Session A3- Removing barriers at road crossings using stream simulation techniques in the northeast United States

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Redesigning Road Crossings with Stream Simulation Techniques and MA Stream Crossing Standards

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& Ecohydrology for Fish Passage

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Outline

- MA Stream Crossing Standards
- Stream Simulation
- Mitchell Brook Case Study
Massachusetts River and Stream Crossing Standards

- First 2006, Revised 2011
- Endorse Stream Simulation Approach
- Guidance / Performance standards
- Not prescriptive measures
- Major Goals:
  - Fish and other Aquatic Organism Passage (AOP)
  - River / Stream Continuity
  - Wildlife Passage
Massachusetts River and Stream Crossing Standards (2006)

- General Standards
  - Open Bottom or Embedded Culvert (1ft)
  - Natural bottom substrate
  - Span channel width (min 1.2 x BF width)
  - Low flow channel for comparable depths and velocities at low flows
  - Openness > 0.25 m

- Optimum Standards
  - Open Bottom Arch or Bridge
  - Span channel and banks (min 1.2 x BF + banks) with headroom for dry passage
  - Min height of 6 ft, Openness > 0.75 m (where wildlife passage is significantly inhibited)
  - Min height of 4 ft, Openness > 0.5 m
Massachusetts River and Stream Crossing Standards (2011)

**General Standards**
- Spans or
- Culverts
  - Min 2ft Embedment
  - Min 2ft, 25% ()
  - 2 x D84
- Span min 1.2 x BF width
- Natural stream substrate
- **Match bedforms** -->
  depths & velocities at varied flows
- Openness > 0.82 ft (0.25 m)
- **Continuous Banks**

**Optimum Standards**
- Bridge
- Span 1.2 x BF width + Banks
- Natural stream substrate
- **Match bedforms** -->
  depths & velocities at varied flows
- Min height of **8 ft**
  Openness > 2.46 ft (0.75 m)
  (where wildlife passage is significantly inhibited)
- Min height of **6 ft**
  Openness > 1.64 ft (0.5 m)
- Continuous Banks
  - Headroom for wildlife
Stream Simulation

- Developed in Washington State
- Detailed in USFS Manual
- Alternative approach to species-specific designs
- Avoids flow constriction during normal conditions
- Mimics diversity and complexity of natural stream channel through a crossing structure
  - Intended to accommodate normal movements of aquatic organisms
  - Presents no more of an obstacle to movement than the natural channel
Stream Simulation Design Elements

From *Stream Simulation: an Ecological Approach to Providing Passage for Aquatic Organisms at Road-Stream Crossings*

- Crossing Alignment
- Lateral Channel Adjustment
- Control Points US / DS
- Reference Slope
- Reference Bed Characteristics
- Bed Particle Size Distribution
- Bank Rocks / Isolated Boulders Sizes
- Bankfull Width
- Flood Capacity
- Bed Mobility
Case Study:
Mitchell Brook Culvert Replacement

- Conway Road crossing Mitchell Brook, Town of Whately, Franklin County, MA
- Tributary to West Brook
- Part of West Brook stream continuity study
- Several project partners
  - American Rivers
  - The Nature Conservancy
  - Conte Anadromous Fish Research Center (USGS)
Mitchell Brook Setting

- Drainage Area – 225 acres (0.35 sq. mi.)
- Entirely forested watershed
- Gravel road, owned by Town
Site Assessment

- Existing perched 36” CMP
- Monitored eastern brook trout passage
- Gravel / cobble channel with bedrock influence
Site Assessment

- Geomorphic Survey
  - Cross-sections / Bankfull dimensions
  - Longitudinal profile
  - Wolman pebble counts
- Existing culvert slope – 5%
- Riffle slope US – 8%
Design Constraints / Considerations

- Shallow cover over existing pipe
- Bedrock influence
  - Footings for culvert
  - Substrate stability, boulder embedment
- Steep reach – how to best simulate the bedrock influenced pool/riffle system
- Road width required for Town DPW future pavement section
Design Constraints / Considerations

- General standards attainable
  - Arch, Substrate, Width, Low flows, Openness

- Optimal standards would require significantly raising road elevation to achieve > 0.50m Openness and height standard.
Design Features: Planview

- Perpendicular alignment
- Laterally contained
- Boulders in banks & mid-channel to provide varied hydraulic habitat
- Boulders sized to withstand high flows (24-26”)
- Continuous banks
- Low flow channel
Design Features: Cross-sections

- Openness 0.36 m
- Cross-sectional area 37.65 SF min.
- 4.8 FT rise min.
Design Features: Profile

- **US / DS Control Points**
- **Proposed Slope (7%) / Length consistent w/ US riffle**
- **Substrate depth to vary w/ bedrock**
- **Scour pool to be filled**
Design Features:
Cross-sections

- 12' span x 6' rise
- Adequate Width (1.2 x bankfull)
- Existing culvert
- Low flow channel
- Boulder placement in Banks & midchannel
- Continuous bank lines
Design Features: Bed Gradation

- Mimic particle size distribution of US riffle
- Increase fine sediment fraction (pebble count bias)
- Convert to US Sieve sizes for contractor / quarry
- Size boulders to resist high flows
HEC-RAS modeling

- Increased cross-sectional area increases flood capacity (25-yr overtopping flow)
- Results used to size boulders
- Results between simulated reach and upstream reach showed generally consistent velocities, depths and shear stresses
Related PH Project

Working with PA Trout Unlimited (Bucks County Chapter) to assess all road crossings in Cooks Creek watershed (Delaware River tributary)

- Identified all stream crossings (~100)
- Developed assessment protocol
- Trained volunteers for initial field assessment
  - Prioritize crossings
  - Conduct follow-up assessments
  - Develop conceptual restoration plans
- Possibly first in PA
Resources

UMASS River and Stream Continuity Project
www.streamcontinuity.org

MA Riverways Program
www.mass.gov/dfw/der/riverways/index.htm

USFS Stream Simulation Manual

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Discussion
### Bankfull Characteristics Comparison

<table>
<thead>
<tr>
<th>USGS Regression Equations</th>
<th>NE Eqs.</th>
<th>MA Eqs.</th>
<th>MA Eqs.</th>
<th>Field Survey Data (PH1)</th>
<th>Field Survey Difference * (%)</th>
<th>HEC-RAS Model Results (%)</th>
<th>HEC-RAS Model Difference * (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drainage Area (sq. mi.)</td>
<td>0.36</td>
<td>0.38</td>
<td>0.38</td>
<td>-----</td>
<td>-----</td>
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<tr>
<td>Bankfull width (ft)</td>
<td>8.41</td>
<td>11.10</td>
<td>11.00</td>
<td>9.95</td>
<td>-10.0</td>
<td>7.03</td>
<td>-44.0</td>
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<td>Bankfull mean depth (ft)</td>
<td>0.73</td>
<td>0.70</td>
<td>0.80</td>
<td>1.24</td>
<td>43.1</td>
<td>1.08</td>
<td>29.8</td>
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<tr>
<td>Bankfull cross-sectional area (ft$^2$)</td>
<td>5.95</td>
<td>7.20</td>
<td>8.40</td>
<td>9.34</td>
<td>10.6</td>
<td>4.59</td>
<td>-58.7</td>
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<tr>
<td>Bankfull discharge (ft$^3$/s)</td>
<td>17.28</td>
<td>14.50</td>
<td>21.10</td>
<td>-----</td>
<td>-----</td>
<td>21.1</td>
<td>-----</td>
</tr>
</tbody>
</table>

(1) As obtained from USGS abstract entitled Equations for Estimating Bankfull-Channel Geometry in Northeastern US

(2) As obtained from G. Bent (USGS), via email correspondence using MA specific eqs., using drainage area (DA) and both DA and Mean Basin Slope (MBS) as explanatory variables

(3) HEC-RAS model results, using existing conditions. Values shown are reach averages for Mitchell Brook upstream of culvert

* Difference calculated using USGS MA eqs. With DA & MBS
Culvert Retrofitting: Making the Case

- Dams in MA -- >2,900 dams (ASDSO 2008)
- Stream Crossings in MA -- > 28,500 road and railroad crossings (MA Riverways GIS)
- MA crossings outnumber dams ~10x
- Significant potential impact
- Need for restoration
Regional Efforts

- **Guidelines/standards**
  - MA River and Stream Crossing Standards (2006)
  - CT Stream Crossing Guidelines (2008)
  - VT Stream Crossing Guidelines (2009)
  - NH Stream Crossing Guidelines (2009)

- **UMASS River and Stream Continuity Project**
  - Volunteer assessments of road-stream crossings in MA and NE states
A legacy of early American small-scale industrialization, there are at least 279 dams on the tributaries and mainstem of the Chicopee River.

The intersection of the stream network with roads and railroads results in an estimated 2,160 crossings.