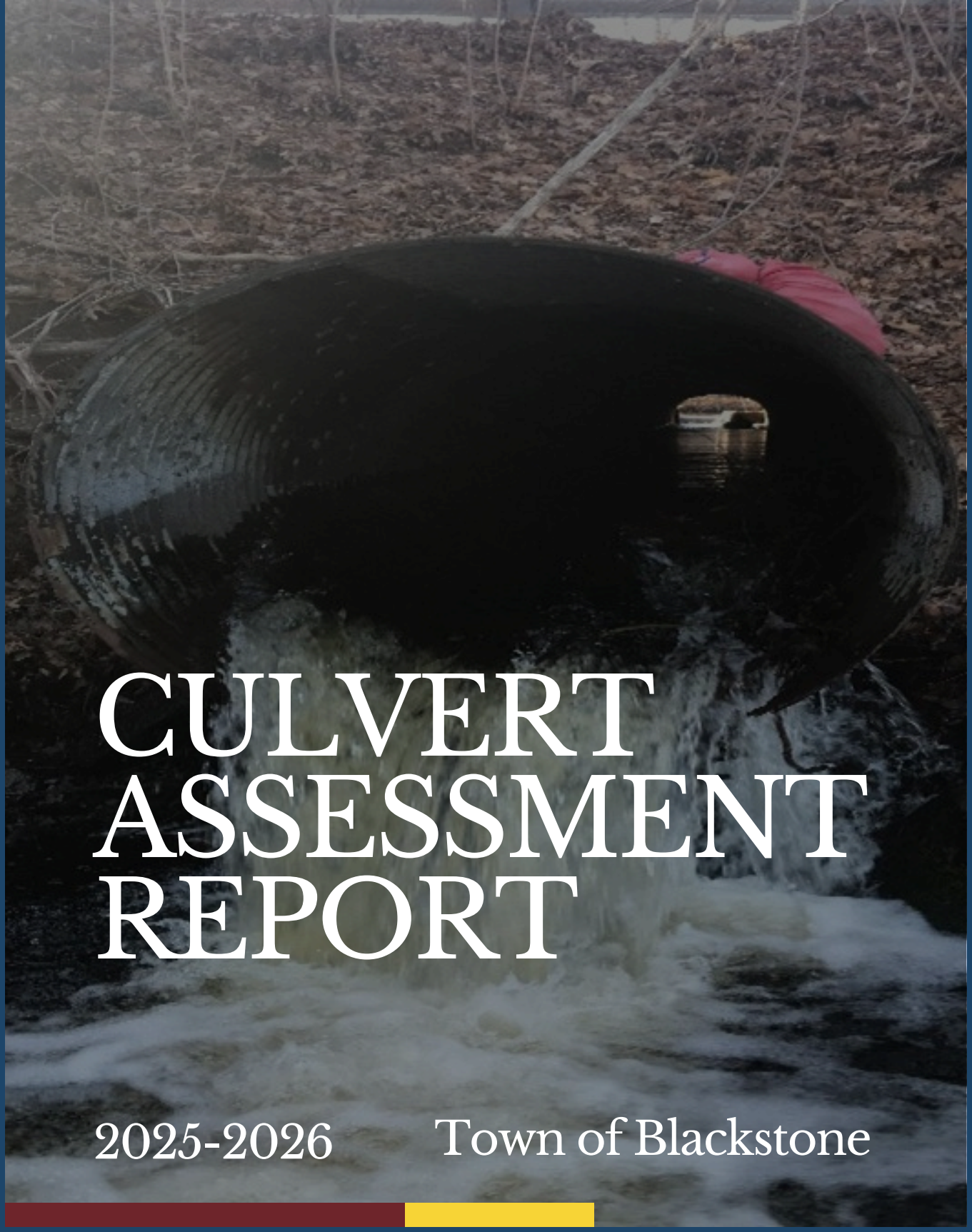


CULVERT ASSESSMENT REPORT

2025-2026

Town of Blackstone

Prepared by CENTRAL MASSACHUSETTS Regional Planning Commission

Table of Contents

Background

The Central Massachusetts Regional Planning Commission (CMRPC) began its Culvert Assessment Program in FFY 2021 as part of its Unified Planning Work Program (UPWP). As part of CMRPC's other data collection efforts, culvert assessments focus primarily on federal-aid eligible roads in the planning region. The purpose of this program is to help communities build resiliency through flood risk protection and mitigation by identifying culvert locations and prioritizing undersized culverts for replacement or restoration. This is especially important as the impacts from climate change and severe weather become increasingly frequent and many culverts are undersized relative to current stream flows. The CMRPC Water Module provides more details regarding the threats of climate change and the impacts of vulnerable culverts on transportation infrastructure, emergency services, inland buildings, economic loss, and more.

To assess culverts staff have received training and guidance from the North Atlantic Aquatic Connectivity Collaborative (NAACC) – a network focused on the aquatic passability at road-stream crossings.

The goal of the CMRPC culvert assessments and inventory for the Town of Blackstone is to provide a detailed list, report, and interactive mapping platform to help town officials identify and plan for culvert replacement or repairs.

North Atlantic Aquatic Connectivity Collaborative (NAACC)

The NAACC began in 2015 with startup funding from the North Atlantic Landscape Conservation Cooperative (NALCC) and US Department of the Interior (DOI) Hurricane Sandy Mitigation funds. The funds were used by the University of Massachusetts Amherst to convene a group of partners to develop a unified protocol for assessing aquatic passability at road-stream crossings and develop a programmatic infrastructure to support crossing assessments. As part of its efforts, the NAACC has:

- Developed a unified protocol, data form, scoring system, and database for road-stream crossing assessments to identify bridges and culverts that are problematic from an aquatic connectivity perspective.
- Launched in-person and online training and certification program to ensure data quality.
- Created online database for crossing assessment data.
- Developed web-based tools.
- Encouraged and supported efforts to conduct crossing assessments throughout the region.

The NAACC has separate protocols for both non-tidal and tidal streams, and they partner with the Massachusetts Division of Ecological Restoration (DER) to provide training and advise the group.

To ensure data quality the NAACC has set up a hierarchy of roles to maintain training, assessments, and data. It has separated these roles into three main categories, as summarized in **Table 1** on the following page.

Table 1: NAACC Roles, Responsibilities, and Training Requirements

Roles	Responsibilities	Training Requirements
L3 (Level 3) Coordinator	• Update field protocols • Create/update scoring systems • Develop QA/QC procedures • Maintain the online database • Spread news/updates to NAACC community	Must be referred to by other Central Coordinators
L2 (Level 2) Coordinator	• Oversee surveys in their geographic area • Recruit/supervise L1 Coordinators • Coordinate training • Ensure implementation of QA/QC procedures • Add/edit data and add/edit Lead Observers	• Certification as a Lead Observer • Online Coordinator training unit • Pass online Coordinator training unit test
L1 (Level 1) Coordinator	• Recruit/supervise Lead Observers • Create maps and determine survey locations • Establish standards and expectations for safety • Ensure adherence to protocols and QA/QC procedures • Field audit 10% of a Lead Observer's first 50 records • Review and approve data uploaded to database • Add/edit data, and add/edit Lead Observers	• Certification as a Lead Observer • Online Coordinator training unit • Must pass online Coordinator training unit test
Lead Observer	• Lead survey teams • Coordinate survey materials and schedules • Collect field data • Match survey locations to xy codes • Ensure assessments are done safely • Enter data into online database	• Non-tidal protocol training (in-person/online) and pass quiz • Non-tidal field training • Shadow a certified Lead Observer/Coordinator (20 crossings)

Currently, CMRPC staff have one L1 Coordinator and multiple Lead Observers to assess and upload data to the NAACC online database. CMRPC also partners with the NAACC and other stakeholders to host training opportunities within the region when available. According to GIS data provided by the NAACC, there are over 5,000 culverts in the CMRPC region. Many of these culverts have not been assessed. By training others in the region, especially municipal staff, everyone can work together to assess all culverts in the region and identify those that need repair or replacement.

Assessments

Culvert assessments in the Town of Blackstone were conducted in 2025-2026. Per the NAACC online database, there are at least 69 crossings (e.g., culverts, small bridges, and bridges) in the Town of Blackstone. 21 structures are along federal-aid eligible roadways, which staff focused on for data collection efforts. In these efforts, six crossings were either inaccessible, partially inaccessible, or deemed no crossing in the field. Additionally, staff assessed two crossings that were not along federal-aid eligible roadways, as requested by Town of Blackstone staff during initial outreach in 2025. This includes a total of 23 locations that were visited for data collection efforts.

Assessments included the verification of the structure location, NAACC non-tidal field assessment, and photos of the inlet, outlet, upstream, and downstream (if possible). The data collected during these assessments can be found in this report, the ArcGIS Online Dashboard, and on the NAACC online database.

Not included in the CMRPC culvert assessment efforts are:

- Inspection of bridges (these are regularly inspected by MassDOT)
- Inspection of the interior of the culverts
- Hydraulic analysis or structural analysis
- Inspection of culverts along Interstates or dangerous areas along state routes
- Inspection of culverts along non-federal aid eligible roadways (unless otherwise requested)

ArcGIS Online Dashboard

In addition to this report, which includes a table and a map, CMRPC has developed an interactive ArcGIS Online Dashboard. The dashboard includes an interactive map, charts and filters, different layers (e.g., MassDOT Bridges and FEMA Flood Zones), and links to key resources, including this report.

The Dashboard is available to the public and is a great resource for the town to map culverts and identify vulnerable crossings.

View the Town of Blackstone Culvert Dashboard.

Grants and Future Repairs

The NAACC culverts scoring system can be used to help identify crossings that may need repairs or replacement. The barrier types (explained in **Table 2**) can be used to determine which culverts should be prioritized relative to the others. The “Moving Forward” section will review

recommendations for priority culverts based on these scores. This section will also review grant opportunities to help fund costly culvert repair or replacement projects.

Definitions

Culvert

According to MassDOT, a culvert is a structure with a span of less than 10 feet in length that supports a roadway or other access way over a stream or waterbody. According to the MassDOT Roadway Culverts GIS Layer, MassDOT has a total of 5,863 culverts in their statewide online database, which includes 1 municipally-owned culvert in the Town of Blackstone.[1]

Visit the Town of Blackstone Culvert Dashboard to view the MassDOT culverts.

Short Span Bridge

According to MassDOT, a short span bridge is a structure with a span between 10 feet and 20 feet that supports a roadway or other access way over a water body or stream. These are categorized as "BRI" structures. According to the MassDOT Bridges GIS Layer, there are 2 municipally-owned short span bridges in the Town of Blackstone.[1]

Visit the Town of Blackstone Culvert Dashboard to view the MassDOT short span bridges.

Bridge

According to MassDOT, a bridge is a structure with a span of 20 feet or greater. These are categorized as National Bridge Inventory (NBI) structures. MassDOT inspects NBI bridges on a bi-annual basis. According to the MassDOT Bridges GIS Layer, there are 10 bridges in the Town of Blackstone. Four of these structures are owned by MassDOT and five of these structures are municipally-owned.[1]

Visit the Town of Blackstone Culvert Dashboard to view the MassDOT bridges.

CMRPC Culvert Assessments

CMRPC used the **NAACC Non-Tidal Aquatic Connectivity Stream Crossing Survey Data Form** (see **Appendix 1** for a copy of the form) to assess crossings in the Town of Blackstone. CMRPC digitized the paper form using ArcGIS Survey123 to improve overall field data collection. In addition to images of the inlet, outlet, upstream, and downstream, other data that is collected for an assessment includes:

- Flow condition
- Alignment

[1] "MassDOT Bridge and Structure Viewer (accessible version)" - https://gis.massdot.state.ma.us/bridges/

- Tailwater scour pool
- Constriction
- Inlet/outlet dimensions
- Outlet drop to water surface and stream bottom
- Physical barriers
- Water velocity

The completed assessment data for a culvert is then uploaded to the NAACC Data Center where it receives scoring for Aquatic Passability and Barrier Type (see **Appendix 2** to review the scoring system). CMRPC uses the numeric scoring system defined by the NAACC to record and map the Barrier Type of culverts. For mapping purposes, NAACC bases the following narrative descriptors for different ranges of aquatic passability and barriers in **Table 2** below.

Table 2: NAACC Culvert Aquatic Passability Scoring Categories*

Aquatic Passability Score	Barrier Type
1.00	No Barrier
0.80 - 0.99	Insignificant Barrier
0.60 - 0.79	Minor Barrier
0.40 - 0.59	Moderate Barrier
0.20 - 0.39	Significant Barrier
0.00 - 0.19	Severe Barrier

**The relationship between these categories and the actual passability for fish and other aquatic organisms is relatively unknown and is still a fruitful area for future research. The concept of aquatic passability is complicated and includes many variables that make it difficult to create a definitive scoring system. The best way to approach these aquatic passability scores and barrier types is that they represent the degree to which a crossing deviates from an ideal. It is assumed that crossings that are very close to the ideal (scores over 0.6) will present only minor or insignificant barriers to aquatic organisms. Structures that are farthest from the ideal (scores below 0.4) are likely to be either significant or severe barriers.*

The NAACC Data Center includes an individual assessment report for each culvert, which has its images, data, and scoring results.

Culvert Inventory and Results

Overview

As was previously mentioned, there are about 69 culverts in the Town of Blackstone and 21 structures along federal-aid eligible roads.

Staff completed culvert assessments along federal-aid eligible roads in the Town of Blackstone. These included:

- Blackstone Street
- Elm Street
- Summer Street
- Lincoln Street
- Park Street
- Farm Street
- Federal Street
- Main Street (Route 122)
- Canal Street
- Saint Paul Street
- Mendon Street

Staff also completed two culvert assessments that were requested by Town of Blackstone staff. These were not located along federal aid roadways. These included:

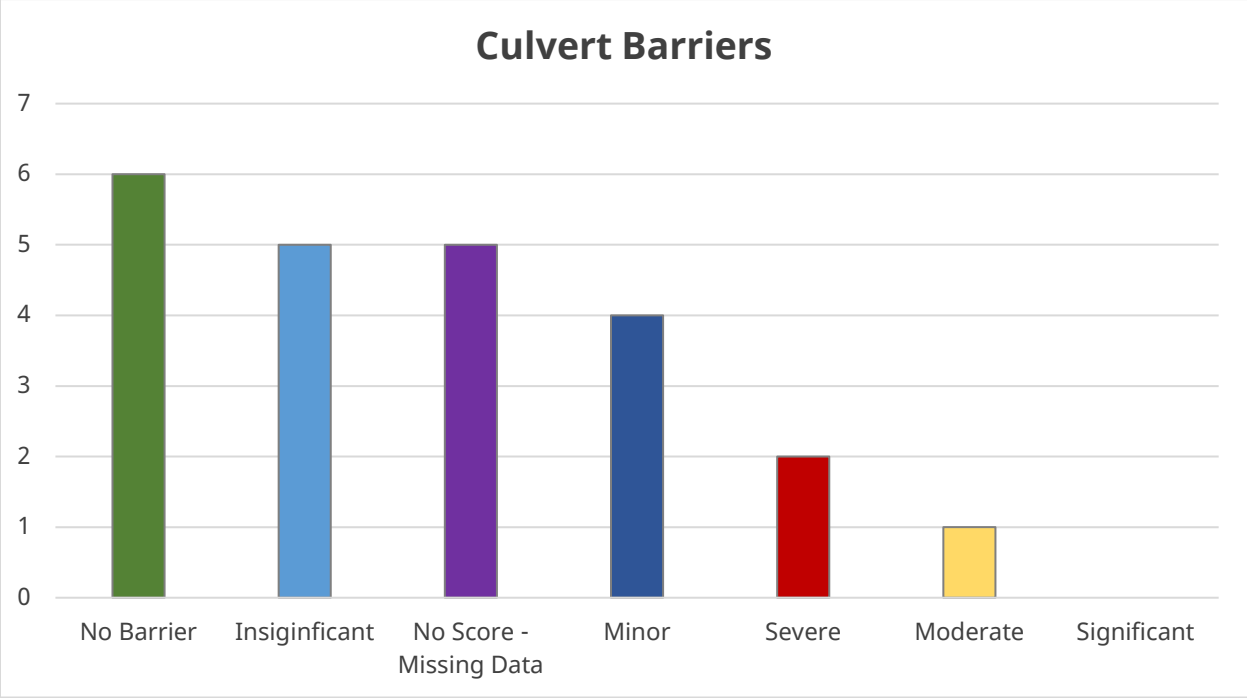
- Mendon Street
- Farm Street (north of Summer Street)

Staff do not assess culverts along Interstates as part of data collection efforts.

Culvert Results

In total, CMRPC staff assessed all 21 locations along the federal-aid eligible roads and 2 town-requested culverts that were not along federal-aid eligible roads. Below, **Figure 1** displays the 2025-2026 CMRPC assessment results grouped by Barrier Type, as previously defined in Section 2.

Figure 1: 2025-2026 Town of Blackstone CMRPC Assessment Results by Barrier



All 6 culverts that are labeled as “No Barrier” are either Bridge Adequate or No Crossing.

On the following page, **Table 3** summarizes the results for each culvert assessment. The table includes the NAACC Crossing Code, road name, NAACC Aquatic Passability (AP) Score, NAACC Barrier Type, flood zone. There were locations on the NAACC GIS layer that either did not have a culvert or were inaccessible/partially inaccessible when visited in the field. Those locations are also noted on the table. The crossing code can be clicked to view the structure on the NAACC Data Center for a full report of the structure, including its images and assessment data.

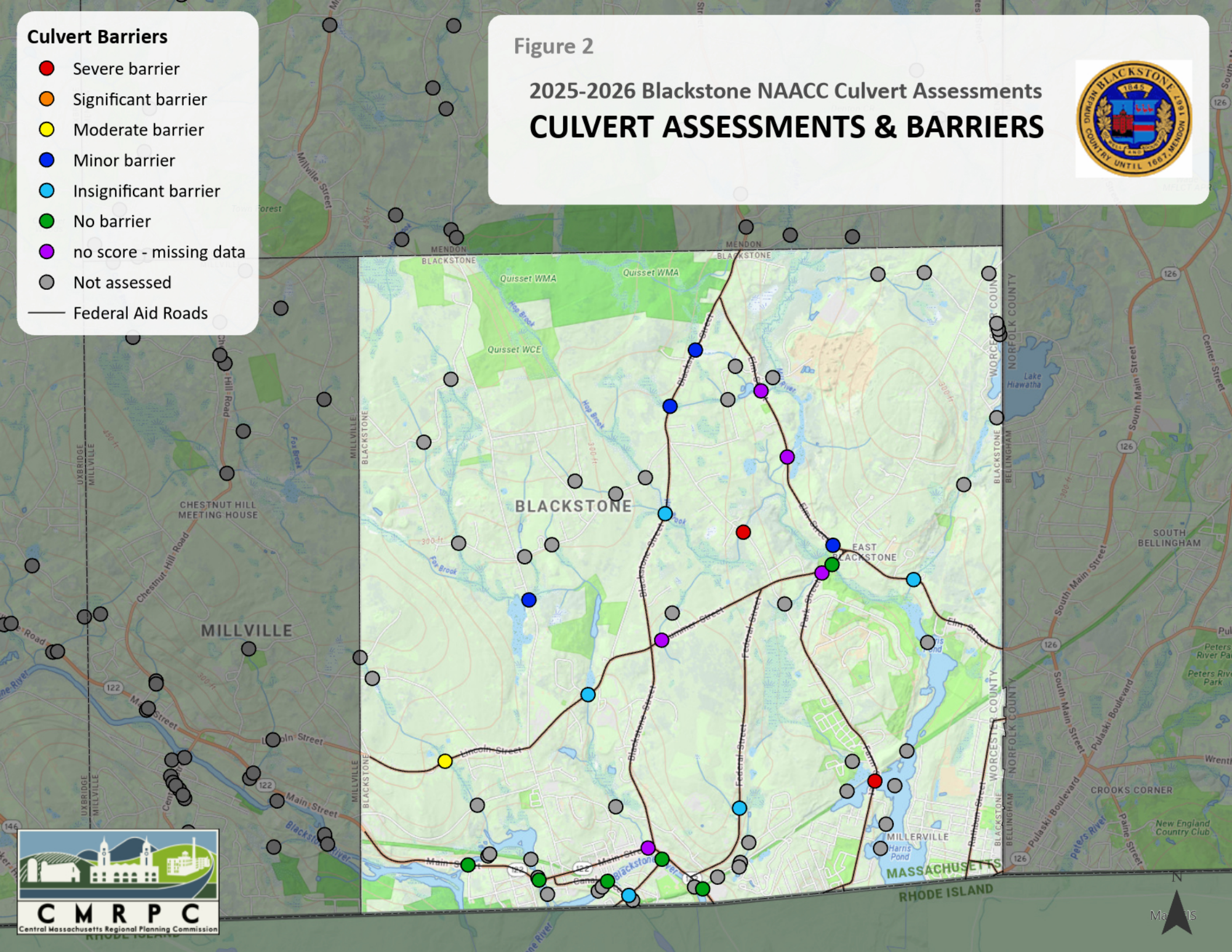
Table 3: 2025-2026 Town of Blackstone CMRPC Assessment Results

Crossing Code	Road	Barrier Type	Crossing Type	Flood Zone	Notes
xy4204321771524686	Farm Street	Severe	Culvert	Yes	Hop Brook; considerable outlet drop
xy4202438771511287	Farm Street	Severe	Culvert	Yes	Considerable outlet drop and scour pool; connects to Harris Pond
xy4202588771555071	Lincoln Street	Moderate	Culvert	No	Aldrich Brook; outlet drop; outlet debris build-up
xy4204222371515560	Elm Street	Minor	Culvert	No	Mill River tributary; debris build-up; large scour; flood zone upstream
xy4203809171546532	Mendon Street	Minor	Culvert	Yes	Fox Brook; box culvert; outlet deeper than inlet
xy4205699371529571	Blackstone Street	Minor	Culvert	No	Inlet drop
xy4205274271532150	Blackstone Street	Minor	Culvert	No	May be undersized
xy4203962771507347	Elm Street	Insignificant	Culvert	Yes	Quick Stream; dry passage; ok condition
xy4203092471540507	Lincoln Street	Insignificant	Culvert	No	Fox Brook; dam upstream feeding into culvert; new culvert

Crossing Code	Road	Barrier Type	Crossing Type	Flood Zone	Notes
xy4201573271536357	Saint Paul Street	Insignificant	Bridge	Yes	25’ span; ok condition
xy4202233571525079	Federal Street	Insignificant	Multiple Culvert	No	Inlet inaccessible (residential property)
xy4204461271532651	Blackstone Street	Insignificant	Culvert	Yes	Hop Brook; box culvert; good condition
xy4204076871515657	Summer Street	No Barrier	Bridge Adequate	Yes	Mill River; Bridge; good condition; not structurally deficient
xy4201689471545504	Main Street	No Barrier	Bridge Adequate	Yes	Blackstone River; Bridge; good condition;
xy4201847171532975	Saint Paul Street	No Barrier	Bridge Adequate	Yes	Blackstone River; Bridge; good condition
xy4201622371528833	Main Street	No Barrier	No Crossing	-	No crossing at location
xy4201803871552734	Main Street	No Barrier	Bridge Adequate	Yes	Blackstone River; bridge; good condition
xy4201680071538524	Canal Street	No Barrier	Bridge Adequate	Yes	Blackstone River; bridge; okay condition; dam downstream
xy4203504471533008	Summer Street	No Score – Missing Data	Inaccessible	No	Inlet/outlet covered by extreme overgrowth

Crossing Code	Road	Barrier Type	Crossing Type	Flood Zone	Notes
xy4205390171522887	Elm Street	No Score – Missing Data	Partially Inaccessible	Yes	Outlet inaccessible due to extreme overgrowth
xy4204013071516686	Park Street	No Score – Missing Data	Inaccessible	Yes	Could not locate culvert, if there is one
xy4201931971534395	Main Street	No Score – Missing Data	Inaccessible	Yes	Inaccessible due to property blockage
xy4204890471520218	Elm Street	No Score – Missing Data	Inaccessible	Yes	Inaccessible due to fencing/guardrails

On the following page, **Figure 2** shows a map of the assessment results in the Town of Blackstone. The map displays culverts by barrier type and federal-aid eligible roads.


Culvert Barriers
Severe barrier
Significant barrier
Moderate barrier
Minor barrier
Insignificant barrier
No barrier
no score - missing data
Not assessed
Federal Aid Roads
Figure 2
2025-2026 Blackstone NAACC Culvert Assessments
CULVERT ASSESSMENTS & BARRIERS
BLACKSTONE
MILLVILLE
MENDON
EAST BLACKSTONE
SOUTH BELLINGHAM
MILLERVILLE
CROOKS CORNER
MASSACHUSETTS
RHODE ISLAND
Quisset WMA
Quisset WCE
Hog Brook
Fox Brook
Lake Hiawatha
Harris Pond
CHESTNUT HILL MEETING HOUSE
Chestnut Hill Road
Millville Street
Hill Road
Blackstone Street
Federal Street
Lincoln Street
Main Street
South Main Street
Pulaski Boulevard
Elm Street
Pond Street
Paine Street
Center Street
Peters River
New England Country Club
NORFOLK COUNTY
WORCESTER COUNTY
CMRPC
Central Massachusetts Regional Planning Commission

Moving Forward

Recommendations

After assessing the culvert structures, prioritizing which culverts to replace or repair is an important next step. While it is important to begin reviewing the culverts that received scores between severe and moderate barriers, it is equally as important to review every culvert's potential for repair or replacement. **Table 4** below lists the top 5 culverts that staff recommend prioritizing for potential repair, replacement, and related flood prevention improvements (i.e., debris removal).

Table 4: Town of Blackstone Culvert Prioritization List

Crossing Code	Road	Barrier	Flood Zone	Notes
xy4204321771524686	Farm Street	Severe	Yes	Hop Brook; considerable outlet drop
xy4202438771511287	Farm Street	Severe	Yes	Considerable outlet drop and scour pool; connects to Harris Pond
xy4202588771555071	Lincoln Street	Moderate	No	Aldrich Brook; outlet drop; outlet debris build-up
xy4205274271532150	Blackstone Street	Minor	No	May be undersized
xy4205699371529571	Blackstone Street	Minor	No	Inlet drop

Funding

Funding for the repair or replacement of stream crossings can be a substantial challenge for many municipalities. However, there are many federal and state funding opportunities that help support culvert repair or replacement projects, like the Massachusetts Division of Ecological Restoration (DER) Culvert Replacement Municipal Assistance (CRMA) Grant Program or the MassDOT Community Culvert Grant Program. Staff highly suggest that the Town of Blackstone consider the following grant programs summarized in **Table 5**, on the following page, to repair or replace the vulnerable culverts identified in this report, or any other prioritized culverts.

Table 5: Culvert Funding Opportunities

Funding Opportunity	About	Link
Culvert Replacement Municipal Assistance (CRMA) Grant	For communities in Massachusetts interested in replacing an undersized, perched, and/or degraded culvert located in an area of high ecological value. Funding encourages applicants to replace aging culverts with better designed crossings that meet improved structural and environmental design standards and flood resiliency criteria. Projects are required to meet the goals of the Massachusetts Stream Crossing Standards.	https://www.mass.gov/how-to/culvert-replacement-municipal-assistance-grant-program
MassDOT Community Culvert Grant Program	The Community Culvert Grant Program provides funding to municipalities for the modernization, repair, replacement, removal, and improved resiliency of culverts. Tribal governments may also apply. To be considered for funding, culverts must be on a local public way with an existing span of 10 feet or less. Both new and ongoing projects may be considered for funding. The Community Culvert Grant Program was launched in 2025.	https://transportationgrantcentral.mass.gov/s/program/a3Ics000001U0GYEA0/community-culvert-grant-program
Municipal Small Bridge Program	For communities in Massachusetts for the replacement, preservation, and rehabilitation of eligible bridges. Bridges must be on local public ways and must be on the State Bridge Inventory with a span between 10-20 feet.	https://www.mass.gov/municipal-small-bridge-program

Funding Opportunity	About	Link
Municipal Vulnerability Preparedness (MVP) Grant Program	The MVP grant program provides support for communities in Massachusetts to identify climate hazards, assess vulnerabilities, and develop action plans to improve resilience to climate change. Communities that complete the MVP process are eligible for MVP Action Grant funding to implement priority actions identified through the MVP planning process.	https://resilientma.mass.gov/mvp/
CMMPO Transportation Improvement Program (TIP)	The TIP is a planning document that lists all highway, bridge, transit, and intermodal projects in Central Massachusetts that are programmed to receive federal-aid funding. Projects that improve air quality and safety, projects of regional and statewide significance, and non-federal aid projects fully funded by the state are included in the TIP. Use MassDOT MaPIT to initiate new projects to be considered for the TIP.	https://www.mass.gov/info-details/massdot-highway-initiating-a-project
National Culvert Aquatic Organism Passage (AOP) Grant Program	Awards grants for projects for the replacement, removal, and repair of culverts or weirs that meaningfully improve or restore fish passage for anadromous fish.	https://www.fhwa.dot.gov/engineering/hydraulics/culverthyd/aquatic/culvertaop_grants.cfm

Funding Opportunity	About	Link
Building Resilient Infrastructure and Communities (BRIC)	FEMA/MEMA annual grant program to implement hazard mitigation projects that reduce risks from disasters and natural hazards. There is an added focus on infrastructure projects benefiting disadvantaged communities, nature-based solutions, and climate resilience and adaptation. The funds are administered through MEMA. Culverts are eligible for this grant.	https://www.mass.gov/service-details/building-resilient-infrastructure-and-communities-bric-flood-mitigation-assistance-fma-grant-programs
Flood Mitigation Assistance (FMA) Program	FEMA/MEMA annual grant program to reduce or eliminate long-term risk of flood damage to buildings, manufactured homes, and other structures insured under the National Flood Insurance Program (NFIP).	https://www.mass.gov/service-details/building-resilient-infrastructure-and-communities-bric-flood-mitigation-assistance-fma-grant-programs
Hazard Mitigation Grant Program (HMGP)	Massachusetts provides funding to projects that reduce loss of life, protect natural resources, property, infrastructure, public health, and the economy from natural hazards and climate change impacts through hazard mitigation and climate adaptation projects. Provides funding after a disaster to help reduce or eliminate risk to lives and property from natural hazards. Among the eligible projects includes drainage and culvert improvements. Funding is available to all communities.	https://www.mass.gov/info-details/hazard-mitigation-grant-program-hmgp#:~:text=The%20HMGP%20provides%20funds%20to,and%20property%20from%20natural%20hazards.

Training Opportunities

There are at least 46 culvert locations throughout the Town of Blackstone that have not been assessed. For opportunities to complete training to become a NAACC Lead Observer and assess local culverts, please **contact Zack Blais, Transportation Principal Planner, at zblais@cmrpc.org.**

Appendices

Appendix 1

This appendix includes the NAACC Non-Tidal Aquatic Connectivity Stream Crossing Survey Field Form that is used by CMRPC staff to conduct the culvert assessments. An individual must be certified as a NAACC Lead Observer to assess culverts using this form and upload the data to the NAACC Data Center.

AQUATIC CONNECTIVITY

Stream Crossing Survey

DATA FORM

DATABASE ENTRY BY _____ ENTRY DATE _____

DATA ENTRY REVIEWED BY _____ REVIEW DATE _____

CROSSING DATA

Crossing Code _____ **Local ID** (Optional) _____

Date Observed (00/00/0000) _____ **Lead Observer** _____

Town/County _____ **Stream** _____

Road _____ **Type** ☐ MULTILANE ☐ PAVED ☐ UNPAVED ☐ DRIVEWAY ☐ TRAIL ☐ RAILROAD

GPS Coordinates (Decimal degrees) ☐☐.☐☐☐☐☐ °N Latitude — ☐☐.☐☐☐☐☐ °W Longitude

Location Description

Crossing Type ☐ BRIDGE ☐ CULVERT ☐ MULTIPLE CULVERT ☐ FORD ☐ NO CROSSING ☐ REMOVED CROSSING ☐ BURIED STREAM ☐ INACCESSIBLE ☐ PARTIALLY INACCESSIBLE ☐ NO UPSTREAM CHANNEL ☐ BRIDGE ADEQUATE

Number of Culverts/ Bridge Cells _____

Photo IDs INLET _____ OUTLET _____ UPSTREAM _____ DOWNSTREAM _____ OTHER _____

Flow Condition ☐ NO FLOW ☐ TYPICAL-LOW ☐ MODERATE ☐ HIGH

Crossing Condition ☐ OK ☐ POOR ☐ NEW ☐ UNKNOWN

Tidal Site ☐ YES ☐ NO ☐ UNKNOWN

Alignment ☐ FLOW-ALIGNED ☐ SKEWED (>45°)

Road Fill Height (Top of culvert to road surface; bridge = 0) _____

Bankfull Width (Optional) _____ **Confidence** ☐ HIGH ☐ LOW/ESTIMATED

Tailwater Scour Pool ☐ NONE ☐ SMALL ☐ LARGE

Constriction ☐ SEVERE ☐ MODERATE ☐ SPANS ONLY BANKFULL/ ACTIVE CHANNEL ☐ SPANS FULL CHANNEL & BANKS

Crossing Comments

STRUCTURE 1

Structure Material ☐ METAL ☐ CONCRETE ☐ PLASTIC ☐ WOOD ☐ ROCK/STONE ☐ FIBERGLASS ☐ COMBINATION

OUTLET

Outlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED

Outlet Armoring ☐ NONE ☐ NOT EXTENSIVE ☐ EXTENSIVE

Outlet Grade (Pick one) ☐ AT STREAM GRADE ☐ FREE FALL ☐ CASCADE ☐ FREE FALL ONTO CASCADE ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Outlet Dimensions **A. Width** _____.____ **B. Height** _____.____ **C. Substrate/Water Width** _____.____ **D. Water Depth** _____.____

Outlet Drop to Water Surface _____.____ **Outlet Drop to Stream Bottom** _____.____ **E. Abutment Height** (Type 7 bridges only) _____.____

L. Structure Length (Overall length from inlet to outlet) _____.____

INLET

Inlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED

Inlet Type ☐ PROJECTING ☐ HEADWALL ☐ WINGWALLS ☐ HEADWALL & WINGWALLS ☐ MITERED TO SLOPE ☐ OTHER ☐ NONE

Inlet Grade (Pick one) ☐ AT STREAM GRADE ☐ INLET DROP ☐ PERCHED ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Inlet Dimensions **A. Width** _____.____ **B. Height** _____.____ **C. Substrate/Water Width** _____.____ **D. Water Depth** _____.____

ADDITIONAL CONDITIONS

Slope % (Optional) _____ **Slope Confidence** ☐ HIGH ☐ LOW

Internal Structures ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER _____

Structure Substrate Matches Stream ☐ NONE ☐ COMPARABLE ☐ CONTRASTING ☐ NOT APPROPRIATE ☐ UNKNOWN

Structure Substrate Type (Pick one) ☐ NONE ☐ SILT ☐ SAND ☐ GRAVEL ☐ COBBLE ☐ BOULDER ☐ BEDROCK ☐ UNKNOWN

Structure Substrate Coverage ☐ NONE ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ UNKNOWN

Physical Barriers (Pick all that apply) ☐ NONE ☐ DEBRIS/SEDIMENT/ROCK ☐ DEFORMATION ☐ FREE FALL ☐ FENCING ☐ DRY ☐ OTHER

Severity (Choose carefully based on barrier type(s) above) ☐ NONE ☐ MINOR ☐ MODERATE ☐ SEVERE

Water Depth Matches Stream ☐ YES ☐ NO-SHALLOWER ☐ NO-DEEPER ☐ UNKNOWN ☐ DRY

Water Velocity Matches Stream ☐ YES ☐ NO-FASTER ☐ NO-SLOWER ☐ UNKNOWN ☐ DRY

Dry Passage through Structure? ☐ YES ☐ NO ☐ UNKNOWN **Height above Dry Passage** _____

Comments

5/26/16

STRUCTURE 2

Structure Material ☐ METAL ☐ CONCRETE ☐ PLASTIC ☐ WOOD ☐ ROCK/STONE ☐ FIBERGLASS ☐ COMBINATION

OUTLET

Outlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED **Outlet Armoring** ☐ NONE ☐ NOT EXTENSIVE ☐ EXTENSIVE

Outlet Grade (Pick one) ☐ AT STREAM GRADE ☐ FREE FALL ☐ CASCADE ☐ FREE FALL ONTO CASCADE ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Outlet Dimensions **A. Width**_____.___ **B. Height**_____.___ **C. Substrate/Water Width**_____.___ **D. Water Depth**_____.___

Outlet Drop to Water Surface_____.___ **Outlet Drop to Stream Bottom**_____.___ **E. Abutment Height** (Type 7 bridges only)_____.___

L. Structure Length (Overall length from inlet to outlet)_____.___

INLET

Inlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED

Inlet Type ☐ PROJECTING ☐ HEADWALL ☐ WINGWALLS ☐ HEADWALL & WINGWALLS ☐ MITERED TO SLOPE ☐ OTHER ☐ NONE

Inlet Grade (Pick one) ☐ AT STREAM GRADE ☐ INLET DROP ☐ PERCHED ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Inlet Dimensions **A. Width**_____.___ **B. Height**_____.___ **C. Substrate/Water Width**_____.___ **D. Water Depth**_____.___

ADDITIONAL CONDITIONS

Slope % (Optional)_____ **Slope Confidence** ☐ HIGH ☐ LOW | **Internal Structures** ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER_____

Structure Substrate Matches Stream ☐ NONE ☐ COMPARABLE ☐ CONTRASTING ☐ NOT APPROPRIATE ☐ UNKNOWN

Structure Substrate Type (Pick one) ☐ NONE ☐ SILT ☐ SAND ☐ GRAVEL ☐ COBBLE ☐ BOULDER ☐ BEDROCK ☐ UNKNOWN

Structure Substrate Coverage ☐ NONE ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ UNKNOWN

Physical Barriers (Pick all that apply) ☐ NONE ☐ DEBRIS/SEDIMENT/ROCK ☐ DEFORMATION ☐ FREE FALL ☐ FENCING ☐ DRY ☐ OTHER

Severity (Choose carefully based on barrier type(s) above) ☐ NONE ☐ MINOR ☐ MODERATE ☐ SEVERE

Water Depth Matches Stream ☐ YES ☐ NO-SHALLOWER ☐ NO-DEEPER ☐ UNKNOWN ☐ DRY

Water Velocity Matches Stream ☐ YES ☐ NO-FASTER ☐ NO-SLOWER ☐ UNKNOWN ☐ DRY

Dry Passage through Structure? ☐ YES ☐ NO ☐ UNKNOWN **Height above Dry Passage**_____

Comments

STRUCTURE 3

Structure Material ☐ METAL ☐ CONCRETE ☐ PLASTIC ☐ WOOD ☐ ROCK/STONE ☐ FIBERGLASS ☐ COMBINATION

OUTLET

Outlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED **Outlet Armoring** ☐ NONE ☐ NOT EXTENSIVE ☐ EXTENSIVE

Outlet Grade (Pick one) ☐ AT STREAM GRADE ☐ FREE FALL ☐ CASCADE ☐ FREE FALL ONTO CASCADE ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Outlet Dimensions **A. Width**_____.___ **B. Height**_____.___ **C. Substrate/Water Width**_____.___ **D. Water Depth**_____.___

Outlet Drop to Water Surface_____.___ **Outlet Drop to Stream Bottom**_____.___ **E. Abutment Height** (Type 7 bridges only)_____.___

L. Structure Length (Overall length from inlet to outlet)_____.___

INLET

Inlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED

Inlet Type ☐ PROJECTING ☐ HEADWALL ☐ WINGWALLS ☐ HEADWALL & WINGWALLS ☐ MITERED TO SLOPE ☐ OTHER ☐ NONE

Inlet Grade (Pick one) ☐ AT STREAM GRADE ☐ INLET DROP ☐ PERCHED ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Inlet Dimensions **A. Width**_____.___ **B. Height**_____.___ **C. Substrate/Water Width**_____.___ **D. Water Depth**_____.___

ADDITIONAL CONDITIONS

Slope % (Optional)_____ **Slope Confidence** ☐ HIGH ☐ LOW | **Internal Structures** ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER_____

Structure Substrate Matches Stream ☐ NONE ☐ COMPARABLE ☐ CONTRASTING ☐ NOT APPROPRIATE ☐ UNKNOWN

Structure Substrate Type (Pick one) ☐ NONE ☐ SILT ☐ SAND ☐ GRAVEL ☐ COBBLE ☐ BOULDER ☐ BEDROCK ☐ UNKNOWN

Structure Substrate Coverage ☐ NONE ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ UNKNOWN

Physical Barriers (Pick all that apply) ☐ NONE ☐ DEBRIS/SEDIMENT/ROCK ☐ DEFORMATION ☐ FREE FALL ☐ FENCING ☐ DRY ☐ OTHER

Severity (Choose carefully based on barrier type(s) above) ☐ NONE ☐ MINOR ☐ MODERATE ☐ SEVERE

Water Depth Matches Stream ☐ YES ☐ NO-SHALLOWER ☐ NO-DEEPER ☐ UNKNOWN ☐ DRY

Water Velocity Matches Stream ☐ YES ☐ NO-FASTER ☐ NO-SLOWER ☐ UNKNOWN ☐ DRY

Dry Passage through Structure? ☐ YES ☐ NO ☐ UNKNOWN **Height above Dry Passage**_____

Comments

STRUCTURE 4

Structure Material ☐ METAL ☐ CONCRETE ☐ PLASTIC ☐ WOOD ☐ ROCK/STONE ☐ FIBERGLASS ☐ COMBINATION

OUTLET

Outlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED **Outlet Armoring** ☐ NONE ☐ NOT EXTENSIVE ☐ EXTENSIVE

Outlet Grade (Pick one) ☐ AT STREAM GRADE ☐ FREE FALL ☐ CASCADE ☐ FREE FALL ONTO CASCADE ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Outlet Dimensions **A. Width**_____.____ **B. Height**_____.____ **C. Substrate/Water Width**_____.____ **D. Water Depth**_____.____

Outlet Drop to Water Surface_____.____ **Outlet Drop to Stream Bottom**_____.____ **E. Abutment Height** (Type 7 bridges only)_____.____

L. Structure Length (Overall length from inlet to outlet)_____.____

INLET

Inlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED

Inlet Type ☐ PROJECTING ☐ HEADWALL ☐ WINGWALLS ☐ HEADWALL & WINGWALLS ☐ MITERED TO SLOPE ☐ OTHER ☐ NONE

Inlet Grade (Pick one) ☐ AT STREAM GRADE ☐ INLET DROP ☐ PERCHED ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Inlet Dimensions **A. Width**_____.____ **B. Height**_____.____ **C. Substrate/Water Width**_____.____ **D. Water Depth**_____.____

ADDITIONAL CONDITIONS

Slope % (Optional)_____ **Slope Confidence** ☐ HIGH ☐ LOW | **Internal Structures** ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER_____

Structure Substrate Matches Stream ☐ NONE ☐ COMPARABLE ☐ CONTRASTING ☐ NOT APPROPRIATE ☐ UNKNOWN

Structure Substrate Type (Pick one) ☐ NONE ☐ SILT ☐ SAND ☐ GRAVEL ☐ COBBLE ☐ BOULDER ☐ BEDROCK ☐ UNKNOWN

Structure Substrate Coverage ☐ NONE ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ UNKNOWN

Physical Barriers (Pick all that apply) ☐ NONE ☐ DEBRIS/SEDIMENT/ROCK ☐ DEFORMATION ☐ FREE FALL ☐ FENCING ☐ DRY ☐ OTHER

Severity (Choose carefully based on barrier type(s) above) ☐ NONE ☐ MINOR ☐ MODERATE ☐ SEVERE

Water Depth Matches Stream ☐ YES ☐ NO-SHALLOWER ☐ NO-DEEPER ☐ UNKNOWN ☐ DRY

Water Velocity Matches Stream ☐ YES ☐ NO-FASTER ☐ NO-SLOWER ☐ UNKNOWN ☐ DRY

Dry Passage through Structure? ☐ YES ☐ NO ☐ UNKNOWN **Height above Dry Passage**_____

Comments

STRUCTURE 5

Structure Material ☐ METAL ☐ CONCRETE ☐ PLASTIC ☐ WOOD ☐ ROCK/STONE ☐ FIBERGLASS ☐ COMBINATION

OUTLET

Outlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED **Outlet Armoring** ☐ NONE ☐ NOT EXTENSIVE ☐ EXTENSIVE

Outlet Grade (Pick one) ☐ AT STREAM GRADE ☐ FREE FALL ☐ CASCADE ☐ FREE FALL ONTO CASCADE ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Outlet Dimensions **A. Width**_____.____ **B. Height**_____.____ **C. Substrate/Water Width**_____.____ **D. Water Depth**_____.____

Outlet Drop to Water Surface_____.____ **Outlet Drop to Stream Bottom**_____.____ **E. Abutment Height** (Type 7 bridges only)_____.____

L. Structure Length (Overall length from inlet to outlet)_____.____

INLET

Inlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED

Inlet Type ☐ PROJECTING ☐ HEADWALL ☐ WINGWALLS ☐ HEADWALL & WINGWALLS ☐ MITERED TO SLOPE ☐ OTHER ☐ NONE

Inlet Grade (Pick one) ☐ AT STREAM GRADE ☐ INLET DROP ☐ PERCHED ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Inlet Dimensions **A. Width**_____.____ **B. Height**_____.____ **C. Substrate/Water Width**_____.____ **D. Water Depth**_____.____

ADDITIONAL CONDITIONS

Slope % (Optional)_____ **Slope Confidence** ☐ HIGH ☐ LOW | **Internal Structures** ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER_____

Structure Substrate Matches Stream ☐ NONE ☐ COMPARABLE ☐ CONTRASTING ☐ NOT APPROPRIATE ☐ UNKNOWN

Structure Substrate Type (Pick one) ☐ NONE ☐ SILT ☐ SAND ☐ GRAVEL ☐ COBBLE ☐ BOULDER ☐ BEDROCK ☐ UNKNOWN

Structure Substrate Coverage ☐ NONE ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ UNKNOWN

Physical Barriers (Pick all that apply) ☐ NONE ☐ DEBRIS/SEDIMENT/ROCK ☐ DEFORMATION ☐ FREE FALL ☐ FENCING ☐ DRY ☐ OTHER

Severity (Choose carefully based on barrier type(s) above) ☐ NONE ☐ MINOR ☐ MODERATE ☐ SEVERE

Water Depth Matches Stream ☐ YES ☐ NO-SHALLOWER ☐ NO-DEEPER ☐ UNKNOWN ☐ DRY

Water Velocity Matches Stream ☐ YES ☐ NO-FASTER ☐ NO-SLOWER ☐ UNKNOWN ☐ DRY

Dry Passage through Structure? ☐ YES ☐ NO ☐ UNKNOWN **Height above Dry Passage**_____

Comments

STRUCTURE 6

Structure Material ☐ METAL ☐ CONCRETE ☐ PLASTIC ☐ WOOD ☐ ROCK/STONE ☐ FIBERGLASS ☐ COMBINATION

OUTLET

Outlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED **Outlet Armoring** ☐ NONE ☐ NOT EXTENSIVE ☐ EXTENSIVE

Outlet Grade (Pick one) ☐ AT STREAM GRADE ☐ FREE FALL ☐ CASCADE ☐ FREE FALL ONTO CASCADE ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Outlet Dimensions **A. Width**_____.___ **B. Height**_____.___ **C. Substrate/Water Width**_____.___ **D. Water Depth**_____.___

Outlet Drop to Water Surface_____.___ **Outlet Drop to Stream Bottom**_____.___ **E. Abutment Height** (Type 7 bridges only)_____.___

L. Structure Length (Overall length from inlet to outlet)_____.___

INLET

Inlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED

Inlet Type ☐ PROJECTING ☐ HEADWALL ☐ WINGWALLS ☐ HEADWALL & WINGWALLS ☐ MITERED TO SLOPE ☐ OTHER ☐ NONE

Inlet Grade (Pick one) ☐ AT STREAM GRADE ☐ INLET DROP ☐ PERCHED ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Inlet Dimensions **A. Width**_____.___ **B. Height**_____.___ **C. Substrate/Water Width**_____.___ **D. Water Depth**_____.___

ADDITIONAL CONDITIONS

Slope % (Optional)_____ **Slope Confidence** ☐ HIGH ☐ LOW | **Internal Structures** ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER_____

Structure Substrate Matches Stream ☐ NONE ☐ COMPARABLE ☐ CONTRASTING ☐ NOT APPROPRIATE ☐ UNKNOWN

Structure Substrate Type (Pick one) ☐ NONE ☐ SILT ☐ SAND ☐ GRAVEL ☐ COBBLE ☐ BOULDER ☐ BEDROCK ☐ UNKNOWN

Structure Substrate Coverage ☐ NONE ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ UNKNOWN

Physical Barriers (Pick all that apply) ☐ NONE ☐ DEBRIS/SEDIMENT/ROCK ☐ DEFORMATION ☐ FREE FALL ☐ FENCING ☐ DRY ☐ OTHER

Severity (Choose carefully based on barrier type(s) above) ☐ NONE ☐ MINOR ☐ MODERATE ☐ SEVERE

Water Depth Matches Stream ☐ YES ☐ NO-SHALLOWER ☐ NO-DEEPER ☐ UNKNOWN ☐ DRY

Water Velocity Matches Stream ☐ YES ☐ NO-FASTER ☐ NO-SLOWER ☐ UNKNOWN ☐ DRY

Dry Passage through Structure? ☐ YES ☐ NO ☐ UNKNOWN **Height above Dry Passage**_____

Comments

STRUCTURE 7

Structure Material ☐ METAL ☐ CONCRETE ☐ PLASTIC ☐ WOOD ☐ ROCK/STONE ☐ FIBERGLASS ☐ COMBINATION

OUTLET

Outlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED **Outlet Armoring** ☐ NONE ☐ NOT EXTENSIVE ☐ EXTENSIVE

Outlet Grade (Pick one) ☐ AT STREAM GRADE ☐ FREE FALL ☐ CASCADE ☐ FREE FALL ONTO CASCADE ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Outlet Dimensions **A. Width**_____.___ **B. Height**_____.___ **C. Substrate/Water Width**_____.___ **D. Water Depth**_____.___

Outlet Drop to Water Surface_____.___ **Outlet Drop to Stream Bottom**_____.___ **E. Abutment Height** (Type 7 bridges only)_____.___

L. Structure Length (Overall length from inlet to outlet)_____.___

INLET

Inlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED

Inlet Type ☐ PROJECTING ☐ HEADWALL ☐ WINGWALLS ☐ HEADWALL & WINGWALLS ☐ MITERED TO SLOPE ☐ OTHER ☐ NONE

Inlet Grade (Pick one) ☐ AT STREAM GRADE ☐ INLET DROP ☐ PERCHED ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Inlet Dimensions **A. Width**_____.___ **B. Height**_____.___ **C. Substrate/Water Width**_____.___ **D. Water Depth**_____.___

ADDITIONAL CONDITIONS

Slope % (Optional)_____ **Slope Confidence** ☐ HIGH ☐ LOW | **Internal Structures** ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER_____

Structure Substrate Matches Stream ☐ NONE ☐ COMPARABLE ☐ CONTRASTING ☐ NOT APPROPRIATE ☐ UNKNOWN

Structure Substrate Type (Pick one) ☐ NONE ☐ SILT ☐ SAND ☐ GRAVEL ☐ COBBLE ☐ BOULDER ☐ BEDROCK ☐ UNKNOWN

Structure Substrate Coverage ☐ NONE ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ UNKNOWN

Physical Barriers (Pick all that apply) ☐ NONE ☐ DEBRIS/SEDIMENT/ROCK ☐ DEFORMATION ☐ FREE FALL ☐ FENCING ☐ DRY ☐ OTHER

Severity (Choose carefully based on barrier type(s) above) ☐ NONE ☐ MINOR ☐ MODERATE ☐ SEVERE

Water Depth Matches Stream ☐ YES ☐ NO-SHALLOWER ☐ NO-DEEPER ☐ UNKNOWN ☐ DRY

Water Velocity Matches Stream ☐ YES ☐ NO-FASTER ☐ NO-SLOWER ☐ UNKNOWN ☐ DRY

Dry Passage through Structure? ☐ YES ☐ NO ☐ UNKNOWN **Height above Dry Passage**_____

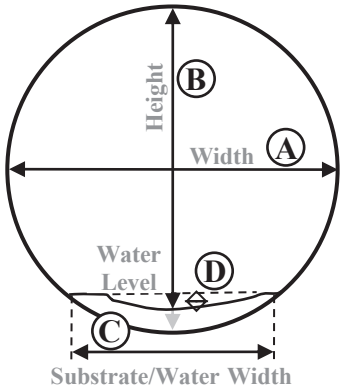
Comments

Structure Shape & Dimensions

1) Select the Structure Shape number from the diagrams below and record it on the form for Inlet and Outlet Shape.
2) Record on the form in the approriate blanks dimensions **A**, **B**, **C** and **D** as shown in the diagrams;
   C captures the width of water or substrate, whichever is wider; for dry culverts without substrate, C = 0.
   D is the depth of water -- be sure to measure inside the structure; for dry culverts, D = 0.
3) Record Structure Length (**L**). (Record abutment height (**E**) only for Type 7 Structures.)
4) For multiple culverts, also record the Inlet and Outlet shape and dimensions for each additional culvert.

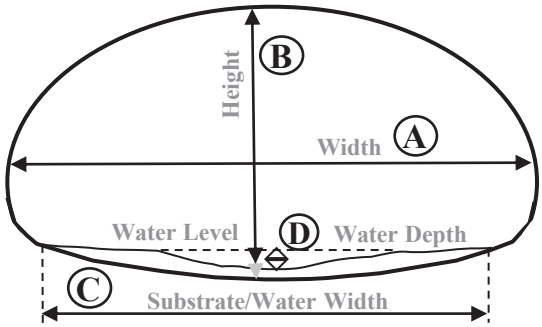
NOTE: Culverts 1, 2 & 4 may or may not have substrate in them, so height measurements (B) are taken from the level of the "stream bed", whether that bed is composed of substrate or just the inside bottom surface of a culvert (grey arrows below show measuring to bottom, black arrows show measuring to substrate).

1



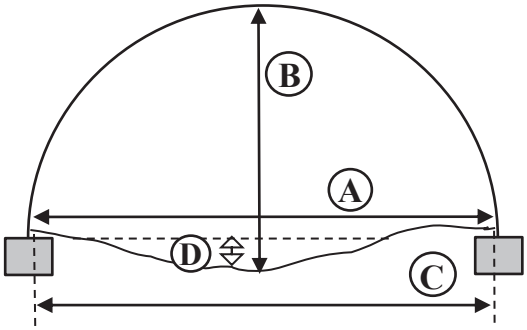
Round Culvert

2



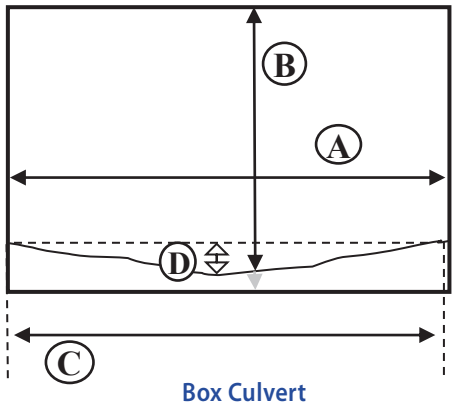
Pipe Arch/Elliptical Culvert

3



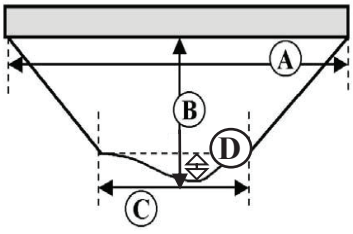
Open Bottom Arch Bridge/Culvert

4



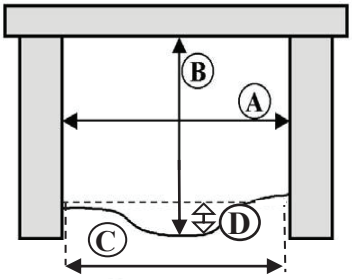
Box Culvert

5



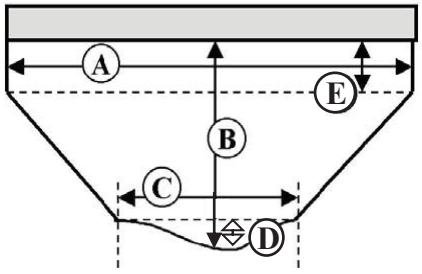
Bridge with Side Slopes

6



Box/Bridge with Abutments

7



Bridge with Abutments and Side Slopes

Appendix 2

This appendix includes the NAACC document that explains the scoring system involved in evaluating aquatic passability at road-stream crossings. This scoring system was adopted by the NAACC Steering Committee in November 2015.

Scoring Road-Stream Crossings as Part of the North Atlantic Aquatic Connectivity Collaborative (NAACC)

Adopted by the NAACC Steering Committee
November 10, 2015

INTRODUCTION

The North Atlantic Aquatic Connectivity Collaborative (NAACC) was launched in 2015 with a rapid assessment protocol for evaluating aquatic passability at road-stream crossings and an online database (https://www.streamcontinuity.org/cdb2) for storing and scoring data collected using this protocol. Two scoring systems are proposed to evaluate aquatic passability at road-stream crossings. The first is a coarse screen for use in classifying crossings into one of three categories: "Full AOP" (Aquatic Organism Passage), "Partial AOP," and "No AOP." The second system is an algorithm for computing an aquatic passability score, ranging from 0 (low) to 1 (high), for each road-stream crossing. These two scoring systems are not particular to any taxonomic or functional group but instead seek to evaluate passability for the full range of aquatic organisms likely to be found in rivers and streams.

NAACC COARSE SCREEN

Table 1 below identifies characteristics and conditions that allow crossings to be classified as providing "Full AOP," "Reduced AOP," or "No AOP."

Table 1. NAACC Coarse Screen

Metric	Flow Condition	Crossing Classification		
		Full AOP	**Reduced AOP**	**No AOP**
		If all are true	*If any are true*	*If any are true*
Inlet Grade		At Stream Grade	Inlet Drop or Perched	
Outlet Grade		At Stream Grade		Cascade, Free Fall onto Cascade
Outlet Drop to Water Surface		= 0		≥ 1 ft
Outlet Drop to Water Surface/ Outlet Drop to Stream Bottom				> 0.5
Inlet or Outlet Water Depth	Typical-Low	> 0.3 ft		< 0.3 ft w/Outlet Drop to Water Surface > 0
	Moderate	> 0.4 ft		< 0.4 ft w/Outlet Drop to Water Surface > 0
Structure Substrate Matches Stream		Comparable or Contrasting		
Structure Substrate Coverage		100%	< 100%	
Physical Barrier Severity		None	Minor or Moderate	Severe

The primary objective of the coarse screen is to identify those crossings that are likely to be a barrier to most or all species and those that are likely to provide something close to full aquatic organism passage. If it is necessary to get a better feel for how bad those crossing are that are labeled as "reduced AOP" one can use the numeric scoring system.

NAACC NUMERIC SCORING SYSTEM

The numeric scoring algorithm is based on the opinions of experts who decided both the relative importance of all the available predictors of passability as well as a way to score each predictor. Scoring involves three steps: (1) generating a component score for each predictor variable, (2) combining these predictions with a weighted average to generate a composite score for the crossing, and (3) assigning a final score based on the minimum of the composite score or the component score for the *outlet drop* variable.

Variables Used

Crossing assessments are generally done during "typical low-flow conditions." Some variables are important for assessing conditions at the time of the survey; others provide indirect evidence of likely conditions at higher flows.

Inlet Grade: The position of the structure invert relative to the stream bottom at the inlet.

Outlet Drop: Outlet drop is based on the variable *Outlet Drop to Water Surface* unless the value for *Water Depth Matches Stream* = "Dry" in which case outlet drop is based on the variable *Outlet Drop to Stream Bottom*.

Physical Barriers: This variable covers a wide variety of circumstances ranging from obstructions to dewatered culverts or bridge cells that represent physical barriers to aquatic organism passage.

Constriction: The relative width of the crossing compared to the width of the stream. "Severe" = <50%, "Moderate" = 50-100%; other options include "Spans Only Bankfull/Active Channel" and "Spans Full Channel & Banks." *Constriction* is an indirect indicator of potential velocity issues at higher flows.

Water Depth: Water depth in the structure relative to water depths found in the natural channel at the time of survey.

Water Velocity: Water velocity in the structure relative to water velocities found in the natural channel at the time of survey.

Scour Pool: Presence/absence of a scour pool at the crossing outlet and size relative to the natural stream channel. *Scour Pool* is an indirect indicator of potential velocity issues at higher flows. *Scour pool* is included solely as an indicator of velocities at higher flows. It is not based on the effects of the pool itself which can actually be positive for fish passage.

Substrate Matches Stream: An assessment of whether the substrate in the structure matches the substrate in the natural stream channel. *Substrate Matches Stream* is used to evaluate how a discontinuity in substrate might inhibit passage for species that either use substrate as the medium for travel (e.g., mussels) or require certain types of substrate for cover during movements (e.g., crayfish, salamanders, juvenile fish).

Substrate Coverage: Degree to which a crossing structure is covered by substrate. *Substrate Coverage* is directly related to passability for some aquatic species that require substrate or that tend to avoid areas that lack cover. It is also an important element of roughness that can create areas of low-velocity water (boundary layers) utilized by weak-swimming organisms. *Substrate Coverage* is also an indirect indicator of potential velocity issues at higher flows.

Openness: Cross-sectional area of the structure opening divided by the structure length (distance between inlet and outlet) measured in feet. *Openness* is calculated for both the inlet and outlet and the lower value is assigned to the structure. If there are multiple structures at a crossing the value for the structure with the highest *Openness* is assigned to the crossing as a whole. Turtles are believed to be affected by the *Openness* of a crossing structure; other species may be affected as well.

Height: Maximum height of the crossing structure. This variable is parameterized so that it only comes into play for very small structures.

Outlet Armoring: Presence/absence of streambed armoring (e.g., riprap, asphalt, concrete) at the outlet and the relative amount of armoring. Armoring is considered “extensive” if the length (upstream to downstream) of the streambed that is armored is greater or equal to half the bankfull width of the natural stream channel. *Outlet Armoring* is an indirect indicator of potential velocity issues at higher flows.

Internal Structures: Presence/absence of structures inside a culvert or bridge (e.g. weirs, baffles, supports). The *Internal Structures* variable is used in the scoring algorithm as it relates to the potential for creating turbulence within a crossing structure. To the extent that *Internal Structures* physically block the movement of aquatic organisms it is covered by the *Physical Barriers* variable.

Step 1: Component Scores

The component scores are not meant to equate to passability. In each case the component score is intended the cover the full range of problems (assessable by our protocol) associated with that variable: from 0 (worst case) to 1 (best case). For *inlet grade*, having an inlet drop or perched inlet is the worst case among the options, thus they score "0." This is not meant to say that all structures with inlet drops are impassible. The effect of *inlet grade* on passability scores is controlled by the weight it is given in computing the composite score (see Step 2 below).

Scoring categorical predictors is simply a matter of assigning a score for each possible category. Table 2 lists all of the categorical predictors and the scores associated with each category.

Scoring continuous predictors requires a function to convert the predictor to a score. There are three continuous predictors and three associated functions. The functional forms used were chosen because they have shapes desired by the expert team or because they fit the series of points specified by the expert team. Appendix A includes the r code defining each of these functions (“x” is the measured value for each variable).

The scoring equation for *Openness* is:

(1) $s_o = a(1 - e^{-kx(1-d)})^{1/(1-d)}$

Where S_o is the score for openness, a=1, k=15, and d = 0.62
when openness is recorded in feet.

The equation for Height is:

(2) $s_h = \min(\frac{ax^2}{b^2 + x^2}, 1)$

Where S_h is the component score for height, a = 1.1, and b=2.2
when height is recorded in feet.

The equation for Outlet Drop is:

(3) $s_{od} = 1 - \frac{ax^2}{b^2 + x^2}$

Where S_{od} is the Outlet Drop component score, a=1.029412, and b=0.51449575
when outlet drop is recorded in feet.

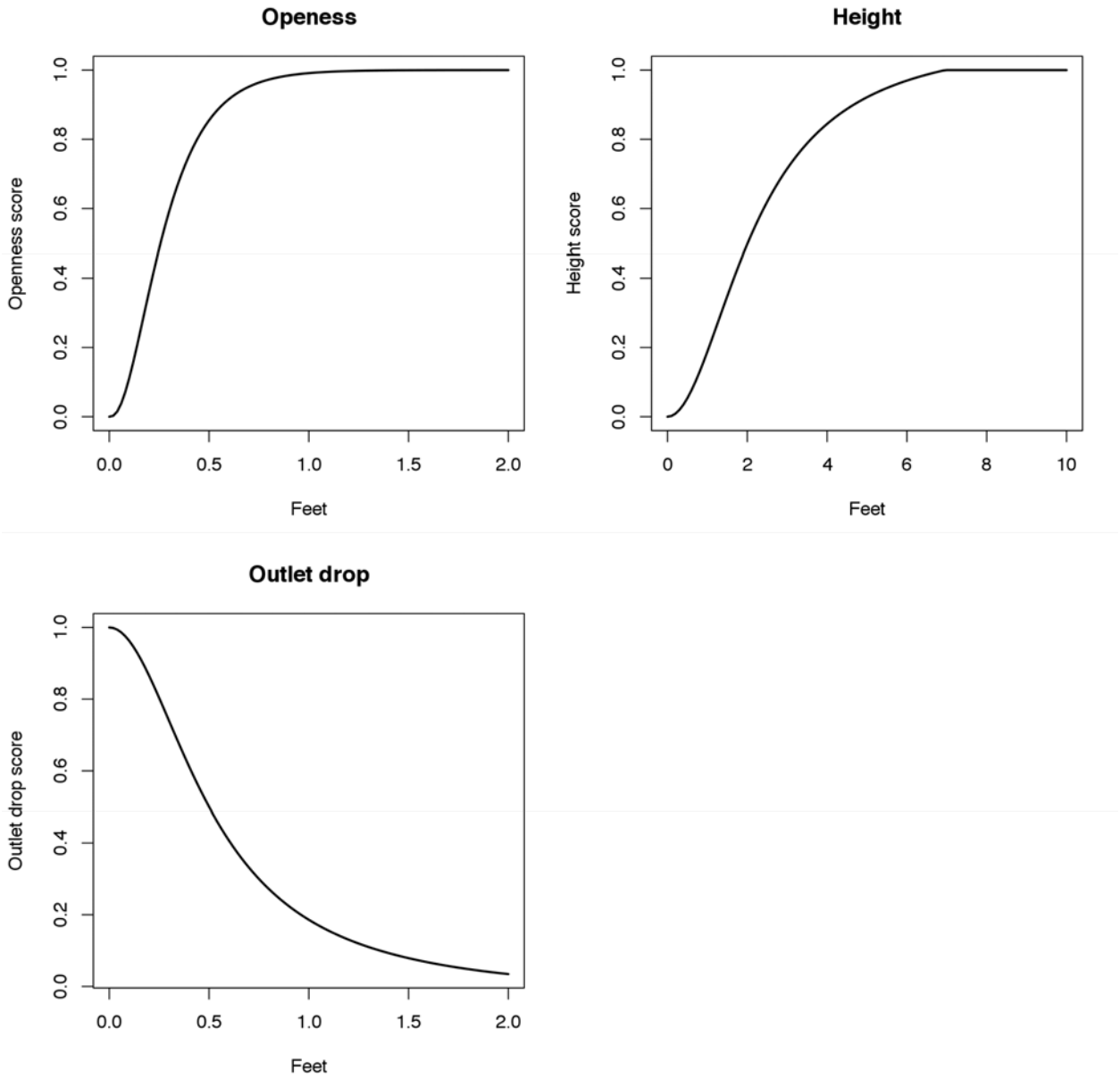


Figure 1. Continuous predictor variables

Table 2. Component scores for categorical variables used in calculating the crossing score

parameter	level	score
Constriction	severe	0
Constriction	moderate	0.5
Constriction	spans only bankfull/active channel	0.9
Constriction	spans full channel and banks	1
Inlet grade	at stream grade	1
Inlet grade	inlet drop	0
Inlet grade	perched	0
Inlet grade	clogged/collapsed/submerged	1
Inlet grade	unknown	1
Internal structures	none	1
Internal structures	baffles/weirs	0
Internal structures	supports	0.8
Internal structures	other	1
Outlet armoring	extensive	0
Outlet armoring	not extensive	0.5
Outlet armoring	none	1
Physical barriers	none	1
Physical barriers	minor	0.8
Physical barriers	moderate	0.5
Physical barriers	severe	0
Scour pool	large	0
Scour pool	small	0.8
Scour pool	none	1
Substrate coverage	none	0
Substrate coverage	25%	0.3
Substrate coverage	50%	0.5
Substrate coverage	75%	0.7
Substrate coverage	100%	1
Substrate matches stream	none	0
Substrate matches stream	not appropriate	0.25
Substrate matches stream	contrasting	0.75
Substrate matches stream	comparable	1
Water depth	no (significantly deeper)	0.5
Water depth	no (significantly shallower)	0
Water depth	yes (comparable)	1
Water depth	dry (stream also dry)	1
Water velocity	no (significantly faster)	0
Water velocity	no (significantly slower)	0.5
Water velocity	yes (comparable)	1
Water velocity	dry (stream also dry)	1

Some notes about the component scores

1. The option "clogged/collapsed/submerged" for *inlet grade* is an option surveyors use to indicate that it was not possible to measure the structure's dimensions. If the inlet is clogged or collapsed enough to affect passability it will be covered under *physical barriers*. This is why it receives a "1" instead of a "0", because problems associated with this option are covered by the *physical barriers* variable.

2. The rationale for giving a component score of "1" to "unknown" for *inlet grade* is similar to that for "clogged/collapsed/submerged." It is hard to know how to interpret "unknown." However, if conditions at the inlet are creating a physical barrier to passage it will be covered under *physical barriers*.

3. We included *inlet grade* as a variable in addition to *physical barriers* because inlet drops create both velocity and physical barrier (jump barrier) issues. The physical barrier issues are covered by the *physical barriers* variable. The *inlet grade* variable captures the velocity issues at the inlet. Perched inlets can create depth issues at low flows (if water can't get into the structure inlet). These may not be apparent at the time of the survey. Thus, the presence of a perched inlet is a concern even if it doesn't represent a physical barrier ("dry") at the time when the survey is conducted.

4. The variable *internal structures* is included to account for turbulence issues. There is likely to be turbulence associated with weirs and baffles when these are included inside crossing structures. If they also create physical barriers they will be covered by the *physical barriers* variable. They are often included in structures to help aquatic organism passage but they sometimes do more harm than good and may be good for some species while creating problems for others. The inclusion of well-designed weirs or baffles is likely to improve the component scores for water depth and water velocity. They get docked a little in our scoring system for introducing turbulence.

5. It is difficult to know how to score the "other" option under *internal structures* because it is difficult to know what, if any, impact these other structures will have on turbulence. If, however, they represent a physical barrier they will be covered under the *physical barriers* variable.

Step 2: Weighted Composite Scores

An expert team of nine people provided input on how the variables should be weighted based on best professional judgement. The weights used with the component scores are listed in table 3. The weights are simply the means of the nine weights for each variable provided by the experts. We display the weights out to three decimal places not to suggest that we know the weights to this level of precision but to reduce overall error in the model by not introducing an additional source of error (rounding error). The composite score is the sum of the products of each component score and its weight.

Table 3. Weights associated with each parameter in the scoring algorithm.

parameter	weight
Outlet drop	0.161
Physical barriers	0.135
Constriction	0.090
Inlet grade	0.088
Water depth	0.082
Water velocity	0.080
Scour pool	0.071
Substrate matches stream	0.070
Substrate coverage	0.057
Openness	0.052
Height	0.045
Outlet armoring	0.037
Internal structures	0.032

Step 3: Final Aquatic Passability Score

The final Aquatic Passability Score is the lower of either the composite score or the *Outlet Drop* component score. The rationale for this is that although many factors can affect aquatic organism passage, when an outlet drop is above a certain size it becomes the predominant factor that determines passability.

Aquatic Passability Score = Min[Composite Score, *Outlet Drop* score]

Mapping Aquatic Passability Scores

For mapping purposes, we assigned narrative descriptors for different ranges of aquatic passability as follows.

Descriptor	Aquatic Passability Score(s)
No barrier	1.0
Insignificant barrier	0.80 – 0.99
Minor barrier	0.60 – 0.79
Moderate barrier	0.40 – 0.59
Significant barrier	0.20 – 0.39
Severe barrier	0.00 – 0.19

People often ask about the relationship between these categories and actual passability for fish and other aquatic organisms. At this point the relationship is unknown and we regard it as a fruitful area for future research. The concept of aquatic passability is complicated and includes: variation in the swimming and leaping abilities of individuals within a species (what proportion of the population can pass), variability in passage requirements for a broad diversity of species that inhabit rivers and streams (what proportion of species can pass), and the timing of passability (for what proportion of the year is the structure passable).

For now, the best way to consider the aquatic passability scores is that they represent the degree to which crossings deviate from an ideal. We assume that those crossings that are very close to the ideal (scores > 0.6) will present only a minor or insignificant barrier to aquatic organisms. Those structures that are farthest from the ideal (scores < 0.4) are likely to be either significant or severe barriers. These are, however, arbitrary distinctions imposed on a continuous scoring system and should be used with that in mind.

APPENDIX A - R code for continuous scoring functions.

```
#-------------------------------------------------------------------------#
# define function for Openness score calculation
#-------------------------------------------------------------------------#
calc.openness.score <- function(x){
        # Using von Bertalanffy functional form (Bolker pg 97)
        a = 1
        k = 15
        d=0.62
        return(a * (1-exp(-k*(1-d)*x))^(1/(1-d)))
        # note exp is based on e not 10.
}

#-------------------------------------------------------------------------#
# Define Function for Calculating Height Scores
#-------------------------------------------------------------------------#
calc.height.score <- function(x){
        a <- 1.1
        b <- 2.2
        # Use Holling Type II function (Bolker pg 92):
        result <- a*x^2/(b^2 + x^2)
        result[result > 1] <- 1 # Truncate results to 1
        return(result)
}


#-------------------------------------------------------------------------#
# Define Function for Calculating Outlet Drop Scores
#-------------------------------------------------------------------------#
calc.outlet.drop.score <- function(x){
        a <- 1.029412
        b <- 0.51449575
        score <- 1 - a*x^2/(b^2 + x^2)
        score[x > 36] <- 0
        return(score)
}
```