Modeling Hydraulic Structures

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Discussion:
- Bridges
- Culverts
- In-Line Structures
Bridges
Flow Transitions Through Bridges

Typical flow transition pattern
Idealized flow transition pattern for 1-dimensional modeling
Contraction and Expansion Coefficients

- Coefficients range from 0.1 to 0.5
- Used to define headloss effects on flow of contraction into the bridge and expansion out of the bridge
- Use judgment, and calibration if possible.
Defining Ineffective Flow Areas
Ineffective Area Option

- Used to restrict flow area
- Access from Bridge Editor
- Adjust lateral distance based on bounding sections distance from bridge
- Use computed contract and expansion ratios or 1:1 (CR) and 1:2 (ER) for a first estimate
- Initial guess of ineffective elevations based on top of road and low chord elevations.
HEC-RAS Bridge Hydraulic Computations

- The bridge routines in HEC-RAS have the ability to model:
  - Low Flow (Class A, B, and C)
  - Low flow and weir flow
  - Pressure flow (orifice or sluice gate types)
  - Pressure and weir flow
  - Highly submerged flows (energy equation)
HEC-RAS Low Flow Bridge Hydraulics Methodologies

- Energy Balance
- Momentum Balance
- Yarnell Regression Equation (Subcritical flow only)
- WSPRO Bridge Method (Subcritical flow only)
HEC-RAS High Flow Bridge Hydraulic Methods

- Energy Balance
- Pressure and Weir Flow
Unique Bridge Problems
Floating Debris

- **Floating Debris** checked will provide for Pier 1 debris input.
- **Set Wd/Ht for all** defines for all piers.
- Debris will rise and fall with water up to the top of the pier.
Unique Bridge Problems - Perched Bridges

- Flood flow would be low under bridge and overbank flow around the bridge.
- Energy method would be better when a large percentage of flow is in overbank
- Alternative method would be to model as Multiple Opening with Conveyance zones
Unique Bridge Problems - Low-Water Bridges

- Carries only low flow under the bridge
- High flow is usually submerged
- Better to use energy-based method
- Could use Pressure and Weir with high submergence criterion to cause the switch to Energy Method.
Unique Bridge Problems - Parallel Bridges

- Two bridges do not have twice the loss
- Very close could be modeled as one, OR two linked with 1 Xsec
- If flow expands between, add sections to model transition.
Unique Bridge Problems - Multiple Bridge Opening

- Multiple culvert sets and bridges with side relief openings are examples
- How to model in Ch. 7, Reference Manual and Ch. 6 of HEC-RAS User’s Manual
Computational Procedure for Multiple Opening

- Program assumes a flow distribution
- Energy computed for each opening
- Energies compared for each opening
- Flows are adjusted and procedure is repeated
- Program iterates until convergence or maximum number of trials
HEC-RAS Culvert Modeling Capabilities

- **HEC-RAS Computes Energy Losses:**
  - Reach immediately downstream from culvert
  - Through culvert
  - Reach immediately upstream of culvert

- **HEC-RAS Models:**
  - Single culverts (9 standard shapes)
  - Multiple identical culverts (25)
  - Multiple non-identical culverts (10 types)
  - With Version 3.0, analysis of open bottom culverts is automated
Cross Section Locations

CONTRACTION REACH

LENGTH OF CULVERT

EXPANSION REACH

FLOW

CULVERT

FLOW

1

2

3

4
Culvert Shapes and Materials

- Circular
- Box (Rectangular)
- Semi-Circle
- Low Profile Arch
- High Profile Arch
- Elliptical
- Pipe Arch
- Arch
- ConSpan
Limitations

For each culvert, constant

► Cross sectional area
► Bottom slope
► Flow
Unusually Shaped Culverts – Approximate with existing shapes

- Area
- Invert Elevation
- Crown Elevation or top of box
Horizontal and Adverse Culvert Slopes

The culvert routines also allow for horizontal and adverse culvert slopes. The primary difference is that normal depth is not computed for a horizontal or adverse sloping culvert. Outlet control is either computed by the direct step method for an unsubmerged outlet or the full flow equation for a submerged outlet.
In-Line Structures

- Inline gated spillways and uncontrolled over-flow weirs.
- Can be used to model the following:
  - Large Dams
  - Run of the river Structures
  - Drop Structures or natural drops
  - Dam breaks
Inline Spillways and Weirs

- Radial gates (often called Tainter gates)
- Vertical lift gates (Sluice gates)
- Ogee or Broad Crested Weir shapes for both gated spillways and overflow weirs
- Gate equations can handle low flow, normal gate flow (upstream submerged) or fully submerged gate flow (both ends submerged)
- Up to 10 gate groups can be defined at any river crossing. Up to 25 identical gates per group.
Sluice Gates

\[ Q = C W B \sqrt{2gH} \]

Where: 
- \( H \) = Upstream energy head \((Z_U - Z_{sp})\)
- \( C \) = Coefficient of discharge, 0.5 to 0.7
Radial Gates

\[ Q = C \sqrt{2g} W T^{TE} B^{BE} H^{HE} \]

Where: \( H = Z_U - Z_{sp} \)  \hspace{1cm} C = \text{Discharge Coefficient, typically 0.6 – 0.8}
Low Flow Through Gates

\[ Q = C L H^{3/2} \]
Uncontrolled Over-Flow Weirs

- Can represent Emergency Spillway or flow over entire Embankment.
- Uses Standard Weir Equation
- Can have Ogee or Broad Crested weir shape
- Weir flow submergence is calculated
Cross Section Locations

- Overflow Weir
- Gated Spillways
- Inline Weir
- River Stationing is 2.5
Entering Inline Spillway/Weir Data
Gated Spillway/Weir Output

- The following output tables are available for inline spillways/weirs:
  - Output at Each Gate Location
  - Output at All Gate Locations by Profile
Cross Section View of Inline Weir and Gated Spillway
Water Surface Profiles for Inline Weir and Gated Spillway
Hydraulic Structures

- Use caution and judgment in modeling hydraulic structures – does the output make sense?
- Field observations of the structures under various flow conditions is helpful
Questions?