How to Create Stream Smart Crossings

The Golden Rule:
Let the stream act like a stream
Stream Smart Options

1) **Avoid** creating a crossing
2) **Remove** the crossing
3) **Open bottom** structure that spans or exceeds channel
   - Abutments for temporary bridge
   - Bridge or 3-sided box culvert
   - Arch culvert
4) **Embedded** culvert
5) **Hydraulic designs**
Open bottom structures

Temporary Bridge Deck

Bridge

Bottomless Box Culvert

Arch Culvert
Embedded pipes

Photo: John Gilbert
Embedded box culvert
Liners don’t achieve Stream Smart outcomes!
Rules of Thumb (4 S’s)

Span the stream

Set elevation right

Slope and skew match stream

Substrate in the crossing
Don’t pinch the stream
Span the stream
(and exceed it where possible)
How undersized culverts constrict stream flow and become perched

Culvert that does not span the channel set at stream grade

Water backs up at inlet

Flow accelerates in culvert

Turbulence scours at end of culvert

Low flow barrier

Free Fall (perch)

Plunge pool created

Over Time…
Real World – Blanchard

2008

2010
Rules of Thumb (4 S’s)

Span the stream

Set elevation right

Slope and skew match stream

Substrate in the crossing
Set elevation right

What is Upstream?

Downstream (Outlet)
Indicators of elevation problems

Looking downstream

Looking upstream

Inlet

Outlet
A stream channel rediscovered!
Indicators of correct elevation

[Images: Looking downstream and Looking upstream]
Seamless inlets and outlets
Stream Profile

Used to find correct elevation and slope

- Water Level
- Culvert
- Road Surface
- Stream Bottom
- New, Larger, Lower Culvert
- Pool Bottom Elevations
- Survey Stations
- Stream Slope
Stream Profile Example 1

Accumulated Sediment Upstream

The Minimum

The Best Way

2% Slope
Stream Profile Example 2

Road Surface

“Berm”

DISTANCES IN FEET, LOOKING DOWNSTREAM

ELEVATION IN FEET

9 ft
Rules of Thumb (4 S’s)

Span the stream

Set elevation right

Slope and skew match stream

Substrate in the crossing
Substrate in the crossing
Stream Smart Sizing

Step 1: Field Assessment
- Stream profile
- Stream cross-section

Step 2: Project Design
- Structure Choice
- Elevations
- Hydrology
- Hydraulics
Step 1: Field Assessment

What volume of flow are we allowing for?

- 50-, 100- or 500-year storm event?

What species are we concerned about?

- Fish, amphibians, mammals, invertebrates?
Step 1: Field Assessment

- Geomorphic Map
- Stream Profile
  - Bed elevation
  - Slope
  - Scour potential
  - Footer depth
  - Road /structure height
- Cross Section
  - Structure span width
- Bed characterization
  - Stream bed material size
  - Bank material size

Grace Levergood / NHDES
Step 1: Field Assessment

Determine the stream profile
to determine elevation and slope

Measure **well upstream and downstream** from existing crossing structure - 20-30 times the width of the stream in distance.
Step 1: Field Assessment

Stream Profile

- Cross-Section 1
- Road Surface (464.5')
- Existing 4' culverts (3)
- Cross-Section 3
- Bedrock at bank
- Pool Scour Limit

1.1% Slope
Step 1: Field Assessment

Determine the stream cross-section to set the opening area of the crossing.

Measure both upstream and downstream of crossing in an undisturbed location, and average measurements.

Average Stream Width = 6’
Average Depth = 1’
Step 1: Field Assessment

Cross-section

Bankfull Width = 16.7'
Bankfull Depth = 2.5'
Bankfull XS Area = 42 sq ft
Step 2: Structure Choice

### Box Culvert Shell Cross Section

- **Corrugated Shell**

<table>
<thead>
<tr>
<th>Structure #</th>
<th>$R_v$</th>
<th>$R_h$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-39</td>
<td>297.50&quot;</td>
<td>90.250&quot;</td>
</tr>
<tr>
<td>40-67</td>
<td>258.75&quot;</td>
<td>37.375&quot;</td>
</tr>
<tr>
<td>88-143</td>
<td>310.75&quot;</td>
<td>43.825&quot;</td>
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</table>
# Comparison of Stream Crossing Structures

<table>
<thead>
<tr>
<th>Crossing Structure Type</th>
<th>Material</th>
<th>Cost</th>
<th>Life Span (years)</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bridge A</td>
<td>Steel-reinforced concrete abutments (poured in-place) and decking on steel I-beam stringers</td>
<td>$$$</td>
<td>50-75</td>
<td>Natural bottom, durability, snow-plowable</td>
<td>High cost</td>
</tr>
<tr>
<td>Bridge B</td>
<td>Precast concrete block abutments with steel I-beam stringers and timber deck (possibly paved or alternate decking)</td>
<td>$</td>
<td>50-75; timber redeck</td>
<td>Natural bottom, low cost; simplicity</td>
<td>Limited abutment height and deck life; snow plowing may be limited</td>
</tr>
<tr>
<td>Bridge C (3-Sided Box Culvert)</td>
<td>Steel-reinforced concrete, galvanized steel or aluminum</td>
<td>$$</td>
<td>50-75</td>
<td>Natural bottom, simplicity</td>
<td>Span/weight of sections can limit installation options; assembly required for metal plate structures</td>
</tr>
<tr>
<td>Open Bottom Arch</td>
<td>Galvanized Steel, aluminum, steel-reinforced concrete</td>
<td>$$</td>
<td>50-75</td>
<td>Natural bottom, ease of transport, can be low profile</td>
<td>Care must be taken to install and protect footings, assembly required for metal plate structures</td>
</tr>
<tr>
<td>Embedded Box Culvert</td>
<td>Steel-reinforced concrete, galvanized steel, aluminum</td>
<td>$$</td>
<td>50-75</td>
<td>Natural bottom; variety of configurations</td>
<td>Must span stream and be set below stream elevation to avoid outlet perch; limited by bedrock</td>
</tr>
<tr>
<td>Embedded Pipe Arch</td>
<td>Galvanized steel, aluminum</td>
<td>$ - $$</td>
<td>20-50</td>
<td>Natural bottom; wide for given volume; low cost of steel</td>
<td>Short life (steel); not for use with ledge; limited sizes</td>
</tr>
<tr>
<td>Embedded Round Pipe</td>
<td>Galvanized steel, aluminum, plastic, steel-reinforced concrete</td>
<td>$</td>
<td>20-75</td>
<td>Natural bottom; lowest cost</td>
<td>Limited to smaller sizes; not for use with ledge</td>
</tr>
<tr>
<td>Round Pipe (at stream grade) Not Recommended</td>
<td>Galvanized steel, aluminum, plastic, steel-reinforced concrete</td>
<td>$</td>
<td>20-75</td>
<td>Lowest cost</td>
<td>Rarely adequate for fish passage (develops outlet perch); limited to smaller sizes</td>
</tr>
</tbody>
</table>

Maine Stream Smart Crossings January 2018
## Structure Comparison

<table>
<thead>
<tr>
<th>Bridge</th>
<th>Embedded Pipe</th>
<th>Open Bottom Arch</th>
<th>Traditional Pipe</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost</strong></td>
<td>$$</td>
<td>$</td>
<td>$$</td>
</tr>
<tr>
<td><strong>Lifespan</strong></td>
<td>50-75 (yrs)</td>
<td>20-75 (yrs)</td>
<td>50-75 (yrs)</td>
</tr>
<tr>
<td><strong>Pros</strong></td>
<td>AOP, Durable</td>
<td>Low cost</td>
<td>AOP</td>
</tr>
<tr>
<td><strong>Cons</strong></td>
<td>High cost</td>
<td>Only for small crossings</td>
<td>Assembly</td>
</tr>
</tbody>
</table>

### Cost
- Bridge: $$$
- Embedded Pipe: $1
- Open Bottom Arch: $$
- Traditional Pipe: $2

### Lifespan
- Bridge: 50-75 (yrs)
- Embedded Pipe: 20-75 (yrs)
- Open Bottom Arch: 50-75 (yrs)
- Traditional Pipe: 20-75 (yrs)

### Pros
- Bridge: AOP, Durable
- Embedded Pipe: Low cost
- Open Bottom Arch: AOP
- Traditional Pipe: Low cost

### Cons
- Bridge: High cost
- Embedded Pipe: Only for small crossings
- Open Bottom Arch: Assembly
- Traditional Pipe: Poor AOP, Only for small crossings
Comparison of Costs Over 50 Years: 72" CMP vs Stream Simulation Alternatives
Stream-Smart: Open Arch

pre-restoration

2009 site

post-restoration

New channel cross section

20'

Photo by K. Mueller
Stream-Smart: Small bridge on low volume road

Before

After
Stream-Smart: Embedded Box Culvert

Before

After
Stream-Smart: 3-Sided Box Culvert

Before

After
Stream-Smart: Concrete Arch Culvert

Before

After
Step 2: Elevations

Proposed Crossing - Inlet Elevation - Revised

- 15' Deck Length
- Road Surface at 97.25' Elevation
- 9" H x 9" W Curbing
- 3.75' W x 2' H x 15' L Deck Sections
- 2' x 2' Abutment Blocks of varying lengths (4', 5', 6', 8', 10' & 12')
- Corner blocks act as deadman to stabilize abutments
- Estimted Capacity ≈ 50 ft^3
- Inlet Elevation ≈ 91.5'
- 6' x 6' Corner Blocks
- Bottom of Abutment Blocks ≈ 89.0'

Note: Proposed road elevation assumes paving over bridge deck.
Step 2: Hydrology

USGS StreamStats

### Hydrology & Hydraulic Analysis

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Value</th>
<th>Units</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Drainage Area</td>
<td>0.41</td>
<td>sq. miles</td>
<td>Area that drains to crossing</td>
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<tr>
<td>Wetlands</td>
<td>0.0</td>
<td>percent</td>
<td>Percentage of NWI storage</td>
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<tr>
<td>Elevation</td>
<td>600</td>
<td>feet</td>
<td>Mean basin elevation</td>
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<tr>
<td>Precipitation</td>
<td>45.9</td>
<td>inches</td>
<td>Mean annual precipitation</td>
</tr>
<tr>
<td>Aquifer</td>
<td>0.0</td>
<td>percent</td>
<td>Percentage of land underlain by sand &amp; gravel aquifers</td>
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<tr>
<td>X-coordinate</td>
<td>421595</td>
<td>UTM</td>
<td>Basin centroid E/W location</td>
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<tr>
<td>Y-coordinate</td>
<td>4957950</td>
<td>UTM</td>
<td>Basin centroid N/S location</td>
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<table>
<thead>
<tr>
<th>Return</th>
<th>Peak</th>
<th>References</th>
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<tr>
<td>T (yr)</td>
<td>Q₀ (ft³/s)</td>
<td></td>
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<tr>
<td>1.1</td>
<td>14.8</td>
<td>Hodgkins, G., 1999. Estimating the magnitude of peak flows for streams in Maine for selected recurrence intervals</td>
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<tr>
<td>2</td>
<td>31.4</td>
<td>Water-Resources Investigations Report 99-4008</td>
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<td>5</td>
<td>49.9</td>
<td>US Geological Survey, Augusta, Maine</td>
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<tr>
<td>10</td>
<td>63.9</td>
<td>Lombard, P. &amp; Hodgkins, G., 2015</td>
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<tr>
<td>25</td>
<td>83.2</td>
<td>Peak Flow Regression Equations for Small, Unaged Streams in Maine: Comparing Map-Based to Field-Based Variables</td>
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<tr>
<td>50</td>
<td>98.7</td>
<td>Water-Resources Investigations Report 2015-5049</td>
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<tr>
<td>100</td>
<td>115.3</td>
<td>US Geological Survey, Augusta, Maine</td>
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<tr>
<td>500</td>
<td>157.7</td>
<td></td>
</tr>
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</table>

Porter Crossing 10405 - West Branch Tenmile Brook at Sarah Bridge Road

Crossings
- **Barrier**
- **Potential Barrier**
- **No Barrier**
- **Unknown**
- **Drainage Area Boundary**
- **Known Brook Trout Habitat**

Map created by A. Abbott 11/10/17

Area of detail
HY-8 Hydraulic Analysis Program of the U.S. Federal Highway Administration provides results for the above peak flow estimates for the proposed crossing design, and indicates that the crossing as proposed will successfully pass the expected 100-year storm event.

Note that prediction errors are quite large when using regression equations to estimate flows and bankfull widths based on drainage area. It is best to account for potentially larger flows at these return intervals.
Design & Installation Considerations

- Permits
- In stream work window (July 15 - Sept 30)
- Controlling water during construction
- Sediment & erosion control
- Embedding – building bed and banks
- Bedrock & unstable soils
Controlling Water
When might you seek help?

- Complicated legacy effects
- When you can’t find natural channel
- Tidal streams
- Safety or traffic issues
Rules of Thumb (4 S’s)

Span the stream
Set elevation right
Slope and skew match stream
Substrate in the crossing

The Golden Rule: Let the stream act like a stream