Culvert Design Process

Hydrology
↓
Site Assessment
↓
Alignment and Profile
↓
Bed and Banks
↓
Structure
↓
Sediment Mobility & Stability

Some low gradient bed and bank design options

- BFW, tailwater control, no structure
- A few structural elements
- Rock bars for thalweg development
- Rock banks and bars
Can structures be too wide?

- Maybe - in sand bed streams with low flows
- Without structure to create banks or a thalweg
- Sand spreads out to create a flat, uniform bed
- Shallow water may impede passage of some sp.

Example of an open-bottom arch from Michigan.

Can structures be too wide?

Bridge Width = 16'
Bridge Width/BFW = 138%
Ave BFW = 11.7'

Example of bridge on Spring Cr near Durango in SW WI.
BFW, tailwater control, no structure

Drainage Area = 10.6 sq mi  
BFW Est (E Reg) = 16.5'  
Min BFW Graph = 12'

Simpson at FR 2386

Brule at FR 2193

Elvoy at Rock Dam Road

Rock bars for thalweg development  
NB Oconto W Trib at Hwy 64

- Culvert width = 8.0 ft  
- BFW = 8 ft (ave)  
- Culvert width/BFW = 100%  
- Culvert length = 135 ft  
- CL/BFW = 16.9

- 1 wavelength = 8'x10=80 ft  
- 5 bars/wavelength  
- Bar spacing=80/5=16 ft  
- Total bars=135/16=8 bars  
- Bar spacing adjusted slightly to fit culvert
Rock bars for thalweg development
NB Oconto Middle Trib at Hwy 64

Stream Profile at Hwy 64 Middle Crossing (64224)

Rock banks and bars
Torpee Cr at Hwy 32
Bed design objectives

• Simulate natural bed
  – shape
  – diversity
  – roughness
  – mobility
  – permeability

Bed shape

Rountree XSec 2

Bankfull width?
Bankfull?

HEC-RAS output
Diversity and roughness

From site sketch, photos, profile, pebble count & key pieces

Mobility and permeability

- Depends upon well-graded bed materials (pebble count)
Banks, bands

Debris

Bands

Reference channel shape

Bank

Key pieces

- Largest size materials in the reference reach
- Measure A, B, and C dimensions
- Stable pieces that maintain channel form
- Provide hydraulic and habitat diversity
Profile control options

Move aggraded material to fill scoured area, then armor both surfaces.

- For an insiced channel, a steeper connecting channel can be used
- A stability analysis is required

Profile control options
grade controls – rock bands

- Riffle or riffle/step structures
- Constructed with a band of primarily larger (D84-D100) size unsorted rocks.
- They help form channel cross-section and profile shape.
Natural compound profiles & channel disturbance scenarios

Aggradation of inlet is most likely, loss of pipe capacity
Provide permanent grade controls on steeper grade

Aggradation of outlet is most likely, loss of pipe capacity

Headcut to outlet is most likely

Transitions

Hourglass shape

Restore downstream banks for stability and continuous banklines

Restore upstream alignment and transition to remove backwater scour and restore sediment and bed material transport.
Tie channel edges to stream

Bed material design

Use reference reach gradation
- Pebble count of reference channel for $D_{100}$, $D_{84}$ and $D_{50}$
- Account for large roughness features
- Make sure you have at least 5% fine materials
- Can use Fuller-Thompson equations to adjust fine portion of the bed mix (see Stream Sim. Manual)
Pebble count interpretation exercise

Rountree Trib. pebble-count

Streambed Sediment Mix
Unnamed Trib to Rountree at W Main Street, Platteville, WI

Cumulative Percent Finer

Particle Size (mm)

0.1  1.0  10.0  100.0  24  1000.0
### Bed material example

**Trout Creek**

<table>
<thead>
<tr>
<th>Size class</th>
<th>Reference (in)</th>
</tr>
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<tbody>
<tr>
<td>D100</td>
<td>22</td>
</tr>
<tr>
<td>D84</td>
<td>6.5</td>
</tr>
<tr>
<td>D50</td>
<td>2.0</td>
</tr>
<tr>
<td>D16</td>
<td>0.3</td>
</tr>
<tr>
<td>D5</td>
<td>sand</td>
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</tbody>
</table>

### Bed mix composition

<table>
<thead>
<tr>
<th>% Composition</th>
<th>Nominal Category</th>
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</thead>
<tbody>
<tr>
<td>7</td>
<td>Boulder (8-20 in)</td>
</tr>
<tr>
<td>17</td>
<td>Large Cobble (4-8 in)</td>
</tr>
<tr>
<td>20</td>
<td>Sm. Cobble (2-4 in)</td>
</tr>
<tr>
<td>22</td>
<td>Gravel (3/4-2 in)</td>
</tr>
<tr>
<td>28</td>
<td>Sand and finer (&lt;3/4 in)</td>
</tr>
</tbody>
</table>
Bed material examples

- Walk-behind Bobcat to install materials
- Fan for air quality in confined space
- Sheet piling to divert water
Example, continued

Substrate volume exercise