Improving the relationship between the river and the road.

Stream Restoration and Aquatic Organism Passage Opportunities During Post Flood Roadway Repair: An FHWA look at multipurpose objectives.
Acknowledgements

- United States Forest Service
- Colorado Department of Transportation
- Colorado Water Conservation Board
- Wildland Hydrology
- Crane Associates
- Round River Design
Agenda

• Who is this guy?
• What do highways have to do with river restoration?
• Stability in Rivers
• Natural Channel Design
• Aquatic Organism Passage
• Bioengineering and Large Woody Debris
• A look at FHWA work on:
  – U.S. Hwy 36
  – County Road 47
  – County Road 43 and
  – Sage Creek Road
Federal Lands Highway Division Offices

Central Federal Lands Highway Division (CFLHD)

Serves 14 central, western, and southwestern states & Pacific Territories

https://flh.fhwa.dot.gov/
Lane’s Balance:
An understanding that a stable river carries water, sediment and debris, even during high water, without drastic changes occurring in the depth, width, length, or slope of the channel.
Channel Evolution

Process

The adverse consequences of:

• accelerated sediment supply,
• accelerated bank erosion rates,
• degradation,
• aggradation from channel disturbance,
• Stream flow changes,
• sediment budget changes and
• many other causes can lead to channel change.

Image Source: Schumm Model
A River out of balance
Working with the river...

Understand the natural stable tendencies of rivers can accelerate the recovery processes.

Stream width is a function of:
- streamflow occurrence and magnitude
- size and type of transported sediment
- bed and bank materials of the channel

A channel can have a stable width even though the stream is migrating laterally at a constant annual rate.

Stream channel morphology is often described in terms of a width/depth ratio related to the bankfull stage cross-section.

Source: Wildland Hydrology
Make channels deep and flat for flood conveyance!

The Trapezoidal Channel Design Issues:
- Over-widened, one size fits all design
- Interrupts typical stream processes
- Water Temperature
- Habitat Loss
- ETC.
Riparian Zone:

- Multi-Stage Channel Design.
- Multi-Objective Approach.
- CHANNEL COMPLEXITY!!!
Advantages of the multiple stage channel

1. Vegetation establishment on the banks in different zones due to favorable soil moisture
2. Streambank erosion rates are decreased and rooting depth and density are increased
3. Near-bank stress is reduced because the flows are spread-out onto the next highest level
4. During drought, the low flow channel provides sufficient depth for fish habitat
5. During high flows, the low flow channel maintains the sediment transport capacity

Source: Wildland Hydrology.
Advantages of the multiple stage channel

6. Increases in the magnitude and frequency of flood peaks can be dispersed out of channel and onto a floodplain or flood-prone area.

7. Recreational activities and trails can be created on the floodplain and flood-prone area.

8. A more natural, visually pleasing river setting.

9. A decrease in flood stages for the same magnitude flood due to improved hydraulic and sediment transport efficiency.

10. Improved habitat and ecological diversity.

Source: Wildland Hydrology.
Aquatic Organism Passage

- FHWA
- HEC 26: *Culvert Design for Aquatic Organism Passage.*

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Fish Biology</td>
<td>Fish biological abilities and requirements for successful movement.</td>
</tr>
<tr>
<td>3 Culverts as Barriers</td>
<td>Details the types of barriers presented by culverts that were not designed with a fish's biological capacities in mind.</td>
</tr>
<tr>
<td>4 Inventory/Assessment/Prioritization</td>
<td>Importance of the hydraulic assessment, inventory and prioritization of road stream crossing projects. Includes a discussion of commonly used techniques, as well as synthesis and recommendations for future prioritization.</td>
</tr>
<tr>
<td>5 Hydrology</td>
<td>Discussion and comparison of hydrology used in the design of culverts for fish passage. Available techniques and recommended methods are included.</td>
</tr>
<tr>
<td>6 Design</td>
<td>Necessary considerations for the design or retrofit of a new or existing roadway-stream crossing installation.</td>
</tr>
<tr>
<td>7 Current Design Procedures</td>
<td>Details the current state of fish passage design, including design scenarios from across the country. Covers new installations, culvert replacements, and retrofits.</td>
</tr>
<tr>
<td>8 Case Studies/Design Examples</td>
<td>Case studies and/or basic examples of culvert design, installation and retrofit have been included to clarify the design process.</td>
</tr>
<tr>
<td>9 Construction/Maintenance</td>
<td>Common scenarios and recommendations for culvert construction and maintenance.</td>
</tr>
<tr>
<td>10 Monitoring</td>
<td>Suggested monitoring considerations to ensure long term success of culvert installations, replacements or retrofits.</td>
</tr>
<tr>
<td>11 Future Research Needs</td>
<td>Recommendations based on literature review and perceived gaps in current knowledge.</td>
</tr>
</tbody>
</table>
Aquatic Organism Passage
Passage Assessment Process

NATIONAL INVENTORY AND ASSESSMENT PROCEDURE:
For Identifying Barriers to Aquatic Organism Passage at Road-Stream Crossings

United States Department of Agriculture Forest Service
National Technology and Development Program
7700—Transportation Management
November 2005; Figure V-1.
Bioengineered Streambanks

- The Stream bank is not a rigid structure to be built in place, but a dynamic system that is naturally resilient.
- Plant roots stabilize the soil while streambank vegetation provides wildlife habitat and helps to dissipate flood velocities.
- Bioengineering techniques include placing logs and root wads in strategic locations, rapid establishment of shrubs in the active channel through live branch layering, and bank protection and floodplain wetland restoration with specially selected plantings and native seed mixes.

Bioengineered Techniques

• Rootwad Installation
• Brush/Tree Revetment
• Post Plantings
• Fiberschines
• Brush Trench
• Brush Mattress
• Brush Layer
• Vertical Bundles

• Living Cribwalls
• Brush Layering
• Engineered Log Jams
• Etc!!!
Woody Debris has a Multitude of Benefits

- Bank Stabilization
- Aquatic Habitat
- Energy Dissipation
Too Much Woody Debris?
Bank and Channel Complexity
Reduces Velocities & Erosion
Rip Rap Reduces Complexity and Opportunities for Riparian Vegetation
Reinforced Streambanks

• Prior to roadway construction rivers and streams generally meandered back and forth along smooth, sinuous paths, the width of these meanders varying primarily due to valley slope.

• However, when man-made structures such as bridges and culverts are placed along stream channels, this natural pattern is interrupted as the streams are forced to flow around tight bends or through narrow constrictions. In cases like this, protecting the roadway embankment through solely natural channel design can be a tough sell...
Structure Design and Replacement

Benefits:

- Accounts for Natural Channel Conditions
- Removes Unnecessary Channel Constrictions
- Promotes Riparian Connectivity
- Accommodates Aquatic and Terrestrial Passage Through Crossing.
Project Highlights

• Colorado Flood Recovery (Large AOP and River Restoration)
  – US Highway 36 from Lyons to Estes Park
  – County Road 47
  – Larimer County Road 43

• Wyoming Sage Creek Project (Small Scale AOP)
  – Big Sandstone Creek
  – Little Sandstone Creek
+ Large Drainage Area: Approx. 138,186 acres
Excessive Rainfall

Colorado Flood Event, 9-16 September 2013
Annual Exceedance Probabilities (AEPs) for Worst Case 24-hour Rainfall

Hydrometeorological Design Studies Center
Office of Hydrologic Development, National Weather Service
National Oceanic and Atmospheric Administration

http://www.nws.noaa.gov/oh/hdscl/

Created: 17 September 2013
Precipitation frequency estimates are from NCEA Atlas 14, Volume 9, Version 2.
Rainfall values come from 5-hour multi-sensor data.

Colorado Flood Event, 9-16 September 2013
Annual Exceedance Probabilities (AEPs) for Worst Case 7-day Rainfall

Hydrometeorological Design Studies Center
Office of Hydrologic Development, National Weather Service
National Oceanic and Atmospheric Administration

http://www.nws.noaa.gov/oh/hdscl/

Created: 24 September 2013
Precipitation frequency estimates are from NCEA Atlas 14, Volume 9, Version 2.
Rainfall values come from 5-hour multi-sensor data.
U.S. Highway 36

• An ambitious goal!
  – Redesign and Build 2.5 miles of US 36 for flood resilience while improving stream function and maintaining traffic to flood impacted communities.
  – In a six month period over 200,000 cubic yards or rock excavation and blasting, roadway armorment, stream restoration, drainage improvements, and roadway structural section were completed.

• Construction Estimates:
  – 50 Million Dollars
  – 24-48 Months to complete

Actuals:
  – 20 Million Dollars
  – 9 Months
Embankment Armoring

- We can protect the road...
Embankment Armoring

- We can protect the road and improve floodplain and river function!
Where the River Meets the Road

Along stretches of North St. Vrain Creek and the Little Thompson River, the cooperative U.S. Highway 36 project is shifting the road away from the streams into blasted canyon walls and bioengineering tiered river channels to accommodate varying flow levels—each with improved connection to the floodplain. The goal? A better road, healthier streams and a more resilient system.
U.S. Highway 36

Project: CO ER U.S. 36 Repair and Reconstruction
Legend:
- MILEPOINTS
- Construction Limits
- Boulder Parcel Boundaries
- 17950_sites (Historic Sites)
- US36 Project Sites
- Toe of Fill
- Larimer Parcel Boundaries
- Centerline
- Transition
- STREMS
- Edge of Pavement
- Top of Cut

1 inch = 200 feet

Figure 2:
Site 3-5 Pre and Post Comparison
Date: December 2013
Boulder County, CO
Approximate Roadway Location. Subject to change.
U.S. Hwy 36; Saint Vrain River
Post Flood
U.S. Hwy 36; Little Thompson River
Post Flood-2013
County Road 47
Important Lessons from U.S. Hwy 36 and County Road 47

- Recovery actions typically follow a rapid schedule. (Strike while the iron is hot mentality)
- Without watershed master plans; long-term goals for river restoration can be hard to identify quickly.
- Identify restoration opportunities that coincide with repairs to maximize efficiency.
- Traffic Control can be difficult. Sections of roadway were left over widened so that traffic could be accommodated. These areas could receive additional restoration at a later date.
- Collaborate, collaborate, collaborate… Many people will be involved throughout process. Establish mutual goals and understand that not all conversations go as smoothly as you would like.
Larimer County Road 43

Another ambitious goal!
• Redesign and Rebuild a majority of Larimer County Road 43 for flood resilience while improving stream function and maintaining traffic to flood impacted communities with 1 hour delays and allowable longer closures.

Project length of 10 miles
– 5 miles of complete reconstruction
– 3.5 miles of heavy reconstruction
– 1.5 miles of spot repair and surfacing (overlay)

Major Scopes of Work
– Earthwork, rock excavation and blasting (250,000 CY)
– Bridge construction (11 bridges)
– Riprap armorment construction (50,000 CY, from onsite generated rock)
– Drainage
– Hot Asphalt Concrete Pavement (30,000 tons)
– Stream Restoration

Construction Estimates:
– 100 Million Dollars
– 3-5 Years to complete

Actuals:
– 50 Million Dollars
– 2 Years
River Crossing Concepts

- Multi-stage channel through crossing.
- Floodplain reconnection

Source: AYERS, Big Thompson Master Plan
Numerous River Crossing...
Notes:
-River Restoration Areas are conceptual. Detailed plans will be submitted in separate application.
-NWP 14: Proposed Fill totals 18,589 Square Feet (0.43 Acre)
-Box Culvert 1 would be removed: 1,285 square feet (0.029 acre)

Figure 6:
County Road 43: Waters of the U.S. Assessment
Date: July 2014
Larimer County, CO
LCR 43 Post Flood
Bridge 3
LCR 43 Post Flood
Bridge 3
LCR 43 Post Flood Bridge 4

**Notes:**
- River Restoration Areas are conceptual. Detailed plans will be submitted in separate application.
- NWP 14: Proposed fill totals 18,589 square feet (0.43 acre)
- Box Culvert 1 would be removed: 1,285 square feet (0.029 acre)
LCR 43 Post Flood
Bridge 4
LCR 43 Post Flood
Bridge 4
LCR 43 Post Flood
Bridge 4
LCR 43 Post Flood-2016
Bridge 4 – Bioengineering and AOP
LCR 43 Box Culvert
LCR 43 Box Culvert
LCR 43 Post Flood-2016
Road and River Flip Flop
LCR 43 Embankment Armoring
Wyoming Sage Creek Project
Big Sandstone Creek

SAGE CREEK ROAD – BIG SANDSTONE STREAM CROSSING
STA. 3370+69.21
DETAIL A – PLAN VIEW

KEY PIECES (TYP):
- EMBED ANGULAR RIPRAP WITH CUBIC DIMENSION OF 24" - 36". EMBED HALFWAY INTO STREAMBED MATERIAL APPROX. SPACING 8'-12'.

CONSTRUCT V-WEIR WITH ANGULAR RIPRAP HAVING AN 24" - 36" CUBIC Dimension AT OUTLET. SEE X-SECTION C.

FILL IN EXIST PLUNGE POOL WITH NATIVE STREAMBED MATERIAL. SEE TABLE 1 FOR GRADATION.

PLACE NATIVE STREAMBED CHANNEL MATERIAL. SEE TABLE 1 FOR GRADATION.

FILL SLOPE AROUND PIPE INLET TO Q100 WSE. FF-03 Sect 25t. SEE X-SECTION B.

CLASS 5 RIPRAP ON FILL SLOPE AROUND PIPE OUTLET TO Q100 WSE. FF-03 Sect 25t. SEE X-SECTION B.

NOTE: - TABLE 1 – ROCK GRADATION AND CROSS SECTIONS B, C, D & E ARE ILLUSTRATED ON THE FOLLOWING SHEETS
- DESIGN IN PIPE BASED ON ASSUMED PIPE LENGTH OF 90'

CONSTRUCT INVERTED V-WEIR AT INLET WITH ANGULAR RIPRAP BETWEEN PIPE AND EDGE OF STREAMBED. SEE X-SECTION E & D.

10' INVERTED WEIR

6'

10' POOL 20' RIFFLE 20' POOL

LENGTH OF STREAMBED RECONSTRUCTION=100'

CLASS 5 RIPRAP UNFILL SLOPE AROUND PIPE INLET TO Q100 WSE. FF-03 Sect 25t. SEE X-SECTION B

NOTE: - TABLE 1 – ROCK GRADATION AND CROSS SECTIONS B, C, D & E ARE ILLUSTRATED ON THE FOLLOWING SHEETS
- DESIGN IN PIPE BASED ON ASSUMED PIPE LENGTH OF 90'

CONSTRUCT STREAMBANK WITH ANGULAR RIPRAP WITH CUBIC DIMENSION OF 24" - 30". FILL voids AND INTERSTICIAL SITES WITH NATIVE STREAMBED MATERIAL MEETING TABLE 1 GRADATION. MAINTAIN MIN. 4" WIDTH BETWEEN PIPE AND EDGE OF STREAMBED. SEE X-SECTION E & D.

NOTE: - TABLE 1 – ROCK GRADATION AND CROSS SECTIONS B, C, D & E ARE ILLUSTRATED ON THE FOLLOWING SHEETS
- DESIGN IN PIPE BASED ON ASSUMED PIPE LENGTH OF 90'
Big Sandstone Creek

SAGE CREEK ROAD – BIG SANDSTONE STREAM CROSSING
STA. 3370+69.21
NTS

CROSS SECTION A
UPSTREAM/DOWNSTREAM
DETAIL AND PROFILE
NTS

CROSS SECTION B
PROFILE VIEW
NTS

CROSS SECTION C
UPSTREAM/DOWNSTREAM
PROFILE VIEW
NTS

MAGR CROSS SECTION AT INLET/OUTLET OF PIPE (PIPE AND FILL SLOPE DELETED FOR CLARITY)
MAX. 8' ABOVE PROPOSED STREAMBED ELEV
NTS

STREAMBED PROFILE AT INLET/OUTLET WEIR
MAX. 8' ABOVE STREAMBED ELEV
NTS

STREAMBED CHANNE MATERIAL SEE TABLE FOR SPECIFICATION

SHEET 2 OF 3
Big Sandstone Creek

SAGE CREEK ROAD – BIG SANDSTONE STREAM CROSSING
STA. 3370+69.21
NTS

TABLE 1
ROCK GRADATION FOR NATIVE STREAMBED CHANNEL MATERIAL

<table>
<thead>
<tr>
<th>PARTICLE SIZE</th>
<th>% VOLUME</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 8 mm</td>
<td>10%</td>
</tr>
<tr>
<td>9–64 mm</td>
<td>25%</td>
</tr>
<tr>
<td>65–128 mm</td>
<td>50%</td>
</tr>
<tr>
<td>129–362 mm</td>
<td>15%</td>
</tr>
</tbody>
</table>

KEY PIECES — Angular Rock having 24” Cubic Dimension

PLACED FILLER MATERIAL

FULL ALL Voids BETWEEN INDIVIDUAL STREAMBED SIMULATION ROCKS AND ALL Voids LEFT DURING PLACEMENT OF Channel ROCKS AND Streambed SIMULATION ROCK ADJOINING TO Fittings, CONCRETE STRUCTURES, OR STRUCTURAL ROCKS. ALL Voids LEFT DURING PLACEMENT OF Native Streambed MATERIAL Placed shall EXTEND TO a DEPTH EQUAL TO the BOTTOM OF Native Streambed MATERIAL Placed. IF NEEDED, metal TAMPERING RODS AND SIMILAR HAND-OPERATED EQUIPMENT TO FORCE MATERIAL INTO ALL Voids AND SUFFICIENT Voids BETWEEN THE STRUCTURE AND ROCKS AND BETWEEN INDIVIDUAL ROCKS. FULL EXTEND TO 100 PERCENT OF THE ROCKS Height BETWEEN LAYERS AND 50 PERCENT OF THEIR Height ON THE Bed Surface OR AS SHOWN ON THE DRAWING.
Big Sandstone Creek
Little Sandstone Creek
Little Sandstone Creek
Little Sandstone Creek
Key Benefits of these concepts

• Reduce maintenance costs.
• Reduce societal impacts of road closures.
• Reduce or replace rip-rap with rough woody structures and other bioengineered designs that enhance aquatic habitat.
• Reduce frequency of habitat impacts to aquatic habitat from repetitive repairs infrastructure.
Questions

???
References.

• USDA Forest Service, National Inventory and Assessment Procedure, 2005.
• http://www.r5.fs.fed.us/restoration/Aquatic_Organism_Passage/guidance.shtml
• http://www.stream.fs.fed.us/fishxing/index.html
Acknowledgements

• Dave Rosgen and Wildland Hydrology
  http://wildlandhydrology.com/

• Jeff Crane of Crane Associates
  http://craneassociates.net/

• Mike Blazewitz of Round River Design
  http://roundriverdesign.com/