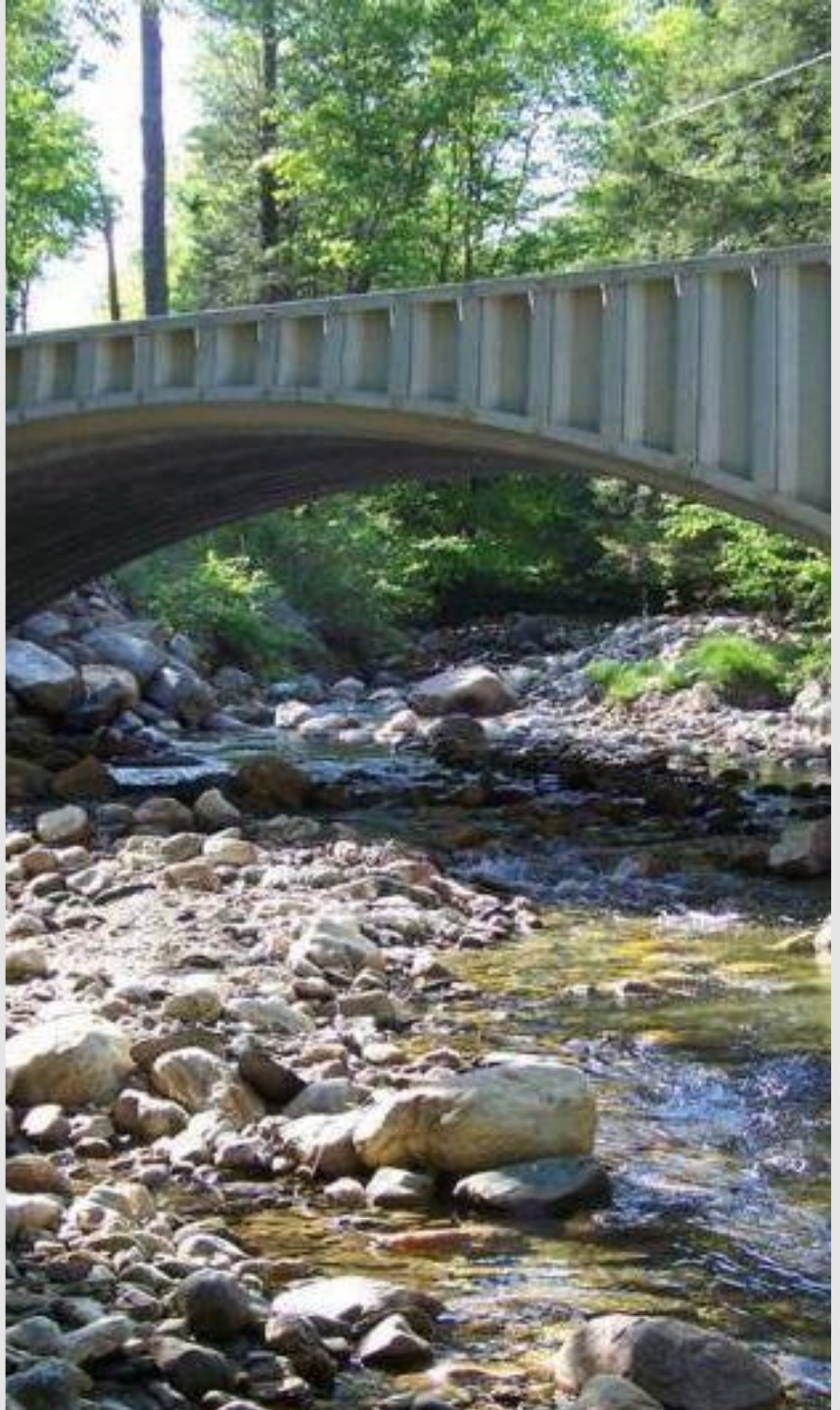
A GIS-BASED HYDRAULIC MODELING TOOL FOR MASSACHUSETTS STREAM CROSSING REPLACEMENT PROJECTS IN USGS STREAMSTATS

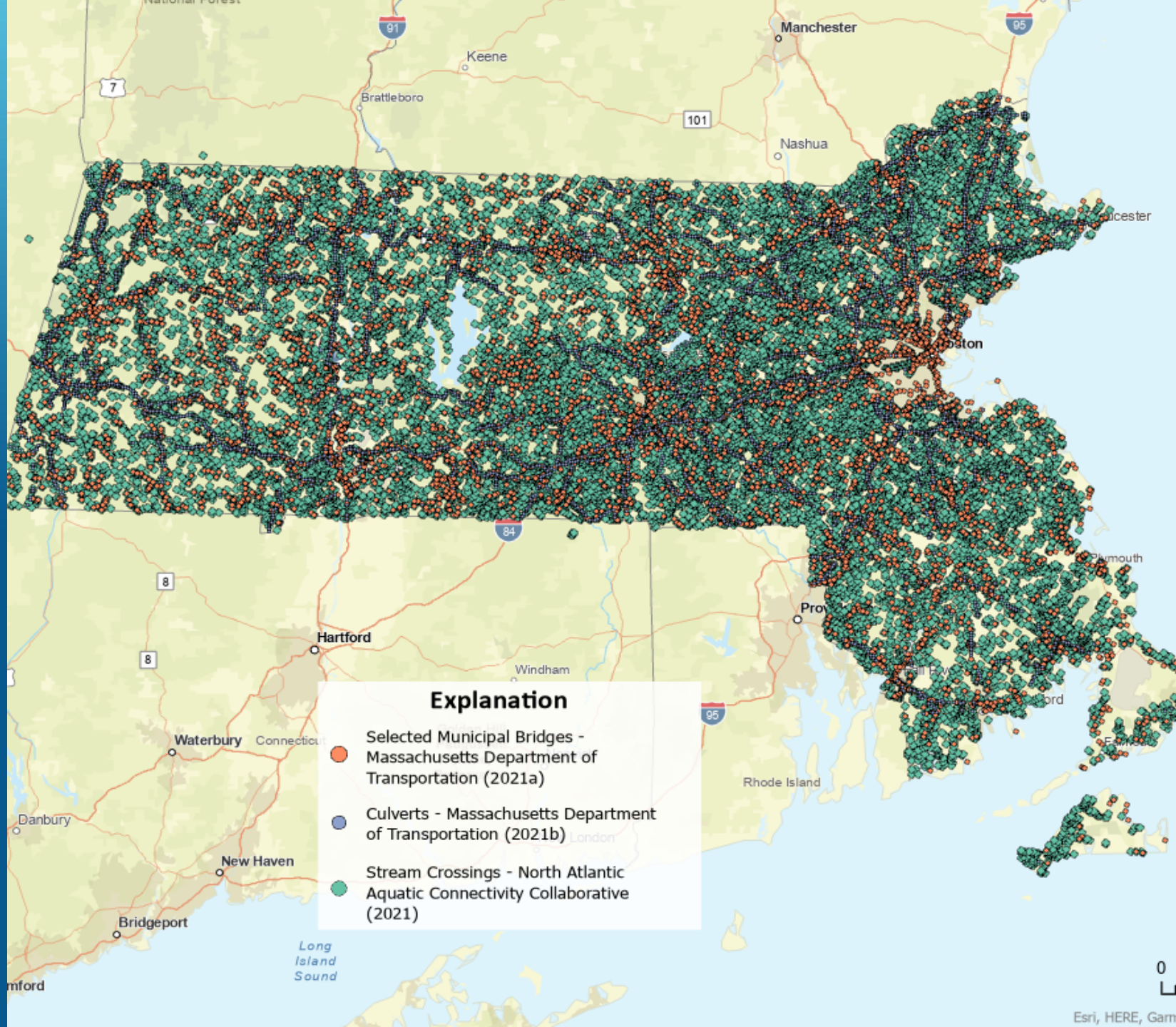
Gardner Bent
U.S. Geological Survey
New England Water Science Center



MASSACHUSETTS STREAM CROSSINGS

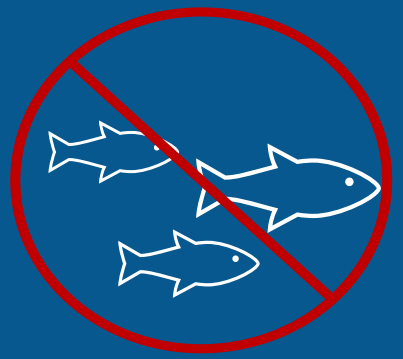
Photo courtesy of *MassDOT, Massachusetts Culverts and Small Bridges Working Group*

USGS



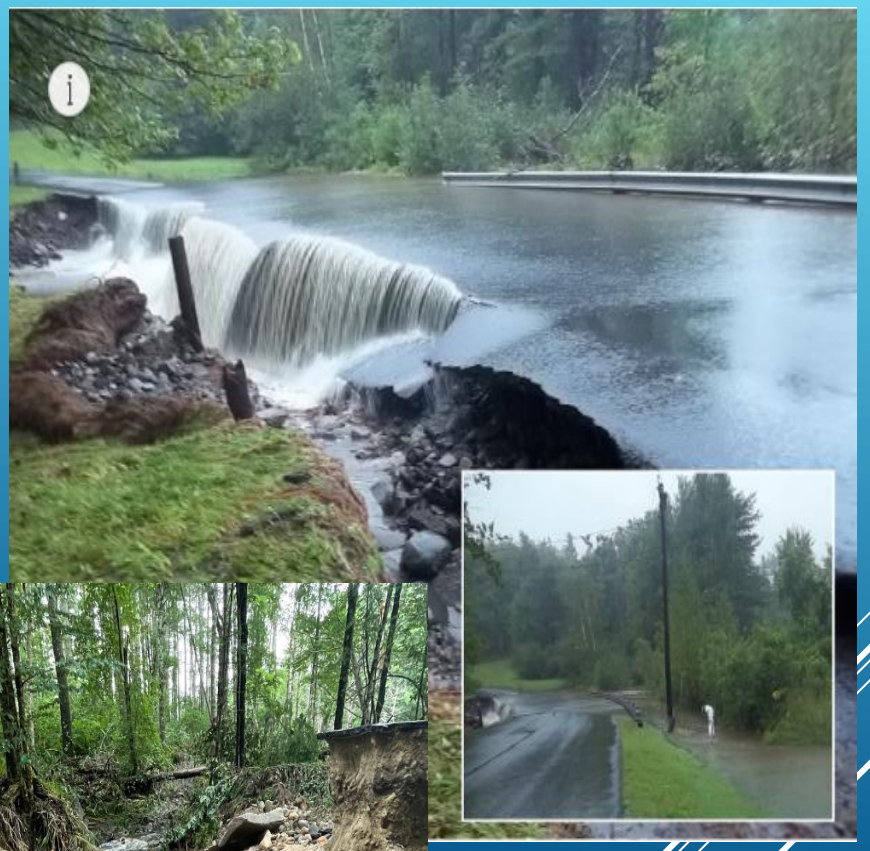
Undersized Culverts

- Outlet drops
- Restrict aquatic organism passage (AOP) to spawning, feeding, and cold-water habitat
- Restrict wildlife passage
- Reduce stream connectivity
- Extreme low flow
- Restrict sediment transport



Undersized Culverts

- Create high flow velocities
- Cause road flooding
- Clogging/debris
- Create significant backwater during flooding events
- Cause road washouts
- Create scour and erosion
- Create extreme low flows



Photos courtesy of *University of Massachusetts at Amherst, River Smart Communities*

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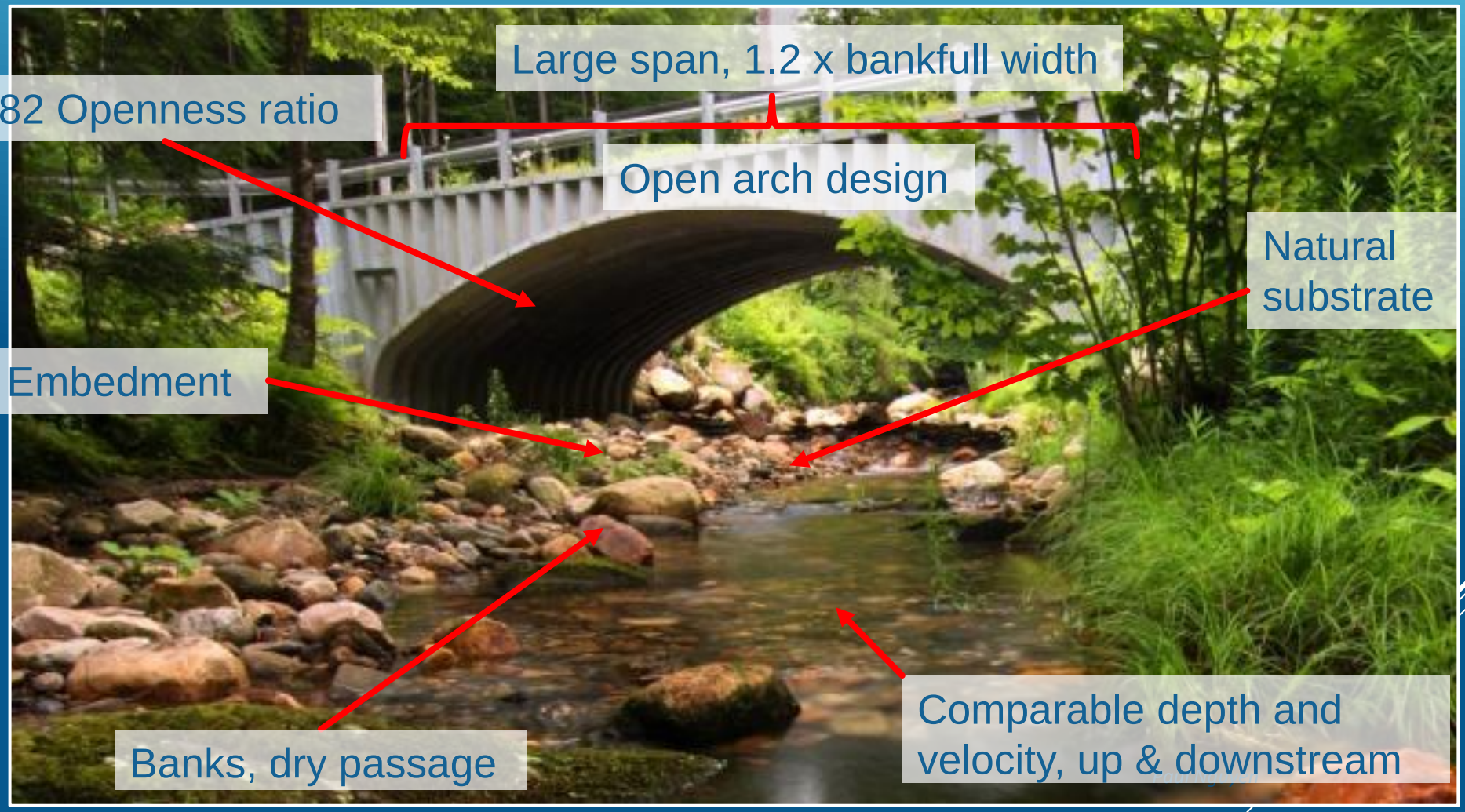
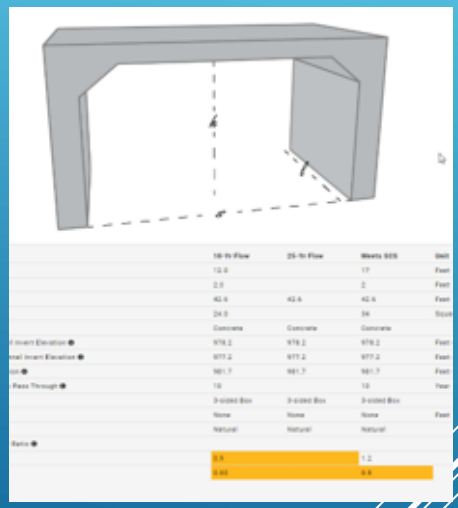
MASSACHUSETTS STREAM CROSSING STANDARDS

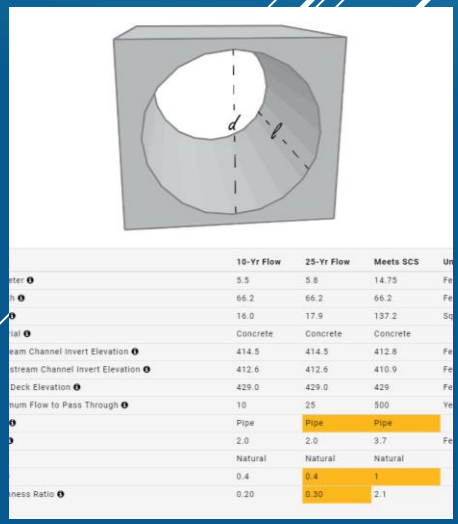


USGS

Project Goals and Objectives

- Create hydraulic models for about 20,000 stream crossing sites in Massachusetts
- Develop culvert designs to convey flood flows and meet the Massachusetts Stream Crossing Standards
- Publish culvert designs on USGS StreamStats
- Assist MassDEP in facilitating stream crossing replacement projects





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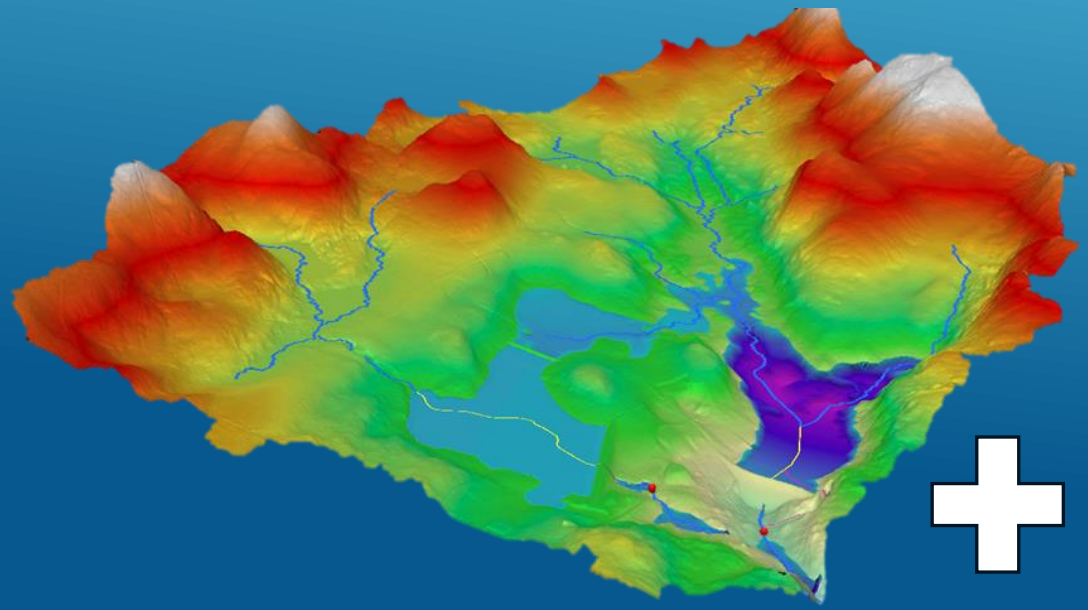
GIS-BASED HYDRAULIC MODEL DEVELOPMENT



+

python™

+Arcpy functions

+

RAS

US Army Corps of Engineers

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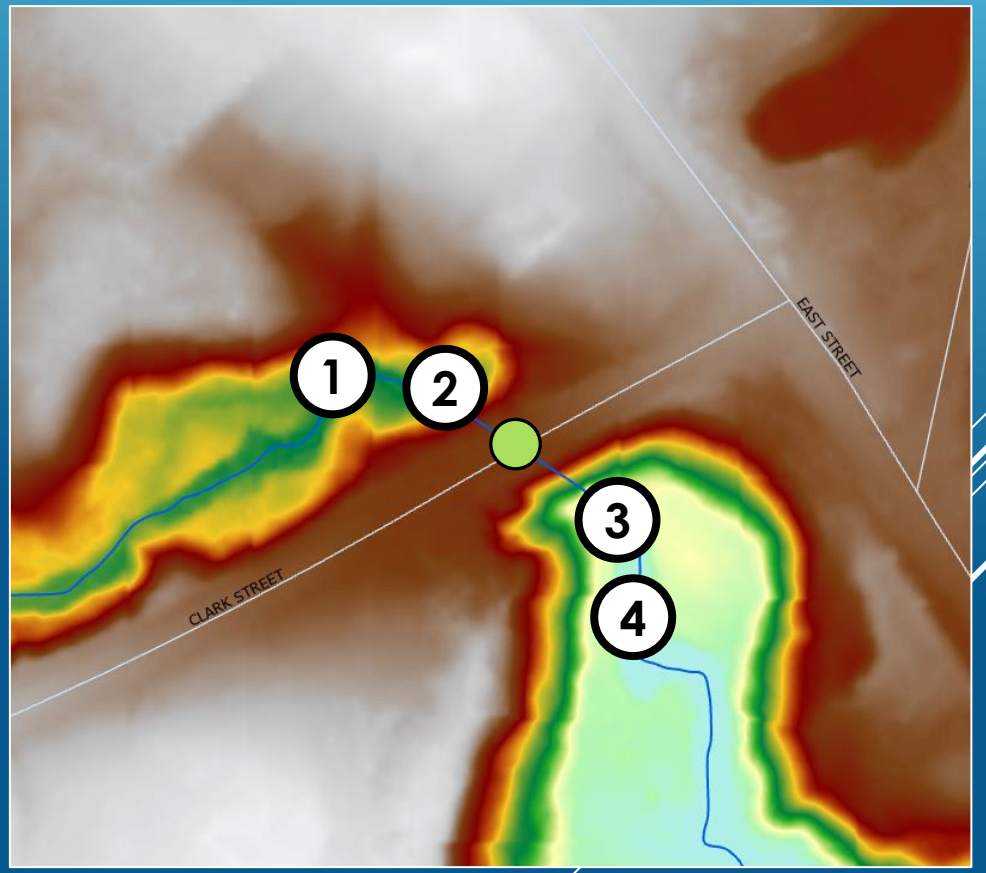
GIS-Based Hydraulic Model Development

Looking Upstream

Upstream Face

Downstream Face

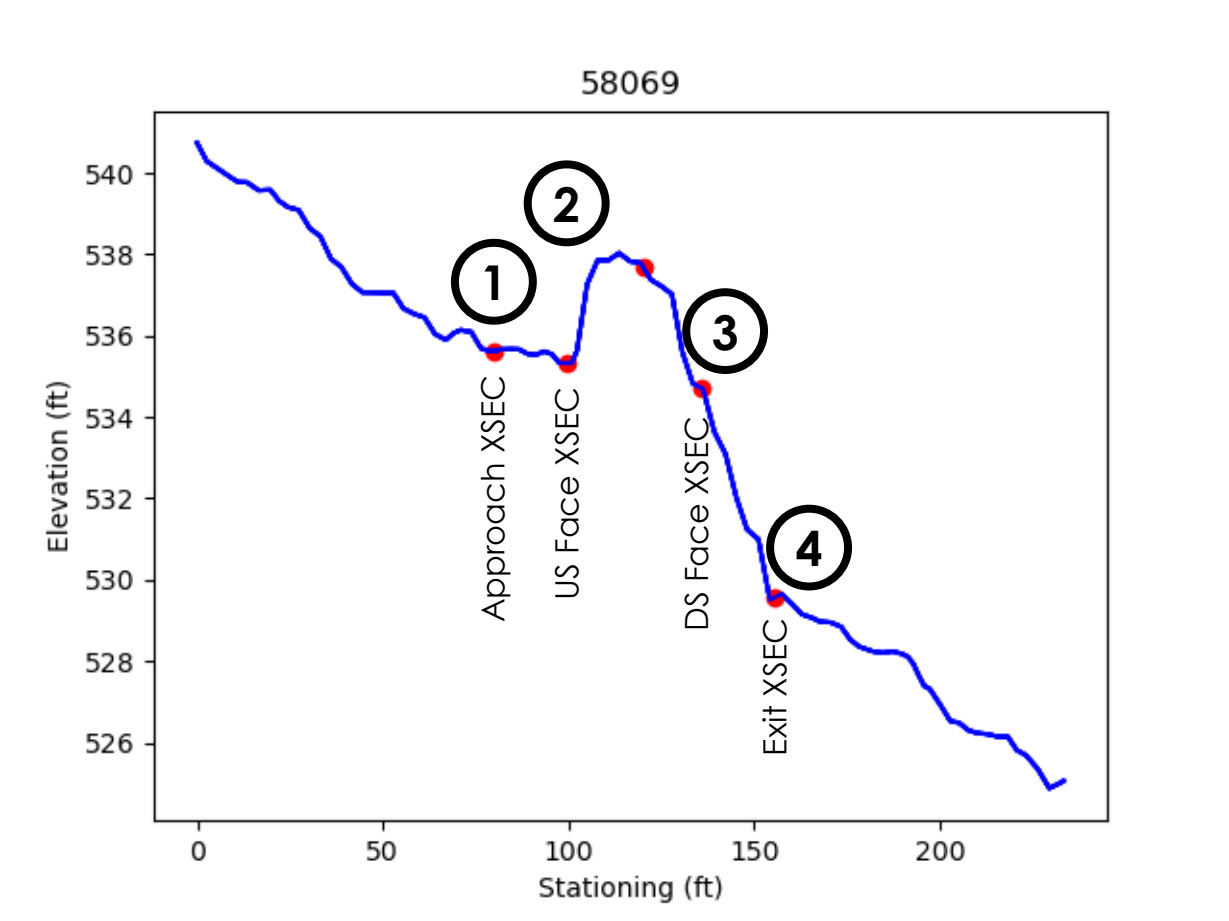
Looking Downstream

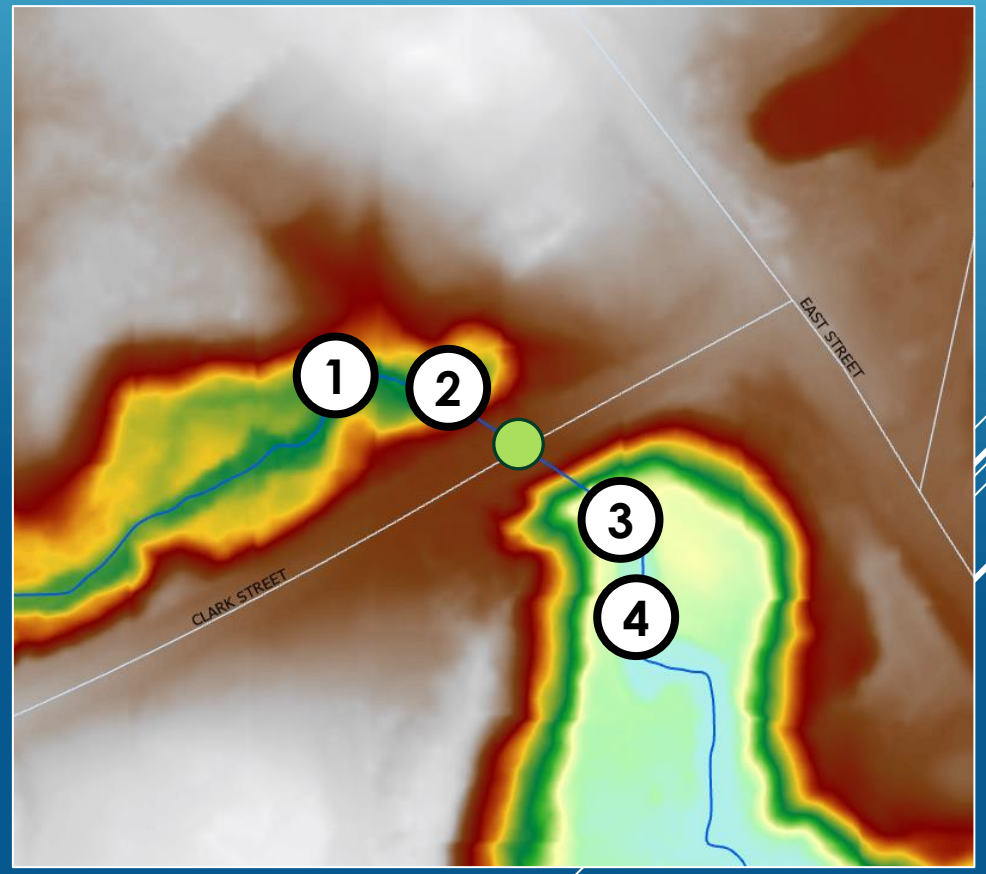


USGS

Unnamed Tributary to Manhan River, Southampton, MA

GIS-Based Hydraulic Model Development – Lidar Derived Elevation Data

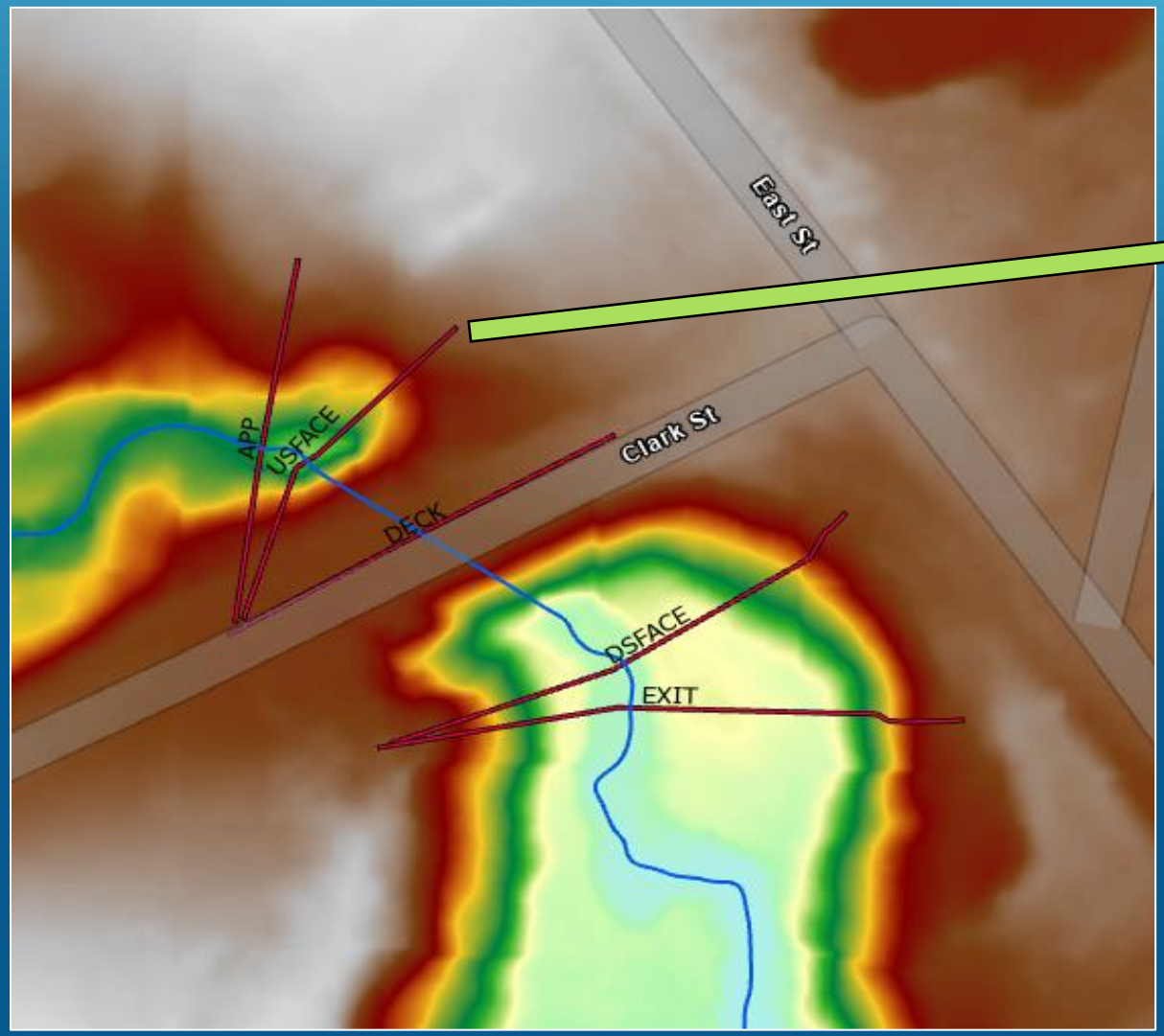


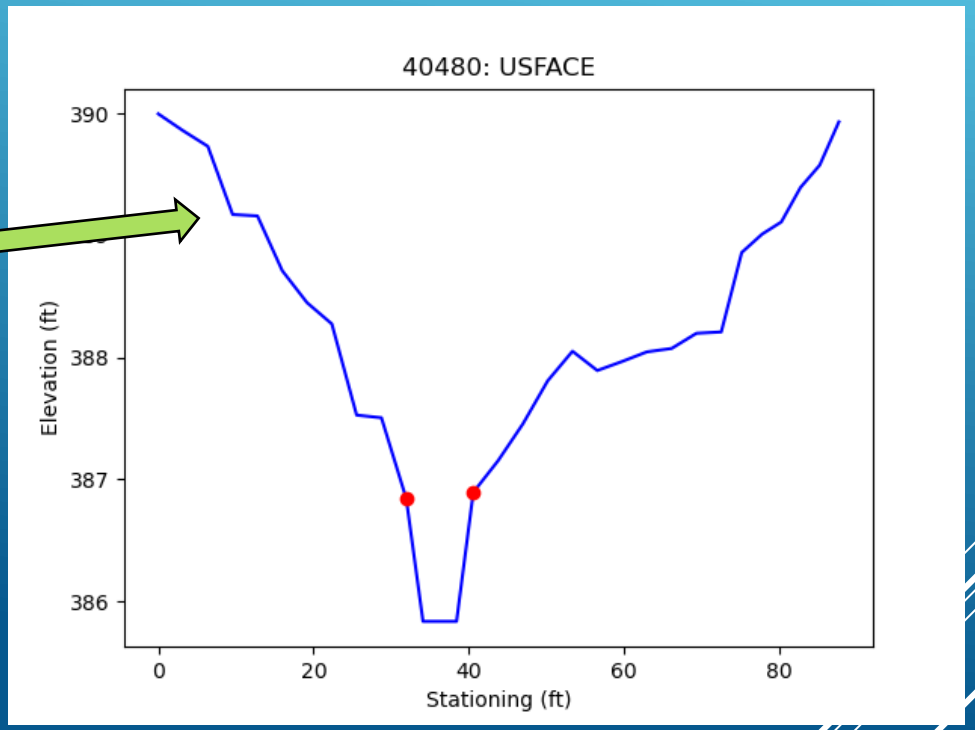


USGS

Unnamed Tributary to Manhan River, Southampton, MA

GIS-Based Hydraulic Model Development – Cross Sections



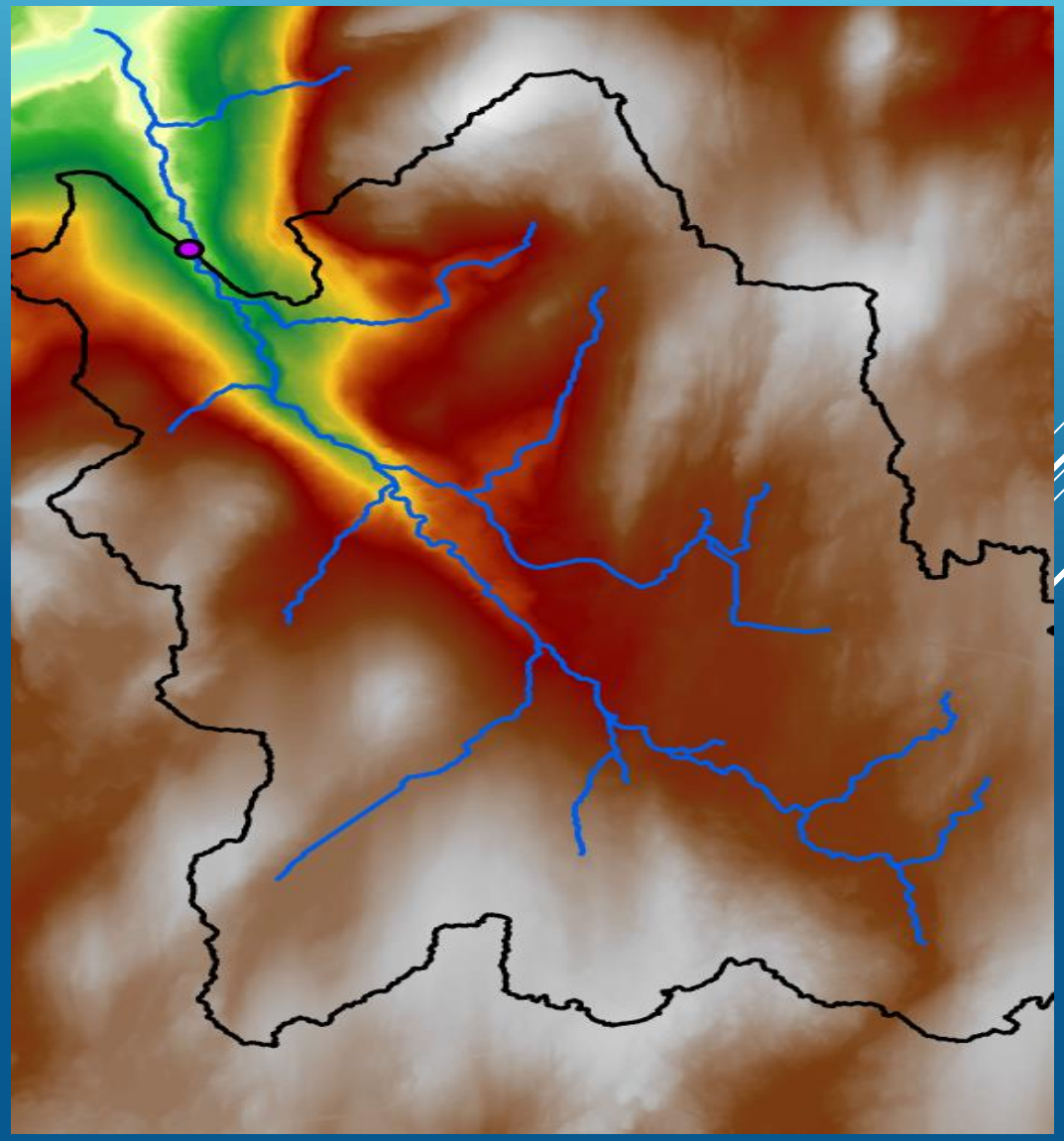


- Channel width and depth determined by Massachusetts Bankfull Channel Geometry Equations (Bent and Waite, 2013)

USGS

GIS-Based Hydraulic Model Development – Flood Flows

- Massachusetts regional regression equations for estimating peak flows (Zarriello, 2017)
- Estimate 10-, 4-, 2-, and 1-percent annual exceedance probability (AEP) flood flows (10-, 25-, 50-, and 100-, and recurrence intervals)
- Equations based on drainage area, mean basin elevation, and storage (water bodies and wetlands)



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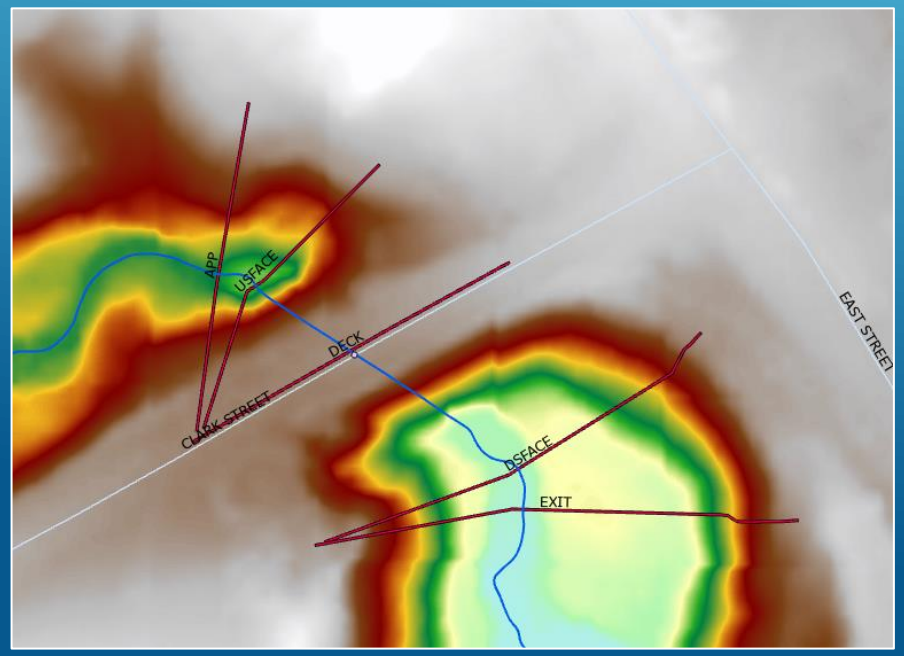
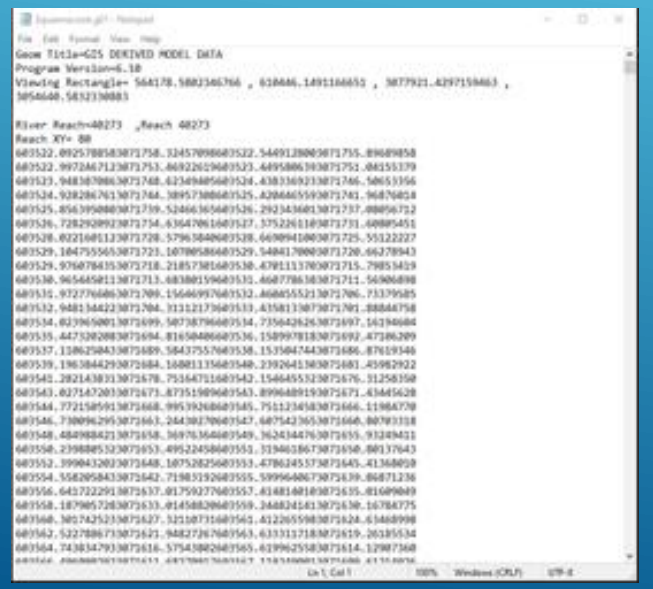
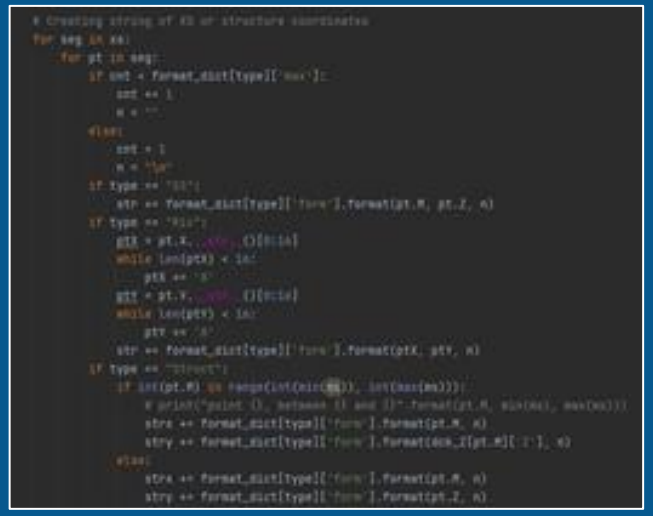
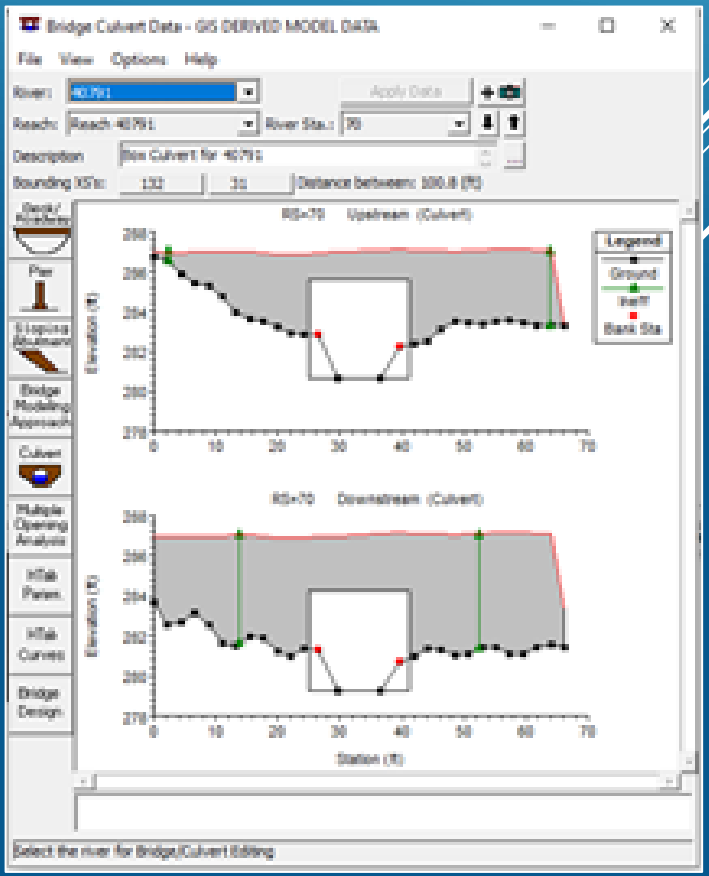
Creation of HEC-RAS Model Files









USGS

CULVERT - HYDRAULIC DESIGN FLOW

Unacceptable

Maximum Extent Practicable (MEP)

Replacement in-kind

Baseline MassDOT Hydraulic Design Flow (10-, 4-, 2- or 1-percent AEP flood flow)

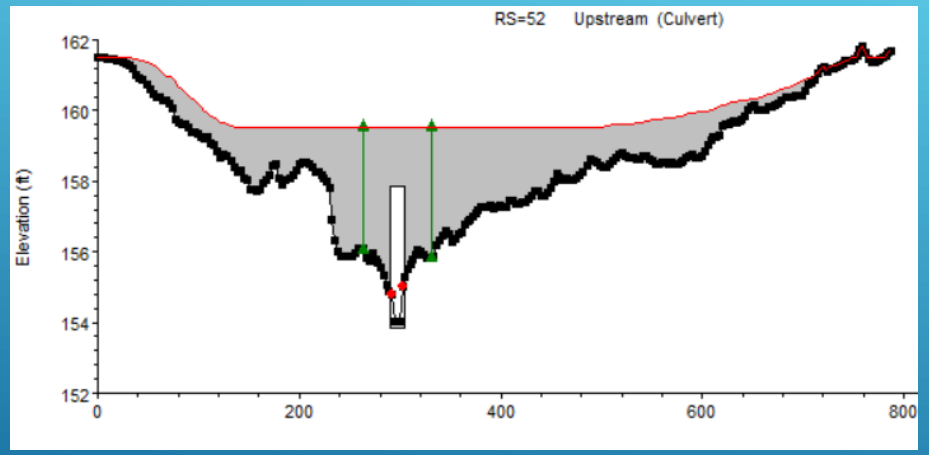
- Habitat Quality
- Stream connectivity

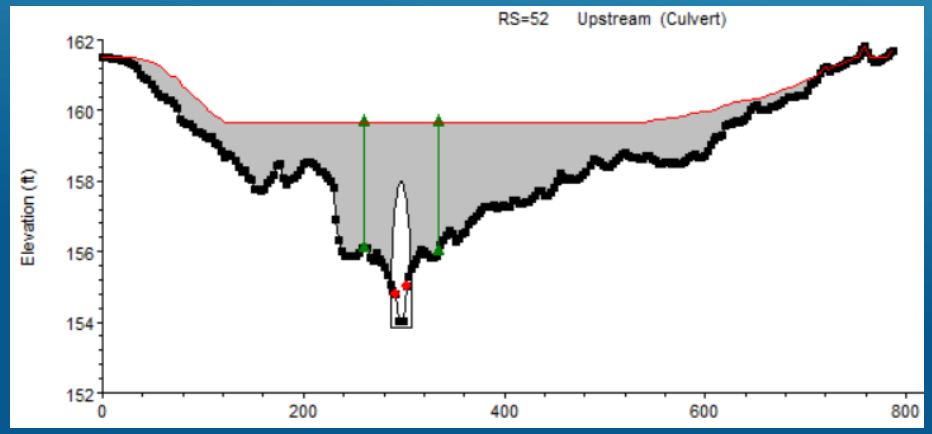
Stream Crossing Standards Design

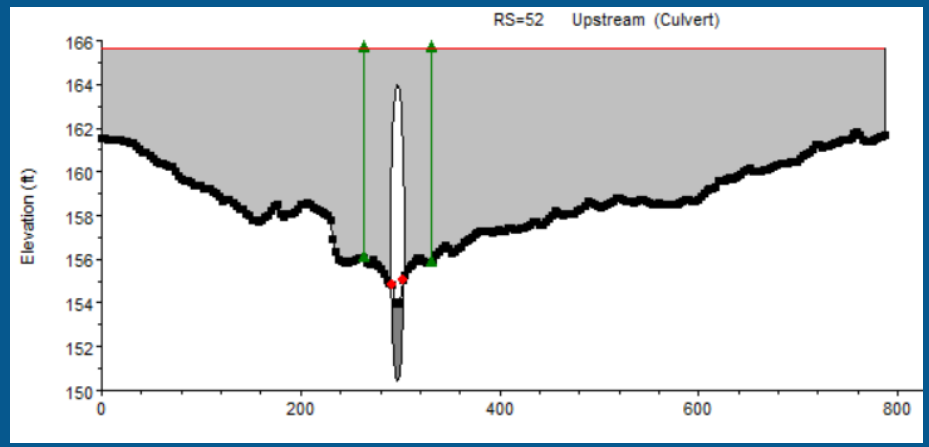
USGS

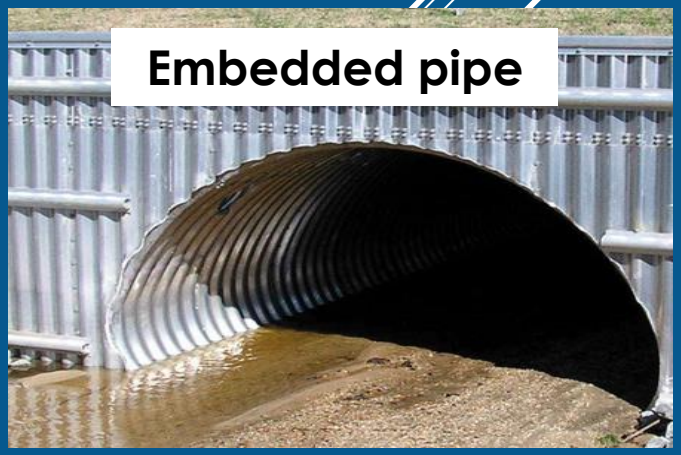
Preliminary Culvert Designs

- Culverts types:
  - 3-sided box
  - 3-sided arch
  - Embedded pipe
- Convey 10-, 4-, 2-, and 1-percent AEP flood flows
- Meet stream crossing standards









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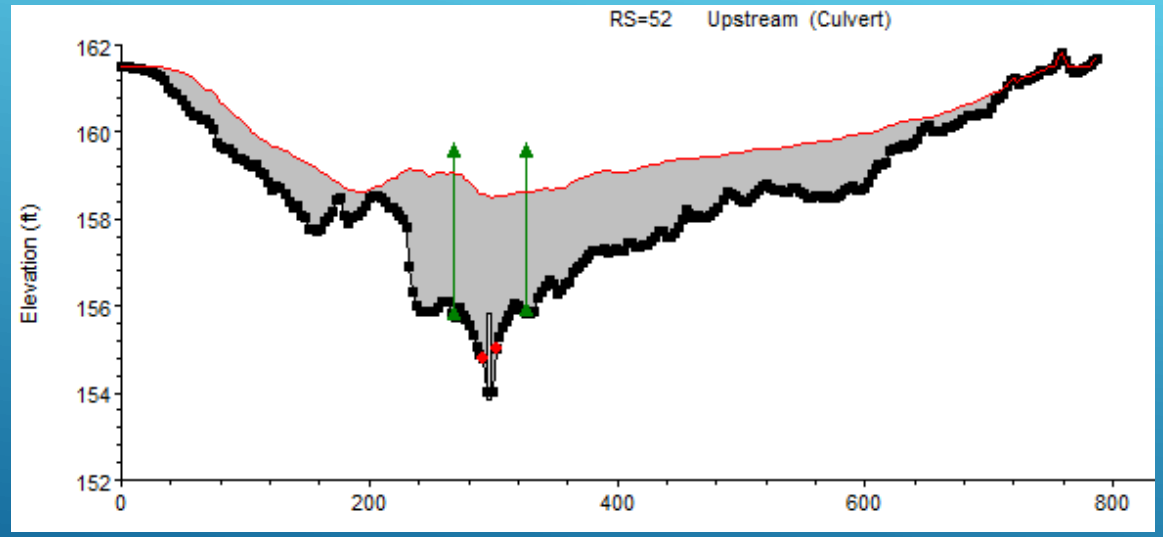
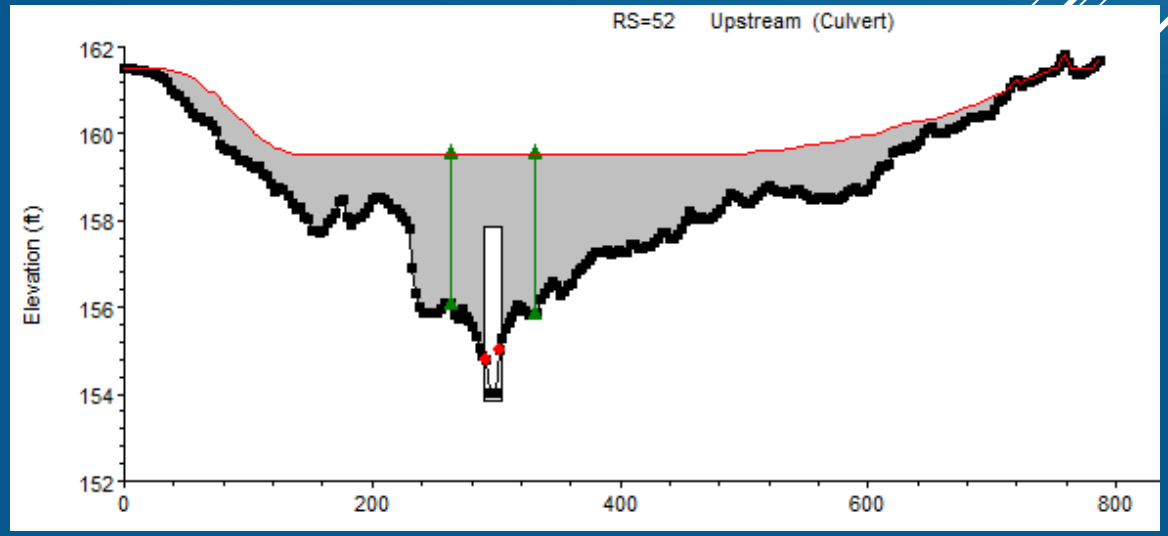
Hydraulic Models

- Manning's n-values of 0.045 for channel and 0.10 for overbank
- Freeboard of at least 1 ft, and 2 ft if specified by MassDOT Chap. 85 Section 35
- Precast concrete sizes for box and pipe culverts
- Arch sizes limited to those in HEC-RAS
- Stream crossing sites with drainage areas < or = 2 mi^2 and < 20% impervious area
- Minimum spans:
  - 10% AEP = 0.8 x BFW
  - 4% AEP = 0.9 x BFW
  - 2% and 1% AEP = 1.0 x BFW
  - SCS = 1.2 x BFW





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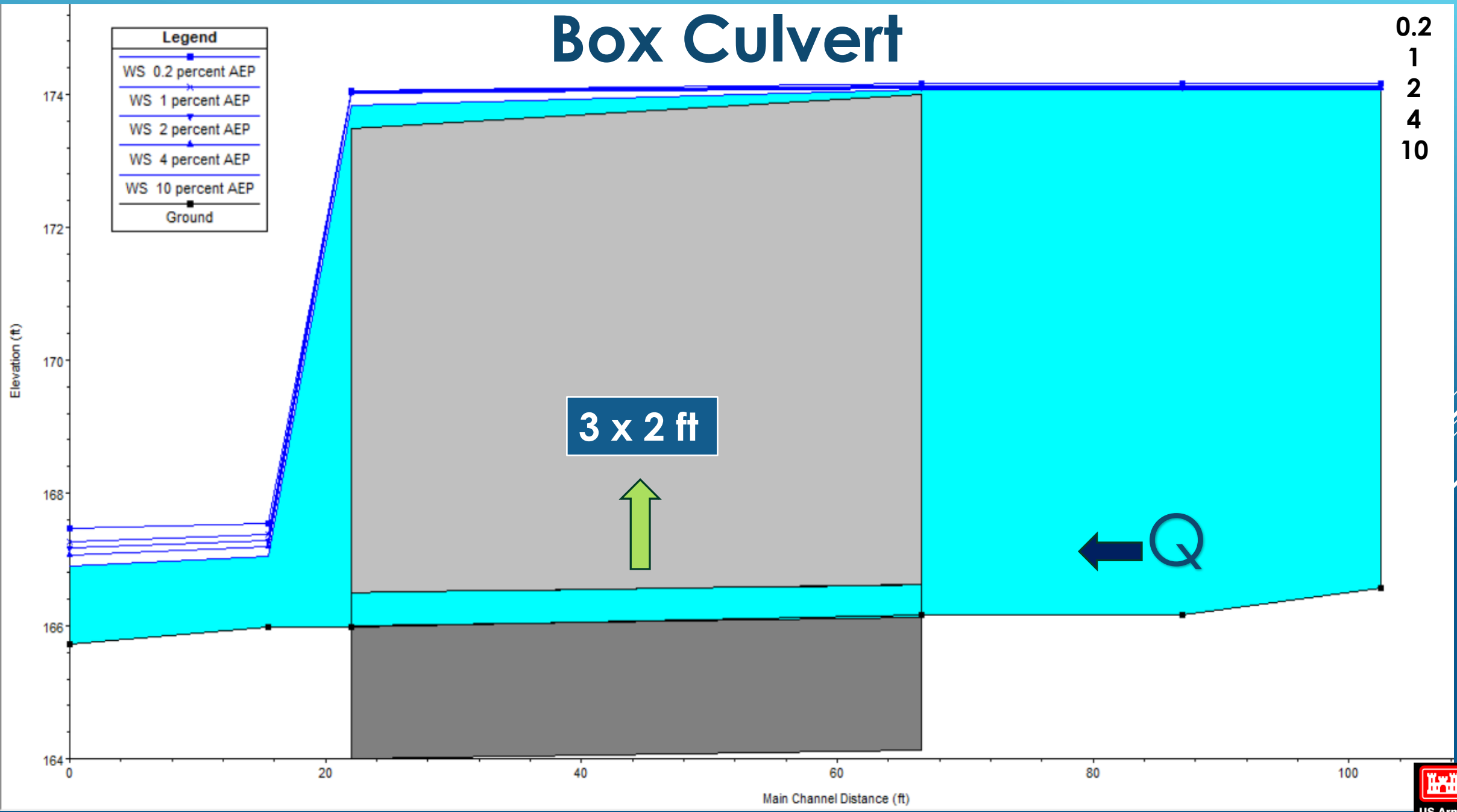
Box Culvert



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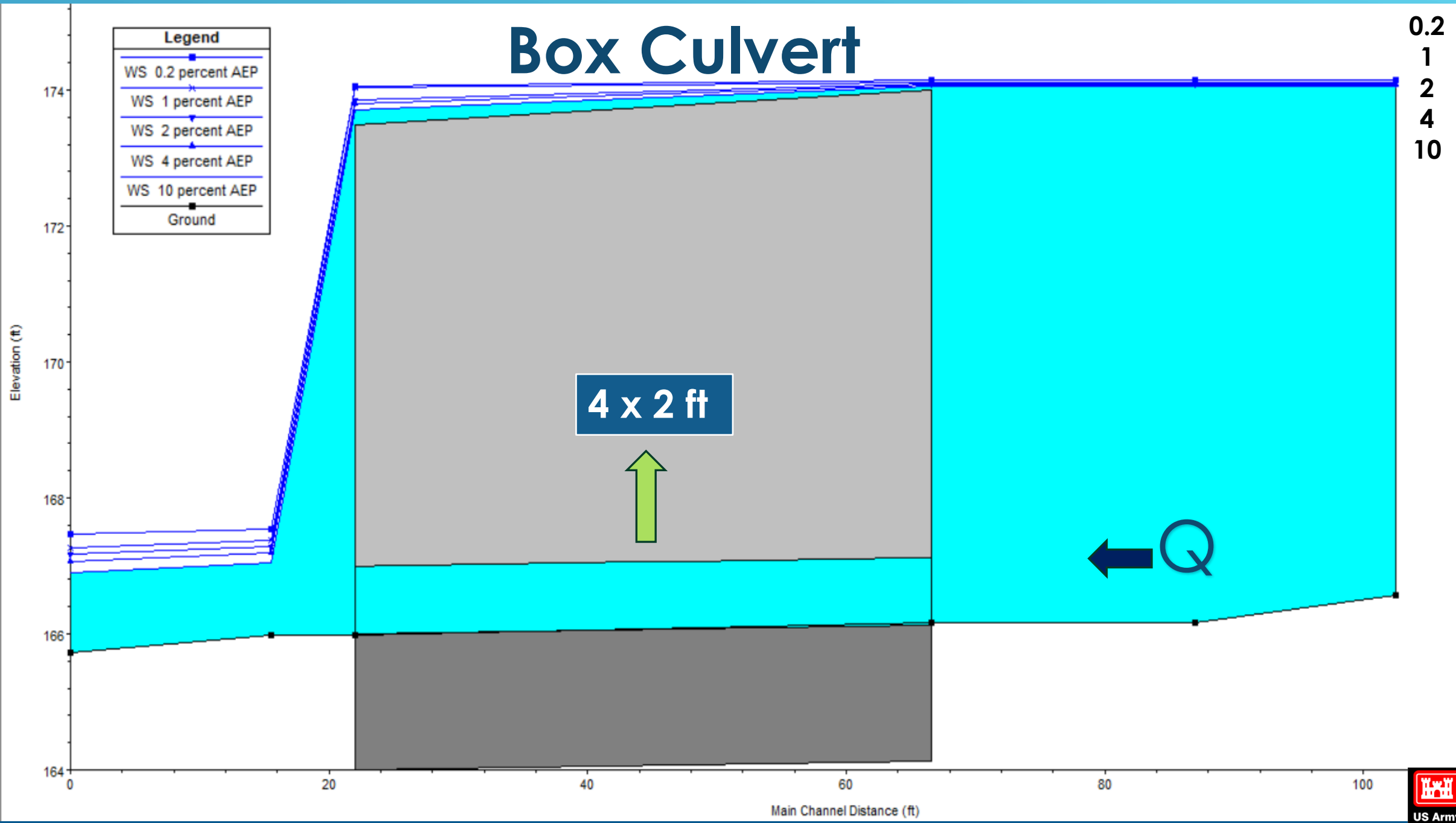
Box Culvert



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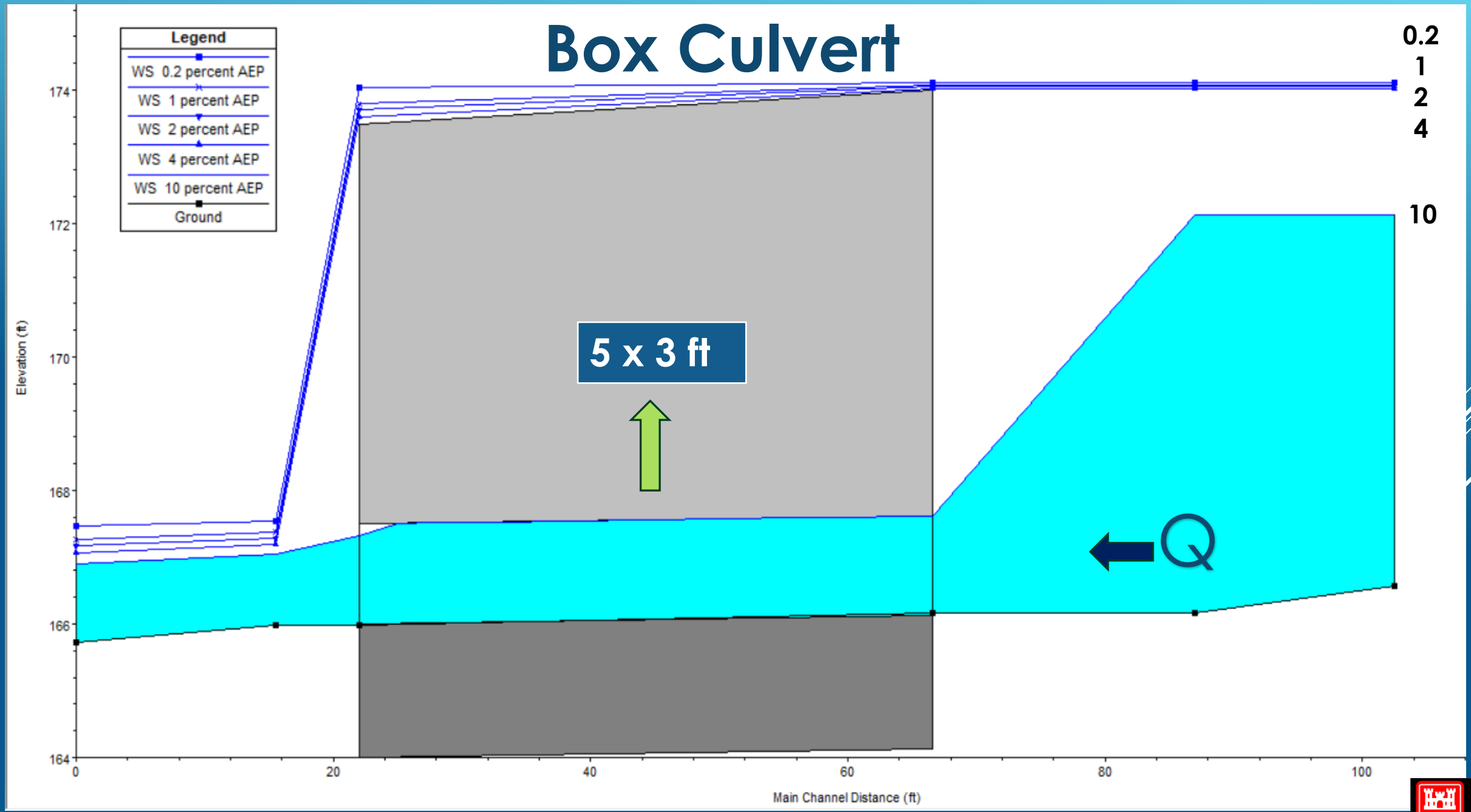
Box Culvert



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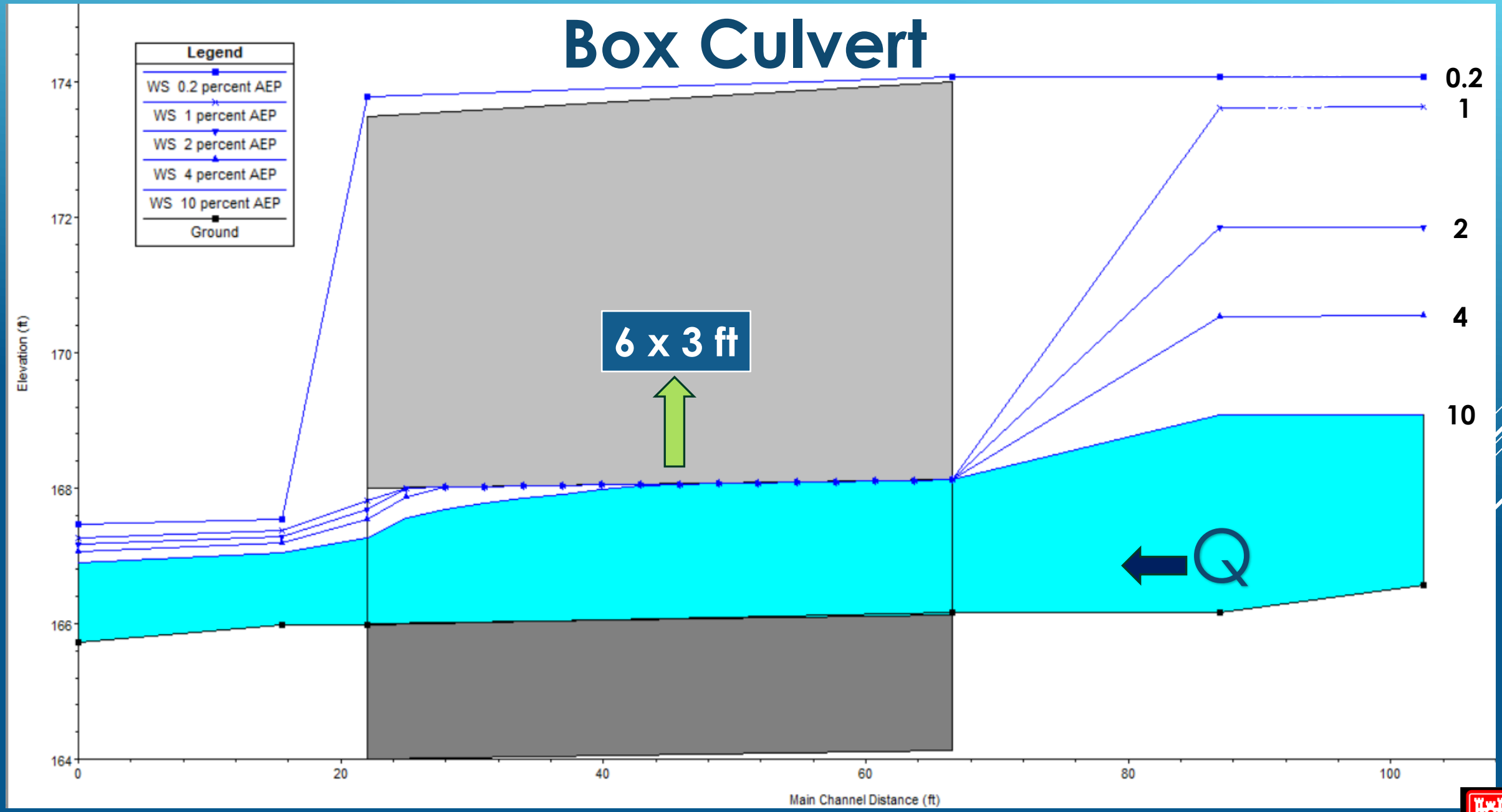
Box Culvert



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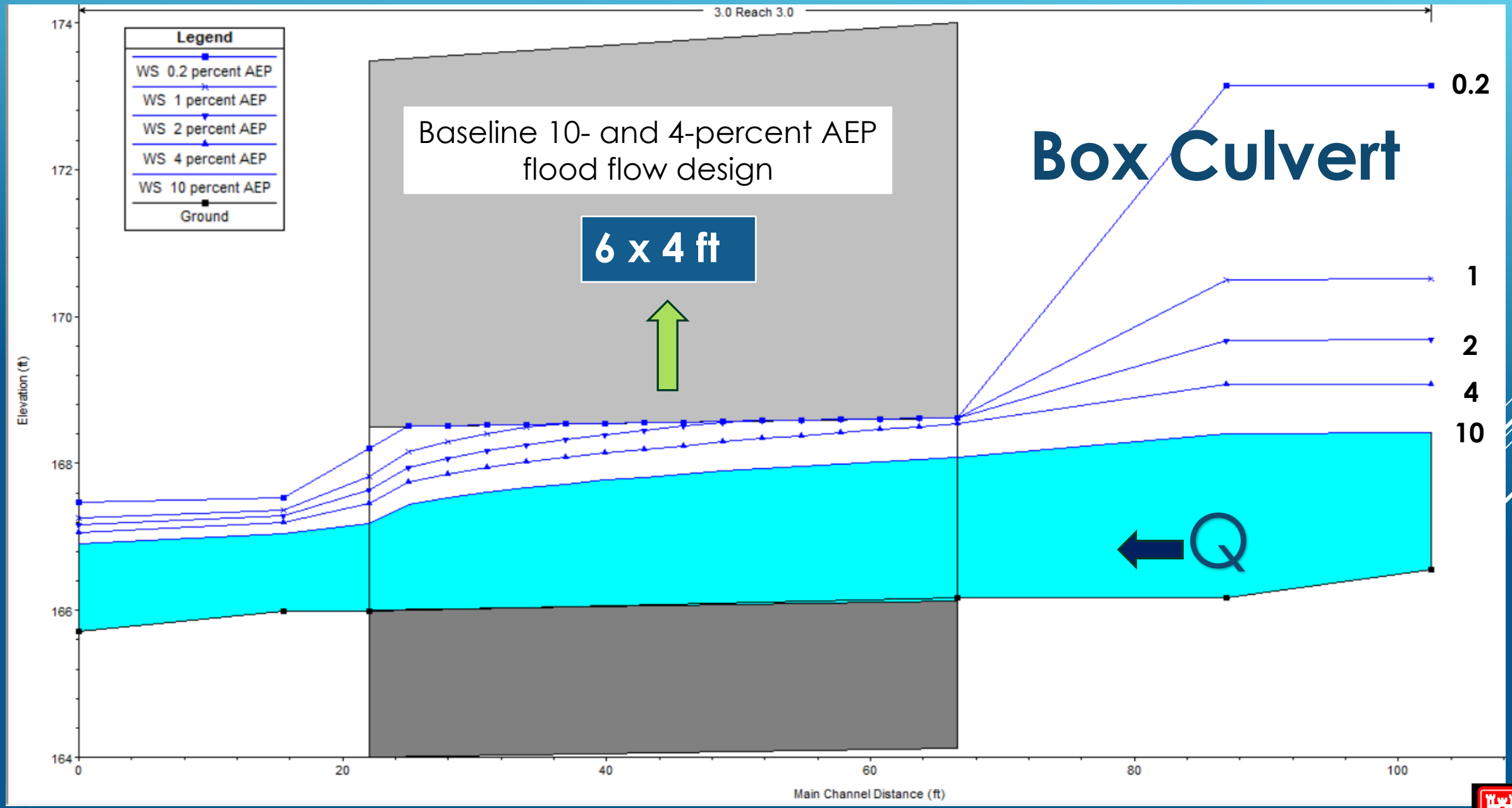

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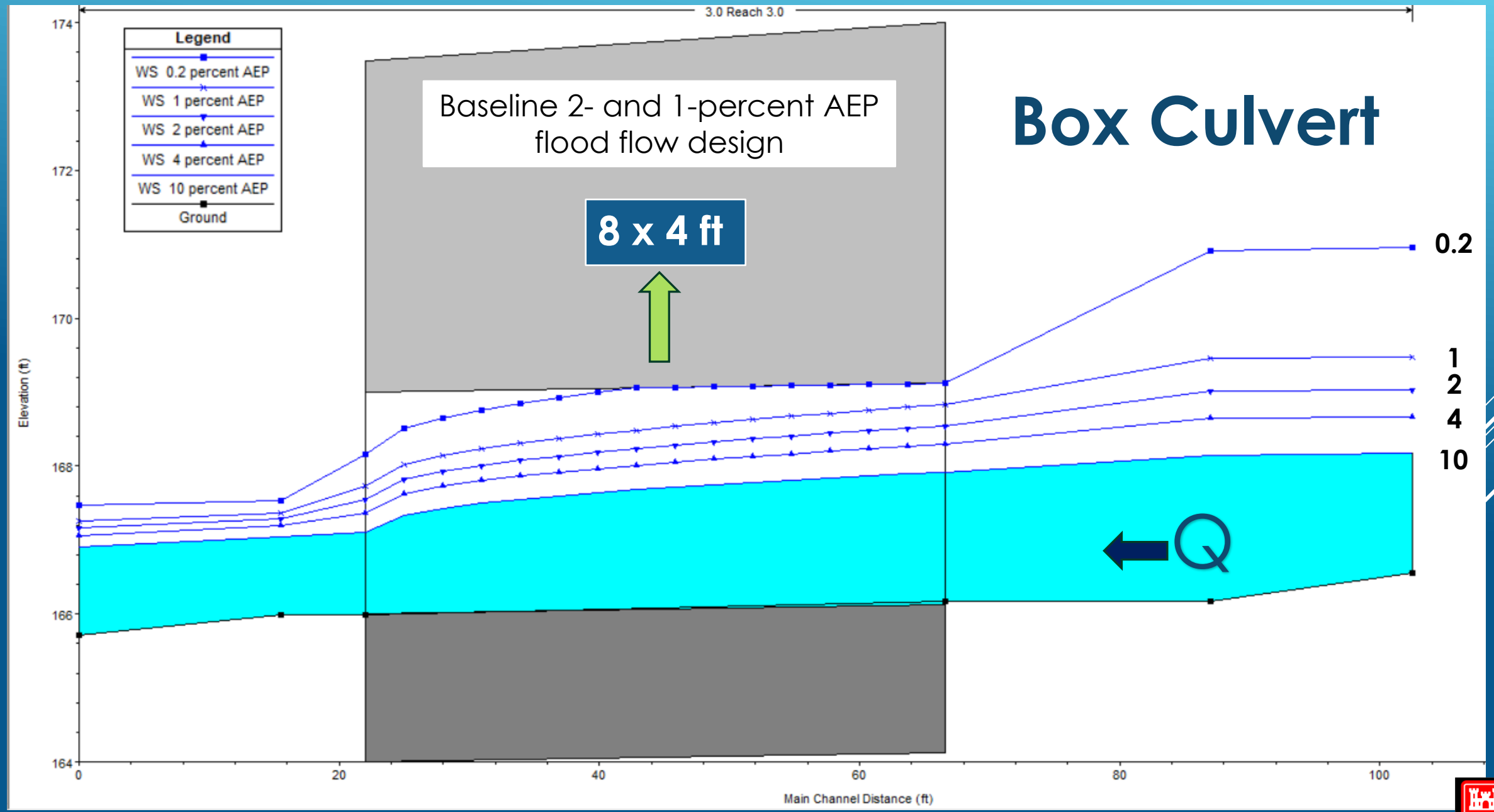

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STREAM HABITAT QUALITY AND CONNECTIVITY CHARACTERISTICS

Unacceptable

Maximum Extent Practicable (MEP)

Replacement in-kind

Baseline MassDOT Hydraulic Design Flow (10-, 4-, 2- or 1-percent AEP flood flow)

- Habitat Quality
- Stream connectivity

Stream Crossing Standards Design

USGS

HABITAT QUALITY

BioMap Aquatic Score

Coldwater Fisheries Resource

Diadromous Fish Run

Area of Critical Environmental Concern

Wild & Scenic River

Photos courtesy of *MA DFW, USFS, MA EOEEA, Kenneth Zirkel*

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STREAM CONNECTIVITY RESTORATION POTENTIAL

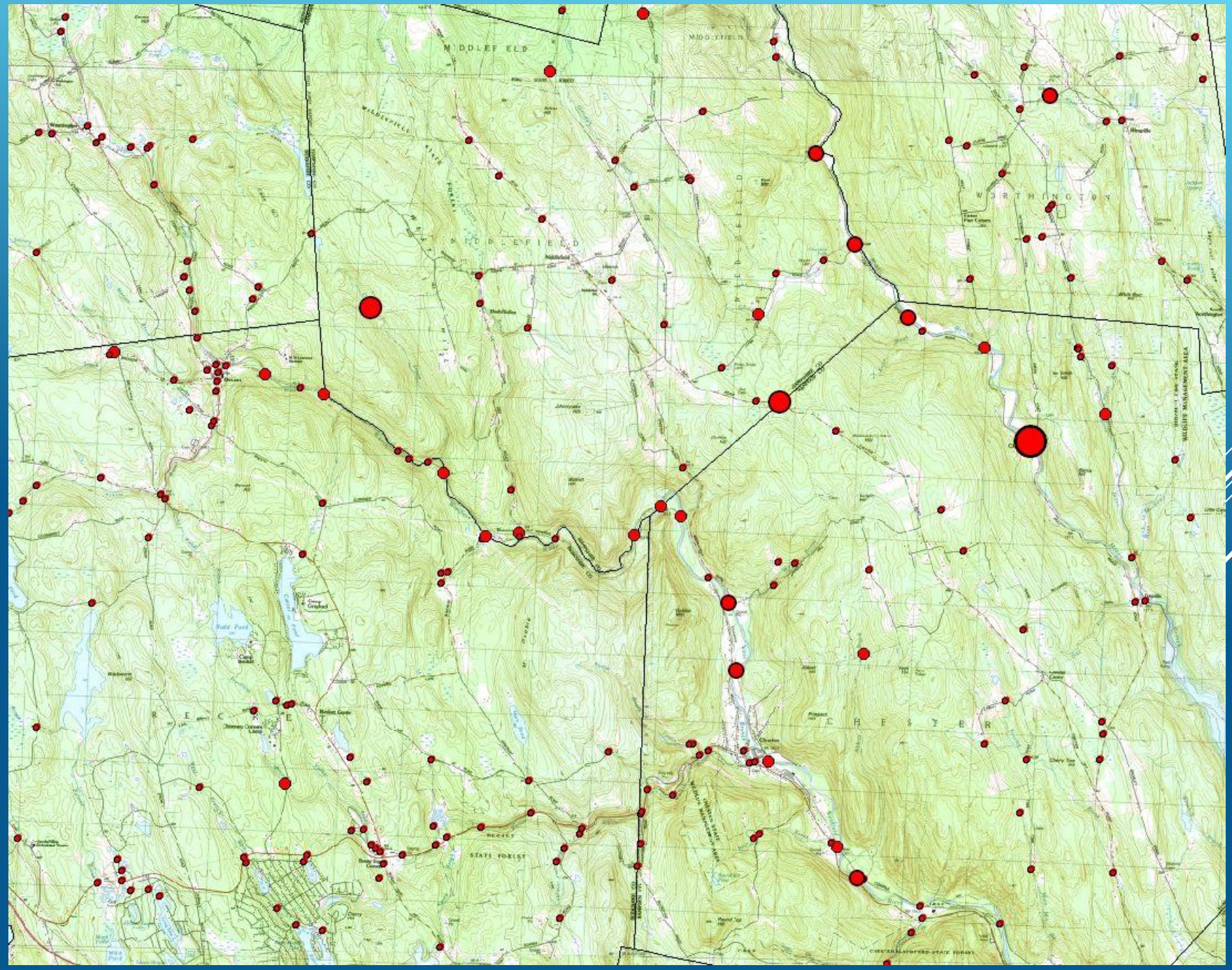

Photo courtesy of *University of Massachusetts at Amherst, Conservation Assessment and Prioritization System*

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STREAM CROSSING STANDARDS DESIGN

Unacceptable

Maximum Extent Practicable (MEP)

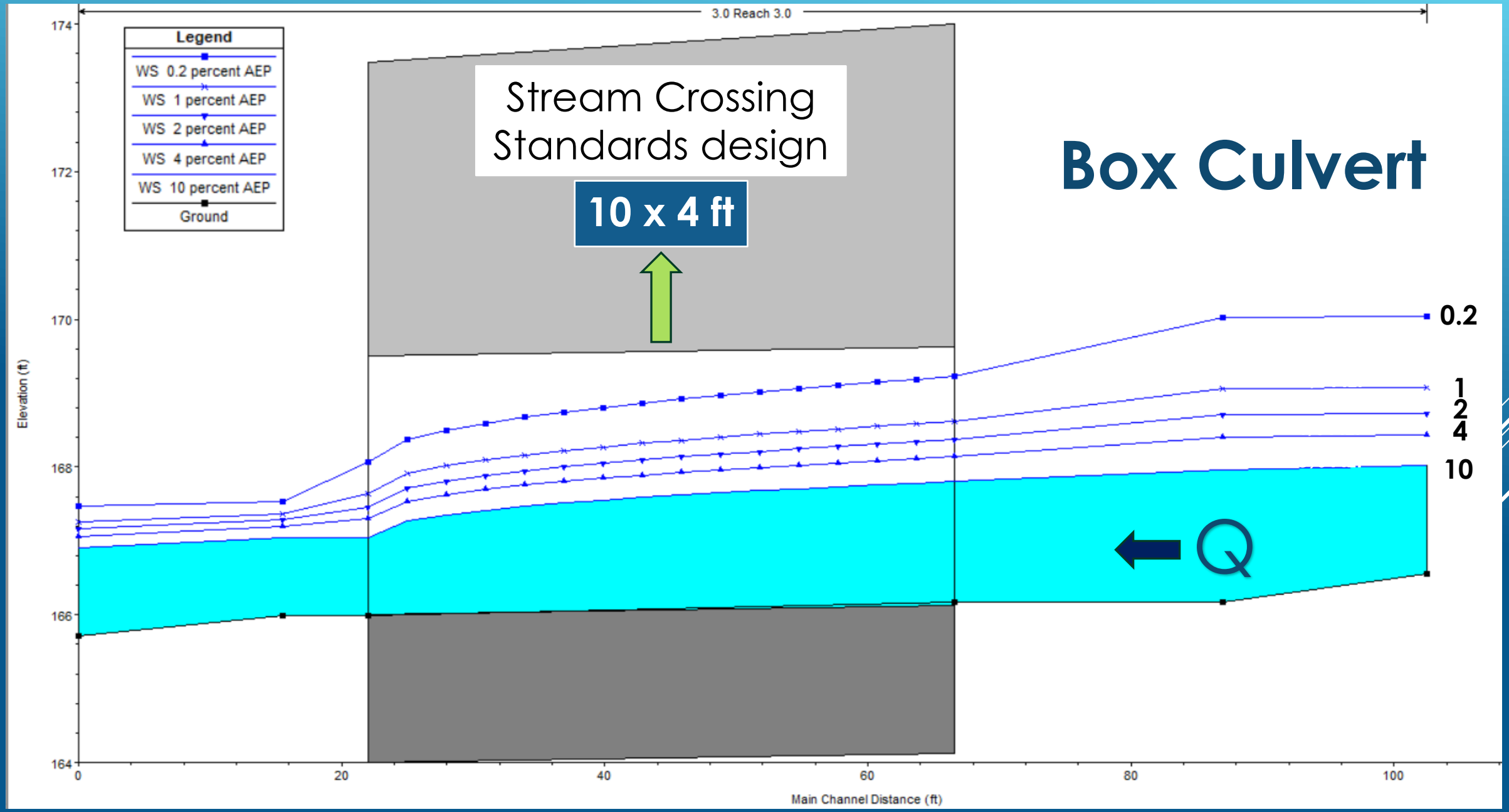
Replacement in-kind

Baseline MassDOT Hydraulic Design Flow (10-, 4-, 2- or 1-percent AEP flood flow)

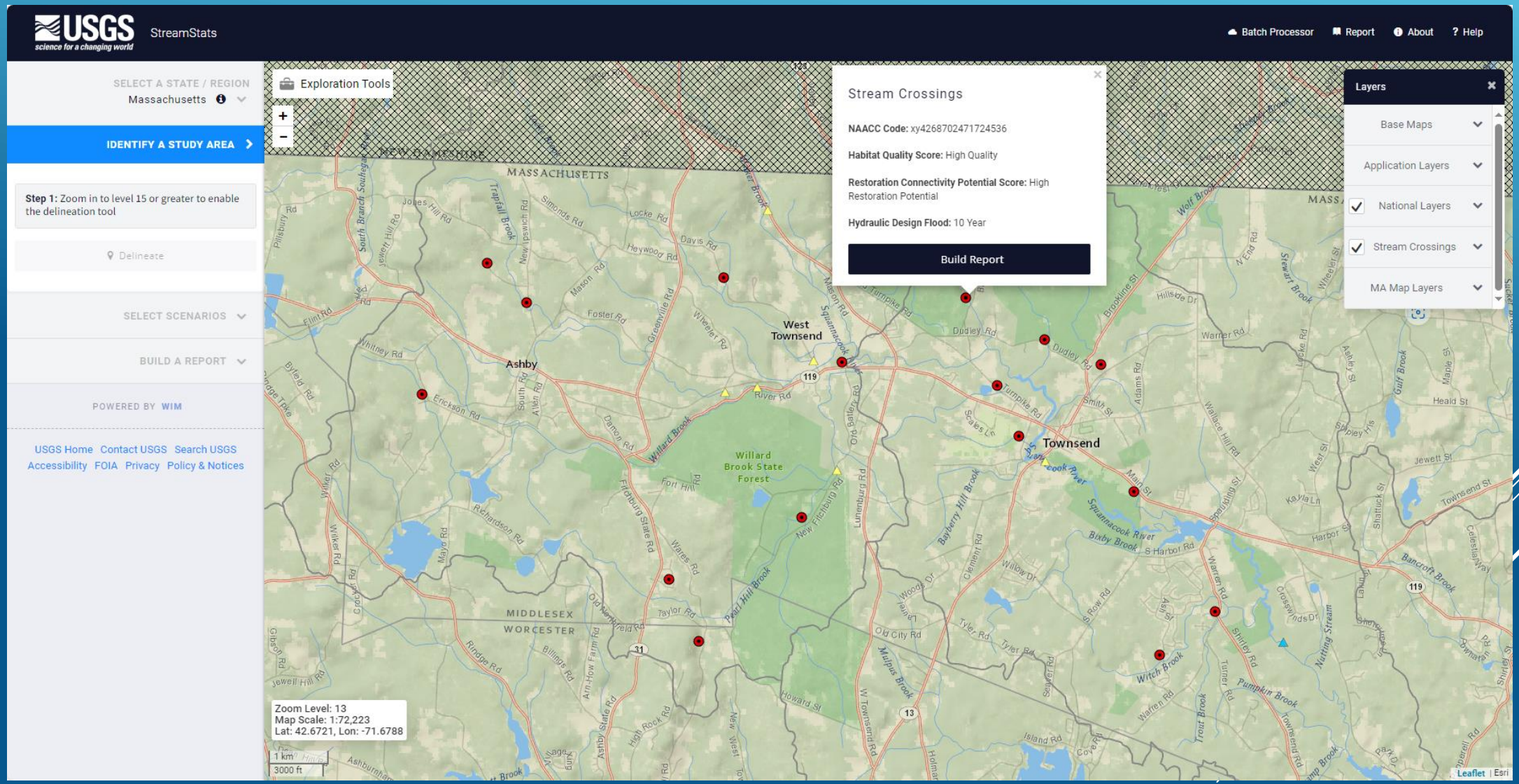
- Habitat Quality
- Stream connectivity

Stream Crossing Standards Design

USGS


3.0 Reach 3.0
Legend
WS 0.2 percent AEP
WS 1 percent AEP
WS 2 percent AEP
WS 4 percent AEP
WS 10 percent AEP
Ground
Stream Crossing Standards design
10 x 4 ft
Box Culvert
0.2
1
2
4
10
Q
Elevation (ft)
Main Channel Distance (ft)
174
172
170
168
166
164
0
20
40
60
80
100

STREAMSTATS WEB APPLICATION



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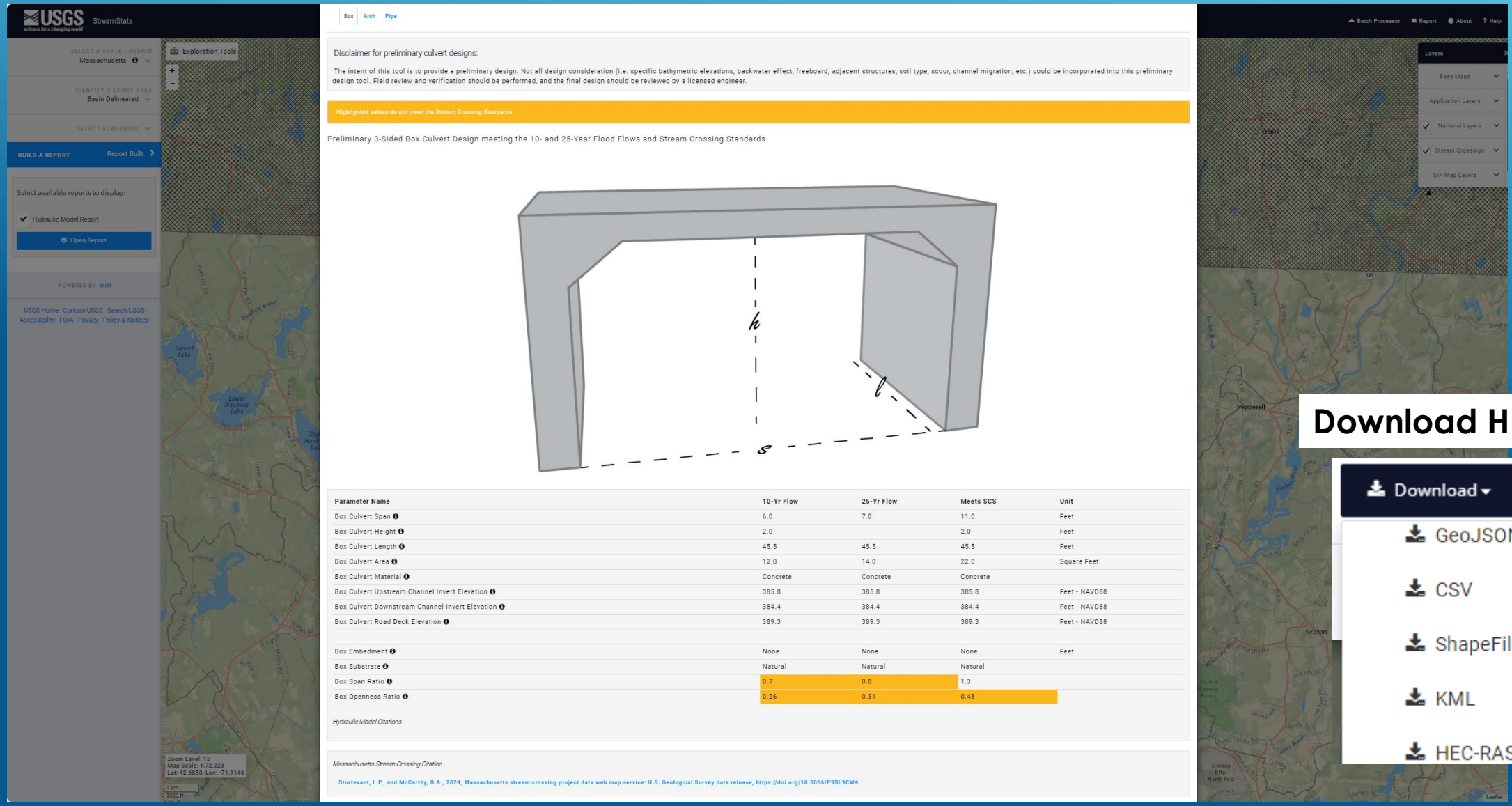
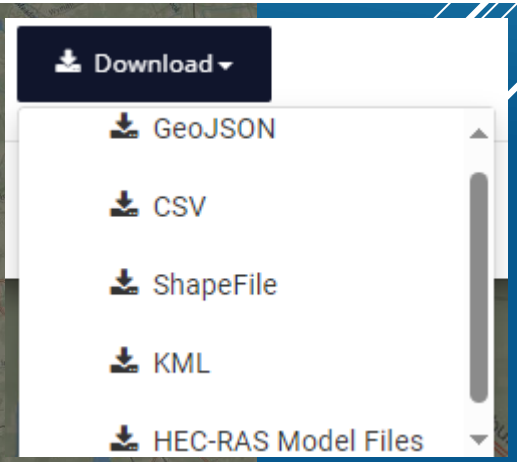
https://streamstats.usgs.gov/ss/

STREAMSTATS WEB APPLICATION



Download HEC-RAS files



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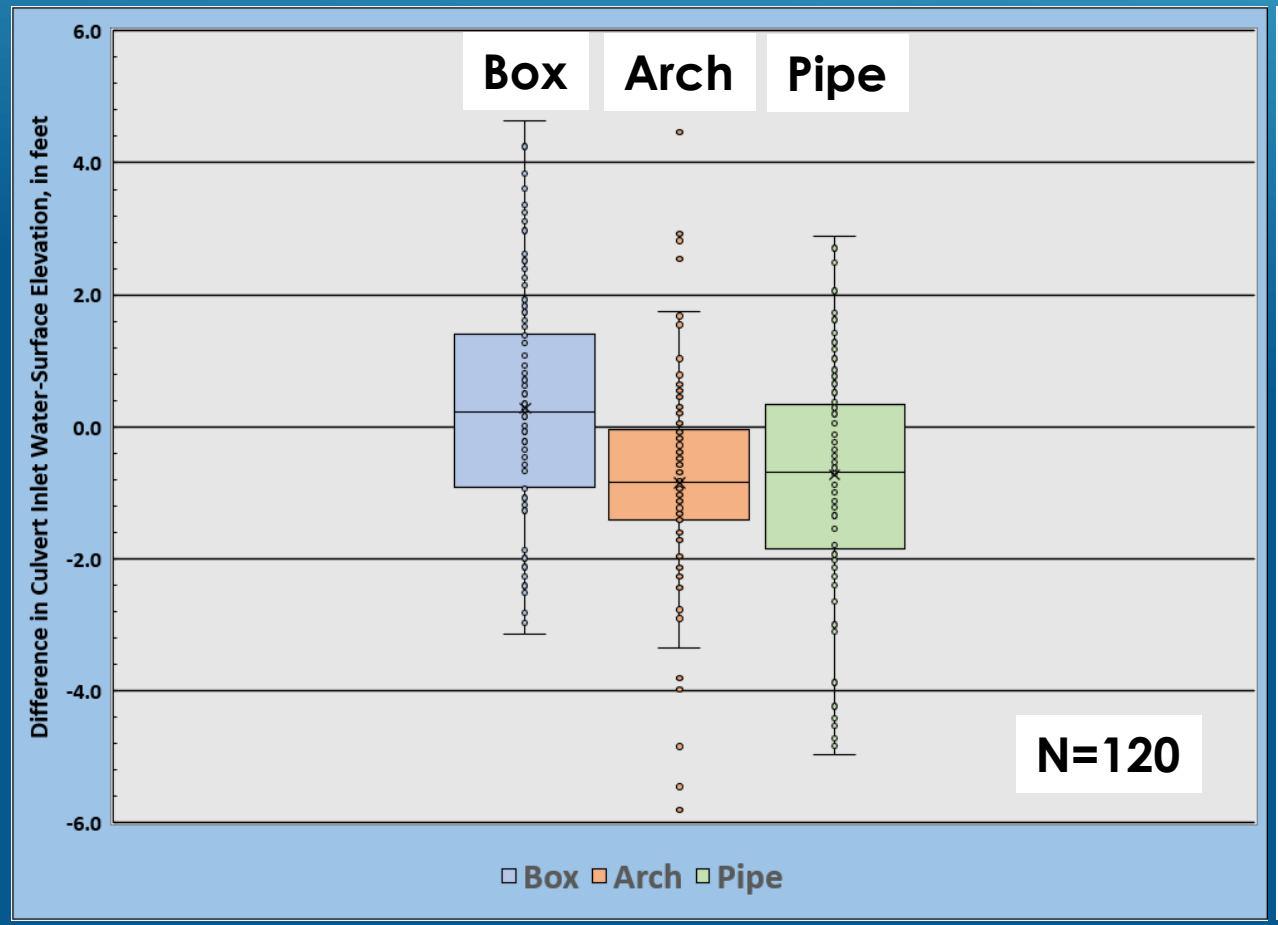
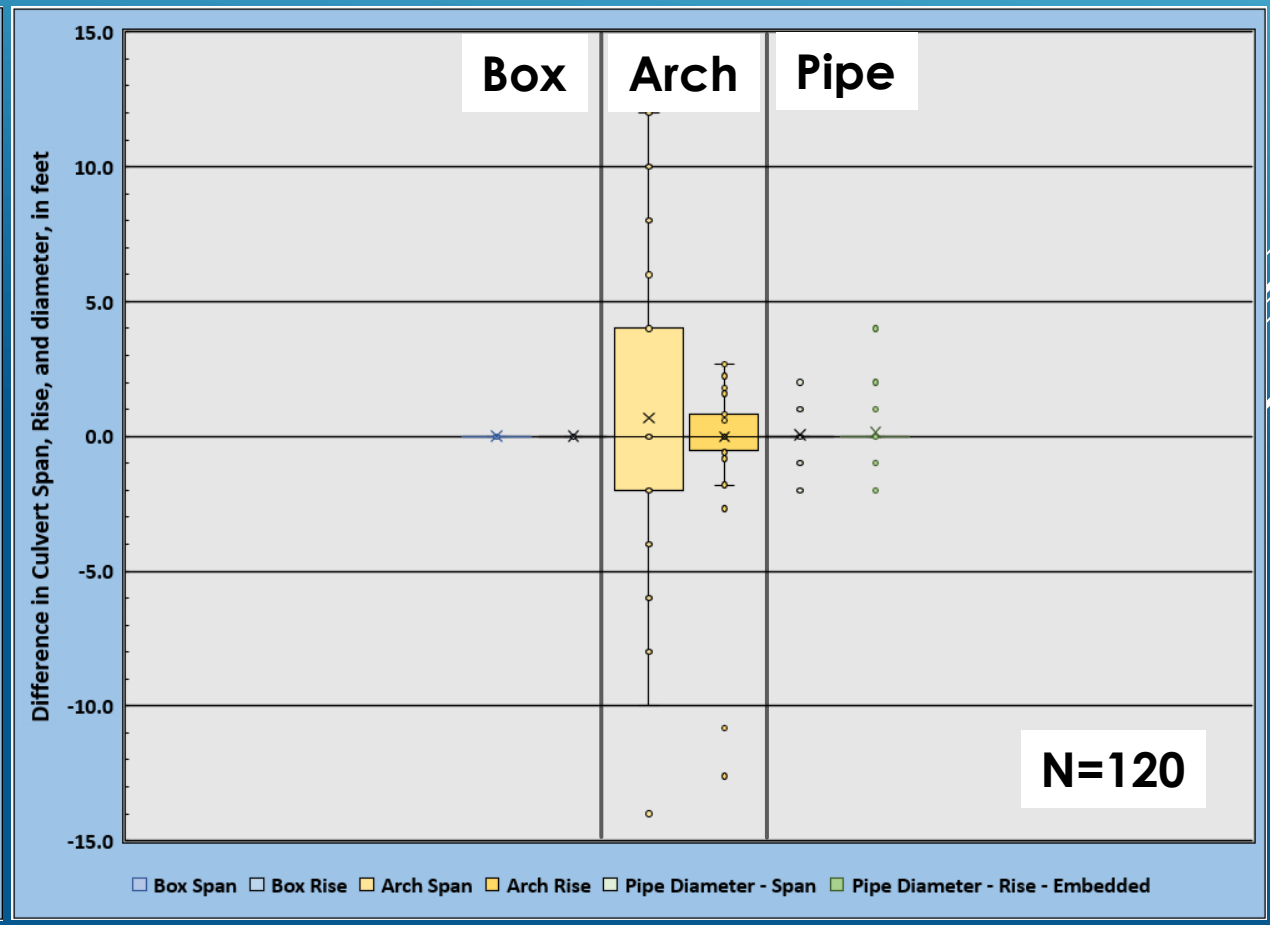
https://streamstats.usgs.gov/ss/

Comparison of GIS- and Field-Based Hydraulic Models

- Have 46 comparison sites with both GIS- and field-based hydraulic models across Massachusetts
- Comparing selected model inputs and outputs, such as thalweg elevations, water-surface elevations, velocities, culvert dimensions, etc.





USGS

Provisional Data – Subject to Revision – Do Not Copy or Release

Questions

USGS Team

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Mass DEP and UMass Teams

Lisa Rhodes, David Hilgeman, Christina Wu, Tom Maguire, and Scott Jackson (UMass Amherst)

Project Webpage

USGS science for a changing world