Vegetation effects on river hydraulics

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Sacramento River below Hood
Sacramento River below Sacramento
Vegetation effects on river hydraulics

• Floodway conveyance, velocity response, & near-bank erosion
• Effects of vegetation-free areas next to levees
• Erosion around trees
• Wind wave/boat wake effects
River hydraulics

- Water flows downhill - gravity

- Resistance to flow characterized by “boundary resistance”:
  - Manning's n-values express boundary surface roughness
  - Manning’s equation quantifies boundary resistance
Manning’s equation

\[ Q = \frac{1.486}{n} R^{\frac{2}{3}} A S^{\frac{1}{2}} \]

Where \( Q \) = discharge (cubic feet per second)
\( n \) = Manning's roughness coefficient
\( R \) = hydraulic radius (ft) = \( P/A \) (wetted perimeter/area)
\( A \) = flow area (ft\(^2\))
\( S \) = energy slope (energy loss per ft of channel)

Manning's n-values are used to characterize boundary surface roughness.
What do typical Central Valley river sections look like?

- Very wide with respect to depth
- River bed and overbanks form most of wetted perimeter ("boundary")
- Banks (including levees) comprise small fraction of wetted perimeter
- Vegetation on levees typically a small contribution to overall flow resistance
Representation of river cross sections

Undistorted plot of river section

Sac River section
River = Sacramento River
Reach = Abv Sacramento
RS = 78.75

Plan: With vegetation
8/23/2007

Legend
WS PF 1
Ground
Levee
Bank Sta

How we typically view sections
Feather and Sacramento River cross sections

Feather River RS 33.0

Elevation (ft)

Distance (ft)

Sacramento River - RM 78.75

Elevation (ft)

Distance (ft)

20H:1V distortion

4H:1V distortion
Tree & shrub corridors near levees

Wallace, Clifford, Dwyer and Hershey (1994)
Reduced conveyance due to levee vegetation

- Hydrologic Engineering Center’s River Analysis System (HEC-RAS) computer program used for analysis
  - Runs for typical cross sections with and without levee vegetation
  - Comparisons based on change in conveyance capacity for typical river section
  - HEC-RAS provides data on velocity distributions in river cross section
Computed reduction in conveyance capacity

Change in conveyance of typical river sections on four Sacramento Valley rivers (vegetation on levees vs. no vegetation)

<table>
<thead>
<tr>
<th>River</th>
<th>Reduction in conveyance, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feather River</td>
<td>1.6</td>
</tr>
<tr>
<td>Bear River</td>
<td>5.6</td>
</tr>
<tr>
<td>Yuba River</td>
<td>3.3</td>
</tr>
<tr>
<td>Sacramento River</td>
<td>2.4</td>
</tr>
</tbody>
</table>
Effects of vegetation-free areas next to levees

- Increase in velocity near banks
- Potential for increase in scour on levee slopes
- In general, higher roughness equates to lower near-bank velocity and lower shear stresses
Effect of vegetation on velocity

Velocity profiles with submerged and unsubmerged vegetation (Fischenich, 2000)
Typical near-bank velocities

Feather River Section Plan: without veg 8/23/2007
River = Feather Reach = Typ section RS = 2

Station (ft) Elevation (ft)

Legend
- WS PF 1
- 1 ft/s
- 2 ft/s
- 3 ft/s
- 4 ft/s
- 5 ft/s
- Ground
- Bank Sta

n = 0.035 V = 1.5 ft/sec

n = 0.080 V = 0.6 ft/sec

Channel V = 4.1 ft/sec
Bank $n = 0.035$
$V = 1.5 \text{ ft/sec}$

Channel
$V = 4.1 \text{ ft/sec}$
Bank $n = 0.080$
$V = 0.6$ ft/sec

Channel
$V = 4.1$ ft/sec
Wave runup on levees

- Estimates depend on wind wave characteristics, levee geometry, and levee surface conditions
- Wave runup elevations represent expected height of a breaking wave up the levee slope
Relative wave runup for different surfaces

- Grassed levees act as smooth surface
- Shrub and tree vegetation will attenuate waves to some degree
- Vegetation also provides additional erosion protection
- Rock and riprap provide the greatest degree of protection
Rock and riprap

• Based on Dutch experience, reduction factor in wave height for rock and riprap structures varies between 0.5 and 0.6
• Rock and riprap structures impede runup not only by slope roughness, but also by permeability of riprap and under layers placed over an impermeable slope

*Estimating Irregular Wave Runup on Rough, Impermeable Slopes*,
Steven A. Hughes, USACE
Grass mat provides high erosion resistance:

- Due to structure of **root layer** and not, as often thought, the thickness of layer of grass leaves and stems above ground
- Plant roots also important in keeping particles of soil together
Effects of rooting of grass mat

• Well-rooted grass mats can resist 1-2 days of sustained exposure to flood velocities
  • Typically very little sod erosion; even parts above ground remain intact
• Poorly rooted grass mats may fail within a few hours
• What is required is an actively growing, perennial grass (sod forming)
Effectiveness of plant roots

- Plant roots keep particles in soil together
- Very fine root hairs and fungal threads in soil keep fine soil particles together, anchored within the substrate
- Coarser plant roots keep large and small particles together in a network
- Network of fine and coarse roots makes sod a strong, springy and flexible layer that can deform without tearing

Erosion resistance of grassland as dike covering, Technical Advisory Committee on Flood Defence, The Netherlands
Erosion around trees

- Hydraulic model study by USACE tested use of tree stands as a method for protecting levee embankments from waves caused by wind and boat-generated wakes.
- 12 plans covered a range of thickness of tree stands, using 4-in.- & 12-in.-diameter tree stems, with and without defoliated branch systems.

*Levee Wave Wash Protection by Trees; Hydraulic Model Investigation.*
D. G. Markle, WES, USACE 1979
Erosion around trees (continued)

- For tree stems without branches, wave reduction was small (9 to 15% of wave height)
- For tree stems with branch systems, maximum wave attenuation was 45 percent, although the average was less

*Levee Wave Wash Protection by Trees; Hydraulic Model Investigation.*
D. G. Markle, WES, USACE 1979
Case Study - Williams River in Australia

- Riparian vegetation was cleared with only small pockets of remnant vegetation
- Significant portion of river has either no trees or limited stands 1-2 trees wide, and little or no understory vegetation
- Later recommended a riparian reforestation program to restore a vegetative buffer and reduce bank erosion

Williams River Bank Erosion Study, Final Report, GHD Pty. Ltd., NSW
Recommendations – Williams River

- Provide bank resilience and roughness with mixture of deep rooted and shallow rooted plants to stabilize and bind soil
- Use shallow-rooted plants to provide ground cover to protect top of bank from potential erosion by flood flows
- Use trees and shrubs to decrease velocity of flood flows to reduce scour potential
- Implement a boating management plan to reduce impacts of boating practices and minimize wake erosion
Concerns – Williams River

- Restoring vegetation along the river would increase hydraulic resistance during flood events.
- Could potentially increase flood heights and reduce flood protection.
Pros and cons

• Levee armoring with properly designed woody material and vegetation will:
  • Slow floodwater velocity near banks
  • Dissipate wave energy
  • Reduce scouring potential
  • Increase soil shear strength
• Minor decreases in river conveyance capacity on wide, perennial channels
Benefits of vegetation near levees

Vegetation can be desirable and can positively affect the maintenance and stability of levees.

- Levee designs should incorporate woody materials as corridor plantings between the levee and river channel
- Protective vegetated cover on levee structure is desirable if inspection & flood fighting capability is maintained
Risks of removing vegetation

- Banks and levee slopes may be exposed to greater near-bank velocity and wind and boat wake wave scour
- Protection from wave runup may be reduced, especially on slopes without rock