Designing Stream Crossings for Wildlife Passage

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Comprehensive Environmental Inc.

Annual Environmental Conference

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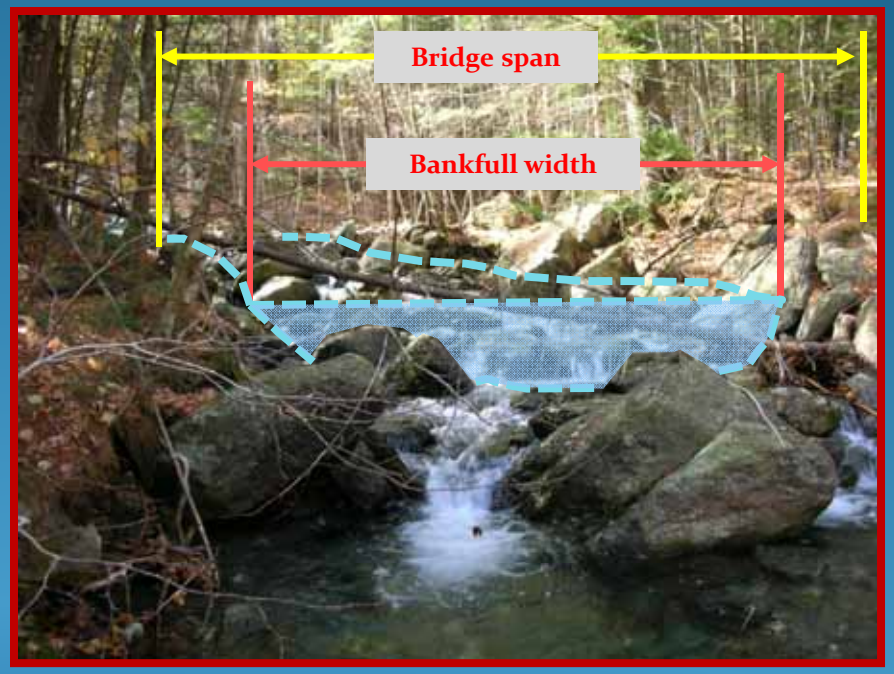
Designing Stream Crossings for Wildlife Passage Overview of this Presentation:

- Design Standards (New and Replacement Crossings)
  - River and Stream Crossing Standards
  - Civil Engineering Practices
  - Stream Crossing Stability in a Dynamic Environment
- Culvert Replacements
  - Constraints at Existing Structures
  - Range of Alternatives
- Recommended Design Resources

Design for the Stream Crossing Standards
New or Replacement Structures

- Cross Section Geometry
- Streambed Material
- Vertical Alignment
- Stability Considerations



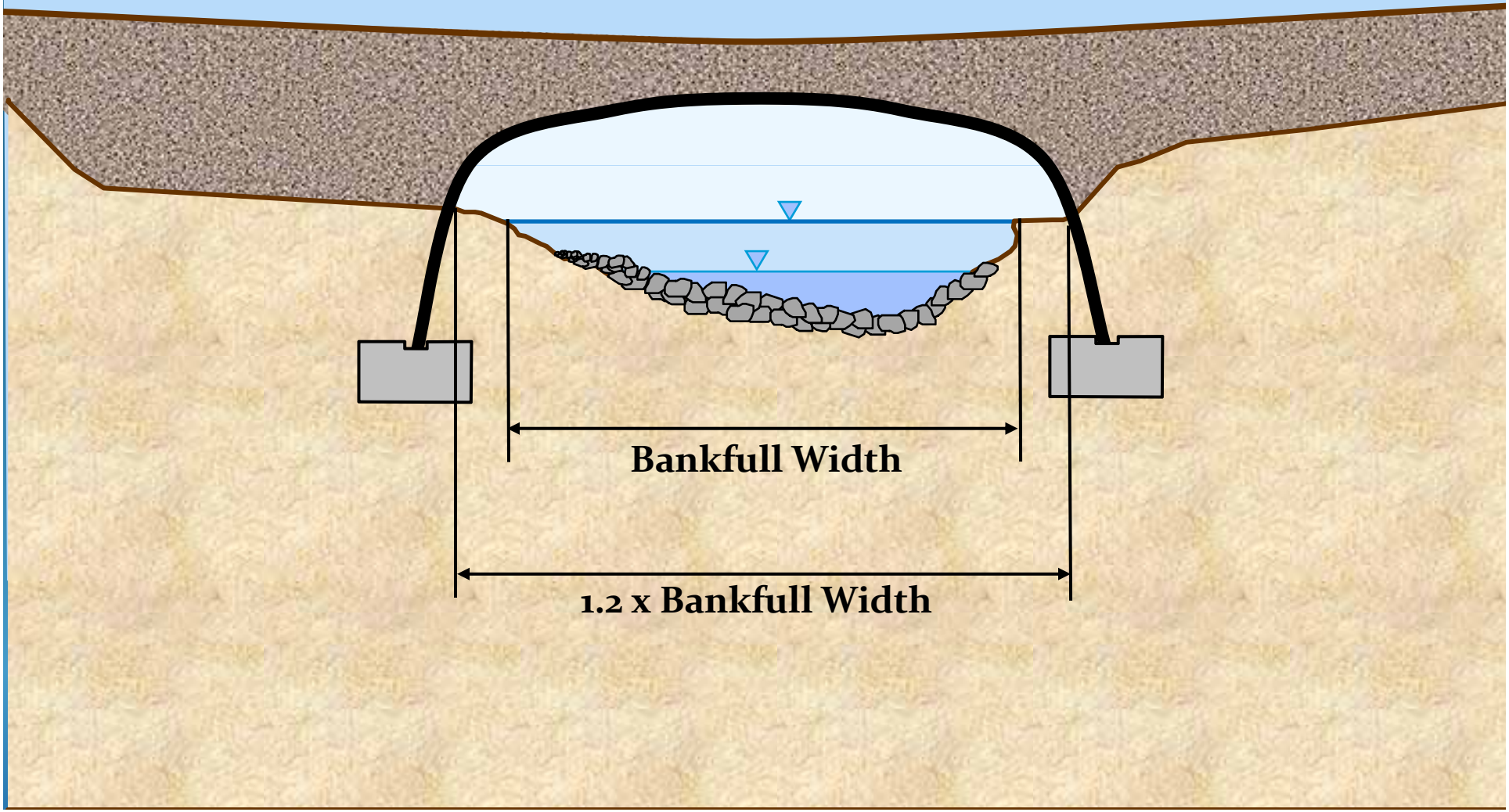
In addition to applicable “conventional” engineering design standards…

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**

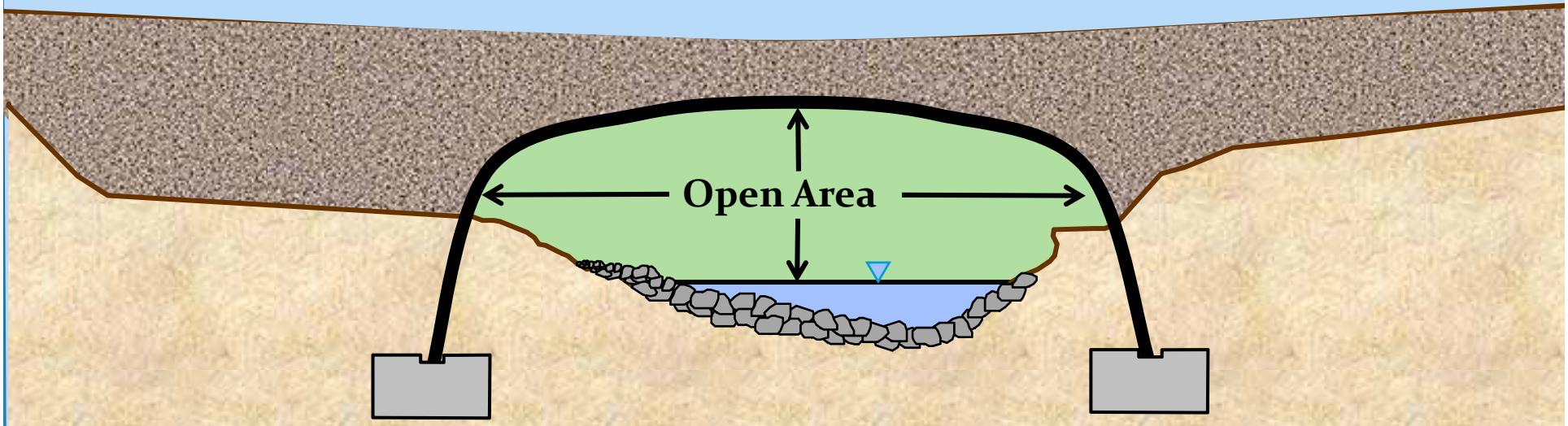
Geometry (size)

Span: bridge or open bottom culvert



Geometry (size)

Span: bridge or open bottom culvert



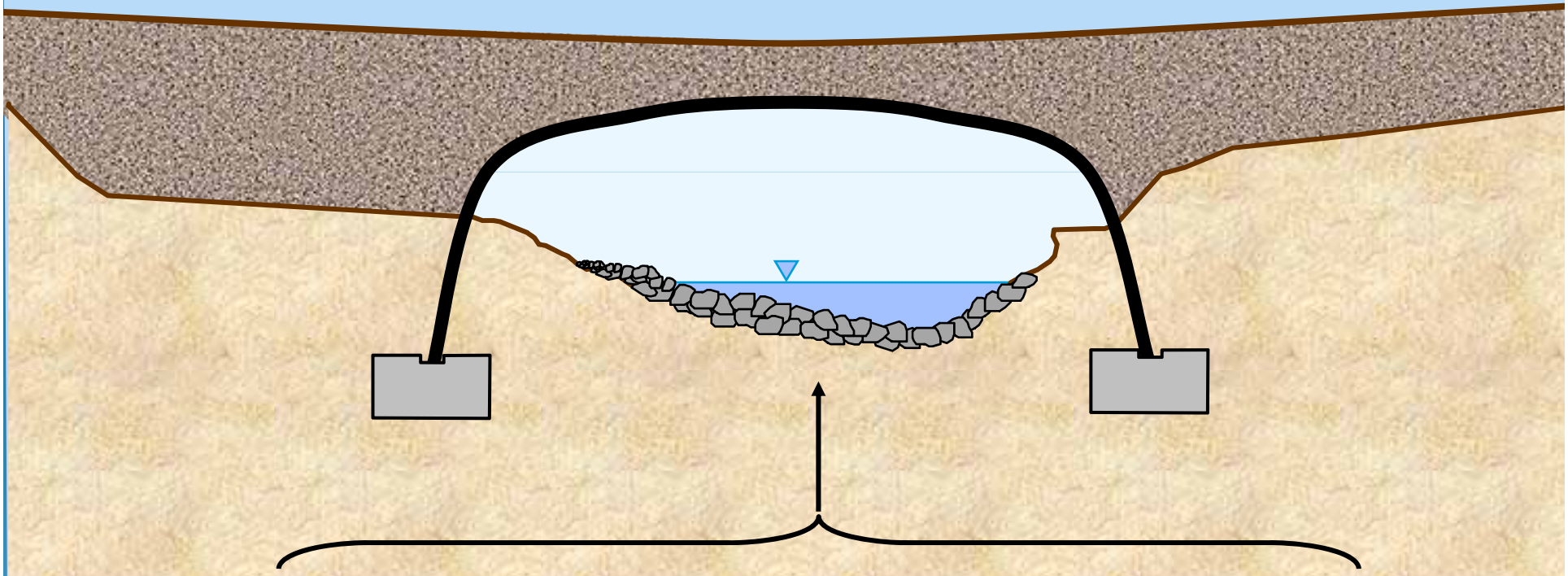
$$\frac{\text{Open Area (m}^2\text{)}}{\text{Structure Length (m)}} = \text{Openness Ratio (m)}$$

Openness Ratio (m) ≥ 0.25m for General Standards

≥ 0.50m to 0.75m for Optimum Standards

Streambed

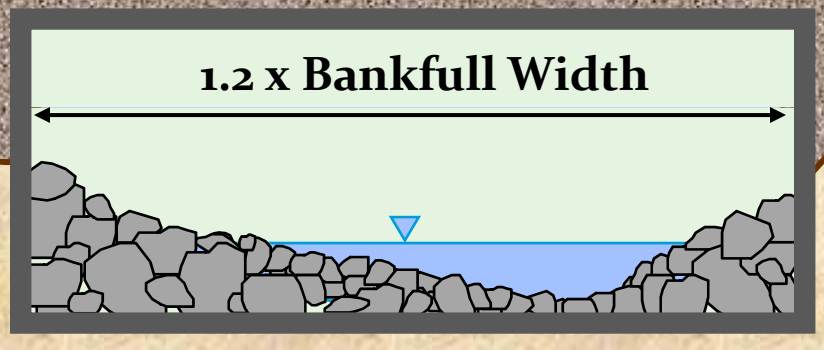
Span: bridge or open bottom culvert



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

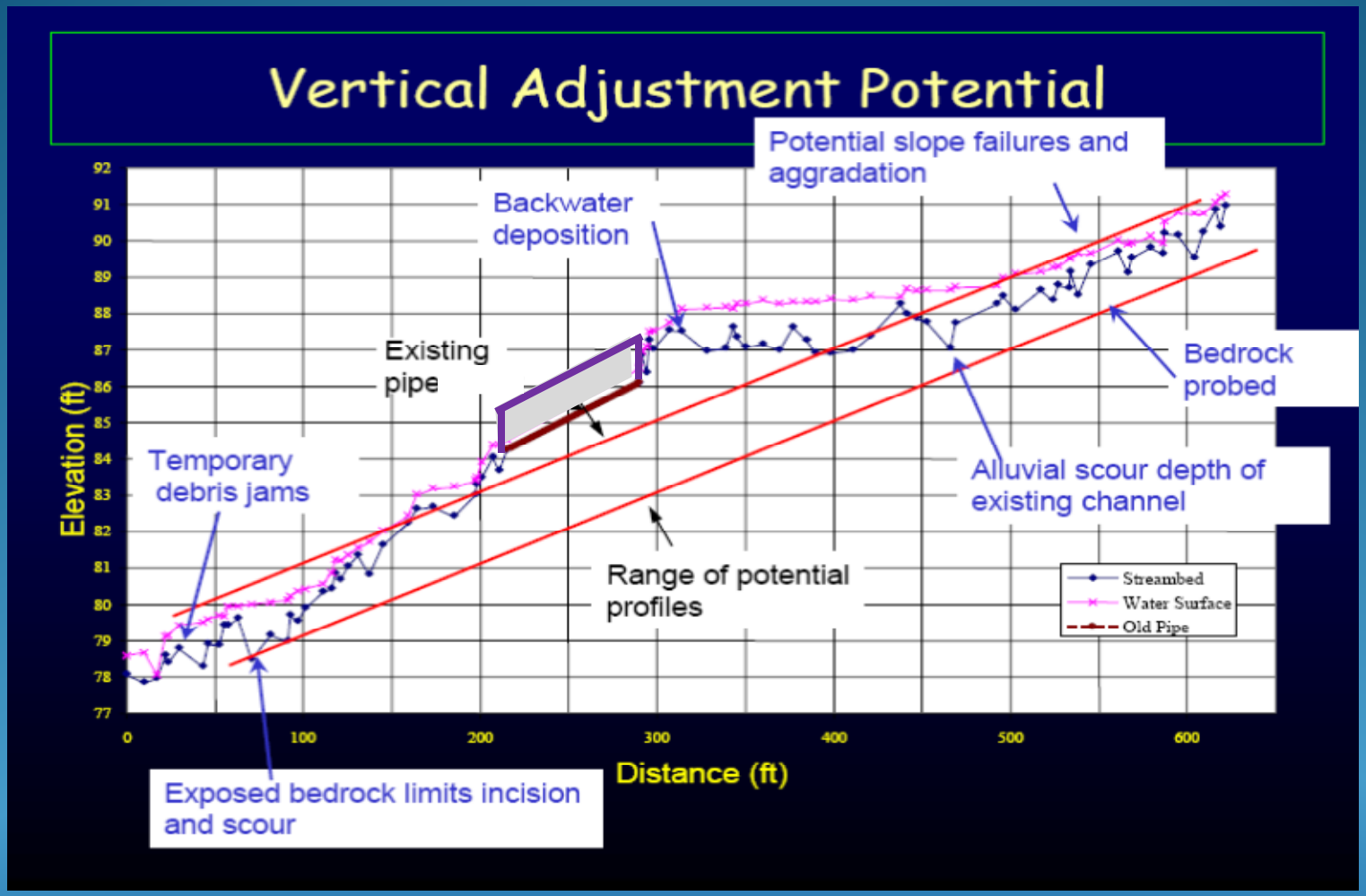
Culvert with Stream Simulation



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

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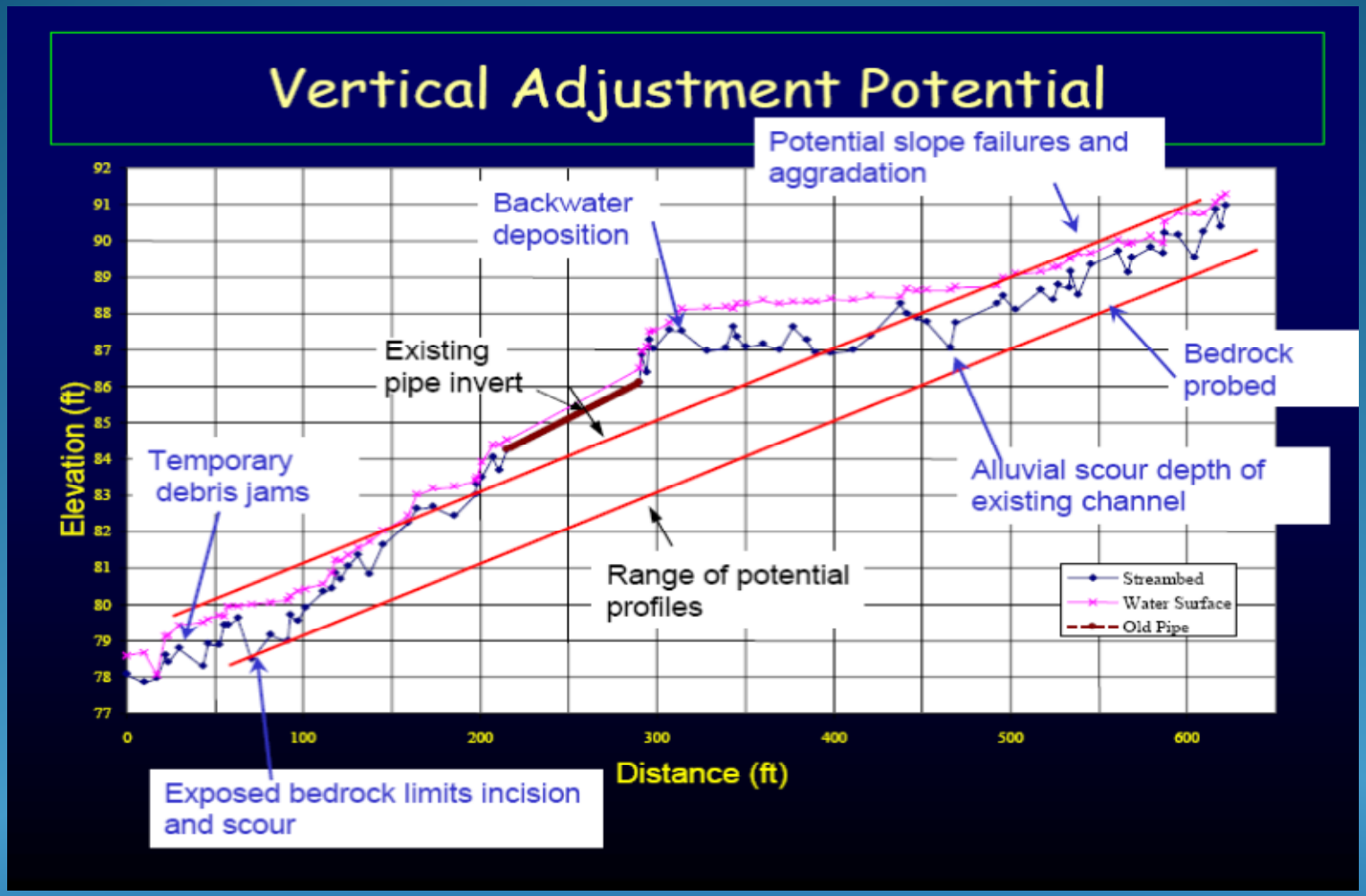

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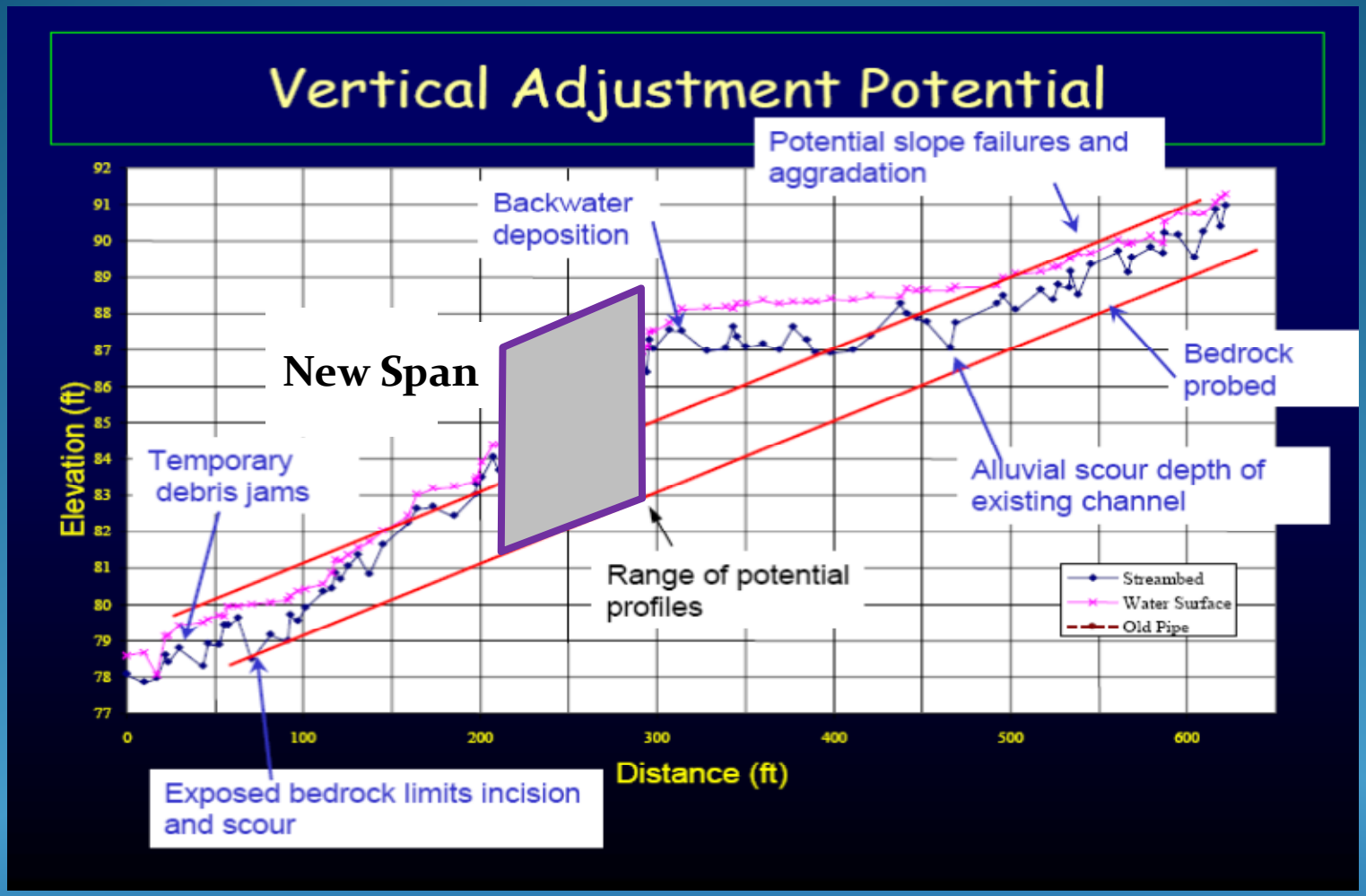

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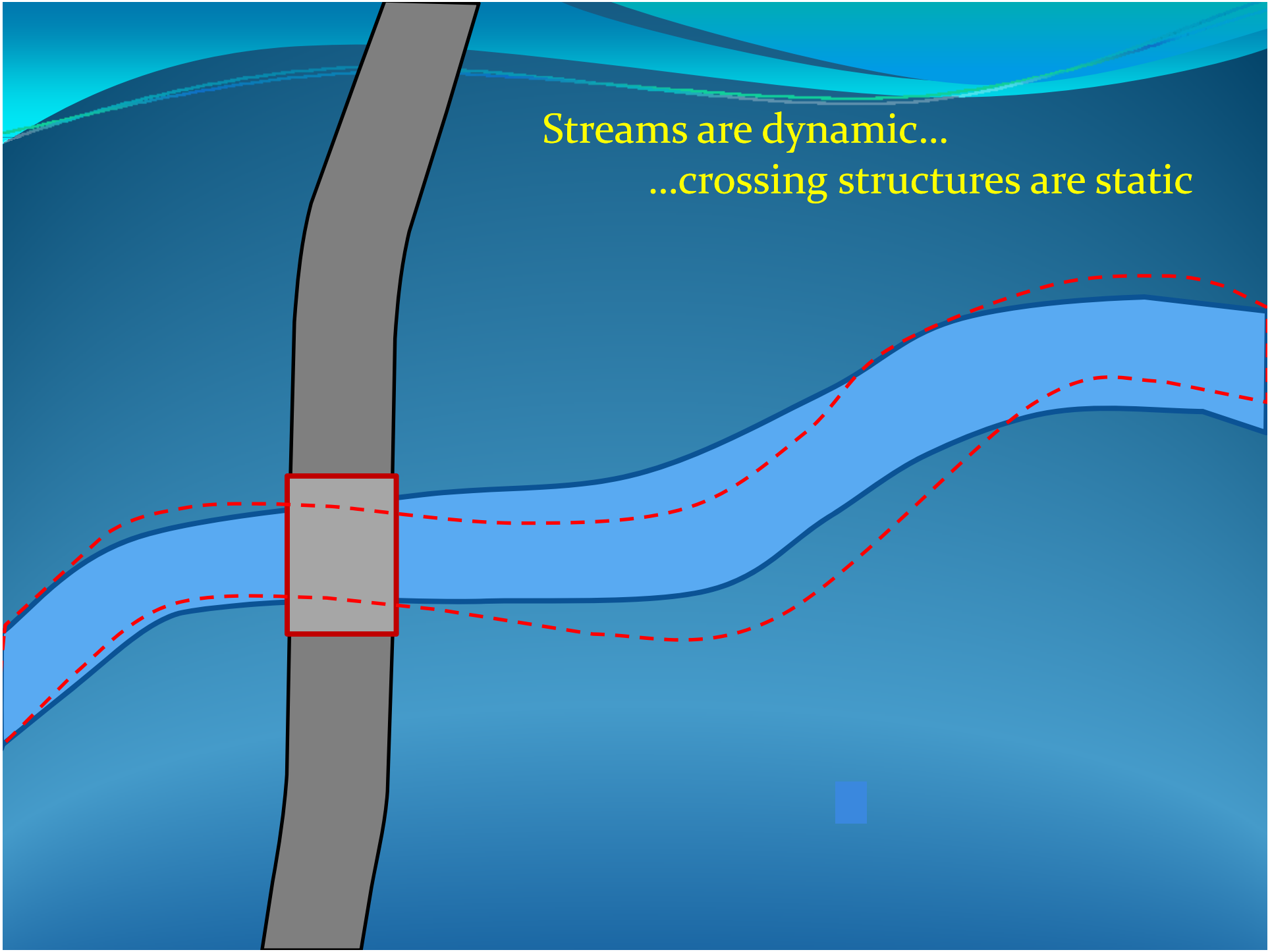
Stability Considerations

Streams are dynamic!

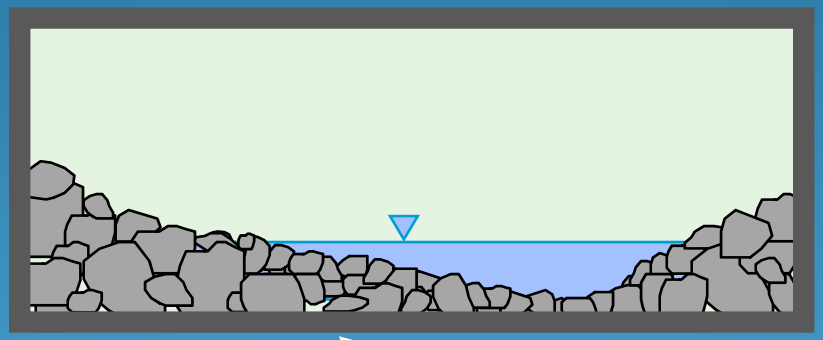
Bridges and culverts are static (or intended to be)!


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…

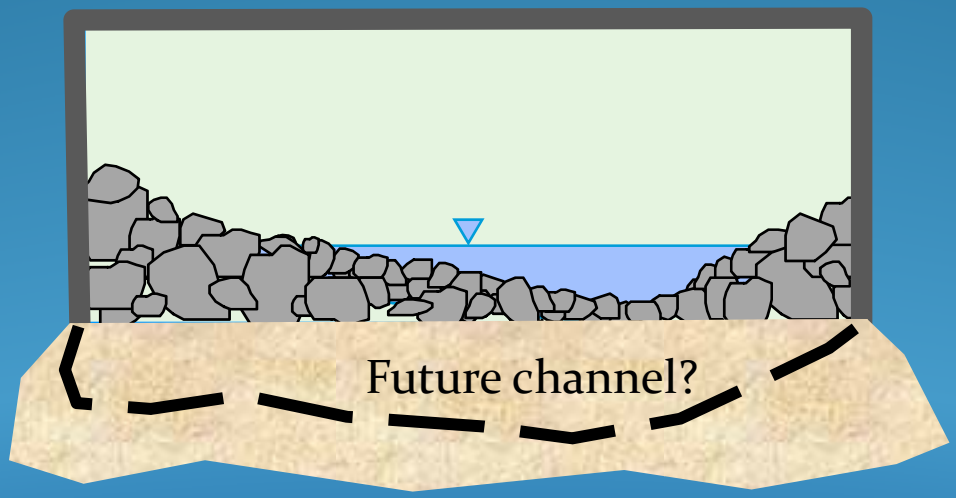
….culverts are rigid

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

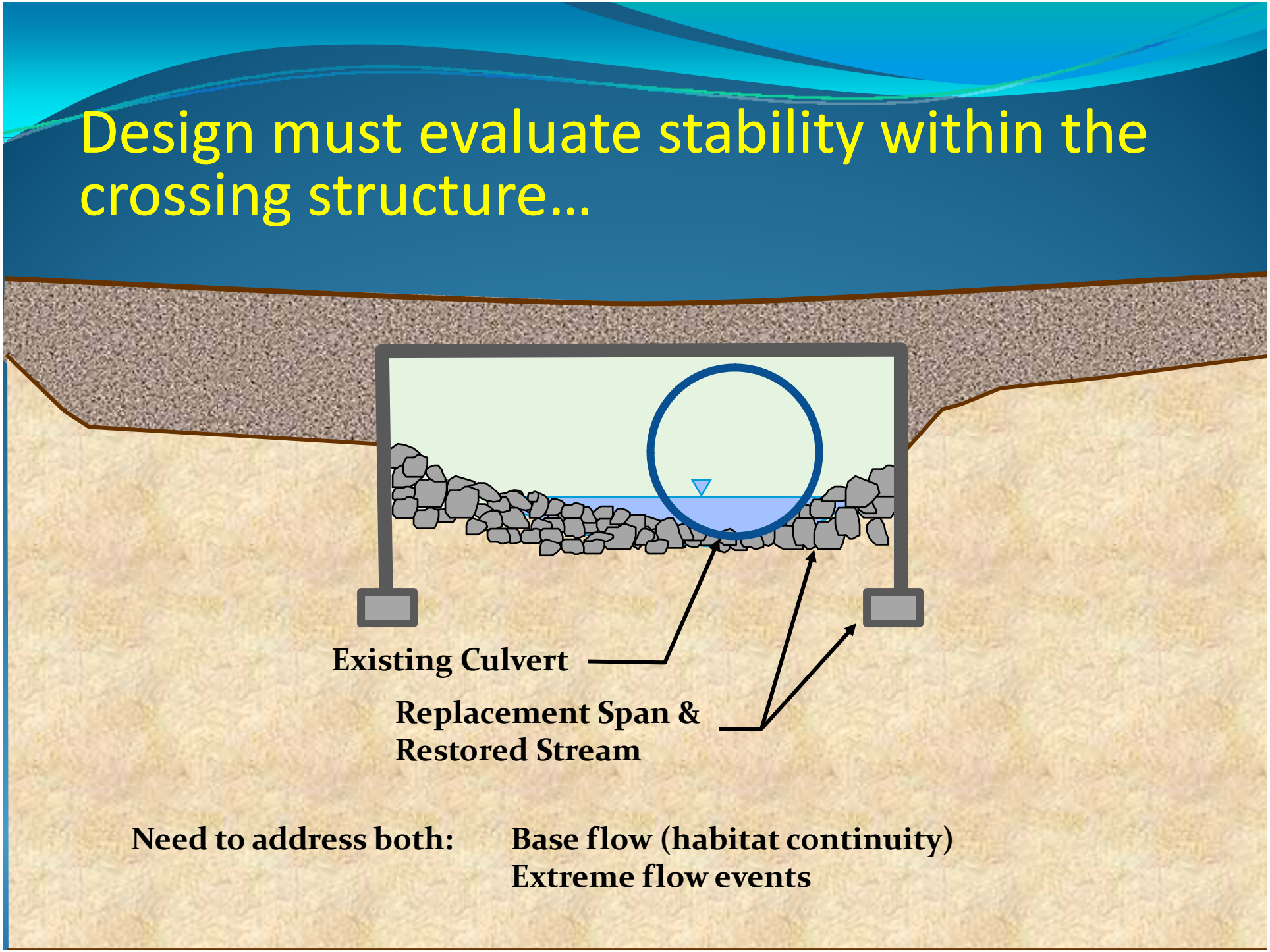
…however, this can (and must be addressed by design.

Design for stability

Requires analysis of

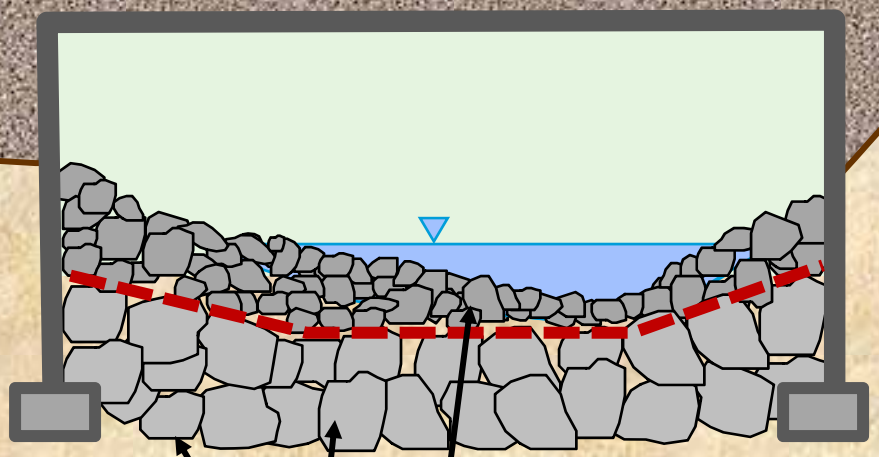
- Stability of the crossing structure: **protect (sustain) the bridge!**
- Dynamic stability of the streambed material: **sustain the streambed!**

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…

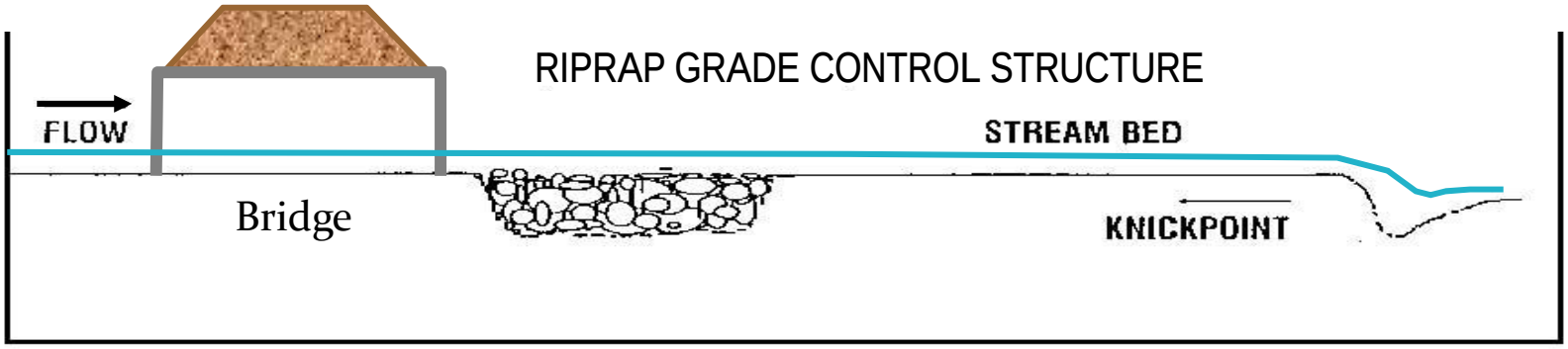


Design to simulate streambed material and bedform

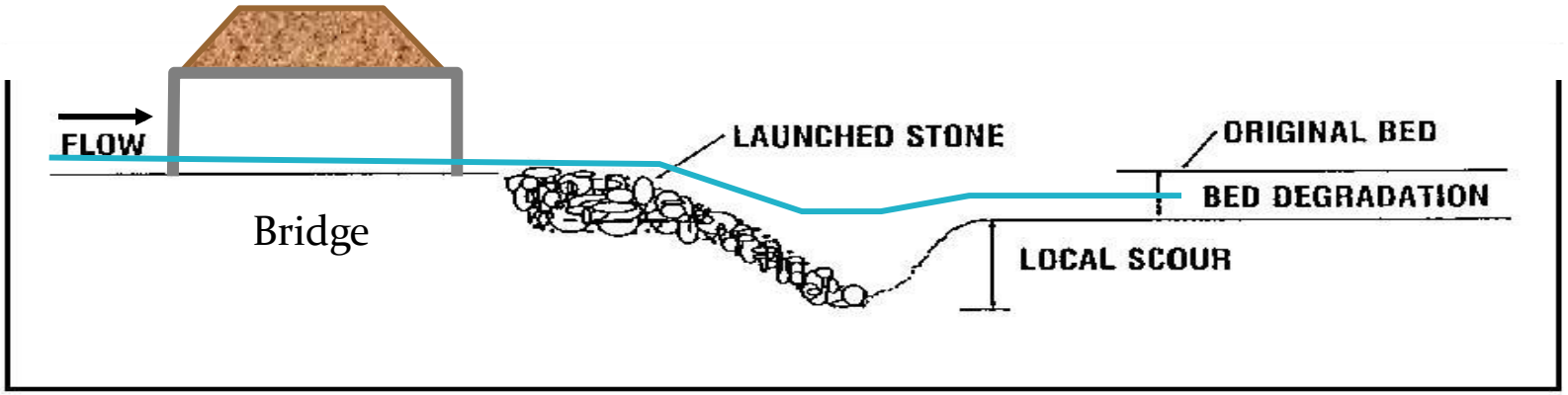
Design to address foundation scour and streambed stability

Stream Simulation with Stable Sub-bed

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



Figures 6.2a As Built Riprap Grade Control Structure with Sufficient Launch Stone to Handle Anticipated Scour



Figures 6.2b Launching of Riprap at Grade Control Structure in Response to Bed Degradation and Local Scour

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:

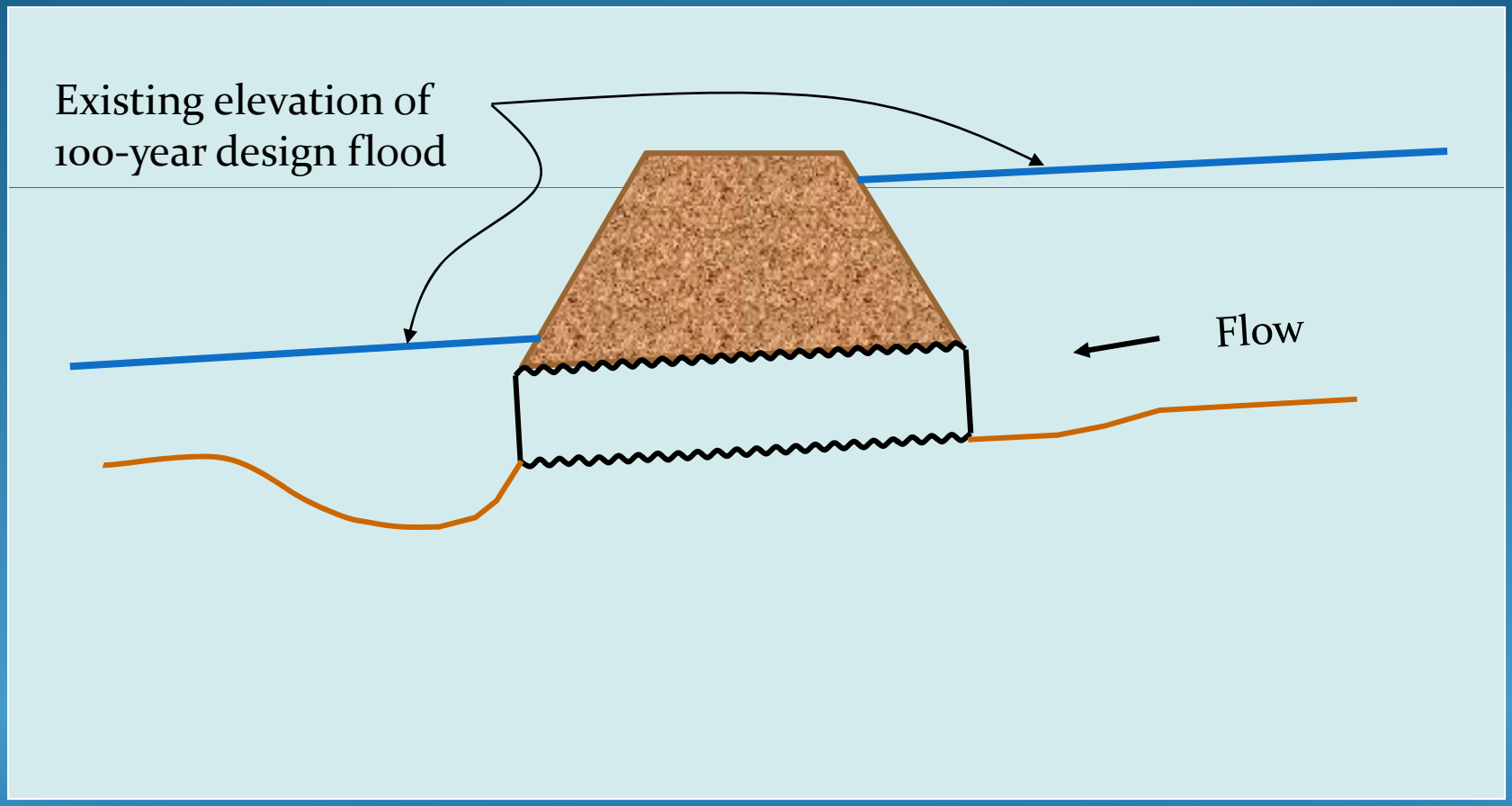
- Vertical alignment limitations
- Existing utilities
- Historic structures

Constraints affecting replacement to provide wildlife passage:

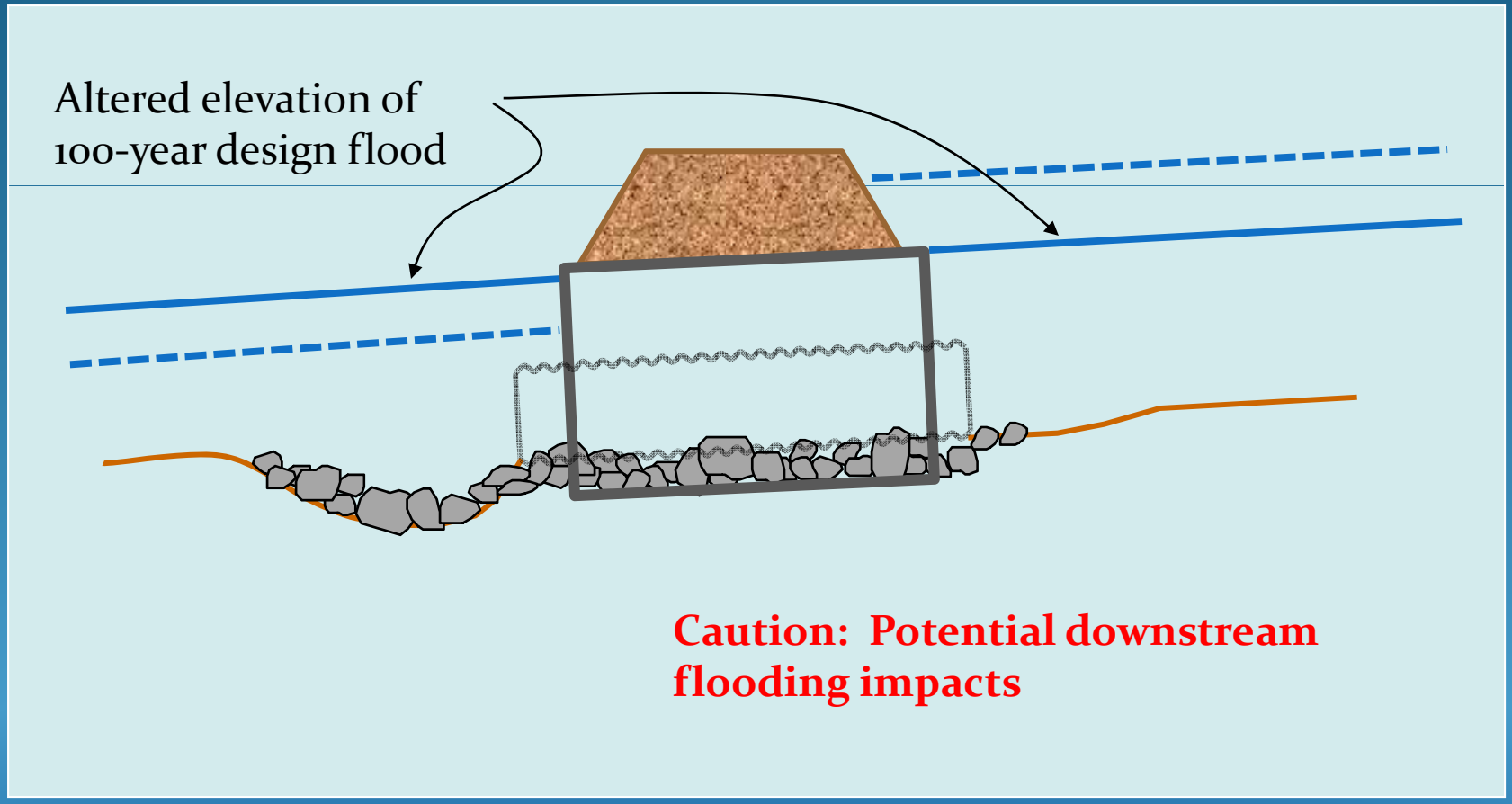
- Construction-phase logistics
  - Maintaining road traffic
  - Maintaining stream flow (water handling)
- Costs and funding priorities

Mitchell Brook – before and during construction

Flood Profile Impacts



Flood Profile Impacts

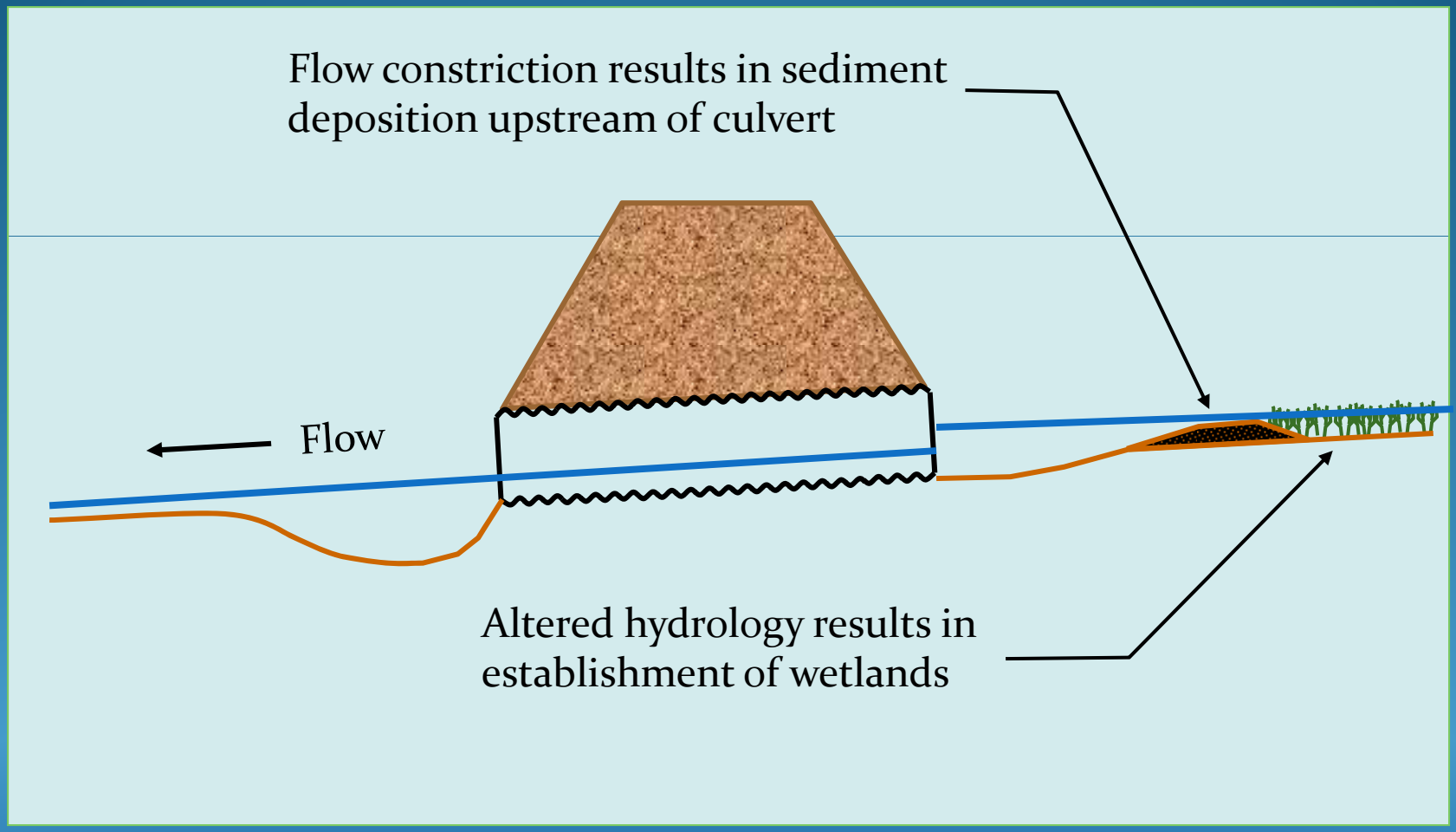


Addressing Flood Profile Impacts:

- 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



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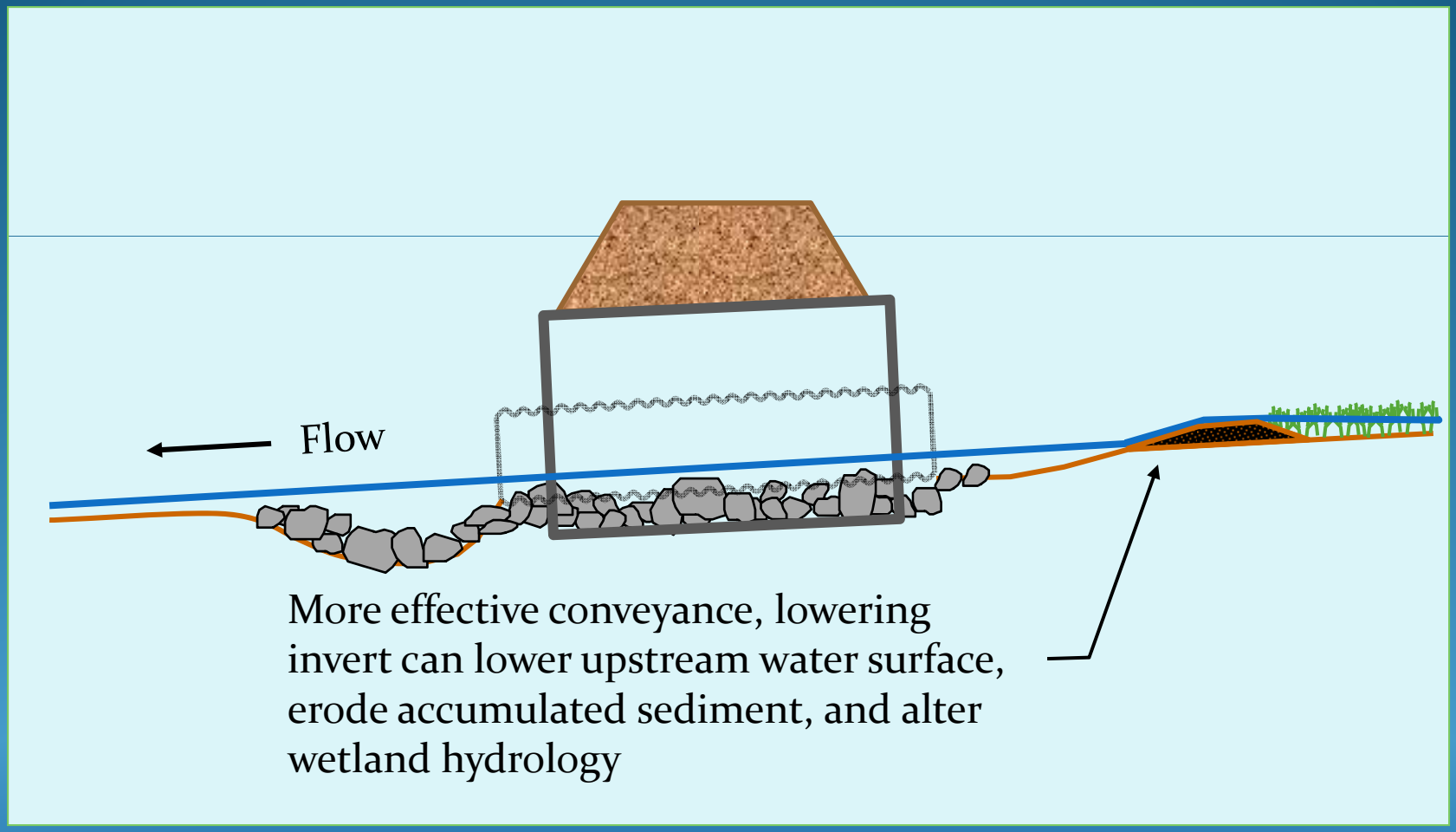
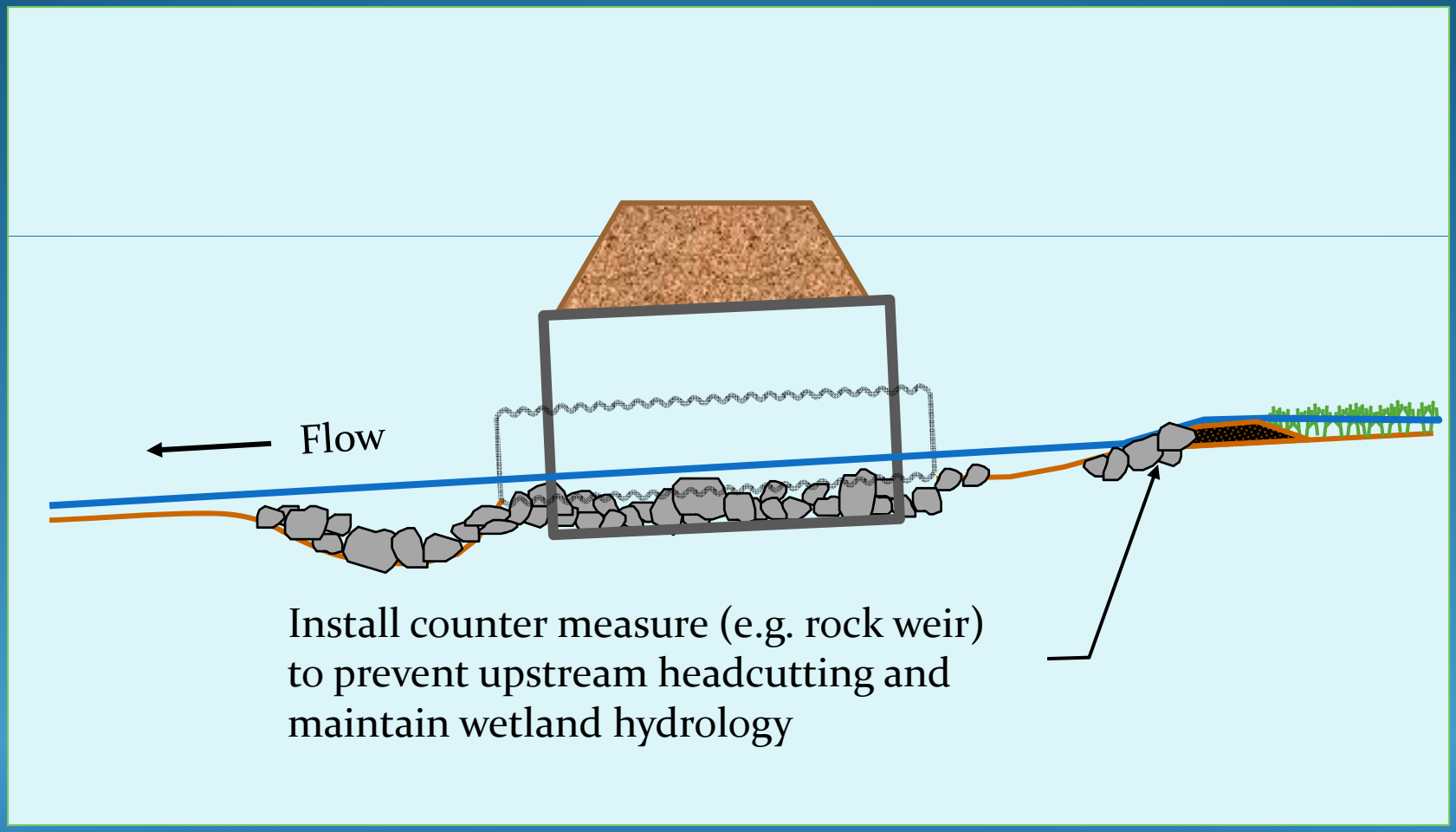


Addressing Road-Impounded Wetlands:

- 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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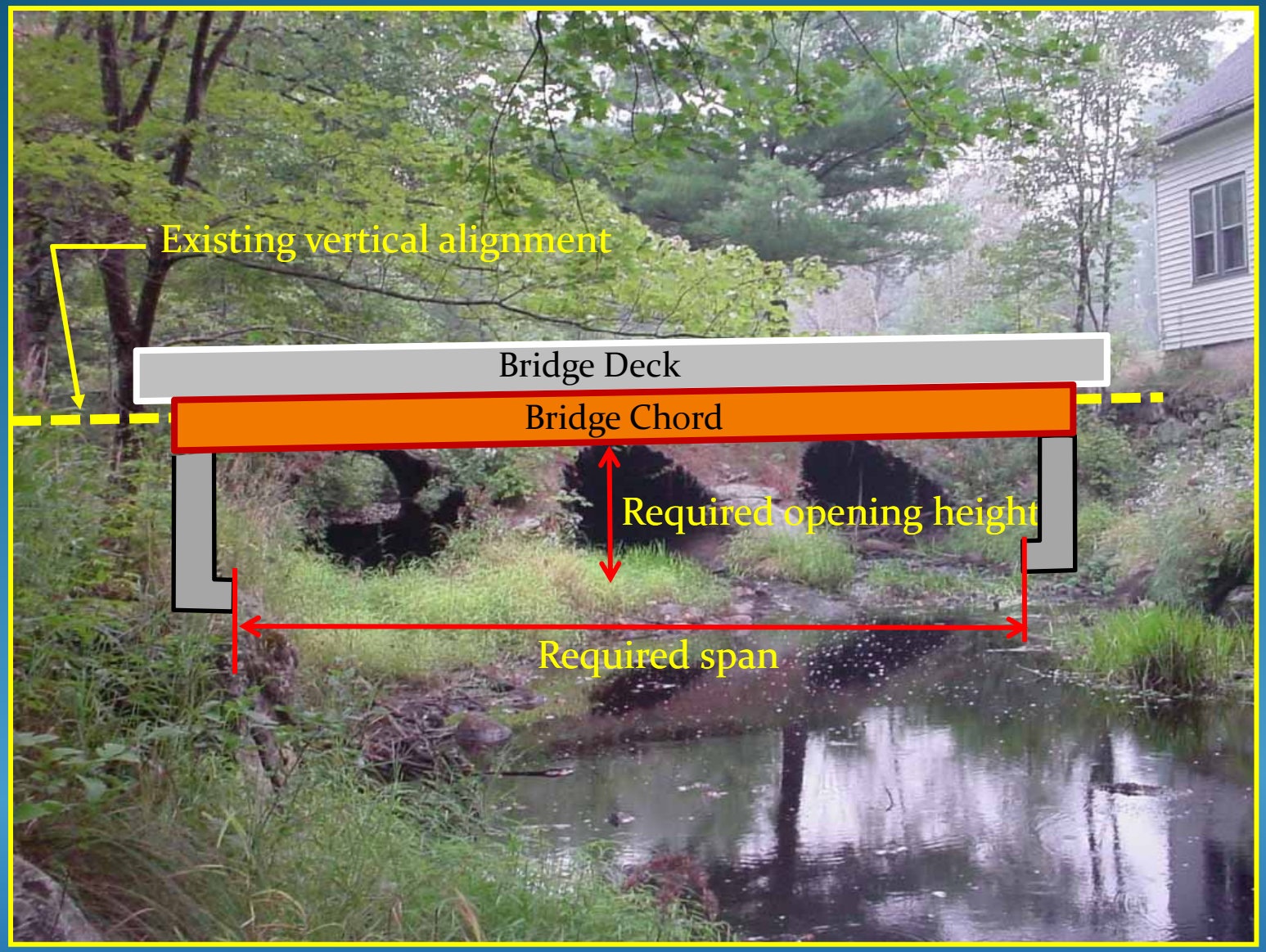

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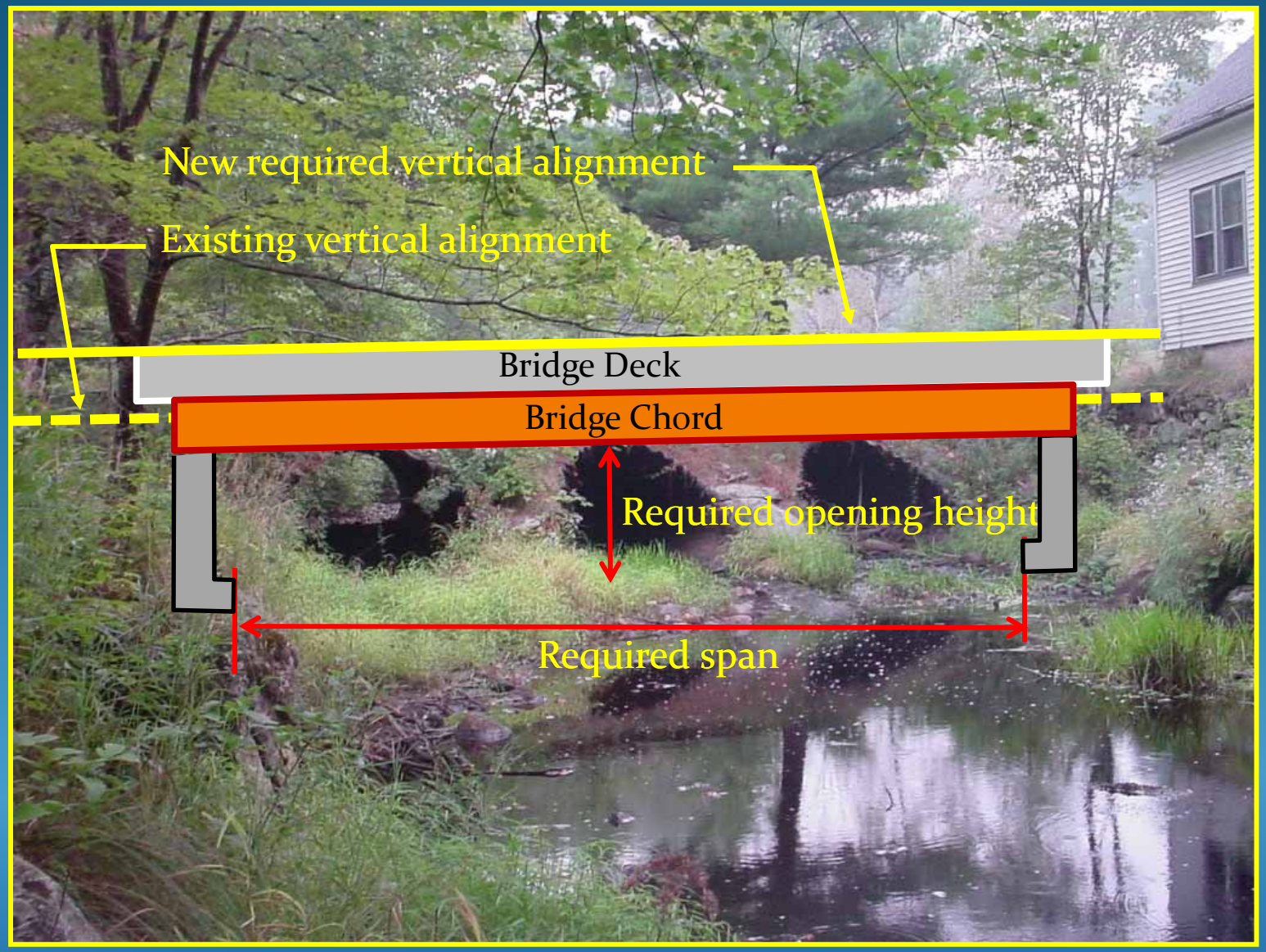

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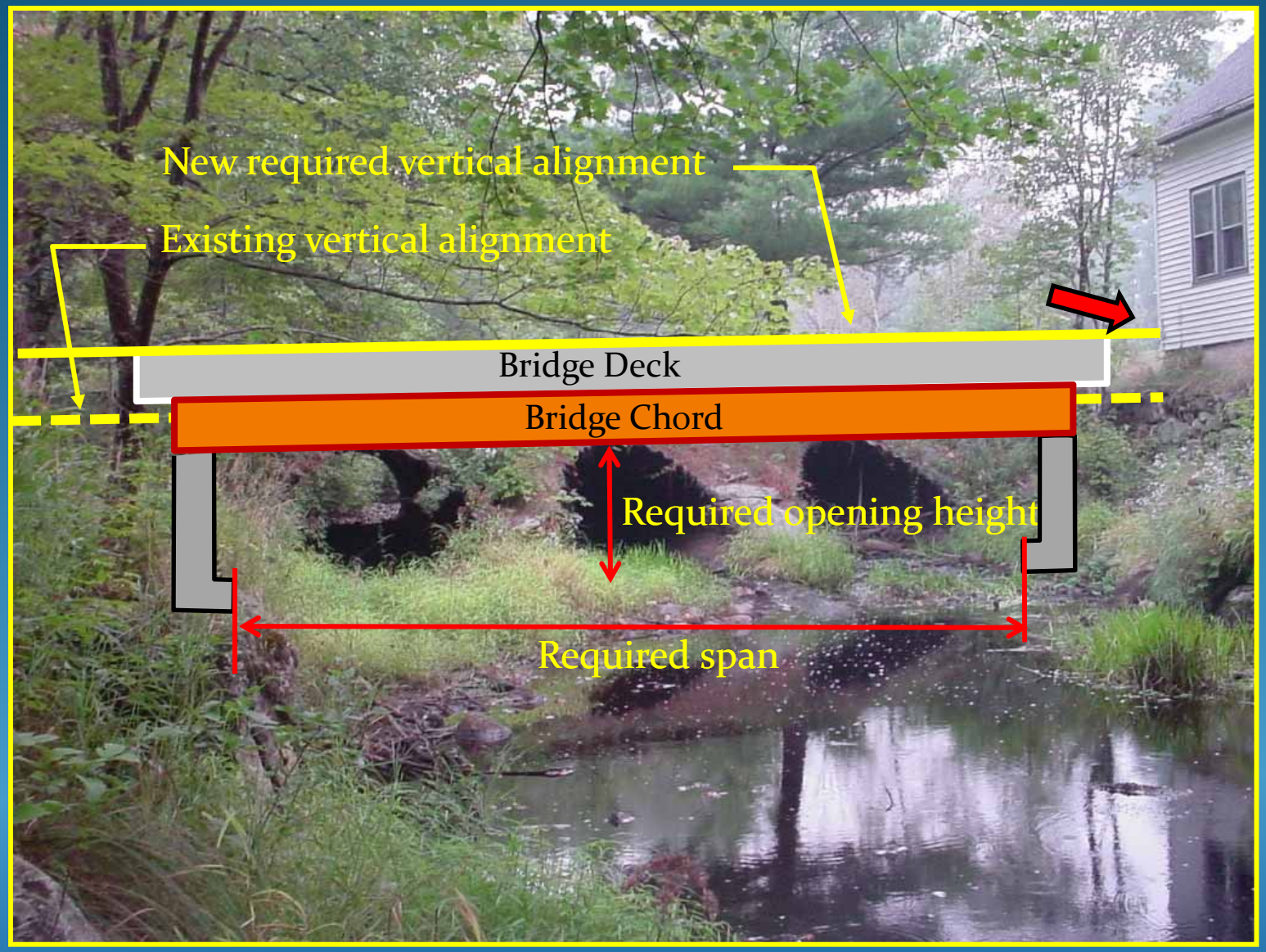


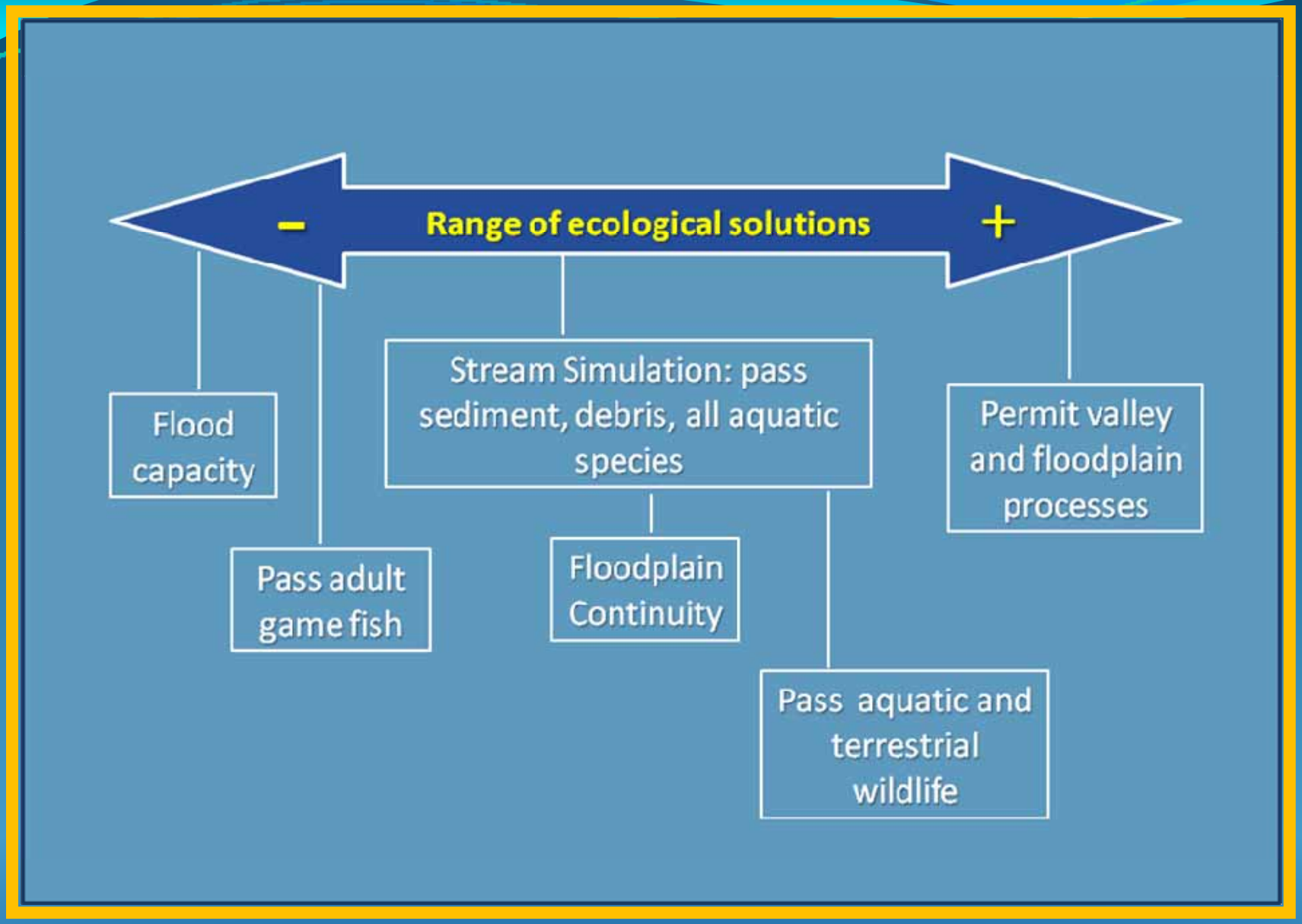
Existing Utilities

Urban channel alteration & degradation

Urban channel alteration & degradation

Urban channel alteration & degradation

Constraints, constraints…
…Some crossings need to be fixed!



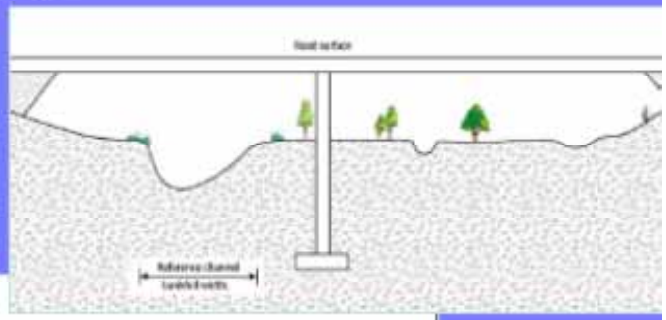
Adapted from Gubernick, Culvert Summit 2006

Design Approaches Continuum

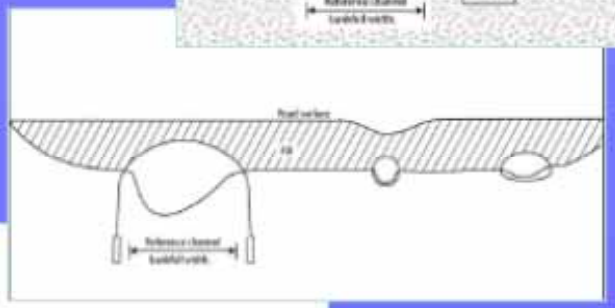
Determined by project objectives, stream and design realities

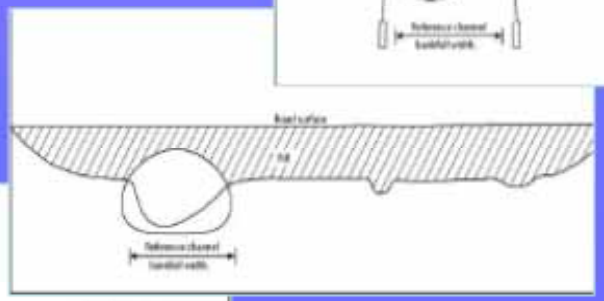
Not all streams can be or require stream sim.!

Valley and floodplain processes

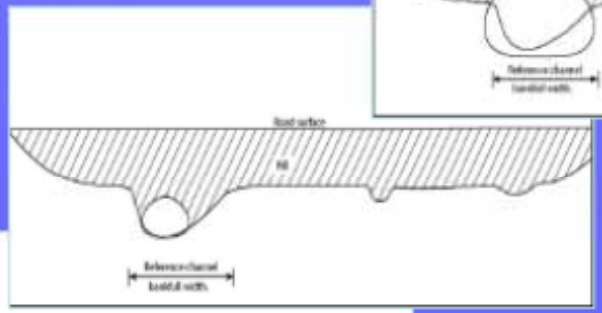


SS with floodplain continuity

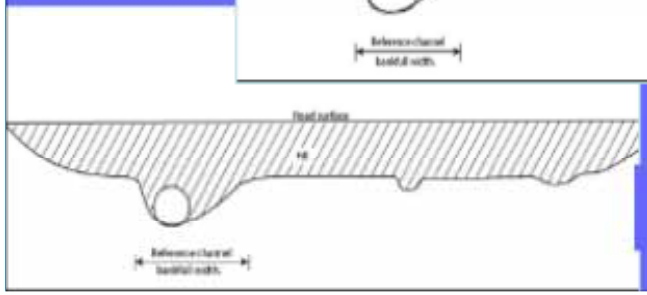




Stream simulation



Hydraulic design

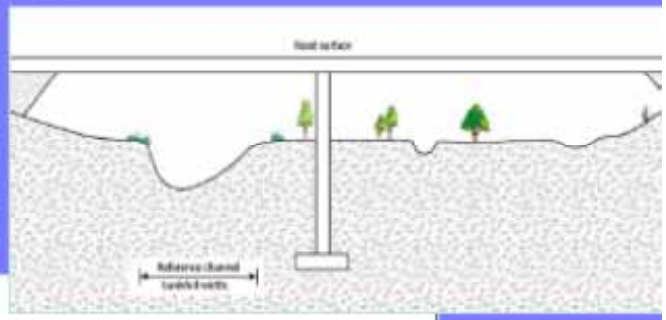


Flood capacity

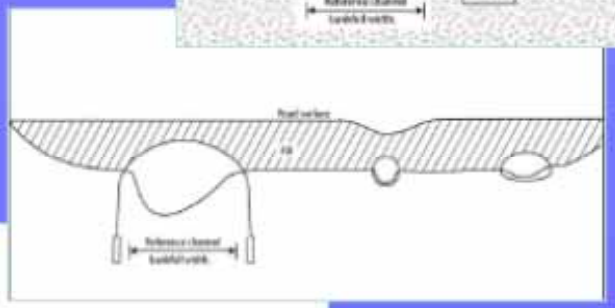
Design Approaches Continuum

Determined by project objectives, stream and design realities

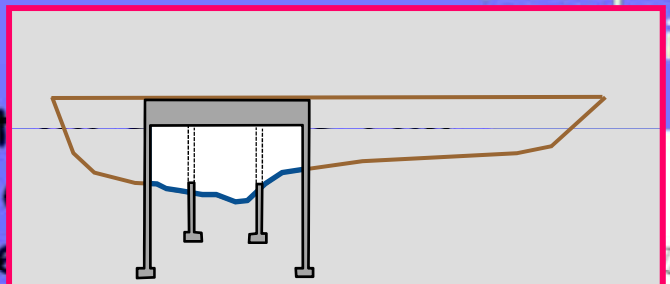
Valley and floodplain processes



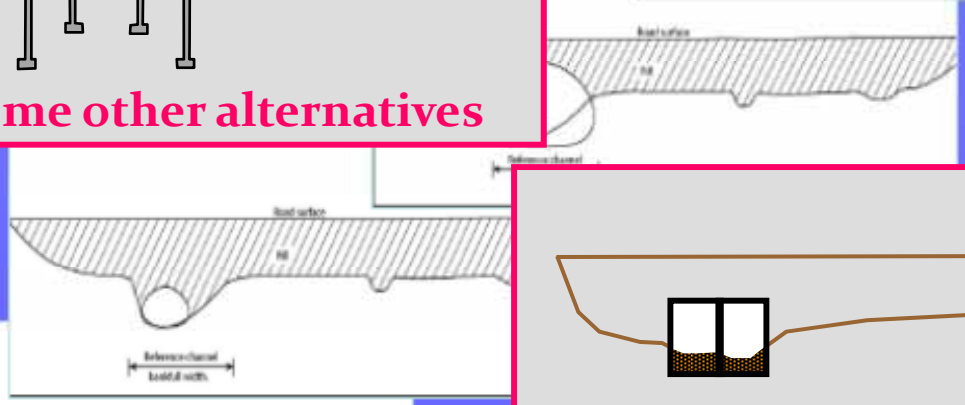
SS with floodplain



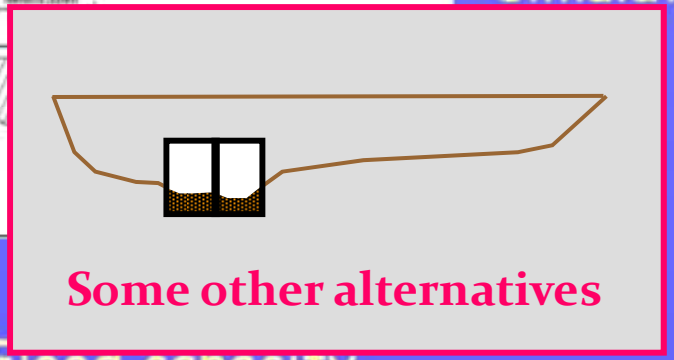
Not be stre



Some other alternatives



Stream simulation



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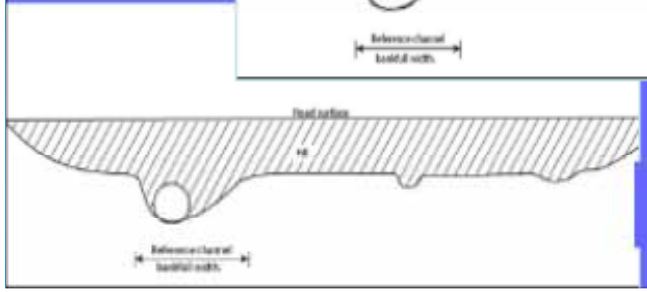


Flood capacity

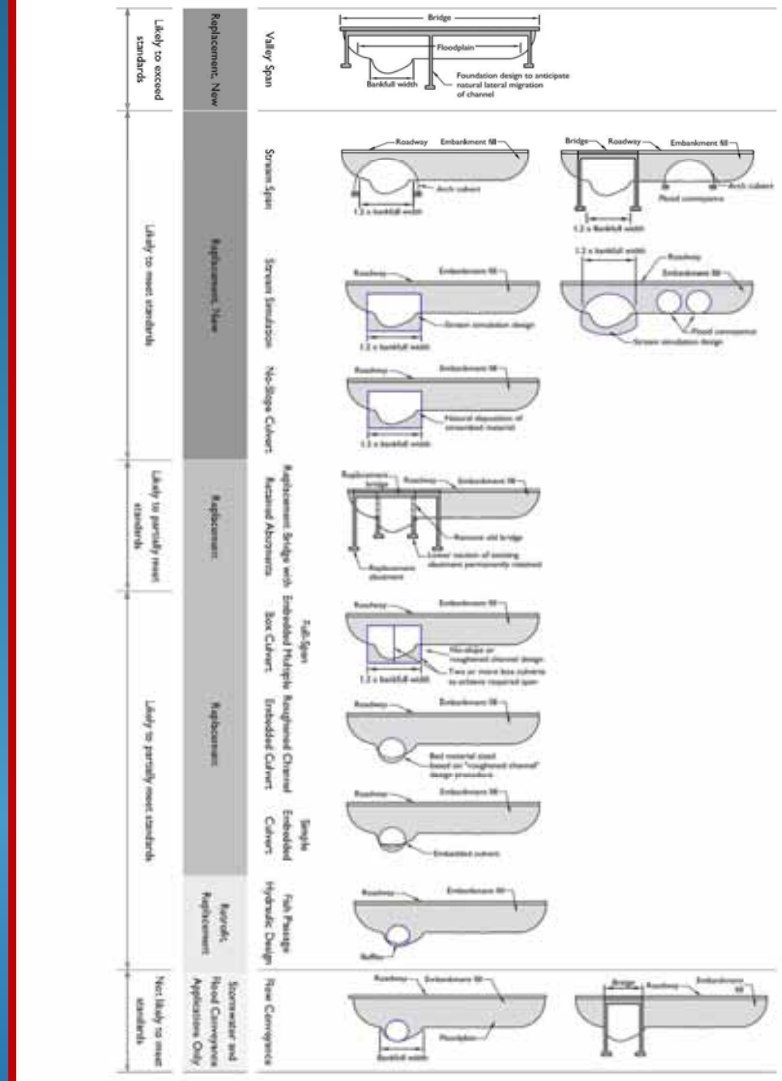
Bob Gubernick, Tongass N.F.

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:

- "No-Slope" design*
- "Stream Simulation" 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

“No Slope” design option

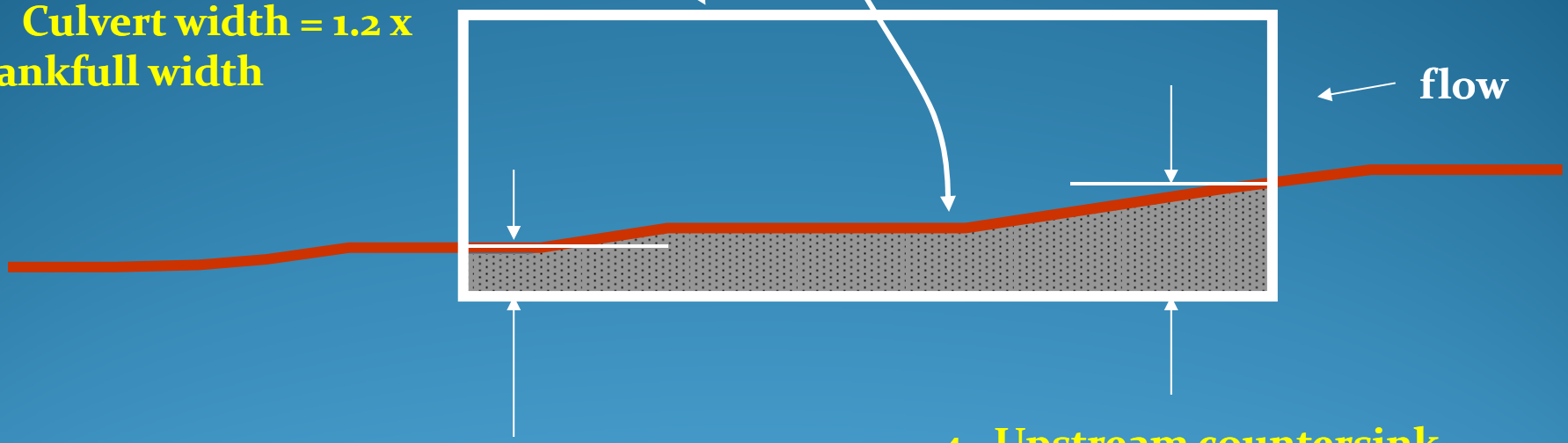
- Applicable only to culverts, not bridges or bottomless structures
- Suitable for new structures or replacements
- Generally limited to locations with natural gradients less than 3%
- Most likely applicable to streams with fine-grained, mobile bed material

"No Slope" design option

1. Culvert installed with flat invert gradient

2. Culvert width = 1.2 x bankfull width

5. Bed material = native material, either installed or "recruited"



3. Downstream countersink 20% of rise, minimum, or greater depth if required by MA Standards

4. Upstream countersink 40% of rise, maximum

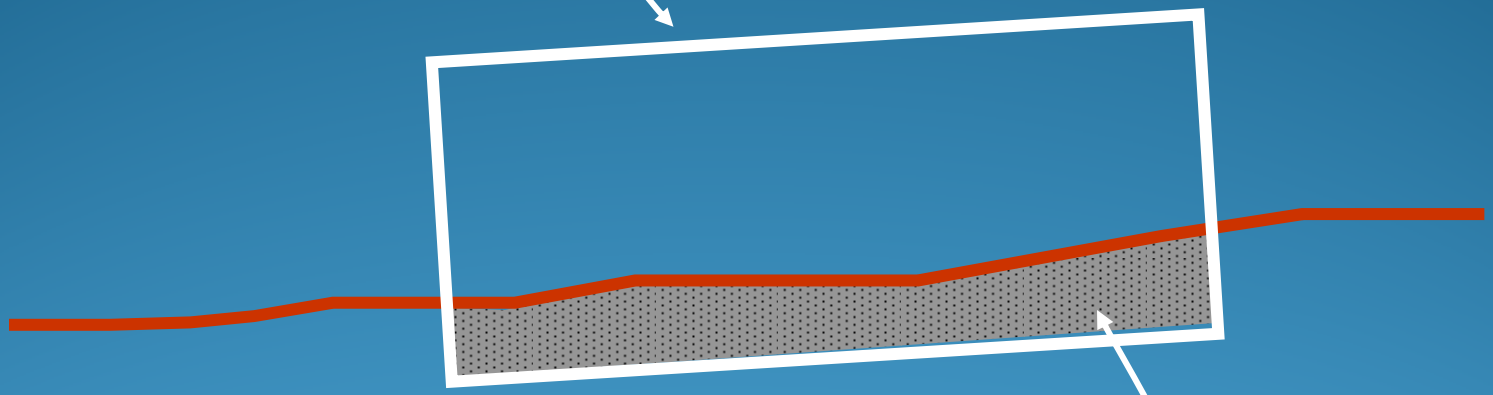
Note: Given countersink requirements (#3,#4), maximum length of culvert will be limited by slope of stream ($L \leq 0.2*D/s$)

Stream Simulation Design

- Applicable to new and replacement culverts
- Applicable to replacements of pipe culverts with bottomless culverts or bridge spans
- Applicable to new clear-span structures where stream alignment would be altered
- Suited to moderate to high channel gradient, and locations with narrow stream valleys
- Greater than 6% gradient may have limitations
- Structure cross section size must be sufficient to permit access for stream bed construction

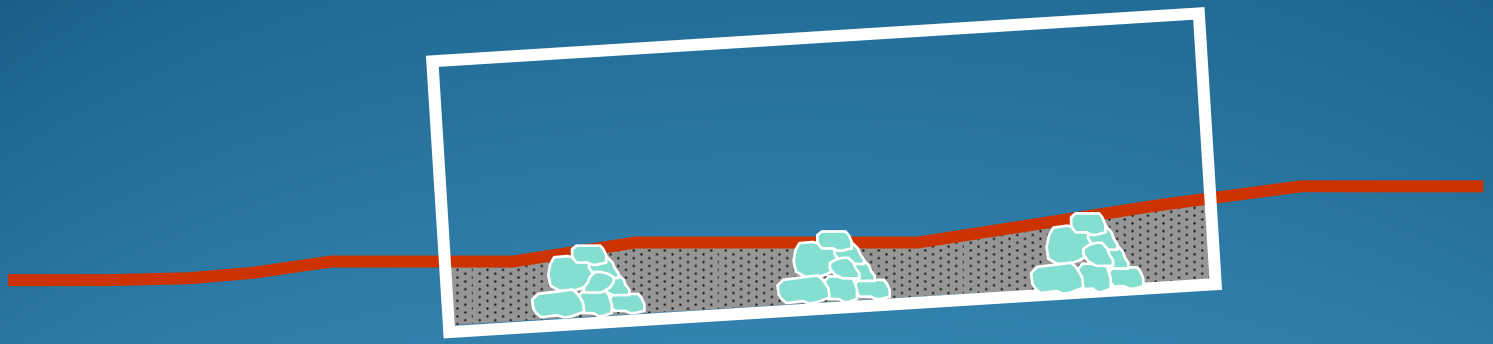
Stream Simulation Design

Culvert installed with sloped invert

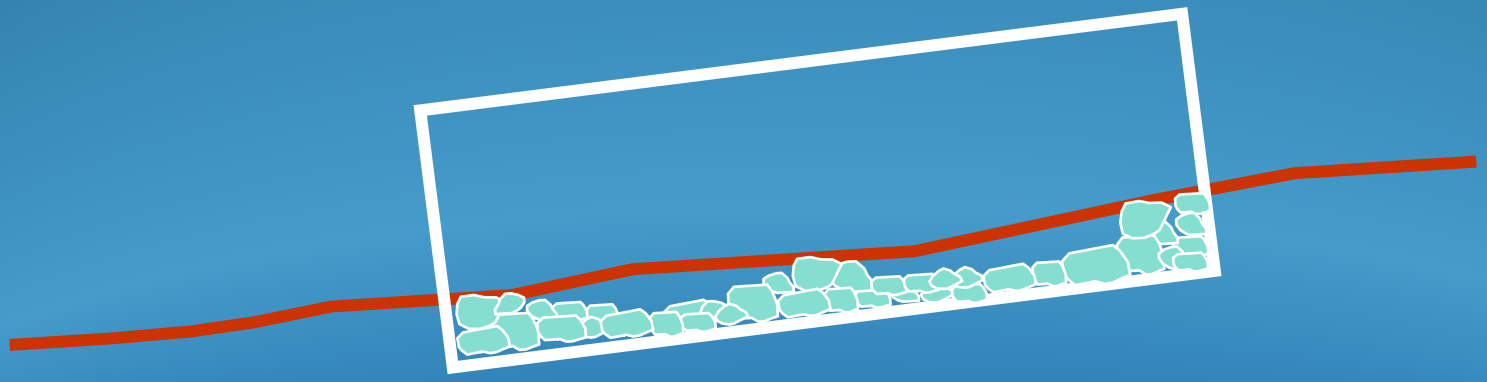


Bed consists of various materials and bed forms designed based on geomorphologic analysis of local stream bed or suitable "reference" stream

Stream Simulation Design



Alluvial (e.g., cobble/gravel)

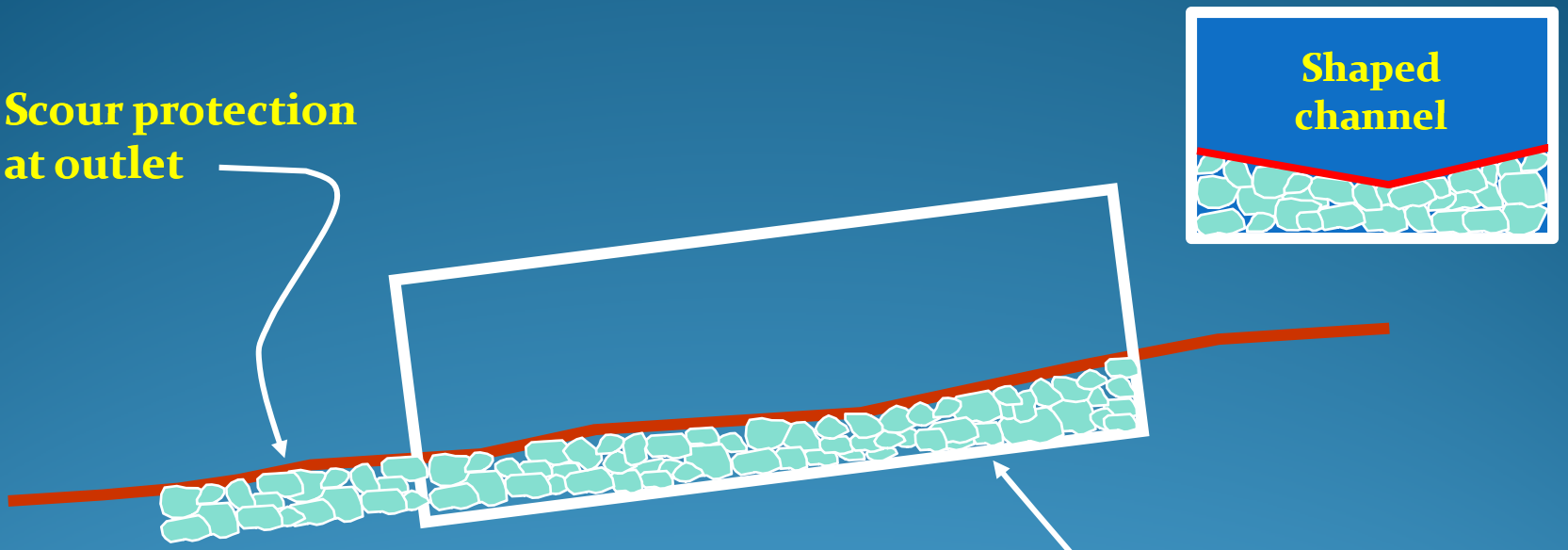


Non-alluvial (e.g. step-pool)

Roughened Channel Design

- Applicable to new and replacement culverts, where not feasible to provide width > 1.2 bankfull width
- Suited to moderate to high channel gradient, and locations with narrow stream valleys
- Structure cross section size must be sufficient to permit access for stream bed construction
- May require scour protection (e.g., armoring) of channel at the culvert outlet
- Not recommended for flat-gradient streams with fine-grained mobile bed material (consider "no-slope" design instead.

Roughened Channel Design



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

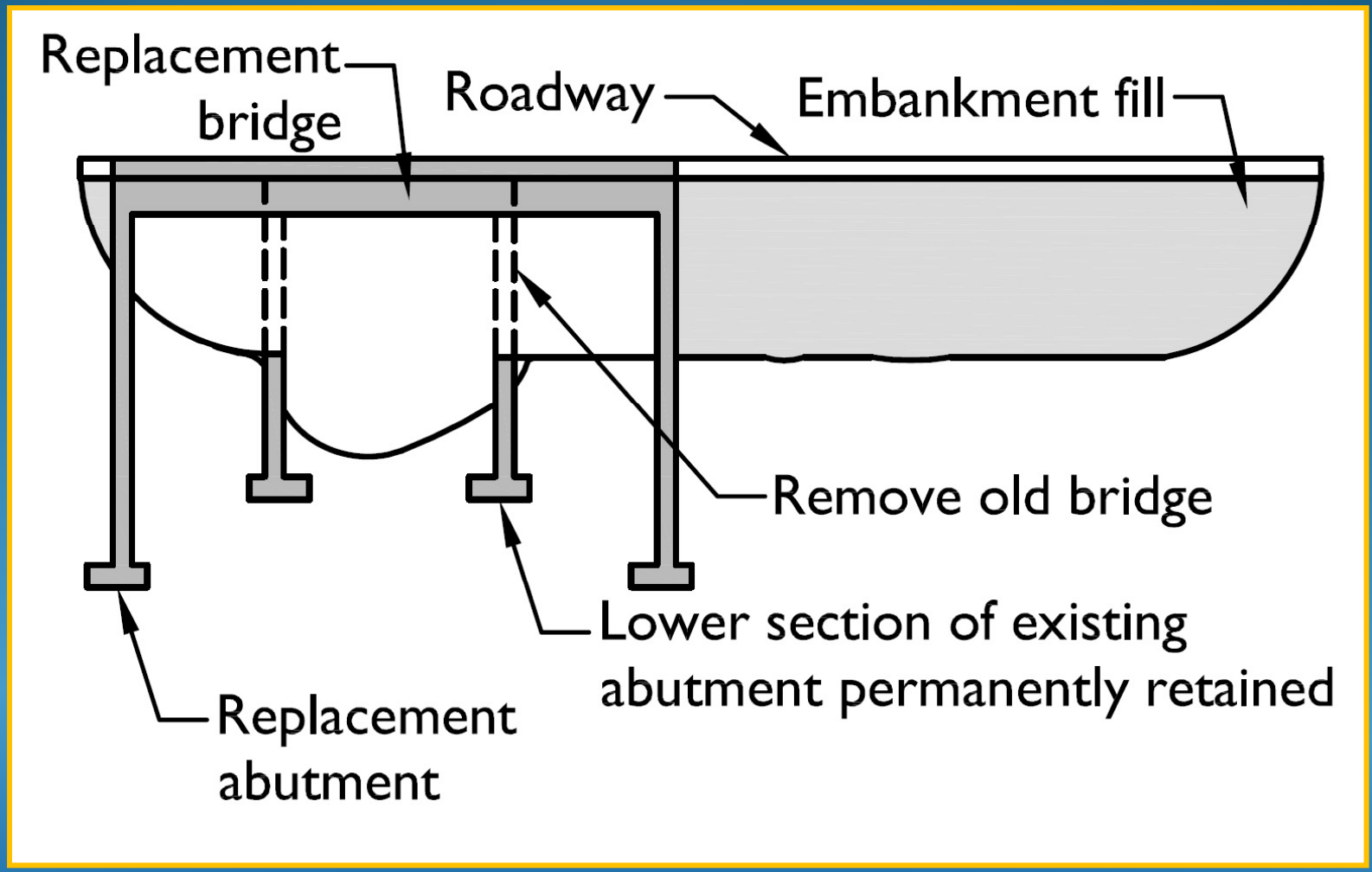

08/17/2011


08/16/2011


08/28/2011

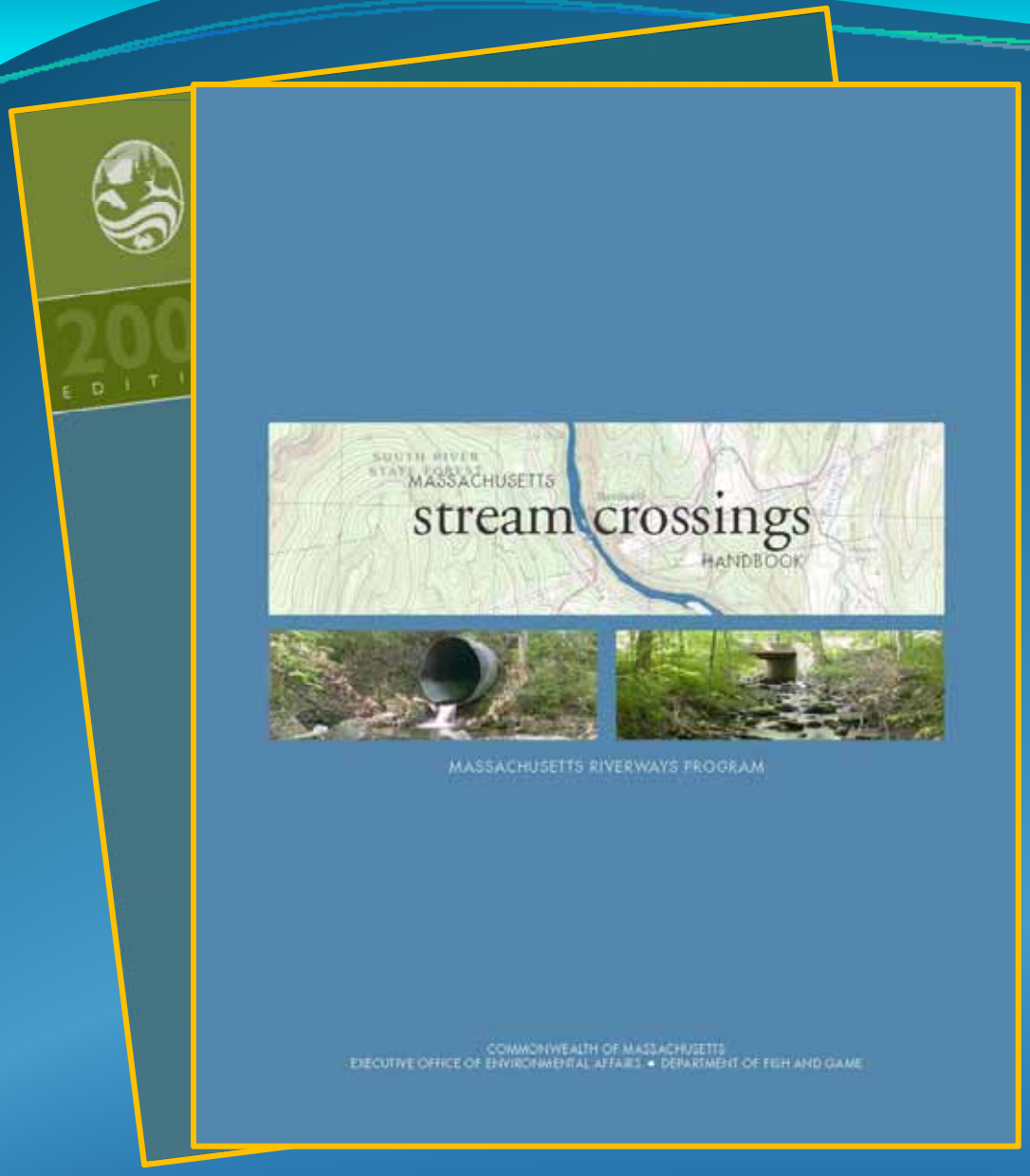
February 2013

Bridge Replacement with Retained Abutments



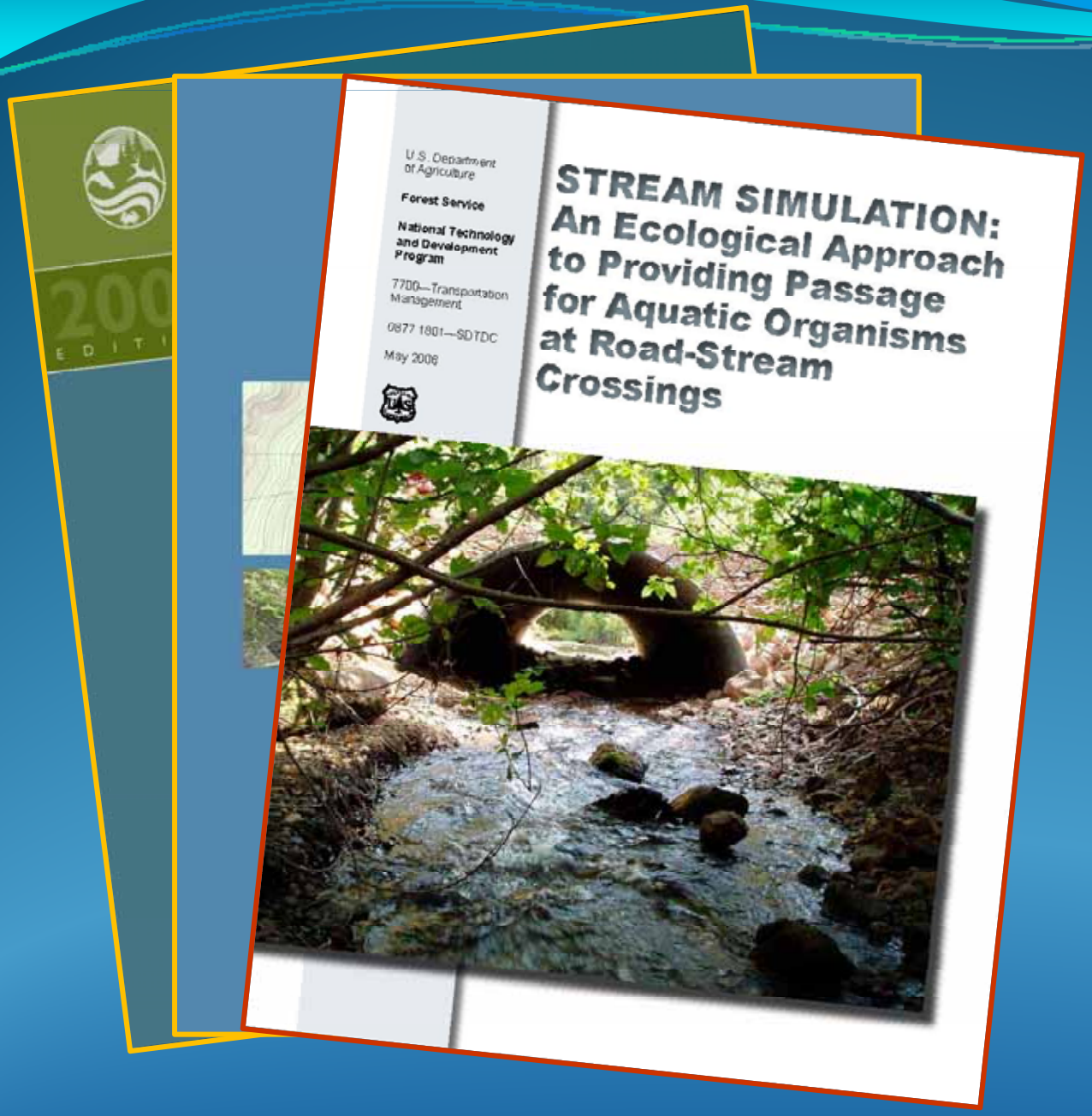
Design References and Guidance

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

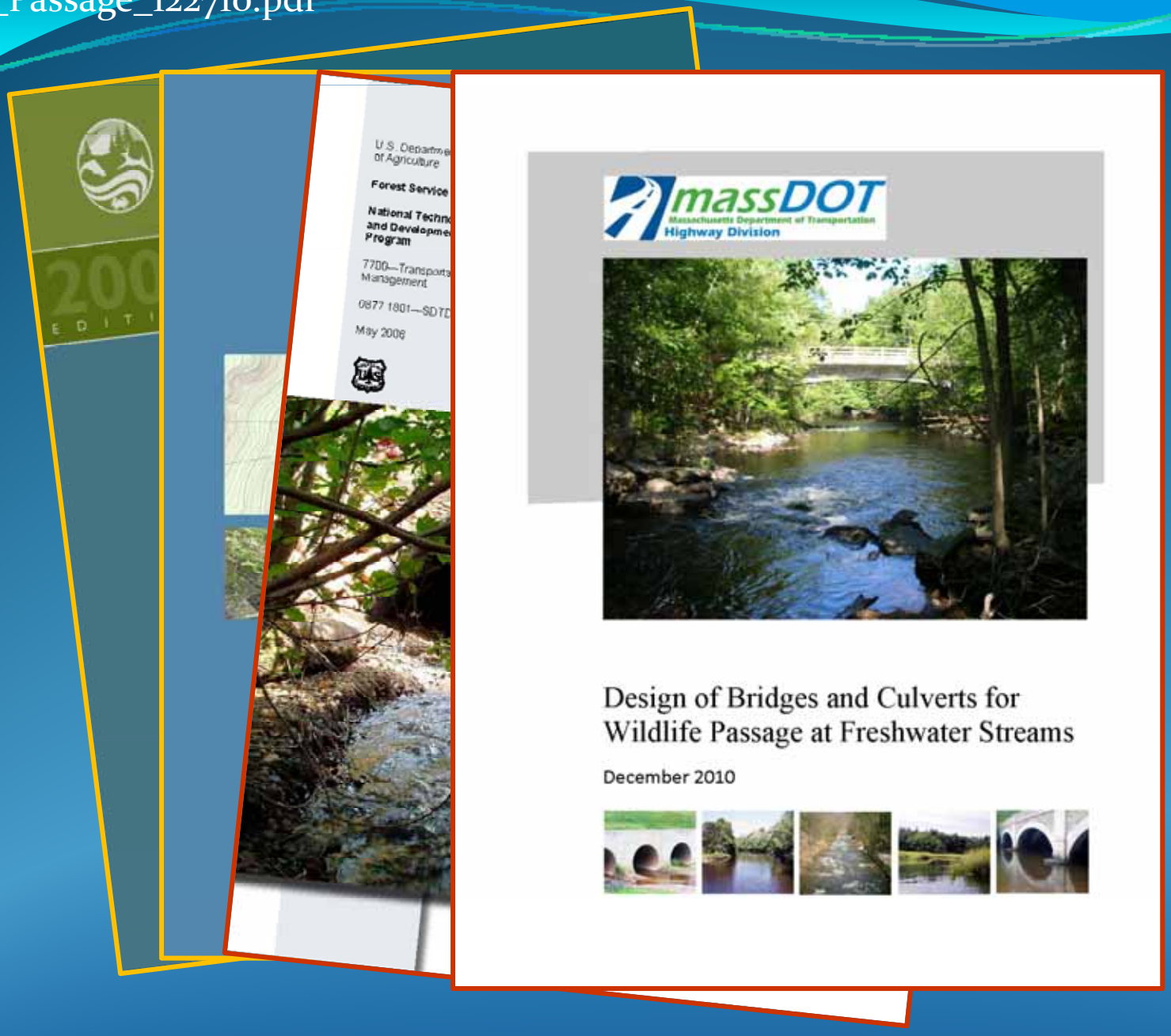


http://www.mass.gov/dfwele/der/freshwater/rivercontinuity/guidancedoc.htm

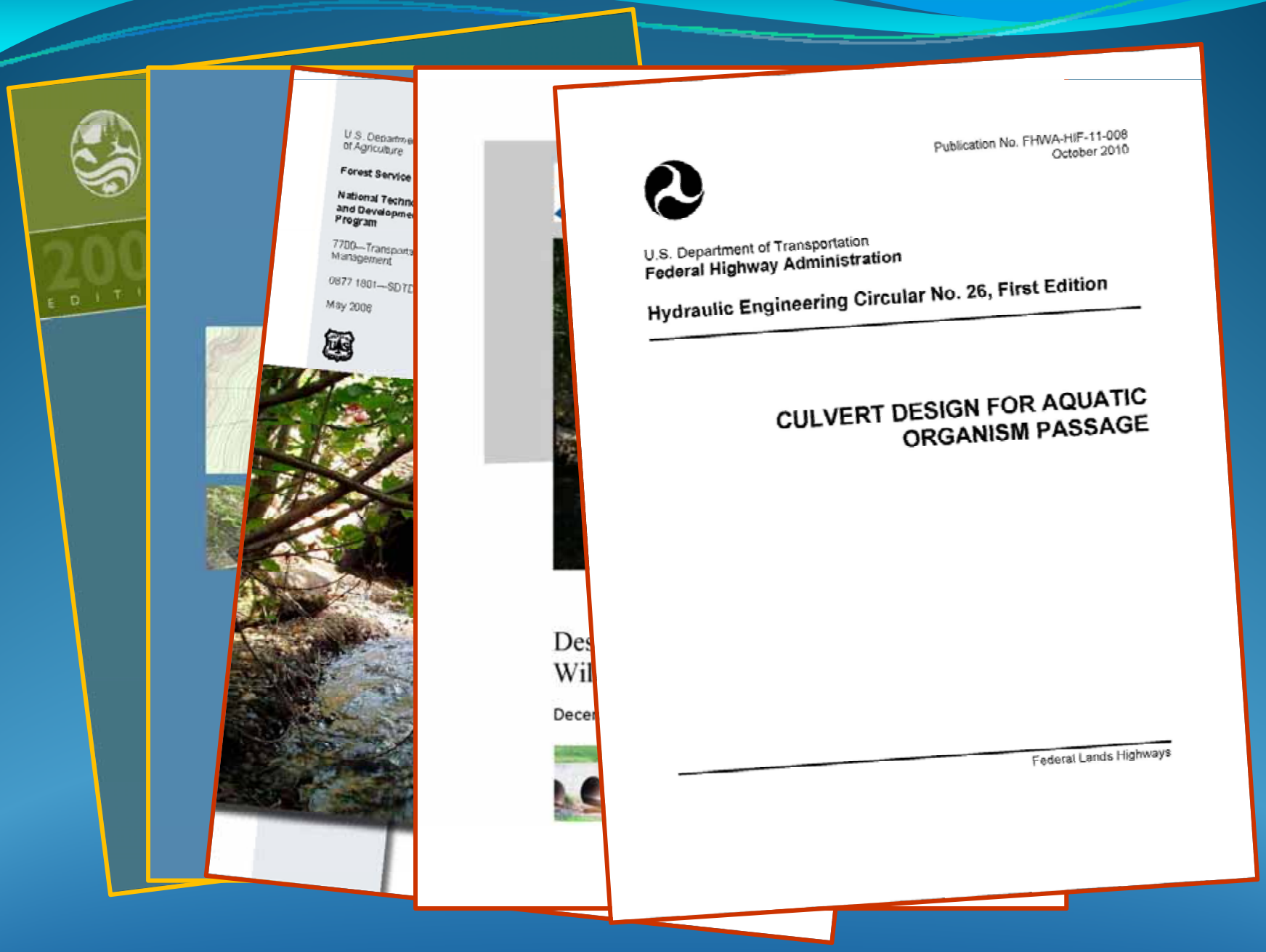
http://www.fs.fed.us/eng/pubs/pdf/StreamSimulation/index.shtml



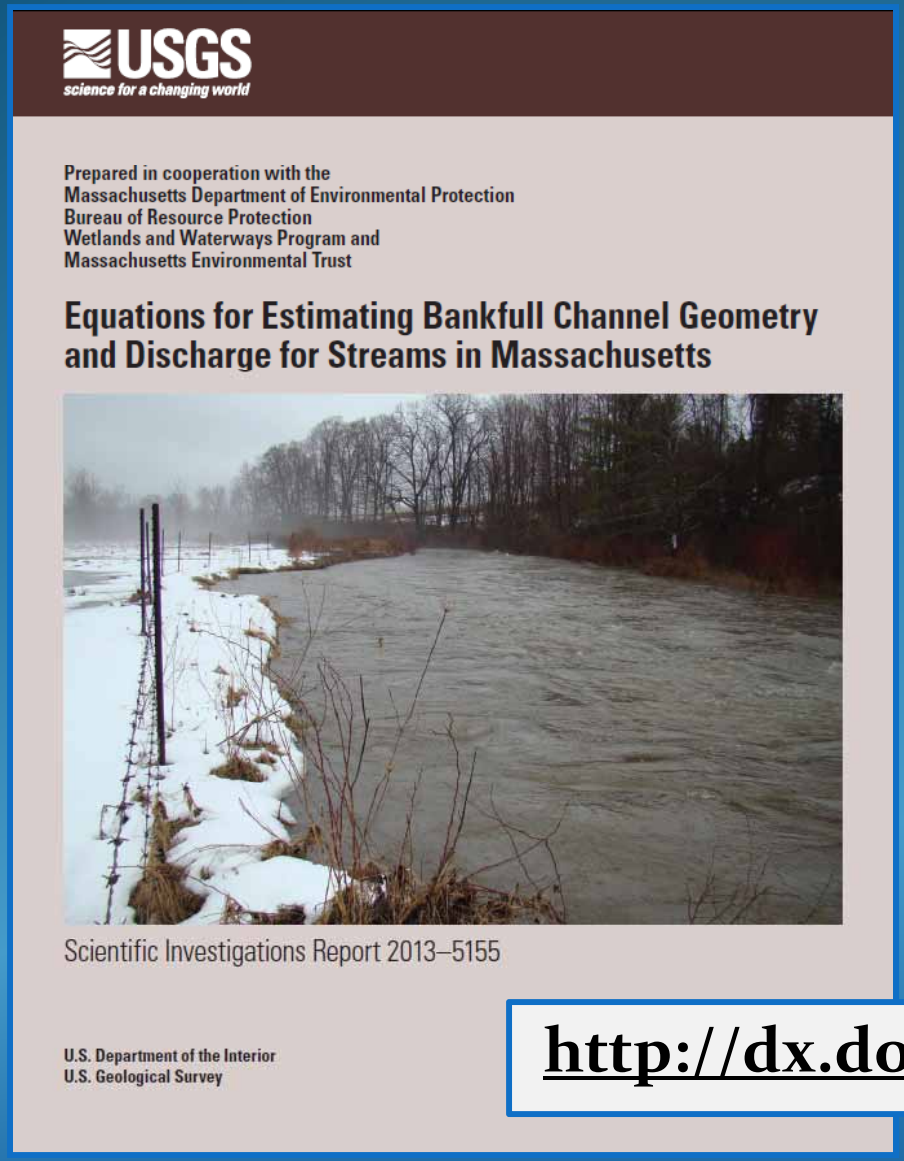
http://www.mhd.state.ma.us/downloads/projDev/Design_Bridges_Culverts_Wildlife_Passage_122710.pdf



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



New within the past year:



USGS Regression Equations now available for Massachusetts

Soon to be added to USGS StreamStats:

http://water.usgs.gov/osw/streamstats/massachusetts.html

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

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