

Aquatic Organism Passage (AOP)



Construction Elements



Disclaimer



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Unless otherwise noted, FHWA and US Forest Service National Stream and Aquatic Ecology Center are the sources of all images in this presentation.

Key Construction Elements

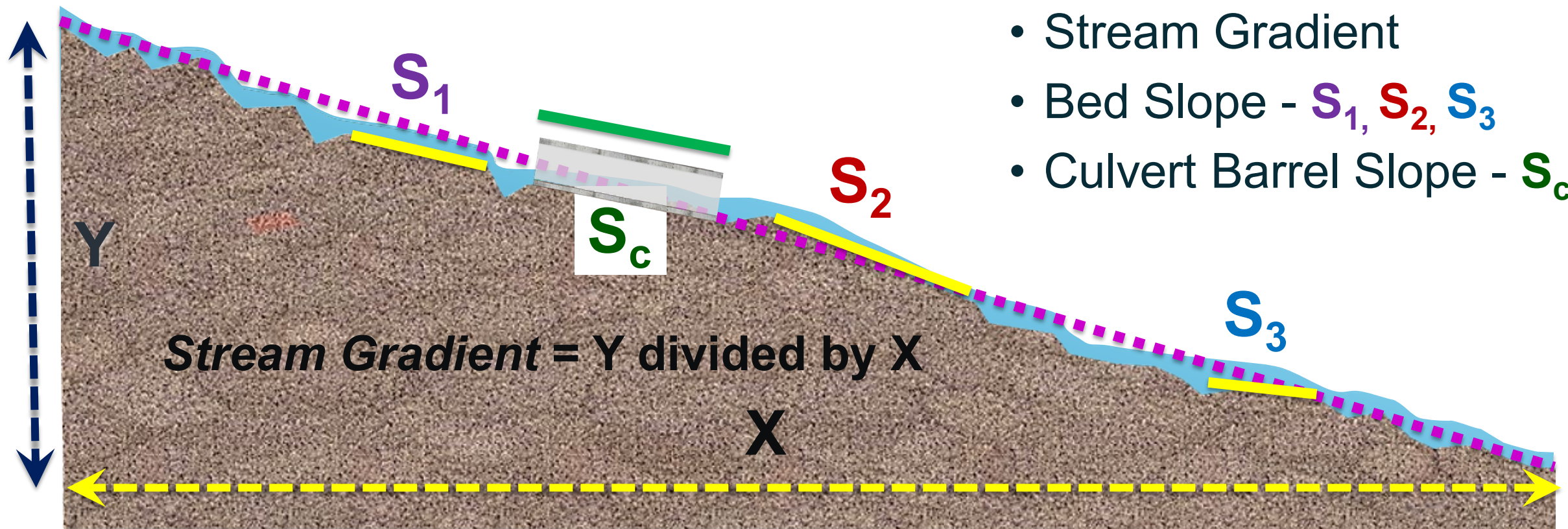


1. Slopes
2. Streambed Material
3. Bankfull Width
4. Bed Features
5. Grade Control Elevations
6. Accommodating Elements

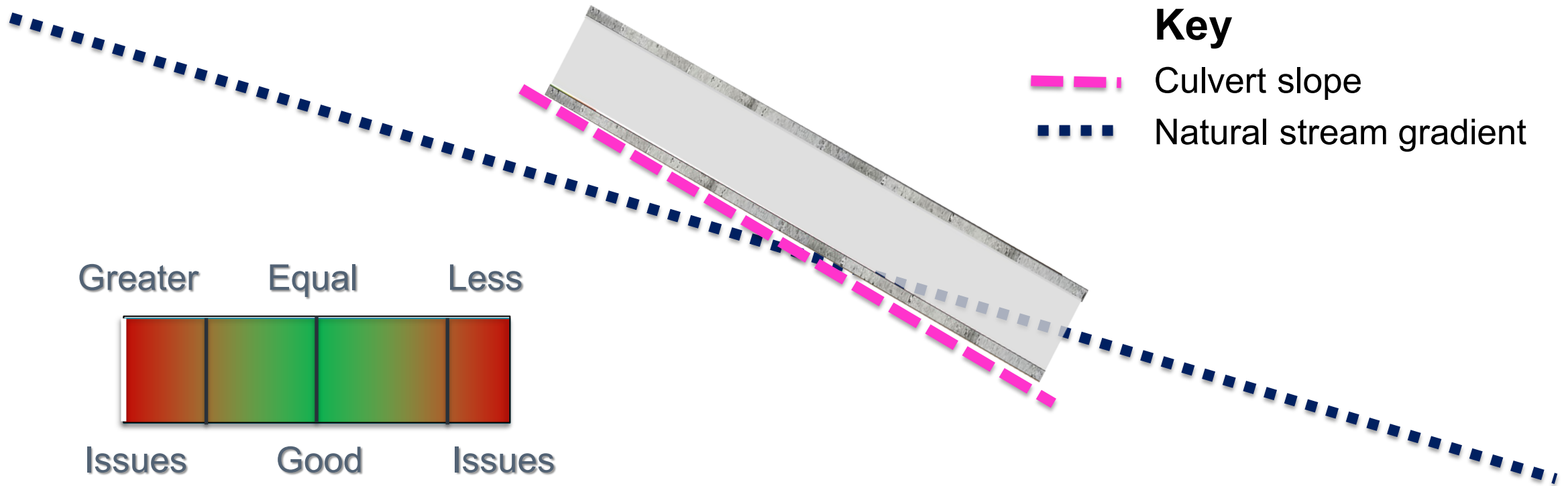
What Do We Mean by Slope?

Types of Slopes

- Stream Gradient
- Bed Slope - S_1, S_2, S_3
- Culvert Barrel Slope - S_c

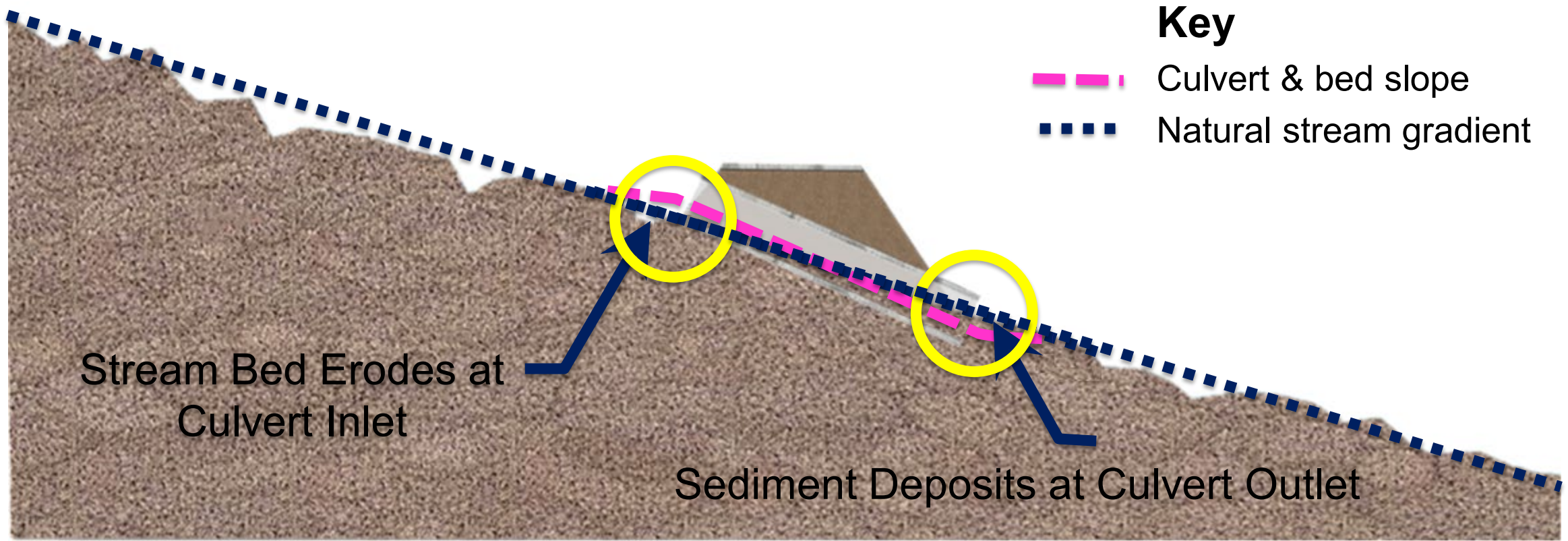


Differences in Culvert Bed & Stream Gradient Slopes



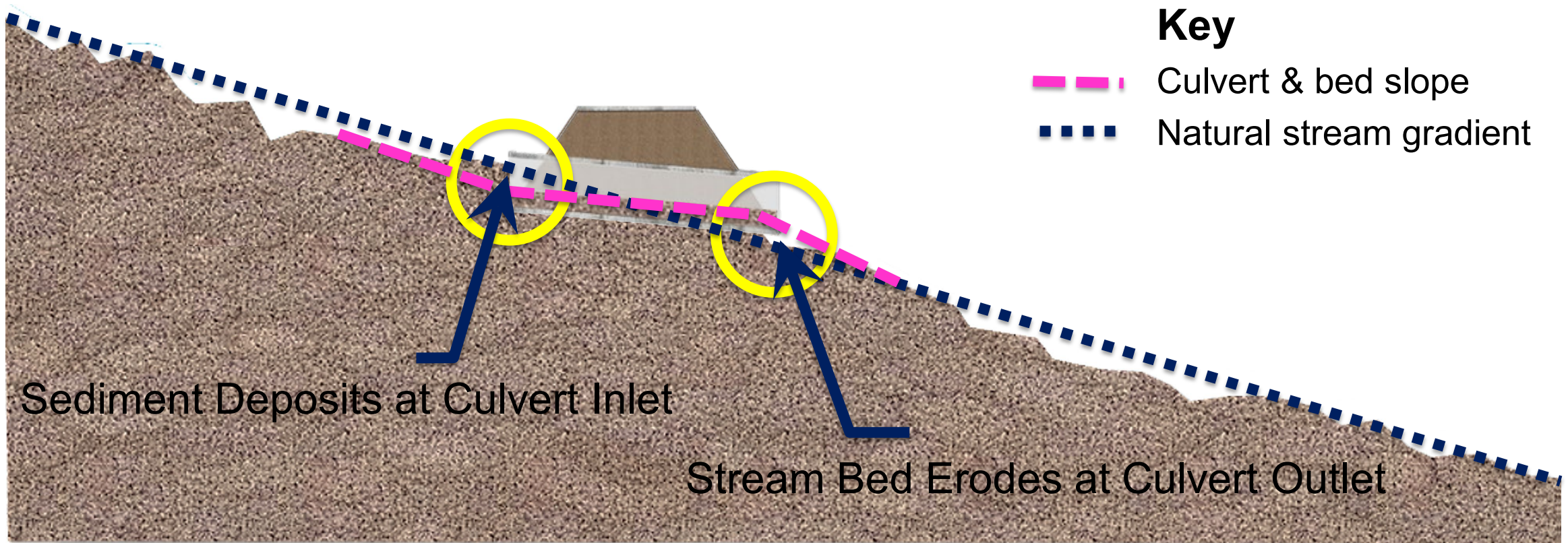
Slopes – Culvert & Stream Gradient

Scenario A: Culvert Bed Slope > Stream Gradient



Slopes – Culvert & Stream Gradient

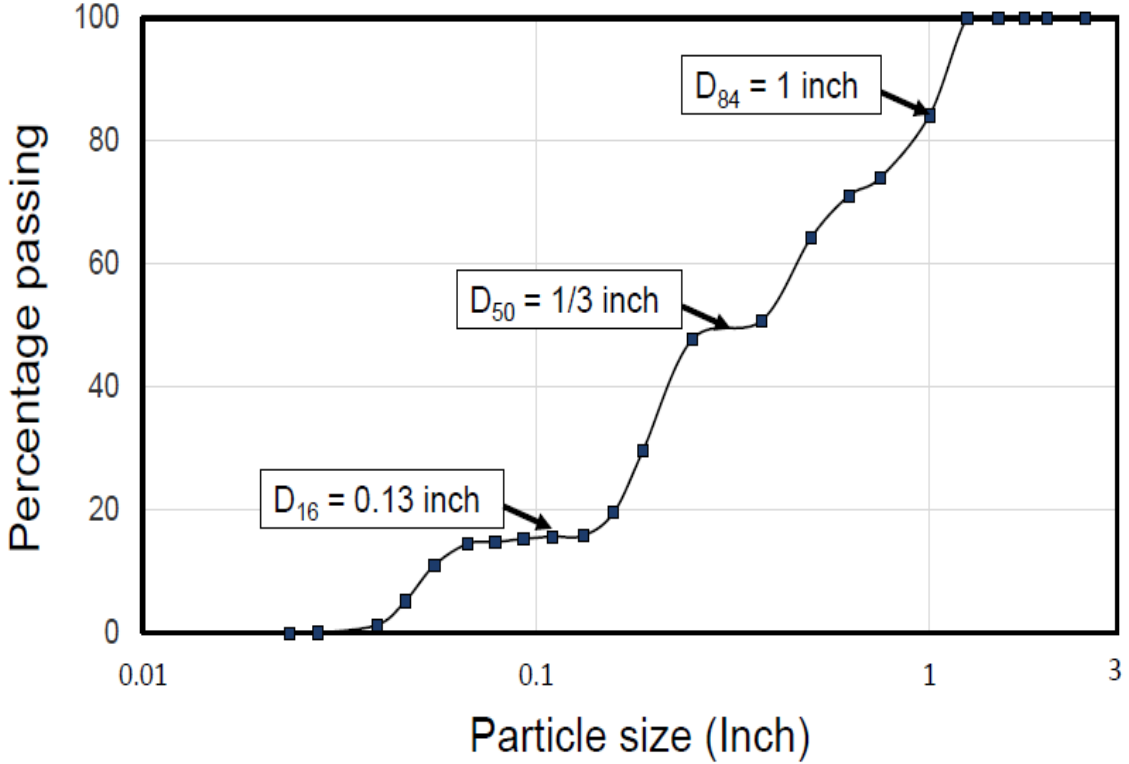
Scenario B: Culvert Bed Slope $<$ Stream Gradient



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What is the Streambed Material Mix?



Source: FHWA

Why is Streambed Material Mix Critical?

Scenario A: Too Fine Potential Outcomes

- Unstable bed



- May erode fines away from inside the culvert



Why is Streambed Material Mix Critical?

Scenario B: Too Coarse



- Potential Outcomes
 - Overly stable bed
 - Promotes flow submergence
 - May cause perched bed

Why is Streambed Material Mix Critical?

Design Mix to simulate Natural Streambed



Photo credit – Lyle Zevenbergen – TetraTech. Used with permission.

Where We Are ...

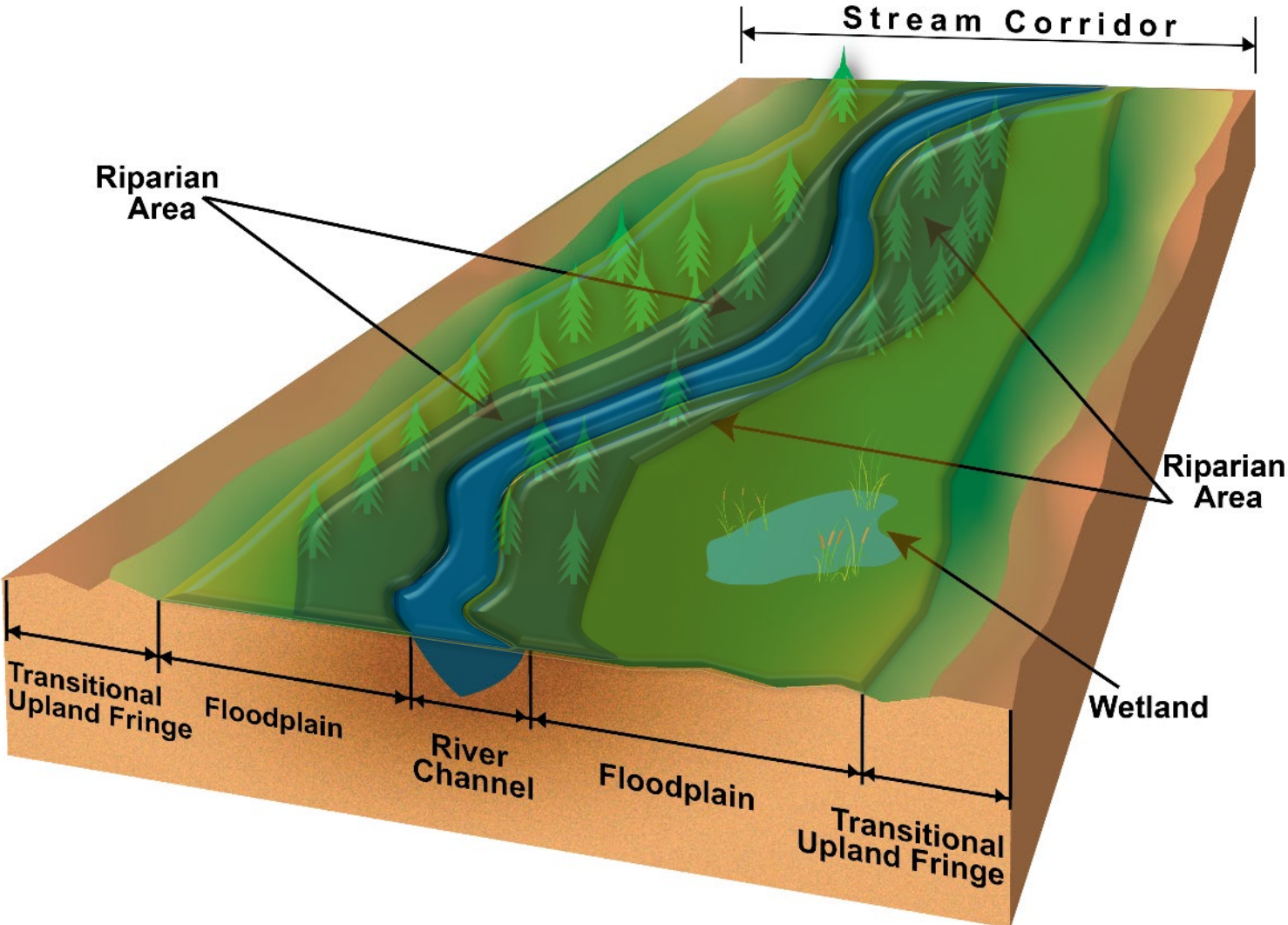


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Overview of Riverine Areas



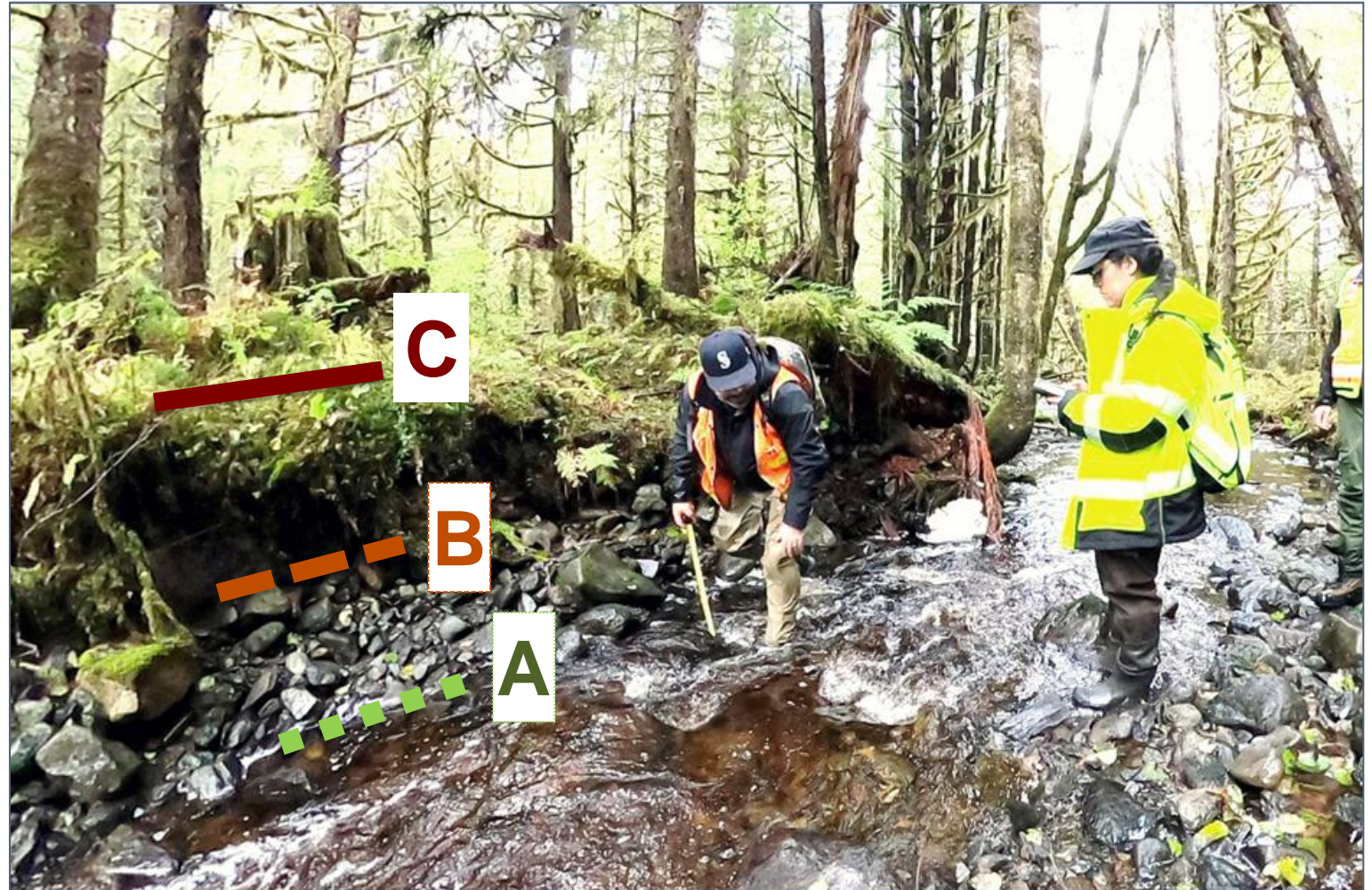
What are Some Components of Active Channels?

Key

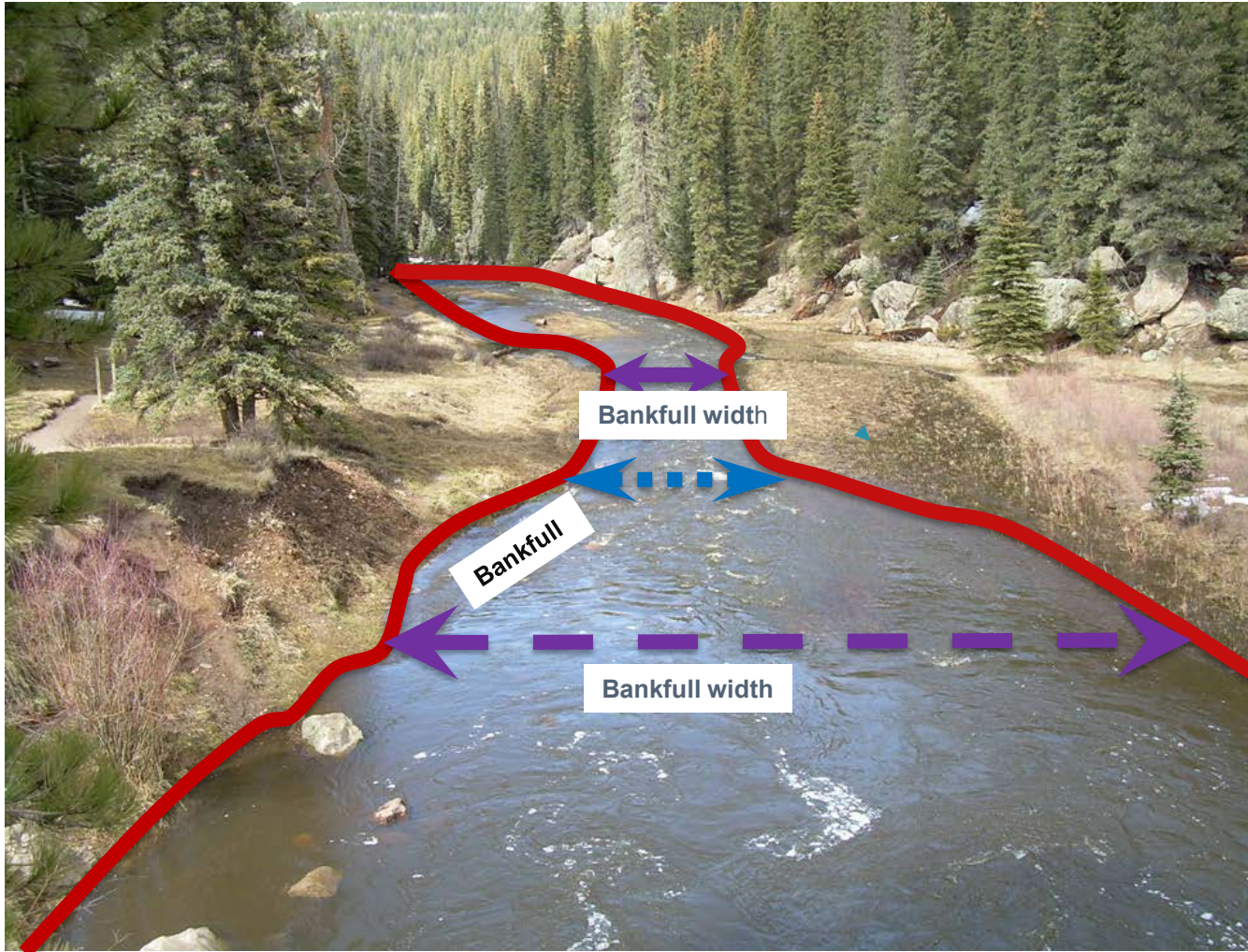
A  **Wetted
Perimeter**

B  **Bankfull**

C  **Floodplain**



What does “Bankfull” mean?



- **Bankfull** refers to water flowing within the banks just before it spills out into the floodplain.
- **Bankfull width** is the width of that flowing water.
- There can be **several different bankfull widths**, even within a short distance of each other.

What Are Bed Features?

- Confine flow to natural bankfull



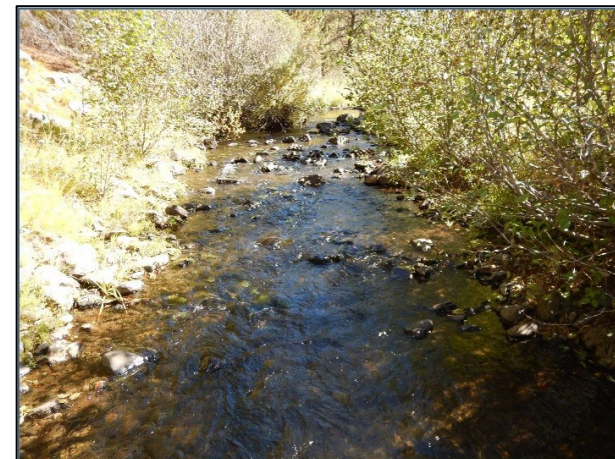
- Decrease flow velocities



- Provide fish resting opportunities



- Stabilize bed and grade



What are Inside Bank Features?

Replicate Natural Bed Features within Culvert or under Bridge



Different stream gradients require different bed & bank features

Where We Are ...

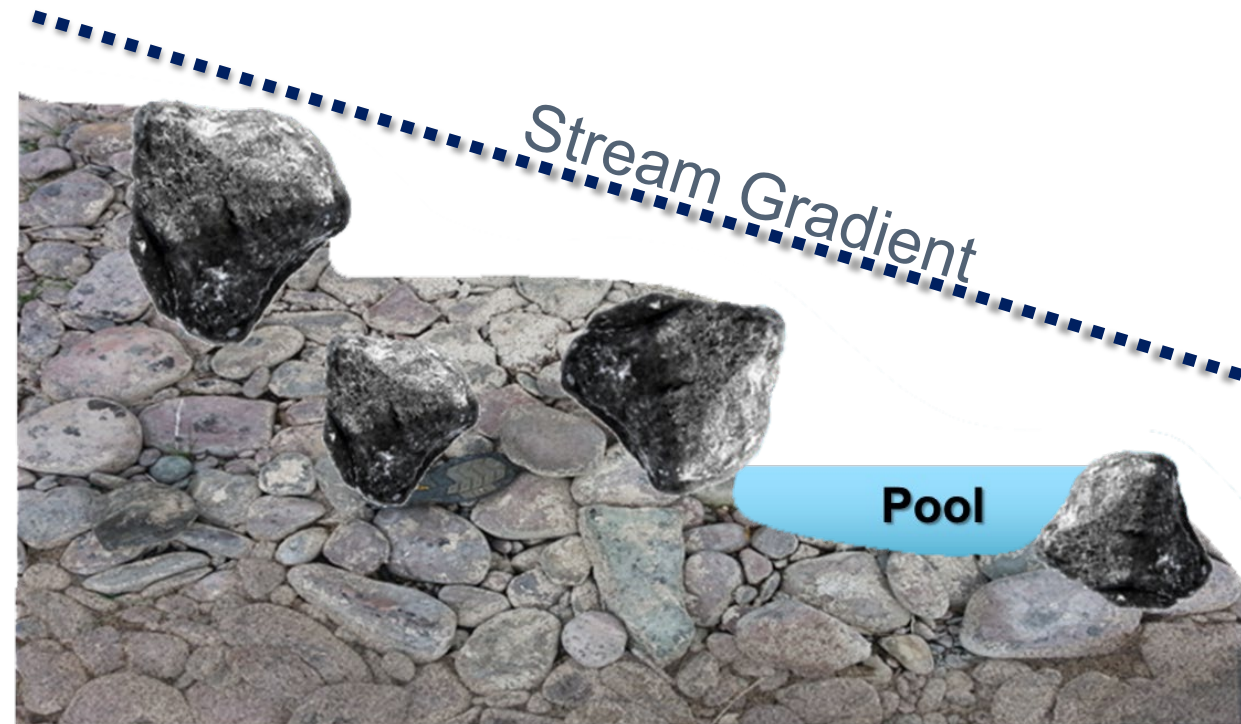
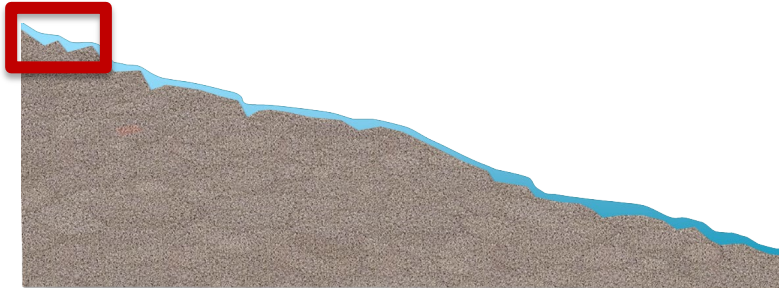


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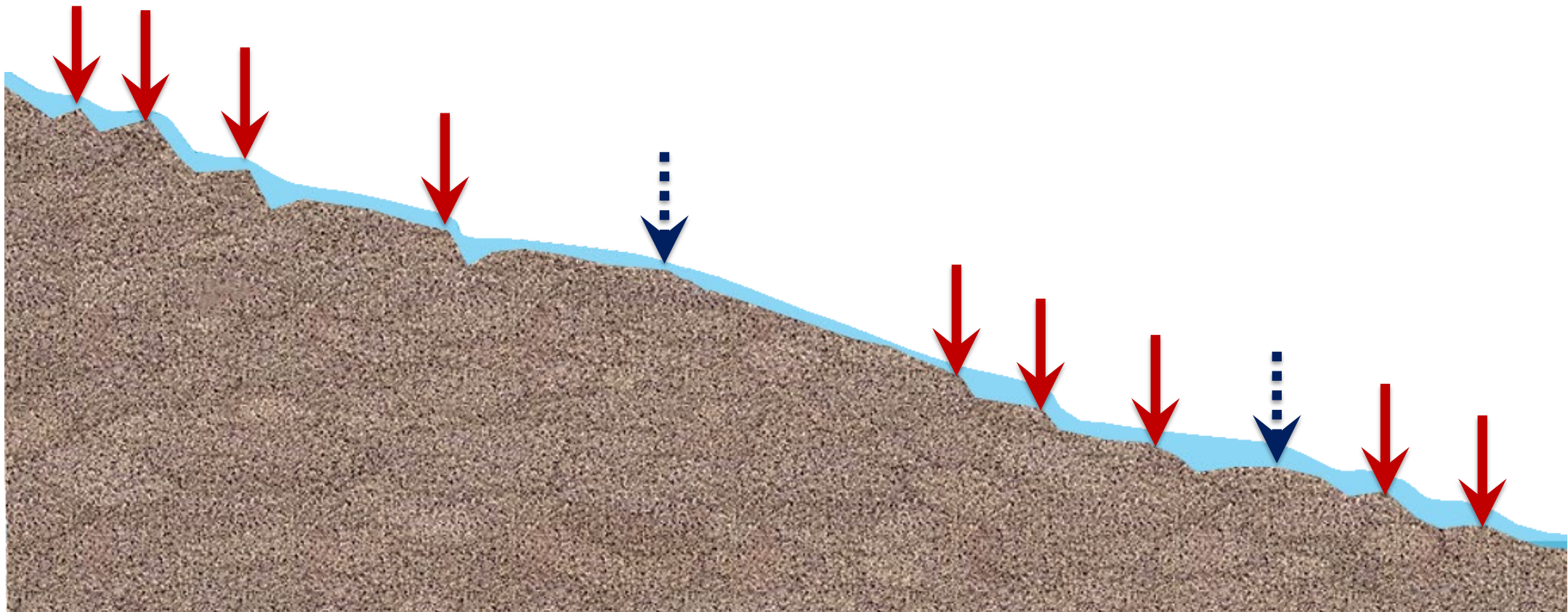


What Are Grade Controls?



Why Are Grade Controls Critical?

- Define bed slope
- Control degradation
- Stabilize bed and grade
- Maintain backwater



Natural Grade Controls



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Boulder Cobble Weir



Log Sills



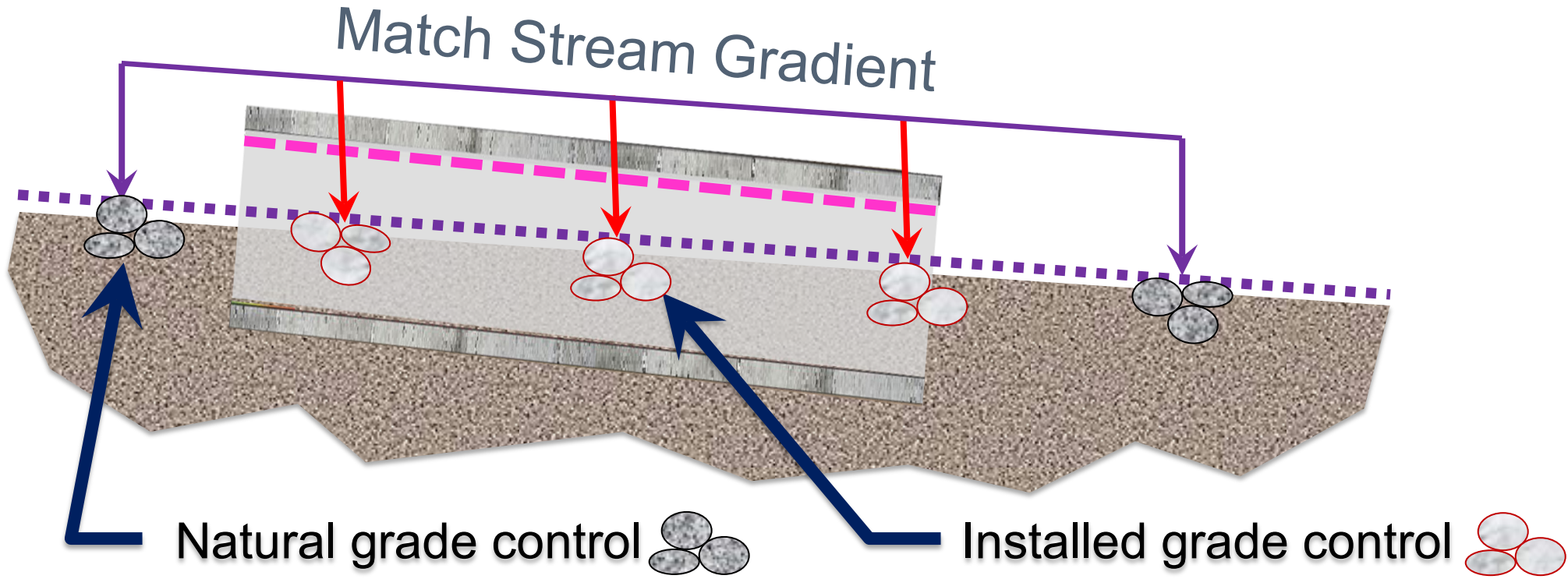
Bedrock Outcrops



Boulder Lag Deposits



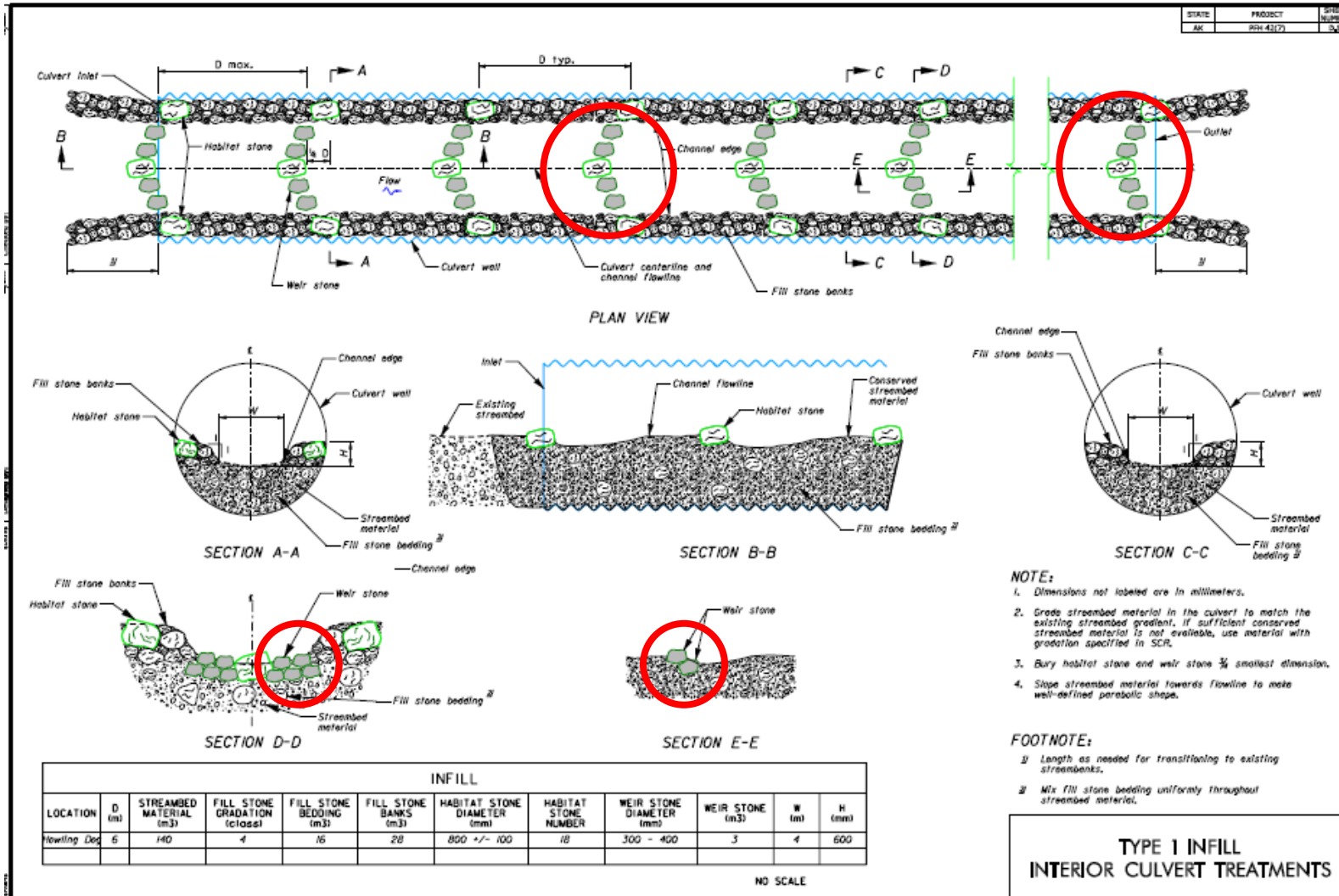
Constructed Grade Controls



Why are Inside Bank & Bed Features Critical?

Bank & bed features include:

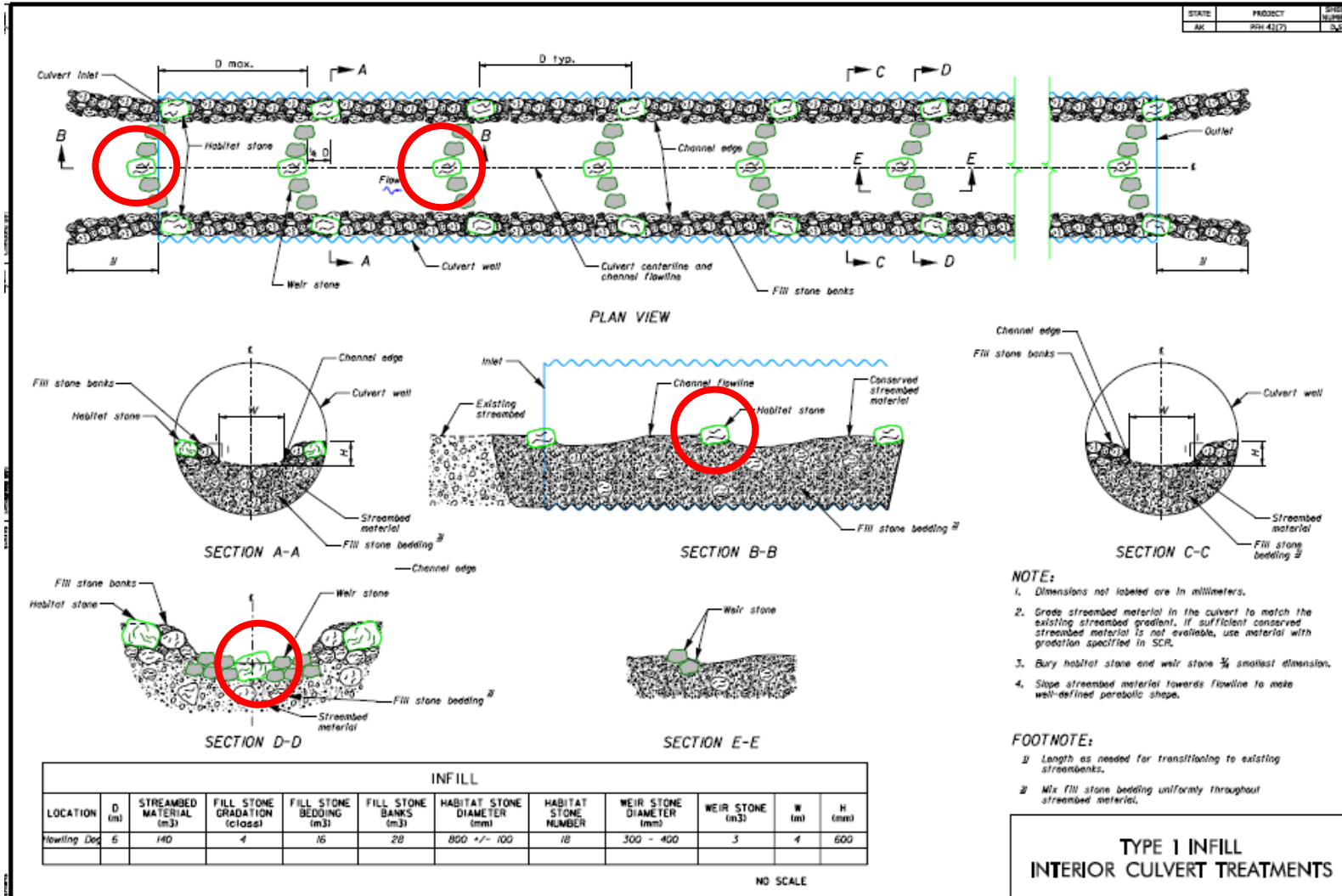
- Stone Weirs



Why are Inside Bank & Bed Features Critical?

Bank & bed features include:

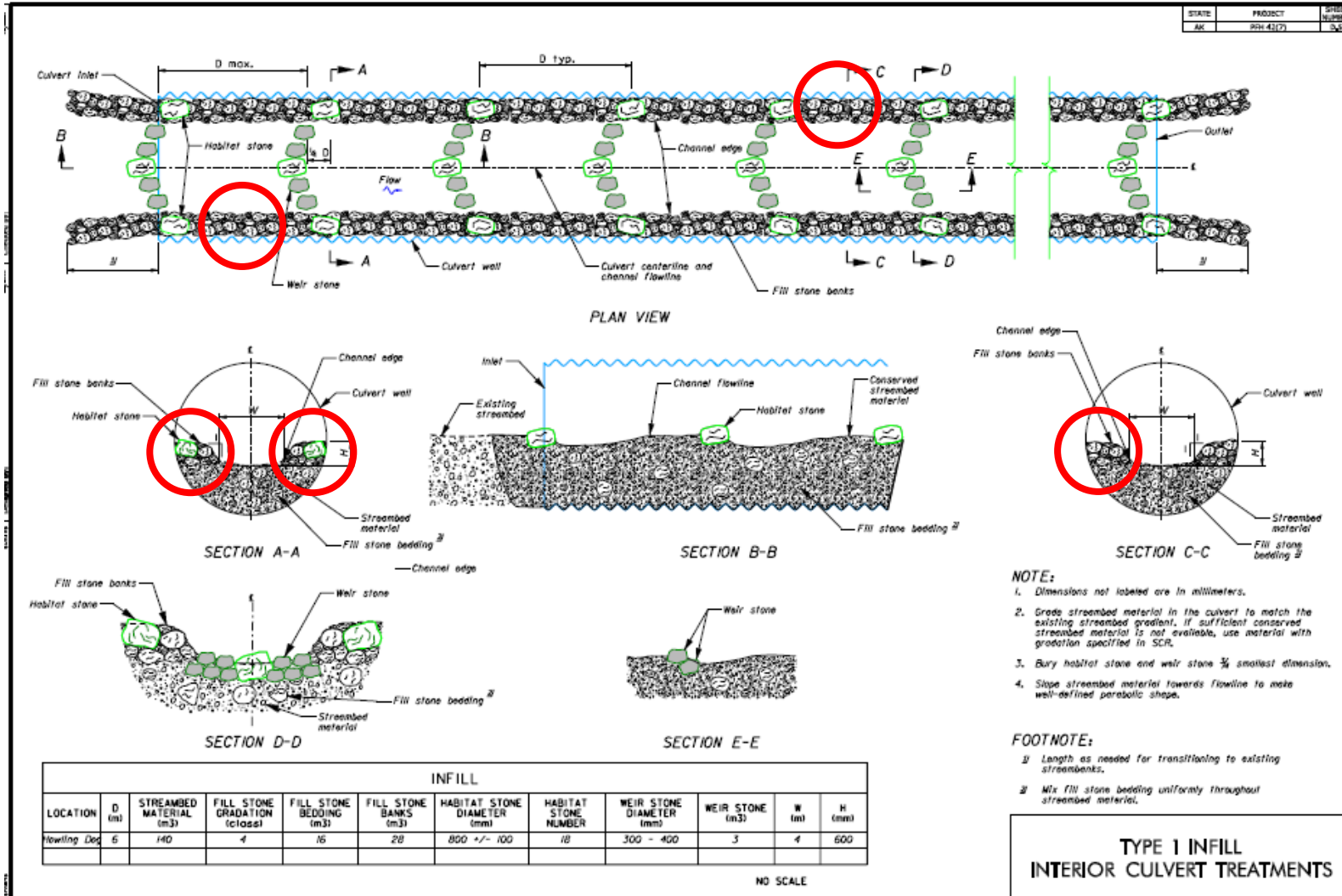
- Fish Passage Boulders



Why are Inside Bank & Bed Features Critical?

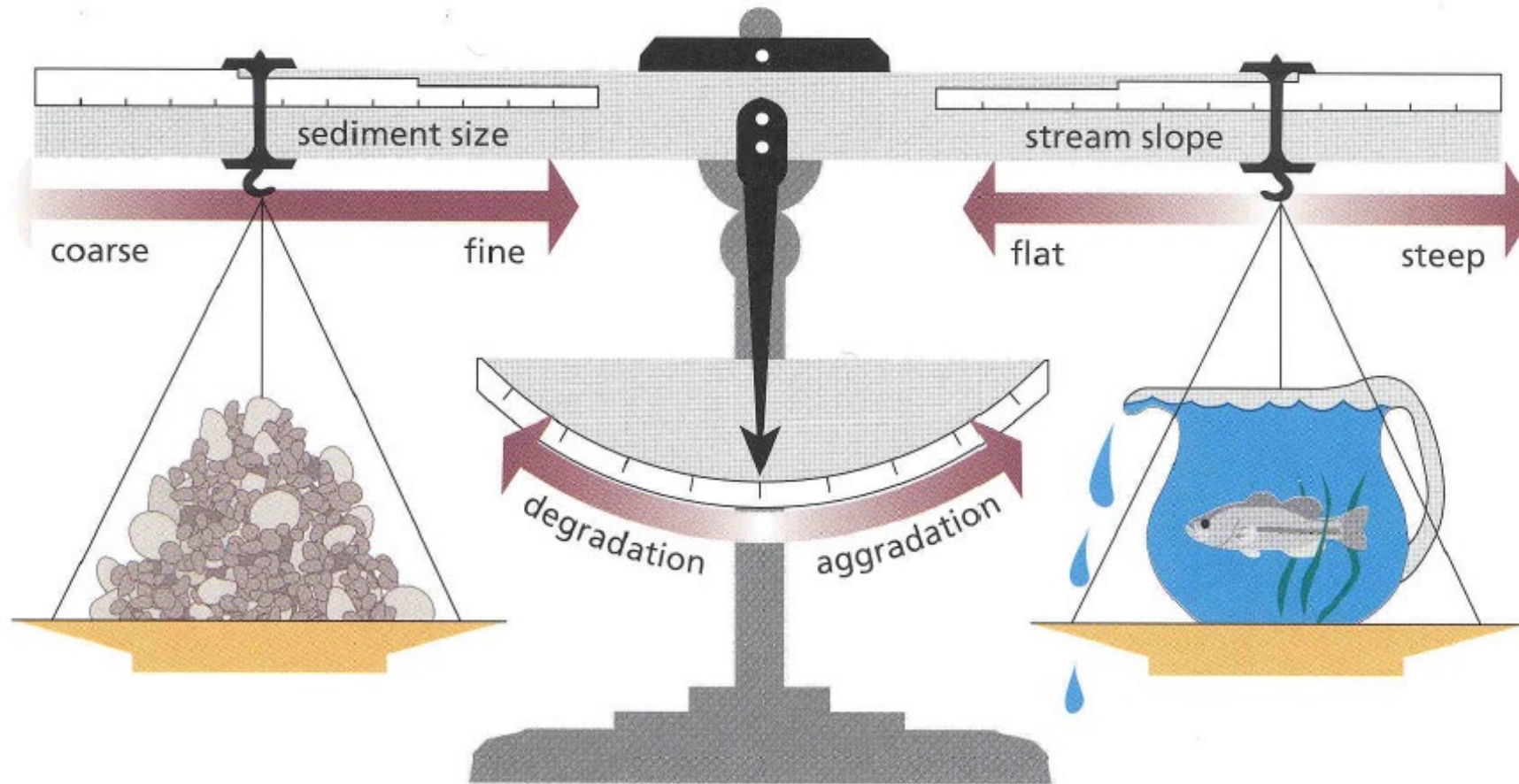
Bank & bed features include:

- Bank Stones



How Do These Elements Fit Together?

Balance of All Elements



$$Q_s \cdot D_{50} \propto Q_w \cdot S$$

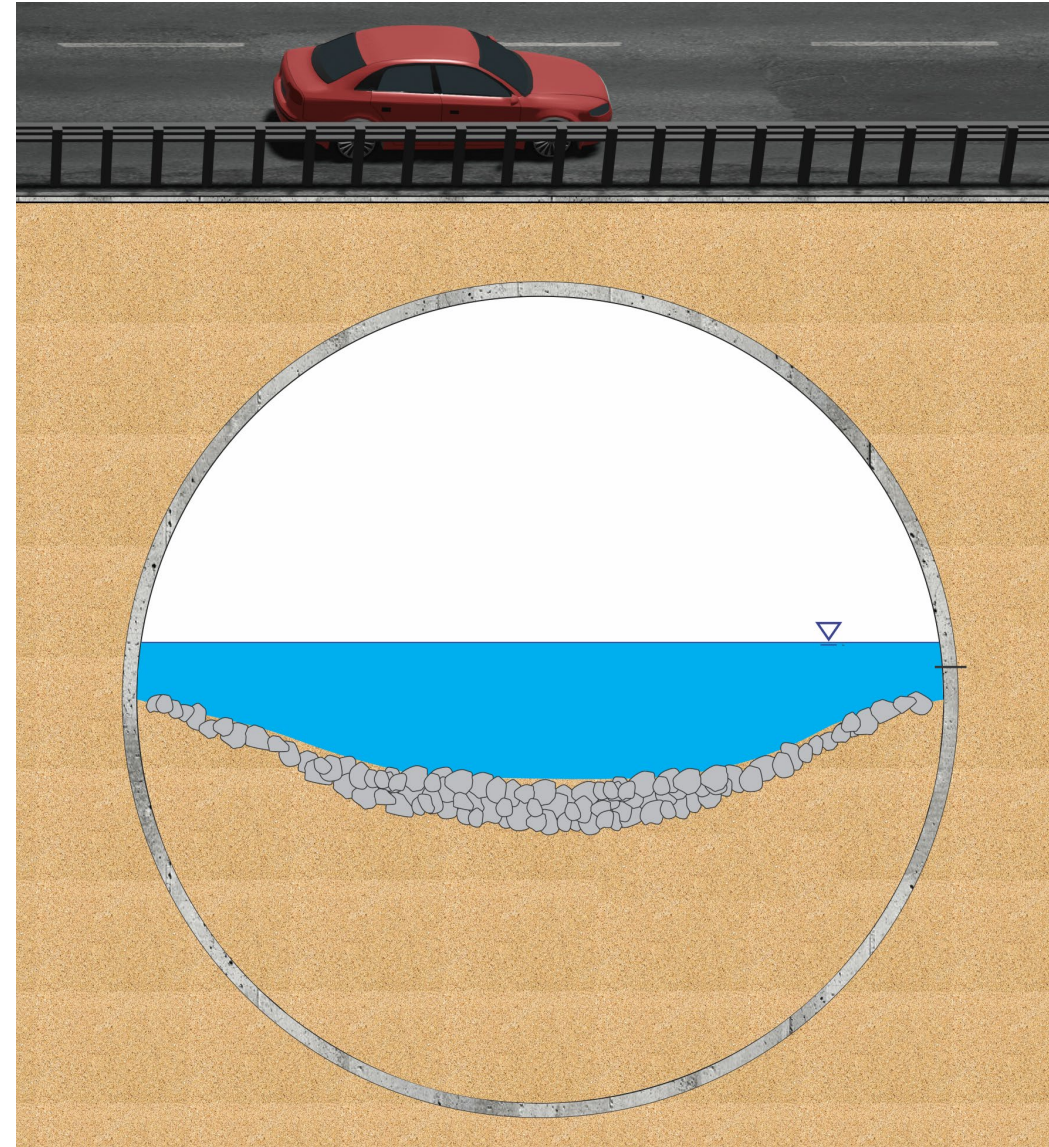
from Lane, 1955; in FISRWG, 1998

Where We Are ...



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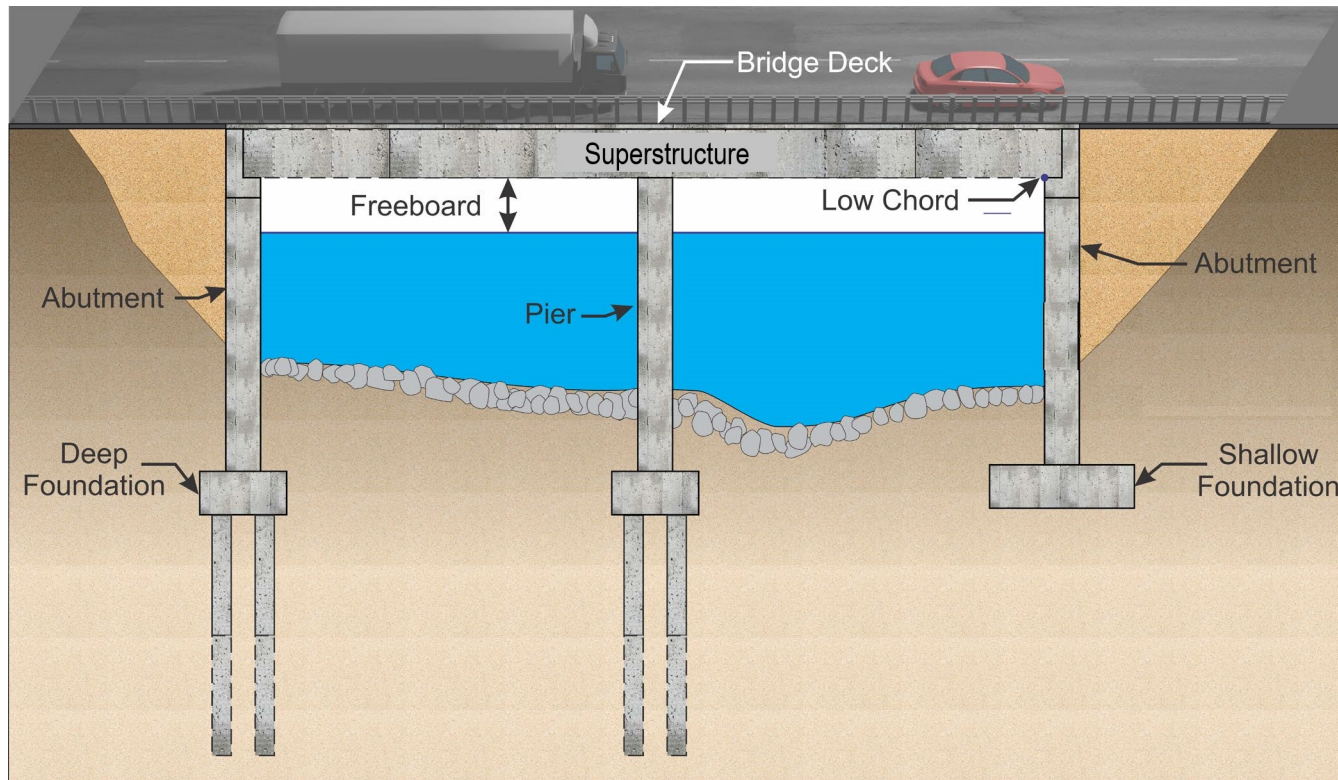


Bridges & Culverts



Approaches for Bridges

- **Structural Deck & Foundations**



- **Benefits**

- Wider Spans
- Can Accommodate Elements
- Mitigates Passage Barriers

- **Potential Issues**

- Higher Costs
- Shallow Foundation
 - *Scour more likely to cause instability*
- Deep Foundation
 - *Additional costs*

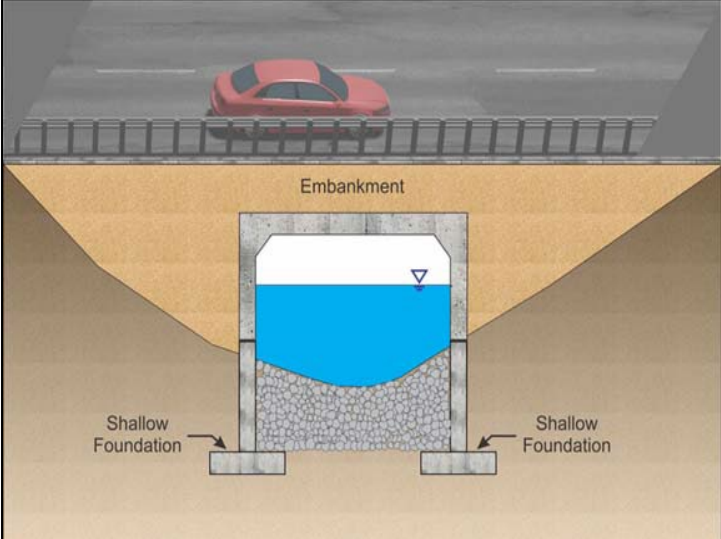
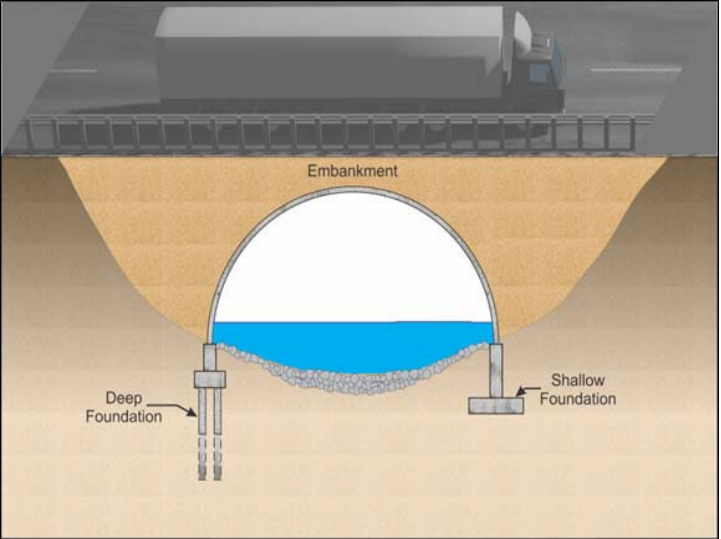
Approaches for Culverts

- **Historical**
 - Benefits
 - Less Expensive
 - Potential Issues
 - Accommodating Elements
 - ❌ Slope may not align
 - ❌ No Streambed Material
 - ❌ Usually < Bankfull Width
 - ❌ No Bed Features
 - ❌ No Grade Control Elevations
 - Barrier to Aquatic & Terrestrial Species



Accommodating Desired Elements

Approaches for Culverts - Arch or Box on Foundations



Approaches for Culverts



Arch or Box on Foundations

- Benefits
 - Can Accommodate Elements
 - Mitigates Passage Barriers
- Potential Issues
 - Cost of Materials
 - Constructability
 - Undermining of embankment
 - Shallow Foundation
 - *Scour may cause instability*
 - Deep Foundation
 - *Additional costs*

Approaches for Culverts

- **Buried Culvert**

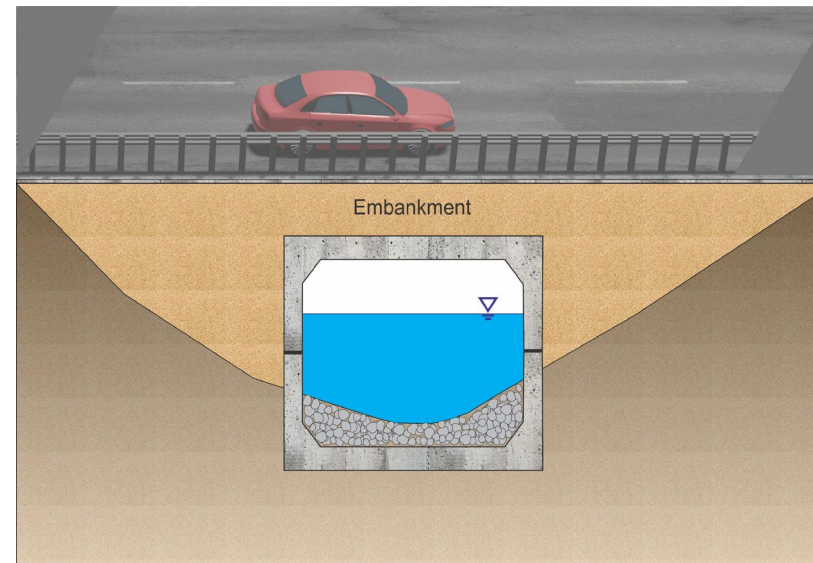
- **Benefits**

- Available Sizes & Shapes
- Structurally Robust
- Can Accommodate Elements
- Mitigates Passage Barriers

- **Potential Issues**

- Some Limits on Span (Width)
- Constructability

Elements of Site & Budget usually dictate desirability versus other approaches



Why is Burial Depth Critical?

Burial Depth ...



- Helps maintain streambed material
- Allows for stream profile adjustment (degradation)
- Too little burial depth - promotes streambed material scour
- Too much burial depth - costs more and promotes possible flow submergence

How Much Burial Might a Culvert Need?



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Construction Inspection



Why is Inspection Critical?

- Not all contractors have the same skill level or experience
- Fish pipe construction may require contractor training
- Enforce all specifications from the start
- Let the contractor know of unacceptable work

Important: Know your contractual authority

Important Actions & Considerations

- Fish removal
- Survey controls
- Traffic control
- Erosion control
- Dewatering
- Excavation
- Bed Preparation
- Inspect Materials
- Banding culverts
- Streambed Material
- Bed structure construction
- Grade control structures
- Internal structures

Survey Controls



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Questions to Consider ...

- How will they do it?
 - Pump or bypass channel?
- What is the terrain layout?
- How long will the install take?
- What flows do you expect?



Questions to Consider ...

- Does contractor have enough pumping or diversion capacity?
- Dewatering calculations: 1 cfs = 449 GPM

Beware of water pumps & old pumps!



Wide, Suitable & Safe?



Bed Preparation

- Check construction survey & design for errors
- Place bedding material
- Compact
- Resurvey for final elevation
- Place & align pipe



Inspect Materials Before Installation



Banding Culverts



- Watertight gasket seal
- Align corrugations
- Space band equally
- Clean rocks out of corrugations



Banding Culverts

- Tighten evenly (don't overtighten)
- Expect some gaps in pipe arches, fill with foam or extra gasket materials if fill is fine grained



Multi-plate Assembly

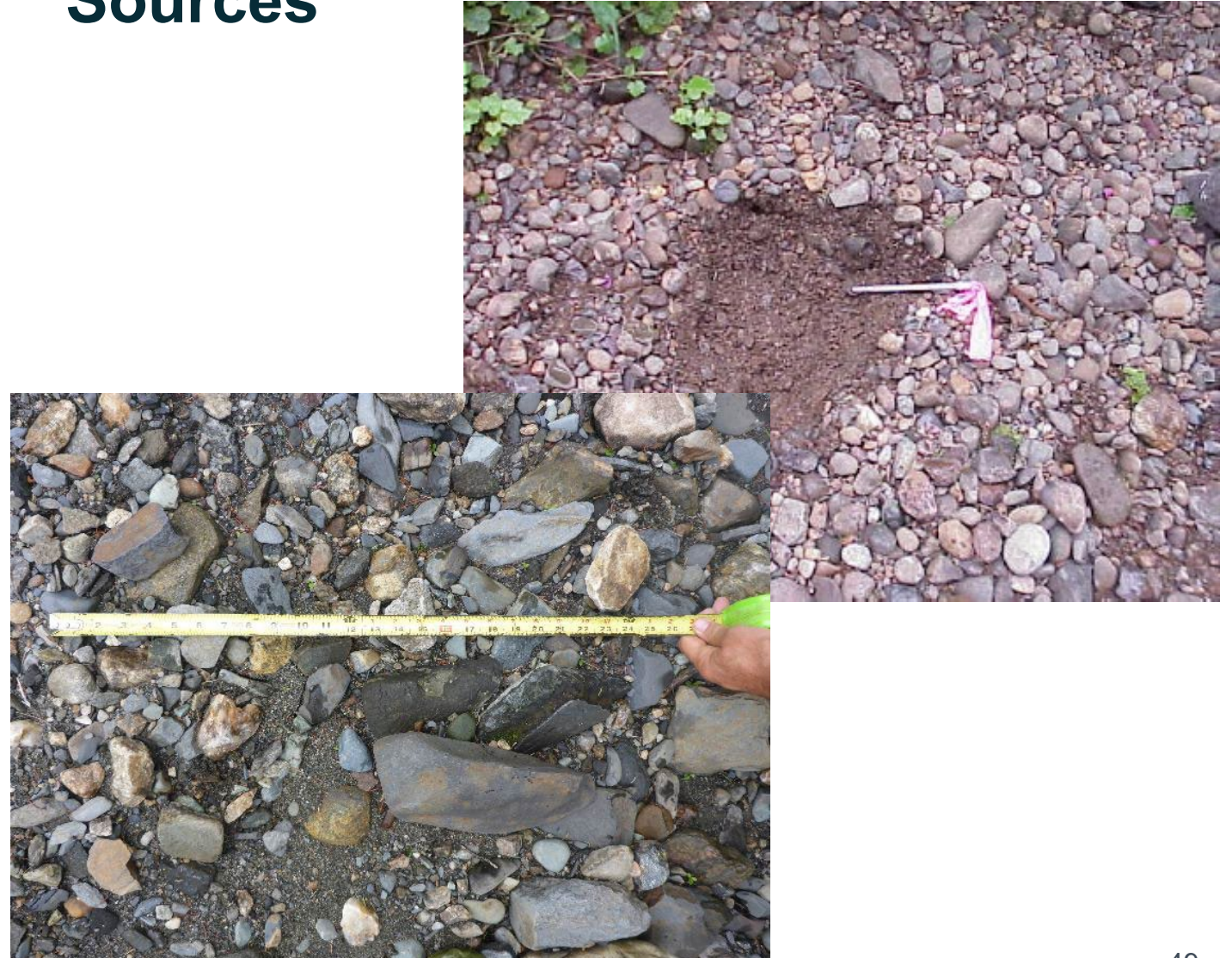


- Three plate junctions can be tricky
 - Some shapes easier than others.
 - Use pry bar, align corners then intermediate bolts
- Keep plates loose until all are connected.
 - Follow the manufacturers tightening requirements.
- Channel type anchors are more difficult to align.
 - Grouted slots allow wiggle room.



Sources

- Salvaged
 - Material removed from aggraded channel
- Conserved streambed material
 - Uncovered streambed kept in place
 - Old bedding reused as backfill



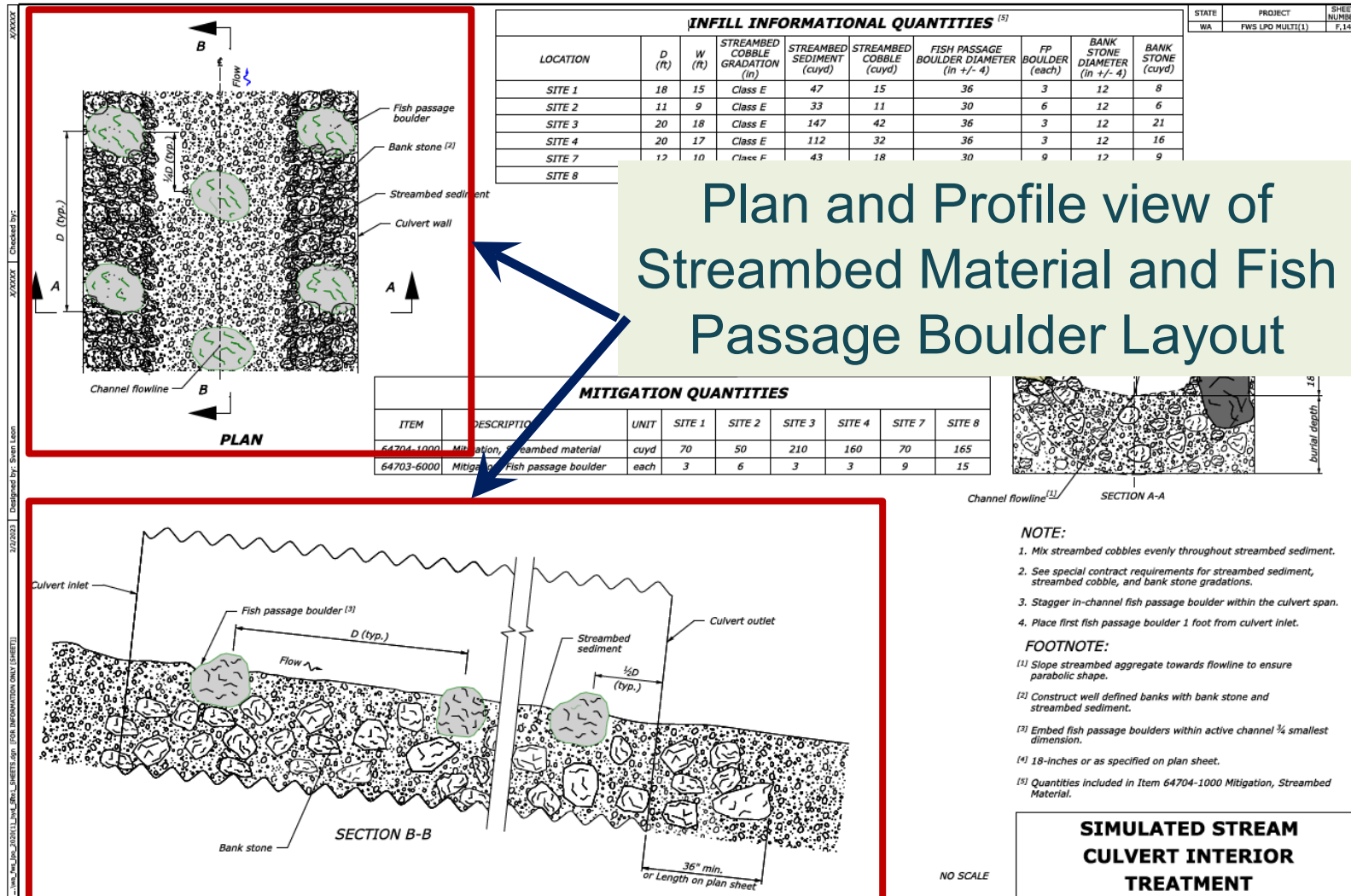
Production

- Inspect and verify material gradations
- Don't know what you received without inspection!
- Ensure thorough mixing
- Prevent segregation



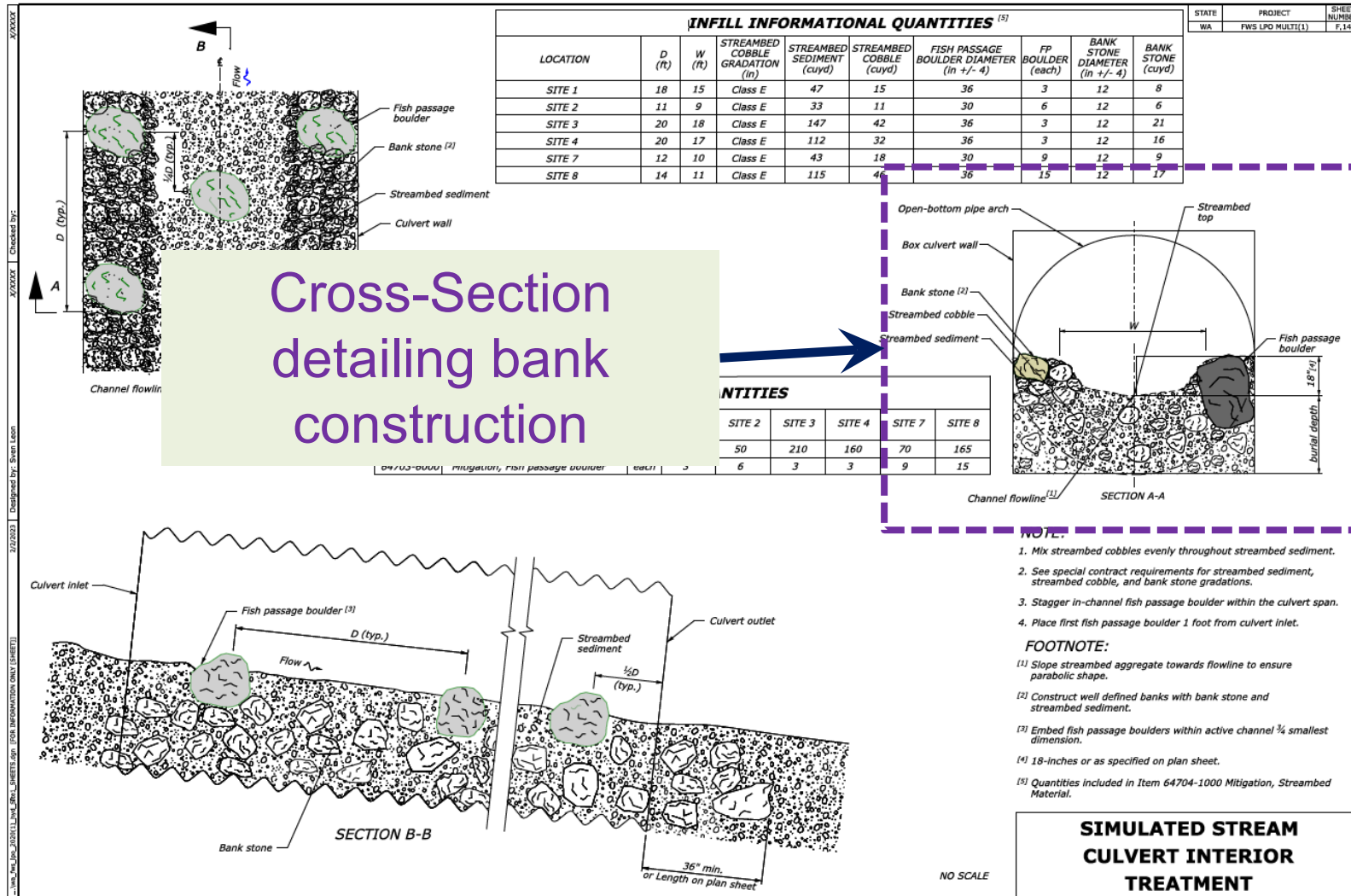
Streambed Material - Design

Example of Typical Plan Set

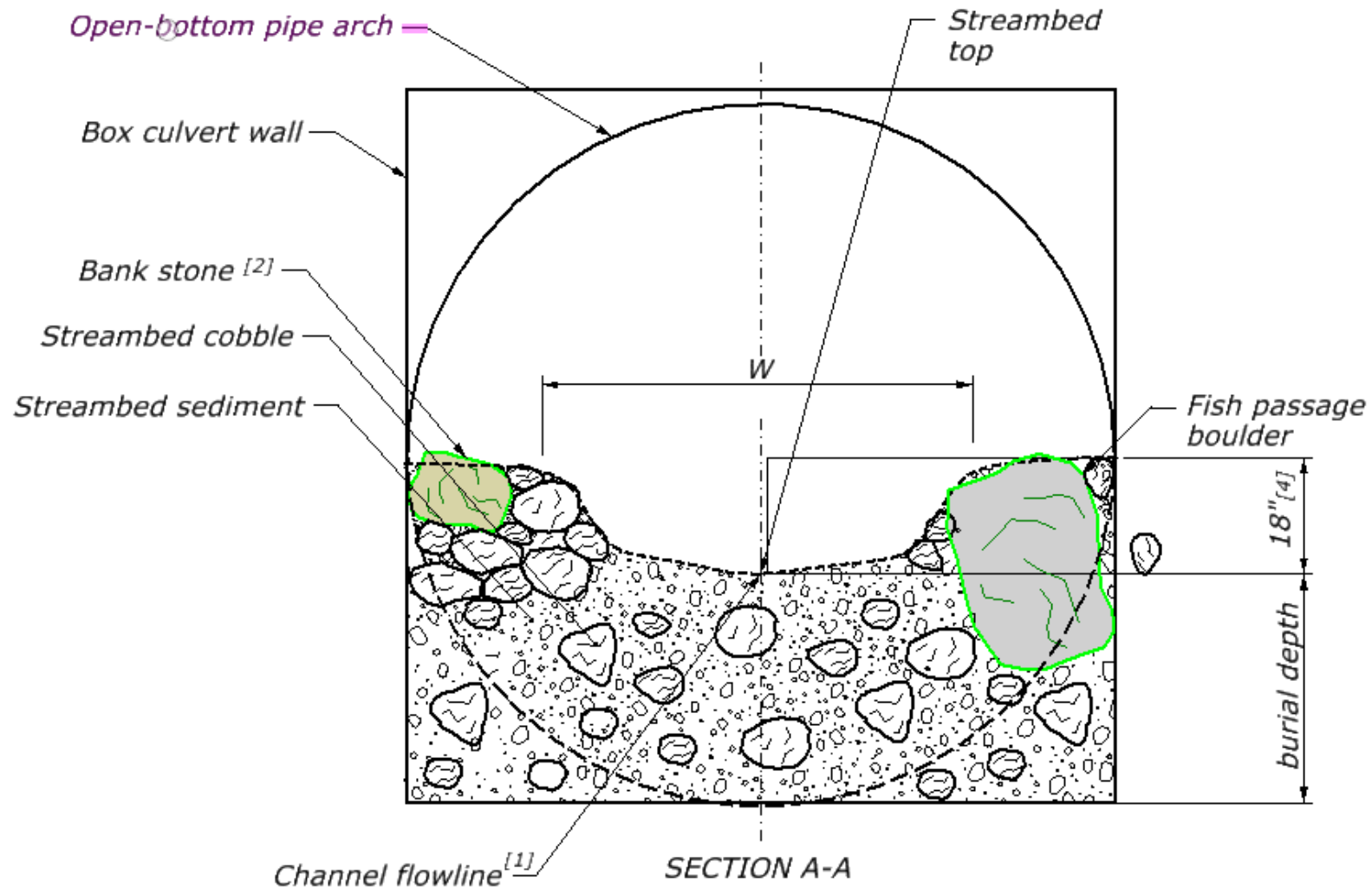


Streambed Material - Design

Example of Typical Plan Set



Example of Typical Plan Set



Conceptual Material Specification

- Construct test section prior to placement of streambed material for each gradation specified.
- Test section incidental to placement of streambed material.
- Test section will be tested to ensure that voids are satisfactorily filled, for visual acceptance by the CO.
 - Voids are satisfactorily filled when water, equivalent to the low flow rate of the stream, does not go subsurface and there is no perceivable difference in low flow rate from upstream of the channel work limits to downstream of channel work limits.
 - Water shall be free from contaminants, chlorination and any additive that has risk to fish or other ecological life.

Placement

- ➔
1. Place material in layer (no greater than 12" – 18")
 2. Compact layer
 3. Wash in fines to fill voids and seal bed
- Repeat to design depth*

GOAL = Well-graded, compacted, low permeability mass



Methods

- Method depends on size of pipe and materials
- Weirs and banks require hand placement
- Make sure there is air flow (fans) with gas equipment
- Mix at source, haul and remix at site.
 - *Mixing in place is difficult to do well.*



Bed Structure Construction - Bed Features

- Mark feature elevations on culvert wall or footings
 - Step locations; thalweg elevation; bank elevations
- Select specific step and footer rocks...
 - Shape matters → Be picky!
- Step rocks need to fit together tightly
 - May require trying rock placement a couple times

Construction



Post-Construction Monitoring



Bed Structure Construction - Backfilling & Compaction

- Weigh/anchor down before compaction
 - Pipe arches/culverts can “float” when backfilling under haunches
- Ensure culverts backfilled to design cover height
- Ensure proper compaction



- Keep it slow
 - Don't break the coffer dam!
- Stage re-watering
 - Depends on water quality requirements
- Before Releasing Flow:
 - Wash fines into placed streambed material
 - This can be done before filling downstream sump back in.
- Turbid Water:
 - Must (1) recycle or (2) capture & treat during this process.



Thank You!



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