Hydraulic Analysis Methods for Restoration

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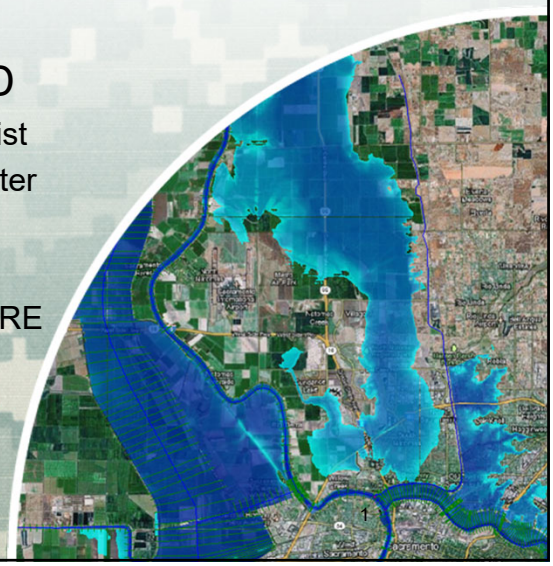
Includes Content by:
Gary W. Brunner, P.E., D.WRE



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Hydrology vs Hydraulics

HEC-HMS

How Much?

When?

HEC-RAS

Where? (Who)

How Deep?

2

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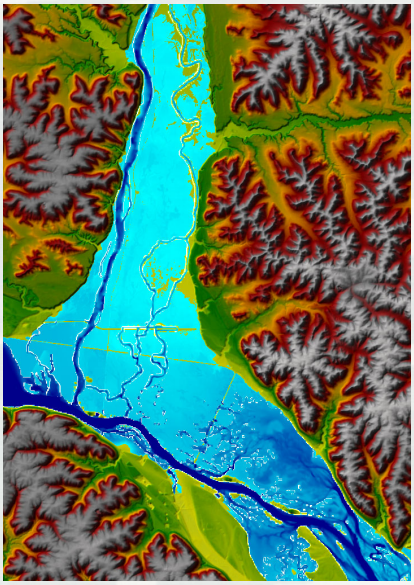
Hydraulic Products for Restoration Analyses

- Hydraulics Results
  - Depth
  - Inundation Boundary
  - Velocity
    - 1D-2D-3D?
- Channel Response
  - Channel Forming Discharge
  - Channel Stability Analysis
  - Mobile Bed Modeling (1D-2D)
- Water Quality Modeling



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What Can I Get From My RAS Nerd?

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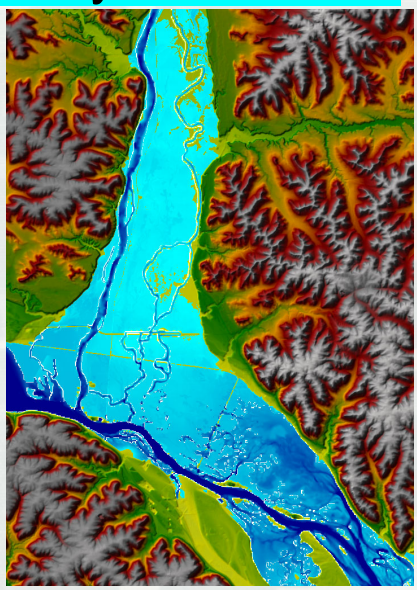

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What Can I Get From My RAS Nerd?

- Hydraulics Results
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Today's Workshop

Tomorrow's Workshop

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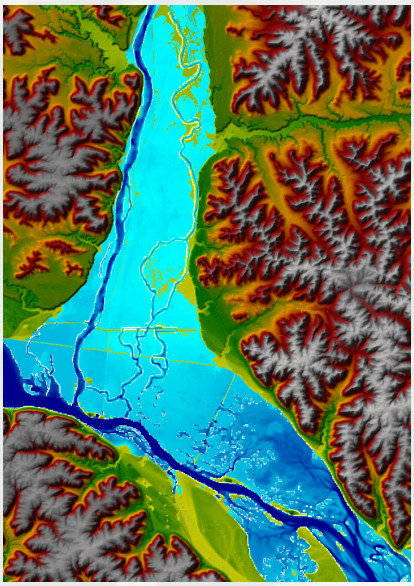

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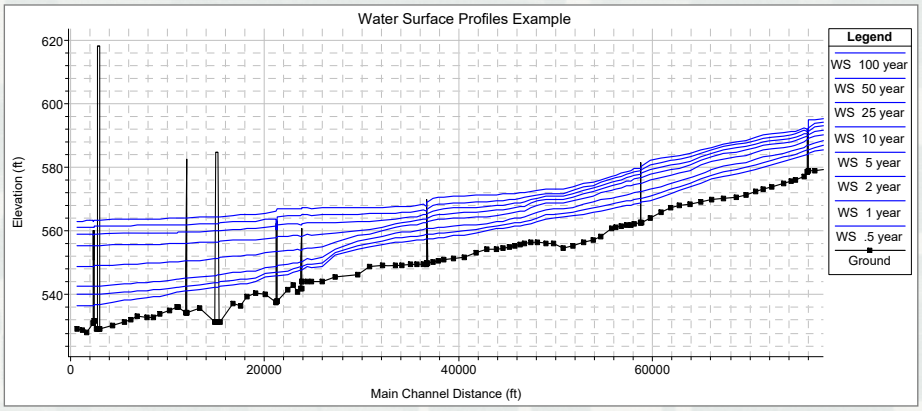
Water Surface Profiles



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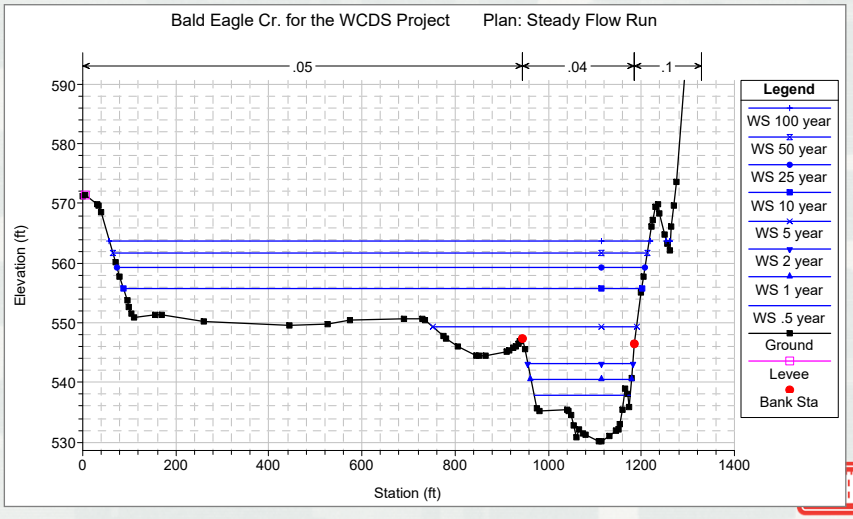
Water Depth
(Channel and Floodplain)



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Water Surface Elevations

- Water surface elevations and depths need to be computed for a range of flows from low to high.
- This information can be used in many ways:
  - Determining stage vs. duration relationships
  - Calculating required minimum flow rates
  - Determining what flow rate will put water into the overbank area.
  - Evaluating the effects of large events on wetlands and channel restoration projects
  - Calculating fluctuations in stages due to fluctuations in flow rates from an upstream project (reservoir).

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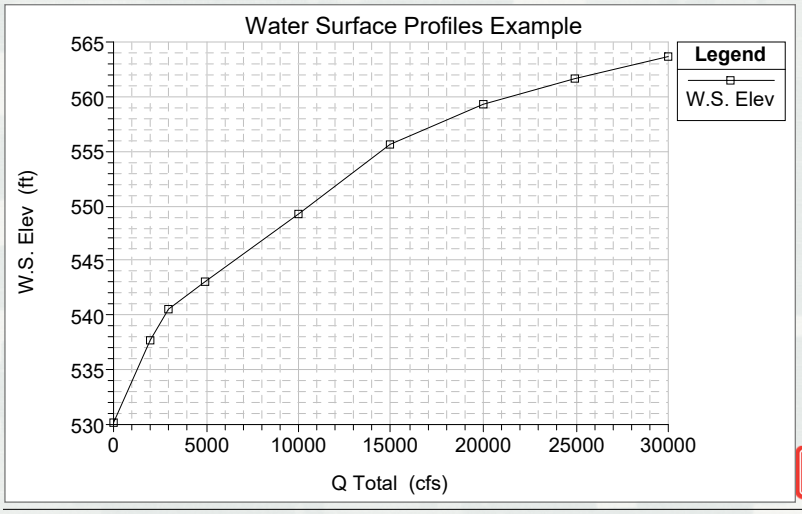
Computed Rating Curve at a Cross Section



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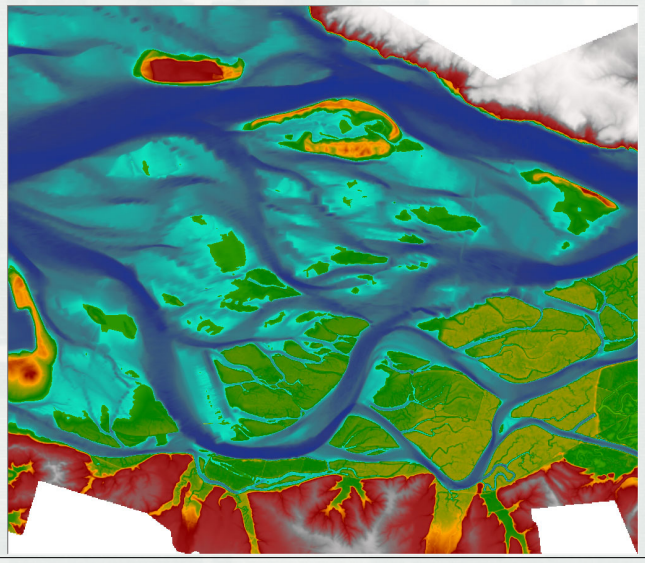
Water Depth – RAS-Mapper



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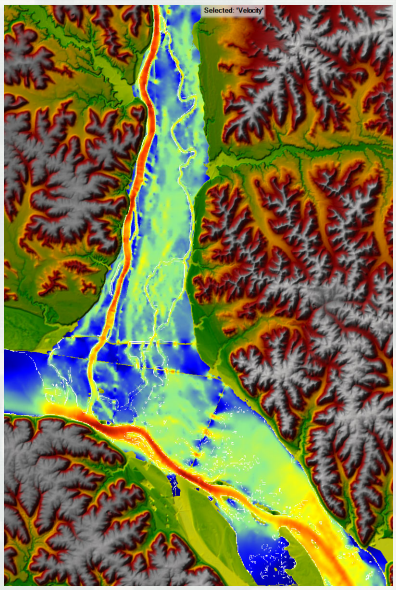

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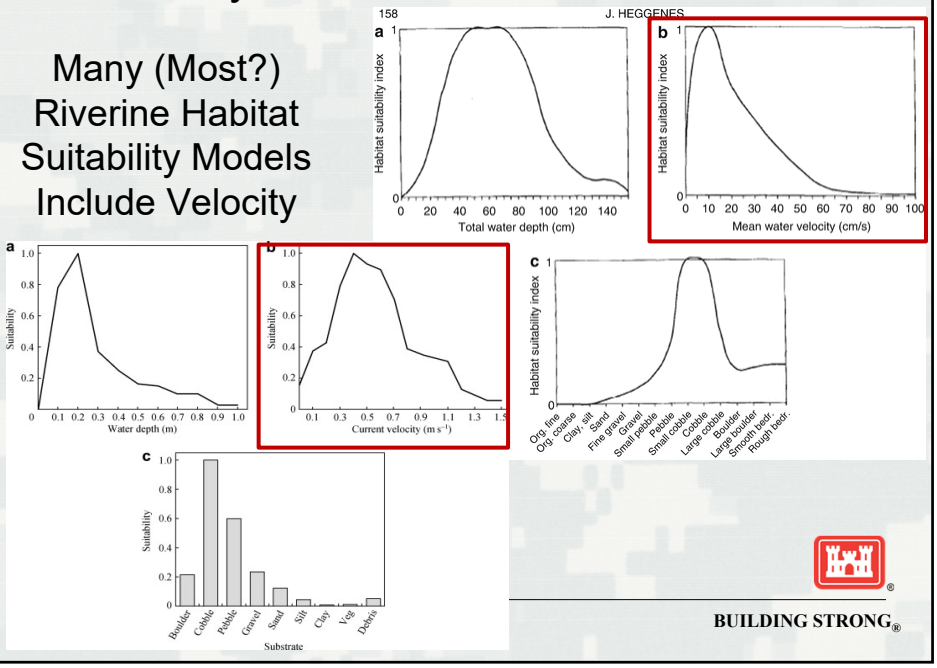
Velocity Matters More in Restoration

Many (Most?) Riverine Habitat Suitability Models Include Velocity



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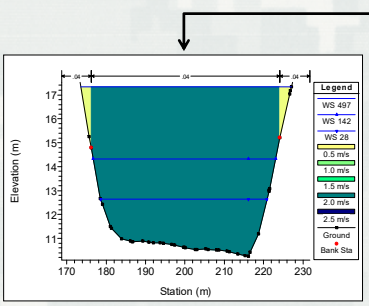
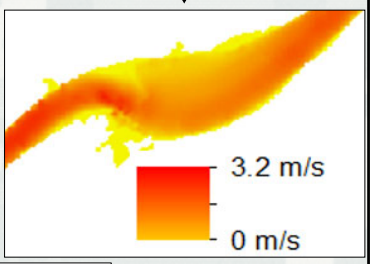
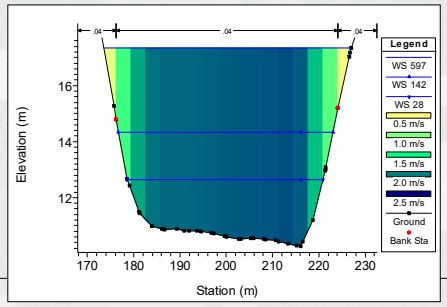
Velocity (3 Options)



1D Cross-Section Average



2D



Distributed 1D

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Velocities

- Velocities are required to evaluate many aspects of restoration projects.

  Examples:
  - ▶ Sediment transport calculations
  - ▶ Channel stability (erosion and deposition)
  - ▶ Plant stability
  - ▶ Fish passage, spawning, and general habitat
  - ▶ Habitat for other aquatic species
  - ▶ Hydraulic structure design (structures for stream stability or habitat improvements)

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Velocities

- The level of detail in velocity information varies with the different levels of hydraulic models.
- Manning's Equation – provides a single average velocity at a cross section for a given flow rate:

$$\overline{V} = \frac{1.49}{n} R^{2/3} S_f^{1/2}$$

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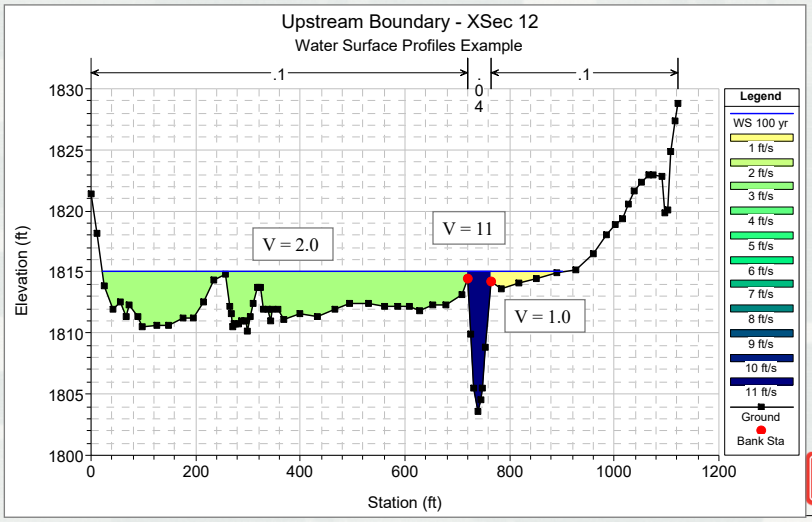
Channel and Floodplain Average Velocities



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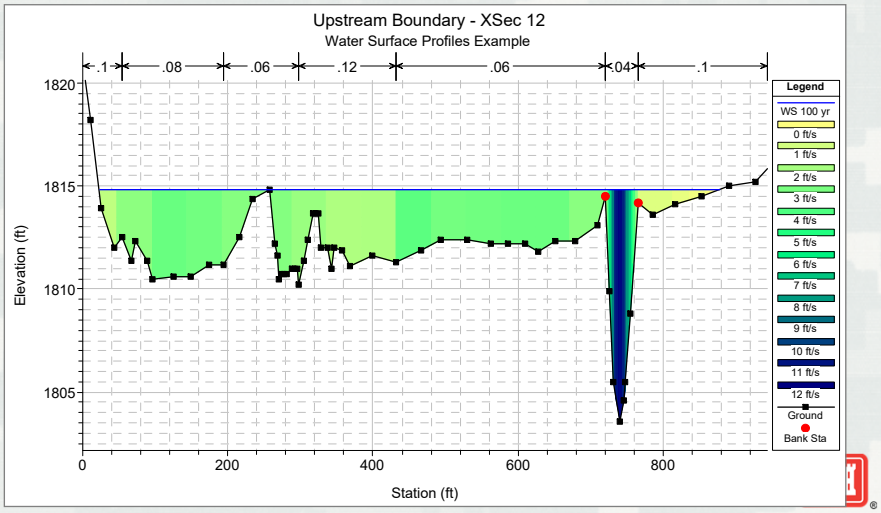
Detailed Velocity Slices



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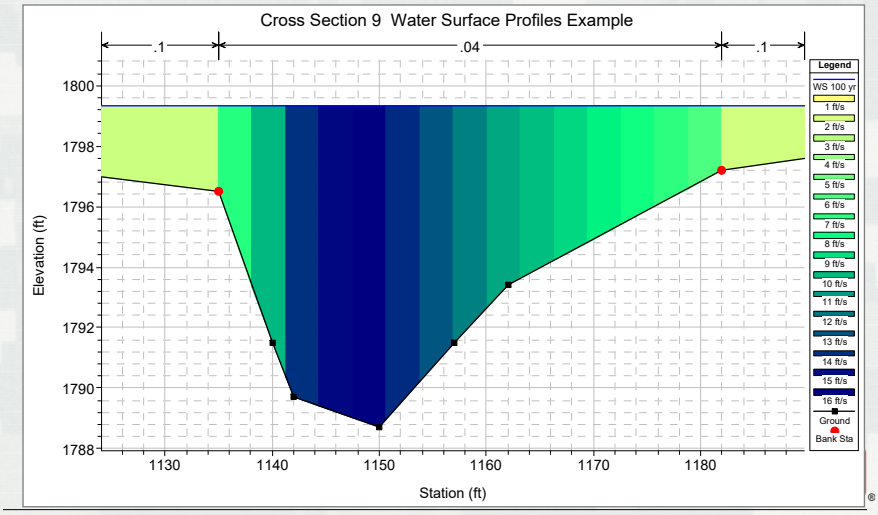
Main Channel Velocities



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1D Hydraulic Model Velocities

- One dimensional models calculate velocities with the assumption that the flow is perpendicular to the cross sections.
- Velocities are horizontally as well as depth averaged.

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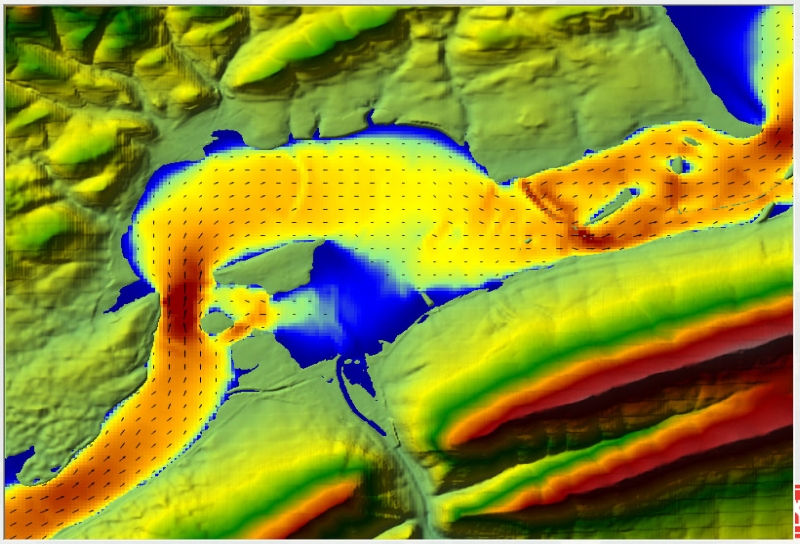
Two-Dimensional Model Velocities



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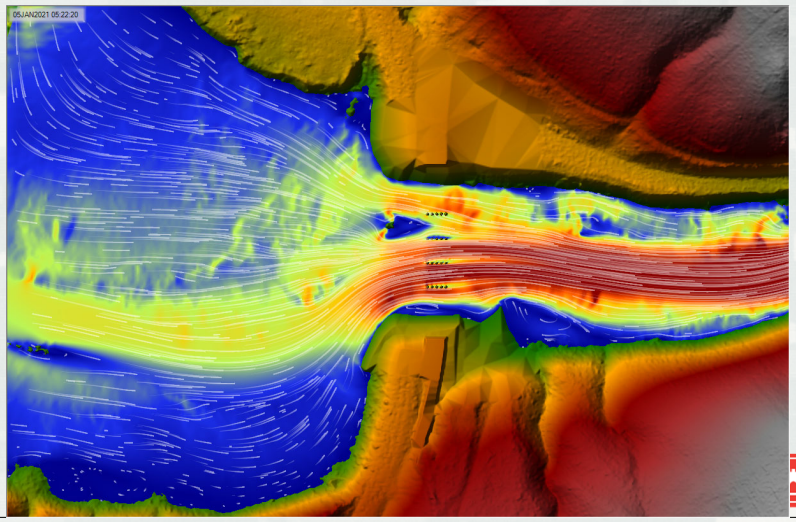
Multi-Dimensional Model Velocities-Continued



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So….

…2D or not 2D?

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Hydrologic Engineering Center

Modeler Application Guidance for Steady vs Unsteady, and 1D vs 2D vs 3D Hydraulic Modeling

August 2020

https://www.hec.usace.army.mil/publications/TrainingDocuments/TD-41.pdf

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SELECTING BETWEEN ONE-DIMENSIONAL AND TWO-DIMENSIONAL HYDRODYNAMIC MODELS FOR ECOHYDRAULIC ANALYSIS

S. A. GIBSON[a]* AND G. B. PASTERNACK[b]
[a] Hydrologic Engineering Center, Davis, California, USA
[b] Department of Land, Air, and Water Resources, University of California at Davis, Davis, California, USA

RIVER RESEARCH AND APPLICATIONS
River Res. Applic. (2015)

Three Reaches	Three Flows
Leveed Reach	Base Flow
Meandering Reach	Bankfull Flow
Anastomosing Reach	Flood Flow

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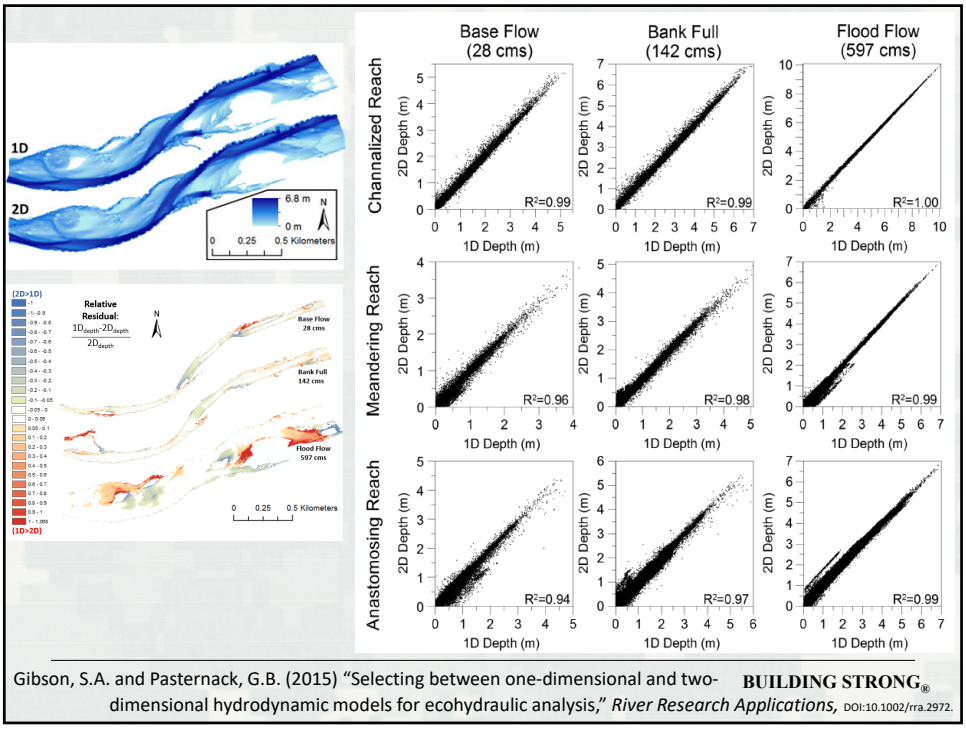

Gibson, S.A. and Pasternack, G.B. (2015) "Selecting between one-dimensional and two-dimensional hydrodynamic models for ecohydraulic analysis," *River Research Applications,* DOI:10.1002/rra.2972.

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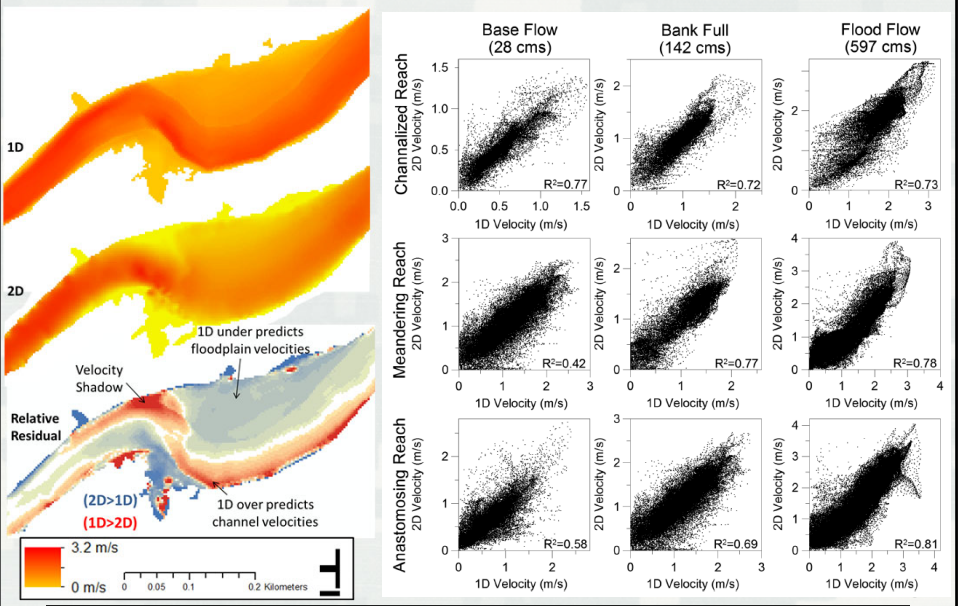

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Model Selection

- The appropriate model for a given hydraulic study is dependent on many factors:
  - Study objectives
  - Data availability
  - Hydraulic considerations
  - Required Accuracy
  - Required Hydraulic Outputs
  - Modeling requirements (time, experience, cost)
  - Ease of application

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Hydraulic Products for Restoration Analyses

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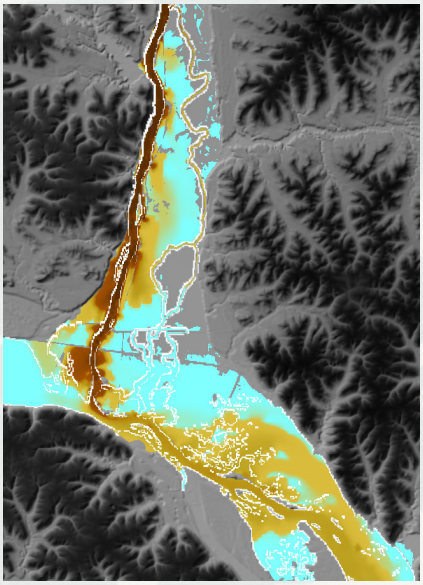

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A Brief Digression About Morphological Failure Modes

Morphological failure modes are one of the most common (maybe the most common) failure mode of our channelization projects: FRM or Restoration.

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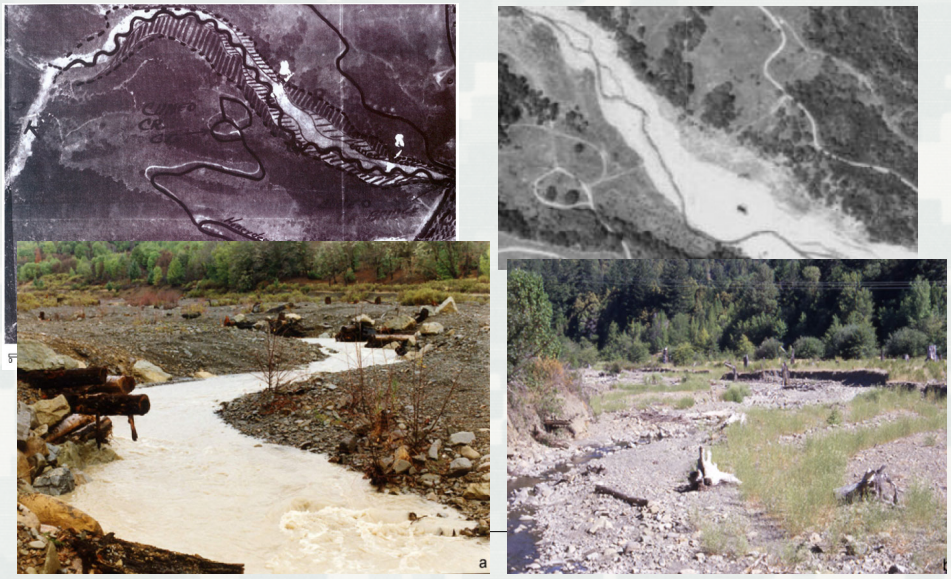
A Brief Digression About Morphological Failure Modes



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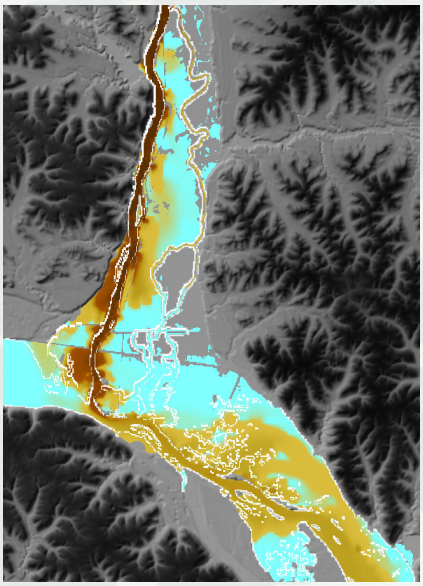

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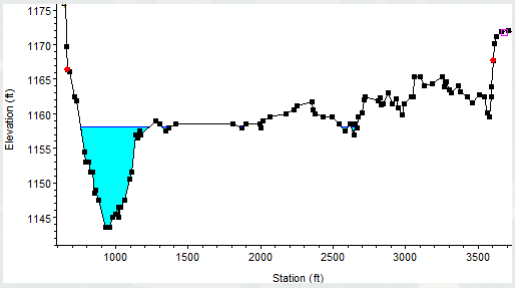
Philosophical Question

Why are river channels the shape and size they are?

What determines how much flow the channel can carry before it spills into the floodplain?



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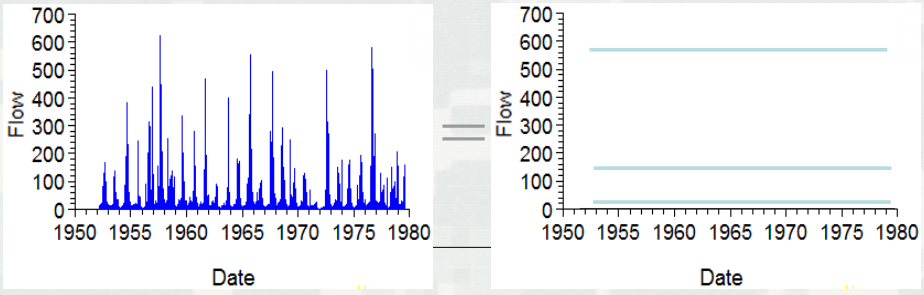
"Channel Forming Discharge"

"The single steady discharge which would produce the same cross section morphology, alluvial features, planform geometry, and dimensions as those generated by the actual flow regime." (Inglis, 1949)



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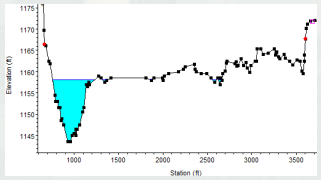
Channel Forming Discharge

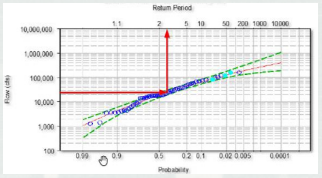
Three Options

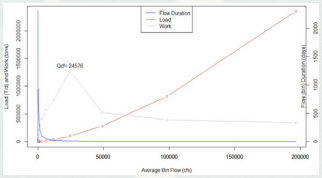
1. Bankfull Discharge

2. Recurrence Interval

3. Effective Discharge







If you are designing a channel, it might be worth asking:

What flow should the channel carry?

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Bankfull Discharge

- Choosing the Bankfull Discharge as the channel forming discharge is a simple logical step – the flow most responsible for forming the channel is the flow that fills the channel.
- But it can be difficult to determine definitively.
- And bankfull can depart from the other methods in incised channels or rivers in arid environment.

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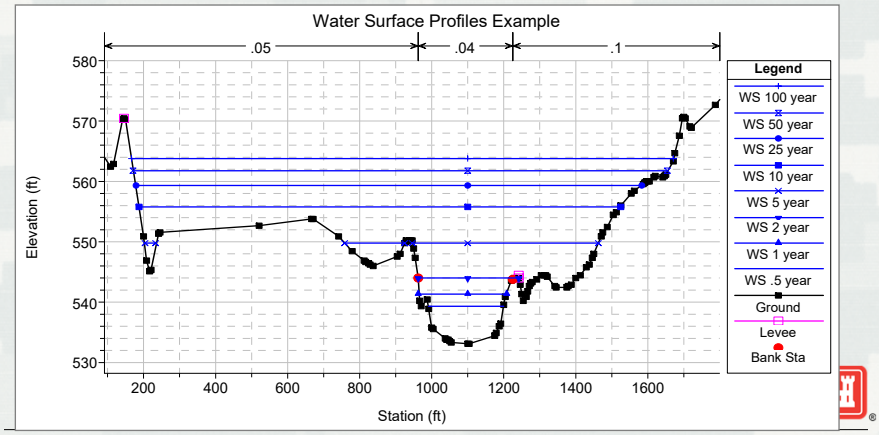
What is the Bankfull Stage?

- Stage just before overbank flow
- Lower limit of perennial vegetation.



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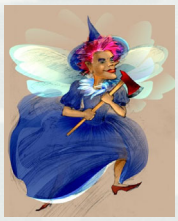
Effective Discharge

The flow that moves the most sediment over time



Wolman and Miller's Parable of Magical Woodcutters

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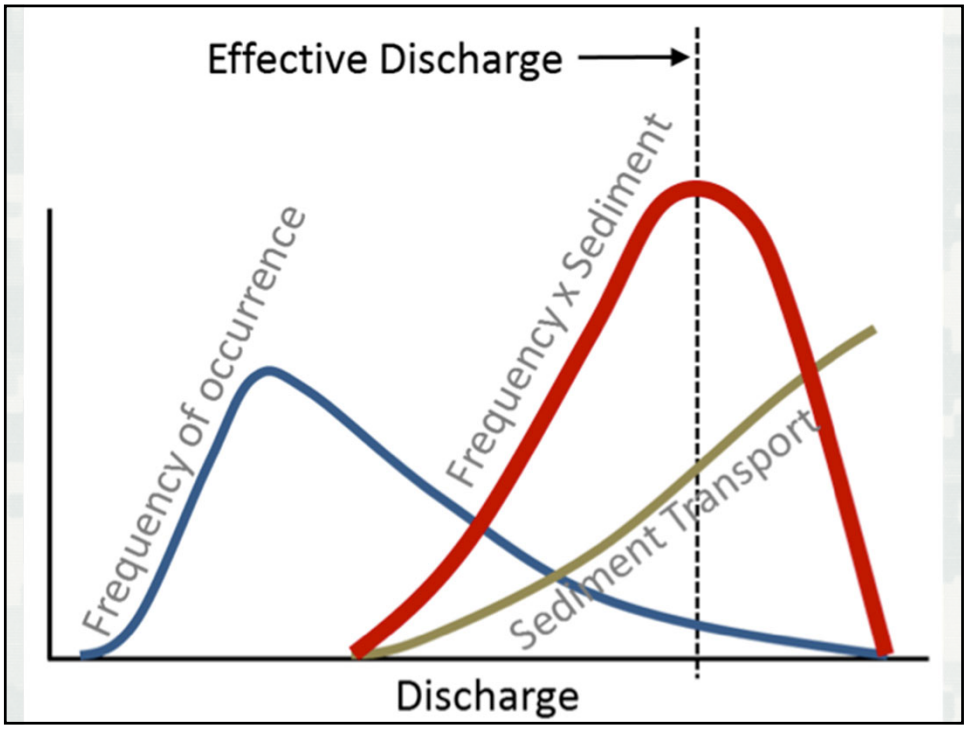

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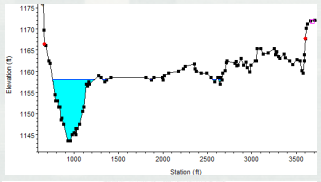

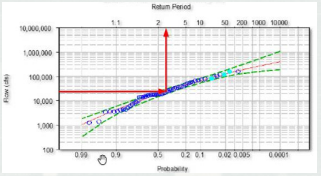

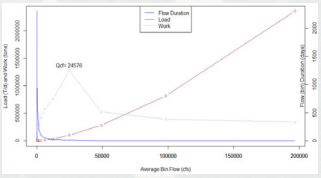

So, which should you use?

(d) All of the above.

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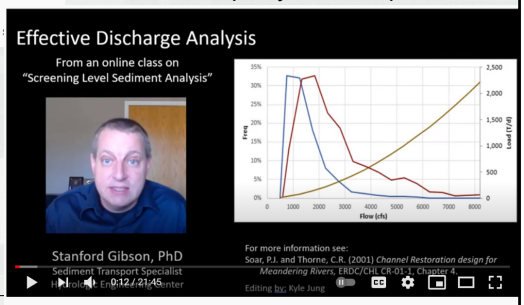
More on the Channel Forming Discharge

Channel Forming Discharge (Part 1): Three Methods (feat. Dr John Shelley)
258 views • Sep 11, 2020 6 0 SHARE

https://youtu.be/4pufoxJxiSo

https://youtu.be/4pufoxJxiSo



Channel Forming Discharge Part 2: Computing an Effective Discharge
142 views • Feb 9, 2021 4 0 SHARE SAVE

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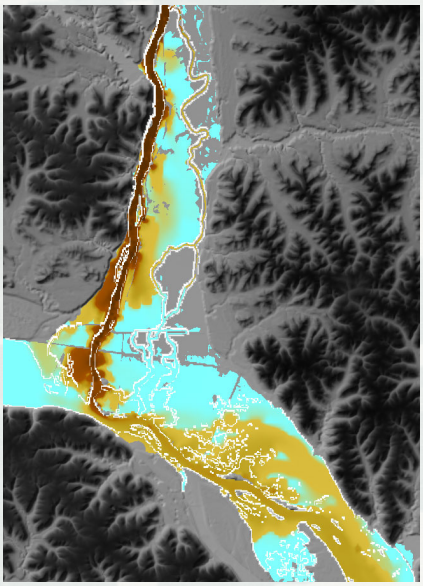

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Channel Stability Design and Analysis in HEC-RAS

- Stable Channel Design and Analysis
  - ▶ Copeland's Method
  - ▶ Regime Theory
  - ▶ Tractive Force Methods (Lane, Shields)
- Sediment Transport Capacity
  - ▶ 6 different transport functions

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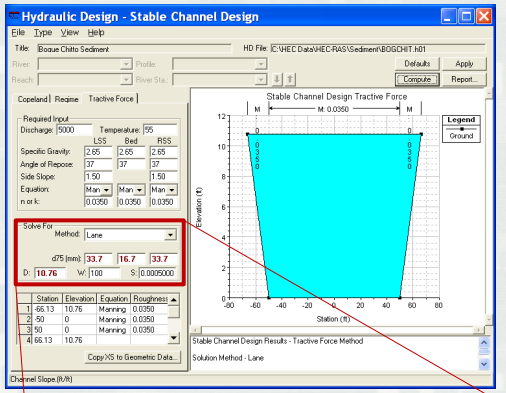
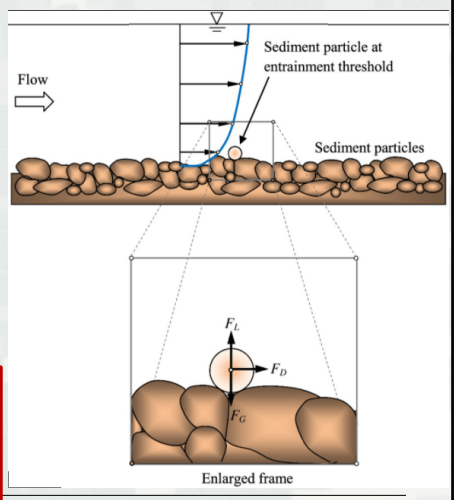
Stable Channel Design and Analysis Tractive Force





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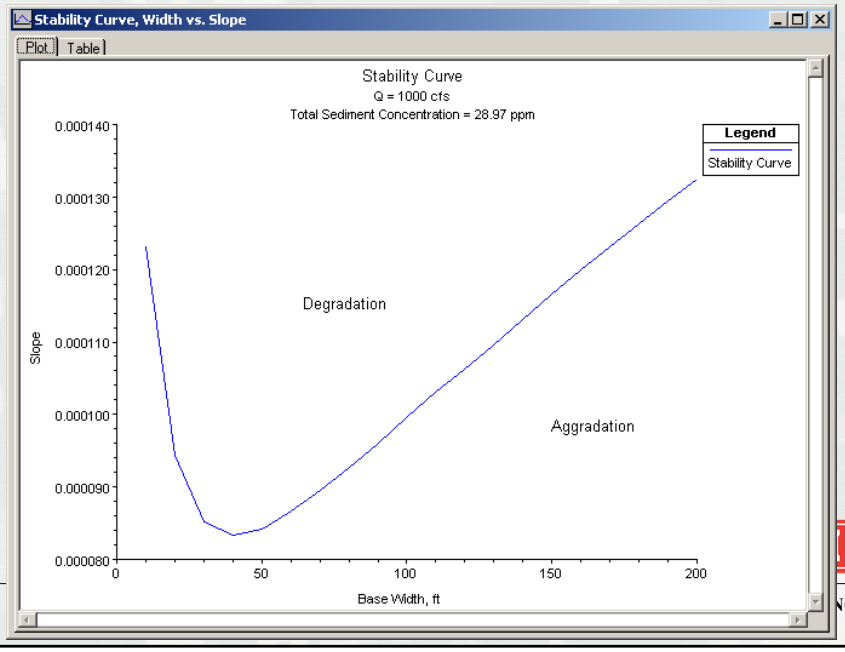
Copeland's Method



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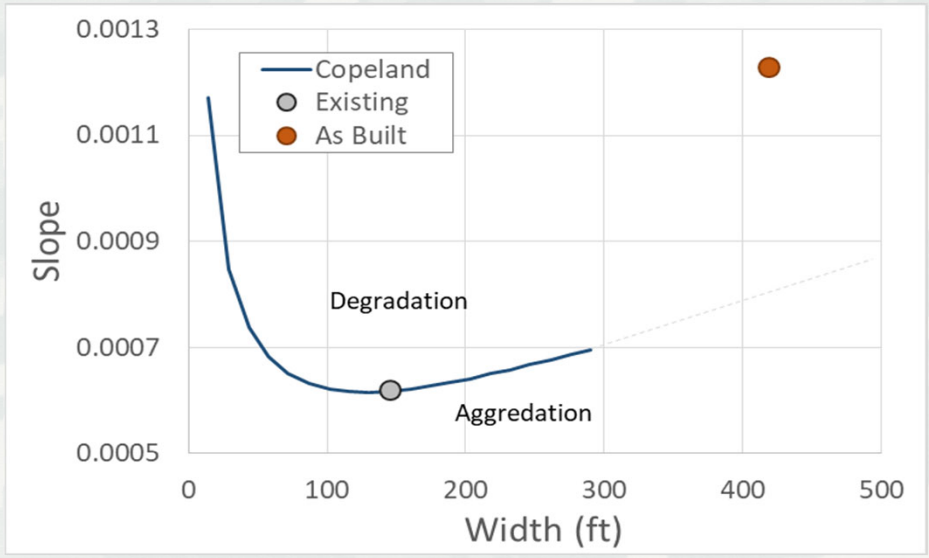
Copeland's Method



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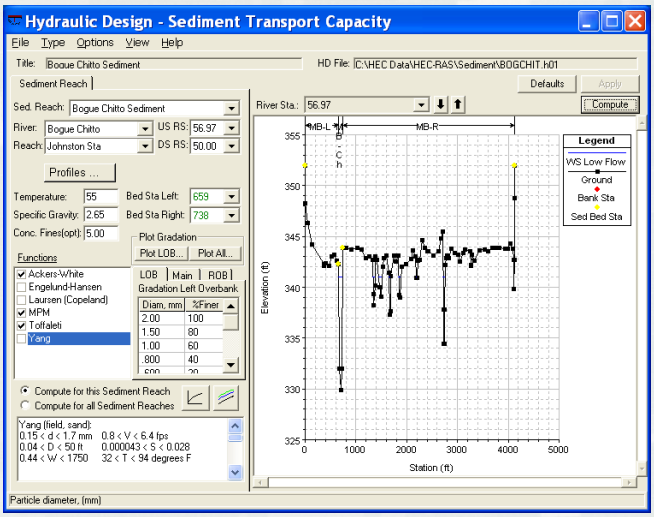
Sediment Transport Capacity Calculations



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Transport Capacity vs. Flow

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Best used to test relative differences (e.g. current and design).

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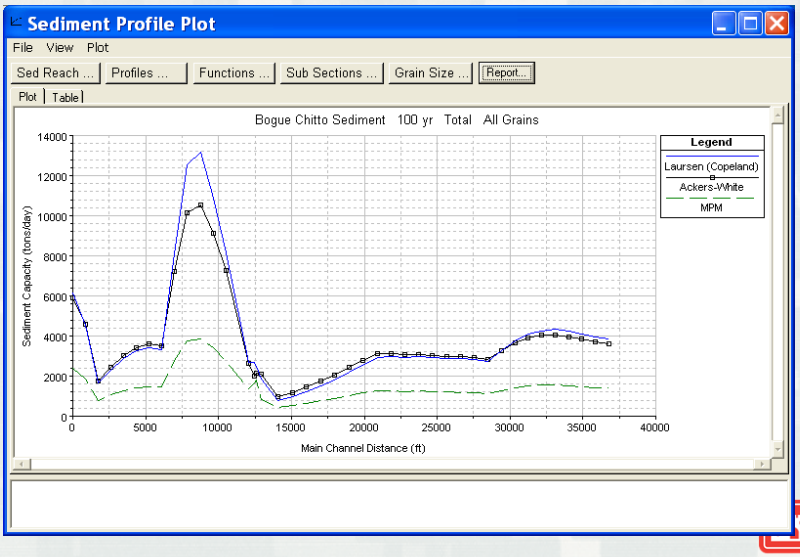
Transport Capacity vs. Channel Distance



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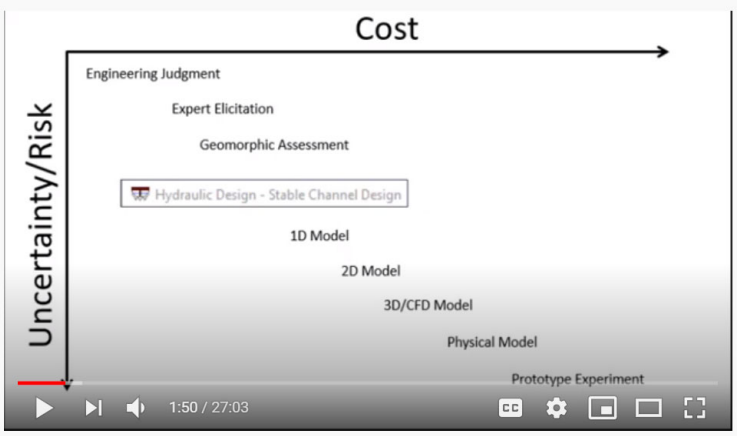
For more on the Stable Channel Design Tools:



Stable Channel Design Draft

Unlisted

https://youtu.be/Z3eCii4VbZ4

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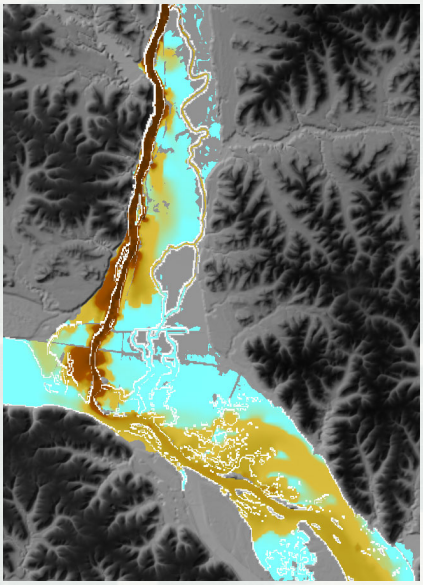
Hydraulic Products for Restoration Analyses

- Hydraulics Results
  - ▶ Depth
  - ▶ Inundation Boundary
  - ▶ Velocity
    - 1D-2D-3D?
- Channel Response
  - ▶ Channel Forming Discharge
  - ▶ Channel Stability Analysis
  - ▶ Mobile Bed Modeling (1D-2D)
- Water Quality Modeling



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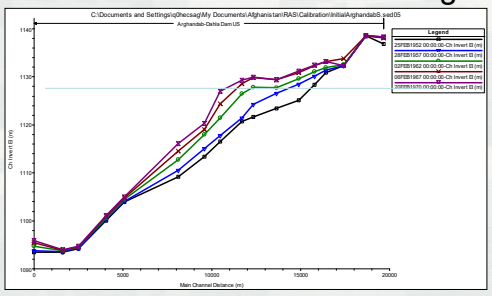
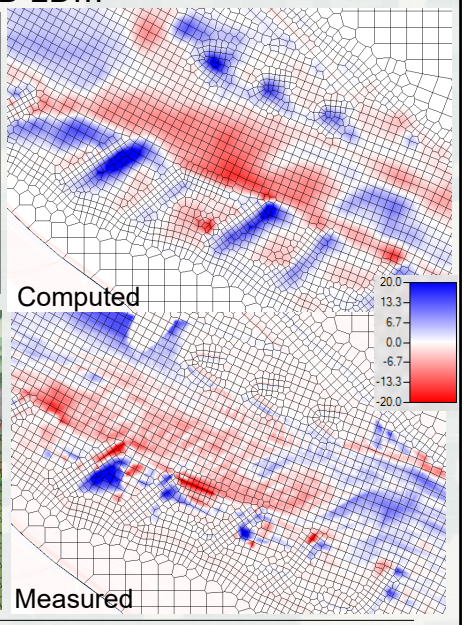
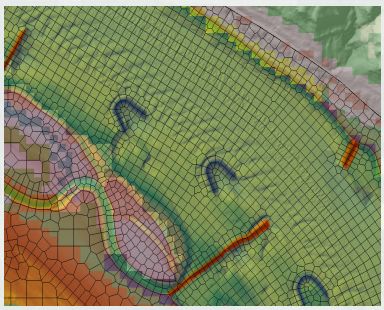
Mobile Bed Sediment Modeling 1D-2D…







…More Tomorrow

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Hydraulic Products for Restoration Analyses

- Hydraulics Results
  - Depth
  - Inundation Boundary
  - Velocity
    - 1D-2D-3D?
- Channel Response
  - Channel Forming Discharge
  - Channel Stability Analysis
  - Mobile Bed Modeling (1D-2D)
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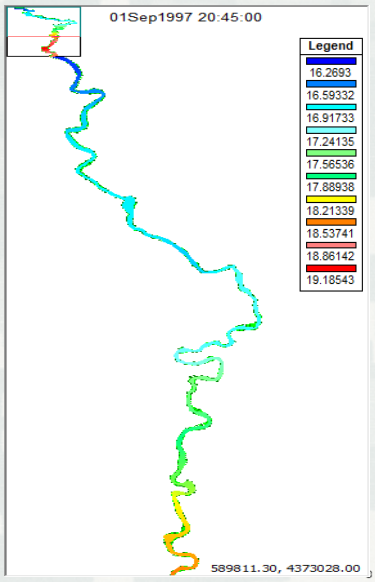

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Water Quality Modeling

- HEC-RAS can perform water temperature analysis and Nutrient Fate and Transport modeling
  - Nitrite; Nitrate; Organic Nitrogen; Ammonia; Organic Phosphorus; Phosphorus; Algae; Carbonaceous Biological Oxygen Demand; and Dissolved Oxygen

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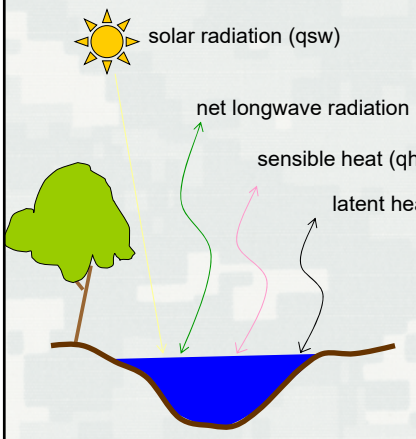
Source/Sink Term for Temperature (Energy Budget)



solar radiation (qsw) f (site location, time of day, day of year, atmospheric turbidity, cloud cover)

net longwave radiation (qlw) f (air temperature, water temperature)

sensible heat (qh) f (temperature gradient, wind, a&b)

latent heat (qe) f (vapor pressure gradient, wind, a&b)

$$q_{net} = q_{sw} + q_{lwn} + q_h + q_e$$

Planned:

- ground heat conduction
- shading (topographic, riparian)

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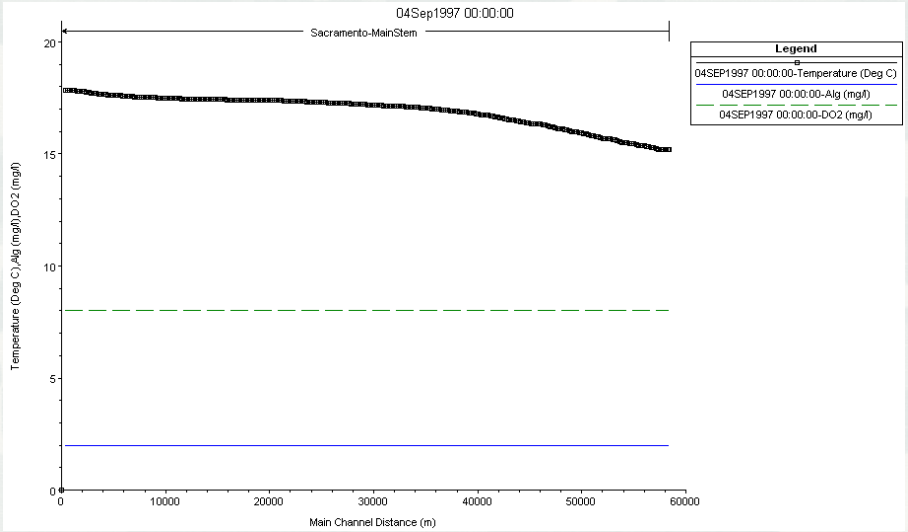
HEC-RAS Animation of Temperature, Algae, and Dissolved Oxygen



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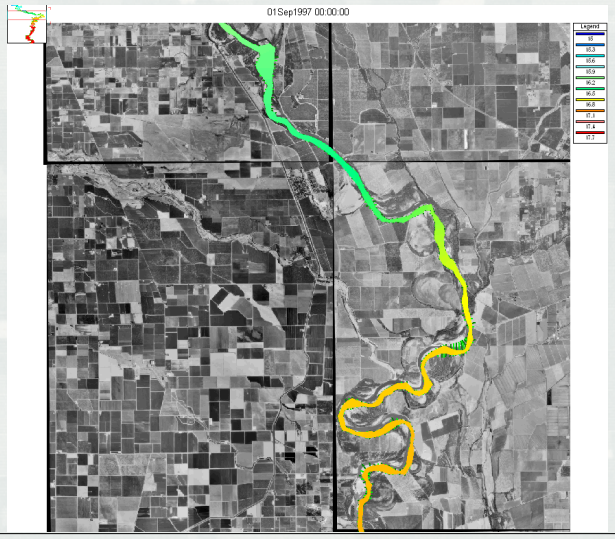
Map View of Sacramento Temperature Model



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Summary

- This lecture provided an overview of the type of information that can be provided from Hydraulic Model Studies
- Students learned how hydraulic information can be used in a restoration study
- The types of hydraulic models available were discussed, as well as what type and level of detail they can provide.
- Students were made aware of the available features within HEC-RAS that can assist in performing a restoration study.

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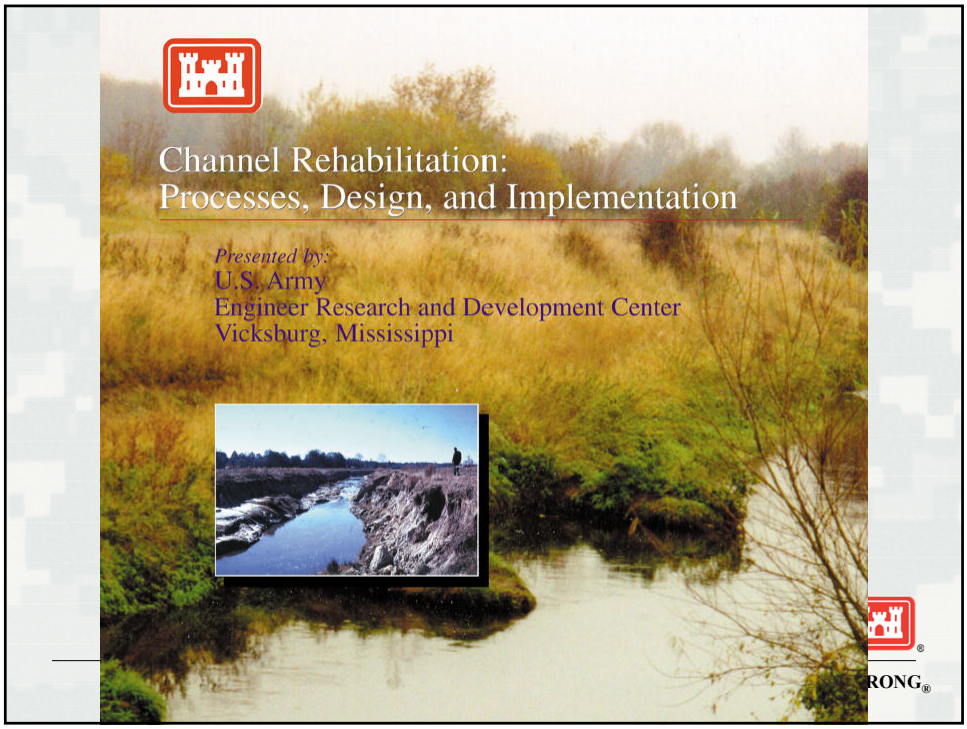
Channel Rehabilitation:
Processes, Design, and Implementation
Presented by:
U.S. Army
Engineer Research and Development Center
Vicksburg, Mississippi
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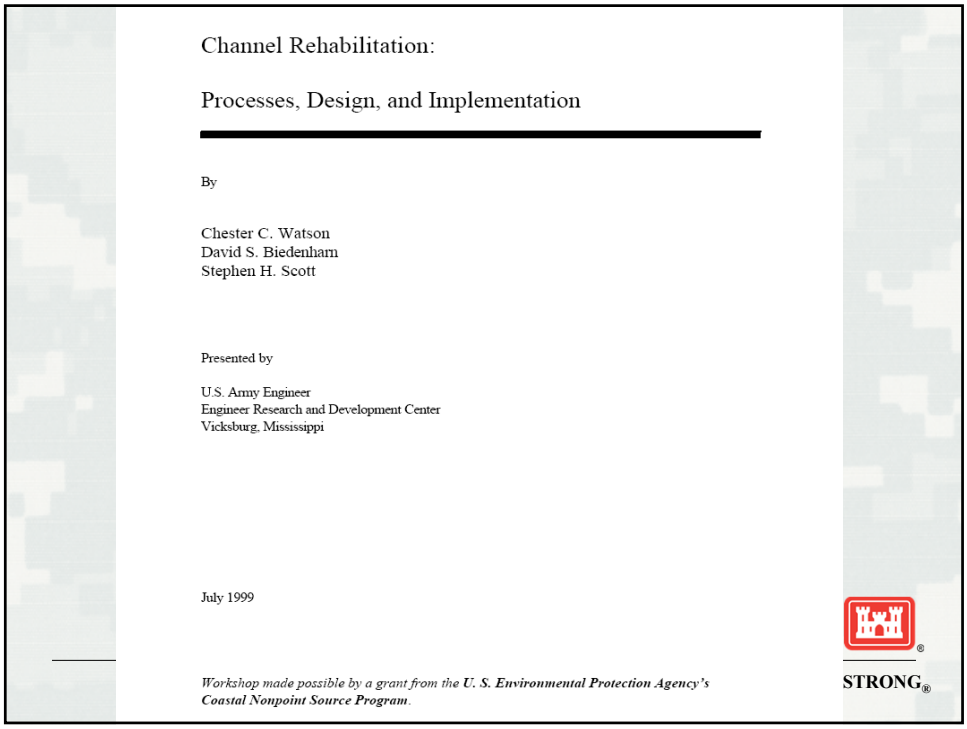
Channel Rehabilitation:
Processes, Design, and Implementation
By
Chester C. Watson
David S. Biedenharn
Stephen H. Scott
Presented by
U.S. Army Engineer
Engineer Research and Development Center
Vicksburg, Mississippi
July 1999
Workshop made possible by a grant from the U. S. Environmental Protection Agency's Coastal Nonpoint Source Program.
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ERDC/CHL TR-01-28

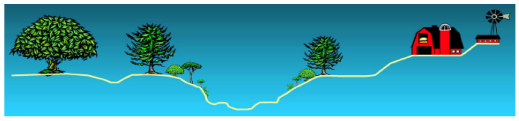
Coastal and Hydraulics Laboratory

US Army Corps of Engineers®
Engineer Research and Development Center

Hydraulic Design of Stream Restoration Projects

Ronald R. Copeland, Dinah N. McComas, Colin R. Thorne, Philip J. Soar, Meg M. Jonas, and Jon B. Fripp

September 2001



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