REGIONAL CULVERT INVENTORY SUMMARY REPORT

DECEMBER 2025

BANGOR AREA COMPREHENSIVE
BACTS
TRANSPORTATION SYSTEM

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Regional Culvert Inventory Summary Report

December 2025

Prepared by Stillwater Environmental Engineering, Inc.
In cooperation with *BACTS* and the communities listed below:

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Brewer
Hampden
Hermon
Milford
Old Town
Orono
Orrington
Penobscot Nation
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** Unless otherwise noted, all photos were taken by Stillwater Environmental Engineering, Inc.*

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Commonly Used Terms & Acronyms

BACTS	Bangor Area Comprehensive Transportation System
BMP	Best Management Practice
GDB	Geodatabase - A centralized repository for geographic and spatial data, storing various datasets such as feature classes, rasters, and tables in a single location
GIS	Geographic Information System - A computer system that captures, stores, analyzes, and displays data related to positions of specific features on the Earth's surface
Hydrologic and Hydraulic (H&H) Study	A H&H Study analyzes surface water movement through a watershed to predict peak discharge (cubic feet per second or CFS) at a crossing and uses this flow data to analyze the hydraulic performance of a crossing to determine appropriate sizing.
IF&W	Maine Department of Inland Fisheries and Wildlife
MDEP	Maine Department of Environmental Protection
MDOT	Maine Department of Transportation
NASSCO	National Association of Sewer Service Companies
NRPA	Natural Resources Protection Act
NWI	National Wetlands Inventory
PACP	Pipeline Assessment Certification Program
Road Classification: Arterial Roads	Roads with high traffic capacity and low access ratings, typically classified as controlled-access highways.
Road Classification: Cross Collectors	Roads that service traffic from local streets to arterial roads. These roads can be characterized by lower speed limits, stop signs, signaled intersections, and traffic circles.
SEE	Stillwater Environmental Engineering
UIS	Urban Impaired Stream
Urban Compact	Refers to the urbanized area characterized by population size and density, as defined by MDOT
USFWS	United States Fish and Wildlife Service

Executive Summary

Stillwater Environmental Engineering, Inc. (SEE) was contracted by the Bangor Area Comprehensive Transportation System (BACTS) to assist with the preparation of a comprehensive culvert inventory for municipalities located in the greater Bangor area. These municipalities are highlighted in **Figure 1**. This infrastructure inventory provides a strong reference base that can inform decisions and guide future phases of work. The goal of this initial phase was to create a centralized, standardized database of regional culvert crossing assets that municipalities and their partners can use for future assessments geared toward resilience planning and to aid in allocating resources for the current and future maintenance of each municipality's existing drainage system.

Primary Goal of the Culvert Inventory:

Goal: Contribute to a regional asset database that enables BACTS to make informed capital planning decisions, prioritize limited funds, and strengthen funding applications.	**Action**: Create a comprehensive infrastructure inventory of existing culvert assets & vulnerabilities in the greater Bangor Urbanized Area.

This culvert inventory and capacity analysis builds on previous municipal-centered efforts to centralize and standardize a regional infrastructure index, with specific data to assist in securing funding and in prioritizing project improvements to address ongoing regional challenges and ensure the resilience of the greater Bangor area. This report describes the standardization process and methodologies and summarizes the findings of the 2025 culvert inventory. An overview of recommendations and approaches for future analysis and prioritization processes will be included in the next steps of this project. This report is accompanied by a geodatabase of the culvert inventory for the most vulnerable crossings in the greater Bangor Urbanized Area.

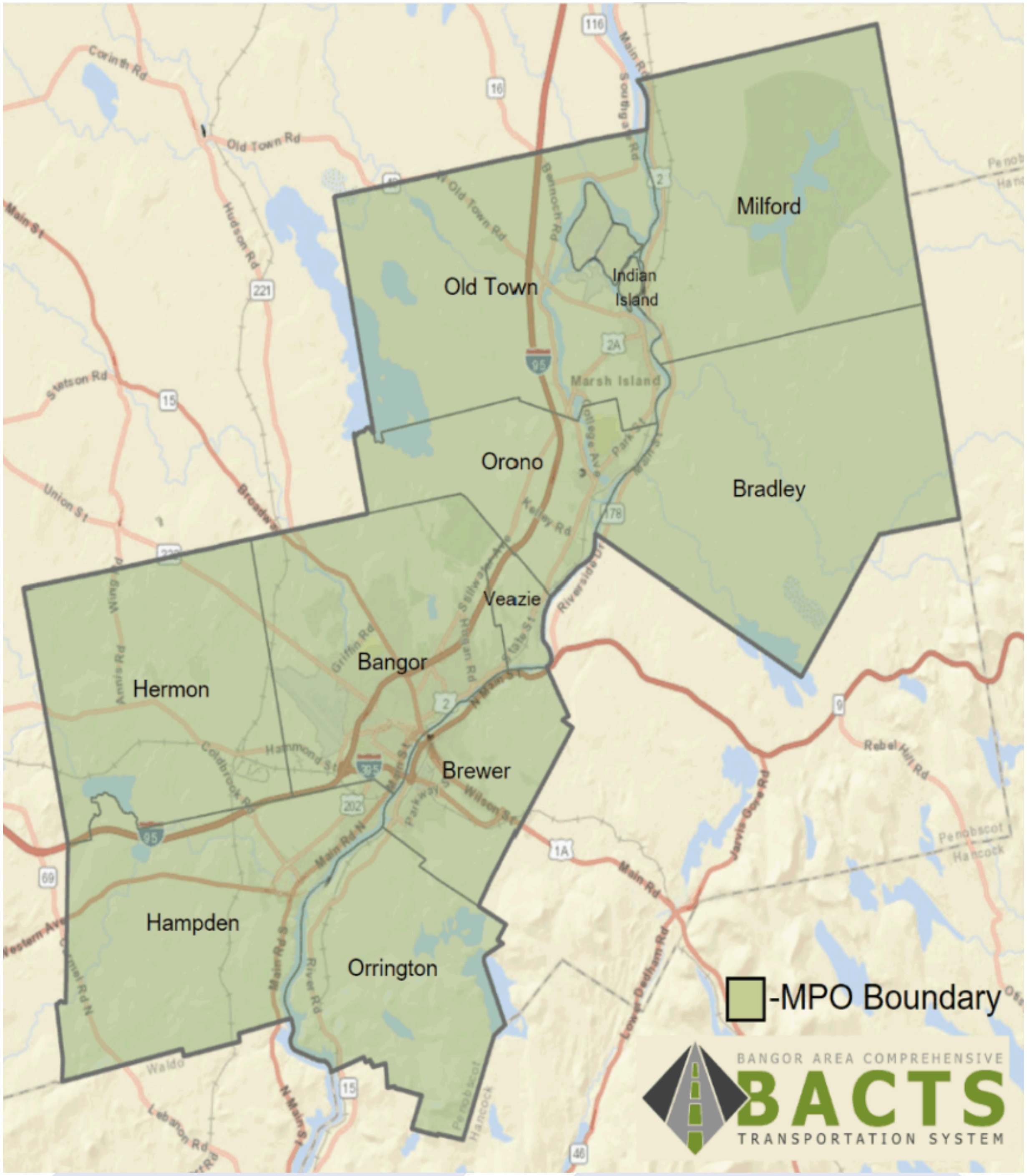


Figure 1: Map of the municipalities BACTS serves in the greater Bangor Urbanized Area.
Map generated by BACTS, obtained from https://bactsmpo.org/what-is-bacts/.

1. Introduction

This report is intended to help municipal staff and officials understand and apply the data collected during this initial phase to guide future work–including prioritizing projects, sequencing plans, modeling watersheds, and identifying targeted improvements. This report is being provided as a reference to data users, and any extraneous information has not been included. It provides a concise summary of this initial inventory phase, including categorized recommendations for crossing improvements for future project phases. Accordingly, it is organized into the following sections:

- ★ Data Collection Methodology
  Describing the general data collection process, which was completed for each culvert crossing.
- ★ Data Analysis
  Describing the procedures associated with field data analysis and quality control.
- ★ Geodatabase Preparation and Use
  Describing the process associated with the preparation of the comprehensive culvert crossing geodatabase and methods for use.
- ★ Culvert Improvement Recommendations
  Providing recommendations for future studies that would yield valuable data for the BACTS region related to these culvert crossings and associated infrastructure.

2. Data Collection Methodology

The data collection phase of this project included reviewing existing municipal data, establishing prioritized inspection stages for culvert crossings, and developing standardized field data-collection procedures. The data collection methods and variables are detailed later in this section.

Existing culvert crossing data were provided by BACTS representatives in GIS format, prepared by merging multiple data layers from multiple municipalities, and supplemented with BACTS-driven field verification. Some errors and inconsistencies were anticipated and encountered during the field inspections. Any errors and inconsistencies are discussed in more detail in **Section 3** later in this report.

During the first data collection stage, inspections were conducted at all currently mapped culvert crossings under cross-collectors and arterial roads within the Urban Compact areas, which are MDOT-designated areas with high population and density. Note that interstate road crossings were not observed in this inventory, as these roads are under state and federal jurisdiction. This Stage 1 dataset included **236** culvert crossings.

Given the large number of crossings outside the Urban Compact and the limited remaining budget/time for the 2025 field season, Stage 2 efforts were prioritized by selecting culverts located within 75 feet of mapped protected natural resources (rivers, streams, or wetlands). This 75-foot setback is typically associated with the Natural Resources Protection Act (NRPA) mandatory buffer zone in Maine for development adjacent to natural resources. Crossings within this 75 ft buffer from streams, rivers, and wetlands have a greater impact on surface water quality, are typically associated with larger drainage areas, and therefore pose a greater risk of failure during severe weather events. This prioritization yielded **210** crossings outside the Urban Compact area but within 75 feet of a mapped surface water. Once these culvert crossings were inspected, Stage 3 included **29** additional culverts outside the Urban Compact and the 75 ft surface water buffer. Given the available time and budget, this did not include all remaining crossings outside the Urban Compact; approximately **415** (Stage 4) remain and will need to be collected in the future. SEE's staged process for prioritizing crossing inspections completed during the 2025 field season (Stages 1, 2, and 3) and the remaining crossing inspections (Stage 4) is summarized in **Table 1** below. The Greater Bangor Urban Compact, associated with the BACTS communities, is shown in **Figure 2** below.

Table 1: Summary of Data Collection Inspection Stages

Date Collection Stage		Number of Culverts Inspected
Stage 1	Culverts inside the Urban Compact.	236
Stage 2	Culverts outside the Urban Compact within 75 ft of a mapped surface water feature**	210
Stage 3	Culverts outside of the Urban Compact, not within 75 ft of a mapped surface water feature	29
Stage 4	Remaining Culvert Inspections: culverts inside the BACTS region, outside of the Urban Compact, and not in proximity (within a 75 ft radius) to a mapped surface water**.	~ 415

* All field inspections were conducted between July 1st - September 1st, 2025.
** USFWS National Wetlands Inventory layer.

2.1. Field Data Collection & Tools

Prior to data collection, SEE built a field data-collection application on the Fulcrum mobile platform. This platform was chosen due to its ease of use across diverse field conditions and its highly customizable data-collection interface. Although alternative data collection applications may integrate more seamlessly with GIS software, SEE's practical, field-based experience indicates that an intuitive, simple data collection process reduces technician errors and streamlines post-season quality control.

The crossing inventory data collection involved locating structures and recording qualitative and quantitative culvert conditions, positions, and elevations, along with photographs of the structures and their surroundings. Data collection procedures were guided by the Maine Stream Crossing Survey Manual (May 2012), developed by Alex Abbott of the Gulf of Maine Coastal Program, U.S. Fish and Wildlife Service. Teams of two SEE field technicians collected data from July to September 2025 using the equipment outlined in **Table 2**.

Table 2: Field Equipment Summary & Description

Field Equipment	Description
Rangefinder (200' Laser Rods)	To measure channel widths, crossing dimensions, crossing length, and pool length.
Waders	These allow field staff to survey tailwater pools and deeper portions of the stream and protect their legs from abrasions and poison ivy.
Optical Level	For reading the vertical distance on the depth rod when measuring the inlet and outlet road fill height.
Level Rod	For measuring the vertical distance of the inlet and outlet road fill height.
Laser Level	For reading the vertical distance on the depth rod when measuring the inlet and outlet road fill height.
Yard Stick	To measure water and pool depth, roadway, and culvert measurements.
100' measuring tape	To measure in cases where the rangefinder is impractical.
Shovel	To clear sediment from the inlet/outlet.
Tablet with Fulcrum Application	To use for the data collection.
Flashlight	To inspect the inside condition and substrate of the crossing.
High Visibility Vest	Brightly colored, reflective vests are used to make data collectors visible on the road.

Data were collected using standardized, systematic procedures. Using an intuitive citizen-science-style workflow, completed step by step through the Data Collection Categories outlined below, ensured consistent, comparable assessments across all surveyed culverts.

Data Collection Categories

In-take
- Site ID
- Date
- Time
- Inspectors

Structure
- Crossing Type
- Flow Status
- Specific Structure Type
- Site Location Information (Precise GPS-based data collection)
- Number of Pipes
- Pipe Material
- Corrugation
- Crossing Size (inches)

Inlet Condition
- Inlet Condition
- Inlet drop (inches)
- Water depth (inches) (as applicable)
- Road Fill Height (feet)
- Photos of the inlet

Upstream Condition
- Channel Width
- Channel Width Units (yards/feet)
- Photos of the upstream

Outlet Condition
- Outlet Condition
- Outlet drop (inches)
- Water depth (inches) (as applicable)
- Road Fill Height (feet)
- Photos of the outlet

Downstream Condition
- Channel Width
- Channel Width Units (yards/feet)
- Photos of the downstream

Crossing Condition - General
- Roadway Surface Type
- Road Surface Width (yard)
- Roadway Pavement/Gravel Width
- Culvert Estimated Length (yards)
- Crossing Photos

Additional Notes
- Rough Condition Assessment
- Additional Comments

At each crossing, data collection began with measurements and photo documentation of the culvert structure and condition, the inlet and upstream conditions, and the outlet and downstream conditions, followed by broad-view observations of the conditions surrounding the culvert site. **Figure 3** shows the general plan view of a culvert and the associated terminology.

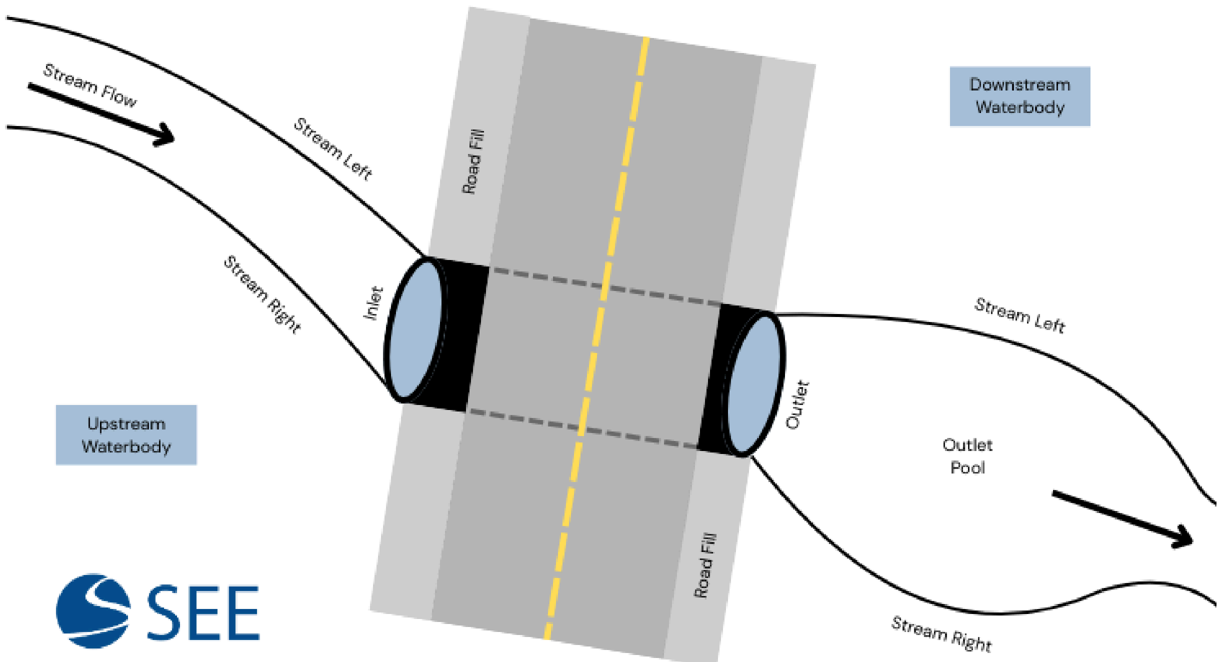


Figure 3: Plan view of culvert crossing terminology (NH SADES Stream Crossing Assessment 8.0, 2019).

In addition to the intuitive, consistent data collection workflow, each data entry field in each data collection category required either a simple numeric input or predefined options in a dropdown menu, simplifying data collection and reducing post-processing. For specific field technician observations, a "Notes" section was included at the bottom of the form. A generic example of the inspection form is included in **Appendix 1**. For reference, the elements of a culvert crossing and techniques for collecting data are detailed in **Section 2.2**. A brief overview of inspection fields is included below. More detailed information concerning each inspection item is included in **Appendix 2**.

2.2. Elements of a Culvert Crossing

The data collection procedures are key to the accuracy and functionality of the Culvert Inventory. All subsequent analyses, recommendations, and project prioritizations depend on the quality and consistency of measurements collected by field technicians. Beyond the workflow described above, each technician was trained in proper measurement methods and in handling various field scenarios before beginning data collection. **Figure 4** illustrates the culvert elements measured and their definitions. For a description and visual examples of crossing and structure types, refer to the Field Collection Protocol SOP in **Appendix 2**.

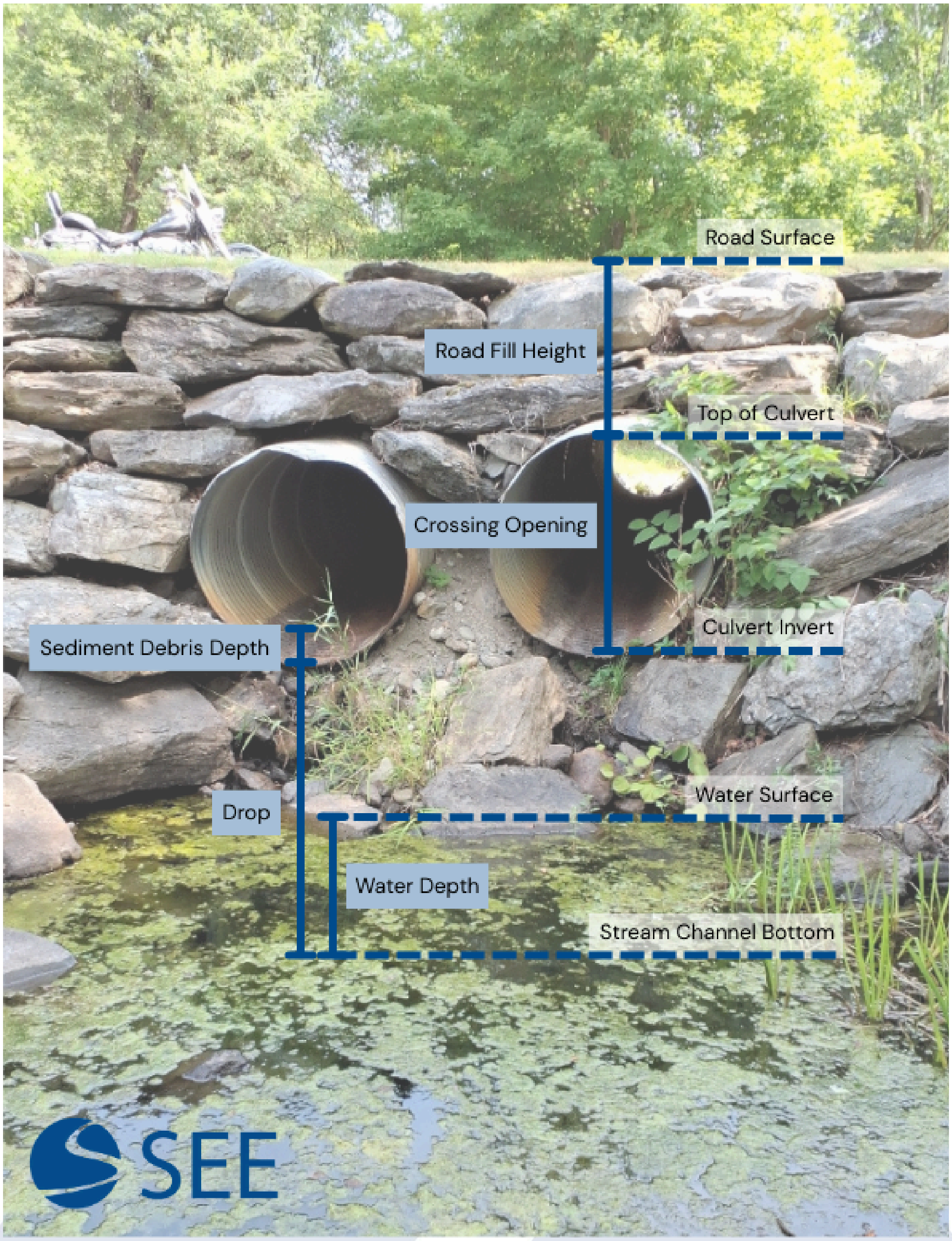


Figure 4: Definitions of measurements of a culvert.

3. Data Analysis

Culvert data analysis and quality control were conducted throughout the field season and after data collection ended. Using standard engineering practices, SEE performed an initial assessment that assigned each culvert to a status category. During processing, the geodatabase was cleaned by removing or correcting duplicate points, missing crossings, mislocated crossings, and records with duplicate ID numbers. The field status categories and contextual issues are described below and summarized in **Table 3**.

Table 3: Summary of Inspection Data

Culvert Crossings Inspection Status	Number of Crossings
Inspected	386
Follow-up	20
Could not locate	46
Duplicated	23

Not Inspected (default)	All inspection data points were imported into Fulcrum as "Not Inspected".
Inspected	If no issues or questions arose at a site, the crossing was marked as "Inspected".
Follow-up Required	A site was marked as requiring "Follow-Up" if a portion of the crossing (inlet or outlet) couldn't be located, couldn't be inspected due to safety concerns, was on private property, or appeared to be behind a locked gate.
Could Not Locate	Crossings that could not be located are likely buried, misidentified in the original dataset, or no longer exist.
Duplicates	Duplicate crossings were identified where two points existed in a single crossing location (sometimes consisting of two culverts) or where separate points existed at both the inlet and outlet of a crossing.

*Note: Multiple culverts were identified with duplicated site IDs for culverts in different locations. In these cases, these additional culvert IDs remained the same with "-1" added as a suffix.

After this process, the technical staff reviewed the field technicians' initial crossing condition ratings for accuracy and revised them as needed. Crossings were categorized as "Good", "Fair", or "Poor" based on the visible condition of the structures. Crossings rated "Poor" showed clear evidence of significant issues likely to lead to failure, flooding, or other environmental impacts in the near future. Culverts categorized as "Fair" condition appear to need repairs or maintenance but are less likely to fail or cause significant environmental impacts in the immediate future. This approach was implemented to prioritize a manageable number of high-priority structures, enabling repairs to begin as quickly as possible. **Figure 5** shows the distribution of these condition ratings in the BACTS region.

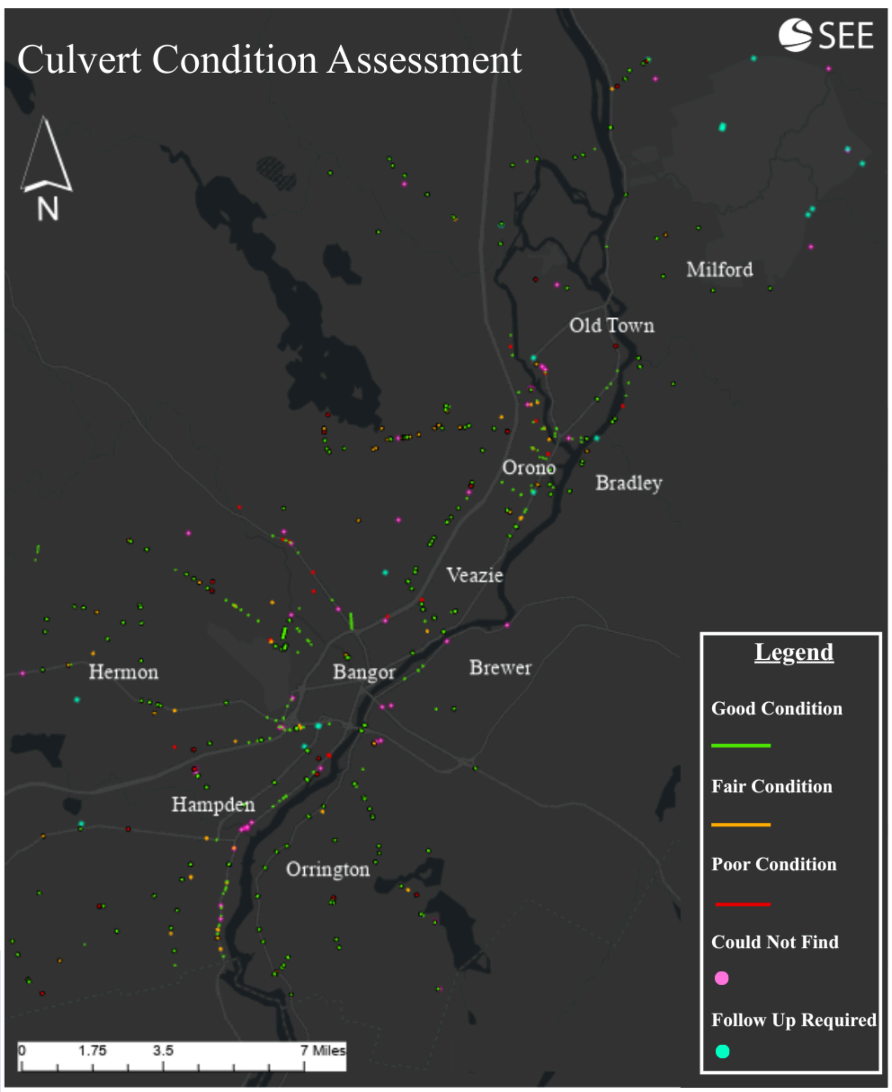


Figure 5: Map view of the distribution of culvert conditions across the BACTS region.

More detailed structural characterization (cover depth, hydraulic deficiencies, and internal structural deficiencies that cannot be observed without a camera) should be conducted in future project phases using this improved geodatabase. **Table 4** below highlights the most common failure, maintenance, and repair issues encountered in the field.

Table 4: Examples of Common Culvert Maintenance Issues

Maintenance Issues	Figure Number
Large Sinkhole	Figure 6
Severe Road Cracking/Heaving	Figure 7
Structural Failures Visible from Inlet/Outlet	Figure 8 & 9
Severe Undersizing	Figures 10, 11, & 12
Submerged Culverts	Figures 10 & 12
Blocked Inlet/Outlet	Figure 13 & 19
Perched Outlet	Figures 14 & 15
Rusted Inverts	Figures 16 - 18
Partially or Completely Blocked Inlet Grate	Figures 20, 21, & 22

Note that multiple completely or partially blocked inlet grates were observed during the site assessments. Inlet grates are not inherently problematic, but left unmaintained, they can cause upstream ponding and flooding. Beavers will also frequently make dams at these locations (**Figures 20-22**).

Figure 6: Example of a *sinkhole* located at an inspected culvert during the 2025 field season (Culvert ID # 216).

Figure 7: Example of *cracking/heaving* located at an inspected culvert during the 2025 field season (Culvert ID # 224).

Figure 8: Example of *structural failures* visible at the inlet/outlet of a culvert inspected during the 2025 field season (Culvert ID # 124).

Figure 9: Example of *structural failures* visible at the inlet/outlet of a culvert inspected during the 2025 field season (Culvert ID # 195).

Figure 10: Example of an *undersized and submerged* culvert inspected during the 2025 field season (Culvert ID # 131).

Figure 11: Example of an *undersized* culvert inspected during the 2025 field season (Culvert ID # 344).

Figure 12: Example of a *submerged* culvert inspected during the 2025 field season (Culvert ID # 268).

Figure 13: Example of a blocked culvert inspected during the 2025 field season (Culvert ID # 33).

Figure 14: Example of a *perched* culvert inspected during the 2025 field season (Culvert ID # 78).

Figure 15: Example of a *perched* culvert inspected during the 2025 field season (Culvert ID # 1053).

Figure 16: Example of a *rusted* culvert inspected during the 2025 field season (Culvert ID # 218).

Figure 17: Example of a *rusted* culvert inspected during the 2025 field season (Culvert ID # 343).

Figure 18: Example of a *rusted* culvert inspected during the 2025 field season (Culvert ID # 216).

Figure 19: Example of a *blocked* culvert inspected during the 2025 field season (Culvert ID # 214).

Figure 20-22: Example of culverts with inlet grates inspected during the 2025 field season (L to R: Culvert ID # 305, 361, 1035)

4. Geodatabase Preparation and Use

All culvert data are accessible in a geodatabase for use by BACTS municipalities via ArcGIS Pro (desktop version). **Table 5** below presents the feature layers and a description of each field for user reference.

The geodatabase is organized so that each culvert location, inspection result, and referenced dataset is stored in a consistent, structured format. Each culvert point includes a comprehensive set of inspection attributes documenting structural condition, site characteristics, environmental observations, and photo attachments. These attributes ensure that every location is represented with consistent standardized information, roadway context, and surrounding environmental conditions.

Table 5: Geodatabase Feature Layers and Descriptions

Feature Layers	Description
Culverts- Good Condition	Culverts that show no significant structural or hydraulic issues and are functioning normally with minor wear. Each feature also includes an attribute identifying whether it is located within 75 ft of a mapped surface water feature.
Culverts- Fair Condition	Culverts with moderate concerns, such as sediment buildup, erosion, damaged ends, or aging infrastructure; functioning but recommended for monitoring. Each feature also includes an attribute identifying whether it is located within 75 ft of a mapped surface water feature.
Culverts- Poor Condition	Culverts with significant structural defects or high-risk indicators that may require repair, redesign, or advanced engineering assessment. Each feature also includes an attribute identifying whether it is located within 75 ft of a mapped surface water feature.
Culverts- Follow Up Required	A site was marked as requiring "Follow-Up" if a portion of the crossing (inlet or outlet) couldn't be located, couldn't be inspected due to safety concerns, was located on private property, or appeared to be located behind a locked gate
Culverts- Could Not Locate	Crossings that could not be located are likely buried, misidentified in the original dataset, or no longer exist.

Table 5: Geodatabase Feature Layers and Descriptions *(Continued)*

Feature Layers	Description
Highway Corridor Priority (HCP)	MaineDOT roadway classifications (1-5) are used to identify regionally significant corridors and evaluate transportation importance.
Jurisdiction	MaineDOT Roadway maintenance responsibility categories
Maine Parcels - Organized Towns	Parcel boundaries are used to identify ownership and validate site locations.
USFW National Wetlands Inventory (NWI)	Wetland and surface-water habitat classifications were clipped to the BACTS watershed for proximity and environmental context analysis.
Urban Compact	Areas formally designated as urban boundaries where roadway maintenance responsibilities shift from the state to the municipality.

4.1. Geodatabase User Guide Overview

To assist municipalities in navigating the Culvert Inventory Geodatabase, SEE has developed a detailed User Guide, included in **Appendix 3**. This guide provides clear instructions for accessing the project in ArcGIS Pro, reviewing the feature layers, and working with key components, including attribute tables and associated photographs. It is designed to help users efficiently locate information within the gdb and understand how the data is organized for analysis and decision-making.

4.2. Key Considerations

Municipal users should exercise caution when interacting with the dataset because the geodatabase relies on a variety of system managed fields and internal mechanisms that support ArcGIS Pro's data integrity, indexing, and attachment frameworks. System-generated fields such as OBJECTID, GlobalID, and the geometry fields play crucial roles in maintaining feature identity, supporting edit tracking, and ensuring that ArcGIS can correctly reference each feature during map operations and geoprocessing tasks. Altering or removing these fields can corrupt relationship classes, orphan attachments, disrupt edit histories, and prevent ArcGIS from correctly rendering or querying features. Additionally, rearranging, renaming, or deleting any files, folders, or geodatabases within the project directory will break the data paths ArcGIS relies on to display and manage layers.

5. Future Project Recommendations

The comprehensive inventory and condition assessment of existing culvert infrastructure within the BACTS region has identified structures requiring preventive maintenance, repair, and/or replacement to sustain functionality, hydraulic capacity, wildlife connectivity (where applicable), public safety, and/or improve infrastructure resilience. This section outlines recommended next-step projects to advance regional resiliency efforts, including:

- ★ **Completing Data Collection**
  Inspect all remaining cross-connectors and arterials located outside of the Urban Compact that were not included in the Phase I (summer 2025) effort.
- ★ **Prioritized Hydrologic and Hydraulic Studies**
  Complete hydrologic and hydraulic (H & H) studies of prioritized crossings associated with larger and/or more vulnerable roadways and watersheds.
- ★ **Prioritized Repairs/Maintenance**
  Implement maintenance, repairs, and/or upgrades for high-priority crossings.
- ★ **Prioritized Camera Inspections**
  Complete subsurface camera inspections (closed circuit television or CCTV) of prioritized crossings where no apparent signs of imminent failure exist, but failure would pose a significant hazard to public safety or the environment.
- ★ **Grant Applications**
  Use Phase I data to develop and submit grant applications to fund future repairs, maintenance, and upgrades to regional crossings.
- ★ **Ongoing Geodatabase Maintenance**
  Continue updating and improving the existing geodatabase as new crossings are added, existing crossings are improved/maintained, or new, more accurate data is acquired.

5.1. Completing Data Collection

To ensure an accurate, complete, and comprehensive dataset, all remaining identified culverts located outside the Urban Compact and the 75-foot surface water buffer that have not been mapped/inspected as of December 2025 should be prioritized for inspection. Accounting for the existing self-reported mapping data from municipalities, the total number of culverts would be approximately 415.

Figure 23: View of SEE field technicians collecting culvert data.

5.2. Prioritized Hydrologic and Hydraulic Studies

To effectively prepare for future resiliency planning, H&H studies should be completed for prioritized crossings associated with high-priority infrastructure. Priority should be given to crossings that serve larger drainage areas, crossings related to streams and rivers, and crossings that support critical infrastructure (e.g., high-traffic roadways, emergency routes, buried utilities).

Figure 24: Example view of the hydrologic and hydraulic modeling viewport.

H&H studies model how surface water moves through a watershed and estimate the associated impacts (peak discharge and flooding elevations) of various storm events (e.g., 2-Year, 10-Year, 50-Year, and 100-Year return frequencies). These storm events refer to rainfall events with a 50%, 10%, 2%, and 1% chance of occurring in any given year, respectively. Other return frequencies can also be used for modelling, depending on project goals. Typically, return probabilities and precipitation curves are based on NOAA Atlas 14 data, often with additional storm volumes that reflect projected increases in storm intensity due to climate change.

5.3. Prioritized Repairs/Maintenance

Municipalities should use the geodatabase to prioritize targeted maintenance, repairs, and upgrades based on crossing condition assessments. Culverts rated in *poor condition* should be addressed first, ahead of lower-priority needs. Where stream crossings are involved, repairs or replacements should follow StreamSmart design principles (**Section 5.3.3**), if possible.

Figure 25: View of a culvert crossing requiring maintenance/replacement that was inspected during the summer of 2025 field assessment (Culvert ID # 379).

Given budget and staffing constraints, a phased maintenance strategy is recommended for short-term planning, concentrating on culverts with the highest failure risk. Over the longer term, municipalities should prioritize grant applications to help fund additional repairs and upgrades.

5.3.1. Improvement Prioritization Grading Matrix

SEE recommends that each municipality develop a grading matrix system to evaluate and prioritize culvert repairs/upgrades based on three main categories:

- ➔ Value to municipality (high/medium/low);
- ➔ Ease of installation and maintenance (easy/moderate/difficult); and
- ➔ Overall priority (high/medium/low).

Depending on municipal priorities, these categories could consider factors such as proximity to streams and other water bodies, areas of high economic value, emergency corridors, locations adjacent to vulnerable populations, flood risk, maintenance needs, cost-investment bracket, maintenance feasibility, impact on wildlife habitat, and stream connectivity. This assessment framework incorporates StreamSmart Principles (**Section 5.3.3**) to guide design and prioritize culvert improvements.

5.3.2. Culvert Maintenance

In addition to the failing structures referenced above, effort should be made to identify municipal crossings with a higher risk of blockage due to debris accumulation (wood/leaves, sediment, trash, etc.) and/or aquatic rodent (beaver and muskrat) activity. These crossings require regular inspections and maintenance, especially before major rain events, to minimize the risk of flooding and/or road failures. Where possible, inspection and maintenance schedules could be automated using geodatabase attributes, work order systems, and weather forecasts.

Figure 26: View of a culvert crossing requiring maintenance/replacement that was inspected during the summer of 2025 field assessment (Culvert ID # 8).

Some high-risk crossings may also warrant upgrades to deter aquatic rodents, such as inlet/outlet modifications ("Beaver Deceivers"). Because each site has unique constraints, these measures require careful field measurements, design, installation, and ongoing maintenance. Tracking rodent-related risk and installed deterrents could be incorporated into future project phases as a dedicated geodatabase layer.

Where staffing or funding is limited, targeted aquatic rodent removal may be the only practical option—particularly at severely undersized or embedded crossings. However, removal is temporary and must often be repeated (sometimes annually). Since aquatic rodents can benefit stream and wetland ecosystems when managed appropriately, complete watershed removal is not recommended.

5.3.3. StreamSmart Culvert Crossing Design Guidance

Municipalities are encouraged to implement StreamSmart principles during any culvert improvements associated with stream crossings. These principles are designed to accommodate natural fluvial processes—such as flooding and woody debris—while maintaining fish and aquatic organism passage so that the stream channel can function without obstruction. StreamSmart designs also protect infrastructure integrity and public safety, enhance connectivity of aquatic and wildlife habitats, and increase stormwater capacity. Additional information on StreamSmart Principals is provided in **Appendix 4**.

To improve a culvert crossing to ensure successful wildlife and habitat connectivity and resilient infrastructure utilizing StreamSmart principles, the culvert design should take into account the following design elements (the 4 S's):

- ➔ **SPAN**: The culvert must span the stream, allowing for the passage of aquatic and terrestrial wildlife.
- ➔ **SET ELEVATION**: The culvert must be set at the streambed elevation.
- ➔ **SLOPE**: The slope of the culvert must match the natural slope of the stream.
- ➔ **SUBSTRATE**: The crossing must include natural stream substrate (stream bed material - sediment and rocks) within the culvert.

Below are examples of culverts inspected during the 2025 field season that incorporate some StreamSmart Principles.

Figure 27: Example of a culvert spanning the stream channel (Culvert ID # 117).

Figure 28: Example of a crossing that includes natural stream substrate (Culvert ID # 289).

Figure 29: Example of a crossing that spans the stream channel, includes natural stream substrate, and is likely set at the elevation of the stream bed and natural slope of the stream. (Culvert ID # 118).

Figure 30: Example of a culvert that includes natural stream substrate (Culvert ID # 1032).

5.4. Prioritized Camera Inspections

Additional subsurface camera inspections should be prioritized for crossings that lack clear visual signs of failure (e.g., significant pavement cracking, severe corrosion, large sinkholes). These inspections can strengthen condition-based prioritization and provide supporting documentation for grant applications.

Figure 31: View of storm drain CCTV staging.

Typically, more costly and technical evaluations, such as the National Association of Sewer Service Companies (NASSCO) Pipeline Assessment Certification Program (PACP), are best reserved for high-priority locations where failure would pose substantial risks to infrastructure, public safety, or aquatic habitat. Given the large number of culverts in the BACTS region, this type of effort should be used selectively, and only when obvious high-priority defects, such as those detailed earlier in **Figures 6-22,** are *not* evident. Where severe defects are clearly visible, detailed camera ratings would add little value relative to their cost because repair or replacement is already warranted.

When conducted, prioritized camera inspections should be performed or reviewed by qualified contractors able to assign PACP ratings. These standardized, quantifiable scores are beneficial for interpreting extensive footage and improving both project prioritization and competitiveness for future grant funding.

5.5. Grant Applications

Using the collected data, municipalities and/or BACTS can apply for grants to support prioritized maintenance, repairs, and upgrades. Over the long term, communities should proactively target grant applications to culverts with the highest failure risk and/or the most severe consequences if they fail—such as those on high-traffic roads, emergency routes, or near buried utilities. These crossings typically pose the highest threats to public safety, access, and environmental connectivity and health.

5.6. Ongoing Geodatabase Maintenance

Geodatabase maintenance is crucial for effective asset management. The current dataset is a snapshot in time and should be updated and supplemented regularly as infrastructure is improved, removed, or repaired. Outdated data is of little value and cannot be relied upon. Periodic evaluation of the system's effectiveness, software upgrades, and mapping improvements should also be considered.

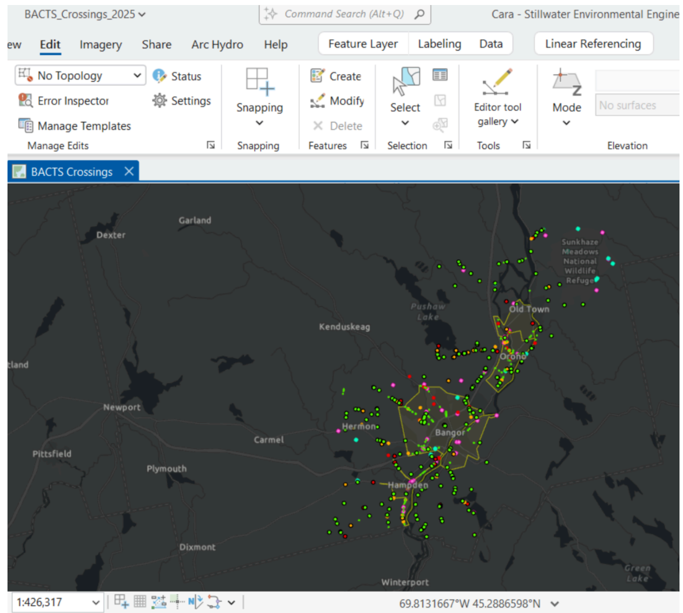


Figure 32: View of the BACTS culvert inventory geodatabase on GIS.

Geodatabase maintenance could also include creating a web-based ArcGIS Online version so users without ArcGIS Pro can access the dataset. Budget and schedule limits prevented this in the initial project phase, but it could be developed with relatively little effort by using the current ArcGIS Pro geodatabase as a template.

Future project phases could also include integrations between the geodatabase and municipal work order systems, as well as with other automation tools. This initial phase of data collection should be viewed as the beginning of a larger project to collect, maintain, upgrade, and improve regional culvert data. An important aspect of implementing this project will be meeting with municipal stakeholders to evaluate how they use the existing geodatabase and determine which updates would most improve usability. The value of this data collection is only realized if end users (municipal stakeholders) can access, understand, and use the system. This goal should not be overlooked during the collection of additional data and the geodatabase upgrade.

6. Appendix

Appendix 1. Fulcrum Inspection Form Example

2025 BACTS Crossings

FULCRUM INSPECTION FORM EXAMPLE

11/13/2025, 3:32:32 PM EST

CREATED

11/13/2025, 3:32:32 PM EST
by Cara Belanger

UPDATED

11/13/2025, 3:32:32 PM EST
by Cara Belanger

STATUS

Not Inspected

PROJECT

No Project

ASSIGNED TO

No Assignment

Site ID	FULCRUM INSPECTION FORM EXAMPLE
Date	July 1, 2025
Time	13:27
Inspector(s)	Morgan Jones
Is the culvert crossing present?	Yes

Culvert Crossing Present

Structure

Crossing Type	Stream
Flow Status	Flowing
Specific Structure Type	Round Culvert
How Many Pipes?	1
Pipe Material	Concrete
Corrugations	Yes
Crossing Opening Size (inches)	1

Inlet Condition

Inlet Condition	At Stream Grade
Inlet Drop (inches) - invert to stream bed	1
Inlet Water Depth (inches)	1
Obstructions?	Yes
Sediment/Debris Depth (inches)	1
Road Fill Height (ft)	1
Additional Comments?	
Inlet Photos	

Upstream Condition

Channel Width (yd/ft)	1
Channel Width Units	Yards
Upstream Photos	
Additional Comments?	

Outlet Condition

Outlet Condition	At Stream Grade
Outlet Water Depth (inches)	1
Obstructions?	Yes
Sediment/Debris Depth (inches)	1
Road Fill Height (ft)	1
Outlet Photos	
Additional Comments?	

Downstream Condition

Channel Width (yd/ft)	1
Channel Width Units	Yards
Downstream Photos	
Additional Comments?	

Crossing Condition

Crossing Type	Road
Roadway Surface Type	Paved
Roadway Pavement/Gravel Width (yd)	1
Roadway Surface Width (yd)	1
Crossing Structure Estimated Length (yd)	1
Crossing Photos	

Rough Condition Assessment	Poor (Major Repairs)
Additional Comments?	

Appendix 2. Field Data Collection SOP

BANGOR AREA COMPREHENSIVE BACTS TRANSPORTATION SYSTEM

BACTS

Regional Culvert Inventory

Culvert Data Collection Protocol

July - September 2025

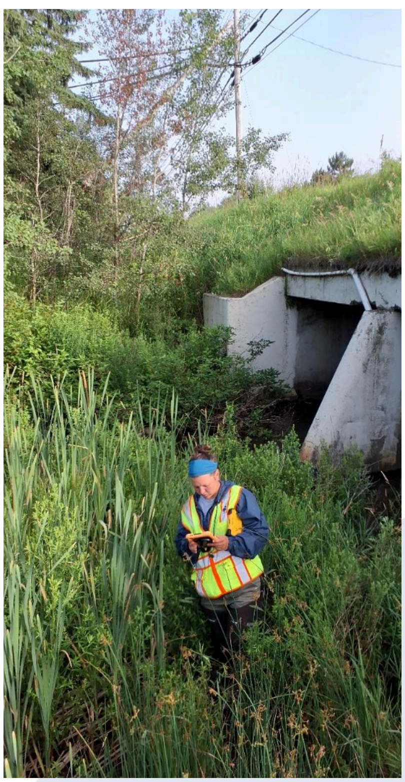


Table of Contents

1. Overview

This protocol describes the procedures for performing field data collection for the Bangor Area Comprehensive Transportation System (BACTS) regional culvert crossing inventory. This crossing inventory collection will involve locating and documenting relative structural conditions, photographs, positions, and elevations of culverts along non collector and arterial roads in the 11 municipalities within the BACTS urban service area. The following protocol describes data collection procedures using a Fulcrum field collection application developed by SEE.

2. Pre-Fieldwork Preparation

Five SEE field technicians will be trained on the data collection protocol, this will allow two teams of two to simultaneously collect data with an additional staff member available in case of sickness or other absence. When the field technicians are working simultaneously, they will collect data in separate municipal areas. Each team will be provided with and responsible for the following equipment:

Rangefinder (200' Laser Rods)	To measure channel widths, crossing dimensions, crossing length and pool length.
Waders	These allow observers to survey tailwater pools and deeper portions of the stream and protect data collector's legs from abrasions and poison ivy.
Optical Level	For reading the vertical distance on the depth rod when measuring the inlet and outlet road fill height.
Level Rod	For measuring the vertical distance of the inlet and outlet road fill height.
Laser Level	For reading the vertical distance on the depth rod when measuring the inlet and outlet road fill height.
Yard Stick	To measure water and pool depth, and roadway and culvert measurements.
100' measuring tape	To measure in cases where the rangefinder will not work. AND to use as a solid object for the rangefinder.
Shovel	To clear sediment from the inlet/outlet.
Tablet with Fulcrum Application	To use for the data collection.
Battery Charging Bank & Cord	To charge tablets in the field.
High Visibility Vest	Brightly colored, reflective vests so data collectors are visible on the road.
Flashlight	To inspect the inside condition and substrate of the crossing.
First Aid Kit	To deal with any minor injuries, cuts, scrapes, etc. Insect Repellant, sun protection, etc.

3. Field Data Collection Application: Fulcrum

The field data collection app in Fulcrum is called "**2025 BACTS Crossings**".

SEE Staff will drive to each site location (all crossing sites are identified in fulcrum) in teams of two where they will collect relevant data based on the following sections. The field inspections and following Standard Operating Procedure (SOP) were guided by the Maine Stream Crossing Survey Manual (May 2012) created by Alex Abbott from Gulf of Maine Coastal Program U.S. Fish and Wildlife Service.

Intake

Record the date, time, field technician inspectors, and if a culvert is present at the point. In the case where a culvert is not present, add photos and additional observations in the Fulcrum app.

Structure

- ☐ Crossing Type [Stream, wetland drainage, drainage ditch, field]
- ☐ Flow Status [Flowing, Not Flowing]
- ☐ Specific Structure Type [Round Culvert, Pipe Arch Culvert, Open Bottom, Box Culvert]
- ☐ Site Location Information [Update precise geolocation as a line]
- ☐ Number of Pipes
- ☐ Pipe Material [Concrete, Metal, Black Plastic (HDPE), White PVC, Green PVC]
- ☐ Corrugation [Yes, No]
- ☐ Crossing Size (inches)

Inlet/Outlet Condition

- ☐ Inlet Condition [At Stream Grade, Deformed, Blocked/Obstructed, Embedded]
- ☐ Outlet Conditions [At Stream Grade, Outlet Cascade, Outlet Drop, Deformed, Blocked/Obstructed, Embedded]
- ☐ Inlet/Outlet drop (inches)
- ☐ Inlet/Outlet Water depth (inches)
- ☐ Obstruction [Yes, No]
- ☐ Sediment/Debris Depth (inches)
- ☐ Road Fill Height (ft)
- ☐ Photos of the inlet

Upstream/Downstream Condition

- ☐ Channel Width
- ☐ Channel Width Units → (yd/ft)
- ☐ Photos of the upstream/downstream conditions

Crossing Condition - General

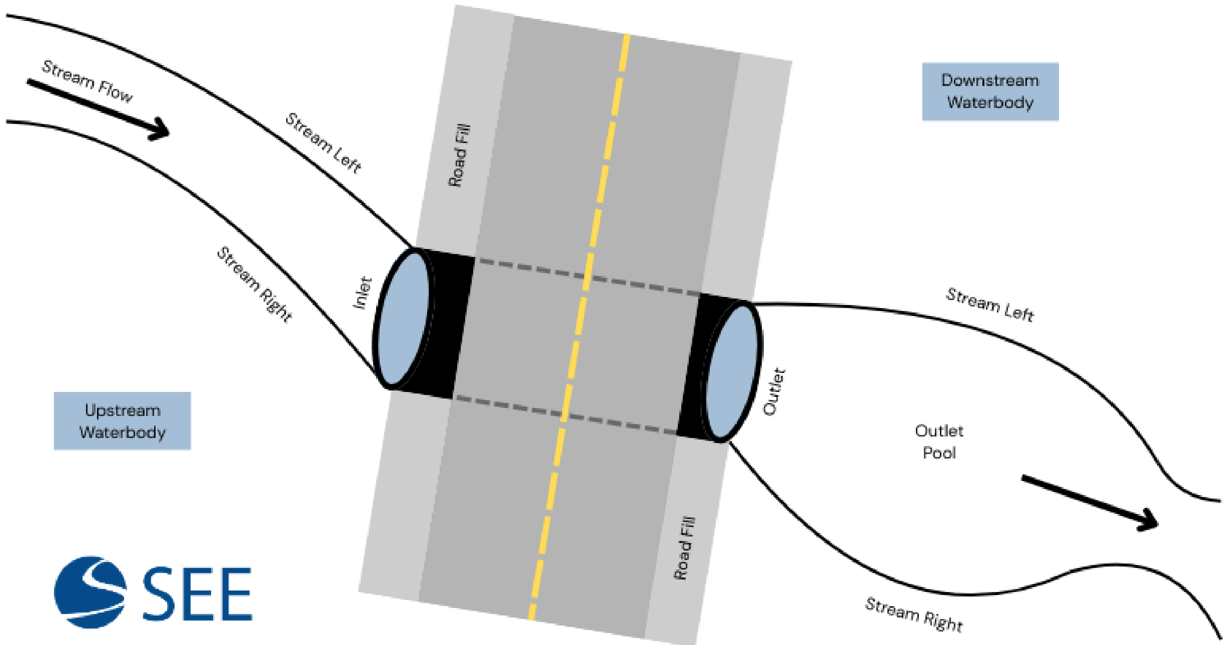
- ☐ Roadway Surface type [Road, Driveway]
- ☐ Road Surface Width (yd) [Paved, Unpaved, Railroad, Trail]
- ☐ Roadway Pavement/gravel Width
- ☐ Culvert Estimated Length (yd)
- ☐ Crossing Photos

Additional Notes

- ☐ Rough Condition Assessment [Good, Fair, Poor]
- ☐ Additional Comments

4. Reference Condition Photos

Parts of a Crossing



Crossing Type

STREAM - A channelized depression in the landscape that has defined channel banks and transports water either intermittently or perennially to lower elevations. If the stream is dry during the time of survey, use the presence of bankfull indicators to determine whether the waterbody is a stream.



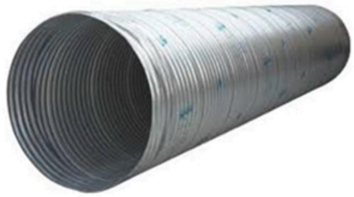
WETLAND - A waterbody that does not have defined channel banks and is in an area where the water table is at or above the land surface throughout the year. The soil is saturated with water and vegetation and there is often standing or slowly flowing water. If there is flowing water moving downstream through the crossing, but it is surrounded by wetland and you are unable to collect at least three bankfull widths due to lack of a defined channel, then classify as a wetland.

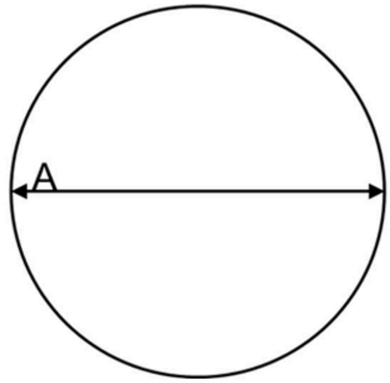



DRAINAGE DITCH - A structure at a depression or indentation in the landscape that holds water only during, or directly following, precipitation and is not located on the natural stream/waterbody network. Engineered landforms including storm water retention ponds, roadside ditches, and landscaped drainages do not have natural bankfull indicators because they are fabricated and the banks are constructed.

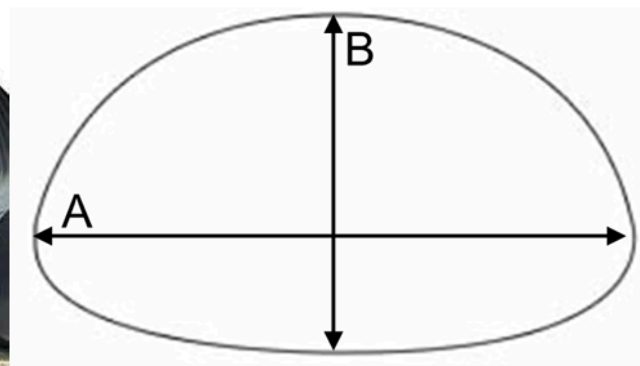

Specific Structure Type

ROUND CULVERT

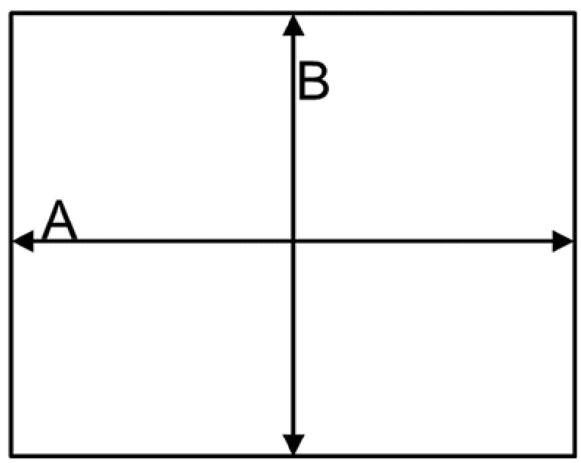




PIPE ARCH CULVERT



BOX CULVERT



OPEN BOTTOM ARCH

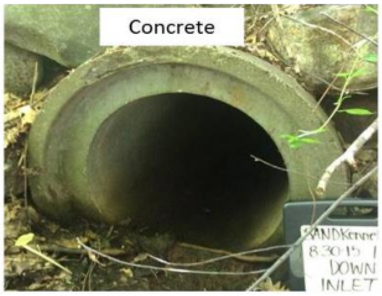
Number of Pipes

IDENTICAL STRUCTURES AT A CROSSING

DIFFERENT SHAPED, SIZED, AND BLOCKED PIPES

Pipe Material / Corrugation

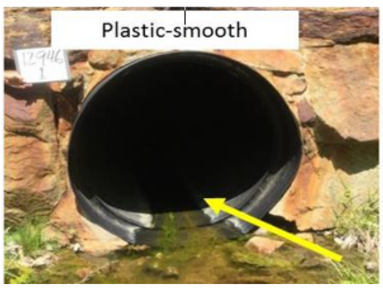
CONCRETE



METAL

METAL

PLASTIC - HDPE



WHITE PVC

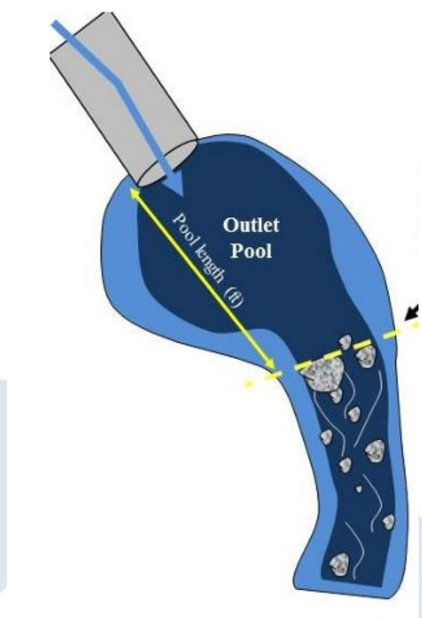
GREEN PVC

Inlet/outlet Condition

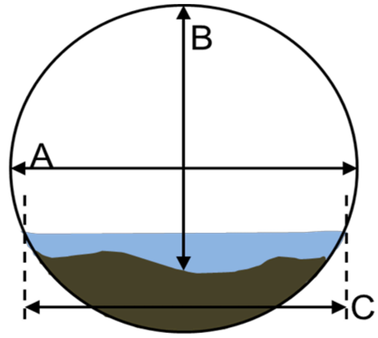
AT DITCH/STREAM GRADE - The outlet invert is at or below the water surface and the water exiting the crossing is at the same elevation as downstream, with no drops as it exits the conduit.

DROP - The outlet invert is above the downstream water surface. *** ONLY FOR OUTLETS ***

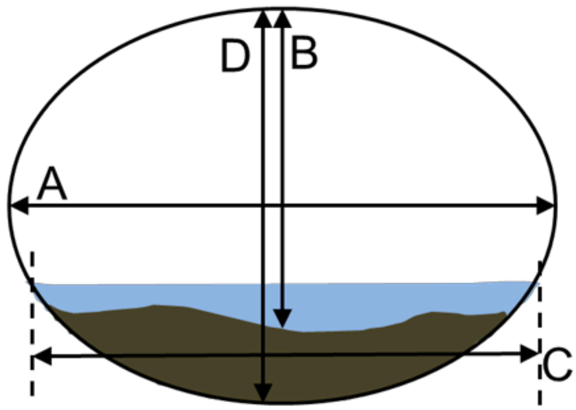
Pool



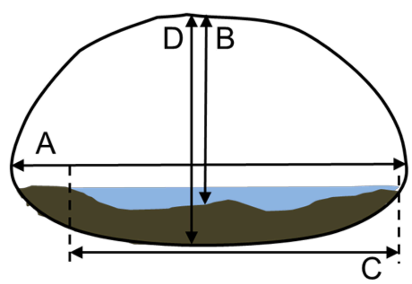
EMBEDDED ROUND CULVERT - Invert is below the streambed surface



EMBEDDED ELLIPTICAL CULVERT

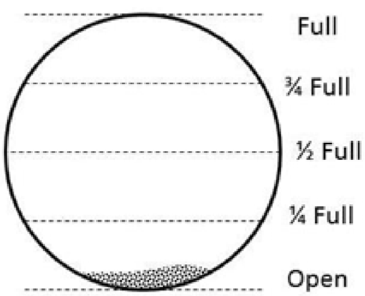


EMBEDDED PIPE ARCH CULVERT

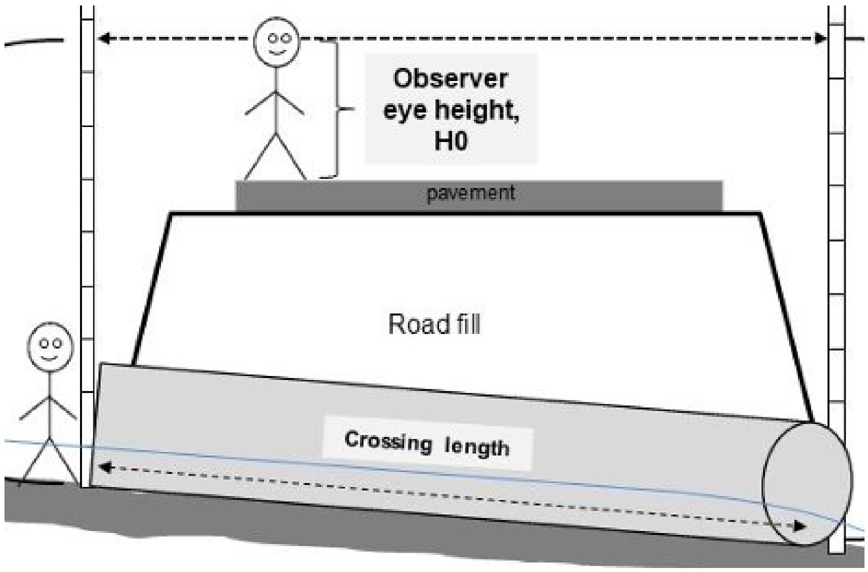


Blocked Examples

CLOGGED STRUCTURES WITH SEDIMENT



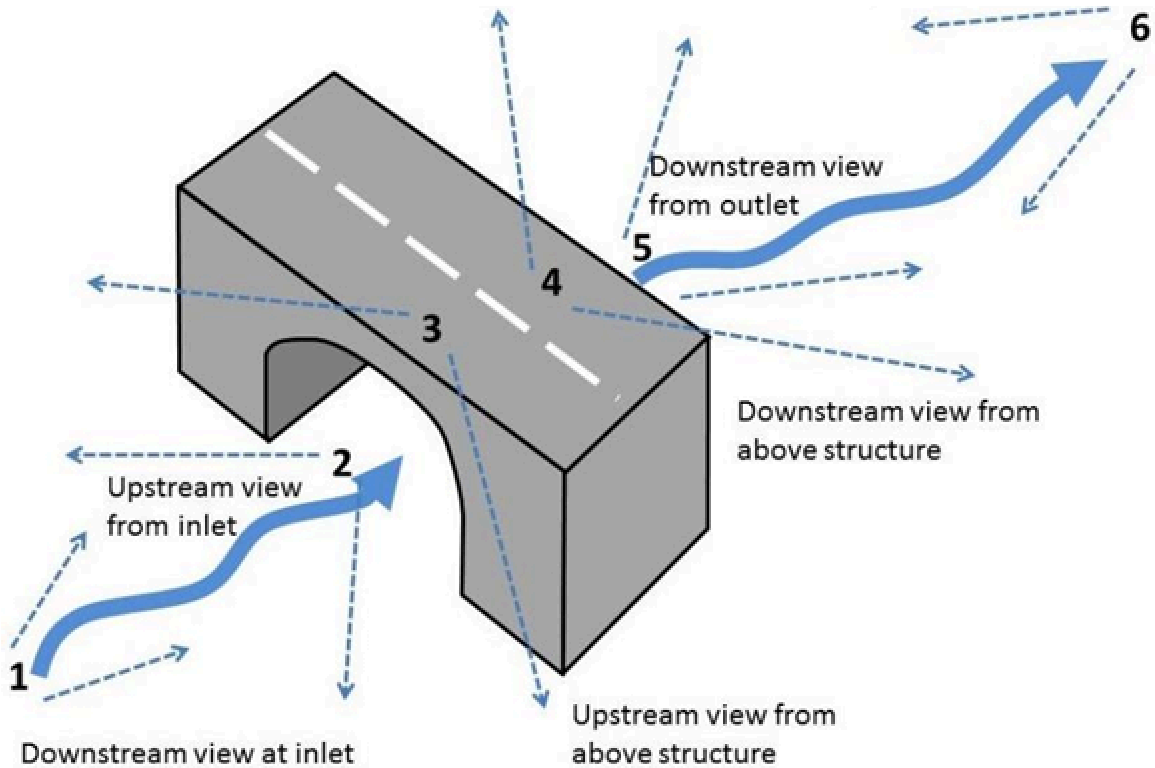
Road Fill Height (ft)



Bankfull Width

Bankfull: a channel's flow capacity, specifically the point where water begins to overflow onto the floodplain.

Photo Direction Examples



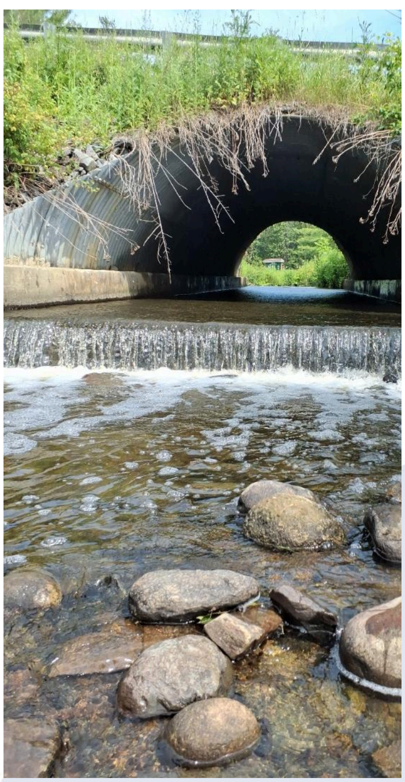
Appendix 3. Culvert Inventory Geodatabase User Guide

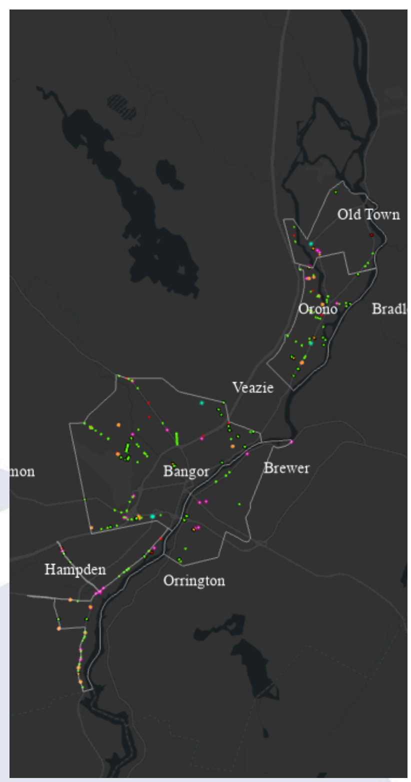
BACTS

Regional Culvert Inventory

Culvert Inventory Geodatabase User Guide

September - December 2025





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1. Overview

This user guide outlines procedures for municipalities in the Bangor Area Comprehensive Transportation System (BACTS) region for using, navigating, and maintaining the Culvert Inventory Geodatabase. This geodatabase consolidates a large amount of infrastructure data to support informed watershed analysis, project prioritization, and grant applications.

This guide details each layer and how to navigate the relevant data. The geodatabase summarizes the crossing inventory, including specific locations, photographs, positions, elevations, condition assessments, and additional general information about culverts on non-interstate roads within the Greater Bangor Urbanized Area. This inventory specifically focuses on culverts located under non-interstate roads within two geographic areas:

1. Inside the Greater Bangor Urban Compact, and
2. Outside the Greater Bangor Urban Compact within a 75-foot buffer of surface waters (rivers, streams, wetlands, etc.).

Additional information about culvert inventory can be found in the *Regional Culvert Inventory Summary Report (December 2025)*.

This user guide provides clear, step-by-step instructions for municipal staff to access and maintain the geodatabase, supporting informed decisions on infrastructure, watershed analysis, and grants.

2. Geodatabase Structure

The Regional Culvert Inventory Geodatabase is designed to organize and store all relevant information about culvert crossings in a consistent, accessible format. It includes feature classes, tables, and associated metadata that collectively support mapping, analysis, and long-term asset management. This section provides a detailed overview of the core components within the geodatabase, including how to open and navigate its contents, view features in both map and attribute formats, and understand the information stored within each dataset.

2.1. Opening the Geodatabase in ArcGIS Pro

The first step to viewing, editing, and analyzing the geodatabase is to open it properly. The geodatabase is stored as an ArcGIS Pro project package. The package contains a basemap, culvert inventory layer files, reference layer files, and all supporting metadata in a single compressed file. To open the interactive culvert inventory map, locate the ArcGIS Pro Project file (.aprx). Double-click the file to launch ArcGIS Pro and open the map automatically. All the layers, symbology, and geodatabase connections will already be configured. Users must have a current, licensed version of ArcGIS Pro installed for the project to load correctly. Note that older or outdated versions may not support specific tools, symbology settings, or geodatabase formats in this geodatabase package. Once opened, the map is ready for viewing, navigation, and analysis.

2.2. Saving and Exporting Data

Any edits to the geodatabase can be saved by clicking the save icon in the upper-left corner of ArcGIS Pro. Users should regularly save the project. Saving the project updates the .aprx file and maintains consistency across map settings, symbology, and layer configurations. Users can share a copy of the map by clicking Share on the top-left ribbon, then exporting it to a PDF. To share the dataset, right-click a layer in the contents pane (**Section 2.2**), select Data, then Export Features to create a new feature class or shapefile. To share the entire project, users can create a compressed project package by choosing Share on the top ribbon, then Project. A Package Project display will appear on the right with options to upload the package to an online account or save it as a file. This action bundles the map and all its supporting files into a single portable file (.ppkx) that can be easily transferred or opened on another computer or an online account.

2.3. Contents Pane

The Contents Pane in ArcGIS Pro serves as the control center for visualizing and managing the data within any given map. The pane displays all loaded and active layers, tables, and elements. It allows users to turn layers on/off, adjust drawing order via the virtual hierarchy (layers above appear on top of other layers), import group datasets, and access layer properties. The pane updates automatically as layers are added or removed, providing a structured view of every component in the map. If the Contents Pane is closed or does not appear automatically, it can be reopened at any time by navigating to the View tab on the ribbon and selecting Contents. **Figure 1** shows the Contents Pane in the BACTS Regional Culvert Inventory Geodatabase.

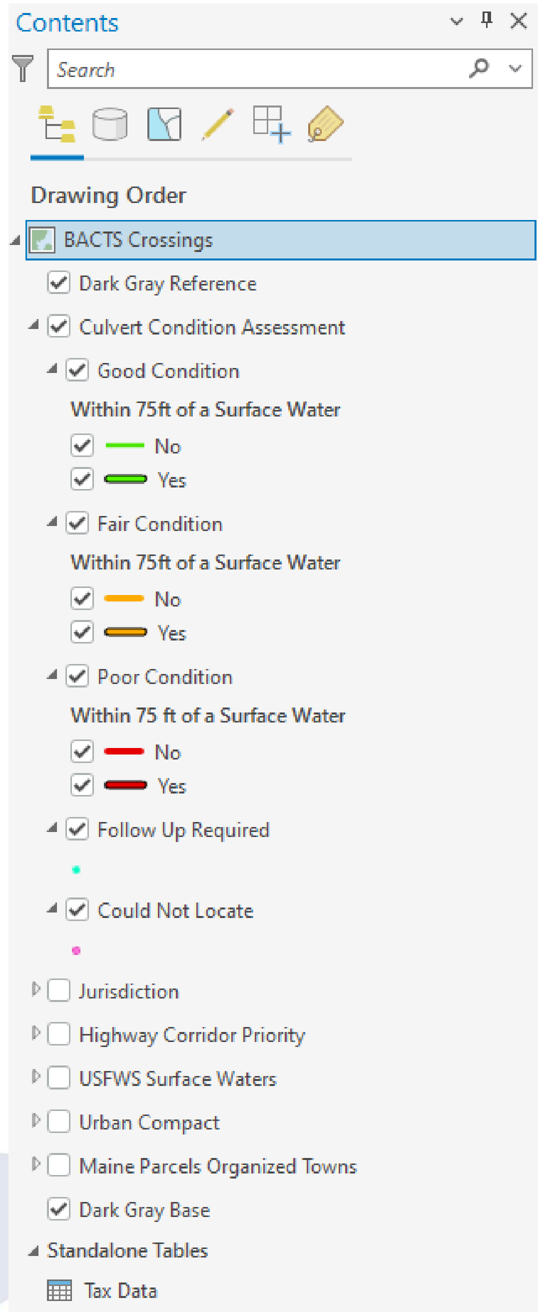


Figure 1: Contents Pane

2.4. Catalog Pane

The Catalog Pane in ArcGIS Pro provides access to all data, folders, geodatabases, and project resources. It functions as a navigation hub where users can browse to the project's file geodatabase, view available feature classes, and add layers directly to the map. The pane displays data in an organized structure, making it easy to locate and manage datasets, import new files, and review the contents of the geodatabase. For municipalities using this geodatabase, the Catalog Pane serves as an essential starting point, enabling staff to quickly locate relevant layers, load them into a map, and access the information needed for planning, maintenance, and reporting tasks. If the Catalog Pane is closed or does not appear automatically, it can be reopened by navigating to the View tab on the ribbon and selecting Catalog Pane. **Figure 2** below shows the Catalog Pane.

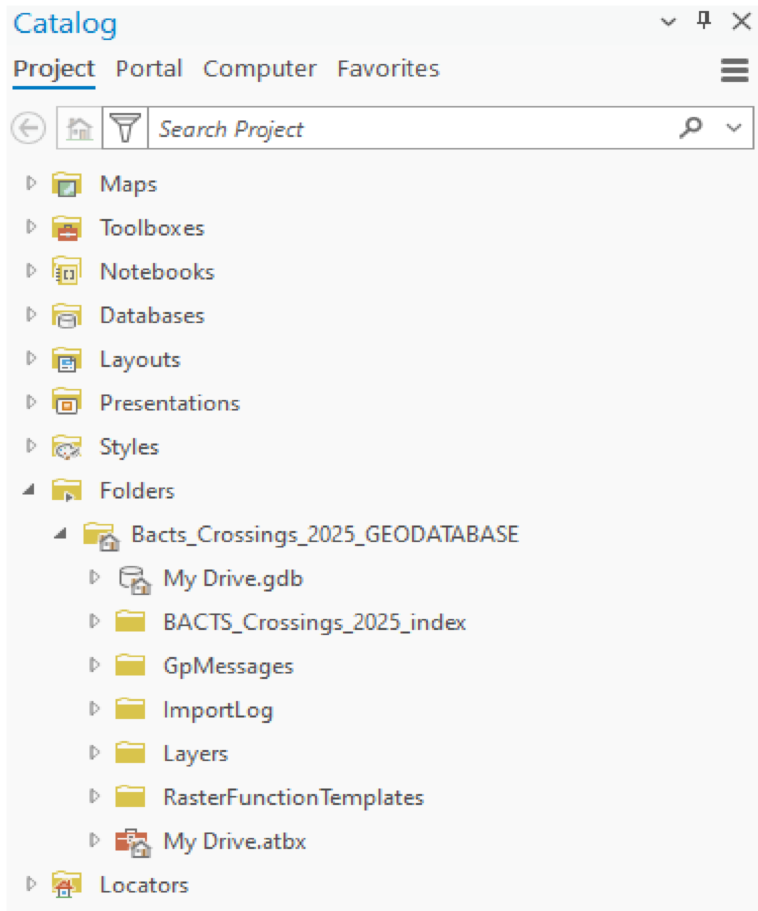
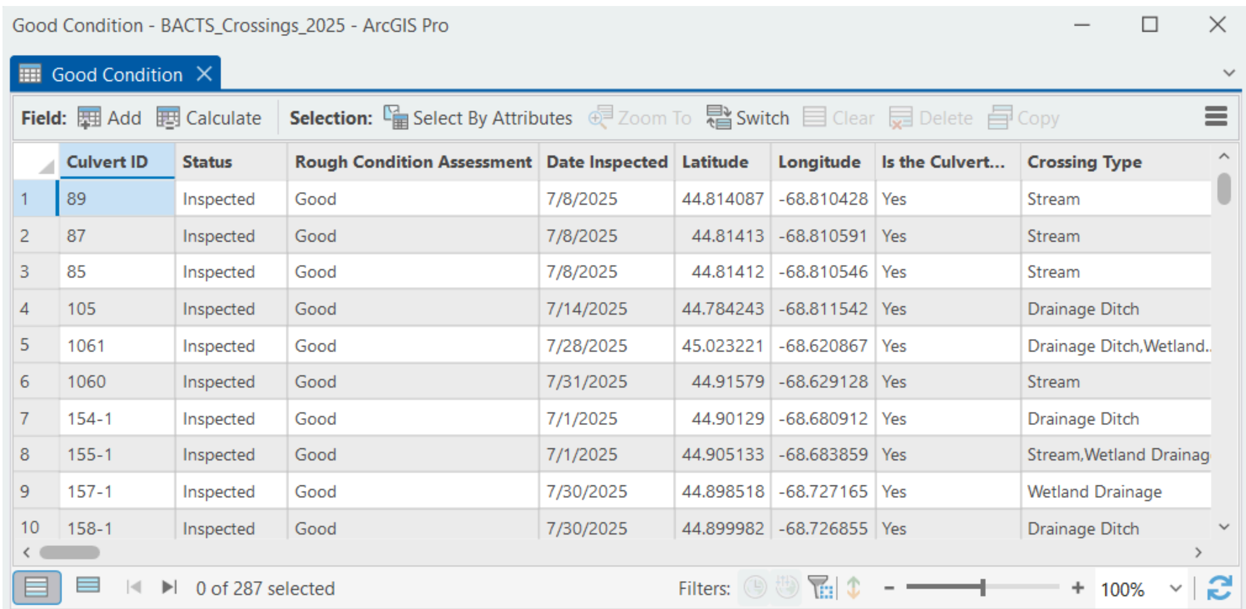


Figure 2: Catalog Pane

2.5. Viewing Attribute Tables

Every feature layer in a GIS geodatabase is associated with an attribute table. Attribute tables in ArcGIS Pro serve as repositories for information associated with each point, line, or polygon. For the BACTS Regional Culvert Inventory Dataset, this includes the specific geographic locations, culvert crossings inspection measurements, jurisdiction values, overall condition assessments, and photographs collected during fieldwork. This allows for a variety of data inputs and analysis. Each row represents a single geographic feature on the map, and each column (field) contains a specific type of information about that feature. To view the attribute table for any layer, right-click the feature layer in the Contents Pane and select Attribute Table, which opens a tab displaying all records, fields, and associated data for that layer. **Figure 3** below shows the attribute table of "Culvert Condition Assessment: Good".



	Culvert ID	Status	Rough Condition Assessment	Date Inspected	Latitude	Longitude	Is the Culvert...	Crossing Type
1	89	Inspected	Good	7/8/2025	44.814087	-68.810428	Yes	Stream
2	87	Inspected	Good	7/8/2025	44.81413	-68.810591	Yes	Stream
3	85	Inspected	Good	7/8/2025	44.81412	-68.810546	Yes	Stream
4	105	Inspected	Good	7/14/2025	44.784243	-68.811542	Yes	Drainage Ditch
5	1061	Inspected	Good	7/28/2025	45.023221	-68.620867	Yes	Drainage Ditch,Wetland..
6	1060	Inspected	Good	7/31/2025	44.91579	-68.629128	Yes	Stream
7	154-1	Inspected	Good	7/1/2025	44.90129	-68.680912	Yes	Drainage Ditch
8	155-1	Inspected	Good	7/1/2025	44.905133	-68.683859	Yes	Stream,Wetland Drainag
9	157-1	Inspected	Good	7/30/2025	44.898518	-68.727165	Yes	Wetland Drainage
10	158-1	Inspected	Good	7/30/2025	44.899982	-68.726855	Yes	Drainage Ditch

Figure 3: Example of "Good Condition" attribute table

While most fields in the attribute table are visible to the user (see **Appendix 2** of the Summary Report for details on each field), ArcGIS also maintains several system-generated fields that are only visible in the *Fields View*. **Figure 4** below highlights Field Views in the attribute table. These fields are not meant for editing but are essential for how the geodatabase manages, tracks, and displays data behind the scenes. They allow ArcGIS to uniquely identify features, store geometry, support attachments, and maintain relationships between tables. Hidden fields can be viewed by opening the layer's Attribute Table (more information in **Section 2.5.1**), selecting the Fields View tab, and enabling any fields that are not visible by default.

Fields: Good Condition - BACTS_Crossings_2025 - ArcGIS Pro

Fields: Good Condition

Current Layer: Good Condition

Visible	Read Only	Field Name	Alias	Data Type	Allow NULL
✓	✓	OBJECTID	OBJECTID	Object ID	
✓		Shape	Shape	Geometry	✓
✓		_title	Culvert ID	Text	✓
✓		_status	Status	Text	✓
✓		rough_condition_assessment	Rough Condition Assessment	Text	✓
✓		date_	Date Inspected	Date	✓
✓		_latitude	Latitude	Double	✓
✓		_longitude	Longitude	Double	✓
✓		is_the_culvert_crossing_present_	Is the Culvert Crossing Present?	Text	✓
✓		crossing_type	Crossing Type	Text	✓
✓		flow_status	Flow Status	Text	✓
✓		specific_structure_type	Specific Structure Type	Text	✓
✓		how_many_pipes	How Many Pipes?	Long	✓
✓		pipe_material	Pipe Material	Text	✓
✓		corrugations	corrugations	Text	✓
✓		crossing_opening_size_inches	Crossing Opening Size (Inches)	Double	✓
✓		inlet_condition	Inlet Condition	Text	✓
✓		inlet_drop_inches_invert_to_stream_bed	Inlet Drop (Inches)- Invert to Stream Bed	Long	✓
✓		inlet_water_depth_inches	Inlet Water Depth (Inches)	Double	✓
✓		blocked_inlet	Obstructions?	Text	✓
✓		sedimentdebris_depth_inches_inlet	Sediment/Debris Depth (Inches)	Double	✓
✓		road_fill_height_intlet	Road Fill Height	Double	✓
✓		additional_comments_upstream1	Additional Comments	Text	✓
✓		additional_inlets_if_multiple_different	Additional Inlets if Multiple & Different	Long	✓
✓		channel_width_ft_upstream	Channel Width (ft)	Double	✓
✓		channel_width_units_upstream	Channel Width Units	Text	✓
✓		additional_comments_upstream3	Additional Comments	Text	✓
✓		outlet_condition	Outlet Condition	Text	✓

Figure 4: Fields View Tab

2.5.1. Hidden Fields in the Geodatabase

The hidden fields within the BACTS Regional Culvert Inventory are described below. These fields can be made visible in the attribute table by opening the Fields View, locating the “Visible” column, and selecting the checkbox for each field you want to display. After adjusting visibility, users must click Save on the Fields tab in the ribbon to apply the changes. Once saved, the user can return to the attribute table, where the newly unhidden fields will now appear. This allows municipalities to control which attributes are visible during editing and analysis while keeping the table organized and focused on the most relevant information. **Figure 5** shows the Fields view tab, highlighting the visible and read-only columns.

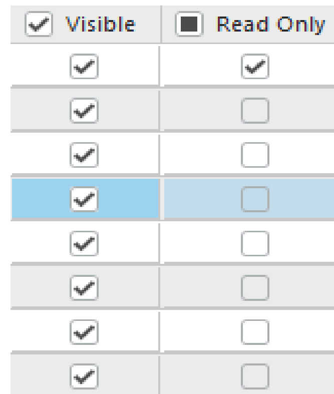


Figure 5: Fields View Tab; Visible & Read Only

OBJECTID - An ArcGIS Pro system-created number that assigns each feature a unique row in the table. This column helps ArcGIS keep track of selections and edits, but doesn’t contain any meaningful project information. It should not be edited or deleted.

GlobalID - A permanent, unique identifier assigned automatically to each geographic feature (a row in the attributes table). Unlike OBJECTID, it stays the same even if the data is copied or moved. This field is important for tracking edits and managing layer elements, such as attachments or photos. This value will not change.

Record ID - A project-specific identifier used to track each culvert feature’s geographic location across field forms, spreadsheets, and the geodatabase. In this project, the Record ID allows each culvert feature to be consistently identified across multiple layers and datasets, enabling accurate cross-referencing during geoprocessing and other analytical workflows. This value will not change.

Shape/ Geometry - The geometry of each feature (point, line, or polygon) is established when a feature is created and determines what kinds of spatial analyses can be performed. The geometry field also ensures that features are stored with consistent spatial definitions, allowing layers to align and overlay properly during mapping and analysis.

2.6. Viewing Attachments

The photographs associated with each culvert inspection (inlet, outlet, upstream, downstream, and crossing images) are stored as attachments in ArcGIS Pro. To view attachments in ArcGIS, open the attribute table for the layer and click the paperclip icon (Manage Attachments) for the feature you want to inspect. Alternatively, clicking a feature on the map displays a pop-up panel with the associated attributes. If attachments are enabled, the photos or documents will appear in the panel at the bottom of the pop-up view. **Figure 6** below shows an example of a pop-up panel associated with a map feature.

Good Condition - 98

Additional Inlet: Photo 4	<Null>
Additional Outlet: Photo 1	<Null>
Additional Outlet: Photo 2	<Null>
Additional Outlet: Photo 3	<Null>
Additional Outlet: Photo 4	<Null>
Additional Outlet: Photo 5	<Null>
Within75ft_SW	Yes

upstream_photos3_a3841849-8396-4460-accc-f138939ad4ac.jpg

Figure 6: Pop-up Panel for feature layer Good Condition, Culvert ID:98

3. Geodatabase Maintenance

The accuracy and overall usefulness of the geodatabase depend on regular updates by Town staff and other system users. As culverts are replaced, modified, or newly identified, or when more precise survey or field information becomes available, these changes should be incorporated into the geodatabase. Routine maintenance ensures that the infrastructure data remains current, reliable, and consistent with field conditions.

3.1. Adding Features

When field inspections or construction projects identify a new culvert, or when an existing culvert is moved to a different location, a new feature should be added to the GIS layer to ensure the map accurately reflects current conditions.

To add a new point to a layer, users must open the **Edit tab** and click **Create** to activate the **Create Features Pane**. In this pane, the user selects the target feature class and then chooses the appropriate construction tool for the layer's geometry, such as Point, Line, or Polygon, before digitizing the new feature directly on the map in its correct location or shape. The user then clicks the map at the desired area to create the feature. Attribute fields populate automatically in the Attributes pane, where the user can review and modify values as needed before applying and saving the edit.

3.2. Editing Existing Features

Edits or deletions may be required when municipal staff document that a culvert has been replaced, relocated, maintained, or improved, or when updated survey or field information provides more accurate location or attribute details. Municipal staff may also initiate updates when planning new construction or system improvements that require modifying or removing existing features in the GIS. Features may be deleted when a culvert has been removed or relocated.

Existing features can be modified by choosing the **Select** tool on the **Edit tab** and clicking the feature to activate it**.** Geometric edits can then be performed using tools such as **Move** to relocate the feature, Reshape to adjust its geometry, or other construction tools that allow refinement of its spatial representation depending on the feature class type. Attribute updates are performed within the **Attributes pane,** where all editable fields become available once the feature is selected, allowing the user to modify and apply changes to the underlying attribute data. Additional descriptive information or map notes can be added using the Annotation or Text tools if the project requires labeled or callout-based context. Features may also be removed by **selecting** them and pressing **Delete,** or by using the **Delete** command on the Edit tab. After completing all actions, users must click **Save** on the **Edit tab** to write the edits to the geodatabase and ensure data integrity is maintained.

3.3. Maintaining Stable Data Connections

Maintaining stable data connections is essential to ensure the Culvert Inventory Geodatabase functions smoothly. When required fields or structural elements are removed or altered, the underlying relationships that connect features to their attributes and attachments can become corrupted. Likewise, modifying the folder structure, such as renaming, moving, or deleting project files, breaks the file paths that ArcGIS relies on to locate and draw data. ArcGIS stores only references to these datasets, not the datasets themselves. Hence, any disruptions to those paths prevent the software from accessing the information, resulting in a red exclamation point next to the affected layer. If this occurs, users can attempt to restore the connection by right-clicking the exclamation point, selecting **Data**, then clicking **Repair Data Source**, and navigating to the correct file location. If the original file has been removed or altered beyond repair, the layer may not be recoverable. For this reason, users should avoid rearranging or deleting any files within the project directory and follow the User Guide's recommended workflows to preserve the integrity and functionality of the geodatabase.

4. ACTS Culvert Inventory Feature Layers Descriptions

The BACTS Regional Culvert Inventory Geodatabase maintains a comprehensive inventory of culvert infrastructure, which is organized in ArcGIS Pro into several distinct feature layers. Each layer captures unique information about the culverts in the region. The feature layers included in this geodatabase are described in detail below.

4.1. Culvert Condition Assessment

The Culvert Condition Assessment provides a standardized evaluation of the inspected culvert crossings in the BACTS region. Each culvert was field-verified, assessed, and assigned an inspection status reflecting the level of follow-up needed (Inspected, Follow-Up Required, or Could Not Locate). For locations where complete assessments were possible, culverts were categorized into Good, Fair, or Poor condition based on visible structural and hydraulic indicators. To incorporate environmental context in the evaluation and to prioritize culverts to inspect, culverts were also screened for their proximity to surface waters using a 75-ft buffer. This combined approach allows the dataset to identify not only the physical condition of each structure but also its potential interaction with surrounding wetland and aquatic resources.

Table 1 summarizes all classification attributes assigned during the evaluation process.

- **Condition Class** represents the observed structural integrity of inspected culverts, ranging from Good to Poor based on surface-level indicators such as erosion, deformation, sediment buildup, or visible deterioration.
- **Proximity to Surface Waters** accounts for the environmental sensitivity of each culvert. Culverts flagged within a 75 ft radius to surface water features (rivers, streams, lakes, etc.) were derived by clipping the National Wetlands Inventory (NWI) data to the watershed and generating a 75-ft buffer around mapped surface waters.
- **Inspection Status** indicates the level of field verification achieved at each site, distinguishing fully inspected culverts from those requiring additional review or those that could not be located.

Table 1: Feature layer descriptions for the Culvert Condition Assessment.

Feature Layer	Categorization	Definition
Condition Class	Good	Culvert shows no significant structural or hydraulic issues; functioning as designed.
	Fair	Moderate concerns observed (sediment buildup, erosion, damaged ends, aging signs). The culvert is functioning but should be monitored or receive routine maintenance.
	Poor	Significant structural defects or high maintenance needs were visible; they may need replacement, redesign, or advanced assessment.
Proximity to Surface Water (75 ft)	Yes	Culvert lies within 75 ft of a mapped surface water feature (river, stream, brook, pond, wetland). Elevated hydrologic and erosion influence is likely.
	No	No mapped surface water feature within 75 ft. Lower hydrologic risk, though local drainage issues may still exist.
Inspection Status	Follow-Up Required	Inlet or outlet not fully accessible or visible; safety concerns, private property, or locked gates prevented full inspection; requires a second visit.
	Could Not Locate	Culvert could not be found in the field; it may be buried, removed, or misidentified in older datasets; flagged for future verification.

4.2. Highway Corridor Priority

MaineDOT's [Highway Corridor Priority (HCP)] layer classifies roadway segments into five statewide priority levels based on their importance to mobility, connectivity, and economic activity across Maine. HCP categories reflect roadway function, traffic volume, and statewide significance, ranging from high-capacity interstate corridors to locally maintained streets. Integrating the HCP layer into culvert and crossing assessments helps identify where structural deficiencies may have greater transportation impacts or where improvements may benefit critical travel routes.

Table 2: Feature layer descriptions for the Highway Corridor Priority.

Feature Layer	Categorization	Definition
Highway Priority	Priority 1 Roads	Includes the Maine Turnpike, interstate system, and key National Highway System (NHS) principal arterials (e.g., State Route 9 Brewer–Calais, US Route 2 Newport–Gilead, US Route 1 Houlton–Madawaska). Represents ~1,873 miles (8% of total mileage) but carries 40% of all vehicle miles traveled (VMT) statewide.
	Priority 2 Roads	High-priority non-NHS arterials such as State Route 161 Caribou–Ft. Kent, State Route 15 Bangor–Greenville, US Route 1 Ellsworth–Eastport, and State Route 4 Farmington–Rangeley. About 1,252 miles (5% of roadway miles) but carries 18% of statewide traffic.
	Priority 3 Roads	Remaining arterials and major collectors (e.g., US Route 202 China–Hampden, State Route 5 Cornish–Fryeburg, State Route 6 Lincoln–Topsfield, US Route 1 Baileyville–Houlton). Roughly 1,257 miles (5% of mileage), carrying 12% of statewide traffic.
	Priority 4 Roads	Remaining major collector highways, minor collectors, and many State Aid roads with shared state–municipal maintenance responsibility. Approximately 4,670 miles (20% of mileage), carrying 17% of statewide traffic.
	Priority 5 Roads	Local roads and municipal streets, maintained year-round by municipal partners. Although they represent about 14,446 miles (61% of total roadway mileage), they carry only 13% of statewide traffic.

* *MaineDOT Highway Corridor Priority (HCP) System, Asset Management Glossary.*

4.3. Jurisdiction

MaineDOT's Jurisdiction layer represents roadway segments categorized by the entity responsible for their general maintenance. This layer provides authoritative jurisdictional attribution used to identify maintenance authority and support transportation network analysis. The table below summarizes all roadway jurisdiction types used by MaineDOT. These categories distinguish between state-maintained highways, toll roads, shared State Aid routes, municipally maintained ways (year-round or seasonal), and other specialized or undefined road types.

Table 3: Feature layer descriptions for the Jurisdiction.

Feature Layer	Categorization	Definition
Jurisdiction	State Highway	Roads fully maintained by the State of Maine, typically major or regionally significant corridors.
	Toll Highway	Roads requiring toll payment, maintained by the Maine Turnpike Authority or similar tolling entities.
	State Aid	Roads where maintenance responsibilities are shared between the state and the municipality under Maine's State Aid program.
	Town Maintained Way *(Year-Round)*	Municipal roads are maintained continuously throughout the year, including plowing and regular service.
	Town Maintained Way *(Summer Only)*	Municipal roads are maintained only during the summer months; typically, they are not plowed or maintained in winter.
	Town Maintained Way *(Winter Only)*	Roads are maintained only in the winter months (rare category) and are used for seasonal access.
	Seasonal Parkway	Special-use or limited-access roads open only during certain seasons, often used for recreational or scenic access.
	Other	Roads not fitting standard categories, including private roads, unmaintained ways, or unusual access routes.

* *Maine Department of Transportation (MaineDOT) Map Viewer — Road Jurisdiction Layer.*

4.4. Maine Parcels Organized Towns

The Maine Digital Parcel Viewer provides a comprehensive, statewide collection of digital tax parcel boundaries for both Organized Towns and Unorganized Territories. Real property data in Maine is maintained by the government entity responsible for assessing and collecting property taxes, meaning that parcel data originates from both municipal assessing offices and the Maine Revenue Service. The dataset is compiled and standardized by the Maine Office of GIS and the Maine GeoLibrary to support property assessment, land use planning, municipal services, and regional analysis. Where available, parcel polygons are linked to assessor attribute information through the Maine Parcels Organized Towns ADB table, offering detailed ownership and valuation data for many communities.

4.5. USFW Surface Waters

The National Wetlands Inventory (NWI), developed and maintained by the U.S. Fish & Wildlife Service (USFWS), provides a nationally consistent geospatial database of wetland and deepwater habitat types across the United States. For this project, the NWI wetlands dataset was clipped to the watershed boundary to identify wetland features surrounding culvert locations and to support proximity and environmental sensitivity analyses. NWI data is produced through remote sensing and periodic updates; some wetlands may be unmapped or reflect past conditions. Field verification is recommended for site-specific applications.

4.6. Urban Compact

The Maine State Urban Boundaries Layer, developed and maintained by Maine DOT, identifies areas formally designated as Urban Compact zones. These areas typically occur within town and city centers where higher development density, pedestrian activity, and municipal infrastructure warrant a shift in roadway maintenance responsibilities from the state to the municipality. For this project, the Urban Compact layer was clipped to the study region's geographic area to ensure only relevant municipal compact boundaries were included and to avoid processing unnecessary statewide data.

Appendix 4. StreamSmart Guidance

MAINE

Stream Crossings

new designs to restore stream continuity

Jacques Tardie/Project SHARE

Project SHARE Bowles Brook Restoration

Brook Trout

Thousands of miles of streams flow through Maine. These streams are habitat for a variety of fish, birds, insects, reptiles, mammals, and amphibians, and they provide recreational opportunities and economic benefits to Maine residents. Maine also has an extensive network of roads that are vital to the social and economic health of our communities. Wherever a road crosses a stream, a bridge or culvert made that crossing possible. Most bridges allow streams and the wildlife that they support to pass freely under them, but incorrectly sized, poorly placed, or damaged bridges and culverts can prevent fish and wildlife from accessing food, breeding areas, and other important habitat particularly on smaller streams. Fortunately, efforts are underway to improve road-stream crossings. With proper stream crossing sizing and installation, our streams can function naturally, our fish and wildlife can freely migrate, and our roads can be improved.

COMMON PROBLEMS WITH ROAD-STREAM CROSSINGS

UNDERSIZED CROSSINGS
restrict natural stream flow, causing several problems including scouring and erosion, high flow velocity, clogging, and ponding.

SHALLOW CROSSINGS
have water depths too low for many organisms to move through them and may lack appropriate bed material.

PERCHED CROSSINGS
are above the level of the stream bottom at the downstream end. Perching erodes streambeds and can prevent wildlife from migrating upstream. They can result from either improper installation or from years of downstream bed erosion.

Above images courtesy of Ethan Nadeau of Biodrawversity.com

scouring and erosion

high flow velocity

clogging

ponding

low flow areas

damaged culvert

Road-stream crossings that do not allow fish and wildlife to freely migrate are most often undersized structures that would not meet today's design criteria for fish passage. This is primarily because designs were historically based on standards only intended to protect roads.

In many cases, crossings that were once wildlife-friendly are now barriers to migration because of:

- clogging at inlets,
- scouring and erosion around outlets,
- deteriorating construction materials, or
- stream channels shifting out of alignment with the structure.

These problems result in further long-lasting effects on natural systems by:

- degrading stream water quality, and
- isolating large portions of habitat, which in turn alters natural dispersal patterns for fish and wildlife.

Incorrectly sized, poorly placed, or damaged bridges and culverts tend to have a shorter service life. They usually require frequent maintenance and extensive repairs that place a significant demand on the limited resources of towns, forestry companies, and other private landowners.

Safe, stable, and fish and wildlife friendly stream crossings, on the other hand, can accommodate wildlife and protect stream health while reducing expensive erosion and structural damage.

Fortunately, efforts are underway to improve road-stream crossings.

BOX AND PIPE CULVERTS

Box and pipe culverts are the most common structures used for road-stream crossings. However, they are not as effective at allowing fish and wildlife to migrate compared to bridges or open-arch culverts, especially if they are incorrectly sized or installed. When box and pipe culverts are used, some simple steps can be taken to make them more friendly to fish and wildlife:

- Avoid installing culverts that are 60 feet or longer.
- Include secondary culverts on floodplains to pass high flows.
- The widths and depths of the culverts should match those of the natural banks and full stream channels.
- Ensure that they are level and that the streambeds are "flat." In other words, avoid using box and pipe culverts in areas with slopes greater than two percent.
- Embed the culverts into the natural streambed to at least 20 percent of the culvert height at the downstream end.
- Choose corrugated pipe over smooth bore.

culvert properly embedded into streambed

SLIPLINING

Inserting a smooth plastic liner inside an existing culvert may save money in the short term, but it raises water levels and increases flow velocities, which removes bed material and increases downstream scour. These problems make passage more difficult for fish and wildlife.

KEY FEATURES OF GOOD ROAD-STREAM CROSSINGS

bridge

open-arch culvert

Good road-stream crossings simulate the upstream and downstream characteristics of the natural stream channel. Well-designed crossings:

- use *natural substrate* within the crossing;
- match the natural *water depths* and *velocities*; and
- are *wide and high* relative to their length. Structures should be at least 1.2 times the natural stream bank width so they can retain natural substrates and allow fish, wildlife, floods, and debris to pass.

Bridges and open-arch designs are the preferred structure types because they allow characteristics of the natural stream channel to be simulated. Replicating the slope, dimensions and streambed material creates water depths and velocities similar to the natural channel. These structures are also capable of handling a range of flows and will allow most organisms to freely pass through them.

Safe, stable, and fish and wildlife friendly stream crossings can accommodate wildlife and protect stream health while reducing expensive erosion and structural damage.

Above images courtesy of UMASS

WHY UPGRADE ROAD-STREAM CROSSINGS?

Stream crossing designs have improved. Structures based on today's designs:

- **Require less frequent repairs.**
  Upgrading Maine's road-stream crossings will reduce long-term maintenance costs and periodic losses of use. Newer designs also last longer. For example, open-arch culverts can last in excess of 75 years.
- **Help wildlife access stream natural areas.**
  Upgrading will in turn improve fishing, hunting, and wildlife observation opportunities for Maine's residents and visitors.
- **Handle a wider range of flows.**
  Climate change is increasing the amount and intensity of precipitation. A study in Keene, New Hampshire revealed that 30 to 80 percent of the city's culverts were likely to fail under projected flow conditions. Upgrading will prevent or minimize the potential negative impacts of increased flow conditions on Maine's infrastructure.

Grant funding and technical assistance may be available to help defray costs for new stream crossings that are more friendly to wildlife.

HELP CARE FOR OUR STREAMS

We now understand that a well-designed road-stream crossing should meet our transportation needs *and* allow for natural stream functions and wildlife migration. The Maine Forest Service, the U.S. Fish and Wildlife Service Gulf of Maine Coastal Program, and many other state, federal and NGO partners are eager to work with towns, agencies, and private landowners to improve fish passage at crossings. The goal is to accomplish several objectives: to spread the word of why we need to fix these culverts, to demonstrate improvements in crossing designs, to help find funding to share restoration costs, and, in the end, to restore passage for fish and wildlife in our streams.

American Shad

Blueback Herring

Alewife

Produced by Maine Forest Service, GOMC-NOAA Community Based Habitat Restoration Partnership, and USFWS Gulf of Maine Coastal Program.