The Notorious R.C.G.: Hydraulics Around Reed Canary Grass (Phalaris Arundinaceae)

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EISI Program
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Reed Canary Grass Intro

- Vigorous & Aggressive Invasive Species
- Widespread Throughout The U.S.
- Tolerant Of Wide Range Of Conditions
- Rapidly Dominates Stream Channels
- Impacts Hydraulics & Sediment Deposition
Why Do We Care?

- Dense Stands of RCG Overtake Stream Channel
- Increased Flow Resistance From Vegetation Drag
- Decreased Velocities/Conveyance
- Decreased Sediment Transport Rates
- Sediment Aggradation in Stream Channel
- Pools Fill With Sediment
- Loss of Habitat for Fish & Other Organisms
- Flooding During High Discharges
Presentation Overview

I. Collaborative Aspects of Project

(Presented by Brian & Nathan)

Research Question:

What plant/synthetic material could be used as a surrogate in flume studies to accurately represent the flexibility of RCG?

- RCG Measurement Data
- RCG Material Property Estimates
- Surrogate Selection for Flume Studies

II. Velocity Profiles Through RCG

(Analyzed & presented by Nathan Sadowsky)

III. Effects of RCG on Flow Resistance

(Analyzed & presented by Brian Draeger)
## RCG Measurements

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Median</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td># Stems/Plot</td>
<td>89.5</td>
<td>93.3</td>
<td>45.0</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>99.1</td>
<td>106.8</td>
<td>44.3</td>
</tr>
<tr>
<td>Diameter (mm)</td>
<td>2.75</td>
<td>2.61</td>
<td>0.78</td>
</tr>
<tr>
<td># Blades/Stem</td>
<td>6.0</td>
<td>6.3</td>
<td>1.2</td>
</tr>
<tr>
<td>Blade Length (cm)</td>
<td>24.0</td>
<td>23.4</td>
<td>4.5</td>
</tr>
<tr>
<td>Blade Width (cm)</td>
<td>1.30</td>
<td>1.26</td>
<td>0.33</td>
</tr>
</tbody>
</table>

![Diameters of RCG](chart1.png)

![Heights of RCG](chart2.png)
Force Deflection Tests For Estimating Material Properties

Bending Stiffness \( k \)

\[
k = \frac{F}{w} \left[ \frac{N}{m} \right]
\]

Flexural Rigidity \( J \)

\[
J = EI = \frac{F L^3}{w 3} \left[ Nm^2 \right]
\]

Moment of Inertia \( I \)

\[
I = \frac{\pi d^4}{64} \left[ m^4 \right]
\]

Elastic Modulus \( E \)

\[
E = \frac{J}{I} \left[ \frac{N}{m^2} \right]
\]
### RCG Material Property Estimates

<table>
<thead>
<tr>
<th>Material Property</th>
<th>Median</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bending Stiffness ($k \ [N/\text{m}]$)</td>
<td>0.473</td>
<td>0.535</td>
<td>0.272</td>
</tr>
<tr>
<td>Flexural Rigidity ($J \ [Nm^2]$)</td>
<td>0.027</td>
<td>0.030</td>
<td>0.018</td>
</tr>
<tr>
<td>Elastic Modulus ($E \ [\text{GPa}]$)</td>
<td>5.36</td>
<td>5.82</td>
<td>2.87</td>
</tr>
</tbody>
</table>

**Common Reed**

$$E \approx 5.92 \pm 0.50 \text{ GPa}$$

$$E \approx 19.3 \pm 3.0 \text{ GPa}$$

Frostick et al., 2014
Selected Surrogate: Shenandoah Switchgrass

RCG $\bar{E} \approx 5.8 \text{ GPa}$

Shenandoah $\bar{E} \approx 5.1 \text{ GPa}$
Merryfield Hydraulics Flume
Attempts To Attain Fully-developed Flow

Addition of Second Diffuser

Velocity Profile 2.5 ft Downstream

Velocity Profile 8.5 ft Downstream
Velocity Profiles through Reed Canary Grass

I. Intro: How does reed canary grass affect velocity profiles at varying water depths?

II. Methods – ADV Measurements

III. Results
   I. Contour Plots
   II. Depth Plots

IV. Discussion

V. Conclusion/Further Work
ADV Measurements

Lower Depth Trial

Higher Depth Trial
Lower Depth Trial – Average Velocities
Lower Depth Trial – Depth = 4 cm
Lower Depth Trial – Depth = 8 cm
Lower Depth Trial – Depth = 12 cm
Lower Depth Trial – Depth = 15 cm
Lower Depth Trial – Velocity Profiles
Higher Depth Trial – Average Velocities

![Diagram showing ADV Measurement Placements 2 with a grid overlay.]

![Graph showing average velocities with a color gradient indicating velocity values from 0 to 30 cm/s.]
Higher Depth Trial – Depth = 4 cm
Higher Depth Trial – Depth = 9 cm
Higher Depth Trial – Depth = 14 cm
Higher Depth Trial – Depth = 19 cm
Higher Depth Trial – Depth = 24 cm
Higher Depth Trial – Depth = 30 cm
Higher Depth Trial – Velocity Profiles

![Graph showing velocity profiles across different cross sections with a plant located at a specific depth in Cross Section 3.](image-url)
Discussion

• At both water depths, velocity distributions were similar

• Near-bed velocities
  • High near-bed velocities suggest that scouring (not sedimentation) would occur
  • Rhizomes and dead vegetation at base of plant were not modeled

• Fully developed flow did not occur
Conclusion/Further Work

• Reed canary grass has an effect on velocities independent of depth
• Shenandoah switch grass works well as surrogate
• Ground level plant structure needs to be modeled
• Sediment experiments should be conducted
III. Effects of RCG On Flow Resistance

Research Question:

How does the presence of RCG affect flow resistance, in terms of drag coefficients, with variations in plant patch to channel width blockage ratios and over a range of flow depths?

3 Patch Sizes Used: 6x6” 9x6” 12x6”

Blockage Ratios: 50% 75% 100%

3 Flow Depths Used: ~6” ~8.5” ~14”
Flow Resistance – Drag Coefficients:

Momentum Balance

\[ \sum F_x = \int U \rho_w (\vec{V} \cdot \hat{n}) dA \]

\[ \sum F_x = F_{p,1}^0 - F_{p,2}^0 - F_D - F_{\text{Bed}} = \rho_w \Delta A \left[ \sum_{j=1}^{k} U_{1j}^2 - \sum_{j=1}^{k} U_{2j}^2 \right] \]

\[ F_D = \frac{1}{2} \rho_w C_D A f U_{AP}^2 = \rho_w \Delta A \left[ \sum_{j=1}^{k} U_{1j}^2 - \sum_{j=1}^{k} U_{2j}^2 \right] \]

\[ C_D = \frac{\rho_w \Delta A \left[ \sum_{j=1}^{k} U_{1j}^2 - \sum_{j=1}^{k} U_{2j}^2 \right]}{\frac{1}{2} \rho_w A f U_{AP}^2} = \frac{2 \Delta A \left[ \sum_{j=1}^{k} U_{1j}^2 - \sum_{j=1}^{k} U_{2j}^2 \right]}{A_f U_{AP}^2} \]
Selection of Cross Sections Within Flume

Plan View of Flume

CS_{AP}  CS_1  CS_2  CS_2

0 ft  2.5 ft  3.5 ft  5 ft  7 ft  8.5 ft  10 ft

NTS

Sluice Gate

Tail Weir

Vegetation Patch
Approximating Frontal Areas
Drag Coefficient Results

Using velocity measurements at 8.5 ft from sluice gate as downstream CS of CV
Using velocity measurements at 7.0 ft from sluice gate as downstream CS of CV
Discretize Into a Greater # of Sub-areas
Move Downstream Cross Section Away From Patch

Plan View of Flume

Sluice Gate

0 ft

FLOW

Vegetation Patch

Tail Weir

NTS

8.5 ft

10 ft

CS₂

Move Downstream Cross Section Away From Patch
Move Downstream Cross Section Away From Weir

Plan View of Flume

- Sluice Gate
- Tail Weir
- FLOW
- Vegetation Patch
- CS$_2$
- Move Downstream Cross Section Away From Weir
Conclusion

• Drag Coefficient Results Not Considered Valid
• Repeat Experiments & Discretize Into More Sub-areas
• Repeat Experiment In A Longer Flume To Avoid Patch Wake Zone & Tail Weir Influences

Future Works

• 1st Develop More Reliable Methods to Estimate Drag Coefficients
• Determine How Drag Coefficients Vary With Different Degrees Of Submergence & Plant Bending
• Determine How Variations In Stem Densities, Patch Widths, And Patch Lengths Alter Drag Coefficient Estimates