Effects of Riparian Vegetation on Channel Hydraulics and Flow Conveyance

Andrew P. Hood

Sustainable Resources Group Intn'l Inc.

Presented at: Ecology, Restoration, and Management of Hawaiian Stream and Riparian Systems, Windward Community College, May 22, 2008

Objectives

- **Present overview of hydraulic variables that control flow regime in open channels**
- **Identify relationship of bed and bank material on flow conveyance**
- **Discuss how riparian vegetation morphology varies among vegetation types and its effect on channel roughness**

Channel Issues in Hawai`i

Does vegetation within channels reduce flow conveyance?

- From an engineering perspective, vegetation in channels has been seen as a nuisance
- Widely thought that vegetation increases flooding

Examples of Maintained versus Vegetated Channels

Channel Types in Hawai`i

1. Natural-Non Prismatic
   - Riparian zone may be comprised of native and/or non native species
   - Channel in state of quasi-equilibrium
2. Channelized-Non Hardened
   - Riparian zone may be comprised of native and/or non native species
   - Channel generally incised
3. Channelized-Hardened-Prismatic
   - Maybe bed and/or sides

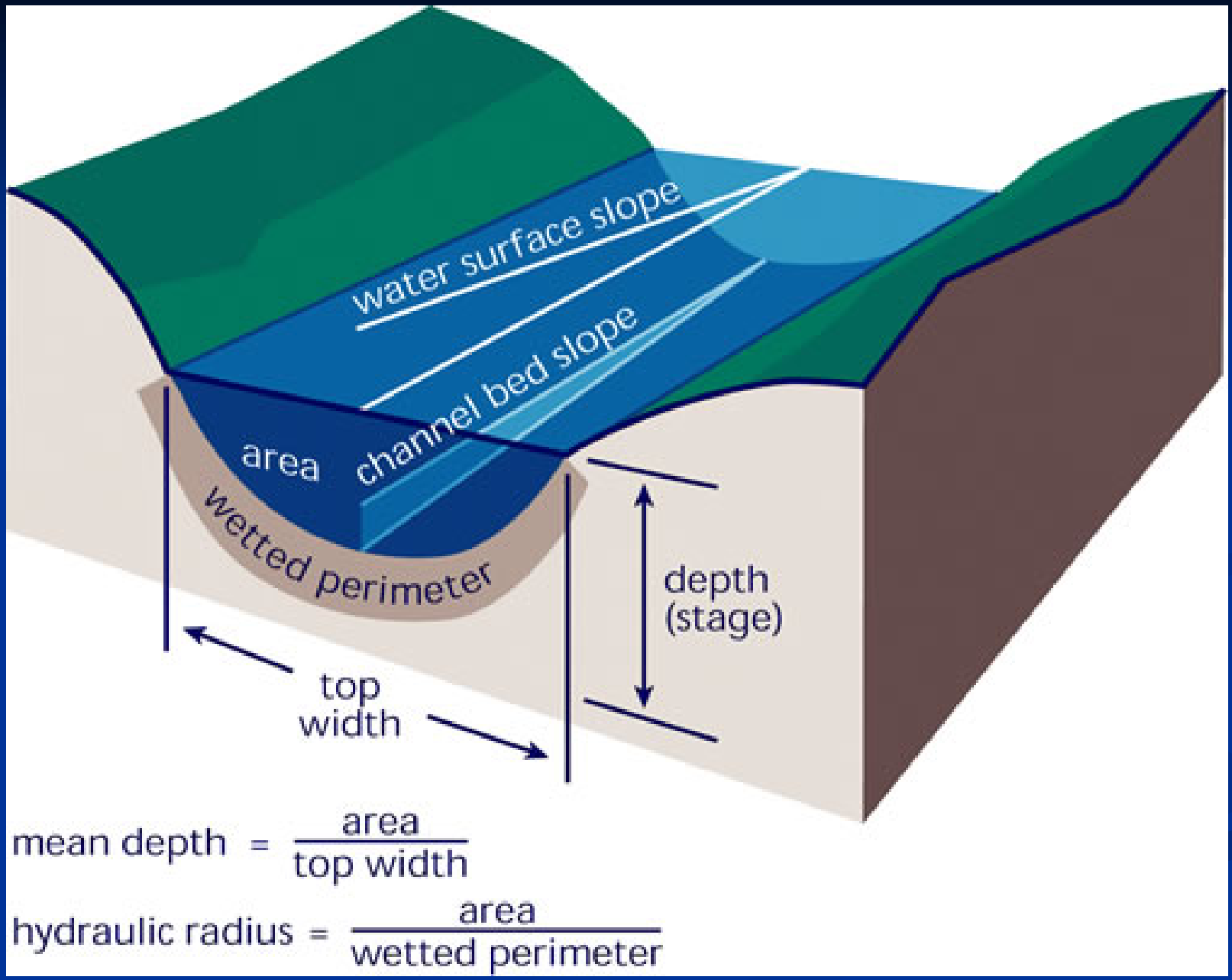
Natural Non-Prismatic Channel

Channelized-Non Hardened

Channelized-Hardened

Hydraulic Variables of Open Channels

- Channel width: w (ft)
- Channel depth: d (ft)
- Cross sectional area: A (ft^2)
- Wetted perimeter: Pw (ft)
- Hydraulic radius: r = A/Pw (ft)
- Channel gradient (slope): S (ft/ft)



$$\text{mean depth} = \frac{\text{area}}{\text{top width}}$$

$$\text{hydraulic radius} = \frac{\text{area}}{\text{wetted perimeter}}$$

Manning's Equation

- Developed by Robert Manning in 1890
- Most widely used 1D equation for open channel flows

$$V = 1.486/\ n\ (r^{2/3}\ S^{1/2})$$

Where:

V = average velocity of flow (ft/sec),

n = coefficient of roughness,

r = hydraulic radius (ft),

S = slope of hydraulic gradient (ft/ft).

Using Manning's Equation to Compute Discharge

Discharge (Stream flow)

Q = capacity (ft^3/s),

$$Q = VA$$

Product of

- A = area of cross section (ft^2)
- V = velocity (ft/s) [determined from Manning's equation]

Velocity Varies

- With distance from bed
- With distance from banks
- Downstream
- Over time

Bed and Bank Material

- Material that water flows over in channels has varying roughness and is assigned an n value
- Roughness can vary across channel and longitudinally
- In general, the rougher the material the greater the resistance to flow

- Example of roughness (n) values:
  - Concrete, $n = 0.01$
  - Rocky stream, $n = 0.052$
  - 1.5 ft tall sedge, $n = 0.061$

Riparian Vegetation Effects on Roughness

1. Plant morphology and material properties are significant factors in estimating n value:
   - Flexible versus Rigid
     - Sedges (*Carex sp*) - Flexible with high modulus of elasticity
       - Able to withstand inundation and high velocities
       - As flow depth increases, roughness decreases
     - Trees - Rigid with low modulus of elasticity (*not all*)
       - Potential to fail
       - Roughness constant with flow depth

Riparian Vegetation Effects on Roughness

2. Studies show inverse relationship between root diameter and tensile strength
   - Woody plants often contain tap or heart roots
     - Low total root surface area in contact with soil relative to plant mass
     - Large heavy plants can possibly surcharge steep slopes
   - Phreatophyte (riparian plants) supported by fibrous roots
     - High total root surface area in contact with soil relative to plant mass

Water Surface Elevation Under Varying Vegetation Regime

Analysis using Manning's Equation was performed to compare estimated water surface elevations under two conditions:

- Vegetated with combination of native and non-native vegetation
- Non vegetated following "channel maintenance"

- Manning's n was varied under both scenarios while all other variables were held constant

Analysis Location

Analysis of Water Surface Elevation Differences Under Varying Vegetation Regime

Actual Flow Event
(following channel maintenance with minimal vegetation)

Q (discharge) = 65 cfs

Manning's n = 0.045

Depth = 4.50 feet

Modeled Flow Event
(increase in dense vegetation)

Q (discharge) = 65 cfs

Manning's n = 0.075

Depth = 4.65 feet

Change in vegetative conditions or coefficient of roughness (Manning's n) have minimal impact on flow depth (~0.15 ft)

Analysis of Water Surface Elevation Differences Under Varying Vegetation Regime

Nine additional hypothetical runs were made in which Manning's n value was varied to represent changes in vegetation types across channel

- Maximum water depth was estimated at 8.5 feet under conditions of complete tree blockage in channel (representative of Hau stand)

Summary

- Riparian adapted species (phreatophytes) have minimal impact on flow conveyance
- Current management of riparian corridors is to completely remove vegetation, resulting in flooding concerns
- Riparian zones should be managed by utilizing species that can withstand inundation without adversely altering flow conveyance