Fish Passage, Stream Design, Bridge Scour

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Fish Passage

Top: SR 542 High Creek, built 2016
Bottom: SR 9 Lake Creek, built 2015
Fish Passage—Why is it Important?

- Improves fish access
- Helps in protecting and restoring fish populations
- Federal Court Injunction

SR 532 Secret Creek, built 2016
Fish Passage—Why is it Important?

Salmon Life Cycle

Death from:
- temperature changes
- disturbance of gravel
- pollution
- predators

EGGS incubate in gravel (3,000 eggs)

Death from spawning

SPAWNING SALMON return to the stream of their birth to lay the eggs of the next generation before dying (1-2 return to spawn)

COURTSHIP

ALEVINS emerge from gravel (810 hatch)

STEELHEAD, CUTTHROAT, SOCKEYE, AND SOME CHINOOK LIVE IN FRESH WATER AS JUVENILES

FRY live and grow in freshwater streams

CHUM, PINK AND SOME CHINOOK MIGRATE DIRECTLY TO SALT WATER

SMOLTS adapt to salt water (81 make it to the ocean)

Death from:
- predators
- habitat destruction
- delays in downstream migration

ADULT SALMON mature in the ocean from two to seven years (5-6 reach adulthood)

Death from:
- predators
- fishing
- delays in migration
What is a Fish Barrier?

- Anything that hinders any life stage of fish from moving through a water way

- Types:
  - Velocity
  - Water depth
  - Water Surface drop
  - Slope
  - Tidegate or Floodgate
### What is a Fish Barrier?

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Range</th>
<th>Passability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Surface Drop</td>
<td>≥ 0.8 ft</td>
<td>≥ 0.8 ft to &lt; 1.6 ft</td>
<td>0.67</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≥ 1.6 ft to &lt; 3.3 ft</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≥ 3.3 ft</td>
<td>0</td>
</tr>
<tr>
<td>Slope (Culverts ≤ 60 feet length)</td>
<td>≥ 1%</td>
<td>≥ 1% to &lt; 2%</td>
<td>0.67</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≥ 2% to &lt; 4%</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≥ 4%</td>
<td>0</td>
</tr>
<tr>
<td>Slope (Culverts ≥ 60 feet length)</td>
<td>≥ 1%</td>
<td>≥ 1% to &lt; 2%</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≥ 2%</td>
<td>0</td>
</tr>
<tr>
<td>Velocity (Level B Results)</td>
<td></td>
<td>&lt; 2 ft/s over criterion for 6 in trout</td>
<td>0.67</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≥ 2 ft/s over criterion for 6 in trout</td>
<td>0.33</td>
</tr>
<tr>
<td>Depth (Level B Results)</td>
<td>≤ 1 ft</td>
<td>≥ 0.5 ft to &lt; 1.0 ft</td>
<td>0.67</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≥ 0.16 ft to &lt; 0.5 ft</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≥ 0.16 ft</td>
<td>0</td>
</tr>
</tbody>
</table>

Converted from metric. Table 3.3 from WDFW Fish Passage Barrier and Surface Water Diversion Screening Assessment and Prioritization Manual
By the numbers...

- Statewide 1,989 culverts are barriers on the highway system
- 1,530 are fish barriers with more than 200m of upstream habitat
- As of 2016 WSDOT completed 301 projects statewide and improved access to 1,000 miles of upstream habitat
Who does the work?

- **Stream Design: HQ**
  Hydraulics or an engineer approved by HQ Hydraulics (Region or consultant)

- **Roadway Geometrics:**
  Project Offices
  - Burlington PEO (Mikkel Lamay)
  - Sno-King Design (John Chi)
  - Olympia PEO (Kim Mueller)
  - Chehalis PEO (Colin Newell)
  - Wenatchee PEO (Dan Lewis)

*SR 112 Trib to Pysht River*
So my project has a barrier...

- Contact HQ ESO/Hydraulics at the beginning of the project (scoping phase if possible)
- A Hydraulic Design Report (PHD/FHD) will be needed.
- HQ Hydraulics will work with you to create a design that meets the WAC and injunction

SR 112 Jansen Creek, built 2016
We need to put in what?

- New structures are often much larger than existing
- Stream simulation min: 1.2*bankfull width+2 ft.
- Unconfined floodplains can yield structures larger than stream simulation

SR 542 Anderson Creek, unaffected reach
SR 542 Anderson Creek Before
SR 542 Anderson Creek After
Anderson Creek Hydrograph

USGS 12210900 ANDERSON CREEK AT SMITH ROAD NEAR GOSHEN, WA

Discharge, cubic feet per second


Provisional Data Subject to Revision
Anderson Creek Gage Depth

USGS 12210900 ANDERSON CREEK AT SMITH ROAD NEAR GOSHEN, WA

--- Provisional Data Subject to Revision ---

- Gage height
- * Measured gage height
- Gage Pooling
Queets River Gage Depths

USGS 12040500 QUEETS RIVER NEAR CLEARWATER, WA

Gage height, feet

Oct 12 2017
Oct 13 2017
Oct 14 2017
Oct 15 2017
Oct 16 2017
Oct 17 2017
Oct 18 2017
Oct 19 2017

Provisional Data Subject to Revision

--- Gage height
--- Operational limit (minimum)
Anderson Creek Gage Depth

USGS 12210900 ANDERSON CREEK AT SMITH ROAD NEAR GOSHEN, WA

--- Provisional Data Subject to Revision ---

- Gage height
- Measured gage height
- Flow at station affected by ice
- Gage Pooling
Anderson Creek Downstream

Above: 10/2/15, Below: 11/18/15

Above: 11/2/15, Below: 12/14/15
Anderson Creek Upstream

Above: 10/6/15, Below: 11/14/15

Above: 11/2/15, Below: 12/14/15
Stream Design
PEO/AEO Roles

- Work with hydraulics office to identify constraints
- Provide CAD/InRoads Support
  - HQ Hydraulics has training material, standard templates, and cells for modeling streams
  - Working with CAE to get the Plans Prep manual updated
  - For support contact Catherine LaPointe
- Lead in coordination between Tribes, Agencies, Property Owners, support groups, Etc.
- Roadway geometrics/construction planning
Guidance Documents

- FHWA HEC 18
- FHWA HEC 20
- FHWA HEC 23
- WSDOT HM Chapter 7 (major update coming soon)
- WDFW Water Crossing Design Guidelines (WCDG)
- WDFW Integrated Stream Protection Guidelines (ISPG)
Overview

• Methods to assess site conditions and reference reach (Stream Survey, Stream Gaging, Pebble Count/Grab Samples, etc)
• Understanding basin hydrology, stream/river hydrodynamics, and sediment supply
• Importance of understanding design is site specific
• Hydraulic Modeling
• Methods used to design streambed gradation
• Methods for constructing design
Methods to Assess Site Conditions

- Reference Reach
- Stream Gaging/Hydrology Investigation
- Stream Survey (i.e. Longitudinal Profile, Cross Sections, Geomorphic Features, etc)
- Wolman Pebble Count/Grab Samples
- Photographs
- Site Visits
Appropriate Reference Reach

• Stream simulation is meant to mimic natural conditions in a unaffected reach
• Reference reach assists the designer in determining the appropriate slope, sediment size, and channel shape
• Reference reach should have a basin size that is similar to the crossing in question
Basin Hydrology
## Site Conditions

### Longitudinal, Cross-Sectional and Plan Views of Major Stream Types

<table>
<thead>
<tr>
<th>STREAM TYPES</th>
<th>PLAN VIEW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aa+</td>
<td>A</td>
</tr>
<tr>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>D</td>
<td>D A</td>
</tr>
<tr>
<td>D A</td>
<td>E</td>
</tr>
<tr>
<td>E</td>
<td>F</td>
</tr>
<tr>
<td>F</td>
<td>G</td>
</tr>
</tbody>
</table>

### Table: Site Conditions

<table>
<thead>
<tr>
<th></th>
<th>Braided</th>
<th>Regime</th>
<th>Pool-Riffle</th>
<th>Plane-Bed</th>
<th>Step-Pool</th>
<th>Cascade</th>
<th>Bedrock</th>
<th>Colluvial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Bed Material</td>
<td>Variable</td>
<td>Sand</td>
<td>Gravel</td>
<td>Gravel, cobble</td>
<td>Cobble, boulder</td>
<td>Boulder</td>
<td>N/A</td>
<td>Variable</td>
</tr>
<tr>
<td>Bedform Pattern</td>
<td>Lateral</td>
<td>Multi-layered</td>
<td>Lateral</td>
<td>None</td>
<td>Vertically</td>
<td>None</td>
<td>*</td>
<td>Variable</td>
</tr>
<tr>
<td>Reach Type</td>
<td>Response</td>
<td>Response</td>
<td>Response</td>
<td>Transport</td>
<td>Transport</td>
<td>Transport</td>
<td>Source</td>
<td></td>
</tr>
<tr>
<td>Dominant Roughness Elements</td>
<td>Bedforms (bars, potholes)</td>
<td>Sinuosity, bedforms (ripples, bars, bends)</td>
<td>Bedforms (bars, potholes), grains, LWD, sinuosity, banks</td>
<td>Grains, banks</td>
<td>Bedforms (steps, potholes), grains, LWD, banks</td>
<td>Grains, banks</td>
<td>Boundaries (bed &amp; banks)</td>
<td>Grains, LWD</td>
</tr>
<tr>
<td>Dominant Sediment Sources</td>
<td>Fluvial, bank failure, debris flow</td>
<td>Fluvial, bank failure, inactive channel</td>
<td>Fluvial, bank failure, inactive channel, debris flow</td>
<td>Fluvial, bank failure, debris flow</td>
<td>Fluvial, hillside, debris flow</td>
<td>Fluvial, hillside, debris flow</td>
<td>Fluvial, hillside, debris flow</td>
<td></td>
</tr>
<tr>
<td>Sediment Storage Elements</td>
<td>Overbank, bedforms</td>
<td>Overbank, bedforms, inactive channel</td>
<td>Overbank, bedforms, inactive channel</td>
<td>Overbank, inactive channel</td>
<td>Bedforms</td>
<td>Lee &amp; Stoss (sides of flow obstructions)</td>
<td>*</td>
<td>Bed</td>
</tr>
<tr>
<td>Typical Slope (m/m)</td>
<td>5 &lt; 0.03</td>
<td>5 &lt; 0.001</td>
<td>0.001 to 5 and 5 &lt; 0.02</td>
<td>0.01 to 5 and 5 &lt; 0.03</td>
<td>0.03 to 5 and 5 &lt; 0.08</td>
<td>0.08 to 5 and 5 &lt; 0.30</td>
<td>Variable</td>
<td>5 &lt; 0.20</td>
</tr>
<tr>
<td>Typical Confinement</td>
<td>Unconfined</td>
<td>Unconfined</td>
<td>Unconfined</td>
<td>Variable</td>
<td>Confined</td>
<td>Confined</td>
<td>Confined</td>
<td></td>
</tr>
<tr>
<td>Pool Spacing (Channel Widths)</td>
<td>Variable</td>
<td>5 to 7</td>
<td>5 to 7</td>
<td>none</td>
<td>1 to 4</td>
<td>&lt; 1</td>
<td>Variable</td>
<td>Variable</td>
</tr>
</tbody>
</table>

Source: Montgomery and Buffington, 1993.
Wolman Pebble Count/Grab Samples
Channel Alignment

- Review As-builts and RoW plans
- Review project geometric constraints
- Bend severity vs. length of structure
- Local topography
- Reduce impacts to vegetation/sensitive areas when possible
Channel Alignment
Channel Alignment
Identify existing key features:
- Overbank areas
- Thalweg
- Bankfull
Channel Shape

9+50

4+10

9+50

4+10
Proposed Section

EF WILDCAT CREEK SECTION B
EFWC 4+13.00 TO EFWC 4+45.00
Hydraulic Modeling

2D model of the Sauk-Suiattle confluence with water elevation contours and velocity vectors.

Bank stabilization project on SR 530.
Sediment Movement
Sediment Supply

(Sediment LOAD) x (Sediment SIZE) ≥ (Stream SLOPE) x (Stream DISCHARGE)
Sediment Supply

Aggradation

Degradation
Methods to Size Sediment

- Critical Unit Discharge (Bathurst)
- Modified Shields Equation
- Pebble Counts
Materials

9-01.11(1) Streambed Sediment

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percent Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 1/2&quot; square</td>
<td>100</td>
</tr>
<tr>
<td>2&quot; square</td>
<td>65 – 100</td>
</tr>
<tr>
<td>1&quot; square</td>
<td>50 – 85</td>
</tr>
<tr>
<td>No. 4</td>
<td>26 – 44</td>
</tr>
<tr>
<td>No. 40</td>
<td>16 max.</td>
</tr>
<tr>
<td>No. 200</td>
<td>5.0 – 9.0</td>
</tr>
</tbody>
</table>

Standard Specification 9-03.11(1)
### Materials

**9-03.11(2) Streambed Cobbles**

<table>
<thead>
<tr>
<th>Approx. Size</th>
<th>Percent Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4&quot; Cobbles</td>
</tr>
<tr>
<td>12&quot;</td>
<td>100</td>
</tr>
<tr>
<td>10&quot;</td>
<td>100</td>
</tr>
<tr>
<td>8&quot;</td>
<td>100</td>
</tr>
<tr>
<td>6&quot;</td>
<td>100</td>
</tr>
<tr>
<td>5&quot;</td>
<td>70 max.</td>
</tr>
<tr>
<td>4&quot;</td>
<td>100</td>
</tr>
<tr>
<td>3&quot;</td>
<td>40 max.</td>
</tr>
<tr>
<td>2&quot;</td>
<td>40 max.</td>
</tr>
<tr>
<td>1 ½&quot;</td>
<td>40 max.</td>
</tr>
<tr>
<td>¾&quot;</td>
<td>10 max.</td>
</tr>
</tbody>
</table>

**Standard Specification 9-03.11(2)**

- **4" Cobbles**
- **6" Cobbles**
- **8" Cobbles**
- **10" Cobbles**
- **12" Cobbles**

![Stone images](image1.jpg)

![Stone images](image2.jpg)
Materials

Sediment Gradation

Coarser Cobble Mix

Percent Finer vs. Grain Size [in]
Sediment—Final Product
Bridge Scour

Bridge washes out

FORKS — A sander-dump truck and a log truck plunged into the Bogachiel River early Friday after a washout on Highway 101 took out part of this bridge. The bridge, about six miles south of Forks, left one person dead and three wrecked vehicles in the river. (AP Laserphoto)
Why is it Important?

- Most common cause of bridge failure
- Determines the necessary depth of foundation

Location: SR 542 Gallup Creek
Cause: Flood washed out abutment, dropped 4'6"; 1962
Types of Scour

- Contraction Scour
- Local Scour
- Long Term Degradation
- Lateral Migration
Types of Scour
What Causes It?

Water around an obstruction (foundation, debris, etc) removes sediment and leaves behind a hole.

Location: SR 508 Bear Creek
Cause: Flood/Debris bent center and 2 trusses
What can be done?

• Existing Structures:
  – Regular inspections
  – Monitor (Plan of Action)
  – Apply countermeasures
• New Structures:
  – Plan for scour and design appropriately
Questions?