Wave Attenuation by Vegetation: Role in Sediment Trapping and Retention

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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 (Stoessel 2007)
Waves Through Vegetation


- 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 from 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/m² on a regular grid
- Did not attempt to simulate leaf structure
Important Nondimensional Parameters for Physical Models

- Reynolds Number \( \text{Re} = \frac{UL}{\nu} \)
- Rouse Number \( P = \frac{w_s}{\kappa u_*} \)
- Froude Number \( Fr = \frac{U}{\sqrt{gL}} \)
- Keulegan-Carpenter Number \( K_C = \frac{VT}{L} \)
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

![Graph showing wave height attenuation by vegetation](image)
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.
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