# 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/

# Stability

## 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.

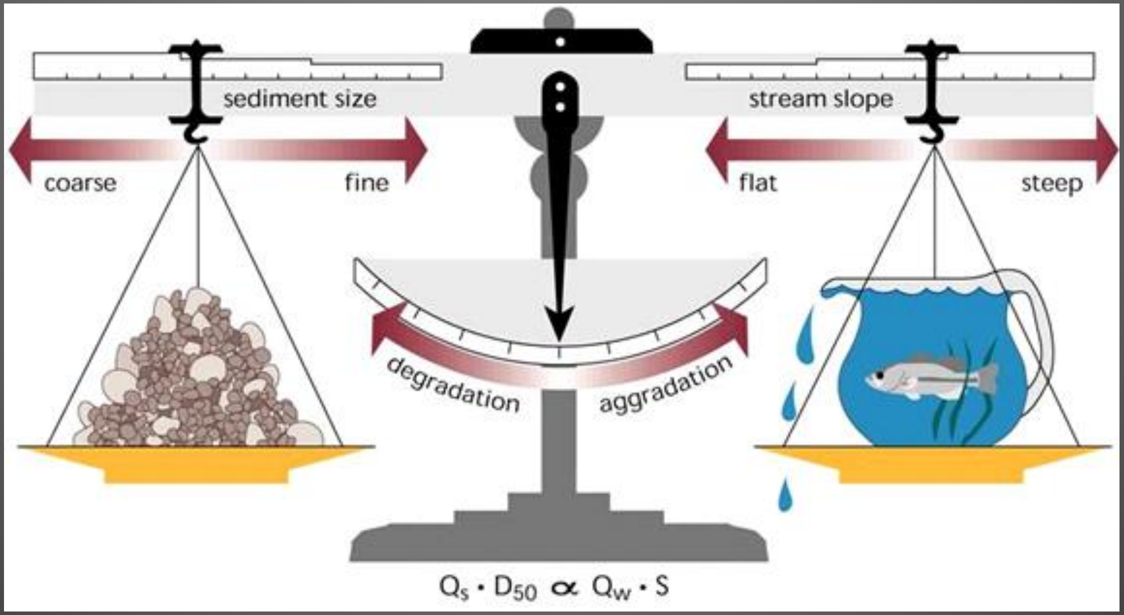


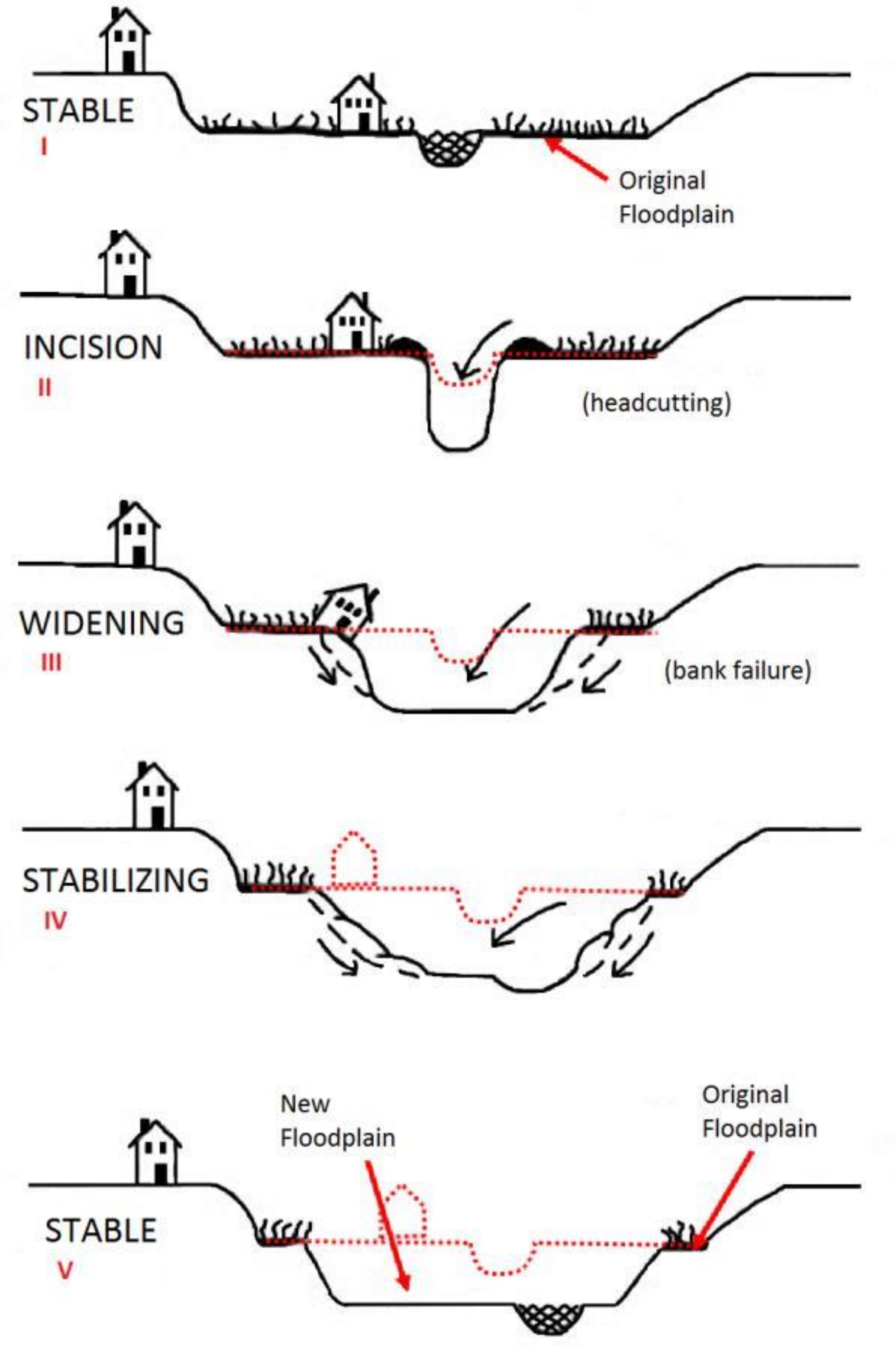

Image Source: Lane, E.W. 1955.

# Channel Evolution Process

The adverse consequences of:

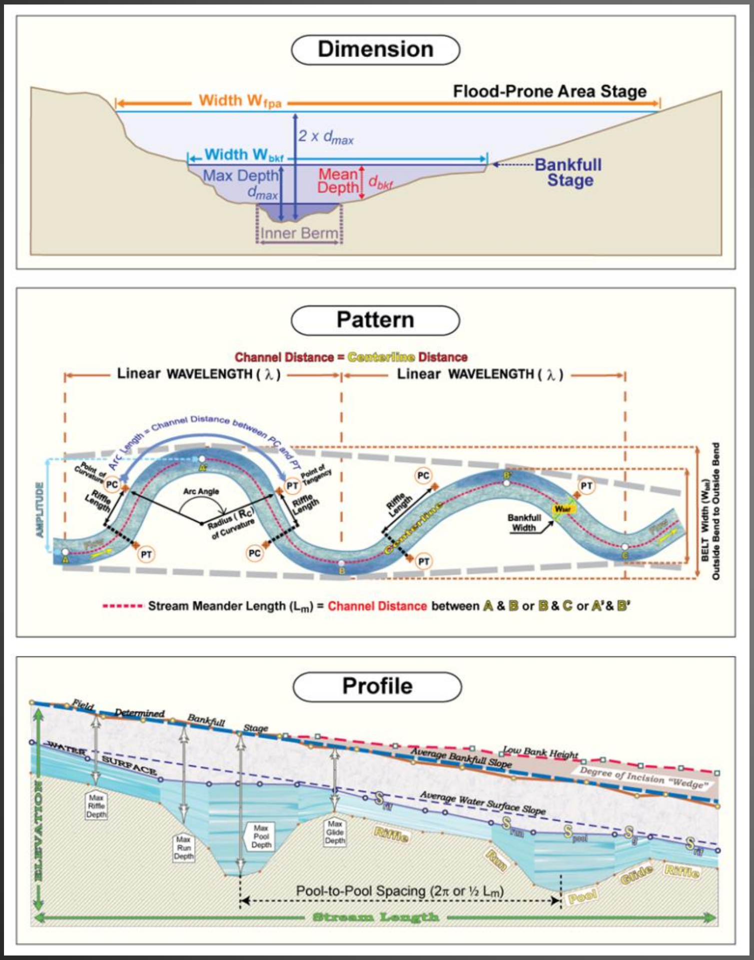
- accelerated sediment supply,
- accelerated bank erosion rates,
- degradation,
- aggradation from channel disturbance,
- Stream flow changes,
- sediment budget changes and
- many other causes can lead to channel change.

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

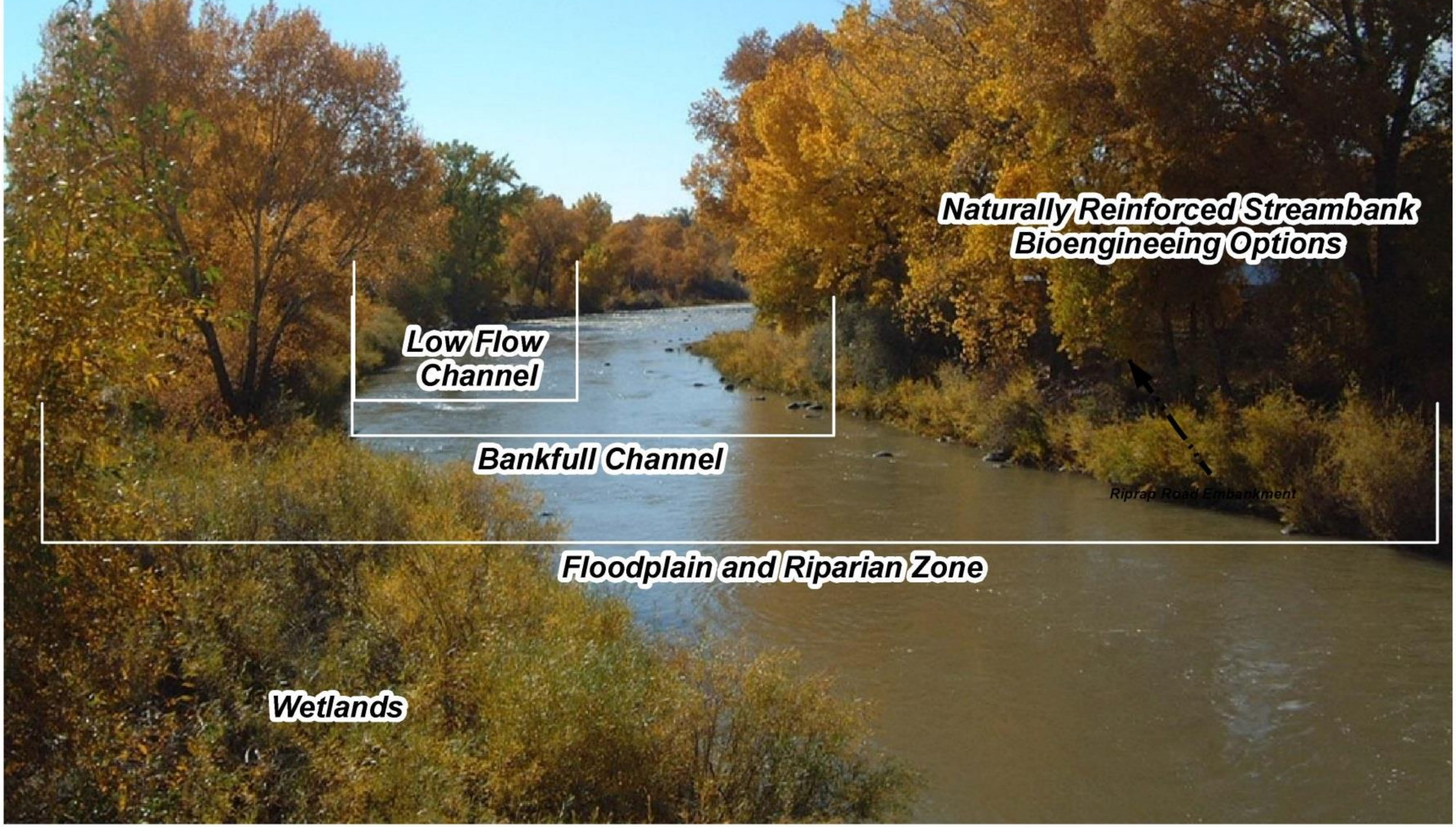
# Make channels deep and flat for flood conveyance!

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.*

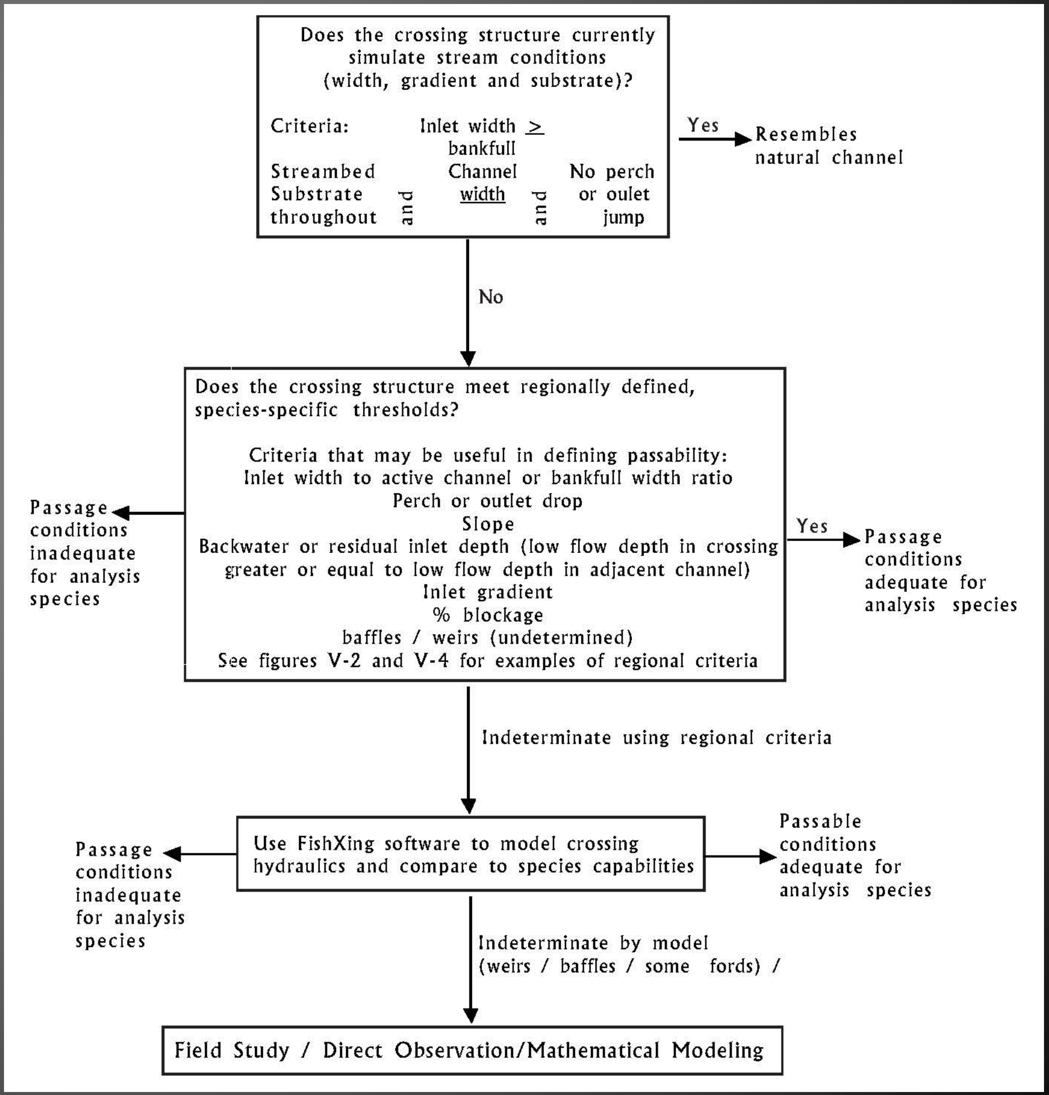
| Chapter | Description |
|---|---|
| 2 Fish Biology | Fish biological abilities and requirements for successful movement. |
| 3 Culverts as Barriers | Details the types of barriers presented by culverts that were not designed with a fish's biological capacities in mind. |
| 4 Inventory/Assessment/Prioritization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

# 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 2005F; 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.

Riparian Functions

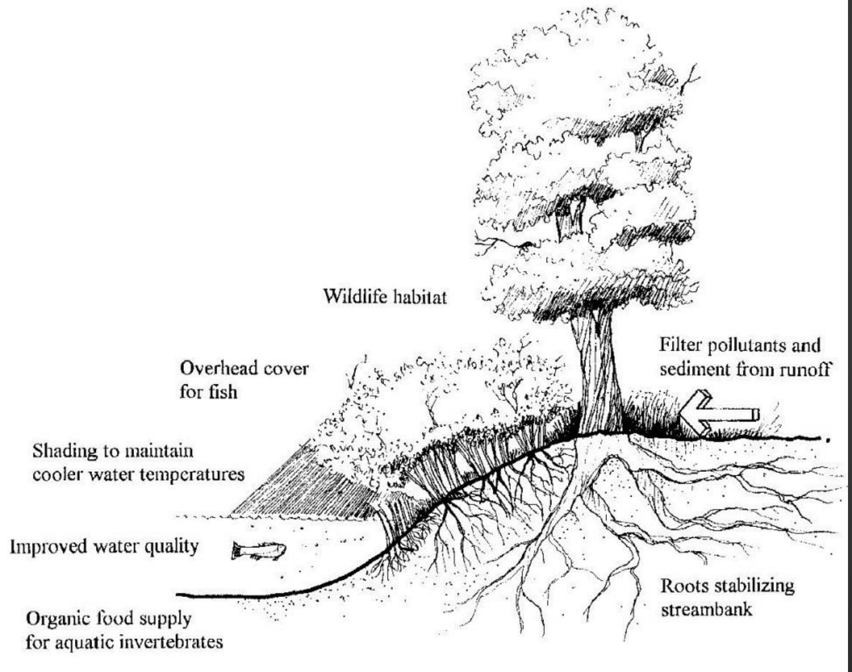
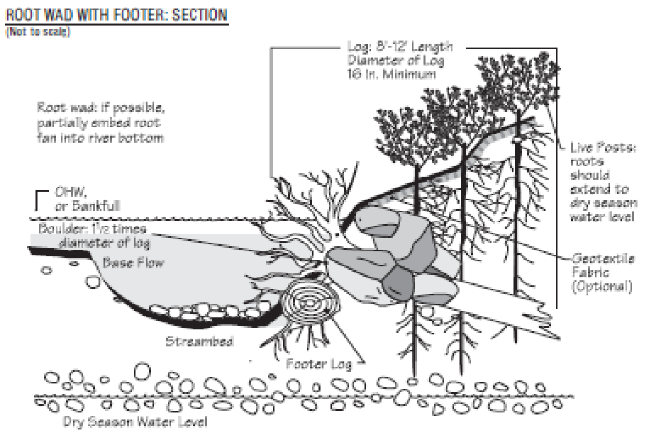
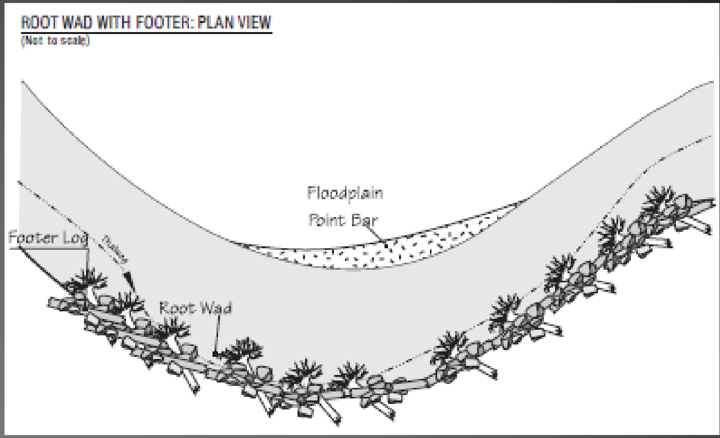


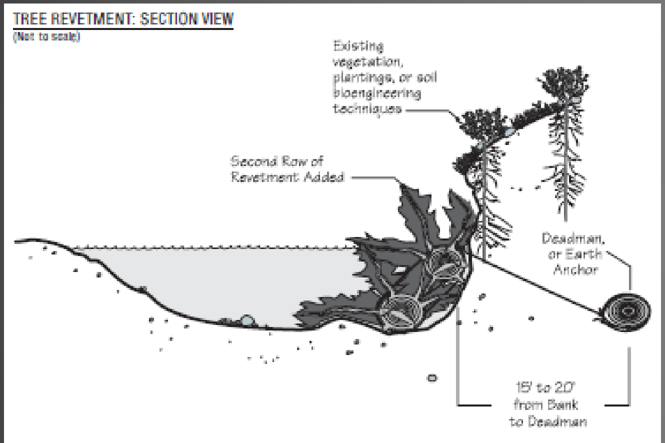

Image Source: *The Practical Streambank Bioengineering Guide, 1998*

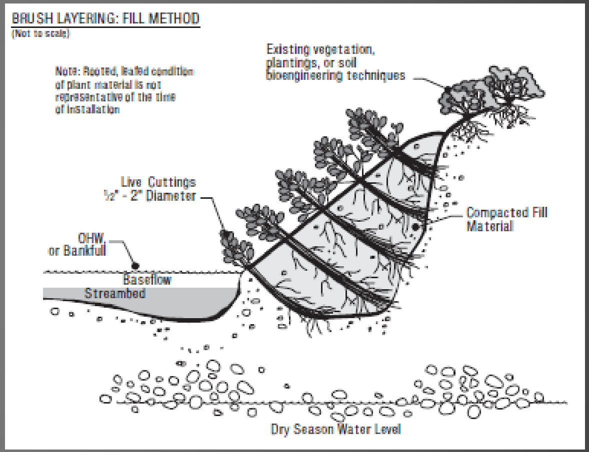
# Bioengineered Techniques

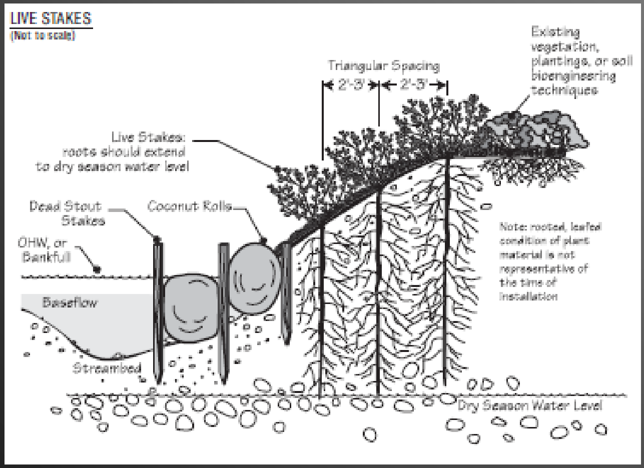
- Rootwad Installation
- Brush/Tree Revetment
- Post Plantings
- Fiberschines
- Brush Trench
- Brush Mattress
- Brush Layer
- Vertical Bundles
- Living Cribwalls
- Brush Layering
- Engineered Log Jams
- Etc!!!

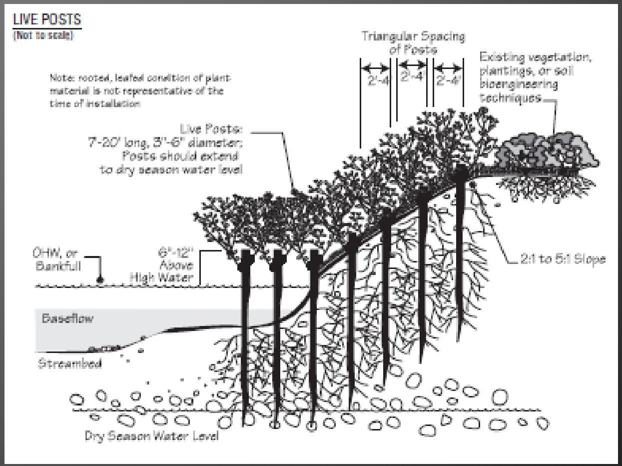

ROOT WAD WITH FOOTER: SECTION
(Not to scale)
Log: 8'-12' Length
Diameter of Log
16 In. Minimum
Root wad: If possible, partially embed root fan into river bottom
Live Posts: roots should extend to dry season water level
OHW, or Bankfull
Boulder: 1½ times diameter of log
Base Flow
Geotextile Fabric (Optional)
Streambed
Footer Log
Dry Season Water Level


ROOT WAD WITH FOOTER: PLAN VIEW
(Not to scale)
Floodplain
Point Bar
Footer Log
Root Wad


TREE REVETMENT: SECTION VIEW
(Not to scale)
Existing vegetation, plantings, or soil bioengineering techniques
Second Row of Revetment Added
Deadman, or Earth Anchor
15' to 20' from Bank to Deadman


BRUSH LAYERING: FILL METHOD
(Not to scale)
Note: Rooted, leafed condition of plant material is not representative of the time of installation
Existing vegetation, plantings, or soil bioengineering techniques
Live Cuttings ½" - 2" Diameter
Compacted Fill Material
OHW, or Bankfull
Baseflow
Streambed
Dry Season Water Level


LIVE STAKES
(Not to scale)
Existing vegetation, plantings, or soil bioengineering techniques
Triangular Spacing
2'-3'
2'-3'
Live Stakes: roots should extend to dry season water level
Dead Stout Stakes
Coconut Rolls
OHW, or Bankfull
Note: rooted, leafed condition of plant material is not representative of the time of installation
Baseflow
Streambed
Dry Season Water Level


LIVE POSTS
(Not to scale)
Triangular Spacing of Posts
2'-4'
2'-4'
2'-4'
Existing vegetation, plantings, or soil bioengineering techniques
Note: rooted, leafed condition of plant material is not representative of the time of installation
Live Posts: 7-20' long, 3"-6" diameter; Posts should extend to dry season water level
OHW, or Bankfull
6"-12" Above High Water
2:1 to 5:1 Slope
Baseflow
Streambed
Dry Season Water Level

# Woody Debris has a Multitude of Benefits

- *Bank Stabilization*
- *Aquatic Habitat*
- *Energy Dissipation*

# *Too Much Woody Debris?*

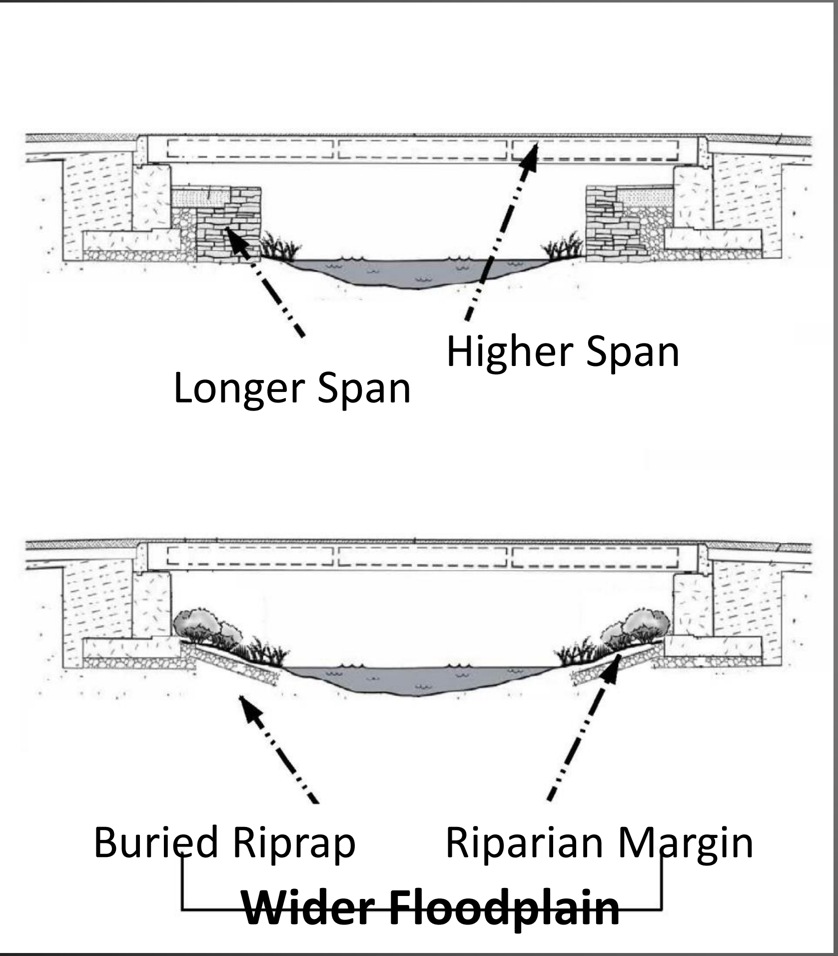
# Bank and Channel Complexity Reduces Velocities & Erosion

# 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



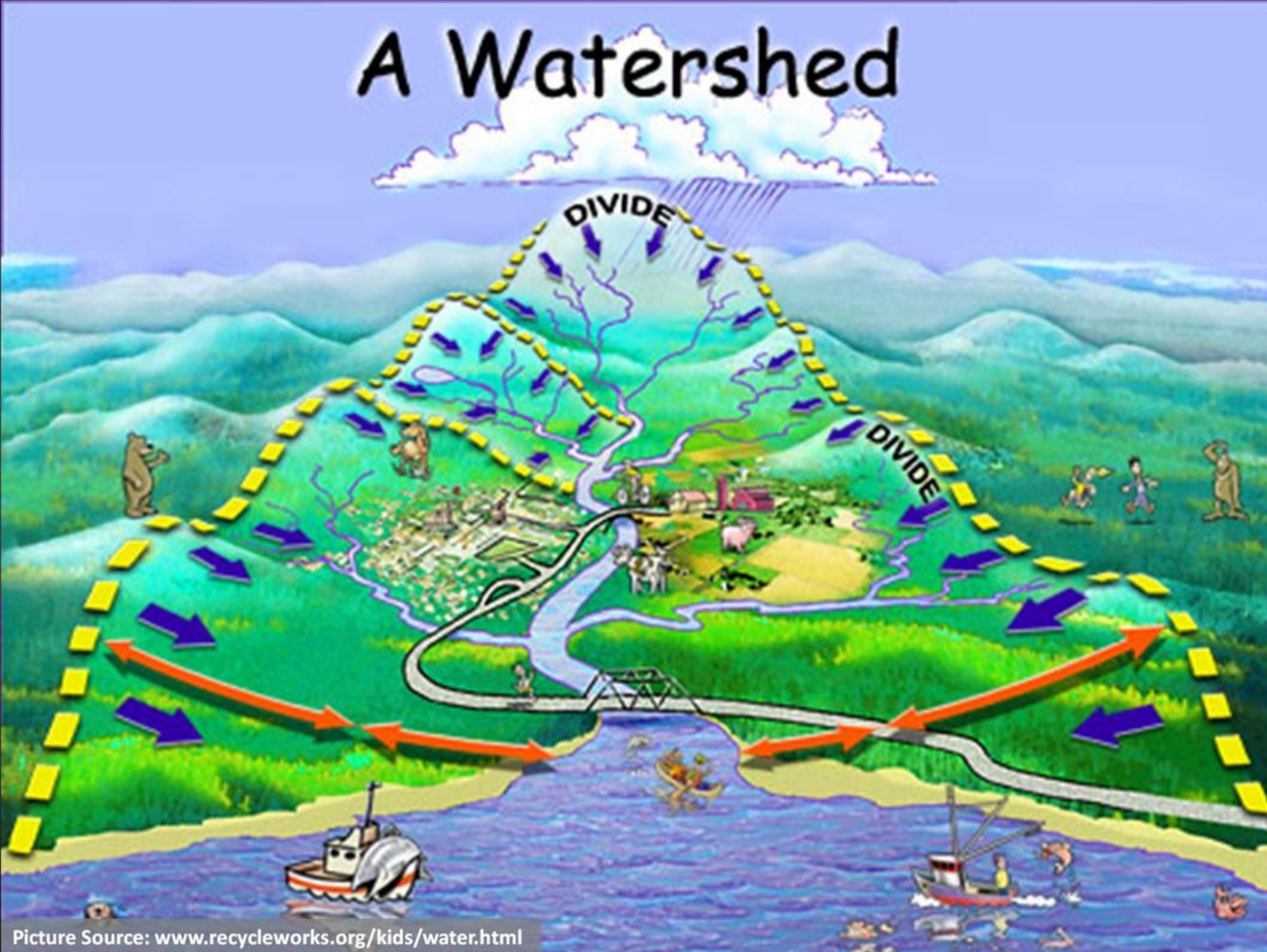

Benefits:

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

# Project Highlights

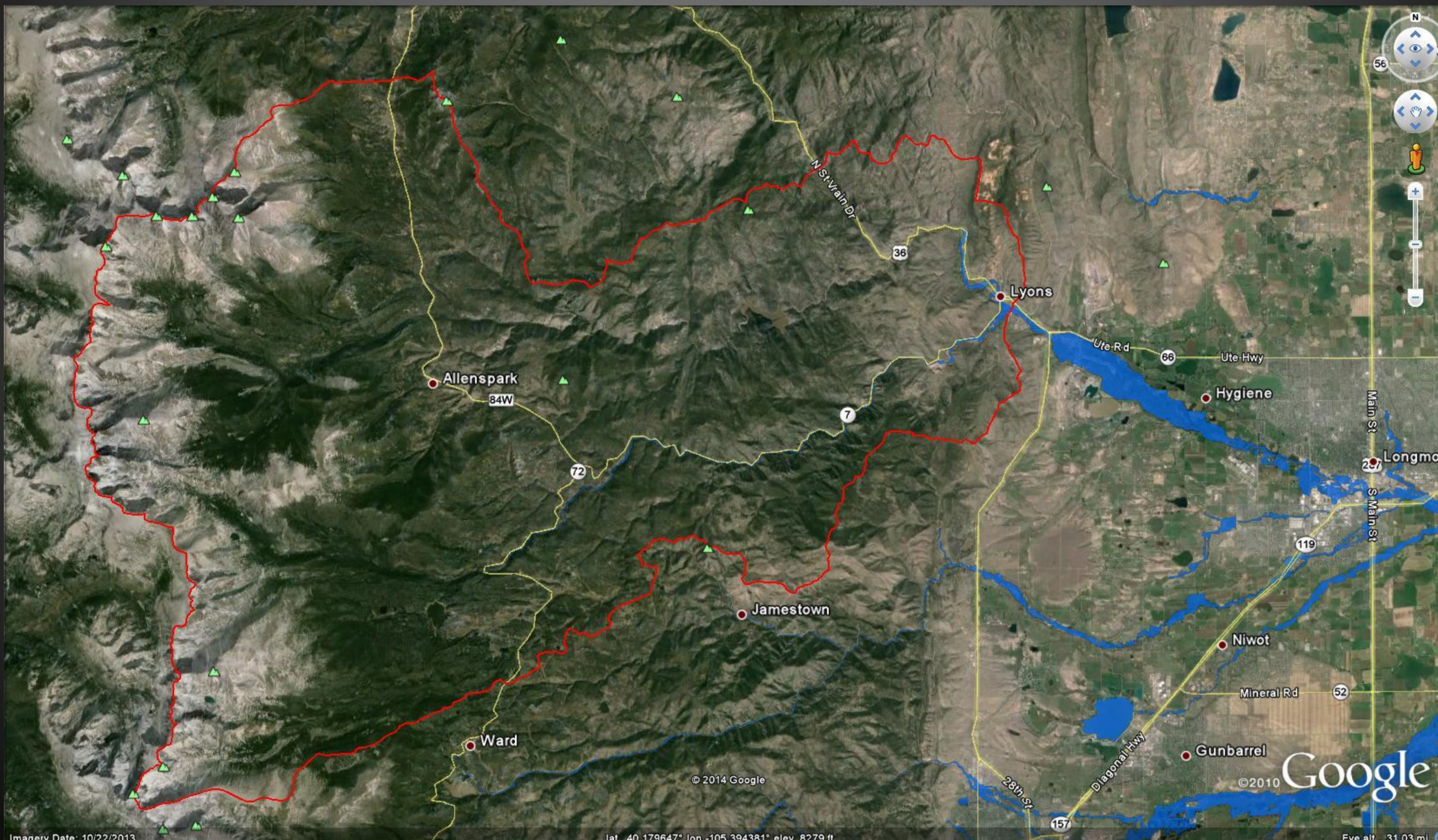
- Colorado Flood Recovery (Large AOP and River Restoration)
  - US Highway 36 from Lyons to Estes Park
  - County Road 47
  - Larimer County Road 43

- Wyoming Sage Creek Project (Small Scale AOP)
  - Big Sandstone Creek
  - Little Sandstone Creek

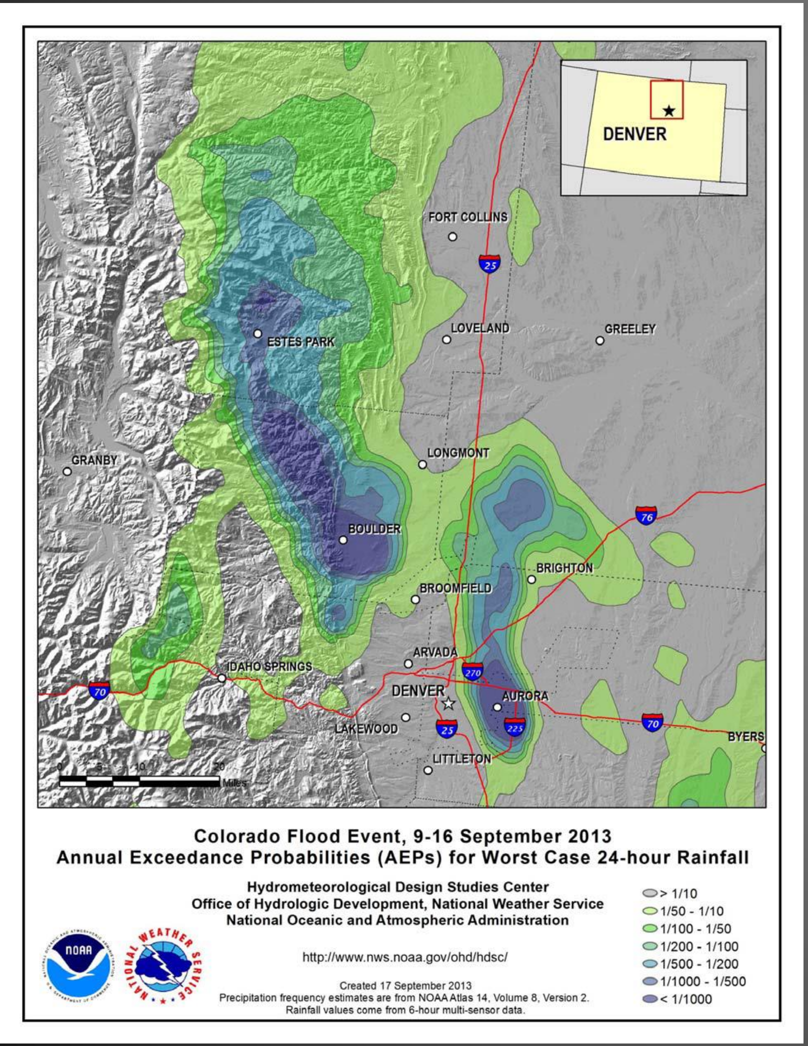


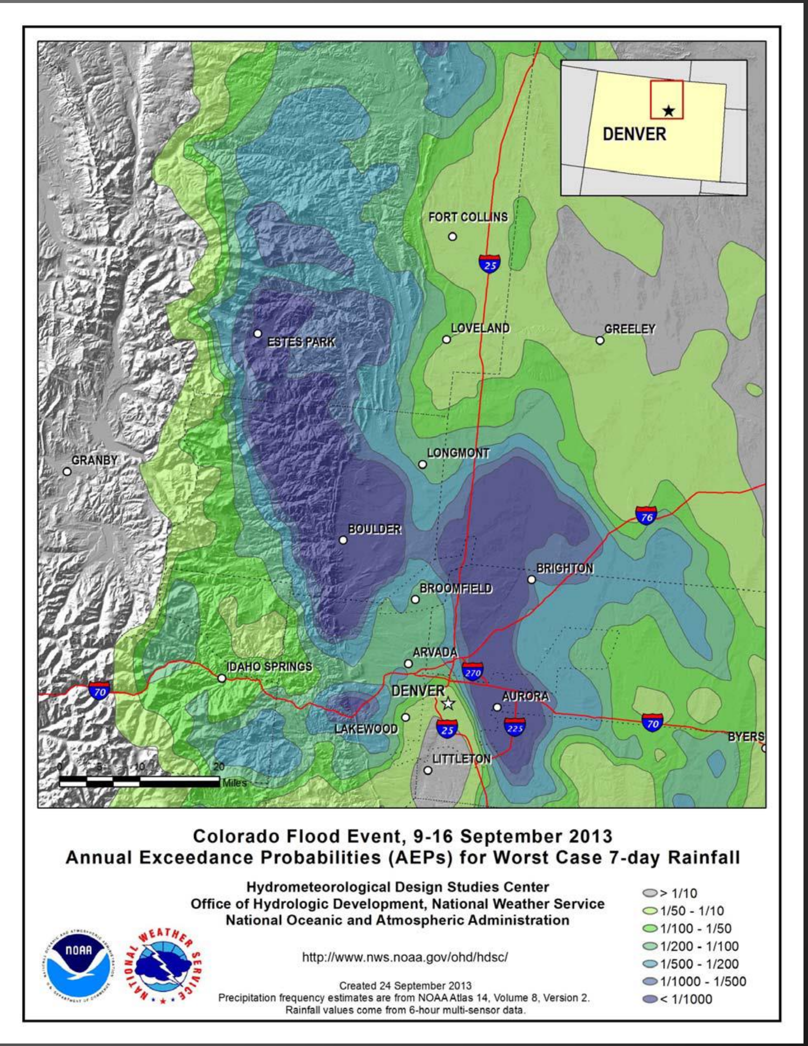

Picture Source: www.recycleworks.org/kids/water.html

# + Large Drainage Area: Approx. 138,186 acres



# Excessive Rainfall



# U.S. Highway 36

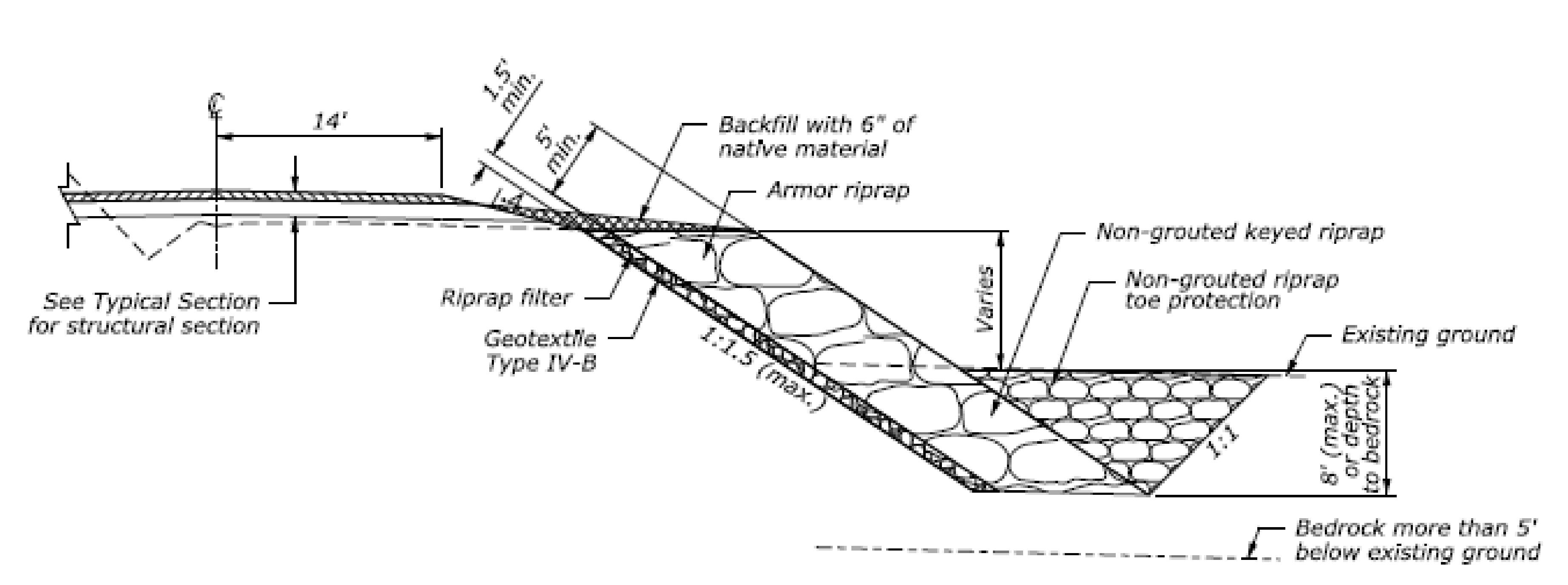
- An ambitious goal!
  - Redesign and Build 2.5 miles of US 36 for flood resilience while improving stream function and <u>*maintaining traffic*</u> to flood impacted communities.
  - In a six month period over 200,000 cubic yards or rock excavation and blasting, roadway armorment, stream restoration,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

- <u>Construction Estimates:</u>
  - 50 Million Dollars
  - 24-48 Months to complete

  <u>Actuals:</u>
  - 20 Million Dollars
  - 9 Months

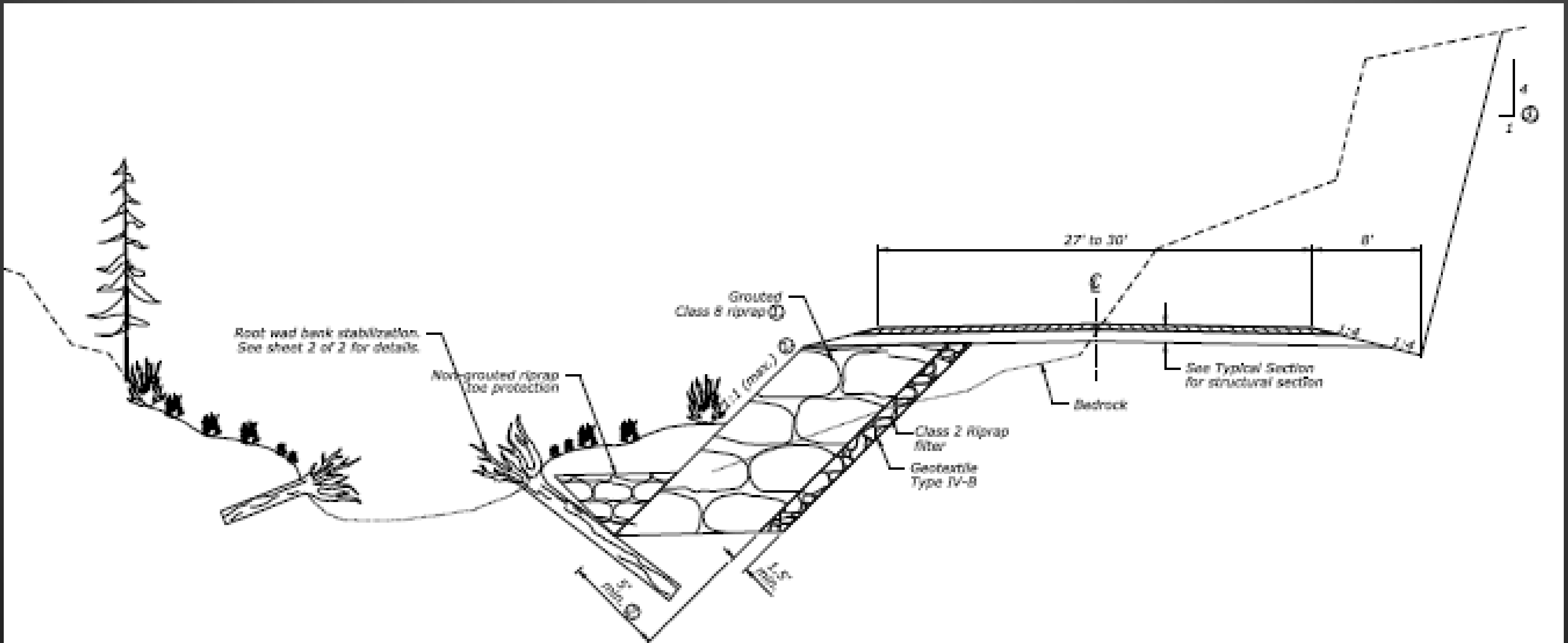
# Embankment Armoring

- We can protect the road…



# Embankment Armoring

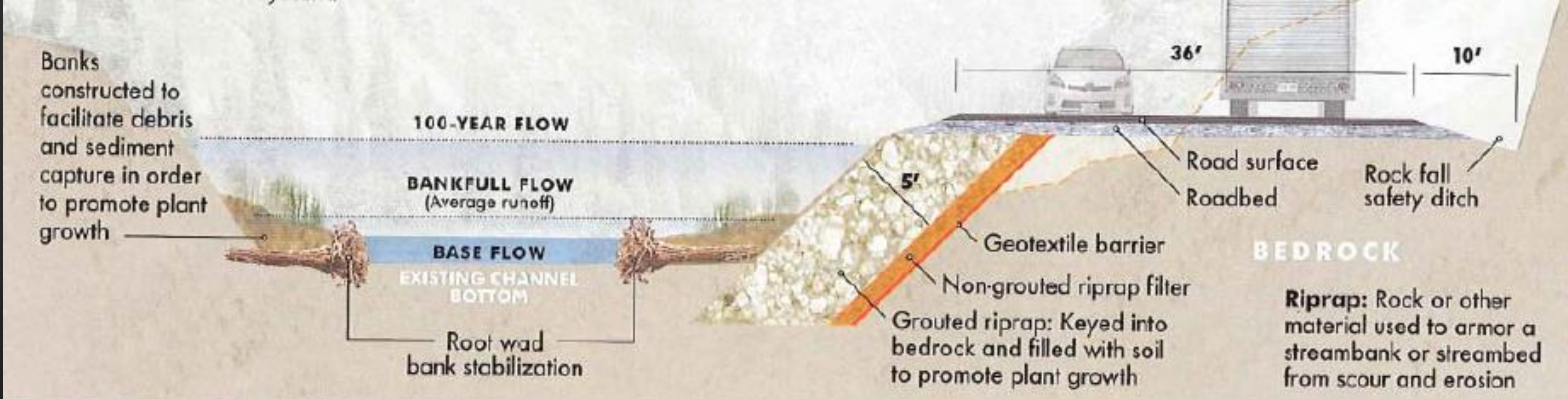
- We can protect the road and improve floodplain and river function!




**PROPOSED REPAIR TYPICAL SECTION**

# 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


Federal Highway Administration-
Central Federal Lands
Highway Division

**Project: CO ER U.S. 36 Repair and Reconstruction**

**Legend:**

- MILEPOINTS
- US36 Project Sites
- Centerline
- Edge of Pavement
- Construction Limits
- Toe of Fill
- Transition
- Top of Cut
- Boulder Parcel Boundaries
- Larimer Parcel Boundaries
- STREAMS
- LOCAL_ROADS
- 17950_sites (Historic Sites)

1 inch = 200 feet

0 100 200 Feet

0 0.02 0.04 Miles

N

**Figure 2:**
**Site 3-5 Pre and Post Comparison**

**Date: December 2013**

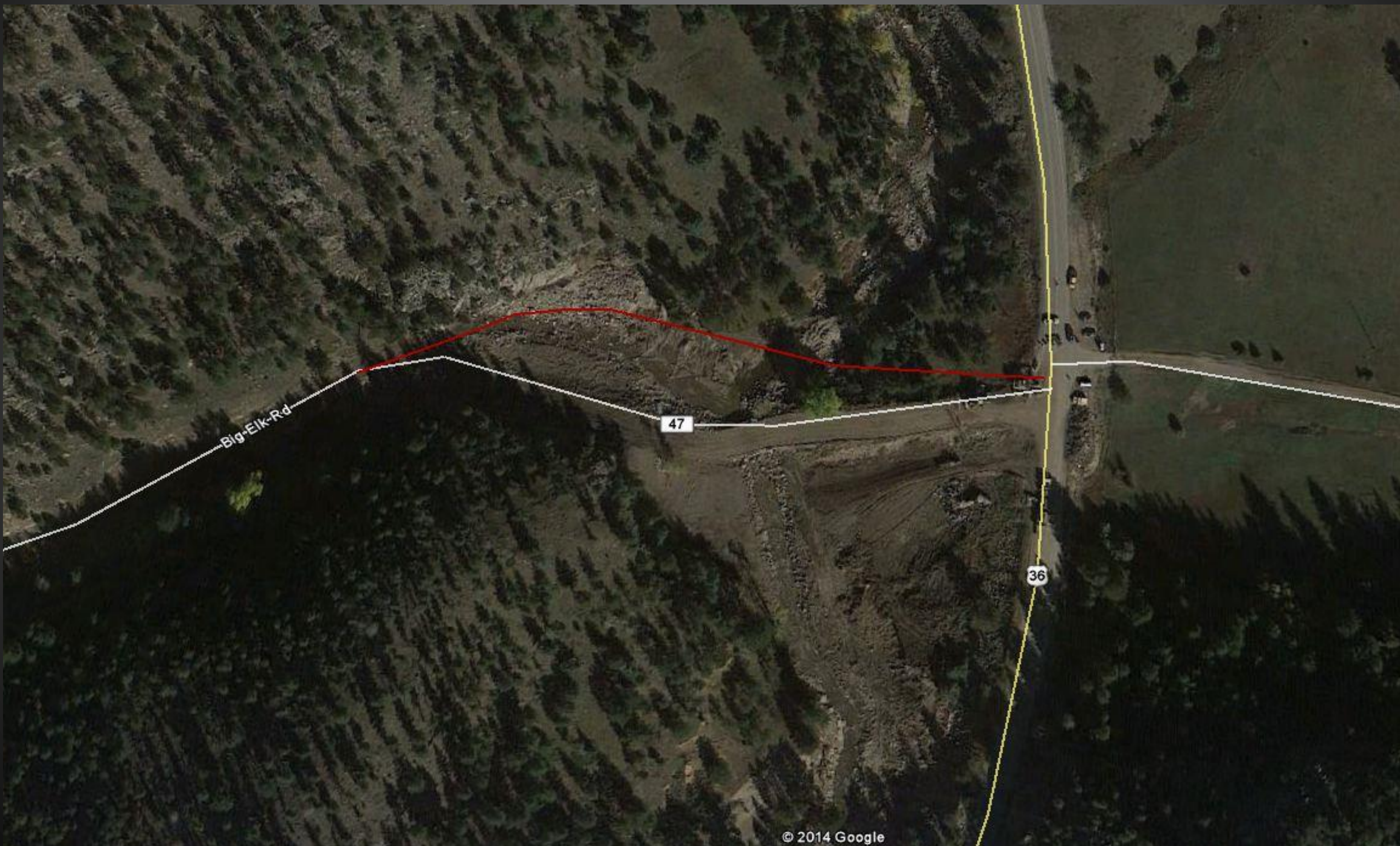
**Boulder County, CO**

**Approximate Roadway Location.**
**Subject to change.**

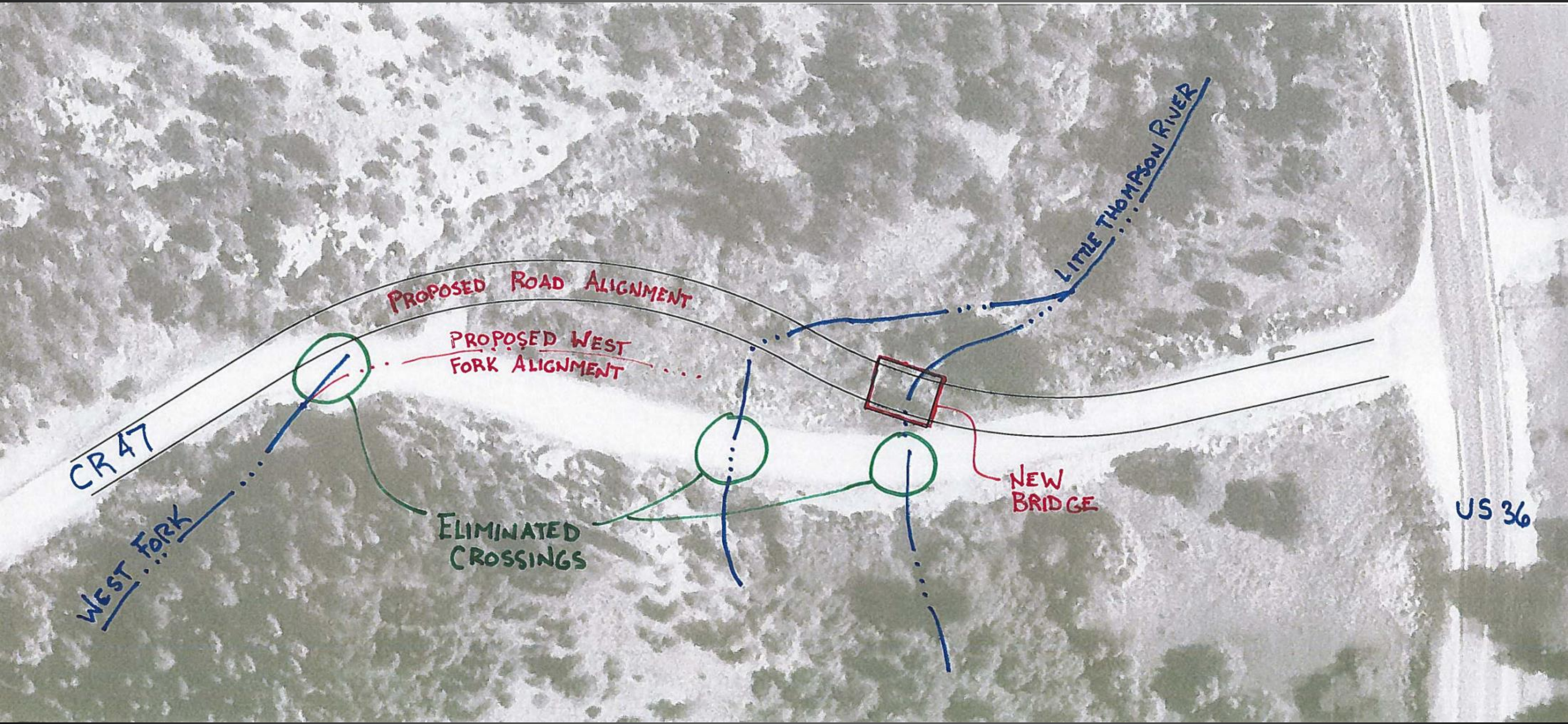
# U.S. Hwy 36; Saint Vrain River Post Flood

# U.S. Hwy 36; Little Thompson River Post Flood-2013

# County Road 47



# County Road 47



# 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

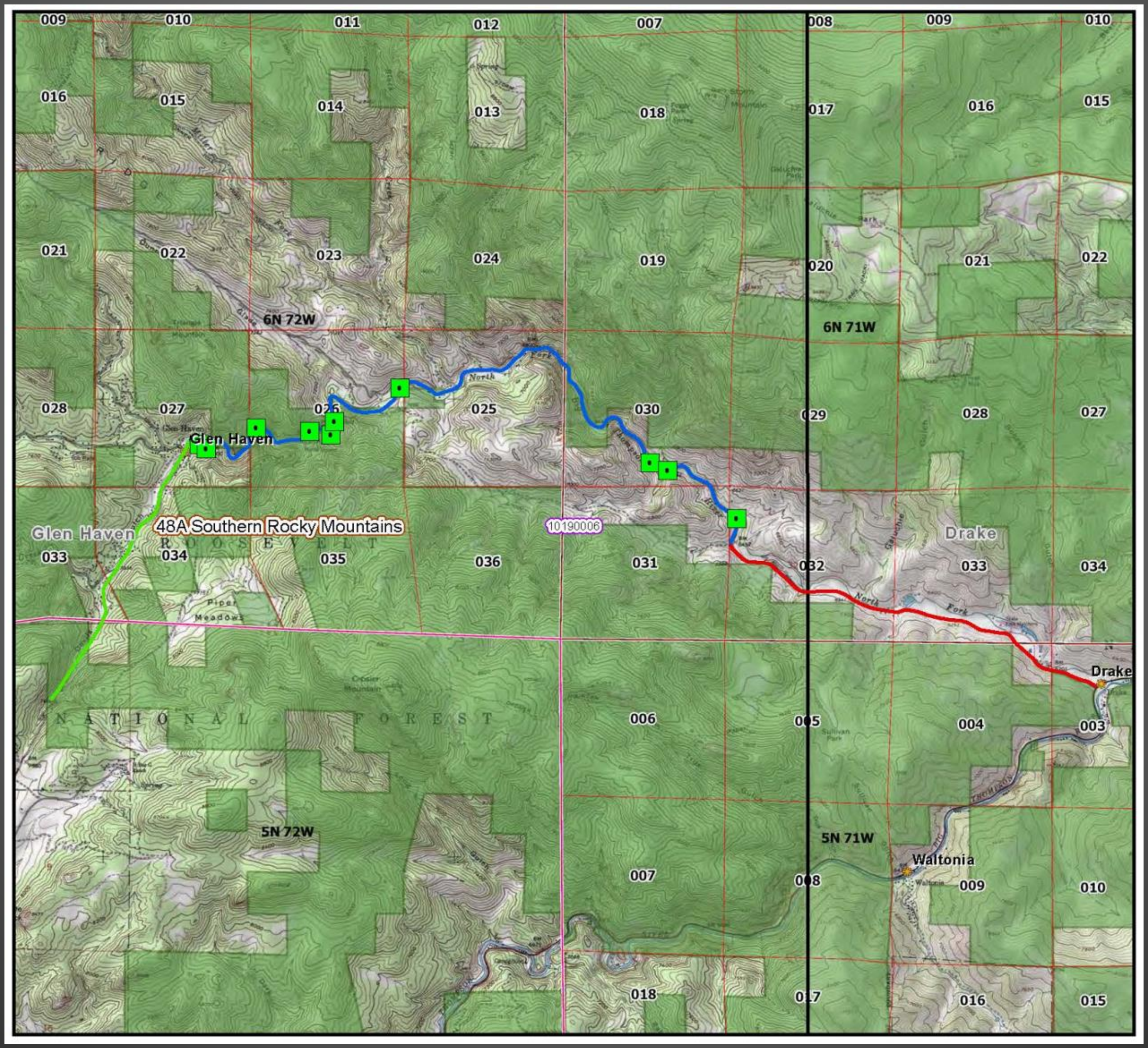
Construction Estimates:

- 100 Million Dollars
- 3-5 Years to complete

Actuals:

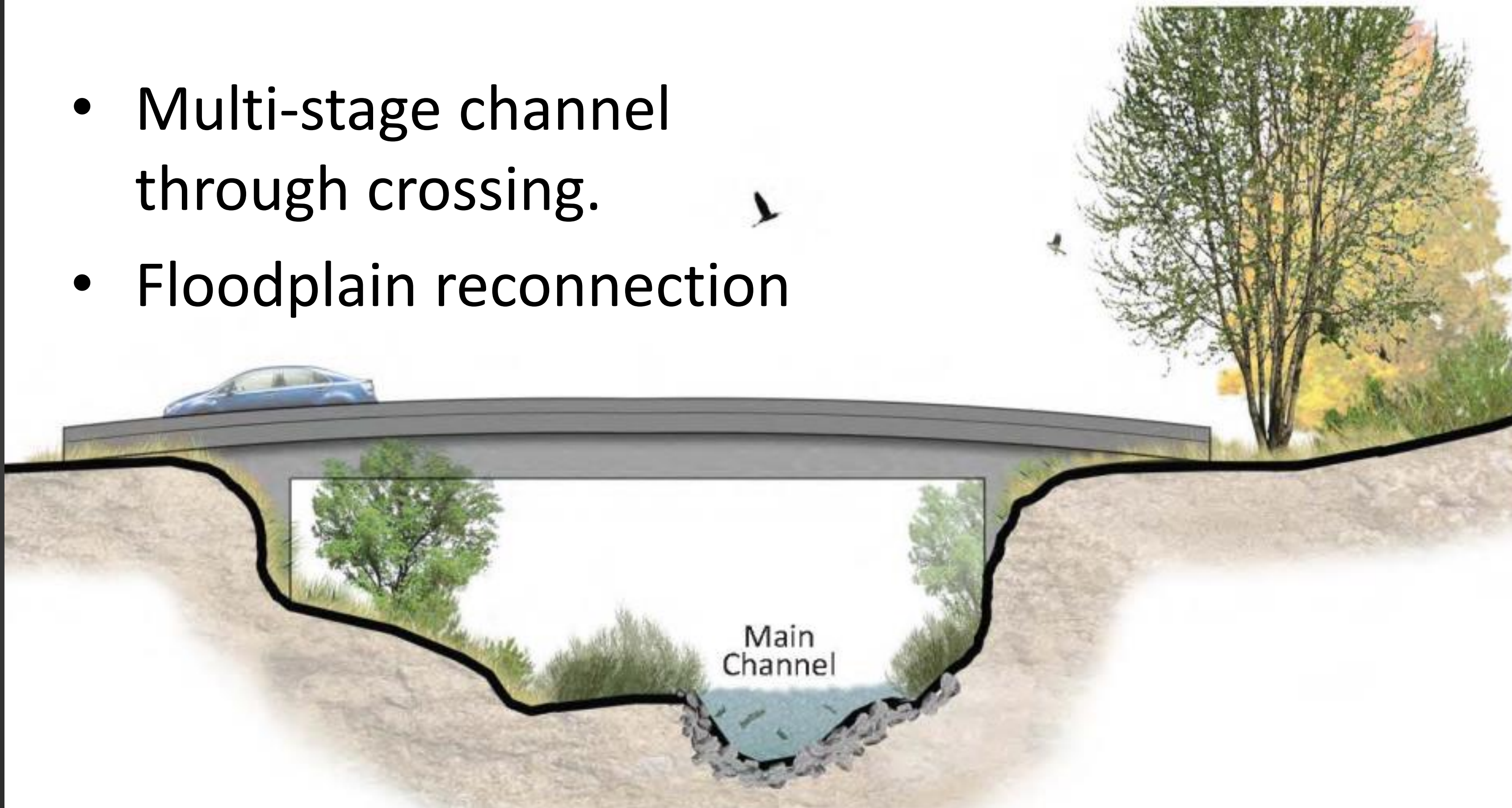
- 50 Million Dollars
- 2 Years

# Larimer County Road 43



# River Crossing Concepts

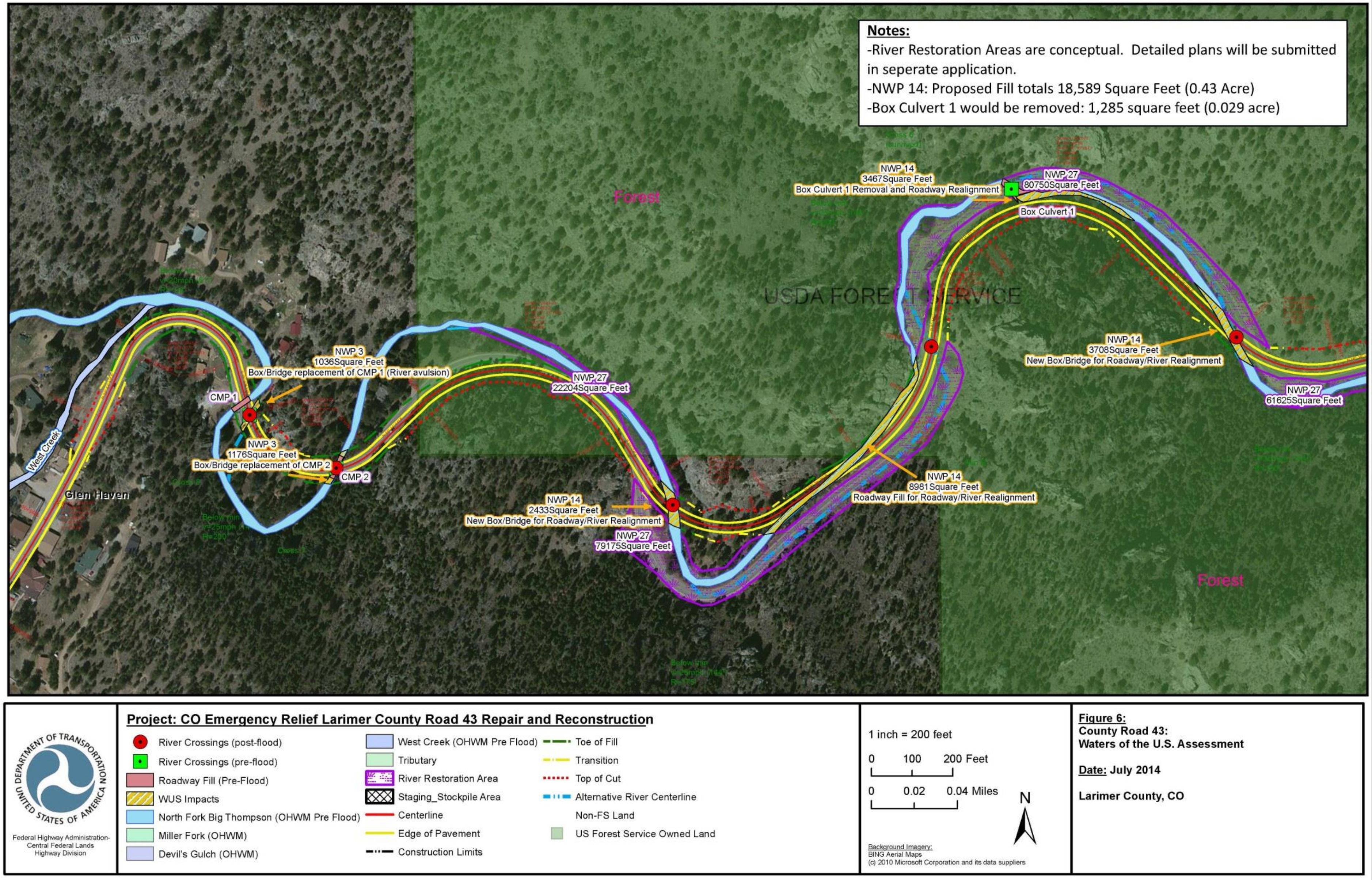
- Multi-stage channel through crossing.
- Floodplain reconnection



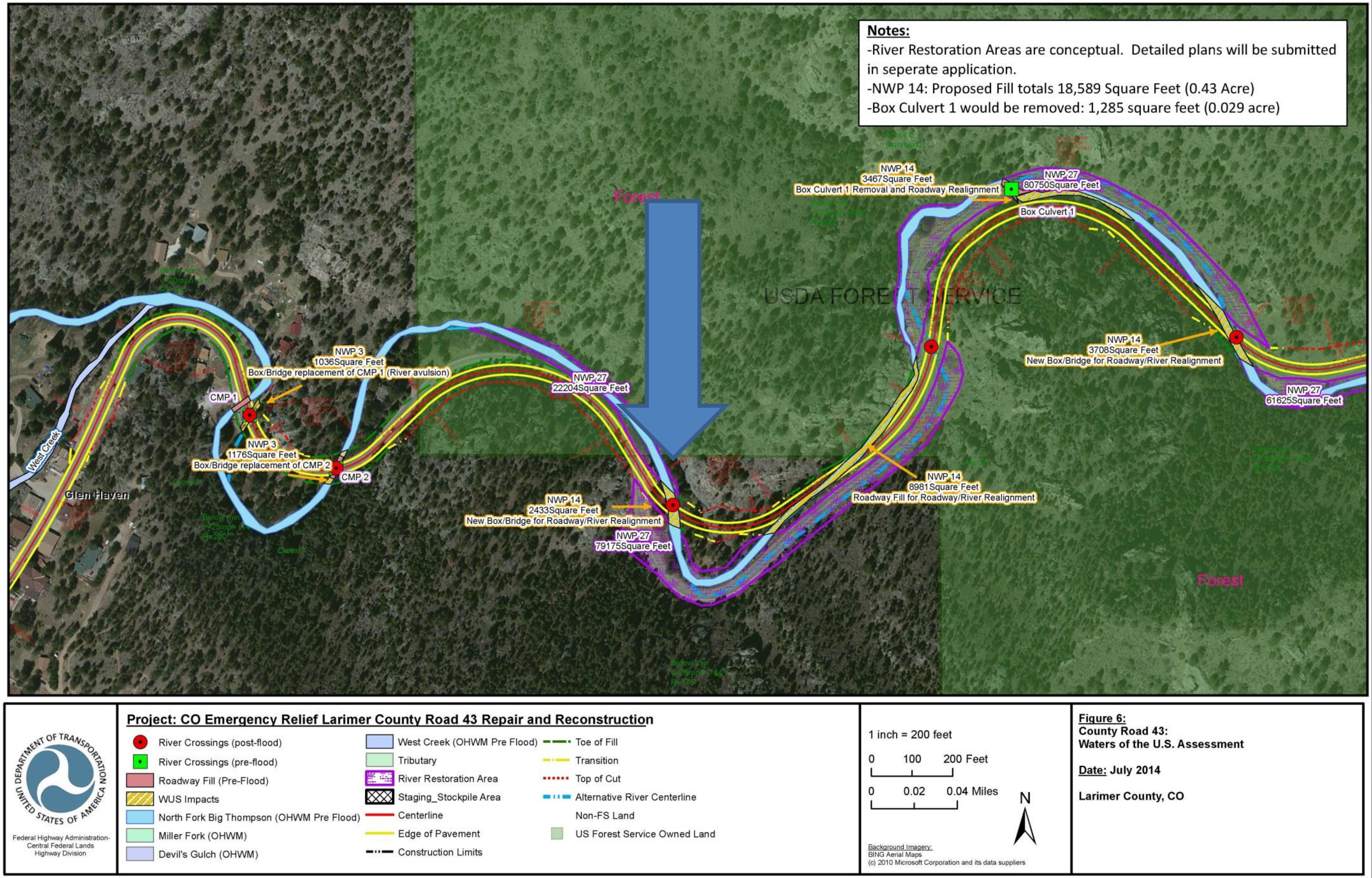

**Bridge - Increased Opening Size**

Source: AYERS, Big Thompson Master Plan

# Numerous River Crossing…



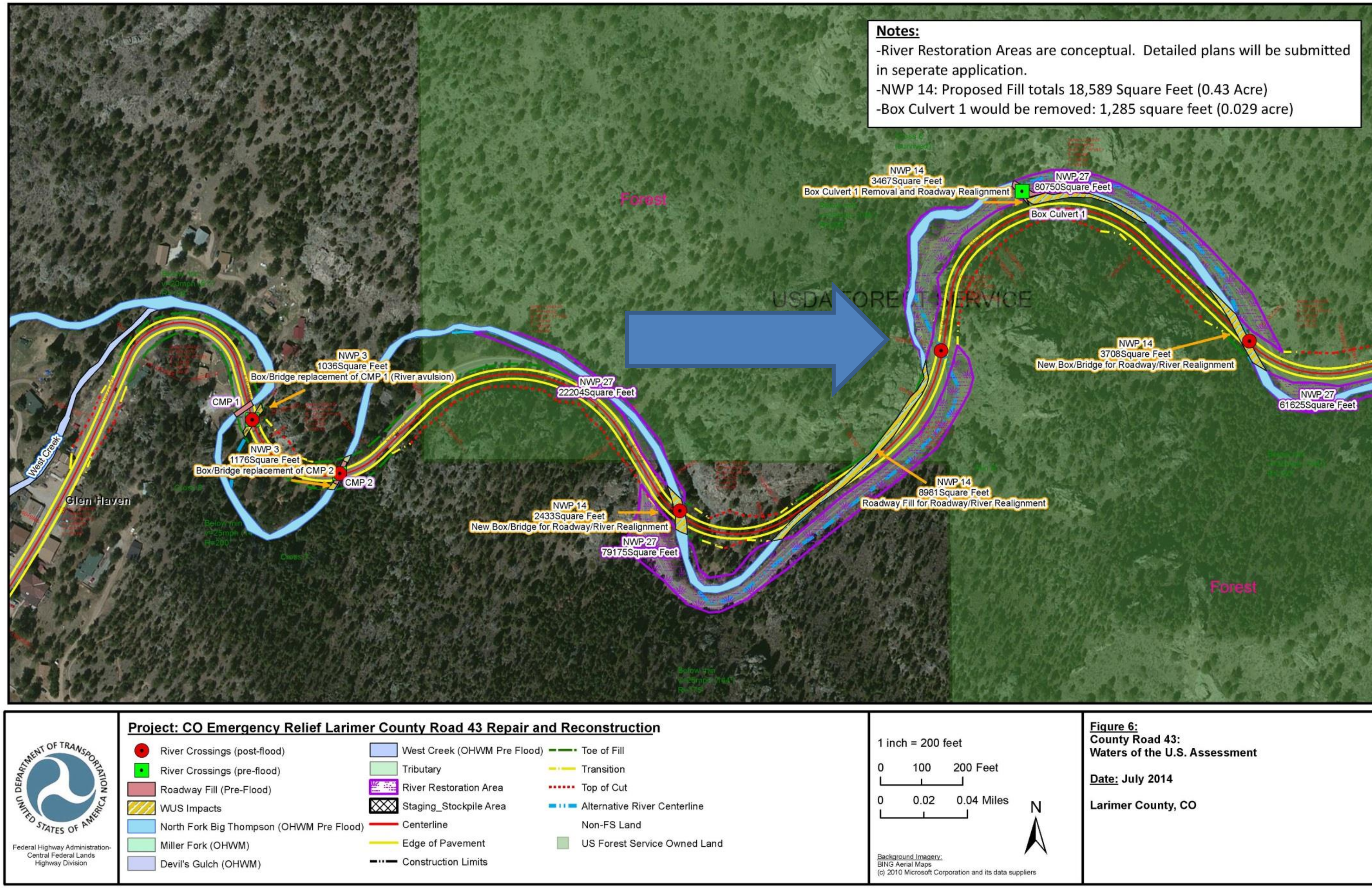
# Bridge 3


Notes:
-River Restoration Areas are conceptual. Detailed plans will be submitted in seperate 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)
NWP 14
3467Square Feet
Box Culvert 1 Removal and Roadway Realignment
NWP 27
80750Square Feet
Box Culvert 1
Forest
USDA FOREST SERVICE
NWP 3
1036Square Feet
Box/Bridge replacement of CMP 1 (River avulsion)
CMP 1
NWP 27
22204Square Feet
NWP 14
3708Square Feet
New Box/Bridge for Roadway/River Realignment
NWP 27
61625Square Feet
West Creek
NWP 3
1176Square Feet
Box/Bridge replacement of CMP 2
CMP 2
Glen Haven
NWP 14
8981Square Feet
Roadway Fill for Roadway/River Realignment
NWP 14
2433Square Feet
New Box/Bridge for Roadway/River Realignment
NWP 27
79175Square Feet
Forest
Project: CO Emergency Relief Larimer County Road 43 Repair and Reconstruction
River Crossings (post-flood)
River Crossings (pre-flood)
Roadway Fill (Pre-Flood)
WUS Impacts
North Fork Big Thompson (OHWM Pre Flood)
Miller Fork (OHWM)
Devil's Gulch (OHWM)
West Creek (OHWM Pre Flood)
Tributary
River Restoration Area
Staging_Stockpile Area
Centerline
Edge of Pavement
Construction Limits
Toe of Fill
Transition
Top of Cut
Alternative River Centerline
Non-FS Land
US Forest Service Owned Land
DEPARTMENT OF TRANSPORTATION UNITED STATES OF AMERICA
Federal Highway Administration-Central Federal Lands Highway Division
1 inch = 200 feet
0 100 200 Feet
0 0.02 0.04 Miles
N
Background Imagery:
BING Aerial Maps
(c) 2010 Microsoft Corporation and its data suppliers
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



# LCR 43 Post Flood
# Bridge 4

# LCR 43 Post Flood
# Bridge 4

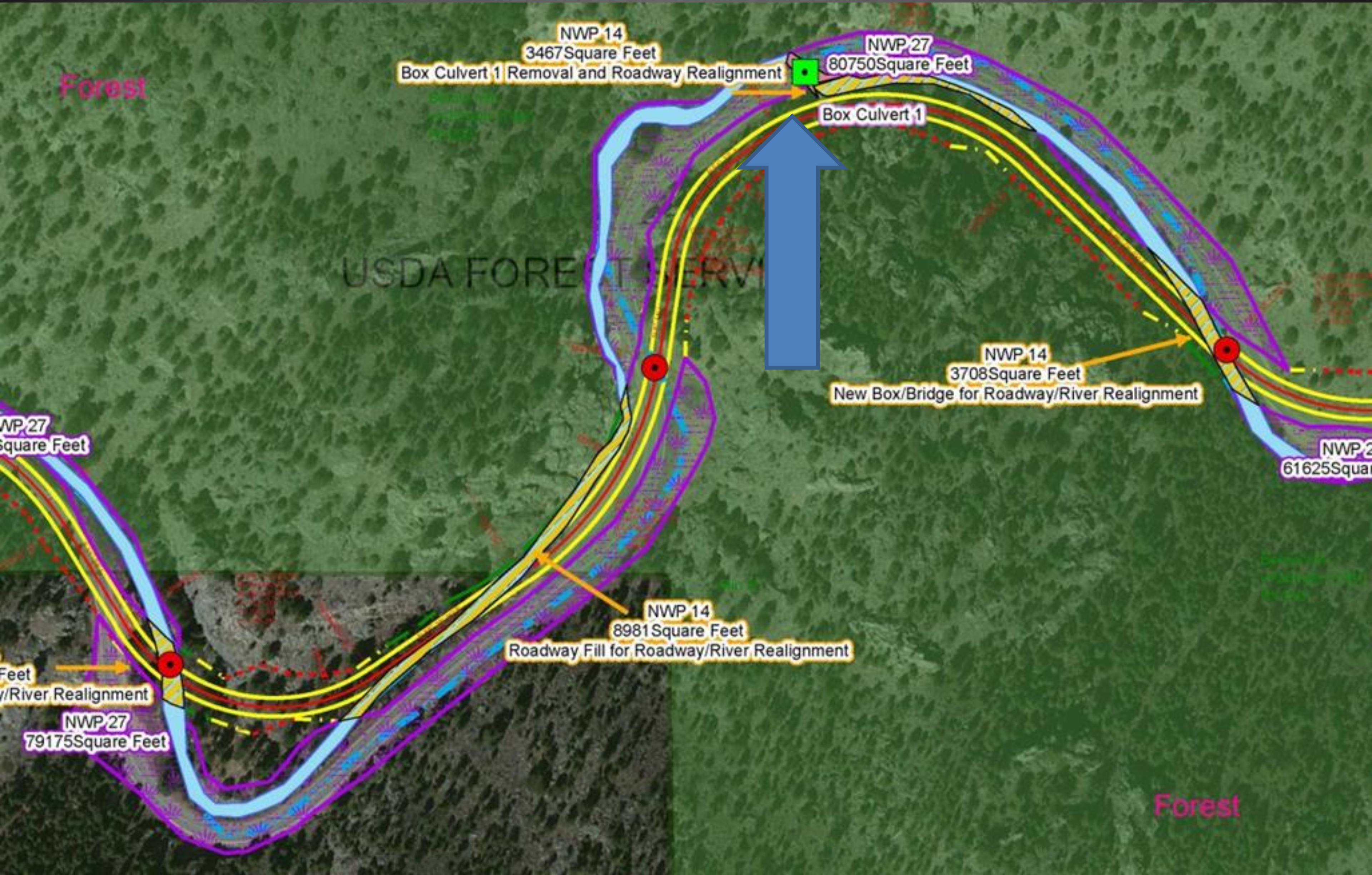
# LCR 43 Post Flood
# Bridge 4

# 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

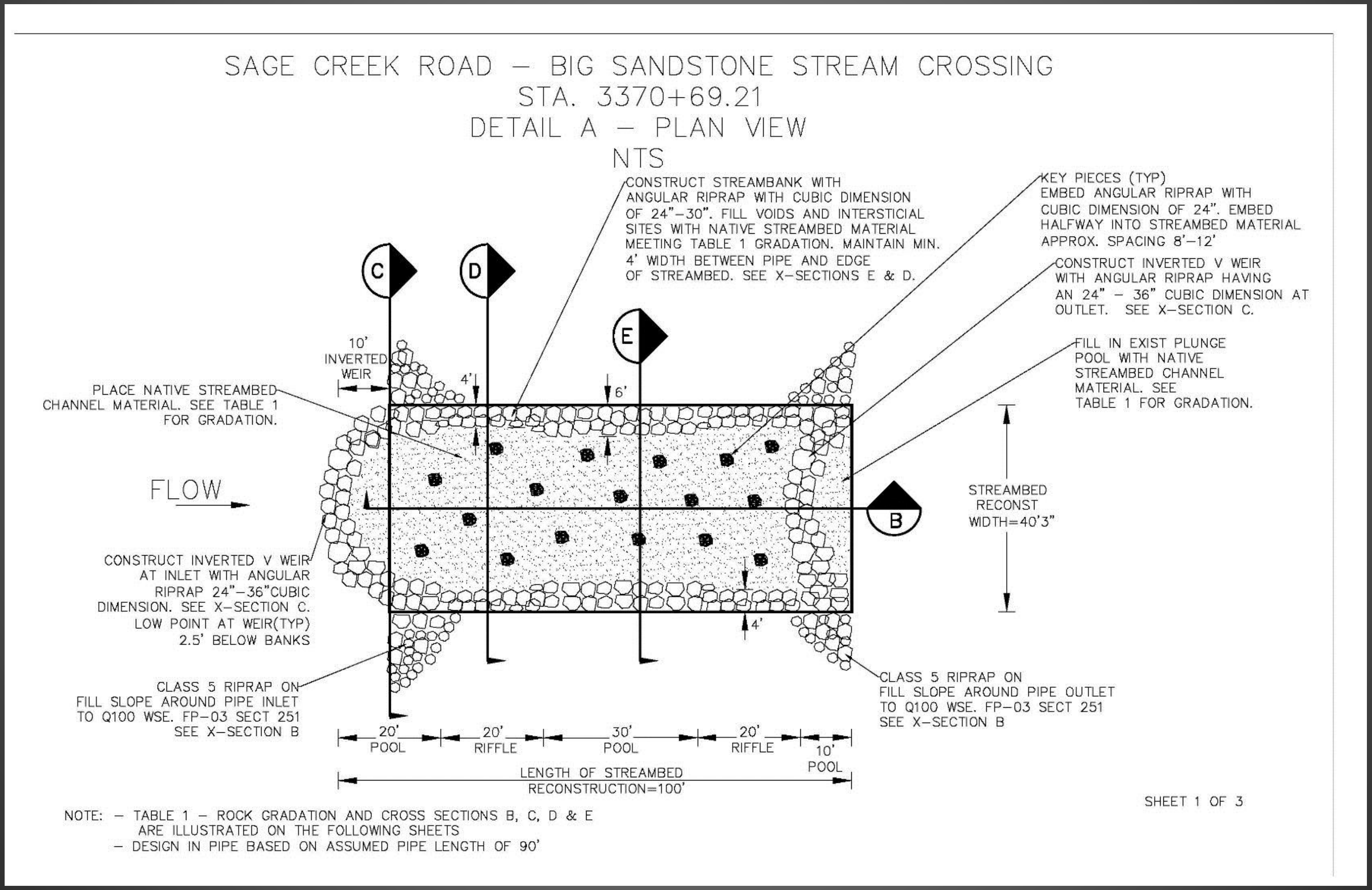


# LCR 43 Box Culvert

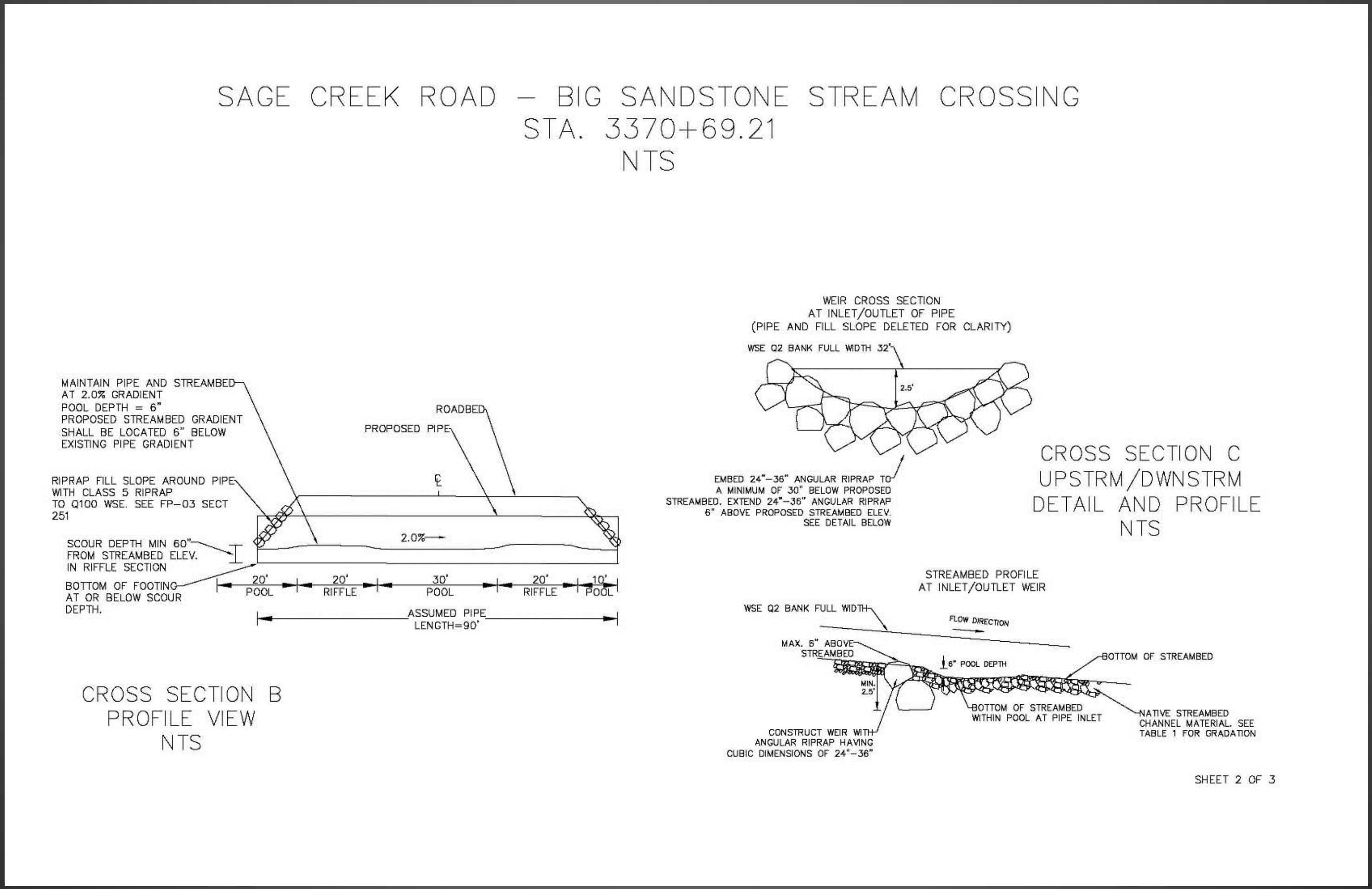
# LCR 43 Post Flood-2016
# Road and River Flip Flop

# LCR 43 Embankment Armoring

# Wyoming Sage Creek Project
# Big Sandstone Creek

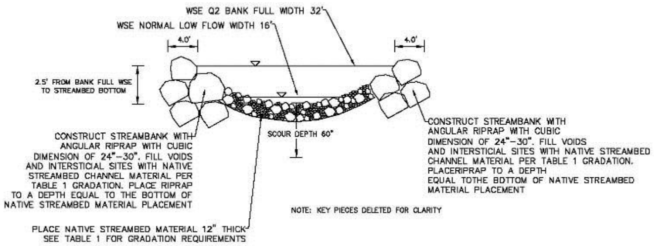


# Big Sandstone Creek



# Big Sandstone Creek

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

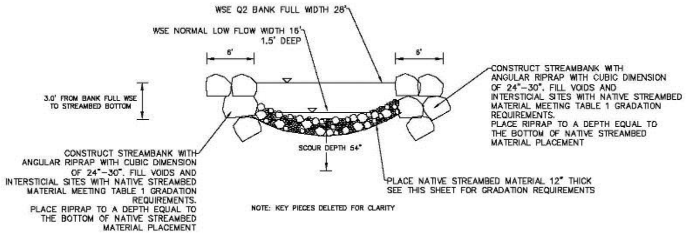



CROSS SECTION D
RIFFLE DETAIL
NTS

TABLE 1
ROCK GRADATION FOR NATIVE
STREAMBED CHANNEL MATERIAL

| PARTICLE SIZE | % VOLUME |
|---|---|
| < 8 mm | 10% |
| 9–64 mm | 25% |
| 65–128 mm | 50% |
| 129–362 mm | 15% |

KEY PIECES – Angular Rock having 24" Cubic Dimension




CROSS SECTION E
POOL DETAIL
NTS

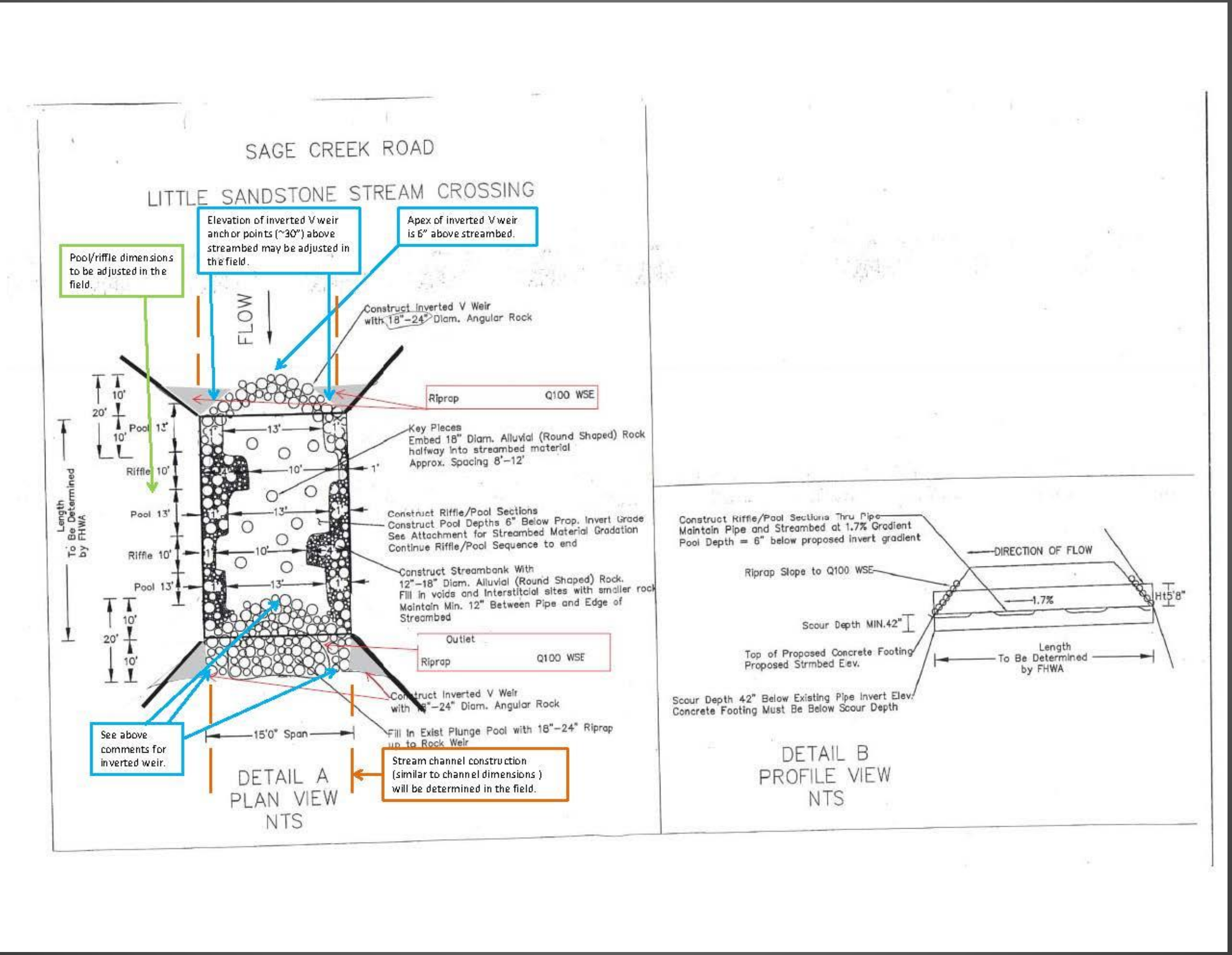
PLACED FILLER MATERIAL

FILL ALL VOIDS BETWEEN INDIVIDUAL STREAMBED–SIMULATION ROCKS AND ALL VOIDS LEFT DURING PLACEMENT OF CHANNEL ROCKS AND STREAMBED–SIMULATION ROCK ADJACENT TO FOOTINGS, CONCRETE STRUCTURES, OR CORRUGATED PIPES WITH SELECT BORROW AS SPECIFIED IN FP–03 SUBSECTION 704.07. USE WATER PRESSURE, METAL TAMPING RODS, AND SIMILAR HAND–OPERATED EQUIPMENT TO FORCE MATERIAL INTO ALL SURFACE AND SUBSURFACE VOIDS BETWEEN THE STRUCTURE AND ROCKS AND BETWEEN INDIVIDUAL ROCKS. FILL SHALL 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 DRAWINGS.

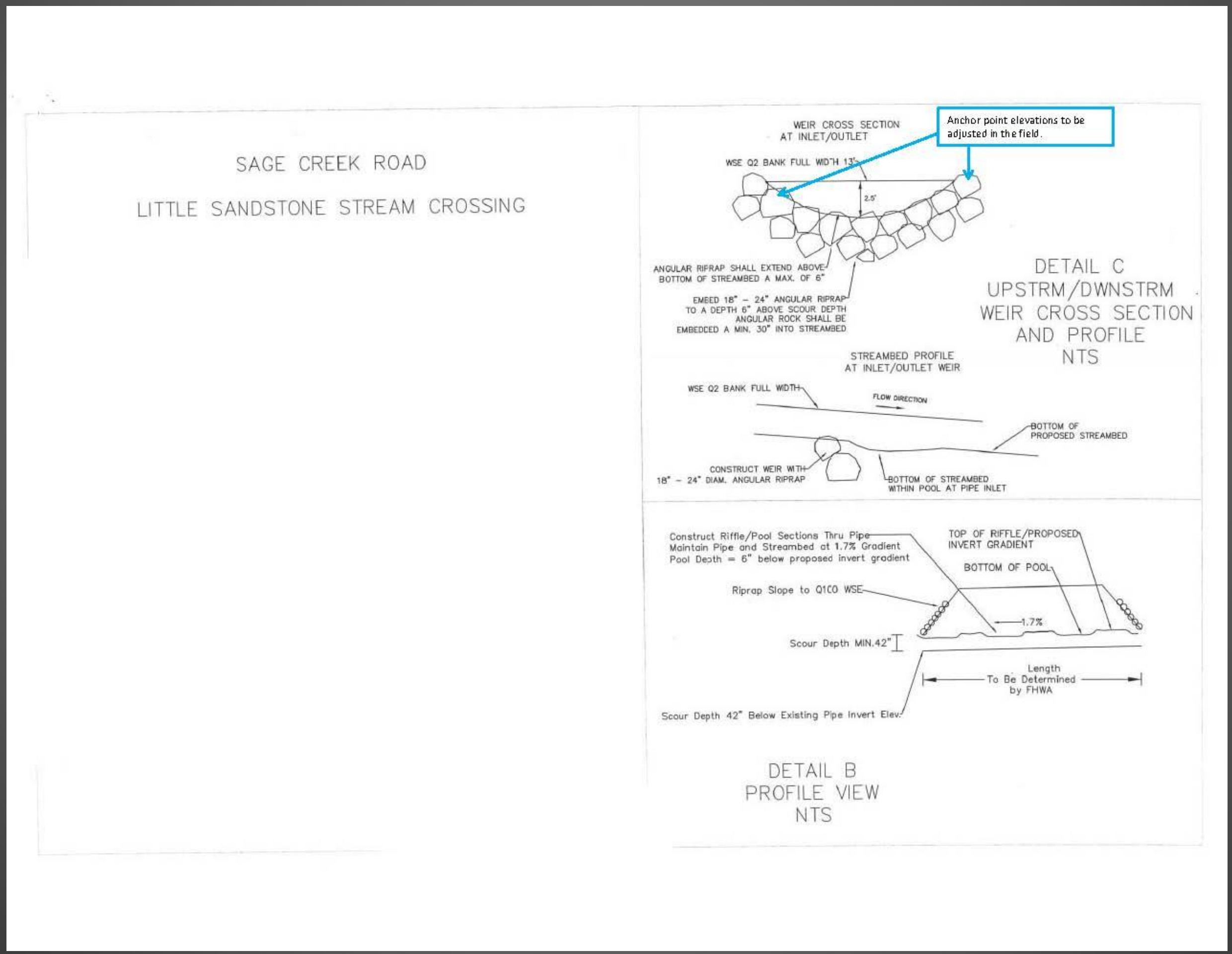
SHEET 3 OF 3

# Big Sandstone Creek

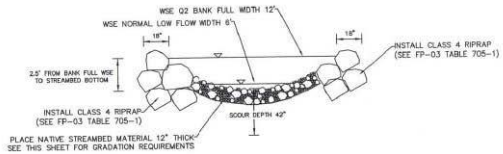
# Little Sandstone Creek



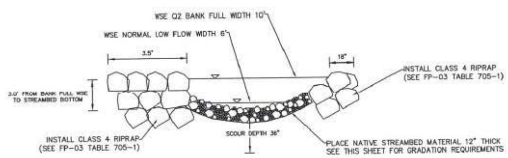
# Little Sandstone Creek



# Little Sandstone Creek




DETAIL D
RIFFLE CROSS SECTION
NTS




DETAIL E
POOL CROSS SECTION
NTS

TABLE 1
ROCK GRADATION FOR NATIVE
STREAMBED CHANNEL MATERIAL

| PARTICLE SIZE | % VOLUME |
|---|---|
| < 8 mm | 10% |
| 9–64 mm | 25% |
| 65–128 mm | 50% |
| 129–362 mm | 15% |

KEY PIECES – Angular Rock having 18" Approx. Cubic Dimension

# 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/

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  http://craneassociates.net/

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  http://roundriverdesign.com/