Wave Attenuation by Vegetation: Role in Sediment Trapping and Retention

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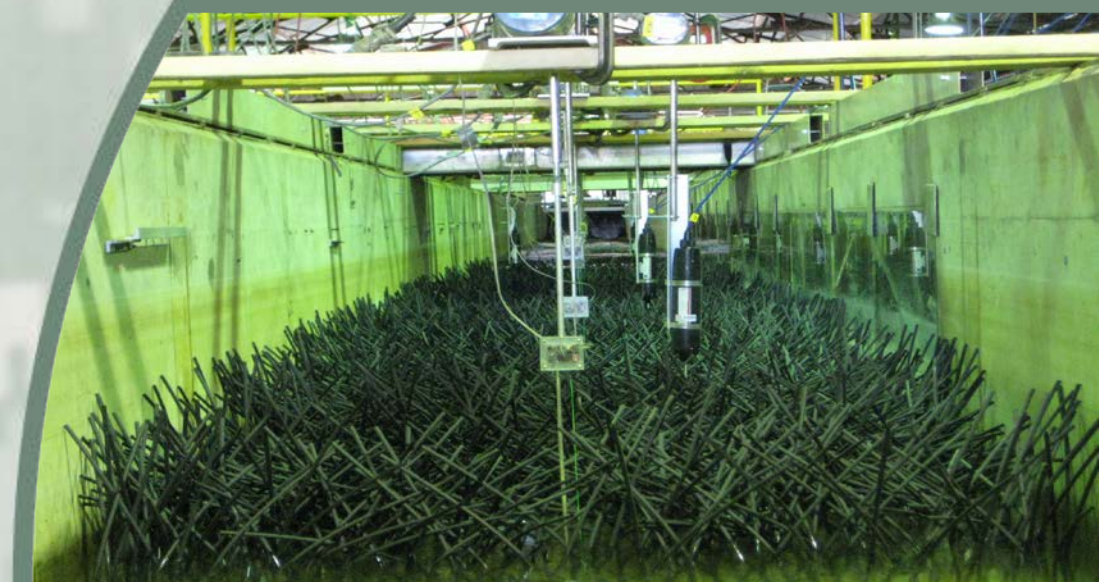

COASTAL AND HYDRAULICS LABORATORY

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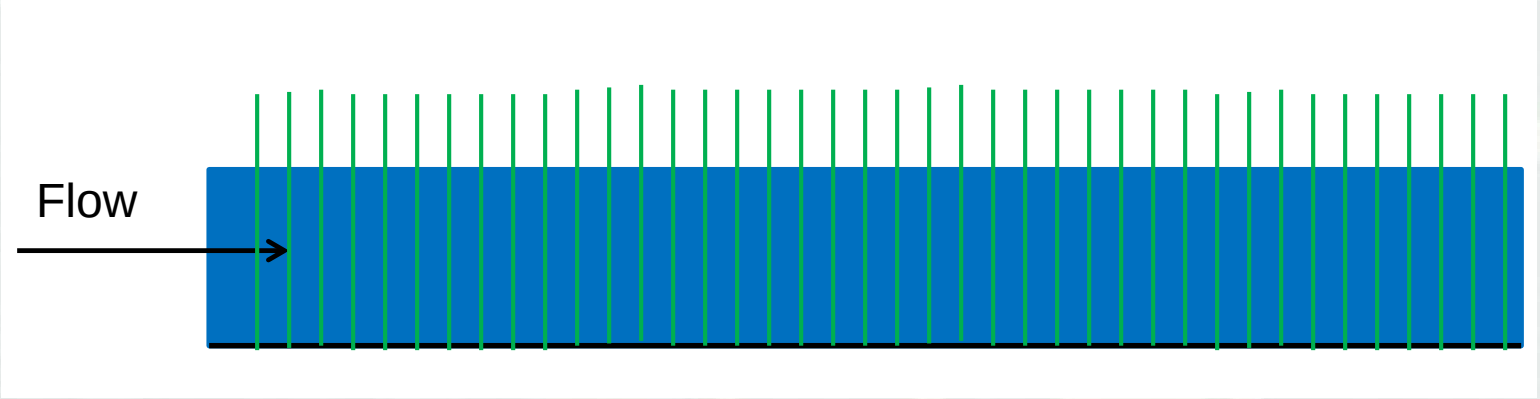
Flow Through Vegetation

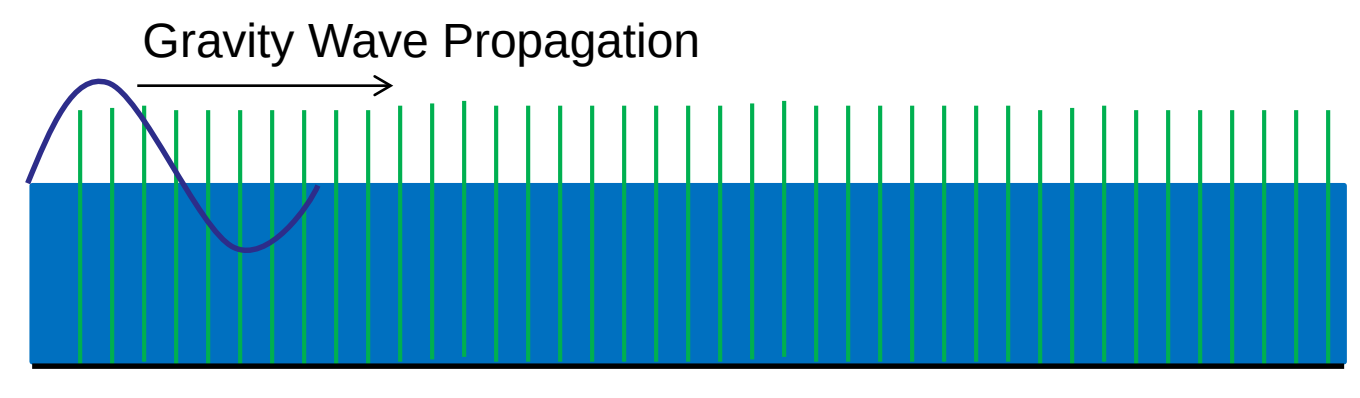
- Manning's n for river stage forecasting or storm surge levels
- Measurements of mixing/turbulence (Nepf 1999)
- High-fidelity numerical modeling (Stoesser 2007)



Waves Through Vegetation

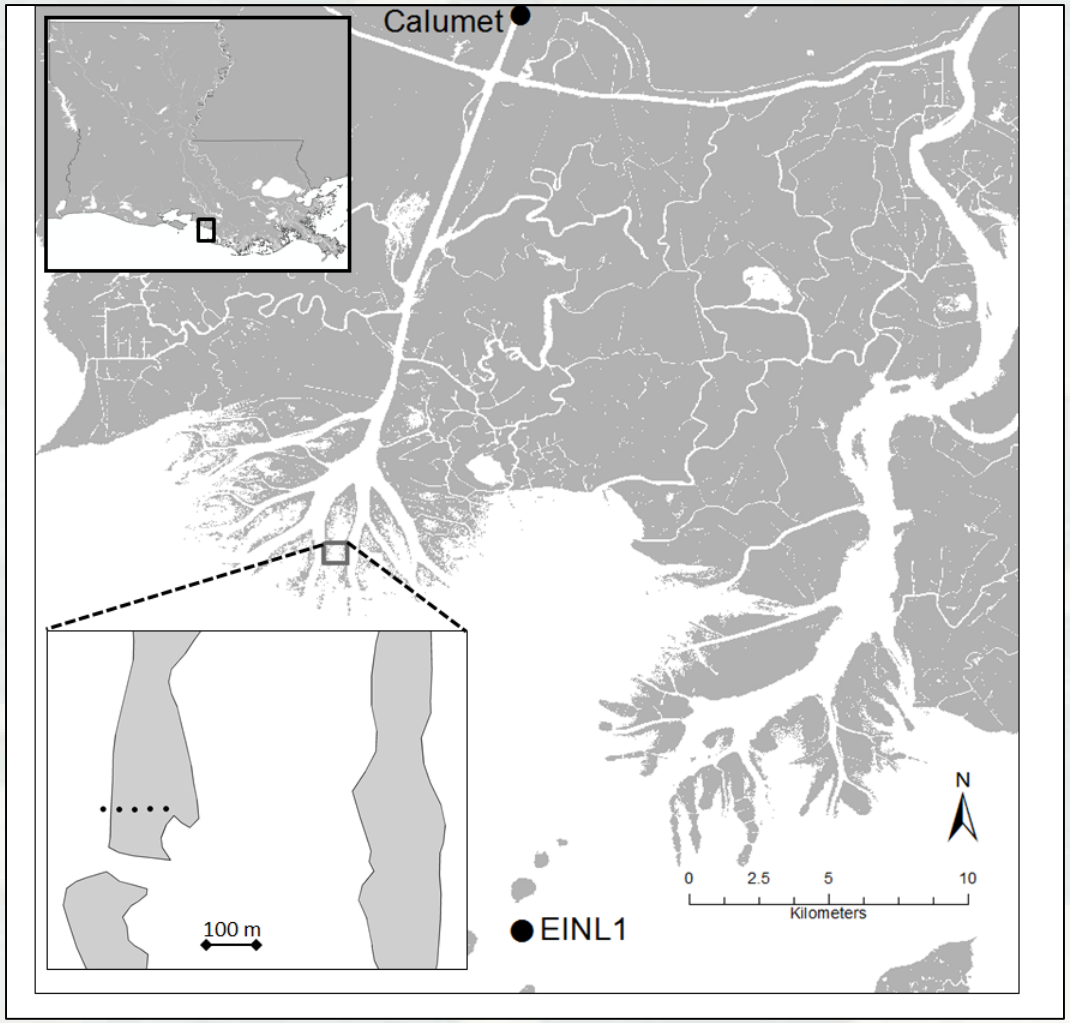
- Wave attenuation for tropical/extra tropical coastal residency (Dalrymple et al. 1984, Kobayashi et al. 1993, Mendez et al. 2004, Anderson and Smith, 2013)

- Limited work on mixing/turbulence and sediment transport



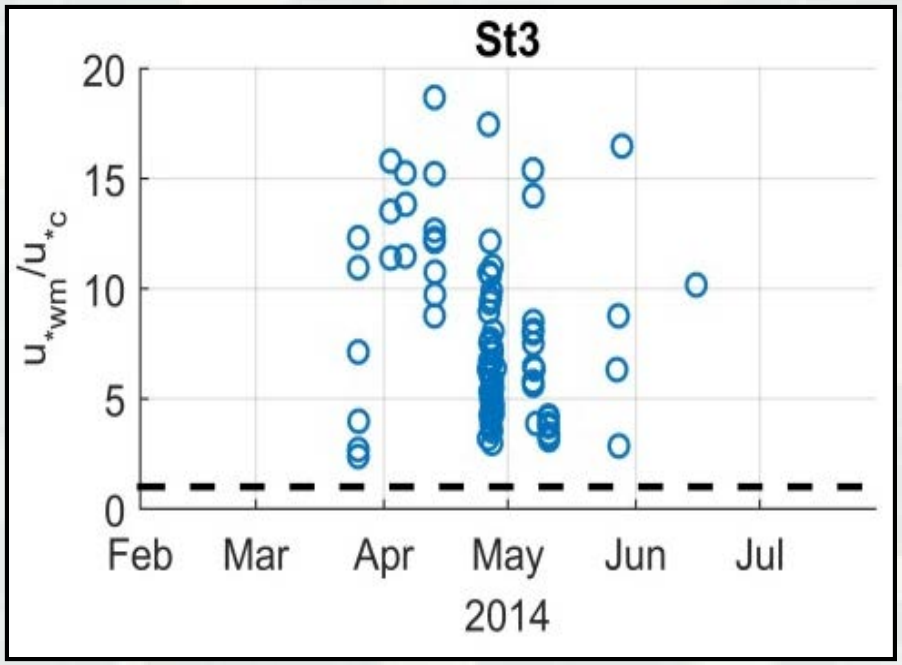
Field Observation

- 4 platforms on Mike Island, Wax Lake Delta, Louisiana
- ½ year deployment
- Measured currents, waves, suspended sediment concentration and deposition



Importance of Wave Energy

- Wave energy can initiate sediment motion
- Wave energy can keep sediment in suspension
- Small currents can move the sediment if suspended
- Attenuated wave energy can result in deposition



Wax Lake, Mike Island, Station 3
Bed Shear Stress, 100m from main channel

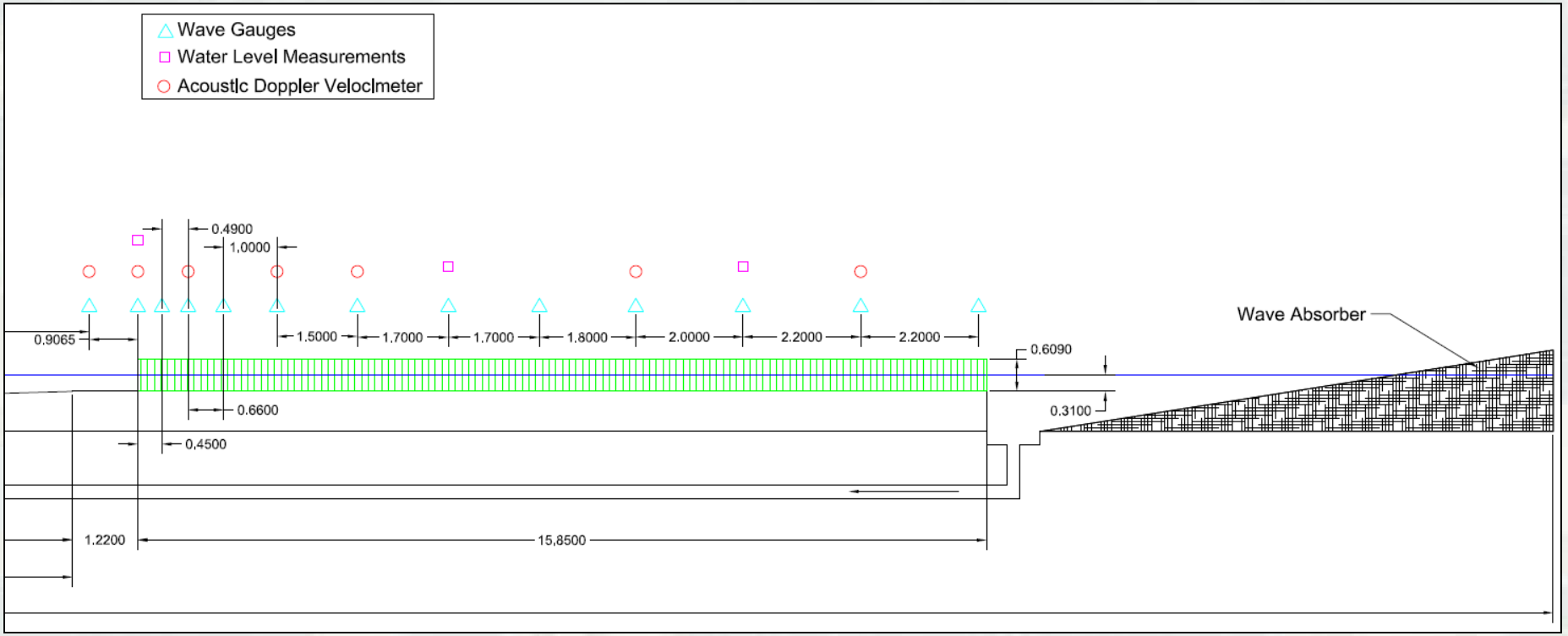
Role of Physical Model

- Allows for the study of physical processes
- Greater control than field observations
- Results in model improvement and reduced uncertainty

(Physical Models and Laboratory Techniques in Coastal Engineering – S. Hugdes)

Physical Model

- 63 meters long, 1.5 meters wide wave flume
- Generate regular and irregular waves with peak periods, T_p, ranging form 1.5s to 4.0s
- Wave heights ranging from 8 to 15cm
- Water depth of 31 cm
- Flow rates of 10.5, 24.4 and 44.5 l/s



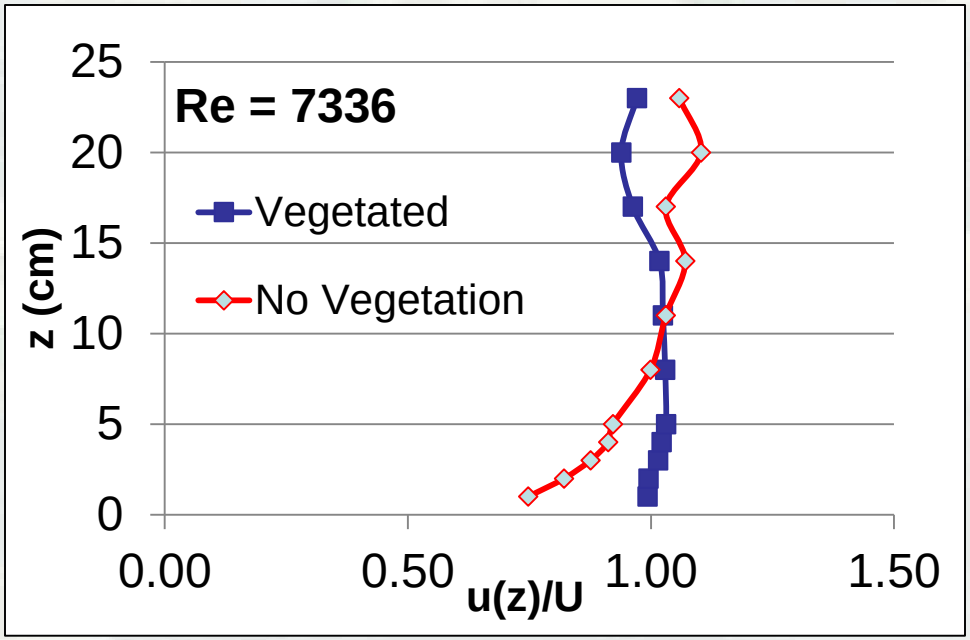
Artificial Plant Parameters

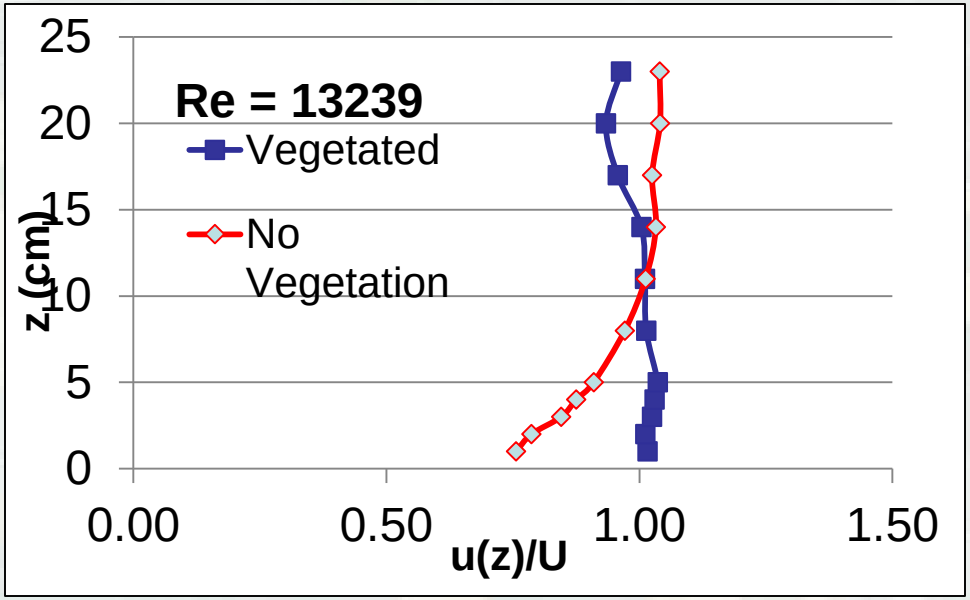
- Vegetation was constructed from ¼ inch polyolefin tubing (heat shrink tubing), 61 cm tall
- Polyolefin has comparable bulk modulus of elasticity to *Spartina alterniflora*
- Stem density of 400 stems/m^2 on a regular grid
- Did not attempt to simulate leaf structure

Important Nondimensional Parameters for Physical Models

- Reynolds Number $\mathrm{Re} = UL / \nu$
- Rouse Number $P = w_s / \kappa u_*$
- Froude Number $Fr = U / \sqrt{gL}$
- Keulegan-Carpenter Number $K_C = VT / L$

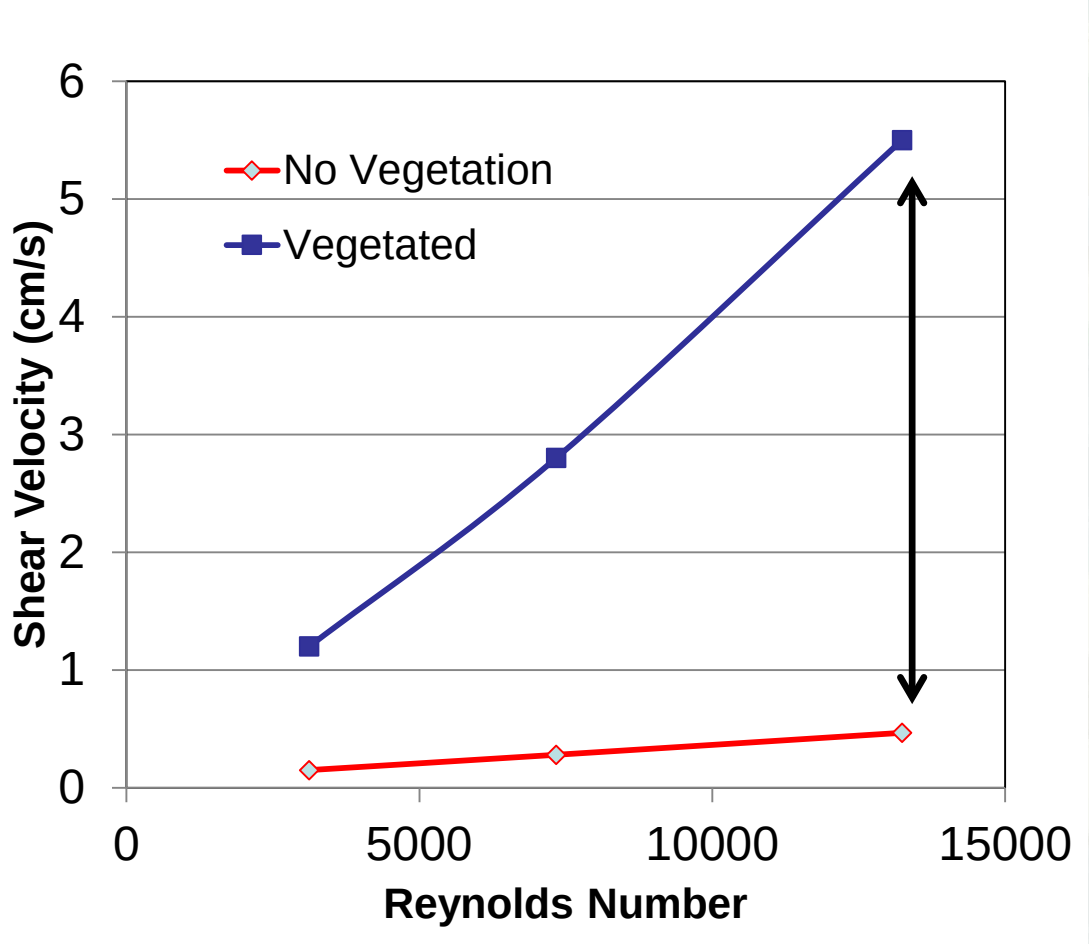
Flow through Vegetation -Vertical Velocity Profiles





- Velocity profiles are in agreement with law of wall without vegetation
- Vegetation greatly enhances mixing
- Vegetated velocity profiles are uniform across depth
- Mixing is being driven by flow around vegetation in addition to the boundary layer

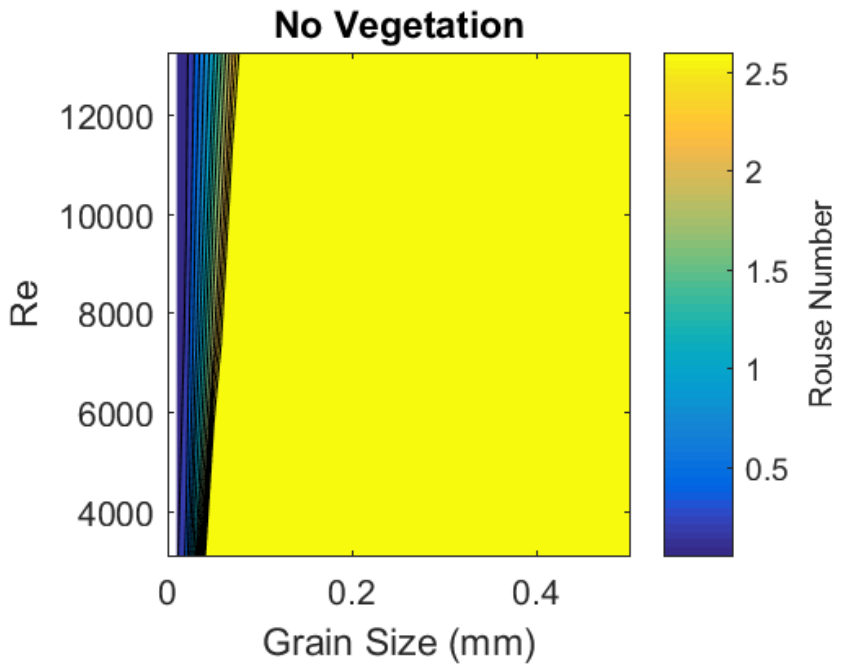
Shear Velocity

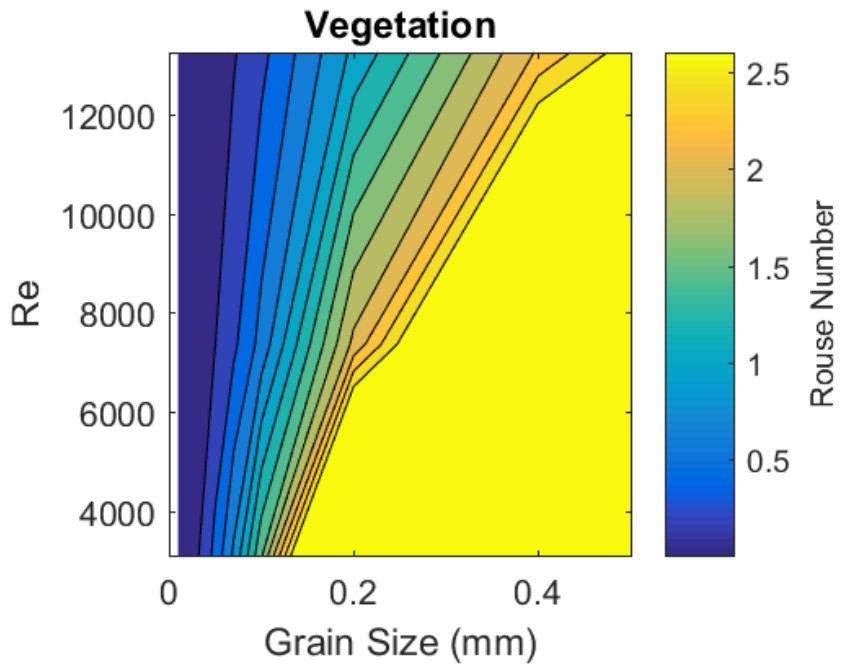


- Shear velocity is synonymous with shear stress in fluid
- Increases in shear velocity equates to greater mixing and greater sediment transport

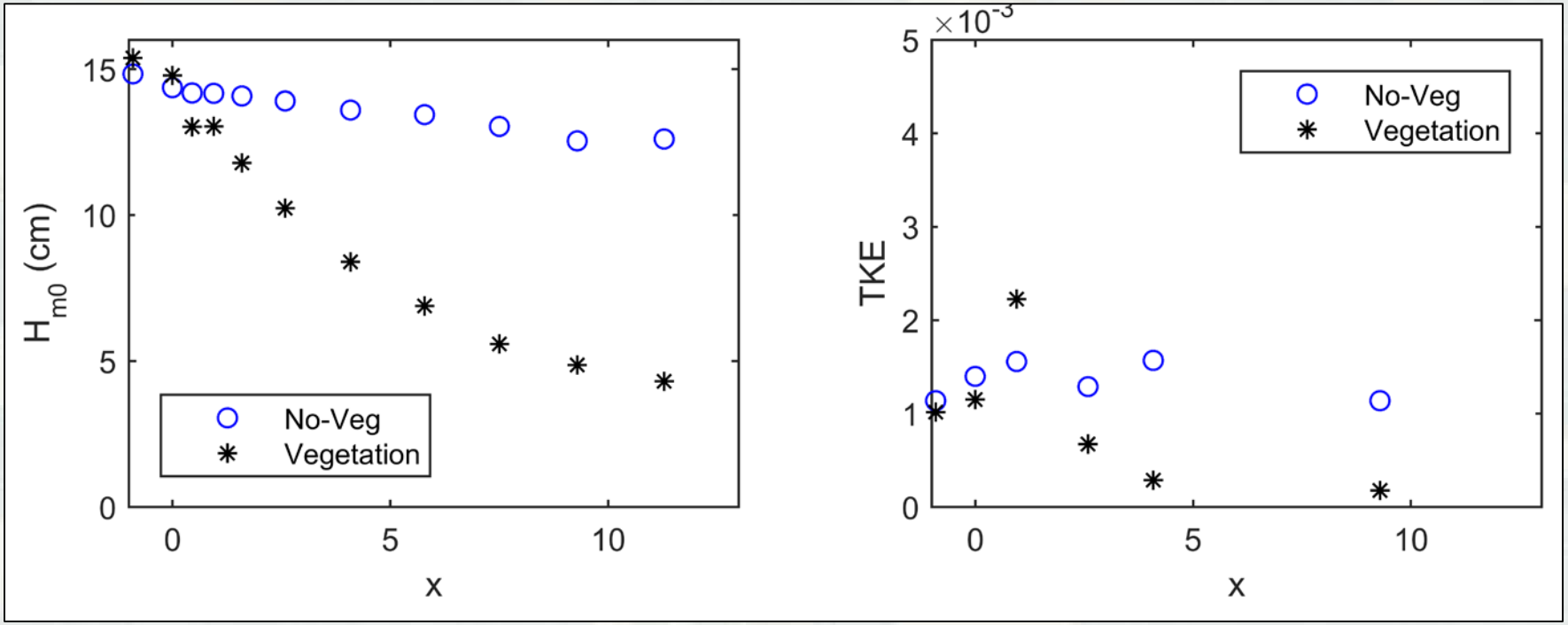
Changes to Sediment Transport

- Change in Rouse Number, P, with vegetated flow
- Vegetation moves sediment transport from bed load to suspended or wash load

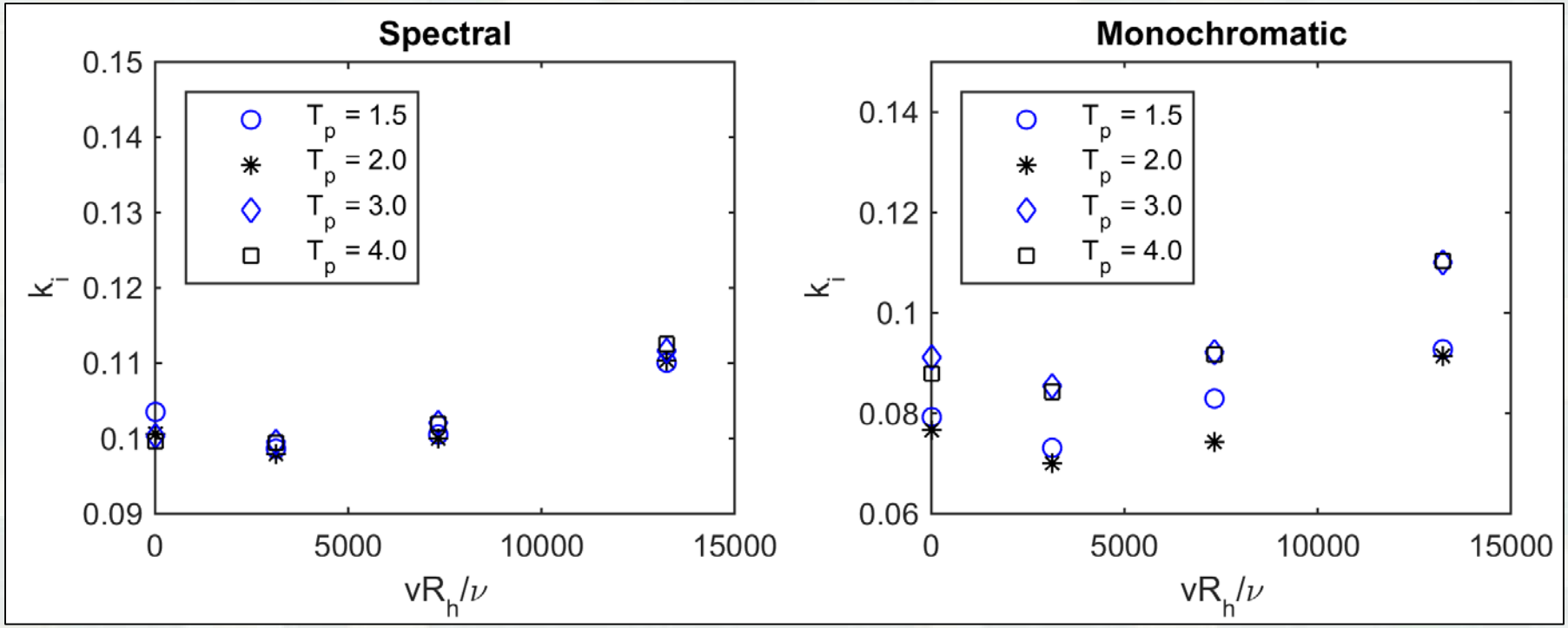




Wave Height Attenuation by Vegetation

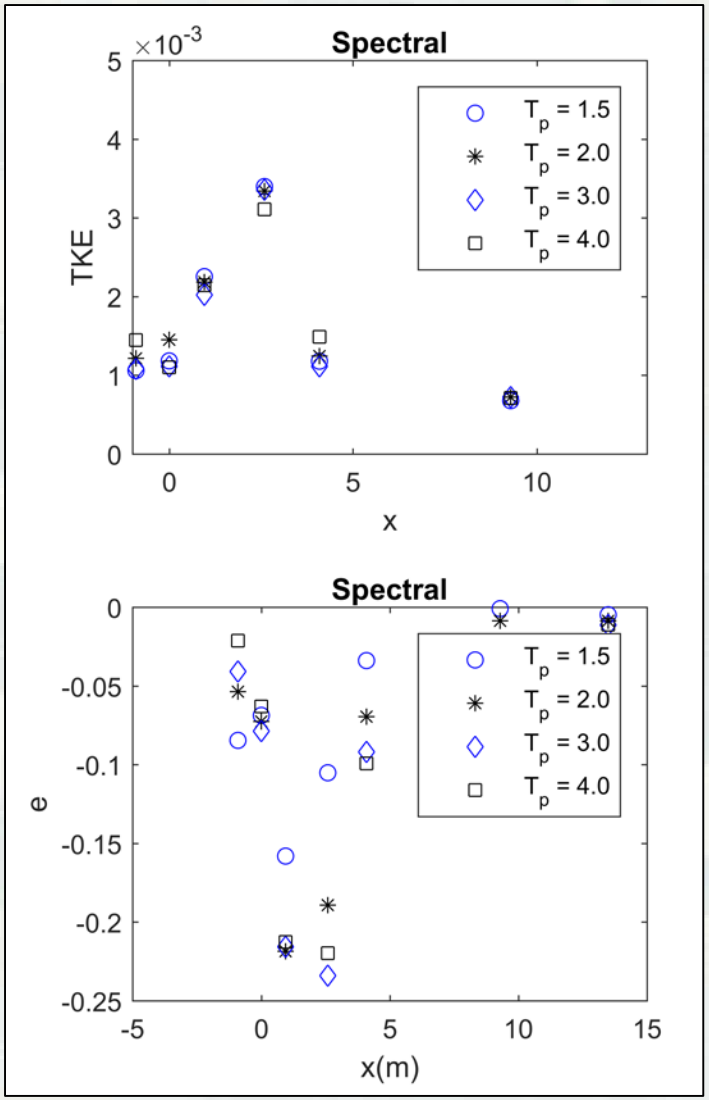


Wave Dissipation with Currents



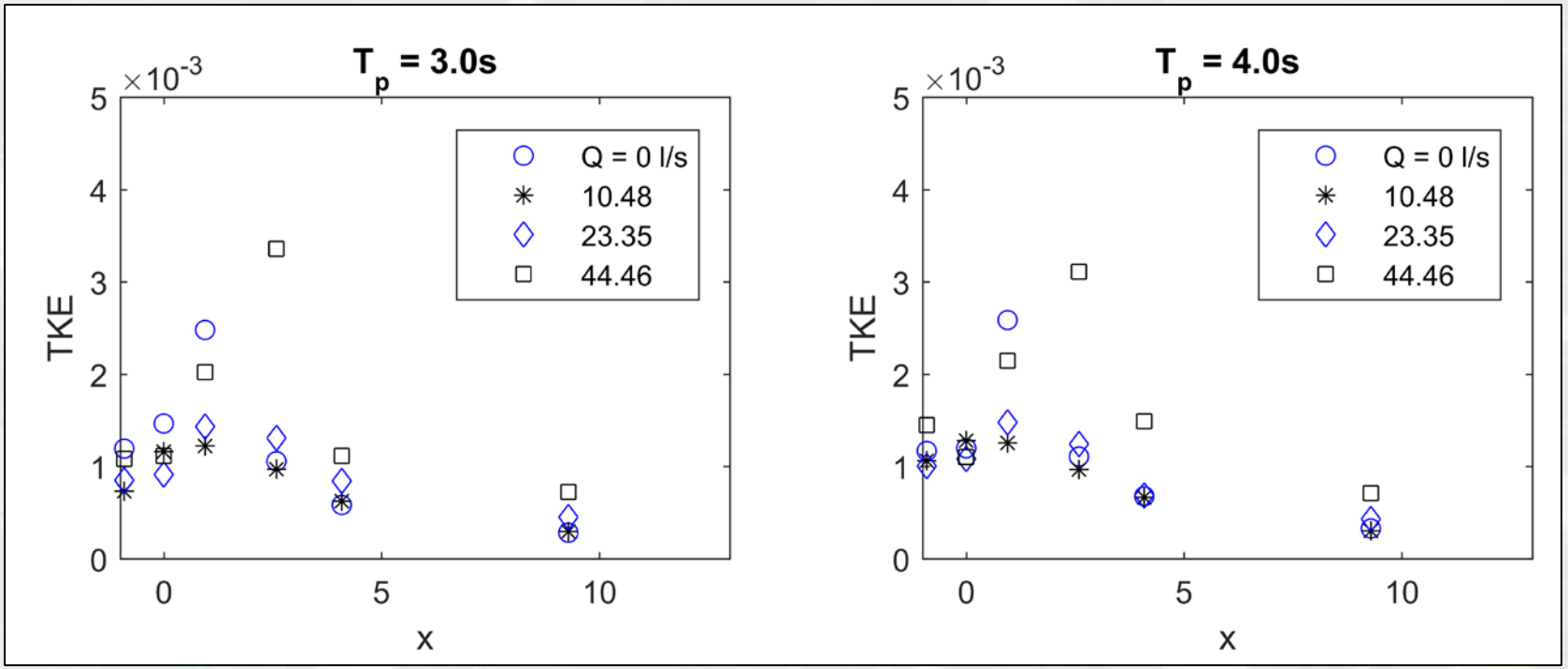
- Decay coefficient, k_i, captures the reduction in wave height due to vegetation
- For both regular and irregular wave conditions, a small current reduces wave attenuation
- Increasing mean flow (increase in Reynolds number) increases wave attenuation

TKE and Dissipation



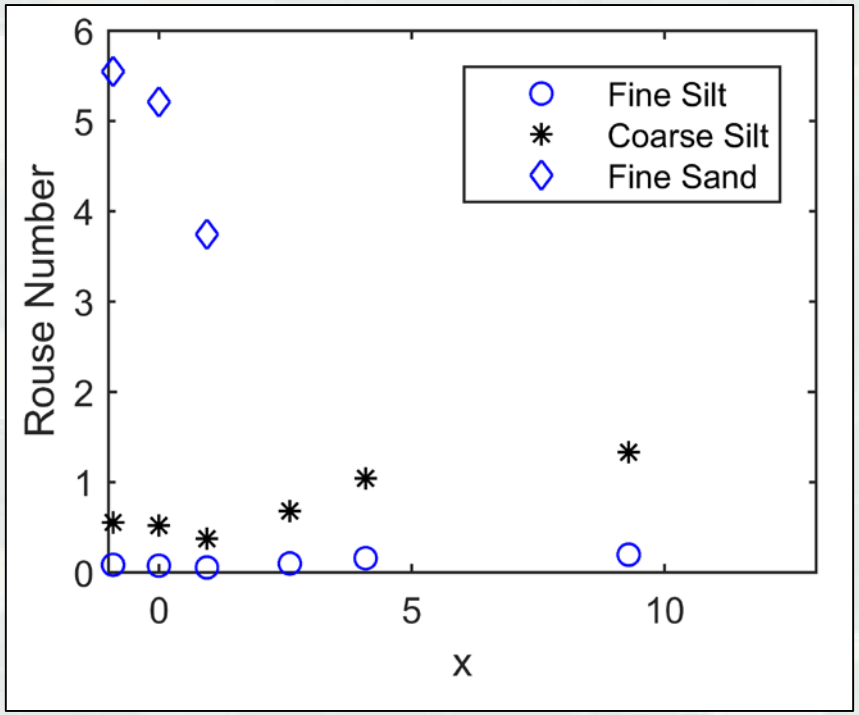
- Waves interacting with vegetation greatly increase turbulent kinetic energy, TKE, and dissipation, e.
- Increases in TKE correspond to increase in shear velocity and Rouse number, P.

Turbulent Kinetic Energy



- Wave propagating through vegetation with flow had similar TKE.
- Largest TKE values seen with no flow and highest flow

Modes of Transport



- Fine silt would move through vegetation in suspension
- Coarse silt transport would transition from suspension to bedload
- Fine sand may move at beginning of vegetation

Conclusions

- Physical modeling provides a method to directly study physical processes
- Including vegetation effects on wave height, mixing and sediment transport is important to reduce model uncertainty
- Flow through vegetation reduces the Rouse number (increased shear stress)
- Vegetation does reduce wave energy but not before resulting in a mixing/shear stress increase near the beginning of the vegetated region