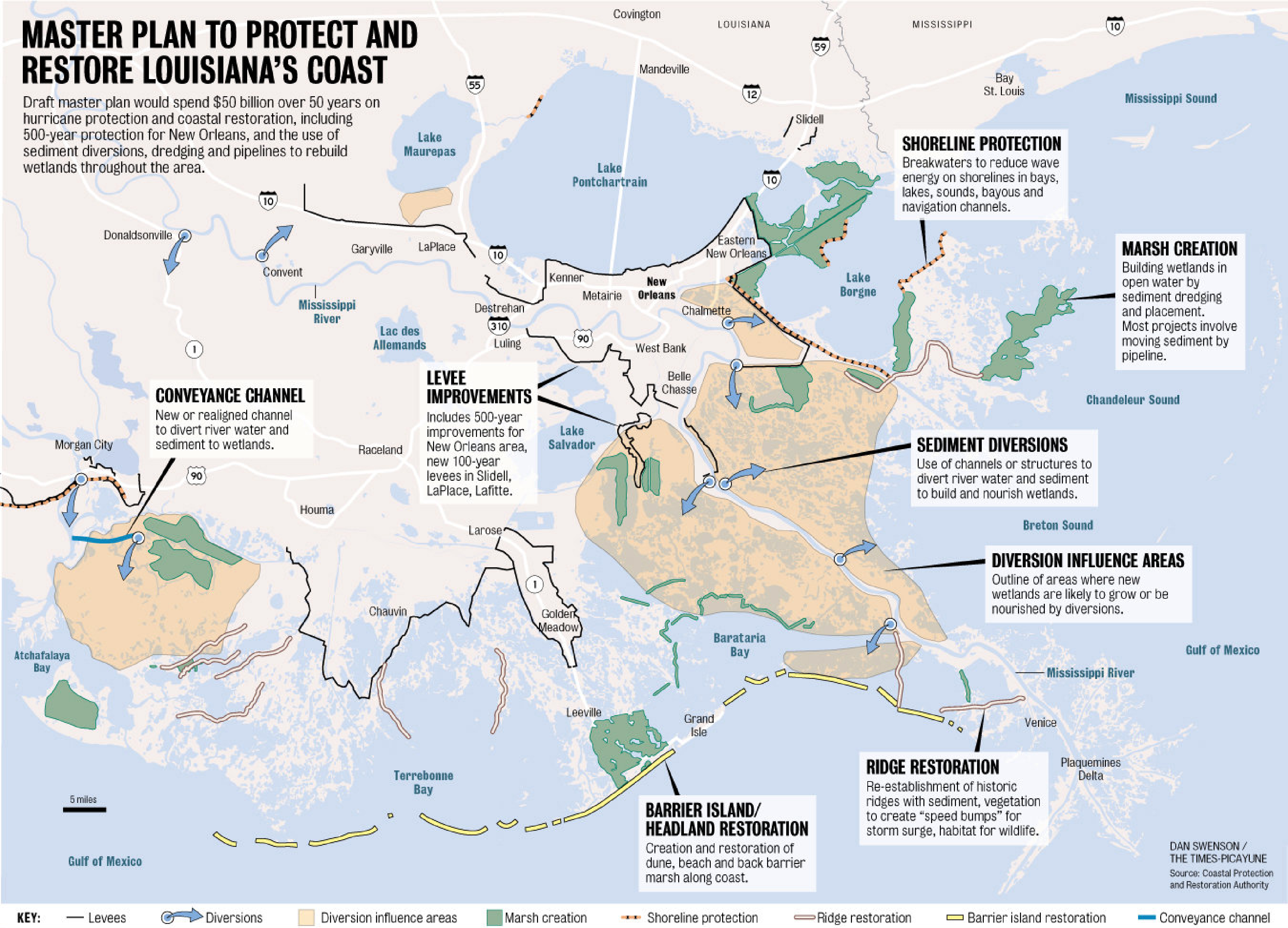


Results

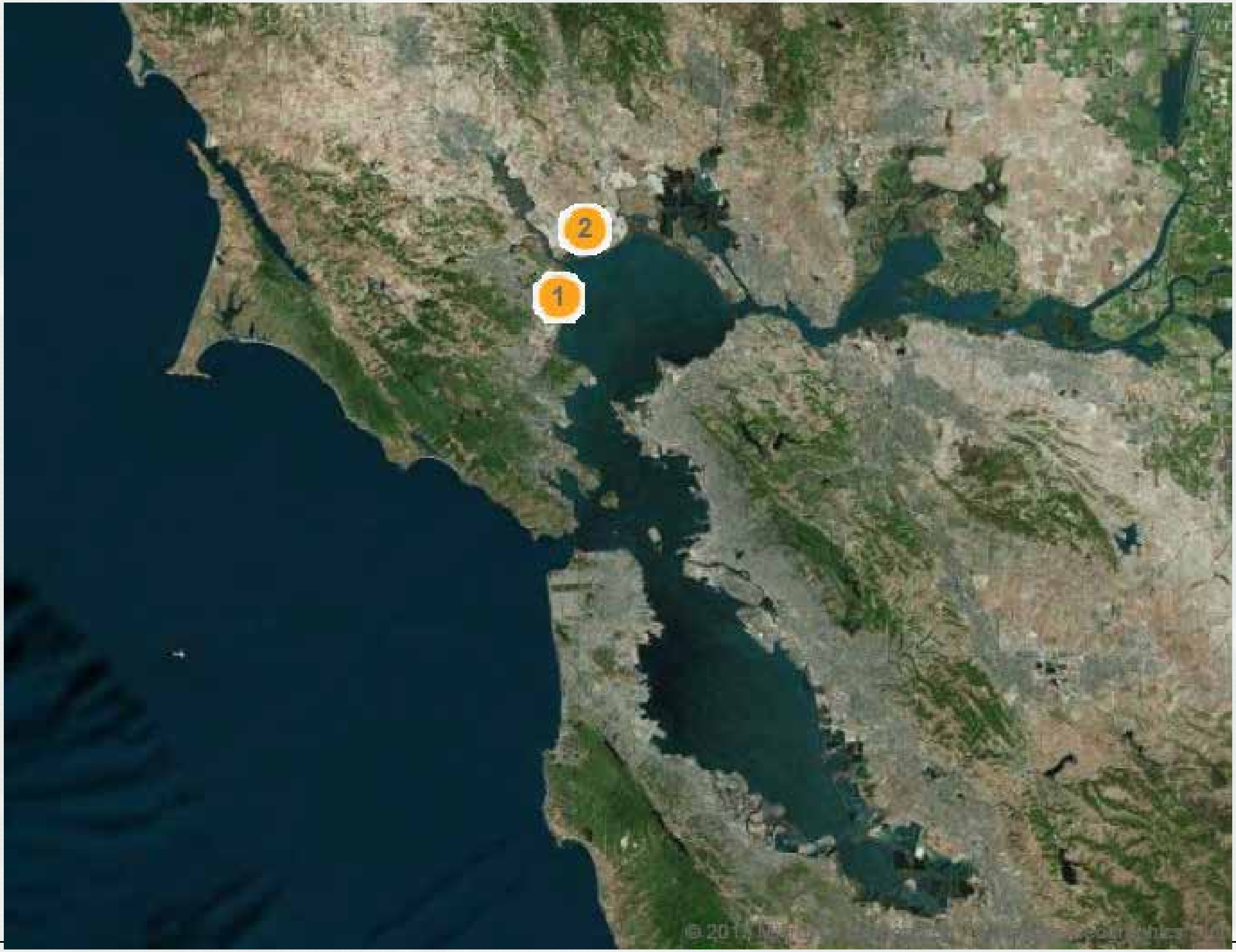
- Lab data
  - Shows expected trends with vegetation parameters
  - Good correlation between C_D and Re for submerged vegetation
  - Higher C_D for emergent conditions
- Need to attempt larger validation for broader vegetation types and hydrodynamic conditions
  - Data exists, but no one has tried to 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.



San Francisco Bay

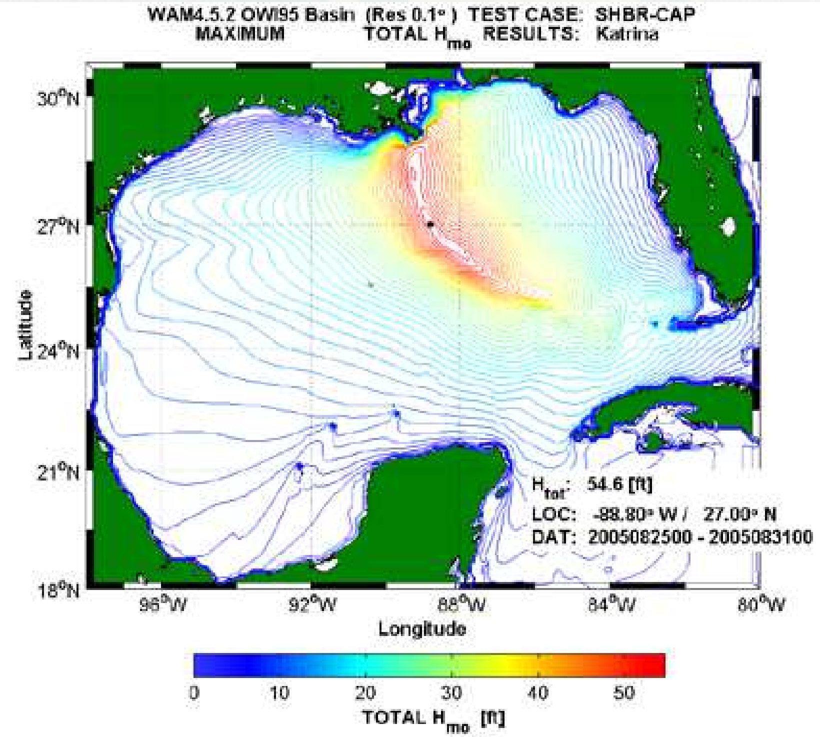


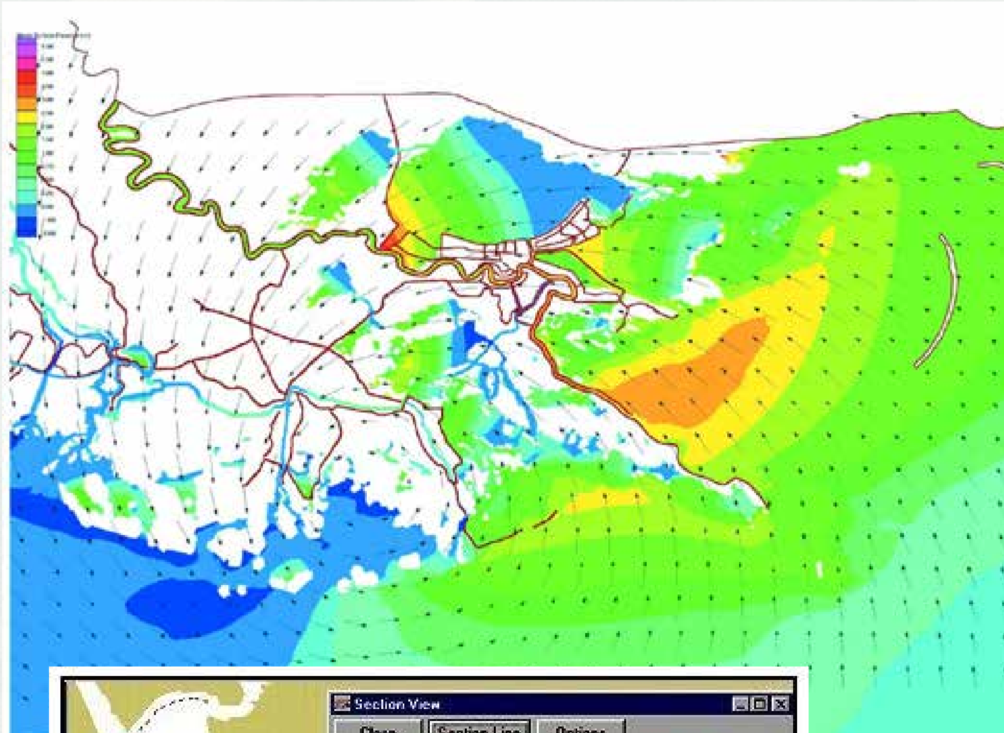
Engineer Research & Development Center

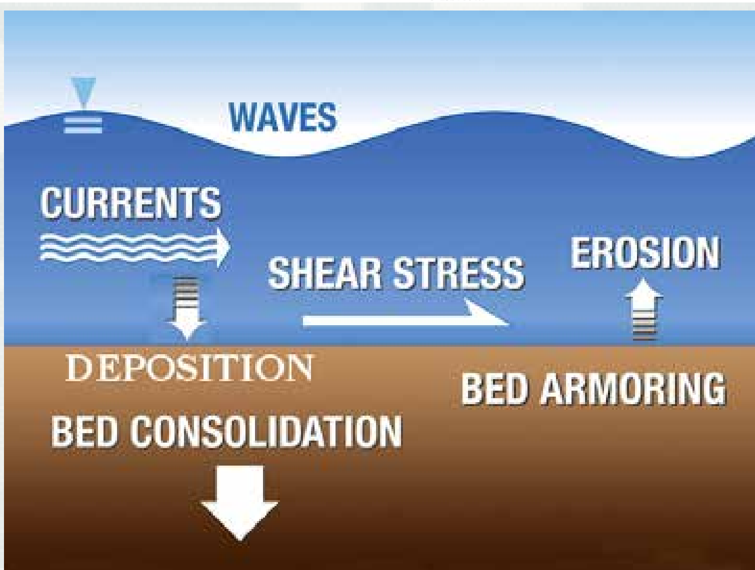
- In Vicksburg, Mississippi
  - Coastal and Hydraulics Laboratory
  - Environmental Laboratory
  - Geotechnical and Structures Laboratory
  - Information Technology Laboratory
- In Alexandria, Virginia: Geospatial Research Laboratory
- In Champaign, Illinois: Construction Engineering Research Laboratory
- In Hanover, New Hampshire: Cold Regions Research and Engineering Laboratory

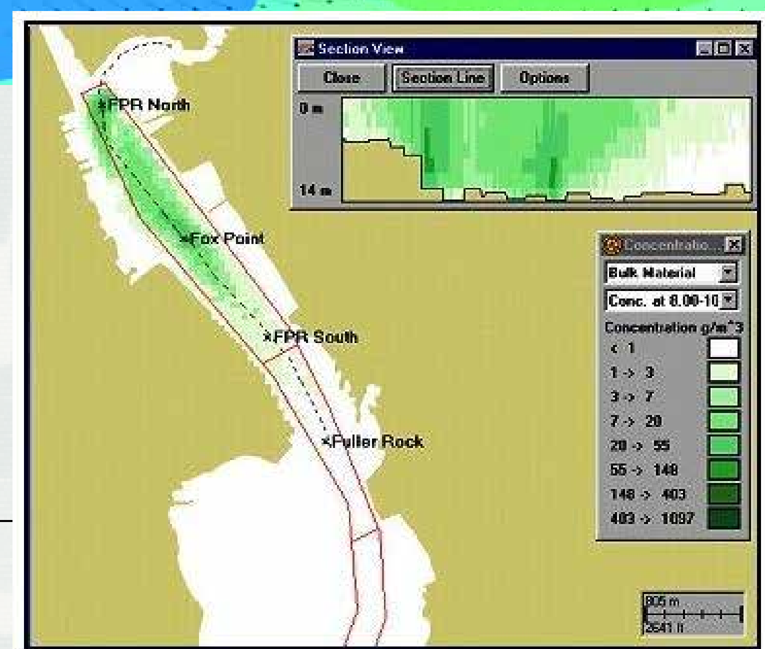
Coastal Processes at CHL

Coastal Processes









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Coastal Processes