Designing Stream Crossings for Wildlife Passage

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Comprehensive Environmental Inc.

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Designing Stream Crossings for Wildlife Passage Overview of this Presentation:

- Smart Stream Crossing Design
  - Using Stream Crossing Standards and Engineering Practices to develop safe, passable crossings
- Culvert Replacements
  - Unique challenges at replacement crossings, and some possible alternatives to achieve habitat improvement
- Recommended Design Resources

Smart Stream Crossing Design:

1. Design for Stream Continuity

2. Design for Capacity and Stability

3. Design for Resilience

Smart Stream Crossing Design:

1. Design for Stream Continuity

Apply the Stream Crossing Standards*:

Convey the "bankfull discharge" through the crossing in a sustainable, natural channel

(for replacement structures: to the extent practicable)

*Applicable for non-tidal streams…

For tidal streams: preserve or restore natural tidal exchange.

Smart Stream Crossing Design:

1. Design for Stream Continuity

2. Design for Capacity and Stability

   Convey a range of greater than bankfull flows, while sustaining this natural channel and the structure

Smart Stream Crossing Design:

1. Design for Stream Continuity

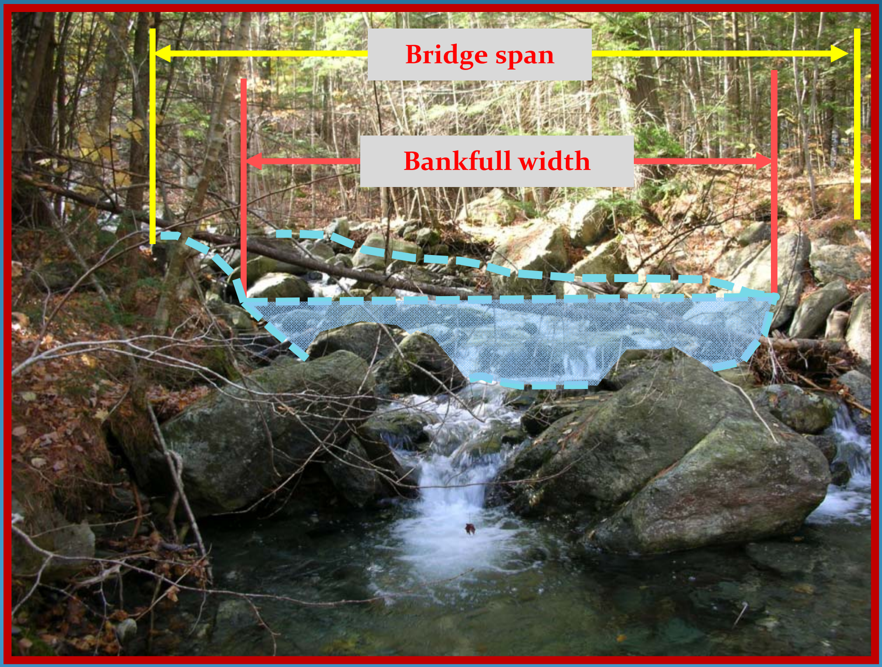
2. Design for Capacity and Stability

3. Provide for Resilience

    Withstand extreme events without losing the structure

Design for the Stream Crossing Standards
New or Replacement Structures

- Stream Crossing Standards:
  - Cross Section Geometry
  - Streambed Material
  - Vertical Alignment
  - Stability Considerations



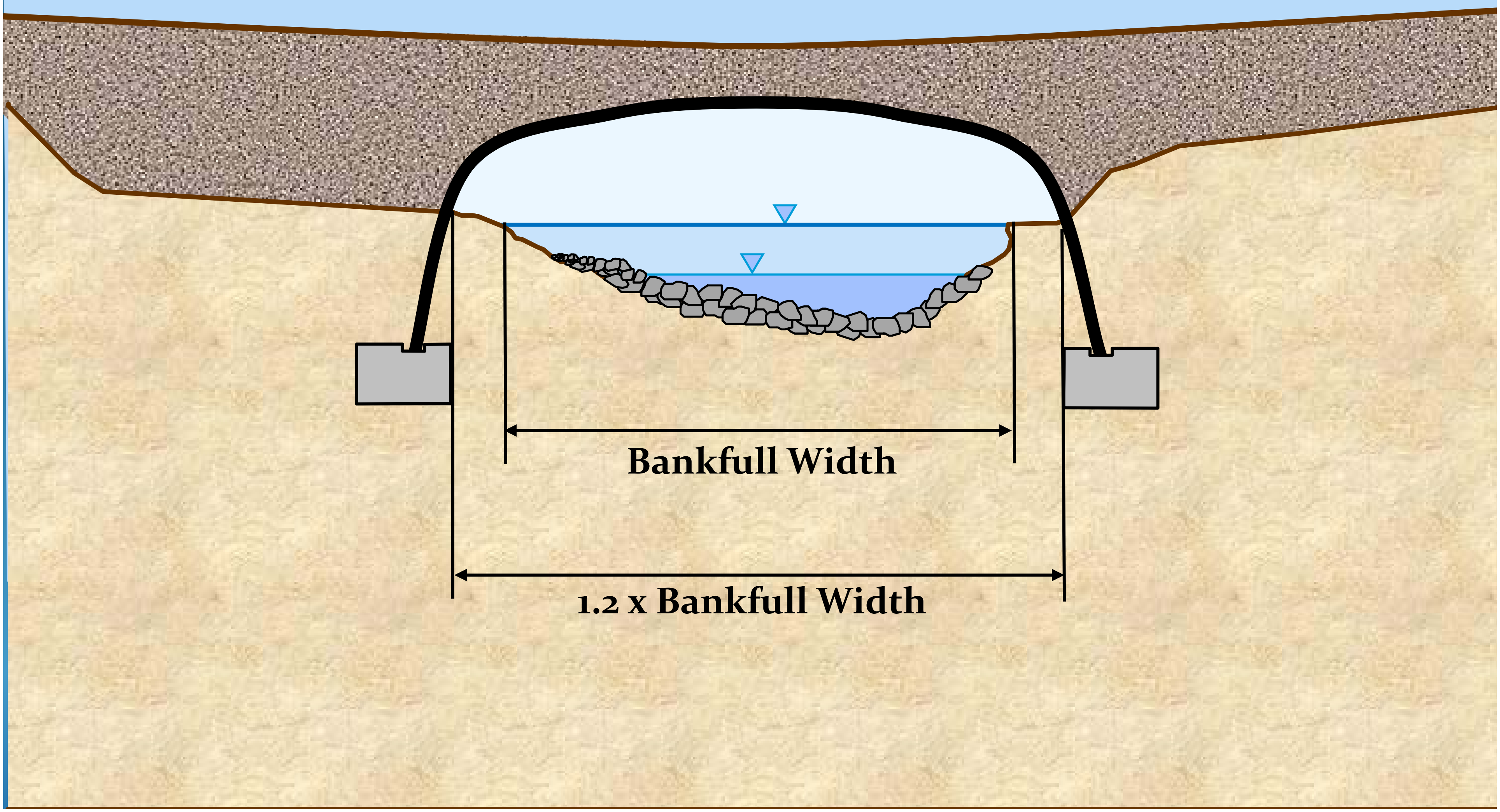
In addition to applicable "conventional" engineering design standards…

Engineering Design Standards

- MGL Chapter 85
  - Requires review by MassDOT District/Bridge
  - Applies to any span >10 ft (including multiple barrels)
- Design to MassDOT/ASHTO bridge standards
  - Hydraulic report
  - Geotechnical report
  - Structural design requirements
  - Scour analysis/scour protection at spans

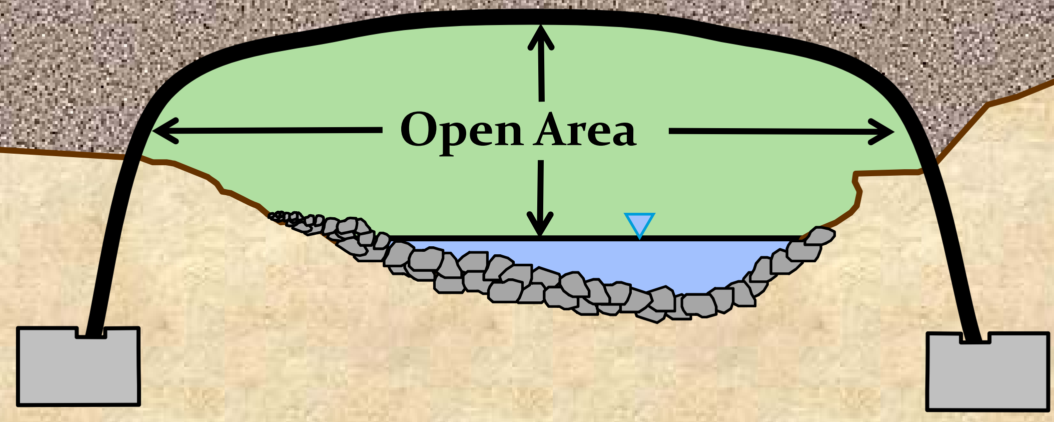
Geometry (size)

Span: bridge or open bottom culvert



Geometry (size)

Span: bridge or open bottom culvert



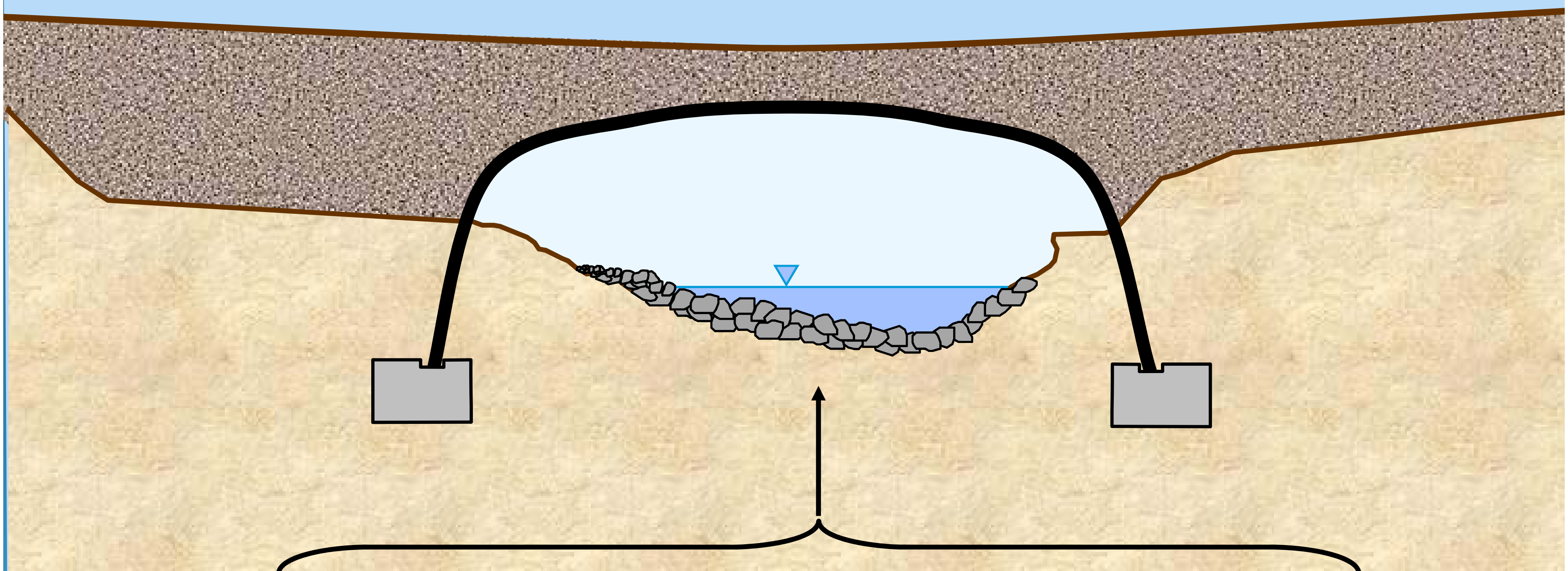
$$\frac{\text{Open Area } (m^2)}{\text{Structure Length } (m)} = \text{Openness Ratio } (m)$$

Openness Ratio (m) $\geq$ 0.25m for General Standards

$\geq$ 0.50m to 0.75m for Optimum Standards

Streambed

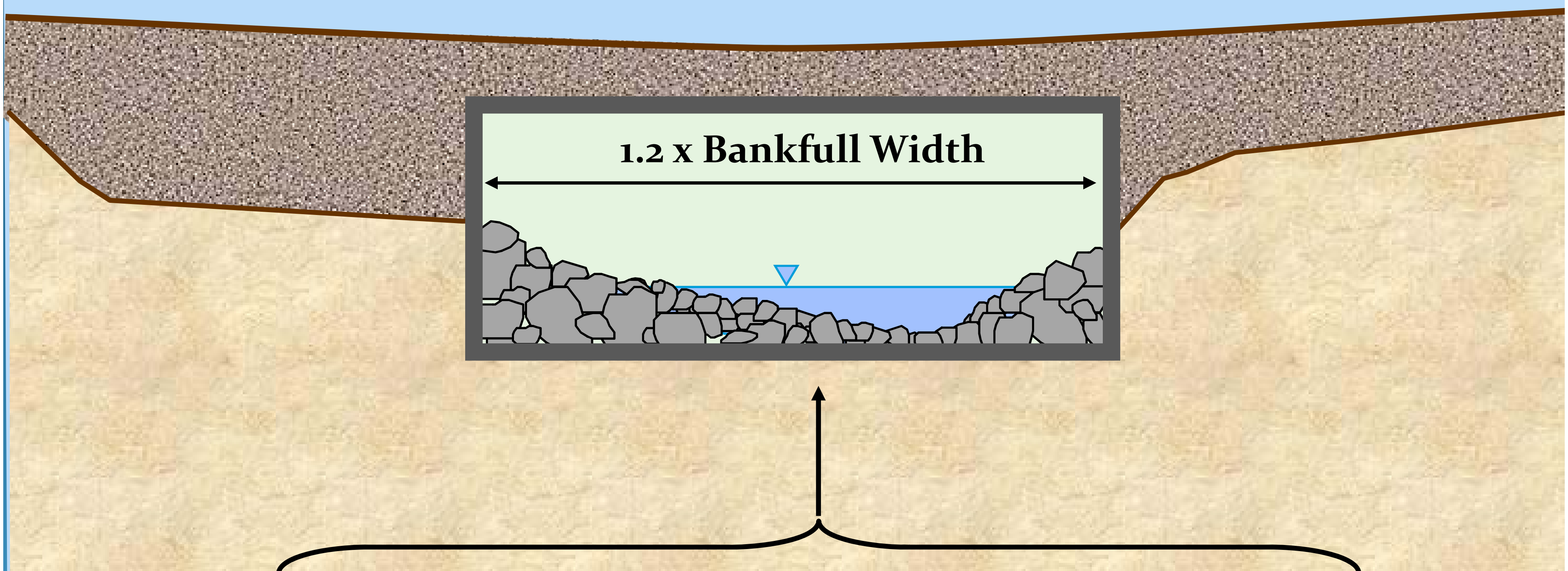
Span: bridge or open bottom culvert



Preserve existing stream bed (preferred);
or if necessary,
Provide for bed material comparable to natural channel and that results in depths and velocities at a variety of flows.

Streambed

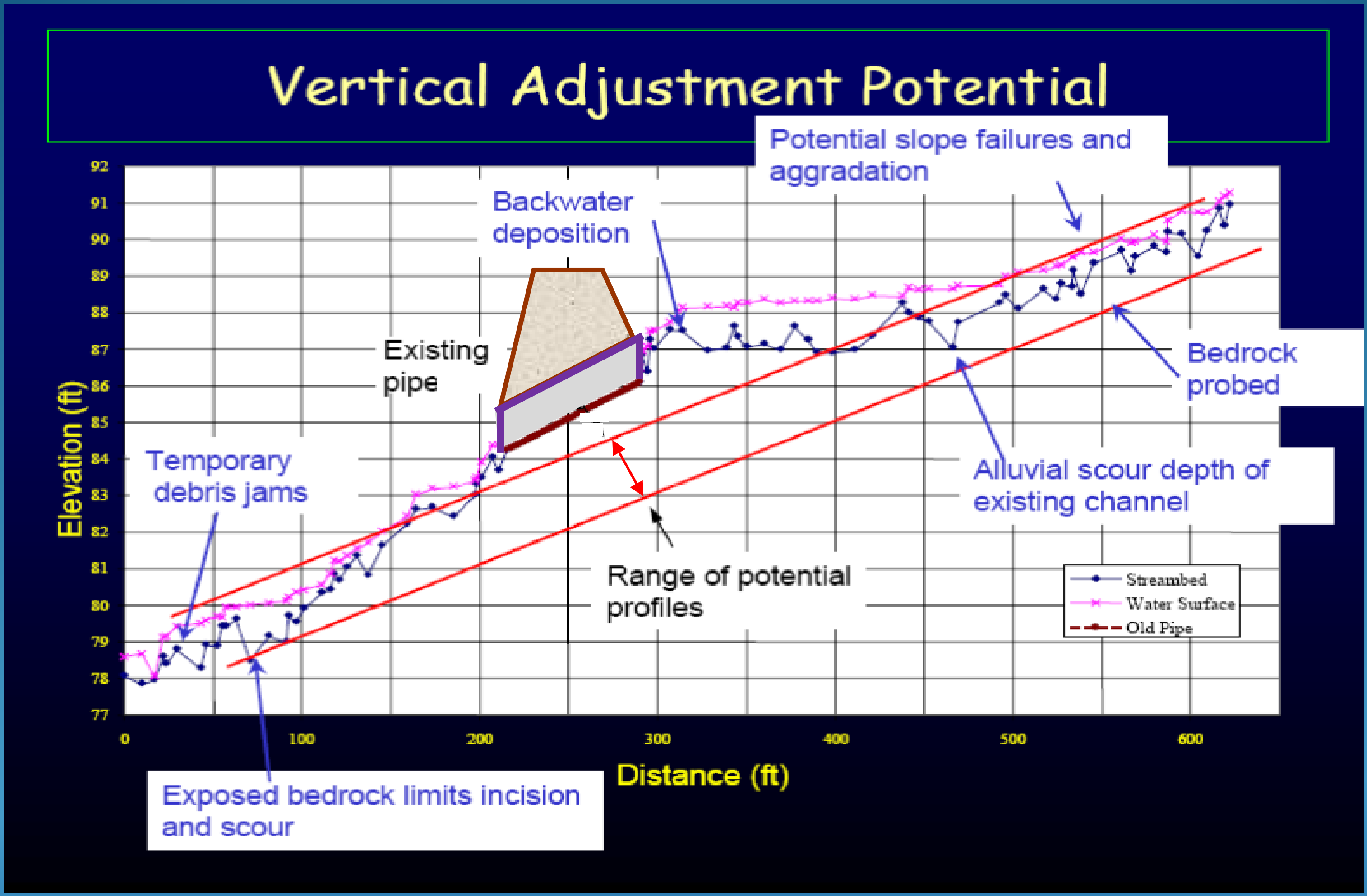
Culvert with Stream Simulation



Provide for bed material comparable to natural channel and that results in depths and velocities at a variety of flows.

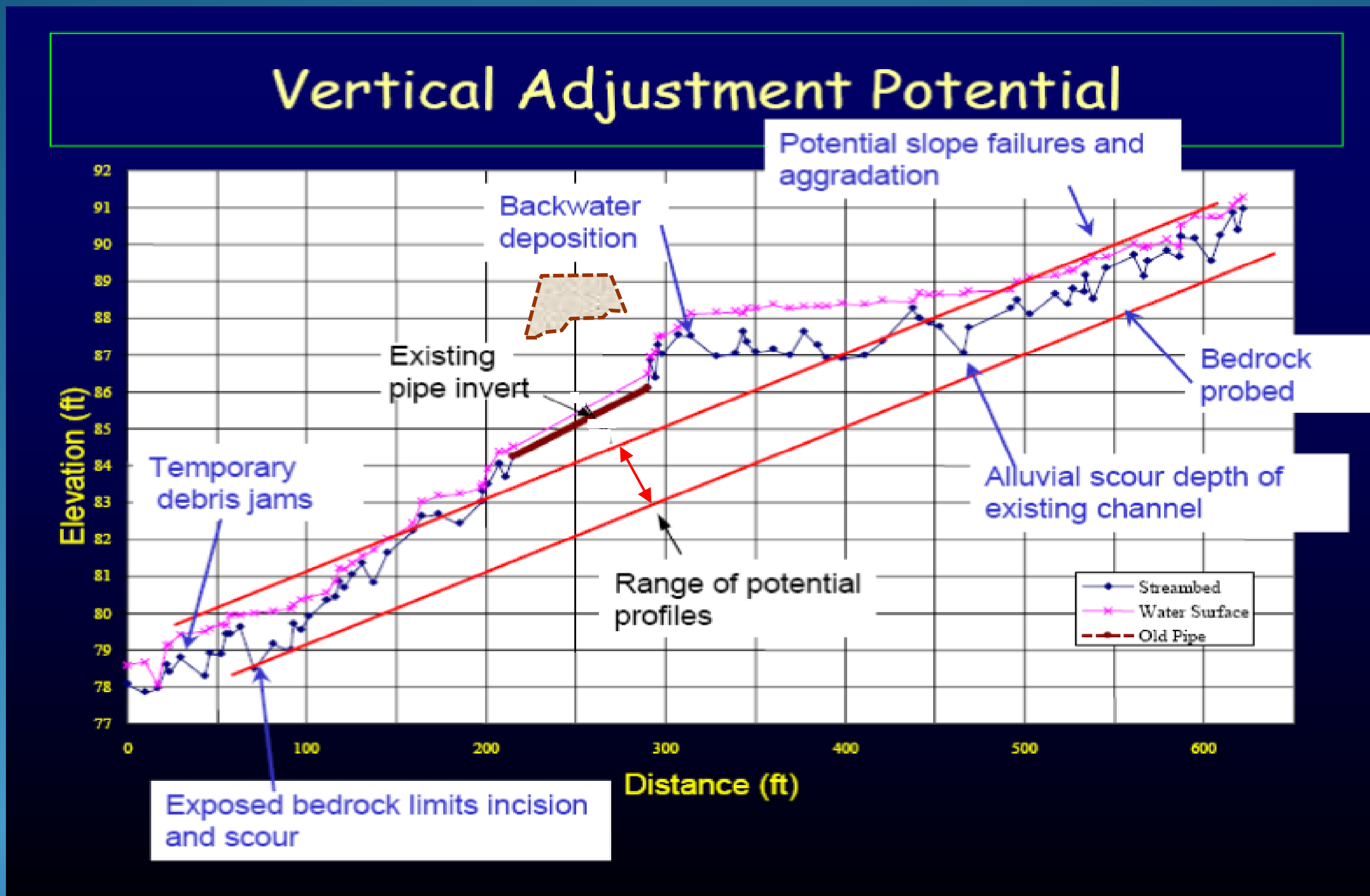
Vertical Alignment

Analysis of the “Long Profile”



From Gubernick & Bates, Stream Simulation Design for AOP, Culvert Summit 2006

Analysis of the "Long Profile"



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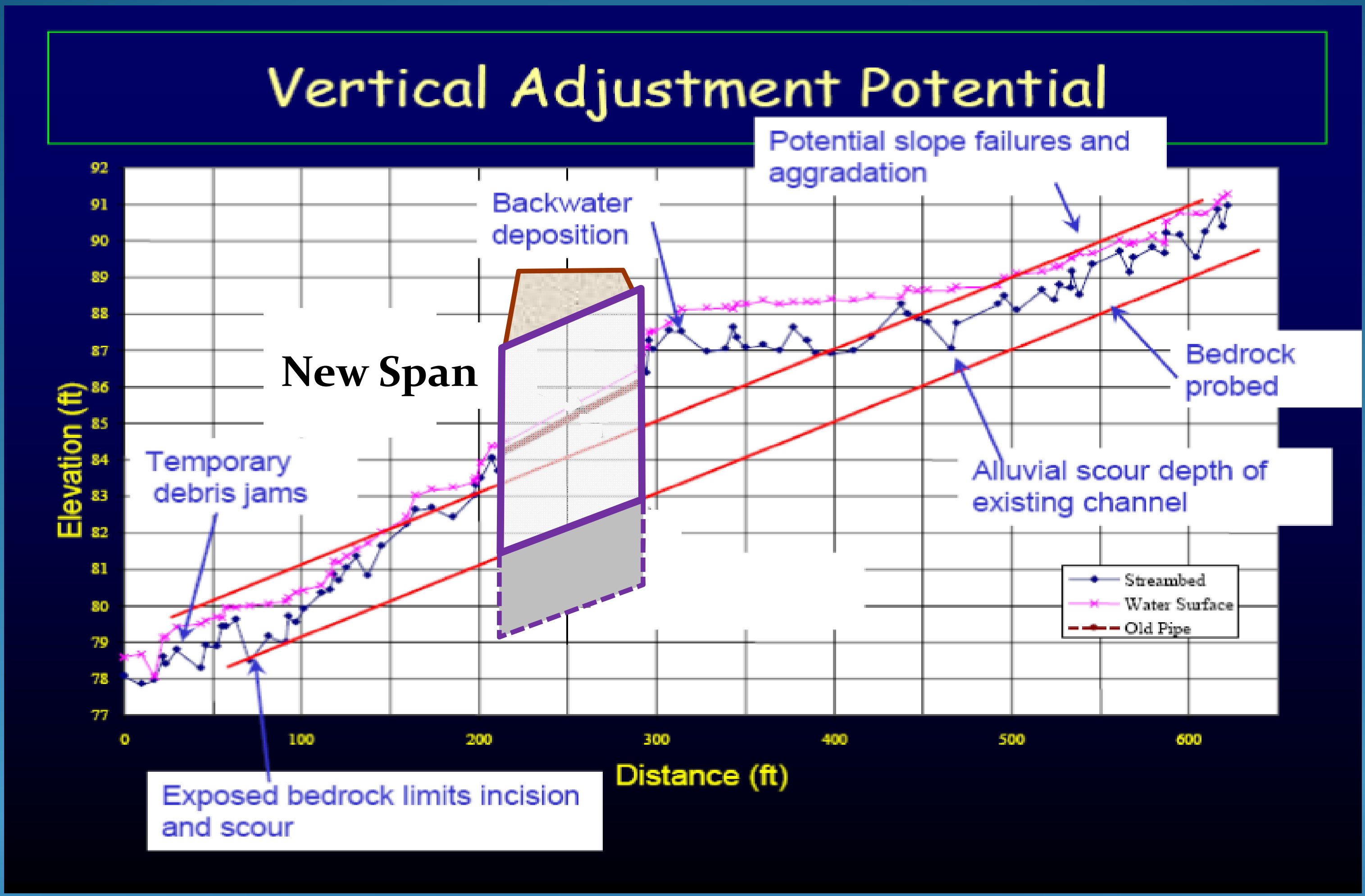
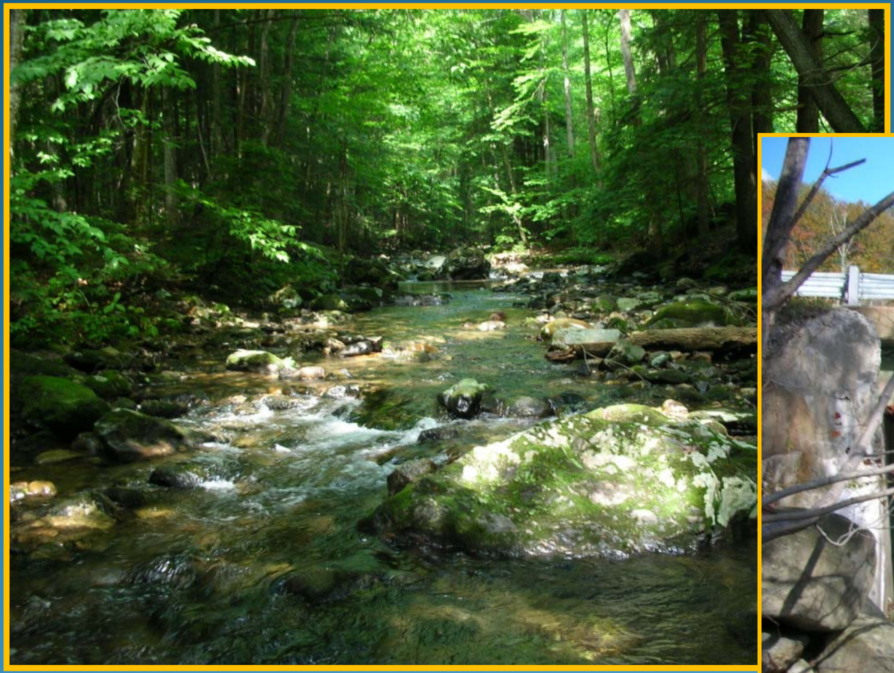


From Gubernick & Bates, Stream Simulation Design for AOP, Culvert Summit 2006

Stability Considerations

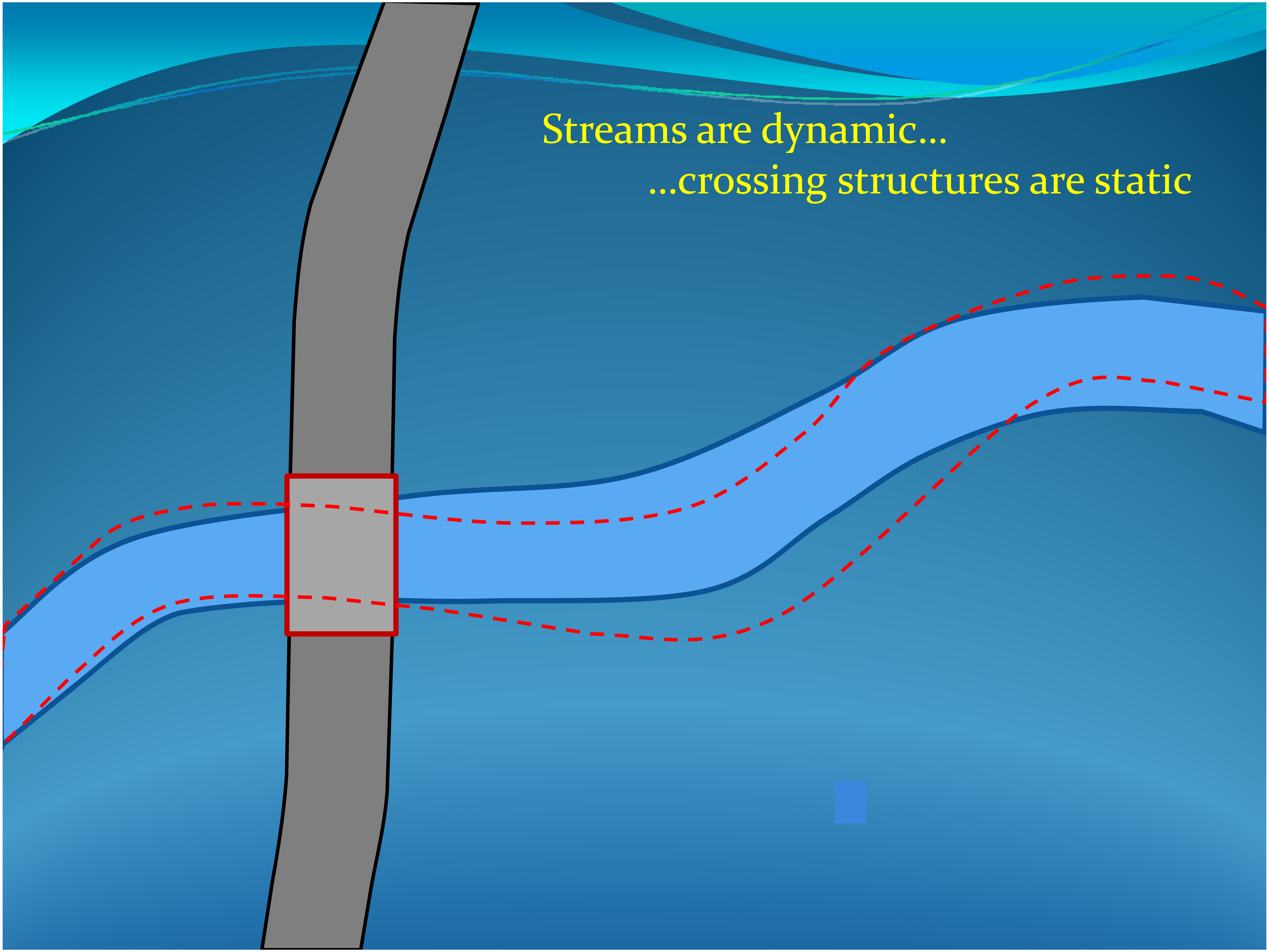
Streams are dynamic!



Bridges and culverts are static (or intended to be)!

Streams are dynamic…

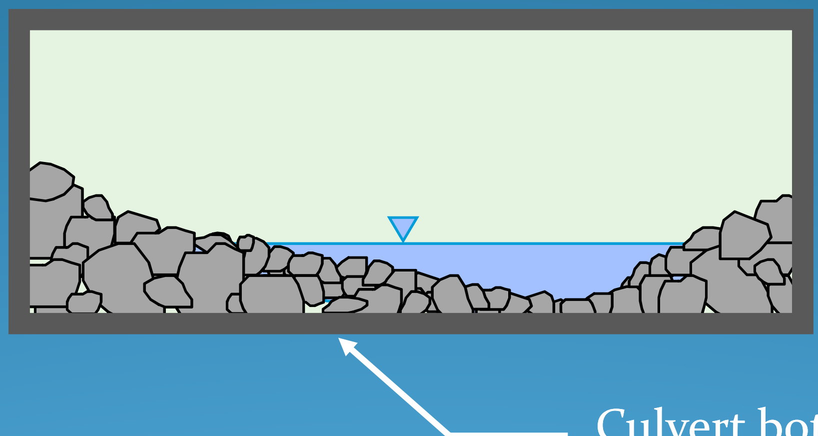
…crossing structures are static



Streams are dynamic…

Culverts are rigid horizontally and vertically

Stream bed horizontal and vertical adjustment limited to material in the culvert



Culvert bottom acts as a “grade control” structure

Streams are dynamic…

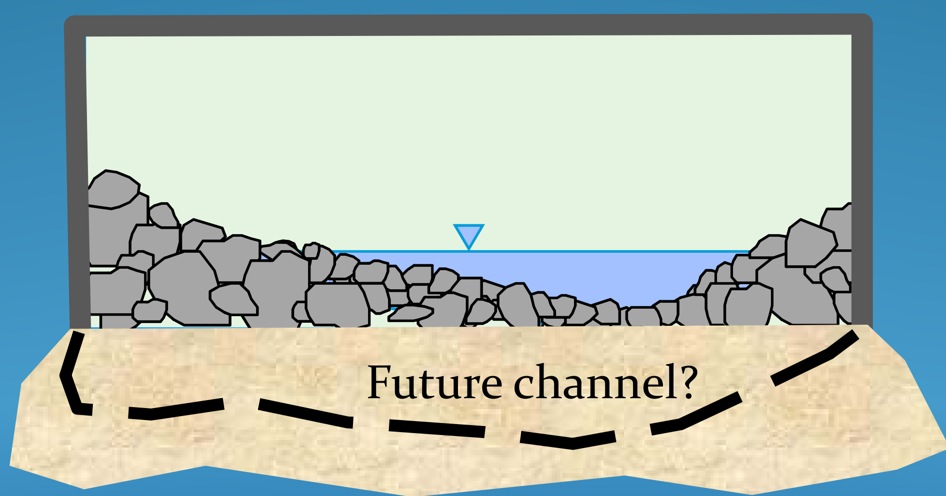
….culverts are rigid

However, "stream simulation" culvert design can prevent this condition

Streams are dynamic…

Bridges and open bottom culverts are rigid horizontally **(unless undermined!)**

Stream bed vertical adjustment is not limited by the bottom of the structure



Streams are dynamic…

…bridges are rigid horizontally

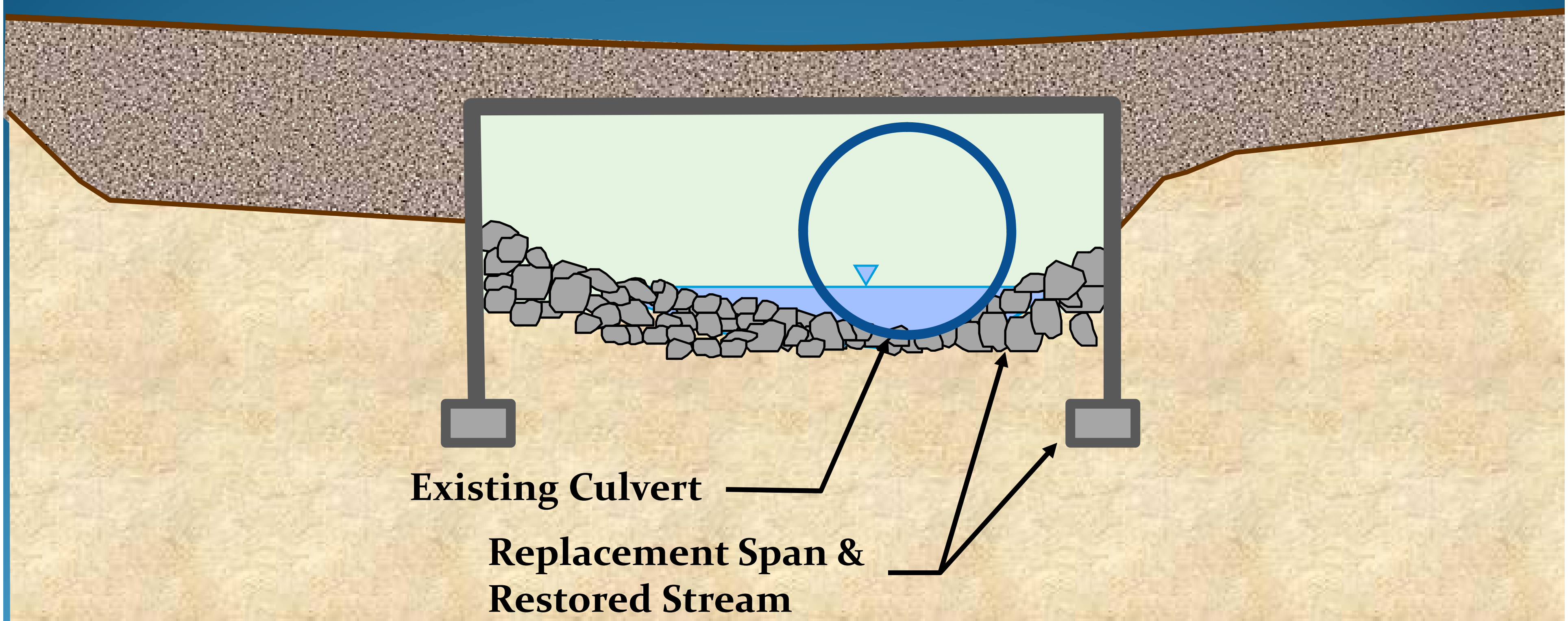
…however, this can (and must be addressed by design.

Design for stability

Requires analysis of

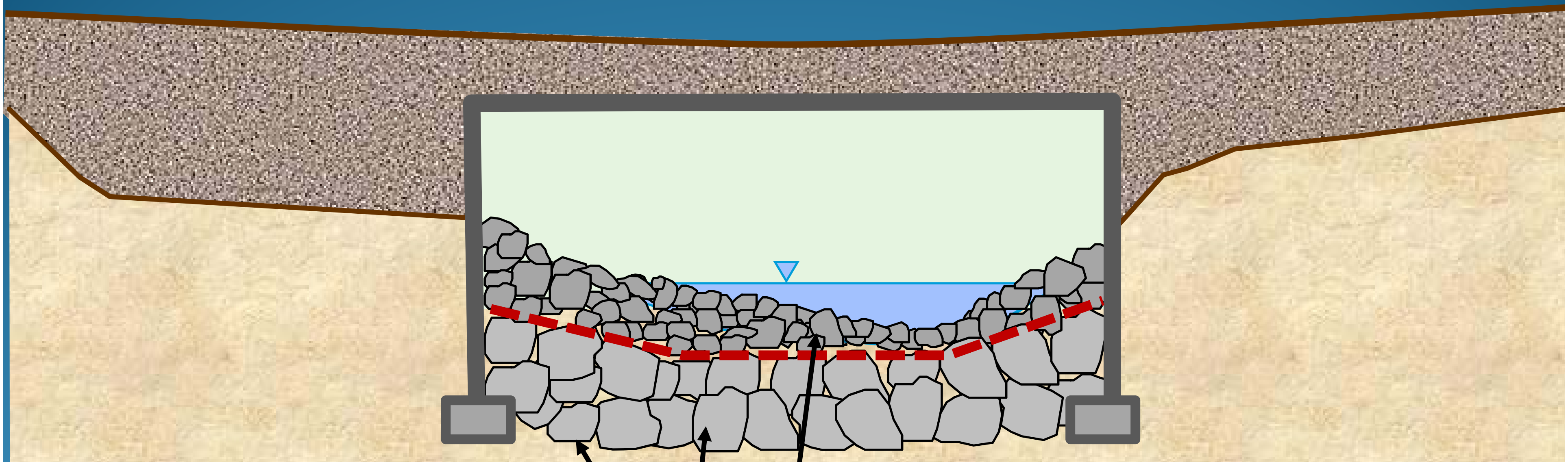
- Stability of the crossing structure: **protect (sustain) the bridge!**
- Dynamic stability of the streambed material: **sustain the streambed!**

Design must evaluate stability within the crossing structure…



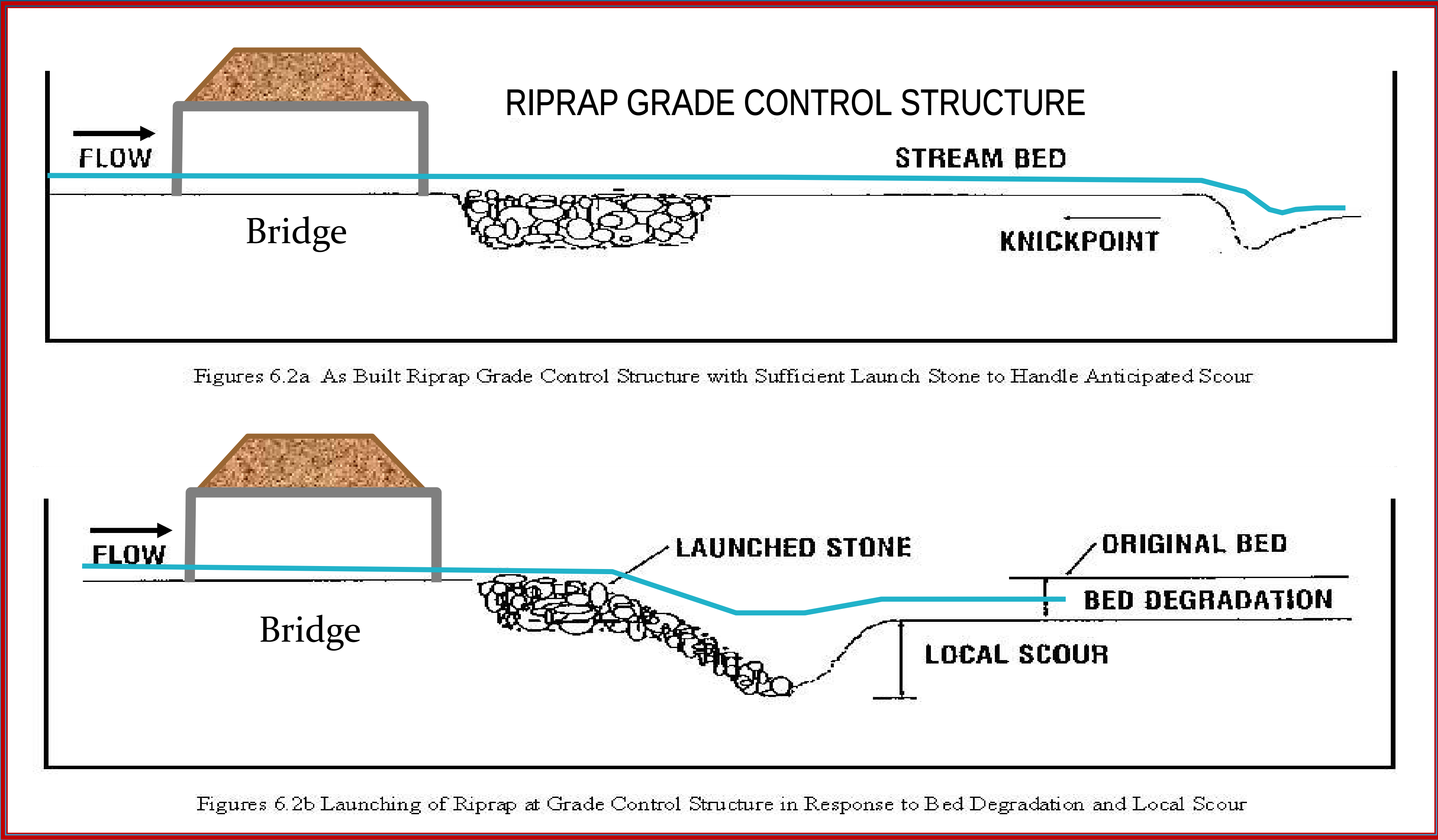
Need to address both: Base flow (habitat continuity)
Extreme flow events

In some cases, design may need to provide for stability within the crossing structure…



Stream Simulation with Stable Sub-bed

In some cases, design may need to consider stabilizing the channel…



Adapted from: US Army Engineer Research and Development Center (1999), Channel Rehabilitation: Processes, Design, and Implementation

What about replacements?

Constraints affecting replacement to provide wildlife passage:

- Flood management concerns
    - Conveyance capacity
    - Impacts on existing flood profiles
- Potential wetland alteration
    - Road impounded wetlands
- Potential “head cut” considerations

Constraints affecting replacement to provide wildlife passage:

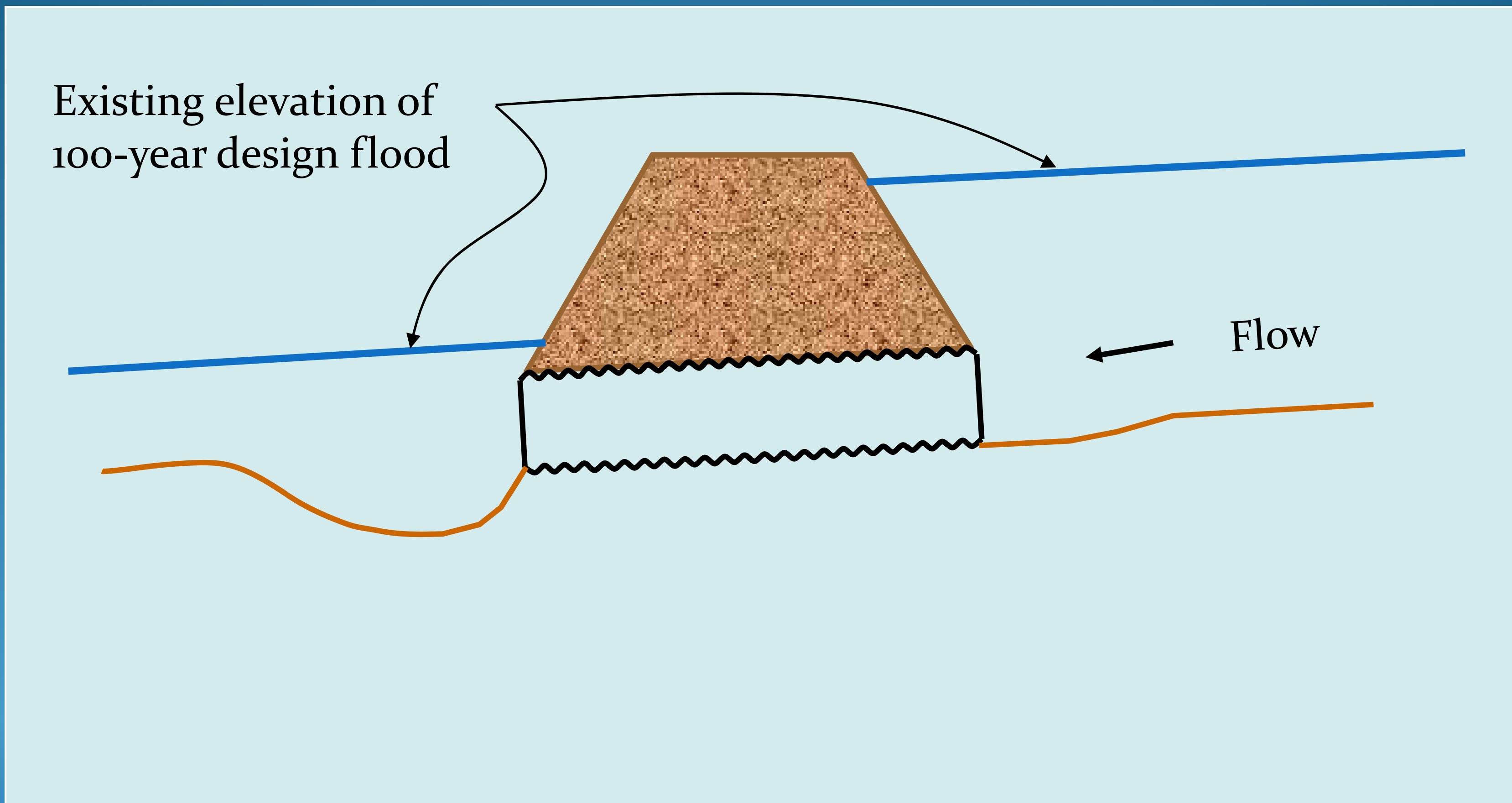
- Vertical alignment limitations
- Existing utilities
- Historic structures

Constraints affecting replacement to provide wildlife passage:

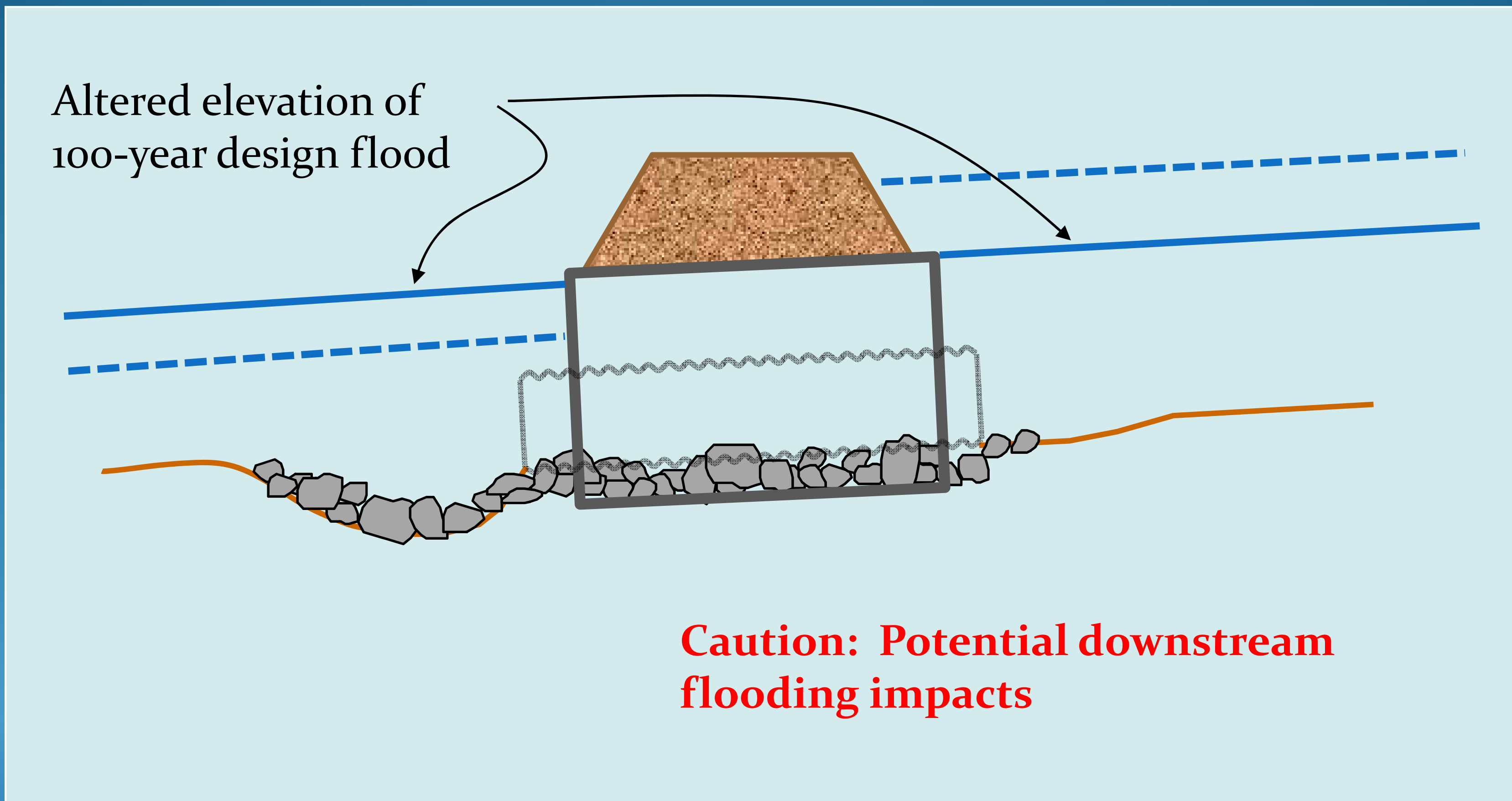
- Construction-phase logistics
  - Maintaining road traffic
  - Maintaining stream flow (water handling)
- Costs and funding priorities

Mitchell Brook – before and during construction

Flood Profile Impacts



Flood Profile Impacts

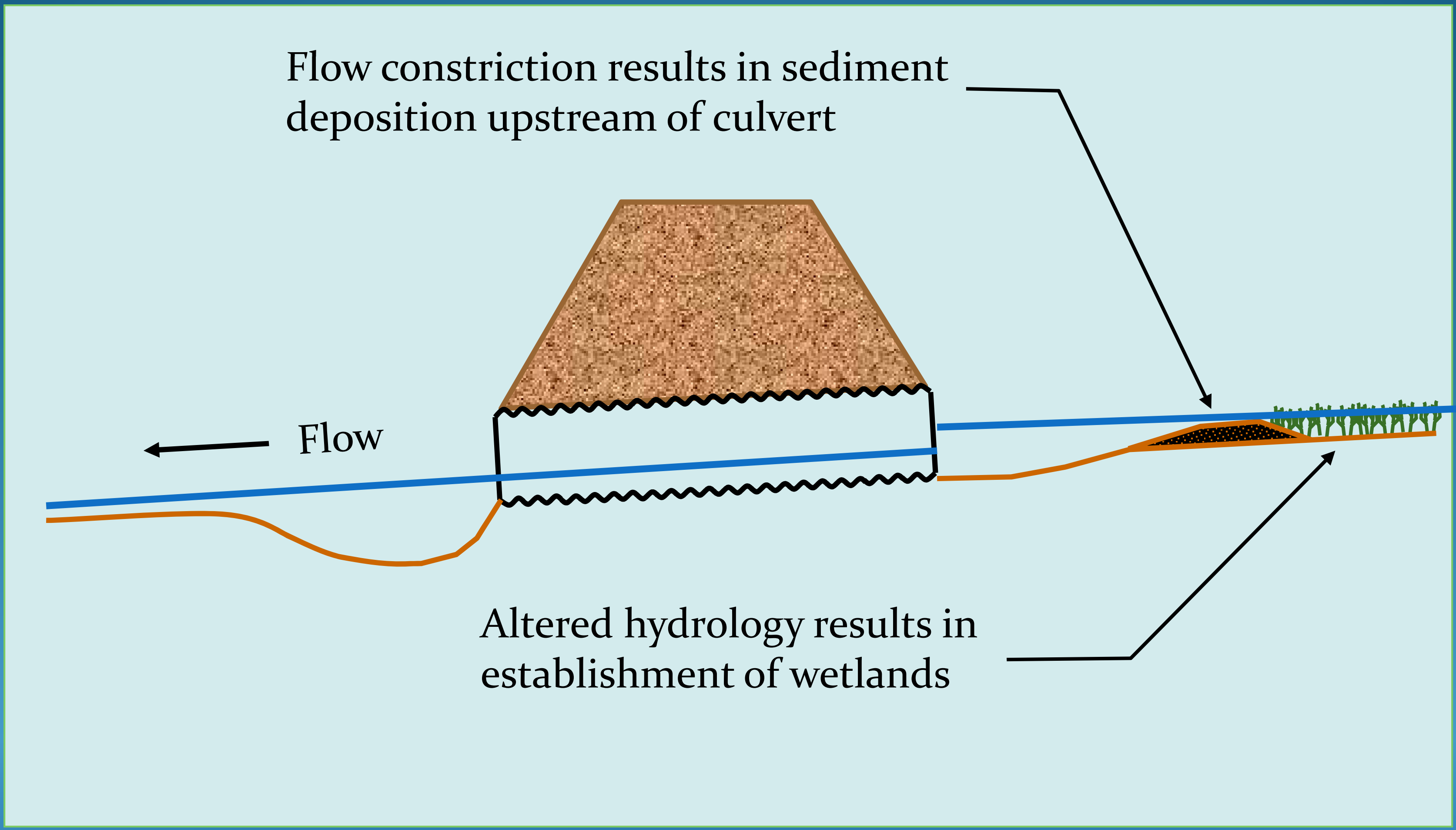


Addressing Flood Profile Impacts:

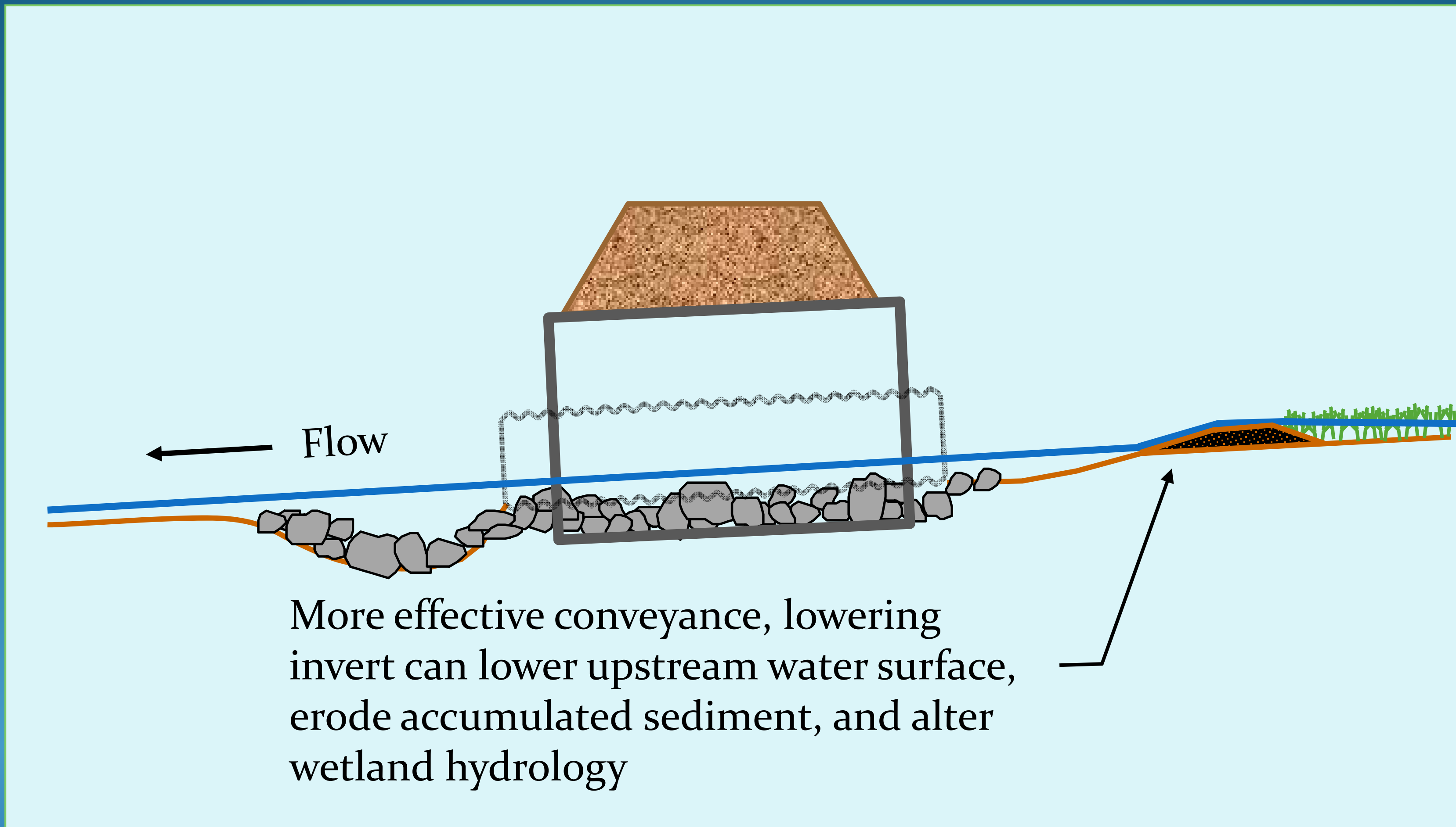
- Compliance with Federal Executive Order 11988
- Determine if potential for alteration exists
- Determine whether the impact can be addressed
- If yes to above, determine if CLOMR is required
  - Document and file application
- If no to above, explore other ways to mitigate for habitat disconnection:
  - May require a lesser restoration of habitat connection

Road-Impounded Wetlands

Road-Impounded Wetlands



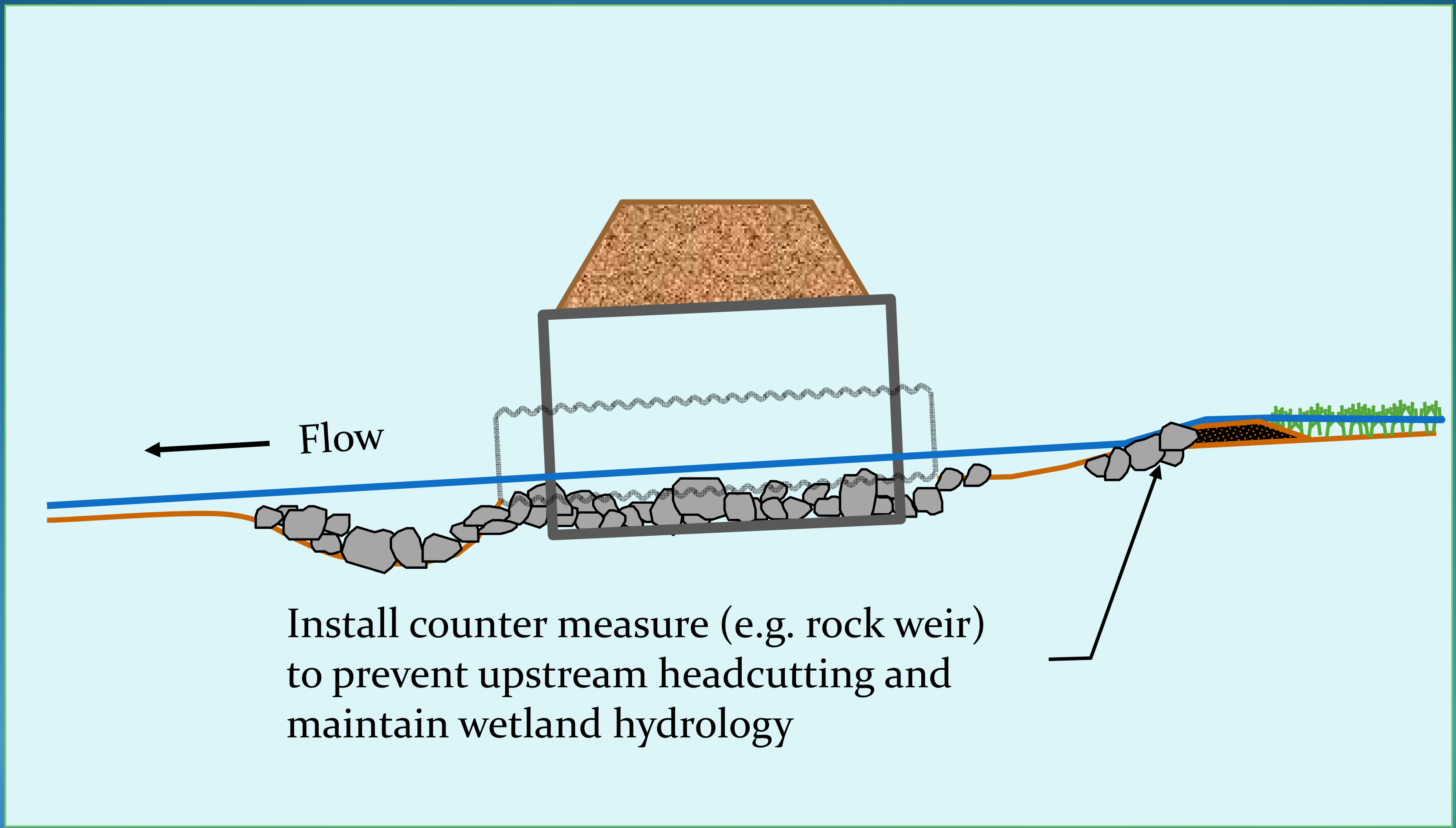
Road-Impounded Wetlands



Addressing Road-Impounded Wetlands:

- Determine if potential for alteration exists
- Determine whether the "gain" offsets the "loss"
- If yes to above, can it be permitted?
  - Consultation with resource agencies
- If no to above, explore other ways to mitigate for habitat disconnection:
  - In-stream mitigation may be warranted:
    - Application of stream restoration techniques to offset or correct impacts

Road-Impounded Wetlands



Vertical alignment constraints

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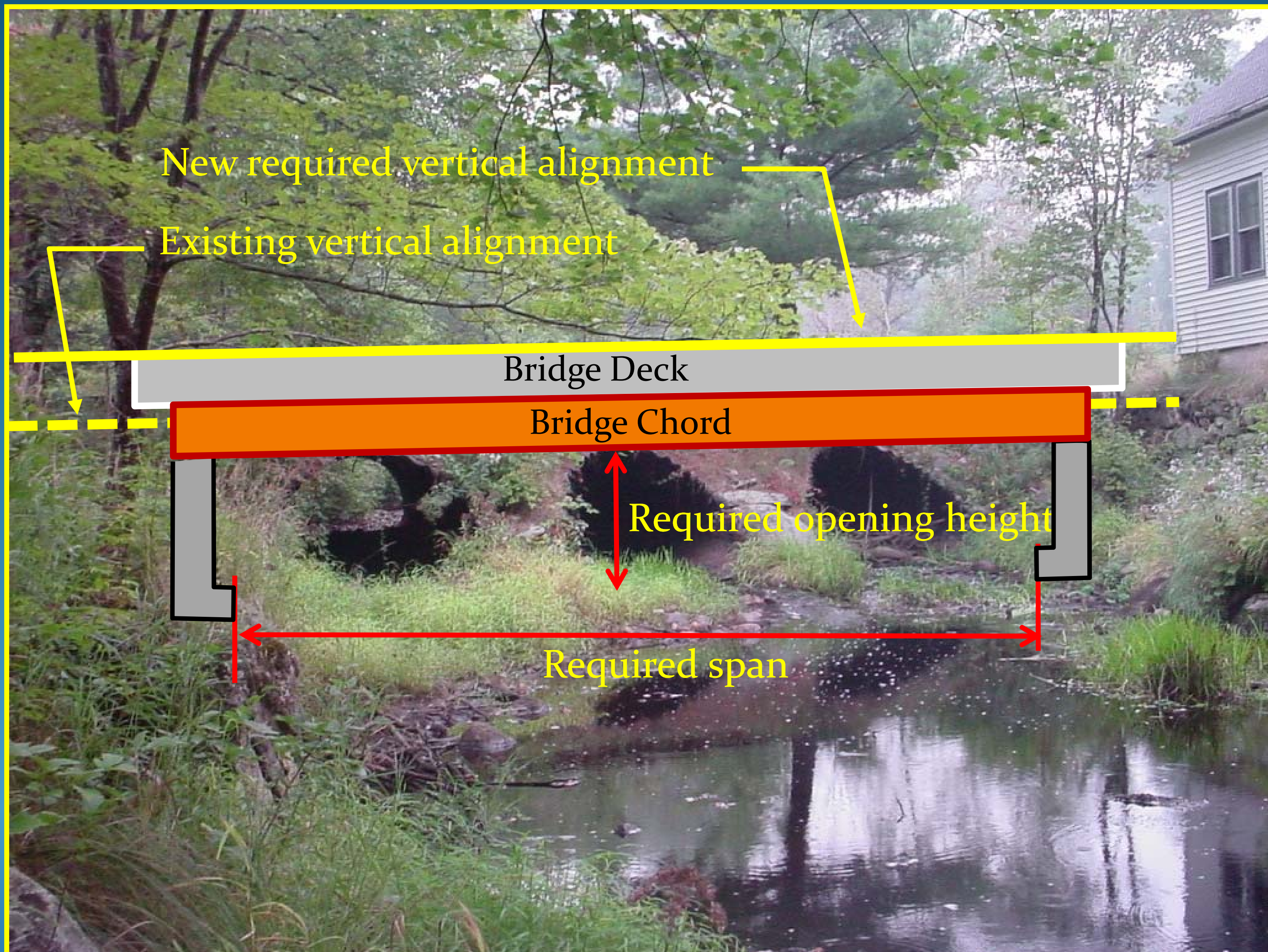


Vertical alignment constraints

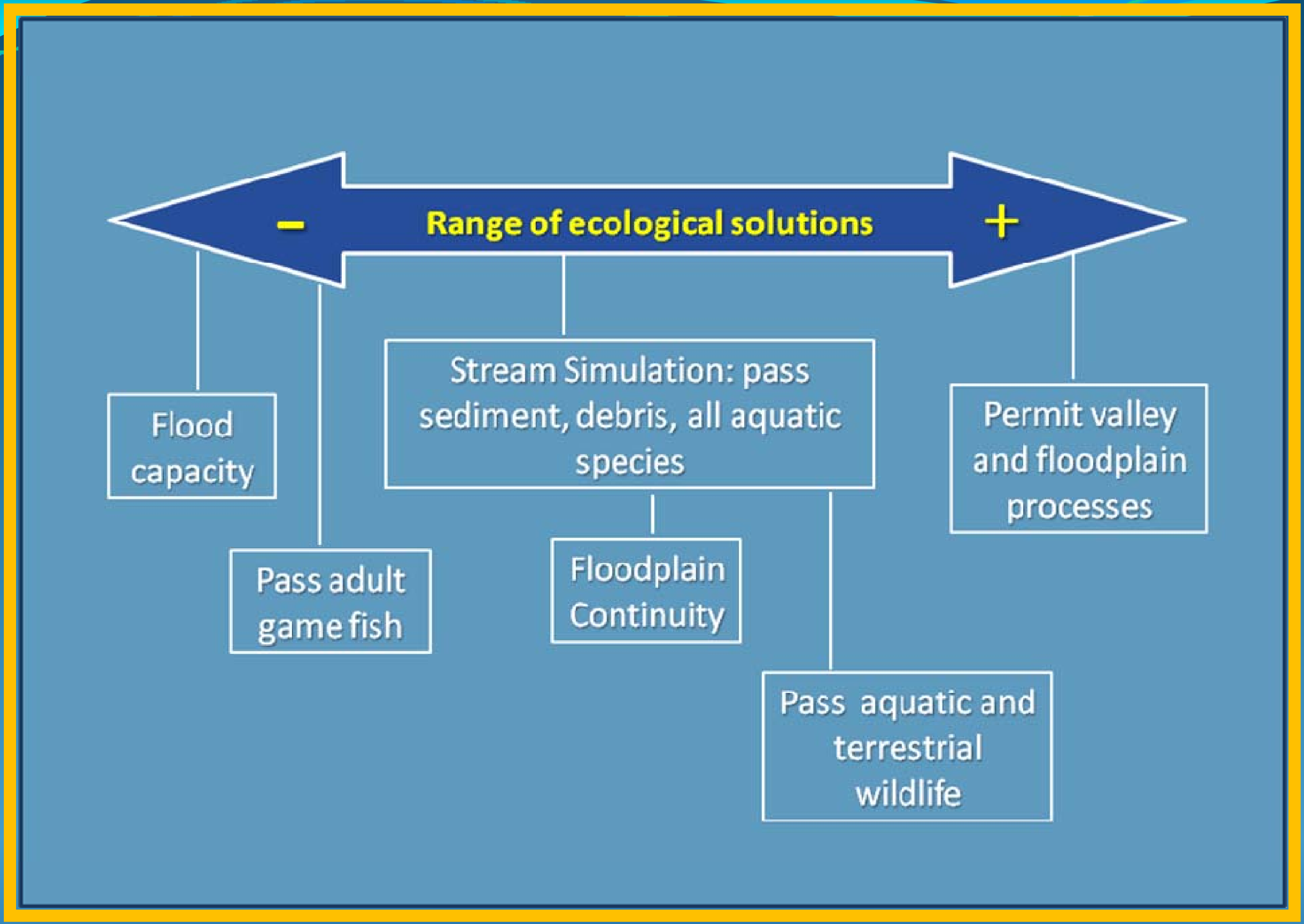
Existing Utilities

Urban channel alteration & degradation

Urban channel alteration & degradation

There are constraints, but we still have to address the problem…

…what are the options?



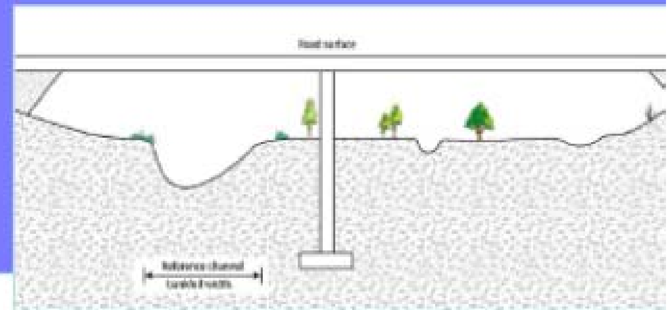
Adapted from Gubernick, Culvert Summit 2006

Design Approaches Continuum

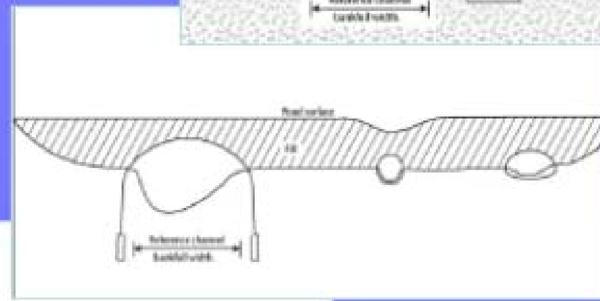
Determined by project objectives, stream and design realities

Not all streams can be or require stream sim.!

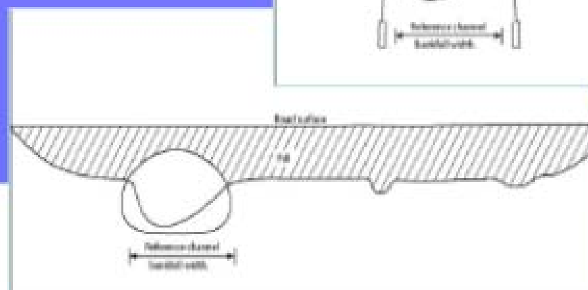
Valley and floodplain processes



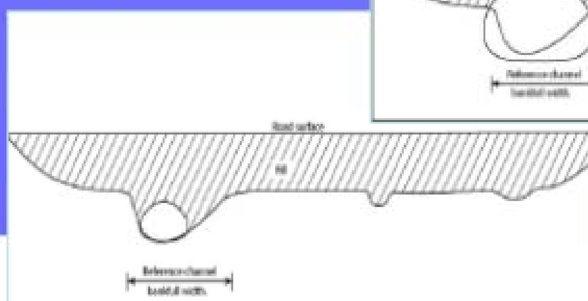
SS with floodplain continuity



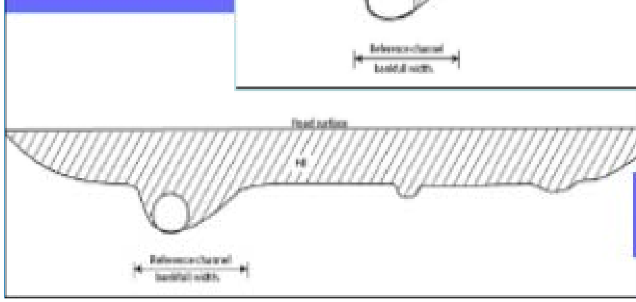
Stream simulation

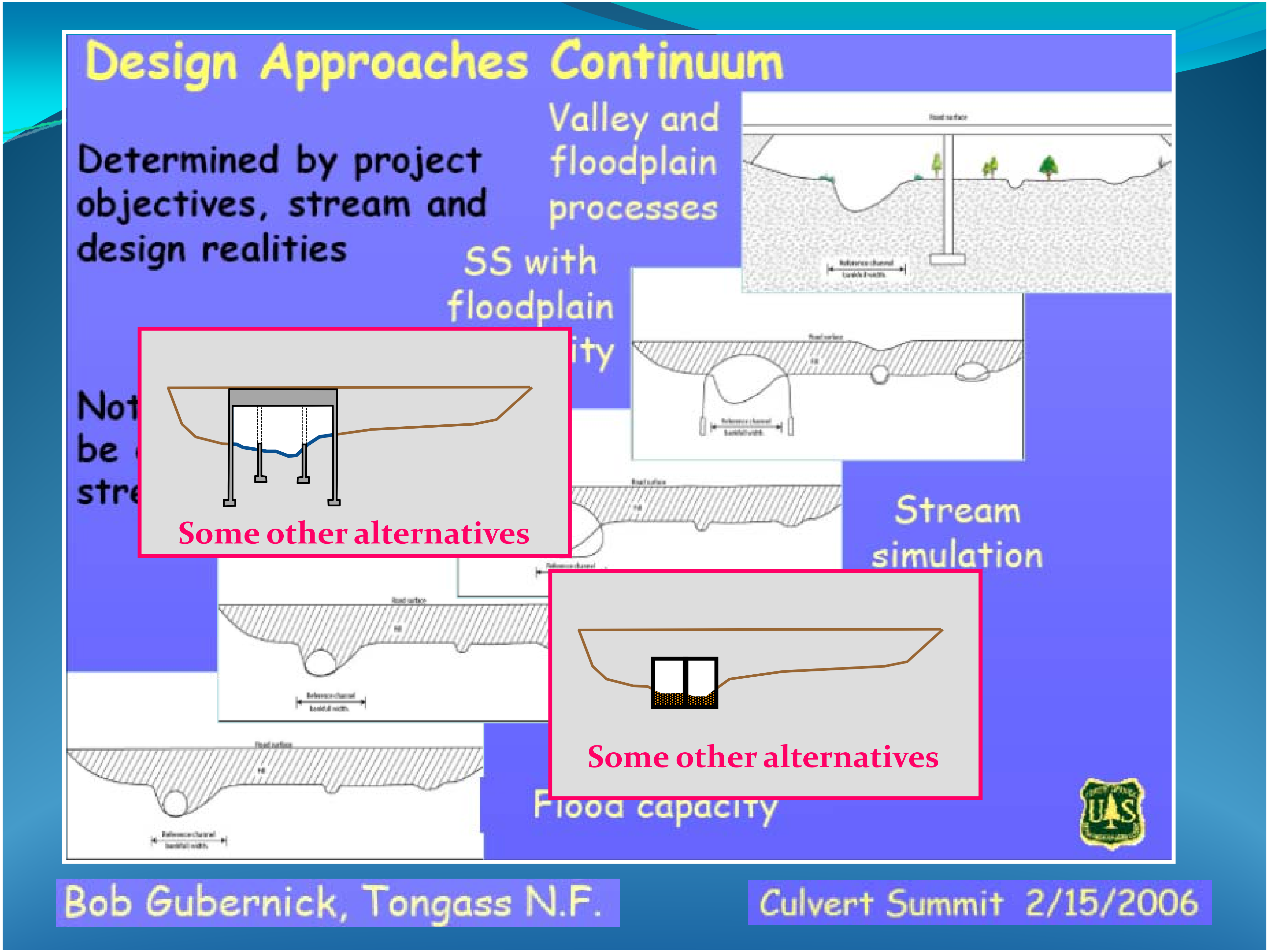


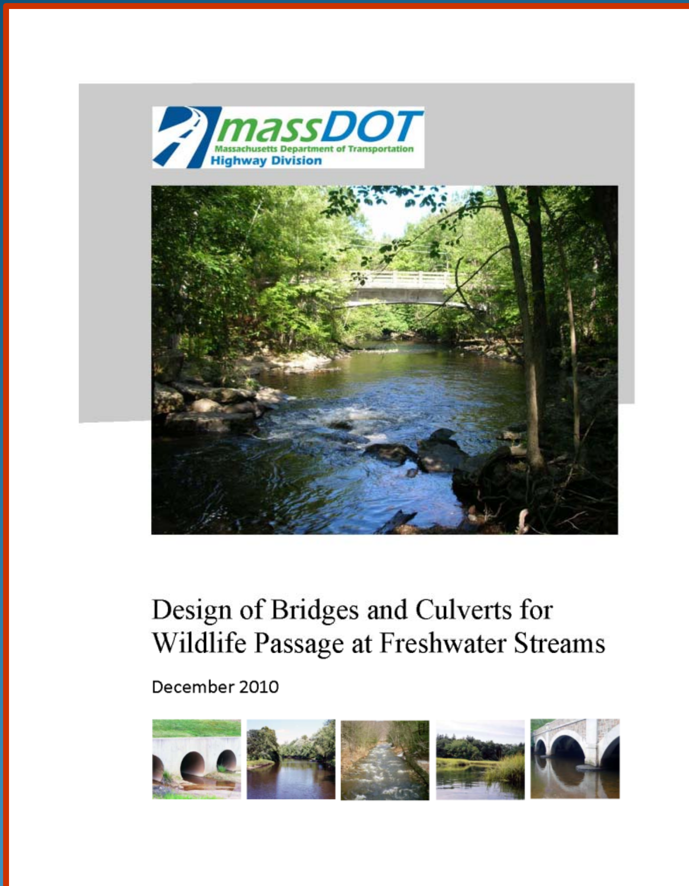
Hydraulic design

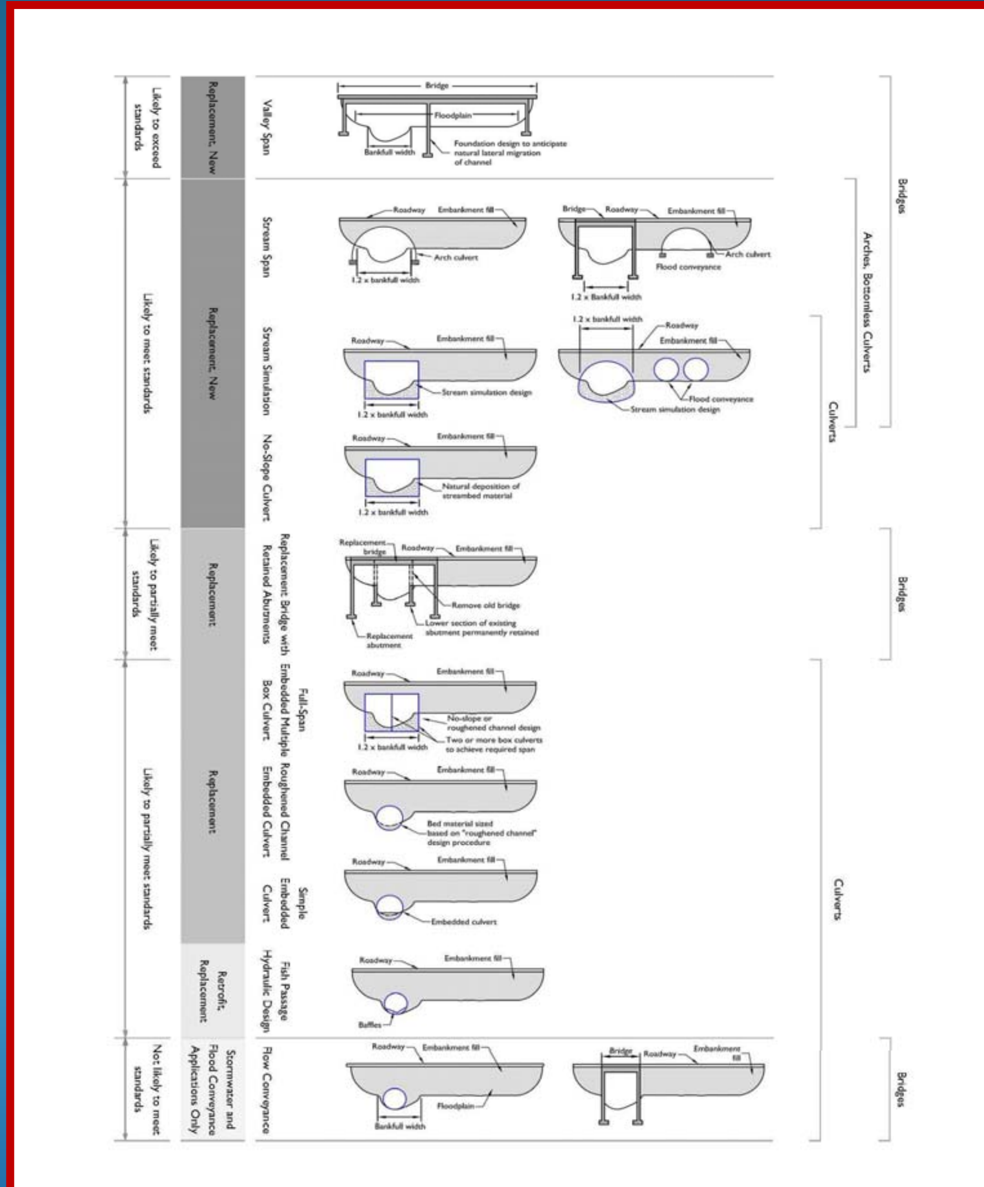


Flood capacity




Design Approaches Continuum
Determined by project objectives, stream and design realities
Valley and floodplain processes
SS with floodplain
Stream simulation
Some other alternatives
Some other alternatives
Flood capacity
Bob Gubernick, Tongass N.F.
Culvert Summit 2/15/2006


massDOT
Massachusetts Department of Transportation
Highway Division
Design of Bridges and Culverts for
Wildlife Passage at Freshwater Streams
December 2010



Design methodology for providing stream bed continuity at road crossings

Examples:

- "Stream Simulation" design*
- "No-Slope" design*
- "Roughened Channel" design*
- Bridge replacement with retained abutments**

*Based on work by: Kozmo (Ken) Bates (formerly with Washington DFW) and USDA Forest Service

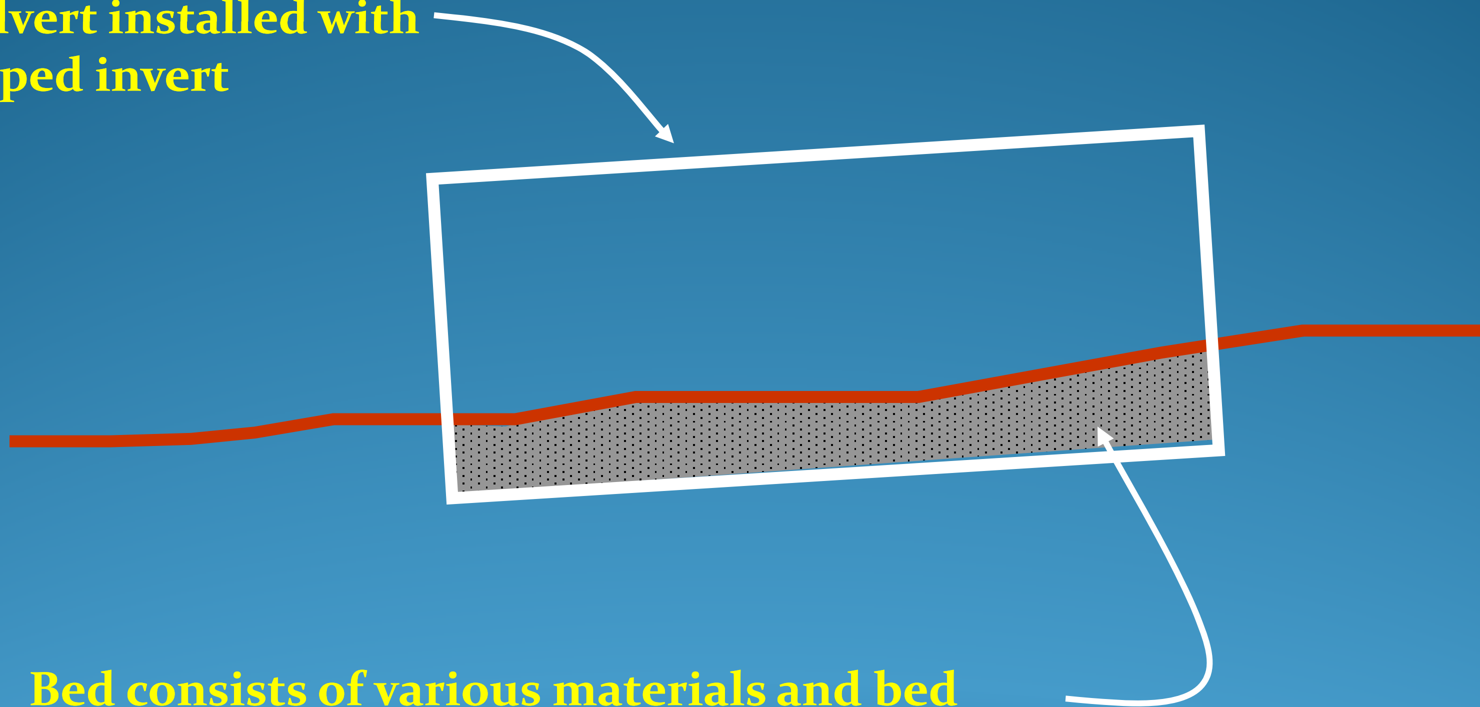
**Based on MassDOT practices

Stream Simulation Design

- Applicable to
  - new and replacement culverts
  - replacing pipe culverts with bottomless culverts or bridge spans
  - new clear-span structures where stream alignment would be altered
- Moderate to high channel gradient, and locations with narrow stream valleys
- Greater than 6% gradient may have limitations
- Size large enough for access to construct stream bed

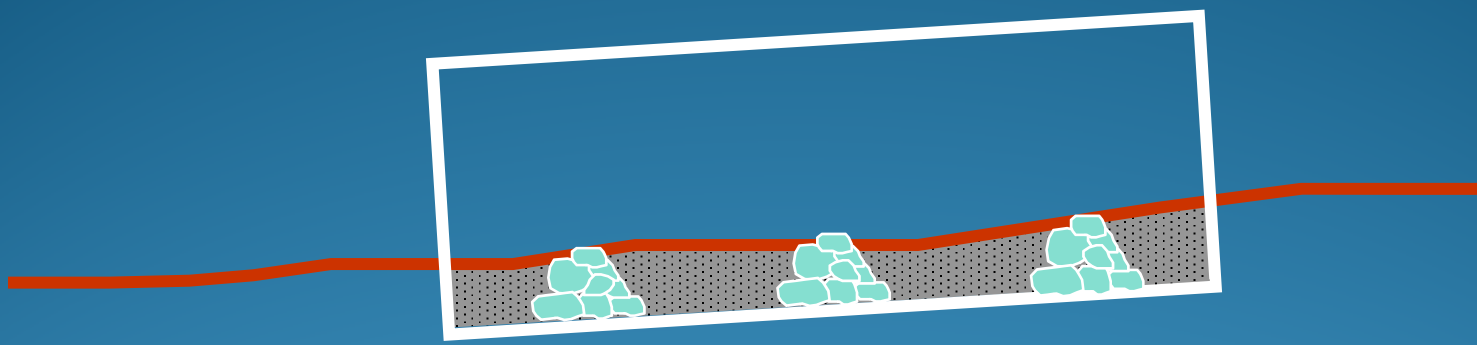
Stream Simulation Design

Culvert installed with sloped invert

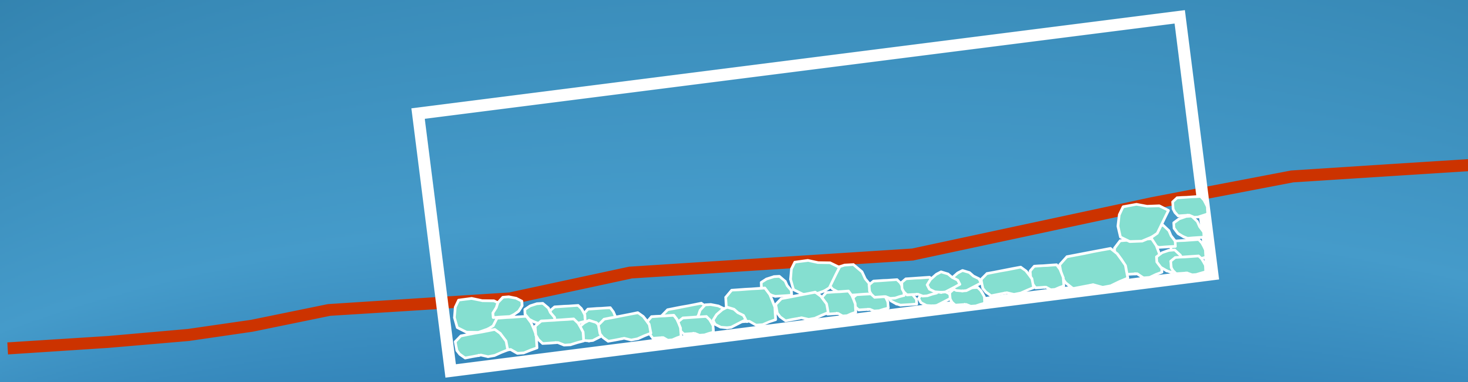


Bed consists of various materials and bed forms designed based on geomorphologic analysis of local stream bed or suitable "reference" stream

Stream Simulation Design



Alluvial (e.g., cobble/gravel)

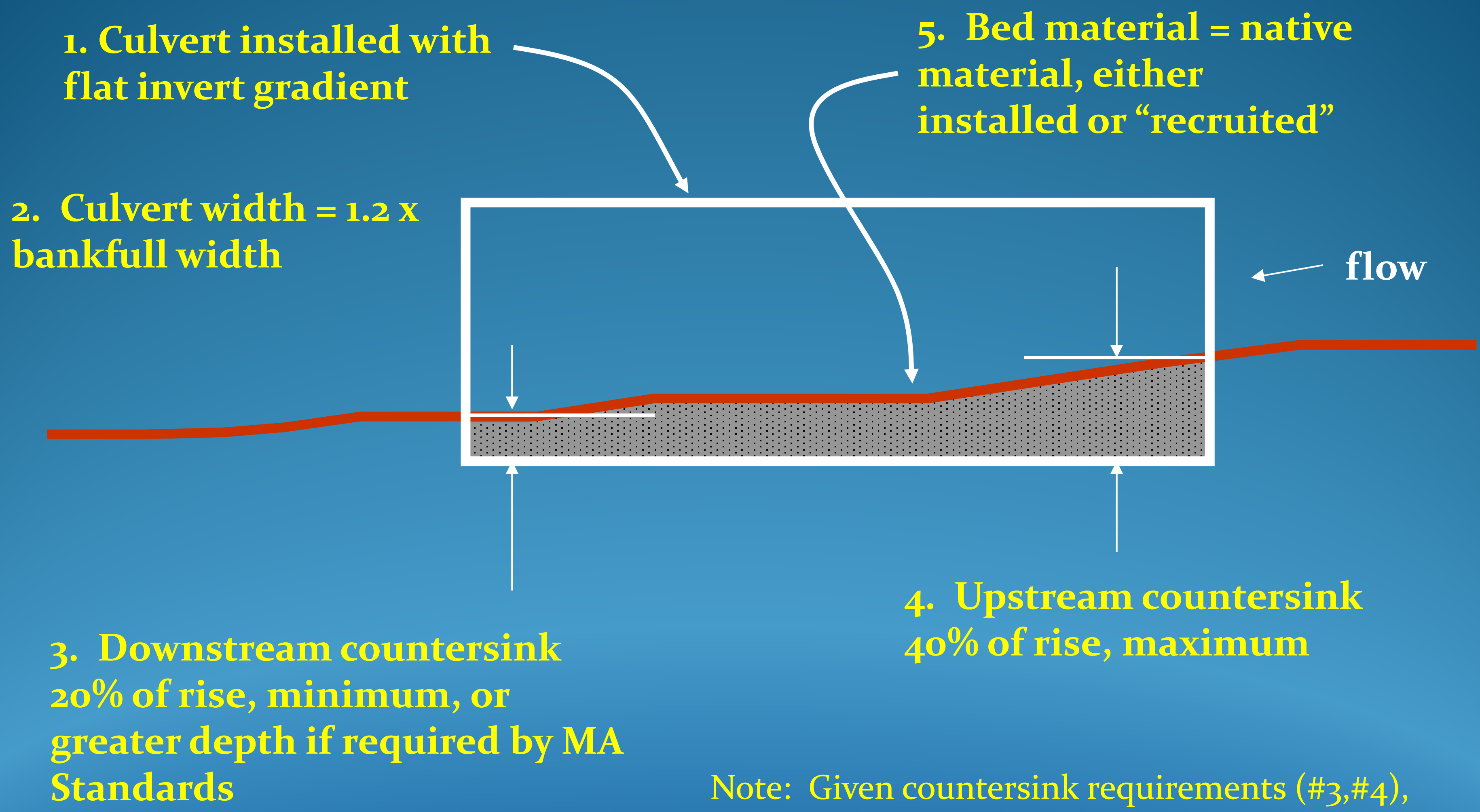


Non-alluvial (e.g. step-pool)

“No Slope” design option

- Applicable to
  - New structures or replacements
  - Culverts only
  - Not suitable for bridges or bottomless structures
- Generally limited to streams with natural gradients less than 3%
- Most likely applicable to streams with fine-grained, mobile bed material

"No Slope" design option



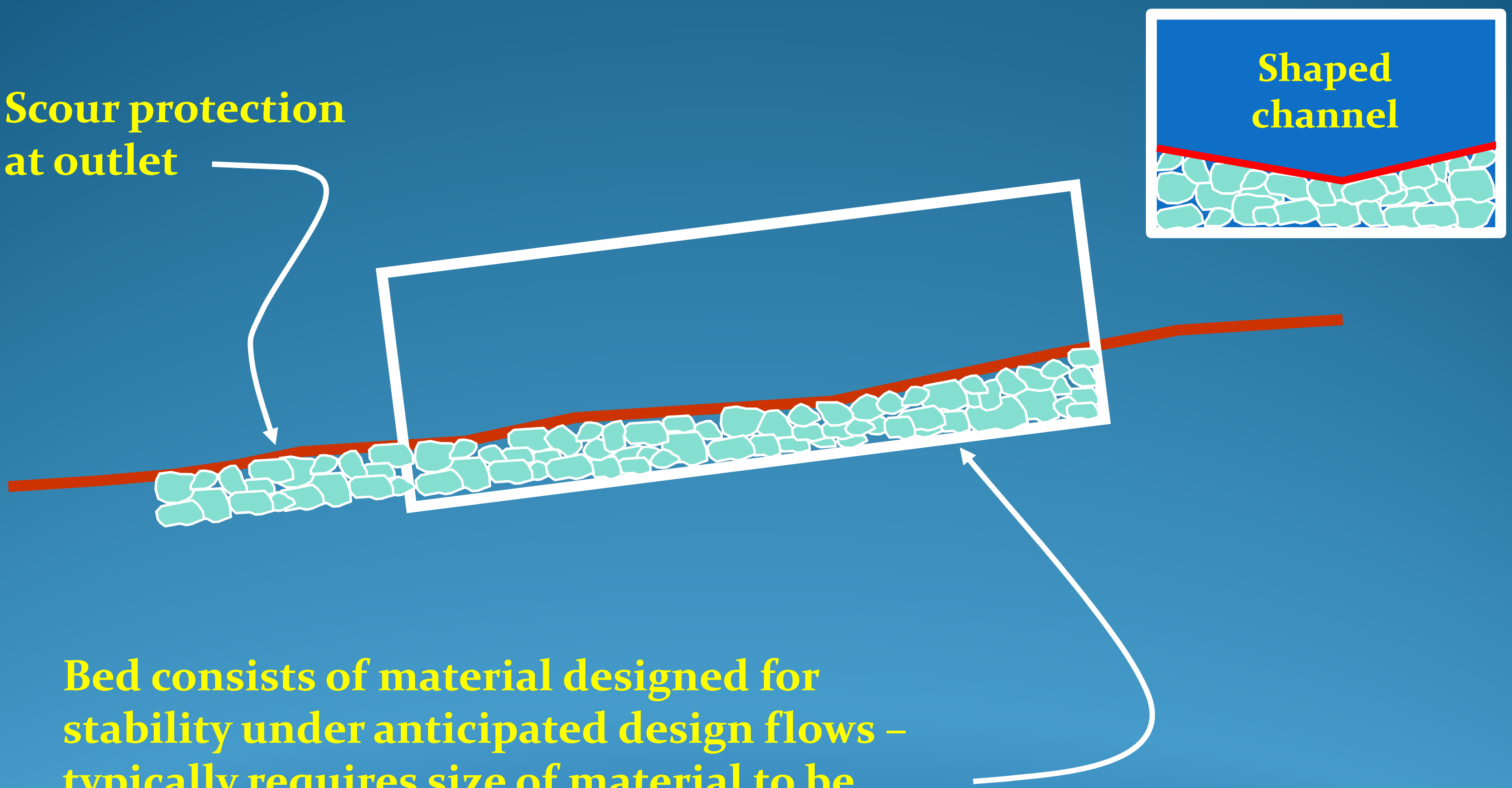
Note: Given countersink requirements (#3,#4), maximum length of culvert will be limited by slope of stream ($L \leq 0.2*D/s$)

Roughened Channel Design

- Applicable to
  - New and replacement culverts, where not feasible to provide width > 1.2 bankfull width
- Moderate to high channel gradient, and locations with narrow stream valleys
- Not recommended for flat-gradient streams with fine-grained mobile bed material (consider "no-slope" design instead.
- Size large enough for access to construct stream bed
- May require scour protection (e.g., armoring) of channel at the culvert outlet

Roughened Channel Design

Scour protection at outlet

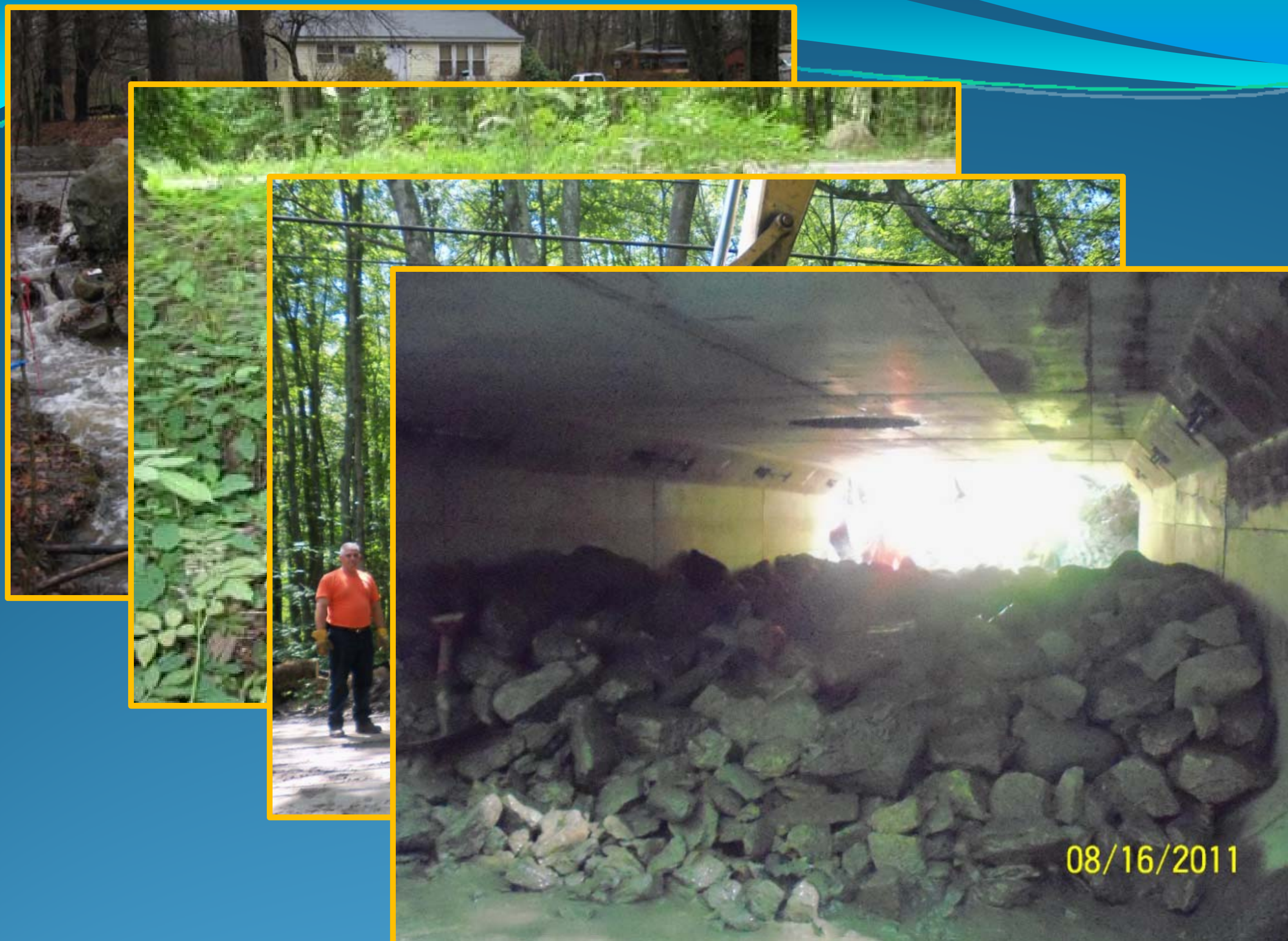


Bed consists of material designed for stability under anticipated design flows – typically requires size of material to be comparable to the larger material found in natural channel

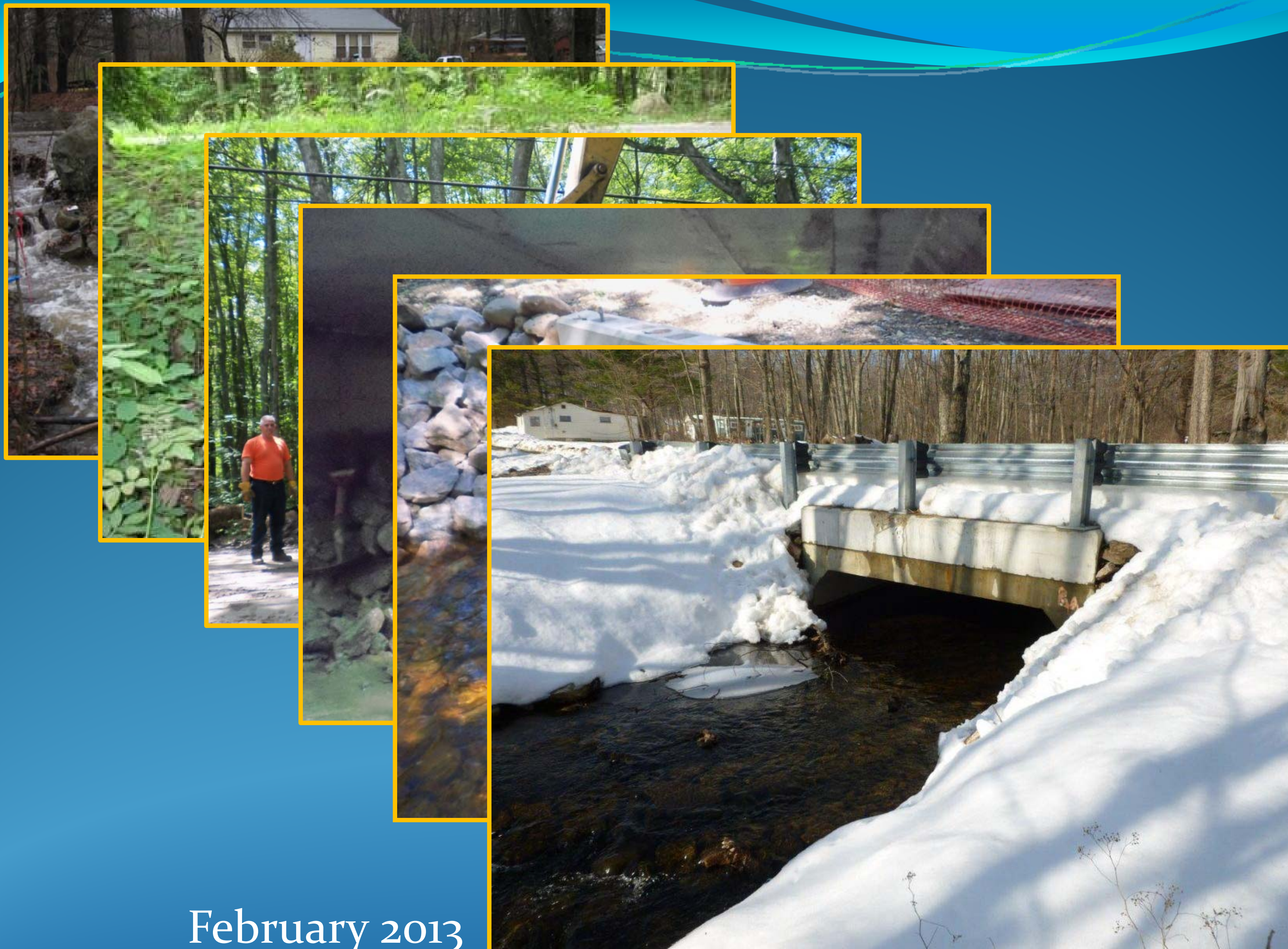
Before replacement

Before replacement


08/17/2011

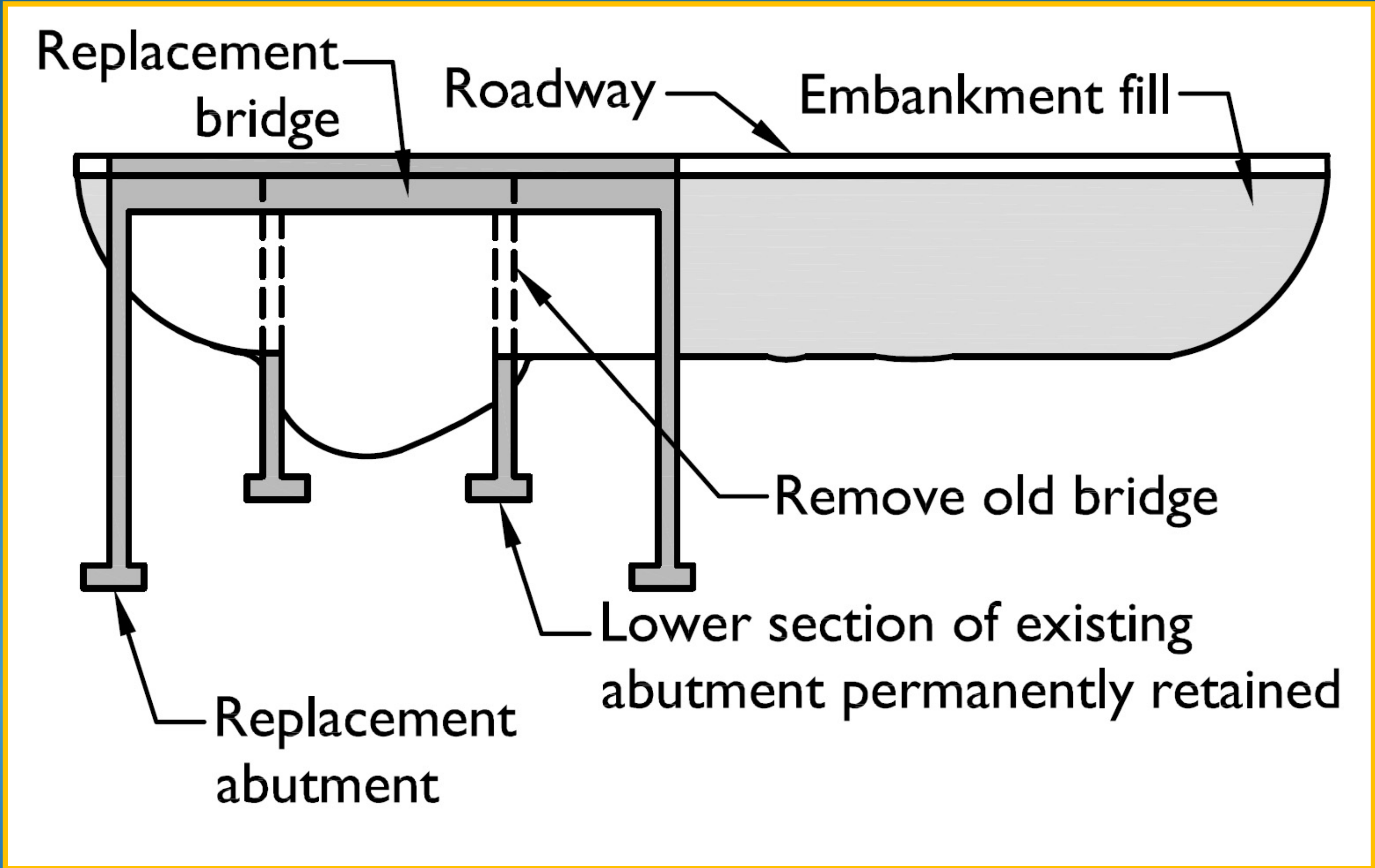

08/16/2011


08/28/2011



February 2013

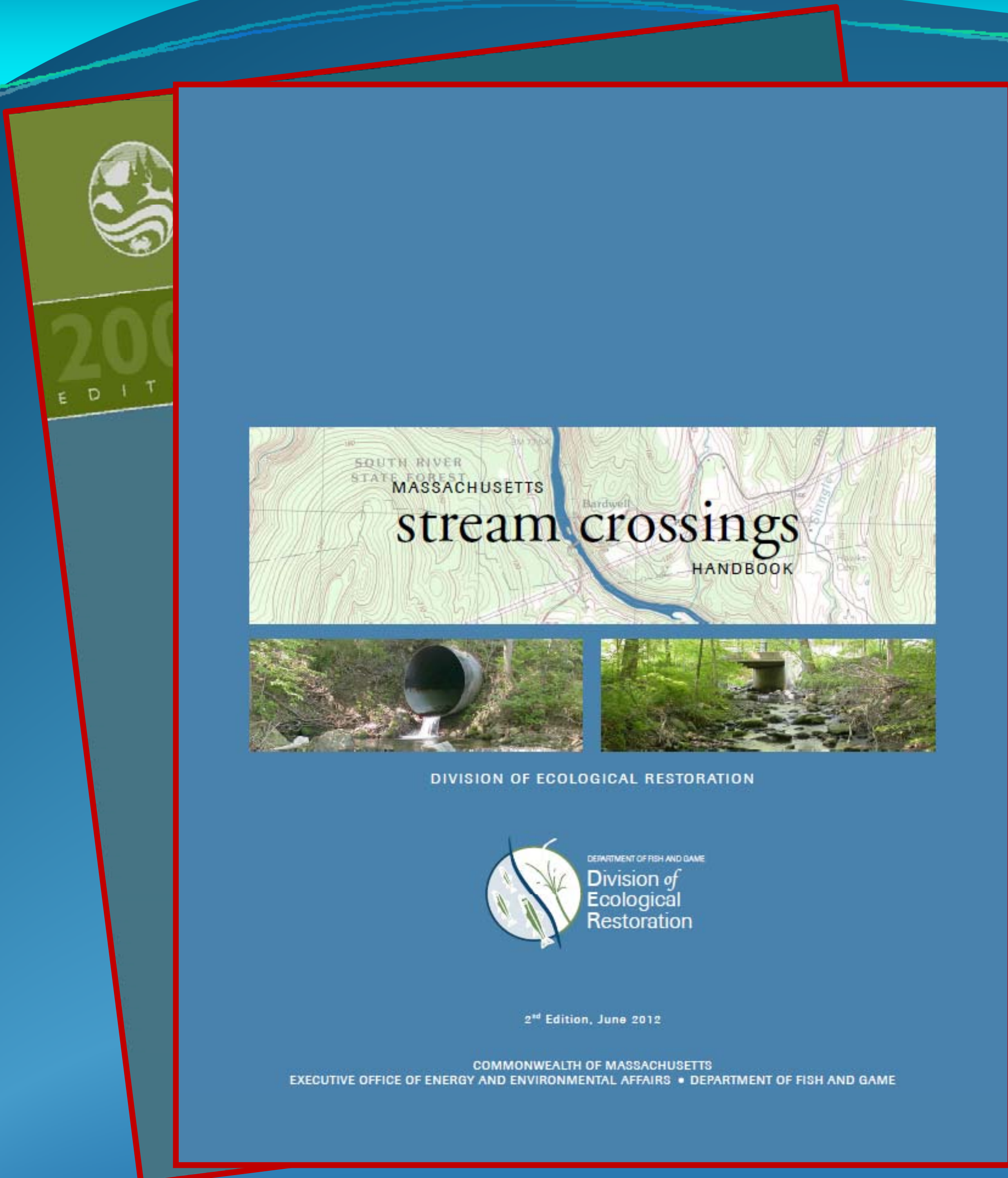
Bridge Replacement with Retained Abutments



Design References and Guidance

Note:
Document of is now of historical interest: updated information now provided in later guidance documents.

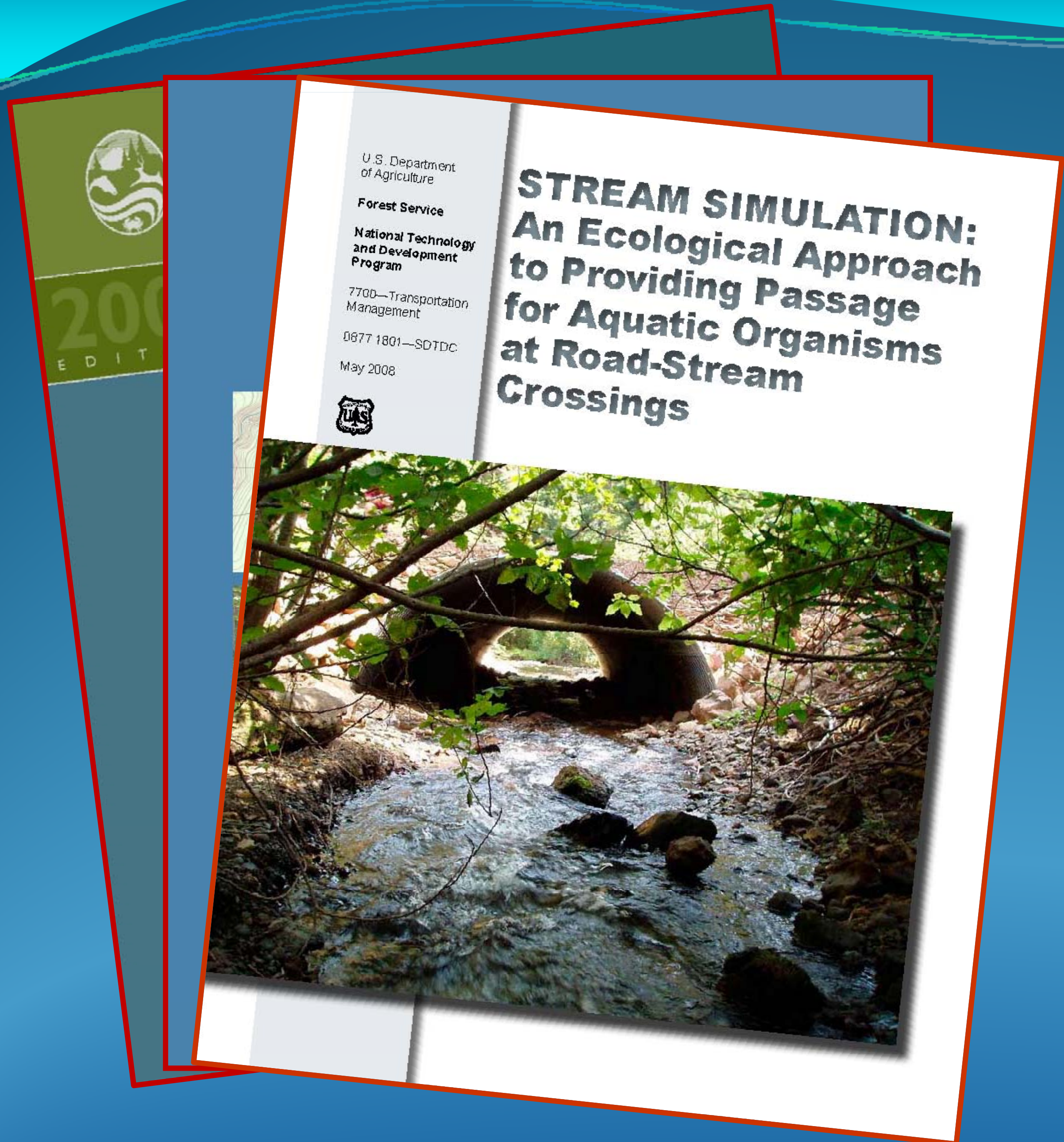
http://wdfw.wa.gov/publications/00049/



Note:
Document updated in 2012.

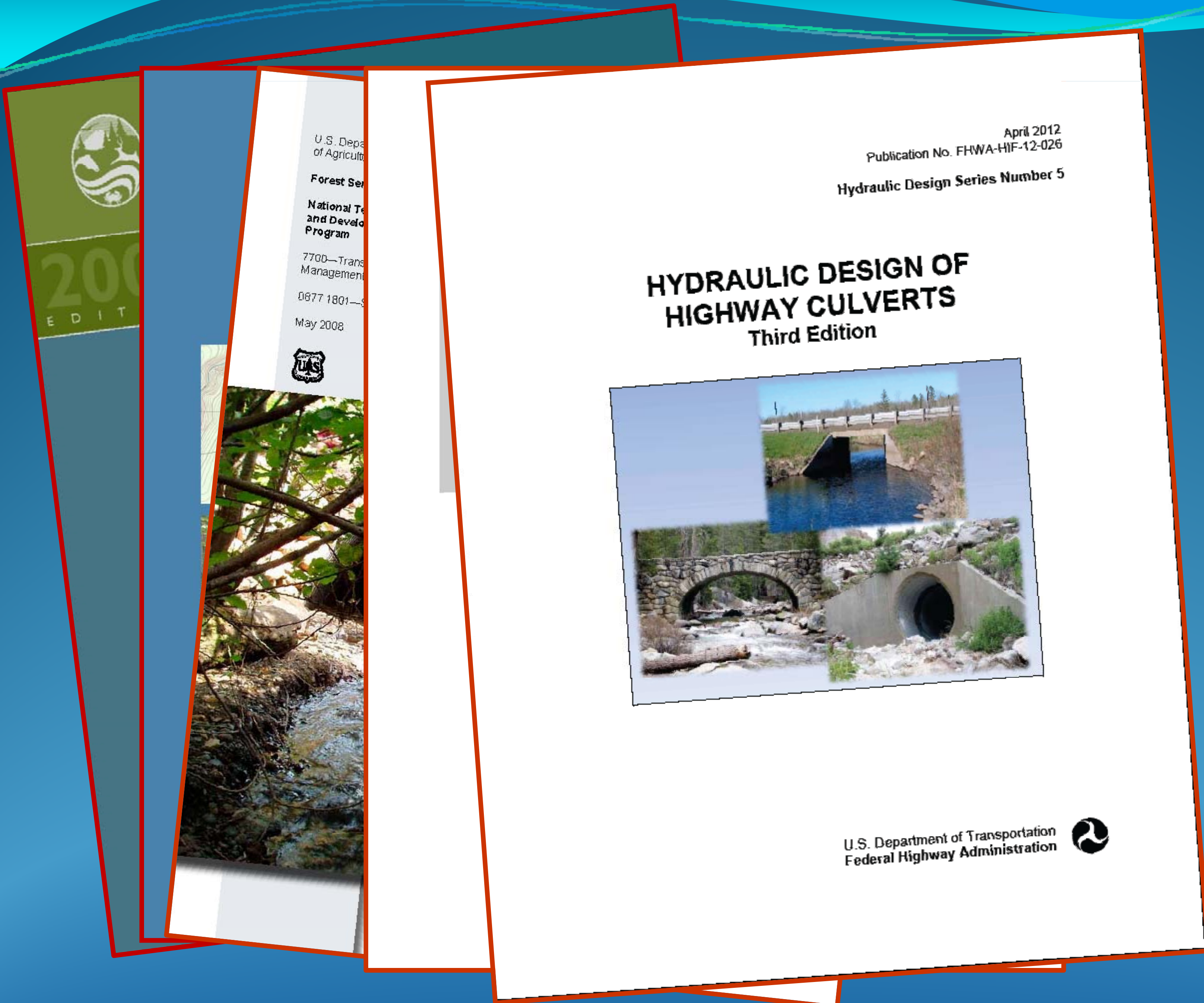
http://www.mass.gov/eea/docs/dfg/der/pdf/stream-crossings-handbook.pdf

http://www.fs.fed.us/eng/pubs/pdf/StreamSimulation/index.shtml



http://www.massdot.state.ma.us/Portals/8/docs/environmental/wetlands/WildlifePassagesBridgeDesign122710.pdf

http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=7&id=13



http://www.fhwa.dot.gov/engineering/hydraulics/pubs/11008/index.cfm

Publication No. FHWA-HIF-11-008
October 2010

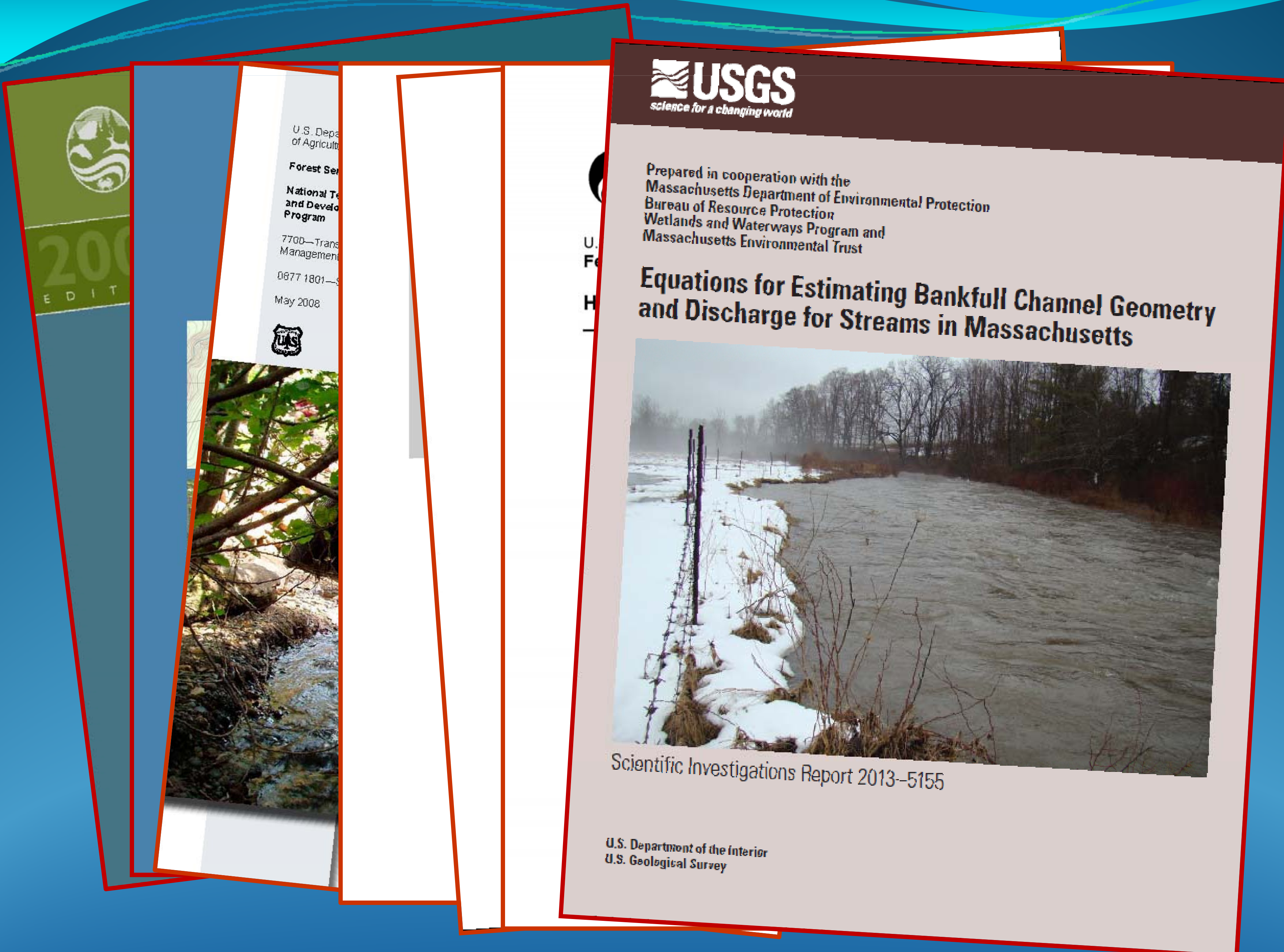
U.S. Department of Transportation
Federal Highway Administration

Hydraulic Engineering Circular No. 26, First Edition

CULVERT DESIGN FOR AQUATIC ORGANISM PASSAGE

Federal Lands Highways

http://dx.doi.org/10.3133/sir20135155



Questions?

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