Rhode Island Department of Transportation

Road-Stream Crossing Assessment Handbook

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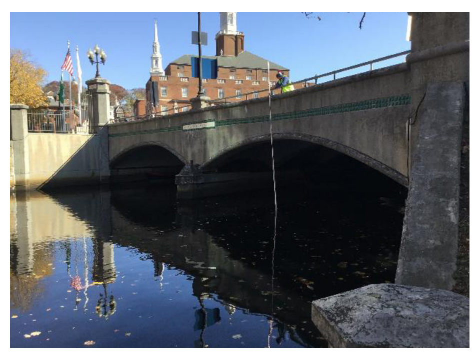

prepared by FUSS & O'NEILL

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Section 1: Introduction to the Handbook

The Rhode Island Department of Transportation (RIDOT) Road-Stream Crossing Assessment Handbook is a guidance document and decision-making tool to assist RIDOT and municipalities proactively identify road-stream crossings in Rhode Island that should be a priority for replacement or upgrade. This section of the Handbook provides an overview of the issues related to road-stream crossings and describes the assessment framework for prioritizing crossings based on multiple factors. This section also describes the purpose of the Handbook, organization and use of the Handbook, development of the Handbook including stakeholder involvement, and limitations of the Handbook.

1.1 Background

1.1.1 Why Assess Road-Stream Crossings?

Road-stream crossings are structures such as bridges, culverts, and fords that carry a roadway or other transportation route across a river or stream. With an estimated 4,000 crossings statewide, road-stream crossings are a critical component of Rhode Island's transportation infrastructure.

Improperly designed, outdated, or undersized crossings can be flooding and washout hazards, and failures can cost millions of dollars in property and infrastructure damage. Rhode Island's transportation infrastructure is also aging and vulnerable to the effects of climate change, including more intense and frequent storms, increased inland and coastal flooding, and sea level rise.

Undersized stream crossings can also serve as barriers to the passage of fish and other aquatic organisms along a river system. This alters aquatic habitat and disrupts river and stream continuity, putting aquatic populations and even ecosystems at risk. On the other hand, adequately sized stream crossings can provide improved passage for terrestrial organisms which might otherwise cross the roadway and endanger themselves and human drivers through wildlife-vehicle collisions.

Replacing undersized crossings with larger structures that are less susceptible to failure can increasing public safety and reducing ecological impacts, while providing improved aquatic and terrestrial wildlife passage. Proactively upgrading these structure **before** they fail can also save money in the long term by avoiding the costs of the upstream and downstream impacts of failure, emergency response measures, lost business and tourism due to lack of viable roads and utilities, and environmental cleanups.

As the number of crossings needing replacement typically far exceeds the amount of funding available for their replacement, **the greatest benefit of performing a comprehensive road-stream crossing assessment within a given municipality or watershed is the guidance it can provide to planners in determining how to most effectively spend limited funds.**

1.2 Purpose of the Handbook

1.2.1 Scope of the Handbook

The objective of road-stream crossing prioritization is to identify important crossing sites for replacement or upgrade, given limited resources and funding. This Handbook provides a standardized, screening-level assessment methodology to help determine which stream crossings should be a priority for replacement or upgrade.

The Handbook is intended for use by RIDOT, other Rhode Island state agencies, and municipalities and watershed organizations that are interested in prioritizing road-stream crossings for replacement or upgrade. Given the variety of potential users of the Handbook, the methodology has been designed to facilitate comparison of crossings assessed by different users in different regions of the state. The methods are designed to limit the use of proprietary analysis software and use publically-available data where possible. Use of this Handbook does not require expertise in aquatic organism passage, hydraulics, or fluvial geomorphology. Input from experts in these fields may be helpful in interpreting the final prioritization results. The analysis team should include members who are experienced using a geographic information system (GIS) such as ArcGIS to perform data collection and spatial analyses. Field data collection and desktop assessments described in this Handbook require the use of GIS.

Completion of a road-stream crossing prioritization assessment using a data-driven approach can also better position the project owner to receive grant funding. Some grant programs may be more likely to select a road-stream crossing replacement project for funding if there is evidence that a systematic method has been used to demonstrate why the crossing is a priority for replacement.

The methodology described in this Handbook assesses road-stream crossings based on the major factors that contribute to crossing failures, including:

- Hydraulic capacity of the existing crossing under current climate, topographic, and land cover conditions
- Hydraulic capacity of the crossing under projected future climate change conditions
- Vulnerability of the crossing to geomorphic conditions
- Structural condition of the crossing
- Potential flooding impacts at failure, including impacts to
  - Impacts to existing infrastructure, and
  - Impacts to transportation services
- The degree to which the crossing allows aquatic organism passage
- The potential ecological benefits of replacing a crossing with a larger one

1.2.2 How do These Methods Differ from Others?

While many other methods and protocols have been developed to prioritize road-stream crossings, most focus narrowly on one or two main concerns (e.g., aquatic passability, structural condition, or hydraulic risk under current [as opposed to future] climate conditions). This Handbook builds on those methods and describes new methods to incorporate all of these concerns into one comprehensive prioritization method that can support crossing replacement efforts by multiple different stakeholders. The methods are designed so that the manner in which field data is used to determine component scores for each major decision factor, and how these component scores are then combined into a single priority ranking, is repeatable for different assessment teams and transparent to stakeholders. The ability to assess crossings based on their component scores also allows the user to customize the prioritization based on local or agency concerns or on available funding. For example, if funding is available for the stream habitat and connectivity restoration through crossing replacement, ranking or sorting the crossings based on the *Aquatic Benefit Score* (*Section 13.3.2*) may be more appropriate than selecting a crossing based purely on the *Relative Priority Ranking* (*Section 13.3.3*).

In addition, new tools have been developed for use with this Handbook in order to facilitate efficient data collection and analysis. These new tools include:

- A comprehensive digital field data collection form with built-in data validation rules that can be used on any mobile device, including personal smartphones or tablets. The digital field form attaches photographs taken using the mobile device directly to the record for each crossing.
- A PDF field form that can be printed off for use in the field if mobile devices are not available or malfunction in the field
- A sample web application hosted on RIDOT's ArcGIS Online account to facilitate quality control of data following field data collection
- A calculation spreadsheet with assessment formulas pre-programmed according to the methods described in the Handbook

1.2.3 Important Definitions

- <u>*Road-Stream Crossing*</u>*:* Any bridge, culvert, ford, or remnant thereof that crosses flowing, "blue-line" perennial streams or the water bodies (e.g. lakes and ponds) that blue line streams enter and exit. For this Handbook a blue-line stream is a perennial stream that appears on a 7.5 minute USGS quadrangle map as a blue line. In the field a stream is defined by characteristics such as a streambed and defined streambanks[1]. Streams are created through natural processes of surface runoff, erosion, and deposition and are typically mapped in GIS as hydrography layers. Drainage ditches are **not** considered streams for the purpose of this Handbook, as they are subject to different processes than streams.

- *Bridge*: Any crossing that has a deck supported by abutments (or stream banks). Abutments may be earthen or constructed of wood, stone masonry, concrete, or other materials. A bridge may have multiple cells, divided by one or more piers.
- *Culvert*: Any crossing structure that is buried under some amount of fill. Culverts generally do not have separate bridge decks, and are typically constructed of concrete, stone masonry, plastic, or metal. Crossings with embedded bottoms or supported on footings with open bottoms but that are buried under fill are considered culverts, but may be assessed in a similar manner as a bridge during the assessment if the shape is similar. Multiple culvert structures may exist at a single road-stream crossing. Such crossings shall be assessed as part of the same crossing site, but each structure shall be assessed separately for certain parameters

  In this Handbook, culverts refer only to structures that carry flowing streams. They are sometimes referred to locally as "cross culverts," "stream culverts," or "carrying culverts." Culverts that convey drainage swales, which are sometimes referred to as "drainage culverts," are not considered stream crossings for the purpose of this Handbook. Drainage swales are typically artificially constructed or excavated for the purpose of conveying excess stormwater runoff, and are not created by natural processes.
- *Ford*: A shallow, open stream crossing in which vehicles typically pass through the water. Fords may be armored to decrease erosion and may include one or more pipes to allow flow through the ford ("vented ford").

Note that these definitions differ from the definitions of "bridge" and "culvert" given in Chapter 1 of the RIDOT *Bridge Inspection Manual* (October 2013, as amended), which cites 23 CFR 650.305 in defining a bridge as, "A structure including supports erected over a depression or an obstruction, such as water, highway, or railway, and having a track or passageway for carrying traffic or other moving loads, and having an opening measured along the center of the roadway of more than [twenty] 20 feet between undercopings of abutments or spring lines of arches, or extreme ends of openings for multiple boxes; it may also include multiple pipes, where the clear distance between openings is less than half of the smaller contiguous opening." For the purpose of this Handbook, bridges are defined by the presence of a deck and a lack of fill, and may have a length shorter than 20 feet.

Similarly, the RIDOT *Bridge Inspection Manual* defines a culvert as, "A structure designed hydraulically to take advantage of submergence to increase hydraulic capacity. Culverts, as distinguished from bridges, are usually covered with embankment and are composed of structural material around the entire perimeter, although some are supported on spread footings with the streambed serving as the bottom of the culvert. Culverts may qualify to be considered bridge length." For the purpose of this Handbook, the embankment cover is the defining feature of a culvert; submergence is not required for a crossing to fit the definition of a culvert. Culverts and other crossings types that use flood-resilient designs do not experience submergence under typical flows.

1.2.4 What This Handbook is Not

This Handbook is not:

- **A road-stream crossing design manual:** This Handbook does not provide guidance regarding the design of replacement stream crossings, or the regulatory permitting pathway for such

[1] If the user wishes to extend these methods to crossings over ephemeral streams (a.k.a. intermittent streams), the methodology would still be appropriate with only minor changes regarding the hydrography data source used to identify road-stream crossing locations.

designs. Although stream crossing guidance is provided in the Rhode Island Department of Environmental Management's *Wetland BMP Manual: Techniques for Avoidance and Minimization*, Chapter 9 "Wetland Crossings," as of this writing, comprehensive statewide stream crossing design standards have not yet been adopted in Rhode Island.

- **A survey methodology for final crossing design:** Although the information gathered using the field and desktop assessment methods described in this Handbook may provide some insights into design challenges and requirements at a given site, the data and assessment methods are insufficient for final design of a replacement crossing. In addition, although efforts have been made to allow for data validation and QA/QC, there is potential for error in data collection and analysis. Data may also become out of date as crossings are replaced or large storms or floods influence the condition of the crossing. Findings should therefore be verified in the field before making a final decision to replace or upgrade a stream crossing, and a formal survey should be performed by a licensed surveyor before designing a replacement crossing structure.
- **A standard for detailed hydrologic and hydraulic analysis methods:** The hydrologic and hydraulic analysis results obtained using the screening-level methods described in this Handbook should not be used for design purposes. Additional hydrologic and hydraulic analysis is required to support the design and permitting of road-stream crossing upgrades or replacements.
- **A guide to <u>which</u> watersheds or municipalities should be assessed first:** Conducting a road-stream crossing assessment at watershed or municipal scale can require a significant amount of funding and time (up to a year). State agencies may need work with municipalities and watershed organizations to determine where a road-stream crossing assessment is most appropriate.
- **An assessment methodology for stormwater and other drainage pipes:** This assessment methodology applies only to road-stream crossings, i.e. bridges or culverts. It is not appropriate for assessment of stormwater conveyances or other drainage pipes or structures. Bridges, culverts, and other water conveyances are defined for the purpose of this Handbook in *Section 1.2.2.*
- **A replacement for the RIDOT Bridge Inspection Manual, the RIDOT Linear Stormwater Manual, or the Rhode Island Stormwater Design and Installation Standards Manual:** This Handbook is intended to complement, but not replace, these other manuals. This Handbook does not eliminate the responsibility of the user to comply with any state or federal regulations or guidelines.

1.3 Organization and Use of the Handbook

1.3.1 Field Assessment: Sections 2-4 and Appendices A-C

Sections 2-4 describe the field assessment process, including the initial planning phase prior to the fieldwork, field data collection, and quality checks of the field data in the office after the data has been collected.

Appendices A-D contain reference documents that will be helpful throughout the field assessment, including a paper copy of the field form, a field equipment checklist, safety information, and examples of good and bad field photographs.

1.3.2 Desktop Assessment: Sections 5-12

Sections 5-12 describe the methods to be used for the "desktop" (in-office) assessments. Several of these assessments require data from the field assessment, and therefore cannot be performed until this data is gathered. In addition, some of the assessments require analysis of geospatial data.

The desktop assessment considers:

- Existing streamflow conditions
- Existing hydraulic capacity of the stream crossing
- Vulnerability of the crossing to future climate change based on projected increases in extreme precipitation, sea level rise, and storm surge
- Structural condition of the crossing
- Geomorphic compatibility of the structure with the channel, and major geomorphic risk factors
- Potential impacts to emergency and local transportation services in the event of failure of the crossing
- Potential flood impacts upstream and downstream of the crossing
- Aquatic organism passage and the potential aquatic habitat value restored as a result of a crossing replacement or upgrade

1.3.3 Crossing Prioritization: Section 13

Section 13 describes the methods used to prioritize road-stream crossings for potential replacement or upgrade based on both risk of failure and potential ecological. The final scoring method uses the traditional mathematical definition of risk as the product of the likelihood of an event and the severity of the event's impact. The final result is a relative priority (High, Medium, or Low) for each crossing. *Section 13* methodology integrates the field data and scoring from the assessments described in *Sections 5-12.* Structure prioritization cannot be performed until these assessments have been completed.

1.3.4 Next Steps - Implementation: Section 14

Section 14 discusses additional issues that should be considered in the final selection and implementation of priority crossing replacements based on the results of the assessment methodology described in this Handbook. This section also provides information on cost, funding sources, and typical permitting considerations for flood-resilient and stream-friendly crossing replacement projects.

1.3.5 Reference Items: Appendices E-G

Appendix E is a glossary of terms and abbreviations used in the Handbook and its appendices, as well as a glossary of the fields used in the digital field form.

Appendix F contains a blank analysis worksheet (pre-programmed Excel spreadsheet) that can be downloaded and used to analyze stream crossings according to the methods outlined in this Handbook.

Appendix G is a supplement to *Section 10: Flood Impact Potential* and outlines detailed GIS analysis procedures that may be used to complete this assessment.

1.3.6 Woonasquatucket River Watershed Pilot Study: Appendix H

The methods described in this Handbook were tested and refined through the completion of a pilot study in the Woonasquatucket River watershed. The pilot study report is provided in *Appendix H*. The pilot study report provides an example application of the assessment methods described in the Handbook.

1.3.7 Frequently Asked Questions: Appendix I

Appendix I is a compilation of frequently asked questions that may be helpful to the user.

1.4 Use of Local Geospatial Data

Where available, municipalities or other users of the Handbook may wish to use local GIS or other relevant data in place of the statewide data sets described in the Handbook. Such local data may be more up-to-date, complete, or accurate. Examples include:

- downscaled climate and rainfall projections for a specific region or municipality
- stream crossing locations that would be particularly disruptive to emergency, commercial, or local traffic that are not otherwise captured by E911 data or functional road classification
- crossing locations that are frequently damaged during floods
- data on the extent and quality of aquatic habitat at a given crossing

The user should carefully weigh the potential advantages and disadvantages of substituting local data for the statewide data described in the Handbook. While the some local data may improve the accuracy of the assessment results, the use of local data sets can also limit the ability to compare results from different road-stream crossing assessment efforts across the state. The user should consult with RIDOT about the benefits and disadvantages of data substitution before undertaking a stream crossing assessment project.

1.5 Development of the Handbook

The Rhode Island Department of Transportation (RIDOT) led the development of this Handbook, with input and assistance from a stakeholder group consisting of representatives from other state agencies, watershed groups, and Rhode Island municipalities. Stakeholders in this project included:

- Rhode Island Executive Climate Change Coordinating Council (EC4), which includes RIDOT and the following member agencies
    - RI Coastal Resources Management Council (CRMC)
    - RI Department of Administration
    - RI Department of Health (RIDOH)
    - RI Division of Planning
    - RI Emergency Management Agency (RIEMA)
    - RI Infrastructure Bank (RIIB)
    - RI Office of Energy Resources
    - RI Division of Public Utilities and Carriers
    - RI Department of Environmental Management (RIDEM)
    - The Rhode Island Commerce Corporation (CommerceRI)
- Save the Bay
- Rhode Island municipalities
- the Woonasquatucket River Watershed Council

Stakeholder input was obtained through multiple stakeholder meetings and review comments on draft project deliverables.

RIDOT also worked closely with an engineering consultant team led by Fuss & O'Neill, Inc., while Field Geology Services supported the development of the fluvial geomorphic assessment methods described in *Section 8: Geomorphic Impact Potential*.

RIDOT and Fuss & O'Neill collaborated with members of the North Atlantic Aquatic Connectivity Collaborative (NAACC), who generously provided information regarding their assessment methods, trainings, and assessment modules that were under development as of the writing of this document. The experience of these individuals and the information provided was invaluable in guiding the development of this Handbook.

The Handbook was developed with the goal of making the methodology accessible to users statewide, particularly to assist municipalities with decision-making regarding maintenance and upgrades of culverts within their jurisdiction, as well as watershed organizations and other groups interested in conducting road-stream crossing assessments. The Handbook draws heavily on established methods developed by others, particularly the NAACC, as well as professional experience of the authors.

The assessment methodology described in this Handbook is not meant to replace other established methods. Instead, this document is designed to build upon and maintain compatibility with the NAACC's assessment methodologies for aquatic passability and structural condition and with the NAACC Data Center (https://naacc.org/naacc_data_center_home.cfm). Maintaining this compatibility will reduce confusion for anyone working regionally (e.g., in watersheds such as the Blackstone River Watershed or Wood-Pawcatuck River Watershed, which cross state lines); will support future collaboration with the NAACC; and will potentially make the data suitable for upload to the NAACC database (provided the data is gathered by field staff trained as certified observers under NAACC guidelines – see *Section 2.2.4*), and available for use in regional research efforts.

1.6 Future Updates to the Assessment and Prioritization Methodology

This Handbook provides a standardized, screening-level methodology to efficiently identify priority stream crossings for replacement or upgrade using information collected from field surveys and other readily-available statewide data sets. Future enhancements to the assessment and prioritization methodology are recommended as new data sources become available for use in Rhode Island and as the stream crossing assessment and prioritization practice continues to evolve, with ongoing contributions from state and federal agencies, university research, watershed organizations, and engineering practitioners. Future anticipated or recommended enhancements to the Handbook include:

- Tidal Crossing Assessment Methodology
  - Update the assessment methods for tidal crossings as currently available methods are tested and refined
- Future Climate Change
  - As our ability to better understand and predict the impacts of climate change improves, update projected changes in streamflow and sea level rise and the associated assessment methods
- Flood Impact Potential
  - Refine the methods for defining flood impact areas and further automate the analysis methods to improve the accuracy and efficiency of this assessment
  - Consider other types of potential impacts resulting from crossing failure such as impacts to ecological resources, recreation, and tourism
- Aquatic Organism Passage
  - Update the CAPS Critical Linkages dataset with RIDOT-specific roads and streams data layers for more accurate and complete data coverage across the state of Rhode Island
  - Incorporate new statewide data and information on aquatic habitat quality
  - Incorporate improved methods for considering network connectivity of barriers (including dams) on the same river system

When comparing results from different assessment efforts, the user should note any differences in the methodology used. Any changes to the methodology should be made with careful consideration of the comparability of future assessments with the results of previous assessments.

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Section 2: Initial Assessment Planning

This section describes the initial planning required for conducting a road-stream crossing assessment, including the initial identification of assessment locations and other preparations prior to beginning field data collection. Thorough and comprehensive planning can result in better quality data and can reduce data gaps and data collection inefficiencies. These guidelines will help field data collectors ensure that all necessary resources are in place prior to mobilizing for field data collection.

2.1 Planning for Field Work

2.2.1 Roles

The likelihood of successful data collection can be significantly increased by clearly defining team member roles within the project and the field crew, and designating appropriate responsibilities. The following positions are recommended for this work.

- ***Assessment Coordinator*****:** This person serves as the project manager for the overall assessment project and is in charge of making decisions for the project team. This person is ultimately responsible for the work product and will direct all other team members' work as well as the project schedule. The Assessment Coordinator will direct desktop data analysis, field work, and scheduling. The Assessment Coordinator is responsible for ensuring that all necessary internal and external communication pathways are in place.
- ***Lead Field Data Collector*****:** The Lead Field Data Collector is responsible for obtaining the information necessary to access the sites, understanding field equipment usage and field operation procedures, packing the equipment for field days, navigating to the field sites, collecting data, abiding by safety rules and successfully completing field work. The Lead Field Data Collector is responsible for the quality and completeness of the field data on the field data form for a given site and is the lead team member in charge of safety. This role also requires the minimum qualifications and training of the NAACC for conducting field assessments.
- ***Assistant Field Data Collectors*****:** In the field, a minimum field crew size of two people is required for safety and to obtain accurate measurements. The Assistant Field Data Collector(s) should assist the Lead Field Data Collector in obtaining necessary data and for complying with safety rules.

Lead and Assistant Field Data Collectors should be trained in culvert assessment data collection, such as training provided through the NAACC. Training requirements are addressed in the *Section 2.2.4: Training*.

2.2.2 Field Data Collection Methods

Field data can be collected digitally using a tablet computer or smartphone, or using paper forms. Digital field data collection is preferred and strongly recommended whenever possible to reduce the level of effort and potential for errors associated with manual data entry. A field data equipment checklist is provided as *Appendix B* of this Handbook.

<u>Digital Field Data Collection</u>

A digital data form has been created for use in the field on a mobile device (i.e., tablet or smartphone) with internet and GPS capabilities. The user will need to download the free Survey123 application on their mobile device in order to use the form. The user will also need to coordinate with RIDOT to access RIDOT's ArcGIS Online Account through Survey123 in order to download the digital data form. Close coordination with RIDOT is recommended to ensure the appropriate hardware and software is used for field data collection.

The digital data form has been designed to upload alldigitally collected field data directly to RIDOT's ArcGIS Online account. The user will need to log in to RIDOT's ArcGIS Online account to complete Quality Control (QC) and analysis of the data. It is recommended that QC of the data be performed on a copy of the field data saved in ArcGIS online rather than through a desktop program such as ArcGIS Pro, in order to maintain data integrity.

The tablet computers or smartphones used for field data collection should be familiar to the user and should be waterproof and shockproof. If a GPS is not integral to the digital data collector, an external GPS device shall be used to either connect to the tablet via Bluetooth or wire, or at the least, to be able to provide correct coordinates for manual entry into the field data form on the digital data collector. If using a digital data collector, bring extra batteries or charging devices and bring a sufficient number of paper field data forms as backup in case the digital data collector fails. If the digital data collector cannot take photographs, bring a digital camera.

Paper Forms

If using paper forms to collect field data, it is best to print the field data forms on **waterproof paper**. Bring along more copies of the field data form than you intend to use as back up. Bring **extra clipboards, pencils/pens and erasers** than needed, in case some fail. Bring **printed copies of crossing maps**, **a GPS receiver** and a **digital camera with extra batteries**.

NAACC Certification

The field assessments and assessment methodologies require multiple steps and require complete and standardized data in order to complete a useful prioritization. Completion of the NAACC Lead Observer Training is recommended for **at least** one member of each field crew assessing road-stream crossings. This will ensure that data is collected as completely and accurately as possible. It will also allow the data gathered to be uploaded to the NAACC's regional online database, reducing duplication of stream crossing survey efforts and making the data available to researchers and other stakeholders for analysis, as only data contributed by NAACC-certified observers may be entered in the NAACC's regional database.

2.2.3 Equipment

In addition to the data collection materials mentioned above, field work will require the following equipment and materials:

- A printed copy of the *Section 3* of this Handbook (printed on waterproof paper if possible)
- Measuring implements (in feet and tenths--decimal feet rather than inches)
  - ✓ **100-Foot Reel Tape** for measuring structure lengths and widths, as applicable
  - ✓ **6 foot Pocket Tape** ("Pocket Rod") to measure structure widths, as applicable
  - ✓ **16-Foot (min.) Stadia Rod and Survey Level/Equipment** to measure relative structure elevations, slope and water depth. If survey equipment is not available for use for field data collection, refer to the NAACC Stream Crossing Survey Data Form Instruction Guide for other acceptable (although less accurate) methods for determining the slope of the structure and relative height measurements.
- **Safety Vests** that are brightly colored and reflective (preferably with pockets to hold equipment)
- **Safety Cones for increasing visibility in high-traffic areas**
- **Waders or Hip Boots** to stay dry while allowing access to pools, deeper streams or areas of thick vegetation
- **Flashlight** to inspect the inside of structures
- **Rangefinder accurate within a maximum of 1-foot (optional)** to safely take measurements without crossing structures, busy roadways or streams
- **Sun, Insect, and Poison Ivy Protection** (e.g. hat, sunglasses, sunscreen, insect repellant, poison ivy soap and prevention, as needed)
- **First Aid Kit**
- **Cell Phone** in case of emergency, for coordination, and to communicate with survey coordinators, as necessary
- **Pocket Calculator** to run quick calculations in the field; if your cell phone has a calculator that can perform the needed calculations, this is also acceptable.

2.2.4 Training

All field data collectors should complete training to become familiar with this Handbook, the purpose of data collection, and need for quality data collection. Field data collectors should gain practice through completing site visits of crossings with an experienced field data collector. Road-stream crossing assessment training should meet the minimum requirements of the NAACC or similar crossing assessment programs.

Survey Equipment Training

Use of survey equipment (survey level and stadia rod, or other available survey equipment) is necessary to collect the required field data for this assessment. If survey equipment is not available for use for field data collection, refer to the NAACC Stream Crossing Survey Data Form Instruction Guide for other acceptable (although less accurate) methods for determining the slope of the structure and relative height measurements.

All members of the field data collection team should be trained on how to properly use the survey equipment, either by a licensed surveyor or other professional trained in surveying. Proper use of survey equipment is imperative for accurate data collection.

It is the responsibility of the Assessment Coordinator to ensure that all team members have appropriate survey training. Survey training should include:

- Setting up survey equipment
- Reading survey scope
- Holding stadia rod
- Completing survey calculations/ recording readings

For this assessment, all survey measurements shall be taken relative to the downstream invert of the road-stream crossing structure.

2.2 Identifying Possible Road-Stream Crossing Assessment Locations

The first step in preparing for road-stream crossing assessments is to identify the crossing locations that will be assessed. Initial identification of these locations consists of the following steps:

- Download and intersect the current “RIDOT Roads” layer with the “Rivers and Streams”, “Lakes Ponds and Reservoirs”, and “Marine and Estuarine Waters” layers from Rhode Island Geographic Information System (RIGIS) at http://www.rigis.org/ to identify possible stream crossing locations. Include crossings located on the border of your assessment area such as streams that follow municipal boundaries.
- Download and review previously surveyed crossings from the NAACC Data Center at https://naacc.org/naacc_data_center_home.cfm as an additional source of crossing locations. Pay attention to the date of data collection, as some of the crossing data may be outdated. Crossings identified in the NAACC database that do not correspond to crossing locations derived from intersecting roads and streams GIS data layers (as described above) should be reviewed in the field to determine if they should be included in the assessment.
- **Crossing codes shall be consistent with NAACC methods of assigning crossing codes.** The crossing code is the unique identifier assigned to each crossing and is composed of the prefix “xy” followed by the latitude and longitude of the site, with decimal degree latitude and longitude values at seven-digit numbers. For instance, a crossing located at 42.32914 degrees north and -72.67522 degrees West will have the crossing code “xy42329147267522”. Crossing codes from the initial desktop analysis shall constitute the official crossing IDs and shall be used to identify proposed crossings to be assessed. GPS coordinates of each crossing as collected in the field will be compared to the official crossing

ID/XY coordinate to make sure the team is in the correct location.

- It is the Assessment Coordinator's role to review and refine the final list of crossings to be assessed in the field based on the above information and any other known or anticipated crossings in the field.

2.3 In-Office Data Assessment Prior to Field Work

After identifying crossings for assessment, additional work should be completed in the office before beginning fieldwork. This information will allow the field crew to conduct fieldwork more easily and efficiently.

2.3.1 Bridge Identification Number

If a bridge is state-owned, the Bridge Identification Number (BIN) may be available through VUEWorks and can be entered into the field form prior to going into the field. This can be helpful in confirming whether you are at the correct site for a crossing.

2.3.2 Initial Determination of Tidal Influence

For the purposes of this assessment, a crossing is considered to be tidally influenced if it is presently located waterward of the Rhode Island Mean Higher High Water (MHHW) line. This is most easily determined for a large set of crossings by comparing the crossing locations to the MHHW line in GIS. This data is available from RIGIS as "Inundation Polygons: MHHW with 0ft SLR) at http://www.rigis.org/datasets/inundation-polygons-mhhw-with-0ft-slr?geometry=-76.734%2C40.781%2C-66.28%2C42.221.

Alternatively, the presence of tidal conditions can be determined from the MHHW boundary limit for the state of Rhode Island, which can be found in the online StormTools application available at http://www.beachsamp.org/stormtools/. Local knowledge from municipalities and/or watershed organizations about the extent of tidal influence should be considered in the determination of tidally influenced crossings as well. Note that these criteria do not account for projected sea level rise due to climate change, which is addressed in *Section 7: Climate Change Vulnerability* of this Handbook.

If the site is marked as a tidal site on the digital form, the fields related to tidal information will be made unavailable to save time and effort. Similarly, these fields would not need to be filled out on the paper form. In this case, *Section 2.3.3* can be disregarded.

2.3.3 Tide Charts and Tide Prediction

If a crossing is determined to be tidally influenced, the tide chart for the nearest tide chart location should be determined and noted on the field form under *Tide Chart Location.*

The selected tide chart should then be used to determine the predicted time of low tide and mark it in the form under *Tide Prediction*.

2.3.4 Hydraulic Analysis Program

The hydraulic analysis program(s) to be used in *Section 6: Existing Hydraulic Capacity* should be selected prior to completing the field data collection. On the section of the form labeled *Using HY-8?*, indicate whether HY-8 will or might be used. If HY-8 is indicated on the form, the measurements required for HY-8 will be made available on the digital data form and should be filled out on the paper form. If *No* is selected, these fields will be unavailable on the digital data form to save time and effort, and do not need to be filled out on the paper form.

2.4 Site Assessment

2.4.1 Navigation to the Site

It is the Lead Field Data Collector's responsibility to plan safe and efficient navigation plans to access all sites. Utilizing GPS systems, mapping applications or printed maps can increase the efficiency of locating sites in the field. Providing site navigation and location information is the responsibility of the Lead Field Data Collector.

2.4.2 Site Access Issues

Easy access to road-stream crossing sites should be readily available on most public roads, though it is important to be aware of the right-of-way to avoid inadvertently trespassing on private land. Access to interstate highways and railroads is generally much more limited, and these sites should not be accessed. For other cases where crossing access is limited, you are responsible for contacting the appropriate owner or manager of those crossings to request access to conduct field work. Similarly, for crossings on private roads, you should make concerted efforts to notify private landowners to request permission to conduct field work on their lands. It may help to work with a local land trust, municipality or county government, or state resource agency to gain access from these landowners, as they often have similar needs for conducting habitat assessments or other resource assessments. **Assessments that require access to private property will not be conducted without permission from the property owner**.

2.4.3 Equipment Setup

The Lead Field Data Collector is responsible for ensuring that equipment is in working order and that sufficient backup equipment is brought into the field to complete the work. Prior to dispatching, the field data collectors shall confirm that all equipment is functioning and shall confirm that he/she is familiar with that equipment available for use. Ideally, the same equipment should be used for the entire assessment (i.e., same equipment is used at all crossing sites). Upon arrival at the site, the field data collectors shall set up and test equipment as necessary in order to obtain the measurements required at that site.

2.5 Safety[2]

Safety is the first priority for all field work and must be considered during the site assessment planning phase, prior to mobilization. All field data collectors should review this section prior to conducting any field work. *Appendix C* of this Handbook contains a Job Hazard Analysis template and a draft RIDEM Field Safety SOP. The Lead Field Data Collector should complete the Job Hazard Analysis and all Assistant Field Data Collectors should review and sign it prior to mobilization. All team members should also review and become familiar with the draft RIDEM Field Safety SOP prior to mobilization. Streams can be hazardous places, so take care to sensibly evaluate risks before beginning field data collection at each site. While the efforts to record data about crossings are important, they are not nearly as important as personal safety and well-being.

The Lead Field Data Collector should lead a required tailgate safety meeting at the start of each field day with discussion of this Handbook, the job hazard analysis, and other site-specific safety considerations.

Field data collection should be undertaken by field crews of at least two people to facilitate taking measurements, making decisions in challenging situations and recording data, and to increase safety. There are usually multiple ways to effectively estimate some dimensions without risk. For example, an accurate laser rangefinder is a safe way to measure longer distances when conditions are unsafe, such as measuring culvert lengths through the barrel of the culvert instead of across a busy road.

Communication with office personnel should be maintained to ensure that crews return safely at the end of a work day.

2.5.1 Traffic Control and Vehicle Safety

Working around roads can be dangerous, so be sure to wear highly visible clothing (safety vests in bright colors with reflective material). Take care when parking and exiting your vehicle, and when crossing busy roads. All applicable RIDOT policies and requirements relative to traffic control must also be followed at all times. Various permissions and safety protocols may need to be acquired/ followed based on crossing location and the type of road (e.g., municipal versus state-owned). It is the responsibility of the Assessment Coordinator to

[2] Adapted (with permission) partially from the NAACC Stream Crossing Survey Data Form (2016) Instruction Guide and New Hampshire's Tidal Crossing Assessment Protocol (Steckler et al., 2017).

ensure that all necessary permissions, protocols and information are obtained from the appropriate municipal or state jurisdictions prior to mobilization.

2.5.2 In-Stream Safety

Do not enter a stream or walk down a steep slope when the other field data collector is not there to watch you. Avoid wading into streams (even small ones) at high flows and entering pools of unknown depths. Take care when scaling steep and rocky embankments. **Never enter a culvert or bridge opening.** Minimize contact with water as much as possible, water borne pathogens are common, and can make you sick. Use hand sanitizer if you come in contact with water.

2.5.3 General Safety

Below is a summary of some of the known safety risks and precautions that should be taken.

- **When using a telescoping leveling rod or stadia rod, be aware of overhead utility lines** and take care not to operate in any way that potentially puts the rod in contact with overhead utilities.
- Be prepared for **biting insects**. Consider wearing long sleeved clothes and using insect repellent. Check closely for ticks after each field day.
- Avoid wildlife. Threatened or rabid animals can be dangerous.
- Wear a hardhat in areas with overhead hazards.
- Roadsides and upland freshwater or salt marsh edges are often covered with **poison ivy**. Take care to identify poison ivy and avoid contact with leaves, stems, or other parts of the plant, especially if you are allergic. Also avoid other poisonous plants, including but not limited to stinging nettles, poison oak, and/or poison sumac.
- Follow **wader safety guidelines**, including:
  - ✓ Wear a personal flotation device.
  - ✓ Move slowly to stay in control and minimize falling; expect slippery conditions.
  - ✓ Beware of mucky substrate that you may sink into, uneven footing, poor visibility into the water, and variable water currents.
  - ✓ Use the leveling rod as your third point of support. Always maintain two points of contact as you move. In deeper areas, test depths with the leveling rod to make sure you don’t overtop your waders.
  - ✓ Use a wading belt when wearing chest waders. If you fall over, the belt will help keep water from flowing into the legs and boots of the waders, allowing for easier escape from the river.
  - ✓ Walk forward, not backward. Find stable footing around rocks and boulders rather than stepping on slippery high points.
  - ✓ Use common sense-do not wade into an area that is clearly too deep or where water velocities are too fast.
  - ✓ Use caution when next to a stream crossing structure. Be alert for hazards on the ceiling, uneven footing, and increased flow velocities in the structure. Never enter a structure.
- Follow **tidal safety guidelines**. Note that:
  - ✓ Marine clay, which is inevitable and abundant in tidal habits, is extremely slippery. Slippery conditions exist within the stream, along the stream banks, on the salt marsh, and along the road fill slope. Use caution when moving around and through these slippery conditions.
  - ✓ Many salt marshes are lined with historic ditches, some fairly small and some deep and wide. Ditches can be over-grown and present a hidden tripping or falling hazard. If you can’t easily step over a ditch, or navigate across the ditch easily, walk around the ditch or to a point where you can easily step over. Take care when pushing off and landing, as ditch edges can be slippery, slough off, and be hidden under droopy tall grasses.

- ✓ Many tidal crossing sites are exposed, with limited shading and relief from the sun. Be prepared with sunscreen, ample water, sunglasses and a hat.

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Section 3: Field Data Collection

This section describes the field data collection process for road-stream crossing assessments, including how to complete the field data form.

3.1 Introduction

This section of the handbook is largely adapted with permission from the assessment methods and documentation prepared by the North Atlantic Aquatic Connectivity Collaborative (NAACC). NAACC is a group of organizations, institutions, and governmental bodies focused on improving aquatic connectivity in the Northeast. NAACC has developed protocols and trainings for assessing road-stream crossings and has developed a regional database for collected data for the purpose of identifying priority structures for replacement to improve aquatic connectivity. More data on NAACC can be found at https://streamcontinuity.org/index.htm. The NAACC methods have been comprehensively reviewed and tested, and have proven to be effective for road-stream crossing assessments. This section has been adapted to meet RIDOT's specific needs and purposes.

Accurate, consistent, and precise field data collection is imperative for the success of road-stream crossing assessments. The information collected in the field will be used in setting priorities for road-stream crossing upgrades and replacements. Following the guidance and methods described in this section of the handbook will greatly increase the likelihood of useful field data collection and successful crossing improvements.

3.2 Field Work Mobilization

3.2.1 Locating Crossings in the Field

Once the road-stream crossings have been identified using the methods described in *Section 2: Initial Assessment Planning,* the next step is to determine a strategy for efficiently completing the field data collection process. Work with your Assessment Coordinator and team to decide which group of crossings will be visited on a given day. Prior to heading into the field, review mapping to determine a data collection plan and route to most efficiently target your locations for the day. It is recommended that you plan out routes and access, and bring field data forms for more sites than you think you will be able to visit in a single day, in case you get ahead of schedule. Bring maps into the field to help you navigate to sites.

Prior to mobilizing, it is the Lead Field Data Collector's responsibility to know which direction the stream is flowing at each crossing site to be visited in a given day, such that the upstream and downstream assessments can be completed appropriately. In the field it may be difficult to tell upstream from downstream, especially during certain conditions (e.g., no flow or in a flat section of river with stagnant water).

3.2.2 When to Collect Field Data

Several factors may impact your ability to collect quality data at a given site. Typically, the best times to collect field data at road-stream crossings are as follows:

- during low-flow events (typically summer or early fall, preceded by several dry days)
- during non-rush hour traffic times
- during mild weather events (avoid heavy rains, winds, excessive heat days, if possible)
- during diurnal low tide periods for sites that are tidally influenced

Tidal crossings assessments should be scheduled using a tide chart, although it should be noted that high and low tides at specific crossings will not correspond exactly to the high and low tide times listed on tide charts, which predict tides for a specific coastal point. Generally, the further inland a crossing is, the more the high and low tide will be delayed relative to the coast, the lower the tidal range will be, and the longer the window of time during which the crossing will be near low tide. In addition, at low tide, problems with culvert placement and constriction become immediately obvious, especially if the culvert is placed too high (Purinton and Mountain, 1996).

Prior to heading to a site, review mapping to determine if adjacent land uses or roadway usage may impact your ability to complete a field visit at a given time or on a given date (e.g., school zones that are likely to have bus traffic in the morning and mid-afternoon, planned construction, etc.).

3.3 Completing the Field Data Form

One field data form should be used for each road-stream crossing, which may include single or multiple culverts/bridge cells. The field data form has a general information section with entry fields pertaining to the crossing as a whole, and sections that pertain to each culvert or bridge cell. It is essential to gather information on each culvert or bridge cell for accurate evaluation of the entire crossing.

Collect data as completely and accurately as possible and ensure that the data are entered properly. It is worth taking time in the field to ensure that data are collected appropriately and comprehensively in order to avoid costly rework or unusable data.

3.3.1 Form Data to be Filled in the Office

If *Section 2.3* of this handbook has been completed, some information should already be known before heading into the field. This data may include:

- *State or Local ID and/or Local Name* (if the site has a state Bridge Identification Number)
- *Tidal Site?*
- *Tide Prediction*
- *Tide Chart Location*
- *Hydraulic Program*

3.3.2 Field Data Collection Overview

The field data forms and handbook are organized such that the field crew will collect data regarding the stream condition and the entire crossing first. The field crew will then move on to assessing the inlet and outlet of each individual structure or bridge cell in turn, **without entering the structure**.

3.3.3 Locating Procedures and Site Identification

In all cases where the field crew cannot locate a mapped crossing or discover an unmapped crossing, it is essential to check the crossing location carefully to ensure that they have navigated correctly to the intended crossing and are not entering a mapped crossing as an unmapped crossing.

Unmapped Sites

The field crew may encounter unmapped crossings in the field, or it may be unclear whether a crossing found in the field is one on the map because its location may not exactly match the map. In most cases, the crossing should be within 100-200 feet of the planned crossing location. The field crew also may encounter unmapped crossings because either the road or stream was not mapped, as in the case of a road built to service a new development, or because there is an error in the road or stream data used to generate the crossing locations.

If there is no other crossing within 100-200 feet of a found crossing, or if there are multiple crossings located in the same vicinity, assign a temporary *Crossing Code* to the crossing. The temporary *Crossing Code* shall follow the same naming mechanism as other crossing codes with the 16-character xy-code, and shall be followed by the notation “NEW XY” to indicate that the crossing site should be added to the map.

Nonexistent Crossings

Mapped crossings may not exist in the field. If you try to navigate to a site and are certain that there is no crossing in the vicinity, select the “No Crossing” option for *Crossing Type* on the field data form. Some crossings may not actually exist due to errors in generating the crossing points. Another possibility is that there may have been a crossing at one time, but it has been removed. For these sites, select the “Removed Crossing” option. Similarly, sometimes an entire stream reach has been moved, particularly underground. In this case, select “Buried Stream” for *Crossing Type.*

3.3.4 Site Photographs

It is essential that all photos be associated with the correct crossing. If you take photos with a digital camera, smart phone, or tablet computer, record the photo numbers assigned by the camera on the field data form in the space for each required photo (plus any additional photos you choose to take). To record the correct photo numbers from any camera, each person taking photos must be familiar with the numbering system of the camera used.

It can be very helpful to have additional photos, especially when important characteristics are not captured on the four required photos. For instance, if there is extreme erosion at the site, or if other aspects of the crossing make it a likely barrier to connectivity, indicate risk of structural failure, or make the crossing a particularly hazardous flood location, it is useful to capture these with one or two additional photos. Other useful photos include structures, infrastructure, or land use upstream or downstream of the crossing, to document potential flooding impacts in the event of failure of the crossing. **If you take multiple photos at a site in order to choose the best ones later, you must record on the data form the ID numbers of all photos taken at the site.**

A simple way to know which photos were taken at a particular site is to use a black marker on a white dry-erase board to record the date and Crossing Code, and to have the first photo at the crossing show this white board displaying the date and Crossing Code. The white board should be strategically placed in the photo so that it is legible and does not block key features of the crossings. This will make the photo readily identifiable with the appropriate crossing. Some people have noted that white dry-erase boards and white paper reflect so much light that they are often "washed out" in the photos, making the codes written on the board impossible to read. Use of a small blackboard and chalk may be preferable depending on light conditions.

Note: The digital field form automatically labels each required photo and many of the optional photos that are commonly taken at a crossing site.

Here are several additional tips for taking useful photos (examples of good and bad photos are included in *Appendix D* of this handbook):

- Always include more than just the structure or stream area you are photographing. It is important to capture the context of the site as well as the crossing structure itself. Remember that with digital photos, anyone reviewing the data can zoom in to see detail.
- Include a stadia rod in photos of the inlet and outlet to help verify measurements later, and as a general reference for scale.
- Use a date/time stamp to code each photo.
- To minimize storage space but still allow a reasonable quality image, each photo should be between 100 and 500 kilobytes in size when downloaded. Set your camera to record in low to medium resolution (e.g. "1 Megaipixel") to minimize storage space used.
- Review photos at the site to discard bad photos and to confirm all required photos are in focus and capture important information about the site.
- If you have not used the camera before, practice taking photos in dark or mixed light situations, which are common at stream crossings.

3.4 Field Visit Completion

Prior to leaving a site, the Lead Field Data Collector shall ensure that all entry fields on the field data form have been completed to the best of their ability and that measurements were taken accurately. Confirm that any necessary comments have been recorded. Do not attempt to remember something to include on the field data form at a later time.

If using a paper version of the field data form, ensure that your notes and entries are legible as someone other than the Lead Field Data Collector will be completing the quality control (QC) review. Ensuring that data is complete while still at the site is crucial in avoiding re-work or revisiting the site.

Section 3: Field Data Collection

3.5 Crossing Data

3.5.1 General Information

Complete this section for the entire crossing. Choose only one option for the fields with check boxes.

GPS Coordinates: Record the site's latitude and longitude in decimal degrees to five (5) decimal places (this will require your device to reference the WGS84 Datum). Use of a GPS (Global Positioning System) receiver is required, but your smart phone or tablet computer may include this capability.

- *Location Format*: Use Latitude-Longitude decimal-degrees (often listed in a GPS menu as "hddd.ddddd").
- Stand above the stream centerline, and ideally on the road centerline, when taking the GPS point. However, use judgment when determining whether it is safe to stand on the road centerline beware of traffic.

In the digital field form, the GPS coordinates are automatically populated based on the crossing location point selected at the top of the form.

Crossing Code: This is the 16-character "xy-code" assigned to each mapped crossing. Be very careful to record the correct numbers, as they represent the precise latitude and longitude of the planned crossing, which can be compared with the actual location you record as GPS Coordinates below.

In the digital field form, the crossing code is automatically populated based on the crossing location point selected at the top of the form.

State or Local ID and/or Local Name: Rhode Island State Bridge Identification Number (BIN) if applicable; otherwise use other local ID (if applicable)

Date Observed: Date that the crossing was evaluated, following the form MM/DD/YYYY.

Inspection Start Time and End Time: The times of the start and end of the site visit, following the form HH:MM – HH:MM. Record the time in 24-hour time or include "AM" or "PM" for each start and end time.

In the digital field form, the *Inspection Start Time* is recorded automatically when the form is opened.

Lead Field Data Collector: The full name of the field work team leader responsible for the quality of the data collected.

Assistant Field Data Collector(s): The initials of other team members assisting with the field work.

Municipality: The name of the municipality in which the crossing is located. If a structure is located on the border of two municipalities, include the name of both municipalities.

County: The name of the county in which the crossing is located according to the map. This item will autopopulate in the digital field form based on the municipality selected.

Stream: The name of the stream taken from the map, or if not named on the map, the name as known locally, or otherwise listed as *Unnamed*. Stream name should be consistent with names in USGS TopoView available at https://ngmdb.usgs.gov/topoview/. Note that using other maps (such as GoogleMaps) may lead to inaccurate naming.

Road: The name of the road taken from the map or from a road sign. Numbered roads should be listed as "Route #", where # is the route number, with multiple numbers separated by "/" when routes overlap at the crossing (e.g., "Route 1/95"). For driveways, trails, or railroads lacking known names, enter *Unnamed.*

Road Type: Choose only one option:

- *Multilane*: >2 lanes, including divided highways (assumed paved)
- *Paved*: public or private roads

Section 3: Field Data Collection

- *Unpaved*: public or private roads
- *Driveway*: serving only one or two houses or businesses (paved or unpaved)
- *Trail*: primarily unpaved, or for all-terrain vehicles only, but includes paved recreational paths
- *Railroad*: with tracks, whether or not currently used

Location Description: Provide enough information about the exact location of the crossing so that others with your field data form would be confident that they are at the same crossing that you evaluated. For example, the description might include "100 feet north of 87 Hill Road," "across from the telephone pole #65," or "driveway north of Smith Road off Route 66." This information could also include additional location information, such as a site identification number used by road owners or managers. Take photos as necessary to document the location of referenced features in relation to the crossing.

Crossing Type: If a crossing is found at the planned location, choose the **one** most appropriate option. These definitions are based on the NAACC definitions for road-stream crossings, and, having been developed to facilitate road-stream crossing assessments, may differ from other sources and uses. The following definitions should be used for RIDOT road-stream crossing assessments.

- *Bridge***:** A bridge has a deck supported by abutments (or stream banks). It may have more than one cell or section separated by one or more piers, in which case enter the number of cells to *Number of Culverts/Bridge Cells*.
- *Culvert***:** A culvert consists of a structure buried under some amount of fill. Select this option only if the crossing contains only one culvert structure or section. If it is a single culvert, you need only complete the first *Structure 1 Data* section.
- *Multiple Culverts***:** If there is more than one culvert structure or section, select this option and indicate the number of culverts in *Number of Culverts/Bridge Cells*. Later in the site visit, data must be entered in sections for additional structures in *Structure 2 Data, Structure 3 Data,* etc.
- *Ford***:** A ford is a shallow, open stream crossing, in which vehicles pass through the water. Fords may be armored to decrease erosion, and may include pipes to allow flow through the ford (this is called a *vented ford)*.

Figure 3-1: Example of a road-stream crossing consisting of a bridge with side slopes and abutments.

Figure 3-2: Example of a road-stream crossing consisting of multiple box culverts. (Image credit: NAACC)

Figure 3-3: Example of a ford. (Image Credit: Keith Evans)

Section 3: Field Data Collection

If a crossing mapped while completing the fieldwork preparation in *Section 2* cannot be found or accessed, select one of the following crossing types:

- *No Crossing:* There is no crossing where anticipated, usually because of incorrect road or stream location on maps. No further data is required. (Be sure you are in the correct location before choosing this option.)
- *Removed Crossing:* There is evidence that a crossing existed previously at the site but has been removed, such that the stream now flows through the site with no provision for vehicles to cross over it. Continue to complete the field data form to the extent possible. Include information in *Crossing Comments* to explain your observations. For instance, indicate if an old culvert pipe is seen at the site, or if removal of the previous crossing structure did not completely eliminate the barrier to aquatic passage.
- *Buried Stream:* The planned crossing site does not include an inlet and/or outlet, likely because a stream previously in this location has been rerouted and/or buried, probably underground. Fill out the form to the extent possible.
- *Inaccessible:* Data collection is not possible because roads or trails to the crossing are not accessible. This may be due to private property posting, gates, poor condition, or other factors. Record in *Crossing Comments* why the site is inaccessible. No further data is required.
- *Partially Inaccessible:* Use this option when you can access a crossing well enough to collect some but not all required data. This is most likely to occur when you cannot access either the inlet or outlet side of a crossing and cannot reasonably estimate the dimensions or assess characteristics such as inlet grade, outlet grade, scour pool or tailwater armoring.
- *No Upstream Channel:* This option is for situations where water crosses a road through a culvert but no road-stream crossing occurs because there is no channel up-gradient of the road. This can occur at the very headwaters of a stream or where a road crosses a wetland that lacks a stream channel on the upstream side of the crossing. Fill out the form to the extent possible.
- *Bridge Adequate:* Coordinators have the option of using this classification for large bridges for which it is apparent that they present no barrier to aquatic organism passage, do not restrict hydraulic capacity, and do not impact geomorphic stream function. If it is feasible and safe to take the required measurements of the structure, this option should not be used. However, if it is infeasible to obtain measurements (i.e., the opening is greater than 100 feet in a single dimension or otherwise inaccessible due to its size), *Crossing Structure Data* (*Section 3.1.3*) only need be completed for the parameters that can be safely obtained. This option should only be selected for a small number of crossings, if appropriate. Use with caution.

Number of Culverts/Bridge Cells: For all bridges with multiple sections or cells, and for all multiple culverts, you must enter the number of those cells or culvert structures.

Photo IDs: A minimum of five (5) digital photos should be taken at all sites, including the following:

- *Crossing inlet*: The inlet of the crossing. The portion of the road directly above the crossing structures should be visible in the image, if possible.
- *Crossing outlet*: The outlet of the crossing. The portion of the road directly above the crossing structures should be visible in the image, if possible.
- *Upstream Channel*: Stream channel upstream of crossing.
- *Downstream Channel*: Stream channel downstream of crossing.
- *Roadway*: Roadway carried by crossing structure.

These photos are immensely useful in setting priorities for restoration. Other photos that may be useful include photos of structures, infrastructure, or land use upstream or downstream of the crossing, to document potential flooding impacts in the event of failure of the crossing.

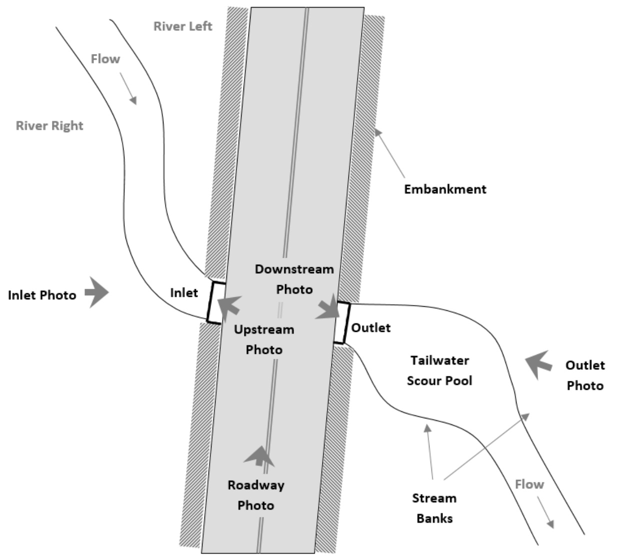

Figure 3-4: Diagram indicating photo locations in relation to a crossing structure. (Image adapted with permission from the NAACC)

Utilities: Record the presence of any utilities at the site that might be impacted by failure of the crossing or complicate any effort to replace the crossing. Utilities may be visible above, alongside, or attached to the underside of the bridge, or their presence may be indicated by markings or valves on the road surface. Detailed information (e.g., type of utility or company name, color and content of painted markings) can be included in the Notes/Comments section. Additional photos of infrastructure such as pipes, valves, and manholes can help document the utilities present.

- *Overhead wires:* Electrical, telephone or cable wires.
- *Water:* Visible pipes carrying drinking water, either in or on the substrate, suspended within the structure(s), or otherwise associated with the crossing. If the pipes are unmarked, the presence of a water valve at the road surface near the crossing will indicate the presence of water lines below.
- *Sewer pipes:* Visible pipes carrying waste water, either in or on the substrate, suspended within the structure(s), or otherwise associated with the crossing. If the pipes are unmarked, the presence of a manhole at the road surface near the crossing will indicate the presence of sewer lines below.
- *Gas line:* Pipes for natural gas (often not visible at the surface and only indicated by valves or markers, which are typically painted yellow). The pipes may be either in or on the substrate, suspended along or within the structure(s), or otherwise associated with the crossing.
- *Other*: Include any other type of utility installation not covered above. The presence of utilities may be indicated by old “Dig Safe” (a.k.a. “Call before you dig”) indicators painted on the pavement. Categories of utilities that are not included in the above options may include buried telecommunications utilities or buried electric wires.
- *None*: No utilities are visible.

Road-Killed Wildlife: Select *Yes* if any road-killed wildlife are observed near the crossing and provide comments on the observations. Check *No* if no road-killed wildlife is observed.

Observed Wildlife: Select *Yes* if any living wildlife and/or any “Wildlife Crossing” signs are observed near the crossing and provide comments on the observations. Check *No* if no living wildlife or “Wildlife Crossing” signs are observed.

3.5.2 *Stream Data*

Complete this section for the entire crossing. Choose only one option for the fields with check boxes.

Road Crest Height: Use surveying equipment or other available tools to measure the height of the roadway crest above the **upstream** crossing invert or the thalweg (the deepest part of the channel) of the bridge/culvert bottom if the crossing does not have a hardened bottom. Assume the elevation of the downstream invert or stream thalweg is at 0.0 feet, so if the elevation difference between the downstream invert/thalweg and roadway crest is 3.2 feet, report *Roadway Crest Height* as 3.2 feet. Measure this value to the nearest tenth of a foot.

Road Fill Height: To the nearest tenth of a foot, measure the height of fill material between the top of the crossing structure(s) and the road surface on the **upstream** side of the crossing. This is best measured with two people when the road surface or fill height is above a surveyor's height, with one person holding a stadia rod, and the other sighting the elevation of the road surface from the side (see *Figure 3-6*). For multiple culverts with differing amounts of fill over them, provide an average fill height.

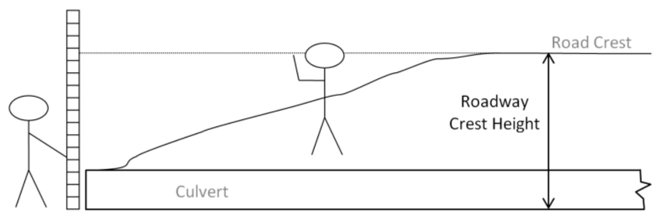

Figure 3-5: Measurement of Road Crest Height. (Image adapted with permission from the NAACC)

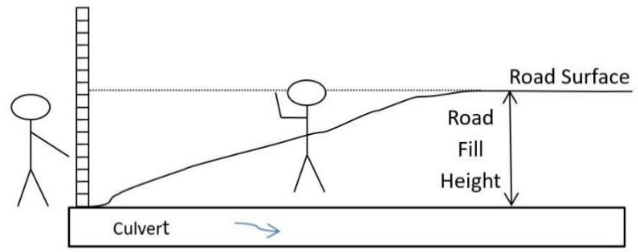

Figure 3-6: Measurement of Road Fill Height. (Image adapted with permission from the NAACC)

Roadway Crest Height vs. Road Fill Height

This handbook calls for measurement of Roadway Crest Height in order to complete the hydraulic assessment described in *Section 6*. Note that *Road Fill Height* can be calculated using *Equation 3-1*.

Equation 3-1: Road Fill Height

$$Road\ Fill\ Height = Roadway\ Crest\ Height - Inlet\ Height$$

This equation can be useful for calculating *Road Fill Height* if the *Road Fill Height* is too small to measure easily (less than 0.5 feet)

Alternatively, if the field crew can successfully measure *Road Fill Height* and the *Inlet Height*, this equation can be used to calculate *Roadway Crest Height* in locations where it exceeds the length of the field crew's tape measure or stadia rod.

Note: Road-stream crossings are not always located at the lowest point of the road. **At these sites, measure the relative elevation of the low point in the road and record it in the *crossing comments*.**

Flow Condition: Check the appropriate box to indicate how much water is flowing in the stream. Normally, the value selected for the first perennial crossing of the day will hold for all perennial sites in the area during that day, unless a rainfall event changes the situation. Choose only one option at each site.

- *No Flow*: No water is flowing in the natural stream channel. Typical of extreme droughts for perennial streams, or frequent conditions for intermittent or ephemeral streams.
- *Typical-Low*: The most commonly used and expected value for visits conducted during summer low flows, particularly on perennial streams. Water level in the stream will typically be below the level of non-aquatic vegetation, exposing portions of stream banks and bottom.

Section 3: Field Data Collection

- *Moderate*: Select when recent rains have raised water levels at or above the level of herbaceous (non-woody) stream bank vegetation.
- *High*: Select rarely, when flows are very high relative to stream banks, making data collection very difficult or impossible. Normally due to very recent, or ongoing major rain events. Avoid collecting field data under high flows as data will not reflect the most typical flow conditions for the site.

Alignment: Indicate the overall alignment of the crossing structure(s) relative to the stream at the inlet(s). Compare the crossing centerline to the centerline of the stream where it enters the crossing, as shown in *Figure 3-7*.

- *Sharp Bend:* The stream bends to approach the structure from an angle of 45° to 90°.
- *Mild Bend:* The stream bends to approach the structure from an angle of 5° to 45°.
- *Naturally Straight:* Flow enters the structure straight-on with no channelization evident
- *Channelized Straight:* Flow enters the structure straight-on, due to channel modification. Indicators of channelization include: armored stream banks, channel just upstream of straightened section is naturally sinuous, or documentation of past channel-straightening activities.

When determining the alignment of the structure relative to the stream, be careful not to confuse the alignment of low-flow channels through upstream sediment deposits with the alignment of the stream corridor. Assessing the alignment relative to the orientation of flow channels at extremely low flows may cause the field team to assess the alignment as a sharp bend when it should actually be a mild bend or straight. Alignment of the structure should instead be assessed relative to the stream corridor (i.e., the direction of streamflow at moderate and high flows).

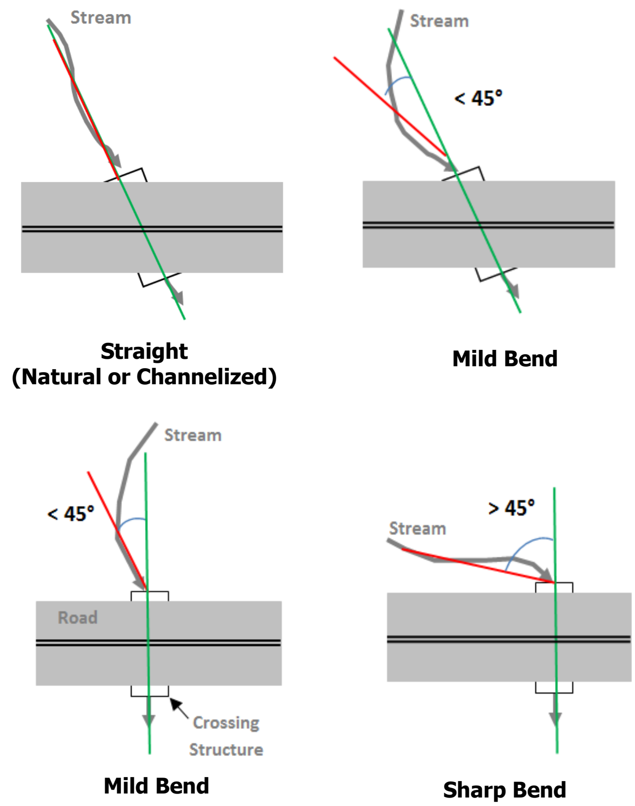

Figure 3-7: Depictions of possible Road-Stream Alignments. (Image adapted with permission from the NAACC)

Bankfull Width: This is a measure of the active stream channel width at bankfull flow, which is the point at which water completely fills the stream channel and where additional water would overflow into the floodplain. The measurements should be taken as follows:

- At a minimum, three bankfull width measurements should be taken to promote high confidence in the measurement. Record the average of all three measurements on the field data form.
- If three measurements are entered into the digital field data form, the form will automatically calculate an average Bankfull Width.
- The measurements should be taken to the nearest tenth of a foot, and average should be reported to the nearest half of a foot.
- If possible, the measurements should be taken in a part of the channel outside of the influence of

the crossing. Typically, this requires the measurements to be take the measurements approximately 5-10 bankfull widths upstream of the crossing, or approximately 100-300 feet upstream. In many cases it may not be possible to access the channel this far upstream, in which case the measurements should be made at the following distance intervals.

- If the stream width is greater than 10 feet, start 30 feet from the structure (upstream or downstream) and take bankfull width measurements every 20 feet proceeding in the direction opposite the structure.
- If the stream width is less than ten feet, start 30 feet from the structure (upstream and downstream) and take bankfull width measurements ever 10 feet proceeding in the direction opposite the structure.

Estimates of the frequency of bankfull flows vary, but they may happen as often as twice a year, or only once every one or two years. When measured with high confidence (see *Bankfull Width Confidence*), bankfull width can be an extremely useful measurement, but this measurement can be difficult and time-consuming, and it will not be possible for all sites (even with experienced field data collectors).

Measure the width from bank to bank at the selected locations. Indicators of bankfull flow (shown in *Figure 3-8* as a red line) include:

- <u>Abrupt transition from bank to floodplain</u>**:** The point of change from a vertical bank to a more horizontal surface is the best identifier of bankfull stage, especially in low-gradient meandering streams.
- *<u>Top of point bars</u>***:** The point bar consists of channel material deposited on the inside of meander bends. Set the top elevation of point bars as the lowest possible bankfull.
- *<u>Bank undercuts</u>***:** Maximum heights of bank undercuts are useful indicators of bankfull flow in steep channels lacking floodplains.
- *<u>Changes in bank material</u>***:** Changes in the particle size of sediment (rocks, soil, etc.) may indicate the upper limits of bankfull flows, with larger sediments exposed to more frequent channel-forming flows.
- *<u>Change in vegetation</u>***:** Look for the low limit of woody vegetation, especially trees, on the bank, or a sharp break in the density or type of vegetation.

Figure 3-8: Examples of bankfull height indicated by an abrupt transition from bank to floodplain (marked by red lines). (Image adapted with permission from NAACC)

Section 3: Field Data Collection

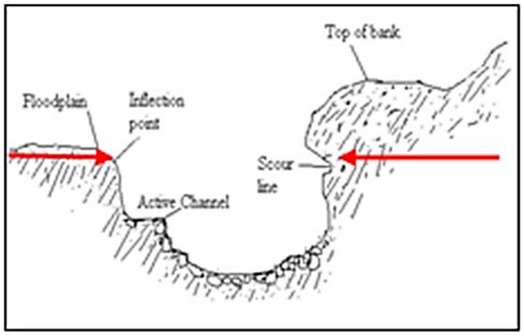

Figure 3-9: Elevation view of a stream channel indicating the bankfull height, and showing an undercut on the right side of the image. (Image credit: NAACC)

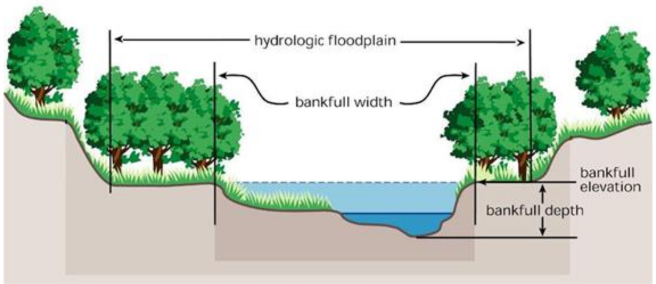

Figure 3-10: Diagram depicting the bankfull width, bankfull depth, and bankfull elevation within a stream corridor. (Image adapted from Georgia Adopt-A-Stream "Visual Stream Survey" manual. Georgia Department of Natural Resources, 2002)

Bankfull Width Confidence: This qualifies the Bankfull Width based on your experience with its measurement and whether sufficient criteria were met in your measurements. Choose only one option.

- _High_: Select this option only when you are highly confident that your selection of Bankfull Width meets **all** of the following criteria:
  - ✓ Clear indicators are present to define the limits of Bankfull Width.
  - ✓ The recorded value is an average of at least three measurements
  - ✓ All measurements of Bankfull Width were taken in undisturbed locations well upstream and downstream of the crossing.
  - ✓ No tributaries enter between the crossing and your area(s) of measurements.
  - ✓ No measures taken at stream bends, pools, braided channels, or close to stream obstructions.
- _Low/Estimated_***:*** Select this when **any** of the above criteria cannot be met.

Note that many rivers in Rhode Island have been disturbed by human interactions. Bankfull Width may be a Low Confidence measurement at many crossing locations.

Constriction: Regardless of whether you measured Bankfull Width above, this element assesses how the width of the crossing (including all of its structures) compares to the width of the natural stream channel. Refer to the above section on determining Bankfull Width for reference. Two other ways of assessing the width of the natural stream channel consider the width of the active channel or the wetted channel.

The **active channel** is the area of the stream that is very frequently affected by flowing water. The width of the active channel can often be very close to the Bankfull Width when stream banks are very steep. The **wetted channel** is simply the area of the stream that contains water at the time of site visit, which may be significantly less than the active channel, depending on flow.

Refer to *Figure 3-11* and check the appropriate description from the list below to assess how constricted the flow of the stream is by the crossing compared to either the bankfull, active, or wetted channel. Choose only one option.

- _Severe_***:*** The total crossing width (sum of widths of all crossing structures) is less than 50% of the bankfull or active width of the natural stream, or the total wetted width of the crossing is less than 50% of the wetted width of the stream.
- _Moderate_**:** The total crossing width is *greater than* 50% of the bankfull or active width of the natural stream, but less than the full bankfull or active channel width.

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- *Spans Only Bankfull/Active Channel*: The crossing encompasses the approximate width of the bankfull or active channel.
- *Spans Full Channel & Banks*: The crossing completely spans beyond the *Bankfull Width* of the natural stream, as often evidenced by banks within the crossing structure.

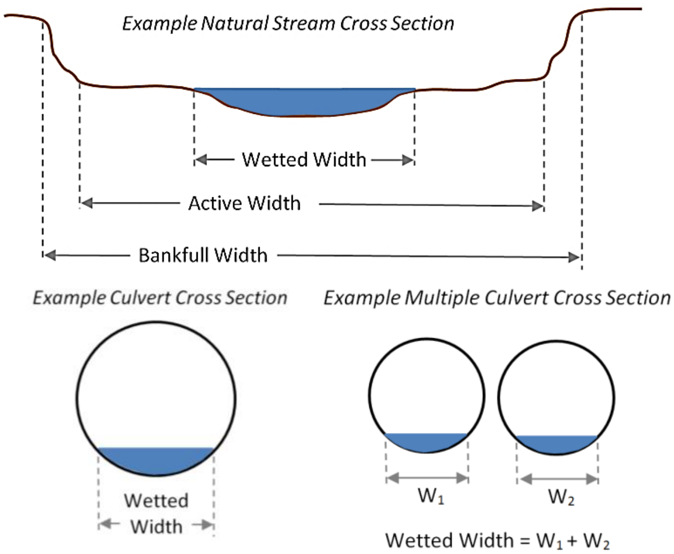

Figure 3-11: Wetted width in natural streams and various culvert configurations. (Image credit: NAACC)

Tailwater Scour Pool: The pool created downstream of a crossing as a result of high flows exiting the crossing. A scour pool is considered to exist when its size (a combination of length, width, and depth) is larger than reference pools found in the natural stream.

- *None*: No tailwater pool exists at the site.
- *Small*: The tailwater pool less than 2X larger than the channel and pools downstream in any dimension.
- *Large*: The tailwater pool is 2X deeper, 2X longer, or 2X wider than the channel and pools downstream.

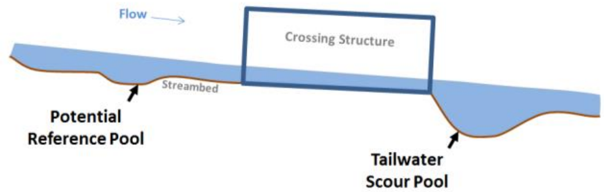

Figure 3-12: Tailwater scour pool and possible reference pool.

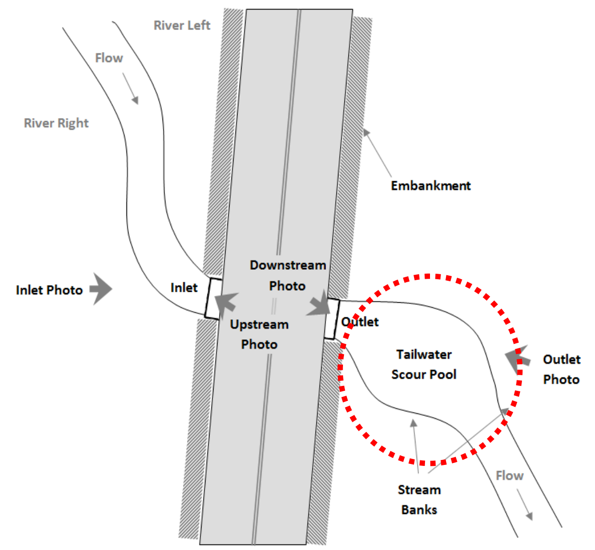

Figure 3-13: Location and form of a tailwater scour pool, indicated in the red circle. (Image adapted with permission from the NAACC)

Significant Break in Valley Slope: Record whether the crossing occurs downstream of a steeper section of channel and therefore causes a break in valley slope.

- *Yes*: The crossing is located on a stream segment with a gentle gradient, that is within 1/3 mile of and **downstream** of a steeper section of the channel.
- *No:* The crossing does not meet the above condition
- *Unknown*: If your view upstream is obscured by vegetation or other obstacles, mark *"Unknown"* on the field form and use a topographic map to make the determination after returning from the field. *Figure 3-15* is an example of a topographic map that depicts a road-stream crossing located at a significant break in valley slope.

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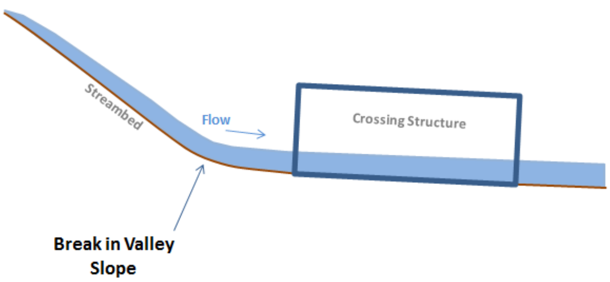

Figure 3-14: Diagram of a significant break in valley slope.

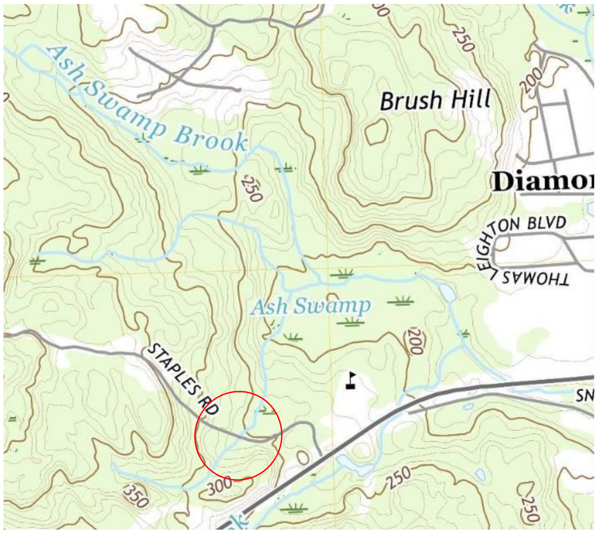

Figure 3-15: Example of a road-stream crossing located at a significant break in valley slope (circled in red) as depicted on a topographic map.

Bank Erosion: Check the degree of bank erosion height observed **both upstream and downstream** of the structure. Note that raw substrate occurring below the bankfull elevation is not considered erosion, unless associated with active bank failures, fractures, slabbing, or undercutting.

- <u>*High*</u>: Nearly continuous erosion along banks, especially on medium to high banks.
- <u>*Low*</u>: Occasional erosion along banks, mostly found on low banks.
- <u>*None:*</u> No bank erosion is evident.

Sediment Deposition: Record whether unvegetated sediment deposits are located *Upstream*, *Downstream*, and/or *Within the structure* (check all that apply). Mark/ select *None* if deposits are not visible. Deposits are areas where sediment is built up above the streambed elevation and are commonly located along the inside of meander bends, at locations where a tributary enters a mainstem channel, along channel margins, or in the middle of the channel. Some mid-channel deposits may occur as steep riffles.

Elevation of sediment deposits greater than or equal to ½ bankfull height: Check *Yes* or *No* to indicate whether sediment deposits observed upstream, downstream, and in the structure fill the channel to an elevation that is greater than or equal to half of the bankfull elevation. The bankfull height (also sometimes called bankfull depth) can be estimated for this assessment as the difference between the elevation at bankfull width and the elevation of the thalweg, or deepest part, of the channel.

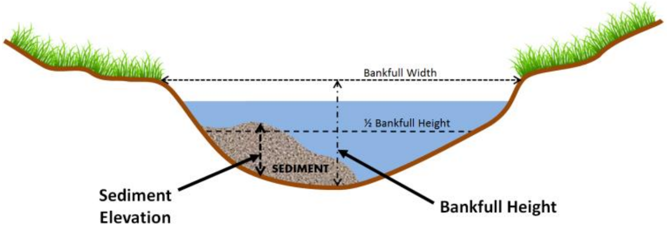

Figure 3-16: Diagram depicting a sediment deposit that is greater than ½ bankfull height.

Stream Substrate: Choose only one option from *Table 3-1* to indicate the most common or dominant substrate type in the stream channel (outside of the structure). If you cannot assess the type, select *Unknown*.

Table 3-1: Stream Substrate Sizes

Substrate Type	Size (Feet)	Approximate Relative Size
Silt	< 0.002	Finer than salt
Sand	0.002 – 0.01	Salt to peppercorn
Gravel	0.01 – 0.2	Peppercorn to tennis ball
Cobble	0.2 – 0.8	Tennis ball to basketball
Boulder	> 0.8	Bigger than a basketball
Bedrock	Unmeasurable	Unknown - buried

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Crossing Comments: Use this area for brief comments about any aspect of the overall site visit that warrants additional information. Do **not** use this section for comments about particular structures. Comment boxes for each structure are provided elsewhere on the form.

Using HY-8: Record whether HY-8 will be used in completing the assessment in *Section 6: Existing Hydraulic Capacity*. This should be determined prior to field data collection.

The following fields only need to be filled out if HY-8 will be used for *Section 6*: *Existing Hydraulic Capacity*.

Road Surface Type: Choose only one option.

- *Paved:* The road surface is covered with a hard material such as concrete or asphalt.
- *Gravel*: the road surface is covered with gravel, crushed rock, or similar material.
- *Grass*: The road surface consists of grass with or without dirt ruts.

Estimated Crest (Overtopping) Length: Measure the estimated length (parallel to the road centerline) of overtopping to the nearest foot. Note that the lowest road elevation (and therefore the overtopping point)

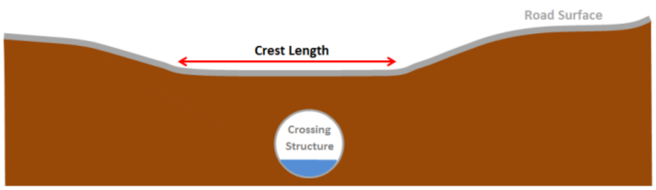

Figure 3-17: Measurement of Crest (overtopping) Length along the top of the roadway.

Top Width:
Measure the top width (roadway crest width) of the roadway embankment at the roadway surface to the nearest tenth of a foot. The measurement should:

- be taken perpendicular to the direction of the roadway (see *Figure 3-18*), and
- include the shoulders, traffic lanes, and median.

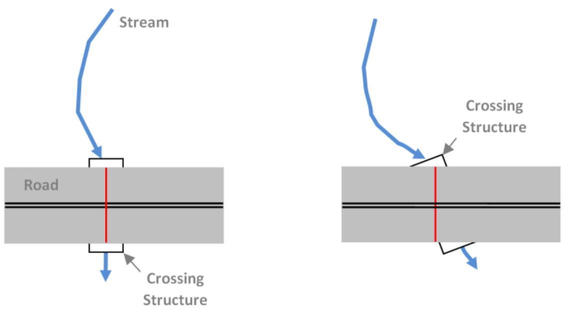

Figure 3-18: Direction of measurement of top width indicated by the red line perpendicular to the roadway. (Image adapted with permission from the NAACC)

Bottom Width: To the nearest half foot, measure the bottom width of the channel. To take the measurement, identify the point on each side of the channel where the slope changes significantly from a steeper bank to a shallower channel bed slope. This will be close to but slightly above the channel bottom elevation. The measurement should be taken between these two points, with the measuring tape is held level, and perpendicular to the stream centerline.

At a minimum, take three bottom width measurements. If possible, the measurements should be taken in a part of the channel outside of the influence of the crossing. It may not be possible to access a part of the channel outside of the crossing's influence, in which case the measurements should be made at the distance intervals described below.

- If the stream width is greater than 10 feet, start 30 feet from the structure (upstream and downstream) and take bankfull width measurements every 20 feet proceeding in the direction opposite the structure.
- If the stream width is less than ten feet, start 30 feet from the structure (upstream and downstream) and take bankfull width measurements ever 10 feet proceeding in the direction opposite the structure.
- The average of all three measurements should be recorded on the field data sheet.

- The measurements should be taken to the nearest tenth of a foot, and the average should be reported to the nearest half of a foot.

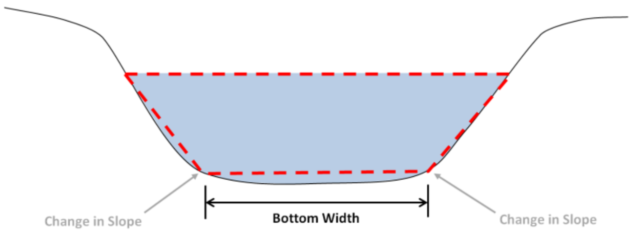

Figure 3-19: Measurement of bottom width. (Image adapted with permission from the NAACC)

Channel Slope: To the nearest half a percent, measure the channel slope by using one of the methods described below. Channel bottom elevations for the channel slope should be measured downstream of the tailwater scour pool (if present) and upstream of any scour pools formed immediately upstream of the culvert.

Note that this measurement is difficult to measure accurately without the proper tools. In general, the ease and accuracy of these different methods relates directly to the cost of the tools needed, with the most easy-to-use and accurate measurement tools costing more.

1. Use an **auto level or other accurate survey instrument** to measure the vertical difference between upstream and downstream channel bottom elevations, then calculate the slope according to *Equation 3-2*.

Equation 3-2: Stream Slope

$$Stream\ Slope = 100 \times \frac{Downstream\ Elev. - Upstream\ Elev.}{Distance\ between\ Measurements}$$

where
$Upstream\ elevation\ measurements\ taken\ using\ a\ survey\ level\ will\ be\ smaller\ than\ downstream\ elevation\ measurements.\ \ If\ using\ a\ different\ instrument, adjust\ the\ equation\ accordingly$

2. The simplest accurate method for measuring slope is to use an accurate **laser rangefinder/ hypsometer with a slope function**, and to measure from upstream to downstream at the same height in relation to each channel bottom. For instance, a person with a known eye height of 5.0 feet sights from upstream by standing on in the channel upstream to the 5.0 foot mark on a stadia rod in the channel downstream. You must take at least three measurements and average them, and be sure the instrument is set to read in percent, not degrees. This method will not work for sites where you cannot sight directly over the road surface or through the culvert or bridge opening.

Side Slope: Select the option that most closely corresponds with the measured side slope (measured as a ratio of the horizontal distance to 1 foot of horizontal distance). Options include <0.5:1 (steeper than 0.5:1), 0.5:1, 1:1, 2:1, 3:1, 4:1, 5:1, >5:1 (flatter than 5:1). Enter the side slope for each bank. Note that the left and right banks are assigned while looking downstream.

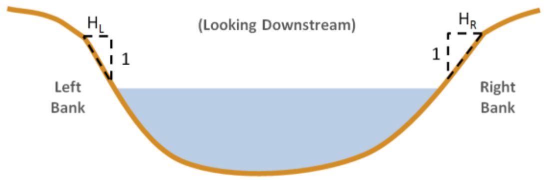

Figure 3-20: Measurement of channel side slope.

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3.5.3 Tidal Data

Complete this section for the entire crossing if the crossing is tidally influenced (as determined in *Section 2* or through observation of site conditions).

Tidal Site?: Check *Yes* if the site is tidally influenced (as determined in *Section 2* or through observation of site conditions). Otherwise, check *No*.

Tide Stage: Check a single box to indicate whether the field visit occurred during:

- *Low Slack Tide*: Low tide, water may be present in the channel but is not flowing
- *Low Ebb Tide*: Low, outgoing tide (water in the channel is flowing downstream)
- *Low Flood Tide*: Low, incoming tide (water in the channel is flowing upstream)
- *Unknown*: Low tide, but you are unsure whether the tide is incoming (flood), outgoing (ebb), or slack.
- *Other*: Select this option if the field visit occurs at any point in the tidal cycle other than low tide. Indicate when (what stage) in the tidal cycle the field visit occurred, in the blank space provided

Your field visit should only be conducted during low tide. However if you assess a crossing at some other point in the tidal cycle, select *Other* and indicate when in the cycle the field work was completed. Tide stage can be determined based on online tide charts if not apparent in the field. It is recommended that NOAA tide data (available from https://tidesandcurrents.noaa.gov/tide_predictions.html?gid=1411) is used from the station nearest the field site.

Tide Prediction: Record the nearest estimated time at low tide for the site based on an appropriate tide chart.

Tide Chart Location: Record the location of the tide chart used to enter the *Tide Prediction*.

Road Flooded at High Tide: Based on indicators of high water at the site such as water stains (preferred) on nearby structures or vegetation, or wrack lines, select a single option:

- *Yes*: The road is likely to be flooded at high tide.
- *No*: The road is not likely to be flooded at high tide.
- *Unknown*: It is not possible to determine whether the road will be flooded at high tide due to a lack of indicators or other factors.

Vegetation Above/Below: Considering vegetative structure (trees, shrubs, herbaceous plants) and species composition compare the vegetative communities above and below the crossing and choose the most appropriate characterization below. Transitions from salt water to freshwater plants are particularly significant.

- *Comparable:* vegetative structure and species composition are not noticeably different
- *Slightly Different:* differences in vegetative structure and species composition are evident, but small
- *Moderately Different:* differences in vegetative structure and species composition are obvious and substantial, but similarities remain
- *Very Different:* vegetative structure and species composition are so different that different vegetative communities occur above and below the crossing. This typically occurs where there is a salt marsh below and a freshwater wetland above the crossing.
- *Unknown:* Choose this option if it is impossible to assess vegetation above and/or below the crossing, due to time of year or lack of a vantage point for observations.

Tide Gate Type (if present): Tide gates can be assumed to impede at least some aquatic passage. Choose the most appropriate option from among the following.

- *None*: Choose this option if no tide gate is associated with the structure.
- *Stop Logs*: A tide gate that uses boards or logs to control the movement of water or adjust water elevations up-gradient of the crossing
- *Flap Gate*: A tide gate on hinges that opens just enough to allow water to flow downstream but passively closes (due to water pressure) to prevent water flowing upstream with incoming tides; most are top-hinged, but there are also side-hinged and bottom-hinged flap gates.
- *Sluice Gate*: A tide gate or other water management devise that opens by sliding up from the bottom via hand crank or power mechanism to regulate the amount of water flowing upstream or downstream
- *Self-regulating Tide Gate*: Self-regulating tide gates are fixed with floats or some other mechanism that allows unregulated flow at times, but restricts high flows to prevent upstream flooding.
- *Other (describe)*: Choose this option for tide gates that don't match any of the descriptions above.

Figure 3-21: Stop log tide gate. (Image credit: NAACC)

Figure 3-22: Flap tide gate. (Image credit: NAACC)

Figure 3-23: Sluice tide gate. (Image credit: Nigel Cox)

Figure 3-24: Self-regulating tide gate. (Image credit: URI)

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3.5.4 Crossing Structure Data

Choose only one option for structure data fields except when identifying Internal Structures and Physical Barriers.

When there are multiple culverts and/or bridge cells, number them from left to right, **while looking downstream toward the culvert inlet**. The left-most structure is Structure 1, and structure numbers increase to the right. See examples below.

Figure 3-25: Examples of numbered structures. (Image credit: NAACC)

For each structure, complete the following information.

Structure Material: Record here the primary material of which the structure is made, i.e., the material that makes up the majority of the structure. When in doubt, focus on the material that is most in contact with the stream.

If a structure is made of two materials, such as a bridge with concrete abutments and a steel deck structure, a metal culvert that has been lined along its entire bottom with concrete, or a crossing with different types of structures at inlet and outlet, you may select two options. **In this case, or if *Combination* is selected, describe the configuration of the structure materials in *Structure Comments*.**

Figure 3-26: Material - Concrete.

Figure 3-27: Material – Fiberglass.

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Figure 3-28: Material – Corrugated plastic (internal surface as well as external). (Image credit: NAACC)

Figure 3-29: Material – Stone (Image credit: NAACC)

Figure 3-30: Material – Combination of stone and concrete. (Image credit: NAACC)

Figure 3-31: Material – Smooth plastic. (Image credit: NAACC)

Figure 3-32: Material – Smooth metal.

Figure 3-33: Material – Corrugated metal. (Image credit: NAACC)

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Structure Comments: Use this area to briefly comment on any aspects of the **structure** needing more information. Enter comments about the overall crossing in the *Crossing Comments* box earlier in the form.

Structure Length (Dimension L): To the nearest foot, measure the length of the structure at its top.

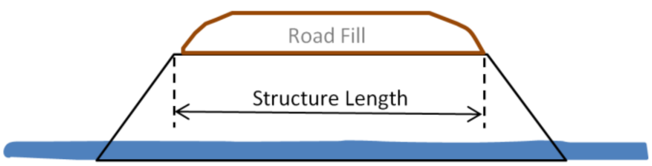

Figure 3-34: Diagram indicating where to measure length of the road-stream crossing structure. (Image credit: NAACC)

Inlet Elevation, Outlet Elevation: The elevation of the invert at the structure outlet and at the structure inlet. Measure to the nearest tenth of a foot. See *Equation 3-2* for more information.

Slope %: To the nearest tenth of a percent, measure the percent slope of the crossing from inlet to outlet by using one of the methods described below. Note that this measurement or estimate is necessary important to calculating the hydraulic capacity of the crossing, and is difficult to measure accurately without the proper tools. In general, the ease and accuracy of these different methods relates directly to the cost of the tools needed, with the most easy-to-use and accurate measurement tools costing more.

1. Use an **auto level or other accurate survey instrument** to measure the vertical difference between inlet and outlet invert elevations, then calculate the slope using *Equation 3-1* (page 3-15).

   If using the digital field form, the user has the option to auto-calculate *Slope %* by entering the *Structure Length*, *Inlet Elevation*, and *Outlet Elevation*. This feature was developed assuming that the user would be measuring elevations with a survey level and survey rod, resulting in a lower value at the inlet as measured directly off the survey rod. If the *Inlet Elevation* value entered into the digital form is greater than the *Outlet Elevation* value, the resulting *Slope %* will have a negative value. Users should be aware of this when making measurements, and convert measurements or adjust their measurement methods accordingly.

2. The simplest accurate method for measuring slope is to use an accurate **laser rangefinder or hypsometer with a slope function**, and to measure from inlet to outlet at the same height in relation to each invert. For instance, a person with a known eye height of 5.0 feet sights from one end of a culvert by standing on top of the inlet to the 5.0 foot mark on a stadia rod on top of the outlet. You must take at least three measurements and average them, and set the instrument read in percent, not degrees.

Structure Slope Compared to Channel Slope: Visually identify whether the structure is placed at a slope different than that of the channel.

- *Higher:* The crossing slope is greater than the natural slope of the streambed.
- *Lower:* The crossing slope is lower (flatter) than the natural slope of the streambed.
- *About the same:* The crossing slope is the same or approximately the same as the streambed slope.

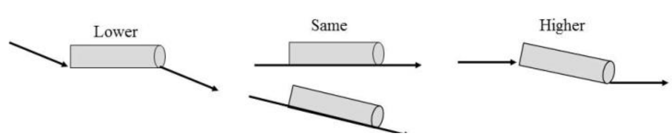

Figure 3-35: Diagram showing Structure Slope compared to Channel Slope. (Image Credit: New Hampshire Culvert Assessment Protocol [NH Agencies Version 6.0])

Slope Confidence: Rate the confidence you have in your slope measurement or estimate according to the criteria below.

- *High:* Used method (1), **or** used method (2) taking multiple measurements and averaging them.
- *Low:* Used other methods.

Outlet Shape: Refer to the diagrams on the last page of the field data form, and record the structure number that best matches the shape of the structure opening observed at the inlet of the culvert. This is usually simple, but when a shape seems unusual, you should carefully choose the most reasonable option from among the eight available. This information is used to determine the open area inside the structure above any water or substrate, so the shape is vital to accurately calculate area. Choose only one option.

1. *Round Culvert*: This is a circular pipe. It may or may not have substrate inside, even though the diagram on the field form shows a layer of substrate. It may be compressed slightly in one dimension, and should be considered round unless it is truly squashed so that it reflects a pipe arch or elliptical shape (*Shape 2*).
2. *Pipe Arch/Elliptical Culvert*: This is essentially a squashed round culvert, where the lower portion is flatter, and the upper portion is a semicircular arch, or as on the right below, more of a pure ellipse. It may or may not have substrate inside (the diagram on the field form shows a layer of substrate).
3. *Open Bottom Arch Bridge/Culvert*: This structure will often look like the top half of a round culvert, but will not have a bottom. There will be either buried metal or concrete footings, or concrete footings that rise above the channel bottom, to stabilize it. There will be natural substrate throughout the structure. To distinguish between an embedded Pipe Arch Culvert and an Open Bottom Arch, note that the sides of the Pipe Arch curve inward in their lower section, while the sides of the Open Bottom Arch will run straight downward into the streambed substrate or to a vertical footing. Open Bottom Arches may be confused with embedded Round Culverts but tend to be larger than most Round Culverts. This shape could also be selected for certain bridges that have a similar arched shape and are not well represented by other bridge types (*Shapes 5*, *6*, or *7*).
4. *Box Culvert*: These structures are usually made of concrete or stone, but sometimes of corrugated metal with a slightly arched top. Typically, they have a top, two sides, and a bottom. A box culvert **without** a bottom, called a bottomless box culvert, should be classified as a *Box/Bridge with Abutments* (*Shape 6*). If you cannot tell if the structure has a bottom, classify it as a *Box/Bridge with Abutments* (*Shape 6*). *Figure 3-39* shows *Box Culverts* (*Shape 4*).
5. *Bridge with Side Slopes*: This is a bridge with angled banks that extend up to the bottom of the road deck. This type will have no obvious abutments, though they may be buried in the road fill.
6. *Box/Bridge with Abutments:* This is a bridge or bottomless box culvert with vertical sides.
7. *Bridge with Side Slopes and Abutments:* This is a bridge with sloping banks and vertical abutments (typically short) that support the bridge deck. (Circles in *Figure 3-43* and *Figure 3-44* indicate the abutments.)
8. *Ford*: A ford is a shallow, open stream crossing that may have a minimal structure to stabilize where vehicles drive across the stream bottom.
9. *Unknown*: Select when a structure's shape is unidentifiable for any reason. Typically, the inlet shape may be unidentifiable because it is submerged or completely blocked with debris.
10. *Removed*: Select when the structure is no longer present.

Figure 3-36: Outlet shape – Round.

Figure 3-37: Outlet shape –Pipe arch/elliptical. (Image credit: NAACC)

Figure 3-38: Outlet shape – Open-bottomed arch culvert and bridge. (Image credit: US Fish & Wildlife Service)

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Figure 3-39: Outlet shape – Box culverts.

Figure 3-40: Example of a bridge with side slopes. (Image credit: NAACC)

Figure 3-41: Examples of a box culvert and bridge with abutments. (Image credit: NAACC)

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Figure 3-42: Example of a bridge with abutments. (Image credit: NAACC)

Figure 3-43: Examples of bridges with abutments and side slopes. The abutments are indicated by the red circles. (Image credit: NAACC)

Figure 3-44: Examples of bridges with abutments and side slopes. The abutments are indicated by the red circles. (Image credit: NAACC)

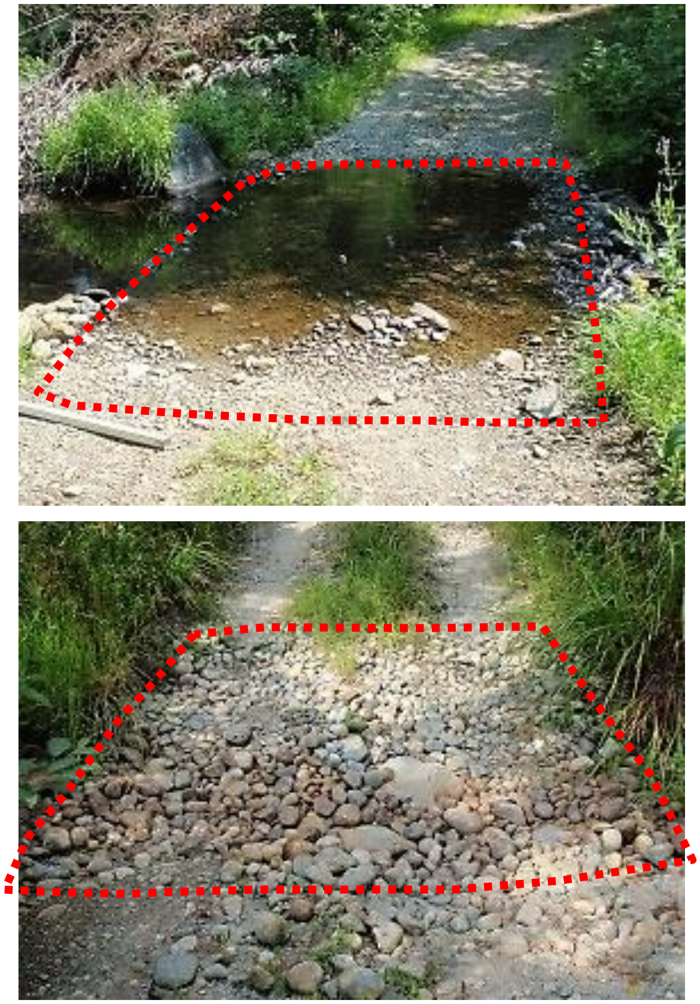

Figure 3-45: Examples of fords. (Image credit: NAACC)

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Figure 3-46: Example of a removed crossing. (Image credit: Washington Department of Fish and Wildlife)

Outlet Apron: Select from the options to indicate the presence and extent of material placed **in the streambed** below the outlet for the purpose of diffusing flow and minimizing scour. The most common forms of apron are a layer of riprap (angular rock) placed below the outlet or concrete poured in the streambed extending from the outlet. A few pieces of rock that may have fallen into the stream near the structure's outlet do not constitute outlet armoring. **Armoring of the road embankment and stream banks should not be confused with an apron covering the stream bottom at the outlet.** Choose only one option. Refer to the images in *Figure 3-47* through *Figure 3-49* for examples of each option.

- *Extensive:* Select this option only if you observe an extensive layer of material covering an area more than 50% of the stream width, which was put in place specifically to minimize scour at the outlet.
- *Not Extensive*: There is a layer of material covering less than 50% of the stream width placed purposefully below the outlet specifically to minimize the effects of scour.
- *None*: This situation represents the majority of crossing structures. You may observe rocks that have fallen from the embankment or that are natural to the stream. Most cascades do not constitute an apron unless specifically put in place to minimize scour at the outlet.

Figure 3-47: Examples of crossings with an extensive outlet apron. (Image Credit: NAACC and Fuss & O'Neill)

Figure 3-48: Examples of crossings with an outlet apron that is not extensive. (Image credit: NAACC)

Figure 3-49: Examples of crossings with no outlet apron. (Image credit: NAACC)

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Outlet Grade: Outlet grade is an observation of the relative elevation of the structure to the streambed and how water flows as it exits the structure. This is not a quantification of stream slope (gradient). Choose only one option.

- *At Stream Grade***:** The bottom of the outlet of the structure is at approximately the same elevation as the stream bottom (there may be a small drop from the inside surface of the structure down to the stream bottom), such that **water does not drop downward at all** when flowing out of the structure. Such outlets can normally be considered to be "backwatered" by the downstream stream bed.
- *Free Fall:* The outlet of the structure is above the stream bottom such that **water drops** vertically when flowing out of the structure.
- *Cascade:* The outlet of a structure is raised above the stream bottom at the outlet such that **water flows very steeply downward across rock or other hard material** when flowing from the structure. This may appear as series of small waterfalls at the outlet.
- *Free Fall Onto Cascade:* The outlet of the structure is raised above the stream bottom at the outlet such that **water drops vertically onto a steep area of rock or other hard material, then flows very steeply downward** until it reaches the stream.

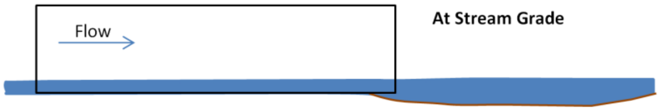

Figure 3-50: Diagram depicting a culvert with an outlet at stream grade. (Image credit: NAACC)

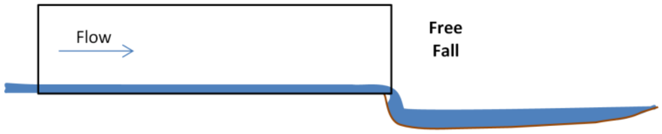

Figure 3-51: Diagram depicting a culvert with a free fall at the outlet. Image credit: NAACC

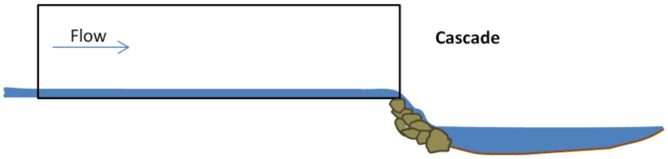

Figure 3-52: Diagram depicting a culvert with a cascade at the outlet. (Image credit: NAACC)

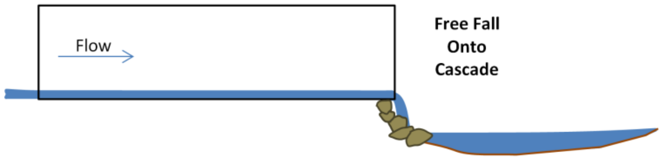

Figure 3-53: Diagram depicting a culvert with a free fall onto a cascade at the outlet. (Image credit: NAACC)

Figure 3-54: Example of a culverts with outlet at stream grade. (Image credit: NAACC)

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Figure 3-55: Examples of culverts with outlets at stream grade. (Image credit: NAACC)

Figure 3-56: Examples of culverts with a free fall at the outlet. (Image credit: NAACC)

Figure 3-57: Examples of culverts with cascades at the outlet. (Image credit: NAACC)

Figure 3-58: Examples of culverts with free falls onto cascades at the outlet. (Image credit: NAACC)

Figure 3-59: Examples of culverts with a free fall onto cascades at the outlet. (Image credit: U.S. Fish and Wildlife Service, NAACC)

Outlet Dimensions: Four measurements should be taken at the outlet **inside** all structures. The four measurements are shown on the diagrams on the last page of the field data form, and are described below.

- <u>*Dimension A, Structure Width*</u>**:** To the nearest tenth of a foot, measure the full width of the structure outlet according to the location of the horizontal arrows labeled *A* in the diagrams. Take this measurement of the **inside** of the structure.
- <u>*Dimension B, Structure Height*</u>**:** To the nearest tenth of a foot, measure the height of the structure outlet according to the location of the vertical arrows labeled *B* in the diagrams. Take this measurement **inside** of the structure. If there is no substrate inside, this will be the full height of the structure from bottom to top. If there is substrate inside, this will be the height from the top of the stream bottom substrate up to the inside top of the structure.
- <u>*Dimension C, Substrate/Water Width*</u>**:** To the nearest tenth of a foot, measure the width of either the substrate layer in the bottom of the structure or the width of the water surface, whichever is <u>wider</u> according to the general location indicated by the arrows labeled *C* in the diagrams. This measurement must be taken <u>inside</u> of the structure near the outlet. Some rules of thumb for Dimension C are below:
  - ✓ When there is no substrate in a structure, measure only the width of the water surface.
  - ✓ When there is no water in a structure, but there is substrate, measure the width of substrate.
  - ✓ When there is no substrate or water in a structure, C = 0 feet.
- <u>*Dimension D, Water Depth*</u>***:*** To the nearest tenth of a foot (except when < 0.1 foot, to the nearest hundredth of a foot), measure the average depth of water in the structure at the outlet according to the location of the vertical arrows labeled D in the diagrams. This measurement must be taken inside the structure. When there are lots of different depths due to a very uneven bottom, take several measurements and record the average.

Internal Crossing Measurements

Remember to use caution when measuring or observing structures, particularly inside the road-stream crossing. **Do not enter** the structure, especially if the crossing shows signs of damage that may reduce safety. All measurements, including those taken inside the structure, can generally be taken while standing outside the structure opening.

Two additional measurements should be taken for all structures with an Outlet Grade marked as *Free Fall, Cascade* or Free *Fall onto Cascade*. These measurements are *Outlet Drop to Water Surface* and *Outlet Drop to Stream Bottom*.

Outlet Drop to Water Surface: This measurement is only applicable to *Free Fall, Cascade,* and Free *Fall onto Cascade* outlets. To the nearest tenth of a foot, measure from the **inside** bottom surface of the structure (not the top of the water) down to the water surface outside the structure. For *Cascade* and *Free Fall onto Cascade* structures, measure to the surface of the water at the bottom of the cascade. The red arrows in *Figure 3-60* indicate where to make this measurement. When assessing *At Stream* Grade structures or dry structures in streams without flow or water in an outlet pool, this measurement must be *zero*.

Outlet Drop to Stream Bottom: To the nearest tenth of a foot, measure from the inside bottom surface of the structure (**not** the top of the water) down to the stream bottom at the place where the water falls from the outlet. For *At Stream* Grade structures, this may be hard to measure, and may bea very small drop. For *Cascade* and *Free Fall onto Cascade* structures, measure the full vertical drop to the stream bottom at the end of the cascade. The red arrows in *Figure 3-61* indicate where to make this measurement.

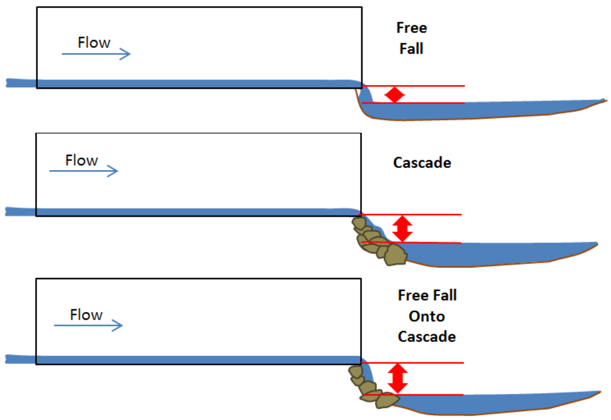

Figure 3-60: Diagrams depicting the measurement of the outlet drop to the water surface at a culvert with a free fall at the outlet (top), a culvert with a cascade at the outlet (middle), and a free fall onto a cascade at the outlet (bottom). (Image credit: NAACC)

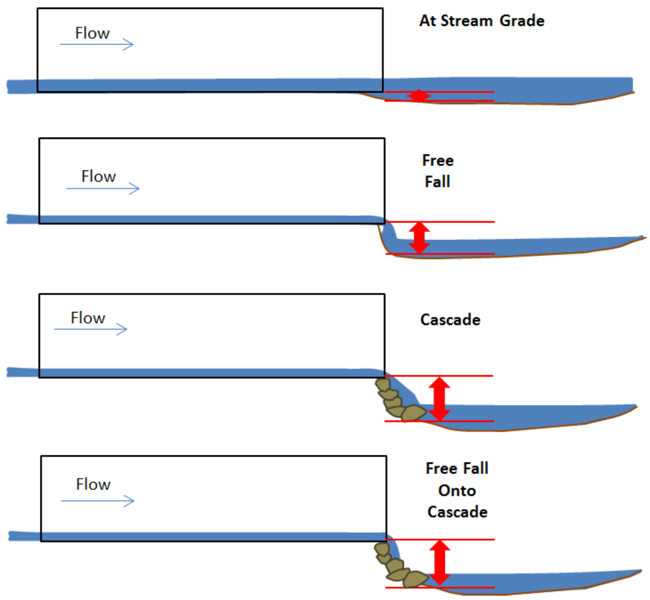

Figure 3-61: Diagrams depicting the measurement of the outlet drop to the stream bottom at a culvert with an outlet at stream grade (top), a free fall at the outlet (second from top), a culvert with a cascade at the outlet (second from bottom), and a free fall onto a cascade at the outlet (bottom). (Image credit: NAACC)

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Abutment Height: *Dimension E*: This measurement is only taken when for a *Bridge with Side Slopes and Abutments* (*Shape 7*). To the nearest foot, measure the height of the vertical abutments from the top of the side slopes up to the bottom of the bridge deck structure.

Figure 3-62: Examples of bridges with side slopes and abutments. The red circles indicate the abutments. (Image credit: NAACC)

Note: The digital field form jumps to *Outlet Structural Condition Data* at this point, before continuing to *Inlet Data*. Instructions for assessing structural condition are provided starting on page 3-53.

Inlet Shape: Refer to the diagrams on the last page of the field data form, and record here the number that best matches the shape of the structure at its inlet. Refer to the instructions for *Outlet Shape* for examples and photos.

Inlet Type: Choose only one option for the style of a culvert inlet, which affects how water flows into the crossing, particularly at higher flows. The drawings in *Figure 3-63* are meant as general guides, but refer to *Figure 3-64* through *Figure 3-74* for more specific images of each type.

- *Projecting*: The inlet of the culvert projects out from (is not flush with) the road embankment.
- *Headwall with Square Edge*: The inlet is set flush in a vertical wall, often composed of concrete or stone. The edge of the inlet is square to the headwall face.
- *Headwall with Grooved, Beveled or Chamfered Edge*: The inlet is set flush in a vertical wall, often composed of concrete or stone. The edge of the inlet is not square to the face of the headwall and has a grooved, beveled or chamfered shape.
- *Wingwalls*: The inlet is set within angled walls meant to funnel water flow. These walls can be composed of the same material as the culvert, or different material. It is relatively rare to see wingwalls without a headwall.
- *Headwall with Square Edge & Wingwalls*: The inlet is set flush in a vertical wall, often composed of concrete or stone, and has angled walls to funnel flow. The edge of the inlet is square to the headwall face.
- *Headwall with Grooved, Beveled or Chamfered Edge and Wingwalls*: The inlet is set flush in a vertical wall, often composed of concrete or

stone. The edge of the inlet is not square to the face of the headwall and has a grooved, beveled or chamfered shape.

- *Mitered to Slope:* The inlet is angled to fit **flush with the slope of the road embankment.** Note that many mitered culverts project out from the embankment and should be recorded as *Projecting.*
- *Other:* The inlet does not have the above characteristics, but there may be some other inlet characteristics that do not match any of the above types and which may limit or enhance flow into the culvert (but are not *Physical Barriers)*, in which case select *Other* and explain in *Structure Comments.*
- *No Inlet Treatment:* The inlet does not have the above characteristics.

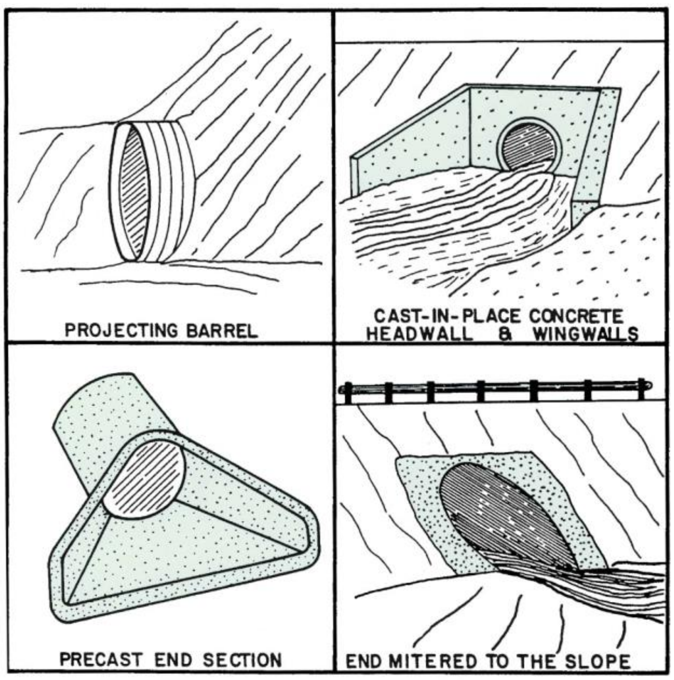

Figure 3-63: Four standard inlet types. (Image credit: California Salmonid Stream Habitat Restoration Manual (April 2003) Part IX, Fish Passage Evaluation at Stream Crossings)

Figure 3-64: Examples of crossings with projecting inlets.

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Figure 3-65: Examples of crossings with headwalls with square edges. (Image credit: NAACC)

Figure 3-66: Example of a crossing with headwall with square edges. (Image credit: NAACC)

Figure 3-67: Example of crossings with headwalls with a chamfered or beveled edge.

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Figure 3-68: Examples of crossings with wingwalls. (Image credit: NAACC)

Figure 3-69: Examples of crossings with wingwalls and headwalls with square edges. (Image credit: NAACC)

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Figure 3-70: Example of a headwall with beveled or chamfered edge and wingwalls (Image credit: Schall et al., 2012).

Figure 3-71: Examples of crossings with inlets that are mitered to the slope. (Image credit: NAACC, National Park Service)

Figure 3-72: Example of a crossing with inlet that is mitered to the slope. (Image credit: NAACC)

Figure 3-73: Examples of bridges where none of the above characteristics occur (Image credit: Steckler Tidal Module)

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Figure 3-74: Examples of culverts where none of the above characteristics occur. (Image credit: NAACC)

Inlet Grade: An observation of the relative elevation of the stream bottom as it enters the structure. This is **not** a quantification of stream slope (gradient). Choose only one option.

- *At Stream Grade***:** The inlet of the structure is at approximately the same elevation as the stream bottom upstream of the structure.
- *Inlet Drop***:** Water in the stream has a near-vertical drop from the stream channel down into the inlet of the structure. This usually occurs because sediment has accumulated just upstream of the inlet. The drop should be very obvious and not typical of natural drops in that stream. If there is a debris blockage or dam at the inlet, mark *At Stream Grade* in this section, and **use *Physical Barriers* to record those features** instead.
- *Perched*: The structure inlet is above the surface of water in the stream. Little water passes through the structure during normal low summer flows, though the stream has water upstream and downstream of the crossing. Water can enter the structure only at higher flows. This is a relatively rare condition, found mostly on very small streams. At such sites, there is generally water backed up above the inlet. In some cases water may be seeping underneath the structure and emerging below the structure outlet at the downstream end of the structure.

  If you observe a perched inlet, measure the distance (in decimal feet) from the invert to the water surface in the pool or channel above the crossing.
- *Clogged/Collapsed/Submerged***:** The structure inlet is either full of debris, collapsed, or completely underwater (not usually all three), making inlet measurements impossible. This may be found in places where beavers or debris have plugged a structure inlet so completely that water has backed up and covered the inlet, or

where a crossing has collapsed to the point that it cannot be measured at its inlet.

- *Unknown:* The inlet cannot be located or observed, or for some reason you cannot determine the *Inlet Grade*, or take any inlet measurements.

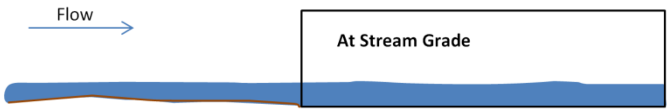

Figure 3-75: Diagram depicting a crossing with the inlet at stream grade. (Image credit: NAACC)

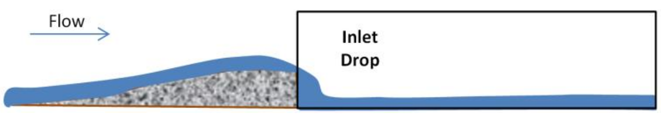

Figure 3-76: Diagram depicting a culvert with an inlet drop at the inlet. (Image credit: NAACC)

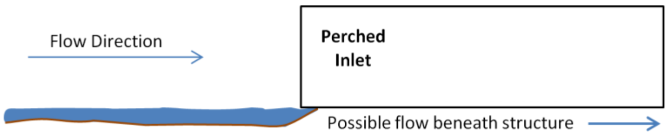

Figure 3-77: Diagram depicting a culvert with a perched inlet. (Image credit: NAACC)

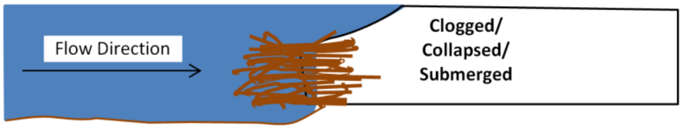

Figure 3-78: Diagram depicting a culvert with clogged, collapsed, and submerged inlet. (Image credit: NAACC)

Figure 3-79: Examples of crossings with the inlet at stream grade. (Image credit: NAACC)

Figure 3-80: Example of a crossings with an inlet drop. (Image credit: NAACC)

Figure 3-81: Examples of crossings with perched inlets. (Image credit: NAACC)

Figure 3-82: Example of a crossing with a clogged inlet. (Image credit: NAACC

Inlet Dimensions: There are four basic measurements to take at the inlet and outlet of each structure; these four measurements are to be made from the **inside** of the structure using a pocket tape measure or reel measure. These are shown on the diagrams on the last page of the field data form.

- <u>*Dimension A, Structure Width*</u>***:*** To the nearest tenth of a foot, measure the full width of the structure inlet according to the location of the horizontal arrows labeled *A* in the diagrams. Take this measurement **inside** of the structure.
- <u>*Dimension B, Structure Height*</u>**:** To the nearest tenth of a foot, measure the height of the structure inlet according to the location of the vertical arrows labeled *B* in the diagrams. Take this measurement **inside** of the structure. This may be the full height of a culvert pipe if there is no substrate inside, or if there is substrate, it will be the height from the top surface of the substrate up to the inside top of the structure.
- <u>*Dimension C, Substrate/Water Width*</u>**:** To the nearest tenth of a foot, measure the width of **either** the substrate layer in the bottom of the structure, or the width of the water surface, whichever is wider, according to the general location indicated by the arrows labeled *C* in the diagrams. Take this measurement **inside** of the structure at the inlet. Some rules of thumb for Dimension C are below:
  - ✓ When there is no substrate in a structure, measure the width of the water surface.
  - ✓ When there is no water in a structure, but there is substrate, measure the width of substrate.
  - ✓ When there is no substrate or water in a structure, C = 0 feet.
- <u>*Dimension D, Water Depth*</u>***:*** To the nearest tenth of a foot (except when < 0.1 foot, to the nearest hundredth of a foot), measure the average depth of water in the structure at the inlet according to the location of the vertical arrows labeled D in the diagrams. This measurement must be taken of the inside the structure. When there are many different water depths due to a very uneven structure bottom, take several measurements and record the average

Note: The digital field form jumps to *Inlet Structural Condition Data* at this point, before continuing to *Aquatic Organism Passage Data*. Instructions for assessing structural condition are provided starting on page 3-53.

3.5.5 Aquatic Organism Passage Data

Complete this section for each structure. Choose only one option for the fields with check boxes.

Internal Structures: Indicate the presence of structures inside the crossing structure. These may include baffles or weirs used to slow flow velocities and help to pass fish, as well as trusses, rods, piers or other structures intended to support a crossing structure, but which may interfere with flow and aquatic organism passage. *Figure 3-83* and *Figure 3-84* are examples of internal structures. Choose any option(s) that apply.

- *None:* There are no apparent structures inside the crossing structure.
- *Baffles/Weirs:* Baffles (partial width) or weirs (full width, notched or not) are incorporated into the structure, either inside or at its outlet, to help aquatic organisms move through the structure.
- *Supports:* Some type of structural supports, such as bridge piers, vertical or horizontal beams, or rods apparently meant to support the structure, are observed inside the crossing structure.
- *Other:* Structure(s) other than the categories above are present inside the crossing structure. Provide a very brief description of those structures here, or more fully describe them under *Structure Comments*. **Do not** include here items such as bedrock, material blockages, structural deformation, or inlet fencing to exclude beavers, which will be recorded below as *Physical Barriers*.

Structure Substrate Matches Stream: Choose only one option based on a comparison of the substrate (e.g., rock, gravel, sand) inside the structure and the substrate in the natural, undisturbed stream channel.

- *None*: Select this option when there is very little (e.g., a thin layer of silt or a few pieces of rock) or no substrate inside the structure.
- *Comparable*: The substrate inside the structure is similar in size to the substrate in the natural stream channel.
- *Contrasting*: The substrate inside the structure is different in size from the substrate in the natural channel.
- *Not Appropriate*: The substrate inside the structure is very different in size (usually much larger) than the substrate in the natural stream channel. This condition is rarely observed.
- *Unknown*: There is no way to observe if there is substrate inside the structure or what type it is. Select this option when deep, fast, or dark water or other factors do not allow direct observation.

Structure Substrate Type: Choose only one option from the table below to indicate the most common or dominant substrate type inside the structure. If you are certain that the structure contains substrate, but cannot assess the type, select *Unknown*. If there is no substrate in the structure, select *None*.

Table 3-2: Structure Substrate Sizes

Substrate Type	Size (Feet)	Approximate Relative Size
Silt	< 0.002	Finer than salt
Sand	0.002 – 0.01	Salt to peppercorn
Gravel	0.01 – 0.2	Peppercorn to tennis ball
Cobble	0.2 – 0.8	Tennis ball to basketball
Boulder	> 0.8	Bigger than a basketball
Bedrock	Unmeasurable	Unknown - buried

Figure 3-83: Examples of crossings with baffles and weirs. (Image credit: NAACC)

Figure 3-84: Examples of supports inside of road stream crossings. (Image credit: NAACC)

Structure Substrate Coverage: Choose one option, based on the extent of the substrate inside the crossing structure as a **continuous** layer across the entire bottom of the structure from bank to bank (side to side).

- *None***:** Substrate covers less than 25% of the length of the structure, or there is no substrate inside the structure at all.
- *25%***:** Substrate covers *at least* 25% of the length of the structure.
- *50%***:** Substrate covers *at least* 50% of the length of the structure.
- *75%***:** Substrate covers *at least* 75% of the length of the structure.
- *100%***:** Substrate forms a **continuous** layer throughout the **entire** structure.
- *Unknown***:** It is not possible to directly observe whether substrate forms a continuous layer on the structure bottom.

Physical Barriers: Select **any** of these barrier types in or associated with the structure, including those associated with Inlet Grade or blockages, or Internal Structures. If a barrier feature affects more than one structure at a crossing (e.g., a beaver dam is constructed across the entire stream, forming a barrier to multiple structures), include it for **all** affected structures. Fore structures have a combination of physical barriers, **check all barrier types that apply.**

- *None***:** There are no physical barriers associated with this structure aside from any already noted under *Outlet Grade*. **Do not mark outlet drops that were already recorded under in *Outlet Grade* as physical barriers.**
- *Debris/Sediment/Rock***:** Woody debris or synthetic material, rock, or sediment blocks the flow of water into or through the structure. This can consist of wood or other vegetation, trash, sand, gravel, or rock. Do **not** check this option if you observe only very small amounts of debris that are likely to be washed away during the next rain event. Sediment inside a structure that constitutes an appropriate stream bed should **not** be marked as a physical barrier.
- *Deformation***:** The structure is deformed in such a way that it **significantly** limits flow or inhibits the passage of aquatic organisms. This does not include minor dents and slightly misshapen structures.
- *Free Fall***:** In addition to its *Outlet Grade*, which may include a *Free Fall*, the structure has one or more **additional** vertical drops associated with it. These may include a dam at the inlet, a vertical drop over bedrock inside the structure, or some other feature likely to inhibit passage of aquatic organisms. Note that a *Free Fall* inside a structure is often more limiting than similar size drops found in an undisturbed natural reach of the same stream which occurs where there may be multiple paths for organisms to follow. A *Free Fall* can exist because of a debris blockage; in this case **both** physical barriers would be recorded.
- *Fencing***:** The structure has some sort of fencing, often at the inlet to deter beavers or to prevent debris from entering the structure. Depending on the mesh size of that fencing, it may directly block the movement of aquatic and terrestrial organisms, and it may become clogged with debris. If also blocked with debris, be sure to check *Debris/Sediment/Rock* as a *Physical Barrier* type as well.
- *Dry***:** There is no water in this structure, though water is flowing in the stream. Note that if you recorded *No Flow* for crossing *Flow Condition*, you should not select *Dry* here, as we expect a dry structure at a dry crossing; it is not in itself a physical barrier. This barrier type helps to identify passage problems associated with overflow or secondary crossing structures.
- *Other*: There may be different situations that do not fit clearly into one of the above categories, but may still represent significant

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physical barriers to aquatic organism passage. Examples include tide gates and beaver exclusion devices. Use this option to capture such situations, and add relevant information in *Structure Comments*. *Figure 3-92 and Figure 3-93* are examples of some unusual physical barriers which may not fit under Physical Barrier categories listed above.

Figure 3-85: Stone acting as a physical barrier. (Image credit: NAACC)

Figure 3-86: Debris acting as physical barriers. (Image credit: NAACC)

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Figure 3-87: Deformation acting as physical barriers. (Image credit: NAACC)

Figure 3-88: Free falls acting as physical barriers. (Image credit: NAACC)

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Figure 3-89: Fencing acting as physical barriers. (Image credit: USDA)

Figure 3-90: Fencing acting as physical barriers. (Image credit: NAACC)

Section 3: Field Data Collection

Figure 3-91: Dry culverts (indicated by the red boxes) acting as physical barriers. (Image credit: NAACC)

Figure 3-92: An anti-beaver attached to a crossing inlet acting as a physical barrier at a crossing. This physical barrier would be classified as “*Other*.” (Image credit: NAACC)

Figure 3-93: A dam with no free fall acting as a physical barrier at a crossing. This physical barrier would be classified as “*Other*.” (Image credit: NAACC)

Section 3: Field Data Collection

Figure 3-94: An example of a structure with multiple barriers. The culvert on the left is deformed and dry. (Image credit: NAACC)

Figure 3-95: An example of a crossing structure with multiple barriers. The culvert is deformed by displaced stones, blocked by debris, and dry. (Image credit: NAACC)

Figure 3-96: An example of a crossing structure with multiple barriers. The culvert is deformed and blocked by debris. (Image credit: NAACC)

Figure 3-97: An example of a structure with multiple barriers. The culvert on the left is deformed (bent upward) and blocked by debris. (Image credit: NAACC)

Figure 3-98: An example of a crossing structure with multiple barriers: the culvert is blocked by debris and fencing. (Image credit: NAACC)

Figure 3-99: An example of a crossing structure with multiple barriers: the culvert is deformed, blocked by debris, and dry. (Image credit: NAACC)

Figure 3-100: An example of multiple barriers, including fencing and a vertical drop. (Image credit: NAACC)

Figure 3-101: An example of multiple structures at a crossing, each with a physical barrier. The lower, rectangular stone culvert is blocked by fallen stones. The two metal culverts above are dry. (Image credit: NAACC)

Section 3: Field Data Collection

Physical Barrier Severity: Decide on an overall severity for each structure by considering the severity of each of the different *Physical Barriers* present before selecting the overall severity based on the **most severe physical barrier** affecting that structure. Severity ratings are outlined in *Table 3-3*. The digital data form allows the user to record the *Physical Barrier Severity* for each *Physical Barrier* before selecting the *Overall Physical Barrier Severity*, guiding the user through the process of choosing the most appropriate severity rating for the structure and providing backup data for the final selection. ***Do* not** consider information already captured in *Outlet Grade*. If any barrier affects more than one structure at a crossing, it should be included in the severity rating for each structure affected.

Table 3-3: Physical Barrier Severity

Physical Barrier	Severity	Severity Definition
None	*None*	No physical barriers exist - **apart from** Outlet Grade
Debris/Sediment/Rock *Logs, branches, leaves, silt, sand, gravel, rock*	*None*	None beyond few leaves or twigs as may occur in stream
	Minor	< 10% of the open area of the structure is blocked
	Moderate	10% - 50% of open area blocked
	Severe	> 50% of open area of structure blocked
Deformation *Significant dents, crushed metal, collapsing structures*	*None*	Small dents and cracks that have an insignificant effect on flow
	Minor	Flow area is reduced by < 10%
	Moderate	Flow area is reduced by between 10% - 50%
	Severe	Flow area is reduced by > 50%
Free Fall *Vertical or near-vertical drop*	*None*	No vertical drop exists - **apart from** Outlet Grade
	Minor	0.1 - 0.3 foot vertical drop - **apart from** Outlet Grade
	Moderate	0.3 - 0.5 foot vertical drop - **apart from** Outlet Grade
	Severe	> 0.5 foot vertical drop - **apart from** Outlet Grade
Fencing *Wire, metal grating, wood*	*None*	No fencing exists in any part of the structure
	Minor	Widely spaced wires or grating with > 0.5 foot (6 inch) gaps
	Moderate	Wires or grating with 0.2 - 0.5 foot (~ 2-6 inches)spacing
	Severe	Wires or grating with < 0.2 foot (~ 2 inch) spacing
Dry	*Minor*	May be passable at higher flows
	Moderate	Probably impassable at higher flows
	Severe	Impassable at higher flows
Other	*Minor*	Use best judgment based on above standards
	Moderate	Use best judgment based on above standards
	Severe	Use best judgment based on above standards

Water Depth Matches Stream: Compare the water depth inside the structure with the water depth in the natural stream channel **away from the influence of the crossing**. Choose only one option.

- *Yes*: The depth in the crossing falls **within the range of depths naturally occurring in that reach of the stream and for comparable distances** along the length of the stream. For example, if a structure has a water depth of 0.2 feet through the entire structure's length of 60 feet, and are comparable sections of the stream with a 0.2 foot water depth for approximately 60 feet of the channel, select *Yes*.
- *No-Shallower*: This means that the water depth in the crossing is **less than** depths that occur naturally in a similar length of the undisturbed stream, or the shallower depth through the structure covers a greater length than occurs in the natural stream.
- *No-Deeper:* This means that the water depth in the crossing is **greater than** depths that occur naturally in a similar length of the undisturbed stream. This is rarely observed.
- *Unknown*: A comparison of structure depth to natural stream depth is not possible.

Water Velocity Matches Stream*:* Compare the water velocity inside the structure with the velocity in the natural stream channel **away from the influence of the crossing.** Choose only one option.

- *Yes*: The water velocity in the crossing **falls within the range of velocities naturally occurring in that reach of the stream for comparable distances.** If velocities in the crossing are observed in the natural stream channel, and those velocities persist over the same distance as the structure length, select *Yes.*
- *No-Faster:* This means that the water velocity in the structure is **greater than** velocities that occur naturally in a similar length of the undisturbed stream, or that the velocity through the structure persists over a longer distance than occurs in the natural stream.
- *No-Slower:* This means that the velocity in the crossing is **less than** velocities that occur naturally in a similar length of the undisturbed stream. This is rarely observed.
- *Unknown*: A comparison of structure velocity to natural stream velocity is not possible.

Dry Passage Through Structure?:

- *Yes:* There is a continuous, dry stream bank along at least one side of the structure (within the structure) that connects to upstream and downstream streambanks, or there is otherwise continuous dry passage through the structure that allows the safe movement of terrestrial or semi-aquatic animals.
- *No:* There is no dry passage, the dry passage is not continuous, or the dry passage through the structure does not connect with stream banks upstream or downstream.
- *Unknown*: It is not possible to determine if continuous dry passage exists through this structure.

If there is no water flowing in the structure, then there is continuous dry passage through the structure.

Height above Dry Passage: If there is dry passage through the structure, measure the average height from the dry stream bank to the top of the structure directly above (i.e., the clearance) to the nearest tenth of a foot. If both stream banks are dry and connected, record the higher measurement. If the structure has no water flow, measure the average height above the bottom of the structure or dry stream bed to the top of the structure.

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Inspection End Time: The times of the end of the site visit, following the form HH:MM – HH:MM. Record the time in 24-hour time or include "AM" or "PM" for each start and end time.

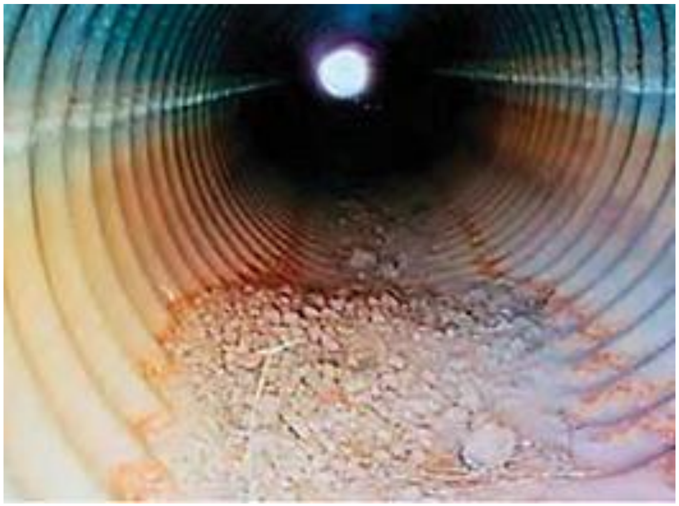
In the digital field form, tap the "Refresh" button at the end of the *Inspection End Time* field to automatically record the time the form is completed

Section 3: Field Data Collection

3.5.6 Structural Condition

For each structure, complete the following information. Choose only one option for structure condition data fields.

Invert Condition



Adequate: Minor corrosion and pitting occurring. No holes or distortion. Cannot penetrate metal with sharp point of chipping hammer (metal). Minor isolated spalls (concrete). (Image credit: NAACC)

Poor: Perforations visible and/or connection hardware is failing (metal). Heavy abrasion and scaling with exposed steel reinforcement (concrete). Heavy abrasion or scour damage (plastic). Displaced mortar and/or blocks, holes in invert area (masonry). (Image credit: NAACC)

Critical: Holes or section loss with extensive voids beneath invert, and/or embankment/roadway damage. Holes and gaps with extensive infiltration of soil, bedding or backfill material (masonry). (Image credit: NAACC)

Remember to take good quality photos of any deficiencies in condition, and check your photos before leaving the site. See *Appendix D* for more guidance on taking photos.

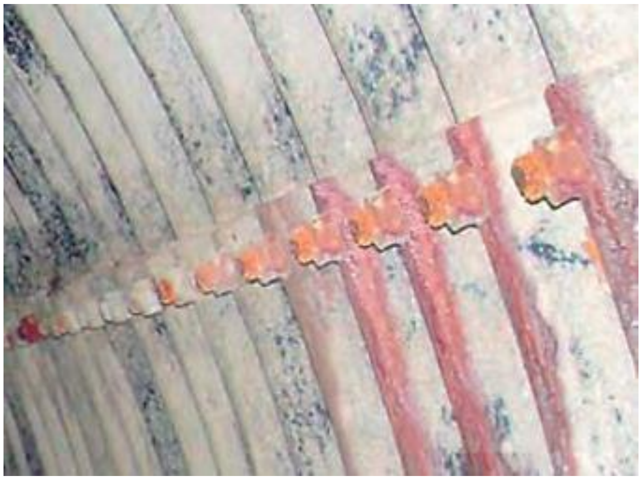
Joint & Seam Condition

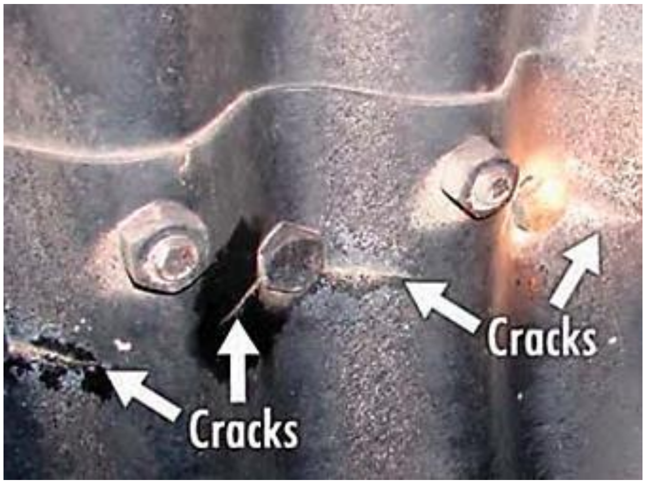
<u>Adequate</u>: Minor separation of joints and seams up to 1”. Minor backfill infiltration. (Image credit: NAACC)

<u>Poor</u>: Significant separation of joints and seams between 1” to 3”. Infiltration of backfill into culverts. Voids visible in fill through offset joints. Missing mortar or displace blocks (masonry). (Image credit: NAACC)

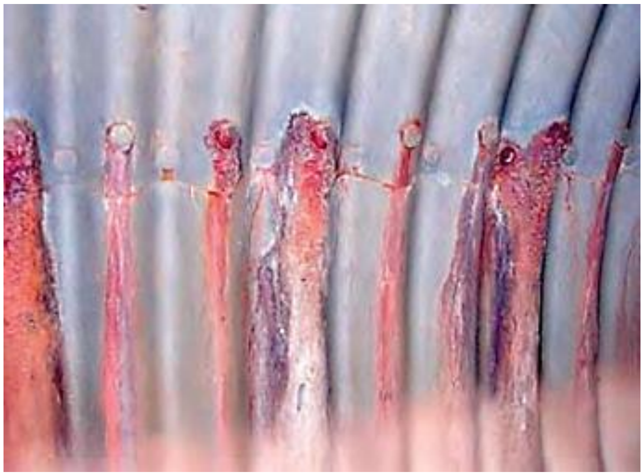
<u>Critical</u>: Severe separation of joints and seams greater than 3”. Significant infiltration of soil backfill into culvert and accompanying embankment or roadway damage. Large voids in fill visible through offset joints. (Image credit: NAACC)

Barrel Condition/ Structural Integrity (Metal)





***Adequate*:** Minor cracking around bold holes or seams at isolated sections. (Image credit: NAACC)



***Poor*:** Significant cracking and/or deterioration along bolt holes and isolated seams of plates. (Image credit: NAACC)

***Critical*:** Severe cracking and or deterioration along bolt holes and along seams of plates. (Image credit: NAACC)

Section 3: Field Data Collection

Barrel Condition/ Structural Integrity (Plastic)

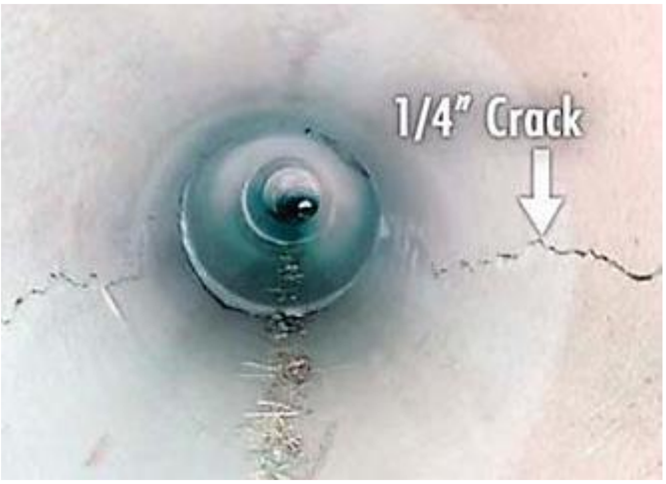
Adequate: Minor isolated rip or tear caused by debris less than 6" in length and ½" in width. Minor cuts or gouges to end sections from maintenance or construction activities. (Image credit: NAACC)

Poor: Cracking, splits or tears over 6" in length and up to ¾" in width. Openings in pipe causing loss of backfill material. (Image credit: NAACC)

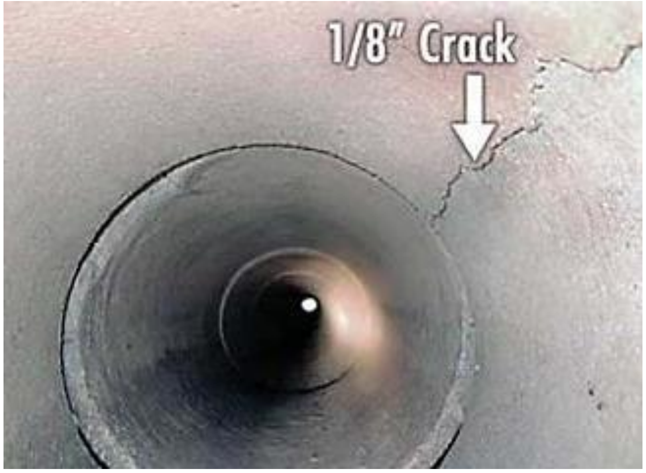
Critical: Cracking, splits, punctures, or tears over 6" in length and over 1" in width. Openings in pipe causing loss of backfill material. (Image credit: NAACC)

Section 3: Field Data Collection

Barrel Condition/ Structural Integrity (Concrete)



Adequate: Longitudinal cracks less than 1/8" in width. Spalls up to ¼" deep. (Image credit: NAACC)



Poor: Longitudinal cracks between 1/8" -1/4" in width. Significant infiltration of soil and/or leakage of water. Heavy rust staining. Spalls larger than ½" deep. Exposed steel reinforcement in sides and top of barrel. (Image credit: NAACC)

Critical: Severe cracking and spalls greater than ½" on culvert walls (concrete). Cracks, tears, splits, bulges, holes or section loss have led to extensive infiltration of soil, structural failure, voids, and embankment/roadway damage. Sections of culvert are partially collapsed, major corrosion of rebar. (Image credit: NAACC)

Headwall/Wingwall Condition

Adequate: Minor spalls and cracks less than 1/8" in width. No exposed rebar or surface evidence of rebar corrosion. Minor settlement of the wall. (Image credit: NAACC)

Poor: Significant spalls and cracks between 1/8" to ¼" in width. Cracking or braking off of flakes or chips affecting >50% of area. Exposed rebar with corrosion. Significant settlement of the wall. (Image credit: NAACC)

Critical: Extensive deterioration with loss of concrete. Corrosion of rebar and extensive section loss. Extensive settlement of the wall. Partially or totally collapsed with damage to embankment/roadway. (Image credit: NAACC)

Embankment Piping

Adequate: Embankment moist only in areas surrounding culvert barrel. No evidence of flow or sediment transport observed. (Image credit: NAACC)

Poor: Evidence of seepage through the embankment along the outside of the culvert barrel. Sediment transport not observed. (Image credit: NAACC)

Critical: Evidence of flow through embankment along the outside of culvert barrel. Evidence of sediment transport, voids, or sink holes observed.
(Image credit: NAACC)

Apron/Scour Protection Condition

Adequate: Some minor undermining of culvert and small scour hole. Some deterioration of joint between apron and headwall. (Image credit: NAACC)

Poor: Significant undermining of culvert and evidence of scour hole. Significant deterioration of joint between apron and headwall. (Image credit: NAACC)

Critical: Extensive undermining of culvert and development of a large hole under structural element of the culvert. Substantial deterioration of joint between apron and headwall. (Image credit: NAACC)

Armoring


<u>Adequate:</u> Minor displacements of armor. No significant erosion of embankment where armor has been displaced. (Image credit: NAACC)

<u>Poor</u>: Significant displacements, undermining, or deterioration of armor leading to some erosion of embankment. (Image credit: Scott O'Dell)

<u>Critical</u>: Armor Partially or totally failed, causing embankment or roadway damage, or undermining of the culvert barrel or footings. Armor displaced from streambanks and culvert embankment may have been deposited in streambed. (Image credit: NAACC)

Section 3: Field Data Collection

Cross-Section Deformation (Metal)

- *Adequate:* Minor distortions isolated within the structure resulting in flattening of invert and/or crown. Isolated sections are slightly non-symmetrical. Span dimension is within 5<15% of design.
- *Poor:* Significant distortions within the structure resulting in flattening of invert and/or crown of structure. Span dimension is within 15-20% of design.
- *Critical:* Severe distortions and deflection within the structure. Flattening of the crown or invert. Structure is partially collapsed. Span dimension is greater than 20% of design.

METAL	CULVERT SIZES						
	12"	24"	36"	48"	60"	72"	84"
GOOD	< 12 1/2	< 25 3/16	< 37 3/4	< 50 1/4	< 63	< 75 1/2	< 88 1/4
FAIR (5% - 15%)	12 1/2 - 13 3/4	25 3/16- 27 1/2	37 3/4 - 41 1/2	50 1/4 - 55 1/4	63 - 69	75 1/2 - 82 3/4	88 1/4- 96 1/2
POOR (15% -20%)	13 3/4- 14 1/2	27 1/2- 28 3/4	41 1/2 - 43 1/4	55 1/4 - 57 1/2	69 - 72	82 3/4 - 86 1/2	96 1/2 - 101
CRITICAL (>20%)	> 14 1/2	> 28 3/4	> 43 1/4	> 57 1/2	> 72	> 86 1/2	> 100

Cross-Section Deformation (Plastic)

- *Adequate:* Minor isolated distortions and dimpling within the structure. Pipe deflection is <10% from original shape.
- *Poor:* Significant distortions; wall buckling; flattening of invert/crown throughout the structure; cracking/tearing 10-20% from original shape.
- *Critical:* Severe distortions; wall buckling. Flattening of invert/crown throughout structure. Cracking /tearing present. Pipe deflection greater than 20% of original shape.

PLASTIC	CULVERT SIZES						
	12"	24"	36"	48"	60"	72"	84"
GOOD	< 12 1/2	< 25 3/16	< 37 3/4	< 50 1/4	< 63	< 75 1/2	< 88 1/4
FAIR (5% - 10%)	12 1/2 - 13 1/4	25 3/16- 26 3/8	37 3/4 - 39 1/2	50 1/4 - 52 3/4	63 - 66	75 1/2 - 79 1/4	88 1/4 - 92 1/2
POOR (10% -15%)	13 1/4- 13 3/4	26 3/8- 27 1/2	39 1/2 - 41 1/2	52 3/4 - 55 1/4	66 - 69	79 1/4 - 82 3/4	92 1/2 - 96 1/2
CRITICAL (>15%)	> 13 3/4	> 27 1/2	> 41 1/2	> 55 1/4	> 69	> 82 3/4	> 96 1/2

Longitudinal Alignment

Adequate: No significant misalignment of pipe.

Poor: Significant horizontal or vertical misalignment of the pipe. (Note: Do not confuse this with constructed pipe bends.)

Critical: Significant misalignment of the pipe resulting in deformation of the pipe or embankment/roadway damage. Significant bend or jogs in the culvert resulting in gaps filled with stone that are vulnerable to collapse (concrete/masonry).

Footing Condition

Adequate: Minor to moderate deterioration. Moderate cracking, scaling or leaching; minor delamination or spalling (concrete). Moderate weathering; minor joint deterioration (masonry). Slight settlement or undermining. Minor footing exposure. (Image credit: NAACC)

Poor: Extensive deterioration. Extensive cracking, scaling or leaching; delamination or spalling may be present (concrete). Extensive weathering; significant joint deterioration (masonry). Significant settlement or undermining. Footing exposed and undermined. (Image credit: NAACC)

Critical: Severe or critical deterioration. Function or structural capacity of the structure has been severely impacted; immediate repairs or structural analysis may be required. Severe cracking, scaling, delamination or spalling (concrete). Severe weathering, failed joints or displaced masonry blocks (masonry). Severe settlement or undermining. (Image credit: NAACC)

Section 3: Field Data Collection

Level of Blockage

__Adequate__: Blockage is 0-30% of opening.

Note that very small amounts of debris that are likely to be washed away during the next rain event should not be considered a blockage. Leaves or other debris that are less than 30% of the opening and could be easily washed away should be marked as adequate. Any blockage (leaves or otherwise) that is not easily cleared should be considered poor or critical. (Image credit: NAACC)

__Poor__: Blockage is 30-75% of opening. (Image credit: NAACC)

__Critical__: Blockage is >75% of opening. (Image credit: NAACC)

Flared End Section Condition (if present)

Adequate: Minor cracking, deterioration or deformation. Minor undermining. (Image credit: NAACC)

Poor: Significant cracks, piping or undermining affects >50% of appurtenance. End crushed or separated from barrel. (Image credit: NAACC)

Critical: Deterioration is significantly effecting performance, and/or causing embankment and/or roadway damage. (Image credit: NAACC)

Buoyancy or Crushing

Adequate: Hydraulic uplift and deformation not apparent. Hydraulic uplift overcome by a combination of the weight of the pipe, weight of the fill material over the pipe, and the weight of the water in the pipe. (Image credit: NAACC)

Poor: Light to moderate denting or deformation of inlet and/or outlet of flexible pipe culverts. The invert of the inlet is at the streambed elevation (no uplift). (Image credit: NAACC)

Critical: Invert of inlet bent upward above stream bed or mitered edges crumpled inward. (Image credit: NAACC)

Section 4: Quality Control

This section provides guidance on completing quality control (QC) of the field data, calculations and final work product.

4.1 The Importance of QC

QC of data is essential for successful road-stream crossing assessments. In this project QC will focus on ensuring that data is gathered completely and correctly. Data or results that are incorrect or missing can have a significant impact on the quality of the final product as well as the recommendations determined based on the assessment.

This emphasis is placed on QC because:

- quality data and work result in quality deliverables and recommendations
- small errors could significantly impact recommendations
- data will be used for assessment and comparison of culverts across the state, and may impact decisions made by RIDOT regarding road-stream crossing infrastructure
- data may also be uploaded to the NAACC database for use by others, and could therefore influence research results and broader design and policy recommendations and decisions for the entire Northeastern United States

4.2 Standard Procedures

4.2.1 General QC Procedures

Standard QC procedures will promote consistent and efficient QC efforts and higher data quality.

An important aspect of QC is the archiving of paper forms and digital backups of electronic forms and photos. The following tips will help in this regard:

- Keep data well organized in a central location with secure backups, to avoid loss of data that might occur with the failure of a single computer or device.
- Devise with your crew a straightforward convention for naming and organizing paper and electronic files (e.g. organize these in folders by week, month, and year) to ensure that you can find them quickly and efficiently. The names of files associated with specific stream crossings should include the crossing code to reduce the chance of confusing one crossing file with another.

QC of the data will generally be performed digitally for digitally collected data, following data upload. It is recommended that QC of the data be performed on a copy of the field data saved in ArcGIS online, rather than through a desktop program such as ArcGIS Pro, in order to maintain data integrity.

4.2.2 QC of Field Data

The first step in the QC is described in the *Section 3: Field Data Collection.* In this step, the Lead Field Data Collector must ensure that the field data form is completed correctly and completely **before** leaving the site.

Further QC of field data should not be performed by the Lead Field Data Collector. Instead, it should be completed by another team member to ensure multiple individuals are able review the data. This individual (the QC Coordinator) may be the Assessment Coordinator or another qualified individual.

The QC Coordinator should follow the following steps in performing QC of the field data forms and/or digital field data uploaded from paper forms:

- Review the digital data or paper for every crossing.
- If any data is missing, conflicts with photographic evidence, or shows other discrepancies, the QC coordinator should contact the Lead Field Data Collector to discuss the discrepancies.
  - ✓ If the discrepancies can be resolved to the QC Coordinator's satisfaction through discussion with the Lead Field Data Collector, the QC Coordinator should note any changes

made and initial and date the QC portion of the field form. QC Status may be marked "Final."

✓ If the discrepancies cannot be resolved through discussion with the Lead Field Data Collector, the QC Coordinator should initial and date the QC portion of the field form and mark the QC Status as "Follow Up." The site should be revisited by the field team in order to confirm or gather this data.

✓ If no discrepancies are found, the QC Coordinator should initial and date the QC portion of the field form. QC Status may be marked "Final."

The QC Coordinator should complete QC of the field data as soon as possible after the data is collected so that any discrepancies can be discussed with the Lead Field Data Collector while the fieldwork is still fresh in the Lead Field Data Collector's mind. This will also allow any additional site visits necessary for correction or completion of data to be completed in a timely manner.

Detecting and Addressing Errors in Field Data

The following minimum guidelines should be followed in reviewing the field data:

- Make sure the distance between the crossing point data and the center point of the crossing is not too large, preferably less than 15 m (approximately 50 feet).
- If the crossing type is Multiple Culverts, make sure that data more than one crossing structure is entered. Similarly, for bridges, make sure the number of structures entered matches the number of bridge cells indicated.
- Confirm that the culvert characteristics are consistent with the crossing type.
- Confirm that measurements seem reasonable.
- Check that substrate type and coverage agree with the crossing type. For example:
  - if the crossing is a bridge and therefore has no bottom, then the substrate generally should be comparable (although there are rare exceptions)
  - if less than 25% of the structure length is covered with substrate, substrate should be "None"
- If a physical barrier is indicated, confirm that it is an actual barrier and is appropriately characterized. Common mistakes make when evaluating physical barriers are:
  - treating an outlet drop as a physical barrier;
  - failing to treat an inlet drop as a physical barrier; and
  - including physical barriers that are not associated with integral to the crossing itself (e.g. beaver dams, or other dams, upstream or downstream of the crossing).

Do not expect that field staff will remember details that are not marked on the field data form. The sooner a team can upload and QC the data following fieldwork, the better.

Correcting Crossing Location Errors

Common sources of crossing location errors include:

1. When using the digital field data form, the location is recorded wherever the user is standing when they open the data entry window for a new crossing. If the user is not standing at the crossing, the location will be recorded at that incorrect location and will be uploaded upon form submission (unless the user manually opens the location window and moves the location marker, or "refreshes" the location while standing in the correct crossing location.
2. A new stream road-crossing record may appear to overlap with an existing road-stream crossing record if a previously assessed crossing is re-assessed (accidentally or by plan), or if a new

crossing being assessed is located very close to the previously assessed crossing. This error will most likely become apparent when attempting to upload field data to the existing RIDOT stream crossing database.

The following procedures will help resolve discrepancies in crossing location data:

- If a stream crossing record already exists at the same location as the new stream crossing record being reviewed:
  - Contact the Lead Field Data Collector to determine whether there are two distinct crossings at that location or only one.
    - ✓ If there are not two separate crossings, treat the new stream crossing record as the same crossing as the existing crossing record.
    - ✓ If the new crossing is confirmed as a separate crossing by the Lead Field Data Collector, then QC Status may be marked as "Final" (assuming any other errors or discrepancies in the record have been addressed).
- If an existing stream crossing record already exists very close to the location of the new stream crossing record being reviewed, but it is offset from the road or the stream, then:
  - Check the road and stream shapefiles used to generate the road-stream crossing location to see if the existing stream crossing record is located on the stream and road polylines in the shapefiles.
    - ✓ If you can determine with certainty that the new stream crossing record being reviewed is actually the same crossing as the existing crossing record, move the new data to the existing crossing record. Compare with additional data on the existing crossing if necessary to determine if there are any discrepancies that should be addressed. In general, existing data should be replaced with the new, updated data unless the QC Coordinator finds significant errors or potential for errors in the new data. In this case, professional judgment should be used to determine which data is most accurate.
    - ✓ If you can determine with certainty that the "new" crossing is in fact a new, unmapped crossing, then QC Status may be marked as "Final" (assuming any other errors or discrepancies in the record have been addressed).
- If a new crossing is warranted but the location data was collected in the wrong spot and needs to be adjusted then:
  - First, contact the Lead Field Data Collector and ask that they confirm the exact location of the crossing and move the crossing to the correct location (at the precise intersection of a road and a stream). Then QC Status may be marked as "Final" (assuming any other errors or discrepancies in the record have been addressed).

<u>Automated Data Validation</u>
Within the digital field data form, some QC has been automated by data validation rules (rules programmed into the database and digital data forms to reduce data entry errors). The form/ app will alert the user of the following errors:

- if someone attempts to submit data with a required field that is empty,
- if a measurement is not entered with the correct precision,
- if the data type entered is incorrect (e.g., text is entered where a numerical value is necessary),
- or other such errors.

4.2.3 QC of Desktop Analyses

QC of any individual desktop analysis should not be performed by the same staff member who has performed that analysis and should be completed by another team member to ensure multiple individuals are able to provide input on and review the data. This other team member may be the QC Coordinator or another qualified staff member (even if they are responsible for different analyses).

All formulas used in auto-filled spreadsheets or other batch calculation tools should be checked by a qualified staff member.

For any data is not calculated by batch processes, QC of every calculation would be time consuming and possibly impractical (depending on the number of crossings in the study). For individual calculations or scores not determined by a repeated/auto-filled calculation, the QC Coordinator should determine an appropriate percentage of the calculations for QC (typically at least 5-10% of the calculations).

4.2.4 QC of Prioritized Crossings

The final prioritization should be reviewed by project staff and by stakeholders in order to determine whether priorities align with the project goals.

4.3 Common Sources of Error

Common sources of error reported from previous road-stream crossing assessments include:

- Poor planning and mapping, resulting in confusion over crossing locations and rushing field data collection to make up for lost time
- Lack of understanding of purpose of measurements, which may result in inaccurate field measurements
- Lack of understanding of vocabulary associated with road-stream crossing assessments, which may result in inaccurate field measurements
- Lack of training in filling out the field form and/or field data collection methods
  - May lead to a lack of understanding of the methods to be used of measurements
  - May result in inaccurate field measurements or data entry
- Inaccurate field measurements, such as:
  - Reading the survey rod or tape wrong
  - Measurements made in the wrong orientation relative to the crossing
  - Disagreement on who should measure or has measured a field
- Inaccurate field estimates
  - This is commonly influenced by human bias
- Use of dysfunctional, uncalibrated, or inappropriately set up field equipment, such as:
  - Survey rod not properly extended
  - Survey level not properly set up/leveled/calibrated
  - Failure of field equipment
  - Rushing through navigation, data collection, and equipment setup
- Lack of planning for equipment failure
- Poor data collection
  - Lack of care and precision in measurements and observations
  - Recording field data in the wrong fields on the field form
- Not entering data, scanning paper data forms, or performing data QC soon after data collection.
  - Delays can result in loss, destruction, or mixing of data forms

Section 5: Existing Streamflow Conditions

This section provides guidance on estimating existing streamflow conditions at each crossing, which will facilitate hydraulic analysis of road-stream crossings in *Section 6*.

5.1 Introduction

Estimates of streamflow are necessary to evaluate the hydraulic capacity of road-stream crossings and the likelihood of hydraulic failure under various flood scenarios. Streamflows are often analyzed for specific return intervals, which are sometimes referred to as “design storms” or “storm events” (when referring to precipitation amounts) or “flood events” (when referring to flood flows and flood levels), all of which refer to the probability of a storm or flood occurring in any given year.

For this assessment, annual peak streamflow (i.e., flood flow) is estimated for 10-, 25-, 50-, and 100-year return intervals, which are consistent with the design storms utilized in Rhode Island Freshwater Wetlands Permitting (RIDEM, 2007) and the Rhode Island Stormwater Design and Installation Standards Manual (RIDEM & CRMC, 2015), as well as in common bridge and culvert designs. Note that the 10-, 25-, 50-, and 100-year return interval flood flows have a 10%, 4%, 2%, and 1% chance of occurring in any given year (*Table 5-1*).

Table 5-1: Recurrence Intervals and Probabilities of Occurrence

Recurrence Interval (years)	Probability of Occurrence in Any Given Year	Percent Chance of Occurrence in Any Given Year
100	1 in 100 (0.01)	1%
50	1 in 50 (0.02)	2%
25	1 in 25 (0.04)	4%
10	1 in 10 (0.1)	10%

The streamflow estimates developed using the techniques described in this section will be used to assess hydraulic risk of failure under present climate conditions (in *Section 6: Existing Hydraulic Capacity*) and future climate conditions (in *Section 7: Future Climate Assessment*).

5.1.1 USGS Regional Regression Equations

The United States Geological Survey (USGS) has developed regional regression equations for estimating natural streamflow for ungaged stream sites based on streamflow statistics at stream gages in southeastern New England and on basin characteristics (Zarriello et al., 2012; Bent et al., 2014). These regional regression equations have been incorporated into StreamStats, a web application developed by the USGS that can be used to estimate annual peak discharge at user-specified locations along a stream network.

StreamStats also uses the drainage area ratio method (Zarriello et al., 2012) to estimate flows at ungaged locations when the drainage area is outside the recommended range for which the regression equations were developed (approximately 0.5 to 300 square miles). The drainage area ratio method is based on the assumption that the streamflow at a site along a stream is the same per unit drainage-basin area as that at a nearby hydrologically similar site.

5.2 Data Needs

5.2.1 Field Data

No field data is needed for this section.

5.2.2 GIS Data

GIS data may be needed for this section, but those needs will vary based on the need to use a rainfall-runoff model and the model and methodology selected.

5.2.3 Other Data

Other data may be required to support the use of a rainfall-runoff model depending on the model and methodology selected.

5.3 Methodology

Use of a consistent, repeatable streamflow estimation methodology is important to ensure that the assessment results can be compared across multiple road-stream crossing sites. It is therefore important to follow the methodology outlined in this section in the order in which it is described.

The evaluation utilizes the USGS StreamStats Web Application (StreamStats) to estimate peak streamflow, where feasible. Streamflow estimates provided by StreamStats will be used in the hydraulic capacity analyses described in *Section 6* and *Section 7* of this Handbook. RIDOT has determined that for the purpose of the screening-level assessments presented in this Handbook, the potential errors associated with peak streamflow estimates generated by StreamStats are acceptable even when the input parameters are outside of the range for which the regional regression equations were originally developed.

If StreamStats cannot provide peak streamflow estimates because the input parameters are too far outside of the suggested range, an adaptation of the drainage area ratio method or available rainfall-runoff model should be utilized as described in *Sections 5.3.1* and *5.3.2*.

5.3.1 USGS StreamStats

The following steps outline the method for obtaining peak streamflow estimates for a road-stream crossing site using USGS StreamStats. The directions below are provided for Version 4.3.0 of the StreamStats program. Note that periodic changes to the program may alter the exact steps and the order in which they are taken.

1. Navigate to the USGS StreamStats Web Application (https://StreamStats.usgs.gov/ss/) and zoom to or search for the road-stream crossing location.
2. On the left side of the screen, in the "select a state/region" header, click on "Rhode Island".
   - Note that StreamStats may use/ display different stream or road data layers than those used to identify crossings or those observed in the field. The user should use their professional judgment in selecting the correct point for delineation. The user can also change the base map displayed by selecting "Base Maps" in the upper right corner of the web application and selecting one of the base maps listed.
3. To delineate a contributing watershed in StreamStats, select "Delineate" and then click on the location of the road-stream crossing on the map. Wait for the delineation process to complete.
   - If the desired location appears to be within 250 feet of a stream crossing shown on the same road in StreamStats, utilize the crossing location shown in StreamStats. However, if there are multiple crossings shown in StreamStats, use your best judgment to determine which is appropriate for the structure inspected in the field. It can be helpful to review field photos and compare GPS locations to help determine the location of the structure in the StreamStats application.
   - If there is no stream layer shown in the StreamStats application at the location of the crossing, move on to *Section 5.3.2*. A rainfall-runoff model is required to estimate peak streamflow in this situation.
4. Review the delineation to make sure it looks appropriate.
   - If the delineation does not look appropriate, select "Edit Basin" and add or subtract areas to correct the delineation until you are satisfied with the delineation. Select "Submit Edited Basin" and allow the basin to reload.
5. Once satisfied with the delineation, use the black "Download Basin" button to download the basin data, if desired.
6. Select "Continue".
7. Select "Peak-Flow Statistics" to calculate flood flows and "Low Flow Statistics" to calculate dry weather flows. Then click "Continue". Basin characteristics will automatically be calculated. Wait for the program to process. When available, select "Continue" again, then select "Build a Report".

8. Record the following Peak-Flow Statistics and Low Flow Statistics.

   - 10-Year Peak Flow
   - 25-Year Peak Flow
   - 50-Year Peak Flow
   - 100-Year Peak Flow
   - 7 Day 10 Year Low Flow (7Q10)

   Save the report, if desired for future reference.

   It is common for StreamStats to report one or more parameters (i.e., drainage area, stream density, percent slope, or mean basin elevation) outside of the suggested range for which the regional regression equations were originally developed. Even in these cases, the StreamStats results should be used despite the greater degree of uncertainty in the streamflow estimates, as these estimates are sufficient for a screening-level analysis.

9. If the report does not provide values for the Peak-Flow Statistics, move on to *Section 5.3.2* different method.

   StreamStats may return values of 0 or may not return values for Peak-Flow Statistics if the Basin Characteristics used to calculate these statistics are out of a defined range for the regression equations used. In Rhode Island, these parameters include drainage area, stream channel density, and percent of the drainage area made up of storage (e.g. lakes or ponds). This is most likely to occur in small watersheds.

Batch Processing

StreamStats provides a Batch Processing Tool, which may be useful in performing the StreamStats analysis for large numbers of crossings. However, users should be careful to read all information about the tool before using it and review the output closely for any errors that may have occurred in the analyses.

5.3.2 Drainage Area Ratio Method (if necessary)

If peak streamflow estimates are not available from StreamStats, the drainage area ratio method or a rainfall-runoff model (*Section 5.3.3*) should be used to estimate peak flows. It is recommended that the assessment coordinator select a single method or model for use at all necessary crossing locations for the entire assessment. As stated, it is likely that most crossing locations for which streamflow estimates are not available from StreamStats will be small watersheds. Therefore, methods and models appropriate for smaller watersheds should be used. The drainage area ratio method may be preferred over a rainfall-runoff model because the drainage area ratio method is less time-consuming and requires less technical expertise than a rainfall-runoff model.

The drainage-area ratio method is based on the assumption that the streamflow at a site along a stream is the same per unit drainage-basin area as that at a hydrologically similar site near the crossing and within the same watershed. Use *Equation 5-1* to estimate streamflow using the drainage area ratio method (Emerson et al., 2005):

Equation 5-1: Drainage Area Ratio Method for Streamflow Estimation

$$Y = \left(\frac{A_y}{A_x}\right) X$$

where

$$Y = estimated\ streamflow\ (cfs)\ for\ site\ of\ interest$$

$$A_y = the\ drainage\ area\ (sq.mi.)\ for\ the\ site\ of\ interest$$

$$A_x = the\ drainage\ area\ (sq.mi.)\ for\ the\ reference\ watershed\ or\ station$$

$$X = estimated\ streamflow\ (cfs)\ for\ the\ reference\ watershed\ or\ station$$

The reference watershed or station should be a nearby crossing that was successfully delineated in StreamStats or, if available, a nearby gaged streamflow station. Ideally, the reference watershed should be 0.5 to 1.5

times the size of the watershed for the site of interest and the flow regime, land-use, and physical characteristics of the two watersheds should be similar (Bent et al., 2014).

The drainage-area ratio method is typically used to estimate streamflow at ungaged locations using streamflow values from a gaged location as a reference. The accuracy of using the drainage-area ratio method to estimate streamflow at an ungaged site using another ungaged site as a reference has not been evaluated. However, using the method in this manner is considered appropriate for a screening-level analysis.

5.3.3 Rainfall-Runoff Model

If peak streamflow estimates are not available from StreamStats, a rainfall-runoff model that is familiar to the user may be utilized to estimate peak flows as an alternative to the drainage area ratio method.

WinTR-20 is a publicly-available single event watershed-scale runoff and routing model developed by the Natural Resources Conservation Service (NRCS) that can be utilized to estimate peak flows for most watersheds. The program computes direct runoff and develops hydrographs resulting from any synthetic or natural rainstorm. The model software, general information, support materials, and training resources are available from the NRCS website.

5.4 Recording Streamflow Estimates

As described in *Section 5.3.1 Step 8*, record the following information from either the StreamStats output or rainfall-runoff program output:

- 10-Year Peak Flow
- 25-Year Peak Flow
- 50-Year Peak Flow
- 100-Year Peak Flow
- 7 Day 10 Year Low Flow (7Q10)

Note that the crossings are not directly scored based on this data. The peak flow data will be used in the hydraulic capacity analyses in *Section 6* and *Section 7* as $Q_{R.I.}$, the flowrate associated with a given flood return interval.

Section 6: Existing Hydraulic Capacity

This section describes the process for estimating the hydraulic capacity of road-stream crossings, in order to assess hydraulic risk of failure under present climatic conditions.

6.1 Introduction

Culverts and bridges are designed to allow water to flow under roads and other manmade infrastructure, and are typically designed to convey a specific design flow rate. The adequacy of a stream crossing structure is dictated by its capacity relative to peak discharge, as well as a number of other factors including drainage area, roadway classification, allowable headwater, freeboard, maximum outlet velocity, backwater, and scour.

In Rhode Island, stream culverts are generally designed to convey the 25- or 50-year frequency peak discharge, while larger structures including bridges are often designed for larger events such as the 100-year frequency peak discharge.

Hydraulic failure at a road-stream crossing occurs when the flowrate in the stream exceeds the capacity of the culvert to pass flow, resulting in backwater flooding behind the crossing and potential overtopping of the crossing. Crossings that do not have sufficient capacity to pass flows with low return intervals have a higher risk of failure.

The hydraulic capacity of a road-stream crossing can change over time through deformation of or damage to the crossing structure, repairs or alterations to the structure, or other changes over the decades-long lifetime of the crossing. In addition, older crossings may not have been designed to the current standard, and data regarding the crossing's flow capacity may no longer be available. Also, peak flow rates may have changed since the crossing was constructed, due to changing climatic conditions and/or watershed development. *Section 7: Climate Change Vulnerability* addresses the vulnerability of road-stream crossings to future climate change based on projected increases in extreme precipitation and streamflow.

Note that the severity of potential impacts of hydraulic failure at a crossing is assessed separately in *Section 10: Flood Impact Potential* and *Section 11: Disruption of Transportation Services*.

6.2 Data Needs

6.2.1 Field Data

Field data required for the use of the CulvertMaster hydraulic analysis software (the preferred method) includes:

- Tidal Site? (*Section 3.5.3)*
- Structure Material (*Section 3.5.4)*
- Inlet Shape (*Section 3.5.4)*
- Inlet Type (*Section 3.5.4)*
- Inlet Dimensions (*Section 3.5.4)*
  - A, Structure Width
  - B, Structure Height
  - C, Substrate/Water Width
  - D, Water Depth
- Outlet Shape (*Section 3.5.4)*
- Outlet Dimensions (*Section 3.5.4)*
  - A, Structure Width
  - B, Structure Height
  - C, Substrate/Water Width
  - D, Water Depth
- Abutment Height (*Section 3.5.4)*
- Structure Length (*Section 3.5.4)*
  - Where structure length could not be measured in the field, estimate structure length using Google Earth Pro or a similar program by measuring from the known end of the crossing to the estimated location of the inaccessible inlet or outlet.
- Slope % (*Section 3.5.4)*
  - For structures where slope data is not available, use a slope of 0.5% for hydraulic capacity calculations.

If using the HY-8 hydraulic analysis software, the following additional field data are required:

- Road Crest Height (*Section 3.5.2)*
- Road Surface Type (*Section 3.5.2)*
- Estimated Crest (Overtopping) Length (*Section 3.5.2)*

- Top Width (*Section 3.5.2)*
- Bottom Width (*Section 3.5.2)*
- Channel Slope (*Section 3.5.2)*
- Side Slope (Right and Left Banks) (*Section 3.5.2)*
- Stream Substrate (*Section 3.5.2)*

Table 6-1 outlines the field data requirements and corresponding model input parameters for the hydraulic analysis; *Figure 6-1* displays the relationship between several of these parameters.

6.2.2 GIS Data

No GIS data is needed for this section.

6.2.3 Other Data

This section will use the peak streamflow estimates derived for the following return intervals using the methods described in *Section 5: Existing Streamflow Conditions.*

- 10-Year Peak Flow (cfs)
- 25-Year Peak Flow (cfs)
- 50-Year Peak Flow (cfs)
- 100-Year Peak Flow (cfs)

Flowrate, Headwater, and Tailwater

The flowrate, headwater depth, and tailwater depth values obtained using the methods described in *Section 6* are sufficient for screening-level analysis only, and should not be used for design purposes. Additional hydraulic analysis is required to support the design and permitting of road-stream crossing upgrades or replacements.

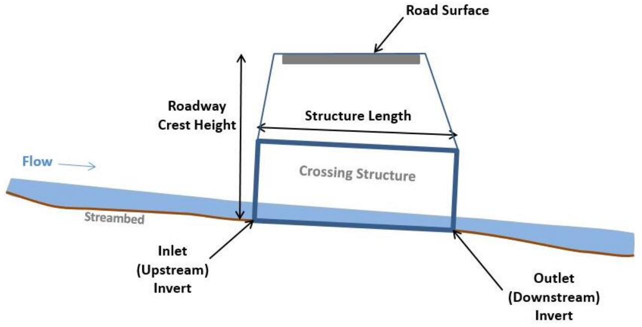


Figure 6-1: Hydraulic field parameters.

Table 6-1: Field Parameters and Hydraulic Analysis Software Input Parameters

Field Parameter(s)	CulvertMaster Input Parameter	HY-8 Input Parameter
See Table 6-2	Allowable Headwater Depth (ft)	--
See Table 6-3	Tailwater Depth (ft)	--
Structure Inlet Shape, Outlet Shape	Shape	Shape
Structure Material	Material	Material
Structure Inlet Dimensions, Outlet Dimensions	Size	Span, Rise
--	--	Embedment Depth
--	Number	Number of Barrels
Structural Material	Manning's n	Manning's n
Structure Inlet Type	Entrance	Inlet Configuration
(Structure) Inlet Elevation	Invert Upstream (ft)	Inlet Elevation (ft)
(Structure) Inlet Elevation	Invert Downstream (ft)	Outlet Elevation (ft)
Structure Length	Length (ft)	Inlet Station, Outlet Station
Structure Slope %	Slope (ft/ft) (Use CulvertMaster calculation)	Inlet and Outlet Stations and Elevations
--	--	Channel Type
Roadway Crest Height	--	Channel Invert Elevation (ft)
Channel Bottom Width	--	Bottom Width (ft)
Side Slope – Left Bank and Right Bank (__:1)	--	Side Slope (__:1)
Channel Slope (%)	--	Channel Slope (ft/ft)
Stream Substrate	--	Manning's n (channel)
Estimated Crest (Overtopping) Length	--	Crest Length
Roadway Crest Height	--	Crest Elevation
Road Surface Type	--	Roadway Surface
Top Width	--	Top Width
Tidal Site?	--	--
--	--	Discharge Method
--	--	Discharge List

6.3 Methodology

6.3.1 Hydraulic Analysis Method Selection

Federal Highway Administration (FHWA) hydraulic analysis methods should be used consistent with the FHWA Hydraulic Design Series Number 5 (HDS 5). The CulvertMaster Hydraulic Analysis and Design Software by Bentley Systems, Inc. is the preferred software for estimating hydraulic capacity of a road-stream crossing structure for this assessment.

Bentley CulvertMaster software uses the HDS 5 methodologies and has the advantage over other software programs of being able to directly calculate flowrates through the crossing structure for specific headwater and tailwater elevations. This software is proprietary and therefore requires purchase of a license prior to use.

The FHWA HY-8 Culvert Hydraulic Analysis Program can be used as an alternative to CulvertMaster. HY-8 is available for free download from the FHWA website. HY-8 also uses FHWA HDS 5 culvert analysis methods, but produces headwater elevations based on estimated discharge. HY-8 requires interpolation of flow capacity from a graph generated for a range of headwater and tailwater elevations.

The Assessment Coordinator is responsible for determining the most appropriate hydraulic analysis program prior to initiating fieldwork. The team members completing and reviewing the hydraulic assessment should be familiar with the specific software to be used and with culvert and bridge hydraulic calculations. Staff familiarity with one program or anther may therefore influence the program selected for the assessment.

Note that input and output parameters for the two models are different (see *Table 6-1*) and that additional field data must be collected if using HY-8 (as indicated on the field data form and in *Section 6.2.1*). If there is uncertainty about which program will be used when fieldwork begins, HY-8 parameters should be collected in the field to ensure they are available for a potential HY-8 analysis. Regardless of the program chosen, the same program should be used for all structures in a single assessment project to create comparable results.

If the hydraulic capacity of the crossing cannot be assessed due to lack of field data, proceed directly to *Section 6.4.1*.

6.3.2 Tidally Influenced Crossings

The hydraulic capacity of crossings in tidal areas varies with tidal conditions. A tidally influenced crossing has its greatest flow capacity at low tide, and its capacity decreases as the tide rises, until it reaches a minimum flow capacity at high tide. Flow through the culvert may even reverse and flow "upstream" under certain tidal conditions. This exchange of flow is crucial for estuarine health, but can exacerbate flooding, particularly if a riverine flood occurs at the crossing during high tide.

Accounting for the complex changes in culvert hydraulics under varying tidal conditions is beyond the scope of this assessment. Appropriate screening-level hydraulic assessment methods may be developed and incorporated into this Handbook in the future. In the interim, tidal crossings should be assessed for hydraulic capacity using the same steps (below) as non-tidal crossings, but should be flagged as tidally influenced for more detailed future assessment. This is particularly important if the tidal crossing in question is determined to be a high priority for replacement or removal, which is quite possible due to the location of tidal crossings at river mouths where diadromous fish and other wildlife will attempt to enter river systems.

6.3.3 CulvertMaster

CulvertMaster input parameters should be selected based on field measurements. Inlet and outlet control are determined by the model, which uses the appropriate calculations for each hydraulic condition. Results from this model are only estimates of flow capacity due to limitations of the software.

The CulvertMaster software uses standard, pre-programmed culvert dimensions. If structures have non-standard dimensions, inputs should be selected to most accurately match actual field conditions. For example, if the hydraulic opening measured in the field is not available as a model input option, an opening area should be selected that most closely matches the cross-sectional area of the crossing opening while taking care to match opening height to the extent possible. Alternately, using Manning's Equation to determine crossing capacity (*Section 6.3.5*).

CulvertMaster is designed to calculate the capacity of culverts (not bridges). While the same equations used in CulvertMaster can be applied to bridges, the maximum culvert dimensions allowable in CulvertMaster are typically exceeded by most bridges. Therefore, for bridges, CulvertMaster input parameters should be selected to match the cross-sectional opening and other structure dimensions as closely as possible. Where the cross-sectional area and other dimensions cannot be approximated with CulvertMaster, other methods should be used such as HY-8 or Manning's equation.

When using CulvertMaster, the user will calculate a *Capacity Ratio*, defined as the ratio of the estimated culvert capacity flow rate at failure (as determined based on headwater depth and tailwater depth) to peak streamflow estimates for various recurrence intervals.

Follow Steps 1-7 to calculate the flow capacity of each structure within the crossing using CulvertMaster (solving for discharge), and the capacity ratio of the crossing.

1. Determine the Allowable Headwater Depth (HW) based on the structure type and material, using *Equation 6*-1 and *Table 6-2*. The headwater depth values in *Table 6-2* represent common failure modes and thresholds for different types of culvert materials.

Equation 6-1: Headwater Depth

$$HW = headwater\ depth\ above\ the\ bottom\ (i.e., invert)\ of\ the\ structure\ at\ the\ structure\ entrance\ or\ inlet$$

Equation 6-1 may be modified per *Equation 6-2* to determine HW for concrete culverts using field data.

Equation 6-2: Headwater Depth at Concrete Culverts

$$HW = RCH - 1 + (|inlet\ el. - outlet\ el.|)$$

where

$$RCH = Road\ Crest\ Height$$
$$inlet\ el. = inlet\ invert\ elevation$$
$$outlet\ el. = outlet\ invert\ elevation$$

2. Determine the appropriate Tailwater Depth (TW) using *Table 6-3*. Tailwater influences culvert capacity only when the culvert is operating under outlet control. Larger tailwater depths may be caused by an obstruction in the downstream channel, such as another road crossing with a bridge or culvert, the confluence with another channel, the existence of a lake, pond, wetland, etc., or tidal conditions. High tailwater alone is capable of making a culvert operate under outlet control, when it would otherwise operate under inlet control.
3. Use CulvertMaster to calculate the structure's flow capacity ($Q_{failure}$, the discharge through the structure at hydraulic failure) based on the Allowable Headwater Depth, Tailwater Depth, and the input parameters outlined in *Table 6-1*.
4. Repeat Steps 1-3 for each structure in the crossing (if multiple structures exist). For crossings with different opening shapes and/or dimensions at the inlet and outlet, calculate the capacity using both (inlet and outlet) dimensions and record the **lower** value. At crossings where either the inlet or outlet cannot be accessed, use the available data for the accessible end of each structure in the calculations.
5. Add up the capacity of each structure in the crossing to determine the overall capacity of the crossing (if multiple structures exist).

Table 6-2: Headwater Depth at Failure[1]

Road-Stream Crossing Structure Type and Material	Allowable Headwater Depth[2] (HW)
Stone Masonry or Wood Culvert	HW = 1.0 x Inlet Height
Smooth or Corrugated Metal or Plastic Culvert[3]	HW = 1.2 x Inlet Height
Concrete Culvert	HW = 1 foot below lowest point in roadway surface
Bridge	HW = 1 foot below lowest point of bottom of bridge deck[4]

[1] Table adapted from MassDOT (unpublished report).
[2] In some cases a lower elevation in the roadway approach to a road-stream crossing may be utilized instead to estimate the allowable headwater depth. It is the responsibility of the Assessment Coordinator to determine when this is appropriate.
[3] Includes fiberglass culverts.
[4] If the roadway surface approaching the crossing is at a lower elevation than the roadway directly over the crossing, such that flow could be diverted around the structure and over the road surface at another point, the lowest value of either 1 foot below the lowest point in the roadway surface or 1 foot below the lowest point of the bottom of the bridge deck should be used to determine the allowable headwater elevation.

Table 6-3: Tailwater Depth at Failure[1]

Crossing Type	Crossing Structure Slope	Tailwater Depth (TW)
Non-Tidal Crossings	> 2%	TW = 0.75 x Outlet Height
	< 2%	TW = 0.75 x Outlet Height when HW/Inlet Height < 1.3 TW = 1.0 x Outlet Height when HW/Inlet Height ≥ 1.3
Tidal Crossings	Not Applicable	TW = 1.0 x Outlet Height
Crossings discharging directly into a lake, pond, or wetland[2]	Not Applicable	Based on elevation of receiving water body or wetland
Crossings with cascade or free fall at the outlet with a significant drop to the normal elevation of the downstream channel	Not Applicable	Based on elevation drop at outlet

[1] Table adapted from MassDOT (unpublished report).
[2] Situations where the tailwater depth is dictated by the water elevation in the downstream receiving water body or wetland and does not vary with flow, where available.

6. Calculate the *Capacity Ratio* for each flood return interval according *Equation 6-3*.

Equation 6-3: Capacity Ratio

$$Capacity\ Ratio_{R.I.} = \frac{Q_{failure}}{Q_{R.I.}}$$

where

$$Q_{failure} = discharge\ at\ hydraulic\ failure\ (i.e., capacity)$$
$$Q_{R.I.} = estimated\ peak\ discharge\ for\ a\ specified\ return\ interval\ (R.I.)\ (determined\ in\ Section\ 5.4)$$

7. Using the *Capacity Ratio*, determine whether the crossing has sufficient capacity at a given return interval according to the following rules:

$$Capacity\ Ratio_{R.I.} > 1.0$$

Crossing has sufficient capacity to convey the return interval peak discharge

$$Capacity\ Ratio_{R.I.} \leq 1.0$$

Crossing is undersized for the return interval peak discharge

6.3.4 HY-8 Culvert Hydraulic Analysis Program

HY-8 Input parameters should be selected based on field measurements. Inlet and outlet control are determined by the model, which uses the appropriate calculations for each hydraulic condition. Results from this model are only estimates of headwater elevation due to the limitations of the software. Pre-programmed culvert dimensions used in the program should be selected to most closely match the measurements obtained in the field.

Follow Steps 1-7, below, to calculate the headwater depth for the crossing using HY-8, and the crossing's *Headwater Ratio,* defined as the ratio of the headwater depth at failure to the headwater depth at selected recurrence intervals.

1. Determine the Allowable Headwater Depth (HW) based on the structure type and material, using *Table 6-2*. A modified HW equation for concrete culverts using data collected in the field is

provided in *Table 6-2* and *Equation 6-2*. This value is assigned to $HW_{failure}$.

2. Specify the Tailwater Depth (TW) calculation method in HY-8. HY-8 allows the use of Manning's Equation to calculate the uniform flow depth in the channel downstream of the culvert, the use of a pre-defined rating curve, or a constant tailwater depth using *Table 6-3*.
3. Use HY-8 to calculate the headwater depth ($HW_{R.I.}$) at the structure. This value will be different for each flood recurrence interval based on Tailwater Depth (TW), other input parameters outlined in *Table 6-1,* and the peak streamflow estimates. Peak streamflow estimates were determined *Section 5: Existing Streamflow Conditions*.

   For crossings with different opening shapes and/or dimensions at the inlet and outlet, calculate the headwater depth using both (inlet and outlet) dimensions and record the **higher** (more conservative) value. At crossings where either the inlet or outlet cannot be accessed, use the available data for the accessible end of the crossing in the calculations.

   The following simplifying assumptions can be made when using HY-8 for road-stream crossing assessments (as determined appropriate by the Assessment Coordinator):

   - In most cases, the Tailwater Channel Type may be represented as a trapezoid.
   - In some cases where the channel has been severely altered, a rectangular channel may more accurately represent the Tailwater Channel Type. In this situation, it is up to the user to determine which channel shape is most appropriate based on the available data.
   - The Culvert Roadway Station can be set to 0.000 feet as a default.
   - Inlet Depressions are not modeled (assume no inlet depression).
   - Culvert Type is assumed to be straight.

   HY-8 is not conducive to analysis of individual structures at multi-structure crossings, as the analysis would produce a different $HW_{R.I.}$ for each individual structure. Therefore, at crossings with multiple structures, the crossing should be modeled as a whole, and $HW_{failure}$ should be selected based on the most vulnerable material (in order to select the most conservative value).
4. Calculate the *Headwater Ratio* based on the results from Steps 1 and 3 and *Equation 6-2*.
5. Using the *Headwater Ratio*, determine whether the crossing has sufficient capacity at a given return interval according to the following rules:

$$Headwater\ Ratio_{R.I.} > 1.0$$

Crossing has sufficient capacity to convey the return interval peak discharge

$$Headwater\ Ratio_{R.I.} \leq 1.0$$

Crossing is undersized for the return interval peak discharge

6.3.5 Manning's Equation

For very large culverts and bridges whose dimensions exceed those provided in CulvertMaster, Manning's equation may be used to estimate the hydraulic capacity of the crossing under open channel flow conditions. For these structures, the allowable headwater depth should be set below the crown of the culvert. The allowable headwater depth for bridges from *Table 6-2* is a reasonably conservative assumption.

6.4 Scoring

6.4.1 Binned Hydraulic Capacity Score

Score each crossing according to *Table 6-4.* The *Binned Hydraulic Capacity Score* should be assigned based on the largest return interval peak discharge that the crossing is capable of passing (i.e., the *Capacity Ratio* greater than 1.0).

Table 6-4: Binned Hydraulic Capacity Score

Hydraulic Capacity Rating (Capacity Ratio > 1.0 for listed Return Interval)	Binned Hydraulic Capacity Score
100-Year	1
50 Year	2
25-Year	3
10 Year	4
< 10-Year	5

If the hydraulic capacity of the crossing cannot be assessed due to lack of field data, assign a *Binned Hydraulic Capacity Score* of 3 to the crossing, as the 25-year flood is a common design flow and over 60% of crossings were found to have adequate capacity to pass the 25-year flood in the pilot study conducted in the Woonasquatucket River watershed (*Appendix H*). Assigning this score will also prevent the crossing from being artificially ranked higher or lower relative to other crossings due only to missing data.

Crossings with a *Capacity Ratio* less than 1 for the 25-year return interval are considered undersized. Crossings with a *Capacity Ratio* less than 1 for the 10-year return interval are considered severely undersized.

6.4.2 Existing Tidal Influence Flag

Culverts that are determined to be tidally influenced based on available mapping or field observations should be flagged as tidal in the culvert records. This will not influence the *Binned Hydraulic Capacity Score* but will indicate to data users that the culvert experiences changes in capacity and potentially flow direction each day, which will inform any further investigation.

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Section 7: Climate Change Vulnerability

This section provides guidance on assessing the vulnerability of road-stream crossings to future climate change based on projected increases in extreme precipitation, sea level rise, and storm surge.

7.1 Vulnerability of Transportation Infrastructure to Climate Change

With over 400 miles of coastline and multiple major inland watersheds, Rhode Island's transportation infrastructure (e.g., roads, bridges, culverts) is vulnerable to the effects of climate change, including more intense and frequent storms, increased inland and coastal flooding, associated storm surge, and sea level rise (Rhode Island Statewide Climate Resilience Action Strategy, 2018).

7.1.1 Increased Precipitation and Flooding

Mean and extreme precipitation in the Northeast has increased during the last century. Rhode Island's average annual precipitation has increased more than 10 inches since 1930, and intense rainfall events (heaviest 1% of all daily events from 1901 to 2012 in New England) have increased 71% since 1958. Over the past 80 years, Rhode Island and southern New England have also experienced a significant increase in both flood frequency and magnitude (Rhode Island Statewide Climate Resilience Action Strategy, 2018).

Climate change is expected to continue contributing to increases in frequency and intensity of extreme precipitation events (Dupigny-Giroux, et al., 2018), which is expected to increase the risk of riverine flooding and make road-stream crossings more susceptible to failure.

7.1.2. Sea Level Rise and Storm Surge

Sea level has risen over 10 inches in Rhode Island since 1930, and the rate of sea level rise in Newport during the period 1986-2016 (3.98 mm/year) has exceeded the global average mean over the same period (Rhode Island Statewide Climate Resilience Action Strategy, 2018). According to the *Fourth National Climate Assessment*, the Northeast has experienced some of the highest rates of sea level rise (SLR) in the United States, and these increases relative to other regions are projected to continue through the end of the century (Dupigny-Giroux, et al., 2018).

In addition to sea level rise, projected increases in the frequency and intensity of coastal storms, storm surge, and increased high tides also threaten Rhode Island's transportation infrastructure. As indicated in *Technical Paper 167: Vulnerability of Municipal Transportation Assets to Sea Level Rise and Storm Surge* (RISPP, 2016), the combined effects of sea level rise and storm surge presents a major challenge to Rhode Island's transportation infrastructure, both via daily tidal flooding of coastal assets and during coastal storms.

With increasing frequency and intensity of storms, sea level rise, and other climate impacts, the integrity and hydraulic capacity of road-stream crossings may be affected, which could directly impact the safety and functionality of the state's roadway and transportation network.

The assessment methodology presented in this section evaluates the increased risk of failure of road-stream crossings associated with projected increases in precipitation, sea level rise, and storm surge.

7.2 Data Needs

7.2.1 Field Data

No field data is needed for this section.

7.2.2 GIS Data

Sea Level Rise Inundation Data

100-Year Storm Surge Event Plus SLR by 2100
http://www.rigis.org/datasets/f5c6e89646c54c8a8d6922b58a199832_0?geometry=-75.683%2C40.795%2C-65.23%2C42.234

- 100-Year Storm Surge Plus 1, 3, 5, and 7 feet of sea level rise
- Increases in water surface elevations are measured relative to Mean Higher High Water (MHHW).

The Sea Level Rise Inundation Data layer was created by the Rhode Island Statewide Planning Program as part of the 2016 Municipal Transportation Assets Vulnerable to Sea Level Rise and Storm Surge Project using inundation data from the STORMTOOLS dataset prepared by the Rhode Island Coastal Resources Management Council. The STORMTOOLS dataset was created to illustrate the predicted level of inundation due to storm surge and sea level rise under climate change scenarios. The dataset can also be accessed directly through the STORMTOOLS website (http://www.beachsamp.org/stormtools/).

7.3 Methodology

7.3.1 Future Peak Streamflow

Future increases in peak streamflow are estimated from projected increases in extreme precipitation due to climate change. For this screening-level assessment, the use of projected changes in precipitation to approximate future changes in streamflow assumes a linear relationship between these two factors. In fact, the relationship between projected changes in precipitation and projected changes in streamflow are unlikely to be linear, as the transformation of precipitation to runoff and streamflow is affected by complex interactions with landscape factors such as the percent of impervious area, the presence and type of vegetation, and prior soil moisture. However, the assumption of this linear relationship provides a reasonable approximation of future flood flows that is also relatively simple to apply in a screening-level analysis.

Projected increases in rainfall for the Northeast currently range between 5%-25% for the 2-year to 100-year storm events under medium to high emissions scenarios by the middle to end of the 21st century (approximately 2100). A projected increase in precipitation of 20% is widely considered appropriate for this region, as it is conservative within this range, and was determined to be consistent with current statewide planning efforts through discussion with RIDOT, the Rhode Island Coastal Resources Management Council, and other member agencies of the Executive Climate Change Coordinating Council (EC4). Although this value of 20% is currently recommended for estimating increases in peak streamflow for this analysis (see *Table 7-1*), an ongoing review of precipitation and streamflow projections is recommended, and the methodology may be updated as projections improve and as planning horizons change over the next 25-50 years (see *Section 7.5*).

Note: The following methods are not applicable to results calculated using HY-8, as the flow multipliers described below cannot be directly applied to headwater depth.

<u>Calculation Methods</u>

Multiply the estimated peak streamflow for a specified return interval ($Q_{R.I.}$) (calculated using the methods outlined in *Section 5*) by a projected percent increase in extreme precipitation (converted to a flow multiplier, M_{2100}, provided in *Table 7-1*) to estimate future streamflow for a given climate change scenario:

Equation 7-1: Future Streamflow for a Given Return Interval

$$Q_{R.I.,2100} = Q_{R.I.} \times M_{2100}$$

where

$$Q_{R.I.,2100} = estimated\ future\ peak\ streamflow\ for\ a\ specified\ return\ interval\ and\ end\ of\ century\ climate\ change\ scenario$$

$$Q_{R.I.} = estimated\ peak\ streamflow\ for\ a\ specified\ return\ interval$$

$$M_{2100} = flow\ multiplier, projected\ change\ in\ extreme\ precipitation\ for\ end\ of\ century\ climate\ change\ scenario$$

Table 7-1: Recommended Flow Multiplier

Planning Horizon (Year)	Projected Percent Change in Extreme Precipitation	Flow Multiplier, M_{Year}
2100	20%	1.20

Sample Calculation

If the existing 10-year peak flow for a culvert is determined to be 10 cfs using the methods outlined in *Section 5 – Existing Streamflow Conditions*, multiply the existing 10-year peak flow by the flow multiplier from *Table 7-1* to calculate the projected 10-year peak flow in 2100, as follows:

$$Q_{10,2100} = Q_{10} \times M_{2100}$$

$$Q_{10,2100} = 10\ cfs \times 1.20$$

$$Q_{10,2100} = 12\ cfs$$

These estimates of potential future streamflow do not account for changes in land cover/land use as a result of future development, as this level of detailed analysis is beyond the scope of this screening-level assessment.

Use *Equation 7-2* to calculate a *Future Capacity Ratio* to evaluate hydraulic risk of failure under potential future climatic conditions.

Equation 7-2: Future Capacity Ratio for a Given Return Interval

$$Capacity\ Ratio_{R.I.,2100} = \frac{Q_{failure}}{Q_{R.I.,2100}}$$

where

$$Q_{failure} = discharge\ at\ hydraulic\ failure\ (i.e., capacity)$$

Future Capacity Ratio values can be interpreted as follows:

$Capacity\ Ratio_{R.I.,2100} > 1.0$
The crossing has sufficient capacity to convey the end-of-century return interval peak discharge.

$Capacity\ Ratio_{R.I.,2100} \leq 1.0$
The crossing is undersized for the end-of-century return interval peak discharge.

Assign a *Binned Future Hydraulic Capacity Score* to each crossing according to *Table 7-2*. The *Binned Future Hydraulic Capacity Score* is assigned based on the largest return interval peak discharge that the crossing is capable of passing.

Table 7-2: Binned Future Hydraulic Capacity Score for Year 2100

Future Hydraulic Capacity Rating (Capacity Ratio > 1.0 for listed Return Interval)	Binned Future Hydraulic Capacity Score (Year 2100)
100-Year	1
50 Year	2
25-Year	3
10 Year	4
< 10-Year	5

If the hydraulic capacity of the crossing could not be assessed due to lack of field data in *Section 5*, assign a *Binned Future Hydraulic Capacity Score* of 3 to the crossing, as the 25-year flood is a common design flow and over 50% of crossings were found to have adequate capacity to pass the 25-year flood even under future climate change conditions in the pilot study in *Appendix H*. Assigning this score will also prevent the crossing from being artificially ranked higher or lower relative to other crossings due only to missing data.

Assign a *Binned Hydraulic Capacity Change Score* according to *Table 7-3*.

Table 7-3: Binned Hydraulic Capacity Change Score

Future Hydraulic Capacity vs. Existing Hydraulic Capacity	Binned Hydraulic Capacity Change Score
Existing and future Hydraulic Capacity Ratings are the same.	1
--	2
The crossing Hydraulic Capacity Rating decreases by one rating (e.g. a crossing rated to convey the 100-year peak streamflow under existing conditions can only convey the 50-year peak streamflow under future conditions).	3
--	4
The crossing Hydraulic Capacity Rating decreases by more than one rating (e.g. a crossing rated to convey the 100-year peak streamflow under existing conditions can only convey the 25-year, 10-year storm, or <10-year peak streamflow under future conditions).	5

If the hydraulic capacity of the crossing could not be assessed due to lack of field data in *Section 5*, assign a *Binned Hydraulic Capacity Change Score* of 3 to the crossing. Although only 25% of crossings received a *Binned Hydraulic Capacity Change Score* of 3 in the pilot study in *Appendix H*, this is a conservative assumption meant to flag the lack of data at these sites but will not artificially increase the *Binned Climate Change Vulnerability Score*.

7.3.2 Future Sea Level Rise and Storm Surge

Road-stream crossings that could be impacted by future sea level rise and storm surge are assessed using sea level rise inundation developed from GIS inundation data layers from the STORMTOOLS Dataset prepared by CRMC. These sea level rise and storm surge scenarios are listed in *Table 7-4*. In addition to the scenarios selected for this analysis (100-year storm surge plus 0, 1, 3, 5, and 7 feet of sea level rise), more recent research has identified a potential worst-case sea level rise scenario of up to approximately 11 feet (Sweet et al., 2017). However, as denoted in the *Table 7-4*, the 7-foot sea level rise scenario is the worst-case scenario for which inundation mapping is currently available statewide in Rhode Island. Storm surge associated with the 100-year storm (one percent annual chance storm) was selected for the analysis because this is the worst-case scenario for which inundation mapping is available.

Table 7-4: Sea Level Rise and Storm Surge Scenarios

Sea Level Rise (ft)	Storm Surge Event	Description and Inundation Data Availability[1]
0	100-year	100-year storm surge (current SLR conditions)
1	100-year	100-year storm surge plus 1 ft SLR
3	100-year	100-year storm surge plus 3 ft SLR
5	100-year	100-year storm surge plus 5 ft SLR
7	100-year	100-year storm surge plus 7 ft SLR. Worst case scenario for which inundation data is available.
11	100-year	100-year storm surge plus 11 ft SLR. Worst case scenario identified by NOAA (2017). No inundation data currently available.

[1]Scenarios not used in the analysis due to a lack of inundation data are shaded in grey.

The analysis of stream crossings for SLR and storm surge, as described in this section, is separate from the analysis of stream crossings for future streamflow based on changes in precipitation. The SLR and storm surge analysis does not include changes in precipitation, changes in storm severity, and riverine flooding or other variables that affect the impact of sea level rise and storm surge such as shoreline erosion.

GIS (ArcMap) Analysis Methodology

1. Open a map file such that the screen shows the *Road-Stream Crossing Sites* layer and the *100-Year Storm Surge Event Plus SLR by 2100* layer.
2. Separate the 0-ft, 1-ft, 3-ft, 5-ft, and 7-ft polygons into separate SLR inundation feature classes using the **Select** tool.
3. Intersect the *Road Stream Crossing Sites* layer with each of the SLR inundation feature classes using the **Intersect** tool to create five layers of crossings. Each layer will be associated with stream crossings that could be impacted under each SLR scenario.

Using *Table 7-5*, assign a *Binned SLR and Storm Surge Score* to each crossing based on the smallest height of sea level rise required to inundate the stream crossing location. The analysis assumes that the crossing elevation is approximately equal to the elevation of the land surface in the digital elevation data that was used to map the inundation areas.

Table 7-5: Binned SLR and Storm Surge Score

Amount of Sea Level Rise Required to Impact Crossing with 100-Year Storm Surge	Binned SLR and Storm Surge Score
7 feet or greater[1]	1
5 feet	2
3 Feet	3
1 Foot	4
0 feet	5

[1]This category includes inland road-stream crossings unaffected by SLR or storm surge.

Note: The analysis does not determine whether a road-stream crossing will be inundated due to SLR and storm surge, but whether it may be **impacted** by SLR and storm surge. Even if a crossing is not overtopped, hydraulic capacity may be significantly reduced, which may also result in reduced aquatic organism passage (addressed in *Section 12: Aquatic Organism Passage*) and increased likelihood of backwater flooding near the crossing location.

7.4 Scoring

7.4.1 Binned Climate Change Vulnerability Score

Calculate a *Binned Climate Change Vulnerability Score* as the maximum of the individual component scores from *Table 7-2* (*Binned Future Hydraulic Capacity Score*), *Table 7-3* (*Binned Hydraulic Capacity Change Score*) and *Table 7-5* (*Binned SLR and Storm Surge Score*).

Table 7-7: Binned Climate Change Vulnerability Score

Maximum of: Binned Future Hydraulic Capacity Score, Binned Hydraulic Capacity Change Score, and Binned SLR and Storm Surge Score	Binned Climate Change Vulnerability Score
1	1
2	2
3	3
4	4
5	5

7.4.2 Future Tidal Influence Flag

Flag crossings that are projected to be tidally-influenced under the future sea level rise and storm surge scenario considered in **Section 7.3.2**. Crossings that are tidally influenced in the future will experience daily changes in flow direction and magnitude which may affect hydraulic capacity. This information may be useful to consider in the final prioritization process.

7.5 Adapting the Methodology to Future Advances in Climate Change Projections and Data

As investigation of climate change continues and models of climate change scenarios become more accurate and more detailed, projections for rainfall, flood levels, storm surge, and sea level rise will almost certainly change. The tools and methods described here are flexible in that:

- The flow multiplier for changes in precipitation and/or peak flow rates can be modified (in a spreadsheet, for example) to reflect advances in climate change research.
- Updated GIS layers can be substituted for the *100-Year Storm Surge Event Plus SLR by 2100* dataset specified above as new data become available.
- The estimates of future streamflow obtained using the method described in this section could be further refined through the use of modified regression equations or rainfall-runoff modeling techniques, at the discretion of the project team.

Additional climate change planning tools and resources include:

- Dupigny-Giroux, L.A., E.L. Mecray, M.D. Lemcke-Stampone, G.A. Hodgkins, E.E. Lentz, K.E. Mills, E.D. Lane, R. Miller, D.Y. Hollinger, W.D. Solecki, G.A. Wellenius, P.E. Sheffield, A.B. MacDonald, and C. Caldwell, 2018: Northeast. In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 669–742. doi: 10.7930/NCA4.2018.CH18; https://nca2018.globalchange.gov/chapter/18/
- Rhode Island Statewide Climate Resilience Action Strategy (July 2018); http://climatechange.ri.gov/documents/resilientrhody18.pdf

- NOAA Technical Report NOS CO-OPS 083: Global and Regional Sea Level Rise Scenarios for the United States (Sweet et al., January 2017); https://tidesandcurrents.noaa.gov/publications/techrpt83_Global_and_Regional_SLR_Scenarios_for_the_US_final.pdf
- Technical Paper 164: Vulnerability of Transportation Assets to Sea Level Rise (Rhode Island Statewide Planning Program, January 2015); http://www.planning.ri.gov/documents/sea_level/2015/TP164.pdf
- Technical Paper 167: Vulnerability of Municipal Transportation Assets to Sea Level Rise and Storm Surge (Rhode Island Statewide Planning Program, September 2016); http://www.planning.ri.gov/documents/sea_level/2016/TP167.pdf
- EPA's Climate Resilience Evaluation and Awareness Tool (CREAT) Climate Scenarios Projection Map; https://epa.maps.arcgis.com/apps/MapSeries/index.html?appid=3805293158d54846a29f750d63c6890e
- STORMTOOLS storm inundation web map (University of Rhode Island, n.d.); http://www.beachsamp.org/stormtools/
- Magnitude of Flood Flows for Selected Annual Exceedance Probabilities in Rhode Island Through 2010 (Zariello et al., 2013); https://pubs.usgs.gov/sir/2012/5109/pdf/sir2012-5109_report_508_rev071112.pdf
- Increasing Trends in Peak Flows in the Northeastern United States and Their Impacts on Design (Walter and Vogel, 2010); https://acwi.gov/sos/pubs/2ndJFIC/Contents/2F_Walter_03_01_10.pdf
- Nonstationarity: Flood Magnification and Recurrence Reduction Factors in the United States (Vogel et al,. 2011); http://engineering.tufts.edu/cee/people/vogel/documents/floodMagnification.pdf
- Overview of a Changing Climate in Rhode Island (Vallee and Giuliano, 2014); http://research3.fit.edu/sealevelriselibrary/documents/doc_mgr/444/Valee%20&%20Giuliano.%202014.%20CC%20in%20Rhode%20Island%20Overview.pdf

Section 8: Geomorphic Impacts

This section provides guidance on assessing the potential for crossing structures to impact geomorphic processes that might, in turn, threaten the structure itself, other adjacent infrastructure, and aquatic organism passage.

8.1 How Geomorphic Impacts Can Threaten Infrastructure

Stream crossings can impact geomorphic processes if the crossing:

- alters the stream channel's planform (e.g., by adding sharp bends in the alignment),
- decreases cross sectional area (e.g., undersized culverts), or
- changes the gradient (e.g., if the gradient of the crossing is less than the channel).

The resulting changes to flood hydraulics and geomorphic processes have the potential to impact the structure itself, nearby infrastructure, and aquatic organism passage in three ways:

1. Flood flows can back up behind the crossing. Water may overtop and damage the road and inundate areas upstream of the crossing.
2. Sediment deposition upstream of the crossing caused by backwater can enhance the risk of overtopping and inundation. Flows can be deflected into the banks where erosion can undermine the crossing's wingwalls or other supporting structures.
3. Scour pools may form downstream due to high velocity flows exiting the crossing. This can undermine the crossing and cause it to collapse, destabilize the adjacent banks where other structures may be located, or decrease aquatic organism passage by creating a barrier at the crossing's outlet.

The geomorphic assessment methodology described in this section of the Handbook focuses on identifying which crossings are at risk of experiencing these problems. Crossings are assigned to one of the following three categories:

1. Crossing that are not prone to and have not experienced geomorphic adjustments
2. Crossings that are prone to but have not experienced geomorphic adjustments
3. Crossings that are prone to and have experienced geomorphic adjustments

The assessment is designed to first establish which crossings have the greatest potential for geomorphic impacts and then identify where those impacts are actually occurring. By subdividing the assessment into potential and observed geomorphic impacts, the assessment team can identify crossings where natural factors are preventing impacts that might otherwise occur as well as crossings where human alterations unrelated to the crossing might impact the channel (e.g., crossings where impacts are observed despite a low potential for impact). The potential and observed geomorphic impacts are then used to establish an overall geomorphic impact score in order to identify crossings that require complete replacement, upgrades or repairs to minimize impacts, or further analysis.

This methodology does not address all of the possible ways crossings can impact geomorphic processes. It is not intended to comprehensively assess how the natural setting or other unrelated human alterations of the channel may limit or contribute to observed channel adjustments around the crossing. Instead, this approach rates the relative likelihood that impacts could occur and documents the type and severity of impacts that have already occurred.

8.2 Data Needs

8.2.1 Field Data Needs

Field data required for this section includes:

- Alignment (*Section 3.5.2*)
- Bankfull Width (*Section 3.5.2*)
- Constriction (*Section 3.5.2*)
- Tailwater Scour Pool (*Section 3.5.2*)
- Significant Break in Valley Slope (*Section 3.5.2*)

- Bank Erosion (*Section 3.5.2*)
- Sediment Deposition (*Section 3.5.2*)
- Elevation of Sediment Deposits Greater Than or Equal to ½ Bankfull Height (*Section 3.5.2*)
- Channel Slope (*Section 3.5.2*)
- Stream Substrate (*Section 3.5.2*)
- Outlet Armoring (*Section 3.5.4*)
- Outlet Grade (*Section 3.5.4*)
- Inlet Grade (*Section 3.5.4*)
- Inlet Dimensions (*Section 3.5.4*)
- Structure Slope % (*Section 3.5.4*)
- Structure Slope Compared to Channel Slope (*Section 3.5.4*)

8.2.2 Other Data Needs (Optional)

The bankfull width of the channel adjacent to the crossing may not represent a natural equilibrium condition of the stream, due to human activities unrelated to the crossing. The equilibrium bankfull width of the channel can be estimated using regional curves that relate the drainage basin area upstream of a given point to channel dimensions. As regional curves have not been developed for Rhode Island, the most appropriate regional curves for Rhode Island are those developed for Massachusetts (https://pubs.usgs.gov/sir/2013/5155/pdf/sir2013-5155.pdf). Use the drainage area calculated in *Section 5: Existing Hydrologic Conditions* to calculate the bankfull width using the regional curves.

Use of the regional curves is not required to complete the assessment of geomorphic impacts. However, it may be useful to determine the equilibrium bankfull width, in order to compare it to the measured bankfull width at the crossing. This comparison may lead to a better understanding of if and how a particular crossing is impacting geomorphic processes.

8.3 Assessment Methodology for Potential Geomorphic Impacts

8.3.1 Potential Geomorphic Impacts

The potential for geomorphic impacts is determined in four ways:

1. characterization of the crossing alignment relative to the channel alignment,
2. comparison of the crossing inlet width to the channel's bankfull width,
3. comparison of the crossing's slope with the channel slope, and
4. characterization of the channel substrate.

8.3.2 Alignment

The alignment of the channel is an important factor for potential geomorphic impacts. The creation of a sharp bend in the channel at the crossing (where none existed previously) can lead to bank instability and backwater during flood flows. This can lead to overtopping of the crossing, flood inundation, and sediment deposition. Alternatively, if the stream alignment has been straightened by channelization, the stream may be prone to adjustment back to a previously sharp bend in the alignment. Assign *a Crossing Alignment Impact Potential Rating* according to *Table 8-1*.

Table 8-1: Crossing Alignment Impact Potential Ratings

Alignment	Impact Rating
Naturally straight	1
Mild bend	2
--	3
Channelized straight	4
Sharp bend	5

8.3.3 Constriction

A comparison of the crossing structure's inlet width with the channel's bankfull width gives a good sense of the potential severity of backwater be upstream of crossings that are narrower than the channel's bankfull width. Calculate the ratio of the *Inlet Width* to the *Bankfull Width* and assign a *Bankfull Width Impact Potential Rating* per *Table 8-2*. A ratio greater than or equal to one indicates that no constriction is created by the crossing. Geomorphic impacts increase with constrictions of 15 percent (Ratio = 0.85) or more, and severe impacts are likely where the constriction exceeds 50 percent (Ratio = 0.50) of the channel's width.

Table 8-2: Bankfull Width Impact Potential Ratings when Bankfull Width Confidence is High

Inlet Width/Bankfull Width Ratio (ft/ft)	Impact Rating
≥1.0	1
1.0-0.85	2
0.85-0.7	3
0.7-0.5	4
≤0.5	5

For crossings where *Bankfull Width Confidence* is low/estimated or where no measurements have been made, assign a *Bankfull Width Impact Potential Rating* using *Table 8-3*.

Table 8-3: Bankfull Width Impact Potential Ratings when Bankfull Width Confidence is Low/Estimated

Constriction	Impact Rating
None – Spans full channel and banks	1
Slight – Spans only bankfull/active channel	2
--	3
Moderate	4
Severe	5

Geomorphic impacts are possible above bankfull stage even where the crossing width exceeds the bankfull width if the approaches to the crossing block flow onto the floodplain. Determining whether flows are blocked from the floodplain by crossing approaches is beyond the scope of this crossing assessment protocol and is not considered in the geomorphic impact score. Further study of prioritized culverts, however, should assess whether floodplain flow is potentially blocked by the crossing approaches.

8.3.4 Slope

The potential for geomorphic impacts at a crossing are greatest where the crossing is situated at a natural break in slope along the channel. At these locations, the crossing structure slope is typically less than the channel slope, which can lead to upstream deposition and bed scour downstream. The potential impact of a crossing with a greater slope than that of the channel is less severe but could potentially lead to undermining and eventual collapse of the structure at its downstream end. Compare the measured slopes of the channel and of the crossing structure and assign a *Channel vs. Crossing Slope Impact Potential Rating* according to *Table 8-4*.

Table 8-4: Channel vs Crossing Slope Impact Potential Ratings

Slope Conditions at Crossing	Impact Rating
No natural break in slope AND crossing structure slope = channel slope	1
No natural break in slope but crossing structure slope greater than channel slope	2
Natural break in slope present but crossing structure = channel slope	3
No natural break in slope but crossing structure slope less than channel slope	4
Natural slope break present AND crossing structure slope different from channel slope (less than or greater than)	5

When the crossing inlet is inaccessible or cannot be found (typically at buried crossings), assume that *Structure Slope Compared to Channel Slope* is "About Equal" and that *Significant Break in Valley Slope* is "No." These conditions are likely to be found at the inlets of buried streams, as these structures are typically built in relatively flat developed areas.

If multiple structures are present and only one has a greater or lesser slope than the channel, assign the *Channel vs. Crossing Slope Impact Potential Rating* based on this structure, as it may be a source of potential geomorphic impacts.

8.3.5 Substrate

The size of the channel's substrate and bank materials are an important indicator of how sensitive the natural system is to human alterations of the channel. Bedrock or boulder substrates are rarely subject to bank erosion or bed scour, while smaller substrate sizes are more prone to geomorphic adjustments due to their greater vulnerability to erosion. Assign a *Substrate Size Impact Potential Rating* according to *Table 8-5*.

Table 8-5: Substrate Size Impact Potential Ratings

Stream Substrate	Impact Rating
Bedrock	1
Boulder	2
Cobble	3
Gravel	4
Sand or Silt/Muck	5

8.4 Assessment Methodology for Observed Geomorphic Impacts

8.4.1 Observed Geomorphic Impacts

Three geomorphic impacts often occur where the channel alignment, bankfull dimensions, and/or gradient have been altered by a stream crossing:

1. Sedimentation upstream and bed incision downstream, which reduces sediment continuity
2. Bank erosion and armoring
3. Rapid gradient changes at the structure's inlet and outlet

8.4.2 Sediment Continuity

A natural channel typically adjusts to maintain continuity of sediment transport (i.e. in natural channels the volume of sediment entering a particular reach is matched by an equal volume of sediment exiting the reach, and no excessive deposition or erosion occurs). Where the continuity of sediment transport has been impacted due to backwater upstream of the inlet, sediment deposition is often observed upstream and a tailwater scour pool is often observed downstream of the crossing. Assign a *Sediment Continuity Impact Rating* based on the degree to which these features are present per *Table 8-6*.

Table 8-6: Sediment Continuity Impact Ratings

<table>
<tr><th>Sediment Deposition, Elevation of Sediment Deposits, and Tailwater Scour Pool</th><th>Impact Rating</th></tr>
<tr><td>No deposition upstream AND no tailwater scour pool</td><td>1</td></tr>
<tr><td>Deposition upstream <½ bankfull height OR small tailwater pool</td><td>2</td></tr>
<tr><td>No deposition upstream AND large tailwater scour pool downstream</td><td rowspan="3">3</td></tr>
<tr><td>Deposition upstream <½ bankfull height AND small tailwater pool</td></tr>
<tr><td>Deposition upstream ≥½ bankfull height AND no tailwater scour pool</td></tr>
<tr><td>Both deposition AND tailwater pool present with either deposition ≥½ bankfull height OR a large tailwater scour large pool</td><td>4</td></tr>
<tr><td>Deposition upstream ≥½ bankfull height AND large tailwater pool</td><td>5</td></tr>
</table>

When the crossing outlet is inaccessible or cannot be found (typically at buried crossings), assume that *Tailwater Scour Pool* is "None." This condition is likely to be found at the outlets of buried streams, as these structures are typically built in relatively flat areas.

8.4.3 Bank Erosion and Armoring

Bank erosion upstream and downstream of a crossing may be indicative of geomorphic impacts caused by the structure. While bed incision and bank erosion are unlikely where armor has been placed, the presence of armor suggests that previous bank or bed instabilities may have required action to protect the structure or other adjacent infrastructure.

Assign a *Bank Erosion and Outlet Armoring Impact Rating* based on the degree to which bank erosion and armor are present per *Table 8-7*.

Table 8-7: Bank Erosion and Outlet Armoring Impact Ratings

Bank Erosion and Outlet Armoring	Impact Rating
No bank erosion or outlet armoring	1
--	2
Low levels of bank erosion and/or Outlet armoring not extensive	3
--	4
High levels of bank erosion and/or extensive outlet armoring	5

Note: -- indicates rating category not used

Although the presence of outlet armoring is not a definitive sign of scour issues at the site (the crossing structure may simply have been over-designed and over-armored), outlet armor is a common response to the scour caused by a crossing's geomorphic impacts. The background research and analysis required to determine whether any single crossing is armored due to geomorphic impacts or is simply over-designed is beyond the scope of this methodology. Including outlet armoring as a parameter in the geomorphic ratings is a conservative approach that will help prevent crossings with geomorphic impacts from being missed in the assessment.

8.4.4 Gradient Changes

Geomorphic adjustments at a crossing can create a perched condition where a sharp grade change is present at the inlet or outlet of the structure. This could inhibit aquatic organism passage and could ultimately undermine the structure. The methods assumes that the structures were installed at grade. The severity of the elevation change between the bottom elevation of the structure and the bed elevation of the channel can be used to assign an inlet and outlet grade impact rating (*Table 8-8*).

Table 8-8: Inlet and Outlet Grade Impact Ratings

Character of Inlet and Outlet Grade	Impact Rating
Both inlet and outlet at stream grade	1
Inlet drop OR cascade at outlet	2
Inlet drop AND cascade at outlet	3
Perched or clogged/collapsed/submerged inlet	4
Free fall or free fall onto cascade at outlet	
Inlet drop AND either free fall or free fall onto cascade at outlet	5

When the crossing inlet are inaccessible or cannot be found (typically at buried crossings), assume that *Inlet Grade* is "At Stream Grade." Use the same assumption for crossing outlets that are inaccessible or cannot be found. This condition is likely to be found at the inlets and outlets of buried streams, as these structures are typically built in relatively flat areas.

Note: Some stream crossings that may not exhibit impacts that are expected given geomorphic conditions directly at the site. In such cases, further analysis may reveal that cumulative effects either worsen or improve conditions at crossings when they are viewed as part of a system.

8.5 Combined Geomorphic Impact Scores

The individual impact ratings established in *Sections 8.2* and *8.3* provide information regarding both the crossing conditions that promote geomorphic impacts (*Tables 8-1 to 8-5*) and the impacts that are already occurring at the crossing (*Tables 8-6 to 8-8*).

Sum the *Crossing Alignment Impact Rating*, *Bankfull Width Impact Potential Rating, Channel vs Crossing Slope Impact Potential Rating*, and *Substrate Size Impact Potential Rating* to determine the *Combined*

Potential Geomorphic Impact Score per *Table 8-9*. . High scores indicate crossings where multiple factors contribute to the potential for geomorphic impacts and are thus more likely to experience geomorphic impacts.

Table 8-9: Combined Potential Geomorphic Impact Score

Combined Potential Geomorphic Impact Score	Likelihood of Geomorphic Impacts
4	Very unlikely
5-8	Unlikely
9-12	Possible
13-16	Likely
17-20	Very likely

The potential for geomorphic impacts at a crossing does not indicate that such impacts are currently occurring. Sum the *Sediment Continuity Impact Rating, Bank Erosion and Armoring Impact Rating*, and *Inlet and Outlet Grades Impact Rating* to determine the *Combined Observed Geomorphic Impact Score* (per *Table 8-10*)

Table 8-10: Combined Observed Geomorphic Impact Scores

Combined Observed Geomorphic Impact Score	Severity of Observed Geomorphic Impacts
3	None
4-6	Minor
7-9	Moderate
10-12	Significant
13-15	Severe

8.6 Binned Overall Geomorphic Impact Score

Distinguishing between **potential** geomorphic impacts and **observed** geomorphic impacts provides a planning tool for prioritizing further studies and actions. To integrate the findings of the geomorphic impact assessment, assign a *Binned Overall Geomorphic Impact Score* based on the sum of the *Combined Potential Geomorphic Impact Score* and the *Combined Observed Geomorphic Impact Score* per *Table 8-11*.

Table 8-11: Binned Overall Geomorphic Impact Score

Sum of the Potential Geomorphic Impact Score and the Observed Geomorphic Impact Score	Binned Overall Geomorphic Impact Score
7	1
8-14	2
15-21	3
22-28	4
28-35	5

8.7 Framework for Addressing Geomorphic Impacts

A comparison of the *Combined Potential Geomorphic Impact Score* with the *Combined Observed Geomorphic Impact Score* can be used to prioritize the next steps to address geomorphic impacts at crossings. *Table 8-12* presents a matrix with the significance and recommendations provided for each scenario that can arise from the comparison of impact ratings.

Table 8-12: Significance of Geomorphic Conditions and Recommendations for Action at Road-Stream Crossings Based on the Combined Potential Geomorphic Impacts Score and the Combined Observed Geomorphic Impacts Score

		Severity of Observed Geomorphic Impacts				
		None	**Minor**	**Moderate**	**Significant**	**Severe**
Likelihood of (Potential) Geomorphic Impacts	**Very Unlikely**	Crossing adequate - No action likely needed	Crossing adequate - No action likely needed	Other human activities may be causing adjustments - No action likely needed	Other human activities may be causing adjustments - Future study required to identify causes	Other human activities may be causing adjustments - Future study required to identify causes
	Unlikely	Crossing adequate - No action likely needed	Crossing adequate - No action likely needed	Other human activities may be causing adjustments - Future study required to identify causes	Other human activities may be causing adjustments - Future study required to identify causes	Other human activities may be causing adjustments - Future study required to identify causes
	Possible	Adjustments possible – Future study suggested to understand why no adjustments occurring	Adjustments expected – Consider retrofitting or stabilization options	Adjustments expected – Consider retrofitting or stabilization options	Adjustments expected – Consider retrofitting or stabilization options	Crossing at least partly cause of adjustment - Priority for replacement
	Likely	Adjustments expected – Future study required to understand why no adjustments occurring	Adjustments expected – Consider retrofitting or stabilization options	Crossing likely cause of adjustment - Consider retrofitting or stabilization options	Crossing likely cause of adjustment - Priority for replacement	Crossing likely cause of adjustment – High Priority for replacement
	Very Likely	Adjustments expected – Future study required to understand why no adjustments occurring	Potential for further adjustment – Consider retrofitting or stabilization options	Crossing likely cause of adjustment - Consider retrofitting or stabilization options	Crossing likely cause of adjustment - Priority for replacement	Crossing likely cause of adjustment – High Priority for replacement

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Section 9: Structural Condition

This section provides guidance on how to assess the structural condition of road-stream crossings.

9.1 Structural Failure at Road-Stream Crossings

9.1.1 Structural Failure Modes

The structural condition of road-stream crossings is an important factor in the identification and prioritization of crossings for repair or replacement. The physical condition of a crossing can determine the likelihood of structural failure during a flood.

Structural failure of a road-stream crossing can occur in multiple ways. Possible failure mechanisms include:

- Deterioration of the invert, until flow along the bottom of the culvert is no longer separated from the soils underneath the culvert. This in turn can lead to embankment piping.
- Deterioration of the joints and seams, which can lead to infiltration of soil into the crossing (blocking the crossing) and leakage of flow into surrounding soils. This in turn can also lead to embankment piping.
- Development of cracks, spalls, or efflorescence in cement crossing structures, leading to eventual blockage or collapse of the crossing.
- Deterioration of the headwalls and/or wingwalls of the crossing, which can lead to the collapse of material above or to the sides of the crossing.
- Erosion of a scour apron or other scour protection, which can lead to degradation of the streambed and undermining of the crossing structure.
- Deformation of the crossing's cross-section, which can reduce hydraulic capacity and lead to blockage or collapse of the crossing.
- Exposure, abrasion, scaling, and other deterioration of the crossing footings, which can lead to undermining and collapse of the structure.
- Blockage of the crossing structure, (independent of other structural factors listed here) due to buildup of debris, growth of vegetation and/or turf, or collapse of materials from above the crossing opening.
- Deterioration of the flared end section (if present), which can lead to undermining, erosion, and/or embankment piping.
- Buoyancy of the crossing structure (typically culvert pipes) due to a lack of the weight necessary to counteract hydraulic uplift. This can prevent flow through the crossing and lead to overtopping and/or embankment piping.
- Development of embankment piping (independent of other structural causes listed here), which can lead to sinkholes in the road surface and even a washout of the structure.

These failure mechanisms can lead to backwater flooding, overtopping, and washout of the crossing.

9.1.2 Structural Condition Assessment Methodology

The methodology presented in this section is adapted from the NAACC's recently released Culvert Condition Assessment Manual (CCAM) (NAACC, 2018), which was developed with input from state transportation departments throughout the Northeast and other stakeholders. The NAACC condition assessment methodology is designed as a rapid assessment tool for use by trained observers (not necessarily engineers) for purposes of flagging crossings that should be examined more closely for potential structural deficiencies. Similarly, the methodology described in this section is also intended as a rapid screening tool for use by trained observers, whether or not they are engineers.

The screening-level methodology presented in this section can be used for both culverts and bridges. It is not intended to replace the more rigorous inspection protocols outlined in the RIDOT Bridge Inspection Manual. However, the screening-level results obtained using the condition assessment methodology described in this section can be compared with and used to augment the more detailed structural condition ratings for bridges and other large crossing structures that are routinely inspected by RIDOT.

9.2 Data Needs

9.2.1 Field Data

The assessment methodology uses the following field data from *Section 3.5: Structural Condition*:

- Invert Condition
- Joint and Seam Condition
- Barrel Condition/Structural Integrity
- Headwall/Wingwall Condition
- Apron/Scour Protection Condition
- Embankment Piping
- Cross Section Deformation
- Longitudinal Alignment
- Footing Condition
- Level of Blockage
- Flared End Section Condition
- Buoyancy or Crushing

9.2.2. GIS Data Needs

No GIS data is needed for this section.

9.3 Calculation of Structural Condition Score

9.3.1 Condition Score

The NAACC structural condition scoring methodology is utilized for this assessment. A condition score is assigned based on Level 1, Level 2, and Level 3 Variables using field data from the Condition Assessment Form and *Tables 9-1* to *9-3.*

Condition scores for Level 1 and Level 2 variables are assigned directly from *Tables 9-1, 9-2A,* and *9-2B*. The Level 3 condition score is calculated using *Equation 9-1*.

Equation 9-1: Level 3 Condition Score

$$Score = 1.0 - (0.1 \times N)$$

where

$$N = number\ of\ variables\ from\ Table\ 9-3\ marked\ "Poor"$$

Note that a variable is only counted **once,** even if it applies to both the inlet and the outlet. For example, if a variable is marked “Critical” at one end of the crossing and “Poor” at the other end of the crossing, count the variable as “Critical” and do not count the other end of the crossing toward the count of “Poor” variables.

The lowest score resulting from the Level 1, Level 2, and Level 3 Variables is the overall condition score for the structure. **The calculated score will range from 0.0 to 1.0. A higher score indicates that the crossing is in better condition, while a lower score indicates that the crossing is in more critical condition.**

9.3.2 Binned Structural Condition Score

Assign the crossing a *Binned Structural Condition Score* according to *Table 9-4*.

9.3.3 Crossings with Multiple Structures

For crossings with multiple structures, score each structure according to the methods in *Section 9.3.1*.

Once each structure is scored, assign the lowest score among the structures as the overall crossing score. This effectively assigns the condition of the most critical structure to the entire road-stream crossing, because the structural condition of the entire crossing is only as good as the condition of the most degraded individual structure.

Use the score for the entire road-stream crossing to determine the *Binned Structural Condition Score* using *Table 9-4*.

9.3.4 Unknown Structural Variable Flag

Flag crossings that have one or more Level 1 variables marked “Unknown” or more than four Level 2 variables marked “Unknown” to inform data users that there is uncertainty surrounding the crossing’s structural condition.

Table 9-1: Level 1 Variables

Number of Variables Marked "Critical" (Inlet, Outlet, or Both)	Condition Score
Any one of the following variables: • Cross Section Deformation • Barrel Condition/Structural Integrity • Footing Condition • Level of Blockage	0.0
None of the above variables are marked "Critical"	1.0

Table 9-2A: Level 2 Variables – Part I

Number of Variables Marked "Critical"	Condition Score
Any three of the following variables (inlet, outlet, or both): • Buoyancy or Crushing • Invert Deterioration • Joints and Seams Condition • Longitudinal Alignment • Headwall/Wingwall Condition • Flared End Section Condition • Apron/Scour Protection Condition (outlet only) • Armoring Condition • Embankment Piping	0.0
Any two of the following variables (inlet, outlet, or both): • Buoyancy or Crushing • Invert Deterioration • Joints and Seams Condition • Longitudinal Alignment • Headwall/Wingwall Condition • Flared End Section Condition • Apron/Scour Protection Condition (outlet only) • Armoring Condition • Embankment Piping	0.1
Any one of the following variables (inlet/outlet/both): • Buoyancy or Crushing • Invert Deterioration • Joints and Seams Condition • Longitudinal Alignment • Headwall/Wingwall Condition • Flared End Section Condition • Apron/Scour Protection Condition (outlet only) • Armoring Condition • Embankment Piping	0.2
None of the above variables are marked "Critical"	1.0

Table 9-2B: Level 2 Variables – Part II

Number of Variables Marked "Poor"	Condition Score
Any three of the following variables (inlet, outlet, or both): • Cross Section Deformation • Barrel Condition/Structural Integrity • Footing Condition • Level of Blockage	0.0
Any two of the following variables (inlet, outlet, or both): • Cross Section Deformation • Barrel Condition/Structural Integrity • Footing Condition • Level of Blockage	0.1
Any one of the following variables (inlet, outlet, or both): • Cross Section Deformation • Barrel Condition/Structural Integrity • Footing Condition • Level of Blockage	0.2
None of the above variables are marked "Poor"	1.0

Table 9-3: Level 3 Variables

Variables marked as "Poor" (inlet, outlet, or both)
Buoyancy or Crushing
Invert Deterioration
Joints and Seams Condition
Longitudinal Alignment
Headwall/Wingwall Condition
Flared End Section Condition
Apron/Scour Protection Condition (outlet only)
Armoring Condition
Embankment Piping

Table 9-4: Binned Structural Condition Score

Lowest Score Resulting from Level 1, Level 2, and Level 3 Variable Assessment	Binned Structural Condition Score
0.81 - 1.00	1
0.61 - 0.80	2
0.41 - 0.60	3
0.21 - 0.40	4
0.0 - 0.20	5

Sample Calculation

The following sample calculation for a road-stream crossing (Crossing xy41874767155492) assessed during the Woonasquatucket River Watershed Pilot Study (*Appendix H).* This sample calculation demonstrates the scoring of Structural Condition at individual crossings using the methodology presented in this section.

Two structures were present at Road-Stream Crossing xy41874767155492. Photos of Structure 1 and screenshots of the structural condition variables recorded in the field forms for each structure are provided below.

Crossing xy41874767155492, Structure 1 inlet.

Crossing xy41874767155492, Structure 1 outlet.

Structure 1:

STRUCTURAL CONDITION ASSESSMENT

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	INLET					OUTLET				
	Adequate	Poor	Critical	Unknown	N/A	Adequate	Poor	Critical	Unknown	N/A
Longitudinal Alignment	X					X				
Level of Blockage	X					X				
Flared End Section					X					X
Invert Deterioration	X					X				
Buoyancy or Crushing	X					X				
Cross-Section Deformation					X					X
Structural Integrity of Barrel	X					X				
Joints and Seams	X					X				
Footings		X						X		
Headwall/Wingwalls	X						X			
Armoring	X						X			
Apron/Scour Protection					X					X
Embankment Piping	X					X				

Structure 2:

STRUCTURAL CONDITION ASSESSMENT

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	INLET					OUTLET				
	Adequate	Poor	Critical	Unknown	N/A	Adequate	Poor	Critical	Unknown	N/A
Longitudinal Alignment	X					X				
Level of Blockage	X					X				
Flared End Section					X					X
Invert Deterioration	X					X				
Buoyancy or Crushing	X					X				
Cross-Section Deformation					X					X
Structural Integrity of Barrel	X					X				
Joints and Seams	X					X				
Footings	X					X				
Headwall/Wingwalls	X					X				
Armoring		X				X				
Apron/Scour Protection					X					X
Embankment Piping	X					X				

Step 1: Assign Level 1 Variable Score
In checking the relevant variables, we note that:

For Structure 1:
- *Cross Section Deformation* is marked "N/A" (not applicable)
- *Barrel Condition/Structural Integrity* and *Level of Blockage* are "Adequate."
- *Footing Condition* is "Poor" at the inlet and "Critical" at the outlet. Since each variable can only be counted once, the worse of the two scores is used. Therefore, *Footing Condition* is considered "Critical" at this structure.
- Since *Footing Condition* is "Critical", the Variable 1 Score for Structure 1 is 0.

For Structure 2:
- *Cross Section Deformation* is marked "N/A" (not applicable).
- *Barrel Condition/Structural Integrity*, *Footing Condition*, and *Level of Blockage* are "Adequate."
- As none of these variables are marked "Critical", the Variable 1 Score for Structure 2 is 1.0.

Step 2: Assign Level 2 Variable Score (Part I)
In checking the relevant variables, we note that:

For Structure 1:
- *Buoyancy or Crushing*, *Invert Deterioration*, *Joint and Seam Condition*, *Longitudinal Alignment*, *Armoring Condition*, and *Embankment Piping* are marked "Adequate."
- *Flared End Section Condition* and *Apron/Scour Protection Condition* are marked "N/A" (not applicable).
- *Headwall/Wingwall Condition* is marked "Adequate" at the inlet and "Poor" at the outlet. Since the worse of the two scores is used, *Headwall/Wingwall Condition* is considered "Poor" for the structure.
- Since none of these variables are marked *Critical*, the crossing does not meet any of the criteria listed in *Table 9-2A* and the Variable 2 Part 1 score for Structure 1 is 1.0

For Structure 2:
- *Buoyancy or Crushing*, *Invert Deterioration*, *Joint and Seam Condition*, *Longitudinal Alignment*, *Headwall/Wingwall Condition*, and *Embankment Piping* are marked "Adequate."
- *Flared End Section Condition* and *Apron/Scour Protection Condition* are marked "N/A" (not applicable).
- *Armoring Condition* is marked "Poor" at the inlet and "Adequate" at the outlet. Since the worse of the two scores is used, *Armoring Condition* is considered "Poor" at this structure.
- Since none of these variables are marked "Critical", the crossing does not meet any of the criteria listed in *Table 9-2A* and the Variable 2 Part 1 score for Structure 2 is 1.0.

Step 3: Assign Level 2 Variable Score (Part II)
In checking the relevant variables, we again note that:

For Structure 1:

- *Cross Section Deformation* is marked "N/A" (not applicable)
- *Barrel Condition/Structural Integrity* and *Level of Blockage* are marked "Adequate."
- *Footing Condition* is marked "Poor" at the inlet and "Critical" at the outlet. Since the worse of the two scores is used, *Footing Condition* is considered "Critical" for the structure.
- Since none of these variables are considered "Poor", the crossing does not meet any of the criteria listed in *Table 9-2B* and the Variable 2 Part 2 score for Structure 1 is 1.0.

For Structure 2:

- *Cross Section Deformation* is marked "N/A" (not applicable).
- *Barrel Condition/Structural Integrity*, *Footing Condition*, and *Level of Blockage* are "Adequate."
- Since none of these variables are considered "Poor", the crossing does not meet any of the criteria listed in *Table 9-2B* and the Variable 2 Part 2 score for Structure 2 is 1.0.

Step 4: Assign Level 3 Variable Score
In checking the relevant variables, we note that:

For Structure 1:

- *Buoyancy or Crushing*, *Invert Deterioration*, *Joint and Seam Condition*, *Longitudinal Alignment*, *Armoring Condition*, and *Embankment Piping* are marked "Adequate."
- *Flared End Section Condition* and *Apron/Scour Protection Condition* are marked "N/A" (not applicable).
- *Headwall/Wingwall Condition* is marked "Adequate" at the inlet and "Poor" at the outlet. Since the worse of the two scores is used, *Headwall/Wingwall Condition* is considered "Poor" for the structure.

Therefore, the calculation of the Variable 3 Score is as follows:

$$N = number\ of\ variables\ from\ Table\ 9-3\ marked\ \text{Poor} = 1$$

$$Score\ = 1.0 - (0.1\ \times N)$$

$$Score\ = 1.0 - (0.1\ \times 1) = \mathbf{0.9}$$

Step 4: Assign Level 3 Variable Score (continued)

For Structure 2:

- *Buoyancy or Crushing*, *Invert Deterioration*, *Joint and Seam Condition*, *Longitudinal Alignment*, *Headwall/Wingwall Condition*, and *Embankment Piping* are marked "Adequate".
- *Flared End Section Condition* and *Apron/Scour Protection Condition* are marked "N/A" (not applicable).
- *Armoring Condition* is marked "Poor" at the inlet and "Adequate" at the outlet. Since the worse of the two scores is used, *Armoring Condition* is considered "Poor" for this structure.

Therefore, the calculation of the Variable 3 Score is as follows:

$$N = number\ of\ variables\ from\ Table\ 9-3\ marked\ \text{Poor} = 1$$

$$Score\ = 1.0 - (0.1\ \times N)$$

$$Score\ = 1.0 - (0.1\ \times 1) = \mathbf{0.9}$$

Step 5: Select the Lowest Score
The scores from Steps 1-4 are summarized below:

Structure 1:

- Level 1 Variable Score = 0.0
- Level 2 Variable Score Part 1 Score = 1.0
- Level 2 Variable Score Part 2 Score = 1.0
- Level 3 Variable Score = 0.9

Structure 2:

- Level 1 Variable Score = 1.0
- Level 2 Variable Score Part 1 Score = 1.0
- Level 2 Variable Score Part 2 Score = 1.0
- Level 3 Variable Score = 0.9

The final score for each structure is the lowest score; 0.0 is the lowest score for Structure 1 while 0.9 is the lowest score for Structure 2. The lowest overall score of 0.0 (for Structure 1) is assigned to the crossing, meaning that this crossing would be assigned a *Binned Structural Condition Score* of 5, using *Table 9-5*.

Step 6: Note any structural variables recorded as "Unknown" with an *Unknown Structural Variable Flag*.
No variables were marked "Unknown" for either Structure 1 or Structure 2, so the Unknown Structural Variable Flag was not used at this crossing.

Section 10: Flood Impact Potential

This section provides guidance on assessing the potential impacts of failure of a road-stream crossing during floods.

10.1 Road-Stream Crossing Failure Modes

Road-stream crossing failures typically occur in the following ways (failure modes):

1. The crossing does not have adequate capacity to convey high flows and water backs up as a result, inundating areas upstream of the crossing.
2. The road-stream crossing erodes and/or collapses, releasing water and sediment downstream in a flood wave. The potential impacts of this type of "wash-out" failure are varied and may include:
   a. A "domino effect" of crossing failures as each failing crossing sends a flood wave downstream that plugs or washes out the next road-stream crossing downstream. The second crossing may also fail and release a flood wave, causing the process to repeat at successive downstream structures.
   b. Erosion of streambanks, causing large releases of sediment into the stream and possibly undermining structures built on the streambank.
   c. Failure of utilities associated with the crossing, and washout of downstream utilities.
3. The road surface floods as the crossing structure overtops, but the crossing remains in place. This failure mode can still be dangerous, as vehicles can be swept off the crossing or stall in rising water when drivers attempt to drive across the flooded crossing. This type of failure may occur in combination with failure mode (1) and/or failure mode (2).

The assessment procedure described in this section of the Handbook focuses on failure modes (1) and (2) and the resulting impacts to existing infrastructure and development. This section does not address failure mode (3), as these impacts are assessed separately in Section 11: Disruption of Transportation Services, which includes potential impacts to emergency services, evacuation routes, and/or general traffic.

The assessment approach described in this section does not address all possible flood impacts, nor does it assume that the potential impacts will occur in any given flood. Instead, the approach considers the relative potential severity of flood impacts on existing infrastructure and development upstream, downstream, and at each crossing site, should the road-stream crossing fail.

10.2 Data Needs

10.2.1 Field Data Needs

Field data required for this section includes:

- Utilities (Section 3.5.1)
- Bankfull Width (Section 3.5.2)
- Constriction (Section 3.5.2)
- Structure Width (Section 3.5.4)

If a crossing inlet could not be found because the stream was buried for an undetermined length, proceed directly to Section 10.4 to score the structure.

10.2.2 GIS Data Needs

Stream Crossing Locations

- This analysis requires the use of the feature class containing the crossing locations and associated field data if field data is collected using digital methods. The user may wish to create a copy of the feature for use specific to this analysis, in order to preserve the original feature class.
- If field data is collected using paper forms, a shapefile containing the crossing location and the average bankfull width for the crossing will have to be created by editing an existing feature class or manually creating a new file.

Hydrologic Features

- The linear stream features and/or polygonal lake, pond, and estuary features originally used to determine crossing locations in Section 2.1:

Identifying Possible Road-Stream Crossing Assessment Locations.

RIGIS Land Cover and Land Use (2011) Layer

- The most recent version of the Land Use and Land Cover layer may be downloaded from the RIGIS website (http://www.rigis.org/datasets/land-use-and-land-cover-2011). This land use/land cover dataset is based on 2011 orthophotos.

RIGIS Flood Hazard Areas

- Digitized flood hazard areas (polygons) compiled from county-based Digital Flood Insurance Rate Map (DFIRM) databases for Rhode Island (http://www.rigis.org/datasets/flood-hazard-areas).

Simple Flood Impact Model

- Download the Simple Flood Impact Model (contact RIDOT for access to the model).
- This tool was created for the analysis described in this section and Appendix G.

10.3 Assessment Methodology

10.3.1 Areas Potentially Impacted by Flooding

Failure of a crossing may result in upstream impacts, downstream impacts, or both. The extent of flooding impacts upstream of a culvert that is blocked by sediment or debris or that has insufficient capacity for a given flood flow is influenced by the height of the crossing embankment, the slope of the upstream channel, and the topography of the floodplain and river corridor. Upstream flooding affects larger areas along streams with significant floodplains as compared to confined stream corridors with minimal floodplains. Backwater flooding may also impact areas along mainstem tributaries upstream of a crossing.

The downstream area impacted by a stream crossing failure is more difficult to estimate without detailed hydraulic analysis. The downstream impact area depends on highly variable site-specific factors, including the height of the road-stream crossing embankment, the types of soils that make up the streambed and banks, and the level of confinement of the stream corridor downstream of the crossing. These factors are difficult to measure for large numbers of crossings, and evaluation of downstream impacts often requires the use of detailed hydraulic models, similar to those required for dam breach analyses.

Due to the complexity of assessing the numerous site-specific factors described above, the methodology described herein determines the area of potential flood impacts upstream and downstream of a crossing using a simplified approach.

10.3.2 GIS Methodology

The following sections summarize the GIS-based analysis methods used to define potential flood impact areas and the level of development and infrastructure potentially impacted within these areas. Detailed GIS analysis procedures are described in Appendix G of this Handbook.

The methodology described in Appendix G is designed for use in ArcMap versions 10 and up, and terminology and inputs are specific to that program. In addition, the methodology requires access to an Advanced User License for ArcMap. If using a different GIS program, the user may have to adapt the methodology accordingly.

10.3.3 Flood Impact Area Determination

For the purpose of this analysis, the upstream and downstream limits of the impact area (i.e., upstream impacts due to backwater flooding and downstream impacts from a breach of the crossing) are defined by a distance measured ½ mile upstream and downstream of the crossing. These limits are established by applying a ½-mile radius around the crossing location.

The lateral extent of the impact area can be estimated using one of two methods, depending on the availability of FEMA flood hazard mapping for the stream crossing of interest.

Estimating Lateral Extent of Flood Impact Area Using FEMA Flood Hazard Mapping

For crossings on streams with flood hazard mapping, the flood impact area is defined by the 1 percent annual chance flood boundary as depicted on the FEMA flood insurance risk mass (FIRMs). Note that flood hazard mapping is not available in all areas.

Estimating Lateral Extent of Flood Impact Area Using Stream Buffer Approach

For crossings where flood hazard mapping within the 0.5-mile radius is unavailable or incomplete, the lateral extent of the potential flood impact area is defined by:

- a stream buffer distance equal to 2 times the Bankfull Width of the stream at the crossing (Equation 10-1), or
- if the Bankfull Width is not available, estimate the stream buffer distance based on the crossing Structure Width and Constriction (Table 10-1). If outlet and inlet widths differ, use the largest width measurement available.

Equation 10-1: Stream Buffer Distance using Bankfull Width

$$Stream\ Buffer\ Distance = 2\ \times Bankfull\ Width$$

Table 10-1: Stream Buffer Calculations using Structure Width

Crossing Structure Constriction Rating	Stream Buffer Distance (Substitute for Equation 10-1)
Severe	4 x Structure Width
Moderate	3 x Structure Width
Spans Only Bankfull Active Channel	2 x Structure Width
Spans Full Channel and Banks	2 x Structure Width

The upstream and downstream limits (0.5-mile radius around the crossing) and lateral extent of flood impacts (flood hazard mapping or stream buffer approach) define a buffer polygon that represents the potential flood impact area for each stream crossing. Tributaries that join the mainstem within the upstream potential flood impact area of a stream crossing are included in the buffer polygon, while tributaries that join the mainstem within the potential flood impact area downstream of the crossing are excluded from the buffer polygon (See Figure 10-1). Some manual editing

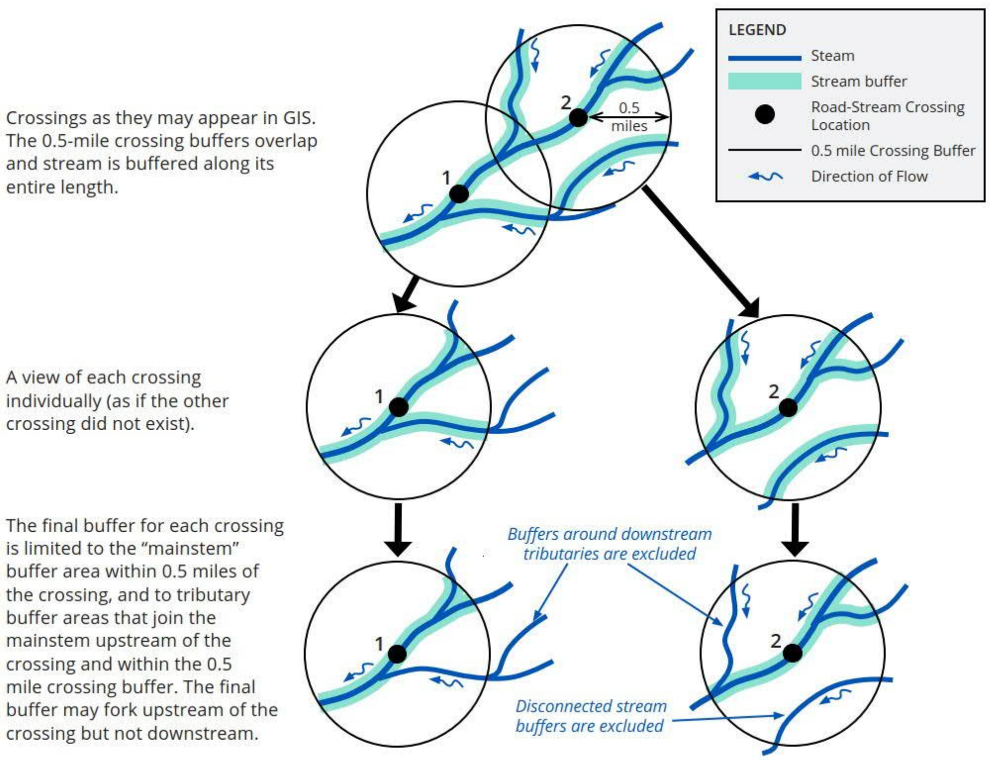

Figure 10-1: Illustration of process for editing stream-crossing buffers. See Appendix G for detailed instructions about how to create the stream buffers in ArcMap.

of the resulting flood impact area

buffer polygons may be necessary to remove buffers on nearby stream segments that would be unaffected by flooding associated with a particular crossing.

These buffer polygons will be used to determine relative degrees of flood impact potential in the area immediately surrounding each crossing. The degree of development and the presence of other crossings and utilities within the buffer will be assessed in Sections 10.3.4-10.3.6 to determine component Flood Impact Ratings, which will be combined to determine a Binned Flood Impact Potential Score for each crossing in Section 10.4

10.3.4 Development within the Flood Impact Area

The degree to which development that could be impacted in a flood is estimated by the percentage of developed land use/land cover within a crossing's potential flood impact area. The following land use/land cover types from the RIGIS Land Cover and Land Use (2011) layer are considered "developed" for the purpose of this analysis:

- Airports
- Cemeteries
- Commercial, commercial/industrial mixed, and commercial/residential mixed
- Confined feeding operations
- Cropland (tillable)
- Developed recreation
- High density residential
- Industrial
- Institutional
- Low density residential
- Medium density residential, medium high density residential, and medium low density residential
- Mines, quarries and gravel pits
- Orchards, groves, nurseries
- Other transportation
- Railroads
- Roads
- Transitional areas (urban open)
- Waste disposal
- Water and sewage treatment

Assign a Flood Impact Rating based on the percentage of developed land use/land cover within the crossing's potential flood impact area, according to Table 10-2.

Table 10-2: Flood Impact Rating for Percent Developed Area

Percent Developed Area within Potential Flood Impact Area Buffer Polygon	Flood Impact Rating
<5% developed area	1
<10% developed area	2
<25% developed area	3
<50% developed area	4
>50% developed area	5

10.3.5 Stream Crossings within the Flood Impact Area

Other upstream or downstream crossings can increase the flood hazard at a given crossing. Upstream crossings can be impacted by backwater flooding, while downstream crossings can be impacted in the event of a crossing washout, leading to a domino effect as described in Section 10.1.

Assign a Flood Impact Rating based on the number of upstream and downstream crossings within the crossing's potential flood impact area, according to Table 10-3.

Table 10-3: Flood Impact Rating for Upstream and Downstream Crossings

Number of Upstream and Downstream Crossings within Potential Flood Impact Area Buffer Polygon	Flood Impact Rating
0	1
--	2
1	3
--	4
>1	5

Note: -- indicates category not used

10.3.6 Impacts to Utilities

Utilities in the right-of-way, such as gas lines, water lines, sewer lines, or telecommunications lines, may cross a stream along with the road. These utilities are often buried within an embankment of a road-stream crossing (at culverts) or attached to the side or underside of the crossing (at bridges). When a road-stream crossing fails via significant erosion, collapse, or washout, any buried or attached utilities are also likely to fail, cutting off service to residents and businesses and creating a potential source of environmental pollution. Repairs to restore the damaged utilities can be costly.

The presence and number of utilities at a crossing is determined during the field data collection phase (Visible Utilities, Section 3.5.1). Assign a Flood Impact Rating based on the number of utilities present at a stream crossing, according to Table 10-4.

Overhead wires are excluded from this assessment, as the risk to overhead utilities is typically lower than that to buried utilities during a crossing failure. However, their presence is recorded during field data collection for project planning purposes (the presence of overhead wires at a crossing replacement site may complicate construction access and safety).

Table 10-4: Flood Impact Rating for Utilities

Utilities Present at the Crossing	Flood Impact Rating
None	1
--	2
Single Utility (Gas, Water, Sewer, or Other) attached to or buried within crossing	3
--	4
Two or more utilities attached to or buried within crossing	5

Note: -- indicates rating not used

10.4 Binned Flood Impact Potential Score

Assign a Binned Flood Impact Potential Score to each crossing based on the sum of the component flood impact ratings for developed area, upstream and downstream crossings, and utilities, according to Table 10-5.

Table 10-5: Binned Flood Impact Potential Scores

Sum of Flood Impact Ratings	Binned Flood Impact Potential Score
3 – 4	1
5 – 7	2
8 - 10	3
11 - 13	4
14 – 15	5

If a crossing inlet could not be found because the stream was buried for an undetermined length, or if the Bankfull Width and Constriction could not be measured at a crossing where flood hazard mapping is not available, assign a Binned Flood Impact Potential Score of 3 to avoid skewing the crossing score toward high or low values.

Note that the Binned Flood Impact Potential Score and the Flood Impact Ratings used to calculate it are relative scores used for comparison of crossings. The scores do not represent a dollar value of impacts or any other quantification of flooding impacts.

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Section 11: Disruption of Transportation Services

This section provides guidance on assessing the potential disruption of transportation services resulting from failure of a road-stream crossing.

11.1 How do Floods Impact Transportation Services?

The failure of road-stream crossings due to flooding can disrupt emergency, commercial, and local transportation services. Failure of road stream crossings can lead to delays or prevent travel by:

- Emergency service vehicles (e.g. ambulances, police, and firefighting vehicles), which need to be able to reach both the sites where emergencies occur and emergency service centers such as hospitals, police stations, and fire stations.
- Commuters attending work, school, or community and social gatherings.
- Commercial traffic, resulting in reduced supply of goods and reduced economic activity.
- Tourist traffic, which can reduce economic activity, particularly in communities where the economy relies on tourism.

The negative impacts on human health and safety, local economies, and community connectedness can be made worse by the fact that crossings washed out during storms can take a very long time to replace or repair. The longer a crossing remains damaged, the more likely potential travelers are to avoid the route. In some locations, the loss of commuter, commercial, and tourist traffic can result in an economic downturn in the affected community.

During the historic flooding that occurred in Rhode Island in 2010, floodwaters inundated roads and caused widespread disruption and damage to transportation infrastructure, including flooding of major interstate routes and washout of road stream crosings on state routes in some areas of the state. Widespread flooding impacts were also felt by Rhode Island's transportation infrastructure during Superstorm Sandy in 2012. In addition to the impacts of major events, there is an increasing occurrence of disruption to transportation systems that happens during "normal" events due to the increase in intensity of rainfall during storms that happen more frequently.

The methodology presented in this section quantifies the potential disruption of transportation services resulting from single crossing failures by considering the functional classification of the roadway (i.e., level of travel mobility and access to property that it provides) and the emergency services that could be affected. This assessment does not address impacts to infrastructure or properties upstream or downstream of the crossing, or impacts to utilities due to failure of the crossing. Those impacts are addressed separately in *Section 10: Flood Impact Potential.*

11.2 Data Needs

11.2.1. Field Data Needs

No field data is needed for this analysis.

11.2.2. GIS Data Needs

RIGIS RIDOT Roads

The "RIDOT Roads" layer may be downloaded from the RIGIS website: http://www.rigis.org/datasets/30943d3301474c1abbf79912cd11b25c_0. This layer contains Federal Highway Administration (FHWA) functional road classification codes under the attribute "FHWA Approved Classification" (f_system).

Rhode Island Highway Functional Road Classification Definitions are provided at http://www.planning.ri.gov/planning-areas/transportation/highway-functional-classification-definitions.php

E-911 Data

E-911 Road Centerlines:
http://www.rigis.org/datasets/e-911-road-centerlines

- Data provided to RI E-911 telecommunicators who direct emergency service providers to locations where emergency assistance is needed.
- Attributes include street class ("StreetClas")
- E-911 primary routes have values of 20, 30, 40 and/or 50 for "StreetClas" field.

Hurricane Evacuation Routes

In 2006, RIEMA, in collaboration with RIDOT and local officials, mapped hurricane evacuation routes. This data is available from RIDOT or RIEMA by request.

11.3 Methodology

Roadway GIS data discussed above (road classifications, E-911 primary routes, and hurricane evacuation routes) can be appended to the crossings GIS data layer by following the steps outlined below. For ease of reference, these layers are referred to in the steps below as follows:

- Crossings — CROSSINGS
- Road Classification — CLASS
- E-911 Routes — E911
- Hurricane Routes — HEVAC

For the methods outlined below to work, the crossing point features must be located on the roadway linear feature (not necessarily on the actual roadway centerline). The steps outlined below were developed using ArcMap 10.6; however, this process can be adapted to other versions of ArcMap.

1. Use the Spatial Join (Analysis) tool to join features from CLASS to CROSSINGS.
   - Target Features: CROSSINGS
   - Join Features: CLASS
   - Output Feature Class: CROSSINGS_JOIN1
   - Join Operation: JOIN_ONE_TO_ONE
   - Keep All Target Features should be checked
   - Field Map of Join Features: Remove all fields added from CLASS except for “F_SYSTEM” or other field with road classification information.
   - Match Option: CLOSEST
   - Search Radius: 50 feet

   Note that driveways and trails are not included in the RIGIS RIDOT Roads layer, and the road classification for these crossings will therefore have to be assigned manually.
2. Use Spatial Join to join features from E911 to CROSSINGS_JOIN1 (created in Step 1).
   - Use same settings as in Step 1 except as described below.
     - Output Feature Class: CROSSINGS_JOIN2
     - Field Map of Join Features: Remove all fields added from E911 except for “StreetClas”.
3. Use Spatial Join to join features from HEVAC to CROSSINGS_JOIN2 (created in Step 2).
   - Use the same rules as in Step 1 except as described below.
     - Output Feature Class: CROSSINGS_DISRUPTION
     - Field Map of Join Features: Remove all fields added from HEVAC except for “ROUTE_TYPE”. Since ROUTE_TYPE is a binary field, it will be used to determine whether or not each crossing is located on a hurricane evacuation route.
4. Export or copy the attribute data for CROSSINGS_DISRUPTION to Excel spreadsheet for calculation of individual *Transportation Disruption Component Ratings* (described in *Section 11.4*).

11.4 Individual Transportation Disruption Component Ratings

Assign three disruption ratings to each crossing according to whether the conditions in *Table 11-1* apply to the crossing.

Table 11-1: Transportation Disruption Component Ratings

Disruption Rating	Hurricane Evacuation Route?	E-911 Primary Route?	Road Classification (Highway Functional Classification)
1	No	No	Local Roads, Trails, Driveways
2	--	--	Major and Minor Collectors
3	Yes	--	Minor Arterials
4	--	--	Other Principal Arterials
5	--	Yes	Interstates, Freeways, and Expressways

11.5 Binned Transportation Disruption Score

Calculate the sum of the three *Transportation Disruption Component Ratings – Hurricane Evacuation Route?*, *E-911 Primary Route?,* and *Road Classification* – to determine a *Binned Transportation Disruption Score* ording to *Table 11-2*. Note that this score is weighted toward emergency access concerns.

Table 11-2: Binned Transportation Disruption Scores

Sum of Transportation Disruption Component Ratings	Binned Transportation Disruption Score
3 - 4	1
5 - 6	2
7 – 9	3
10 - 11	4
12 - 13	5

Note that the *Binned Transportation Disruption Score* and the *Transportation Disruption Component Ratings* used to compute it are relative scores used for comparison of crossings. The scores do not represent a dollar value of impacts or any other quantification of flooding impacts.

11.6 Local Knowledge Flag

The user may wish to flag crossings that have some critical importance not captured in the Transportation Disruption Component Score. For example, crossings could be flagged for the following reasons:

- Local E-911 responders (police, fire, and ambulance) might review the crossings and flag crossings that:
    - would completely cut off a neighborhood from emergency or other services if they failed, or
    - provide access to water supplies for use in firefighting or are of other importance to emergency response but are not mapped as E-911 primary routes.
- Municipal staff or the public might review the data to flag crossings located on local roads that receive a higher-than-expected amount of traffic for local roads (e.g., local roads that happen to serve as commuter routes or convenient detours when major routes such as Interstates and Freeways are cut off).
- Municipal staff or the public may provide records, phtoographs, or anecdotal reports regarding the magnitude and impacts of past floods which may be used to supplement the screening-level assessments performed using the methods outlined in this document.
- Consider flagging crossings that are negatively impacting public or private property. This could include highly constricted crossings that cause erosion of downstream riverbanks or backwater flooding of properties or structures.
- Municipal staff may flag crossings that have been recently replaced, as there may not be public support for replacement. On the other hand, municipal staff may flag crossings that have required frequent repairs due to flooding and crossings that are located on roads likely to be repaved in the next 5 years, as these crossings are likely to receive more public support for replacement due to the associated cost-savings opportunities.

This is not an exhaustive list of reasons for using the *Local Knowledge Flag*, and the user may find additional reasons to use this flag specific to the region in which they are assessing crossings. **Because of the general nature of this flag, notes or comments should always be provided explaining why the crossing is being flagged.**

Flagging crossings systematically in this manner can provide valuable local insights that can help inform the final decision regarding which crossings to upgrade, and will encourage public buy-in to any decisions made using these methods.

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Section 12: Aquatic Organism Passage

This section provides guidance on assessing aquatic organism passage through a crossing structure. The methods described in this section are adapted from the North Atlantic Aquatic Connectivity Collaborative (NAACC) assessment protocol for evaluating aquatic passability of stream crossings.

12.1 How do Road-Stream Crossings Affect Aquatic Organism Passage?

Many fish and other wildlife move between and within waterways in order to forage, reproduce, and find safety from predators and extreme conditions. For some species, this movement is necessary to complete their life cycle.

Road-stream crossings can impede movement in the following ways:

- Outlet drops, inlet drops, and internal baffles or other physical barriers may be too high for an aquatic species to swim, leap, or crawl over.
- Internal structures may create conditions that are too turbulent for wildlife passage.
- Where crossings constrict the stream or where the stream bottom is covered with a concrete apron or other smooth material, flow velocities may be too great for wildlife to move against the flow.
- Structures that lack substrate cover may limit passability for species that avoid areas that lack cover (e.g., crayfish, salamanders, juvenile fish) or that need substrate as a medium for travel (e.g., mussels)
- Long culverts with a small opening size (i.e. culverts with a small Openness value) may present a behavioral barrier. Turtles are believed to be affected by the openness of a crossing structure; other species may be affected as well.

Road structures can be improved for aquatic organism passage (AOP or "fish passage") by modifying, replacing, or removing the structures. Replacing crossing structures with larger culverts or bridges that are better suited to the riverine environment can improve conditions for wildlife to move upstream and downstream through the crossing. In this section, the term "crossing replacement" includes modifying, replacing, or removing a crossing to improve aquatic organism passage.

The potential ecological benefit of removing an existing barrier to aquatic passage is also an important consideration in the crossing prioritization process. The habitat value accessed after a crossing replacement depends on both the quality and the extent of aquatic habitat that is reconnected as a result of replacing the existing crossing with a structure that provides for improved aquatic passage.

The aquatic passage benefits of replacing a road-stream crossing can be limited if other barriers are located upstream of the crossing, as the gains in upstream habitat accessibility could therefore be limited. Similarly, if one or more crossings are located downstream of the crossing being assessed, removal or replacement of that crossing may provide little benefit to diadromous fish (fish that migrate between the ocean and freshwater streams) that must first attempt to navigate the downstream barriers.

In addition, the benefits of replacing a road-stream crossing can be limited if the habitat that is made accessible has poor water quality, lacks cover and food sources, lacks substrate due to erosion, or is otherwise degraded.

12.2 Data Needs

12.2.1 Field Data

As discussed in *Section* 2, road-stream crossing field assessments are generally conducted during "typical low-flow conditions." Some field variables are important for assessing conditions at the time of the survey; others provide indirect evidence of likely conditions at higher flows.

Field data required to assess aquatic organism passage includes:

- Inlet Grade (*Section 3.5.4*)
- Outlet Drop (*Section 3.5.4)*
  - This variable is based on the variable *Outlet Drop to Water Surface* unless the value for *Water Depth Matches Stream* is "Dry" in which case this variable is based on the variable *Outlet Drop to Stream Bottom*.
- Constriction (*Section 3.5.2)*
  - *Constriction* is an indirect indicator of potential velocity issues at higher flows.
- Tailwater Scour Pool (*Section 3.5.2)*
  - *Tailwater scour pool* is an indirect indicator of potential velocity issues at higher flows. *Tailwater 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.
- Structure Dimensions A-D (*Section 3.5.4)*
  - These dimensions are used to calculate the *Openness Measurement* in *Section 12.3*.
  - If the inlet and outlet structure dimensions differ, use the dimensions that result in the smallest cross-sectional area.
- Structure Length (Dimension L) (*Section 3.5.4)*
  - This measurement is used to calculate the *Openness Measurement* in *Section 12.3*.
- Outlet Apron (*Section 3.5.4)*
  - *Outlet Apron* is an indirect indicator of potential velocity issues at higher flows.
  - Referred to as "Outlet Armoring" in the NAACC protocols
- Substrate Matches Stream (*Section 3.5.5)*
  - *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).
- Structure Substrate Coverage (*Section 3.5.5)*
  - *Structure 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.
- Water Depth (*Section 3.5.5)*
  - Water depths that are made significantly deeper or shallower than the rest of the stream by the presence of the road-stream crossing may inhibit passage.
- Water Velocity (*Section 3.5.5)*
  - Water velocities that are made significantly faster or slower than the rest of the stream by the presence of the road-stream crossing may inhibit passage.
- Physical Barriers (*Section 3.5.5)*
  - This variable strictly concerns obstacles that form a physical barrier to passage (rather than indirectly inhibiting passage through hydraulic effects or other impacts)
- Internal Structures (*Section 3.5.5)*
  - 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.

For crossings too large to be measured in the field (e.g. crossings marked as "Bridge Adequate") and crossings where either the inlet or outlet cannot be accessed, proceed directly to *Section 12.4*.

12.2.2 GIS Data

Rhode Island Critical Linkages Data

- The assessment of the ecological benefits of a crossing replacement requires the use of Critical Linkages data developed by the Landscape Ecology Lab at UMass Amherst as part of the Conservation Assessment and Prioritization System (CAPS) program
- The data can be downloaded directly via the following link: http://jamba.provost.ads.umass.edu/web/lcc/bystate/dsl_states_critical_linkages_ri.zip
- The data can also be downloaded by navigating to http://umasscaps.org/data_maps/dsl.html . Scrolling down to the Rhode Island section of the page and click on the link below the "Critical Linkages" heading.

12.3 Aquatic Passability Assessment

The methodology presented in this section is used to assess the passability of a structure for aquatic organisms and other wildlife. The NAACC Numeric Scoring System, as described herein, should be used for all RIDOT assessments. This section has been adapted, with permission, from the document entitled "Scoring Road-Stream Crossings as Part of the North Atlantic Aquatic Connectivity Collaborative (NAACC) Adopted by the NAACC Steering Committee November 10, 2015," which was developed with input from multiple experts in aquatic passability. This document contains additional details on the scoring methodology discussed below. The NAACC Numeric Scoring System methodology is designed as a quantitative but rapid assessment tool for use by trained observers (not necessarily engineers). The assessment is not species-specific, but rather seeks to evaluate passability for the full range of aquatic organisms likely to be found in rivers and streams. This scoring system is based on the opinions of experts who decided both the relative importance of the available predictors of passability as well as a way to score each predictor.

Complete *Sections 12.3.1* through *12.3.5* for each structure at a given crossing.

12.3.1 Categorical Variable Component Scores

Assign a score for each category according to *Table 12-1*, which lists field variables from *Section 12.2.1* and the scores associated with each variable.

The *Categorical Variable Component Scores* alone are not intended as measures of passability, but instead are intended to cover the full range of problems (assessable by the NAACC protocol) associated with a given variable: from 0 (worst case) to 1 (best case). For example, for *Inlet Grade*, having an inlet drop or perched inlet is the worst case among the options, thus scoring a "0." This is not meant to say that all structures with inlet drops are impassible. The effect of each *Categorical Variable Component Score* on the *Aquatic Passability Score* is controlled by the weight it is given in computing the composite score (see *Section 12.3.4*).

12.3.2 Openness Measurement

Calculate the O*penness Measurement* is for both the inlet and outlet using *Equation 12-1*, and assign the lower of the two values to the structure. If there are multiple structures at a crossing, the value for the structure with the highest *Openness Measurement* is assigned to the crossing as a whole.

Equation 12-1: Openness Measurement (feet)

$$Openness\ Measurement = \frac{Structure\ Inlet\ or\ Outlet\ Cross\ Sectional\ Area}{Structure\ Length}$$

Table 12-1: Categorical Variable Component Scores

Field Variable	Level	Component Score
Constriction	Severe Moderate Spans Only Bankfull/Active Channel Spans Full Channel and Banks	0 0.5 0.9 1
Inlet Grade	Inlet Drop Perched Clogged/Collapsed/Submerged Unknown At Stream Grade	0 0 1 1 1
Internal Structures	Baffles/Weirs Supports Other None	0 0.8 1 1
Outlet Apron	Extensive Not Extensive None	0 0.5 1
Physical Barriers	Severe Moderate Minor None	0 0.5 0.8 1
Scour Pool	Large Small None	0 0.8 1
Substrate Coverage	None 25% 50% 75% 100%	0 0.5 0.5 0.7 1
Substrate Matches Stream	None Not Appropriate Contrasting Comparable	0 0.25 0.75 1
Water Depth	No (Significantly Deeper) No (Significantly Shallower) Yes (Comparable) Dry (Stream Also Dry)	0.5 0 1 1
Water Velocity	No (Significantly Faster) No (Significantly Slower) Yes (Comparable) Dry (Stream Also Dry)	0 0.5 1 1

12.3.3 Functions for Openness, Height, and Outlet Drop

Three of the field variables must be converted to scores using functional equations. The equations for these scores – *Openness Component Score*, *Height Component Score*, and *Outlet Drop Component Score* – are presented as *Equations 12-2, 12-3,* and *12-4.*

Equation 12-2: Openness Component Score (S_o), for openness measurement (x) in feet

$$S_o = (1 - e^{-5.7x})^{2.6316}$$

Equation 12-3: Height Component Score (S_h) for height measurement (x) in feet

$$S_h = min\left(\frac{1.1x^2}{4.84 + x^2}\right), 1)$$

Equation 12-4: Outlet Drop Component Score (S_{od}) for outlet drop measurement (x) in feet

$$S_{od} = 1 - \frac{1.029412x^2}{0.26470588 + x^2}$$

12.3.4 Weighted Composite Scores

Compute a weighted average of the *Categorical Variable Component Scores, Openness Component Score, Height Component Score, and Outlet Drop Component Score* using *Equation 12-5* and the weights listed in *Table 12-2*. The result is the *Weighted Composite Score*.

The weights listed in *Table 12-2* were determined by NAACC based on expert opinion from researchers and practitioners in aquatic organism passage. The weights are displayed out to three decimal places to reduce overall error in the model by not introducing a rounding error; the scores will not actually be this precise.

Equation 12-5: Weighted Composite Score

$$Weighted\ Composite\ Score = \sum Component\ Score \times Weight$$

where

Component scores are calculated in Sections 12.3.2 - 12.3.3 and weights are listed in Table 12-2.

Table 12-2: Weights Associated with each *Component Score* in *Equation 12-5: Weighted Composite Score*

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 Apron	0.037
Internal Structures	0.032

12.3.5 Aquatic Passability Score

Calculate the *Aquatic Passability Score* using E*quation 12-5*. The rationale for this equation 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.

Equation 12-5: Aquatic Passability Score

$$\text{Aquatic Passability Score} = \text{Minimum}\,[\text{Weighted Composite Score, Outlet Drop Component Score}]$$

Note that these scores do not explicitly relate to how easy or difficult it is for fish and other aquatic organisms to move through a road-stream crossing. The *Aquatic Passability Score* represents the degree to which a crossing deviates from the ideal crossing. The ideal crossing would be no harder to move through than any nearby portion of the same stream that does NOT have a crossing. It is assumed that crossings with an *Aquatic Passability Score* closer to the ideal (*Aquatic Passability Score* > 0.6) will present only an insignificant or minor barrier to an aquatic organism trying to pass through. Crossings with *Aquatic Passability Scores* further from the ideal (*Aquatic Passability Scores* < 0.4) are more likely to be significant or severe barriers to movement. These distinctions are arbitrarily imposed on a continuous scoring system for ease of comparison and should be used with that in mind.

12.4 Binned Aquatic Passability Score

Once the *Aquatic Passability Score* has been calculated for each structure at the crossing, assign the crossing a *Binned Aquatic Passability Score* based on the structure with the **highest *Aquatic Passability Score*** using to *Table 12-3*.

Although the *Aquatic Passability Score* and the *Binned Aquatic Passability Score* are similarly named, the *Binned Aquatic Passability Score* represents the **relative priority** for replacing a crossing based on aquatic passability considerations, rather than a measure of the passability of the crossing.

Table 12-3: Binned Aquatic Passability Score

Aquatic Passability Score	Descriptor	Binned Aquatic Passability Score
1.00	No Barrier	1
0.80 - 0.99	Insignificant Barrier	
0.60 - 0.79	Minor Barrier	2
0.40 - 0.59	Moderate Barrier	3
0.20 - 0.39	Significant Barrier	4
0.0 - 0.19	Severe Barrier	5

For crossings too large to be measured in the field (e.g. crossings marked as “Bridge Adequate”) and crossings where either the inlet or outlet cannot be accessed, assign a *Binned Aquatic Passability Score* of 3 to prevent the crossing from being artificially ranked higher or lower relative to other crossings due only to missing data.

12.5 Ecological Integrity

Various information sources can be consulted to estimate the quality of habitat that could be restored as a result of a road-stream crossing replacement project.

In Rhode Island, information on high-quality riverine habitats (coldwater and headwater streams, coastal stream habitats, critical habitats for species of conservation concern, etc.) is generally available from site- or watershed-specific evaluations and is not available statewide as consistent, GIS-based indicators. More detailed methods and data sets are available such as the Critical Linkages methodology developed by the Landscape Ecology Lab at UMass Amherst as part of the Conservation Assessment and Prioritization System (CAPS) program.

12.5.1 Ecological Integrity Score

Through their Critical Linkages project, the CAPS team has produced a dataset for each state in the Northeast Region, including Rhode Island. The dataset includes a value called the aquatic Index of Ecological Integrity (IEI) value for each road-stream crossing. The aquatic IEI value represents the relative benefit to ecological health and connectivity that would result from removal of a given crossing.

Determine the IEI value for each road-stream crossing by overlaying the Rhode Island Critical Linkages Data with the road-stream crossings being assessed. The process of associating a CAPS Critical Linkages stream crossing and IEI value with the corresponding RIDOT stream crossing can be automated in ArcGIS using the **Spatial Join** tool. Note that some road-stream crossings in the RIDOT crossings dataset may not be included in the CAPS Critical Linkages crossings dataset due to differences in the data sources used by the NAACC to map roads and streams.

Assign a *Binned Ecological Integrity Score* to each crossing using the crossing's IEI value, per *Table 12-4*. Where an IEI value is not available for a given crossing, assign a *Binned Ecological Integrity Score* of 3. These recommendations are based on an assessment of the distribution of IEI values for all of the stream crossings in the Rhode Island CAPS Critical Linkages dataset, which showed that the majority of the crossings included in the CAPs Critical Linkages dataset (greater than 50%) for Rhode Island have an aquatic IEI value of between 0.5 and 0.7. Note that higher IEI values (and therefore higher *Binned Ecological Integrity Scores*) indicate **greater** relative benefits to aquatic species (upon removal or replacement of a road-stream crossing).

Table 12-4: Binned Ecological Integrity Score

<table>
<tr><th>Aquatic Index of Ecological Integrity (IEI) Value</th><th>Binned Ecological Benefit Score</th></tr>
<tr><td>0.0-0.3</td><td>1</td></tr>
<tr><td>0.31-0.5</td><td>2</td></tr>
<tr><td>0.51-0.7</td><td rowspan="2">3</td></tr>
<tr><td>Unknown/No value</td></tr>
<tr><td>0.71-0.9</td><td>4</td></tr>
<tr><td>0.91-1.0</td><td>5</td></tr>
</table>

12.6 Crossing Flags

12.6.1 Adjacent Crossings Flag

As discussed in the *Section 12.5.1*, reliable information may not exist on the quality or extent of aquatic habitat at a given crossing. Flag any road-stream crossing that has one or more road stream crossings located within either the upstream or downstream impact areas defined in *Section 10: Flood Impact Potential*. Flagging the crossing may provide useful information for final prioritization or allow for a more detailed, site-specific analysis to better estimate the quality and extent of aquatic habitat that could be re-connected by a crossing replacement.

12.6.2 Wildlife Crossing or Roadkill Flag

Flag each road-stream crossing at/near which any of the following were observed:

- Live wildlife crossing the road
- Wildlife crossing signs
- Roadkill

Also note the comments accompanying any of this data. This information will allow observed terrestrial wildlife passage issues to be incorporated into the prioritization process.

Section 13: Prioritization of Road-Stream Crossings

This section provides guidance for prioritizing road-stream crossings for potential replacement or upgrade based on risk of failure and ecological considerations. The prioritization framework presented in this section integrates the scoring system described in previous sections of this Handbook.

13.1 Crossing Prioritization

The objective of road-stream crossing prioritization is to identify important crossing sites for replacement or upgrade, given limited resources and funding. This section presents a screening-level prioritization method that utilizes the results of the field surveys and assessment scoring presented in previous sections of this Handbook. The prioritization approach incorporates a risk-based framework that considers the risk of flooding-related failure as well as the potential benefits of aquatic organism passage. Crossings are assigned a relative priority based on these factors.

13.2 Data Needs

13.2.1 Field Data Needs

No field data is needed for this section.

13.2.2 GIS Data Needs

No GIS data is needed for this section.

13.2.3 Other Data Needs

This assessment utilizes the binned scores (1-5) resulting from the assessments described in *Sections 6-12* of this Handbook, including:

- *Section 6: Existing Hydraulic Capacity*
  - Binned Hydraulic Capacity Score
  - Existing Tidal Influence Flag
- *Section 7: Climate Change Vulnerability*
  - Binned Climate Change Vulnerability Score
  - Future Tidal Influence Flag
- *Section 8: Geomorphic Impacts*
  - Binned Overall Geomorphic Impact Score
- *Section 9: Structural Condition*
  - Structural Condition Score
  - Unknown Structural Variable Flag
- *Section 10: Flood Impact Potential*
  - Binned Flood Impact Potential Score
- *Section 11: Disruption of Transportation Services*
  - Binned Transportation Disruption Score
  - Local Knowledge Flag
- *Section 12: Aquatic Organism Passage*
  - Binned Aquatic Passability Score
  - Binned Ecological Integrity Score
  - Adjacent Crossings Flag
  - Wildlife Crossing or Roadkill Flag

13.3 Assessment Methodology

13.3.1 Crossing Failure Risk

The risk associated with flood-related failure of a stream crossing can be expressed mathematically as the product of the probability of failure (i.e., hazard) and the magnitude of impacts in the event of failure (i.e., vulnerability or degree of loss) (*Equation 13-1*). As described in previous sections of this Handbook, crossing "failure" can include inundation of upstream areas, overtopping of the crossing, significant erosion at the crossing, or complete washout of the crossing.

Equation 13-1: Crossing Failure Risk

$$Failure\ Risk = Probability\ of\ Failure \times Magnitude\ of\ the\ Impact\ of\ Failure$$

Based on this concept, a crossing may pose a high failure risk if:

- the probability of failure is high, even if the magnitude of impacts associated with failure are moderate,
- the probability of failure is moderate but the magnitude of impacts of failure are high, or
- failure is probable and the magnitude of impacts are high.

The probability of crossing failure under current climatic conditions is quantified in four separate binned scores – the *Binned Hydraulic Capacity Score* (*Section 6*), the *Binned Climate Change Vulnerability Score* (*Section 7*), the *Binned Geomorphic Impact Score* (*Section 8*), and the *Binned Structural Condition Score* (*Section 10*).

The magnitude of impacts in the event of failure is represented by the *Impact Score*, which is calculated as the maximum of the *Binned Flood Impact Potential Score* (*Section 10*) and the B*inned Transportation Disruption Score* (*Section 11*) per *Equation 13-2*.

Equation 13-2: Impact Score

$$Impact\ Score = Maximum\begin{bmatrix} Binned\ Transportation\ Disruption\ Score, \\ Binned\ Flood\ Impact\ Potential\ Score \end{bmatrix}$$

Calculate four separate failure risk scores: the *Existing Hydraulic Risk Score* (*Equation 13-3*), *Climate Change Risk Score* (*Equation 13-4*), *Geomorphic Risk Score* (*Equation 13-5*), and *Structural Risk Score* (*Equation 13-6*).

Equation 13-3: Existing Hydraulic Risk Score

$$Existing\ Hydraulic\ Risk\ Score = Binned\ Existing\ Hydraulic\ Capacity\ Score \times Impact\ Score$$

Equation 13-4: Climate Change Risk Score

$$Climate\ Change\ Risk\ Score = Climate\ Change\ Vulnerability\ Score \times Impact\ Score$$

Equation 13-5: Geomorphic Risk Score

$$Geomorphic\ Risk\ Score = Binned\ Geomorphic\ Vulnerability\ Score \times Impact\ Score$$

Equation 13-6: Structural Risk Score

$$Structural\ Risk\ Score = Binned\ Structural\ Condition\ Score \times Impact\ Score$$

The overall failure risk for a crossing is dictated by the highest (i.e., worst-case) level of risk, represented by the *Crossing Risk Score* (*Equation 13-7*), which is calculated as the maximum of the *Existing Hydraulic Risk Score*, *Climate Change Risk Score*, *Geomorphic Risk Score*, and *Structural Risk Score*.

Equation 13-7: Crossing Risk Score

$$Crossing\ Risk\ Score = Maximum\begin{bmatrix} Existing\ Hydraulic\ Risk\ Score, \\ Climate\ Change\ Risk\ Score, \\ Geomorphic\ Risk\ Score, \\ Structural\ Risk\ Score \end{bmatrix}$$

13.3.2 Aquatic Passage Benefit

As discussed in *Section 12: Aquatic Organism Passage*, the potential ecological benefit of removing an existing barrier to aquatic passage is also an important consideration in the crossing prioritization process. Calculation the *Aquatic Passage Benefit Score* per *Equation 13-8*.

Equation 13-8: Aquatic Passage Benefit Score

$$Aquatic\ Passage\ Benefit\ Score = Binned\ Aquatic\ Passability\ Score \times Binned\ Ecological\ Integrity\ Score$$

13.3.3 Priority Scoring

Calculate the *Crossing Priority Score* per *Equation 13-9*). The *Crossing Priority Score* combines the *Crossing Risk Score* and the *Aquatic Passage Benefit Score* by adding the maximum of the two scores to the average of the two scores. This approach ensures that if there is a very high score for one factor, it is preserved. It does however prioritize those crossings that rate highly for both factors.

Equation 13-9: Crossing Priority Score

$$Crossing\ Priority\ Score = Maximum[Aquatic\ Passage\ Benefit\ Score, Crossing\ Risk\ Score] + Average[Aquatic\ Passage\ Benefit\ Score, Crossing\ Risk\ Score]$$

Scale the *Crossing Priority Score* to a range from 0 to 1 according to *Equation 13-10*.

Equation 13-9: Scaled Crossing Priority Score

$$Scaled\ Crossing\ Priority\ Score = \frac{Crossing\ Priority\ Score}{100}$$

Assign a qualitative *Relative Priority Rating* (High, Medium, Low) and priority rank (in order from highest to lowest) based on the *Scaled Crossing Priority Score* according to *Table 13-1*. The *Relative Priority Rating* is a screening-level indicator of a crossing's **relative priority** for potential replacement.

Table 13-1: Relative Priority Ratings

Crossing Priority Score (normalized)	Relative Priority Rating
0.66 – 1.00	High
0.33 - 0.66	Medium
0.00 - 0.33	Low

13.4 Interpreting the Prioritization Results

Upgrade or replacement of higher-rated or higher-priority structures will generally provide greater overall benefits relative to flood resiliency and stream continuity based on a number of factors. The priority ratings are not meant as definitive recommendations since the ratings do not account for replacement costs and other site-specific factors.

The individual risk scores (i.e., the *Existing Hydraulic Risk Score*, the *Climate Change Risk Score*, the *Geomorphic Risk Score*, and the *Structural Risk Score*) and the *Aquatic Passage Benefit Score* should each be considered on a case-by-case basis when evaluating replacement and upgrade of specific structures. In some cases, crossings that are rated as a lower priority overall may still be good candidates for replacement or upgrade to achieve a particular objective such as increased hydraulic capacity, reduced geomorphic vulnerability, or improved aquatic organism passage. For example, if a watershed organization is particularly concerned about aquatic passability within their watershed, they may use the results of the aquatic passability score to select crossings from the overall prioritization results that have both a high relative priority rating and a high *Aquatic Passage Benefit Score*.

Several parameters from the field surveys or individual assessments were flagged, where noted, including:

- existing and future tidal influence
- missing structural data, typically due to lack of access to a crossing to complete field observations
- the presence of upstream and downstream crossings that may limit aquatic passability benefits or be impacted by crossing replacement
- local knowledge regarding impacts to transportation and local or emergency services,
- observed terrestrial wildlife passage issues at specific crossings (such as the presence of wildlife, roadkill, or wildlife crossing signs).

These and other site-specific factors should be considered in the prioritization process. For example, when planning crossing replacements, crossings that have been flagged for terrestrial wildlife passage issues using the *Wildlife Crossing or Roadkill Flag* might be designed for both aquatic and terrestrial passage, in order to improve both ecological health and human safety (by reducing vehicle collisions with wildlife).

Other potential impacts and constraints should also be considered during design and permitting of road-stream crossing replacements. These considerations are discussed in *Section 14: Next Steps*.

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Section 14: Next Steps

This section discusses additional issues that should be considered in the final selection and implementation of priority crossing replacements based on the results of the assessment methodology described in this handbook, as well as cost and other factors that are not captured in the assessment and prioritization process.

14.1 Interpreting the Assessment and Prioritization Results

Once the assessment and prioritization process has been completed, the list of priority crossings should be reviewed with stakeholders to gather feedback and consider factors that are not captured by the assessment methodology in order to reach consensus regarding which crossings to replace or upgrade. During this review, stakeholders should also consider the priority crossings in relation to other infrastructure, including crossings and dams on the same river system, before making a final decision about replacing specific crossings.

Remember that the priority ratings generated using the methodology presented in this handbook are **relative**. Upgrade or replacement of higher-rated or higher-priority structures will generally provide greater overall benefits relative to flood resiliency and stream continuity. The priority ratings are not definitive recommendations since the ratings do not account for cost, feasibility, and other site-specific factors.

The individual risk scores (i.e., the *Existing Hydraulic Risk Score*, the *Climate Change Risk Score*, the *Geomorphic Risk Score*, and the *Structural Risk Score*) and the *Aquatic Passage Benefit Score* should each be considered on a case-by-case basis when evaluating replacement and upgrade of specific structures. Crossings that are rated as medium- or low-priority overall, based on consideration of all of the assessed factors, may still be good candidates for replacement or upgrade to achieve a particular objective such as increased hydraulic/geomorphic capacity or aquatic organism passage.

Once crossings are selected for replacement, the priority crossings should be identified in capital planning for subsequent project implementation (i.e., design, permitting, and construction).

Note: Although generally beneficial **c**rossing replacements can have significant impacts on stream conditions and nearby in-stream infrastructure if these potential impacts are not considered during prioritization and design. In-stream Infrastructure that may be impacted by crossing replacements may include:

- Crossings upstream or downstream of the crossing
- Dams upstream or downstream of the crossing
- Stream gaging stations
- Irrigation canals
- Flood control structures

It is especially important to remember that enlarging a crossing structure can allow larger flows to pass downstream, especially during larger floods. This may result in increased impacts on downstream structures during flood flows. One way to avoid these impacts to is to replace all of the crossings on a stream with appropriately sized crossings, proceeding from downstream to upstream.

14.2 Flood-Resilient and Stream-Friendly Stream Crossing Standards

Existing vulnerable road-stream crossings should be replaced with more flood-resilient and ecologically-beneficial designs. Replacing outdated or inadequate crossings with crossings that maintain natural flow and substrate conditions:

- enhances the resiliency of the transportation system
- reduces erosion and structural damage

- reduces flood impacts to upstream/ downstream infrastructure and property
- increases stream continuity for aquatic organism passage

Better standards and more effective design are critical for enhancing the resiliency and ecological benefits of new and replacement stream crossings. Crossings designed to meet flood-resilient and stream-friendly stream crossing standards have been found to be extremely effective in safely passing water, sediment, and debris during floods, while maintaining safe routes for emergency personnel and residents (MADER, 2012).

Stream crossing standards that promote stream continuity and flood resilience have been adopted – as guidance and, in some cases, regulation – by several states in the northeast U.S. including Massachusetts, New Hampshire, Vermont, Connecticut, Maine, and New York. Such standards, which are generally based on Stream Simulation Design (USFS, 2008), have also been incorporated to varying degrees into the U.S. Army Corps of Engineers general permits. Although stream crossing guidance is provided in the Rhode Island Department of Environmental Management's *Wetland BMP Manual: Techniques for Avoidance and Minimization*, Chapter 9 "Wetland Crossings," at the time of writing comprehensive statewide stream crossing standards have not yet been adopted in Rhode Island.

Establishing statewide guidelines modeled after similar guidelines or standards in neighboring states can help ensure that new and replacement stream crossings are designed to promote flood-resiliency and the natural functions of streams. States that have clear guidelines are better positioned to receive funding assistance toward upgraded stream crossings following major disasters. FEMA post-disaster Public Assistance funding may be used to improve rather than to simply replace stream crossings that sustain significant damage if the state or municipality has adopted, implemented, and consistently applied a set of guidelines prior to the disaster (Levine, 2013).

Implementation of statewide stream crossing standards has been identified as a priority action in the Rhode Island state Hazard Mitigation Plan (under revision at the time of this writing) as part of a broader statewide climate resilience strategy. Until such statewide standards are adopted in Rhode Island, guidance on flood-resilient and stream-friendly road-stream crossing design is available from other states in the region.

Rhode Island municipalities should also consider incorporating improved stream crossing design standards into local land use regulations and design guidance for new permanent stream crossings (roads, driveways, paths, etc.) and replacement crossings. Adoption and implementation of local stream crossing standards can also better position communities to receive post-disaster assistance from FEMA and a greater share of state funding from various programs.

14.3 Permitting Requirements

Permitting requirements for road-stream crossing replacement projects in Rhode Island vary depending on the size and extent of the crossing replacement and the potential for impacts to environmental resources. Stream crossing replacement projects typically require state permitting through the Rhode Island Department of Environmental Management (RIDEM) Office of Water Resources, while coastal stream crossing projects are subject to permitting requirements of the Rhode Island Coastal Resources Management Council (CRMC). Federal approvals may also be required. These could include, but are not limited to, the U.S Army Corps of Engineers (USACE) individual permit or Rhode Island general permit (PGP), as well as coordination with the United States Coast Guard (USCG), United States Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), and the United States Environmental Protection Agency (USEPA). Crossing replacements involving structures with potential historic significance (e.g., stone masonry culverts or historic bridges) may also require coordination with the Rhode Island Historical Preservation & Heritage Commission regarding potential impacts to historic resources. Local review and approvals may be required for compliance with municipal floodplain management ordinances and

General Stream Crossing Standards (adapted from MA, CT, and NY)

Crossing Type

Bridges and bottomless arches, 3-sided box culverts, and other open-bottom culverts are preferred and should be used whenever possible.

Embedment

Four-sided box culverts and pipe culverts, if used, should be embedded into the streambed to at least 20 percent of the culvert height at the downstream invert (a minimum of 2 feet), used only on "flat" streambeds (slopes no steeper than 3%), and installed level.

Substrate

Natural substrate (rocks, gravel, etc.) should be used within the crossing, and it should match the upstream and downstream substrates. The substrate should resist displacement during floods and should be designed so that appropriate material is maintained during normal flows.

Crossing Span/Width

The crossing opening should be at least 1.2 times the bankfull width of the stream, measured bank to bank at the ordinary high-water level or at the edges of terrestrial, rooted vegetation.

Openness

The crossing should have an openness ratio (cross-sectional area divided by crossing length) of at least 0.82 feet, with 1-1.5 feet preferred. The crossing should be wide and high relative to its length.

Water Depth and Velocity

At low flows, water depths and velocities should be the same as they are in natural areas upstream and downstream of the crossing.

Note that this is not a complete list of standards and is provided only as an overview of common stream-crossing standards.

Source: Massachusetts Stream Crossing Standards, Department of Fish and Game (MADER, June 2012)

Section 14: Next Steps

Recommended Approach for Stream Crossing Replacement

- Start with high-priority crossings identified through the assessment process described in this handbook.
- Consider other upstream and downstream crossings (including lower-priority crossings) on the same river system based on individual assessment scores and other factors.
- Generally replace downstream crossings first to:
  - Avoid inadvertently increasing downstream peak flows at outdated or undersized stream crossings by enlarging upstream crossings, and
  - Open up stream segments to passage of fish and other aquatic organisms by starting downstream and progressing upstream.
- Lower-priority crossings downstream of high priority crossings should be considered for replacement if they are hydraulically undersized, have high geomorphic vulnerability, or are in poor structural condition.
- Include priority crossings in Capital Improvement Plans and Hazard Mitigation Plans.
- Implement upgrades as part of planned capital improvements such as road rehabilitation or reconstruction.
- Perform site-specific data collection, geotechnical evaluation, hydrologic and hydraulic evaluation, and structure type evaluation to support design and permitting (see below for typical requirements).

Site Assessment Needs for Stream Crossing Replacement

Geotechnical Evaluation

Perform subsurface investigation and soils analysis.

Site Reconnaissance and Wetland Delineation

Delineate wetlands, perform a riverbed substrate analysis to understand the existing riverbed substrate, and provide data to calculate the design bed material; identify the type and integrity of stream grade controls; identify and flag bankfull width measurement locations and representative cross-sections to be surveyed upstream and downstream of culvert; determine appropriate reference reaches.

Topographic Survey

Perform topographic survey and include other relevant features such as wetlands and waterbodies, headwall/wingwall locations and elevations, centerline elevation of the road, geotechnical boring locations, river longitudinal profiles, culvert invert elevations, top of culvert, representative cross-sections above and below the culvert, mean annual high water, property lines, and roadway right-of-way.

Hydrologic and Hydraulic Study

Conduct a hydrologic analysis of the site, using appropriate methods. Identify typical low flows, the bankfull discharge, and peak flows required for the engineering and design process. The hydraulic analysis should assess existing water depths, velocities, water surface profiles, and potential upstream and downstream impacts of stream crossing modifications.

Traffic Analysis

Analyze the traffic over the project culvert, including volume, peak volume, and type of vehicle traffic.

Structure Type Selection

Compare various crossing types (3-sided culverts, arches, embedded box culverts, and large diameter pipes) based on relative construction cost, ease of construction, and anticipated benefits. For the recommended alternative, provide opinion of probable cost and structure characteristics.

National Flood Insurance Program (NFIP) requirements.

Designers should consult with local, state, and federal officials and regulators early in the project development phase to discuss applicable permitting requirements and to clarify and confirm regulatory review requirements and any additional information needed by the agencies.

14.4 Crossing Replacement Costs

Replacing stream crossings with crossings having larger and more flood-resilient and stream-friendly designs can be more expensive in the short term, sometimes costing 50% to 100% more than in-kind replacements. However, when maintenance and replacement are considered, the average annual cost of an upgraded crossing can be lower over its lifetime than that of an undersized crossing over the same time period (Industrial Economics, Incorporated, 2015; Levine, 2013; Gillespie, et al., 2014) due to the ability of flood-resilient and stream-friendly crossing designs to withstand larger precipitation events (thus extending their lifespan) with less maintenance. Undersized and outdated stream crossings are even less cost-effective when factoring in climate change considerations (more frequent and intense storms and flooding).

14.5 Funding Sources for Stream Crossing Upgrades

As Rhode Island's infrastructure continues to age and is faced with new challenges due to climate change, a sustained source of funding will be required to offset the higher initial cost of upgrading stream crossings. Despite these higher initial costs, stream-friendly crossing upgrades can reduce future damages and save money in the long term by increasing flood resiliency. State and federal transportation funding and traditional municipal funding sources for stream crossing upgrades is currently limited compared to what is needed.

Other potential non-transportation sources of funding for stream crossing upgrades are listed below. Note that this listing is not exhaustive and the availability of these funding sources may vary over time. RIDOT should be consulted for current information on stream crossing replacement funding.

14.5.1 Federal Funding Sources

- NOAA Coastal Resiliency Grants
- NOAA Community-Based Coastal and Marine Habitat Restoration Grants
- Southeast New England Program (SNEP) Watershed Grants
- Eastern Brook Trout Joint Venture
- HUD Community Development Block Grants
- Army Corps of Engineers Aquatic Ecosystem Restoration Program
- NFWF New England Forests and Rivers Fund
- USDA NRCS Funding Programs
    - Emergency Watershed Protection (EWP) Program
    - Watershed and Flood Prevention Operations Program
- FEMA Hazard Mitigation Assistance Grant Programs
    - Pre-Disaster Mitigation (PDM)
    - This program will be replaced by the Building Resilient Infrastructure and Communities (BRIC) program in 2020
    - Flood Mitigation Assistance (FMA)
    - Severe Repetitive Loss (SRL)
    - Hazard Mitigation Grant Program (HMGP)
    - Public Assistance (PA) Grants
        - FEMA post-disaster Public Assistance funding may be used to **improve rather than simply replace** stream crossings that sustain significant damage if the state or municipality has **adopted,** implemented**, and** consistently applied a set of guidelines prior to the disaster (Levine, 2013).

14.5.2 State Funding Sources

- Narragansett Bay and Watersheds Restoration Fund (BWRF)
- CRMC Coastal Habitat Restoration Program
- Rhode Island Infrastructure Bank
- Rhode Island Green Economy Bond

14.5.3 Other Funding Sources

- National Wild and Scenic Rivers System
- National Fish and Wildlife Foundation (NFWF) National Coastal Resilience Fund Grant Program

14.6 Incorporating Priority Stream Crossings into Hazard Mitigation Planning

Priority stream crossings identified using the methodologies outlined in this Handbook, particularly crossings identified as high- and medium-priority, should be incorporated into local and state-wide hazard mitigation planning. Communities that have completed a stream crossing assessment and incorporated priority stream crossings into FEMA-approved Hazard Mitigation Plans (HMPs) are eligible to apply for FEMA Hazard Mitigation Assistance funding for crossing upgrades identified in their plans. In order for road-stream crossing replacement or upgrade projects to be eligible for Hazard Mitigation Assistance funding, crossing upgrade priorities need to be included in the HMPs before floods occur.

The Importance of Partnerships

Establishing partnerships between municipalities, watershed groups, and other conservation organizations, as well as state and federal agencies, can:

- allow better leveraging of funding, especially where funding sources require a match amount,
- bring together people with different backgrounds and varying levels of expertise to help inform an effective stream crossing replacement strategy and to provide the most beneficial solution to stakeholders, and
- spread the workload of managing and completing project elements, allowing work to proceed in a timely manner even if individual stakeholder resources are limited.

Section 15: References

Bent, G.C., Steeves, P., & Waite A.M. (2014). Equations for Estimating Selected Streamflow Statistics in Rhode Island. *U.S. Geological Survey Scientific Investigations Report 2014-5010*. Prepared for the United States Geological Survey. Retrieved from https://pubs.usgs.gov/sir/2014/5010/

Bent, G.C. & Waite, A.M. (2013). Equations for Estimating Bankfull Channel Geometry and Discharge for Streams in Massachusetts. *Scientific Investigations Report 2013-5155.* Retrieved from https://pubs.usgs.gov/sir/2013/5155/pdf/sir2013-5155.pdf

Bentley. (n.d.). *CulvertMaster User Manual*. Link.

Dupigny-Giroux, L.A., Mecray, E.L., Lemcke-Stampone, M.D., Hodgkins, G.A., Lentz, E.E., Mills, K.E., Lane, E.D., Miller, R., Hollinger, D.Y., Solecki, W.D., Wellenius, G.A., Sheffield, P.E., MacDonald, A.B., & Caldwell, C. (2018). Chapter 18: Northeast. In D.R Reidmiller, C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, & B.C. Stewart (Eds.), *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* (pp. 669-742). U.S. Global Change Research Program, Washington, DC, USA. Retrieved from https://nca2018.globalchange.gov/chapter/18/

Emerson, D.G, A.V. Vecchia, & A.L. Dahl. (2005). *Evaluation of Drainage-Area Ratio Method Used to Estimate Streamflow for the Red River of the North Basin, North Dakota, and Minnesota*. Scientific Investigations Report 2005-5017. Developed for the USGS in cooperation with the Bureau of Reclamation. Retrieved from https://pubs.usgs.gov/sir/2005/5017/pdf/sir20055017.pdf

Federal Highway Administration, U.S. Department of Transportation. (2012). *Hydraulic Design of Highway Culverts, Third Edition.* Retrieved from https://www.fhwa.dot.gov/engineering/hydraulics/pubs/12026/hif12026.pdf

Gillespie, N., Unthank, A., Campbell, L., Anderson, P., Gubernick, R., Weinhold, M., et al. (February 2014). Flood Effects on Road-Stream Crossing Infrastructure: Economic and Ecological Benefits of Stream Simulation Designs. Fisheries, 39(2), 62-76.

Georgia Department of Natural Resources. (2002). Adopt-A-Stream "Visual Stream Survey" manual.

Industrial Economics, Incorporated. (January 2015). Community Benefits of Stream Barrier Removal Projects in Massachusetts: Costs and Benefits at Six Sites. Massachusetts Department of Fish and Game, Division of Ecological Restoration. Retrieved from https://www.mass.gov/files/documents/2016/08/wq/phase-iii-benefits-from-stream-barrier-removal-projects.pdf

Levine, J. (2013). *An Economic Analysis of Improved Road-Stream Crossings.* Prepared for The Nature Conservancy, Adirondack Chapter. Retrieved from https://www.cwicny.org/files/Road-Stream%20Crossing%20Economic%20Analysis.pdf

Massachusetts Division of Ecological Restoration (MADER). (2012). *Massachusetts Stream Crossing Handbook*. Massachusetts Department of Fish and Game, Division of Ecological Restoration. Retrieved from https://www.mass.gov/files/documents/2018/08/23/Stream%20Crossings%20booklet%20Web.pdf

Massachusetts Department of Transportation (MassDOT) and University of Massachusetts Amherst. (n.d.; unpublished). Development of Pilot Extreme Flood Vulnerability Assessment Protocols Under Present and Future Climatic Conditions for Roadway Stream Crossing Structures within the Deerfield River Watershed, Massachusetts.

National Park Service. (n.d). *Mount Rainier*. Retrieved from https://www.nps.gov/mora/learn/index.htm

Norman, J. M., Houghtalen, R.J., & Johnston, W.J. (2001). *Hydraulic Design of Highway Culverts, Second Edition*. Prepared for the Federal Highway Administration. Revised May 2005. Retrieved from https://www.fs.fed.us/biology/nsaec/fishxing/fplibrary/FHWA_2005_Hydraulic_design_of_highway_culverts.pdf

North Atlantic Aquatic Connectivity Collaborative (NAACC). Culvert Condition Assessment Manual (CCAM).

North Atlantic Aquatic Connectivity Collaborative (NAACC). (2015). Scoring Road-Stream Crossings. Retrieved from http://streamcontinuity.org/sites/streamcontinuity.org/files/pdf-doc-ppt/NAACC%20Aquatic%20Passability%20Scoring%206-16-16.pdf

North Atlantic Aquatic Connectivity Collaborative (NAACC). (n.d.). *Structural Condition Module*. Unpublished module.

North Atlantic Aquatic Connectivity Collaborative (NAACC). (n.d.). *Tidal Module*. Unpublished module.

North Atlantic Aquatic Connectivity Collaborative (NAACC), including University of Massachusetts Amherst, The Nature Conservancy, and the U.S. Fish and Wildlife Service. (2016). *Stream Crossing Survey Data Form Instruction Guide Version 1.2*. Retrieved from http://streamcontinuity.org/sites/streamcontinuity.org/files/pdf-doc-ppt/NAACC_Instructions%20for%20Field%20Data%20Form%205-22-16.pdf

Purinton, T.A. & Mountain, D.C. (1996). *Tidal Crossing Handbook: A Volunteer Guide to Assessing Tidal Restrictions*. Prepared for the Parker River Clean Water Association. Retrieved from http://pie-rivers.org/documents/TidalCrossingHandbook_1996.pdf

Rhode Island Coastal Resources Management Center (CRMC). (n.d.). *Rhode Island Shoreline Change Special Area Management Plan – STORMTOOLS*. Retrieved from http://www.beachsamp.org/stormtools/

Rhode Island Department of Environmental Management (RIDEM). (2007). *Rules and Regulations Governing the Administration and Enforcement of the Freshwater Wetlands Act.* Retrieved from http://www.dem.ri.gov/pubs/regs/regs/water/wetlnd07.pdf

Rhode Island Department of Environmental Management (RIDEM) and Coastal Resources Management Council (CRMC). (2015*). Rhode Island Stormwater Design and Installation Standards Manual.* Retrieved from http://www.dem.ri.gov/pubs/regs/regs/water/swmanual15.pdf

Rhode Island Department of Transportation (RIDOT). (2013). *Bridge Inspection Manual.* Retrieved from http://www.dot.ri.gov/documents/doingbusiness/RIDOT_Bridge_Inspection_Manual.pdf

Rhode Island Statewide Planning Program (RISPP). (2015). *Technical Paper 164: Vulnerability of Transportation Assets to Sea Level Rise*. Retrieved from http://www.planning.ri.gov/documents/sea_level/2015/TP164.pdf

Rhode Island Statewide Planning Program (RISPP). (2016). *Technical Paper 167: Vulnerability of Municipal Transportation Assets to Sea Level Rise and Storm Surge.* Retrieved from http://www.planning.ri.gov/documents/sea_level/2016/TP167.pdf

Schall, J.D., P.L. Thompson, S.M. Zerges, R.T. Kilgore, & J.L. Morris. (2012.) *Hydraulic Design Series Number 5: Hydraulic Design of Highway Culverts, Third Edition*. Prepared for the Federal Highway Administration Office of Bridge Technology and the National Highway Institute. Publication No. FHWA-HIF-12-026. Retrieved from https://www.fhwa.dot.gov/engineering/hydraulics/pubs/12026/hif12026.pdf

State of Rhode Island. (2018). *Rhode Island Statewide Climate Resilience Action Strategy.* Retrieved from http://climatechange.ri.gov/documents/resilientrhody18.pdf

Steckler, P., Lucey, K., Burdick, B., Glode, J., & Flanagan, S. (2017). *New Hampshire's Tidal Crossing Assessment Protocol*. Prepared for the New Hampshire Department of Environmental Services Coastal Program, Concord, NH. Revised

June 2018. Retrieved from https://northeastoceancouncil.org/wp-content/uploads/2017/09/nh-tidal-crossing-assessment-protocol.pdf

Sweet, W.V., R.E. Kopp, C.P. Weaver, J. Obeysekera, R.M. Horton, E.R. Thieler, C. Zervas. (January 2017). *NOAA Technical Report NOS CO-OPS 083: Global and Regional Sea Level Rise Scenarios for the United States.* Retrieved from https://tidesandcurrents.noaa.gov/publications/techrpt83_Global_and_Regional_SLR_Scenarios_for_the_US_final.pdf

United States Department of Agriculture (USDA). (n.d.). WinTR-20 User Manual. Retrieved from https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=18654.wba

United States Department of Transportation – Federal Highway Administration. (n.d.). HY-8 User Manual. Retrieved from https://www.fhwa.dot.gov/engineering/hydraulics/software/hy8/

United States Environmental Protection Agency (US EPA). (n.d.). *Climate Resilience Evaluation and Awareness Tool (CREAT) Climate Scenarios Projection Map*. Retrieved from https://epa.maps.arcgis.com/apps/MapSeries/index.html?appid=3805293158d54846a29f750d63c6890e

United States Forest Service (USFS). (n.d.). Manning's n Values. Retrieved from http://www.fsl.orst.edu/geowater/FX3/help/FX3_Help.html#8_Hydraulic_Reference/Mannings_n_Tables.htm

United States Forest Service (USFS). (2008). *STREAM SIMULATION: An Ecological Approach to Providing Passage for Aquatic Organisms at Road-Stream Crossings.* Prepared by the Forest Service Stream-Simulation Working Group in partnership with the U.S. Department of Transportation, Federal Highway Administration Coordinated Federal Lands Highway Technology Implementation Program. 7700—Transportation Mgmt 0877 1801—SDTDC. Retrieved from https://www.fs.fed.us/eng/pubs/pdf/StreamSimulation/hi_res/%20FullDoc.pdf

University of Rhode Island (URI). (n.d.). *Rhode Island's Coastal Habitats.* Retrieved from http://www.edc.uri.edu/restoration/html/intro/salt.htm

Vallee, D. and L. Giuliano. (2014). *Overview of a Changing Climate in Rhode Island.* Retrieved from http://research3.fit.edu/sealevelriselibrary/documents/doc_mgr/444/Valee%20&%20Giuliano.%202014.%20CC%20in%20Rhode%20Island%20Overview.pdf

Vogel, R.M., Yaindl, c., & Walter, M. (2011). Nonstationarity: Flood Magnification and Recurrence Reduction Factors in the United States. *Journal of the American Water Resources Association,* 47(3):464-474. Retrieved from https://doi.org/10.1111/j.1752-1688.2011.00541.x

Walter, M. &Vogel, R.M. (2010). Increasing Trends in Peak Flows in the Northeastern United States and Their Impacts on Design. *Second Joint Federal Interagency Conference, Las Vegas, NV, June 27-July 1, 2010.* Retrieved from https://acwi.gov/sos/pubs/2ndJFIC/Contents/2F_Walter_03_01_10.pdf

Zarriello, P.J., Ahearn, E.A., & Levin, S.B. (2012). Magnitude of flood flows for selected annual exceedance probabilities in Rhode Island through 2010. *U.S. Geological Survey Scientific Investigations Report 2012–5109.* Revised March 2013. Retrieved from http://pubs.usgs.gov/sir/2012/5109

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Appendix A: Field Data Form

This Appendix contains a field data form that can be printed for use in the field. Extra printed forms should be taken into the field even if the field crew will primarily use the digital field form for field data collection, in case the mobile device being used breaks or runs low on battery. If possible, print field data forms on waterproof paper to facilitate their use in wet conditions.

Road-Stream Crossing Assessment Field Data Form

QA/QC INITIALS:________ DATE:________

Status ____FINAL ____FOLLOW-UP

CROSSING DATA

pp. 4-5

Crossing Code ____________ **State or Local ID/Name** ____________ **Date** ________ **Start Time** ________ AM / PM

Lead Field Data Collector ____________ **Asst. Field Data Collectors** ____________ **End Time** ________ AM / PM

Municipality ____________ **County** ____________ **Stream** ____________

Road ____________ **Type** ☐ MULTI-LANE ☐ PAVED ☐ UNPAVED ☐ DRIVEWAY ☐ TRAIL ☐ RAILROAD

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

Location Description ____________

____

pp. 5-9

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

Number of Culverts / Cells

Photo #______ INLET **Photo #**______ OUTLET **Photo #**______ ____________ **Photo #**______ ____________

Photo #______ UPSTREAM **Photo #**______ DOWNSTREAM **Photo #**______ ____________ **Photo #**______ ____________

Photo #______ ROADWAY **Photo #**______ ____________ **Photo #**______ ____________ **Photo #**______ ____________

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

Road-Killed or Observed Wildlife ____________ **or None**

Utilities ☐ OVERHEAD WIRES ☐ WATER PIPES ☐ SEWER PIPES ☐ GAS LINE ☐ NONE ☐ OTHER____________

pp. 8-12

Alignment ☐ SHARP BEND ☐ MILD BEND ☐ NATURALLY STRAIGHT ☐ CHANNELIZED STRAIGHT

Road Fill Height ________ **Road Crest Height** ________

Bankfull Width______ **Confidence** ☐ HIGH ☐ LOW/ESTIMATED

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

Tailwater Scour Pool ☐ NONE ☐ SMALL ☐ LARGE

HY-8

pp. 8, 14-15

Using HY-8? ☐ YES ☐ NO **Estimated Overtopping Length** ________ **Crest Width** ________

Road Surface Type ☐ PAVED ☐ GRAVEL ☐ GRASS

Channel Slope________

Side Slope ☐ 5:1 ☐ 4:1 ☐ 3:1 ☐ 2:1 ☐ 1:1 ☐ 0.5:1 ☐ steeper than 0.5:1

GEO.

pp. 12-13

Bank Erosion ☐ HIGH ☐ LOW ☐ ESTIMATED ☐ NONE

Significant Break in Valley Slope ☐ YES ☐ NO ☐ UNKNOWN

Sediment Deposition ☐ UPSTREAM ☐ DOWNSTREAM ☐ WITHIN STRUCTURE ☐ NONE

Stream Substrate ☐ MUCK/SILT ☐ SAND ☐ GRAVEL ☐ COBBLE ☐ BOULDER ☐ BEDROCK ☐ UNKNOWN

Elevation of Sediment Deposits >= 1/2 Bankfull Height ☐ YES ☐ NO

TIDAL

pp. 16-17

Tidal? ☐ YES ☐ NO ☐ UNKNOWN

Tide Chart Location ____________

Tide Prediction ____:____ AM / PM

Tide Stage ☐ LOW SLACK TIDE ☐ LOW EBB TIDE ☐ LOW FLOOD TIDE ☐ UNKNOWN ☐ OTHER ____________

Vegetation Above/Below ☐ COMPARABLE ☐ SLIGHTLY DIFFERENT ☐ MODERATELY DIFFERENT ☐ VERY DIFFERENT ☐ UNKNOWN

Tide Gate Type ☐ NONE ☐ STOP LOGS ☐ FLAP GATE ☐ SLUICE GATE ☐ SELF-REGULATING ☐ OTHER____________

CROSSING COMMENTS

pp. 14

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FORM PUBLISHED: JULY 24, 2019

STRUCTURE 1

pp. 18-32

OUTLET

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

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

Outlet Grade (Pick one) ☐ AT STREAM GRADE ☐ FREE FALL ☐ CASCADE ☐ FREE FALL ONTO CASCADE ☐ 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)____________.____ **OUTLET ELEVATION** __________.____

INLET

pp. 32-39

Inlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED **INLET ELEVATION** __________.____

Inlet Type ☐ PROJECTING ☐ HEADWALL WITH SQUARE EDGE ☐ HEADWALL WITH GROOVED EDGE ☐ HEADWALL WITH SQUARE EDGE AND WINGWALLS ☐ HEADWALL WITH GROOVED/BEVELED EDGE AND WINGWALLS ☐ MITERED TO SLOPE ☐ OTHER ☐ NO INLET TREATMENT

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

pp. 20-21, 40-50

Slope % ____________ **Slope Confidence** ☐ HIGH ☐ LOW **Internal Structures** ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER________

Structure Slope Compared to Channel Slope ☐ HIGHER ☐ LOWER ☐ ABOUT THE SAME

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**____________

STRUCTURAL CONDITION ASSESSMENT

pp. 52-66

	INLET					OUTLET				
	Adequate	Poor	Critical	Unknown	N/A	Adequate	Poor	Critical	Unknown	N/A
Cross Section Deformation										
Barrel Condition/ Structural Integrity										
Footing Condition										
Level of Blockage										
Buoyancy or Crushing										
Invert Deterioration										
Joints and Seams Condition										
Longitudinal Alignment										
Headwall/Wingwall Condition										
Flared End Section Condition										
Apron/Scour Protection Condition										
Armoring Condition										
Embankment Piping										

STRUCTURE COMMENTS

pp. 20

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FORM PUBLISHED: JULY 24, 2019

STRUCTURE 2

pp. 18-32

OUTLET

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

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

Outlet Grade (Pick one) ☐ AT STREAM GRADE ☐ FREE FALL ☐ CASCADE ☐ FREE FALL ONTO CASCADE ☐ 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)_____________.____ **OUTLET ELEVATION** __________.____

INLET

pp. 32-39

Inlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED **INLET ELEVATION** __________.____

Inlet Type ☐ PROJECTING ☐ HEADWALL WITH SQUARE EDGE ☐ HEADWALL WITH GROOVED EDGE ☐ HEADWALL WITH SQUARE EDGE AND WINGWALLS ☐ HEADWALL WITH GROOVED/BEVELED EDGE AND WINGWALLS ☐ MITERED TO SLOPE ☐ OTHER ☐ NO INLET TREATMENT

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

pp. 20-21, 40-50

Slope % __________ **Slope Confidence** ☐ HIGH ☐ LOW **Internal Structures** ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER________

Structure Slope Compared to Channel Slope ☐ HIGHER ☐ LOWER ☐ ABOUT THE SAME

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**__________

STRUCTURAL CONDITION ASSESSMENT

pp. 52-66

	INLET					OUTLET				
	Adequate	Poor	Critical	Unknown	N/A	Adequate	Poor	Critical	Unknown	N/A
Cross Section Deformation										
Barrel Condition/ Structural Integrity										
Footing Condition										
Level of Blockage										
Buoyancy or Crushing										
Invert Deterioration										
Joints and Seams Condition										
Longitudinal Alignment										
Headwall/Wingwall Condition										
Flared End Section Condition										
Apron/Scour Protection Condition										
Armoring Condition										
Embankment Piping										

STRUCTURE COMMENTS

pp. 20

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STRUCTURE 3

OUTLET

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

pp. 18-32

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

Outlet Grade (Pick one) ☐ AT STREAM GRADE ☐ FREE FALL ☐ CASCADE ☐ FREE FALL ONTO CASCADE ☐ 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)________.____ **OUTLET ELEVATION** ________.____

INLET

Inlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED **INLET ELEVATION** ________.____

pp. 32-39

Inlet Type ☐ PROJECTING ☐ HEADWALL WITH SQUARE EDGE ☐ HEADWALL WITH GROOVED EDGE ☐ HEADWALL WITH SQUARE EDGE AND WINGWALLS ☐ HEADWALL WITH GROOVED/BEVELED EDGE AND WINGWALLS ☐ MITERED TO SLOPE ☐ OTHER ☐ NO INLET TREATMENT

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 % ____________ **Slope Confidence** ☐ HIGH ☐ LOW **Internal Structures** ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER________

pp. 20-21, 40-50

Structure Slope Compared to Channel Slope ☐ HIGHER ☐ LOWER ☐ ABOUT THE SAME

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**____________

STRUCTURAL CONDITION ASSESSMENT

pp. 52-66

	INLET					OUTLET				
	Adequate	Poor	Critical	Unknown	N/A	Adequate	Poor	Critical	Unknown	N/A
Cross Section Deformation										
Barrel Condition/ Structural Integrity										
Footing Condition										
Level of Blockage										
Buoyancy or Crushing										
Invert Deterioration										
Joints and Seams Condition										
Longitudinal Alignment										
Headwall/Wingwall Condition										
Flared End Section Condition										
Apron/Scour Protection Condition										
Armoring Condition										
Embankment Piping										

STRUCTURE COMMENTS

pp. 20

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STRUCTURE 4

pp. 18-32

OUTLET

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

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

Outlet Apron ☐ NONE ☐ NOT EXTENSIVE ☐ EXTENSIVE

Outlet Grade (Pick one) ☐ AT STREAM GRADE ☐ FREE FALL ☐ CASCADE ☐ FREE FALL ONTO CASCADE ☐ 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)______________.____

OUTLET ELEVATION ____________.____

INLET

pp. 32-39

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

INLET ELEVATION ____________.____

Inlet Type ☐ PROJECTING ☐ HEADWALL WITH SQUARE EDGE ☐ HEADWALL WITH GROOVED EDGE ☐ HEADWALL WITH SQUARE EDGE AND WINGWALLS ☐ HEADWALL WITH GROOVED/BEVELED EDGE AND WINGWALLS ☐ MITERED TO SLOPE ☐ OTHER ☐ NO INLET TREATMENT

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

pp. 20-21, 40-50

Slope % ______________ **Slope Confidence** ☐ HIGH ☐ LOW

Internal Structures ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER__________

Structure Slope Compared to Channel Slope ☐ HIGHER ☐ LOWER ☐ ABOUT THE SAME

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_____________

STRUCTURAL CONDITION ASSESSMENT

pp. 52-66

	INLET					OUTLET				
	Adequate	Poor	Critical	Unknown	N/A	Adequate	Poor	Critical	Unknown	N/A
Cross Section Deformation										
Barrel Condition/ Structural Integrity										
Footing Condition										
Level of Blockage										
Buoyancy or Crushing										
Invert Deterioration										
Joints and Seams Condition										
Longitudinal Alignment										
Headwall/Wingwall Condition										
Flared End Section Condition										
Apron/Scour Protection Condition										
Armoring Condition										
Embankment Piping										

STRUCTURE COMMENTS

pp. 20

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STRUCTURE 5

OUTLET

pp. 18-32

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

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

Outlet Apron ☐ NONE ☐ NOT EXTENSIVE ☐ EXTENSIVE

Outlet Grade (Pick one) ☐ AT STREAM GRADE ☐ FREE FALL ☐ CASCADE ☐ FREE FALL ONTO CASCADE ☐ 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)_____________.____

OUTLET ELEVATION ___________.____

INLET

pp. 32-39

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

INLET ELEVATION ___________.____

Inlet Type ☐ PROJECTING ☐ HEADWALL WITH SQUARE EDGE ☐ HEADWALL WITH GROOVED EDGE ☐ HEADWALL WITH SQUARE EDGE AND WINGWALLS ☐ HEADWALL WITH GROOVED/BEVELED EDGE AND WINGWALLS ☐ MITERED TO SLOPE ☐ OTHER ☐ NO INLET TREATMENT

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

pp. 20-21, 40-50

Slope % ____________ **Slope Confidence** ☐ HIGH ☐ LOW

Internal Structures ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER________

Structure Slope Compared to Channel Slope ☐ HIGHER ☐ LOWER ☐ ABOUT THE SAME

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**____________

STRUCTURAL CONDITION ASSESSMENT

pp. 52-66

	INLET					OUTLET				
	Adequate	Poor	Critical	Unknown	N/A	Adequate	Poor	Critical	Unknown	N/A
Cross Section Deformation										
Barrel Condition/ Structural Integrity										
Footing Condition										
Level of Blockage										
Buoyancy or Crushing										
Invert Deterioration										
Joints and Seams Condition										
Longitudinal Alignment										
Headwall/Wingwall Condition										
Flared End Section Condition										
Apron/Scour Protection Condition										
Armoring Condition										
Embankment Piping										

STRUCTURE COMMENTS

pp. 20

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STRUCTURE 6

pp. 18-32

OUTLET

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

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

Outlet Grade (Pick one) ☐ AT STREAM GRADE ☐ FREE FALL ☐ CASCADE ☐ FREE FALL ONTO CASCADE ☐ 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)________.___ **OUTLET ELEVATION** ________.___

INLET

pp. 32-39

Inlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED **INLET ELEVATION** ________.___

Inlet Type ☐ PROJECTING ☐ HEADWALL WITH SQUARE EDGE ☐ HEADWALL WITH GROOVED EDGE ☐ HEADWALL WITH SQUARE EDGE AND WINGWALLS ☐ HEADWALL WITH GROOVED/BEVELED EDGE AND WINGWALLS ☐ MITERED TO SLOPE ☐ OTHER ☐ NO INLET TREATMENT

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

pp. 20-21, 40-50

Slope % ________ **Slope Confidence** ☐ HIGH ☐ LOW **Internal Structures** ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER________

Structure Slope Compared to Channel Slope ☐ HIGHER ☐ LOWER ☐ ABOUT THE SAME

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**________

STRUCTURAL CONDITION ASSESSMENT

pp. 52-66

	INLET					OUTLET				
	Adequate	Poor	Critical	Unknown	N/A	Adequate	Poor	Critical	Unknown	N/A
Cross Section Deformation										
Barrel Condition/ Structural Integrity										
Footing Condition										
Level of Blockage										
Buoyancy or Crushing										
Invert Deterioration										
Joints and Seams Condition										
Longitudinal Alignment										
Headwall/Wingwall Condition										
Flared End Section Condition										
Apron/Scour Protection Condition										
Armoring Condition										
Embankment Piping										

STRUCTURE COMMENTS

pp. 20

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STRUCTURE 7

pp. 18-32

OUTLET

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

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

Outlet Grade (Pick one) ☐ AT STREAM GRADE ☐ FREE FALL ☐ CASCADE ☐ FREE FALL ONTO CASCADE ☐ 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)______________.____ **OUTLET ELEVATION** ____________.____

INLET

pp. 32-39

Inlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED **INLET ELEVATION** ____________.____

Inlet Type ☐ PROJECTING ☐ HEADWALL WITH SQUARE EDGE ☐ HEADWALL WITH GROOVED EDGE ☐ HEADWALL WITH SQUARE EDGE AND WINGWALLS ☐ HEADWALL WITH GROOVED/BEVELED EDGE AND WINGWALLS ☐ MITERED TO SLOPE ☐ OTHER ☐ NO INLET TREATMENT

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

pp. 20-21, 40-50

Slope % ______________ **Slope Confidence** ☐ HIGH ☐ LOW **Internal Structures** ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER__________

Structure Slope Compared to Channel Slope ☐ HIGHER ☐ LOWER ☐ ABOUT THE SAME

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**______________

STRUCTURAL CONDITION ASSESSMENT

pp. 52-66

	INLET					OUTLET				
	Adequate	Poor	Critical	Unknown	N/A	Adequate	Poor	Critical	Unknown	N/A
Cross Section Deformation										
Barrel Condition/ Structural Integrity										
Footing Condition										
Level of Blockage										
Buoyancy or Crushing										
Invert Deterioration										
Joints and Seams Condition										
Longitudinal Alignment										
Headwall/Wingwall Condition										
Flared End Section Condition										
Apron/Scour Protection Condition										
Armoring Condition										
Embankment Piping										

STRUCTURE COMMENTS

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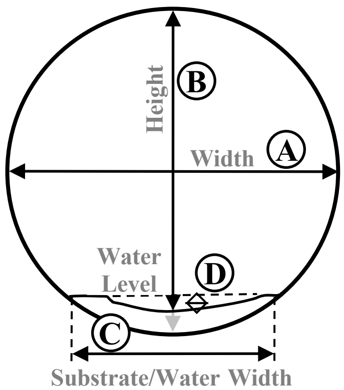
Structure Shape & Dimensions

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 appropriate 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.

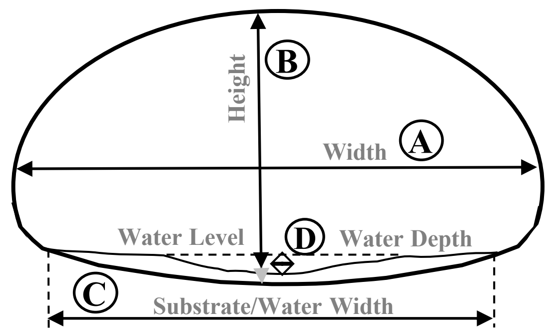
NOTE: Culverts 1, 2 & 4 may or may not have substrate in them, so height measurements (B) are taken from the level of the "stream bed", whether that bed is composed of substrate or just the inside bottom surface of a culvert (grey arrows below show measuring to bottom, black arrows show measuring to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

1



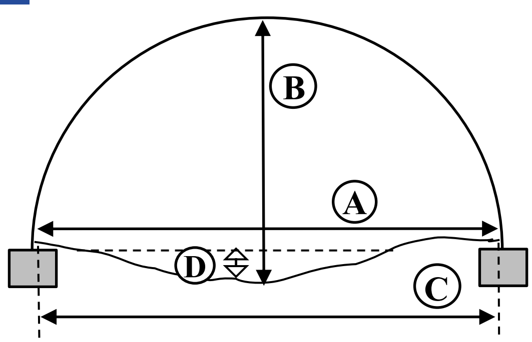
Round Culvert

2



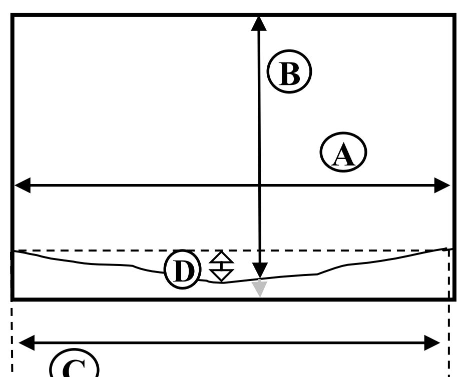
Pipe Arch/Elliptical Culvert

3



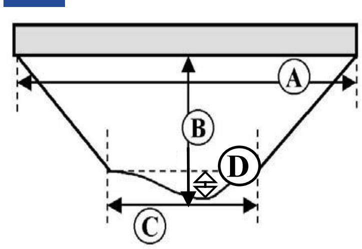
Open Bottom Arch Bridge/Culvert

4



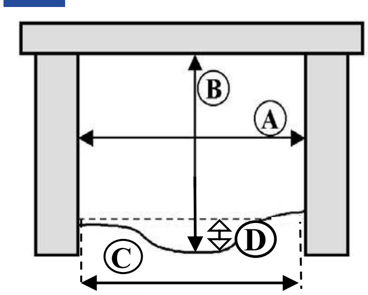
Box Culvert

5



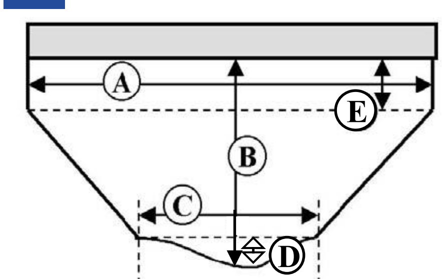
Bridge with Side Slopes

6



Box/Bridge with Abutments

7



Bridge with Abutments and Side Slopes

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Appendix B: Field Equipment List

This Appendix provides a checklist of the field equipment recommended for use in completing road-stream crossing surveys.

B.1 Field Equipment

- ☐ Mobile Device with Survey123 application and RIDOT Road-Stream Crossing Assessment Form downloaded
- ☐ Extra Batteries and/or Charger(s) for Mobile Device
- ☐ Paper Field Data Forms on Waterproof Paper (Bring extra even if you plan to use a mobile device for data collection)
- ☐ Maps of Crossings Printed on Waterproof Paper
- ☐ Clipboards
- ☐ Pens and/or Pencils appropriate for Waterproof Paper used for Printed Maps and Forms (Bring extra)
- ☐ Digital Camera and Extra Batteries/Charger
- ☐ GPS Receiver Accurate within a Maximum of 3 Meters and Extra Batteries/Charger
- ☐ 100-Foot Reel Tape (in feet and tenths)
- ☐ 6-Foot Pocket Tape (in feet and tenths)
- ☐ 16-Foot or 25-foot (25-foot is recommended) Stadia Rod
- ☐ Survey Level/Equipment
- ☐ Safety Vests and Cones
- ☐ Waders or Hip Boots (Chest waders are recommended)
- ☐ Flashlight and/or Headlamp
- ☐ Rangefinder Accurate within a Maximum of 1 Foot (Optional)
- ☐ Pocket Calculator
- ☐ Sun, Insect, and Poison Ivy Protection
- ☐ First Aid Kit
- ☐ Cell Phone

Appendix C: Field Safety

This Appendix provides a sample Job Hazard Analysis (JHA) and a copy of the Rhode Island Department of Environmental Management Standard Operating Procedure (SOP) for General Safety During Fieldwork. These documents should be reviewed and filled out, as appropriate, before conducting road-stream crossing assessment fieldwork.

C.1 Job Hazard Analysis

A new Job Hazard Analysis (JHA) should be completed for each separate road-stream crossing assessment project. A **sample** JHA is attached to this document. The JHA should be updated to reflect project-specific conditions and hazards, and should be reviewed and signed by all Lead and Assistant Field Data Collectors. This document is meant to force each field crew member to stop and think about the hazards they may encounter, but should also be taken into the field with the field team as it will include local emergency contact phone numbers (if properly filled out).

C.2 RIDEM Safety SOP

This Appendix also includes a copy of the Rhode Island Department of Environmental Management (RIDEM) *Standard Operating Procedure (SOP) for General Safety During Fieldwork*. This document may be used as a reference regarding potential field hazards and their avoidance.

Job Hazard Analysis (JHA)
Road-Stream Crossing Assessment Field Data Collection

PROJECT / PROJECT LOCATION:	DATE:	☒ NEW ☐ REVISED

PROJECT / TASK NUMBER:	**TASK ACTIVITY:** Road-stream crossing assessment	**TASK DESCRIPTION:** Field data collection in support of road-stream crossing assessments	
PREPARER(S)	REVIEWED BY	PROJECT CONTACT	EMERGENCY CONTACT
			Emergency - 911 Police(non-emergency) - Fire Department -

MINIMUM REQUIRED PERSONAL PROTECTIVE EQUIPMENT (SEE CRITICAL ACTIONS FOR TASK-SPECIFIC REQUIREMENTS)

☒ HIGH VISIBILITY SAFETY VEST ☒ HARD HAT ☐ LIFELINE / BODY HARNESS ☐ SAFETY GLASSES	☐ GOGGLES ☐ FACE SHIELD ☐ HEARING PROTECTION ☒ SAFETY SHOES ☒ CELL PHONE	☒ WADERS OR HIP BOOTS ☐ PPE CLOTHING TYPE: _______________ ☒ LIFE JACKET (PFD) ☒ FIRST AID KIT	☒ GLOVES (Type: Cold Weather) ☒ FIRE EXTINGUISHER ☒ CONES ☒ OTHER Sunscreen, Insect Repellant, Hand Sanitizer, Specialty Products for Poisonous Plants

JOB STEPS	POTENTIAL HAZARDS	CRITICAL ACTIONS
Site Access	Trip hazards, fall hazard from embankment or structure, wet rocks in the channel, poisonous plants, insects, sunburn, threatening persons, wildlife.	Wear safety vests, and safety boots, wear sunscreen, insect repellent, use specialty products to reduce the potential for irritation from poisonous plants. Verify stability of boulders in channels before crossing, have cell phone on hand. Avoid wildlife, rabid or threatened animals can be dangerous. Leave the site if you perceive a threat.
General Safety	Heat/cold exposure, lightning, transporting equipment, low-ceilinged crossing structures.	Wear weather-appropriate clothing including rain gear and/or winter clothing. Bring sufficient water, a hat and sunscreen to stay hydrated and protected from the sun. Reschedule field work in the event of lightning. Lift equipment safely; do not try to lift equipment that is too heavy and split up loads instead. Wear hardhats where necessary and do not enter crossing structures, especially if crossing strcutres are small or appear to be structurally compromised.
Utilities	Hitting overhead powerlines when survey rod is extended.	Assess area for overhead powerlines. Avoid using fully extended survey rod in areas where there is a potiential to hit overhead powerlines.
In-Stream Safety	Drowning, general near-water hazards, overtopping waders, tidal conditions, overhead hazards,contaminated water,	Wear a PFD when in more than 2 feet of water or when wearing waders. Move slowly to minimize falling; beware of substrate and variable water conditions, find stable footing and avoid slippery points. Do not wade too deep. Beware of changing conditions next to crossing structures, watch out for marine clay, deep tidal ditches or scour holes. Avoid contact with water if possible, use hand sanitizer if contact is unavoidable.

Traffic Control and Vehicle Safety	General roadway hazards, high-velocity vehicles.	Secure worksite with traffic controls where necessary. Wear high-visibility safety vest so you can be seen. Keep eyes open, watch and listen for oncoming traffic. Minimize work in high traffic areas.

Site-Specific Training Requirements: General roadway safety training, RIDEM Safety SOP

Job Hazard Analysis (JHA)
Road-Stream Crossing Assessment Field Data Collection

Field Team Member Review of JHA

I have read and understand the JHA and will comply with the provisions contained herein. All applicable RIDOT policies and requirements relative to traffic control will be followed at all times. Various permissions and safety protocols will be acquired/ followed based on crossing location and the type of road (e.g., municipal versus state-owned). All necessary permissions, protocols and information will be obtained from the appropriate municipal or state jurisdictions prior to mobilization.

Name Printed	Signature	Date

Rhode Island Department of Environmental Management
Office of Water Resources
235 Promenade Street, Providence RI 02908

TITLE AND APPROVAL PAGE

Standard Operating Procedure for General Safety During Fieldwork

SOP No.: WR-W-40
Revision No.: 0
Originator Name: Mark Nimiroski/Katie DeGoosh

APPROVALS:

Deputy Chief of Water Quality & Standards:

Sue Kiernan

______________________	______________________	__________
Printed Name	Signature	Date

RIDEM Quality Assurance Manager:

Richard Enander

______________________	______________________	__________
Printed Name	Signature	Date

TMDL Program

Elizabeth Scott

______________________	______________________	__________
Printed Name	Signature	Date

DISTRIBUTION

(x) Surface Water Monitoring & Assessment (Sue Kiernan) By:_____Date :_____

(x) TMDL Program (Elizabeth Scott) By:_____Date :_____

(x) Quality Assurance Manager, RIDEM (Richard Enander) By:_____Date :_____

Contents

1.0 APPLICABILITY

This SOP applies to all Office of Water Resources (OWR) Monitoring and Assessment staff involved in performing fieldwork. Exemption from the use of this SOP for project work shall be allowed for reasons of inapplicability determined by management discretion.

2.0 PURPOSE

This SOP establishes general safety protocols for working in the field. It sets a consistent method for safe collection of data in the field and explains the regulations and rationale behind each policy. Also provided are contact information, forms for proper documentation, and other information intended to assist field personnel in doing their jobs safely.

3.0 DEFINITIONS

3.1 RIDEM – Rhode Island Department of Environmental Management

3.2 OWR –Office of Water Resources

3.3 SOP – Standard Operating Procedure

3.4 QA – QUALITY ASSURANCE refers to a systematic process to ensure production of valuable, accurate, reliable, reproducible and defensible environmental data.

3.5 QC – QUALITY CONTROL refers to the activities performed to affirm production of valuable, accurate, reliable, reproducible and defensible environmental data.

3.6 QI – QUALITY IMPROVEMENT refers to any act or process performed to enhance the value, accuracy, reliability, reproducibility or defensibility of environmental data collected.

3.7 ANALYST refers to any RIDEM OWR staff and contractual staff working on RIDEM OWR projects conducting fieldwork including, but not limited to, scientists, engineers, and seasonal employees.

3.8 PROJECT MANAGER refers to any person or persons supervising RIDEM OWR personnel and contractual staff who are conducting fieldwork for RIDEM OWR projects.

4.0 RESPONSIBILITIES

4.1 TRAINING

RIDEM OWR staff who conduct fieldwork for any project or program should complete the RIDEM Quality System Awareness Training Program with appropriate documentation from the Quality Assurance Manager if available.

Many OWR staff will be working with boats, therefore it is suggested that they take the online boater education course which can be accessed at: http://www.boat-ed.com/ri/ri_internet.htm. Certification of this online training is not required.

It is recommended that one member of each field team should be trained in administering first aid. Training typically needs to be renewed every two years.

4.2 RESPONSIBILITIES OF ANALYST

The analyst is responsible for verifying that the necessary equipment is brought into the field, especially personal protective equipment such as proper clothing and shoes, boots, gloves, etc. It is the analyst's responsibility to confirm that this type of equipment, when provided by the project manager, is in proper working order and/or in appropriate amounts to provide safety for the entire field team. Should any equipment malfunction or require repair or reordering it is the responsibility of the analyst to inform the employer/project manager of any problems.

The analyst is required to use good judgment in assessing the safety of each field situation. Because conditions in the field can change rapidly, the safety of each work site cannot be assessed for all conditions in advance. If the analyst discovers a condition that does not allow work to be conducted safely at a site, it is their responsibility to notify the project manager so that action can be taken to ensure that work can be done safely, or suspended until conditions allow the work to be done safely.

It is the responsibility of the analyst to notify project managers of any training that has expired and needs to be renewed.

4.3 RESPONSIBILITIES OF THE PROJECT MANAGER

The project manager is responsible for providing the materials, resources, and/or guidance necessary to perform fieldwork in a safe manner. The project manager is responsible for ensuring that the analyst has the proper equipment for each station visit, and that the equipment is up to current standards and in proper operating condition. If the analyst finds a condition at a site that is unsafe, it is the responsibility of the project manager to take actions to allow work to be conducted safely. Such actions might include purchasing supplies or equipment or finding alternative sites. The project manager is responsible for ensuring that any necessary training is provided to the analyst. Further, the program manager shall ensure annual review and periodic revisions to this SOP as necessary to reflect current needs and standards as well as renew this SOP every five years.

5.0 QUALITY CONTROL

5.1 QUALITY ASSURANCE PLANNING CONSIDERATIONS

No standard quality assurance protocol exists for safety evaluation. At a minimum, this document should be reviewed after any incident to ensure that the procedures that were in place were properly followed. If necessary, they should be revised to prevent future incidents and new procedures that are needed should be incorporated into this plan.

6.0 GUIDELINES AND PROCEDURES

If an employee does not feel safe completing an assigned task, they should stop working and contact their direct supervisor. Every effort will be made to ensure that safe completion of the job is possible and any concerns will be addressed.

6.1 COMMUNICATION

Communication of planned work with team members and management is an essential part of any task that takes place outside of the office. In order to make sure that employees receive timely help in the event of an incident, a clear communications strategy needs to be in place ahead of time, particularly for cases where individuals do not report back when they were expected to. Any incidents need to be reported in a timely fashion as described below:

6.1.1 Teamwork

Generally, fieldwork is conducted in teams of at least two for safety reasons. In the event of accident, injury or sudden illness to one of the team members, there will be someone else available to help. Any illness or medical condition should be communicated to teammates, including any conditions that are only occurring on that day, such as dehydration or fatigue. However, due to privacy concerns, disclosure is only recommended, not required.

6.1.2 Daily Field Plan and Float Plan

The field plan is written documentation, completed by a member of the field crew before departure, which details the destination, vehicle (and boat if applicable), and crew of any planned field day. The field plan is designed to provide emergency personnel with the information that they need to locate people quickly, especially if staff are sick or injured and unable to seek help on their own. Filling out a field plan is required for any days when crews are heading out for field work. The basic information included on the form is: the type of car and boat (if applicable), personnel, and itinerary. Field plans should be posted in a common location. A supervisor or designee should be notified when personnel are heading out into the field, and also notified of their return. During field investigations requiring a boat, a float plan detailing further information should be filled out. A copy of a float plan is attached as Appendix B, or online at: http://www.floatplancentral.org/download/USCGFloatPlan.pdf

6.1.3 Emergency Contact Information

Copies of emergency contact information for field personnel should be kept in OWR near the field plan. Copies should also be brought into the field in case of an emergency. This information will be sealed and only used if necessary. The emergency contact forms are located in Appendix C.

6.1.4 Incident Reporting

In the event of an incident, such as an accident or injury during working hours, the project manager should be notified within 24 hours, and an incident/injury report (form S-41A) should be completed. A certificate of dependency status form, authorization for release of confidential information, and accident witness affidavit must be completed within 5 days of the incident. The appropriate forms and information are included in Appendix D. Additional information can be found at the State of Rhode Island Division of Human Resources http://www.hr.ri.gov/stateemployee/forms1/. Any questions you have regarding these forms can be answered by the Office Manager.

6.1.5 Important RIDEM Phone Numbers

Name	**Office**	**Extension**	**Cell**
Sue Kiernan	401-222-4700	7600	
Katie DeGoosh	401-222-4700	7211	401-575-7484
Jane Sawyers	401-222-4700	7239	319-331-7457
Mark Nimiroski	401-222-4700	7545	401-835-5632
Office Manager	401-222-4700	7214	
RIDEM Enforcement	401-222-2284 401-222-3070		

6.2 PHYSICAL HAZARDS

A variety of hazards exist associated with collecting environmental data in the field, and the descriptions below are meant to outline some of them. It is likely that hazards will be encountered that are not covered by the information below, so each employee needs to be aware of their surroundings.

6.2.1 First Aid Kit

Basic first aid kits will be provided and are an important part of any set of field supplies to ensure that minor injuries can be quickly treated. At least one member of each field team should be certified in first aid training. First aid kits will be restocked on a regular basis, however, if you find supplies are low, notify a supervisor.

6.2.2 Proper Attire and Personal Protective Equipment

Sturdy clothes and shoes should be worn when conducting fieldwork. Sandals and shorts are not as protective as boots and long pants against poison ivy, insect stings, briars, or acid splashes.

Equipment that will be provided to employees when necessary include: Work gloves, latex or nitrile gloves for sampling, chest or hip waders, life jackets, goggles, high visibility vests (for traffic or hunting season), and hard hats. If there is a piece of equipment that is needed to safely complete the job, contact the supervisor. Hats with brims/visors are not provided, but are encouraged on sunny days, particularly when working on boats.

6.2.3 Traffic

Distractions such as cell phones should be avoided while driving. Texting is prohibited and illegal. Excessive speed is never acceptable in a state vehicle. A manageable workload will be assigned so the job can be completed without having to rush from site to site.

When arriving at a worksite, the vehicle should be parked in a safe location, and the hazard lights should be turned on. Federal law requires the use of high-visibility safety apparel by all workers within the public right-of-ways of all roads open to public travel (USDOT-FHA, 2009). Awareness of local traffic is advised when stepping out of a vehicle at a work site.

Some sites will require the use of traffic cones. Supervisors will provide employees guidance on which sites require cones. A sample diagram of a traffic control plan has been provided (Figure 1). Examples of different work site set-ups are shown in Figures 2-4.

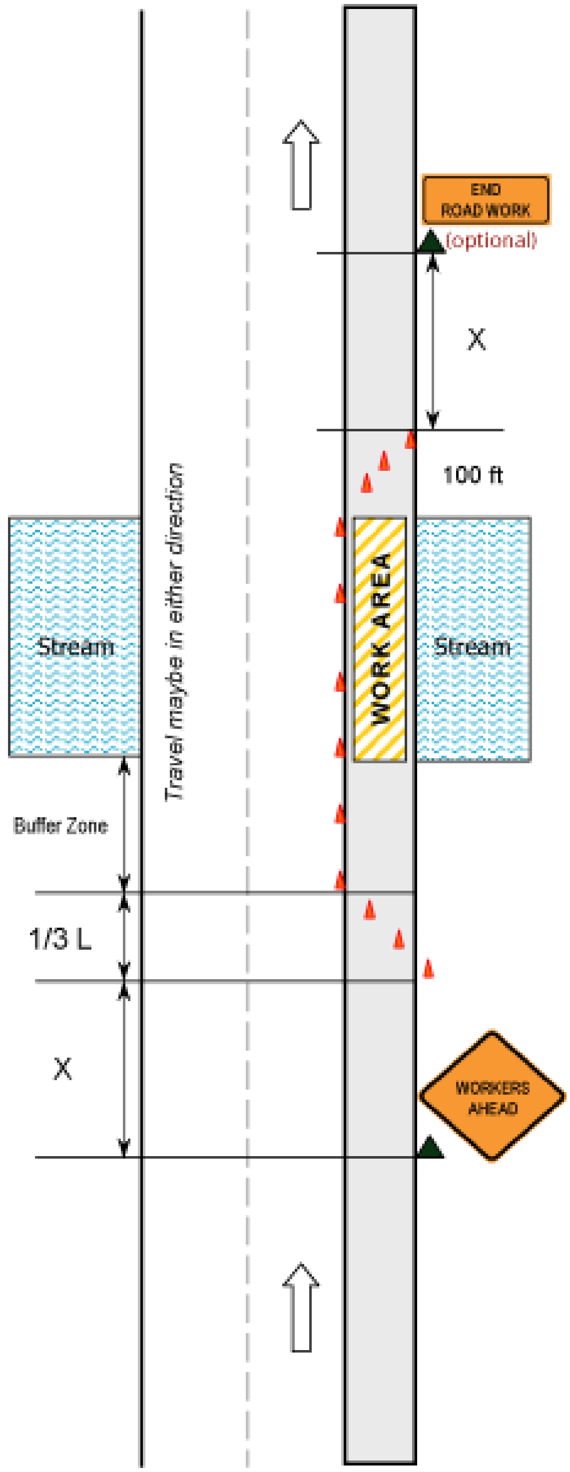

Figure 1. Diagram of a traffic control plan for short term, greater than one hour. From U.S. Department of Transportation, Federal Highway Administration, 2009).

Figure 2. Cones set up on relatively high speed state route. Travel lanes are not blocked, and work will be less than one hour.

Figure 3. Vehicle parked on low-traffic low-speed road for short-duration work.

Figure 4. Analysts collecting samples from a bridge on sidewalk.

6.2.4 Slips, Trips, and Falls

Slips, trips and falls are often underestimated job hazards, therefore focus and awareness of work environment is very important. When working outside and wading in streams the potential to encounter these hazards is even greater. Common hazards include steep and slippery banks, rocky and mucky bottoms, slippery rocks, and deep pools. Highly turbid water can make these hazards difficult to see. In conducting fieldwork it is important to have proper footwear (including chest waders or hip boots when entering streams). It may be necessary when wading in dark or turbid water to use a pole or stick for support, or to determine the depth of a pool. Always walk in streams slowly and with caution to ensure sound footing on unstable substrates or in swift moving water.

6.2.5 Overhead Hazards

Fieldwork conducted in streams often means that personnel will be working under bridges. Loose, falling concrete may be encountered on older bridges. Low bridges or culverts provide the additional risk of bumping your head. Passing motorists may throw trash into a stream from the window of a moving vehicle or unsecured materials may come off of vehicles. Broken tree limbs can become dislodged during high winds. When working in such conditions a hard-hat should be worn, and these are available in the sampling center. Whenever possible, it is best to be a safe distance upstream or downstream from any bridges for the above reasons.

Falling, collisions (with stationary or moving objects) and hits to the head can result in concussions. What may seem like a mild bump or blow to the head can disrupt how the brain works and is a serious issue. These signs or symptoms can show up immediately after an injury, or may not be noticed until days or weeks later.

6.2.6 Cuts, Punctures, and Abrasions

Sharp objects found in the field, especially in turbid water, can be difficult to see. Broken glass, bolts, nails, or other sharp rusty metal, and broken branches on fallen trees, are among the things that can puncture waders and skin, or unprotected skin when reaching into the water with bare hands. Contaminated water entering cuts can cause infection or illness. If it is vital to job completion to move rocks or bed sediment around, use a shovel or other tool to do so, and wear the appropriate gloves.

It is not required as a condition of employment, but it is suggested that personnel be up to date on tetanus shots to ensure that cuts do not result in contracting this disease. Tetanus is the infection of the nervous system when spores of the bacteria *Clostridium tetani* enter the body through a cut or wound causing severe muscle spasms. The time between infection and the first sign of symptoms is typically 7 to 21 days. Most cases of tetanus in the United States occur in those who have not been properly vaccinated against the disease. (National Center for Biotechnology Information, 2011)

6.2.7 Batteries

The department has several battery powered trolling motors that require the use of a heavy-duty deep-cycle battery. These batteries have a handle, but are heavy (40 lbs) so care should be used in lifting and carrying the batteries to vehicles and field sites. These batteries use sulfuric acid as the electrolyte, so extreme caution should be used if batteries become damaged and start to leak. Any leaks should be neutralized with baking soda. Training should be provided for employees who are unfamiliar with charging batteries. General precautions for charging include care in connecting the charger to the battery terminals, with black to negative and red to positive. If clamps touch each other, you can be shocked. Batteries should be charged in a well ventilated area, because the charging procedure can produce hydrogen gas, which can be explosive. Trickle charging is the most effective way to extend the batteries lifespan, so the charger should be set to 2A automatic charge for most applications. Analysts should avoid putting anything on top of the batteries when loading field equipment. Connecting the terminals with a conductive material such as a metal clipboard could result in electrical shock, overheating or fire.

Figure 5. Battery and charger in sampling center.

6.2.8 Water Safety

If an employee becomes unconscious for any reason, for example: head strike, heat stroke, or medical condition, drowning can happen in what would seem to be a negligible amount of water. Additionally, deep scour holes can be hidden by turbid water, and heavy equipment (such as a fish shocking backpack) could make it impossible for even a strong swimmer to keep their head above water. Focus and awareness of work environment is very important in such cases. Always walk in streams slowly with caution to ensure sound footing on unstable substrates or in swift moving water. It may be necessary when wading in dark or turbid water to use a pole or stick for support, or to determine the depth of a pool.

<u>Boating -</u> It is Office policy that life jackets will be worn at all times when working from boats.

6.2.9 Hunting Season

Any time field work occurs during hunting season, employees are required to follow the guidelines for wearing solid daylight fluorescent orange attire. This is most important near public state management areas, or near private property where hunting is allowed with permission of owner.

Hunting Season &Time of year	Amount of solid daylight fluorescent orange that must be worn
Wild turkey hunting season (generally in May)	200 square inches (size of hat)
Small game/muzzle loading/archery season 3rd Saturday in October – last day February*	200 square inches (size of hat)
*Shotgun deer season (generally in December)	500 square inches (hat & vest)

High visibility yellow is not an acceptable substitution for the fluorescent orange described in the regulations. Full information on blaze orange wearing requirements are available at: http://www.dem.ri.gov/programs/bnatres/fishwild/pdf/huntabs.pdf

6.3 CHEMICAL HAZARDS

Staff should read the Chemical Hygiene Plan maintained with OWR. If an analyst needs to handle chemicals directly, they are required to take the Chemical Hygiene Plan training, and sign off in the training log book. Materials Safety Data Sheets (MSDS) any potentially hazardous materials are available so that employees will be aware of any additional safety precautions. MSDS are kept in the sampling center and give detailed information on any hazardous substances that are located there. The regulatory agency responsible for hazardous and toxic substances is the Rhode Island Department of Labor and Training (RIDLT). Additional information is available at: http://www.dlt.ri.gov/occusafe/RighttoKnow.htm.

6.3.1 Acid Preservatives

Sample bottles are obtained from the HEALTH State Laboratories. Some bottles may contain acid as a sample preservative. Bottles that contain acid are clearly labeled with orange tape "caution: acid, corrosive." Occasionally bottles will leak, and the outside of the bottles can become covered with a small amount of acid. If you touch a bottle accidentally, and the bottle feels wet, acid will feel slippery between your fingers, like soapy water. If skin contact with acid occurs, rinse the affected area immediately with a lot of cold water. When this acid reacts with boxes or paper labels, a dark purplish-black stain can show up on boxes or bottle labels (Figure 6). Use caution with these bottles. Acid can cause serious skin irritation and burns, and can do serious damage to your eyes. Any time the sample bottles are is being handled; gloves should be worn. If and when you deal with the acid directly, goggles should be worn in addition to gloves. Eyewash stations located in the sink area of the sampling center (Figure 7) will be shown to employees, and field eyewash will be provided (Figure 8).

Figure 6. Preserved bottle with acid leak.

Figure 7. Eyewash station located in sink area of sampling center.

Figure 8. Portable eyewash to be carried in field vehicle.

6.3.2 Ethanol

Ethanol is used for preservation of biological samples collected in the field. This is a flammable liquid that should not be exposed to open flame or spark. Storage of this liquid will be in the yellow cabinets marked “Flammable” that are located in the Sampling Center (Figure 9). Ethanol should not be left in field vehicles during the summer.

Figure 9. Flammables cabinet in RIDEM sampling center.

6.4 WEATHER RELATED HAZARDS

Sampling can occur during a variety of weather conditions, and the analysts should monitor weather and be appropriately prepared.

6.4.1 Thunderstorms and High Wind

Severe weather, including summer thunderstorms can develop quickly, so weather forecasts should be checked daily, especially if boats will be used. If there is lightning, analysts should stop working and find shelter. When boating pay attention to warnings of high wind speeds, as wind gusts can increase chances of capsizing, and make it difficult to safely operate a boat.

6.4.2 Heat Related Illness

For sampling conducted during hot weather, staff should bring sufficient drinking water to prevent dehydration, heat exhaustion, and heatstroke. Other precautions to avoid heat related illness are to wear loose fitting, lightweight, light-colored clothing and a lightweight, wide brimmed hat. Excess, dark or tight clothing holds in heat and doesn't let your body cool properly because it inhibits sweat evaporation.

Communication with teammates is very important during hot weather. If you begin to feel ill, always let another crew member know. Heat illnesses can begin with symptoms such as heavy sweating, fatigue, thirst and muscle cramps. Should you begin to feel these symptoms, stop work to rest in a cool spot, drink fluids, apply water to your skin and loosen clothing. This prompt treatment can prevent symptoms from developing into heat exhaustion.

Heat exhaustion is a result of overheating that is usually caused by exposure to high temperatures combined with high humidity and strenuous physical activity. Symptoms of heat exhaustion can include heavy sweating, cool, moist skin with goose bumps, a weak, rapid pulse, dizziness, nausea, fatigue, headache, muscle cramps. Signs and symptoms of heat exhaustion may develop suddenly, or over time. If not treated, heat exhaustion can lead to heatstroke, a life-threatening condition that occurs when your body temperature reaches 104º F.

6.4.3 Air Quality Alert Days

During the summer on hot, humid, sunny days, air quality alerts are issued when the air quality is expected to reach unhealthy levels due to elevated levels of ground-level ozone. Ozone is formed as a result of chemical reactions caused by the presence of nitrogen oxides and volatile organic compounds (VOCs) from automobile and industrial emissions. These compounds react with oxygen in the air in the presence of heat and strong sunlight to produce ground-level ozone, the primary ingredient of smog.

High levels of ozone can cause eye, nose and throat irritation, coughing, chest pain, shortness of breath, increased susceptibility to respiratory infection and aggravation of asthma and other respiratory ailments. These symptoms can be worsened by exercise or other strenuous activity. It is important to be aware that individuals react differently when exposed to ozone levels in the unhealthy range. (http://www.dem.ri.gov/programs/benviron/air/ozoneinfo.htm).

6.4.4 Sunburn

Sunburn is a first or second degree burn that is caused by overexposure to sunlight. To protect employees from sunburn, sunscreen will be provided, and should be used when personnel will be working in areas that are exposed to sun. Hats with a brim and sunglasses are not provided but are recommended for field work as well. Boats are a particular concern due to a lack of shade and sunlight intensified by reflection off of the water.

6.5 CONTAMINATED WATER

A particular site may be targeted for sampling because the waters are known to be contaminated. In any cases where contaminants are known, personnel will be alerted to the site specific dangers. When conditions are not known it is best to assume that the water is contaminated. The analyst should take all safety precautions to minimize exposure to contaminants by avoiding direct skin contact by using personal protective equipment (gloves, waders, etc.).

6.5.1 Water-Bourne Pathogens

Bacteria, viruses, and other pathogens can be found in stream and lake waters in Rhode Island. Many streams are sampled by RIDEM ARM for enterococci and fecal coliform bacteria but there may be other water-borne pathogens that are not tested. Exposure to such pathogens should be minimized by using gloves to protect skin from contact with water. Open cuts and sores are particularly susceptible to infection. Analysts should be diligent about hand washing; at a minimum waterless hand cleaner should be used. Water from streams should never be consumed by field personnel.

6.5.2 Cyanobacteria

Cyanobacteria are also known as blue-green algae and are a natural part of surface water. Cyanobacteria can produce toxins that can cause harm to humans and animals. Skin rashes, and irritation of the nose, eyes, and or throat are common side effects that result from skin contact with water containing algal toxins. If water containing algal toxins is ingested, health effects include stomach ache, diarrhea, vomiting, and nausea. Young children and pets are generally more at-risk to algal toxins than adults, because they are more likely to ingest contaminated water. Other health effects, which are rarer, include dizziness, headache, fever, liver damage, and nervous system damage.

The Department of Health (RIDOH) and the Department of Environmental Management (DEM) advise the public via press release to avoid recreational activities where blue-green algae (or cyanobacteria) bloom has been detected. For up-to date information go to: http://www.health.state.ri.us/healthrisks/harmfulalgaeblooms/

6.5.3 Chemical Pollution

In rare cases where water or sediment is known to be contaminated with chemical hazards and/or waste to a point where exposure will create danger to personnel, they should not enter or sample the stream. Retreat a safe distance away and contact your supervisor to determine further action necessary. Also notify RIDEM Enforcement (401) 222-3070 or the RIDEM Office of Compliance and Inspection (OCI) at (401) 222-1360, as needed.

6.6 INSECT BITES AND WILDLIFE

Encounters with wildlife should be minimized. For specific questions about a particular species consult the fact sheets provided by the RI Division of Fish and Wildlife: http://www.dem.ri.gov/programs/fish-wildlife/wildlifehuntered/wildlifemanagement/. Whether dead or alive, wildlife should be avoided.

6.6.1 Mosquitoes

Mosquitoes in Rhode Island have been known to carry West Nile Virus or Eastern Equine Encephalitis. More information about the cooperative mosquito monitoring program with RIDEM and RIDOH and results of testing in RI can be found at: http://www.health.ri.gov/data/arboviralsurveillance/. During certain times of year, and in certain locations it is very important to use insect repellant and long sleeves and pants to avoid exposure to these diseases. Repellant will be available, both with and without DEET. Insect repellant containing DEET should only be applied to clothing, avoiding skin contact, but be aware that DEET may discolor some clothing materials.

(A) WEST NILE VIRUS
The West Nile virus is a type of virus known as a flavivirus. Mosquitoes carry the highest amounts of virus in the early fall. The risk of disease decreases as the weather becomes colder and mosquitoes die off. Few people develop severe disease or even notice any symptoms at all. Risk factors for developing a more severe form of West Nile virus include elderly or very young, or immunocompromzed individuals.

*(*B) EASTERN EQUINE ENCEPHALITIS (EEE)
Eastern equine encephalitis virus is transmitted to humans from infected mosquitoes. It is a rare illness in humans, and only a few cases are reported in the United States each year. Most cases occur in the Atlantic and Gulf Coast states. Most persons infected with the virus have no apparent illness. Severe cases of this disease (involving encephalitis, an inflammation of the brain) begin with the sudden onset of headache, high fever, chills, and vomiting. The illness may then progress into disorientation, seizures, or coma. This is one of the most severe mosquito-transmitted diseases in the United States with approximately 33% mortality and significant brain damage in most survivors. There is no specific treatment for this disease; care is based on symptoms (Centers for Disease Control, 2011).

6.6.2 Ticks

There are two types of ticks that you are likely to encounter in the field in Rhode Island: Deer Ticks and Wood Ticks, (Dog Ticks). (Figures 10, 11).

(A) LYME DISEASE
Lyme disease is an infection caused by *Borrelia burgdorferi*, a type of bacterium called a spirochete that is carried by deer ticks. An infected tick can transmit the spirochete to the humans and animals it bites. Borrelia burgdorferi infects other species of ticks but is known to be transmitted to humans and other animals only by the deer tick (also known as the black-legged tick) and the related Western black-legged tick. Studies have shown that an infected tick normally cannot begin transmitting the spirochete until it has been attached to its host about 36-48 hours, therefore the best line of defense against Lyme Disease, is to examine yourself at least once daily and remove any ticks before they become engorged (swollen) with blood. (American Lyme Disease Foundation, 2010)

Early symptoms may include fever, headache, fatigue, depression, and a bull's eye shaped rash (Figures 12, 13). If this disease is not treated, symptoms may involve the joints, heart, and central nervous system. In many cases, the infection is eliminated by antibiotics, especially if the illness is treated early. Delayed or inadequate treatment can lead to the more serious symptoms, which can be disabling and difficult to treat. If a bull's-eye-shaped rash appears around the bite within a few days, you should contact a health professional. It is sometimes beneficial to keep the removed tick for later identification.

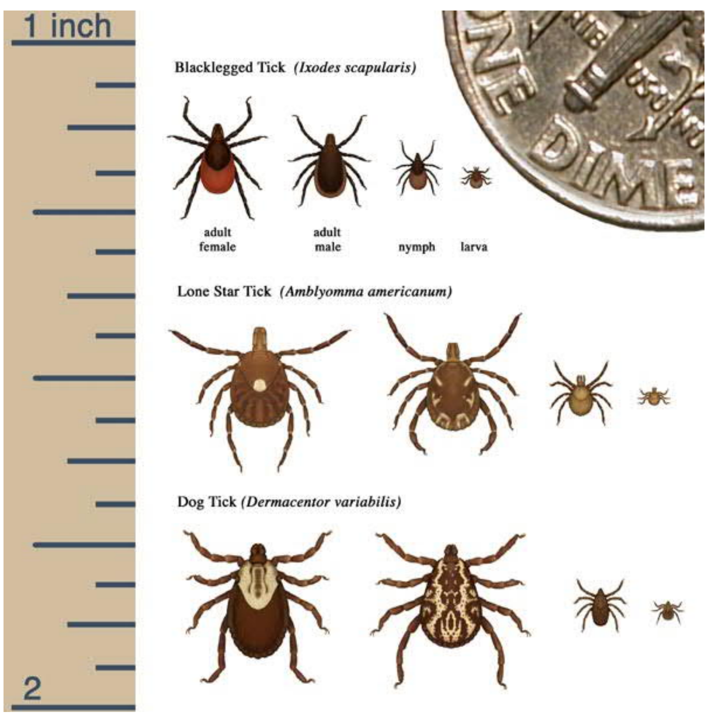

Figure 10. Tick identification (Photo from Canadian Lyme Disease Foundation).

Figure 11. Deer tick (photo from National Geographic).

Figure 12. Bull's-eye rash and deer tick (photos from Natural Pain Relief Guide).

Figure 13. Bull's-eye rash (photo from RealHelpWithLyme.com).

6.6.3 Stinging Insects and Spiders

The most well-known poisonous spiders found in Rhode Island are the Black Widow and Brown Recluse spiders. These species are not native to the Northeast, so although they are found in the Northeast, they are typically not encountered. It is possible for an insect bite to be mistaken for a spider bite, and the most urgent concern with such bites is a severe allergic reaction, or anaphylaxis. Symptoms of this include: shock, lightheadedness, wheezing, difficulty breathing, swelling, etc. If someone is experiencing these symptoms, DO NOT HESITATE to call 911. Seconds can save a life. Any personnel with allergies to bees are not required to but should notify their supervisor, and let teammates know where epi-pens are kept.

6.6.4 Mammals

Many animals in the state can be infected with rabies. Uncommon behavior should be noted, and such animals should be avoided. Examples include, but are not limited to: nocturnal animals active during the day, or especially when exhibiting exceptional boldness or disorientation.

6.6.5 Snakes

A reference on the snakes of Rhode Island was produced by the Department; refer to link below.

http://www.dem.ri.gov/programs/bnatres/fishwild/pdf/risnakes.pdf

(A) POISONOUS SNAKES

There are no poisonous snakes in Rhode Island, according to the above referenced document, however, remnant populations of timber rattlesnakes exist in nearby Massachusetts.

(B) NON-POISONOUS SNAKES

Bites from non-poisonous snakes can be serious, and should be treated by a doctor. Development of tetanus or infections of the wound are several things that could be of concern. Snakes will not typically be aggressive unless cornered, so it is best to avoid them, as with all wildlife. Common non-poisonous snake shown below (Figure 14).

Figure 14. Northern water snake.

6.6.6 Snapping Turtles

Snapping turtles are very common in Rhode Island, and can grow to several feet across. They inhabit muddy banks, but will migrate to higher ground to lay eggs in the spring. They are commonly seen swimming in wadeable rivers, and in lakes in Rhode Island. Be aware when in dark or turbid water. Although they typically will swim away if encountered in water, snapping turtles have powerful jaws, and can easily sever fingers or bite through waders. They have very flexible necks (Figure 15), and can bite even if they are picked up by the shell. Personnel should avoid these as with all wildlife.

Figure 15. Snapping turtle with neck extended (photo from Chelydra.org).

6.6.7 Swans and Geese

Swans and geese are very common in Rhode Island. They can become aggressive (Figure 16) when defending their territory; they can bite if they feel threatened, or sense a threat to their nests. They should be avoided as with other wildlife.

Figure 16. Aggressive swan at Mishnock Lake in West Greenwich, RI.

6.6.9 Small Alligators Reported

Although extremely uncommon, a few reports note small alligators have been found in select waterbodies. It is believed these animals start out as exotic pets (permitted or not), and are sometimes discarded into local streams. It is not expected that an alligator could survive a winter in Rhode Island, however irresponsible pet owners continue to keep, and sometimes discard them in local waterways. Be on notice that however unlikely, alligators may be in the field, and even small ones can be dangerous. If you think you see an alligator, evacuate a site immediately and notify RIDEM Enforcement.

6.6.8 Dead Animals

Dead animals can carry a number of pathogens, and should be avoided. Parasites that are associated with carcasses (fleas, flies, maggots) can transmit disease. If there is a dead animal directly interfering with a work site, it is reasonable to contact a supervisor to make other arrangements, such as sampling another site and coming back another day when the carcass is gone.

6.7 POISONOUS PLANTS

There are several types of plants that can cause rash or irritation that should be avoided. It is possible that certain people might be more or less sensitive to certain plants. Field personnel should be familiar with the plants listed below at a minimum.

6.6.1 Poison Ivy

Poison Ivy is very common in Rhode Island, and it has many forms of growth, typically, this plant grows with clusters of three shiny leaves (Figure 17), which are red in the spring after budding (Figure 18), green in the late spring and summer, and red in the fall. It often has white berries. The vines of this plant have fibrous hairs that help it to attach to trees, making the vines look hairy (Figure 19). The leaves and vines of the poison ivy plant are covered in Urushiol oil. Only 1 nanogram of this oil is needed to cause a rash. (Poison Ivy, Oak and Sumac Information Center, 2011). Oil can remain on clothing for long periods of time, so care should be taken when handling clothing that has touched this plant until it has been washed. Shoelaces and shoes are of particular concern after walking through poison ivy. It is important that field personnel be able to identify the plants, and stay away from them as much as possible; however, prompt rinsing with copious amounts of water and Technu poison ivy treatment will often rinse the oil off skin, preventing a rash from developing. Technu will be made available. If a rash does occur, Calagel is located in the first aid kit.

Figure 17. Poison ivy clinging to a rock. Three leaf pattern shown.

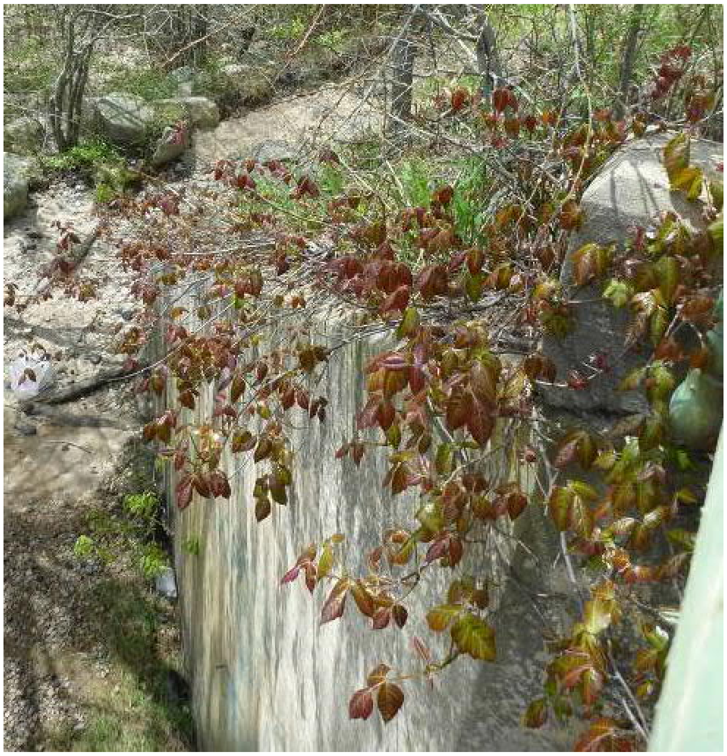

Figure 18. Poison ivy in early spring exhibiting a reddish color and three leaf pattern.

Figure 19. Poison ivy vines on a tree. The sap from these vines can cause skin irritation.

6.7.1 Poison Sumac

This plant also occurs in Rhode Island, and actually is more potent In terms of its potential to cause rash than its' relatives poison ivy and poison oak. This plant is a shrub or small tree, up to 20 feet in height, and is most prevalent in moist areas, such as wetlands.

6.7.2 Stinging Nettles

This plant is more common in wet areas of southern and coastal Rhode Island than in the rest of the State. The leaves and stems are very hairy (Figure 20) with non-stinging hairs and stinging hairs whose tips come off when touched, transforming the hair into a needle that will inject several chemicals: acetylcholine, histamine, 5-HT, or serotonin, and possibly formic acid (Wikipedia, 2011). The affected area will hurt almost immediately, and will often become inflamed with a rash for several days after. It is best to avoid this plant; however a single layer of clothing will usually provide sufficient protection.

Figure 20. Stinging Nettles (photo from Wikipedia, 2011).

7.0 REFERENCES

American Lyme Disease Foundation. What is Lyme Disease: accessed 04/19/2011 at: http://www.aldf.com/lyme.shtml

Canadian Lyme Disease Foundation: accessed 04/19/2011 at: http://www.canlyme.com/ticks.html

Centers for Disease Control, Eastern Equine Encephalitis: accessed 04/20/2011 at: http://www.cdc.gov/EasternEquineEncephalitis/

Chelydra.org: accessed 01/09/2017 at: http://www.chelydra.org/snapping_turtle_snapper_photo_gallery.html

Floatplancentral. About float plans. Accessed 04/20/2011 at: http://www.floatplancentral.org/

National Center for Biotechnology Information, West Nile Virus, accessed 04/20/2011 at: http://www.ncbi.nlm.nih.gov/pubmedhealth/PMH0004457/

National Geographic: accessed 04/19/2011 at: http://animals.nationalgeographic.com/animals/bugs/deer-tick/

Natural-Pain-Relief-Guide.com: accessed 04/19/2011 at: http://www.natural-pain-relief-guide.com/lyme-disease-bulls-eye-rash.html

Poison Ivy, Oak and Sumac Information Center: accessed 04/19/2011 at: http://poisonivy.aesir.com/img/pictures/pi-pics-may/index.php

Rhode Island Hunting and Trapping 2016-2017 Regulation guide. Accessed 01/09/2017 at: http://www.dem.ri.gov/pubs/regs/regs/fishwild/hunt1011.pdf

RealHelpWithLyme.com: accessed 04/19/2011 at: http://www.understandmylabtest.com/Picture-Gallery.html

U.S. Department of Transportation, Federal Highway Administration, 2009 Manual on Uniform Traffic Control Devices. 864 p.

Wikipedia, Stinging Nettle. Accessed 04/19/2011 at: http://en.wikipedia.org/wiki/Stinging_nettle

Appendix A: Questionnaire for completed safety training.

Questionnaire for safety related training

Name and date:
Please rate the course for each question 1 through 5,
1. Inadequate
2. Below expectations
3. Adequate
4. Above expectations
5. Superior

1. Is the training you received applicable to your job?

1 2 3 4 5

2. Is this course useful to your professional development?

1 2 3 4 5

3. Was there ample class time to cover the topic adequately?

1 2 3 4 5

4. Was the instructor well informed and able to answer your questions?

1 2 3 4 5

5. Were course materials (handouts, literature) of good quality and useful aids to learning?

1 2 3 4 5

6. Was course multimedia (movies, PowerPoint presentations) of high quality and useful to your understanding of the material?

1 2 3 4 5

7. Were hands on activities or demonstrations available, and if so were they useful to your understanding of the material?

1 2 3 4 5

8. Would you recommend this training to your coworkers?

1 2 3 4 5

9. Would you take this same course again if it is required to keep certifications current?

1 2 3 4 5

10. How would you rate the overall quality of the training you received?

1 2 3 4 5

Please describe any specific concerns you have about this training that need to be addressed?

Appendix B: Example of completed float plan

FLOAT PLAN

INSTRUCTIONS: Complete this plan before you go boating and leave it with a reliable person who can be depended upon to notify the Coast Guard, or other rescue organization, should you not return or check-in as planned. If you have a change of plans after leaving, be sure to notify the person holding your Float Plan. For additional copies of this plan, visit: www.floatplancentral.org

www.cgaux.org

Do NOT file this plan with the U.S. Coast Guard

www.uscgboating.org

VESSEL

IDENTIFICATION:

Name & Hailing Port: RIDEM CANOE from Providence
Document / Registration No. NA HIN NA
Year & Make 1970
Length 15 Type Canoe Draft ___ Hull Mat. Aluminium
Color GREEN
Prominent Features ___

PROPULSION:

Primary– Type Paddle No. Eng.___ Fuel Capacity ___
Auxiliary–Type Electric OB No. Eng.___ Fuel Capacity ___

COMMUNICATION:

Radio Call Sign ___
DSC MMSI No. ___
Radio-1: Type ___ Ch./ Freq. Monitored ___
Radio-2: Type ___ Ch./ Freq. Monitored ___
Cell / Satellite No. Katie: 401-575-7484 Jane; 319-331-7457
E-mail Mark: 401-835-5632 Jason 203-240-8626

NAVIGATION: (Check all on board)

☒ Maps ☒ Charts ☐ Compass ☒ GPS / DGPS
☐ Radar ☐ Sounder ☐ ___

SAFETY & SURVIVAL

VISUAL DISTRESS SIGNALS:

☐ Electric S-O-S Light
☐ Orange Flag
☐ Orange Smoke
☐ Red Flares

PFDs: (Do not count Type IV devices)

3 Quantity On Board

AUDIBLE DISTRESS SIGNALS:

☐ Bell
☐ Horn / Siren
☒ Whistle

GROUND TACKLE:

☒ Anchor. Line Length 15 ft

OTHER GEAR:

☐ Drogue / Sea Anchor
☐ EPIRB ___
☐ Fire Extinguisher
☐ Flashlight / Searchlight
☐ Food & Water for ___ days
☐ Foul Weather Gear
☐ Life raft / Dinghy
☐ Personal Locator Beacon
☐ Signal Mirror
☒ First Aid Kit
☐ ___
☐ ___

PERSONS ONBOARD

OPERATOR:

Name RIDEM OWR STAFF
Age ___ Gender ___ Notes (Special medical condition, can't swim, etc.) ___
Address Room 200, 235 Promenade Street
Has experience: ☒ with this Vessel ☒ with Area
City Providence State RI Zip Code 02908
Home phone office 401-222-4700
Vehicle (Year, Make & Model) '12 Equinox, '04 & '06 Escape, '98 Winstar
Vehicle License No. 1869, 1583 , 2140, 789
Trailer will be parked at: ___
Trailer License No. ___

PASSENGERS / CREW:

	Name & Address	Age	Gender	Notes (Special medical condition, can't swim, etc.)
1.	Katie DeGoosh	33	F	see medical Emergency form in clipboard/envelope
2.	Mark Nimiroski	42	M	see medical Emergency form in clipboard/envelope
3.	Jane Sawyers	31	F	see medical Emergency form in clipboard/envelope
4.	Jason Carey	23	M	see medical Emergency form in clipboard/envelope
5.	Elizabeth Futoma or Chelsea Blatchley	23	F	see medical Emergency form in clipboard/envelope

Attach "Supplemental Passenger List" if additional passengers or crew on board.

ITINERARY

	DATE	TIME	LOCATION / WAYPOINT	MODE OF TRAVEL	REASON FOR STOP	CHECK-IN TIME
Depart						
Arrive						
Depart						
Arrive			ITINERARIES WILL BE WRITTEN ON FIELD			
Depart						
Arrive			CALENDAR; CHECK IN WILL BE AT 3:30			
Depart						
Arrive						
Depart						
Arrive						

Attach "Supplemental Itinerary" if there are additional locations or waypoints.

Contact 1: see medical emergency forms Phone Number ___
Contact 2: ___ Phone Number ___

If you have a genuine concern for the safety or welfare of any persons on board the Vessel described above, who have not returned or checked-in in a reasonable amount of time, then follow the step-by-step instructions on the *Booting Emergency Guide™* included with this float plan, or on the Internet at:

www.floatplancentral.org/help/BoatingEmergencyGuide.htm

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Rhode Island Department of Environmental Management

EMERGENCY CONTACT INFORMATION

In the event you are involved in an accident or other emergency while at work, it is very important that we have on file the name(s) of person(s) you would want to be contacted. We, therefore, urge you to print out this form and complete the information requested.

Your Name: ______________________________

Address: ______________________________

Phone #: ______________________________

Primary person **to be notified in case of an emergency:**

Name: ______________________________

Relationship: ______________________________

Home Address: ______________________________

Telephone: ______________________________

Business Address: ______________________________

Business Telephone: ______________________________

Secondary person **to be notified in case of an emergency:**

Name: ______________________________

Relationship: ______________________________

Home Address: ______________________________

Telephone: ______________________________

Business Address: ______________________________

Business Telephone: ______________________________

Please be sure to keep this form updated with the RIDEM/Human Resources Office, Room 350, 235 Promenade St., Providence, RI 02908

(Rev. 01/06)

If you have any medical conditions that would become important if you are injured in the field, you can write them here and they will be sealed with the rest of your emergency contact information, to be opened only in an emergency.

Appendix D Incident reporting information and forms

Copy → Supervisors
Chiefs
Principals

STATE OF RHODE ISLAND AND PROVIDENCE PLANTATIONS

INTER-OFFICE MEMORANDUM

RECEIVED
MAY 7 2007
ENVIRONMENTAL MANAGEMENT
OFFICE OF WATER RESOURCES

TO: Distribution/RIDEM Management List DATE: May 7, 2007

FROM: Paul E. Pysz
Human Resources Administrator
Human Resources Service Center/Environmental Management

RE: REPORTING OF WORK RELATED INJURIES

This memo is sent as a reminder to all Divisional and/or supervisory staff that it is your responsibility to report any witnessed or claimed work related injury to the Office of Human Resources by completing the following attached forms **within 5 days of injury:**

Incident/Injury Report Form (S-41A)
Employee's Certificate of Dependency Status Form (DWC-04 (01/03)
Authorization for Release of Confidential Information
Accident Witness Affidavit

Under Section 28-32-1 of R I General Laws, an employer is required to submit a first report of injury within 10 days of injury. In case of fatal injury, the first report of injury is required within 48 hours. **An employer can be fined $250.00 for failure to report said injuries for each incident.** All state departments have been notified that this penalty will be strictly enforced.

The Incident/Injury Report Form (S-41A) should be initialed by the supervisor and signed by the Division or Section Head and forwarded to the Office of Human Resources, 235 Promenade Street, Room 350, Providence, RI. Also, the Employee's Certificate of Dependency Status must be completed, signed by the employee, and attached to the injury report along with any medical documentation that has been provided, if any.

Please remember that our insurance carrier is responsible for determining if this is a valid claim. Filling out the First Report of Injury is not an admission of liability. All reports received will be date stamped upon receipt by this Office.

Attachments

DEM INCIDENT/INJURY REPORT FORM (9/99)

Please report all injuries within 24 hours

Report Number: ____________ Account Number: ____________
Birthdate: ____________ Base Entry Date: ____________

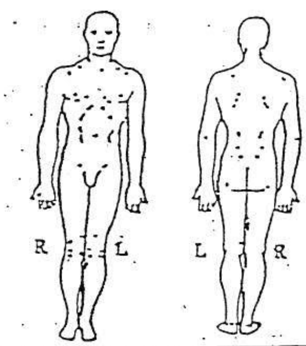
Last Name: ____________ Middle Initial: ______ First Name: ____________
Address: ____________ City: ____________ State: ______ Zip: ______
Phone Number: ____________ Social Security Number: ____________ Sex: Male ____ Female ____
Job Title: ____________ Building/Area Normally Assigned: ____________
Regularly Scheduled Work Days (Please circle): SU MO TU WE TH FR SA What Shift Are You Assigned To? ____________
Date of Incident: ____________ Time of Incident: ____________ Time Workday Started: ____________
Building Or Area Where Accident Occurred: ____________ State if Employers Premise: ____Yes ____No
Do You Have Supplemental Employment? ____Yes ____No Number of Dependents: ____________
Describe How The Injury Occurred: ____________

What Was The Employee Doing When Injured or Exposed? ____________
Describe and Illustrate (Below) Your Injury: ____________

Name The Object Or Substance Which Directly Injured The Employee: ____________

Has Employee Returned To Work? ______Yes ______No
If Yes, Date Returned To Work: ____________
If No, Probable Length of Disability: ____________
Is The Injury Expected To Be A Permanent Disability: ______Yes ______No
Date Employer First Knew of Injury: ____________

INDICATE ON THESE FIGURES THE AFFECTED BODY PART(S) AT TIME OF INJURY:



Name of Treating Physician: ____________ Phone Number: ____________
Address: ____________ City/Town: ____________ State: ______ Zip: ______
Hospital Name: ____________ Phone Number: ____________
Address: ____________ City/Town: ____________ State: ______ Zip: ______
Witness Name (Print): ____________ Phone Number: ____________
Address: ____________ City/Town: ____________ State: ______ Zip: ______

Employee Signature ____________ Date ____________

PLEASE HAVE SUPERVISOR COMPLETE REPORT ON REVERSE SIDE

1

State of Rhode Island

☐ PLEASE CHECK IF CORRECTION OF PRIOR REPORT

EMPLOYEE'S CERTIFICATE OF DEPENDENCY STATUS

Department of Labor and Training, Division of Workers' Compensation

Phone (401) 462-8100 TDD (401) 462-8006

DWC No. ____________

Insurer File No. ____________

1. EMPLOYEE INFORMATION:		2. CLAIM INFORMATION:	
SSN	☐Male ☐Female	Employer	
Name		*Claim Administrator*	State Employees' Workers' Compensation
Address		*Address*	One Capitol Hill
City, State, Zip		*City, State, Zip*	Providence, RI 02908-5866
Phone	Date of Birth	Date of Injury	Date of Incapacity

THE EMPLOYEE MUST COMPLETE ALL REQUIRED INFORMATION:

Please return this form to your employer's workers' compensation *Claim Administrator*. If they do not receive this completed form promptly, it may result in a delay of your claim.

3. MARITAL STATUS & EXEMPTION INFORMATION: (Needed to calculate your weekly compensation payment)

Were you married at the time of your injury? ☐Yes ☐No Spouse Name: ____________

If Yes, does your spouse work? ☐Yes ☐No If Yes, Spouse SSN**: ____________

Please put an appropriate number on each line – you are entitled to one exemption for yourself and one for your spouse.

Yourself 1

Spouse ______

Total Dependents Listed Below ______

Total Other ______ (Other: You may be entitled to additional exemptions if you or your spouse are over 65 or blind. Please contact your employer's workers' compensation Claim Administrator for further information)

Total Number of Exemptions ______

4. DEPENDENT INFORMATION List each dependent child below. A dependent child includes:

- Children under the age of eighteen living with you or whom you were required to support at the time of the injury
- Children you support who are over eighteen but who are mentally or physically incapacitated from earning
- Children under the age of twenty-three who are full-time students at an accredited educational facility

Dependent's Name:	Dependent's Date of Birth:	Dependent's Social Security Number:**	If over 18 and under 23, Full-Time Student?	
			☐Yes	☐No
			☐Yes	☐No
			☐Yes	☐No
			☐Yes	☐No
			☐Yes	☐No
			☐Yes	☐No
			☐Yes	☐No
			☐Yes	☐No
			☐Yes	☐No
			☐Yes	☐No

Employee Signature: Date:

** Completion of the Social Security Number for Spouse and Dependents is optional.

Employee Note: DO NOT return this form to the Department of Labor and Training - RETURN TO *Claim Administrator*

DWC-04 (01/03) *For instructions visit our web site: www.dlt.ri.gov/wc*

Rhode Island Department of Environmental Management
Office of Human Resources
235 Promenade Street, Room 350
Providence, RI 02908
Telephone No.: 222-2774; Fax No.: 222-6174

Authorization for Release of Confidential Information

Claimant's Name: ______________________________

Date: ______________________________

Birth Date: ______________________________

Social Security #: ________________ **ID#:** __________

I authorize physicians, clinicians, counselors, hospitals, counseling agencies, clinics, etc., and all attending thereto to furnish full and complete medical, diagnostic, treatment, clinical, counseling, service reports and billing records, and other information hereby requested by the R.I. Department of Environmental Management on behalf of the R.I. Division of State Employees Workers' Compensation.

The information being sought is to be used in evaluation of a pending workers' compensation claim. Failure to authorize release of this information may cause a delay in processing that claim.

This authorization is valid until revoked by written request to R.I. Department of Environmental Management.

Neither the R.I. Department of Environmental Management, nor the R.I. Division of State Employees Workers' Compensation will ***not*** release any information supplied except in accordance with law.

I agree that a photocopy of this authorization shall be valid as the original.

Signed this ____________ **day of** ______________, **20**___.

Witness: **Patient/Claimant:**

______________________________ ______________________________

III. WITNESS REPORT FORM

Report Number: ______________________________ (For Office Use Only)

RE: ______________________________
(Name of Injured Employee)

Did you witness an incident/accident involving the Employee identified above? ________Yes ________No

Date and Time of the incident/accident: Date: ______________________ Time: ______________

Building or area where incident/accident occurred: ______________________________

Give a step by step description of what you witnessed: ______________________________

To the best of your knowledge, describe the body parts affected as a result of the incident/accident: ______________

Identify any other witnesses who were present: ______________________________

Witness Name (Print)	Signature	Date

Address	City/Town	State	Zip	Phone Number

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Appendix D: Good vs. Bad Field Photographs

This appendix provides examples of good and bad field photos of road-stream crossings and tips for capturing good photographs.

D.1 Examples of Good Field Photographs

A photograph of the inlet, outlet, downstream channel, upstream channel, and roadway is required at each crossing. Ideally, all aspects of the structure, stream channel, and the area surrounding the crossing should be captured within these five photographs. Additional photographs should be taken if necessary to fully document the conditions at the crossing. Good photographs should include context of the surrounding crossing; therefore, it is usually necessary to step several feet back from the structure to capture a good photograph.



Figure D-1. Examples of good inlet photographs that show the surrounding context of the structure including the structure invert, the fill, and armoring.



Figure D-2. Examples of good outlet photographs that are taken far enough away from the structure so that the entire structure is visible and the surrounding fill, armoring, and streambanks are captured.

Appendix D: Good vs. Bad Field Photographs



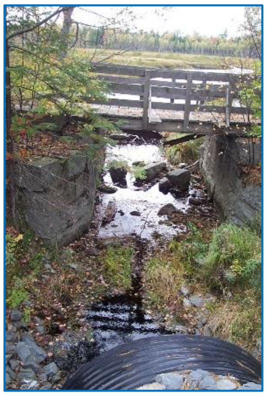

Figure D-3. Examples of good upstream photographs that capture the stream channel as far as the eye can see and include the streambanks on each side. More context can usually be captured by taking the photograph from the roadway or the top of the structure rather than from in the stream.



Figure D-4. Examples of good downstream photographs that capture the stream channel as far as the eye can see and include the streambanks on each side. More context can usually be captured by taking the photograph from the roadway or the top of the structure rather than from in the stream.



Figure D-5. Examples of good roadway photographs. The roadway photograph should show the condition of the roadway directly over the crossing and include any notable markers that would help locate the crossing in the future.

Figure D-6. Examples of additional photographs that may need to be taken if all features of a crossing are not captured in the five standard photographs (upstream, inlet, downstream, outlet, and roadway). These photos may be necessary to show appurtenant structures, damage, or other unique conditions.

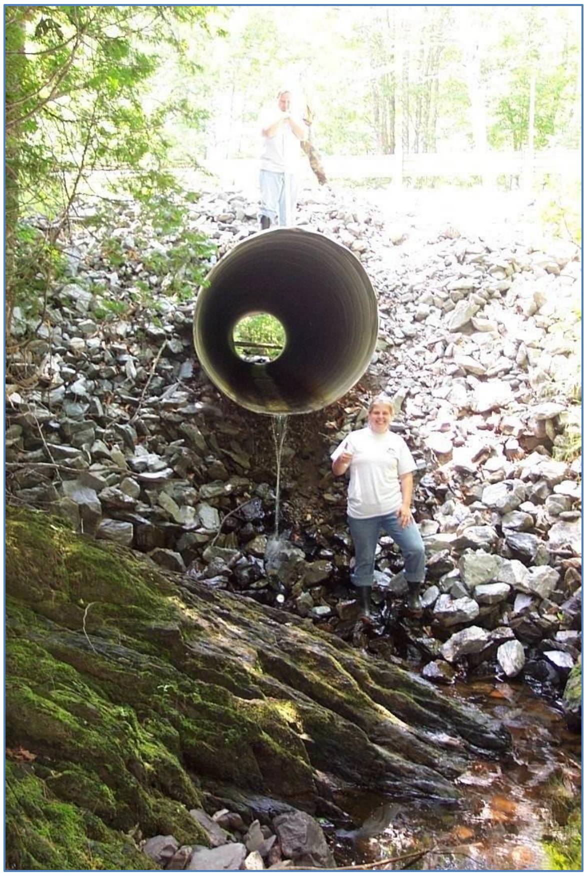

Figure D-7. An additional example of a good photograph. This photo shows adequate context around the structure, including a field data collector in a safe position near the structure for scale, the roadway and bank above the culvert, and the stream downstream of the culvert (including the full width of the culvert). Note that the photograph is overexposed, reducing the available contextual information about the road at the top of the photograph. (Image credit: NAACC)

Figure D-8. An additional example of a good photograph. The photo shows the structure opening and surrounding armor, the roadway and bank above, and the stream outside of the structure (including the full width of the stream). The photograph also shows a Field Data Collector standing in a safe position near the structure, which provides a reference for the scale of the objects in the photograph (Image credit; NAACC)

D.2 Examples of Bad Field Photographs

Bad photographs include photos that are taken too close to a structure and therefore do not include surrounding context, photos that are overexposed or highly reflect the water, and photos that are blocked by vegetation. Some examples of bad photographs are presented below with recommendations on how to improve the photos.

Figure D-9. An example of a photograph of a culvert that shows very little context around the culvert that is the subject of the photograph. The photo could be improved by taking a head-on photograph of the culvert and backing up to capture more context (Image credit: NAACC).

Figure D-10. An example of a photograph of a culvert that shows no context around the culvert that is the subject of the photograph. The photo is also confusing due to the high reflection. This photo could be improved by taking a distant photo of the culvert head-on from the shoreline (you can always zoom in on digital imags to better see the structure) (Image credit: NAACC).

Figure D-11. An example of a downstream photograph that shows very little context of the crossing. Note that the photo is also overexposed, which limits the information available in the photo. This photo could be improved by adjusting the angle of the photo to capture more of the downstream channel and adjusting the settings to avoid overexposure (Image credit: NAACC).

Figure D-12. An example of a photograph of a culvert that shows very little context due to the proximity of the photo to the structure and the tree branch blocking the view. This photo could be improved by stepping back several feet to capture the surrounding context of the culvert and adjusting the location from which the photo is taken to avoid the tree branch (Image credit: NAACC).

Figure D-13. Examples of photographs of culverts that show too little context. These photos could be improved by stepping back several feet to take the photo (Image credit: NAACC).

Figure D-14. Additional examples of photographs that contain too little context. These photos could be improved by adjusting the location from which the photo is taken to capture more context, or taking additional photos from different viewpoints to capture the entirety of the crossing.

Figure D-15. This photograph is not very useful because the structure and stream channel are hidden behind the dense vegetation. This photo could be improved by taking the photograph from a different location or angle, or taking multiple photographs to adequately capture the crossing.

Figure D-16. While this photograph adequately shows the crossing structure, it could be improved by stepping several feet back to capture the surrounding context including the stream, armoring, and fill.

Appendix E: Glossary

This Appendix provides a quick reference of terms and abbreviations used in the Handbook.

E.1 Terms

1% Annual Chance Flood (100-Year Flood) - A flood of such magnitude that it has a 1% chance of occurring or being exceeded in a given year.

Abrasion – With regard to structural condition, wear or erosion of the inside of a pipe due to repetitive friction.

Anadromous – A term to describe migratory fish that spend the majority of their lives in saltwater but return to freshwater to spawn.

Apron – Erosion protection within the streambed at the inlet or outlet of the crossing, consisting of riprap or concrete.

Aquatic Organism Passage (AOP) – Modification or removal of barriers that restrict or impede movement of aquatic organisms in order to facilitate that movement.

Bankfull Flow - The point at which water completely fills the stream channel and where additional water would overflow into the floodplain.

Bankfull Width – A measurement of the width of the active stream channel at **Bankfull Flow**.

Bridge – A crossing that has a deck supported by abutments. Abutments may be earthen or constructed of wood, stone, masonry, concrete or other materials. A bridge may have multiple cells, divided by one or more piers.

Capacity – See *Hydraulic Capacity*.

Climate Change – The long-term alteration of temperature and weather patterns as a result of global warming. While climate change is occurring on a global scale, the effects of climate change are unique to specific regions and locations.

Culvert – Any crossing structure that is buried under some amount of fill. In this Handbook, culverts refer only to structures that carry flowing streams. They are sometimes referred to locally as "cross culverts," "stream culverts," or "carrying culverts."

Data Validation – Rules programmed into a database and digital data forms to reduce data entry errors.

Efflorescence – With regard to structural condition, a crystalline deposit of salts on the surface of porous constructed materials, caused by the outward migration of internally held salts in the presence of water.

Fish Passage – See *Aquatic Organism Passage*.

Fluvial Geomorphology – The study of the interactions between flowing water and the physical landscape, including water and sediment transport.

Geomorphic – Relating to the shape of the landscape and landforms. Geomorphic impacts to road-stream crossings occur when the crossing alters the surrounding stream channel and landscape.

GIS – A computer framework used to edit, store, integrate and display geographically referenced data.

Hydraulic Capacity – The amount of water that a crossing can safely convey, usually corresponding to a specific design storm or flow rate.

Hydrology – The study of the occurrence, distribution, movement and properties of water and its interactions with the physical, biological, and chemical environment.

Inland (Non-Tidal) – Regions of the state located landward of the Rhode Island *Mean Higher High Water* line.

Appendix E: Glossary

Inlet – The end of the crossing at which the stream enters the crossing.

Invert – The bottom surface of a pipe.

Mean Higher High Water – A measurement representing the vertical extent of tidal influence in a specific area, obtained by taking the average of the higher high water height of each tidal day observed over the National Tidal Datum Epoch.

Migratory Fish – Fish that regularly move from freshwater to saltwater or vice versa**,** usually to spawn or feed.

Manning's coefficient/Manning's n – A coefficient used in Manning's Equation for open channel flow that represents the roughness or friction of the channel, based on the channel substrate or material.

Multiple Culvert – A crossing with more than one culvert present.

North Atlantic Aquatic Connectivity Collaborative (NAACC) – An organization dedicated to enhancing aquatic connectivity in the North Atlantic region that has developed road-stream crossing materials that served as reference in developing this Handbook. These materials include road-stream crossing assessment protocols, training and certificate programs, and an online database to serve as a repository for crossing assessment data.

Non-tidal Crossing – Crossings that are located landward of the Rhode Island *Mean Higher High Water* line (if not specified as tidal or referring to tidal crossing, assume a crossing or parameter is non-tidal).

Outlet – The end of the crossing at which the stream exits the crossing.

Peak Flow Rate – The maximum instantaneous rate of water passing a given point after a runoff event.

Prioritization – The process of using the results of the field survey and vulnerability assessments to assign a relative priority score to crossings that are important to replace or upgrade.

QA/QC – The process of reviewing field data after collection for accuracy and completeness.

Rainfall-Runoff Model – A numerical hydrologic model applied at a watershed scale that simulates runoff volume and watershed, channel, and water-control structure behavior under varying rainfall frequencies. Several different models are available that may require varying inputs and produce varying outputs.

Reference Pool – Naturally occurring pools within a stream channel that are not created from the influence of a road-stream crossing structure. These reference pools should be used as a comparison to determine whether a tailwater scour pool is present at the outlet of a crossing.

Resiliency – The ability to anticipate, prepare for and respond to hazardous events. Flood resiliency is increased by identifying and replacing high-risk crossings through road-stream crossing assessment.

Road-Stream Crossing – Structures such as bridges, culverts, or fords that carry a roadway across a river or stream.

Runoff – The portion of rainfall that does not infiltrate into the ground but rather flows across the land's surface before entering a waterbody.

Scaling – With regards to structural condition, the build-up of a mineral layer on the surface of a pipe.

Sea Level Rise – Global and regional increase in the level of the ocean over time that is expected to continue in the future, largely attributed to the effects of global warming.

Slope – Gradient (Rise over run) of a culvert or stream channel.

Spall – With regard to structural condition, a section of a concrete structure that is flaking, pitting, or cracking and may result in the exposure of the underlying aggregate.

Storm Surge – A temporary rise in sea level associated with a storm measured as the height of the water above the normal predicted astronomical tide.

STORMTOOLS – A dataset created by the Rhode Island Coastal Resources Management Council that illustrates the predicted level of inundation due to storm surge and sea level rise under climate change scenarios.

Stream Geomorphology – See *Fluvial Geomorphology*.

Tailwater Scour Pool – A pool created downstream of a crossing as a result of high flows exiting the crossing.

Terrestrial Passage – A continuous dry streambank through a road-stream crossing structure that connects the upstream and downstream streambanks and provides for the safe movement of terrestrial animals through the structure.

Thalweg – The deepest part of a stream channel.

Tidal Crossing – A crossing that is located waterward of the Rhode Island *Mean Higher High Water* line.

Tidal Range – The difference in height between low tide and high tide.

Watershed – An area of land from which all surface water and precipitation drains to a common point or outlet.

Wrack – A line of seaweed and other debris deposited by the sea, representing the general location of the high tide line.

E.2 Abbreviations

AOP – Aquatic Organism Passage

cfs – cubic feet per second

CRMC – Rhode Island Coastal Resources Management Council

EC4 – Rhode Island Executive Climate Change Coordinating Council

GIS – Geographic Information System

MHHW – Mean Higher High Water

NAACC – North Atlantic Aquatic Connectivity Collaborative

NAVD88 – North American Vertical Datum of 1988

QA/QC – Quality Assurance/Quality Control

RIDEM – Rhode Island Department of Environmental Management

RIDOT – Rhode Island Department of Transportation

SLR – Sea level rise

E.3 Team Member Roles

Assessment Coordinator – Project manager for the overall assessment project; directs field work, desktop analyses, and scheduling; responsible for making project decisions and reviewing the final product.

Lead Field Data Collector – Party responsible for ensuring the quality and completeness of field data; responsible for obtaining site access, understanding field procedures and equipment, collecting all field data and following safety procedures; recommended to obtain NAACC Lead Observer status.

Appendix E: Glossary

Assistant Field Data Collector – Serves as the second person in the 2-person field crew; assists the Lead Field Data Collector in collecting field data and following safety procedures.

QC Coordinator – The person responsible for ensuring Quality Control (QC) is completed according to the guidelines in the *Section 4: Quality Control*. This individual may be the Assessment Coordinator or another qualified individual.

E.4 Field Form Data Dictionary

This section serves as a data dictionary for users of the Digital Data Collection Form and the Crossing Analysis Spreadsheet. When data is exported to Excel from GIS it is recommended that the "Use field alias as column header" option be selected so that the column headers on the exported data match the data field headers as they appear in the Digital Data Collection Form. If this option is not selected when data is exported, the following data dictionaries can be used to relate the column headers from GIS to the data field headers as they appear in the Digital Data Collection Form.

Crossing Field Data Dictionary	
Field Name Alias	**GIS Field Name (as exported from GIS)**
objectid	objectid
GlobalID	globalid
Crossing Code	crossingcode
Latitude	Lat
Longitude	Lon
State or Local ID and/or Local Name	loc_id
Date Observed	obsrv_date
Inspection Start Time	time_insp_strt
Lead Field Data Collector	lead_inspector
Assistant Field Data Collector(s)	asst_inspectors
Other Assistant Field Data Collector(s)	unlist_inspectors
Municipality	municpNM
County	countyNM
Stream Name	streamNM
Road Name	roadNM
Road Type	roadTYP
Location Description	loc_desc
Crossing Type	crossingTYP
Number of Culverts/Bridge Cells	culvertsTotal
Additional Photo	AddPhoto
How Many Additional Photos?	addphotoNum
Road Crest Height	roadCrest
Road Fill Height	roadFill
Utilities	utilities

Crossing Field Data Dictionary	
Field Name Alias	**GIS Field Name (as exported from GIS)**
Other Utilities	utilityOther
Road-Killed Wildlife	roadKilled
Road-Killed Wildlife Description	roadKilledWildlife
Observed Wildlife	WildlifeObserved
Observed Wildlife Description	WildlifeObservedTYP
Using HY-8?	HY8_use
Road Surface Type	roadSurfType
Estimated Crest Length	crest_Length
Top Width	topWidth
Flow Condition	flowCond
Alignment	alignment
Bankfull Width (1)	bankFullWdth1
Bankfull Width (2)	bankFullWdth2
Bankfull Width (3)	bankFullWdth3
Bankfull Width Average	bankFullWdthAVG
Bankfull Width Confidence	bankFullConf
Constriction	constriction
Tailwater Scour Pool	tailwater
Significant Break in Valley Slope	breakSlope
Bank Erosion	bankErosion
Sediment Deposition	sedDeposit
Elevation of Sediment Deposits Greater than or Equal to 1/2 Bankfull Height	sedDepHafFulll
Crossing Comments	crossingComments
Bottom Width	bottomWidth
Channel Slope	channelSlope
Left Bank Slope	lefBankSlope
Right Bank Slope	rightBankSlope
Stream Substrate	streamSubstrate
Tidal Site	tidalSite
Tidal Stage Comments	tidalStage
Tidal Comments	tidalStageOther
Tidal Prediciton	tidePrediciton
Tide Chart Location	tideChartLoc
Road Flooded at High Tide	roadFloodTide
Vegetation Above/Below	tideVegetation
Tide Gate Type	tideGate
Tide Gate Comment	tideGateOther
Inspection End Time	time_insp_end

Structure Field Data Dictionary	
Field Name Alias	**GIS Field Name (as exported from GIS)**
objectid	objectid
GlobalID	globalid
Structure Material	structureMaterial
Structure Length	structureLength
Structure Comments	structureComments
Inlet Shape	inletShape
Inlet Type	inletType
Inlet Grade	inletGrade
Inlet Dimensions: A - Structure Width	inletStrWidth
Inlet Dimensions: B - Stucture Height	inletStrHeight
Inlet Dimensions: C - Structure Substrate/Water Width	inletStrWtrFill
Inlet Dimensions: D - Structure Water Depth	inletStrWtrDpth
Slope	slope
Slope Confidence	slopeConfidence
Culvert Slope Compared to Channel Slope	CulSlp2ChnlSlp
Invert Condition	invertCondition
Joint & Seam Condition	jointSeamCondition
Barrel Condition/Structural Integrity	barrelCondtition
Headwall/Wingwall Condition	HWoWWcondition
Apron/Scour Protection Condition	apronScourProtectionCondition
Embankment Piping	embankmentPiping
Cross-Section Deformation (Metal)	xsectionDeformationMTL
Cross Section Deformation (Plastic)	xsectionDeformationPLSTC
Longitudinal Alignment	longitudianlAlignment
Footing Condition	footingCondition
Level of Blockage	blockageLevel
Flared End Section Condition	flaredEndSectionCondition
Buoyancy or Crushing	buoyancyoCrushing
Inlet Armoring Condition	armoring
Outlet Shape	outletShape
Outlet Armoring	outletArmoring
Outlet Grade	outletGrade
Outlet Dimensions: A - Structure Width	outletStrWidth
Outlet Dimensions: B - Structure Height	outletStrHeight
Outlet Dimensions: C - Substrate/Water Width	outletStrFill
Outlet Dimensions: D - Water Depth	outletWtrDpth
Outlet Drop to Water Surface	outletDrop

Structure Field Data Dictionary	
Field Name Alias	**GIS Field Name (as exported from GIS)**
Outlet Drop to stream bottom	outletDTstreamBTM
Outlet Dimensions: E - Abutment Height	outletAbutmentHt
Outlet Condition	outletCondition
Joint & Seam Condition	OjointSeamCondition
Barrel Condition/Structural Integrity	ObarrelCondtition
Headwall/Wingwall Condition	OHWoWWcondition
Apron/Scour Protection Condition	OapronScourProtectionCondition
Embankment Piping	OembankmentPiping
Cross-Section Deformation (Metal)	OxsectionDeformationMTL
Cross Section Deformation (Plastic)	OxsectionDeformationPLSTC
Longitudinal Alignment	OlongitudianlAlignment
Footing Condition	OfootingCondition
Level of Blockage	OblockageLevel
Flared End Section Condition	OflaredEndSectionCondition
Buoyancy or Crushing	ObuoyancyoCrushing
Outlet Armoring Condition	Oarmoring
Internal Structures	intStructures
Internal Structures - Other	intStructOther
Structure Substrate Matches Stream	strSubstrateVstream
Structure Substrate Type	strSubstrateType
Stucture Substrate Coverage	strSubstrateCover
Physical Barrier Type	physicalBarriers
Physical Barriers	physicalBarriersOther
Overall Physical Barrier Severity	physicalBarrierSeverity
Debris/ Sediment/ Rock Severity	SeveritydebrisSedimentRock
Deformation Severity	deformationSeverity
Free Fall Severity	freeFallSeverity
Fencing Severity	fencingSeverity
Dry Severity	drySeverity
Other Severity	otherSeverity
Water Depth Matches Stream	wtrDpthVstream
Water Velocity Matches Stream	wtrVelocVstream
Dry Passage Through Structure?	dryPassage
Height above Dry Passage	dryPassageHeight
ParentGlobalID	parentglobalid
CreationDate	CreationDate
Creator	Creator

Structure Field Data Dictionary	
Field Name Alias	**GIS Field Name (as exported from GIS)**
EditDate	EditDate
Editor	Editor
xy Crossing Code	CrossingCode
Inlet Elevation	inletElev
Outlet Elevation	outletElev
Outlet Invert Condition	OinvertCondition
Inlet Cross Section Deformation	xsectionDeformation
Outlet Cross Section Deformation	OxsectionDeformation
Crossing Code	ParentCrossingCode

Appendix F: Crossing Analysis Spreadsheets

This Appendix consists of pre-programmed vulnerability analysis spreadsheets with sufficient rows to assess 200, 500, or 100 crossings. The formulas in these spreadsheets are direct implementations of the methods outlined in this Handbook. This Appendix is available in digital form only.

Appendix G: GIS Methods for Section 10

This Appendix provides a detailed GIS methodology that may be used to complete the analysis described in Section 10: Flood Impact Potential.

G.1 Data Needs

G.1.1 Field Data Needs

Field data required for this section includes:

- Visible Utilities (Section 3.5.1)
- Bankfull Width (Section 3.5.2)
- Constriction (Section 3.5.2)
- Structure Width (Section 3.5.4)

G.1.2 GIS Data Needs

Stream Crossing Locations

- This analysis requires the use of the feature class containing the crossing locations and associated field data (if field data were collected using digital methods).
- If field data were collected using paper forms, a shapefile containing the crossing location and the average bankfull width value for each crossing will have to be created via editing of a pre-existing shapefile or manual creation of a new file.

Hydrologic Features

- The linear stream features and/or polygonal lake, pond, and estuary features originally used to determine crossing locations in Section 2.1: Identifying Possible Road-Stream Crossing Assessment Locations.

RIGIS Land Cover and Land Use (2011) Layer

- The most recent version of the Land Use and Land Cover layer may be downloaded from the RIGIS website (http://www.rigis.org/datasets/land-use-and-land-cover-2011). This land use/land cover dataset is based on 2011 orthophotos.

RIGIS Flood Hazard Areas

- Digitized flood hazard areas (polygons) compiled from county-based Digital Flood Insurance Rate Map (DFIRM) databases for Rhode Island (http://www.rigis.org/datasets/flood-hazard-areas).

Simple Flood Impact Model

- Download the Simple Flood Impact Model from (contact RIDOT for access to the model).
- This tool was created for the analysis described in Section 10.3.

G.2 GIS Methodology

The following methodology is designed for use in ArcMap, and terminology and inputs are specific to that program. In addition, Steps 13-17 require access to an Advanced User License for ArcMap. If using a different GIS program, the user may have to adapt the methodology accordingly.

Using GIS, the upstream/downstream extent of potential flood impacts is defined by creating 0.5-mile buffers around the road-stream crossing points. The lateral extent of potential flood impacts is defined based on FEMA flood hazard mapping (if available) or by creating bankfull width buffers (buffer distance equal to two times bankfull width) around the stream centerlines.

G.2.1 Buffer Creation

1. Create a Buffer centered on the crossing location, with a buffer distance set at 0.5 miles. The buffer features created will retain all attributes from the crossing points, including the Average Bankfull Width value. Name the output file "Crossing_Buffer_halfmile.shp"

   If FEMA flood hazard data is available for some crossings, skip to Steps 13-25 and complete the analysis for crossings with FEMA mapping first.

2. Create a Buffer around each stream centerline and/or water body polygon of 0.5 feet to convert the line feature to a polygon feature. Name the output file "Stream_Buffer_halffoot.shp"

- Check that the units are in feet, as the program may default to different units.
- Select "ALL" from the drop-down menu next to "Dissolve Type".

3. Use the Intersect tool to create an intersection of "Crossing_Buffer_halfmile.shp" from Step 1 and Stream_Buffer_halffoot.shp" from Step 2. Name the file "Buffer_Intersections.shp".

4. Begin an editing session for the "Buffer_Intersections.shp" file and delete all features from the attribute table. After saving your edits and ending the editing session, save this empty shapefile in a new, empty folder called "ModelOutput". This empty shapefile is a blank dataset that has schema matching the output of the model used in Steps 5-7.

5. Navigate to the Simple Flood Impact Model toolbox.

6. Right-click on the Simple Flood Impact Model in the toolbox and select "Edit." Edit the inputs using the following guidelines:
   - Iterate Feature Selection tool input: "Crossing_Buffer_halfmile.shp"
   - Iterate Feature Selection tool output file name: "I_Crossing_Buffer.shp"
   - Intersect tool input: "I_Crossing_Buffer.shp" and "Stream_Buffer_halffoot.shp" (two input files)
   - Intersect tool output file name: "Intersect_%n%.shp"
   - Intersect tool output file destination (save to): "ModelOutput" folder
   - Append tool input: "Intersect_%n%.shp"
   - Append tool target: "Buffer_Intersections.shp" (located in "ModelOutput" folder)
   - Append tool output: "Buffer_Intersections.shp" (located in "ModelOutput" folder)
   - Append tool schema type = "TEST"

7. Run the Simple Flood Impact Model. The model will add features to "Buffer_Intersections.shp", resulting in a shapefile containing a 1-foot wide stream polygon for each crossing point. These stream polygons are centered on each crossing point but may overlap with each other.

8. Create a copy of "Buffer_Intersections.shp" in the project folder and title it "Buffer_Intersections_Edited.shp".

9. Open an editing session for "Buffer_Intersections_Edited.shp".

10. Going row by row, select each entry in the attribute table and use the Cut Polygons and/or Reshape Feature tools (located on the Editor toolbar) to remove the portions of the 1-foot wide stream buffer that have been created around tributaries that join the stream downstream of the crossing being assessed. Also remove stream segments that fall within the ½ mile buffer around the stream crossing but are "cut off" on both ends by the boundary of the ½ mile buffer (see Figure G-1 for an illustration of the buffer editing process).
    - Note that for each crossing you are only removing the portions of the stream polygon that apply to that crossing (i.e. fall within the ½ mile buffer radius). Some tributaries removed for one crossing may be valid for another crossing if the second crossing is located on or downstream of that tributary.
    - Before removing tributaries, confirm which direction is upstream of the crossing and which is downstream. Tributaries that enter the stream upstream of the crossing should not be removed.

    Save your edits frequently throughout this step and when finished and end the editing session.

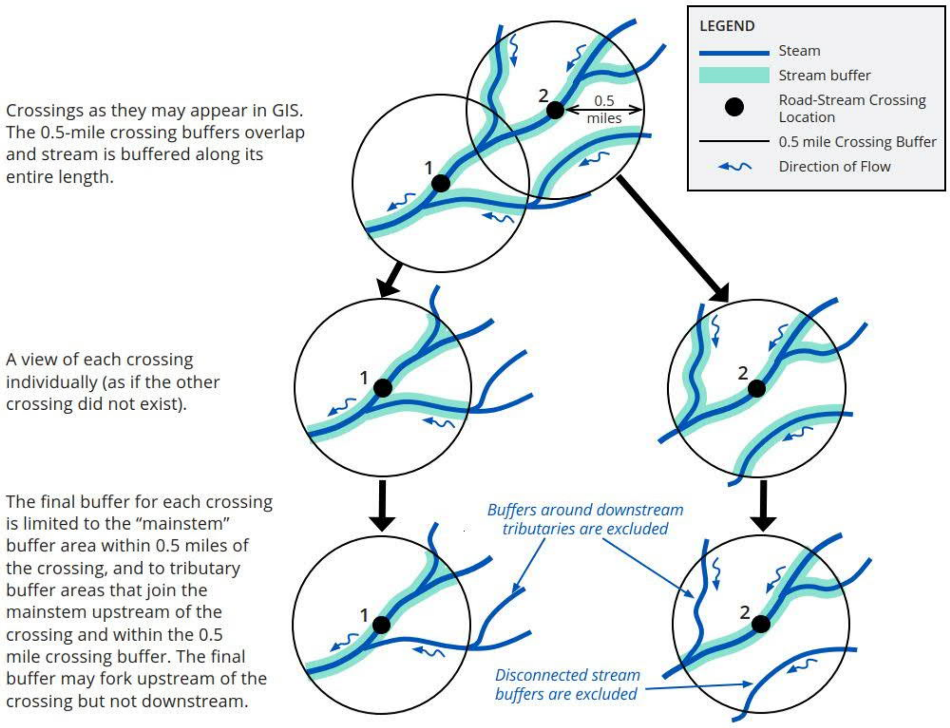

Figure G-1: Illustration of the road-stream crossing buffer editing process.

11. Open the attribute table for "Buffer_Intersections_Edited.shp" and create a new field called 2XBANKFULL, which represents the buffer width. Use the Field Calculator to calculate field using Equation 10-1, repeated here for your convenience:

Equation 10-1: Buffer Width

$$2XBANKFULL = 2 \times bankFullWdthAVG$$

Check that the units of bankFullWdthAVG are in feet, as the program may default to different units. If bankfull width was measured in units other than feet, apply the appropriate conversion to Equation 10-1 in the Field Calculator. In addition, check the units of your current data frame in GIS. If the data frame has default units other than feet, apply the appropriate conversion to Equation 10-1 in the Field Calculator.

If bankfull width was not measured in the field (due to an upstream wetland, inaccessibility, etc.), bankfull width for the purpose of this analysis can be estimated using the values recorded in the Constriction field according to Table G-1.

Table G-1. Buffer Width Estimate Formulas

Crossing Structure Constriction Rating (From Field Data)	Buffer Width Calculation (Enter into Field Calculator)
Severe	2XBANKFULL = 4 x Structure Width
Moderate	2XBANKFULL = 3 x Structure Width
Spans Only Bankfull Active Channel	2XBANKFULL = 2 x Structure Width
Spans Full Channel and Banks	2XBANKFULL = 2 x Structure Width

12. Create a Buffer around "Buffer_Intersections_Edited.shp" using the Field option for the buffer distance. Once the

Field radio button is selected, a dropdown box will light up immediately beneath. Select 2XBANKFULL from the list of fields in the dropdown box. Name the output file "2xBankfullWidth.shp".

FEMA Flood Hazard Data as Buffers
If using the FEMA National Flood Hazard Layer (NFHL), use the following method in place of Steps 2-10. Note that this data will likely not be available for all crossings in your assessment, and that Steps 2-10 will still need to be completed for crossings without NFHL data.

13. After completing Step 1, perform a visual inspection of the study area to identify 0.5-mile crossing buffers where the NFHL covers all stream reaches within that buffer, and select the corresponding 0.5-mile buffers. Make note of the crossing codes associated with these buffers, as they will be analyzed separately from the rest.

14. Using the latest downloaded NFHL, open an editing session to remove all polygons except for those defining the 100-year flood boundary (e.g., 500-year boundary). Use the Dissolve tool to combine these polygons into one continuous polygon in a layer titled "100YR_Dissolved.shp".

15. Replicate Steps 3 and 4. Use the Intersect tool with "Crossing_Buffer_halfmile.shp" and "100YR_Dissolved.shp" as the inputs. Save the output as "100YR_Buffers.shp" in a new, empty folder called "FEMA_ModelOutput". Remember to remove all features from "100YR_Buffers.shp" before continuing as detailed in Step 4.

16. Run the Simple Flood Impact Model detailed in Steps 6 and 7, using "100YR_Dissolved.shp" in place of "Stream_Buffer_halffoot.shp":
    - Iterate Feature Selection tool input: "Crossing_Buffer_halfmile.shp"
    - Iterate Feature Selection tool output file name: "I_Crossing_Buffer.shp"
    - Intersect tool input: "I_Crossing_Buffer.shp" and "100YR_Dissolved.shp" (two input files)
    - Intersect tool output file name: "Intersect_%n%.shp"
    - Intersect tool output file destination (save to): "FEMA_ModelOutput" folder
    - Append tool input: "Intersect_%n%.shp"
    - Append tool target: "100YR_Buffers.shp" (located in "FEMA_ModelOutput" folder)
    - Append tool output: "100YR_Buffers.shp" (located in "FEMA_ModelOutput" folder)
    - Append tool schema type = "TEST"

17. Proceed to the Step 10 procedure to remove flood polygons on tributaries entering the stream downstream of the crossing. For this editing step, make a copy of the model output ("100YR_Buffers.shp") and name it "100YR_Buffers_Edited.shp".

18. Perform the two analyses outlined in Steps 19-25 using "100YR_Buffers_Edited.shp" in place of "2xBankfullWidth.shp" for the crossings identified in Step 13. For these crossings, ignore the results of the bankfull width approach.

G.2.2 Calculation of Land Cover Percentages

19. Download the most recent land cover dataset from RIGIS. As of April 2019, this is the Land Use and Land Cover (2011) Version D dataset, which was last updated March 2017. The dataset is in vector form, and is referred to below as "LULC_2011.shp".

20. With an ArcGIS Advanced License enabled, run the Tabulate Intersection tool:
    - Input Zone Features: "2xBankfullWidth_Edited.shp"

- Zone Fields: Crossing Code field
- Input Class Features: “LULC_2011.shp”
- Output Table: “FloodImpact_LandUse”
- Class Fields: “Description” (the land use description)
- Sum Fields: optional, can serve as a check that areas are correctly calculated by the tool
- Output Units: optional

21. Convert “FloodImpact_LandUse” to an Excel workbook using the Table to Excel tool. The Output Excel File name must include “.xls” at the end.

22. In Excel, reclassify the following land use types as “developed” (all others as “undeveloped”):
    - Airports
    - Cemeteries
    - Commercial, commercial/industrial mixed, and commercial/residential mixed
    - Confined feeding operations
    - Cropland (tillable)
    - Developed recreation
    - High density residential
    - Industrial
    - Institutional
    - Low density residential
    - Medium density residential, medium high density residential, and medium low density residential
    - Mines, quarries and gravel pits
    - Orchards, groves, nurseries
    - Other transportation
    - Railroads
    - Roads
    - Transitional areas (urban open)
    - Waste disposal
    - Water and sewage treatment

23. Use Pivot Tables to calculate the fraction of developed land within each crossing buffer:
    - Rows: xyCode
    - Columns: Developed/Undeveloped
    - Values: PERCENTAGE
    - Change Count of Percentage to Sum of Percentage.
    - Apply the Sum of Percentage for the developed land uses to the ranking methodology.

G.2.3 Determination of the Number of Crossings within Each Crossing Buffer

24. Run the Spatial Join tool:
    - Target Features: “2xBankfullWidth.shp” (as edited in Step 10)
    - Join Features: Original crossing point feature class
    - Join Operation: One to Many
    - Keep all target features.
    - Remove all attributes from the Field Map, except for CROSSINGCODE.
    - Match Option: WITHIN_A_DISTANCE
    - Search radius: 0.5 miles

    Output feature class will have a feature for each crossing that falls within that buffer. Thus, if an xycode is listed three times, that means there are three crossings located within 0.5 miles of that crossing, which means that there are two crossings within the buffer (other than the one in the middle we are analyzing).

25. Apply a rating to each crossing based on the percentage of its buffer that consists of developed area and the number of stream crossings located within the buffer, using Table 10-2.

Appendix H: Pilot Study

The methods described in this Handbook were tested and refined through the completion of a pilot study in the Woonasquatucket River watershed. This Appendix contains the pilot study report and attachments. The pilot study report provides an example of the application of the assessment methods described in the Handbook for users to follow while implementing their own study.

Woonasquatucket River Watershed Pilot Study Road-Stream Crossing Assessment

Rhode Island Department of Transportation

Providence, Rhode Island

July 15, 2019

FUSS & O'NEILL

317 Iron Horse Way, Suite 204
Providence RI, 02908

20141278.B10

FUSS & O'NEILL

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Rhode Island Department of Transportation

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1 Introduction

1.1 Background

Inadequate or undersized road-stream crossings can be flooding and washout hazards and can serve as barriers to the passage of fish and other aquatic organisms. As precipitation events become more intense and less predictable as a result of climate change, inadequate or undersized road-stream crossings are expected to pose a greater threat of failure; flooding damage to homes and businesses, transportation infrastructure, and utilities; and stream channel erosion. The Woonasquatucket River watershed in northern Rhode Island has experienced extensive flooding and flood-related damages in recent years, due in part to inadequate or undersized road-stream crossings. Prolonged heavy rain in February and March of 2010 led to record-breaking floods in Rhode Island that resulted in widespread damage throughout the Woonasquatucket River watershed.

In collaboration with Fuss and O'Neill and members of a stakeholder group, the Rhode Island Department of Transportation (RIDOT) developed a Road-Stream Crossing Assessment Handbook (herein referred to as the Handbook) to serve as a guidance document and decision-making tool for identification of road-stream crossings in Rhode Island that should be prioritized for replacement or upgrade. The assessment methodology in the Handbook prioritizes road-stream crossings based on flood-related vulnerability under present and future climate conditions while also considering barriers to aquatic organism passage.

1.1.1 Purpose

The purpose of this Pilot Study is to implement the recommended methodology in the Handbook through the assessment of selected road-stream crossings in the Woonasquatucket River watershed. The Pilot Study is intended to serve as an example of how to apply the field data collection, assessment, and prioritization methods in the Handbook. The Pilot study will also be used to refine the methodology in the Handbook, which will be finalized upon completion of the study.

The assessments consisted of field surveys of individual stream crossings, followed by analysis of the field data to assign vulnerability ratings to each crossing based on the methodology recommended in the Handbook. Multiple factors were included in the analysis, including hydraulic capacity, structural condition, geomorphic risk, aquatic organism passage, transportation and emergency services, other flooding impacts, and climate change considerations. The vulnerability ratings were then used to prioritize structures for upgrade or replacement.

This Pilot Study report summarizes the results of the road-stream crossing field surveys and vulnerability assessment conducted utilizing the methodology of the Handbook. Recommendations are presented based on field observations and the vulnerability assessment and prioritization process. This report also addresses lessons learned by using the Handbook to conduct road-stream crossing assessments in the Woonasquatucket River watershed study area. These lessons are incorporated directly into the discussion of the methods and results so that readers completing their own road-stream crossing assessments can refer to the pilot study on a section-by-section basis in coordination with their progress through the

Handbook. The methods contained in the Handbook are described generally in this report; the reader should refer to the Handbook for further details regarding the methodology.

1.1.2 Location

The Woonasquatucket River watershed is a 50-square mile watershed located in northeastern Rhode Island (**Figure 1**). The watershed includes portions of the municipalities of North Smithfield, Smithfield, Glocester, Johnston, North Providence, Providence and Cranston. Hydrologic features in the watershed include several tributaries, ponds, reservoirs, and the 19-mile long Woonasquatucket River. The headwaters of the river are located in North Smithfield, from which the river flows southeast to the City of Providence, where it joins with the Mohassuck River before emptying into Narragansett Bay. The Woonasquatucket River watershed was selected for the Pilot Study primarily because it includes a mixture of urban and rural land use, which differentiates the watershed from other locations in the state where road-stream crossing surveys have been conducted (such as the mostly rural Wood-Pawcatuck watershed).

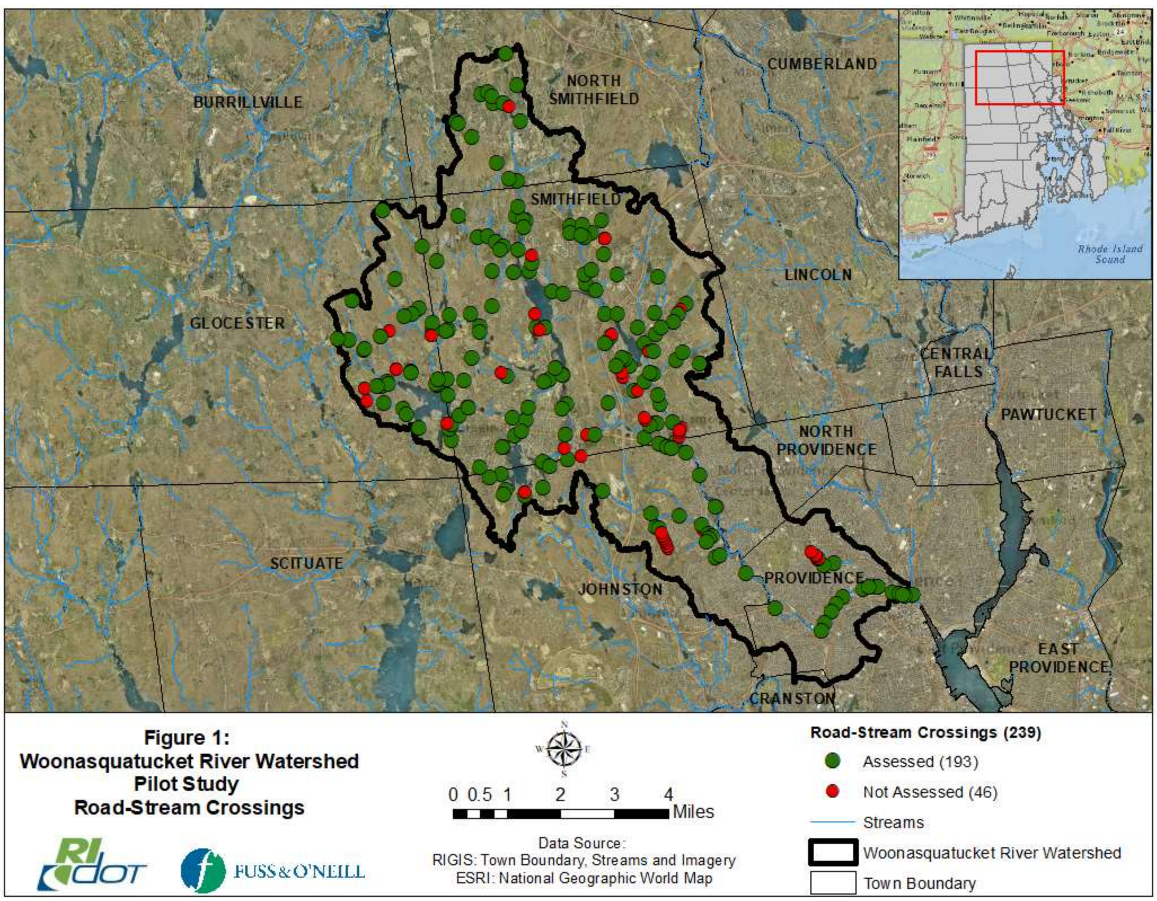


Figure 1. Selected road-stream crossings in the Woonasquatucket River watershed

2 Assessment Methods

2.1 Identification of Road Stream Crossings to be Assessed

Road-stream crossings to be included in the assessment were initially identified based on mapped intersections of the "RIDOT Roads" data layer with the "Rivers and Streams", "Lakes Ponds and Reservoirs" and "Marine and Estuarine Waters" data layers available from the Rhode Island Geographic Information System (RIGIS). Additional crossings were identified through comparison of the mapped crossings with the North Atlantic Aquatic Connectivity Collaborative (NAACC) database of crossing locations.

Two hundred and thirty-nine (239) road-stream crossings in the Woonasquatucket River watershed were ultimately selected for field surveys. Additional crossings were located under highways or highway ramps, but these were omitted from the selection due to access and safety concerns. The locations of the selected crossings are shown on the Road-Stream Crossing Sites data layer on the watershed map in **Figure 1**. Each crossing was assigned a unique crossing code composed of the prefix "xy" followed by the latitude and longitude of the crossing location to 7 digits in decimal degrees.

2.2 Field Work

2.2.1 Preparation

Several tasks were completed prior to initiating the field assessments:

- Field staff achieved NAACC Lead Observer status through a combination of online, classroom and field-based training.
- A Job Hazard Analysis (JHA) was completed to identify potential hazards and appropriate safety equipment. The JHA was reviewed and signed by all field personnel.
- Bentley CulvertMaster was selected as the hydraulic analysis program prior to initiating field visits, as this affects the manner in which field data is collected. See **Handbook Section 6: Existing Hydraulic Capacity** for additional information about program selection.
- Tidal crossings were identified to ensure the tidal section of the field form was filled out for the appropriate crossings. For the Pilot Study, the 13 crossings located downstream of the dam at Rising Sun Mills off of Valley Street in Providence were considered tidal, based on local knowledge available from the project team's past experience working in the watershed. According to the methodology in **Handbook Section 2.3.2**, a crossing should be considered tidal if it is located waterward of the Rhode Island Mean Higher High Water (MHHW) line, as depicted on the "Inundation Polygons: MHHW with 0ft SLR" data layer available from RIGIS. None of the crossings in the Woonasquatucket River watershed are located waterward of the MHHW line as depicted in the data layer. When discrepancies such as this are noted between available mapping and local knowledge, the analyst's judgement and site observations should ultimately be used to decide whether a crossing is tidal or not.

- Crossing locations were screened for access issues so that arrangements could be made before going into the field if necessary. Crossings located on multi-lane state highways and highway ramps were removed from the list of crossings to be assessed, due to safety concerns. No other access issues were identified during the desktop analysis.
- The digital RIDOT road-stream crossing assessment form was loaded onto a GPS-enabled tablet (one per field crew) with a preloaded digital version of the field form, the Road-Stream Crossing Sites data layer and aerial imagery for the project locations. Paper forms were brought into the field as a backup method to complete surveys in the event of tablet battery failure or other malfunction. A blank copy of the paper version of the field data form is included as **Handbook Appendix A** and a complete list of field equipment options is available in **Handbook Section 2: Initial Assessment Planning**. A list of equipment used during the Pilot Study is provided below in **Table 1**.

Table 1. Field Equipment utilized during Pilot Study

Field Equipment	Purpose
GPS-enabled tablet preloaded with digital data collection form	Recording field data
Portable battery pack and charging cord	Charging tablet in the field
Paper data collection forms and pens	For use in recording field data in the event of tablet power failure or malfunction
300-foot reel tape in feet and decimal feet	Measuring bankfull width
Pocket tape measure	Measuring structure height, width and length
16-foot and 25-foot stadia rods	Measuring slope and road crest height
Nikon AC 2-S automatic level and tripod	Measuring slope
Measuring wheel†	Measuring structure length across roadways
Flashlight	Increasing visibility within crossing structures
Safety vests and cones	Increasing visibility of field crew members along roadsides for safety
Chest waders	Accessing deep streams and rivers
Sunscreen and insect repellant	Protection from sun exposure and insect bites
Poison ivy soap and prevention treatment	Protection from exposure to poison ivy
First aid kit	Administer first-aid in the field
Cell phone	Photographic site in the event of tablet failure; calculating slope; communication

† A measuring tape is also useful for measuring structure length when the length of the structure extends beyond the roadway since a measuring tape can be held level.

2.2.2 Data Collection

Initial field surveys were performed from September 18, 2018 through November 15, 2018 by a two-person field crew. Each field crew was led by a NAACC-Certified Lead Observer. RIDOT staff assisted with the first several field surveys and with training of the field crew to achieve NAACC Lead Observer certification. Twenty-five (25) crossings were revisited on February 19, 2019 and one (1) crossing was revisited on May 23, 2019 to collect missing data that was identified during Quality Control (QC) review. The QC process and results are further discussed in **Sections 2.2.3 and 3.1.1.**

Field surveys were conducted using the road-crossing assessment procedures detailed in **Handbook Section 3: Field Data Collection**, which were adapted from established methods, particularly those developed by NAACC, and further developed through the professional experience of the authors. General site characteristics (stream and road name, location description, etc.), digital photographs, and GPS coordinates were collected at each crossing. Data to evaluate culvert capacity, structural condition, geomorphic vulnerability, flooding impact potential, and aquatic organism passage at each structure were recorded at each crossing using the tablet and digital field form. Field data were reviewed at the end of each crossing survey and uploaded from the tablet at the end of the day. Uploaded data were saved and managed using ArcGIS Pro version 2.2.2 and ArcGIS Online (**Figure 2**).

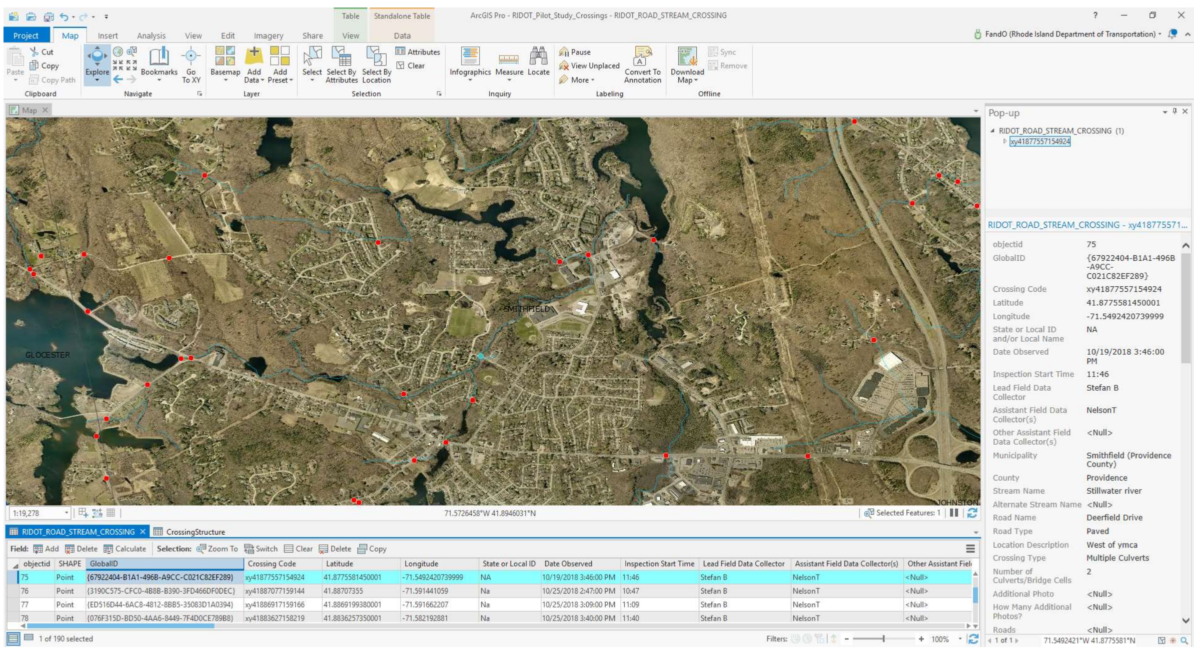


Figure 2. Road-Stream Crossing data management in ArcGIS Pro

There are a variety of circumstances that resulted in collection of some, but not all required data for a crossing including:

- No access was available to the crossing inlet or outlet.
- The upstream or downstream structure was buried or could not be found.
- The inlet or outlet was partially submerged.
- The structure was too large to measure.
- The water was too deep to safely enter.

Crossings with limited access were assessed to the extent possible by estimating the missing parameters when appropriate and/or adjusting the vulnerability assessment scoring based upon the analyst's judgement. All assumptions were noted in the data analysis spreadsheet. The assumptions were made with the intention of capturing any issues that could be identified at the crossing using the partially-collected data, without artificially raising or lowering the crossing score or overall priority. The assumptions made for each vulnerability assessment are explained in **Section 2.3: Assessment Methods**.

2.2.3 Quality Control

Following completion of the stream crossing surveys, field data was checked for quality control purposes. Collected data was reviewed and compared to photos for each crossing. If data was missing or inconsistent with the photos, the Lead Field Data Collector was contacted to review the discrepancies. If the discrepancy could be adequately resolved by the Lead Field Data Collector, the changes were made and noted under "QC Comments". If discrepancies could not be adequately resolved, the crossing was marked to be revisited to resolve the issue or collect the missing data.

The location and crossing code of each crossing was reviewed for accuracy during the QC review. The digital data collection form was set up to automatically collect latitude and longitude at the tablet's location when the form was opened for a particular crossing. If the field crew member holding the tablet was not standing at the correct location at the crossing when opening a new field form, the location recorded was incorrect. Incorrect crossing locations were manually moved to the correct location during QC review, after which the crossing codes were updated to reflect the correct coordinates.

Ideally, QC should be completed by someone other than the Lead Field Data Collector; however due to time and staffing constraints QC for about half of the crossings was completed by the Lead Field Data Collector. See **Handbook Section 4: Quality Control** for a detailed description of recommended QC procedures.

2.3 Assessment Methods

Once the field data was collected and checked, the following methods were used to assess each road-stream crossing.

2.3.1 Existing Streamflow Conditions

Existing peak discharge for common recurrence intervals was estimated using regional regression equations developed by the United States Geological Survey (USGS) for estimating peak flows at ungauged locations (i.e., USGS StreamStats). The StreamStats program allows the user to delineate a watershed at a given location based on the available stream data layer. In cases where the StreamStats stream data layer was not available at the exact crossing location, the analyst's judgement was used to decide if a nearby crossing could be used as an approximation or if an alternative method was required to estimate peak streamflow. Peak streamflow values, 7Q10 low flow values, drainage area, and any out-of-range parameters were recorded for each crossing delineated in StreamStats.

It is common for StreamStats to report one or more parameters outside of the suggested range for which the regional regression equations were originally developed (e.g. drainage area, stream density, percent storage). StreamStats results were used in these cases despite the greater degree of uncertainty, as these streamflow estimates are still appropriate for a screening-level analysis.

The accuracy of the streamflow estimates generated by StreamStats for larger drainage areas was assessed by comparing the streamflow estimates from StreamStats at crossing xy41859167148748 (over the Woonasquatucket River in Johnston) with peak streamflow estimates derived from a USGS gage located about 75 feet downstream of the crossing (USGS gage 01114500). Peak streamflow values were estimated at the USGS gage using the available historical record and were found to be comparable to the streamflow estimates generated by StreamStats (**Table 2**). Crossing xy41859167148748 has a drainage area of 38 square miles and all of the StreamStats parameters were within the suggested range. Streamflow estimates generated by StreamStats can be expected to achieve similar accuracy for crossings with similar circumstances (e.g., larger crossings with no StreamStats parameters out of range).

Table 2. Comparison of peak streamflow estimates generated by StreamStats for crossing xy41859167148748 and the historical record at USGS Gage 0114500

Streamflow Estimation Method	Drainage Area (square miles)	10-year peak streamflow (cfs)	25-year peak streamflow (cfs)	50-year peak streamflow (cfs)	100-year peak streamflow (cfs)
StreamStats (Crossing xy41859167148748)	37.7	1050	1410	1690	2000
USGS Historical Record (USGS Gage 0114500)	38.3	1170	1440	1530	1810

The watershed delineations generated by StreamStats were reviewed in GIS using aerial imagery and the RIGIS "Rivers and Streams" data layer to check the accuracy of the delineations, which can significantly affect the peak streamflow estimates generated by the regional regression equations. Watershed boundaries with gross inaccuracies were manually delineated and an alternative method was used to estimate streamflow values.

The accuracy of the streamflow estimates generated by StreamStats were further assessed by calculating the rate of streamflow per unit land area (cubic feet per second per square mile, or CSM) for all crossings delineated in StreamStats. CSM values can provide a quick, screening-level check of streamflow estimates since flows at a given location are largely influenced by climatic, physiographic (topography, soils, geology, geomorphology, etc.), and development characteristics of the watershed. Given the relatively uniform climate and physiography throughout the Woonasquatucket, CSM values are expected to be relatively consistent, varying somewhat with development characteristics particularly in small drainage areas where peak flows are more strongly influenced by runoff from impervious surfaces. CSM values for crossings in the Woonasquatucket River watershed can be expected to be within approximately 1 order of magnitude of each other.

If the CSM value for a given crossing was more than two orders of magnitude higher or lower than the majority of crossing CSM values, the data were further checked for transcription or related errors. If no such errors were found and one or more parameters were outside of the suggested range for which the regional regression equations were originally developed (e.g. drainage area, stream density, percent storage), the StreamStats streamflow estimates were considered potentially inaccurate and an alternative method was used to estimate streamflow for the crossing. An alternative streamflow estimation method was also required when StreamStats returned values of 0 or no values for peak-flow estimates and when there was no gridded stream network data layer available in StreamStats within the vicinity of the crossing.

For this Pilot Study, the drainage-area ratio method was used as an alternative streamflow estimation method, following the methodology in **Handbook Section 5: Existing Streamflow Conditions**. The drainage-area ratio method is based on the assumption that the streamflow at a site along a stream is the same per unit drainage-basin area as that at a hydrologically similar site near the crossing and within the same watershed. The drainage-area ratio method is typically used to estimate streamflow at ungaged locations using streamflow values from a nearby hydrologically similar gaged location as a reference. It is generally recommended that the drainage area of the reference location be within 0.5 - 1.5 times the size of the drainage area of the ungaged location. Ideally the two watersheds should also be in close geographic proximity and have similar flow regimes, land-use, and physical characteristics (Bent et al., 2014).

For the purposes of this Pilot Study, the drainage-area ratio method was used to estimate streamflow at ungaged locations based on flow estimates derived from the StreamStats regional regression equations at other ungaged sites. The accuracy of using the drainage-area ratio method in this manner (using streamflow estimates from an ungaged site to estimate streamflow at another ungaged site) has not been evaluated. However, using the method in this manner was considered appropriate for a screening-level analysis.

The following factors were considered in choosing a reference watershed for the drainage-area ratio method, listed in order of significance:

1. Comparable level of development (+/- 10 percent of developed area)
2. Comparable amount of wetland storage (+/- 10 percent of wetland coverage)
3. Comparable drainage area (0.5 to 1.5 times the area of the reference watershed)

Level of development was determined as percent developed area in each drainage area using the RIGIS 2011 Land Use and Land Cover[1] data layer. Wetland storage was measured as percent wetland coverage in each drainage area using the 2014 National Wetland Inventory (NWI) data layer for Rhode Island, available from RIGIS.

The factors listed above were used as guidelines. Level of development and wetland storage were prioritized over drainage area because it was not always possible to identify a reference watershed with a drainage area within the preferred size range.

[1] Developed land use was defined as Land Use Codes with values less than 200.

The peak streamflow values generated from the methods described above were used to calculate the existing and future hydraulic capacity, as described below in **Sections 2.3.2 and 2.3.3**. The 7Q10 low flow values were not used directly in the analysis but were recorded to provide further information about the crossings during review of the final prioritization results. Refer to **Handbook Section 5: Existing Streamflow Conditions** for a detailed description of the methodology.

2.3.2 Existing Hydraulic Capacity

The hydraulic capacity of each road-stream crossing was estimated using standard Federal Highway Administration culvert/bridge hydraulic calculation methods following FHWA Hydraulic Design Series Number 5 (HDS-5). Bentley CulvertMaster, a software program which employs HDS-5 methods, was used for the majority of the analysis. Hydraulic capacity was calculated based on data collected in the field. Tailwater depth was selected based on **Table 6-3** in **Handbook Section 6: Existing Hydraulic Capacity**. Headwater depth at failure was defined for each culvert based on **Table 6-2** in **Handbook Section 6: Existing Hydraulic Capacity**.

For concrete culverts, headwater depth is defined as a headwater elevation 1 foot below the lowest point in the roadway surface. At all of the assessed sites, the crossing structure was located in line with the lowest part of the roadway surface; therefore the *Road Crest Height* measurement was typically used in this calculation. *Road Crest Height* measurements should ideally be taken consistently at the upstream end of the culvert, following the methodology in **Handbook Section 3: Field Data Collection**. Taking this measurement at the downstream end of the culvert will result in inconsistent measurements, as the *Road Crest Height* will be higher when measured from downstream. However, during the Pilot Study the measurements had to be taken at the downstream end of some culverts due to factors such as visibility and access. When such deviations are made from the methods, comments should ideally be made in the *Crossing Comments* and/or *Structure Comments* fields, as appropriate. During the Pilot Study, it was not recorded when *Road Crest Height* was measured at the downstream end of the culvert. As a result, it was impossible to determine an accurate value for headwater at failure for concrete culverts. For crossings that are short and/or have shallow slopes, this error can be neglected. For crossings with a large difference in elevation between inlet and outlet, the difference in *Road Crest Height* can potentially be significant.

To minimize the error associated with this gap in field data, it was assumed that the *Road Crest Height* measured in the field was taken at the middle of the crossing (i.e., at an elevation between the inlet and outlet elevations). In CulvertMaster, the headwater elevation is relative to the invert of the outlet pipe. Therefore, instead of using **Eq. (1),** below, to compute the CulvertMaster headwater elevation, **Eq. (2)** was used, where "RCH" refers to *Road Crest Height* and "HW el." refers to the relative elevation above the outlet invert.

$$HW\ el. = RCH - 1 + inlet\ invert\ elevation \qquad Eq.\ (1)$$

$$HW\ el. = RCH - 1 + 0.5 * inlet\ invert\ elevation \qquad Eq.\ (2)$$

To prevent this error from occurring in the future, language was clarified in **Handbook Section 3**: **Field Data Collection** to instruct the user to measure *Road Crest Height* at the upstream end of the culvert unless impossible, and to note in the *Crossing Comments* when a measurement is taken at the downstream end of the culvert.

Hydraulic capacity for bridges and for structures with irregular inlet and outlet dimensions could not be computed accurately in CulvertMaster. For such structures, Manning's equation for uniform open channel flow was used to estimate the crossing hydraulic capacity, assuming headwater at failure to be 1 foot below the bridge deck or inlet obvert.

A Capacity Ratio (defined as the ratio of estimated hydraulic capacity to the estimated peak discharge for a specified return interval) was calculated for each crossing and recurrence interval analyzed (10-year, 25-year, 50-year, and 100-year events). The crossing has sufficient capacity to convey a given return interval peak discharge if the Capacity Ratio for that return interval is greater than or equal to 1. The crossing is undersized for the return interval peak discharge if the Capacity Ratio is less than 1. *Binned Hydraulic Capacity Scores* were assigned based upon the Capacity Ratios and **Handbook Table 6-4**. Refer to **Handbook Section 6: Existing Hydraulic Capacity** for a detailed description of the methodology.

The following assumptions were made for crossings where either the outlet or the inlet was inaccessible, buried, or could not be found.

- If the structure dimensions could not be measured at one end of the crossing structure, the dimensions were assumed to be equal to those measured at the other end of the structure. While culvert inlet and outlet structure dimensions, shape, and material often differ (particularly for buried streams), this assumption was considered the best possible method for completing the analysis in the absence of information on both ends of the crossing structure.

- For structures missing a measured slope or having a measured slope less than or equal to zero, a slope of 0.5% was used for calculation purposes. Whether using Manning's equation or CulvertMaster, a slope less than or equal to zero will result in a discharge of zero. There are many reasons why a slope could be zero or even negative when measured in the field; however, every structure assessed and visited in the field has some nonzero capacity. Culverts are generally designed with a slope close to 1%, but in an effort to be more conservative, a slope of 0.5% was assumed for such structures.

- For crossings without a structure length measurement, structure length was estimated in Google Earth Pro by measuring from the known end of the crossing to the estimated location of the inaccessible inlet or outlet. A slightly shorter structure length than the actual structure length was substituted in the existing and future hydraulic analysis, with the assumption that the resulting calculated hydraulic capacity would exceed the actual hydraulic capacity. If the crossing was not able to pass the 100-year return interval flow with a shorter structure length, it was assumed that it cannot pass the 100-year return interval flow with a longer structure length. For crossings modeled with a shorter structure length, if the existing or future hydraulic Capacity Ratio was calculated to be between 1.00 and 1.10, the crossing was manually assigned the next highest *Binned Hydraulic Capacity Score* or *Binned Future Hydraulic Capacity Score* (as appropriate) to account for the uncertainty in the estimate. For example, if a crossing with an unknown structure length received a *Binned Hydraulic Capacity Score* of 2, but the Capacity Ratio for the existing 25-year peak flow was calculated to be 1.05, the *Binned Hydraulic Capacity Score* would be increased from a 2 to a 3.

- If hydraulic capacity could not be assessed because structure dimensions could not be measured at either the inlet or outlet, a *Binned Hydraulic Capacity Score*, *Binned Future Hydraulic Capacity Score*, and *Hydraulic Capacity Change Score* of 3 was manually assigned.

The assumptions listed above apply to assessment of existing hydraulic capacity as well as future hydraulic capacity, which is detailed in below in **Section 2.3.3**.

2.3.3 Future Climate Change Assessment

Peak discharge under a future climate change scenario was estimated for each road-stream crossing by multiplying existing peak discharge values (see **Section 2.3.1**, above) by a peak flow multiplier of 1.2 (20% increase) for all return intervals. Capacity Ratios were recalculated for each crossing and return interval using these new future peak discharge values. Each crossing was assigned a *Binned Future Hydraulic Capacity Score* according to **Handbook Table 7-2**. A *Binned Hydraulic Capacity Change Score* was also calculated for each crossing, in which the future hydraulic capacity is compared to the existing hydraulic capacity and assigned an appropriate score according to **Handbook Table 7-3**.

Crossings that may be impacted by future sea level rise and storm surge were identified using sea level rise inundation scenarios developed by the Rhode Island Statewide Planning Program (RISPP) and the STORMTOOLS GIS inundation data layer prepared by the Rhode Island Coastal Resources Management Council (CRMC) in partnership with the University of Rhode Island. The Road-Stream Crossing Sites data layer discussed in **Section 2.1** (above) was overlaid with GIS layers representing modeled inundation areas corresponding to 100-year storm surge plus 0, 1, 3, 5, and 7 feet of sea level rise in order to identify crossings that may be inundated under each scenario. A *Binned Sea Level Rise and Storm Surge Score* was assigned to each crossing according to **Handbook Table 7-5**.

A final *Binned Climate Change Vulnerability Score* was assigned to each crossing according to **Handbook Table 7-7**, by taking the maximum of the *Binned Future Hydraulic Capacity Score*, the *Binned Hydraulic Capacity Change Score* and the *Binned Sea Level Rise and Storm Surge Score*. Refer to **Handbook Section 7: Climate Change Vulnerability** for a detailed description of the methodology.

The assumptions made for crossings where either the outlet or the inlet was inaccessible, buried, or could not be found are detailed in **Section 2.3.2** (above).

2.3.4 Geomorphic Vulnerability

The geomorphic vulnerability assessment evaluated the potential for crossing structures to impact geomorphic processes that might, in turn, threaten the structure itself and/or other nearby infrastructure. The assessment procedure distinguishes between crossings that are: 1) not prone to and have not experienced geomorphic adjustments; 2) prone to but have not experienced geomorphic adjustments; and 3) prone to and have experienced geomorphic adjustments. The approach rates the relative likelihood that impacts could occur as well as the type and severity of impacts that have already occurred. Factors that are considered in the assessment include *Alignment*, *Bankfull Width*, *Constriction*, *Tailwater Scour Pool*, *Significant Break in Valley Slope*, *Bank Erosion*, *Sediment Deposition*, *Channel slope*, *Stream Substrate* and other geomorphic parameters listed in **Handbook Section 8.2**.

For two crossings the *Significant Break in Valley Slope* was unknown or unable to be determined in the field. These crossings were reviewed in the office using ArcGIS and the Rhode Island Elevation Contours Map Service provided by RIGIS to determine if a *Significant Break in Valley Slope* was present. A crossing was considered to have a *Significant Break in Valley Slope* if the upstream section was substantially steeper within 1/3 of a mile of the crossing, as evidenced by the contour lines. An example of a crossing with a *Significant Break in Valley Slope* is provided in **Handbook Section 3: Field Data Collection**.

The methodology for assessing geomorphic vulnerability in **Handbook Section 8: Geomorphic Impacts** assigns an individual *Impact Rating* for each of the factors listed above. The individual scores are then summed appropriately to create a *Potential Geomorphic Impact Rating* and an *Observed Geomorphic Impact Rating*. The results of the potential and observed impact scores are then combined to produce a *Binned Overall Geomorphic Impact Score* according to **Handbook Table 8-11**.

The *Potential Geomorphic Impact Rating* detailed in **Handbook Section 8.3** typically includes an individual *Impact Rating* for stream substrate size (**Handbook Table 8-5**, *Substrate Size Impact Potential Ratings*). However, due to an error in the digital data collection form, stream substrate was not collected at the majority of the crossings included in the Pilot Study. Stream substrate type was collected at 87 (45%) of the 193 assessed crossings. For some of these crossings the crossing substrate type was recorded in the *Crossing Comments* and/or *Structure comments* field, while for others, the *Structure Substrate Matches Stream* field was noted as being "Comparable", in which case the structure substrate type could be substituted for the stream substrate type.

The following two methods were tested and compared to determine how to best account for the absence of this data for the majority of the assessed crossings without artificially raising or lowering the geomorphic vulnerability scores:

1. The *Substrate Size Impact Potential Rating* was removed from the *Potential Geomorphic Impact Rating* for all of the assessed crossings in the Pilot Study and **Handbook Table 8-9** was modified according to **Table 3**, below. By removing the *Substrate Size Impact Potential Rating*, the *Potential Geomorphic Impact Rating* has a maximum of 15 rather than 20. To account for this modification, the *Binned Overall Geomorphic Impact Scoring* method described in **Handbook Table 8-11** was modified according to **Table 3**, below.
2. The *Substrate Size Impact Potential Rating* was included in the *Potential Geomorphic Impact Rating* for all of the assessed crossings as described in **Handbook Sections 8.3** and **8.5**. For the 87 crossings for which stream substrate type was available, the *Substrate Size Impact Potential Rating* was assessed as appropriate according to **Handbook Table 8-5**. For the 106 crossings for which stream substrate was not available, a *Substrate Size Impact Potential Rating* of 3 was manually

assigned. **Handbook Tables 8-9** and **8-11** were not modified and were used as described in **Handbook Sections 8.5** and **8.6**.

Table 3. Modifications to Handbook Table 8-9 (left) and Handbook Table 8-11 (right) to account for the removal for the Substrate Size Impact Potential Rating

Combined Potential Impact Rating	Likelihood for Geomorphic Impacts
3	Very unlikely
4-6	Unlikely
7-9	Possible
10-12	Likely
13-15	Very Likely

Sum of Geomorphic Potential Impact Ratings and Observed Geomorphic Impact Ratings	Binned Overall Geomorphic Impact Score
6	1
7-12	2
13-18	3
19-24	4
25-30	5

The results of the two methods described above were compared and the impact of these modifications on the *Binned Overall Geomorphic Impact Scores* and the overall prioritization is discussed in **Section 3.2.5**. Ultimately, it was determined that method # 2 (including the *Substrate Size Impact Potential Rating* as described in the Handbook using the available data for the 87 crossings and manually assigning a score of 3 for all other crossings) was the most appropriate way to account for the absence of stream substrate for the majority of the crossings without artificially raising or lowering the scores. The digital data collection form was adjusted to prevent this error from occurring in the future.

The following assumptions were made for crossings where either the outlet or the inlet was inaccessible, buried, or could not be found:

- *Culvert Slope Compared to Channel Slope* was assumed to be "About Equal".
- *Significant Break in Valley Slope* was assumed to be "None".
- When the outlet could not be found, *Tailwater Scour Pool* was assumed to be "None".
- If the outlet or inlet grade was at stream grade, the end of the structure that could not be assessed was also assumed to be at stream grade and the crossing was assigned an *Inlet and Outlet Grade Impact Rating* of 1 according to **Handbook Table 8-8**.

2.3.5 Structural Condition

The structural condition of all structures at a crossing were assigned ratings and scores based on visual observations of the structure inlet, outlet and barrel. Assessment methods were adapted from the latest version of the NAACC Culvert Condition Assessment Manual, which was developed with input from state transportation departments throughout the Northeast and other stakeholders. The NAACC condition assessment methodology is designed as a rapid assessment tool for use by trained observers for purposes of flagging crossings that should be examined more closely for potential structural deficiencies.

Structural issues that were recorded in the field and are included in the assessment include *Cross-section Deformation, Barrel Condition/Structural Integrity, Footing Condition, Level of Blockage, Buoyancy or Crushing, Invert*

Deterioration, Joint and Seam Condition, Longitudinal Alignment, Headwall/Wingwall Condition, Flared End Section Condition, Apron/Scour Protection Condition, Armoring Condition and *Embankment Piping*. Each of the factors listed above was marked as "adequate", "poor" or "critical" according to the criteria in **Handbook Section 3: Field Data Collection**.

A *Condition Score* is assigned to each crossing based on Level 1, Level 2 and Level 3 variables, as described in **Handbook Section 9.3**. The lowest score resulting from the Level 1, Level 2 and Level 3 variables is considered the *Overall Condition Score* for the crossing. The *Overall Condition Score* ranges from 0 to 1 with a lower score indicating the crossing is in more critical condition. The *Overall Condition Score* was then used to generate a *Binned Structural Condition Score* using **Handbook Table 9-4**. Refer to **Handbook Section 9: Structural Condition** for a detailed description of the methodology.

The following assumptions were made for crossings where either the outlet or the inlet was inaccessible, buried, or could not be found:

- If one or more Level 1 variables or more than four Level 2 variables were marked "Unknown", the crossing was flagged with an *Unknown Structural Variable Flag* for consideration in review of the final prioritization results. The significance and application of the *Unknown Structural Variable Flag* is discussed in **Section 3.2.6** of this document**.**

2.3.6 Flooding Impact Potential

The potential impacts of flooding in the event of crossing failure were assessed using a screening-level approach by examining the existing development, infrastructure, and land use within approximately a 0.5-mile upstream and downstream of the crossing location. The upstream and downstream distance of the potential flood impact area was defined by drawing a 0.5-mile radius around the crossing location. The lateral width of the potential flood impact area was defined in one of three ways:

1. Using the 1 percent annual chance flood boundary as depicted on FEMA flood hazard mapping, where available.
2. In areas where FEMA flood hazard mapping was unavailable or incomplete within the 0.5-mile radius, potential flood impact areas were defined by a stream buffer extending from the stream centerline for a distance equal to 2 times the bankfull width as measured in the field.
3. For crossings where FEMA flood hazard mapping was unavailable or incomplete and bankfull width could not be measured in the field, potential flood impact areas were estimated based on the crossing structure width and degree of constriction according to **Handbook Table 10-1**.

Flood vulnerability within the potential flood impact area was quantified based on the percentage of developed land cover within the potential flood impact area, the presence of upstream or downstream crossings within the potential flood impact area, and any underground utilities (e.g. gas, sewer, water) observed to be buried in the roadway over the crossing or attached to the underside of a bridge. Each crossing was assigned a *Flood Impact Rating* for the three categories mentioned above (developed area, upstream and downstream crossings, and utilities) according to **Handbook Sections 10.3.4** through **10.3.6**. The three *Flood Impact Ratings* were then combined to create a *Binned Flood Impact Potential Score* according to **Handbook Table 10-5**. Refer to **Handbook Section 10: Flood Impact Potential** for a detailed description of the methodology.

The following assumptions were made for crossings where either the outlet or the inlet was inaccessible, buried, or could not be found and FEMA flood hazard mapping was unavailable:

- For crossings where bankfull width was not measured, if the structure dimensions could not be measured at one end of the crossing structure, the dimensions were assumed to be equal to those measured at the other end of the structure. While culvert inlet and outlet structure dimensions, shape, and material often differ (particularly for buried streams), this assumption was considered the best possible method for completing the analysis in the absence of information for both ends.
- Crossings for which the inlet could not be found because the stream was buried for an undetermined length were manually assigned a *Binned Flood Impact Potential Score* of 3.
- Crossings for which both bankfull width and constriction could not be determined were manually assigned a *Binned Flood Impact Potential Score* of 3.

2.3.7 Disruption of Transportation Services

Potential disruption of transportation services at a crossing resulting from failure of the crossing was evaluated by considering the functional classification of the roadway (i.e., level of travel mobility and access to property that it provides) and emergency services that could be affected (E-911 and hurricane evacuation routes). Disruption of transportation services is assumed to occur if the crossing is either overtopped or washed away by flooding, as either failure mode would prohibit the use of the road-stream crossing by traffic.

A GIS analysis was performed for each crossing to determine the functional classification of the roadway and whether the crossing was located on an E-911 primary route and/or hurricane evacuation route according to the methodology in **Handbook Section 11.3**. The methodology in the Handbook recommends using the latest edition of the Highway Performance Monitoring System (HPMS) shapefile for Rhode Island to determine the functional classification of the roadway. The HPMS dataset does not include functional classification for local roads or minor collectors for Rhode Island. The "RIDOT Roads" data layer provided by RIGIS was used to determine the functional classification for crossings located on local roads or minor collectors.

Each crossing was assigned a *Transportation Disruption Component Score* according to **Handbook Table 11-1**. The three *Transportation Disruption Component Scores* were summed to create a *Combined Transportation Disruption Score* which was then used to generate a *Binned Transportation Disruption Score* according to **Handbook Table 11-2**. Refer to **Handbook Section 11: Disruption of Transportation Services** for a detailed description of the methodology.

2.3.8 Aquatic Organism Passage

Aquatic Organism Passage (AOP) was assessed using the latest NAACC protocols and rating system for assessing stream continuity. The method was adapted from the NAACC Numeric Scoring System for AOP, which was developed with input from multiple experts in aquatic passability. The NAACC Numeric Scoring System methodology is designed as a quantitative but rapid assessment tool for use by trained observers. The assessment is not species-specific, but rather seeks to evaluate passability for the full range of aquatic organisms likely to be found in rivers and streams. The AOP assessment considers the following field data:

- *Inlet grade*
- *Outlet drop*
- *Constriction*
- *Tailwater scour pool*
- *Structure dimensions (height, width and length)*
- *Outlet apron*
- *Structure substrate matches stream*
- *Structure substrate coverage*
- *Water Depth*
- *Water Velocity*
- *Physical Barriers*
- *Internal Structures*

For each crossing, a *Component Score* was assigned to the above categories according to **Handbook Table 12-1**. The field data was also used to calculate an *Openness Score*, a *Height Score* and an *Outlet Drop Score* according to the methodology in **Handbook Section 12.3.3**. Each *Component Score* was then assigned a weight according to **Handbook Table 12-2** and a *Composite Score* was generated by summing the products of each *Component Score* and its weight. A *Final AOP Score* was assigned as the lower of either the *Composite Score* or the *Outlet Drop Score*. *Binned AOP Scores* were assigned using the *Final AOP Score* and **Handbook Table 12-3**.

The potential ecological benefit of removing an existing barrier to aquatic passage was assessed using aquatic Index of Ecological Integrity (IEI) values developed by the Landscape Ecology Lab at UMass Amherst as part of the Conservation Assessment and Prioritization System (CAPS) program. The IEI value represents the relative benefit to ecological health and connectivity that would result from the removal of a given crossing. A *Binned Ecological Benefit Score* was assigned to each crossing using the IEI values and **Handbook Table 12-4**. A detailed description of the methodology is available in **Handbook Section 12: Aquatic Organism Passage**.

The following assumptions were made for crossings where either the outlet or the inlet was inaccessible, buried, or could not be found:

- Large bridges for which height could not be measured were manually assigned a *Binned AOP Score* of 1 based on the assumption that a bridge too large to be measured would (in the absence of other *Physical Barriers*) not be a barrier to aquatic organism passage.

- Crossings where either the inlet or outlet could not be found or accessed were manually assigned a *Binned AOP Score* of 3.

2.3.9 Prioritization

The crossing structures were assigned a relative priority for upgrade or replacement based on the results of the individual assessments and consideration of failure risk. Failure risk is defined as the product of the probability of failure of a crossing (i.e., vulnerability) and the potential consequences of failure (i.e., impacts). A crossing may be at risk if the probability of failure is high, if the consequences of failure are high, or both.

Each crossing was assigned an *Impact Score* equal to the maximum of either the *Binned Transportation Disruption Score* or the *Binned Flood Impact Potential Score*. An *Existing Hydraulic Risk Score, Climate Change Risk Score, Geomorphic Risk Score and Structural Risk Score* was calculated for each crossing by multiplying the binned vulnerability score for each assessment by the *Impact Score*. The possible risk scores for each category can range from 1 (lowest risk) to 25 (highest risk).

A low risk score can be produced in multiple ways:

- A low *Impact Score* (e.g., 1) multiplied by a low binned vulnerability score (e.g., 1) will result in a low risk score (e.g., 1)
- A low *Impact Score* (e.g., 1) multiplied by a high binned vulnerability score (e.g., 5) will result in a relatively low risk score (e.g., 5)
- A high *Impact Score* (e.g., 5) multiplied by a low binned vulnerability score (e.g., 5) will also result in a relatively low risk score (e.g., 5)

The highest possible risk score is generated when both the *Impact Score* and the binned vulnerability score are high (e.g. *Impact score* of 5 multiplied by a binned vulnerability score of 5 will result in the highest possible risk score of 25).

An *Aquatic Passage Benefit Score* was generated by multiplying the *Binned AOP Score* by the *Binned Ecological Benefit Score* and can range from 1 (least benefit) to 25 (most benefit).

The overall failure risk for a crossing (represented by the *Crossing Risk Score*) is dictated by the highest (i.e., worst-case) level of risk, which is calculated as the maximum of the *Existing Hydraulic, Climate Change, Geomorphic, and Structural Risk Scores*. A *Crossing Priority Score* was calculated for each crossing by combining the *Crossing Risk Score* with the *Aquatic Passage Benefit Score* according to the methodology in **Handbook Section 13.3.3.** (The two scores are combined by adding the maximum of the two scores to the average of the two scores. This approach ensures that if there is a very high score for one factor, it is preserved. It does however prioritize those crossings that rate highly for both factors). The *Crossing Priority Score* is then re-scaled or normalized to a range from 0 to 1 for ease of interpretation. It is important to note that the *Crossing Priority Score* should only be used for relative comparisons between crossings. See **Handbook Section 13: Prioritization of Road-Stream Crossings** for a detailed description of the methodology.

Several *Crossing Flags* are included in the vulnerability assessment methodology to note information that may be relevant to a crossing but is not captured in the vulnerability assessment. Descriptions and instructions for assigning the following *Crossing Flags* are covered in **Handbook Sections 6.4.1, 7.4.2, 9.3.4, 11.6,** and **12.6**:

- **Existing Tidal Influence:** Crossings that are currently tidally influenced.
- **Future Tidal Influence:** Crossings that are projected to be tidally-influenced under the climate change scenario considered in **Handbook Section 7.3.2**.
- **Unknown Structural Variable:** Crossings that have one of more Level 1 structural variables marked "Unknown" or more than four Level 2 structural variables marked "Unknown".
- **Local Knowledge:** Crossings that are of local importance or have known issues that are not captured in the analysis (e.g., frequent flooding, clogging, or traffic problems) or that have been recently replaced or repaired.
- **Adjacent Crossing:** Other crossings that are located within 0.5 mile upstream or downstream of a crossing.
- **Wildlife Crossing:** Crossings where wildlife, roadkill, and/or wildlife crossing signs were noted in the field.

Flagging a crossing may provide supplemental information that is useful to consider in the final prioritization and in determining which structures to upgrade or replace.

3 Results

3.1 Field Data Collection

Of the 239 road-stream crossings in the Woonasquatucket River watershed that were identified for assessment, 193 crossings (81%) were assessed in the field. These 193 crossings were associated with 241 structures. The distribution of the 193 crossings by municipality is provided in **Figure 3**. The majority of the crossings (53%) are located in Smithfield. Crossings noted as on the North Providence/Johnston line and Providence/Johnston line are located on the main stem of the Woonasquatucket River, which forms the jurisdictional boundary between these municipalities.

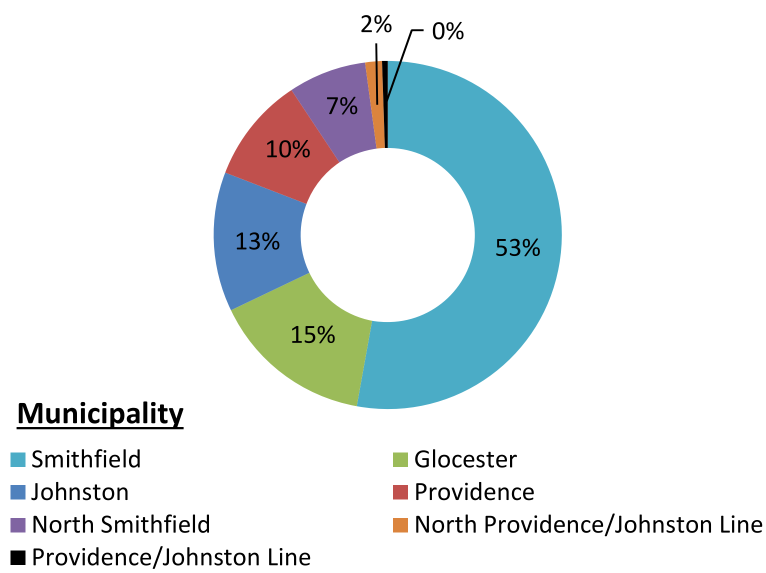


Figure 3. Distribution of 193 Assessed Road-Stream Crossings by Municipality

Forty-six of the 239 crossings (19%) could not be assessed in the field for the following reasons:

- No access....………………………………………………….. 12 crossings
- No crossing/structure at mapped location…………………......13 crossings
- Buried stream with no access………………………………….20 crossings
- Removed crossing……………………………………………..1 crossing

Crossings with no access were generally either located on private property or behind a fence. These crossings could potentially be revisited for assessment in the future if access were arranged. Some of the sites where no crossing or structure could be found at the mapped location were completely dry with no sign of a waterbody, while at others there was water present on either side of the road, suggesting that a crossing may be present but was submerged or collapsed. Buried streams refer to crossings where the stream has been completely rerouted underground and neither an inlet nor outlet could be found. The one crossing recorded as a removed crossing refers to a bridge that no longer conveys water due to an upstream dam. **Figure 1** shows the locations of assessed and unassessed crossings**.**

An average of 10 assessments were completed per day using a typical two-person field crew. Field assessment took approximately 30 minutes per crossing to complete, not including travel time. Time needed for field equipment set-up and break-down and for assessments of crossings with unique circumstances impacted the amount of time spent at each crossing, while travel time impacted the overall time needed to complete field work. Issues that were commonly encountered during the field are summarized in **Table 4.**

Table 4. Issues Commonly Encountered during Field Assessment

Issue	Recommendation
Batteries in tablets draining during field assessment†	• Ensure tablet is fully charged the night before field assessment • Carry a portable battery pack to charge tablets in the field • Bring paper forms to use as a back-up for field data collection. • Cease using tablets once battery charge reaches 10% or less to avoid loss of data
Inability to see stadia rod due to vegetation or steep embankment	• Use a 25-foot stadia rod (as opposed to a 16-foot stadia rod) when possible • Conduct field assessments of heavily vegetated areas in the early spring before leaf-out or in the autumn after leaves have fallen (autumn may be preferable as streamflow is usually lower in the autumn than in the spring).
Tearing of waders on thorns, guardrails, or other structures Overtopping hip waders	• Use waders made out of material that is resistant to tearing. Neoprene waders tore more frequently than nylon waders.
Accessibility issues (private property or dense vegetation) prevented high confidence measurement of bankfull width	• Record bankfull width as low confidence when necessary
Difficulty measuring structure length across busy roads or when structure alignment is not straight	• Use a rangefinder or measuring wheel (as opposed to a measuring tape) to measure structure length if necessary and feasible.

†The battery on a fully charged tablet drained to less than 20% by the second half of a field day during most field assessments. The backup paper field forms were used on 10 occasions due to tablet battery failure.

Key field data and results of the road-stream crossing surveys are included as **Attachment A**. The following general conditions were observed at the surveyed stream crossings:

- **Poor Structural Condition:** Many of the crossings were observed to be in poor condition and in need of significant repairs or replacement. Unstable or deteriorating headwalls or wingwalls were common at many of the crossings. Poor barrel and joint/seam condition and a high level of blockage were also frequently noted.
- **Flow Constriction:** The majority of the assessed culverts and bridges are significantly narrower than the bankfull width of the stream channel and therefore appear to constrict flood flows.

One-hundred and thirty-two (68%) of the crossings were rated as severely constricted, indicating that the bankfull width of the stream channel was at least twice as wide as the structure opening(s). The hydraulic capacities of many of the crossings in the watershed are limited due to undersized crossing structures and/or significant accumulation of sediment at some locations. Fifty-six (29%) of the crossings have insufficient capacity to convey the 10-year peak flow and another 18 (10%) crossings have insufficient capacity to convey the 25-year peak flow.

- **Physical Barriers:** Forty-six (19%) of the 241 assessed structures are classified as moderate or severe barriers to aquatic organism passage. Most physical barriers are caused by debris, sediment or rock. Sixty (25%) of the assessed structures have cascading or freefalling outlets, with 12 (5%) structures having an outlet drop greater than 1 foot.
- **Channel Erosion:** Varying degrees of stream channel erosion were observed in the reaches immediately upstream and/or downstream of the assessed crossings. Twenty-three (12%) crossings were noted as having high bank erosion.
- **Sediment Deposition:** Sediment deposition was observed upstream, downstream or within the structure at 43 of the assessed crossings (22%). Sediment deposition can reduce flow conveyance capacity, increase the potential for blockage or clogging during higher flows, and potentially restrict aquatic passage during low-flow conditions. Thirty-seven crossings (20%) had tailwater scour pools present at the outlet. A tailwater scour pool can indicate inadequate sediment supply due to backwater and sediment deposition at the crossing inlet and/or an undersized structure that is causing an increase in water velocity through the culvert at the outlet. Continuous scour can lead to undermining of the culvert, which can ultimately lead to failure of the structure.

3.1.1 QC of Field Data

QC review took approximately 20 minutes per crossing. Issues that were frequently found during the QC review are listed in **Table 5**, along with suggested solutions to avoid these issues in future assessments. One of the most prevalent problems was missing or improperly saved data. This was likely due to a combination of the field staff's lack of experience using the digital data collection form and the organization of the form. The digital field form was modified as a result to have a more user-friendly organization and to more closely follow the actual field data collection workflow.

Missing data was approached in two ways:

1. When possible, data was estimated using photos and the field crew's memory of the crossing. This method was used for estimating bankfull width with low confidence for six crossings where the value was not saved in the field form. When measurements were not saved for either the inlet or the outlet but were available for the other end, the missing values were estimated based on data available for the other end of the structure if the photos indicated that both ends of the structure were similar in size. When structure length was missing, it was estimated using Google Earth. Whenever data was estimated, it was noted in the field form.

2. Twenty-five (25) crossings with issues that could not be resolved using photos and recollections of the field crew were revisited on February 15, 2019 and one (1) crossing was revisited on May 23, 2019. These crossings were missing data that was essential for the vulnerability assessment and could not be estimated using photos, including slope and road crest height. Crossings that were missing photos were also revisited so that photos could be taken to allow for a more thorough QC review.

Other issues that were frequently encountered during review of the data were discrepancies or uncertainties associated with inlet type, structural condition and physical barriers. High-quality photographs that included appropriate context of the crossing were extremely useful for resolving these issues with the help of the Lead Field Data Collector. Several issues with the digital data collection form were also identified during the QC review:

- The stream substrate field was located in the optional HY-8 section of the field form. Since HY-8 was not chosen for the hydraulic capacity assessment, HY-8 fields were greyed out and therefore not available for assessment. The geomorphic vulnerability assessment subsequently had to be modified to address crossings where stream substrate could not be estimated from photos or substrate material inside the crossing structure, as described above in **Section 2.3.4**.
- Invert condition was mislabeled as "outlet condition" in the outlet section of the field form and therefore was only assessed at the inlet.
- The terms "outlet armoring" and "inlet armoring" were used to describe the covering of the streambed with riprap or concrete, instead of the more accurate term "outlet apron" or "inlet apron". This led to inappropriate assessment of the inlet and outlet apron, which had to be corrected during QC review.

These fields have been updated in the digital data collection form to address these issues. The results of the QC process were used to refine **Handbook Section 3: Field Data Collection**, through addition and clarification of language, figures and diagrams.

Table 5. Commonly encountered issues during QC review of field data

Issue	Solution
Fields not filled out or not saved properly in the digital data collection form	• Make fields that are necessary for assessment required in the digital data collection form • Ensure field staff are trained in the proper use of collection forms • Have field staff submit data from a test crossing prior to collecting official field data so that issues with the use of the field form can be identified and fixed • Have a member of the field crew who did not record the data review data the form for completeness before leaving the site
Latitude and longitude of crossing collected in the wrong location	• Ensure field staff are aware of how and when the digital data collection form automatically collects latitude/longitude, and are familiar with how to update the crossing location in the field
Stream substrate not recorded for the majority of crossings	• The stream substrate field was moved from the HY-8 section to the stream data section on the field form
Invert condition not assessed at the outlet due to mislabeling in the field form	• The field form was updated to include invert condition in the outlet section
Outlet drop treated as a physical barrier	• Ensure field staff are adequately trained prior to conducting field assessments
Inlet type misidentified on several structures, confusion over when to select "none" for the inlet type	• Ensure field staff are adequately trained prior to conducting field assessments
Confusion over the difference between armoring and apron	• Ensure field staff are adequately trained prior to conducting field assessments • Language in the field form and Handbook was clarified to better distinguish between these treatments
Confusion over the presence/absence of a headwall on bridges and stone masonry structures	• Ensure field staff are adequately trained prior to conducting field assessments

3.2 Vulnerability Assessment

The results of the individual vulnerability assessments and the overall prioritization are discussed in the following sections. The overall scores for each vulnerability assessment and the priority ratings are provided in **Attachment J** for each of the high priority crossings. The vulnerability assessment worksheets for each assessment are provided as **Attachments B** through **H**. The prioritization results and ratings for all crossings are provided in **Attachment I**.

3.2.1 Existing Streamflow Conditions

Peak streamflow estimates were generated from StreamStats for 104 (54%) of the 193 crossings. For 3 of these crossings, the StreamStats gridded stream network was not available at the exact crossing location, but began within 250 feet of the crossings and was confirmed in each case to be in the same

headwater drainage area as the crossing. In these cases, the nearest point on the StreamStats gridded stream network was selected as a substitute site for watershed delineation.
For 70 (67%) of the 104 crossings with watersheds delineated in StreamStats, one or more parameters were outside the suggested range for which the regional regression equations were originally developed. The crossings that generated one or more parameters outside of the suggested range of the StreamStats application are noted in the data analysis spreadsheet provided in the digital database. The StreamStats results were still used in these cases, as described in **Section 2.3.1**.

For the remaining 89 (46%) of the 193 crossings, StreamStats could not be used to generate peak streamflow estimates for the following reasons:

- StreamStats returned values of 0 or no values for peak-flow statistics (35 crossings)
- There was no gridded stream network data within the vicinity of the crossing (24 crossings)
- StreamStats generated grossly inaccurate watershed delineations (28 crossings)
- Irregular CSM values were generated (2 crossings)

The drainage area ratio method was used to generate peak streamflow values for these 89 crossings, as described in **Section 2.3.1 and Handbook Section 5: Existing Streamflow Conditions.**

In summary, the use of StreamStats to generate streamflow estimates proved to be difficult for the crossings included in this Pilot Study; a total of 159 (82%) crossings either had parameters that were outside of the suggested range for the StreamStats equations or required use of an alternative peak flow estimation method (i.e., the drainage area ratio method). The difficulty in the use of StreamStats likely stems from the fact that many of the crossing drainage areas are relatively small compared to the drainage areas of the stream gage locations that were used to develop the regional regression equations used in StreamStats. (**Table 6**). The regional regression equations used in StreamStats for the State of Rhode Island were developed using drainage basins ranging from 0.52 to 404 square miles (Bent at al., 2014; Zarriello et al., 2012). While the average drainage area of the 193 assessed crossings is 6.95 square miles, the median drainage area is only 0.43 square miles (**Table 6**). The average drainage area of 6.95 square miles is unrepresentatively high due to a few large drainage areas in the lower part of the watershed. The majority of the crossing drainage areas are small; 82% of the drainage areas are less than 5 square miles and 56% are less than 0.52 square miles. All of the crossings with drainage areas less than 0.52 square miles in size either required the use of the drainage-area ratio method or generated parameters that were outside of the suggested range for the StreamStats equations. **Table 6** provides a summary of the drainage areas for all crossings, grouped by the streamflow estimation method used. StreamStats was most successfully used (no parameters were outside of the suggested range) for the largest watersheds in the Pilot Study. As mentioned in **Section 2.3.1**, the accuracy of StreamStats for larger watersheds is demonstrated by the agreement between the streamflow estimates generated by StreamStats for a crossing with a larger drainage area (crossing xy41859167148748; 38 square miles) and the streamflow estimates generated from the historical record at a nearby USGS gage.

In addition, watershed delineations using StreamStats tend to be more accurate in watersheds with significant topographic relief and well-defined stream networks. In Rhode Island, which is generally characterized by developed, low-relief drainage basins, watershed boundaries tend to be more strongly influenced by drainage features. For example, the Woonasquatucket River watershed is relatively flat, with an average slope of 9.6%[2]. The use of StreamStats for delineating watersheds in developed, low-relief areas can introduce additional error into the streamflow estimates.

Table 6. Summary of streamflow estimation method by drainage area for all assessed crossings

Streamflow Estimation Method	Drainage Area (square miles)			
	Minimum	Maximum	Average	Median
All Combined	0.01	50.80	6.95	0.43
StreamStats (all)	0.04	50.80	12.39	1.27
StreamStats (no parameters outside suggested range)	8.15	50.8	36.54	41.50
StreamStats (at least 1 parameter outside suggested range)	0.04	4.95	0.99	0.53
Drainage Area Ratio Method	0.01	2.07	0.32	0.13

3.2.2 Existing Hydraulic Capacity

Bentley CulvertMaster was used to estimate the crossing hydraulic capacity for 152 (79%) of the 193 crossings while Manning's equation for uniform open channel flow was used to estimate the crossing hydraulic capacity for 38 (20%) of the crossings. Hydraulic capacity could not be calculated for 3 (1%) of the 193 crossings due to missing field data. Assumptions were made to conduct the hydraulic capacity assessment for these 3 crossings as described in **Section 2.3.2**.

The *Binned Hydraulic Capacity Scores* indicate the following (**Figure 4A**):

- Fifty-six (29%) of the 193 assessed crossings are severely hydraulically undersized under existing precipitation and streamflow conditions, having insufficient capacity to convey the 10-year peak flow.
- Another 18 (10%) of assessed crossings are hydraulically undersized relative to the 25-year return interval flow.
- Ninety-three (48%) of the 193 assessed crossings were found to have sufficient capacity to pass the 100-year peak flow under existing conditions.

When the *Binned Hydraulic Capacity Scores* are separated by structure type, the results indicate the following:

- Only 5 (13%) of the 39 assessed bridges have insufficient capacity to convey the 10-year peak flow. One additional bridge (3%) is undersized relative to the 25-year return interval peak flow.

[2] Slope calculated using RIGIS 2011 Statewide Lidar derived from 1-meter resolution digital elevation model. (RIGIS, 2013. Digital Elevation Model; DEM11. Rhode Island Geographic Information System (RIGIS) Data Distribution System, URL: http://www.rigis.org, Environmental Data Center, University of Rhode Island, Kingston, Rhode Island (last date accessed: 25 July 2013)

The majority of the assessed bridges (32 bridges, 82%) are capable of passing the 100-year peak flow (**Figure 4B**).

- Thirty-nine (34%) of the 114 assessed round culverts are severely hydraulically undersized and have insufficient capacity to convey the 10-year peak flow. Another 13 (11%) round culverts are undersized relative to the 25-year peak flow. Forty-five (40%) round culverts are capable of passing the 100-year peak flow (**Figure 4C**).

- Box culverts have the highest percentage of crossings that are of insufficient size to pass the 10-year peak flow with 11 (41%) of the 27 assessed box culverts having insufficient capacity to convey the 10-year peak flow. Another 2 (7%) box culverts are undersized relative to the 25-year peak flow. Nine (33%) box culverts are capable of passing the 100-year peak flow (**Figure 4D**).

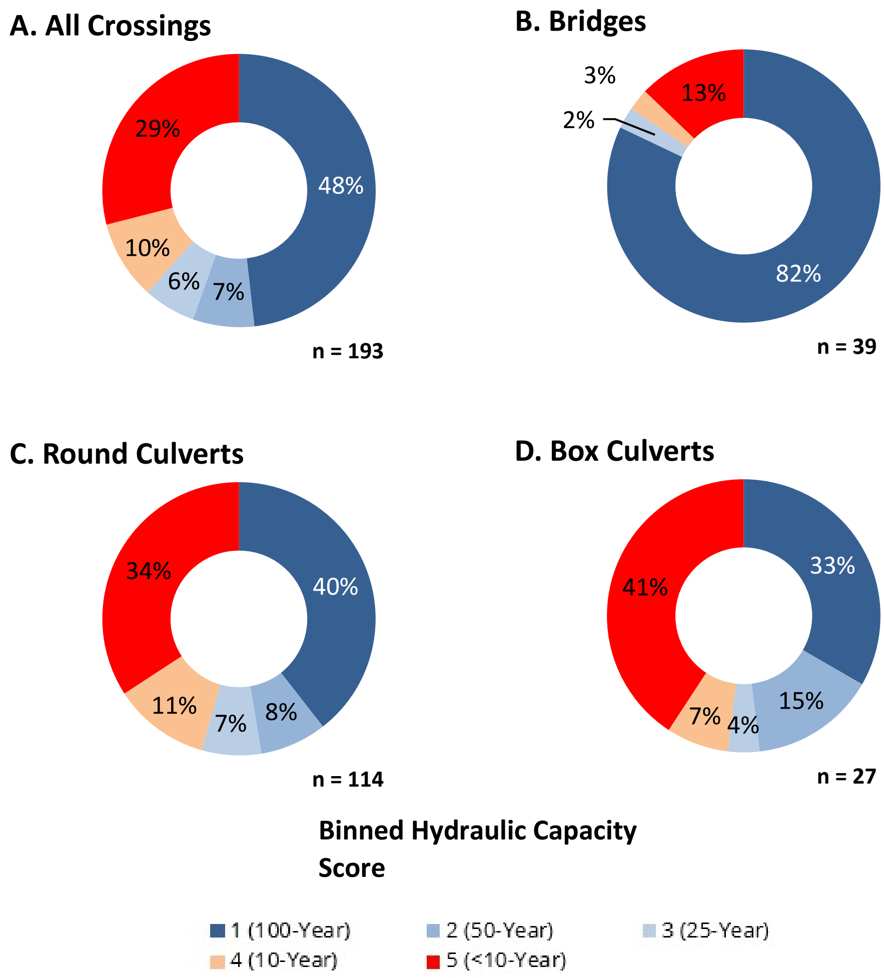


Figure 4. Binned Hydraulic Capacity Scores for all crossings (A) and by structure type (B-D). Scores are assigned based on the largest return interval peak discharge that the crossing is capable of passing. For example, a score of 3 means that the 25-year peak discharge is the largest return interval that the crossing is capable of passing.

† Thirteen crossings are not included in the figure for the following reasons: 1) The structure type is known to be different at the inlet and the outlet. Structures where either the inlet or outlet type were unknown were included in the category corresponding to the known end of the structure. 2) The crossing included multiple culverts of different structure types (e.g., one round culvert and one box culvert located at one crossing). 3) The structure type does not fall into the above categories (e.g., arched culverts and elliptical culverts).

Of the 141 crossings that are round or box culverts, 29 (21%) have multiple structures while 112 (79%) consist of a single structure. **Figure 5** compares the *Binned Hydraulic Capacity Scores* for round or box culvert crossings with multiple structures and single structures. The results indicate the following:

- Seven (24%) of the 29 crossings with multiple structures are severely undersized and are incapable of conveying the 10-year peak flow. Another 5 (17%) are incapable of conveying the

25-year peak flow. Twelve (42%) crossings with multiple structures are capable of passing the 100-year peak flow (**Figure 5A**).

- Forty-three (38%) of the 112 crossings with a single structure are severely undersized and are incapable of conveying the 10-year peak flow. Another 10 (9%) are incapable of conveying the 25-year peak flow. Forty-two (38%) crossings with a single structure are capable of passing the 100-year peak flow (**Figure 5B**).

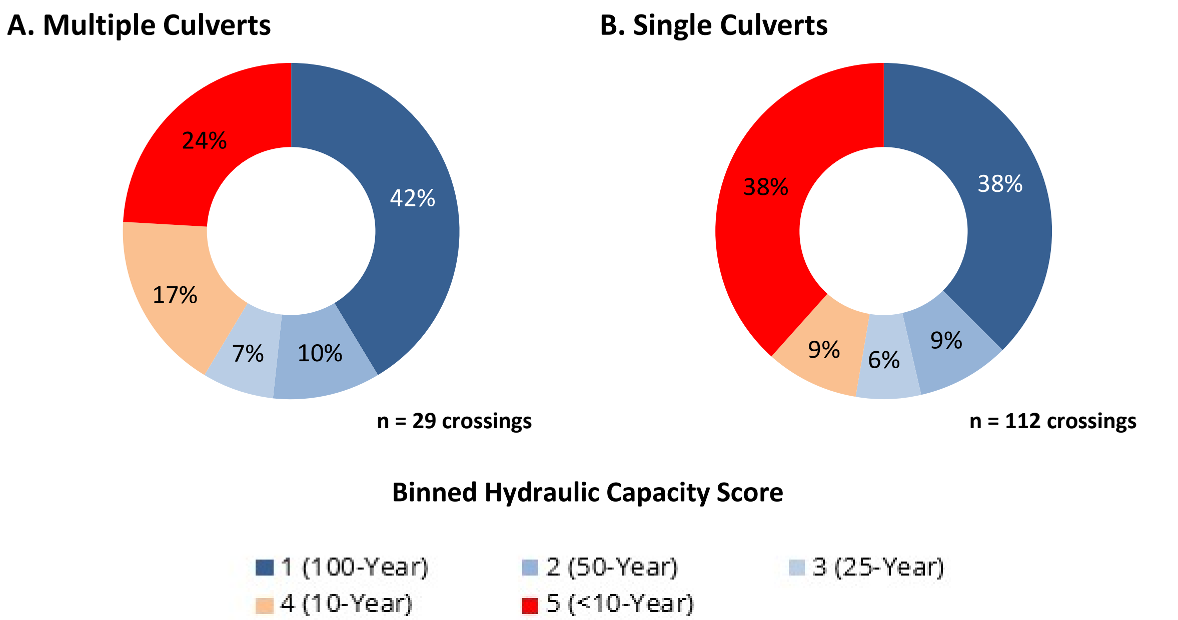


Figure 5. ***Binned Hydraulic Capacity Scores*** **for crossings with multiple culverts/structures (A) and crossings with a single culvert/structure (B). Scores are assigned based on the largest return interval peak discharge that the crossing is capable of passing. For example, a score of 3 indicates that the 25-year peak discharge is the largest return interval that the crossing is capable of passing.**

The *Hydraulic Risk Scores* (*Binned Hydraulic Capacity Score* multiplied by the *Impact Score*) for the 193 assessed crossings are summarized in **Figure 6**. The distribution of scores is skewed to the low and high extremes, with a disproportionate amount of crossings receiving very low or very high scores. *Hydraulic Risk Scores* may tend to be lower if a large number of crossings have recently been replaced to facilitate flood resiliency and/or aquatic passage. Based on the number of older structures seen in the field, this factor likely isn't a major contributor to the number of low *Hydraulic Risk Scores*. The high number of crossings with low *Hydraulic Risk Scores* may partially be a result of the number of bridges in the watershed. Bridges are generally better sized to accommodate larger storms and therefore are likely to have less hydraulic risk than culverts. Many of the crossings with low hydraulic risk are also located in the northern, more rural part of the watershed where flooding impacts would be less severe (**Figure 7**). The disproportionate number of crossings receiving high *Hydraulic Risk Scores* may be due to historic institutional installation of undersized structures. Structures that may have been adequately sized at the time of installation may now be undersized due to increases in extreme precipitation, flood frequency and flood severity over the last century in Rhode Island (Rhode Island Statewide Climate Resilience Action Strategy, 2018).

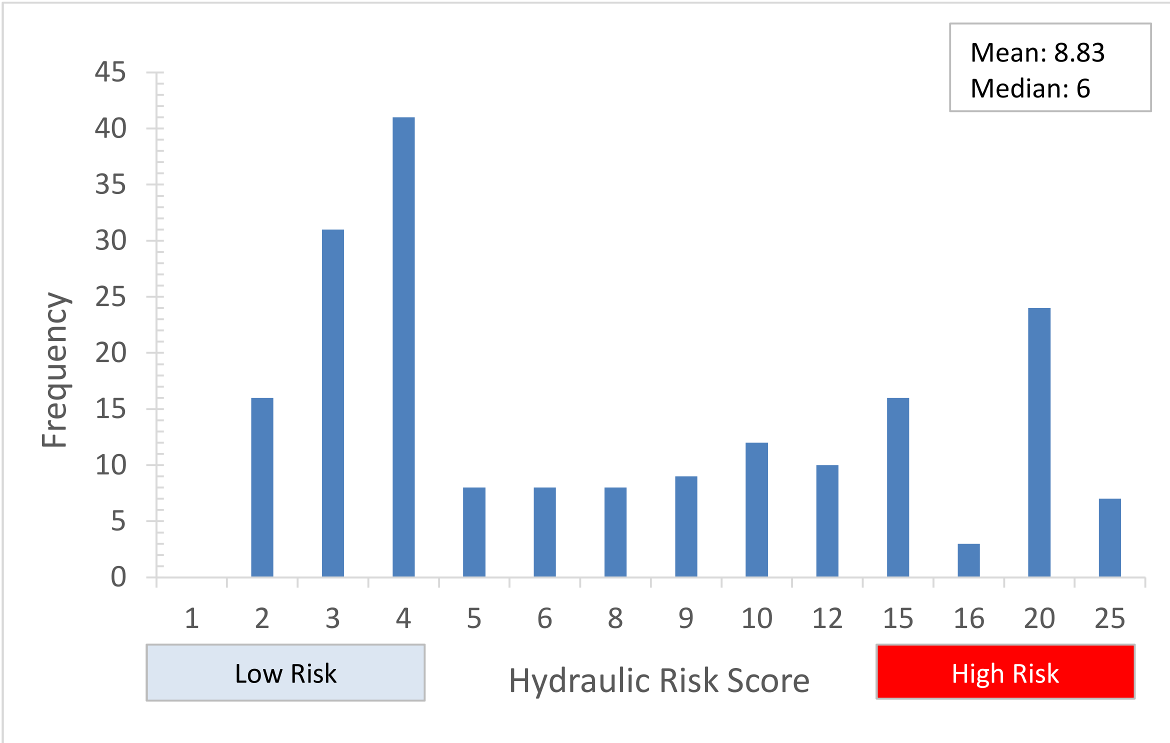


Figure 6. Histogram showing the distribution of Hydraulic Risk Scores for all crossings.

The crossings that received the highest possible *Hydraulic Risk Score* of 25 are listed below in **Table 7**. All of these crossings received a *Binned Hydraulic Capacity Score* of 5 and an *Impact Score* of 5, indicating that they are incapable of passing the 10-year peak flow and have high flood and transportation disruption impact potential in the event of failure. The crossings with the highest *Hydraulic Risk Scores* are located in densely developed areas of Providence, Johnston and Smithfield, with a few others scattered throughout the watershed (**Figure 7**). Photos of the inlets of two of the crossings that received the highest *Hydraulic Risk Scores* (xy41822527143992 and xy41866427149748) are provided in **Figure 8**. These photos demonstrate that both smaller culverts and larger bridges can have high hydraulic risk.

Table 7. Crossings with the highest Hydraulic Risk Scores

Crossing Code	Road Name	Municipality	Stream Name	Crossing Type	Hydraulic Risk Score (1-25)
xy41822527143992	Valley Street	Providence	Woonasquatucket River	Bridge	25
xy41828647142862	Acorn Street	Providence	Woonasquatucket River	Bridge	25
xy41841257148494	Waterman Avenue	Johnston	Unnamed tributary to Assapumpset Brook	Culvert	25
xy41842197148400	Diaz Street	Johnston	Unnamed tributary to Assapumpset Brook	Culvert	25
xy41866427149748	Dean Street	Johnston	Unnamed tributary to Woonasquatucket River	Culvert	25
xy41874767155492	Austin Avenue	Smithfield	Stillwater River	Culvert	25
xy41890917151543	Farnum Pike	Smithfield	Unnamed tributary to Georgiaville Pond	Partially Inaccessible	25

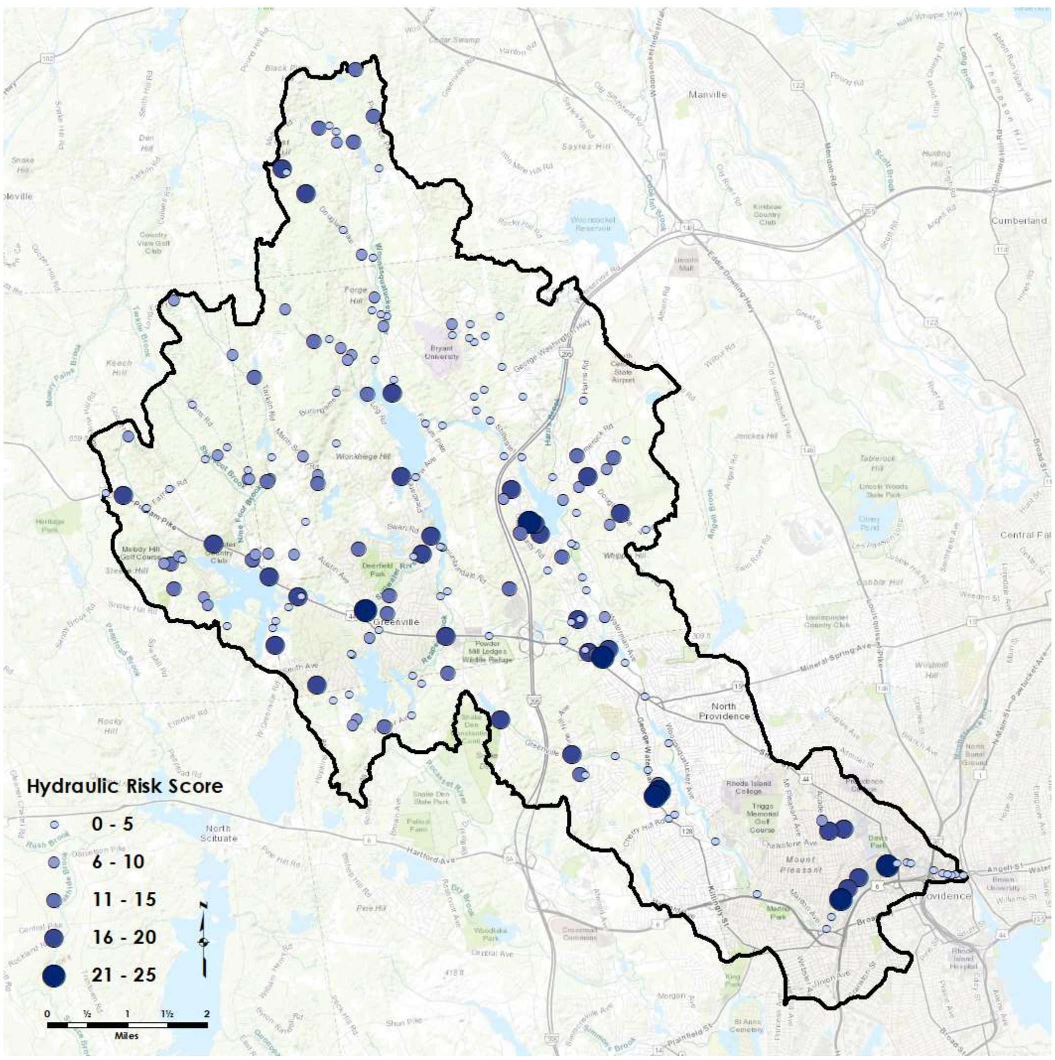


Figure 7. Spatial Distribution of Hydraulic Risk Scores.

Figure 8. Two of the crossings that received the highest Hydraulic Risk Scores: xy41822527143992 (left) on Valley Street in Providence over the Woonasquatucket River and xy41866427149748 on Dean Street in Johnston at an unnamed tributary to the Woonasquatucket River.

All of the crossings that received the highest possible *Hydraulic Risk Score* are also among the crossings that received the highest possible *Climate Change Risk Scores* (**Section 3.2.3**). Crossings xy41841257148494 on Waterman Avenue in Johnston, xy41874767155492 on Austin Avenue in Smithfield, and xy41890917151543 on Farnum Pike in Smithfield are also among the crossings that received the highest possible *Structural Risk Scores*. All 7 of the crossings that received the highest possible *Hydraulic Risk Scores* are also among the top priority crossings overall (**Attachment J**).

3.2.3 Future Climate Change Assessment

Assuming a future increase in peak flowrates of 20% under future climate change conditions:

- Sixty-seven (35%) crossings are expected to be undersized for the 10-year peak flow
- An additional sixteen (8%) crossings are expected to be undersized for the 25-year return interval peak flow
- Only 80 (41%) crossings are expected to be able to pass the 100-year return interval peak flow

Figure 9 summarizes the *Hydraulic Capacity Scores* under existing and future conditions. Compared to the distribution of Existing *Hydraulic Capacity Scores* (**Figure 9A)**, under the future streamflow scenario more crossings will be severely undersized (unable to pass the 10-year peak flow) and fewer crossings will be capable of passing the 100-year peak streamflow.

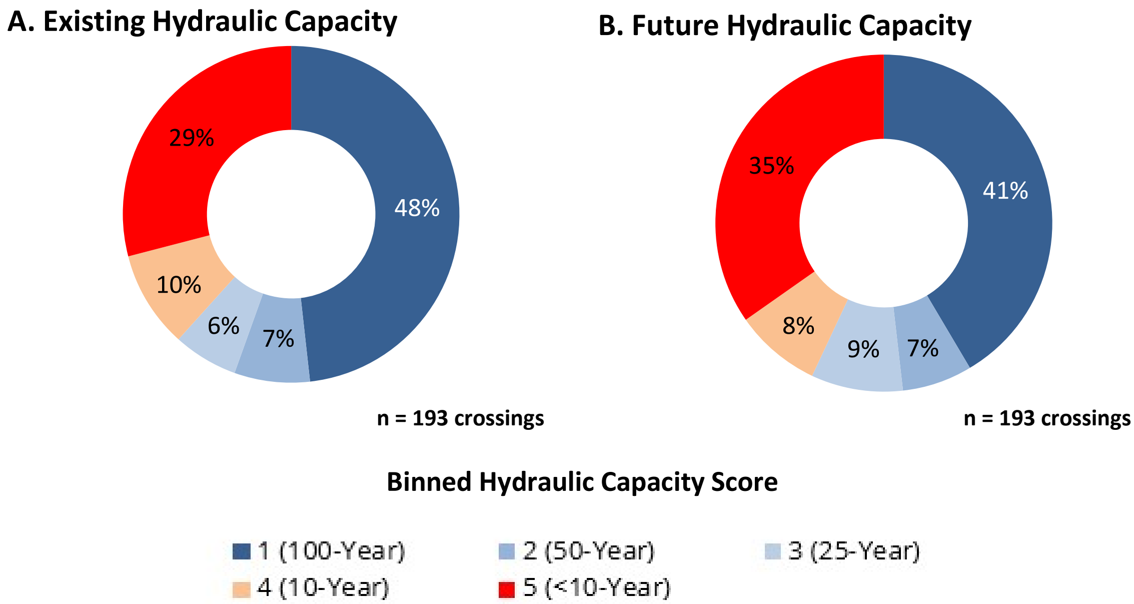


Figure 9. Existing *Binned Hydraulic Capacity Scores* (A) vs. Future *Binned Hydraulic Capacity Scores* (B) for all crossings. The Future Hydraulic Capacity assessment assumes a 20% increase in peak streamflow for all return intervals analyzed. Scores are assigned based on the largest return interval peak discharge that the crossing is capable of passing. For example, a score of 3 indicates that the 25-year peak discharge is the largest return interval that the crossing is capable of passing.

The *Binned Hydraulic Capacity Change Score* compares the existing *Binned Hydraulic Capacity Score* of a crossing to its future *Binned Hydraulic Capacity Score*. The distribution of *Binned Hydraulic Capacity Change Scores* are provided in **Figure 10**. The results indicate that:

- One hundred forty-four (75%) crossings received a *Binned Hydraulic Capacity Change Score* of 1, indicating that the existing *Binned Hydraulic Capacity Score* is equal to the future *Binned Hydraulic Capacity Score* and that a 20% increase in streamflow will not affect the ability of most crossings to convey the assessed return interval peak flows (**Figure 10**)**.** This does not indicate that streamflow will not increase in the future or that the crossing will be unaffected; the likelihood of a crossing's hydraulic capacity being exceeded in any given year is projected to increase regardless of whether the crossing's *Binned Hydraulic Capacity Score* is expected to change.
- Forty-nine (25%) of the 193 assessed crossings received a score of 3, indicating that the *Binned Hydraulic Capacity Score* increased by one level (e.g., from 2 to 3 or from 4 to 5) under the future climate scenario.
- No crossings (0%) received a score of 5, which would indicate that the *Binned Hydraulic Capacity Score* increased by more than one score (e.g., from 2 to 4 or from 3 to 5) under the future climate scenario.

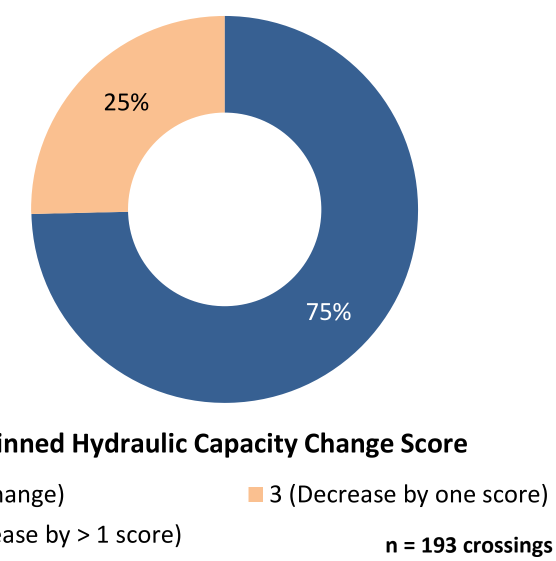


Figure 10. Binned Hydraulic Capacity Change Scores for all crossings. The Hydraulic Capacity Change score compares the existing hydraulic capacity to the future hydraulic capacity. A score of 1 indicates the existing hydraulic capacity score is equal to the future hydraulic capacity score; a score of 3 indicates existing hydraulic capacity score decreases by one rating under the future climate change scenario and a score of 5 indicates the existing hydraulic capacity decreases by more than 1 rating.

The climate change vulnerability assessment also considers the impacts of future sea level rise on road-stream crossings. Under the assessed future sea level rise and storm surge scenarios:

- One hundred and seventy-eight (92%) of the assessed crossings are not expected to be impacted by the future sea level rise and storm surge scenarios considered in the analysis (**Figure 11**).
- One (1%) crossing is expected to be impacted by the 100-year storm surge plus 5 feet of sea level rise.
- Fourteen (7%) crossings are projected to be impacted by the 100-year storm surge under current conditions (with 0 feet of sea level rise).
- The 15 crossings that are projected to be impacted by the sea level rise scenarios considered in this analysis are located in Providence on the main stem of the lower Woonasquatucket River. Thirteen of these fifteen crossings are located in the tidal zone of the river.

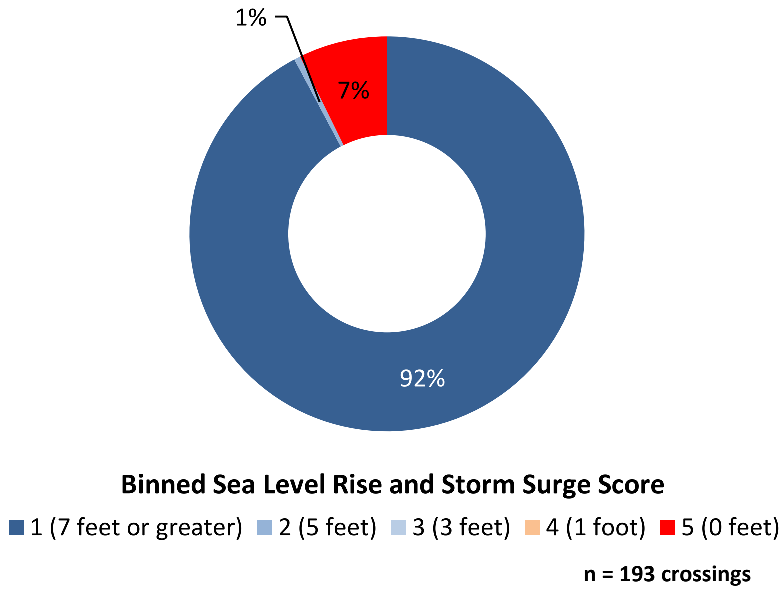


Figure 11. Binned sea level rise and storm surge scores. A score of 1 indicates that the crossing will not be impacted by the 100-year storm plus 7 feet of sea level rise. A score of 5 indicates that the crossing is already impacted by the 100-year storm surge, with no sea level rise.

The *Binned Climate Change Vulnerability Score* takes the maximum of the *Binned Future Hydraulic Capacity Score*, the *Binned Hydraulic Capacity Change Score,* and the *Binned Sea Level Rise and Storm Surge Score*. The distribution of the *Binned Climate Change Vulnerability Scores* are provided in **Figure 12** and the results indicate that:

- Seventy-seven (40%) of the 193 assessed crossings have high climate change vulnerability
- Seventy (40%) of the assessed crossings have low climate change vulnerability
- The remaining 46 (24%) crossings have moderate climate change vulnerability.

The *Binned Climate Change Vulnerability Scores* for most of the assessed crossings were driven by the *Binned Future Hydraulic Capacity Change Score* since the majority of the crossings are not affected by the sea level rise scenarios considered and have a low *Binned Hydraulic Capacity Change Score*.

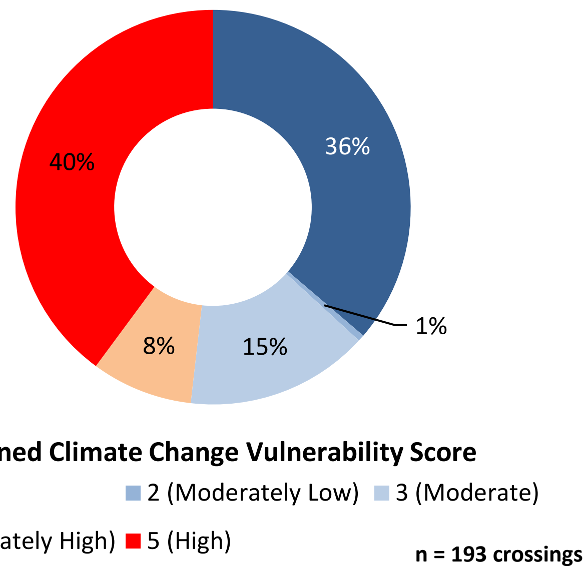


Figure 12. Binned Climate Change Vulnerability Scores for all crossings

The *Future Climate Change Risk Scores* (*Binned Climate Change Vulnerability Score* multiplied by the *Impact Score*) for the 193 assessed crossings are summarized in **Figure 13.** The distribution of *Future Climate Change Risk Scores* is similar to the distribution of *Hydraulic Risk Scores* (**Section 3.2.2**), with the majority of crossings receiving very low or very high scores, but with a notable shift toward higher scores. This is consistent with expectations, as the future climate change assessment is partially based on applying a 20% increase to peak flows calculated during the existing hydraulic capacity assessment.

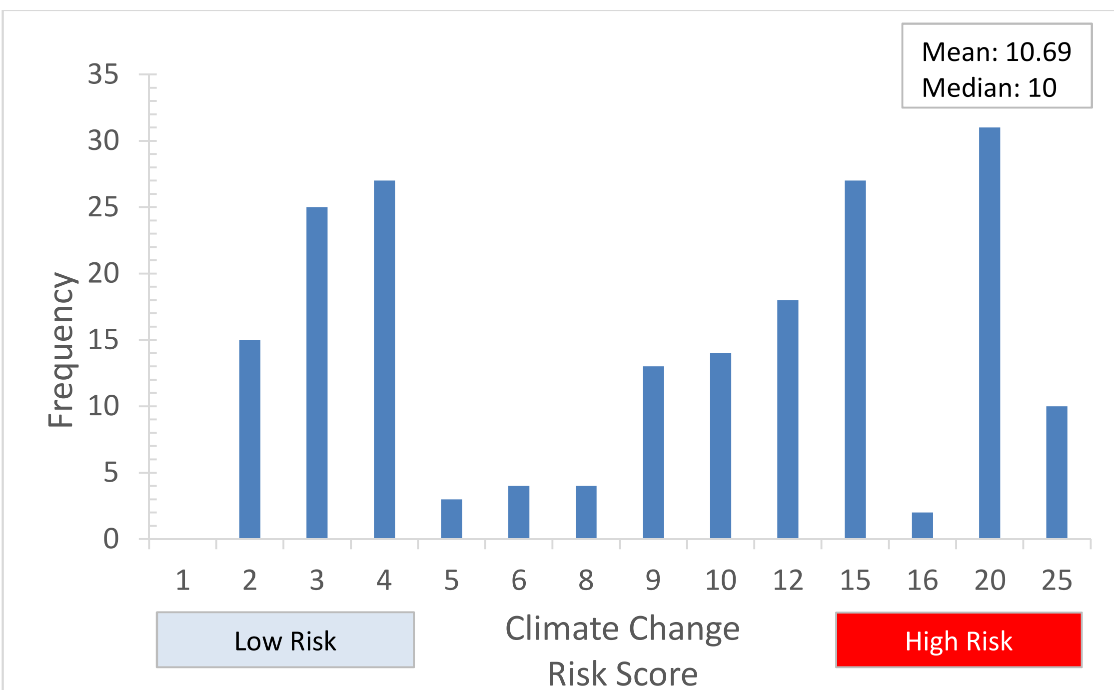


Figure 13. Histogram showing the distribution of Climate Change Risk Scores for all crossings

The spatial distribution of the *Future Climate Change Risk Scores* is provided in **Figure 14**. Many of the crossings located in the lower part of the watershed on the main stem of the Woonasquatucket River in Providence have high hydraulic risk scores, due to potential sea level rise impacts. Other high risk crossings are distributed throughout the watershed. The 10 crossings with the highest *Future Climate Change Risk* Scores are listed in **Table 8**. Seven of these crossings are among the crossings with the highest *Hydraulic Capacity Risk Scores*. All ten of the crossings with the highest *Future Climate Change Risk Scores* are also among the top priority crossings overall (**Attachment J**).

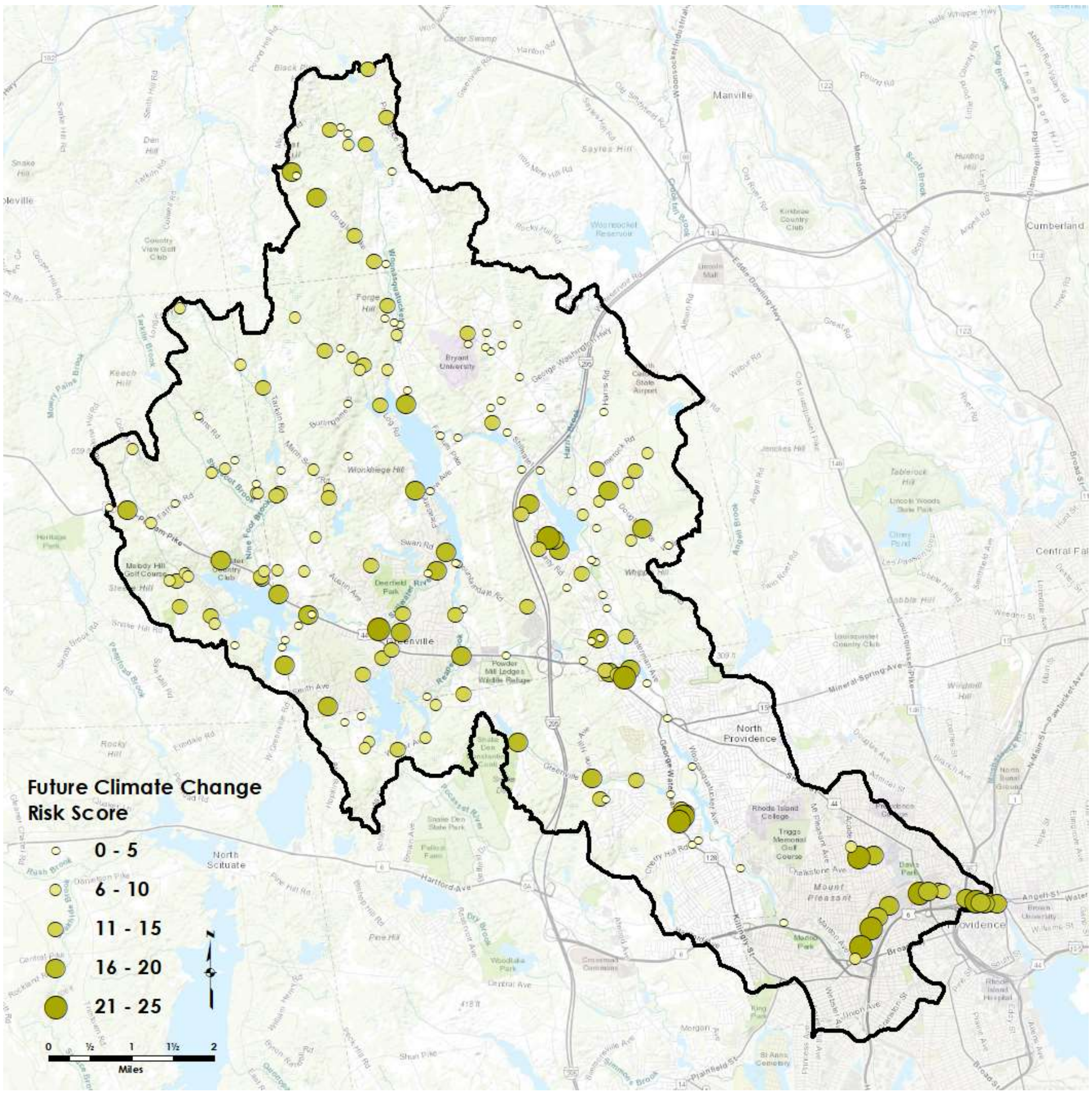


Figure 14. Spatial Distribution of Climate Change Risk Scores.

Table 8. Crossings with the highest *Climate Change Risk Scores*

Crossing Code	Road Name	Municipality	Stream Name	Structure Type	Climate Change Risk Score (1-25)
xy41819437144226	Delaine Street	Providence	Woonasquatucket river	Bridge	25
xy41822527143992	Valley Street	Providence	Woonasquatucket river	Bridge	25
xy41827207141547	Francis Street	Providence	Woonasquatucket river	Bridge	25
xy41828647142862	Acorn Street	Providence	Woonasquatucket river	Bridge	25
xy41834977144282	Pleasant Valley Parkway	Providence	Unnamed tributary to Woonasquatucket River	Culvert	25
xy41841257148494	Waterman Avenue	Johnston	Unnamed tributary to Assapumpset Brook	Partially Inaccessible	25
xy41842197148400	Diaz Street	Johnston	Unnamed tributary to Assapumpset Brook	Culvert	25
xy41866427149748	Dean Street	Johnston	Unnamed tributary to Woonasquatucket River	Culvert	25
xy41874767155492	Austin Avenue	Smithfield	Stillwater River	Multiple Culverts	25
xy41890917151543	Farnum Pike	Smithfield	Unnamed tributary to Georgiaville Pond	Partially Inaccessible	25

The methodology in **Handbook Section 7: Climate Change Vulnerability** is based on the most current climate change data available for the State of Rhode Island. As mentioned in **Handbook Section 7.3.2**, recent research has identified a potential worst-case sea level rise scenario of approximately 11 feet (Sweet et al., 2017); however at the time of this assessment the 7-foot sea level rise scenario was the worst-case scenario for which inundation mapping was available. Additional crossings may be impacted by the 100-year storm surge plus 11 feet of sea level rise but could not be identified by this assessment due to data availability. The future hydraulic capacity assessment was based on a projected increase in streamflow of 20%; however this projection may increase or decrease with advances in climate change science. Climate change projections are likely to evolve and change in the future as models become more accurate and detailed. As updated climate data and projections become available, users may wish to revisit the climate change vulnerability analysis and update the road-stream crossing prioritization results accordingly (in coordination with RIDOT).

3.2.4 Geomorphic Vulnerability

The distribution of *Binned Overall Geomorphic Impact Scores* for all crossings are available in **Figure 15.** According to the results in **Figure 15A**:

- Fourteen (7%) of the 193 assessed crossings have significant geomorphic vulnerability (score of 4).
- One-hundred and nine (56%) of the assessed crossings were rated as having moderate geomorphic vulnerability (*Binned Overall Geomorphic Impact Score* of 3)
- The remaining 70 (36%) have low geomorphic vulnerability (score of 2)

- No crossings received the highest possible *Binned Overall Geomorphic Impact Score* of 5, which would indicate severe geomorphic vulnerability, or the lowest possible score of 1, which would indicate insignificant geomorphic vulnerability.

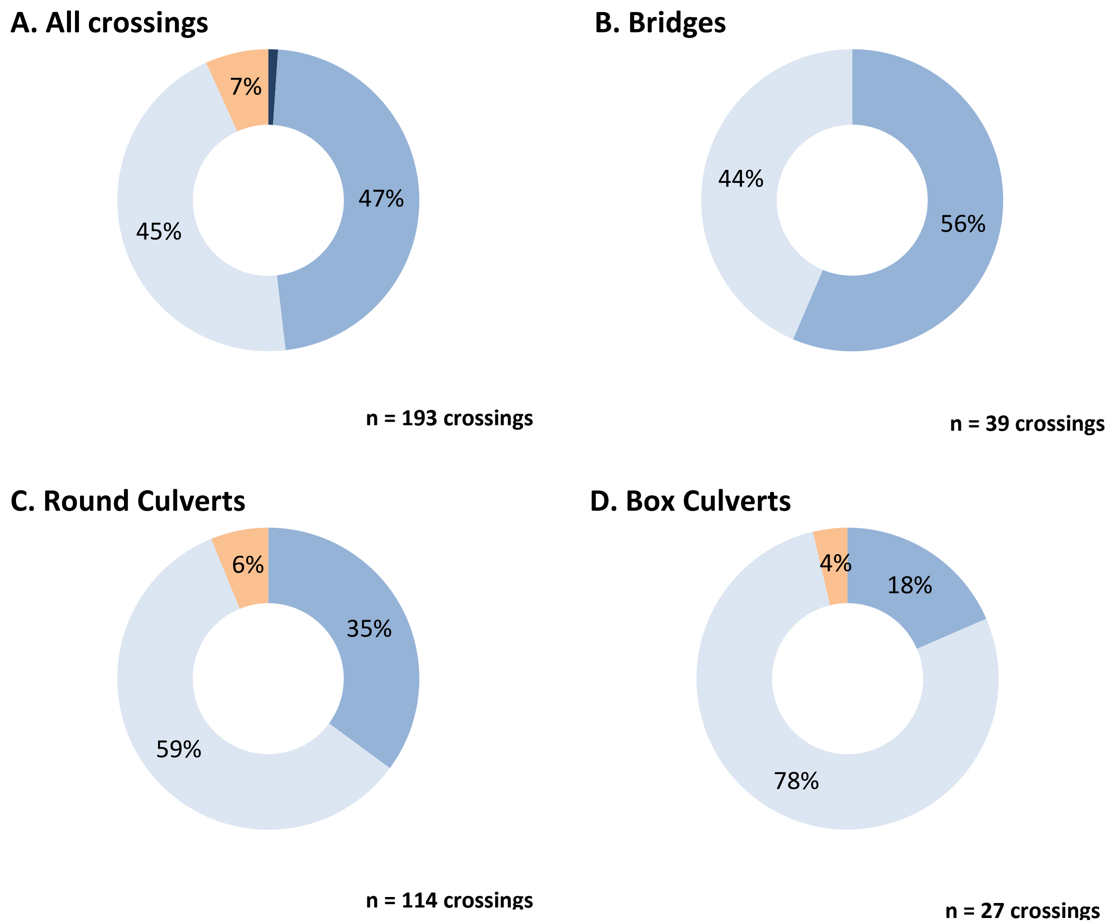


Figure 15. Binned Overall Geomorphic Impact Scores for all crossings (A) and by structure type (B-D). A score of 1 indicates the lowest geomorphic vulnerability while a score of 5 indicates highest geomorphic vulnerability.

† Thirteen crossings are not included in the figure for the following reasons: 1) The structure type is known to be different at the inlet and the outlet. Structures where either the inlet or outlet type were unknown were included in the category corresponding to the known end of the structure. 2) The crossing included multiple culverts of different structure types (e.g. one round culvert and one box culvert located at one crossing). 3) The structure type does not fall into the above categories (e.g. arched culverts and elliptical culverts).

As discussed above in **Section 2.3.4**, stream substrate type was not recorded for the majority of the assessed crossings and the following two methods were assessed to determine how to best account for the absence of this data without artificially raising or lowering the geomorphic vulnerability scores:

1. The *Substrate Size Impact Potential Rating* was removed from the calculation of the *Combined Geomorphic Potential Impact Rating* as described in **Section 2.3.4.**
2. The *Substrate Size Impact Potential Rating* was included in the calculation of the *Combined Geomorphic Potential Impact Rating* as described in **Handbook Sections 8.3** and **8.5**. The recorded stream substrate was used when available (87 crossings), and a score of 3 was manually assigned for the

Substrate Size Impact Potential Rating for the 106 crossings for which stream substrate was not recorded in the field.

A comparison of the distribution of *Binned Overall Geomorphic Impact Scores* using each of the methods described above is provided in **Figure 16**. Removing the *Substrate Size Impact Potential Rating* from the *Combined Geomorphic Potential Impact Rating* results in more crossings receiving a low or insignificant *Binned Overall Geomorphic Impact Score* (score of 1 or 2):

- When the *Substrate Size Impact Potential Rating* is not included in the analysis, 2 (1%) crossings received a score of 1, 91 (47%) crossings received a score of 2, 87 (45%) crossings received a score of 3, and 13 (7%) crossings received a score of 4. (**Figure 16A**).
- When the *Substrate Size Impact Potential Rating* is included in the analysis, 0 (0%) crossings received a score of 1, 70 (36%) crossings received a score of 2, 109 (57%) crossings received a score of 3, and 14 (7%) crossings received a score of 4 (**Figure 16B**).
- There was no change to the number of crossings that received a score of 5 (0 crossings; 0%).

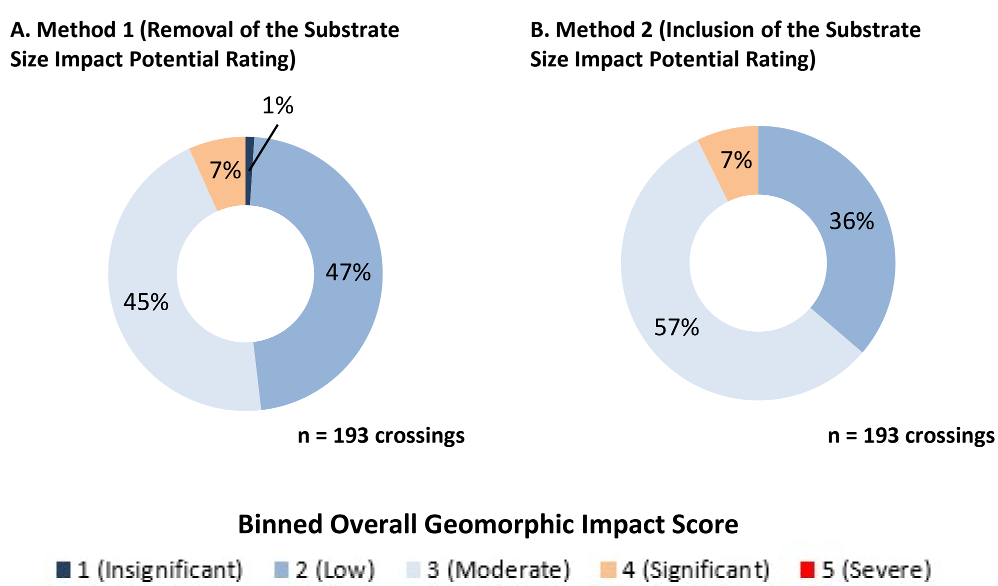


Figure 16. Comparison of the distribution of Binned Overall Geomorphic Impact Scores resulting from modified scoring that excludes the Substrate Size Impact Potential Rating (A) and the traditional scoring described in the Handbook that includes the Substrate Size Impact Potential Rating (B). These two methods were compared to determine how to best account for the lack of stream substrate type data for the majority of the assessed crossings.

To avoid artificially lowering the *Binned Overall Geomorphic Impact Scores*, Method #2 (inclusion of the *Substrate Size Impact Potential Rating* as described in **Section 2.3.4**) was used in the Pilot Study. These results demonstrate that removing a single piece of data from the analysis can artificially lower the *Binned Overall Geomorphic Impact Score* and make the crossings appear less vulnerable to geomorphic impacts than they actually are. It is therefore important to attempt to collect as much field data as possible and to make reasonable assumptions as described in this report to account for missing data when necessary.

Using Method #2, no crossings received a *Binned Overall Geomorphic Impact Score* of 5 or 1, indicating that no crossings have insignificant (score of 1) or severe (score of 5) geomorphic vulnerability. The scoring methodology was reviewed in order to determine why no crossings received a *Binned Overall Geomorphic Impact Score* of 5 or 1.

In order to achieve a score of 5, the sum of the *Combined Observed Geomorphic Impact Score* and the *Combined Potential Geomorphic Impact Score* must be greater than 28 (according to **Handbook Table 8-11**). This can only be achieved under certain scoring combinations when the *Combined Potential Geomorphic Impact Score* is greater than 13 (i.e., the potential for geomorphic impacts is considered "Likely" or "Very Likely") and the *Combined Observed Geomorphic Impact Rating* is greater than 8 (i.e., the observed geomorphic impacts are "Moderate", "Significant" or "Severe"). The average *Combined Potential Geomorphic Impact Score* for all assessed crossings is 11.19, while the average *Combined Observed Geomorphic Impact Score* for all crossings is 5.13, indicating that it is unlikely that a crossing would have had combined scores of 28 or greater.

In order to achieve a score of 1, the sum of the *Combined Observed Geomorphic Impact Score* and the *Combined Potential Geomorphic Impact Score* must be 7 or lower (according to **Handbook Table 8-11**). This result can only be achieved when one of the scores is 4 or lower and the other is 3 or lower. Considering the average *Combined Potential Geomorphic Impact Score* of 11.19, and the average *Combined Observed Geomorphic Impact Score* of 5.13, it is also unlikely that a crossing would have a combined score of 7 or lower.

The individual geomorphic impact ratings that are used to create the *Combined Potential Geomorphic Impact Score* and the *Combined Observed Geomorphic Impact Score* are described in **Handbook Section 8.3** and **8.4** and each can range from 1 to 5, with a higher score indicating greater geomorphic impacts. **Table 9** lists the individual geomorphic impact ratings used in the assessment and the average score for each individual impact rating for the 193 assessed crossings.

Table 9. Individual Geomorphic Impact Rating Scores

Potential Geomorphic Impacts		Observed Geomorphic Impacts	
Individual Impact Rating	**Average Score**	**Individual Impact Rating**	**Average Score**
Crossing Alignment	2.2	Sediment Continuity	1.4
Bankfull Width	4.5	Bank Erosion and Outlet Armoring	1.8
Channel and Crossing Structure Slope	1.2	Inlet and Outlet Grade	1.9
Substrate Size Potential Impact†	3.2	-	-

†As described in **Section 2.3.4**, due to missing *Crossing Substrate* data the *Substrate Size Impact Potential Rating Score* was manually entered as 3 for 106 (55%)of the crossings.

The average individual impact scores are particularly low for the observed geomorphic impact factors (*Sediment Continuity*, *Bank Erosion and Outlet Armoring*, and *Inlet and Outlet Grade*). One possible reason for the low scores is that many of the crossings were installed at a relatively shallow slope (average channel and crossing structure slope score of 1.2). Bank erosion is less likely near culverts with a shallow slope because flow velocities are typically relatively slow. The inlet and outlet grade is also less likely to be perched or have a drop at culverts with a shallow slope.

The potential individual geomorphic impact scores are slightly higher than the observed geomorphic impact scores. The *Bankfull Width Impact Rating* has the highest average score of all of the individual geomorphic impact scores, at 4.5. This is likely due to the fact that 132 (68%) of the 193 assessed crossings were rated as severely constricted. The *Substrate Size Potential Impact Rating* has an average score of 3.2, which is due in part to the 106 crossings for which a score of 3 was manually entered, as discussed above. The combined effect of the crossings generally showing low observed geomorphic impacts and moderate potential geomorphic impacts is that the *Binned Overall Geomorphic Impact Scores* fall in the middle range and there is a lack of values at either extreme (1 or 5).

The assessed bridges generally received lower *Binned Overall Geomorphic Impact Scores* than culverts (**Figure 15B, 15C and 15D**). Bridges that were assessed in the field were typically aligned with the stream channel and tended to be larger in size, resulting in less constriction of the stream channel. The assessed bridges were also typically constructed with a continuous open, natural streambed through the structure, which eliminates inlet/outlet grade impacts and lessens sediment continuity impacts.

The Geomorphic Risk Scores (*Binned Overall Geomorphic Impact Score* multiplied by the *Impact Score*) for the 193 assessed crossings are summarized in **Figure 17**. Although the average *Geomorphic Risk Score* (9.13) is similar to the average *Hydraulic Risk Score* (8.83), the distribution of scores is dramatically different for the two assessments. While the *Hydraulic Risk Scores* tended toward extremely high or low scores, the *Geomorphic Risk Scores* were more moderate. Moderate *Geomorphic Risk Scores* throughout the watershed may stem from historical widespread installation of undersized structures that constrict the stream channel, resulting in moderate potential geomorphic impacts combined with generally low relief throughout the watershed, resulting in lower observed geomorphic impacts.

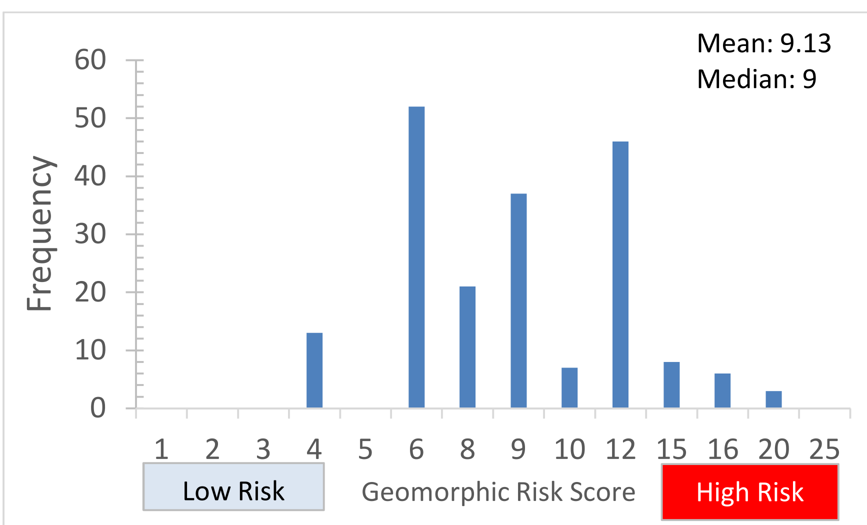


Figure 17. Histogram showing the distribution of Geomorphic Risk Scores for all crossings.

The spatial distribution of the *Geomorphic Risk Scores* is provided in **Figure 18**. The three crossings with the highest *Geomorphic Risk Scores* (score of 20) are xy41834977144282, located on Pleasant Valley Parkway in Providence (unnamed tributary to the Woonasquatucket River), xy41871207155179, located on Putnam Pike in Smithfield (Slack Reservoir outflow) and xy41873187150300 located on Dean Street in Smithfield (Hawkins Brook). The high *Geomorphic Risk Score* for crossing xy41834977144282 is driven by constriction of the stream channel, a perched inlet and small substrate size. Crossing xy41871207155179 has an inlet drop, severe constriction of the channel, and straightening of the stream by channelization which contribute to a high *Geomorphic Risk Score* (**Figure 19**). Extensive outlet armoring, an outlet drop, and misalignment of the crossing with the stream channel contribute to the high *Geomorphic Risk Score* for crossing xy41873187150300 (**Figure 20**).

Other crossings with high *Geomorphic Risk Scores* (score of 16) include:

- xy41835427143915 on Pleasant Valley Parkway in Providence (unnamed tributary to the Woonasquatucket River)
- xy41845877148670 on George Waterman Street in Johnston (Assapumpset Brook)
- xy41861407156668 on Sheffield Road in Smithfield (unnamed tributary to Slack Reservoir)
- xy41867937149613 on Riverside Avenue in Johnston (unnamed tributary to the Woonasquatucket River)
- xy41899147150128 on Douglas Pike in Smithfield (unnamed tributary to Georgiaville Pond)
- xy41910887152828 on Stillwater Road in Smithfield (unnamed tributary to Stillwater Pond)

Crossing xy41834977144282 (located on Pleasant Valley Parkway in Providence) was also among the crossings that received the highest *Future Climate Change* and *Structural Risk Scores*, while crossing xy41910887152828 (located on Stillwater Road in Smithfield) was among the crossings that received the highest *AOP Benefit Scores*. Five of the nine crossings with the highest *Geomorphic Risk Scores* were ranked as high priority (xy41834977144282; xy41871207155179; xy41873187150300; xy41845877148670; xy41867937149613) based on the *Binned Prioritization Score* (**Attachment J**). The other four crossings with the highest *Geomorphic Risk Scores* were ranked as medium priority.

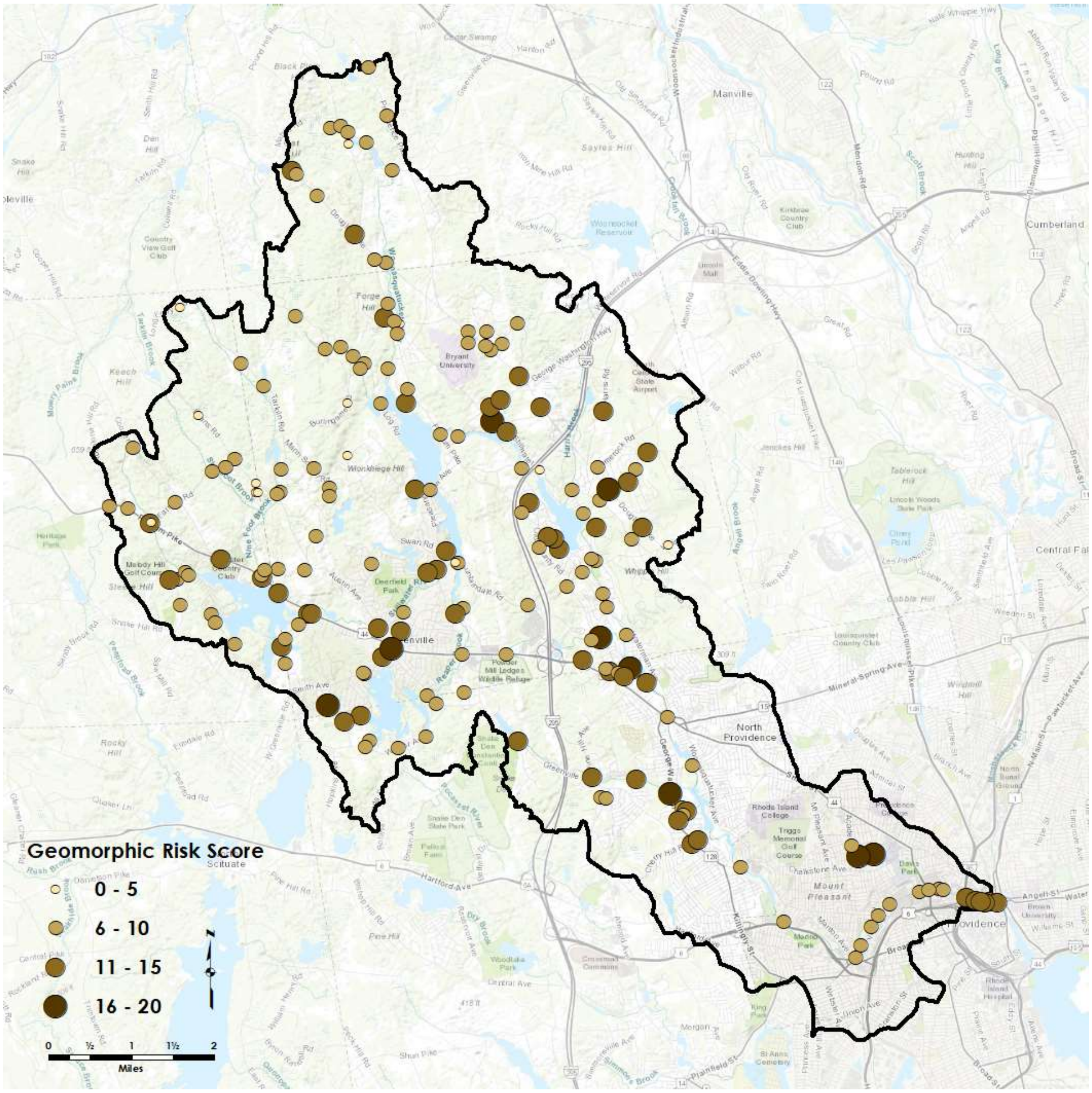


Figure 18. Spatial distribution of Geomorphic Risk Scores.

Figure 19. Inlet drop (left) and severe channel constriction (right) associated with xy41871207155179 on Putnam Pike in Smithfield, at the Slack Reservoir outflow.

Figure 20. Outlet armoring and outlet drop associated with xy41873187150300 on Dean Street in Smithfield (Hawkins Brook).

3.2.5 Structural Condition

The distribution of *Binned Structural Condition Scores* for all assessed crossings is provided in **Figure 21A**. The results indicate:

- Sixty-seven (35%) of the 193 assessed crossings received a *Binned Structural Condition Score* of 5 (critical)
- One hundred and twenty-six (65%) crossings received a score of 1 or 2 (good or satisfactory)
- No crossings received a *Binned Structural Condition Score* of 3 or 4 (Fair or Poor).

The *Binned Structural Condition Scoring* methodology was reviewed to determine why no crossings received a *Binned Structural Condition Score* of 3 or 4 and if this is an accurate reflection of the structural condition of the assessed crossings.

The *Binned Structural Condition Score* is assigned based on the lowest score resulting from the *Level 1*, *Level 2*, and *Level 3 Condition Scores*, according to **Handbook Table 9-4**. A *Binned Structural Condition Score* of 3 is assigned when the lowest of the three scores falls between 0.41 and 0.60 and a score of 4 is assigned when the lowest of the three scores falls between 0.21 and 0.40. For the *Level 1* and *Level 2* assessments, the only possible scores that can be achieved are 0.0., 0.1, 0.2, and 1. Therefore, the only way a *Binned Structural Condition Score* of 3 or 4 can be assigned is if the *Level 3 Condition Score* falls between 0.21 and 0.60 and both the *Level 1* and *Level 2 Condition Scores* are assigned a 1. A *Level 1 Condition Score* of 1 is assigned when none of the variables in **Handbook Table 9-1** are marked as "Critical". A *Level 2 Condition Score* of 1 is assigned when none of the variables in **Handbook Table 9-2A** are marked as "Critical" and none of the variables in **Handbook Table 9-2B** are marked as "Poor".

Level 3 Condition Scores are calculated using **Handbook Equation 9-1**. In order to achieve a *Level 3 Condition Score* between 0.21 and 0.60, 4 to 7 of the variables in **Handbook Table 9-3** need to be marked "Poor". None of the assessed crossings had more than 3 of the variables in **Handbook Table 9-3** marked "Poor", thus making it impossible to achieve a *Binned Structural Condition Score* of 3 or 4.

Of the variables in **Handbook Table 9-3**, the variables that were most commonly marked "Poor" were *Joints and Seams Condition* and *Headwall/Wingwall Condition*. Many of the assessed crossings did not have a *Flared End Section*, *Apron/Scour Protection,* or *Armoring*, in which case the structural condition was marked as "N/A" for these factors and therefore did not contribute to the *Level 3 Condition Score*. These variables were often marked "Adequate" when they were present. Variables that were rarely marked "Poor" in the field include *Embankment Piping* (11 structures marked "Poor"), *Invert Deterioration* (10 structures), *Longitudinal Alignment* (6 structures) and *Buoyancy or Crushing* (5 structures). It therefore appears that the distribution of *Binned Structural Condition Scores* accurately reflects the structural condition of the assessed crossings.

When the *Binned Structural Condition Scores* are separated by structure type, the results indicate the following:

- Thirty-five (90%) of the 39 assessed bridges received a *Binned Structural Condition Score* of 1 (good) while 4 (10%) received a score of 5 (critical) (**Figure 21B**)
- Sixty-eight (60%) of the 114 assessed round culverts received a *Binned Structural Condition Score* of 1 (good) while 42 (37%) received a score of 5 (critical). Four (4%) received a score of 2 (satisfactory) (**Figure 21C**)
- Eleven (41%) of the 27 assessed box culverts received a *Binned Structural Condition Score* of 1 (good) while 13 (48%) received a score of 5 (critical). Three (11%) received a score of 2 (satisfactory) (**Figure 21D**).

As discussed above in **Sections 3.2.2** and **3.2.4**, the assessed bridges generally have greater hydraulic capacity and fewer geomorphic impacts than culverts, which may explain why they are in better structural condition. Structures that are hydraulically undersized or experience significant geomorphic impacts will experience increased stress to all portions of the structure, which will result in a deteriorated structural condition.

Thirty-three (17%) of the assessed crossings received an *Unknown Structural Variable Flag*, indicating that at least one of the four *Level 1* variables was unknown or more than four of the nine *Level 2* variables were unknown. Parameters that were frequently marked "Unknown" in the field include *Structural Integrity of Barrel* and *Joints and Seams Condition*. These items are difficult to assess if the view into the structure is obstructed by water, sediment, or debris. These items were also frequently not assessed for larger bridges where the underside of the structure could not be accessed. Multiple structural condition parameters were marked "Unknown" on partially accessible structures where either the inlet or outlet could not be located or assessed. Crossings with *Unknown Structural Variable Flags* should be further evaluated given the uncertainty surrounding the crossings' structural condition.

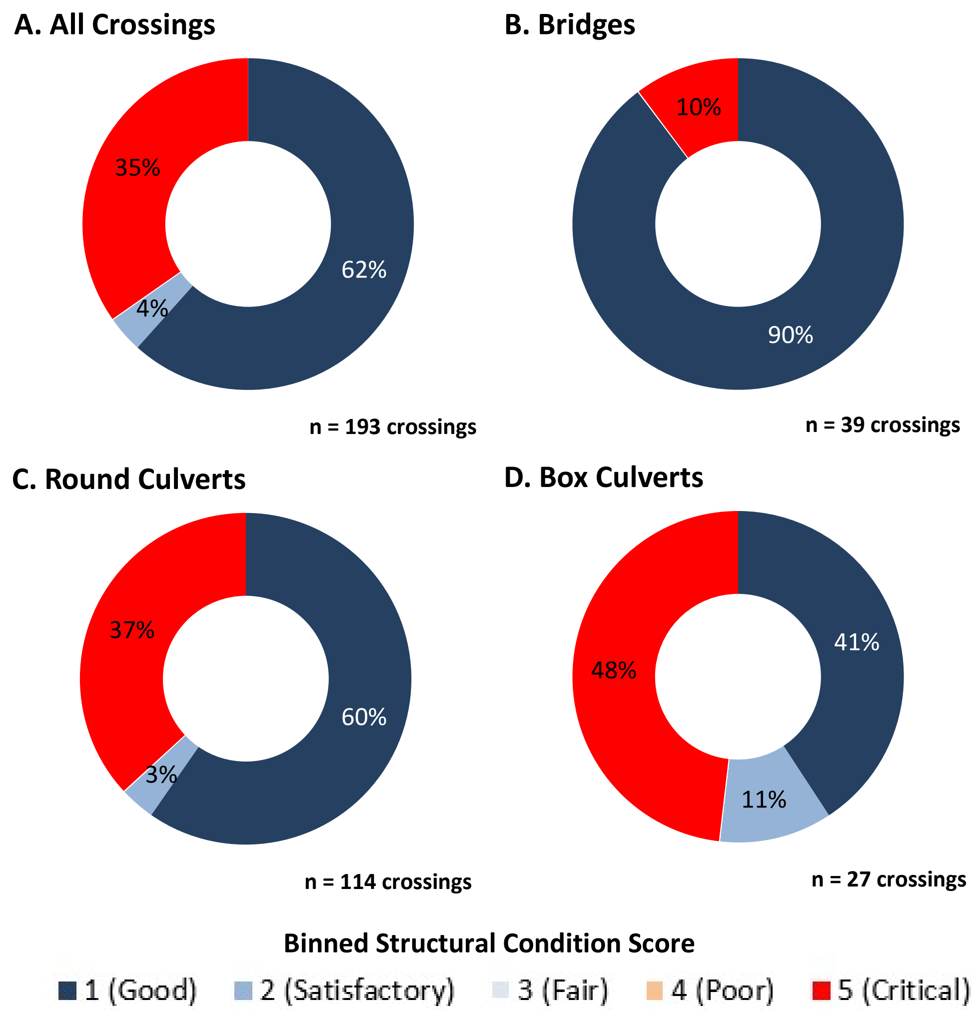


Figure 21. Binned Structural Condition Scores for all crossings (A) and by structure type (B-D). A score of 1 indicates the best structural condition while a score of 5 indicates the worst structural condition.

† Thirteen crossings are not included in the figure for the following reasons: 1) The structure type is known to be different at the inlet and the outlet. Structures where either the inlet or outlet type were unknown were included in the category corresponding to the known end of the structure. 2) The crossing included multiple culverts of different structure types (e.g. one round culvert and one box culvert located at one crossing). 3) The structure type does not fall into the above categories (e.g. arched culverts and elliptical culverts).

The *Structural Risk Scores* (*Binned Structural Condition Score* multiplied by the *Impact Score*) for the 193 assessed crossings are summarized in **Figure 22**. The distribution of *Structural Risk Scores* is skewed similarly to the distribution of *Hydraulic Risk Scores*, with the majority of the crossings having very high or, in particular, very low risk scores. There are several reasons that may explain why there are a high number of crossings with low structural risk:

- Within this region, road-stream crossings may have been constructed using resilient material that is holding up well over time.

- The crossings that have low *Structural Risk Scores* may correlate with the crossings that also have low *Hydraulic Risk Scores* and moderate *Geomorphic Risk Scores*, which would indicate that the structure might generally be exposed to less physical stress over time.
- A large number of crossings may have been recently replaced with new structures. However, as mentioned in **Section 3.2.2**, this is an unlikely explanation due to the number of older structures observed in the field.

The large number of crossings with high *Structural Risk Scores* may correlate with older crossings in the watershed that are failing over time, or with crossings that have higher *Hydraulic* and/or *Geomorphic Risk Scores*, resulting in increased stress on the structure.

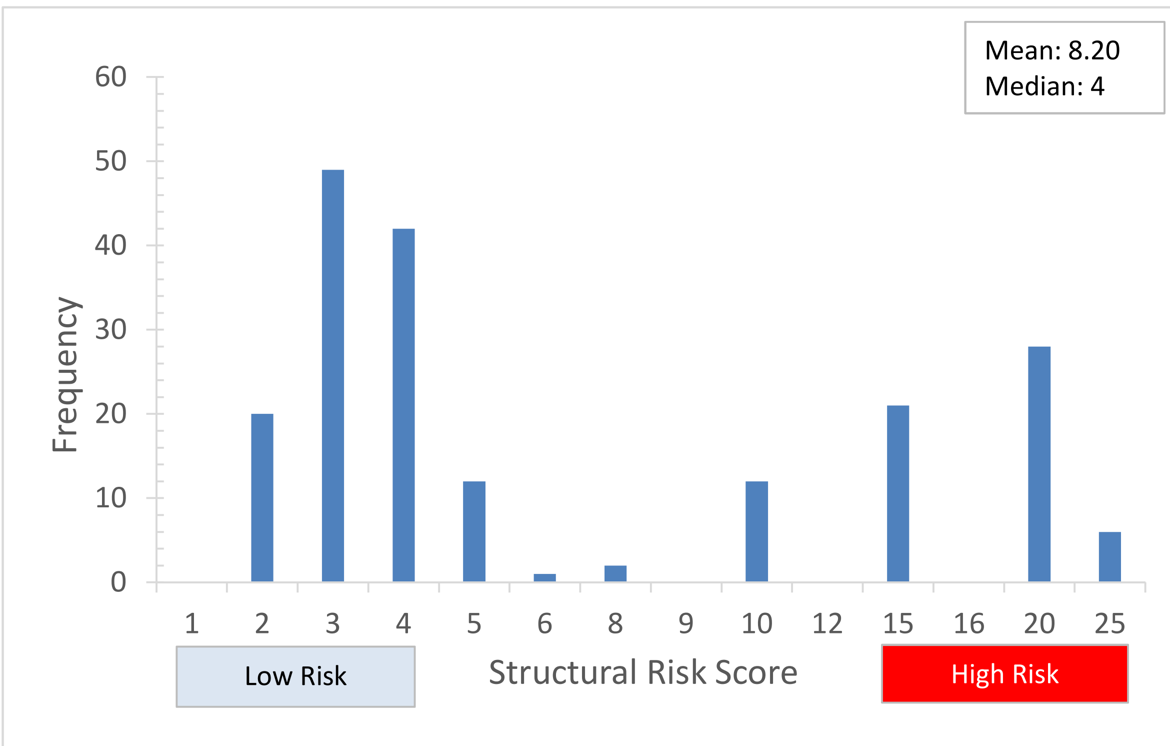


Figure 22. Histogram showing the distribution of Structural Risk Scores for all crossings.

highest structural risk are distributed throughout the watershed. The following six crossings received the highest *Structural Risk Scores*:

- xy41834977144282 on Pleasant Valley Parkway in Providence (Unnamed tributary to Woonasquatucket River)
- xy41841257148494 on Waterman Avenue in Johnston (Unnamed tributary to Assapumpset Brook)
- xy41872697150528 on Esmond Street in Smithfield (Hawkins Brook)
- xy41874767155492 on Austin Avenue in Smithfield (Stillwater River)
- xy41888657151262 on Farnum Pike in Smithfield (Unnamed tributary to Georgiaville Pond)
- xy41890917151543 on Farnum Pike in Smithfield (Unnamed tributary to Georgiaville Pond).

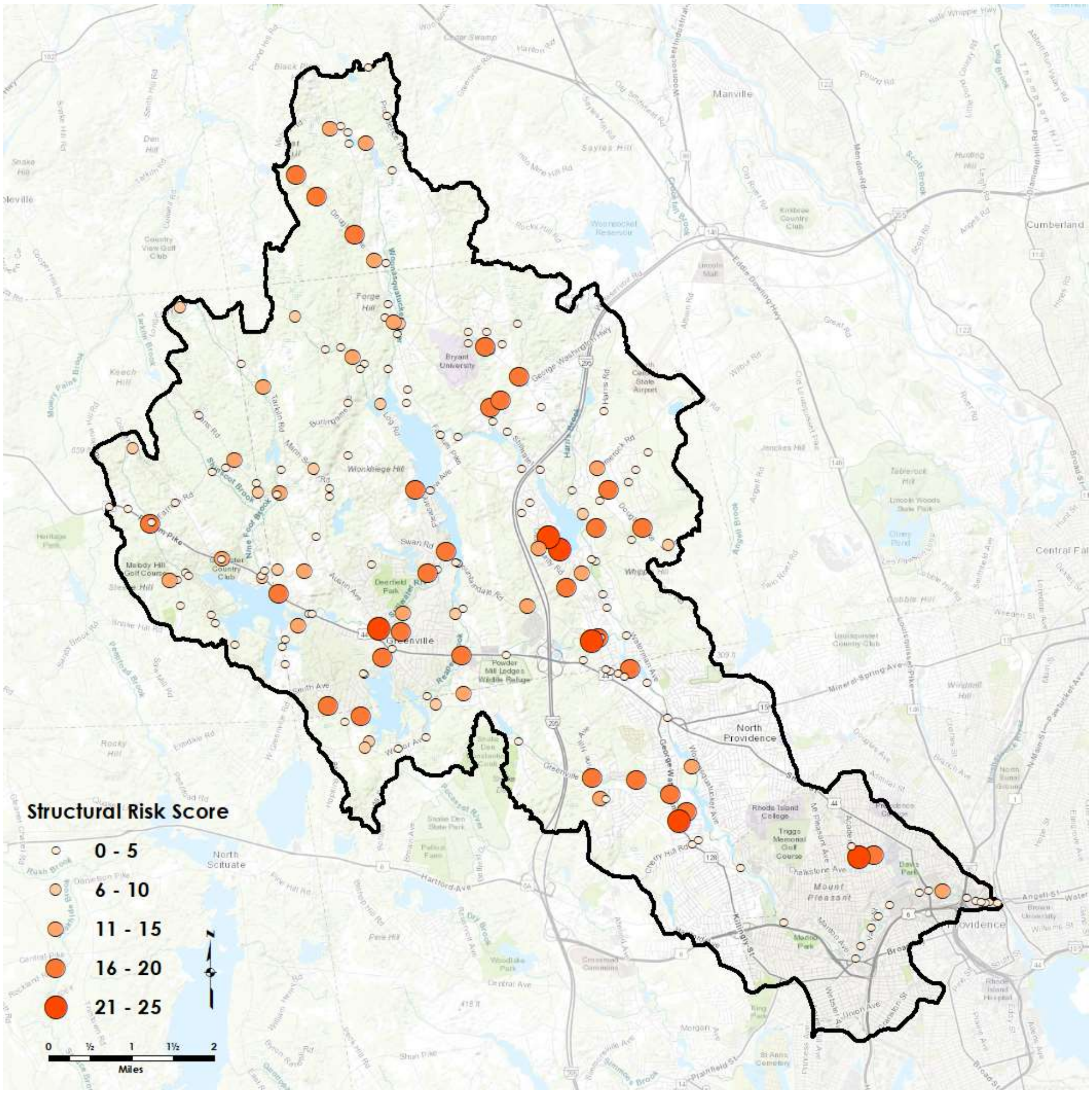


Figure 23. Spatial distribution of Structural Risk Scores

Figure 24 depicts some examples of the structural issues associated with high-risk crossings. Crossings xy41841257148494 and xy41890917151543 also received *Unknown Structural Variable Flags*, indicating that in addition to the structural issues documented in the field, there is the potential for other unknown structural issues. Four of the six crossings with the highest *Structural Risk Scores* are also among the crossings that received the highest *Climate Change Risk Scores*, while three of the four crossings are among those that received the highest *Hydraulic Risk Scores* and one crossing was among those that received the highest *Geomorphic Risk Scores*. All six of the crossings with the highest *Structural Risk Scores* are also among the top priority crossings overall (**Attachment J**).

Figure 24. Poor Barrel Condition of xy41834977144282 on Pleasant Valley Parkway in Providence (unnamed tributary to Woonasquatucket River) (left) and level of blockage of xy41888657151262 on Farnum Pike in Smithfield (unnamed tributary to Georgiaville Pond)(right).

3.2.6 Aquatic Organism Passage

According to the *Binned Aquatic Organism Passage Scores*:

- Eighty-six (45%) of the 193 assessed crossings presented moderate, significant, or severe barriers to aquatic organism passage, with 8 barriers (4%) considered to be severe barriers (**Figure 25A**)
- Fifty-two (27%) of the barriers were determined to provide full aquatic passage and 55 (28%) were assessed as minor barriers
- With regard to structure type, 95% (37 of 39 crossings) of the bridges provided full AOP passage, while round culverts had the highest percentage of severe barriers at 6% (7 of 114 crossings) (**Figure 25B, 25C and 25D**).

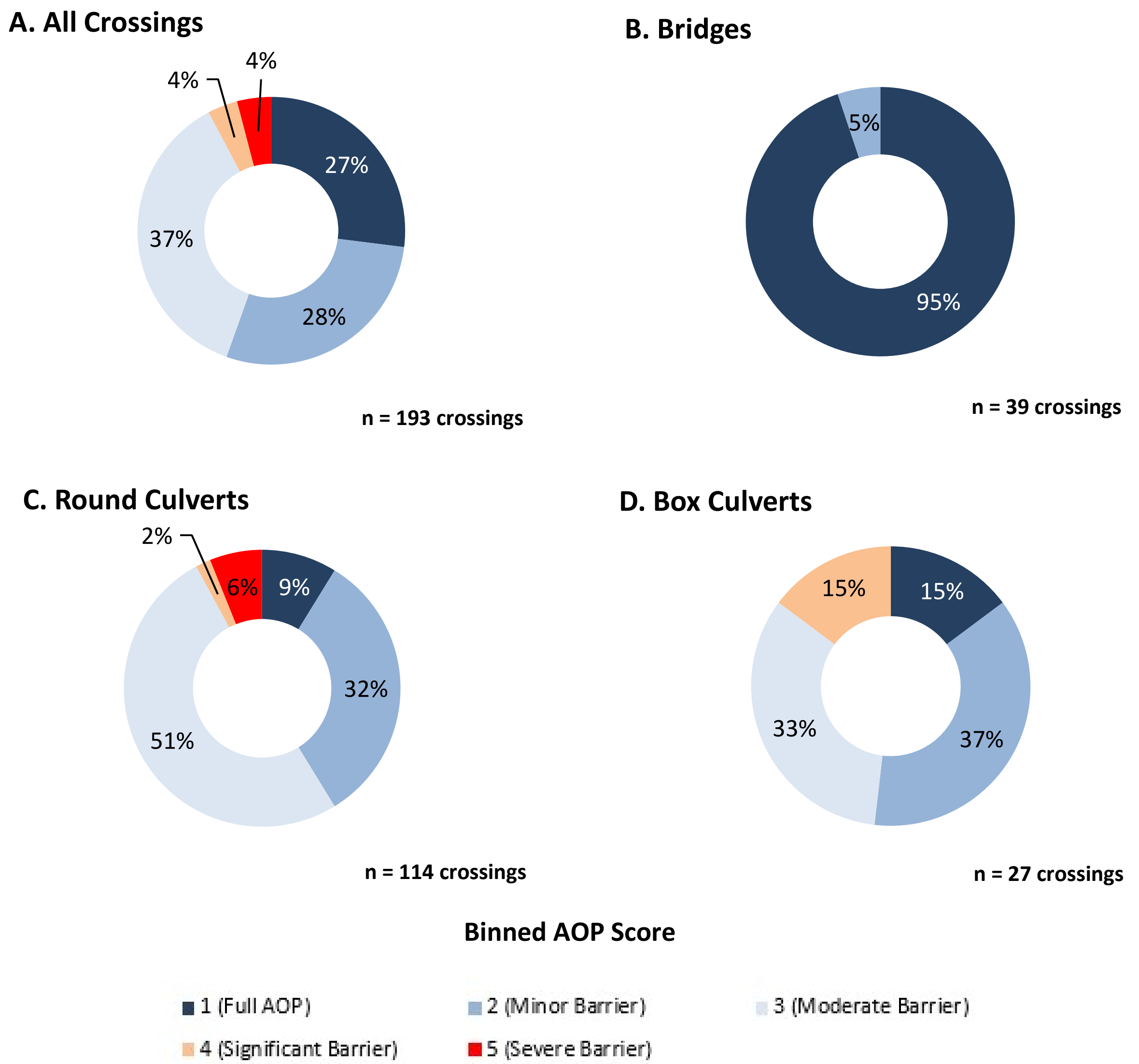


Figure 25. Binned AOP Scores for all crossings (A) and by structure type (B-D).

† Thirteen crossings are not included in the figure for the following reasons: 1) The structure type is known to be different at the inlet and the outlet. Structures where either the inlet or outlet type were unknown were included in the category corresponding to the known end of the structure. 2) The crossing included multiple culverts of different structure types (e.g. one round culvert and one box culvert located at one crossing). 3) The structure type does not fall into the above categories (e.g. arched culverts and elliptical culverts).

With regard to the *Binned Ecological Benefit Scores*:

- Twelve (6%) of the 193 assessed crossings received a score of 5, indicating the highest relative ecological benefit of crossing removal (**Figure 26**).
- One hundred forty-five (75%) of the 193 assessed crossings received a score of 3. Seventy-two (50%) of these 145 crossings were manually assigned a score of 3 because an IEI value was not available for the given crossing (following the methodology in **Handbook Section 12.5.1**).
- Zero (0%) crossings received a score of 1, indicating the lowest relative ecological benefit of crossing removal.

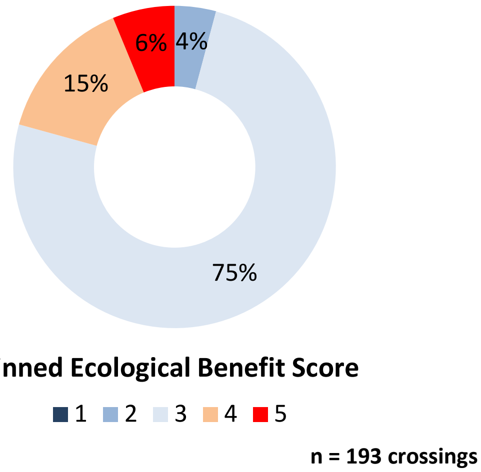


Figure 26. Binned Ecological Benefit Scores for all crossings. A score of 1 indicates lowest ecological benefit while a score of 5 indicates the most ecological benefit.

The *AOP Benefit Scores* (*Binned AOP Score* multiplied by the *Binned Ecological Benefit Score*) for the 193 assessed crossings are summarized in **Figure 27.** The majority of the assessed crossings received low to moderate *AOP Benefit Scores*, indicating that the crossings with the most severe aquatic barriers are located in areas where habitat quality and other characteristics likely limit the ecological benefit to crossing removal. Culvert replacement projects aimed at improving aquatic connectivity may need to incorporate measures such as water quality mitigation and habitat restoration in order to increase the degree of ecological benefit achieved.

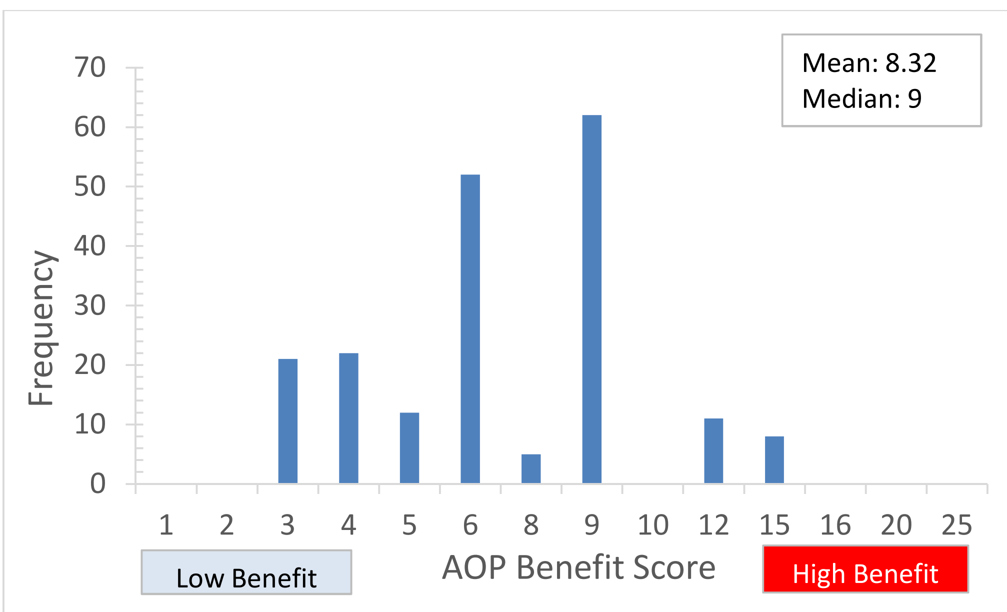


Figure 27. Histogram showing the distribution of AOP Benefit scores for all assessed crossings.

The spatial distribution of the *AOP Benefit Scores* is provided in **Figure 28**. The crossings with the highest *AOP Benefit Scores* are mostly located in Smithfield and Johnston, with a few in North Smithfield and Glocester. There is a cluster of crossings with high *AOP Benefit Scores* surrounding Slack Reservoir in Smithfield and Johnston, and several crossings with high *AOP Benefit Scores* on Assapumpset Brook in Johnston.

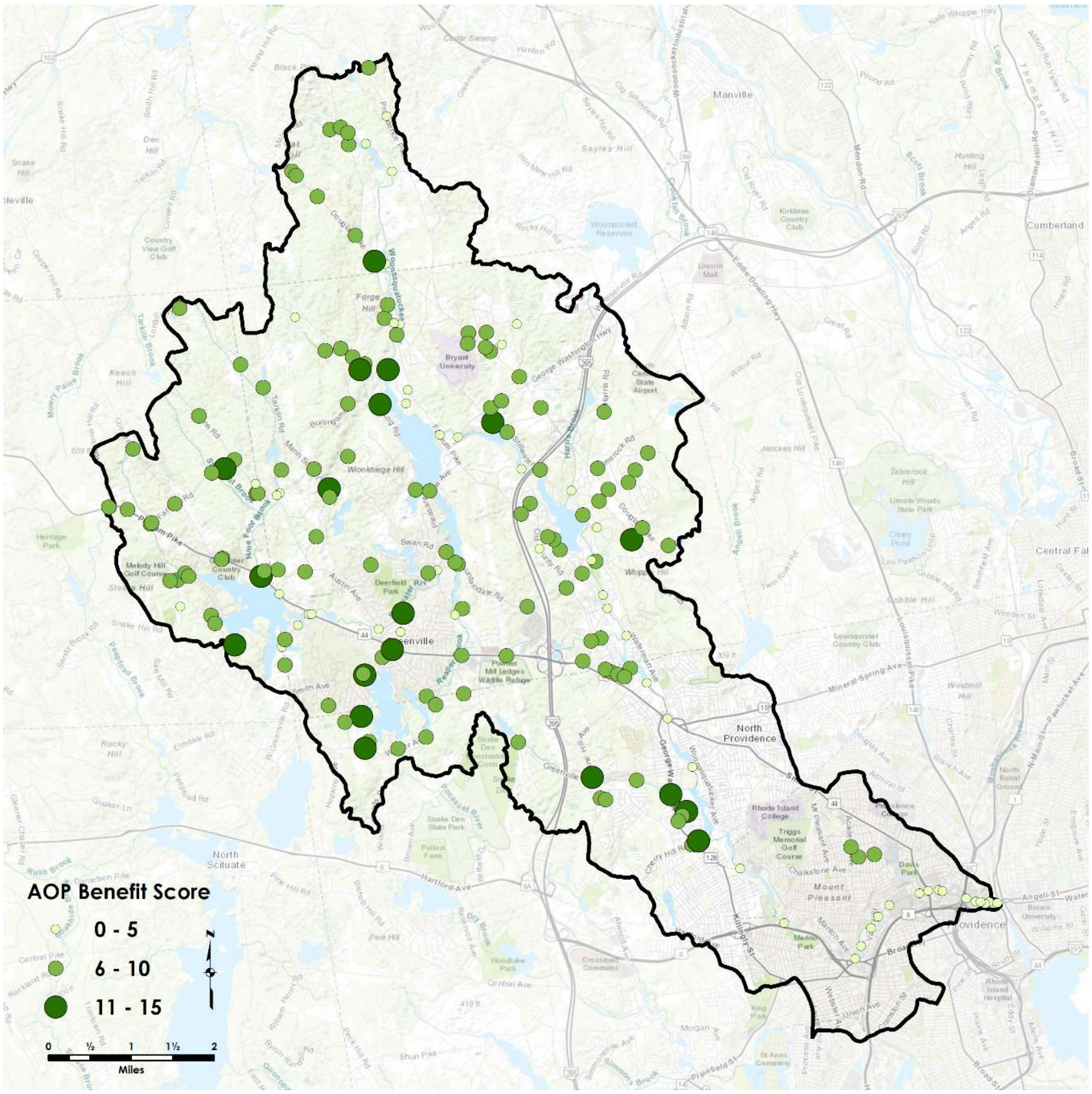


Figure 28. Spatial distribution of AOP Benefit Scores.

The eight crossings that received the highest *AOP Benefit Scores* are listed in **Table 10**. These eight crossings are all associated with an *Outlet Drop* (**Figure 29**). This is not surprising considering the *Outlet Drop* is given significant weight in the determination of the final *Aquatic Passability Score*, as mentioned above in **Section 2.3.8.** 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.

Crossing xy41910887152828 (located on Stillwater Road in Smithfield over an unnamed tributary to the Woonasquatucket River) was among the crossings that received the highest *Geomorphic Risk Scores*. This crossing and crossing xy41848877150503 (located on Pine Hill Avenue in Johnston over Assapumpset Brook) scored as a high priority culverts in the final prioritization based on the *Binned Prioritization Scores* (**Attachment J**).

Table 10. Crossings with the highest *AOP Benefit Score*

Crossing Code	Road Name	Municipality	Stream Name	Structure Type	AOP Benefit Score (1-25)
xy41837797148021	Di Sarro Avenue	Johnston	Unnamed tributary to Woonasquatucket River	Culvert	15
xy41848877150503	Pine Hill Avenue	Johnston	Assapumpset Brook	Culvert	15
xy41853977155807	Winsor Road	Johnston	Unnamed tributary to Slack Reservoir	Culvert	15
xy41871997158854	Aldrich Road	Glocester	Unnamed tributary to Waterman Reservoir	Culvert	15
xy41890377149584	Ridge Road	Smithfield	Unnamed tributary to Woonasquatucket River	Culvert	15
xy41899277156654	Colwell Road	Smithfield	Unnamed tributary to Sprague Reservoir	Culvert	15
xy41902757159093	Farnum Road	Glocester	Unnamed tributary	Culvert	15
xy41910887152828	Stillwater Road	Smithfield	Unnamed tributary to Stillwater Pond	Multiple Culverts	15

Figure 29. Outlet Drops associated with xy41848877150503 on Pine Hill Avenue in Johnston over Assapumpset Brook (left) and xy41890377149584 on Ridge Road in Smithfield over an unnamed tributary to the Woonasquatucket River (right)

3.2.7 Flooding Impact Potential

One hundred thirty-three (69%) of the 193 assessed crossings received low to moderate *Binned Flood Impact Potential Scores* (scores 1 through 3; **Figure 30**). These crossings are spread throughout the watershed (**Figure 31**). The main drivers of the low/moderate *Binned Flood Impact Potential Scores* for these crossings were few utilities associated with the crossing and a low percentage of developed area within the crossing's potential flood impact area. One hundred and twelve (84%) of the 133 crossings that received low to moderate *Binned Flood Impact Potential Scores* did not have any utilities associated with them (no utilities were noted during the field assessment). Eighty seven (65%) of the crossings that received low to moderate *Binned Flood Impact Potential Scores* had less than 10% developed area within the potential flood impact area.

Forty-two (22%) crossings received a score of 4 while 18 (9%) crossings received a score of 5, indicating a high flood impact potential. The 18 crossings that received a score of 5 are located in urbanized areas of Providence, Johnston and Smithfield, where crossing failure would have extensive impacts on infrastructure and development. Five of the six crossings located in Providence are on the main stem of the Woonasquatucket River in downtown Providence. All of the crossings that received a score of 5 had two or more utilities associated with the crossing and two or more other crossings located within the potential flood impact area.

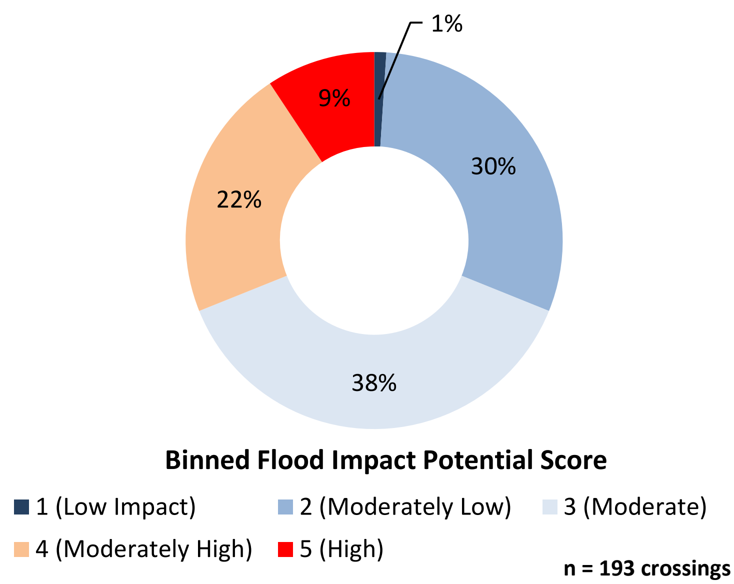


Figure 30. Binned Flood Impact Potential Scores for all crossings. A score of 1 indicates the lowest flood impact potential while a score of 5 indicates the highest flood impact potential.

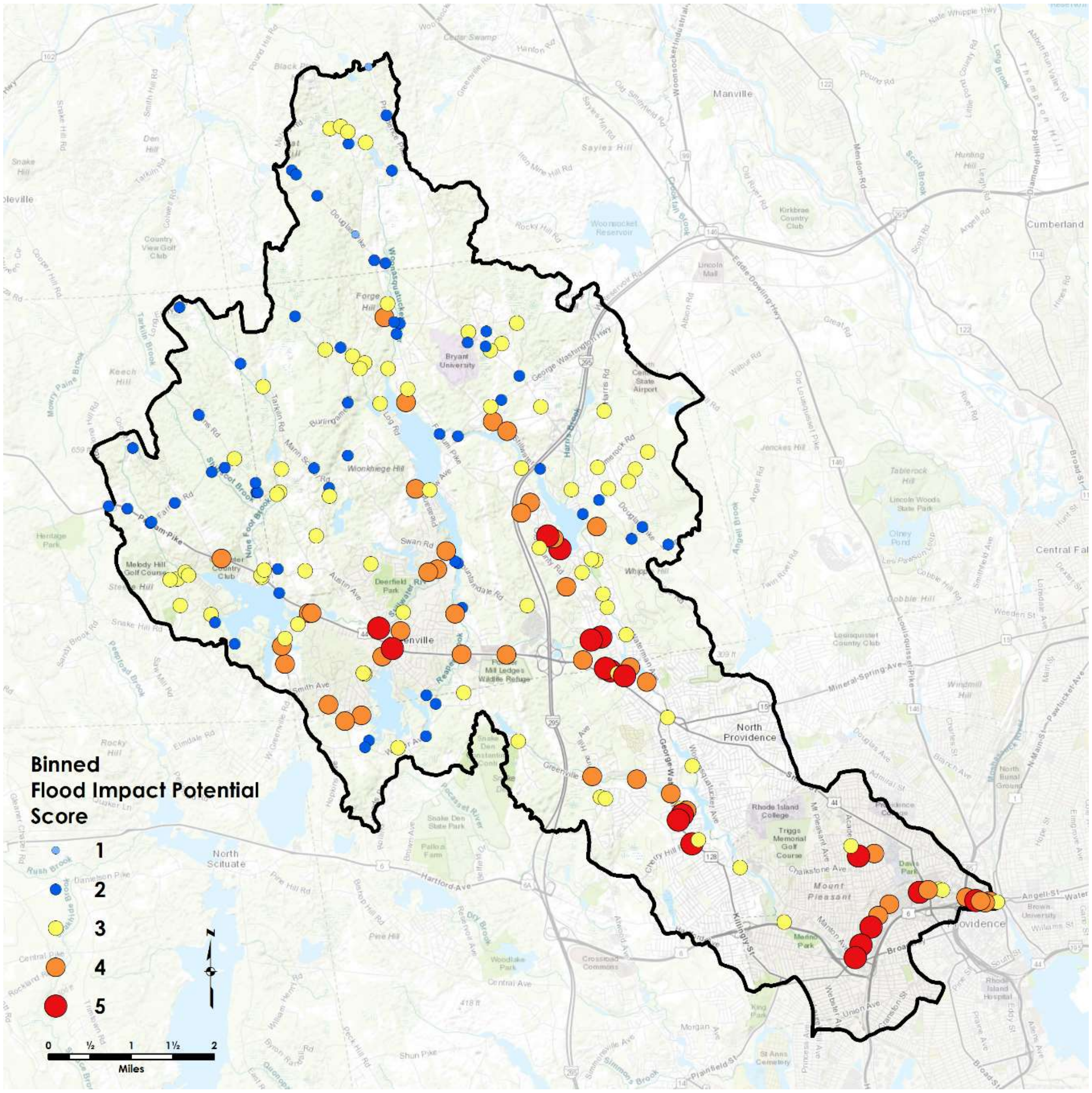


Figure 31. Spatial Distribution of Binned Flood Impact Potential Scores.

3.2.8 Disruption of Transportation Services

One hundred sixty (83%) of the 193 assessed crossings have low to intermediate potential for disruption of transportation services according to the *Binned Transportation Disruption Score* results (score of 1 through 3; **Figure 32**). These crossings are distributed throughout the watershed (**Figure 33**). The main reasons that these crossings received low to intermediate potential for disruption services are because the majority of them are not located on a primary E-911 Route or major roads. One hundred and thirty-five (84%) of the 160 crossings that received low to intermediate *Binned Transportation Disruption Score*s are not located on a primary E-911 route. One hundred and fifty-nine (99%) of the 160 crossings that received low to intermediate *Binned Transportation Disruption Score*s are located on roads classified as "Local Roads, Trails, Driveways", "Major and Minor Collectors", or "Minor Arterials."

Thirty-three (17%) crossings received a score of 4, indicating a moderately high potential for disruption of transportation services. All 33 of the crossings that received a *Binned Transportation Disruption Score* of 4 are located on a primary E-911 route and major roads that are classified as "Other Principal Arterials."

Only three of the 193 assessed crossings are located on a hurricane evacuation route. These three crossings received a *Binned Transportation Disruption Score* of 3 (moderate disruption). If more crossings had been located on a Hurricane Evacuation Route, we would expect to see a shift to more crossings with moderate transportation disruption (*Binned Transportation Disruption Score* of 2 to 3) and fewer crossings with low transportation disruption (*Binned Transportation Disruption Score* of 1).

No crossings received a score of 5 (highest potential for transportation disruption) due to the exclusion of crossings located on interstates, freeways and expressways from this Pilot Study to protect field staff during field data collection (as described in **Section 2.1**).

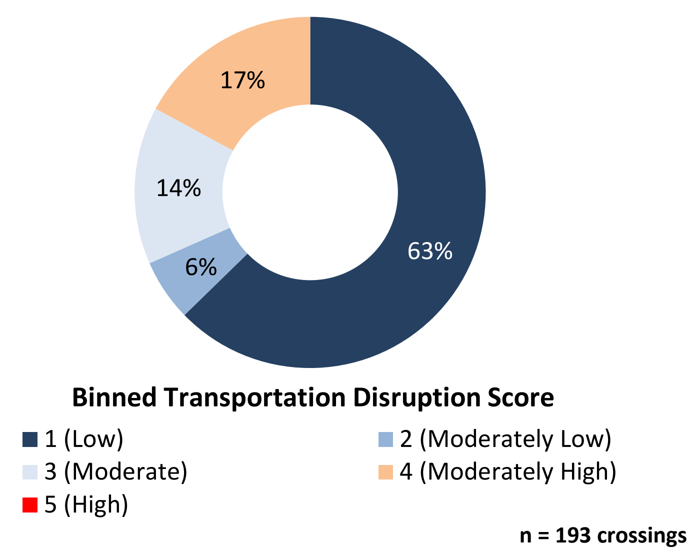


Figure 32. Binned Transportation Disruption Scores for all crossings. A score of 1 indicates the least potential disruption associated with crossing failure while a score of 5 indicates the highest potential disruption.

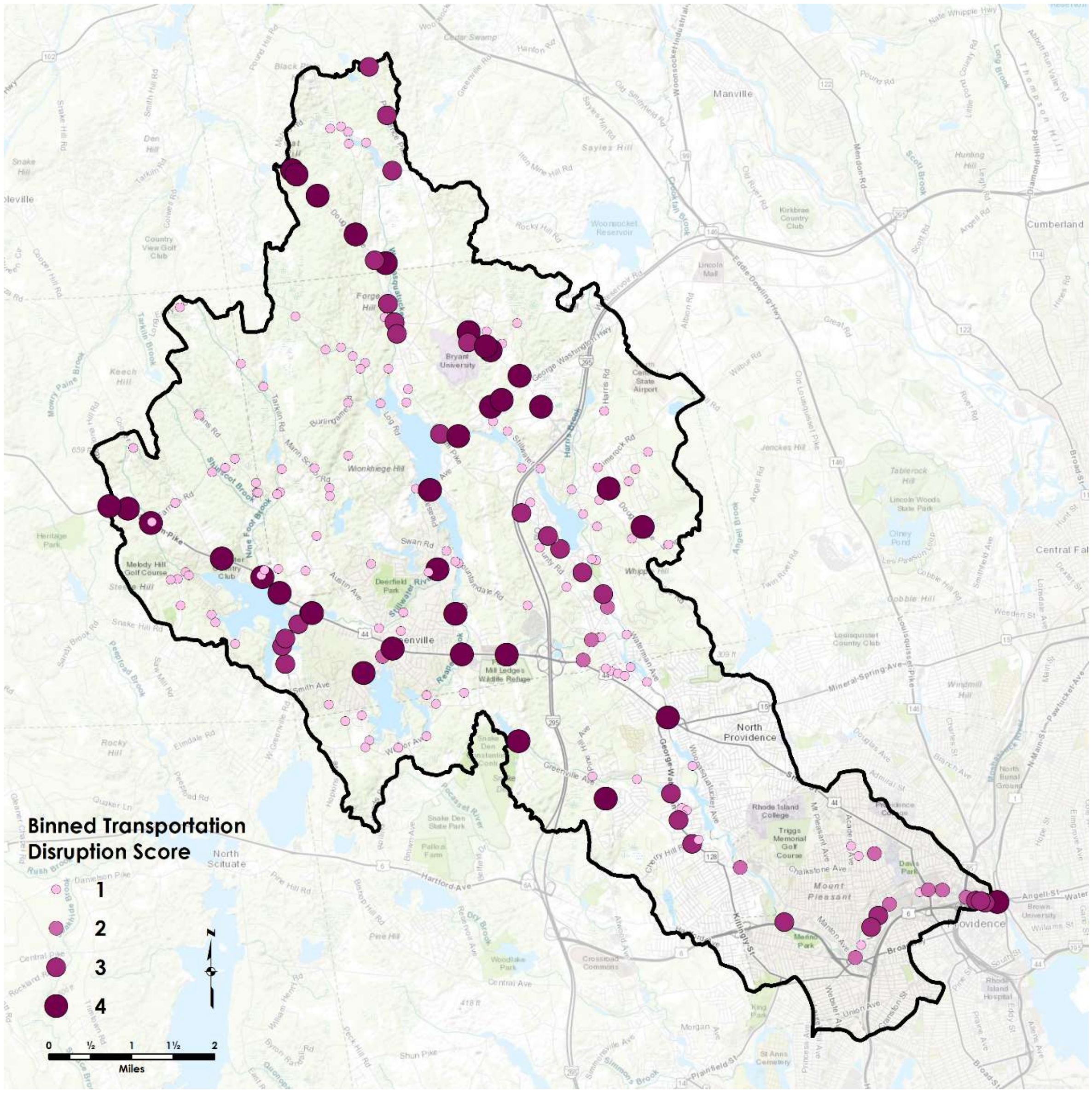


Figure 33. Spatial distribution of Binned Transportation Disruption Scores.

3.2.9 Impact Scores

The crossings with the highest *Impact Scores* (maximum of *Binned Transportation Disruption Score* and *Binned Flood Impact Potential Score*) are listed in **Table 11** and the spatial distribution of *Impact Scores* is provided in **Figure 34.** Eighteen (9%) of the 193 assessed crossings received the highest possible *Impact Score* of 5. Many of the crossings with the highest *Impact Scores* are located in downtown Providence and urban areas of Johnston and Smithfield. As mentioned above in **Section 3.2.8**, no crossings received a *Binned Transportation Disruption Score* of 5. The 18 crossings that received an *Impact Score* of 5 were therefore all driven by high *Binned Flood Impact Potential Scores,* since the *Impact Score* is calculated by taking the maximum of the *Binned Transportation Disruption Score* and *Binned Flood Impact Potential Score*.

Table 11. Crossings with the highest Impact Scores.

Crossing Code	Road Name	Municipality	Stream Name	Structure Type	Impact Score (1-5)
xy41817227144364	Manton Avenue	Providence	Woonasquatucket River	Bridge	5
xy41819437144226	Delaine Street	Providence	Woonasquatucket River	Bridge	5
xy41822527143992	Valley Street	Providence	Woonasquatucket River	Bridge	5
xy41827207141547	Francis Street	Providence	Woonasquatucket River	Bridge	5
xy41828647142862	Acorn Street	Providence	Woonasquatucket River	Bridge	5
xy41834977144282	Pleasant Valley Parkway	Providence	Unnamed tributary to Woonasquatucket River	Culvert	5
xy41837147148177	Waterman Avenue	Johnston	Unnamed tributary to Woonasquatucket River	Culvert	5
xy41841257148494	Waterman Avenue	Johnston	Unnamed tributary to Assapumpset Brook	Partially Inaccessible	5
xy41842197148400	Diaz Street	Johnston	Unnamed tributary to Assapumpset Brook	Culvert	5
xy41866427149748	Dean Street	Johnston	Unnamed tributary to Woonasquatucket River	Culvert	5
xy41867357150081	Mowry Avenue	Johnston	Unnamed tributary to Woonasquatucket River	Multiple Culverts	5
xy41867767150198	Susan Drive	Johnston	Unnamed tributary to Woonasquatucket River	Partially Inaccessible	5
xy41871207155179	Putnam Pike	Smithfield	Slack Reservoir Outflow	Culvert	5
xy41872697150528	Esmond Street	Smithfield	Hawkins Brook	Multiple Culverts	5
xy41873187150300	Dean Street	Smithfield	Hawkins Brook	Multiple Culverts	5
xy41874767155492	Austin Avenue	Smithfield	Stillwater River	Multiple Culverts	5
xy41888657151262	Farnum Pike	Smithfield	Unnamed tributary to Georgiaville pond	Multiple Culverts	5
xy41890917151543	Farnum Pike	Smithfield	Unnamed tributary to Georgiaville pond	Partially Inaccessible	5

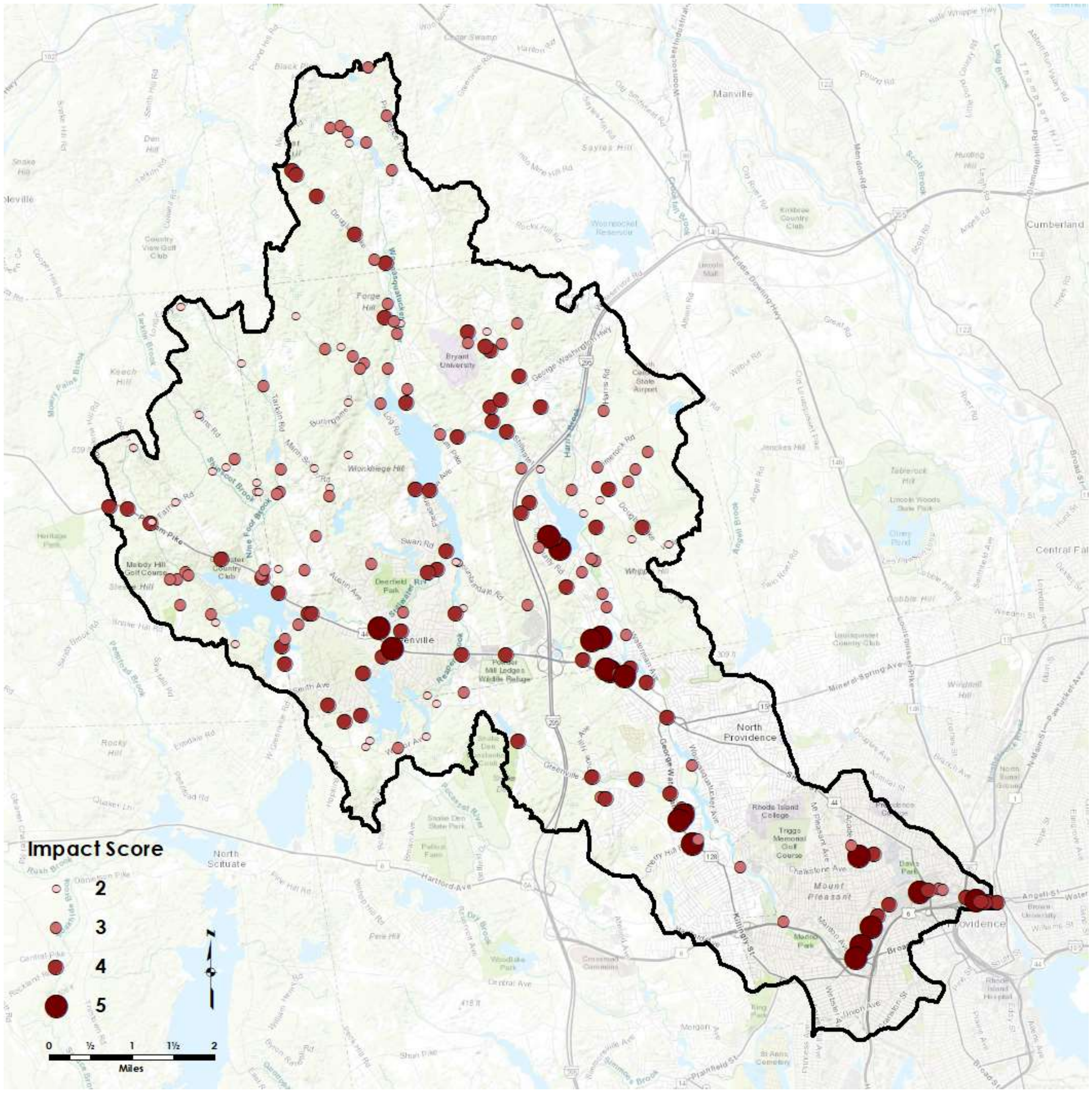


Figure 34. Spatial Distribution of Impact Scores.

3.2.10 Overall Scoring and Prioritization

Of the 193 assessed crossings, 32 (17%) were ranked as high priority, 120 (62%) were ranked as medium priority, and 41 (21%) were ranked as low priority (**Figure 35**). The spatial distribution of *Binned Prioritization Scores* is provided in **Figure 36**. Of the 32 high priority crossings, 11 (34%) are located in Johnston, 11 (35%) are located in Smithfield, 5 (16%) are located in Providence, 3 (9%) are located in Glocester, and 2 (6%) are located in North Smithfield (**Figure 37**). All of the high ranking crossings had an *Impact Score* of 4 or 5, indicating high potential for flood and transportation-related impacts in the event of crossing failure.

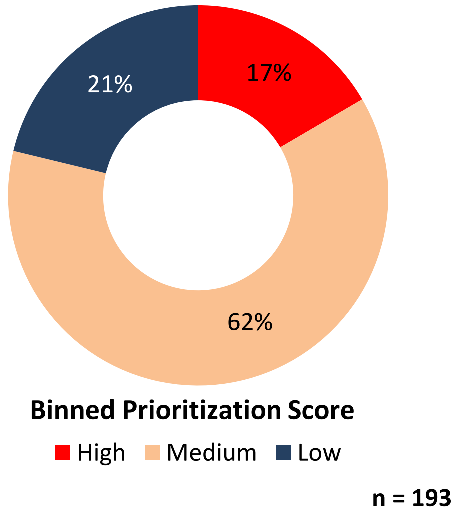


Figure 35. Distribution of Binned Prioritization Scores.

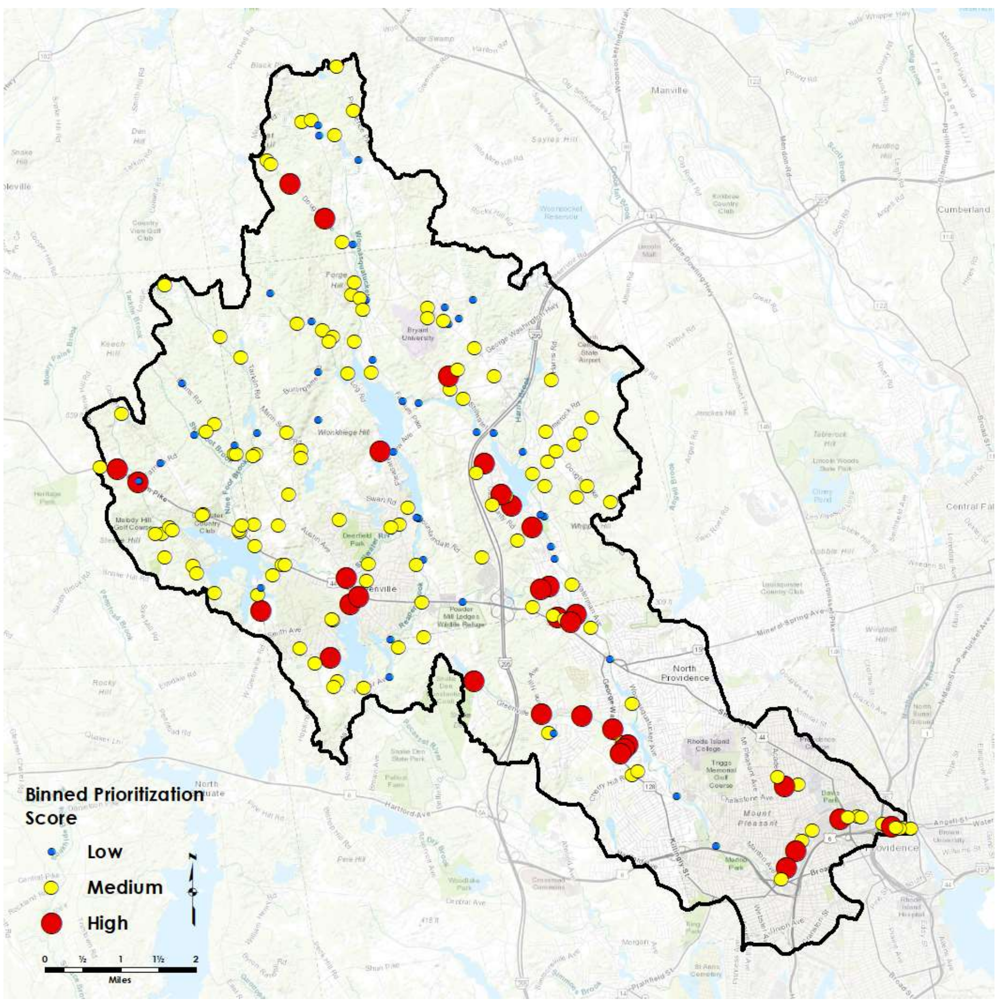


Figure 36. Spatial distribution of Binned Prioritization Scores.

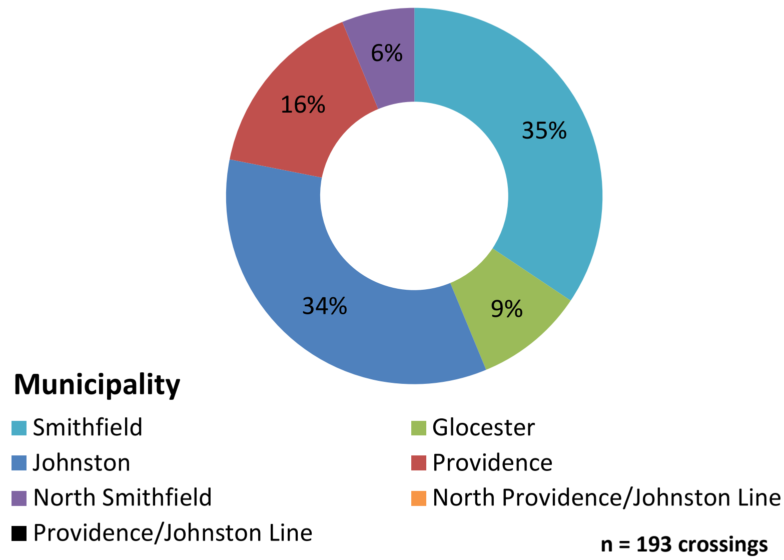


Figure 37. Distribution of high priority crossings by municipality.

The crossings ranked as high priority are listed in **Attachment J**. The twelve crossings that received a *Scaled Crossing Priority Score* greater than 0.75 are highlighted at the top of the table and are considered the highest priority crossings. The results demonstrate the following:

- The high scores for these twelve crossings were largely driven by the *Impact Score,* the *Hydraulic Risk Score*, and the *Climate Change Risk Score.*
- The crossings in the top twelve are all located in Providence, Johnston, or Smithfield, in urbanized areas where crossing failure would have a significant impact. All twelve of the crossings received the highest possible *Impact Score* of 5.
- Ten of the 12 highest priority crossings received the highest possible *Climate Change Risk Score* of 25.
- Nine of the 12 highest priority crossings received a *Hydraulic Risk Score* of 20 or 25.
- All twelve of the top ranking crossings received a *Crossing Risk Score* of 25, indicating that each crossing received the highest possible score of 25 for one of the four Risk Scores (*Hydraulic Risk, Climate Change Risk, Structural Risk or Geomorphic Risk*).
- None of the assessed crossings received a *Geomorphic Risk Score* of 25. Geomorphic risk was not a major factor in the scoring for the high priority crossings.

All twelve of the highest ranking crossings received an *Adjacent Crossing Flag*, indicating that another crossing is within 0.5 mile upstream or downstream of the crossing. Similarly, 177 (92%) of the 193 assessed crossing received an *Adjacent Crossing Flag*. These results highlight the proximity of the crossings to one another within the watershed and the potential for a single crossing failure to impact nearby upstream and/or downstream crossings.

Three of the twelve highest ranking crossings are tidal crossings on the main stem of the Woonasquatucket River (xy41822527143992 on Valley Street, xy41827207141547 on Francis Street and xy41828647142862 on Acorn Street, all in Providence). Crossings xy41822527143992 and xy41828647142862 received a *Binned Hydraulic Capacity Score* of 5, indicating they are undersized for the 10-year peak streamflow. Tidal influence was not considered in the hydraulic capacity analysis. Hydraulic capacity may be significantly reduced, which may also result in reduced aquatic organism passage and increased likelihood of backwater flooding near the crossing location. These three crossings also received an *Unknown Structural Variable Flag*, indicating that one or more of the Level 1 structural variables were marked "Unknown" or more than four Level 2 structural variables were marked "Unknown". This flag indicates there is additional unknown information about these crossing that could place them at higher risk of failure.

Of the twelve top ranking crossings, crossings xy41841257148494 (Waterman Avenue over Assapumpset Brook on in Johnston) and xy41866427149748 (Dean Street over an unnamed tributary to the Woonasquatucket River in Johnston) received the highest *Scaled Crossing Priority Scores* of 0.84. These two crossings also received the highest *AOP Benefit Scores* (score of 9) of the top twelve crossings. The high score for xy41841257148494 is also driven by an *Impact Score* of 5 and *Hydraulic Risk* and *Climate Change Risk Scores* of 25. The high score for xy41866427149748 similarly is also driven by an *Impact Score* of 5 and a *Structural Risk* and *Climate Change Risk Score* of 25.

Crossing xy41884477150737 (located on Farnum Pike in Smithfield over an unknown tributary to the Woonasquatucket River) was initially ranked as medium priority but was ultimately included in the list of high priority crossings based on an *Unknown Structural Variable Flag* and a *Local Knowledge Flag*. Crossing access was limited; the upstream structure and stream could not be found and therefore could not be assessed. Access to the outlet was also limited because the outlet is located between the foundation of an adjacent house and a stone wall, which blocked the view of the structure and physically restricted the field staff from coming in contact with the structure (**Figure 38**). The limited access to this crossing made it difficult to determine the physical characteristics and structural condition of the crossing. However, the location of the outlet within the adjacent house foundation and the assessment of the structural condition of the crossing to the extent possible indicate that the crossing should be considered high priority.

Figure 38. Crossing xy41884477150737 on Farnum Pike in Smithfield over an unnamed tributary to the Woonasquatucket River.

3.2.11 Replacement Recommendations

Handbook Section 14.2 describes considerations for replacement of vulnerable road-stream crossings. Vulnerable crossings should ideally be replaced with crossings that are more flood-resilient and ecologically beneficial. Currently, the state of Rhode Island has not adopted statewide comprehensive stream crossing standards, though implementation of statewide standards has been identified as a priority action in the Rhode Island state Hazard Mitigation Plan. In the meantime, stream crossing standards from other states in New England (Massachusetts, New Hampshire, Vermont, Connecticut and Maine) should be used as guidance for replacing crossings with flood-resilient and ecologically-friendly crossings. A key component to ensuring that crossings are replaced appropriately is ensuring that design storm precipitation amounts are updated to, at a minimum, accurately reflect current precipitation amounts and ideally to consider future projected increases in precipitation consistent with climate change projections.

4 Next Steps

4.1 Phased Implementation Approach

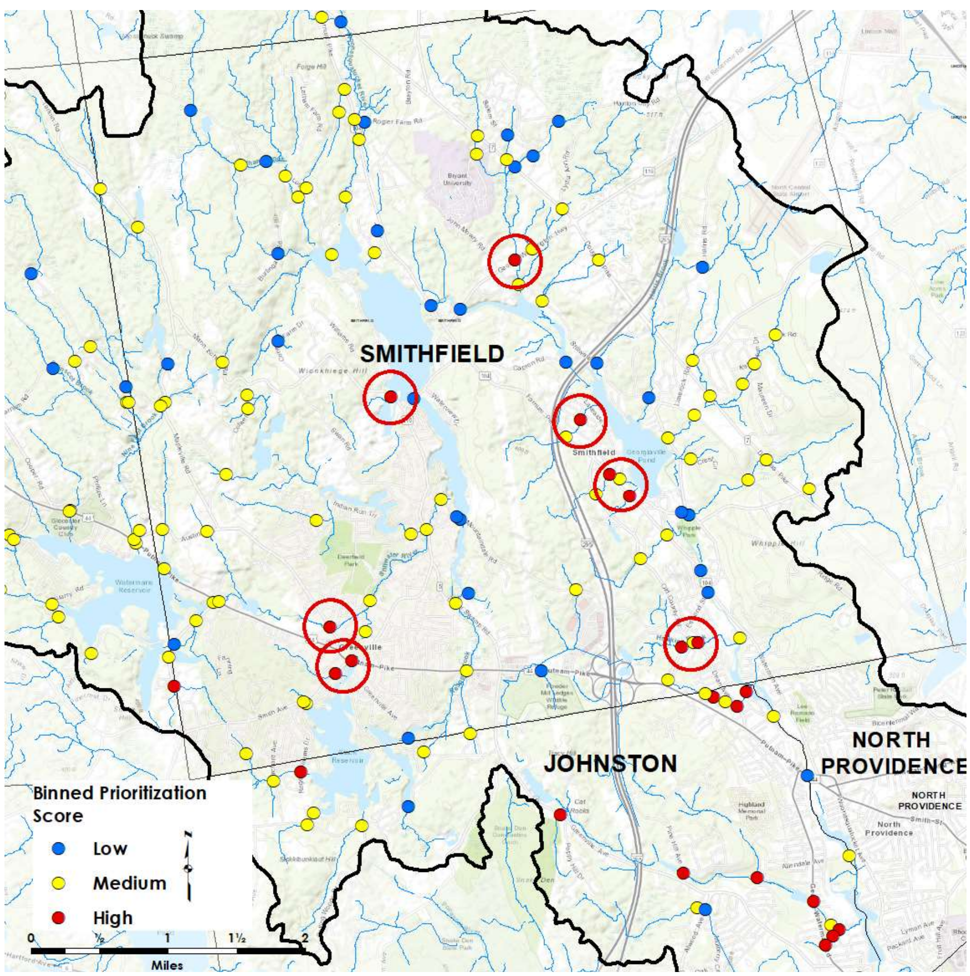
Once the assessment and prioritization process has been completed, several factors should be considered to determine the order in which to implement crossing replacements. These considerations are detailed in **Handbook Section 14: Next Steps – Implementation**. The following general phased approach is recommended for the Woonasquatucket River watershed:

1. Begin by reviewing the high-priority crossings in each municipality with the appropriate municipal staff to determine how priorities in the study align with municipal priorities. Review all vulnerability assessment results and flagging data. Consider including the Woonasquatucket River Watershed Association, other local conservation organizations and potential stakeholders in the review process.
2. If possible, consider beginning in an area where multiple high-priority crossings are located on the same stream reach. Medium and low priority crossings that are upstream or downstream of a high-priority crossing selected for replacement should also be considered for replacement if they are hydraulically undersized, have high geomorphic vulnerability, are in poor structural condition, or limit aquatic passage. Replacing crossings on the same stream reach may require coordination and communication between multiple municipalities.
3. In general, replace downstream crossings first to avoid inadvertently increasing downstream peak flows at outdated or undersized stream crossings. Replacing crossings from downstream to upstream will also provide the quickest benefits to anadromous species (aquatic species migrating upstream from the ocean), where applicable.

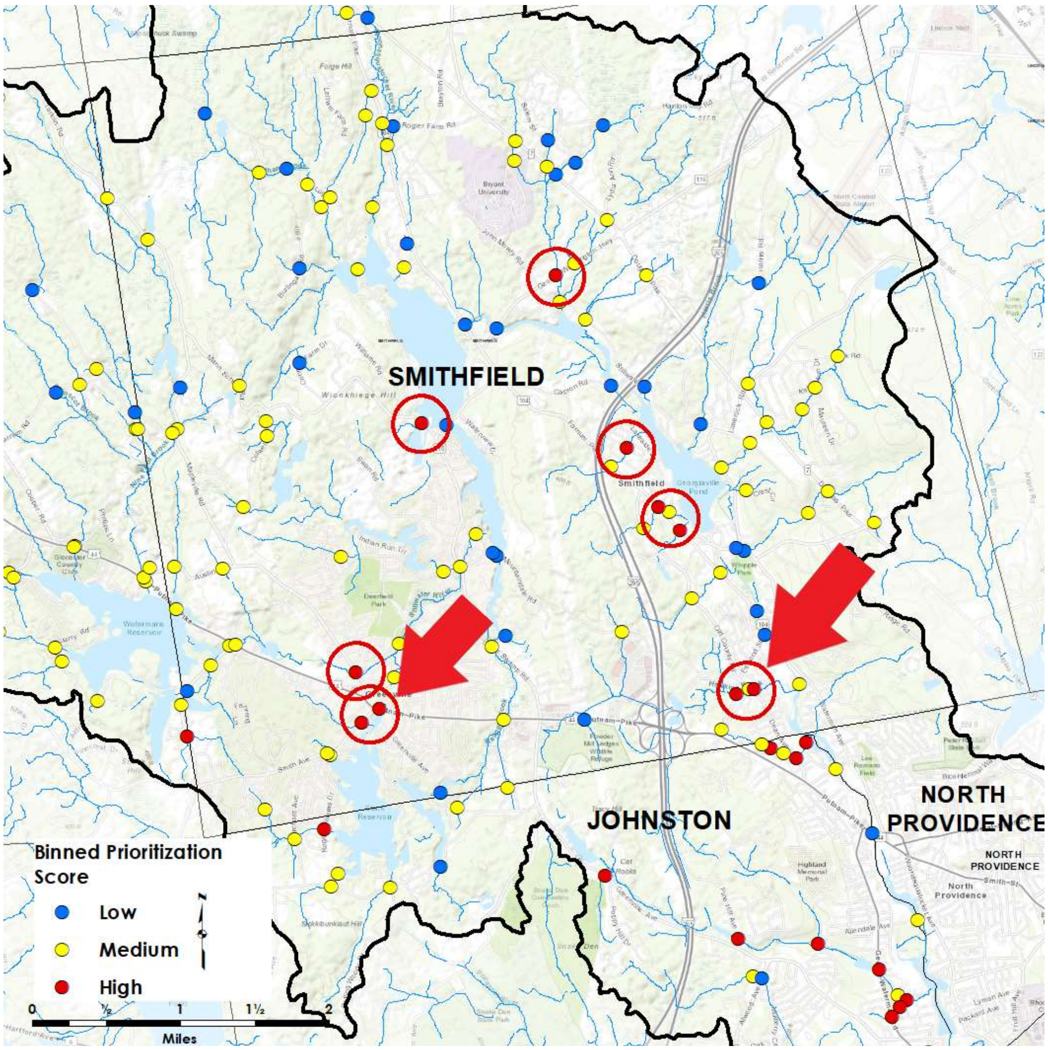
4. Continue this process until all high-priority crossings have been considered and ordered. Multiple additional factors can be considered when deciding the order in which to replace high-priority crossings within a municipality, including:
    - Individual assessment ratings (hydraulic capacity, flooding impact potential, geomorphic vulnerability, structural condition, aquatic organism passage)
    - Crossing flags (existing and future tidal, unknown structural variable, local knowledge, adjacent crossing, wildlife or roadkill)
    - Surrounding infrastructure that may be impacted by replacement or upgrade
    - Estimated costs associated with replacement or upgrade
    - Available funding sources which place emphasis on particular aspects of road-stream crossing replacement, including safety improvements, flood resiliency, and/or ecological restoration

The phased implementation approach is demonstrated below for the Town of Smithfield.

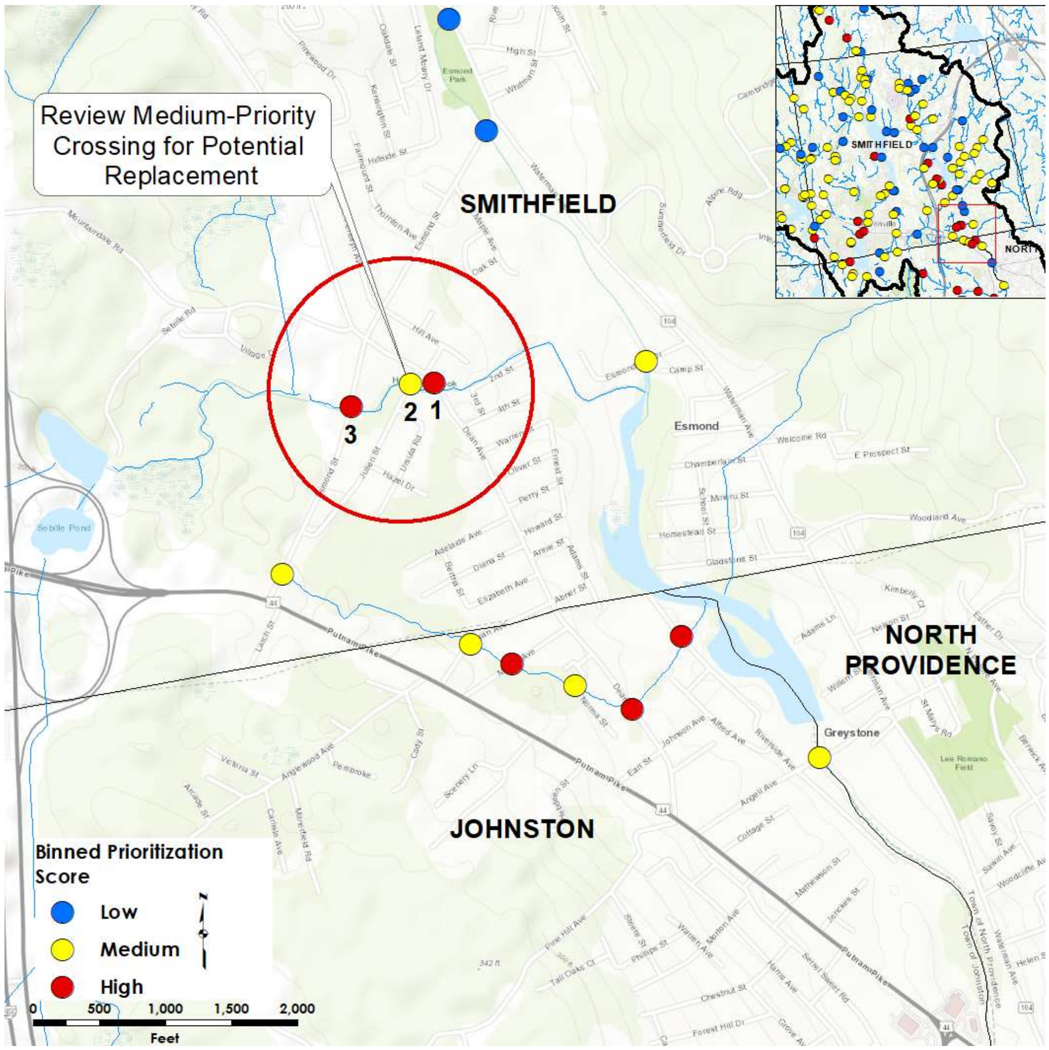
1. Identify high priority crossings in the Town and review the vulnerability assessment results and flagging for each crossing.



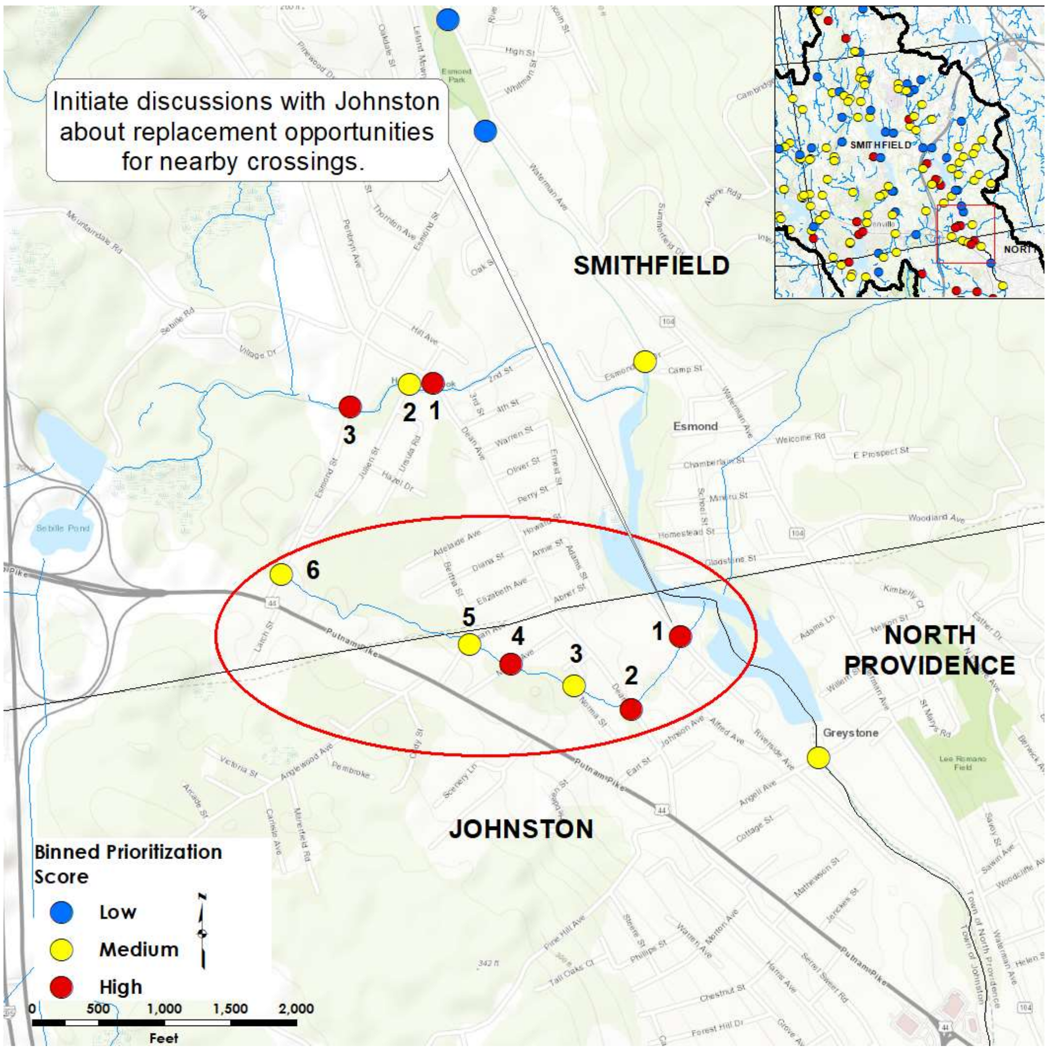
2. Identify locations where multiple high-priority crossings are located on the same branch of a stream:



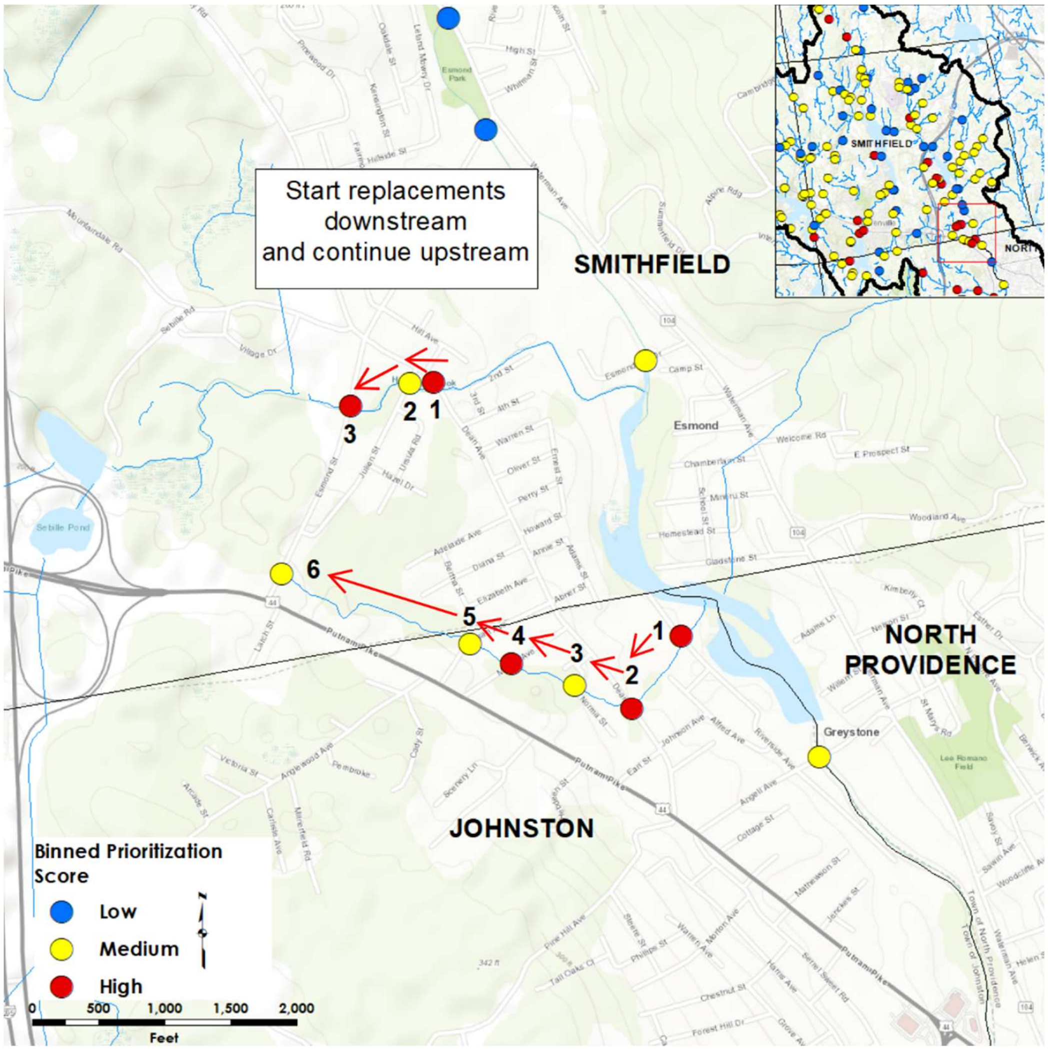
3. Consider additional lower priority crossings on the same stream reach that are upstream or downstream of the crossing that are hydraulically undersized, have high geomorphic vulnerability or are in poor structural condition.



4. Identify nearby crossings in neighboring municipalities that should be considered for replacement and initiate discussions with the town (in this case, Johnston) to pursue joint funding opportunities. Additional lower priority crossings on the same stream reach in the neighboring municipality should again be considered for replacement if they are upstream or downstream of the high priority crossings and are hydraulically undersized, have high geomorphic vulnerability or are in poor structural condition.



5. Prioritize crossing replacements in identified area(s) starting with the furthest downstream structure and working upstream.



6. Continue this process for all high priority crossings in the Town of Smithfield.

4.2 Additional Considerations

The following additional steps should be taken once the order in which to implement crossing replacements has been determined:

1. **Update Municipal Plans**
   - Encourage municipalities to update municipal plans and guidelines, including the municipality's hazard mitigation plan, to include road-stream crossing replacements. Communities with FEMA-approved hazard mitigation plans are eligible to apply for Hazard Mitigation Grant Program funding from FEMA for measures identified in their plans. Each of the communities in the watershed should include the identified road-

stream crossing replacements in their hazard mitigation plan before flooding occurs in order to be eligible to apply.
- Communities should incorporate crossing replacements or upgrades into planned capital improvements such as road rehabilitation or reconstruction to ensure that the crossing replacements are scheduled and budgeted for in the coming years.
- Municipalities should also consider incorporating crossing replacement guidelines into local land use regulations, conservation and open space plans, and design guidelines to better position the community to receive post-disaster assistance from FEMA and a greater share of state funding from various programs.

2. **Coordinate with Potential Project Partners**
   - Coordination between municipalities, watershed organizations, and state and federal agencies can allow for
     - a more effective and comprehensive crossing replacement strategy
     - better leveraging of funding and distribution of the financial burden
     - distribution of responsibilities to stakeholders best suited to fulfill them
     - a smoother permitting process
     - greater public support for the project

3. **Pursue Funding Opportunities**
   - Federal and state transportation funding and traditional municipal funding is currently limited for stream crossing upgrades in Rhode Island. Other potential non-transportation funding opportunities for stream crossing upgrades are provided in **Handbook Section 14.5**.
   - Federal funding opportunities are available from NOAA, the US Army Corps of Engineers, and FEMA programs, among others. State opportunities include Narragansett Bay and Watersheds Restoration Funds and the CRMC Coastal Habitat Restoration Program.

4. **Conduct the Necessary Site Assessments**
   - Site assessments are discussed in **Handbook Section 14: Next Steps - Implementation** and may include geotechnical evaluation, site reconnaissance and wetland delineation, topographic survey, hydrologic and hydraulic study, traffic analysis and structure type selection.

5. **Develop Concept Designs**
   - Concept designs should be generated for crossing replacements using the data gathered during the initial road-stream crossing assessment and the site assessments, and stream crossing standards that promote flood resiliency and ecological benefits.

6. **Obtain Required Permits and Approvals**
   - Permitting requirements specific to Rhode Island are detailed in **Handbook Section 14.3**. Typically a state permit from the Rhode Island Department of Environmental Management (RIDEM) Office of Water Resources or the Coastal Resources

Management Council (CRMC) is required. The necessary federal and state permits and applicable permitting programs will vary for each site based on site location and conditions.

7. **Initiate Crossing Replacement or Upgrade**
   - Update concept designs as required, initiate construction bidding, and ultimately begin crossing upgrade or replacement.

8. **Implement an Ongoing Inspection and Maintenance Program**
   - Regularly inspecting and maintaining road-stream crossings is essential to ensuring their continued proper function. Maintenance may involve clearing blockages and repairing minor defects.

9. **Re-evaluate Crossing Prioritization Based on Updates to the Handbook**
   - As new data sources become available and new information is generated regarding road-stream crossing assessment practices, the assessment and prioritization methodology in the Handbook may be updated. Potential updates are discussed in **Handbook Section 14.7**. Municipalities may wish to update their prioritization list in the future as high-priority crossings are replaced and the methodology in the Handbook is updated.

4.3 Methodology Refinements

In completing this Pilot Study, areas of potential future refinement of the road-stream crossing assessment methodology were identified. These possible refinements are discussed in **Handbook Section 1**.

5 References

Bent, G.C.; Steeves, P.A.; Waite A.M. (2014) Equations for estimating streamflow in Rhode Island: US Geological Survey Scientific Investigations Technical Report 2014-5010.

Rhode Island Statewide Climate Resilience Action Strategy (2018). Accessed at http://climatechange.ri.gov/documents/resilientrhody18.pdf.

Zarriello, P.J.; Ahearn, E.A.; Levin, S.B. (2012) Magnitude of flood flows for selected annual exceedance probabilities in Rhode Island through 2010: US Geological Survey Scientific Investigation Technical Report 2012-5109.

Attachment A

Field Data Summary

Selected Crossing Field Data

Crossing Code	Road Name	Stream Name	Municipality	Crossing Type	Alignment	Bankfull Width	Bankfull Width Confidence	Constriction	Sig. Break in Valley Slope	Tailwater Scour Pool	Sediment Deposition Location	Sediment elevation >1/2 bank height	Bank Erosion	Road-Killed Wildlife	Observed Wildlife	Tidal Site
xy41817227144364	Manton Ave	Woonasquatucket River	Providence	Bridge	Channelized Straight	<Null>	Low / Estimated	Spans Full Channel and Banks	No	None	None	No	None	No	No	No
xy41819437144226	Delaine St	Woonasquatucket River	Providence	Bridge	Naturally Straight	48.00	Low / Estimated	Spans Full Channel and Banks	No	None	None	No	None	No	No	No
xy41822527143992	Valley St	Woonasquatucket River	Providence	Bridge	Channelized Straight	<Null>	Low / Estimated	Spans Full Channel and Banks	No	None	None	No	None	No	No	Yes
xy41823467146025	Glenbridge Ave	Woonasquatucket River	Providence	Bridge Adequate	Naturally Straight	45.00	Low / Estimated	Spans Full Channel and Banks	No	None	None	No	High	No	Yes	No
xy41824557143824	Atwells Ave	Woonasquatucket River	Providence	Bridge	Channelized Straight	<Null>	Low / Estimated	Spans Full Channel and Banks	No	None	None	No	None	No	No	Yes
xy41826547143567	Eagle St	Woonasquatucket River	Providence	Bridge	Channelized Straight	<Null>	Low / Estimated	Spans Full Channel and Banks	No	None	None	No	None	No	No	Yes
xy41826817141330	N/A: Footbridge	Woonasquatucket River	Providence	Bridge	Channelized Straight	<Null>	Low / Estimated	Moderate	No	None	None	No	None	No	No	Yes
xy41826927141044	Steeple St	Woonasquatucket River	Providence	Bridge	Channelized Straight	<Null>	Low / Estimated	Moderate	No	None	None	No	None	No	No	Yes
xy41827107141439	N/A: Footbridge	Woonasquatucket River	Providence	Bridge	Channelized Straight	<Null>	Low / Estimated	Moderate	No	None	None	No	None	No	No	Yes
xy41827117141226	Exchange St	Woonasquatucket River	Providence	Bridge	Channelized Straight	<Null>	Low / Estimated	Moderate	No	None	None	No	None	No	No	Yes
xy41827207141547	Francis St	Woonasquatucket River	Providence	Bridge	Channelized Straight	<Null>	Low / Estimated	Moderate	No	None	None	No	None	No	No	Yes
xy41827747141774	Park St	Woonasquatucket River	Providence	Bridge	Channelized Straight	<Null>	Low / Estimated	Moderate	No	None	None	No	None	No	No	Yes
xy41828647142862	Acorn St	Woonasquatucket River	Providence	Bridge	Channelized Straight	<Null>	Low / Estimated	Spans Full Channel and Banks	No	None	None	No	None	No	No	Yes
xy41829017142325	Promenade St	Woonasquatucket River	Providence	Bridge	Naturally Straight	88.00	Low / Estimated	Spans Full Channel and Banks	No	None	None	No	High	No	No	Yes
xy41829077142660	Dean St	Woonasquatucket River	Providence	Bridge	Channelized Straight	86.00	Low / Estimated	Spans Full Channel and Banks	No	None	None	No	Low	No	Yes	Yes
xy41829207142410	Promenade St	Woonasquatucket River	Providence	Bridge	Channelized Straight	87.00	Low / Estimated	Spans Full Channel and Banks	No	None	None	No	High	No	No	Yes
xy41832947147052	Manson Ave	Dyerville Pond	Providence/Johnston Line	Bridge	Channelized Straight	72.33	Low / Estimated	Moderate	No	None	None	No	None	No	No	No
xy41834977144282	Pleasant Valley Parkway	Unt to Woonasquatucket River	Providence	Culvert	Mild Bend	10.67	High	Moderate	No	None	Upstream	No	Low	No	No	No
xy41835427143915	Pleasant Valley Parkway	Unt to Woonasquatucket River	Providence	Culvert	Channelized Straight	<Null>	Low / Estimated	Spans Only Bankfull / Active Channel	No	None	Upstream, Within Structure	No	None	No	No	No
xy41836747144463	Pleasant Valley Parkway	Unt to Woonasquatucket River	Providence	Partially Inaccessible	Channelized Straight	6.67	Low / Estimated	Moderate	No	Small	Within Structure, Downstream	No	Low	No	No	No
xy41837147148177	Waterman Ave	Unt to Woonasquatucket River	Johnston	Culvert	Mild Bend	<Null>	Low / Estimated	Severe	Yes	None	None	No	None	No	No	No
xy41837797148021	Di Sarro Ave	Unt to Woonasquatucket River	Johnston	Culvert	Naturally Straight	40.00	Low / Estimated	Severe	No	Large	None	No	High	No	No	No
xy41841257148494	Waterman Ave	Unt to Assapumpset Brook	Johnston	Partially Inaccessible	Channelized Straight	15.00	Low / Estimated	Severe	No	<Null>	Upstream	Yes	None	No	Yes	No
xy41842197148400	Diaz St	Unt to Assapumpset Brook	Johnston	Culvert	Mild Bend	20.00	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41842937148299	Armento St	Assapumpset Brook	Johnston	Partially Inaccessible	Sharp Bend	20.00	Low / Estimated	Severe	No	None	Downstream	No	None	No	No	No
xy41843377148416	Diaz St	Assapumpset Brook	Johnston	Multiple Culverts	Naturally Straight	8.00	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41845017150193	Atwood Ave	Unt to Assapumpset Brook	Johnston	Culvert	Naturally Straight	10.00	Low / Estimated	Severe	No	None	Within Structure	No	None	No	Yes	No
xy41845257150309	Carpenter Drive	Unt to Assapumpset Brook	Johnston	Culvert	Naturally Straight	15.00	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41845877148670	George Waterman St	Assapumpset Brook	Johnston	Partially Inaccessible	Channelized Straight	20.00	Low / Estimated	Severe	No	<Null>	None	No	High	No	No	No
xy41848417149462	Clemence Ln	Assapumpset Brook	Johnston	Multiple Culverts	Mild Bend	10.00	Low / Estimated	Severe	No	None	None	<Null>	Low	No	No	No
xy41848877150503	Pine Hill Ave	Assapumpset Brook	Johnston	Culvert	Naturally Straight	15.00	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41850727148167	Allendale Ave	Woonasquatucket River	North Providence/Johnston Line	Bridge	Naturally Straight	47.70	Low / Estimated	Spans Full Channel and Banks	No	None	None	No	High	No	No	No
xy41853897155040	Winsor Rd	Unt to Slack Reservoir	Johnston	Partially Inaccessible	Naturally Straight	19.60	High	Severe	No	None	None	No	None	No	No	No
xy41853977155807	Winsor Rd	Unt to Slack Reservoir	Johnston	Culvert	Sharp Bend	<Null>	Low / Estimated	Moderate	No	None	None	No	None	No	No	No
xy41855037152232	Greenville Ave	Unt to Assapumpset Brook	Johnston	Partially Inaccessible	Channelized Straight	10.00	Low / Estimated	Severe	No	<Null>	None	No	None	No	No	No
xy41855187155720	Barden Ln	Unt to Slack Reservoir	Johnston	Culvert	Naturally Straight	4.00	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41855907154386	Winsor Rd	Unt to Slack Reservoir	Johnston	Culvert	Mild Bend	16.50	High	Severe	No	None	Upstream	No	None	No	Yes	No
xy41858547156285	Orchard Ave	Unt to Slack Reservoir	Johnston	Culvert	Channelized Straight	<Null>	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41859167148748	Putnam Pike	Woonasquatucket River	North Providence/Johnston Line	Bridge	Naturally Straight	<Null>	Low / Estimated	Moderate	No	None	None	No	Low	No	No	No
xy41859507155898	Roger Williams Drive	Unt to Slack Reservoir	Johnston	Culvert	Mild Bend	30.00	Low / Estimated	Severe	No	None	None	No	Low	No	Yes	No
xy41861407156668	Sheffield Rd	Unt to Slack Reservoir	Smithfield	Multiple Culverts	Channelized Straight	15.00	Low / Estimated	Severe	No	Small	Within Structure, Downstream	No	None	No	No	No
xy41861587154159	Greenville Ave	Unt to Slack Reservoir	Johnston	Culvert	Naturally Straight	20.00	Low / Estimated	Severe	No	None	Upstream	Yes	None	No	No	No
xy41863027154374	Greenville Ave	Unt to Slack Reservoir	Smithfield	Multiple Culverts	Naturally Straight	<Null>	Low / Estimated	Moderate	No	None	None	No	None	No	No	No
xy41863507153509	Finne Rd	Unt to Slack Reservoir	Johnston	Culvert	Mild Bend	15.00	Low / Estimated	Moderate	No	None	None	No	None	No	Yes	No
xy41865407149229	Angell Ave	Woonasquatucket River	North Providence/Johnston Line	Bridge	Naturally Straight	<Null>	Low / Estimated	Moderate	No	None	None	No	High	No	No	No
xy41866427149748	Dean St	Unt to Woonasquatucket River	Johnston	Culvert	Sharp Bend	10.00	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41866737155823	Smith Ave Extension	Unt to Slack Reservoir	Smithfield	Culvert	Mild Bend	11.00	High	Severe	No	None	None	No	None	No	No	No
xy41866907149909	Kenton Drive	Unt to Woonasquatucket River	Johnston	Culvert	Channelized Straight	<Null>	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41866937155857	Smith Ave	Unt to Slack Reservoir	Smithfield	Partially Inaccessible	Naturally Straight	9.67	Low / Estimated	Severe	No	None	None	No	None	No	Yes	No
xy41867357150081	Mowry Ave	Unt to Woonasquatucket	Johnston	Multiple Culverts	Channelized Straight	15.00	Low / Estimated	Severe	No	Small	Downstream	No	Low	No	Yes	No
xy41867767150198	Susan Drive	Unt to Woonasquatucket River	Johnston	Partially Inaccessible	Naturally Straight	15.00	Low / Estimated	Severe	No	<Null>	None	No	None	No	No	No
xy41867937149613	Riverside Ave	Unt to Woonasquatucket River	Johnston	Multiple Culverts	Channelized Straight	10.00	Low / Estimated	Severe	No	None	Upstream	No	High	No	No	No
xy41868517157685	West Greenville Rd	Unt	Glocester	Culvert	Naturally Straight	<Null>	Low / Estimated	Severe	No	None	None	No	None	Yes	No	No
xy41869227150721	Edmond St	Unt to Woonasquatucket River	Smithfield	Culvert	Naturally Straight	<Null>	Low / Estimated	Severe	No	Small	Within Structure	No	None	No	Yes	No
xy41869837155412	Smith Ave	Unt to Slack Reservoir	Smithfield	Culvert	Sharp Bend	17.00	Low / Estimated	Severe	No	None	Downstream	Yes	None	No	No	No
xy41870167152512	Putnam Pike	Unt to Hawkins Brook	Smithfield	Culvert	Naturally Straight	<Null>	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41870207153556	Putnam Pike	Reaper Brook	Smithfield	Culvert	Naturally Straight	<Null>	Low / Estimated	Severe	No	Small	None	No	None	No	No	No
xy41871207155179	Putnam Pike	Slack Reservoir Outflow	Smithfield	Culvert	Channelized Straight	30.00	Low / Estimated	Severe	No	Small	None	No	None	No	No	No
xy41871637157756	West Greenville Rd	Waterman Reservoir	Glocester	Bridge	Channelized Straight	<Null>	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41871997158854	Aldrich Rd	Unt to Waterman Reservoir	Glocester	Culvert	Mild Bend	10.73	High	Severe	No	None	None	No	Low	No	No	No
xy41872697150528	Esmond St	Hawkins Brook	Smithfield	Multiple Culverts	Naturally Straight	25.00	Low / Estimated	Severe	No	Small	None	No	None	Yes	No	No
xy41872937157686	West Greenville Rd	Unt	Smithfield	Culvert	Mild Bend	7.50	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41873167150365	Julien St	Hawkins Brook	Smithfield	Culvert	Channelized Straight	<Null>	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41873187150300	Dean St	Hawkins Brook	Smithfield	Multiple Culverts	Sharp Bend	30.00	Low / Estimated	Severe	No	None	Upstream	No	Low	No	No	No
xy41873637149711	Edmond Mill Drive	Woonasquatucket River	Smithfield	Bridge	Naturally Straight	<Null>	Low / Estimated	Moderate	No	None	None	No	Low	No	No	No
xy41874287154980	Pleasant View Circle	Unt to Stillwater River	Smithfield	Partially Inaccessible	Naturally Straight	18.00	Low / Estimated	Severe	Yes	<Null>	Within Structure	No	None	No	Yes	No
xy41874767155492	Austin Ave	Stillwater River	Smithfield	Multiple Culverts	Sharp Bend	<Null>	Low / Estimated	Severe	No	Small	None	No	None	No	No	No
xy41875437157379	West Greenville Ave	Unt to Waterman Reservoir	Smithfield	Bridge	Sharp Bend	13.83	High	Severe	No	None	None	No	Low	No	No	No
xy41875777159319	Old Quarry Rd	Unt to Waterman Reservoir	Glocester	Culvert	Naturally Straight	7.80	High	Moderate	No	Large	None	No	Low	No	No	No
xy41877147159409	Old Quarry Rd	Unt to Waterman Reservoir	Glocester	Culvert	Mild Bend	8.97	High	Severe	No	Small	Upstream	Yes	High	No	No	No
xy41877287153708	Cedar Swamp Road	Reaper Brook	Smithfield	Culvert	Sharp Bend	17.00	Low/Estimated	Severe	No	None	None	No	None	No	No	No

Selected Crossing Field Data

Crossing Code	Road Name	Stream Name	Municipality	Crossing Type	Alignment	Bankfull Width	Bankfull Width Confidence	Constriction	Sig. Break in Valley Slope	Tailwater Scour Pool	Sediment Deposition Location	Sediment elevation >1/2 bank height	Bank Erosion	Road-Killed Wildlife	Observed Wildlife	Tidal Site
xy41877397157132	West Greenville Rd	Stillwater River	Smithfield	Bridge	Channelized Straight	<Null>	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41877427157059	Putnam Pike	Stillwater Brook	Smithfield	Bridge	Sharp Bend	25.00	Low / Estimated	Spans Only Bankfull / Active Channel	No	Small	None	No	Low	Yes	No	No
xy41877557154924	Deerfield Drive	Stillwater River	Smithfield	Multiple Culverts	Naturally Straight	36.00	High	Severe	No	Small	None	No	Low	No	No	No
xy41878177153571	Walter Carey Road	Unt to Mountaindale Reservoir	Smithfield	Culvert	Sharp Bend	6.50	Low/Estimated	Severe	No	None	None	No	None	No	No	No
xy41878417150154	Esmond St	Woonasquatucket River	Smithfield	Bridge	Naturally Straight	<Null>	Low / Estimated	Moderate	No	None	None	No	None	No	No	No
xy41878707160132	Sawmill Rd	Unt to Waterman Reservoir	Glocester	Culvert	Naturally Straight	9.10	High	Severe	No	None	None	No	Low	No	No	No
xy41878737152022	Mountaindale Rd	Unt to Hawkins Brook	Smithfield	Culvert	Naturally Straight	10.75	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41880727150256	Farnum Pike	Woonasquatucket River	Smithfield	Bridge	Naturally Straight	<Null>	Low / Estimated	Spans Only Bankfull / Active Channel	No	None	None	No	None	No	No	No
xy41880887157821	Putnam Pike	Waterman Reservoir	Smithfield	Culvert	Naturally Straight	<Null>	Low / Estimated	Severe	No	None	None	No	None	No	Yes	No
xy41881987151110	Old Country Rd	Unt to Woonasquatucket River	Smithfield	Culvert	Naturally Straight	20.00	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41883167160369	Melody Hill Ln	Unt to Waterman Reservoir	Glocester	Multiple Culverts	Sharp Bend	6.10	High	Severe	No	None	Upstream	Yes	High	No	No	No
xy41883307160203	Sawmill Rd	Unt to Waterman Reservoir	Glocester	Culvert	Naturally Straight	8.00	Low / Estimated	Severe	No	None	Upstream	No	None	No	No	No
xy41883627158219	Putnam Pike	Nine Foot Brook	Glocester	Culvert	Sharp Bend	20.00	Low / Estimated	Severe	No	Large	None	No	None	No	No	No
xy41883977158247	Austin Ave	Nine Foot Brook	Glocester	Culvert	Channelized Straight	25.00	Low / Estimated	Severe	No	Small	None	No	None	No	Yes	No
xy41883977159943	Waterman Lake Drive	Unt to Cutler Brook	Glocester	Multiple Culverts	Mild Bend	4.33	High	Moderate	No	None	None	No	None	No	No	No
xy41884477150737	Farnum Pike	Unt to Woonasquatucket River	Smithfield	Partially Inaccessible	Channelized Straight	6.67	Low / Estimated	Moderate	Unsure	None	None	No	Low	No	No	No
xy41884487160015	Sawmill Rd	Cutler Brook	Glocester	Culvert	Mild Bend	21.77	High	Severe	No	Small	None	No	High	No	Yes	No
xy41884547154339	Indian Run Rd	Unt to Stillwater River	Smithfield	Multiple Culverts	Naturally Straight	40.00	Low / Estimated	Severe	No	None	Downstream, Upstream.	No	None	No	No	No
xy41884807157218	Austin Ave	Unt to Waterman Reservoir	Smithfield	Partially Inaccessible	Naturally Straight	<Null>	Low / Estimated	Severe	No	None	None	No	None	No	Yes	No
xy41884937158168	Stone Bridge Rd	Unt to Nine Foot Brook	Glocester	Partially Inaccessible	Naturally Straight	<Null>	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41885067154130	Pleasant View Ave	Stillwater River	Smithfield	Bridge	Sharp Bend	45.00	Low / Estimated	Moderate	No	None	Within Structure	No	None	No	No	No
xy41885087157849	Austin Avenue	Unt to Waterman Reservoir	Smithfield	Partially Inaccessible	Mild Bend	8.00	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41885967155678	Baldwin Circle	Unt to Stillwater River	Smithfield	Partially Inaccessible	Sharp Bend	10.00	Low / Estimated	Severe	Unsure	None	None	No	High	No	No	No
xy41886157153645	Mountaindale Road	Reaper Brook	Smithfield	Bridge	Mild Bend	30.00	Low / Estimated	Spans Only Bankfull / Active Channel	No	None	None	No	Low	No	No	No
xy41886477153705	Mountaindale Road	Unnamed Wetland adjacent to Reaper Brook	Smithfield	Culvert	Naturally Straight	<Null>	Low / Estimated	Moderate	No	None	Downstream	No	None	No	No	No
xy41886617150419	Fenwood Ave	Unt to Woonasquatucket River	Smithfield	Multiple Culverts	Naturally Straight	11.00	High	Moderate	No	None	None	No	None	No	No	No
xy41886847150523	Whipple Ave	Woonasquatucket River	Smithfield	Bridge	Naturally Straight	<Null>	Low / Estimated	Spans Only Bankfull / Active Channel	No	None	None	No	None	No	No	No
xy41886917159166	Putnam Pike	Unt to Waterman Reservoir	Glocester	Culvert	Sharp Bend	10.00	High	Severe	No	None	None	No	None	No	No	No
xy41887077159144	Valley Rd	Unt to Waterman Reservoir	Glocester	Culvert	Channelized Straight	15.00	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41888247153923	Mountaindale Road	Stillwater River	Smithfield	Multiple Culverts	Channelized Straight	23.17	High	Moderate	No	Small	None	No	None	No	No	No
xy41888657151262	Farnum Pike	Unt to Georgiaville Pond	Smithfield	Multiple Culverts	Naturally Straight	15.00	High	Severe	No	Large	Within Structure, Upstream, Downstream	No	None	No	No	No
xy41888837151740	Old County Rd	Unt to Georgiaville Pond	Smithfield	Culvert	Sharp Bend	10.00	High	Severe	No	None	Within Structure, Downstream	No	None	No	No	No
xy41889357148731	Whipple Rd	Unt to Woonasquatucket River	Smithfield	Culvert	Naturally Straight	11.33	High	Severe	No	None	None	No	None	No	Yes	No
xy41890377149584	Ridge Rd	Unt to Woonasquatucket River	Smithfield	Culvert	Naturally Straight	23.00	Low / Estimated	Severe	No	Small	None	No	Low	No	No	No
xy41890427151403	Sweet Rd	Unt to Georgiaville Pond	Smithfield	Multiple Culverts	Naturally Straight	9.00	High	Severe	No	None	Downstream	No	None	No	No	No
xy41890897156959	Colwell Rd	Unt to Upper Sprague Reservoir	Smithfield	Culvert	Sharp Bend	<Null>	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41890917151543	Farnum Pike	Unt to Georgiaville Pond	Smithfield	Partially Inaccessible	Naturally Straight	7.50	High	Severe	No	<Null>	None	No	None	No	No	No
xy41892467149331	Douglas Pike	Unt to Woonasquatucket River	Smithfield	Multiple Culverts	Mild Bend	<Null>	Low / Estimated	Severe	No	None	Upstream, Within Structure, Downstream	No	Low	No	No	No
xy41892547150396	Crest Drive	Unt to Woonasquatucket River	Smithfield	Multiple Culverts	Naturally Straight	9.33	High	Spans Full Channel and Banks	Yes	None	None	No	None	No	No	No
xy41893077160835	Route 44	Cutler Brook	Glocester	Culvert	Naturally Straight	8.00	Low / Estimated	Moderate	Yes	None	None	No	Low	No	No	No
xy41893317160808	Farnum Road	Cutler Brook	Glocester	Culvert	Naturally Straight	7.00	Low / Estimated	Moderate	No	None	None	No	None	No	No	No
xy41894747150725	Stillwater Rd	Unt to Georgiaville Pond	Smithfield	Multiple Culverts	Naturally Straight	20.50	High	Severe	No	Large	Upstream	No	Low	No	No	No
xy41894887152164	Farnum Pike	Unt to Georgiaville Pond	Smithfield	Partially Inaccessible	Naturally Straight	20.00	High	Severe	No	<Null>	None	No	None	No	No	No
xy41895577161365	Route 44 Putnam Pike	Unt to Cutler Brook	Glocester	Culvert	Naturally Straight	<Null>	Low / Estimated	Severe	No	Small	None	No	None	No	No	No
xy41896047161805	Route 44	Unti to Cutler Brook	Glocester	Culvert	Naturally Straight	<Null>	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41896637160262	Farnum Rd	Unt to Waterman Reservoir	Glocester	Culvert	Sharp Bend	5.17	High	Severe	No	None	None	No	None	No	No	No
xy41896697151958	Old county Rd/Lakeside Drive	Unt to Georgiaville Pond	Smithfield	Culvert	Naturally Straight	12.67	High	Severe	No	Large	None	No	High	No	No	No
xy41897187150342	Ridge Rd	Unt to Georgiaville Pond	Smithfield	Culvert	Naturally Straight	14.33	High	Severe	No	Large	None	No	Low	No	No	No
xy41897827156647	Colwell Rd	Unt to Upper Sprague Reservoir	Smithfield	Partially Inaccessible	Naturally Straight	8.00	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41898117157880	Evan's Rd	Nine Foot Brook	Smithfield	Culvert	Naturally Straight	20.00	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41898457158358	Burlingame Ln	Unt to Nine Foot Brook	Glocester	Culvert	Naturally Straight	11.00	Low / Estimated	Severe	No	None	Within Structure	No	None	No	No	No
xy41898477158323	Burlingame Ln	Unt to Nine Foot Brook	Glocester	Culvert	Naturally Straight	8.00	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41898517157816	Tarkiln Rd	Unt to Nine Foot Brook	Smithfield	Culvert	Naturally Straight	9.00	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41898907154304	Pleasantview Ave	Woonasquatucket Reservoir	Smithfield	Bridge	Naturally Straight	<Null>	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41898957150991	Stillwater Rd	Harris Brook	Smithfield	Bridge	Naturally Straight	17.00	Low / Estimated	Moderate	No	Small	None	No	High	No	No	No
xy41899117154630	Log Rd	Woonasquatucket Reservoir	Smithfield	Culvert	Naturally Straight	<Null>	Low / Estimated	Severe	No	None	None	No	None	No	Yes	No
xy41899147150128	Douglas Pike	Unt to Georgiaville Pond	Smithfield	Culvert	Sharp Bend	17.00	High	Severe	No	Small	Downstream, Upstream	No	High	No	No	No
xy41899277156654	Colwell Rd	Unt to Upper Sprague Reservoir	Smithfield	Culvert	Naturally Straight	<Null>	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41900117158371	Evans Rd	Unt to Shinscot Brook	Glocester	Culvert	Mild Bend	12.77	High	Severe	No	None	None	No	None	No	No	No
xy41900437149662	Catherine Rd	Unt to West River	Smithfield	Partially Inaccessible	Naturally Straight	12.33	Low / Estimated	Severe	No	Large	None	No	High	No	No	No
xy41902037159401	Farnum road	Shinscot Brook	Glocester	Culvert	Sharp Bend	10.00	High	Severe	No	Small	None	No	None	No	No	No
xy41902517157773	Tarkiln Rd	Unt to Nine Foot Brook	Smithfield	Culvert	Naturally Straight	6.00	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41902577149498	Maureen Drive	Unt to West River	Smithfield	Partially Inaccessible	Naturally Straight	11.33	High	Severe	No	Large	None	No	High	No	No	No
xy41902587151720	Stillwater Rd	Unt to Georgiaville Pond	Smithfield	Multiple Culverts	Naturally Straight	8.33	Low / Estimated	Spans Only Bankfull / Active Channel	No	None	Downstream	No	None	No	No	No
xy41902697157007	Mann School Rd	Unt to Upper Sprague Reservoir	Smithfield	Culvert	Naturally Straight	4.30	High	Moderate	No	None	None	No	None	No	No	No
xy41902757152161	Capron Rd	Capron Pond	Smithfield	Bridge	Naturally Straight	35.00	Low / Estimated	Moderate	No	None	None	No	None	No	No	No
xy41902757159093	Farnum Rd	Unt	Glocester	Culvert	Naturally Straight	12.00	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41902877150377	Limerock Rd	Unt to Harris Brook	Smithfield	Multiple Culverts	Mild Bend	6.43	High	Severe	No	None	Within Structure, Downstream, Upstream	No	High	No	No	No
xy41904317158874	Evans road	Unt	Glocester	No Upstream Channel	Naturally Straight	<Null>	Low / Estimated	<Null>	No	None	None	No	None	No	No	No
xy41904937156221	Connors Farm Drive	Unt	Smithfield	Culvert	Naturally Straight	4.00	Low / Estimated	Spans Only Bankfull / Active Channel	No	None	None	No	None	No	No	No
xy41905587149206	Clark Rd	Unt to West River	Smithfield	Multiple Culverts	Naturally Straight	5.83	High	Moderate	No	Small	Upstream	No	High	No	No	No

Selected Crossing Field Data

Crossing Code	Road Name	Stream Name	Municipality	Crossing Type	Alignment	Bankfull Width	Bankfull Width Confidence	Constriction	Sig. Break in Valley Slope	Tailwater Scour Pool	Sediment Deposition Location	Sediment elevation >1/2 bank height	Bank Erosion	Road-Killed Wildlife	Observed Wildlife	Tidal Site
xy41906217161244	Cooper Ave	Cutler Brook	Glocester	Culvert	Sharp Bend	15.00	Low / Estimated	Severe	No	None	None	No	High	No	No	No
xy41908317153647	George Washington Highway	Woonasquatucket River	Smithfield	Bridge Adequate	Naturally Straight	<Null>	Low / Estimated	Spans Full Channel and Banks	No	None	None	<Null>	None	No	No	No
xy41908677154068	Farnum Pike	Woonasquatucket River	Smithfield	Bridge	Mild Bend	100.00	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41909167152497	Stillwater Rd	Unt to Stillwater Pond	Smithfield	Culvert	Naturally Straight	17.43	High	Severe	No	None	Downstream	No	Low	No	No	No
xy41910887152828	Stillwater Rd	Unt to Stillwater Pond	Smithfield	Multiple Culverts	Mild Bend	20.00	High	Severe	No	Small	None	No	High	No	No	No
xy41912007159704	Evans Rd	Unamed to Shinscot Brook	Glocester	Culvert	Naturally Straight	<Null>	Low / Estimated	Moderate	No	None	None	No	None	No	Yes	No
xy41912687150232	Harris Rd	Unt to Harris Brook	Smithfield	Multiple Culverts	Mild Bend	17.00	High	Moderate	No	Small	Upstream	No	High	No	No	No
xy41913457152883	George Washington Highway	Unt to Stillwater Pond	Smithfield	Multiple Culverts	Naturally Straight	17.67	High	Severe	No	Large	None	No	High	No	No	No
xy41913477151701	Douglas Pike	Unt to Stillwater Pond	Smithfield	Culvert	Naturally Straight	18.67	High	Severe	No	None	None	No	None	No	No	No
xy41914027155460	Log Rd	Woonasquatucket Reservoir	Smithfield	Culvert	Naturally Straight	<Null>	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41914137156217	Burlingame Rd	Unt to Woonasquatucket Reservoir	Smithfield	Culvert	Mild Bend	7.00	High	Severe	No	None	None	No	None	No	No	No
xy41914227154859	Industrial Rd S.	Unt to Woonasquatucket Reservoir	Smithfield	Culvert	Naturally Straight	10.93	High	Severe	No	None	None	No	None	No	No	No
xy41914627152630	George Washington Highway	Unt to Stillwater Pond	Smithfield	Culvert	Sharp Bend	10.33	Low / Estimated	Severe	No	Small	None	No	Low	No	No	No
xy41916527154817	Industrial Drive	Unt to Woonasquatucket Reservoir	Smithfield	Culvert	Naturally Straight	31.00	Low / Estimated	Severe	No	None	Downstream, Upstream, Within Structure	No	None	No	No	No
xy41916957158201	Tarkiln Rd	Unt to Nine Foot Brook	Smithfield	Partially Inaccessible	Naturally Straight	<Null>	Low / Estimated	<Null>	No	Large	Downstream	No	None	No	No	No
xy41918867152209	Douglas Pike	Unt to Stillwater Pond	Smithfield	Multiple Culverts	Naturally Straight	21.67	High	Severe	Yes	None	None	No	None	No	No	No
xy41920067155939	Burlingame Rd	Latham Brook	Smithfield	Culvert	Channelized Straight	13.17	High	Moderate	No	None	None	No	None	No	No	No
xy41920097155278	Old Forge Rd	Woonasquatucket River	Smithfield	Culvert	Mild Bend	31.67	High	Severe	No	None	None	No	Low	No	No	No
xy41920937158733	Tarkiln Rd	Unt to Nine Foot Brook	Smithfield	Culvert	Sharp Bend	10.00	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41921057155828	Log Rd	Unt to Latham Brook	Smithfield	Multiple Culverts	Naturally Straight	<Null>	Low / Estimated	Spans Only Bankfull / Active Channel	No	Small	None	No	None	No	No	No
xy41922257156115	Log Rd	Latham Brook	Smithfield	Multiple Culverts	Naturally Straight	12.50	High	Severe	No	None	None	No	None	No	No	No
xy41923277152886	Douglas Pike	Unt to Stillwater Reservoir	Smithfield	Culvert	Naturally Straight	24.23	High	Severe	No	None	None	No	Low	No	No	No
xy41923437156751	Bayberry Rd	Latham Brook	Smithfield	Culvert	Naturally Straight	12.17	Low / Estimated	Severe	No	Small	None	No	None	No	No	No
xy41923797156391	Log Rd	Latham Brook	Smithfield	Culvert	Mild Bend	19.67	Low / Estimated	Severe	No	None	Downstream	No	None	No	No	No
xy41924017152999	Douglas Pike	Unt to Stillwater Reservoir	Smithfield	Culvert	Mild Bend	<Null>	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41924467152624	Essex St	Unt to Stillwater Pond	Smithfield	Bridge	Channelized Straight	10.25	Low / Estimated	Spans Full Channel and Banks	No	None	None	No	Low	No	Yes	No
xy41924627153417	Bryant U. entryway off of Douglas Pike	Unt to Stillwater Pond	Smithfield	Culvert	Naturally Straight	<Null>	Low / Estimated	Severe	No	Small	None	No	None	No	No	No
xy41926177155080	Farnum Pike	Unt to Woonasquatucket River	Smithfield	Culvert	Naturally Straight	<Null>	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41926517153403	Douglas Pike	Unt to Stillwater Pond	Smithfield	Culvert	Mild Bend	<Null>	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41926627152983	Essex St	Unt to Stillwater Pond	Smithfield	Culvert	Mild Bend	10.67	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41927997155005	Rogler Farm Rd	Unt to Woonasquatucket Reservoir	Smithfield	Partially Inaccessible	Naturally Straight	<Null>	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41928037152264	Lydia Ann Rd	Unt to Stillwater Pond	Smithfield	Bridge	Naturally Straight	11.83	Low / Estimated	Spans Only Bankfull / Active Channel	No	None	Within Structure	No	Low	No	No	No
xy41928267155140	Farnum Pike	Woonasquatucket River	Smithfield	Bridge	Mild Bend	21.25	Low / Estimated	Moderate	No	None	None	No	Low	No	No	No
xy41929067155367	Latham Farm Rd	Unt to Woonasquatucket River	Smithfield	No Upstream Channel	Sharp Bend	<Null>	Low / Estimated	Severe	No	None	Downstream, Within Structure	No	None	No	No	No
xy41929207157455	Log Rd	Unt to Latham Brook	Smithfield	Multiple Culverts	Naturally Straight	<Null>	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41930757160155	Long Entry Rd	Unnamed Wetland	Glocester	Culvert	Naturally Straight	<Null>	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41931447155286	Farnum Pike	Unt to Woonasquatucket River	Smithfield	Culvert	Naturally Straight	<Null>	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41938517155343	Douglas Pike	Woonasquatucket River	North Smithfield	Bridge	Naturally Straight	<Null>	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41939037155601	Farnum Pike	Unt to Woonasquatucket River	North Smithfield	Culvert	Naturally Straight	10.33	High	Severe	No	Small	None	No	None	No	No	No
xy41943527156049	Douglas Pike	Unt to Woonasquatucket River	North Smithfield	Culvert	Sharp Bend	4.50	Low / Estimated	Moderate	No	<Null>	Upstream, Within Structure	No	None	No	No	No
xy41950277156940	Douglas Pike	Unt to Woonasquatucket River	North Smithfield	Culvert	Naturally Straight	<Null>	Low / Estimated	Severe	No	None	Downstream	No	None	No	No	No
xy41954007157431	Douglas Pike	Unt to Woonasquatucket River	North Smithfield	Culvert	Mild Bend	<Null>	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41954667155188	Greenville Rd	Woonasquatucket River	North Smithfield	Multiple Culverts	Naturally Straight	18.70	High	Severe	No	None	None	No	None	No	No	No
xy41954727157531	Douglas Pike	Unt	North Smithfield	Culvert	Naturally Straight	5.17	Low / Estimated	Severe	No	None	Upstream	No	None	No	No	No
xy41959377156205	Black Plain Rd	Unt to Primrose Pond	North Smithfield	Culvert	Naturally Straight	<Null>	Low / Estimated	Severe	No	None	Upstream	No	None	No	No	No
xy41959547155800	Pond House Rd	Unt to Primrose Pond	North Smithfield	No Upstream Channel	Channelized Straight	<Null>	Low / Estimated	Moderate	No	None	None	No	None	No	No	No
xy41961437156227	Pond House Rd	Unt to Primrose Pond	North Smithfield	Culvert	Channelized Straight	<Null>	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41962007156644	Mattity Rd	Unt to Primrose Pond	North Smithfield	Culvert	Naturally Straight	<Null>	Low / Estimated	Severe	No	Small	None	No	None	No	No	No
xy41962407156390	Black Plain Rd	Unt to Primrose Pond	North Smithfield	Culvert	Channelized Straight	<Null>	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41964317155322	Providence Pike	Unt to Woonasquatucket River	North Smithfield	Culvert	Sharp Bend	10.40	Low / Estimated	Severe	No	None	None	No	None	No	No	No
xy41972767155740	Providence Pike	Unt to Woonasquatucket River	North Smithfield	Culvert	Channelized Straight	4.37	High	Spans Only Bankfull / Active Channel	No	None	Downstream	No	None	No	No	No

Selected Structure Field Data

Crossing Code	Road Name	Stream Name	Structure Length (ft)	Culvert slope compared to channel slope	Inlet Shape	Inlet Grade	Inlet Width (ft)	Inlet Height (ft)	Inlet Substrate/Water Width (ft)	Outlet Shape	Outlet Grade	Outlet Width (ft)	Outlet Height (ft)	Outlet Substrate/Water Width (ft)	Outlet Drop	Physical Barriers	Structure Substrate Coverage	Structure Substrate Matches Stream	Structure Substrate Type	Water Depth Matches Stream Depth	Water Velocity Matches Stream Velocity
xy41817227144364	Manton Ave	Woonasquatucket River	57	About Equal	(6) Box / Bridge with Abutments	At Stream Grade	53	8.5	53	(6) Box / Bridge with Abutments	At Stream Grade	60.7	8.2	60.7	None	None	Unknown	Unknown	Unknown	Yes	Yes
xy41819437144226	Delaine St	Woonasquatucket River	39	About Equal	(6) Box / Bridge with Abutments	At Stream Grade	53.8	9.3	53.8	(6) Box / Bridge with Abutments	At Stream Grade	53	8	53	None	None	Unknown	Unknown	Unknown	Yes	Yes
xy41822527143992	Valley St	Woonasquatucket River	49	About Equal	(6) Box / Bridge with Abutments	At Stream Grade	43	7	43	(6) Box / Bridge with Abutments	At Stream Grade	43.1	7	43.1	None	None	Unknown	Unknown	Unknown	Yes	Yes
xy41823467146025	Glenbridge Ave	Woonasquatucket River	41	About Equal	(6) Box / Bridge with Abutments	At Stream Grade	167.5	<Null>	71.1	(6) Box / Bridge with Abutments	At Stream Grade	165.1	<Null>	57.3	None	None	1	Comparable	Sand	Yes	Yes
xy41824557143824	Atwells Ave	Woonasquatucket River	63	About Equal	(6) Box / Bridge with Abutments	At Stream Grade	46.1	8.5	40	(6) Box / Bridge with Abutments	At Stream Grade	42.5	8.5	42.5	None	None	Unknown	Unknown	Unknown	Yes	Yes
xy41826547143567	Eagle St	Woonasquatucket River	75	About Equal	(6) Box / Bridge with Abutments	At Stream Grade	42.7	9.5	42.7	(6) Box / Bridge with Abutments	At Stream Grade	46.9	8.5	46.9	None	None	Unknown	Unknown	Unknown	Yes	Yes
xy41826817141330	N/A: Footbridge	Woonasquatucket River	16	About Equal	(3) Open Bottom Arch Bridge / Culvert	At Stream Grade	74.9	16	74.9	(3) Open Bottom Arch Bridge / Culvert	At Stream Grade	74.9	14.4	74.9	None	None	Unknown	Unknown	Unknown	Yes	Yes
xy41826927141044	Steeple St	Woonasquatucket River	83	About Equal	(3) Open Bottom Arch Bridge / Culvert	At Stream Grade	40	17.5	40	(3) Open Bottom Arch Bridge / Culvert	At Stream Grade	38.5	17.5	38.5	None	Minor	Unknown	Unknown	Unknown	Yes	Yes
xy41826927141044	Steeple St	Woonasquatucket River	83	About Equal	(3) Open Bottom Arch Bridge / Culvert	At Stream Grade	41	16	41	(3) Open Bottom Arch Bridge / Culvert	At Stream Grade	38.5	17	38.5	None	Minor	Unknown	Unknown	Unknown	Yes	Yes
xy41827107141439	N/A: Footbridge	Woonasquatucket River	13	About Equal	(3) Open Bottom Arch Bridge / Culvert	At Stream Grade	30	11.6	30	(3) Open Bottom Arch Bridge / Culvert	At Stream Grade	30	11.6	30	None	None	Unknown	Unknown	Unknown	Yes	Yes
xy41827107141439	N/A: Footbridge	Woonasquatucket River	13	About Equal	(3) Open Bottom Arch Bridge / Culvert	At Stream Grade	36	12.7	36	(3) Open Bottom Arch Bridge / Culvert	At Stream Grade	36	12.4	36	None	None	Unknown	Unknown	Unknown	Yes	Yes
xy41827107141439	N/A: Footbridge	Woonasquatucket River	13	About Equal	(3) Open Bottom Arch Bridge / Culvert	At Stream Grade	31.7	13.4	31.7	(3) Open Bottom Arch Bridge / Culvert	At Stream Grade	31.7	14.4	31.7	None	None	Unknown	Unknown	Unknown	Yes	Yes
xy41827117141226	Exchange St	Woonasquatucket River	72	About Equal	(3) Open Bottom Arch Bridge / Culvert	At Stream Grade	83.5	<Null>	83.5	(3) Open Bottom Arch Bridge / Culvert	At Stream Grade	83.5	17	83.5	None	None	Unknown	Unknown	Unknown	Yes	Yes
xy41827207141547	Francis St	Woonasquatucket River	70	About Equal	(3) Open Bottom Arch Bridge / Culvert	At Stream Grade	105	<Null>	105	(3) Open Bottom Arch Bridge / Culvert	At Stream Grade	105	<Null>	105	None	None	Unknown	Unknown	Unknown	Yes	Yes
xy41827747141774	Park St	Woonasquatucket River	53	About Equal	(6) Box / Bridge with Abutments	At Stream Grade	81	8.5	81	(6) Box / Bridge with Abutments	At Stream Grade	81	9	81	None	None	Unknown	Unknown	Unknown	Yes	Yes
xy41828647142862	Acorn St	Woonasquatucket River	43	About Equal	(6) Box / Bridge with Abutments	At Stream Grade	62.1	8	57.7	(6) Box / Bridge with Abutments	At Stream Grade	61.9	9	57.3	None	None	1	Comparable	Cobble	Yes	Yes
xy41829017142325	Promenade St	Woonasquatucket River	51	About Equal	(7) Bridge with Side Slopes and Abutments	At Stream Grade	109.5	10.4	83	(7) Bridge with Side Slopes and Abutments	At Stream Grade	105.5	10.2	84	None	None	1	Comparable	Cobble	Yes	Yes
xy41829077142660	Dean St	Woonasquatucket River	81	About Equal	(7) Bridge with Side Slopes and Abutments	At Stream Grade	108.4	10	78.5	(7) Bridge with Side Slopes and Abutments	At Stream Grade	107.6	9.7	79.2	None	None	1	Comparable	Cobble	Yes	Yes
xy41829207142410	Promenade St	Woonasquatucket River	51	About Equal	(7) Bridge with Side Slopes and Abutments	At Stream Grade	104	11.3	80	(7) Bridge with Side Slopes and Abutments	At Stream Grade	105.8	10	77	None	None	1	Comparable	Cobble	Yes	Yes
xy41832947147052	Manson Ave	Dyerville Pond	59	About Equal	(6) Box / Bridge with Abutments	At Stream Grade	59	7	59	(6) Box / Bridge with Abutments	At Stream Grade	59	7	59	None	None	Unknown	Unknown	Unknown	Yes	Yes
xy41834977144282	Pleasant valley Parkway	Unt to Woonasquatucket River	68	About Equal	(2) Pipe Arch / Elliptical Culvert	Perched	6.1	3.5	6	(2) Pipe Arch / Elliptical Culvert	At Stream Grade	6	3.9	6	None	None	None	None	None	Yes	Yes
xy41835427143915	Pleasant valley Parkway	Unt to Woonasquatucket River	71	About Equal	(2) Pipe Arch / Elliptical Culvert	Perched	6.1	4	6	(2) Pipe Arch / Elliptical Culvert	At Stream Grade	6	3.9	6	None	None	None	None	None	Yes	Yes
xy41836747144463	Pleasant valley Parkway	Unt to Woonasquatucket River	<Null>	<Null>	Unknown	Unknown	<Null>	<Null>	<Null>	(1) Round Culvert	At Stream Grade	5	5	5	None	None	Unknown	Unknown	Unknown	Unknown	Unknown
xy41837147148177	Waterman Ave	Unt to Woonasquatucket River	150	About Equal	(4) Box Culvert	At Stream Grade	6	4	6	(4) Box Culvert	At Stream Grade	6	4	6	None	None	None	None	None	No - Deeper	No - Slower
xy41837797148021	Di Sarro Ave	Unt to Woonasquatucket River	53	About Equal	(1) Round Culvert	At Stream Grade	5	5	2	(1) Round Culvert	Free Fall	5	5	2	1.1	None	None	None	None	No - Shallower	No - Faster
xy41841257148494	Waterman Ave	Unt to Assapumpset Brook	<Null>	About Equal	(6) Box / Bridge with Abutments	At Stream Grade	6	3.2	6	Unknown	<Null>	<Null>	<Null>	<Null>	None	None	0.25	Comparable	Cobble	Yes	Yes
xy41842197148400	Diaz St	Unt to Assapumpset Brook	41	About Equal	(1) Round Culvert	At Stream Grade	3	3	2.4	(1) Round Culvert	At Stream Grade	3	3	2.9	None	None	None	None	None	Yes	Yes
xy41842937148299	Armento St	Assapumpset Brook	<Null>	About Equal	(1) Round Culvert	At Stream Grade	4	4	2	Unknown	<Null>	<Null>	<Null>	<Null>	None	None	None	None	None	No - Shallower	No - Faster
xy41843377148416	Diaz St	Assapumpset Brook	52	About Equal	(1) Round Culvert	At Stream Grade	2.5	2.5	2.5	(1) Round Culvert	At Stream Grade	2.5	2.5	2.5	None	None	None	None	None	Yes	Yes
xy41843377148416	Diaz St	Assapumpset Brook	52	About Equal	(1) Round Culvert	At Stream Grade	2.5	2.5	2.5	(1) Round Culvert	At Stream Grade	2.5	2.5	2.5	None	None	None	None	None	Yes	Yes
xy41845017150193	Atwood Ave	Unt to Assapumpset Brook	100	About Equal	(1) Round Culvert	At Stream Grade	2.5	2.5	2	(1) Round Culvert	At Stream Grade	2.5	2.5	2.5	None	None	0.25	Contrasting	Sand	No - Deeper	No - Slower
xy41845257150309	Carpenter Drive	Unt to Assapumpset Brook	42	Higher	(4) Box Culvert	Inlet Drop	2	0.8	2	(1) Round Culvert	Cascade	2.5	2.5	1.2	None	None	None	None	None	No - Shallower	No - Faster
xy41845877148670	George Waterman St	Assapumpset Brook	<Null>	Lower	(1) Round Culvert	Perched	4	4	2	Unknown	<Null>	<Null>	<Null>	<Null>	None	None	<Null>	None	None	No - Shallower	No - Slower
xy41845877148670	George Waterman St	Assapumpset Brook	<Null>	Lower	(4) Box Culvert	At Stream Grade	10.5	1.5	10.5	Unknown	<Null>	<Null>	<Null>	<Null>	None	Moderate	None	None	None	Yes	<Null>
xy41848417149462	Clemence Ln	Assapumpset Brook	<Null>	About Equal	(1) Round Culvert	At Stream Grade	3.5	3.5	3	(1) Round Culvert	At Stream Grade	3.5	3.5	3	None	Minor	None	None	None	Yes	Yes
xy41848417149462	Clemence Ln	Assapumpset Brook	<Null>	About Equal	(1) Round Culvert	Perched	3.5	3.5	0.5	(1) Round Culvert	Free Fall Onto Cascade	3.5	3.5	0.9	1.2	None	None	None	None	No - Shallower	No - Slower
xy41848877150503	Pine Hill Ave	Assapumpset Brook	43	About Equal	(1) Round Culvert	At Stream Grade	3.5	3.5	2	(1) Round Culvert	Free Fall Onto Cascade	3.5	3.5	1.5	2.4	Severe	None	None	None	No - Shallower	No - Faster
xy41850727148167	Allendale Ave	Woonasquatucket River	21	About Equal	(6) Box / Bridge with Abutments	At Stream Grade	53.5	9	41	(6) Box / Bridge with Abutments	At Stream Grade	53.5	13	43	None	None	1	Comparable	Cobble	Yes	No - Faster
xy41853897155040	Winsor Rd	Unt to Slack Reservoir	600	About Equal	(1) Round Culvert	At Stream Grade	1.5	1.5	1.5	Unknown	<Null>	<Null>	<Null>	<Null>	None	None	None	None	None	No - Shallower	No - Faster
xy41853977155807	Winsor Rd	Unt to Slack Reservoir	35	About Equal	(1) Round Culvert	At Stream Grade	3	3	1.3	(1) Round Culvert	Free Fall Onto Cascade	3	3	1.3	2.1	None	None	None	None	Yes	Yes
xy41855037152232	Greenville Ave	Unt to Assapumpset Brook	<Null>	About Equal	(1) Round Culvert	At Stream Grade	1.5	1.5	1	Unknown	<Null>	<Null>	<Null>	<Null>	None	Severe	None	None	None	No - Shallower	No - Faster
xy41855187155720	Barden Ln	Unt to Slack Reservoir	22	About Equal	(1) Round Culvert	At Stream Grade	1.5	1.5	1.5	(1) Round Culvert	Free Fall	1.5	1.5	0.7	0.1	None	None	None	None	No - Shallower	No - Faster
xy41855907154386	Winsor Rd	Unt to Slack Reservoir	30	About Equal	(1) Round Culvert	At Stream Grade	3	3	3	(1) Round Culvert	At Stream Grade	3	3	3	0	None	None	None	None	No - Shallower	No - Faster
xy41858547156285	Orchard Ave	Unt to Slack Reservoir	55	About Equal	(1) Round Culvert	Inlet Drop	3	3	3	(1) Round Culvert	At Stream Grade	3	3	3	0	None	None	None	None	No - Shallower	No - Faster
xy41859167148748	Putnam Pike	Woonasquatucket River	49	About Equal	(3) Open Bottom Arch Bridge / Culvert	At Stream Grade	56	7.4	56	(3) Open Bottom Arch Bridge / Culvert	At Stream Grade	56	7.9	56	None	None	Unknown	Unknown	Unknown	Yes	Yes
xy41859507155898	Roger Williams Drive	Unt to Slack Reservoir	56	About Equal	(4) Box Culvert	Perched	6	3	5	(4) Box Culvert	Free Fall	6	3	5	0.8	Severe	None	None	None	No - Shallower	No - Faster
xy41861407156668	Sheffield Rd	Unt to Slack Reservoir	<Null>	<Null>	Unknown	Unknown	<Null>	<Null>	<Null>	(1) Round Culvert	At Stream Grade	2	2	1.6	None	None	None	None	None	No - Deeper	No - Slower
xy41861407156668	Sheffield Rd	Unt to Slack Reservoir	195	Lower	(1) Round Culvert	At Stream Grade	3.5	3.5	3.2	(1) Round Culvert	At Stream Grade	4	4	3.6	0	None	None	None	None	No - Deeper	No - Slower
xy41861587154159	Greenville Ave	Unt to Slack Reservoir	100	About Equal	(1) Round Culvert	At Stream Grade	1.5	1.5	0.7	(1) Round Culvert	Free Fall Onto Cascade	1.5	1.5	0.7	0.3	Moderate	0.5	Comparable	Muck / Silt	Yes	Yes
xy41863027154374	Greenville Ave	Unt to Slack Reservoir	68	About Equal	(1) Round Culvert	At Stream Grade	3	3	3	(1) Round Culvert	Cascade	3	3	3	0.8	Minor	None	None	None	No - Shallower	No - Faster
xy41863027154374	Greenville Ave	Unt to Slack Reservoir	68	About Equal	(1) Round Culvert	At Stream Grade	3	3	3	(1) Round Culvert	Cascade	3	3	3	0.6	Minor	None	None	None	No - Shallower	No - Faster
xy41863507153509	Finne Rd	Unt to Slack Reservoir	57	About Equal	(1) Round Culvert	At Stream Grade	2.5	2.5	0.8	(1) Round Culvert	At Stream Grade	3	2.5	2.3	None	None	None	None	None	Yes	Yes
xy41865407149229	Angell Ave	Woonasquatucket River	29	About Equal	(6) Box / Bridge with Abutments	At Stream Grade	55	8.5	46	(6) Box / Bridge with Abutments	At Stream Grade	55	8.5	55	None	None	Unknown	Unknown	Unknown	Yes	Yes
xy41866427149748	Dean St	Unt to Woonasquatucket River	71	About Equal	(1) Round Culvert	Inlet Drop	1.3	1.3	0.9	(1) Round Culvert	At Stream Grade	1.5	1.5	1.5	None	Severe	None	None	None	Yes	Yes
xy41866737155823	Smith Ave Extension	Unt to Slack Reservoir	51	About Equal	(1) Round Culvert	Inlet Drop	3	2.5	3	(1) Round Culvert	Cascade	3	2	3	0.4	None	None	None	None	No - Shallower	No - Faster
xy41866907149909	Kenton Drive	Unt to Woonasquatucket River	48	About Equal	(1) Round Culvert	At Stream Grade	2	2	1.7	(1) Round Culvert	Free Fall Onto Cascade	3	3	1.1	0.3	None	None	None	None	Yes	Yes
xy41866937155857	Smith Ave	Unt to Slack Reservoir	<Null>	<Null>	Unknown	Unknown	<Null>	<Null>	<Null>	(1) Round Culvert	Cascade	1.8	1.5	1.8	0.2	<Null>	<Null>	None	<Null>	Unknown	Unknown
xy41867357150081	Mowry Ave	Unt to Woonasquatucket	42	About Equal	(1) Round Culvert	At Stream Grade	1.5	1.5	1.2	(1) Round Culvert	At Stream Grade	1.5	1.5	1.2	None	None	None	None	None	No - Shallower	No - Faster
xy41867357150081	Mowry Ave	Unt to Woonasquatucket	42	About Equal	(1) Round Culvert	At Stream Grade	1	1	0.8	(1) Round Culvert	At Stream Grade	1	1	1	None	Moderate	None	None	None	No - Shallower	No - Slower
xy41867767150198	Susan Drive	Unt to Woonasquatucket River	<Null>	About Equal	(1) Round Culvert	At Stream Grade	2.5	2.5	2	Unknown	<Null>	<Null>	<Null>	<Null>	None	None	None	None	None	Yes	Yes
xy41867937149613	Riverside Ave	Unt to Woonasquatucket River	43	About Equal	(1) Round Culvert	At Stream Grade	1.5	1.5	0.8	(1) Round Culvert	Free Fall	1.5	1.5	0.8	0.3	None	None	None	None	No - Shallower	No - Faster
xy41867937149613	Riverside Ave	Unt to Woonasquatucket River	43	About Equal	(1) Round Culvert	At Stream Grade	1.5	1.5	0.8	(1) Round Culvert	Free Fall	1.5	1.5	0.7	0.7	None	None	None	None	No - Shallower	No - Faster
xy41867937149613	Riverside Ave	Unt to Woonasquatucket River	43	About Equal	(1) Round Culvert	Perched	1	1	0	(1) Round Culvert	Cascade	1	1	0	None	Severe	None	None	None	No - Shallower	No - Slower
xy41868517157685	West Greenville Rd	Unt	51	About Equal	(1) Round Culvert	At Stream Grade	1	1	1	(1) Round Culvert	At Stream Grade	1	1	1	None	Minor	None	None	None	Unknown	No - Faster
xy41869227150721	Edmond St	Unt to Woonasquatucket River	<Null>	About Equal	(1) Round Culvert	At Stream Grade	2	2	2	(1) Round Culvert	At Stream Grade	2	2	2	None	None	0.5	Comparable	Sand	No - Deeper	No - Slower
xy41869837155412	Smith Ave	Unt to Slack Reservoir	309	About Equal	(1) Round Culvert	Inlet Drop	3.7	3.9	2.2	(1) Round Culvert	At Stream Grade	2.5	1.5	2.5	0	Moderate	1	Comparable	Sand	No - Shallower	No - Faster
xy41870167152512	Putnam Pike	Unt to Hawkins Brook	88	About Equal	(1) Round Culvert	At Stream Grade	2.5	2.5	1	(1) Round Culvert	At Stream Grade	2.5	2.5	2	None	None	None	None	None	Yes	Yes
xy41870207153556	Putnam Pike	Reaper Brook	82	About Equal	(6) Box / Bridge with Abutments	At Stream Grade	8	3.7	8	(6) Box / Bridge with Abutments	At Stream Grade	8	2.6	8	None	None	1	Contrasting	Cobble	No - Deeper	No - Slower
xy41871207155179	Putnam Pike	Slack Reservoir Outflow	120	Higher	(4) Box Culvert	Inlet Drop	8	4.8	8	(2) Pipe Arch / Elliptical Culvert	Free Fall Onto Cascade	3.3	2.6	3	0.2	Severe	None	None	None	No - Shallower	No - Faster
xy41871637157756	West Greenville Rd	Waterman Reservoir	34	About Equal	(6) Box / Bridge with Abutments	At Stream Grade	19.5	7	19.5	(6) Box / Bridge with Abutments	At Stream Grade	19.5	7.2	19.5	None	None	1	Comparable	Cobble	Yes	Yes
xy41871997158854	Aldrich Rd	Unt to Waterman Reservoir	53	About Equal	(1) Round Culvert	At Stream Grade	2	2	1	(1) Round Culvert	Free Fall Onto Cascade	2	2	1	1.3	None	None	None	None	No - Shallower	No - Faster
xy41872697150528	Esmond St	Hawkins Brook	100	About Equal	(1) Round Culvert	At Stream Grade	3.5	3.5	1.5	(1) Round Culvert	At Stream Grade	3.5	3.5	2.6	None	Minor	None	None	None	Yes	Yes
xy41872697150528	Esmond St	Hawkins Brook	100	About Equal	(1) Round Culvert	At Stream Grade	3.5	3.5	2	(1) Round Culvert	At Stream Grade	3.5	3.5	2.8	None	None	None	None	None	Yes	Yes
xy41872937157686	West Greenville Rd	Unt	50	About Equal	(1) Round Culvert	At Stream Grade	1.5	1.5	1.1	(1) Round Culvert	At Stream Grade	1.5	1.5	1.5	None	Severe	None	None	None	No - Deeper	No - Faster
xy41873167150365	Julien St	Hawkins Brook	40	About Equal	(6) Box / Bridge with Abutments	At Stream Grade	4.8	3.6	4.5	(6) Box / Bridge with Abutments	At Stream Grade	5.2	3.2	5.2	0	None	1	Comparable	Cobble	No - Deeper	No - Slower
xy41873187150300	Dean St	Hawkins Brook	100	About Equal	(1) Round Culvert	At Stream Grade	5	5	3.4	(1) Round Culvert	Free Fall	5	5	2.4	0.5	None	None	None	None	No - Shallower	No - Faster
xy41873187150300	Dean St	Hawkins Brook	100	About Equal	(1) Round Culvert	At Stream Grade	5	5	2.2	(1) Round Culvert	Free Fall	5	5	2.4	0.5	None	None	None	None	No - Shallower	No - Faster
xy41873637149711	Edmond Mill Drive	Woonasquatucket River	27	About Equal	(6) Box / Bridge with Abutments	At Stream Grade	30.5	5.8	30.5	(6) Box / Bridge with Abutments	At Stream Grade	32	7.2	32	None	None	1	Comparable	Muck / Silt	Yes	Yes
xy41874287154980	Pleasant View Circle	Unt to Stillwater River	48	About Equal	(1) Round Culvert	At Stream Grade	4	4	3.5	(1) Round Culvert	At Stream Grade	<Null>	<Null>	<Null>	None	None	0.5	Contrasting	Cobble	Yes	Yes

Selected Structure Field Data

Crossing Code	Road Name	Stream Name	Structure Length (ft)	Culvert slope compared to channel slope	Inlet Shape	Inlet Grade	Inlet Width (ft)	Inlet Height (ft)	Inlet Substrate/Water Width (ft)	Outlet Shape	Outlet Grade	Outlet Width (ft)	Outlet Height (ft)	Outlet Substrate/Water Width (ft)	Outlet Drop	Physical Barriers	Structure Substrate Coverage	Structure Substrate Matches Stream	Structure Substrate Type	Water Depth Matches Stream Depth	Water Velocity Matches Stream Velocity
xy41874767155492	Austin Ave	Stillwater River	33	About Equal	(6) Box / Bridge with Abutments	At Stream Grade	9	5	9	(6) Box / Bridge with Abutments	At Stream Grade	6.3	4.3	6.3	None	None	1	Comparable	Boulder	No - Deeper	No - Slower
xy41874767155492	Austin Ave	Stillwater River	33	About Equal	(6) Box / Bridge with Abutments	At Stream Grade	3	5.5	3	(6) Box / Bridge with Abutments	At Stream Grade	6	4.8	6	None	None	1	Comparable	Boulder	No - Deeper	No - Faster
xy41875437157379	West Greenville Ave	Unt to Waterman Reservoir	33	About Equal	(3) Open Bottom Arch Bridge / Culvert	At Stream Grade	9.8	4.6	9.8	(3) Open Bottom Arch Bridge / Culvert	At Stream Grade	10	5	10	None	None	1	Comparable	Sand	Yes	Yes
xy41875777159319	Old Quarry Rd	Unt to Waterman Reservoir	70	About Equal	(1) Round Culvert	At Stream Grade	3	3	1.3	(1) Round Culvert	Free Fall	3	3	1.5	0.3	None	None	None	None	No - Shallower	No - Faster
xy41877147159409	Old Quarry Rd	Unt to Waterman Reservoir	80	About Equal	(1) Round Culvert	At Stream Grade	3	3	1.5	(1) Round Culvert	At Stream Grade	3	3	1.5	0.5	None	None	None	None	No - Shallower	No - Faster
xy41877287153708	Cedar Swamp Road	Reaper Brook	44	About Equal	(6) Box / Bridge with Abutments	At Stream Grade	5.5	2.6	5.5	(6) Box / Bridge with Abutments	At Stream Grade	5.7	2.8	5.7	None	None	1	Comparable	Sand	Yes	Yes
xy41877397157132	West Greenville Rd	Stillwater River	39	About Equal	(6) Box / Bridge with Abutments	At Stream Grade	10	4.7	10	(6) Box / Bridge with Abutments	At Stream Grade	10	5.7	10	None	None	1	Comparable	Cobble	Yes	Yes
xy41877427157059	Putnam Pike	Stillwater Brook	100	About Equal	(6) Box / Bridge with Abutments	At Stream Grade	25.4	7	25.4	(6) Box / Bridge with Abutments	At Stream Grade	25.4	7	25.4	None	None	1	Comparable	Cobble	Yes	Yes
xy41877557154924	Deerfield Drive	Stillwater River	57	About Equal	(1) Round Culvert	At Stream Grade	5	5	5	(1) Round Culvert	At Stream Grade	5	5	4.5	None	None	None	None	None	No - Shallower	No - Faster
xy41877557154924	Deerfield Drive	Stillwater River	57	About Equal	(1) Round Culvert	At Stream Grade	5	5	5	(1) Round Culvert	At Stream Grade	5	5	4.8	None	Minor	None	None	None	No - Shallower	No - Faster
xy41878177153571	Walter Carey Road	Unt to Mountaindale Reservoir	30	About Equal	(1) Round Culvert	At Stream Grade	1.5	1.5	1.5	(1) Round Culvert	At Stream Grade	1.5	1.5	1.5	None	Severe	1	Comparable	Muck / Silt	Yes	Yes
xy41878417150154	Esmond St	Woonasquatucket River	42	About Equal	(6) Box / Bridge with Abutments	At Stream Grade	42.5	10.3	42.5	(6) Box / Bridge with Abutments	At Stream Grade	42.5	10	42.5	None	None	Unknown	Unknown	Unknown	Yes	Yes
xy41878707160132	Sawmill Rd	Unt to Waterman Reservoir	44	About Equal	(1) Round Culvert	Inlet Drop	2	2	1.2	(1) Round Culvert	At Stream Grade	2	2	2	None	None	None	None	None	Yes	Yes
xy41878737152022	Mountaindale Rd	Unt to Hawkins Brook	54	About Equal	(1) Round Culvert	Inlet Drop	1.5	1.5	0.8	(1) Round Culvert	At Stream Grade	1.7	1.7	1.7	None	Moderate	Unknown	Unknown	Unknown	No - Deeper	No - Slower
xy41880727150256	Farnum Pike	Woonasquatucket River	49	About Equal	(6) Box / Bridge with Abutments	At Stream Grade	50	15.5	50	(6) Box / Bridge with Abutments	At Stream Grade	50	15.5	50	None	None	1	Comparable	Cobble	No - Shallower	No - Faster
xy41880887157821	Putnam Pike	Waterman Reservoir	81	About Equal	(1) Round Culvert	Clogged/Collapsed/Submerged	3	3	3	(1) Round Culvert	At Stream Grade	3	3	3	None	Minor	Unknown	Unknown	Unknown	Yes	Yes
xy41881987151110	Old Country Rd	Unt to Woonasquatucket River	90	About Equal	(1) Round Culvert	At Stream Grade	4	4	4	(1) Round Culvert	At Stream Grade	4	4	4	0	Moderate	1	Comparable	Muck / Silt	Yes	Yes
xy41883167160369	Melody Hill Ln	Unt to Waterman Reservoir	37	About Equal	(1) Round Culvert	At Stream Grade	1	1	0.7	(1) Round Culvert	Free Fall Onto Cascade	1	1	0.5	0.3	None	<Null>	None	None	No - Shallower	No - Faster
xy41883167160369	Melody Hill Ln	Unt to Waterman Reservoir	37	About Equal	(1) Round Culvert	At Stream Grade	1	1	0.1	(1) Round Culvert	Free Fall Onto Cascade	1	1	<Null>	0.6	None	<Null>	None	None	No - Shallower	No - Faster
xy41883307160203	Sawmill Rd	Unt to Waterman Reservoir	86	About Equal	(1) Round Culvert	At Stream Grade	2	2	1	(1) Round Culvert	At Stream Grade	2	2	2	None	None	None	None	None	No - Deeper	No - Slower
xy41883627158219	Putnam Pike	Nine Foot Brook	77	About Equal	(4) Box Culvert	At Stream Grade	5	5	5	(4) Box Culvert	At Stream Grade	5	5	5	None	None	None	None	None	Yes	Yes
xy41883977158247	Austin Ave	Nine Foot Brook	42	About Equal	(1) Round Culvert	At Stream Grade	4	4	3.9	(1) Round Culvert	At Stream Grade	4	4	3.9	0	None	None	None	None	No - Shallower	No - Faster
xy41883977159943	Waterman Lake Drive	Unt to Cutler Brook	45	About Equal	(1) Round Culvert	At Stream Grade	2.7	2.7	1.5	(1) Round Culvert	Free Fall	2.7	2.7	1	0.3	None	None	None	None	No - Shallower	No - Faster
xy41883977159943	Waterman Lake Drive	Unt to Cutler Brook	45	About Equal	(1) Round Culvert	At Stream Grade	2.7	2.7	1.5	(1) Round Culvert	Free Fall	2.7	2.7	1	0.5	None	None	None	None	No - Shallower	No - Faster
xy41884477150737	Farnum Pike	Unt to Woonasquatucket River	<Null>	<Null>	Unknown	Unknown	<Null>	<Null>	<Null>	(4) Box Culvert	Cascade	3	2	3	3.7	None	Unknown	Unknown	Unknown	Yes	Yes
xy41884487160015	Sawmill Rd	Cutler Brook	50	About Equal	(4) Box Culvert	At Stream Grade	6	5.1	6	(4) Box Culvert	At Stream Grade	8	5	8	None	None	None	None	None	No - Shallower	No - Faster
xy41884547154339	Indian Run Rd	Unt to Stillwater River	39	About Equal	(1) Round Culvert	At Stream Grade	3.5	3.5	1.8	(1) Round Culvert	Free Fall	3.5	3.5	1.2	0.3	None	None	None	None	No - Shallower	No - Faster
xy41884547154339	Indian Run Rd	Unt to Stillwater River	38	About Equal	(1) Round Culvert	At Stream Grade	3.5	3.5	2	(1) Round Culvert	Free Fall	3.5	3.5	1	0.3	None	None	None	None	No - Shallower	No - Faster
xy41884547154339	Indian Run Rd	Unt to Stillwater River	38	About Equal	(1) Round Culvert	At Stream Grade	3	3	1.2	(1) Round Culvert	Free Fall	3	3	0.01	0.1	Minor	None	None	None	No - Shallower	No - Slower
xy41884547154339	Indian Run Rd	Unt to Stillwater River	39	About Equal	(1) Round Culvert	Perched	3.5	3.5	0.01	(1) Round Culvert	At Stream Grade	4	4	2.2	None	None	0.25	Contrasting	Muck / Silt	No - Shallower	No - Slower
xy41884807157218	Austin Ave	Unt to Waterman Reservoir	<Null>	About Equal	Unknown	Unknown	<Null>	<Null>	<Null>	Unknown	At Stream Grade	<Null>	<Null>	<Null>	None	Severe	Unknown	Unknown	Unknown	Unknown	Unknown
xy41884937158168	Stone Bridge Rd	Unt to Nine Foot Brook	135	<Null>	(1) Round Culvert	Clogged/Collapsed/Submerged	<Null>	<Null>	<Null>	Unknown	<Null>	<Null>	<Null>	<Null>	None	<Null>	Unknown	Unknown	Unknown	Unknown	Unknown
xy41885067154130	Pleasant View Ave	Stillwater River	40	About Equal	(6) Box / Bridge with Abutments	At Stream Grade	20	5.1	20	(6) Box / Bridge with Abutments	At Stream Grade	20	6.2	20	None	None	1	Comparable	Sand	Yes	Yes
xy41885087157849	Austin Avenue	Unt to Waterman Reservoir	44	About Equal	(6) Box / Bridge with Abutments	At Stream Grade	2.3	1	2.3	Unknown	Cascade	<Null>	<Null>	<Null>	None	Severe	1	Comparable	Cobble	Yes	Yes
xy41885967155678	Baldwin Circle	Unt to Stillwater River	<Null>	<Null>	Unknown	Unknown	<Null>	<Null>	<Null>	(1) Round Culvert	At Stream Grade	1.5	1.5	1.2	None	Minor	None	None	None	No - Shallower	No - Faster
xy41886157153645	Mountaindale Road	Reaper Brook	38	About Equal	(7) Bridge with Side Slopes and Abutments	Inlet Drop	25.7	4.5	19	(7) Bridge with Side Slopes and Abutments	At Stream Grade	26	8	26	None	Moderate	1	Contrasting	Boulder	No - Deeper	Yes
xy41886477153705	Mountaindale Road	Unnamed Wetland adjacent to Reaper Brook	37	About Equal	(1) Round Culvert	At Stream Grade	1.5	1.5	1.3	(1) Round Culvert	At Stream Grade	1.5	1.2	1.3	None	None	Unknown	Contrasting	Gravel	Yes	No - Faster
xy41886617150419	Fenwood Ave	Unt to Woonasquatucket River	75	About Equal	(1) Round Culvert	At Stream Grade	2.5	2.5	2.2	(1) Round Culvert	Cascade	2.5	2.5	1.4	0.1	Minor	None	None	None	No - Shallower	Yes
xy41886617150419	Fenwood Ave	Unt to Woonasquatucket River	75	About Equal	(1) Round Culvert	At Stream Grade	2.5	2.5	1.3	(1) Round Culvert	Cascade	2.5	2.5	0.8	0.1	Moderate	None	None	None	No - Shallower	No - Slower
xy41886617150419	Fenwood Ave	Unt to Woonasquatucket River	75	About Equal	(1) Round Culvert	At Stream Grade	2.5	2.5	1.7	(1) Round Culvert	Cascade	2.5	2.5	1.4	0.1	Minor	None	None	None	No - Shallower	No - Slower
xy41886847150523	Whipple Ave	Woonasquatucket River	35	About Equal	(6) Box / Bridge with Abutments	At Stream Grade	49	9.3	49	(6) Box / Bridge with Abutments	At Stream Grade	49	9.2	49	None	None	1	Comparable	Cobble	Yes	Yes
xy41886917159166	Putnam Pike	Unt to Waterman Reservoir	62	About Equal	(1) Round Culvert	At Stream Grade	2	2	1	(1) Round Culvert	At Stream Grade	2	2	2	None	None	None	None	None	Yes	Yes
xy41887077159144	Valley Rd	Unt to Waterman Reservoir	26	About Equal	(4) Box Culvert	At Stream Grade	5	3	5	(4) Box Culvert	At Stream Grade	2	3.2	2	None	Minor	None	None	None	Yes	Yes
xy41888247153923	Mountaindale Road	Stillwater River	51	About Equal	(1) Round Culvert	At Stream Grade	5	5	2.8	(1) Round Culvert	At Stream Grade	5	5	2.8	None	Severe	None	None	None	Yes	No - Slower
xy41888247153923	Mountaindale Road	Stillwater River	51	About Equal	(1) Round Culvert	At Stream Grade	6	6	5	(1) Round Culvert	At Stream Grade	6	6	5	None	Severe	None	None	None	Yes	No - Slower
xy41888657151262	Farnum Pike	Unt to Georgiaville Pond	57	About Equal	(1) Round Culvert	At Stream Grade	2	2	2	(1) Round Culvert	At Stream Grade	2	2	2	None	Moderate	1	Comparable	Sand	Yes	No - Slower
xy41888657151262	Farnum Pike	Unt to Georgiaville Pond	57	About Equal	(1) Round Culvert	At Stream Grade	2	2	2	(1) Round Culvert	At Stream Grade	2	2	2	None	Moderate	1	Comparable	Sand	No - Shallower	No - Slower
xy41888837151740	Old County Rd	Unt to Georgiaville Pond	45	Higher	(1) Round Culvert	Inlet Drop	1.5	1.5	1.4	(1) Round Culvert	At Stream Grade	1.5	1.5	1.2	None	None	0.5	Comparable	Sand	No - Deeper	No - Slower
xy41889357148731	Whipple Rd	Unt to Woonasquatucket River	43	About Equal	(1) Round Culvert	At Stream Grade	2	2	1.2	(1) Round Culvert	At Stream Grade	2	2	0.83	None	None	None	None	None	No - Shallower	No - Faster
xy41890377149584	Ridge Rd	Unt to Woonasquatucket River	56	Higher	(1) Round Culvert	At Stream Grade	2	2	1.5	(1) Round Culvert	Cascade	2	2	1.5	1.2	None	None	None	None	No - Shallower	No - Faster
xy41890427151403	Sweet Rd	Unt to Georgiaville Pond	28	About Equal	(1) Round Culvert	At Stream Grade	2	2	1.2	(1) Round Culvert	Free Fall	2	2	0.9	0.5	None	None	None	None	Yes	Yes
xy41890427151403	Sweet Rd	Unt to Georgiaville Pond	25	About Equal	(1) Round Culvert	Perched	1.5	1.5	0	(1) Round Culvert	Cascade	1.5	1.5	0	0.9	Minor	None	None	None	Unknown	Unknown
xy41890897156959	Colwell Rd	Unt to Upper Sprague Reservoir	31	Higher	(1) Round Culvert	At Stream Grade	1.3	1.3	0.8	(1) Round Culvert	Cascade	1.3	1.3	0.5	None	None	None	None	None	No - Shallower	No - Faster
xy41890917151543	Farnum Pike	Unt to Georgiaville Pond	<Null>	About Equal	(4) Box Culvert	Inlet Drop	2.7	2	2.5	Unknown	<Null>	<Null>	<Null>	<Null>	None	None	1	Comparable	Gravel	Yes	Yes
xy41892467149331	Douglas Pike	Unt to Woonasquatucket River	56	About Equal	(1) Round Culvert	Clogged/Collapsed/Submerged	2	2	2	(1) Round Culvert	At Stream Grade	<Null>	<Null>	<Null>	None	Severe	Unknown	Unknown	Unknown	No - Deeper	No - Slower
xy41892467149331	Douglas Pike	Unt to Woonasquatucket River	56	About Equal	(1) Round Culvert	Clogged/Collapsed/Submerged	2	0.7	2	(1) Round Culvert	At Stream Grade	<Null>	<Null>	<Null>	None	Severe	Unknown	Unknown	Unknown	No - Deeper	No - Slower
xy41892547150396	Crest Drive	Unt to Woonasquatucket River	46	Lower	(3) Open Bottom Arch Bridge / Culvert	At Stream Grade	4	3	4	(3) Open Bottom Arch Bridge / Culvert	At Stream Grade	4	2.1	4	None	Minor	1	Contrasting	Cobble	Unknown	Unknown
xy41892547150396	Crest Drive	Unt to Woonasquatucket River	46	Lower	(3) Open Bottom Arch Bridge / Culvert	At Stream Grade	4	2.4	4	(3) Open Bottom Arch Bridge / Culvert	At Stream Grade	4	1.8	4	None	Moderate	1	Contrasting	Cobble	Unknown	Unknown
xy41892547150396	Crest Drive	Unt to Woonasquatucket River	46	Lower	(3) Open Bottom Arch Bridge / Culvert	At Stream Grade	4	1.5	4	(3) Open Bottom Arch Bridge / Culvert	At Stream Grade	4	1.6	4	None	Severe	1	Contrasting	Cobble	Unknown	Unknown
xy41893077160835	Route 44	Cutler Brook	90	Lower	(4) Box Culvert	At Stream Grade	5	5	5	(4) Box Culvert	At Stream Grade	5	5	5	0.4	Minor	None	None	None	No - Shallower	No - Faster
xy41893317160808	Farnum Road	Cutler Brook	50	About Equal	(2) Pipe Arch / Elliptical Culvert	Inlet Drop	4	4.2	4	(2) Pipe Arch / Elliptical Culvert	At Stream Grade	4	4.2	4	None	<Null>	None	None	None	Yes	Yes
xy41894747150725	Stillwater Rd	Unt to Georgiaville Pond	55	Higher	(1) Round Culvert	At Stream Grade	2.9	3	1.2	(1) Round Culvert	Free Fall	3	3	1.2	0.6	Moderate	None	None	None	No - Shallower	No - Faster
xy41894747150725	Stillwater Rd	Unt to Georgiaville Pond	55	Higher	(1) Round Culvert	At Stream Grade	3	3	1.5	(1) Round Culvert	Free Fall	3	3	2	0.6	Moderate	None	None	None	No - Shallower	No - Faster
xy41894887152164	Farnum Pike	Unt to Georgiaville Pond	<Null>	About Equal	(1) Round Culvert	At Stream Grade	4	4	2	Unknown	<Null>	<Null>	<Null>	<Null>	None	None	None	None	None	Yes	Yes
xy41894887152164	Farnum Pike	Unt to Georgiaville Pond	<Null>	About Equal	(1) Round Culvert	At Stream Grade	4	4	0.7	Unknown	<Null>	<Null>	<Null>	<Null>	None	None	None	None	None	No - Shallower	No - Slower
xy41895577161365	Route 44 Putnam Pike	Unt to Cutler Brook	71	About Equal	(1) Round Culvert	At Stream Grade	1.5	1.5	1	(1) Round Culvert	At Stream Grade	1.5	1.5	0.8	None	None	None	None	None	No - Shallower	No - Faster
xy41896047161805	Route 44	Unti to Cutler Brook	98	About Equal	(1) Round Culvert	At Stream Grade	2	2	1.2	(1) Round Culvert	At Stream Grade	2	2	1.7	None	None	None	None	None	No - Shallower	No - Faster
xy41896637160262	Farnum Rd	Unt to Waterman Reservoir	24	About Equal	(1) Round Culvert	At Stream Grade	1.6	1.6	1	(1) Round Culvert	Cascade	1.3	1.3	0.8	0.5	None	None	None	None	Yes	Yes
xy41896697151958	Old county Rd/Lakeside Drive	Unt to Georgiaville Pond	700	About Equal	(1) Round Culvert	Inlet Drop	2	2	1	(1) Round Culvert	Free Fall Onto Cascade	3	3	0.7	0.8	None	None	None	None	No - Shallower	No - Faster
xy41897187150342	Ridge Rd	Unt to Georgiaville Pond	30	About Equal	(1) Round Culvert	At Stream Grade	4	4	2.8	(1) Round Culvert	At Stream Grade	4	4	2.7	None	None	None	None	None	No - Shallower	No - Faster
xy41897827156647	Colwell Rd	Unt to Upper Sprague Reservoir	<Null>	About Equal	Unknown	Unknown	<Null>	<Null>	<Null>	(1) Round Culvert	Free Fall Onto Cascade	1.1	1.1	0.5	0.4	None	None	None	None	No - Shallower	No - Faster
xy41898117157880	Evan's Rd	Nine Foot Brook	44	About Equal	(6) Box / Bridge with Abutments	At Stream Grade	5	3.5	5	(6) Box / Bridge with Abutments	At Stream Grade	2.5	4	2.5	None	None	1	Comparable	Sand	Yes	Yes
xy41898457158358	Burlingame Ln	Unt to Nine Foot Brook	26	About Equal	(6) Box / Bridge with Abutments	Inlet Drop	2	1.7	2	(6) Box / Bridge with Abutments	At Stream Grade	2	0.9	2	None	Severe	1	Comparable	Cobble	Yes	Yes
xy41898477158323	Burlingame Ln	Unt to Nine Foot Brook	26	About Equal	(6) Box / Bridge with Abutments	At Stream Grade	1.5	1	1.5	(6) Box / Bridge with Abutments	At Stream Grade	2.8	1	2.8	None	Severe	1	Comparable	Gravel	Unknown	Yes
xy41898517157816	Tarkiln Rd	Unt to Nine Foot Brook	45	Lower	(1) Round Culvert	Inlet Drop	1.5	1.5	0.4	(1) Round Culvert	Free Fall Onto Cascade	1.5	1.5	0.3	1.6	None	None	None	None	No - Shallower	Yes
xy41898517157816	Tarkiln Rd	Unt to Nine Foot Brook	29	About Equal	(6) Box / Bridge with Abutments	At Stream Grade	2.5	1	2.5	(6) Box / Bridge with Abutments	At Stream Grade	1	0.5	1	None	Severe	1	Comparable	Cobble	Yes	Yes
xy41898907154304	Pleasantview Ave	Woonasquatucket Reservoir	44	About Equal	(6) Box / Bridge with Abutments	At Stream Grade	28	11.5	28	(6) Box / Bridge with Abutments	At Stream Grade	28	11.5	28	None	None	Unknown	Unknown	Unknown	No - Shallower	No - Faster
xy41898957150991	Stillwater Rd	Harris Brook	34	About Equal	(6) Box / Bridge with Abutments	At Stream Grade	7	7	7	(6) Box / Bridge with Abutments	At Stream Grade	10.5	9.5	10.5	None	None	1	Comparable	Cobble	Yes	Yes

Selected Structure Field Data

Crossing Code	Road Name	Stream Name	Structure Length (ft)	Culvert slope compared to channel slope	Inlet Shape	Inlet Grade	Inlet Width (ft)	Inlet Height (ft)	Inlet Substrate/Water Width (ft)	Outlet Shape	Outlet Grade	Outlet Width (ft)	Outlet Height (ft)	Outlet Substrate/Water Width (ft)	Outlet Drop	Physical Barriers	Structure Substrate Coverage	Structure Substrate Matches Stream	Structure Substrate Type	Water Depth Matches Stream Depth	Water Velocity Matches Stream Velocity
xy41899117154630	Log Rd	Woonasquatucket Reservoir	42	About Equal	(1) Round Culvert	Clogged/Collapsed/Submerged	1.5	1.5	1.5	(1) Round Culvert	At Stream Grade	1.5	1.5	1	None	Severe	None	None	None	No - Shallower	No - Faster
xy41899147150128	Douglas Pike	Unt to Georgiaville Pond	54	About Equal	(4) Box Culvert	Perched	5	4	5	(4) Box Culvert	At Stream Grade	5	4	5	None	None	None	None	None	Yes	Yes
xy41899277156654	Colwell Rd	Unt to Upper Sprague Reservoir	46	About Equal	(1) Round Culvert	At Stream Grade	1.5	1.5	0.8	(1) Round Culvert	Free Fall Onto Cascade	1.5	1.5	0.8	1.5	None	None	None	None	No - Shallower	No - Faster
xy41900117158371	Evans Rd	Unt to Shinscot Brook	50	About Equal	(1) Round Culvert	At Stream Grade	2	2	2	(1) Round Culvert	At Stream Grade	2	2	2	None	Minor	Unknown	Unknown	Unknown	Yes	Yes
xy41900437149662	Catherine Rd	Unt to West River	<Null>	<Null>	Unknown	Unknown	<Null>	<Null>	<Null>	(1) Round Culvert	Free Fall	2.5	2.5	1.5	0.1	None	None	None	None	Yes	No - Faster
xy41902037159401	Farnum road	Shinscot Brook	32	About Equal	(1) Round Culvert	At Stream Grade	3	3	2	(1) Round Culvert	At Stream Grade	3	3	2	None	None	None	None	None	No - Shallower	No - Faster
xy41902517157773	Tarkiln Rd	Unt to Nine Foot Brook	52	About Equal	(1) Round Culvert	At Stream Grade	1.5	1.5	0.8	(1) Round Culvert	At Stream Grade	1	1	0.7	None	None	None	None	None	No - Shallower	No - Faster
xy41902577149498	Maureen Drive	Unt to West River	<Null>	<Null>	Unknown	Unknown	<Null>	<Null>	<Null>	(1) Round Culvert	At Stream Grade	2.5	2.5	1.9	None	None	None	None	None	Yes	Yes
xy41902587151720	Stillwater Rd	Unt to Georgiaville Pond	133	About Equal	(1) Round Culvert	At Stream Grade	3	3	1.2	(1) Round Culvert	At Stream Grade	3	3	2.5	None	Moderate	None	None	None	No - Shallower	No - Faster
xy41902587151720	Stillwater Rd	Unt to Georgiaville Pond	133	About Equal	(1) Round Culvert	At Stream Grade	3	3	1.2	(1) Round Culvert	At Stream Grade	3	3	2.5	None	Moderate	None	None	None	No - Shallower	No - Faster
xy41902697157007	Mann School Rd	Unt to Upper Sprague Reservoir	26	About Equal	(1) Round Culvert	At Stream Grade	1.5	1.5	1.5	(1) Round Culvert	Free Fall	1.5	1.5	1.5	0.1	Severe	None	None	None	No - Shallower	No - Faster
xy41902697157007	Mann School Rd	Unt to Upper Sprague Reservoir	26	About Equal	(1) Round Culvert	At Stream Grade	1.5	1.5	1.5	(1) Round Culvert	At Stream Grade	1.5	1.5	1.5	None	Severe	None	None	None	No - Shallower	No - Faster
xy41902757152161	Capron Rd	Capron Pond	42	About Equal	(6) Box / Bridge with Abutments	At Stream Grade	25	11	25	(6) Box / Bridge with Abutments	At Stream Grade	25	11	25	None	None	1	Comparable	Cobble	Yes	Yes
xy41902757159093	Farnum Rd	Unt	36	Higher	(1) Round Culvert	At Stream Grade	2	2	2	(1) Round Culvert	Cascade	1.5	1.5	1	2	None	None	None	None	No - Shallower	No - Faster
xy41902877150377	Limerock Rd	Unt to Harris Brook	42	About Equal	(1) Round Culvert	At Stream Grade	2	2	2	(1) Round Culvert	At Stream Grade	<Null>	<Null>	<Null>	None	Severe	0.25	Comparable	Sand	No - Deeper	No - Slower
xy41902877150377	Limerock Rd	Unt to Harris Brook	42	About Equal	(1) Round Culvert	At Stream Grade	2	2	2	(1) Round Culvert	At Stream Grade	<Null>	<Null>	<Null>	None	Severe	0.25	Comparable	Sand	No - Deeper	No - Slower
xy41904317158874	Evans road	Unt	38	<Null>	Unknown	Unknown	<Null>	<Null>	0	(1) Round Culvert	At Stream Grade	1	1	<Null>	None	Severe	None	None	None	Unknown	Unknown
xy41904937156221	Connors Farm Drive	Unt	48	About Equal	(3) Open Bottom Arch Bridge / Culvert	At Stream Grade	7	4.5	3.5	(3) Open Bottom Arch Bridge / Culvert	At Stream Grade	7	4.4	0.8	None	Minor	1	Contrasting	Muck / Silt	No - Shallower	No - Faster
xy41905587149206	Clark Rd	Unt to West River	41	About Equal	(1) Round Culvert	Perched	1.5	1.5	1	(1) Round Culvert	Free Fall	1.5	1.5	1	0.5	None	None	None	None	No - Shallower	No - Faster
xy41905587149206	Clark Rd	Unt to West River	42	About Equal	(1) Round Culvert	Perched	1.5	1.5	1.2	(1) Round Culvert	Free Fall	1.5	1.5	1	0.3	None	None	None	None	No - Shallower	No - Faster
xy41906217161244	Cooper Ave	Cutler Brook	28	About Equal	(1) Round Culvert	At Stream Grade	1.5	1.5	1.5	(1) Round Culvert	At Stream Grade	<Null>	<Null>	<Null>	None	Minor	1	Contrasting	Sand	No - Shallower	No - Faster
xy41908317153647	George Washington Highway	Woonasquatucket River	40	About Equal	(7) Bridge with Side Slopes and Abutments	At Stream Grade	154	<Null>	85	(7) Bridge with Side Slopes and Abutments	At Stream Grade	154	<Null>	85	None	None	Unknown	Unknown	Unknown	Yes	Yes
xy41908677154068	Farnum Pike	Woonasquatucket River	35	About Equal	(6) Box / Bridge with Abutments	At Stream Grade	30.8	<Null>	30.8	(6) Box / Bridge with Abutments	At Stream Grade	30	<Null>	30	None	None	1	Comparable	Cobble	Yes	Yes
xy41909167152497	Stillwater Rd	Unt to Stillwater Pond	346	About Equal	(4) Box Culvert	Perched	6	3	6	(4) Box Culvert	At Stream Grade	6	3	6	None	None	None	None	None	No - Shallower	Yes
xy41910887152828	Stillwater Rd	Unt to Stillwater Pond	31	About Equal	(2) Pipe Arch / Elliptical Culvert	At Stream Grade	5	3.7	4.5	(2) Pipe Arch / Elliptical Culvert	Free Fall	5.5	3.6	4.1	2	None	None	None	None	Yes	Yes
xy41910887152828	Stillwater Rd	Unt to Stillwater Pond	31	About Equal	(2) Pipe Arch / Elliptical Culvert	At Stream Grade	6.3	3.3	6	(2) Pipe Arch / Elliptical Culvert	Free Fall	5.5	3.8	3.5	1.8	None	None	None	None	Yes	Yes
xy41912007159704	Evans Rd	Unamed to Shinscot Brook	28	About Equal	(1) Round Culvert	At Stream Grade	3	3	1.5	(1) Round Culvert	At Stream Grade	3	3	2	None	Severe	None	None	None	No - Shallower	No - Faster
xy41912687150232	Harris Rd	Unt to Harris Brook	42	About Equal	(2) Pipe Arch / Elliptical Culvert	At Stream Grade	4	2.8	2.7	(2) Pipe Arch / Elliptical Culvert	Free Fall	4	2.9	2	0.2	None	None	None	None	Yes	Yes
xy41912687150232	Harris Rd	Unt to Harris Brook	41	About Equal	(2) Pipe Arch / Elliptical Culvert	Perched	4	2.9	2.7	(2) Pipe Arch / Elliptical Culvert	Free Fall	4	2.8	1.8	0.2	None	None	None	None	Yes	Yes
xy41913457152883	George Washington Highway	Unt to Stillwater Pond	150	About Equal	(1) Round Culvert	At Stream Grade	2	2	1.9	(1) Round Culvert	At Stream Grade	2	2	2	None	Minor	None	None	None	No - Deeper	Yes
xy41913457152883	George Washington Highway	Unt to Stillwater Pond	150	About Equal	(4) Box Culvert	At Stream Grade	5	4.1	5	(4) Box Culvert	At Stream Grade	5	4	4	None	None	None	None	None	No - Shallower	Yes
xy41913477151701	Douglas Pike	Unt to Stillwater Pond	98	About Equal	(1) Round Culvert	At Stream Grade	2	2	0.9	(1) Round Culvert	Cascade	2	2	0.9	0.2	Minor	None	None	None	No - Shallower	No - Faster
xy41914027155460	Log Rd	Woonasquatucket Reservoir	30	Higher	(4) Box Culvert	At Stream Grade	4	3	4	(4) Box Culvert	At Stream Grade	4	3.5	4	None	<Null>	None	None	None	No - Shallower	No - Faster
xy41914137156217	Burlingame Rd	Unt to Woonasquatucket Reservoir	38	About Equal	(1) Round Culvert	At Stream Grade	3	3	0.5	(1) Round Culvert	At Stream Grade	3	3	1.5	None	Minor	None	None	None	No - Shallower	No - Slower
xy41914137156217	Burlingame Rd	Unt to Woonasquatucket Reservoir	38	About Equal	(1) Round Culvert	At Stream Grade	3	3	1	(1) Round Culvert	At Stream Grade	3	3	1.5	None	Minor	None	None	None	Yes	Yes
xy41914227154859	Industrial Rd S.	Unt to Woonasquatucket Reservoir	80	About Equal	(1) Round Culvert	At Stream Grade	3	3	2.8	(1) Round Culvert	At Stream Grade	3	3	3	None	Minor	1	Comparable	Sand	Yes	Yes
xy41914627152630	George Washington Highway	Unt to Stillwater Pond	74	About Equal	(1) Round Culvert	At Stream Grade	2	2	1.5	(1) Round Culvert	At Stream Grade	2	2	2	None	None	None	None	None	No - Deeper	Yes
xy41916527154817	Industrial Drive	Unt to Woonasquatucket Reservoir	62	About Equal	(1) Round Culvert	At Stream Grade	3	3	2.9	(1) Round Culvert	At Stream Grade	2.9	2.9	2.9	None	None	0.75	Comparable	Muck / Silt	Yes	Yes
xy41916957158201	Tarkiln Rd	Unt to Nine Foot Brook	<Null>	<Null>	Unknown	Unknown	<Null>	<Null>	<Null>	(1) Round Culvert	At Stream Grade	2	2	2	None	Minor	None	None	None	Yes	No - Faster
xy41918867152209	Douglas Pike	Unt to Stillwater Pond	83	Lower	(1) Round Culvert	At Stream Grade	2	2	1.6	(1) Round Culvert	At Stream Grade	2	2	2	None	Minor	None	None	None	No - Deeper	No - Slower
xy41918867152209	Douglas Pike	Unt to Stillwater Pond	83	Lower	(1) Round Culvert	At Stream Grade	2	2	1.8	(1) Round Culvert	At Stream Grade	2	2	2	None	Minor	None	None	None	No - Deeper	No - Slower
xy41920067155939	Burlingame Rd	Latham Brook	33	About Equal	(4) Box Culvert	Inlet Drop	8	3	7.1	(4) Box Culvert	Free Fall	8	3	7	0.7	None	None	None	None	No - Shallower	Yes
xy41920097155278	Old Forge Rd	Woonasquatucket River	42	Higher	(4) Box Culvert	At Stream Grade	9	4	9	(4) Box Culvert	Free Fall	9	4	9	0.8	None	None	None	None	No - Shallower	No - Faster
xy41920937158733	Tarkiln Rd	Unt to Nine Foot Brook	49	About Equal	(1) Round Culvert	At Stream Grade	1.3	1.3	0.7	(1) Round Culvert	At Stream Grade	1.3	1.3	1.3	None	None	None	None	None	No - Shallower	No - Faster
xy41921057155828	Log Rd	Unt to Latham Brook	50	About Equal	(1) Round Culvert	At Stream Grade	1.5	1.5	0.9	(1) Round Culvert	At Stream Grade	1.5	1.5	0.9	0	None	None	None	None	Yes	Yes
xy41921057155828	Log Rd	Unt to Latham Brook	50	About Equal	(1) Round Culvert	At Stream Grade	1.5	1.5	0.8	(1) Round Culvert	At Stream Grade	1.5	1.5	0.8	0	<Null>	None	None	None	Yes	Yes
xy41922257156115	Log Rd	Latham Brook	45	About Equal	(1) Round Culvert	Perched	3	3	2.5	(1) Round Culvert	At Stream Grade	3	3	2.7	None	Severe	None	None	None	No - Shallower	No - Faster
xy41922257156115	Log Rd	Latham Brook	43	About Equal	(1) Round Culvert	At Stream Grade	3.1	3.1	2.5	(1) Round Culvert	At Stream Grade	3.1	3.1	2.6	None	Severe	None	None	None	No - Shallower	No - Faster
xy41923277152886	Douglas Pike	Unt to Stillwater Reservoir	73	About Equal	(4) Box Culvert	At Stream Grade	4	3	3.3	(4) Box Culvert	At Stream Grade	4	3	4	None	None	None	None	None	No - Deeper	Yes
xy41923437156751	Bayberry Rd	Latham Brook	42	About Equal	(1) Round Culvert	At Stream Grade	3	3	2.2	(1) Round Culvert	Free Fall	3	3	2	0.3	None	None	None	None	No - Shallower	No - Faster
xy41923797156391	Log Rd	Latham Brook	29	About Equal	(1) Round Culvert	Perched	4	4	2.5	(1) Round Culvert	At Stream Grade	4	4	2.2	0	<Null>	None	None	None	No - Shallower	No - Faster
xy41924017152999	Douglas Pike	Unt to Stillwater Reservoir	130	About Equal	(1) Round Culvert	At Stream Grade	2	2	0.3	(1) Round Culvert	At Stream Grade	2	2	2	None	Minor	None	None	None	No - Deeper	No - Slower
xy41924467152624	Essex St	Unt to Stillwater Pond	43	About Equal	(6) Box / Bridge with Abutments	At Stream Grade	43.5	11	7.5	(6) Box / Bridge with Abutments	At Stream Grade	43.5	12.8	21.8	None	None	1	Comparable	Boulder	Yes	Yes
xy41924627153417	Bryant U. entryway off of Douglas Pike	Unt to Stillwater Pond	117	About Equal	(1) Round Culvert	Inlet Drop	4	4	3.2	(1) Round Culvert	At Stream Grade	4	4	2.5	None	Minor	None	None	None	No - Shallower	Yes
xy41926177155080	Farnum Pike	Unt to Woonasquatucket River	44	About Equal	(1) Round Culvert	Inlet Drop	1	1	0.9	(1) Round Culvert	At Stream Grade	1	1	1	None	None	None	None	None	Yes	No - Faster
xy41926517153403	Douglas Pike	Unt to Stillwater Pond	61	About Equal	(4) Box Culvert	At Stream Grade	4	3	4	(4) Box Culvert	At Stream Grade	4	3	4	None	None	None	None	None	Yes	No - Faster
xy41926627152983	Essex St	Unt to Stillwater Pond	87	About Equal	(1) Round Culvert	Inlet Drop	3.8	3	1.5	(1) Round Culvert	At Stream Grade	3.9	3	2.3	None	None	0.25	Comparable	Gravel	Yes	Yes
xy41927997155005	Rogler Farm Rd	Unt to Woonasquatucket Reservoir	<Null>	About Equal	(1) Round Culvert	At Stream Grade	1.8	1.6	1.8	Unknown	<Null>	<Null>	<Null>	<Null>	None	None	Unknown	Unknown	Unknown	Yes	Yes
xy41927997155005	Rogler Farm Rd	Unt to Woonasquatucket Reservoir	<Null>	About Equal	(1) Round Culvert	At Stream Grade	1.8	1.5	1.8	Unknown	<Null>	<Null>	<Null>	<Null>	None	None	Unknown	Unknown	Unknown	Yes	Yes
xy41928037152264	Lydia Ann Rd	Unt to Stillwater Pond	36	About Equal	(3) Open Bottom Arch Bridge / Culvert	Unknown	12	5	12	(3) Open Bottom Arch Bridge / Culvert	At Stream Grade	12	5.7	12	None	Minor	1	Contrasting	Sand	Unknown	Unknown
xy41928037152264	Lydia Ann Rd	Unt to Stillwater Pond	36	About Equal	(3) Open Bottom Arch Bridge / Culvert	At Stream Grade	42.9	8.5	16.7	(3) Open Bottom Arch Bridge / Culvert	At Stream Grade	42.9	8.5	17.3	None	Minor	1	Comparable	Gravel	Yes	Yes
xy41928037152264	Lydia Ann Rd	Unt to Stillwater Pond	36	About Equal	(3) Open Bottom Arch Bridge / Culvert	Inlet Drop	12.1	5.1	12.1	(3) Open Bottom Arch Bridge / Culvert	At Stream Grade	12.1	6.4	12.1	None	Minor	1	Contrasting	Sand	Unknown	Unknown
xy41928267155140	Farnum Pike	Woonasquatucket River	37	About Equal	(6) Box / Bridge with Abutments	At Stream Grade	15	5.3	15	(6) Box / Bridge with Abutments	At Stream Grade	15.2	4.8	15.2	None	None	1	Comparable	Cobble	Yes	Yes
xy41929067155367	Latham Farm Rd	Unt to Woonasquatucket River	111	About Equal	(1) Round Culvert	At Stream Grade	1.9	1.9	1.9	(1) Round Culvert	At Stream Grade	2	1.4	2	None	None	0.75	Comparable	Sand	Yes	No - Slower
xy41929207157455	Log Rd	Unt to Latham Brook	33	About Equal	(1) Round Culvert	At Stream Grade	1	1	0.6	(1) Round Culvert	Cascade	1	1	0.5	0.3	Moderate	None	None	None	No - Shallower	No - Slower
xy41929207157455	Log Rd	Unt to Latham Brook	33	About Equal	(1) Round Culvert	Clogged/Collapsed/Submerged	1	1	1	(1) Round Culvert	At Stream Grade	1	1	1	None	None	Unknown	Unknown	Unknown	Yes	Yes
xy41930757160155	Long Entry Rd	Unnamed Wetland	34	About Equal	(1) Round Culvert	At Stream Grade	1	1	0.2	(1) Round Culvert	At Stream Grade	1	1	0.3	None	Minor	None	None	None	No - Shallower	No - Faster
xy41931447155286	Farnum Pike	Unt to Woonasquatucket River	42	About Equal	(1) Round Culvert	At Stream Grade	2.2	1.6	2.2	(1) Round Culvert	At Stream Grade	2.2	1.6	2.2	None	None	None	None	None	Unknown	Unknown
xy41938517155343	Douglas Pike	Woonasquatucket River	37	About Equal	(6) Box / Bridge with Abutments	At Stream Grade	8	4.8	4.8	(6) Box / Bridge with Abutments	At Stream Grade	8	4.7	8	None	None	1	Comparable	Gravel	Yes	Yes
xy41939037155601	Farnum Pike	Unt to Woonasquatucket River	65	About Equal	(4) Box Culvert	At Stream Grade	3	3.1	3	(4) Box Culvert	Free Fall	3	3	3	0.8	Minor	None	None	None	No - Shallower	No - Faster
xy41943527156049	Douglas Pike	Unt to Woonasquatucket River	<Null>	About Equal	(1) Round Culvert	At Stream Grade	2.1	1.2	2.1	Unknown	<Null>	<Null>	<Null>	<Null>	None	None	None	None	None	Unknown	Unknown
xy41943527156049	Douglas Pike	Unt to Woonasquatucket River	<Null>	About Equal	(1) Round Culvert	At Stream Grade	2.2	1.4	2.2	Unknown	<Null>	<Null>	<Null>	<Null>	None	None	None	None	None	Unknown	Unknown
xy41950277156940	Douglas Pike	Unt to Woonasquatucket River	36	About Equal	(1) Round Culvert	At Stream Grade	1.5	1.5	1.5	(1) Round Culvert	At Stream Grade	1.5	1.3	1.5	None	None	None	None	None	No - Shallower	No - Faster
xy41954007157431	Douglas Pike	Unt to Woonasquatucket River	42	About Equal	(1) Round Culvert	At Stream Grade	1.9	1.6	1.8	(1) Round Culvert	At Stream Grade	2	1	2	None	None	Unknown	Comparable	Muck / Silt	Yes	No - Slower
xy41954667155188	Greenville Rd	Woonasquatucket River	46	About Equal	(1) Round Culvert	At Stream Grade	2	2	2	(1) Round Culvert	At Stream Grade	2	2	2	None	None	Unknown	Unknown	Unknown	Yes	Yes
xy41954667155188	Greenville Rd	Woonasquatucket River	46	About Equal	(1) Round Culvert	At Stream Grade	2	2	2	(1) Round Culvert	At Stream Grade	2	2	2	None	None	Unknown	Unknown	Unknown	Yes	Yes
xy41954727157531	Douglas Pike	Unt	56	About Equal	(1) Round Culvert	At Stream Grade	1.5	1.5	0.8	(1) Round Culvert	At Stream Grade	2.5	2.1	2.5	None	None	None	None	None	No - Deeper	No - Slower
xy41959377156205	Black Plain Rd	Unt to Primrose Pond	40	About Equal	(1) Round Culvert	At Stream Grade	3	3	3	(1) Round Culvert	At Stream Grade	3	3	3	None	Minor	None	None	None	Yes	Yes

Selected Structure Field Data

Crossing Code	Road Name	Stream Name	Structure Length (ft)	Culvert slope compared to channel slope	Inlet Shape	Inlet Grade	Inlet Width (ft)	Inlet Height (ft)	Inlet Substrate/Water Width (ft)	Outlet Shape	Outlet Grade	Outlet Width (ft)	Outlet Height (ft)	Outlet Substrate/Water Width (ft)	Outlet Drop	Physical Barriers	Structure Substrate Coverage	Structure Substrate Matches Stream	Structure Substrate Type	Water Depth Matches Stream Depth	Water Velocity Matches Stream Velocity
xy41959547155800	Pond House Rd	Unt to Primrose Pond	57	<Null>	Unknown	Unknown	<Null>	<Null>	<Null>	(1) Round Culvert	Free Fall	1	1	0.6	0.2	None	Unknown	Unknown	Unknown	Unknown	Unknown
xy41961437156227	Pond House Rd	Unt to Primrose Pond	30	About Equal	(6) Box / Bridge with Abutments	At Stream Grade	5	3	5	(6) Box / Bridge with Abutments	At Stream Grade	<Null>	<Null>	<Null>	None	Severe	1	Comparable	Muck / Silt	Yes	Yes
xy41962007156644	Mattity Rd	Unt to Primrose Pond	31	About Equal	(1) Round Culvert	At Stream Grade	3	3	3	(1) Round Culvert	At Stream Grade	3.3	3.3	1.6	None	Minor	None	None	None	No - Shallower	No - Faster
xy41962407156390	Black Plain Rd	Unt to Primrose Pond	32	About Equal	(6) Box / Bridge with Abutments	At Stream Grade	3	2.75	3	(6) Box / Bridge with Abutments	At Stream Grade	3.5	4.6	3.5	None	Severe	1	Comparable	Sand	No - Shallower	No - Faster
xy41964317155322	Providence Pike	Unt to Woonasquatucket River	49	About Equal	(1) Round Culvert	At Stream Grade	2.2	1.6	2.2	(1) Round Culvert	At Stream Grade	2.1	1.5	2.1	None	None	0.75	Comparable	Muck / Silt	Yes	Yes
xy41972767155740	Providence Pike	Unt to Woonasquatucket River	205	Lower	Unknown	Inlet Drop	3	<Null>	<Null>	(1) Round Culvert	At Stream Grade	2.2	2	1	None	Severe	None	None	None	Yes	Yes

Attachment B

Existing Hydraulic Capacity Assessment Worksheet

Existing and Future Hydraulic Capacity Worksheet

Crossing Code	Road Name	Stream Name	Crossing Hydraulic Capacity @ Failure: Capacity - Structure 1 (cfs)	Capacity - Structure 2 (cfs)	Capacity - Structure 3 (cfs)	Capacity - Structure 4 (cfs)	Total Culvert Capacity (cfs)	Drainage Area (mi^2)	Existing Streamflow Conditions: 10-Year Peak Flood (cfs)	25-Year Peak Flood (cfs)	50-Year Peak Flood (cfs)	100-Year Peak Flood (cfs)	500-Year Peak Flood (cfs)	10-Year Capacity Ratio	25-Year Capacity Ratio	50-Year Capacity Ratio	100-Year Capacity Ratio	Future Streamflow Conditions: 10-Year Peak Flood (cfs)	25-Year Peak Flood (cfs)	50-Year Peak Flood (cfs)	100-Year Peak Flood (cfs)	10-Year Capacity Ratio	25-Year Capacity Ratio	50-Year Capacity Ratio	100-Year Capacity Ratio	Scoring: Binned Hydraulic Capacity Score (1-5)	Future Binned Hydraulic Capacity Score (1-5)	Binned Hydraulic Capacity Change Score (1, 3 or 5)	Existing Tidal Flag
xy41817227144364	Manton Ave	Woonasquatucket River	4675.19				4675.19	47.10	1340	1800	2160	2560	3550	3.49	2.60	2.16	1.83	1608	2160	2592	3072	2.91	2.16	1.80	1.52	1	1	1	0
xy41819437144226	Delaine St	Woonasquatucket River	3095.05				3095.05	48.00	1360	1840	2210	2610	3630	2.28	1.68	1.40	1.19	1632	2208	2652	3132	1.90	1.40	1.17	0.99	1	2	3	0
xy41822527143992	Valley St	Woonasquatucket River	1171.88				1171.88	48.00	1360	1840	2210	2620	3630	0.86	0.64	0.53	0.45	1632	2208	2652	3144	0.72	0.53	0.44	0.37	5	5	1	1
xy41823467146025	Glenbridge Ave	Woonasquatucket River	36666.89				36666.89	46.10	1300	1750	2100	2480	3440	28.21	20.95	17.46	14.79	1560	2100	2520	2976	23.50	17.46	14.55	12.32	1	1	1	0
xy41824557143824	Atwells Ave	Woonasquatucket River	1030.65				1030.65	48.20	1370	1850	2220	2630	3660	0.75	0.56	0.46	0.39	1644	2220	2664	3156	0.63	0.46	0.39	0.33	5	5	1	1
xy41826547143567	Eagle St	Woonasquatucket River	1156.30				1156.30	48.50	1380	1870	2240	2660	3690	0.84	0.62	0.52	0.43	1656	2244	2688	3192	0.70	0.52	0.43	0.36	5	5	1	1
xy41826817141330	N/A: Footbridge	Woonasquatucket River	18131.57				18131.57	50.80	1470	1980	2380	2820	3920	12.33	9.16	7.62	6.43	1764	2376	2856	3384	10.28	7.63	6.35	5.36	1	1	1	1
xy41826927141044	Steeple St	Woonasquatucket River	9876.73	9876.73			19753.47	50.80	1470	1990	2390	2830	3940	13.44	9.93	8.27	6.98	1764	2388	2868	3396	11.20	8.27	6.89	5.82	1	1	1	1
xy41827107141439	N/A: Footbridge	Woonasquatucket River	11932.97	8323.02	12577.45		32833.44	50.70	1460	1970	2370	2810	3910	22.49	16.67	13.85	11.68	1752	2364	2844	3372	18.74	13.89	11.54	9.74	1	1	1	1
xy41827117141226	Exchange St	Woonasquatucket River	28718.13				28718.13	50.80	1470	1980	2380	2820	3920	19.54	14.50	12.07	10.18	1764	2376	2856	3384	16.28	12.09	10.06	8.49	1	1	1	1
xy41827207141547	Francis St	Woonasquatucket River	48724.28				48724.28	50.70	1460	1970	2370	2810	3910	33.37	24.73	20.56	17.34	1752	2364	2844	3372	27.81	20.61	17.13	14.45	1	1	1	1
xy41827747141774	Park St	Woonasquatucket River	10363.94				10363.94	50.70	1460	1970	2370	2810	3910	7.10	5.26	4.37	3.69	1752	2364	2844	3372	5.92	4.38	3.64	3.07	1	1	1	1
xy41828647142862	Acorn St	Woonasquatucket River	1157.01				1157.01	50.40	1450	1960	2350	2790	3880	0.80	0.59	0.49	0.41	1740	2352	2820	3348	0.66	0.49	0.41	0.35	5	5	1	1
xy41829017142325	Promenade St	Woonasquatucket River	13529.04				13529.04	50.50	1450	1960	2360	2790	3880	9.33	6.90	5.73	4.85	1740	2352	2832	3348	7.78	5.75	4.78	4.04	1	1	1	1
xy41829077142660	Dean St	Woonasquatucket River	4220.90				4220.90	50.40	1450	1950	2350	2780	3860	2.91	2.16	1.80	1.52	1740	2340	2820	3336	2.43	1.80	1.50	1.27	1	1	1	1
xy41829207142410	Promenade St	Woonasquatucket River	12361.50				12361.50	50.50	1450	1960	2360	2790	3880	8.53	6.31	5.24	4.43	1740	2352	2832	3348	7.10	5.26	4.36	3.69	1	1	1	1
xy41832947147052	Manson Ave	Dyerville Pond	3894.42				3894.42	44.30	1240	1680	2010	2380	3300	3.14	2.32	1.94	1.64	1488	2016	2412	2856	2.62	1.93	1.61	1.36	1	1	1	0
xy41834977144282	Pleasant Valley Parkway	Unt to Woonasquatucket River	131.54				131.54	0.82	110	162	214	266	417	1.20	0.81	0.61	0.49	132	194	257	319	1.00	0.68	0.51	0.41	4	5	3	0
xy41835427143915	Pleasant Valley Parkway	Unt to Woonasquatucket River	192.97				192.97	1.24	282	420	559	691	1120	0.68	0.46	0.35	0.28	338	504	671	829	0.57	0.38	0.29	0.23	5	5	1	0
xy41836747144463	Pleasant Valley Parkway	Unt to Woonasquatucket River						0.80	107	158	208	259	406	0.00	0.00	0.00	0.00	128	189	250	311	0.00	0.00	0.00	0.00	3	3	1	0
xy41837147148177	Waterman Ave	Unt to Woonasquatucket River	365.69				365.69	0.42	20	28	35	43	61	18.10	12.87	10.32	8.47	24	34	43	52	15.09	10.72	8.60	7.06	1	1	1	0
xy41837797148021	Di Sarro Ave	Unt to Woonasquatucket River	186.48				186.48	0.46	22	31	39	47	66	8.49	6.03	4.84	3.97	26	37	46	56	7.07	5.03	4.03	3.31	1	1	1	0
xy41841257148494	Waterman Ave	Unt to Assapumpset Brook	40.76				40.76	1.15	44	60	74	89	123	0.93	0.68	0.55	0.46	52	72	88	107	0.78	0.56	0.46	0.38	5	5	1	0
xy41842197148400	Diaz St	Unt to Assapumpset Brook	30.93				30.93	1.16	44	61	74	90	124	0.70	0.51	0.42	0.34	53	73	89	108	0.58	0.42	0.35	0.29	5	5	1	0
xy41842937148299	Armento St	Assapumpset Brook	134.60				134.60	1.98	75	104	127	153	211	1.79	1.30	1.06	0.88	90	124	152	184	1.49	1.08	0.89	0.73	2	3	3	0
xy41843377148416	Diaz St	Assapumpset Brook	44.17	44.57			88.74	1.97	75	103	126	152	211	1.19	0.86	0.70	0.58	90	124	151	183	0.99	0.72	0.59	0.49	4	5	3	0
xy41845017150193	Atwood Ave	Unt to Assapumpset Brook	63.40				63.40	0.48	24	33	40	48	67	2.68	1.93	1.59	1.31	28	39	48	58	2.24	1.61	1.32	1.09	1	1	1	0
xy41845257150309	Carpenter Drive	Unt to Assapumpset Brook	23.79				23.79	0.46	23	32	39	47	65	1.04	0.75	0.62	0.51	27	38	46	56	0.87	0.62	0.51	0.42	4	5	3	0
xy41845877148670	George Waterman St	Assapumpset Brook						1.86	70	97	119	143	198	0.00	0.00	0.00	0.00	84	117	142	172	0.00	0.00	0.00	0.00	1	1	1	0
xy41848417149462	Clemence Ln	Assapumpset Brook						1.39	53	73	89	107	148	0.00	0.00	0.00	0.00	63	87	107	129	0.00	0.00	0.00	0.00	1	2	3	0
xy41848877150503	Pine Hill Ave	Assapumpset Brook	53.62				53.62	1.21	46	64	78	94	130	1.17	0.84	0.69	0.57	55	76	93	113	0.97	0.70	0.58	0.48	4	5	3	0
xy41850727148167	Allendale Ave	Woonasquatucket River	6560.27				6560.27	38.70	1080	1450	1740	2060	2850	6.07	4.52	3.77	3.18	1296	1740	2088	2472	5.06	3.77	3.14	2.65	1	1	1	0
xy41853897155040	Winsor Rd	Unt to Slack Reservoir	6.99				6.99	0.32	21	29	36	44	62	0.34	0.24	0.19	0.16	25	35	43	53	0.28	0.20	0.16	0.13	5	5	1	0
xy41853977155807	Winsor Rd	Unt to Slack Reservoir	36.52				36.52	0.15	27	39	50	61	93	1.37	0.94	0.73	0.60	32	47	60	73	1.14	0.78	0.61	0.50	4	4	1	0
xy41855037152232	Greenville Ave	Unt to Assapumpset Brook						0.14	9	13	15	19	26	0.00	0.00	0.00	0.00	11	15	18	22	0.00	0.00	0.00	0.00	5	5	1	0
xy41855187155720	Barden Ln	Unt to Slack Reservoir	15.75				15.75	0.17	40	58	75	91	141	0.40	0.27	0.21	0.17	48	70	90	109	0.33	0.23	0.18	0.14	5	5	1	0
xy41855907154386	Winsor Rd	Unt to Slack Reservoir	39.24				39.24	0.35	17	24	29	35	49	2.28	1.64	1.35	1.11	21	29	35	42	1.90	1.37	1.12	0.93	1	2	3	0
xy41858547156285	Orchard Ave	Unt to Slack Reservoir	62.30				62.30	0.30	13	19	23	28	39	4.65	3.31	2.70	2.21	16	23	28	34	3.87	2.76	2.25	1.84	1	1	1	0
xy41859167148748	Putnam Pike	Woonasquatucket River	7807.18				7807.18	37.70	1050	1410	1690	2000	2770	7.44	5.54	4.62	3.90	1260	1692	2028	2400	6.20	4.61	3.85	3.25	1	1	1	0
xy41859507155898	Roger Williams Drive	Unt to Slack Reservoir	158.15				158.15	0.41	28	39	49	59	84	5.69	4.03	3.26	2.69	33	47	58	71	4.74	3.36	2.72	2.24	1	1	1	0
xy41861407156668	Sheffield Rd	Unt to Slack Reservoir	7.80	17.54			25.34	0.16	40	59	76	93	146	0.64	0.43	0.33	0.27	47	70	91	112	0.53	0.36	0.28	0.23	5	5	1	0
xy41861587154159	Greenville Ave	Unt to Slack Reservoir	19.64				19.64	0.06	10	14	18	22	33	1.95	1.36	1.09	0.90	12	17	22	26	1.63	1.13	0.91	0.75	2	3	3	0
xy41863027154374	Greenville Ave	Unt to Slack Reservoir	41.10	41.10			82.20	0.53	21	29	35	42	58	3.91	2.84	2.35	1.95	25	35	42	51	3.26	2.37	1.96	1.62	1	1	1	0
xy41863507153509	Finne Rd	Unt to Slack Reservoir	23.59				23.59	0.12	24	36	48	59	93	0.98	0.66	0.50	0.40	29	43	57	71	0.82	0.55	0.41	0.33	5	5	1	0
xy41865407149229	Angell Ave	Woonasquatucket River	2745.75				2745.75	37.10	1030	1380	1660	1960	2710	2.67	1.99	1.65	1.40	1236	1656	1992	2352	2.22	1.66	1.38	1.17	1	1	1	0
xy41866427149748	Dean St	Unt to Woonasquatucket River	12.38				12.38	0.34	15	21	26	32	45	0.81	0.58	0.47	0.38	18	26	32	39	0.68	0.48	0.39	0.32	5	5	1	0
xy41866737155823	Smith Ave Extension	Unt to Slack Reservoir	23.54				23.54	0.03	6	9	11	14	21	3.89	2.66	2.08	1.70	7	11	14	17	3.24	2.22	1.74	1.42	1	1	1	0
xy41866907149909	Kenton Drive	Unt to Woonasquatucket River	13.16				13.16	0.26	11	16	20	24	33	1.15	0.82	0.67	0.55	14	19	24	29	0.96	0.68	0.56	0.46	4	5	3	0
xy41866937155857	Smith Ave	Unt to Slack Reservoir	14.83				14.83	0.03	6	9	11	13	20	2.55	1.74	1.36	1.11	7	10	13	16	2.12	1.45	1.14	0.93	1	2	3	0
xy41867357150081	Mowry Ave	Unt to Woonasquatucket	8.39	4.30			12.69	0.23	10	15	18	22	30	1.21	0.87	0.70	0.58	13	18	22	26	1.01	0.72	0.59	0.48	4	4	1	0
xy41867767150198	Susan Drive	Unt to Woonasquatucket River	21.51				21.51	0.20	9	13	16	19	27	2.36	1.68	1.37	1.12	11	15	19	23	1.97	1.40	1.14	0.93	1	2	3	0
xy41867937149613	Riverside Ave	Unt to Woonasquatucket River	8.14	9.36	3.65		21.15	0.36	25	35	43	52	74	0.86	0.61	0.49	0.41	29	42	51	62	0.72	0.51	0.41	0.34	5	5	1	0
xy41868517157685	West Greenville Rd	Unt	2.25				2.25	0.04	18	27	35	43	69	0.13	0.08	0.06	0.05	21	32	42	51	0.11	0.07	0.05	0.04	5	5	1	0
xy41869227150721	Esmond St	Unt to Woonasquatucket River	45.39				45.39	0.01	1	1	1	1	1	89.09	64.12	52.66	43.53	1	1	1	1	74.24	53.43	43.88	36.28	1	1	1	0
xy41869837155412	Smith Ave	Unt to Slack Reservoir	11.55				11.55	0.10	6	9	11	13	18	1.82	1.30	1.07	0.89	8	11	13	16	1.52	1.08	0.89	0.74	2	3	3	0
xy41870167152512	Putnam Pike	Unt to Hawkins Brook	79.82				79.82	0.07	3	4	5	6	9	26.25	18.71	15.23	12.47	4	5	6	8	21.87	15.59	12.69	10.39	1	1	1	0
xy41870207153556	Putnam Pike	Reaper Brook	49.56				49.56	1.36	52	71	87	105	145	0.96	0.70	0.57	0.47	62	85	104	126	0.80	0.58	0.48	0.39	5	5	1	0
xy41871207155179	Putnam Pike	Slack Reservoir Outflow	101.73				101.73	1.89	45	62	75	90	121	2.24	1.65	1.36	1.13	54	74	90	108	1.87	1.37	1.13	0.94	1	2	3	0
xy41871637157756	West Greenville Rd	Waterman Reservoir	739.12				739.12	0.24	34	49	61	73	108	21.62	15.12	12.16	10.06	41	59	73	88	18.02	12.60	10.13	8.38	1	1	1	0
xy41871997158854	Aldrich Rd	Unt to Waterman Reservoir	29.21				29.21	0.05	5	7	9	11	15	5.80	4.09	3.32	2.73	6	9	11	13	4.83	3.40	2.77	2.27	1	1	1	0
xy41872697150528	Esmond St	Hawkins Brook	115.56	115.56			231.12	1.02	89	126	156	188	274	2.59	1.83	1.48	1.23	107	151	187	226	2.16	1.53	1.23	1.02	1	1	1	0
xy41872937157686	West Greenville Rd	Unt	15.15				15.15	0.01	0	0	0	1	1	56.04	40.35	33.07	27.36	0	0	1	1	46.70	33.62	27.56	22.80	1	1	1	0
xy41873167150365	Julien St	Hawkins Brook	33.87				33.87	1.03	93	131	162	196	286	0.37	0.26	0.21	0.17	111	157	194	235	0.30	0.22	0.17	0.14	5	5	1	0
xy41873187150300	Dean St	Hawkins Brook	227.43	227.43			454.86	1.05	96	136	168	203	296	4.74	3.34	2.71	2.24	115	163	202	244	3.95	2.79	2.26	1.87	1	1	1	0
xy41873637149711	Esmond Mill Drive	Woonasquatucket River	1308.42				1308.42	34.70	948	1280	1530	1810	2490	1.38	1.02	0.86	0.72	1138	1536	1836	2172	1.15	0.85	0.71	0.60	3	4	3	0
xy41874287154980	Pleasant View Circle	Unt to Stillwater River	77.05				77.05	1.96	49	67	81	98	132	1.56	1.15	0.95	0.79	59	81	97	117	1.30	0.96	0.79	0.66	3	4	3	0
xy41874767155492	Austin Ave	Stillwater River	133.30	82.35			215.65	8.69	312	424	511	609	844	0.69	0.51	0.42	0.35	374	509	613	731	0.58	0.42	0.35	0.30	5	5	1	0

Gray boxes indicate missing data. Yellow boxes indicate assumptions that were made to compensate for missing data. See Pilot Study and Digitial Database for details regarding assumptions.

Existing and Future Hydraulic Capacity Worksheet

Crossing Code	Road Name	Stream Name	Crossing Hydraulic Capacity @ Failure: Capacity - Structure 1 (cfs)	Capacity - Structure 2 (cfs)	Capacity - Structure 3 (cfs)	Capacity - Structure 4 (cfs)	Total Culvert Capacity (cfs)	Drainage Area (mi^2)	Existing Streamflow Conditions: 10-Year Peak Flood (cfs)	25-Year Peak Flood (cfs)	50-Year Peak Flood (cfs)	100-Year Peak Flood (cfs)	500-Year Peak Flood (cfs)	10-Year Capacity Ratio	25-Year Capacity Ratio	50-Year Capacity Ratio	100-Year Capacity Ratio	Future Streamflow Conditions: 10-Year Peak Flood (cfs)	25-Year Peak Flood (cfs)	50-Year Peak Flood (cfs)	100-Year Peak Flood (cfs)	10-Year Capacity Ratio	25-Year Capacity Ratio	50-Year Capacity Ratio	100-Year Capacity Ratio	Scoring: Binned Hydraulic Capacity Score (1-5)	Future Binned Hydraulic Capacity Score (1-5)	Binned Hydraulic Capacity Change Score (1, 3 or 5)	Existing Tidal Flag
xy41875437157379	West Greenville Ave	Unt to Waterman Reservoir	152.99				152.99	0.14	5	7	9	11	15	28.69	20.78	17.02	14.07	6	9	11	13	23.91	17.32	14.19	11.73	1	1	1	0
xy41875777159319	Old Quarry Rd	Unt to Waterman Reservoir	82.85				82.85	0.14	61	90	115	139	222	1.36	0.92	0.72	0.60	73	108	138	167	1.13	0.77	0.60	0.50	4	4	1	0
xy41877147159409	Old Quarry Rd	Unt to Waterman Reservoir	95.47				95.47	0.39	62	89	112	135	204	1.54	1.07	0.85	0.71	74	107	134	162	1.28	0.89	0.71	0.59	3	4	3	0
xy41877287153708	Cedar Swamp Road	Reaper Brook	132.60				132.60	1.78	56	77	93	113	154	2.37	1.73	1.42	1.17	67	92	112	136	1.98	1.44	1.18	0.98	1	2	3	0
xy41877397157132	West Greenville Rd	Stillwater River	306.75				306.75	8.15	285	387	466	555	768	1.08	0.79	0.66	0.55	342	464	559	666	0.90	0.66	0.55	0.46	4	5	3	0
xy41877427157059	Putnam Pike	Stillwater Brook	842.71				842.71	8.16	285	388	467	556	768	2.96	2.17	1.80	1.52	342	466	560	667	2.46	1.81	1.50	1.26	1	1	1	0
xy41877557154924	Deerfield Drive	Stillwater River	174.97	178.99			353.96	10.80	347	471	566	674	929	1.02	0.75	0.63	0.53	416	565	679	809	0.85	0.63	0.52	0.44	4	5	3	0
xy41878177153571	Walter Carey Road	Unt to Mountaindale Reservoir	7.21				7.21	0.04	2	3	4	5	7	3.12	2.23	1.82	1.50	3	4	5	6	2.60	1.86	1.51	1.25	1	1	1	0
xy41878417150154	Esmond St	Woonasquatucket River	10599.29				10599.29	34.40	936	1260	1510	1790	2460	11.32	8.41	7.02	5.92	1123	1512	1812	2148	9.44	7.01	5.85	4.93	1	1	1	0
xy41878707160132	Sawmill Rd	Unt to Waterman Reservoir	25.07				25.07	0.19	26	37	48	59	89	0.98	0.67	0.52	0.43	31	45	57	70	0.81	0.56	0.44	0.36	5	5	1	0
xy41878737152022	Mountaindale Rd	Unt to Hawkins Brook	12.70				12.70	0.08	36	54	70	86	141	0.36	0.24	0.18	0.15	43	65	84	104	0.30	0.20	0.15	0.12	5	5	1	0
xy41880727150256	Farnum Pike	Woonasquatucket River	9169.53				9169.53	34.40	933	1260	1500	1780	2460	9.83	7.28	6.11	5.15	1120	1512	1800	2136	8.19	6.06	5.09	4.29	1	1	1	0
xy41880887157821	Putnam Pike	Waterman Reservoir	65.74				65.74	0.20	94	141	185	227	370	0.70	0.46	0.36	0.29	113	170	222	273	0.58	0.39	0.30	0.24	5	5	1	0
xy41881987151110	Old Country Rd	Unt to Woonasquatucket River	172.30				172.30	0.22	31	44	55	66	97	5.61	3.92	3.16	2.61	37	53	66	79	4.68	3.27	2.63	2.18	1	1	1	0
xy41883167160369	Melody Hill Ln	Unt to Waterman Reservoir	2.77	2.73			5.50	0.01	3	4	5	6	9	2.17	1.48	1.16	0.95	3	4	6	7	1.81	1.24	0.97	0.79	2	3	3	0
xy41883307160203	Sawmill Rd	Unt to Waterman Reservoir	2.20				2.20	0.03	5	7	9	11	17	0.45	0.31	0.24	0.20	6	9	11	13	0.38	0.26	0.20	0.16	5	5	1	0
xy41883627158219	Putnam Pike	Nine Foot Brook	294.32				294.32	3.95	162	221	267	319	442	1.82	1.33	1.10	0.92	194	265	320	383	1.51	1.11	0.92	0.77	2	3	3	0
xy41883977158247	Austin Ave	Nine Foot Brook	150.44				150.44	3.95	162	221	267	319	442	0.93	0.68	0.56	0.47	194	265	320	383	0.77	0.57	0.47	0.39	5	5	1	0
xy41883977159943	Waterman Lake Drive	Unt to Cutler Brook	30.43	30.21			60.64	0.13	26	38	48	59	89	2.33	1.60	1.26	1.03	31	46	58	70	1.94	1.33	1.05	0.86	1	2	3	0
xy41884477150737	Farnum Pike	Unt to Woonasquatucket River						0.29	48	69	86	104	156	0.00	0.00	0.00	0.00	58	83	104	125	0.00	0.00	0.00	0.00	4	4	1	0
xy41884487160015	Sawmill Rd	Cutler Brook	366.61				366.61	1.21	192	276	346	417	631	1.91	1.33	1.06	0.88	230	331	415	500	1.59	1.11	0.88	0.73	2	3	3	0
xy41884547154339	Indian Run Rd	Unt to Stillwater River	73.65	73.88	38.75	71.48	257.76	1.40	99	140	172	208	297	2.59	1.84	1.50	1.24	119	168	207	250	2.16	1.54	1.25	1.03	1	1	1	0
xy41884807157218	Austin Ave	Unt to Waterman Reservoir						0.05	8	11	14	17	26	0.00	0.00	0.00	0.00	9	14	17	21	0.00	0.00	0.00	0.00	3	3	3	0
xy41884937158168	Stone Bridge Rd	Unt to Nine Foot Brook						0.01	1	2	3	4	6	0.00	0.00	0.00	0.00	2	3	3	4	0.00	0.00	0.00	0.00	3	3	3	0
xy41885067154130	Pleasant View Ave	Stillwater River	314.85				314.85	12.80	408	553	665	791	1090	0.77	0.57	0.47	0.40	490	664	798	949	0.64	0.47	0.39	0.33	5	5	1	0
xy41885087157849	Austin Avenue	Unt to Waterman Reservoir	3.50				3.50	0.15	27	39	50	62	94	0.13	0.09	0.07	0.06	32	47	60	74	0.11	0.07	0.06	0.05	5	5	1	0
xy41885967155678	Baldwin Circle	Unt to Stillwater River						0.23	10	14	17	21	30	0.00	0.00	0.00	0.00	12	17	21	26	0.00	0.00	0.00	0.00	5	5	1	0
xy41886157153645	Mountaindale Road	Reaper Brook	372.11				372.11	2.13	63	86	105	126	172	5.92	4.32	3.54	2.95	75	103	126	151	4.93	3.60	2.95	2.46	1	1	1	0
xy41886477153705	Mountaindale Road	Unnamed Wetland adjacent to Reaper Brook	12.30				12.30	0.02	2	2	3	3	4	7.96	5.68	4.68	3.87	2	3	3	4	6.63	4.73	3.90	3.22	1	1	1	0
xy41886617150419	Fenwood Ave	Unt to Woonasquatucket River	47.31	47.57	49.18		144.06	0.72	51	72	89	107	153	2.82	2.00	1.63	1.35	61	86	106	128	2.35	1.67	1.35	1.12	1	1	1	0
xy41886847150523	Whipple Ave	Woonasquatucket River	2245.29				2245.29	33.10	883	1190	1420	1690	2320	2.54	1.89	1.58	1.33	1060	1428	1704	2028	2.12	1.57	1.32	1.11	1	1	1	0
xy41886917159166	Putnam Pike	Unt to Waterman Reservoir	49.37				49.37	0.19	94	141	185	227	372	0.53	0.35	0.27	0.22	112	169	222	272	0.44	0.29	0.22	0.18	5	5	1	0
xy41887077159144	Valley Rd	Unt to Waterman Reservoir	98.88				98.88	0.18	84	127	166	204	332	1.17	0.78	0.60	0.48	101	152	199	245	0.98	0.65	0.50	0.40	4	5	3	0
xy41888247153923	Mountaindale Road	Stillwater River	234.88	318.43			553.31	12.90	412	558	671	798	1100	1.34	0.99	0.82	0.69	494	670	805	958	1.12	0.83	0.69	0.58	4	4	1	0
xy41888657151262	Farnum Pike	Unt to Georgiaville Pond	17.62	17.58			35.20	0.16	26	38	47	57	85	1.34	0.93	0.75	0.62	32	45	57	68	1.11	0.77	0.62	0.52	4	4	1	0
xy41888837151740	Old County Rd	Unt to Georgiaville Pond	11.72				11.72	0.11	56	85	111	136	224	0.21	0.14	0.11	0.09	68	102	133	164	0.17	0.12	0.09	0.07	5	5	1	0
xy41889357148731	Whipple Rd	Unt to Woonasquatucket River	25.16				25.16	0.03	4	6	8	9	14	5.80	4.05	3.26	2.70	5	7	9	11	4.83	3.38	2.72	2.25	1	1	1	0
xy41890377149584	Ridge Rd	Unt to Woonasquatucket River	19.79				19.79	0.56	31	44	54	65	92	0.63	0.45	0.37	0.30	38	53	65	78	0.53	0.38	0.31	0.25	5	5	1	0
xy41890427151403	Sweet Rd	Unt to Georgiaville Pond	6.43	2.89			9.32	0.15	25	36	45	54	81	0.37	0.26	0.21	0.17	30	43	54	64	0.31	0.22	0.17	0.14	5	5	1	0
xy41890897156959	Colwell Rd	Unt to Upper Sprague Reservoir	9.78				9.78	0.07	5	6	8	9	13	2.16	1.54	1.27	1.05	5	8	9	11	1.80	1.28	1.06	0.87	1	2	3	0
xy41890917151543	Farnum Pike	Unt to Georgiaville Pond						0.14	23	34	42	50	76	0.00	0.00	0.00	0.00	28	40	50	61	0.00	0.00	0.00	0.00	5	5	1	0
xy41892467149331	Douglas Pike	Unt to Woonasquatucket River	11.99	1.69			13.68	0.41	20	28	34	42	58	0.67	0.48	0.40	0.33	24	34	41	50	0.56	0.40	0.33	0.27	5	5	1	0
xy41892547150396	Crest Drive	Unt to Woonasquatucket River	55.73	57.03	43.53		156.29	0.02	5	8	10	12	18	30.16	20.64	16.45	13.58	6	9	11	14	25.14	17.20	13.71	11.32	1	1	1	0
xy41893077160835	Route 44	Cutler Brook	412.62				412.62	0.49	54	77	96	117	171	7.60	5.33	4.28	3.53	65	93	116	140	6.33	4.44	3.57	2.94	1	1	1	0
xy41893317160808	Farnum Road	Cutler Brook	111.01				111.01	0.48	53	75	93	113	165	2.11	1.48	1.19	0.98	63	90	112	136	1.76	1.24	0.99	0.82	2	3	3	0
xy41894747150725	Stillwater Rd	Unt to Georgiaville Pond	86.80	87.45			174.25	1.12	270	393	498	600	936	0.65	0.44	0.35	0.29	324	472	598	720	0.54	0.37	0.29	0.24	5	5	1	0
xy41894887152164	Farnum Pike	Unt to Georgiaville Pond						0.27	105	155	197	239	378	0.00	0.00	0.00	0.00	126	186	236	287	0.00	0.00	0.00	0.00	2	3	3	0
xy41895577161365	Route 44 Putnam Pike	Unt to Cutler Brook	9.33				9.33	0.07	13	20	25	31	46	0.70	0.48	0.37	0.31	16	24	30	37	0.58	0.40	0.31	0.25	5	5	1	0
xy41896047161805	Route 44	Unti to Cutler Brook	42.43				42.43	0.02	1	2	3	3	4	29.22	20.72	16.75	13.82	2	2	3	4	24.35	17.27	13.96	11.51	1	1	1	0
xy41896637160262	Farnum Rd	Unt to Waterman Reservoir	12.77				12.77	0.04	2	3	4	5	7	5.50	3.93	3.22	2.65	3	4	5	6	4.59	3.27	2.69	2.21	1	1	1	0
xy41896697151958	Old county Rd/Lakeside Drive	Unt to Georgiaville Pond	2.29				2.29	0.34	146	215	275	333	532	0.02	0.01	0.01	0.01	175	258	330	400	0.01	0.01	0.01	0.01	5	5	1	0
xy41897187150342	Ridge Rd	Unt to Georgiaville Pond	89.28				89.28	1.08	244	353	448	540	838	0.37	0.25	0.20	0.17	293	424	538	648	0.30	0.21	0.17	0.14	5	5	1	0
xy41897827156647	Colwell Rd	Unt to Upper Sprague Reservoir						0.02	2	3	4	5	7	0.00	0.00	0.00	0.00	3	4	5	6	0.00	0.00	0.00	0.00	4	5	3	0
xy41898117157880	Evan's Rd	Nine Foot Brook	31.23				31.23	2.07	80	110	133	159	220	0.39	0.28	0.23	0.20	96	132	160	191	0.33	0.24	0.20	0.16	5	5	1	0
xy41898457158358	Burlingame Ln	Unt to Nine Foot Brook	0.85				0.85	0.04	3	4	5	6	8	0.31	0.22	0.18	0.15	3	5	6	7	0.26	0.19	0.15	0.13	5	5	1	0
xy41898477158323	Burlingame Ln	Unt to Nine Foot Brook	4.00				4.00	0.23	16	22	27	33	45	0.25	0.18	0.15	0.12	19	27	32	39	0.21	0.15	0.12	0.10	5	5	1	0
xy41898517157816	Tarkiln Rd	Unt to Nine Foot Brook	14.30	4.18			18.48	0.25	12	17	21	25	35	1.49	1.08	0.88	0.73	15	21	25	30	1.25	0.90	0.74	0.61	3	4	3	0
xy41898907154304	Pleasantview Ave	Woonasquatucket Reservoir	2943.79				2943.79	15.50	455	616	739	879	1210	6.47	4.78	3.98	3.35	546	739	887	1055	5.39	3.98	3.32	2.79	1	1	1	0
xy41898957150991	Stillwater Rd	Harris Brook	587.68				587.68	1.90	101	140	171	206	292	5.82	4.20	3.44	2.85	121	168	205	247	4.85	3.50	2.86	2.38	1	1	1	0
xy41899117154630	Log Rd	Woonasquatucket Reservoir	7.53				7.53	0.45	58	83	103	125	185	0.13	0.09	0.07	0.06	69	99	124	150	0.11	0.08	0.06	0.05	5	5	1	0
xy41899147150128	Douglas Pike	Unt to Georgiaville Pond	178.54				178.54	1.06	255	370	470	568	885	0.70	0.48	0.38	0.31	306	444	564	682	0.58	0.40	0.32	0.26	5	5	1	0
xy41899277156654	Colwell Rd	Unt to Upper Sprague Reservoir	7.00				7.00	0.09	18	26	33	40	61	0.40	0.27	0.21	0.17	21	31	39	48	0.33	0.23	0.18	0.14	5	5	1	0
xy41900117158371	Evans Rd	Unt to Shinscot Brook	53.74				53.74	0.17	11	15	18	22	31	4.98	3.56	2.94	2.44	13	18	22	26	4.15	2.97	2.45	2.04	1	1	1	0
xy41900437149662	Catherine Rd	Unt to West River	49.94				49.94	0.52	29	41	50	60	85	1.72	1.23	1.00	0.83	35	49	60	73	1.43	1.02	0.83	0.69	2	3	3	0
xy41902037159401	Farnum road	Shinscot Brook	61.98				61.98	0.54	34	48	59	72	102	1.80	1.29	1.04	0.86	41	58	71	86	1.50	1.07	0.87	0.72	2	3	3	0
xy41902517157773	Tarkiln Rd	Unt to Nine Foot Brook	7.17				7.17	0.02	2	4	4	5	8	2.92	2.05	1.64	1.36	3	4	5	6	2.44	1.70	1.37	1.13	1	1	1	0
xy41902577149498	Maureen Drive	Unt to West River						0.44	25	35	42	51	72	0.00	0.00	0.00	0.00	30	41	51	62	0.00	0.00	0.00	0.00	5	5	1	0

Gray boxes indicate missing data. Yellow boxes indicate assumptions that were made to compensate for missing data. See Pilot Study and Digitial Database for details regarding assumptions.

Existing and Future Hydraulic Capacity Worksheet

Crossing Code	Road Name	Stream Name	Crossing Hydraulic Capacity @ Failure: Capacity - Structure 1 (cfs)	Capacity - Structure 2 (cfs)	Capacity - Structure 3 (cfs)	Capacity - Structure 4 (cfs)	Total Culvert Capacity (cfs)	Drainage Area (mi²)	Existing Streamflow Conditions: 10-Year Peak Flood (cfs)	25-Year Peak Flood (cfs)	50-Year Peak Flood (cfs)	100-Year Peak Flood (cfs)	500-Year Peak Flood (cfs)	10-Year Capacity Ratio	25-Year Capacity Ratio	50-Year Capacity Ratio	100-Year Capacity Ratio	Future Streamflow Conditions: 10-Year Peak Flood (cfs)	25-Year Peak Flood (cfs)	50-Year Peak Flood (cfs)	100-Year Peak Flood (cfs)	10-Year Capacity Ratio	25-Year Capacity Ratio	50-Year Capacity Ratio	100-Year Capacity Ratio	Scoring: Binned Hydraulic Capacity Score (1-5)	Future Binned Hydraulic Capacity Score (1-5)	Binned Hydraulic Capacity Change Score (1, 3 or 5)	Existing Tidal Flag
xy41902587151720	Stillwater Rd	Unt to Georgiaville Pond	65.68	66.95			132.63	0.08	4	5	6	7	10	36.34	26.17	21.45	17.74	4	6	7	9	30.29	21.81	17.87	14.78	1	1	1	0
xy41902697157007	Mann School Rd	Unt to Upper Sprague Reservoir	8.56	8.56			17.12	0.06	15	22	28	35	53	1.13	0.77	0.60	0.49	18	27	34	42	0.94	0.64	0.50	0.41	4	5	3	0
xy41902757152161	Capron Rd	Capron Pond	3199.94				3199.94	28.40	722	971	1160	1380	1890	4.43	3.30	2.76	2.32	866	1165	1392	1656	3.69	2.75	2.30	1.93	1	1	1	0
xy41902757159093	Farnum Rd	Unt	16.93				16.93	0.48	20	27	33	40	54	0.86	0.62	0.51	0.43	24	33	39	47	0.72	0.52	0.43	0.36	5	5	1	0
xy41902877150377	Limerock Rd	Unt to Harris Brook	15.44	9.84			25.28	0.29	70	102	128	155	239	0.36	0.25	0.20	0.16	84	122	154	186	0.30	0.21	0.16	0.14	5	5	1	0
xy41904317158874	Evans road	Unt	7.78				7.78	0.02	1	1	2	2	3	8.06	5.75	4.72	3.88	1	2	2	2	6.72	4.79	3.93	3.23	1	1	1	0
xy41904937156221	Connors Farm Drive	Unt	169.66				169.66	0.03	5	7	9	11	17	33.13	23.05	18.48	15.36	6	9	11	13	27.61	19.20	15.40	12.80	1	1	1	0
xy41905587149206	Clark Rd	Unt to West River	12.45	11.86			24.31	0.21	10	14	18	21	30	2.34	1.68	1.38	1.14	12	17	21	26	1.95	1.40	1.15	0.95	1	2	3	0
xy41906217161244	Cooper Ave	Cutler Brook	4.71				4.71	0.09	5	7	8	10	14	0.98	0.70	0.57	0.47	6	8	10	12	0.82	0.58	0.48	0.39	5	5	1	0
xy41908317153647	George Washington Highway	Woonasquatucket River	46094.70				46094.70	25.40	643	864	1040	1230	1680	71.69	53.35	44.32	37.48	772	1037	1248	1476	59.74	44.46	36.93	31.23	1	1	1	0
xy41908677154068	Farnum Pike	Woonasquatucket River						25.00	627	844	1010	1200	1640	0.00	0.00	0.00	0.00	752	1013	1212	1440	0.00	0.00	0.00	0.00	1	1	1	0
xy41909167152497	Stillwater Rd	Unt to Stillwater Pond	97.71				97.71	0.30	14	20	24	30	41	6.79	4.89	4.00	3.31	17	24	29	35	5.65	4.07	3.34	2.76	1	1	1	0
xy41910887152828	Stillwater Rd	Unt to Stillwater Pond	97.86	80.95			178.81	2.14	85	118	143	171	237	2.09	1.52	1.25	1.05	102	142	172	205	1.74	1.26	1.04	0.87	1	2	3	0
xy41912007159704	Evans Rd	Unamed to Shinscot Brook	48.04				48.04	0.29	18	26	32	38	55	2.61	1.86	1.51	1.25	22	31	38	46	2.18	1.55	1.26	1.04	1	1	1	0
xy41912687150232	Harris Rd	Unt to Harris Brook	46.11	48.99			95.10	0.56	27	38	47	57	81	3.55	2.52	2.02	1.66	32	45	56	69	2.96	2.10	1.69	1.38	1	1	1	0
xy41913457152883	George Washington Highway	Unt to Stillwater Pond	10.03	399.05			409.08	1.94	72	99	120	145	199	5.66	4.12	3.41	2.82	87	119	144	174	4.72	3.43	2.84	2.35	1	1	1	0
xy41913477151701	Douglas Pike	Unt to Stillwater Pond	58.39				58.39	0.13	22	32	40	48	72	2.62	1.82	1.46	1.21	27	38	48	58	2.18	1.52	1.22	1.01	1	1	1	0
xy41914027155460	Log Rd	Woonasquatucket Reservoir	76.31				76.31	2.69	104	143	173	207	286	0.73	0.53	0.44	0.37	125	172	208	248	0.61	0.44	0.37	0.31	5	5	1	0
xy41914137156217	Burlingame Rd	Unt to Woonasquatucket Reservoir	56.91	56.02			112.93	0.08	16	23	29	36	54	7.10	4.87	3.84	3.15	19	28	35	43	5.92	4.06	3.20	2.63	1	1	1	0
xy41914227154859	Industrial Rd S.	Unt to Woonasquatucket Reservoir	37.35				37.35	0.31	42	61	78	95	144	0.90	0.62	0.48	0.39	50	73	93	114	0.75	0.51	0.40	0.33	5	5	1	0
xy41914627152630	George Washington Highway	Unt to Stillwater Pond	12.23				12.23	0.05	3	4	5	6	8	4.43	3.16	2.58	2.13	3	5	6	7	3.69	2.63	2.15	1.78	1	1	1	0
xy41916527154817	Industrial Drive	Unt to Woonasquatucket Reservoir	34.41				34.41	0.08	10	15	19	23	33	3.29	2.30	1.85	1.53	13	18	22	27	2.74	1.92	1.54	1.27	1	1	1	0
xy41916957158201	Tarkiln Rd	Unt to Nine Foot Brook	16.29				16.29	0.28	31	44	54	66	97	0.53	0.37	0.30	0.25	37	52	65	79	0.44	0.31	0.25	0.21	5	5	1	0
xy41918867152209	Douglas Pike	Unt to Stillwater Pond	27.47	27.32			54.79	0.35	14	20	24	29	40	3.78	2.74	2.27	1.89	17	24	29	35	3.15	2.28	1.89	1.57	1	1	1	0
xy41920067155939	Burlingame Rd	Latham Brook	113.23				113.23	1.76	59	80	97	116	158	1.93	1.41	1.17	0.98	70	96	116	139	1.61	1.18	0.98	0.81	2	3	3	0
xy41920097155278	Old Forge Rd	Woonasquatucket River	221.31				221.31	4.95	108	147	179	216	293	2.05	1.51	1.24	1.02	130	176	215	259	1.71	1.25	1.03	0.85	1	2	3	0
xy41920937158733	Tarkiln Rd	Unt to Nine Foot Brook	9.37				9.37	0.16	25	36	45	55	83	0.38	0.26	0.21	0.17	30	43	54	66	0.32	0.22	0.17	0.14	5	5	1	0
xy41921057155828	Log Rd	Unt to Latham Brook	10.46	10.37			20.83	0.06	12	18	23	27	41	1.71	1.17	0.92	0.76	15	21	27	33	1.43	0.98	0.77	0.63	3	4	3	0
xy41922257156115	Log Rd	Latham Brook	55.36	50.71			106.07	1.70	55	76	91	109	149	1.91	1.40	1.16	0.97	66	91	109	131	1.60	1.17	0.97	0.81	2	3	3	0
xy41923277152886	Douglas Pike	Unt to Stillwater Reservoir	74.72				74.72	0.80	22	30	36	44	58	3.38	2.48	2.06	1.71	27	36	43	52	2.82	2.07	1.72	1.43	1	1	1	0
xy41923437156751	Bayberry Rd	Latham Brook	41.50				41.50	1.32	35	47	57	68	92	1.20	0.88	0.73	0.61	42	57	68	82	1.00	0.73	0.61	0.51	4	5	3	0
xy41923797156391	Log Rd	Latham Brook	112.08				112.08	1.40	38	52	63	76	102	2.93	2.15	1.78	1.48	46	63	75	91	2.44	1.79	1.49	1.24	1	1	1	0
xy41924017152999	Douglas Pike	Unt to Stillwater Reservoir	19.19				19.19	0.09	4	6	7	9	12	4.45	3.20	2.62	2.17	5	7	9	11	3.70	2.67	2.19	1.81	1	1	1	0
xy41924467152624	Essex St	Unt to Stillwater Pond	10244.01				10244.01	0.60	17	23	27	33	44	615.04	451.57	375.48	311.75	20	27	33	39	512.53	376.31	312.90	259.79	1	1	1	0
xy41924627153417	Bryant U. entryway off of Douglas Pike	Unt to Stillwater Pond	185.75				185.75	0.52	58	83	103	124	182	3.20	2.25	1.80	1.50	70	99	124	149	2.66	1.87	1.50	1.25	1	1	1	0
xy41926177155080	Farnum Pike	Unt to Woonasquatucket River	2.35				2.35	0.02	1	2	2	2	3	1.96	1.40	1.16	0.95	1	2	2	3	1.64	1.17	0.96	0.80	2	3	3	0
xy41926517153403	Douglas Pike	Unt to Stillwater Pond	96.72				96.72	0.49	51	73	91	110	160	1.89	1.33	1.07	0.88	62	87	109	132	1.57	1.11	0.89	0.73	2	3	3	0
xy41926627152983	Essex St	Unt to Stillwater Pond	41.47				41.47	0.05	2	3	4	4	6	18.92	13.62	11.17	9.24	3	4	4	5	15.77	11.35	9.31	7.70	1	1	1	0
xy41927997155005	Rogler Farm Rd	Unt to Woonasquatucket Reservoir	21.01	21.01			42.02	0.02	1	2	3	3	4	28.10	19.95	16.15	13.29	2	3	3	4	23.42	16.63	13.46	11.07	1	1	1	0
xy41928037152264	Lydia Ann Rd	Unt to Stillwater Pond	842.64				842.64	0.54	15	20	24	29	39	56.92	41.79	34.75	28.85	18	24	29	35	47.43	34.83	28.96	24.04	1	1	1	0
xy41928267155140	Farnum Pike	Woonasquatucket River	551.14	3545.10	1017.85		5114.08	4.72	96	131	159	192	260	53.05	39.04	32.16	26.64	116	157	191	230	44.21	32.53	26.80	22.20	1	1	1	0
xy41929067155367	Latham Farm Rd	Unt to Woonasquatucket River	38.90				38.90	0.03	6	9	11	13	20	6.50	4.45	3.51	2.88	7	10	13	16	5.41	3.71	2.93	2.40	1	1	1	0
xy41929207157455	Log Rd	Unt to Latham Brook	5.46	5.41			10.87	0.61	8	10	12	15	19	1.44	1.07	0.89	0.73	9	12	15	18	1.20	0.89	0.74	0.61	3	4	3	0
xy41930757160155	Long Entry Rd	Unnamed Wetland	2.37				2.37	0.05	9	14	17	21	32	0.25	0.17	0.14	0.11	11	16	21	26	0.21	0.14	0.11	0.09	5	5	1	0
xy41931447155286	Farnum Pike	Unt to Woonasquatucket River	11.49				11.49	0.04	7	10	13	16	24	1.62	1.11	0.88	0.72	9	12	16	19	1.35	0.92	0.73	0.60	3	4	3	0
xy41938517155343	Douglas Pike	Woonasquatucket River	287.80				287.80	3.71	62	84	102	123	165	4.66	3.43	2.82	2.34	74	101	122	148	3.88	2.86	2.35	1.95	1	1	1	0
xy41939037155601	Farnum Pike	Unt to Woonasquatucket River	126.78				126.78	0.46	77	111	140	170	258	1.66	1.14	0.91	0.75	92	133	168	204	1.38	0.95	0.75	0.62	3	4	3	0
xy41943527156049	Douglas Pike	Unt to Woonasquatucket River						0.02	3	5	6	7	11	0.00	0.00	0.00	0.00	4	6	7	9	0.00	0.00	0.00	0.00	1	2	3	0
xy41950277156940	Douglas Pike	Unt to Woonasquatucket River	7.36				7.36	0.06	11	17	21	26	39	0.65	0.44	0.35	0.29	14	20	25	31	0.54	0.37	0.29	0.24	5	5	1	0
xy41954007157431	Douglas Pike	Unt to Woonasquatucket River	7.92				7.92	0.01	1	1	2	2	3	8.18	5.62	4.39	3.58	1	2	2	3	6.81	4.68	3.66	2.98	1	1	1	0
xy41954667155188	Greenville Rd	Woonasquatucket River	35.53	35.43			70.96	0.61	17	23	28	33	44	4.21	3.09	2.57	2.14	20	28	33	40	3.51	2.58	2.14	1.78	1	1	1	0
xy41954727157531	Douglas Pike	Unt	18.18				18.18	0.13	27	39	49	60	91	0.68	0.47	0.37	0.30	32	47	59	72	0.57	0.39	0.31	0.25	5	5	1	0
xy41959377156205	Black Plain Rd	Unt to Primrose Pond	48.45				48.45	0.45	29	41	51	62	88	1.66	1.18	0.95	0.78	35	49	61	74	1.38	0.98	0.79	0.65	3	4	3	0
xy41959547155800	Pond House Rd	Unt to Primrose Pond	2.44				2.44	0.07	14	20	26	31	48	0.17	0.12	0.09	0.08	17	24	31	38	0.15	0.10	0.08	0.06	5	5	1	0
xy41961437156227	Pond House Rd	Unt to Primrose Pond	61.36				61.36	1.29	14	18	22	27	35	4.51	3.35	2.75	2.25	16	22	27	33	3.76	2.79	2.29	1.87	1	1	1	0
xy41962007156644	Mattity Rd	Unt to Primrose Pond	24.64				24.64	0.43	39	56	69	83	118	0.63	0.44	0.36	0.30	47	67	82	100	0.52	0.37	0.30	0.25	5	5	1	0
xy41962407156390	Black Plain Rd	Unt to Primrose Pond	31.70				31.70	1.14	12	17	20	25	32	2.56	1.89	1.55	1.27	15	20	24	30	2.13	1.57	1.29	1.06	1	1	1	0
xy41964317155322	Providence Pike	Unt to Woonasquatucket River	14.27				14.27	0.08	16	24	32	40	62	0.89	0.59	0.45	0.36	19	29	38	47	0.74	0.49	0.37	0.30	5	5	1	0
xy41972767155740	Providence Pike	Unt to Woonasquatucket River	13.43				13.43	0.05	9	14	17	21	32	1.45	0.99	0.78	0.64	11	16	21	25	1.21	0.83	0.65	0.54	4	4	1	0

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Attachment C

Climate Change Vulnerability Assessment Worksheet

Climate Change Vulnerability Worksheet

Crossing Code	Road Name	Stream Name	Amount of Sea Level Rise Required to Impact Crossing with 100-yr Storm Surge (ft)	Scoring				Future Tidal Flag
				Future Binned Hydraulic Capacity Score (1-5)	Binned Hydraulic Capacity Change Score (1, 3 or 5)	Binned Sea Level Rise and Storm Surge Score (1-5)	Binned Climate Change Vulnerability Score (1-5)	
xy41817227144364	Manton Ave	Woonasquatucket River	5	1	1	2	2	1
xy41819437144226	Delaine St	Woonasquatucket River	0	2	3	5	5	1
xy41822527143992	Valley St	Woonasquatucket River	0	5	1	5	5	1
xy41823467146025	Glenbridge Ave	Woonasquatucket River	7	1	1	1	1	0
xy41824557143824	Atwells Ave	Woonasquatucket River	0	5	1	5	5	1
xy41826547143567	Eagle St	Woonasquatucket River	0	5	1	5	5	1
xy41826817141330	N/A: Footbridge	Woonasquatucket River	0	1	1	5	5	1
xy41826927141044	Steeple St	Woonasquatucket River	0	1	1	5	5	1
xy41827107141439	N/A: Footbridge	Woonasquatucket River	0	1	1	5	5	1
xy41827117141226	Exchange St	Woonasquatucket River	0	1	1	5	5	1
xy41827207141547	Francis St	Woonasquatucket River	0	1	1	5	5	1
xy41827747141774	Park St	Woonasquatucket River	0	1	1	5	5	1
xy41828647142862	Acorn St	Woonasquatucket River	0	5	1	5	5	1
xy41829017142325	Promenade St	Woonasquatucket River	0	1	1	5	5	1
xy41829077142660	Dean St	Woonasquatucket River	0	1	1	5	5	1
xy41829207142410	Promenade St	Woonasquatucket River	0	1	1	5	5	1
xy41832947147052	Manson Ave	Dyerville Pond	7	1	1	1	1	0
xy41834977144282	Pleasant Valley Parkway	Unt to Woonasquatucket River	7	5	3	1	5	0
xy41835427143915	Pleasant Valley Parkway	Unt to Woonasquatucket River	7	5	1	1	5	0
xy41836747144463	Pleasant Valley Parkway	Unt to Woonasquatucket River	7	3	1	1	3	0
xy41837147148177	Waterman Ave	Unt to Woonasquatucket River	7	1	1	1	1	0
xy41837797148021	Di Sarro Ave	Unt to Woonasquatucket River	7	1	1	1	1	0
xy41841257148494	Waterman Ave	Unt to Assapumpset Brook	7	5	1	1	5	0
xy41842197148400	Diaz St	Unt to Assapumpset Brook	7	5	1	1	5	0
xy41842937148299	Armento St	Assapumpset Brook	7	3	3	1	3	0
xy41843377148416	Diaz St	Assapumpset Brook	7	5	3	1	5	0
xy41845017150193	Atwood Ave	Unt to Assapumpset Brook	7	1	1	1	1	0
xy41845257150309	Carpenter Drive	Unt to Assapumpset Brook	7	5	3	1	5	0
xy41845877148670	George Waterman St	Assapumpset Brook	7	1	1	1	1	0
xy41848417149462	Clemence Ln	Assapumpset Brook	7	2	3	1	4	0
xy41848877150503	Pine Hill Ave	Assapumpset Brook	7	5	3	1	5	0
xy41850727148167	Allendale Ave	Woonasquatucket River	7	1	1	1	1	0
xy41853897155040	Winsor Rd	Unt to Slack Reservoir	7	5	1	1	5	0
xy41853977155807	Winsor Rd	Unt to Slack Reservoir	7	4	1	1	4	0
xy41855037152232	Greenville Ave	Unt to Assapumpset Brook	7	5	1	1	5	0
xy41855187155720	Barden Ln	Unt to Slack Reservoir	7	5	1	1	5	0
xy41855907154386	Winsor Rd	Unt to Slack Reservoir	7	2	3	1	3	0

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Climate Change Vulnerability Worksheet

Crossing Code	Road Name	Stream Name	Amount of Sea Level Rise Required to Impact Crossing with 100-yr Storm Surge (ft)	Scoring				Future Tidal Flag
				Future Binned Hydraulic Capacity Score (1-5)	Binned Hydraulic Capacity Change Score (1, 3 or 5)	Binned Sea Level Rise and Storm Surge Score (1-5)	Binned Climate Change Vulnerability Score (1-5)	
xy41858547156285	Orchard Ave	Unt to Slack Reservoir	7	1	1	1	1	0
xy41859167148748	Putnam Pike	Woonasquatucket River	7	1	1	1	1	0
xy41859507155898	Roger Williams Drive	Unt to Slack Reservoir	7	1	1	1	1	0
xy41861407156668	Sheffield Rd	Unt to Slack Reservoir	7	5	1	1	5	0
xy41861587154159	Greenville Ave	Unt to Slack Reservoir	7	3	3	1	3	0
xy41863027154374	Greenville Ave	Unt to Slack Reservoir	7	1	1	1	1	0
xy41863507153509	Finne Rd	Unt to Slack Reservoir	7	5	1	1	5	0
xy41865407149229	Angell Ave	Woonasquatucket River	7	1	1	1	1	0
xy41866427149748	Dean St	Unt to Woonasquatucket River	7	5	1	1	5	0
xy41866737155823	Smith Ave Extension	Unt to Slack Reservoir	7	1	1	1	1	0
xy41866907149909	Kenton Drive	Unt to Woonasquatucket River	7	5	3	1	5	0
xy41866937155857	Smith Ave	Unt to Slack Reservoir	7	2	3	1	3	0
xy41867357150081	Mowry Ave	Unt to Woonasquatucket	7	4	1	1	4	0
xy41867767150198	Susan Drive	Unt to Woonasquatucket River	7	2	3	1	3	0
xy41867937149613	Riverside Ave	Unt to Woonasquatucket River	7	5	1	1	5	0
xy41868517157685	West Greenville Rd	Unt	7	5	1	1	5	0
xy41869227150721	Esmond St	Unt to Woonasquatucket River	7	1	1	1	1	0
xy41869837155412	Smith Ave	Unt to Slack Reservoir	7	3	3	1	3	0
xy41870167152512	Putnam Pike	Unt to Hawkins Brook	7	1	1	1	1	0
xy41870207153556	Putnam Pike	Reaper Brook	7	5	1	1	5	0
xy41871207155179	Putnam Pike	Slack Reservoir Outflow	7	2	3	1	3	0
xy41871637157756	West Greenville Rd	Waterman Reservoir	7	1	1	1	1	0
xy41871997158854	Aldrich Rd	Unt to Waterman Reservoir	7	1	1	1	1	0
xy41872697150528	Esmond St	Hawkins Brook	7	1	1	1	1	0
xy41872937157686	West Greenville Rd	Unt	7	1	1	1	1	0
xy41873167150365	Julien St	Hawkins Brook	7	5	1	1	5	0
xy41873187150300	Dean St	Hawkins Brook	7	1	1	1	1	0
xy41873637149711	Esmond Mill Drive	Woonasquatucket River	7	4	3	1	4	0
xy41874287154980	Pleasant View Circle	Unt to Stillwater River	7	4	3	1	4	0
xy41874767155492	Austin Ave	Stillwater River	7	5	1	1	5	0
xy41875437157379	West Greenville Ave	Unt to Waterman Reservoir	7	1	1	1	1	0
xy41875777159319	Old Quarry Rd	Unt to Waterman Reservoir	7	4	1	1	4	0
xy41877147159409	Old Quarry Rd	Unt to Waterman Reservoir	7	4	3	1	4	0
xy41877287153708	Cedar Swamp Road	Reaper Brook	7	2	3	1	3	0
xy41877397157132	West Greenville Rd	Stillwater River	7	5	3	1	5	0
xy41877427157059	Putnam Pike	Stillwater Brook	7	1	1	1	1	0
xy41877557154924	Deerfield Drive	Stillwater River	7	5	3	1	5	0

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Climate Change Vulnerability Worksheet

Crossing Code	Road Name	Stream Name	Amount of Sea Level Rise Required to Impact Crossing with 100-yr Storm Surge (ft)	Scoring: Future Binned Hydraulic Capacity Score (1-5)	Binned Hydraulic Capacity Change Score (1, 3 or 5)	Binned Sea Level Rise and Storm Surge Score (1-5)	Binned Climate Change Vulnerability Score (1-5)	Future Tidal Flag
xy41878177153571	Walter Carey Road	Unt to Mountaindale Reservoir	7	1	1	1	1	0
xy41878417150154	Esmond St	Woonasquatucket River	7	1	1	1	1	0
xy41878707160132	Sawmill Rd	Unt to Waterman Reservoir	7	5	1	1	5	0
xy41878737152022	Mountaindale Rd	Unt to Hawkins Brook	7	5	1	1	5	0
xy41880727150256	Farnum Pike	Woonasquatucket River	7	1	1	1	1	0
xy41880887157821	Putnam Pike	Waterman Reservoir	7	5	1	1	5	0
xy41881987151110	Old Country Rd	Unt to Woonasquatucket River	7	1	1	1	1	0
xy41883167160369	Melody Hill Ln	Unt to Waterman Reservoir	7	3	3	1	3	0
xy41883307160203	Sawmill Rd	Unt to Waterman Reservoir	7	5	1	1	5	0
xy41883627158219	Putnam Pike	Nine Foot Brook	7	3	3	1	3	0
xy41883977158247	Austin Ave	Nine Foot Brook	7	5	1	1	5	0
xy41883977159943	Waterman Lake Drive	Unt to Cutler Brook	7	2	3	1	3	0
xy41884477150737	Farnum Pike	Unt to Woonasquatucket River	7	4	1	1	4	0
xy41884487160015	Sawmill Rd	Cutler Brook	7	3	3	1	3	0
xy41884547154339	Indian Run Rd	Unt to Stillwater River	7	1	1	1	1	0
xy41884807157218	Austin Ave	Unt to Waterman Reservoir	7	3	3	1	3	0
xy41884937158168	Stone Bridge Rd	Unt to Nine Foot Brook	7	3	3	1	3	0
xy41885067154130	Pleasant View Ave	Stillwater River	7	5	1	1	5	0
xy41885087157849	Austin Avenue	Unt to Waterman Reservoir	7	5	1	1	5	0
xy41885967155678	Baldwin Circle	Unt to Stillwater River	7	5	1	1	5	0
xy41886157153645	Mountaindale Road	Reaper Brook	7	1	1	1	1	0
xy41886477153705	Mountaindale Road	Unnamed Wetland adjacent to Reaper Brook	7	1	1	1	1	0
xy41886617150419	Fenwood Ave	Unt to Woonasquatucket River	7	1	1	1	1	0
xy41886847150523	Whipple Ave	Woonasquatucket River	7	1	1	1	1	0
xy41886917159166	Putnam Pike	Unt to Waterman Reservoir	7	5	1	1	5	0
xy41887077159144	Valley Rd	Unt to Waterman Reservoir	7	5	3	1	5	0
xy41888247153923	Mountaindale Road	Stillwater River	7	4	1	1	4	0
xy41888657151262	Farnum Pike	Unt to Georgiaville Pond	7	4	1	1	4	0
xy41888837151740	Old County Rd	Unt to Georgiaville Pond	7	5	1	1	5	0
xy41889357148731	Whipple Rd	Unt to Woonasquatucket River	7	1	1	1	1	0
xy41890377149584	Ridge Rd	Unt to Woonasquatucket River	7	5	1	1	5	0
xy41890427151403	Sweet Rd	Unt to Georgiaville Pond	7	5	1	1	5	0
xy41890897156959	Colwell Rd	Unt to Upper Sprague Reservoir	7	2	3	1	3	0
xy41890917151543	Farnum Pike	Unt to Georgiaville Pond	7	5	1	1	5	0
xy41892467149331	Douglas Pike	Unt to Woonasquatucket River	7	5	1	1	5	0
xy41892547150396	Crest Drive	Unt to Woonasquatucket River	7	1	1	1	1	0
xy41893077160835	Route 44	Cutler Brook	7	1	1	1	1	0

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Climate Change Vulnerability Worksheet

Crossing Code	Road Name	Stream Name	Amount of Sea Level Rise Required to Impact Crossing with 100-yr Storm Surge (ft)	Scoring				Future Tidal Flag
				Future Binned Hydraulic Capacity Score (1-5)	Binned Hydraulic Capacity Change Score (1, 3 or 5)	Binned Sea Level Rise and Storm Surge Score (1-5)	Binned Climate Change Vulnerability Score (1-5)	
xy41893317160808	Farnum Road	Cutler Brook	7	3	3	1	3	0
xy41894747150725	Stillwater Rd	Unt to Georgiaville Pond	7	5	1	1	5	0
xy41894887152164	Farnum Pike	Unt to Georgiaville Pond	7	3	3	1	3	0
xy41895577161365	Route 44 Putnam Pike	Unt to Cutler Brook	7	5	1	1	5	0
xy41896047161805	Route 44	Unti to Cutler Brook	7	1	1	1	1	0
xy41896637160262	Farnum Rd	Unt to Waterman Reservoir	7	1	1	1	1	0
xy41896697151958	Old county Rd/Lakeside Drive	Unt to Georgiaville Pond	7	5	1	1	5	0
xy41897187150342	Ridge Rd	Unt to Georgiaville Pond	7	5	1	1	5	0
xy41897827156647	Colwell Rd	Unt to Upper Sprague Reservoir	7	5	3	1	5	0
xy41898117157880	Evan's Rd	Nine Foot Brook	7	5	1	1	5	0
xy41898457158358	Burlingame Ln	Unt to Nine Foot Brook	7	5	1	1	5	0
xy41898477158323	Burlingame Ln	Unt to Nine Foot Brook	7	5	1	1	5	0
xy41898517157816	Tarkiln Rd	Unt to Nine Foot Brook	7	4	3	1	4	0
xy41898907154304	Pleasantview Ave	Woonasquatucket Reservoir	7	1	1	1	1	0
xy41898957150991	Stillwater Rd	Harris Brook	7	1	1	1	1	0
xy41899117154630	Log Rd	Woonasquatucket Reservoir	7	5	1	1	5	0
xy41899147150128	Douglas Pike	Unt to Georgiaville Pond	7	5	1	1	5	0
xy41899277156654	Colwell Rd	Unt to Upper Sprague Reservoir	7	5	1	1	5	0
xy41900117158371	Evans Rd	Unt to Shinscot Brook	7	1	1	1	1	0
xy41900437149662	Catherine Rd	Unt to West River	7	3	3	1	3	0
xy41902037159401	Farnum road	Shinscot Brook	7	3	3	1	3	0
xy41902517157773	Tarkiln Rd	Unt to Nine Foot Brook	7	1	1	1	1	0
xy41902577149498	Maureen Drive	Unt to West River	7	5	1	1	5	0
xy41902587151720	Stillwater Rd	Unt to Georgiaville Pond	7	1	1	1	1	0
xy41902697157007	Mann School Rd	Unt to Upper Sprague Reservoir	7	5	3	1	5	0
xy41902757152161	Capron Rd	Capron Pond	7	1	1	1	1	0
xy41902757159093	Farnum Rd	Unt	7	5	1	1	5	0
xy41902877150377	Limerock Rd	Unt to Harris Brook	7	5	1	1	5	0
xy41904317158874	Evans road	Unt	7	1	1	1	1	0
xy41904937156221	Connors Farm Drive	Unt	7	1	1	1	1	0
xy41905587149206	Clark Rd	Unt to West River	7	2	3	1	3	0
xy41906217161244	Cooper Ave	Cutler Brook	7	5	1	1	5	0
xy41908317153647	George Washington Highway	Woonasquatucket River	7	1	1	1	1	0
xy41908677154068	Farnum Pike	Woonasquatucket River	7	1	1	1	1	0
xy41909167152497	Stillwater Rd	Unt to Stillwater Pond	7	1	1	1	1	0
xy41910887152828	Stillwater Rd	Unt to Stillwater Pond	7	2	3	1	3	0
xy41912007159704	Evans Rd	Unamed to Shinscot Brook	7	1	1	1	1	0

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Climate Change Vulnerability Worksheet

Crossing Code	Road Name	Stream Name	Amount of Sea Level Rise Required to Impact Crossing with 100-yr Storm Surge (ft)	Scoring				Future Tidal Flag
				Future Binned Hydraulic Capacity Score (1-5)	Binned Hydraulic Capacity Change Score (1, 3 or 5)	Binned Sea Level Rise and Storm Surge Score (1-5)	Binned Climate Change Vulnerability Score (1-5)	
xy41912687150232	Harris Rd	Unt to Harris Brook	7	1	1	1	1	0
xy41913457152883	George Washington Highway	Unt to Stillwater Pond	7	1	1	1	1	0
xy41913477151701	Douglas Pike	Unt to Stillwater Pond	7	1	1	1	1	0
xy41914027155460	Log Rd	Woonasquatucket Reservoir	7	5	1	1	5	0
xy41914137156217	Burlingame Rd	Unt to Woonasquatucket Reservoir	7	1	1	1	1	0
xy41914227154859	Industrial Rd S.	Unt to Woonasquatucket Reservoir	7	5	1	1	5	0
xy41914627152630	George Washington Highway	Unt to Stillwater Pond	7	1	1	1	1	0
xy41916527154817	Industrial Drive	Unt to Woonasquatucket Reservoir	7	1	1	1	1	0
xy41916957158201	Tarkiln Rd	Unt to Nine Foot Brook	7	5	1	1	5	0
xy41918867152209	Douglas Pike	Unt to Stillwater Pond	7	1	1	1	1	0
xy41920067155939	Burlingame Rd	Latham Brook	7	3	3	1	3	0
xy41920097155278	Old Forge Rd	Woonasquatucket River	7	2	3	1	3	0
xy41920937158733	Tarkiln Rd	Unt to Nine Foot Brook	7	5	1	1	5	0
xy41921057155828	Log Rd	Unt to Latham Brook	7	4	3	1	4	0
xy41922257156115	Log Rd	Latham Brook	7	3	3	1	3	0
xy41923277152886	Douglas Pike	Unt to Stillwater Reservoir	7	1	1	1	1	0
xy41923437156751	Bayberry Rd	Latham Brook	7	5	3	1	5	0
xy41923797156391	Log Rd	Latham Brook	7	1	1	1	1	0
xy41924017152999	Douglas Pike	Unt to Stillwater Reservoir	7	1	1	1	1	0
xy41924467152624	Essex St	Unt to Stillwater Pond	7	1	1	1	1	0
xy41924627153417	Bryant U. entryway off of Douglas Pike	Unt to Stillwater Pond	7	1	1	1	1	0
xy41926177155080	Farnum Pike	Unt to Woonasquatucket River	7	3	3	1	3	0
xy41926517153403	Douglas Pike	Unt to Stillwater Pond	7	3	3	1	3	0
xy41926627152983	Essex St	Unt to Stillwater Pond	7	1	1	1	1	0
xy41927997155005	Rogler Farm Rd	Unt to Woonasquatucket Reservoir	7	1	1	1	1	0
xy41928037152264	Lydia Ann Rd	Unt to Stillwater Pond	7	1	1	1	1	0
xy41928267155140	Farnum Pike	Woonasquatucket River	7	1	1	1	1	0
xy41929067155367	Latham Farm Rd	Unt to Woonasquatucket River	7	1	1	1	1	0
xy41929207157455	Log Rd	Unt to Latham Brook	7	4	3	1	4	0
xy41930757160155	Long Entry Rd	Unnamed Wetland	7	5	1	1	5	0
xy41931447155286	Farnum Pike	Unt to Woonasquatucket River	7	4	3	1	4	0
xy41938517155343	Douglas Pike	Woonasquatucket River	7	1	1	1	1	0
xy41939037155601	Farnum Pike	Unt to Woonasquatucket River	7	4	3	1	4	0
xy41943527156049	Douglas Pike	Unt to Woonasquatucket River	7	2	3	1	3	0
xy41950277156940	Douglas Pike	Unt to Woonasquatucket River	7	5	1	1	5	0
xy41954007157431	Douglas Pike	Unt to Woonasquatucket River	7	1	1	1	1	0
xy41954667155188	Greenville Rd	Woonasquatucket River	7	1	1	1	1	0

Gray boxes indicate missing data. Yellow boxes indicate assumptions that were made to compensate for missing data. See Pilot Study and Digitial Database for details regarding assumptions.

Climate Change Vulnerability Worksheet

Crossing Code	Road Name	Stream Name	Amount of Sea Level Rise Required to Impact Crossing with 100-yr Storm Surge (ft)	Scoring				Future Tidal Flag
				Future Binned Hydraulic Capacity Score (1-5)	Binned Hydraulic Capacity Change Score (1, 3 or 5)	Binned Sea Level Rise and Storm Surge Score (1-5)	Binned Climate Change Vulnerability Score (1-5)	
xy41954727157531	Douglas Pike	Unt	7	5	1	1	5	0
xy41959377156205	Black Plain Rd	Unt to Primrose Pond	7	4	3	1	4	0
xy41959547155800	Pond House Rd	Unt to Primrose Pond	7	5	1	1	5	0
xy41961437156227	Pond House Rd	Unt to Primrose Pond	7	1	1	1	1	0
xy41962007156644	Mattity Rd	Unt to Primrose Pond	7	5	1	1	5	0
xy41962407156390	Black Plain Rd	Unt to Primrose Pond	7	1	1	1	1	0
xy41964317155322	Providence Pike	Unt to Woonasquatucket River	7	5	1	1	5	0
xy41972767155740	Providence Pike	Unt to Woonasquatucket River	7	4	1	1	4	0

Gray boxes indicate missing data. Yellow boxes indicate assumptions that were made to compensate for missing data. See Pilot Study and Digitial Database for details regarding assumptions.

Attachment D

Geomorphic Impact Potential Assessment Worksheet

Geomorphic Impact Potential Worksheet

Crossing Code	Road Name	Stream Name	Potential for Geomorphic Impacts			Observed Geomorphic Impacts				Scoring			
			Alignment Impact Potential Rating	Bankfull Width Impact Potential Rating	Slope Impact Potential Rating	Substrate Size Impact Potential Rating	Sediment Continuity Impact Rating	Bank Erosion and Outlet Amoring Impact Rating	Inlet and Outlet Grade Impact Rating	Combined Potential Impact Rating	Combined Observed Impact Rating	Sum of Combined Potential and Observed Ratings	Binned Overall Geomorphic Impact Score (1-5)
xy41817227144364	Manton Ave	Woonasquatucket River	4	1	1	3	1	1	1	9	3	12	2
xy41819437144226	Delaine St	Woonasquatucket River	1	1	1	3	1	1	1	6	3	9	2
xy41822527143992	Valley St	Woonasquatucket River	4	1	1	3	1	1	1	9	3	12	2
xy41823467146025	Glenbridge Ave	Woonasquatucket River	1	1	1	5	1	5	1	8	7	15	3
xy41824557143824	Atwells Ave	Woonasquatucket River	4	1	1	3	1	1	1	9	3	12	2
xy41826547143567	Eagle St	Woonasquatucket River	4	1	1	3	1	1	1	9	3	12	2
xy41826817141330	N/A: Footbridge	Woonasquatucket River	4	4	1	3	1	1	1	12	3	15	3
xy41826927141044	Steeple St	Woonasquatucket River	4	4	1	3	1	1	1	12	3	15	3
xy41826927141044	Steeple St	Woonasquatucket River	4	4	1	3	1	1	1	12	3	15	3
xy41827107141439	N/A: Footbridge	Woonasquatucket River	4	4	1	3	1	1	1	12	3	15	3
xy41827107141439	N/A: Footbridge	Woonasquatucket River	4	4	1	3	1	1	1	12	3	15	3
xy41827107141439	N/A: Footbridge	Woonasquatucket River	4	4	1	3	1	1	1	12	3	15	3
xy41827117141226	Exchange St	Woonasquatucket River	4	4	1	3	1	1	1	12	3	15	3
xy41827207141547	Francis St	Woonasquatucket River	4	4	1	3	1	1	1	12	3	15	3
xy41827747141774	Park St	Woonasquatucket River	4	4	1	3	1	1	1	12	3	15	3
xy41828647142862	Acorn St	Woonasquatucket River	4	1	1	3	1	1	1	9	3	12	2
xy41829017142325	Promenade St	Woonasquatucket River	1	1	1	3	1	5	1	6	7	13	2
xy41829077142660	Dean St	Woonasquatucket River	4	1	1	3	1	1	1	9	3	12	2
xy41829207142410	Promenade St	Woonasquatucket River	4	1	1	3	1	5	1	9	7	16	3
xy41832947147052	Manson Ave	Dyerville Pond	4	4	1	3	1	1	1	12	3	15	3
xy41834977144282	Pleasant Valley Parkway	Unt to Woonasquatucket River	2	4	1	5	2	5	4	12	11	23	4
xy41835427143915	Pleasant Valley Parkway	Unt to Woonasquatucket River	4	3	1	3	2	5	4	11	11	22	4
xy41836747144463	Pleasant Valley Parkway	Unt to Woonasquatucket River	4	4	1	3	2	1	1	12	4	16	3
xy41837147148177	Waterman Ave	Unt to Woonasquatucket River	2	5	3	3	1	1	1	13	3	16	3
xy41837797148021	Di Sarro Ave	Unt to Woonasquatucket River	1	5	1	4	3	5	4	11	12	23	4
xy41841257148494	Waterman Ave	Unt to Assapumpset Brook	4	5	1	3	3	1	1	13	5	18	3
xy41842197148400	Diaz St	Unt to Assapumpset Brook	2	5	1	3	1	1	1	11	3	14	2
xy41842937148299	Armento St	Assapumpset Brook	5	5	1	3	1	1	1	14	3	17	3
xy41843377148416	Diaz St	Assapumpset Brook	1	5	1	3	1	1	1	10	3	13	2
xy41843377148416	Diaz St	Assapumpset Brook	1	5	1	3	1	1	1	10	3	13	2
xy41845017150193	Atwood Ave	Unt to Assapumpset Brook	1	5	1	3	1	1	1	10	3	13	2
xy41845257150309	Carpenter Drive	Unt to Assapumpset Brook	1	5	2	3	1	1	3	11	5	16	3
xy41845877148670	George Waterman St	Assapumpset Brook	4	5	4	3	1	5	4	16	10	26	4
xy41845877148670	George Waterman St	Assapumpset Brook	4	5	4	3	1	5	1	16	7	23	4
xy41848417149462	Clemence Ln	Assapumpset Brook	2	5	1	3	1	1	1	11	3	14	2
xy41848417149462	Clemence Ln	Assapumpset Brook	2	5	1	3	1	1	4	11	6	17	3
xy41848877150503	Pine Hill Ave	Assapumpset Brook	1	5	1	3	1	1	4	10	6	16	3
xy41850727148167	Allendale Ave	Woonasquatucket River	1	1	1	3	1	5	1	6	7	13	2
xy41853897155040	Winsor Rd	Unt to Slack Reservoir	1	5	1	3	1	1	1	10	3	13	2
xy41853977155807	Winsor Rd	Unt to Slack Reservoir	5	4	1	3	1	1	4	13	6	19	3
xy41855037152232	Greenville Ave	Unt to Assapumpset Brook	4	5	1	3	1	1	1	13	3	16	3
xy41855187155720	Barden Ln	Unt to Slack Reservoir	1	5	1	3	1	1	4	10	6	16	3
xy41855907154386	Winsor Rd	Unt to Slack Reservoir	2	5	1	3	2	1	1	11	4	15	3
xy41858547156285	Orchard Ave	Unt to Slack Reservoir	4	5	1	3	1	5	2	13	8	21	3
xy41859167148748	Putnam Pike	Woonasquatucket River	1	4	1	3	1	1	1	9	3	12	2
xy41859507155898	Roger Williams Drive	Unt to Slack Reservoir	2	5	1	3	1	3	4	11	8	19	3
xy41861407156668	Sheffield Rd	Unt to Slack Reservoir	4	5	1	3	2	3	1	13	6	19	3
xy41861407156668	Sheffield Rd	Unt to Slack Reservoir	4	5	4	3	2	3	1	16	6	22	4
xy41861587154159	Greenville Ave	Unt to Slack Reservoir	1	5	1	3	3	1	4	10	8	18	3
xy41863027154374	Greenville Ave	Unt to Slack Reservoir	1	4	1	3	1	3	2	9	6	15	3
xy41863027154374	Greenville Ave	Unt to Slack Reservoir	1	4	1	3	1	3	2	9	6	15	3
xy41863507153509	Finne Rd	Unt to Slack Reservoir	2	4	1	3	1	1	1	10	3	13	2
xy41865407149229	Angell Ave	Woonasquatucket River	1	4	1	3	1	5	1	9	7	16	3
xy41866427149748	Dean St	Unt to Woonasquatucket River	5	5	1	3	1	1	2	14	4	18	3
xy41866737155823	Smith Ave Extension	Unt to Slack Reservoir	2	5	1	3	1	3	3	11	7	18	3
xy41866907149909	Kenton Drive	Unt to Woonasquatucket River	4	5	1	3	1	1	4	13	6	19	3
xy41866937155857	Smith Ave	Unt to Slack Reservoir	1	5	1	3	1	1	2	10	4	14	2
xy41867357150081	Mowry Ave	Unt to Woonasquatucket	4	5	1	3	2	1	1	13	4	17	3
xy41867357150081	Mowry Ave	Unt to Woonasquatucket	4	5	1	3	2	1	1	13	4	17	3
xy41867767150198	Susan Drive	Unt to Woonasquatucket River	1	5	1	3	1	1	1	10	3	13	2
xy41867937149613	Riverside Ave	Unt to Woonasquatucket River	4	5	1	5	2	5	4	15	11	26	4

Gray boxes indicate missing data. Yellow boxes indicate assumptions that were made to compensate for missing data. See Pilot Study and Digitial Database for details regarding assumptions.

Geomorphic Impact Potential Worksheet

Crossing Code	Road Name	Stream Name	Potential for Geomorphic Impacts			Observed Geomorphic Impacts				Scoring			
			Alignment Impact Potential Rating	Bankfull Width Impact Potential Rating	Slope Impact Potential Rating	Substrate Size Impact Potential Rating	Sediment Continuity Impact Rating	Bank Erosion and Outlet Amoring Impact Rating	Inlet and Outlet Grade Impact Rating	Combined Potential Impact Rating	Combined Observed Impact Rating	Sum of Combined Potential and Observed Ratings	Binned Overall Geomorphic Impact Score (1-5)
xy41867937149613	Riverside Ave	Unt to Woonasquatucket River	4	5	1	5	2	5	4	15	11	26	4
xy41867937149613	Riverside Ave	Unt to Woonasquatucket River	4	5	1	5	2	5	4	15	11	26	4
xy41868517157685	West Greenville Rd	Unt	1	5	1	3	1	1	1	10	3	13	2
xy41869227150721	Esmond St	Unt to Woonasquatucket River	1	5	1	5	2	1	1	12	4	16	3
xy41869837155412	Smith Ave	Unt to Slack Reservoir	5	5	1	5	1	1	2	16	4	20	3
xy41870167152512	Putnam Pike	Unt to Hawkins Brook	1	5	1	3	1	1	1	10	3	13	2
xy41870207153556	Putnam Pike	Reaper Brook	1	5	1	3	2	1	1	10	4	14	2
xy41871207155179	Putnam Pike	Slack Reservoir Outflow	4	5	2	3	2	3	5	14	10	24	4
xy41871637157756	West Greenville Rd	Waterman Reservoir	4	5	1	3	1	1	1	13	3	16	3
xy41871997158854	Aldrich Rd	Unt to Waterman Reservoir	2	5	1	3	1	1	4	11	6	17	3
xy41872697150528	Esmond St	Hawkins Brook	1	5	1	3	2	1	1	10	4	14	2
xy41872697150528	Esmond St	Hawkins Brook	1	5	1	3	2	1	1	10	4	14	2
xy41872937157686	West Greenville Rd	Unt	2	5	1	3	1	1	1	11	3	14	2
xy41873167150365	Julien St	Hawkins Brook	4	5	1	3	1	1	1	13	3	16	3
xy41873187150300	Dean St	Hawkins Brook	5	5	1	3	2	5	4	14	11	25	4
xy41873187150300	Dean St	Hawkins Brook	5	5	1	3	2	5	4	14	11	25	4
xy41873637149711	Esmond Mill Drive	Woonasquatucket River	1	4	1	3	1	1	1	9	3	12	2
xy41874287154980	Pleasant View Circle	Unt to Stillwater River	1	5	3	3	1	1	1	12	3	15	3
xy41874767155492	Austin Ave	Stillwater River	5	5	1	2	2	1	1	13	4	17	3
xy41874767155492	Austin Ave	Stillwater River	5	5	1	2	2	1	1	13	4	17	3
xy41875437157379	West Greenville Ave	Unt to Waterman Reservoir	5	3	1	5	1	1	1	14	3	17	3
xy41875777159319	Old Quarry Rd	Unt to Waterman Reservoir	1	5	1	5	3	1	4	12	8	20	3
xy41877147159409	Old Quarry Rd	Unt to Waterman Reservoir	2	5	1	3	4	5	1	11	10	21	3
xy41877287153708	Cedar Swamp Road	Reaper Brook	5	5	1	5	1	1	1	16	3	19	3
xy41877397157132	West Greenville Rd	Stillwater River	4	5	1	3	1	1	1	13	3	16	3
xy41877427157059	Putnam Pike	Stillwater Brook	5	3	1	3	2	1	1	12	4	16	3
xy41877557154924	Deerfield Drive	Stillwater River	1	5	1	3	2	1	1	10	4	14	2
xy41877557154924	Deerfield Drive	Stillwater River	1	5	1	3	2	1	1	10	4	14	2
xy41878177153571	Walter Carey Road	Unt to Mountaindale Reservoir	5	5	1	3	1	1	1	14	3	17	3
xy41878417150154	Esmond St	Woonasquatucket River	1	4	1	3	1	1	1	9	3	12	2
xy41878707160132	Sawmill Rd	Unt to Waterman Reservoir	1	5	1	3	1	1	2	10	4	14	2
xy41878737152022	Mountaindale Rd	Unt to Hawkins Brook	1	5	1	3	1	1	2	10	4	14	2
xy41880727150256	Farnum Pike	Woonasquatucket River	1	3	1	3	1	1	1	8	3	11	2
xy41880887157821	Putnam Pike	Waterman Reservoir	1	5	1	3	1	1	4	10	6	16	3
xy41881987151110	Old Country Rd	Unt to Woonasquatucket River	1	5	1	3	1	1	1	10	3	13	2
xy41883167160369	Melody Hill Ln	Unt to Waterman Reservoir	5	5	1	3	3	5	4	14	12	26	4
xy41883167160369	Melody Hill Ln	Unt to Waterman Reservoir	5	5	1	3	3	5	4	14	12	26	4
xy41883307160203	Sawmill Rd	Unt to Waterman Reservoir	1	5	1	5	2	1	1	12	4	16	3
xy41883627158219	Putnam Pike	Nine Foot Brook	5	5	1	3	3	1	1	14	5	19	3
xy41883977158247	Austin Ave	Nine Foot Brook	4	5	1	3	2	1	1	13	4	17	3
xy41883977159943	Waterman Lake Drive	Unt to Cutler Brook	2	4	1	3	1	1	4	10	6	16	3
xy41883977159943	Waterman Lake Drive	Unt to Cutler Brook	2	4	1	3	1	1	4	10	6	16	3
xy41884477150737	Farnum Pike	Unt to Woonasquatucket River	4	4	1	3	1	1	2	12	4	16	3
xy41884487160015	Sawmill Rd	Cutler Brook	2	5	1	3	2	5	1	11	8	19	3
xy41884547154339	Indian Run Rd	Unt to Stillwater River	1	5	1	3	2	1	4	10	7	17	3
xy41884547154339	Indian Run Rd	Unt to Stillwater River	1	5	1	3	2	1	4	10	7	17	3
xy41884547154339	Indian Run Rd	Unt to Stillwater River	1	5	1	3	2	1	4	10	7	17	3
xy41884547154339	Indian Run Rd	Unt to Stillwater River	1	5	1	3	2	1	4	10	7	17	3
xy41884807157218	Austin Ave	Unt to Waterman Reservoir	1	5	1	3	1	1	1	10	3	13	2
xy41884937158168	Stone Bridge Rd	Unt to Nine Foot Brook	1	5	1	3	1	1	4	10	6	16	3
xy41885067154130	Pleasant View Ave	Stillwater River	5	4	1	5	1	1	1	15	3	18	3
xy41885087157849	Austin Avenue	Unt to Waterman Reservoir	2	5	1	3	1	1	2	11	4	15	3
xy41885967155678	Baldwin Circle	Unt to Stillwater River	5	5	1	3	1	5	1	14	7	21	3
xy41886157153645	Mountaindale Road	Reaper Brook	2	3	1	3	1	3	2	9	6	15	3
xy41886477153705	Mountaindale Road	Unnamed Wetland adjacent to Reaper Brook	1	4	1	3	1	1	1	9	3	12	2
xy41886617150419	Fenwood Ave	Unt to Woonasquatucket River	1	5	1	3	1	1	2	10	4	14	2
xy41886617150419	Fenwood Ave	Unt to Woonasquatucket River	1	5	1	3	1	1	2	10	4	14	2
xy41886617150419	Fenwood Ave	Unt to Woonasquatucket River	1	5	1	3	1	1	2	10	4	14	2
xy41886847150523	Whipple Ave	Woonasquatucket River	1	3	1	3	1	1	1	8	3	11	2
xy41886917159166	Putnam Pike	Unt to Waterman Reservoir	5	5	1	3	1	3	1	14	5	19	3
xy41887077159144	Valley Rd	Unt to Waterman Reservoir	4	5	1	3	1	1	1	13	3	16	3

Gray boxes indicate missing data. Yellow boxes indicate assumptions that were made to compensate for missing data. See Pilot Study and Digitial Database for details regarding assumptions.

Geomorphic Impact Potential Worksheet

Crossing Code	Road Name	Stream Name	Potential for Geomorphic Impacts			Observed Geomorphic Impacts				Scoring			
			Alignment Impact Potential Rating	Bankfull Width Impact Potential Rating	Slope Impact Potential Rating	Substrate Size Impact Potential Rating	Sediment Continuity Impact Rating	Bank Erosion and Outlet Amoring Impact Rating	Inlet and Outlet Grade Impact Rating	Combined Potential Impact Rating	Combined Observed Impact Rating	Sum of Combined Potential and Observed Ratings	Binned Overall Geomorphic Impact Score (1-5)
xy41888247153923	Mountaindale Road	Stillwater River	4	5	1	3	2	1	1	13	4	17	3
xy41888247153923	Mountaindale Road	Stillwater River	4	5	1	3	2	1	1	13	4	17	3
xy41888657151262	Farnum Pike	Unt to Georgiaville Pond	1	5	1	5	4	1	1	12	6	18	3
xy41888657151262	Farnum Pike	Unt to Georgiaville Pond	1	5	1	5	4	1	1	12	6	18	3
xy41888837151740	Old County Rd	Unt to Georgiaville Pond	5	5	2	5	1	1	2	17	4	21	3
xy41889357148731	Whipple Rd	Unt to Woonasquatucket River	1	5	1	3	1	1	1	10	3	13	2
xy41890377149584	Ridge Rd	Unt to Woonasquatucket River	1	5	2	3	2	1	2	11	5	16	3
xy41890427151403	Sweet Rd	Unt to Georgiaville Pond	1	5	1	3	1	5	4	10	10	20	3
xy41890427151403	Sweet Rd	Unt to Georgiaville Pond	1	5	1	3	1	5	4	10	10	20	3
xy41890897156959	Colwell Rd	Unt to Upper Sprague Reservoir	5	5	2	4	1	1	2	16	4	20	3
xy41890917151543	Farnum Pike	Unt to Georgiaville Pond	1	5	1	4	1	1	2	11	4	15	3
xy41892467149331	Douglas Pike	Unt to Woonasquatucket River	2	5	1	3	2	1	4	11	7	18	3
xy41892467149331	Douglas Pike	Unt to Woonasquatucket River	2	5	1	3	2	1	4	11	7	18	3
xy41892547150396	Crest Drive	Unt to Woonasquatucket River	1	5	5	3	1	5	1	14	7	21	3
xy41892547150396	Crest Drive	Unt to Woonasquatucket River	1	5	5	3	1	5	1	14	7	21	3
xy41892547150396	Crest Drive	Unt to Woonasquatucket River	1	5	5	3	1	5	1	14	7	21	3
xy41893077160835	Route 44	Cutler Brook	1	4	5	3	1	1	1	13	3	16	3
xy41893317160808	Farnum Road	Cutler Brook	1	4	1	3	1	1	2	9	4	13	2
xy41894747150725	Stillwater Rd	Unt to Georgiaville Pond	1	5	2	3	4	1	4	11	9	20	3
xy41894747150725	Stillwater Rd	Unt to Georgiaville Pond	1	5	2	3	4	1	4	11	9	20	3
xy41894887152164	Farnum Pike	Unt to Georgiaville Pond	1	5	1	3	1	1	1	10	3	13	2
xy41894887152164	Farnum Pike	Unt to Georgiaville Pond	1	5	1	3	1	1	1	10	3	13	2
xy41895577161365	Route 44 Putnam Pike	Unt to Cutler Brook	1	5	1	3	2	1	1	10	4	14	2
xy41896047161805	Route 44	Unti to Cutler Brook	1	5	1	3	1	1	1	10	3	13	2
xy41896637160262	Farnum Rd	Unt to Waterman Reservoir	5	5	1	5	1	1	2	16	4	20	3
xy41896697151958	Old county Rd/Lakeside Drive	Unt to Georgiaville Pond	1	5	1	3	1	5	5	10	11	21	3
xy41897187150342	Ridge Rd	Unt to Georgiaville Pond	1	5	1	3	3	1	1	10	5	15	3
xy41897827156647	Colwell Rd	Unt to Upper Sprague Reservoir	1	5	1	3	1	1	4	10	6	16	3
xy41898117157880	Evan's Rd	Nine Foot Brook	1	5	1	5	1	1	1	12	3	15	3
xy41898457158358	Burlingame Ln	Unt to Nine Foot Brook	1	5	1	3	1	1	2	10	4	14	2
xy41898477158323	Burlingame Ln	Unt to Nine Foot Brook	1	5	1	4	1	1	1	11	3	14	2
xy41898517157816	Tarkiln Rd	Unt to Nine Foot Brook	1	5	4	3	1	1	5	13	7	20	3
xy41898517157816	Tarkiln Rd	Unt to Nine Foot Brook	1	5	1	3	1	3	1	10	5	15	3
xy41898907154304	Pleasantview Ave	Woonasquatucket Reservoir	1	5	1	3	1	1	1	10	3	13	2
xy41898957150991	Stillwater Rd	Harris Brook	1	4	1	3	2	5	1	9	8	17	3
xy41899117154630	Log Rd	Woonasquatucket Reservoir	1	5	1	3	1	1	4	10	6	16	3
xy41899147150128	Douglas Pike	Unt to Georgiaville Pond	5	5	1	3	3	5	4	14	12	26	4
xy41899277156654	Colwell Rd	Unt to Upper Sprague Reservoir	1	5	1	3	1	1	4	10	6	16	3
xy41900117158371	Evans Rd	Unt to Shinscot Brook	2	5	1	3	1	1	1	11	3	14	2
xy41900437149662	Catherine Rd	Unt to West River	1	5	1	3	3	5	4	10	12	22	4
xy41902037159401	Farnum road	Shinscot Brook	5	5	1	5	2	1	1	16	4	20	3
xy41902517157773	Tarkiln Rd	Unt to Nine Foot Brook	1	5	1	4	1	1	1	11	3	14	2
xy41902577149498	Maureen Drive	Unt to West River	1	5	1	3	3	5	1	10	9	19	3
xy41902587151720	Stillwater Rd	Unt to Georgiaville Pond	1	3	1	3	1	1	1	8	3	11	2
xy41902587151720	Stillwater Rd	Unt to Georgiaville Pond	1	3	1	3	1	1	1	8	3	11	2
xy41902697157007	Mann School Rd	Unt to Upper Sprague Reservoir	1	5	1	5	1	1	4	12	6	18	3
xy41902697157007	Mann School Rd	Unt to Upper Sprague Reservoir	1	5	1	5	1	1	1	12	3	15	3
xy41902757152161	Capron Rd	Capron Pond	1	4	1	3	1	1	1	9	3	12	2
xy41902757159093	Farnum Rd	Unt	1	5	2	5	1	1	2	13	4	17	3
xy41902877150377	Limerock Rd	Unt to Harris Brook	2	5	1	5	2	5	1	13	8	21	3
xy41902877150377	Limerock Rd	Unt to Harris Brook	2	5	1	5	2	5	1	13	8	21	3
xy41904317158874	Evans road	Unt	1	3	1	3	1	1	1	8	3	11	2
xy41904937156221	Connors Farm Drive	Unt	1	3	1	3	1	1	1	8	3	11	2
xy41905587149206	Clark Rd	Unt to West River	1	5	1	3	3	5	4	10	12	22	4
xy41905587149206	Clark Rd	Unt to West River	1	5	1	3	3	5	4	10	12	22	4
xy41906217161244	Cooper Ave	Cutler Brook	5	5	1	3	1	5	1	14	7	21	3
xy41908317153647	George Washington Highway	Woonasquatucket River	1	1	1	3	1	1	1	6	3	9	2
xy41908677154068	Farnum Pike	Woonasquatucket River	2	5	1	3	1	1	1	11	3	14	2
xy41909167152497	Stillwater Rd	Unt to Stillwater Pond	1	5	1	3	1	1	4	10	6	16	3
xy41910887152828	Stillwater Rd	Unt to Stillwater Pond	2	5	1	3	2	5	4	11	11	22	4
xy41910887152828	Stillwater Rd	Unt to Stillwater Pond	2	5	1	3	2	5	4	11	11	22	4

Gray boxes indicate missing data. Yellow boxes indicate assumptions that were made to compensate for missing data. See Pilot Study and Digitial Database for details regarding assumptions.

Geomorphic Impact Potential Worksheet

Crossing Code	Road Name	Stream Name	Potential for Geomorphic Impacts: Alignment Impact Potential Rating	Potential for Geomorphic Impacts: Bankfull Width Impact Potential Rating	Potential for Geomorphic Impacts: Slope Impact Potential Rating	Observed Geomorphic Impacts: Substrate Size Impact Potential Rating	Observed Geomorphic Impacts: Sediment Continuity Impact Rating	Observed Geomorphic Impacts: Bank Erosion and Outlet Amoring Impact Rating	Observed Geomorphic Impacts: Inlet and Outlet Grade Impact Rating	Scoring: Combined Potential Impact Rating	Scoring: Combined Observed Impact Rating	Scoring: Sum of Combined Potential and Observed Ratings	Scoring: Binned Overall Geomorphic Impact Score (1-5)
xy41912007159704	Evans Rd	Unamed to Shinscot Brook	1	4	1	3	1	1	1	9	3	12	2
xy41912687150232	Harris Rd	Unt to Harris Brook	2	5	1	3	3	5	4	11	12	23	4
xy41912687150232	Harris Rd	Unt to Harris Brook	2	5	1	3	3	5	4	11	12	23	4
xy41913457152883	George Washington Highway	Unt to Stillwater Pond	1	5	1	3	3	5	1	10	9	19	3
xy41913457152883	George Washington Highway	Unt to Stillwater Pond	1	5	1	3	3	5	1	10	9	19	3
xy41913477151701	Douglas Pike	Unt to Stillwater Pond	1	5	1	3	1	5	2	10	8	18	3
xy41914027155460	Log Rd	Woonasquatucket Reservoir	1	5	2	3	1	3	1	11	5	16	3
xy41914137156217	Burlingame Rd	Unt to Woonasquatucket Reservoir	2	5	1	3	1	1	1	11	3	14	2
xy41914137156217	Burlingame Rd	Unt to Woonasquatucket Reservoir	2	5	1	3	1	1	1	11	3	14	2
xy41914227154859	Industrial Rd S.	Unt to Woonasquatucket Reservoir	1	5	1	5	1	1	1	12	3	15	3
xy41914627152630	George Washington Highway	Unt to Stillwater Pond	5	5	1	3	2	1	1	14	4	18	3
xy41916527154817	Industrial Drive	Unt to Woonasquatucket Reservoir	1	5	1	3	2	1	1	10	4	14	2
xy41916957158201	Tarkiln Rd	Unt to Nine Foot Brook	1	3	1	3	3	1	1	8	5	13	2
xy41918867152209	Douglas Pike	Unt to Stillwater Pond	1	5	5	3	1	1	1	14	3	17	3
xy41918867152209	Douglas Pike	Unt to Stillwater Pond	1	5	5	3	1	1	1	14	3	17	3
xy41920067155939	Burlingame Rd	Latham Brook	4	4	1	2	1	1	5	11	7	18	3
xy41920097155278	Old Forge Rd	Woonasquatucket River	2	5	2	3	1	1	4	12	6	18	3
xy41920937158733	Tarkiln Rd	Unt to Nine Foot Brook	5	5	1	3	1	1	1	14	3	17	3
xy41921057155828	Log Rd	Unt to Latham Brook	1	3	1	3	2	1	1	8	4	12	2
xy41921057155828	Log Rd	Unt to Latham Brook	1	3	1	3	2	1	1	8	4	12	2
xy41922257156115	Log Rd	Latham Brook	1	5	1	3	1	1	4	10	6	16	3
xy41922257156115	Log Rd	Latham Brook	1	5	1	3	1	1	1	10	3	13	2
xy41923277152886	Douglas Pike	Unt to Stillwater Reservoir	1	5	1	3	1	1	1	10	3	13	2
xy41923437156751	Bayberry Rd	Latham Brook	1	5	1	3	2	1	4	10	7	17	3
xy41923797156391	Log Rd	Latham Brook	2	5	1	3	1	1	4	11	6	17	3
xy41924017152999	Douglas Pike	Unt to Stillwater Reservoir	2	5	1	3	1	1	1	11	3	14	2
xy41924467152624	Essex St	Unt to Stillwater Pond	4	1	1	2	1	1	1	8	3	11	2
xy41924627153417	Bryant U. entryway off of Douglas Pike	Unt to Stillwater Pond	1	5	1	3	2	1	2	10	5	15	3
xy41926177155080	Farnum Pike	Unt to Woonasquatucket River	1	5	1	3	1	1	2	10	4	14	2
xy41926517153403	Douglas Pike	Unt to Stillwater Pond	2	5	1	3	1	1	1	11	3	14	2
xy41926627152983	Essex St	Unt to Stillwater Pond	2	5	1	4	1	1	2	12	4	16	3
xy41927997155005	Rogler Farm Rd	Unt to Woonasquatucket Reservoir	1	5	1	3	1	1	1	10	3	13	2
xy41927997155005	Rogler Farm Rd	Unt to Woonasquatucket Reservoir	1	5	1	3	1	1	1	10	3	13	2
xy41928037152264	Lydia Ann Rd	Unt to Stillwater Pond	1	3	1	3	1	1	1	8	3	11	2
xy41928037152264	Lydia Ann Rd	Unt to Stillwater Pond	1	3	1	4	1	1	1	9	3	12	2
xy41928037152264	Lydia Ann Rd	Unt to Stillwater Pond	1	3	1	3	1	1	2	8	4	12	2
xy41928267155140	Farnum Pike	Woonasquatucket River	2	4	1	3	1	1	1	10	3	13	2
xy41929067155367	Latham Farm Rd	Unt to Woonasquatucket River	5	5	1	5	1	1	1	16	3	19	3
xy41929207157455	Log Rd	Unt to Latham Brook	1	5	1	3	1	1	2	10	4	14	2
xy41929207157455	Log Rd	Unt to Latham Brook	1	5	1	3	1	1	4	10	6	16	3
xy41930757160155	Long Entry Rd	Unnamed Wetland	1	5	1	3	1	1	1	10	3	13	2
xy41931447155286	Farnum Pike	Unt to Woonasquatucket River	1	5	1	3	1	1	1	10	3	13	2
xy41938517155343	Douglas Pike	Woonasquatucket River	1	5	1	4	1	1	1	11	3	14	2
xy41939037155601	Farnum Pike	Unt to Woonasquatucket River	1	5	1	3	2	3	4	10	9	19	3
xy41943527156049	Douglas Pike	Unt to Woonasquatucket River	5	4	1	3	2	1	1	13	4	17	3
xy41943527156049	Douglas Pike	Unt to Woonasquatucket River	5	4	1	3	2	1	1	13	4	17	3
xy41950277156940	Douglas Pike	Unt to Woonasquatucket River	1	5	1	3	1	1	1	10	3	13	2
xy41954007157431	Douglas Pike	Unt to Woonasquatucket River	2	5	1	3	1	1	1	11	3	14	2
xy41954667155188	Greenville Rd	Woonasquatucket River	1	5	1	3	1	1	1	10	3	13	2
xy41954667155188	Greenville Rd	Woonasquatucket River	1	5	1	3	1	1	1	10	3	13	2
xy41954727157531	Douglas Pike	Unt	1	5	1	3	2	3	1	10	6	16	3
xy41959377156205	Black Plain Rd	Unt to Primrose Pond	1	5	1	3	2	1	1	10	4	14	2
xy41959547155800	Pond House Rd	Unt to Primrose Pond	4	4	1	3	1	1	4	12	6	18	3
xy41961437156227	Pond House Rd	Unt to Primrose Pond	4	5	1	3	1	1	1	13	3	16	3
xy41962007156644	Mattity Rd	Unt to Primrose Pond	1	5	1	3	2	1	1	10	4	14	2
xy41962407156390	Black Plain Rd	Unt to Primrose Pond	4	5	1	5	1	1	1	15	3	18	3
xy41964317155322	Providence Pike	Unt to Woonasquatucket River	5	5	1	3	1	1	1	14	3	17	3
xy41972767155740	Providence Pike	Unt to Woonasquatucket River	4	4	4	3	1	1	2	15	4	19	3

Gray boxes indicate missing data. Yellow boxes indicate assumptions that were made to compensate for missing data. See Pilot Study and Digitial Database for details regarding assumptions.

Attachment E

Structural Condition Assessment Worksheet

Structural Condition Worksheet

Crossing Code	Road Name	Stream Name	Inlet, Outlet or Barrel Condition A = Adequate P = Poor C = Critical U = Unknown NA = Not Applicable													Scoring						Unknown Structural Variable Flag
			Longitudinal Alignment	Level of Blockage	Flared End Section	Invert Deterioration	Buoyancy or Crushing	Cross-Section Deformation	Structural Integrity of Barrel	Joints & Seams	Footings	Headwalls & Wingwalls	Armoring	Apron/ Scour Protection	Embankment Piping	Level 1 Variables V1 (0.0-1.0)	Level 2 Variables V2 Part 1 (0.0-1.0)	Level 2 Variables V2 Part II (0.0-1.0)	Level 3 Variables V3 (0.0-1.0)	Structural Condition Score (0.0-1.0)	Binned Structural Condition Score (1-5)	
xy41817227144364	Manton Ave	Woonasquatucket River	A	A	NA	NA	A	NA	U	U	A	NA	NA	NA	A	1	1	1	1	1	1	1
xy41819437144226	Delaine St	Woonasquatucket River	A	A	NA	NA	A	A	A	A	A	NA	A	NA	A	1	1	1	1	1	1	0
xy41822527143992	Valley St	Woonasquatucket River	A	A	NA	NA	A	NA	U	U	A	A	NA	NA	A	1	1	1	1	1	1	1
xy41823467146025	Glenbridge Ave	Woonasquatucket River	A	A	NA	NA	A	A	A	A	A	NA	NA	NA	A	1	1	1	1	1	1	0
xy41824557143824	Atwells Ave	Woonasquatucket River	A	A	NA	NA	A	NA	A	U	A	NA	A	NA	A	1	1	1	1	1	1	0
xy41826547143567	Eagle St	Woonasquatucket River	A	A	NA	NA	A	A	A	U	A	A	A	NA	A	1	1	1	1	1	1	0
xy41826817141330	N/A: Footbridge	Woonasquatucket River	A	A	NA	NA	A	A	A	A	A	NA	NA	NA	A	1	1	1	1	1	1	0
xy41826927141044	Steeple St	Woonasquatucket River	A	A	NA	NA	A	NA	A	A	A	A	A	NA	A	1	1	1	1	1	1	0
xy41826927141044	Steeple St	Woonasquatucket River	A	A	NA	NA	A	NA	A	A	A	A	A	NA	A	1	1	1	1	1	1	0
xy41827107141439	N/A: Footbridge	Woonasquatucket River	A	A	NA	NA	A	A	A	U	A	NA	NA	NA	A	1	1	1	1	1	1	0
xy41827107141439	N/A: Footbridge	Woonasquatucket River	A	A	NA	NA	A	A	A	U	A	NA	NA	NA	A	1	1	1	1	1	1	0
xy41827107141439	N/A: Footbridge	Woonasquatucket River	A	A	NA	NA	A	A	A	U	A	NA	NA	NA	A	1	1	1	1	1	1	0
xy41827117141226	Exchange St	Woonasquatucket River	A	A	NA	NA	A	NA	A	A	A	A	A	NA	A	1	1	1	1	1	1	0
xy41827207141547	Francis St	Woonasquatucket River	A	A	NA	NA	A	NA	U	U	A	A	A	NA	A	1	1	1	1	1	1	1
xy41827747141774	Park St	Woonasquatucket River	A	A	NA	NA	A	NA	A	U	A	NA	A	NA	A	1	1	1	1	1	1	0
xy41828647142862	Acorn St	Woonasquatucket River	A	A	NA	NA	A	NA	U	U	A	A	A	NA	A	1	1	1	1	1	1	1
xy41829017142325	Promenade St	Woonasquatucket River	A	A	NA	NA	A	NA	P	A	A	NA	A	NA	A	1	1	0.2	1	0.2	5	0
xy41829077142660	Dean St	Woonasquatucket River	A	A	NA	NA	A	NA	A	A	A	NA	A	NA	A	1	1	1	1	1	1	0
xy41829207142410	Promenade St	Woonasquatucket River	A	A	NA	NA	A	NA	A	A	A	NA	A	NA	NA	1	1	1	1	1	1	0
xy41832947147052	Manson Ave	Dyerville Pond	A	A	NA	NA	A	A	A	A	A	A	A	NA	A	1	1	1	1	1	1	0
xy41834977144282	Pleasant Valley Parkway	Unt to Woonasquatucket River	A	A	NA	P	A	NA	P	A	A	P	A	A	A	1	1	0.2	0.8	0.2	5	0
xy41835427143915	Pleasant Valley Parkway	Unt to Woonasquatucket River	A	A	NA	P	A	NA	P	A	A	P	A	P	A	1	1	0.2	0.7	0.2	5	0
xy41836747144463	Pleasant Valley Parkway	Unt to Woonasquatucket River	U	U	U	U	U	U	U	U	U	A	A	U	U	1	1	1	1	1	1	1
xy41837147148177	Waterman Ave	Unt to Woonasquatucket River	A	A	NA	A	A	NA	A	A	NA	A	A	NA	A	1	1	1	1	1	1	0
xy41837797148021	Di Sarro Ave	Unt to Woonasquatucket River	A	A	NA	A	A	NA	A	A	NA	NA	A	NA	A	1	1	1	1	1	1	0
xy41841257148494	Waterman Ave	Unt to Assapumpset Brook	A	A	U	A	A	U	A	A	U	C	A	U	A	1	0.2	1	1	0.2	5	1
xy41842197148400	Diaz St	Unt to Assapumpset Brook	A	A	NA	A	A	NA	A	A	NA	P	NA	NA	A	1	1	1	0.9	0.9	1	0
xy41842937148299	Armento St	Assapumpset Brook	A	P	U	A	A	NA	A	A	U	A	NA	U	A	1	1	0.2	1	0.2	5	1
xy41843377148416	Diaz St	Assapumpset Brook	A	A	NA	A	A	NA	A	A	NA	NA	NA	NA	P	1	1	1	0.9	0.9	1	0
xy41843377148416	Diaz St	Assapumpset Brook	A	A	NA	A	A	NA	A	A	NA	A	NA	NA	P	1	1	1	0.9	0.9	1	0
xy41845017150193	Atwood Ave	Unt to Assapumpset Brook	A	A	NA	A	A	NA	A	A	NA	A	NA	NA	A	1	1	1	1	1	1	0
xy41845257150309	Carpenter Drive	Unt to Assapumpset Brook	A	A	NA	A	P	A	P	P	NA	A	NA	NA	A	1	1	0.2	0.8	0.2	5	0
xy41845877148670	George Waterman St	Assapumpset Brook	U	U	U	A	U	U	U	U	U	A	U	U	U	1	1	1	1	1	1	1
xy41845877148670	George Waterman St	Assapumpset Brook	A	P	U	A	A	U	A	A	U	A	U	U	A	1	1	0.2	1	0.2	5	1
xy41848417149462	Clemence Ln	Assapumpset Brook	A	P	NA	A	A	A	A	A	NA	NA	NA	NA	A	1	1	0.2	1	0.2	5	0
xy41848417149462	Clemence Ln	Assapumpset Brook	A	A	NA	A	A	NA	A	A	NA	NA	NA	NA	A	1	1	1	1	1	1	0
xy41848877150503	Pine Hill Ave	Assapumpset Brook	A	P	NA	A	A	A	A	A	NA	NA	NA	NA	A	1	1	0.2	1	0.2	5	0
xy41850727148167	Allendale Ave	Woonasquatucket River	A	P	NA	NA	A	NA	A	A	A	A	NA	NA	A	1	1	0.2	1	0.2	5	0
xy41853897155040	Winsor Rd	Unt to Slack Reservoir	A	A	U	A	A	U	U	U	U	U	U	U	U	1	1	1	1	1	1	1
xy41853977155807	Winsor Rd	Unt to Slack Reservoir	P	A	NA	A	P	P	A	A	NA	NA	A	NA	A	1	1	0.2	0.8	0.2	5	0
xy41855037152232	Greenville Ave	Unt to Assapumpset Brook	A	A	A	A	A	A	A	A	U	P	U	U	A	1	1	1	0.9	0.9	1	1
xy41855187155720	Barden Ln	Unt to Slack Reservoir	A	A	NA	P	P	NA	C	C	NA	NA	NA	NA	P	0	0.2	1	0.7	0	5	0
xy41855907154386	Winsor Rd	Unt to Slack Reservoir	A	A	NA	A	A	A	A	A	A	P	NA	NA	P	1	1	1	0.8	0.8	2	0
xy41858547156285	Orchard Ave	Unt to Slack Reservoir	A	A	A	A	A	NA	A	A	A	NA	A	A	A	1	1	1	1	1	1	0
xy41859167148748	Putnam Pike	Woonasquatucket River	A	A	NA	NA	A	NA	A	A	A	A	A	NA	A	1	1	1	1	1	1	0
xy41859507155898	Roger Williams Drive	Unt to Slack Reservoir	A	A	A	A	A	NA	P	A	NA	NA	NA	A	A	1	1	0.2	1	0.2	5	0
xy41861407156668	Sheffield Rd	Unt to Slack Reservoir	U	A	U	U	A	P	A	A	U	A	A	A	A	1	1	0.2	1	0.2	5	1
xy41861407156668	Sheffield Rd	Unt to Slack Reservoir	A	A	NA	A	A	A	A	A	NA	A	A	NA	A	1	1	1	1	1	1	0
xy41861587154159	Greenville Ave	Unt to Slack Reservoir	A	P	NA	C	A	NA	A	A	NA	A	A	NA	A	1	0.2	0.2	1	0.2	5	0
xy41863027154374	Greenville Ave	Unt to Slack Reservoir	A	A	A	A	A	NA	A	A	NA	NA	A	A	A	1	1	1	1	1	1	0
xy41863027154374	Greenville Ave	Unt to Slack Reservoir	A	A	A	A	A	NA	A	A	NA	NA	A	A	A	1	1	1	1	1	1	0
xy41863507153509	Finne Rd	Unt to Slack Reservoir	A	A	NA	A	A	NA	P	A	NA	NA	A	NA	A	1	1	0.2	1	0.2	5	0
xy41865407149229	Angell Ave	Woonasquatucket River	A	A	NA	NA	A	NA	A	A	A	A	NA	NA	A	1	1	1	1	1	1	0
xy41866427149748	Dean St	Unt to Woonasquatucket River	A	A	NA	A	A	NA	A	A	NA	A	A	NA	A	1	1	1	1	1	1	0
xy41866737155823	Smith Ave Extension	Unt to Slack Reservoir	A	A	A	A	A	NA	A	A	NA	NA	A	A	A	1	1	1	1	1	1	0
xy41866907149909	Kenton Drive	Unt to Woonasquatucket River	A	A	NA	A	A	NA	A	A	NA	NA	A	NA	A	1	1	1	1	1	1	0
xy41866937155857	Smith Ave	Unt to Slack Reservoir	A	A	U	U	A	U	A	A	U	U	A	U	A	1	1	1	1	1	1	1
xy41867357150081	Mowry Ave	Unt to Woonasquatucket	A	A	NA	A	A	NA	A	A	NA	NA	NA	NA	A	1	1	1	1	1	1	0
xy41867357150081	Mowry Ave	Unt to Woonasquatucket	A	A	NA	A	A	NA	A	A	NA	NA	NA	NA	A	1	1	1	1	1	1	0
xy41867767150198	Susan Drive	Unt to Woonasquatucket River	A	A	U	A	A	NA	A	A	U	A	U	U	A	1	1	1	1	1	1	1
xy41867937149613	Riverside Ave	Unt to Woonasquatucket River	A	P	NA	A	A	NA	A	A	NA	A	NA	NA	A	1	1	0.2	1	0.2	5	0
xy41867937149613	Riverside Ave	Unt to Woonasquatucket River	A	A	NA	A	A	NA	A	A	NA	A	NA	NA	A	1	1	1	1	1	1	0
xy41867937149613	Riverside Ave	Unt to Woonasquatucket River	A	P	NA	C	A	A	C	A	P	A	NA	P	A	0	0.2	0.1	0.9	0	5	0
xy41868517157685	West Greenville Rd	Unt	A	A	NA	A	P	A	A	A	NA	NA	NA	NA	A	1	1	1	0.9	0.9	1	0
xy41869227150721	Esmond St	Unt to Woonasquatucket River	A	A	A	A	A	NA	U	U	NA	NA	NA	NA	A	1	1	1	1	1	1	1
xy41869837155412	Smith Ave	Unt to Slack Reservoir	P	P	A	A	A	NA	A	A	NA	NA	NA	NA	NA	1	1	0.2	0.9	0.2	5	0
xy41870167152512	Putnam Pike	Unt to Hawkins Brook	A	A	NA	A	A	NA	A	A	NA	A	NA	NA	A	1	1	1	1	1	1	0

Gray boxes indicate missing data. Yellow boxes indicate assumptions that were made to compensate for missing data. See Pilot Study and Digitial Database for details regarding assumptions.

Structural Condition Worksheet

Crossing Code	Road Name	Stream Name	Inlet, Outlet or Barrel Condition A = Adequate P = Poor C = Critical U = Unknown NA = Not Applicable													Scoring						Unknown Structural Variable Flag
			Longitudinal Alignment	Level of Blockage	Flared End Section	Invert Deterioration	Buoyancy or Crushing	Cross-Section Deformation	Structural Integrity of Barrel	Joints & Seams	Footings	Headwalls & Wingwalls	Armoring	Apron/ Scour Protection	Embankment Piping	Level 1 Variables V1 (0.0-1.0)	Level 2 Variables V2 Part 1 (0.0-1.0)	Level 2 Variables V2 Part II (0.0-1.0)	Level 3 Variables V3 (0.0-1.0)	Structural Condition Score (0.0-1.0)	Binned Structural Condition Score (1-5)	
xy41870207153556	Putnam Pike	Reaper Brook	A	A	A	A	A	NA	A	A	A	C	NA	NA	A	1	0.2	1	1	0.2	5	0
xy41871207155179	Putnam Pike	Slack Reservoir Outflow	A	A	NA	A	A	NA	A	A	A	A	A	A	A	1	1	1	1	1	1	0
xy41871637157756	West Greenville Rd	Waterman Reservoir	A	A	NA	A	NA	NA	A	A	A	A	NA	NA	A	1	1	1	1	1	1	0
xy41871997158854	Aldrich Rd	Unt to Waterman Reservoir	P	A	NA	A	A	NA	A	P	NA	P	NA	NA	A	1	1	1	0.7	0.7	2	0
xy41872697150528	Esmond St	Hawkins Brook	A	P	P	A	A	NA	A	A	NA	NA	A	NA	A	1	1	0.2	0.9	0.2	5	0
xy41872697150528	Esmond St	Hawkins Brook	A	A	A	A	A	NA	A	A	NA	A	A	NA	A	1	1	1	1	1	1	0
xy41872937157686	West Greenville Rd	Unt	A	A	NA	A	A	NA	A	A	NA	P	NA	NA	A	1	1	1	0.9	0.9	1	0
xy41873167150365	Julien St	Hawkins Brook	A	A	NA	A	A	NA	A	A	NA	C	NA	NA	A	1	0.2	1	1	0.2	5	0
xy41873187150300	Dean St	Hawkins Brook	A	A	NA	A	A	NA	A	A	NA	A	NA	A	A	1	1	1	1	1	1	0
xy41873187150300	Dean St	Hawkins Brook	A	A	NA	A	A	NA	A	A	NA	A	NA	A	A	1	1	1	1	1	1	0
xy41873637149711	Esmond Mill Drive	Woonasquatucket River	A	A	NA	NA	A	NA	A	U	A	P	NA	NA	A	1	1	1	0.9	0.9	1	0
xy41874287154980	Pleasant View Circle	Unt to Stillwater River	A	A	U	P	A	P	A	A	NA	U	U	U	A	1	1	0.2	0.9	0.2	5	0
xy41874767155492	Austin Ave	Stillwater River	A	A	NA	A	A	NA	A	A	C	P	A	NA	A	0	1	1	0.9	0	5	0
xy41874767155492	Austin Ave	Stillwater River	A	A	NA	A	A	NA	A	A	A	A	P	NA	A	1	1	1	0.9	0.9	1	0
xy41875437157379	West Greenville Ave	Unt to Waterman Reservoir	A	A	NA	A	NA	NA	P	P	P	P	A	NA	NA	1	1	0.1	0.8	0.1	5	0
xy41875777159319	Old Quarry Rd	Unt to Waterman Reservoir	A	A	A	A	A	NA	A	P	NA	NA	NA	A	A	1	1	1	0.9	0.9	1	0
xy41877147159409	Old Quarry Rd	Unt to Waterman Reservoir	A	A	A	A	A	NA	A	P	NA	NA	NA	NA	A	1	1	1	0.9	0.9	1	0
xy41877287153708	Cedar Swamp Road	Reaper Brook	P	A	NA	A	A	NA	A	U	A	P	NA	NA	A	1	1	1	0.8	0.8	2	0
xy41877397157132	West Greenville Rd	Stillwater River	A	A	NA	A	A	NA	A	A	A	P	NA	NA	NA	1	1	1	0.9	0.9	1	0
xy41877427157059	Putnam Pike	Stillwater Brook	A	A	NA	A	NA	NA	A	A	A	P	NA	NA	NA	1	1	1	0.9	0.9	1	0
xy41877557154924	Deerfield Drive	Stillwater River	A	A	NA	A	A	NA	A	A	NA	NA	A	NA	P	1	1	1	0.9	0.9	1	0
xy41877557154924	Deerfield Drive	Stillwater River	A	P	NA	A	A	NA	A	A	NA	A	A	NA	P	1	1	0.2	0.9	0.2	5	0
xy41878417150154	Esmond St	Woonasquatucket River	A	A	A	NA	A	NA	A	A	A	A	NA	NA	A	1	1	1	1	1	1	0
xy41878417150154	Esmond St	Woonasquatucket River	A	A	A	NA	A	NA	A	A	A	A	NA	NA	A	1	1	1	1	1	1	0
xy41878707160132	Sawmill Rd	Unt to Waterman Reservoir	A	A	NA	A	A	NA	A	A	NA	A	A	NA	A	1	1	1	1	1	1	0
xy41878737152022	Mountaindale Rd	Unt to Hawkins Brook	U	P	NA	A	A	NA	C	A	NA	NA	NA	NA	A	0	1	0.2	1	0	5	0
xy41880727150256	Farnum Pike	Woonasquatucket River	A	A	A	NA	A	NA	A	A	A	A	NA	NA	A	1	1	1	1	1	1	0
xy41880887157821	Putnam Pike	Waterman Reservoir	U	P	NA	U	U	NA	U	U	NA	NA	NA	NA	U	1	1	0.2	1	0.2	5	1
xy41881987151110	Old Country Rd	Unt to Woonasquatucket River	A	P	NA	A	A	NA	A	A	NA	A	NA	NA	A	1	1	0.2	1	0.2	5	0
xy41883167160369	Melody Hill Ln	Unt to Waterman Reservoir	A	C	NA	A	A	A	A	A	NA	A	NA	NA	A	0	1	1	1	0	5	0
xy41883167160369	Melody Hill Ln	Unt to Waterman Reservoir	A	C	NA	A	A	A	P	A	NA	A	NA	NA	A	0	1	0.2	1	0	5	0
xy41883307160203	Sawmill Rd	Unt to Waterman Reservoir	A	A	NA	A	A	NA	A	A	NA	A	NA	NA	A	1	1	1	1	1	1	0
xy41883627158219	Putnam Pike	Nine Foot Brook	A	A	NA	A	A	NA	A	P	A	P	A	NA	A	1	1	1	0.8	0.8	2	0
xy41883977158247	Austin Ave	Nine Foot Brook	A	A	NA	A	A	NA	A	A	NA	P	A	NA	A	1	1	1	0.9	0.9	1	0
xy41883977159943	Waterman Lake Drive	Unt to Cutler Brook	A	A	P	A	A	A	A	A	NA	A	A	NA	A	1	1	1	0.9	0.9	1	0
xy41883977159943	Waterman Lake Drive	Unt to Cutler Brook	A	A	A	A	A	A	A	A	NA	A	A	A	A	1	1	1	1	1	1	0
xy41884477150737	Farnum Pike	Unt to Woonasquatucket River	A	C	U	U	A	U	A	A	U	C	A	U	U	0	0.2	1	1	0	5	1
xy41884487160015	Sawmill Rd	Cutler Brook	A	A	NA	A	A	NA	A	A	NA	P	A	NA	A	1	1	1	0.9	0.9	1	0
xy41884547154339	Indian Run Rd	Unt to Stillwater River	P	A	NA	A	A	NA	A	A	NA	C	NA	NA	A	1	0.2	1	0.9	0.2	5	0
xy41884547154339	Indian Run Rd	Unt to Stillwater River	A	A	NA	A	A	NA	A	A	NA	C	NA	NA	A	1	0.2	1	1	0.2	5	0
xy41884547154339	Indian Run Rd	Unt to Stillwater River	A	A	NA	A	A	NA	A	A	NA	C	NA	NA	A	1	0.2	1	1	0.2	5	0
xy41884547154339	Indian Run Rd	Unt to Stillwater River	A	A	NA	A	A	NA	A	A	NA	C	NA	NA	A	1	0.2	1	1	0.2	5	0
xy41884807157218	Austin Ave	Unt to Waterman Reservoir	U	P	NA	U	U	NA	U	U	U	NA	U	NA	U	1	1	0.2	1	0.2	5	1
xy41884937158168	Stone Bridge Rd	Unt to Nine Foot Brook	U	U	NA	U	U	NA	U	U	U	NA	NA	NA	U	1	1	1	1	1	1	1
xy41885067154130	Pleasant View Ave	Stillwater River	A	A	NA	A	A	NA	A	A	A	A	NA	NA	A	1	1	1	1	1	1	0
xy41885087157849	Austin Avenue	Unt to Waterman Reservoir	U	C	U	A	U	NA	U	U	NA	A	NA	U	A	0	1	1	1	0	5	1
xy41885967155678	Baldwin Circle	Unt to Stillwater River	A	A	U	U	A	U	A	A	U	U	U	U	A	1	1	1	1	1	1	1
xy41886157153645	Mountaindale Road	Reaper Brook	A	A	NA	NA	A	NA	A	A	A	A	A	A	A	1	1	1	1	1	1	0
xy41886477153705	Mountaindale Road	Unnamed Wetland adjacent to Reaper Brook	A	A	NA	A	A	NA	A	U	NA	NA	NA	NA	A	1	1	1	1	1	1	0
xy41886617150419	Fenwood Ave	Unt to Woonasquatucket River	A	A	A	A	A	NA	A	A	NA	NA	A	NA	A	1	1	1	1	1	1	0
xy41886617150419	Fenwood Ave	Unt to Woonasquatucket River	A	A	P	A	A	NA	A	A	NA	NA	A	NA	A	1	1	1	0.9	0.9	1	0
xy41886617150419	Fenwood Ave	Unt to Woonasquatucket River	A	A	P	A	A	NA	A	A	NA	NA	A	NA	A	1	1	1	0.9	0.9	1	0
xy41886847150523	Whipple Ave	Woonasquatucket River	A	A	NA	NA	A	NA	A	A	A	A	NA	NA	A	1	1	1	1	1	1	0
xy41886917159166	Putnam Pike	Unt to Waterman Reservoir	A	A	NA	A	A	NA	A	A	A	A	A	A	A	1	1	1	1	1	1	0
xy41887077159144	Valley Rd	Unt to Waterman Reservoir	A	P	NA	A	A	NA	A	A	NA	A	NA	NA	A	1	1	0.2	1	0.2	5	0
xy41888247153923	Mountaindale Road	Stillwater River	A	A	NA	A	A	NA	A	C	NA	C	NA	NA	P	1	0.1	1	0.9	0.1	5	0
xy41888247153923	Mountaindale Road	Stillwater River	A	A	NA	A	A	NA	A	C	NA	C	NA	NA	P	1	0.1	1	0.9	0.1	5	0
xy41888657151262	Farnum Pike	Unt to Georgiaville Pond	A	P	NA	U	A	A	A	A	NA	A	NA	NA	A	1	1	0.2	1	0.2	5	0
xy41888657151262	Farnum Pike	Unt to Georgiaville Pond	A	P	NA	U	A	A	A	A	NA	A	NA	NA	A	1	1	0.2	1	0.2	5	0
xy41888837151740	Old County Rd	Unt to Georgiaville Pond	A	A	NA	A	A	NA	A	A	NA	C	NA	NA	A	1	0.2	1	1	0.2	5	0
xy41889357148731	Whipple Rd	Unt to Woonasquatucket River	A	A	NA	A	A	NA	P	A	NA	NA	A	NA	A	1	1	0.2	1	0.2	5	0
xy41890377149584	Ridge Rd	Unt to Woonasquatucket River	A	A	NA	A	A	NA	A	P	NA	NA	NA	NA	A	1	1	1	0.9	0.9	1	0
xy41890427151403	Sweet Rd	Unt to Georgiaville Pond	A	A	NA	A	A	NA	A	P	NA	A	A	A	A	1	1	1	0.9	0.9	1	0
xy41890427151403	Sweet Rd	Unt to Georgiaville Pond	A	A	NA	A	A	NA	A	P	NA	A	A	A	A	1	1	1	0.9	0.9	1	0
xy41890897156959	Colwell Rd	Unt to Upper Sprague Reservoir	A	A	NA	A	A	NA	A	A	NA	A	A	NA	A	1	1	1	1	1	1	0
xy41890917151543	Farnum Pike	Unt to Georgiaville Pond	U	A	U	P	A	U	P	P	U	A	A	U	A	1	1	0.2	0.8	0.2	5	1
xy41892467149331	Douglas Pike	Unt to Woonasquatucket River	U	U	NA	U	U	U	U	U	NA	C	NA	NA	U	1	0.2	1	1	0.2	5	1

Gray boxes indicate missing data. Yellow boxes indicate assumptions that were made to compensate for missing data. See Pilot Study and Digitial Database for details regarding assumptions.

Structural Condition Worksheet

Crossing Code	Road Name	Stream Name	Inlet, Outlet or Barrel Condition A = Adequate P = Poor C = Critical U = Unknown NA = Not Applicable													Scoring						Unknown Structural Variable Flag
			Longitudinal Alignment	Level of Blockage	Flared End Section	Invert Deterioration	Buoyancy or Crushing	Cross-Section Deformation	Structural Integrity of Barrel	Joints & Seams	Footings	Headwalls & Wingwalls	Armoring	Apron/ Scour Protection	Embankment Piping	Level 1 Variables V1 (0.0-1.0)	Level 2 Variables V2 Part 1 (0.0-1.0)	Level 2 Variables V2 Part II (0.0-1.0)	Level 3 Variables V3 (0.0-1.0)	Structural Condition Score (0.0-1.0)	Binned Structural Condition Score (1-5)	
xy41892467149331	Douglas Pike	Unt to Woonasquatucket River	U	C	NA	U	U	U	U	U	NA	C	NA	NA	U	0	0.2	1	1	0	5	1
xy41892547150396	Crest Drive	Unt to Woonasquatucket River	A	A	NA	NA	A	NA	A	A	A	A	A	A	A	1	1	1	1	1	1	0
xy41892547150396	Crest Drive	Unt to Woonasquatucket River	A	P	NA	A	A	NA	A	A	A	A	A	A	A	1	1	0.2	1	0.2	5	0
xy41892547150396	Crest Drive	Unt to Woonasquatucket River	A	P	NA	A	A	NA	A	A	A	A	A	A	A	1	1	0.2	1	0.2	5	0
xy41893077160835	Route 44	Cutler Brook	A	A	NA	A	A	NA	A	A	NA	C	NA	NA	A	1	0.2	1	1	0.2	5	0
xy41893317160808	Farnum Road	Cutler Brook	A	A	NA	A	A	NA	A	A	A	P	NA	NA	A	1	1	1	0.9	0.9	1	0
xy41894747150725	Stillwater Rd	Unt to Georgiaville Pond	A	A	NA	A	A	NA	A	A	NA	A	A	NA	C	1	0.2	1	1	0.2	5	0
xy41894747150725	Stillwater Rd	Unt to Georgiaville Pond	A	A	NA	A	A	NA	A	P	NA	A	A	NA	C	1	0.2	1	0.9	0.2	5	0
xy41894887152164	Farnum Pike	Unt to Georgiaville Pond	A	A	A	A	A	U	A	A	U	U	A	U	A	1	1	1	1	1	1	1
xy41894887152164	Farnum Pike	Unt to Georgiaville Pond	A	A	A	A	A	U	A	A	U	U	A	U	A	1	1	1	1	1	1	1
xy41895577161365	Route 44 Putnam Pike	Unt to Cutler Brook	A	A	NA	A	A	NA	A	A	NA	A	NA	NA	A	1	1	1	1	1	1	0
xy41896047161805	Route 44	Unti to Cutler Brook	A	A	NA	A	A	NA	A	A	NA	A	NA	NA	A	1	1	1	1	1	1	0
xy41896637160262	Farnum Rd	Unt to Waterman Reservoir	A	A	NA	A	A	NA	A	A	NA	P	NA	NA	A	1	1	1	0.9	0.9	1	0
xy41896697151958	Old county Rd/Lakeside Drive	Unt to Georgiaville Pond	A	A	A	A	A	NA	A	A	NA	P	A	NA	A	1	1	1	0.9	0.9	1	0
xy41897187150342	Ridge Rd	Unt to Georgiaville Pond	A	A	NA	A	A	A	A	A	NA	P	NA	NA	P	1	1	1	0.8	0.8	2	0
xy41897827156647	Colwell Rd	Unt to Upper Sprague Reservoir	A	A	U	U	A	A	A	A	NA	U	U	U	A	1	1	1	1	1	1	1
xy41898117157880	Evan's Rd	Nine Foot Brook	A	A	NA	A	NA	NA	A	A	A	A	NA	NA	A	1	1	1	1	1	1	0
xy41898457158358	Burlingame Ln	Unt to Nine Foot Brook	A	A	NA	A	A	NA	A	U	NA	A	NA	NA	A	1	1	1	1	1	1	0
xy41898477158323	Burlingame Ln	Unt to Nine Foot Brook	U	P	NA	A	A	NA	U	U	NA	P	NA	NA	A	1	1	0.2	0.9	0.2	5	1
xy41898517157816	Tarkiln Rd	Unt to Nine Foot Brook	A	A	NA	A	A	NA	A	A	A	NA	A	NA	A	1	1	1	1	1	1	0
xy41898517157816	Tarkiln Rd	Unt to Nine Foot Brook	A	P	NA	A	A	NA	A	U	NA	C	A	NA	A	1	0.2	0.2	1	0.2	5	0
xy41898907154304	Pleasantview Ave	Woonasquatucket Reservoir	A	A	NA	NA	A	NA	A	A	A	A	NA	NA	A	1	1	1	1	1	1	0
xy41898957150991	Stillwater Rd	Harris Brook	A	A	NA	NA	A	NA	A	A	A	A	A	NA	A	1	1	1	1	1	1	0
xy41899117154630	Log Rd	Woonasquatucket Reservoir	A	C	NA	P	A	A	A	A	NA	P	NA	NA	A	0	1	1	0.8	0	5	0
xy41899147150128	Douglas Pike	Unt to Georgiaville Pond	A	A	NA	A	A	NA	P	A	NA	P	NA	NA	A	1	1	0.2	0.9	0.2	5	0
xy41899277156654	Colwell Rd	Unt to Upper Sprague Reservoir	A	A	NA	A	A	NA	A	A	NA	A	A	A	A	1	1	1	1	1	1	0
xy41900117158371	Evans Rd	Unt to Shinscot Brook	U	A	NA	A	A	NA	A	A	NA	A	NA	NA	A	1	1	1	1	1	1	0
xy41900437149662	Catherine Rd	Unt to West River	U	A	U	U	A	U	A	A	U	U	U	U	A	1	1	1	1	1	1	1
xy41902037159401	Farnum road	Shinscot Brook	A	A	NA	P	A	NA	A	P	NA	A	A	NA	A	1	1	1	0.8	0.8	2	0
xy41902517157773	Tarkiln Rd	Unt to Nine Foot Brook	A	A	NA	A	A	NA	A	A	NA	A	NA	NA	A	1	1	1	1	1	1	0
xy41902577149498	Maureen Drive	Unt to West River	U	A	U	U	A	A	A	A	U	P	U	U	A	1	1	1	0.9	0.9	1	1
xy41902587151720	Stillwater Rd	Unt to Georgiaville Pond	A	A	A	A	A	NA	A	A	NA	NA	A	NA	A	1	1	1	1	1	1	0
xy41902587151720	Stillwater Rd	Unt to Georgiaville Pond	A	A	A	A	A	NA	A	A	NA	NA	A	NA	A	1	1	1	1	1	1	0
xy41902697157007	Mann School Rd	Unt to Upper Sprague Reservoir	A	P	NA	A	A	A	P	A	NA	P	A	NA	P	1	1	0.1	0.8	0.1	5	0
xy41902697157007	Mann School Rd	Unt to Upper Sprague Reservoir	A	P	NA	A	A	A	P	P	NA	P	A	NA	P	1	1	0.1	0.7	0.1	5	0
xy41902757152161	Capron Rd	Capron Pond	A	A	NA	NA	A	NA	A	A	A	A	A	NA	A	1	1	1	1	1	1	0
xy41902757159093	Farnum Rd	Unt	A	A	NA	A	A	NA	A	A	NA	NA	A	NA	A	1	1	1	1	1	1	0
xy41902877150377	Limerock Rd	Unt to Harris Brook	U	P	NA	U	A	A	A	A	NA	P	NA	NA	A	1	1	0.2	0.9	0.2	5	0
xy41902877150377	Limerock Rd	Unt to Harris Brook	U	P	NA	U	A	A	A	A	NA	A	NA	P	A	1	1	0.2	0.9	0.2	5	0
xy41904317158874	Evans road	Unt	U	C	U	U	C	U	C	U	U	U	U	U	U	0	0.2	1	1	0	5	1
xy41904937156221	Connors Farm Drive	Unt	A	A	NA	A	A	A	A	A	NA	A	A	NA	A	1	1	1	1	1	1	0
xy41905587149206	Clark Rd	Unt to West River	A	A	A	A	A	NA	A	A	NA	NA	NA	NA	A	1	1	1	1	1	1	0
xy41905587149206	Clark Rd	Unt to West River	A	A	A	A	A	NA	A	A	NA	NA	NA	NA	A	1	1	1	1	1	1	0
xy41906217161244	Cooper Ave	Cutler Brook	A	P	NA	A	A	NA	A	A	NA	NA	NA	NA	A	1	1	0.2	1	0.2	5	0
xy41908317153647	George Washington Highway	Woonasquatucket River	A	A	NA	NA	A	NA	A	A	A	NA	A	NA	A	1	1	1	1	1	1	0
xy41908677154068	Farnum Pike	Woonasquatucket River	A	A	NA	NA	A	NA	A	A	A	A	A	NA	A	1	1	1	1	1	1	0
xy41909167152497	Stillwater Rd	Unt to Stillwater Pond	U	A	NA	A	A	NA	A	A	NA	A	A	NA	A	1	1	1	1	1	1	0
xy41910887152828	Stillwater Rd	Unt to Stillwater Pond	A	A	NA	A	A	A	A	A	NA	P	A	A	A	1	1	1	0.9	0.9	1	0
xy41910887152828	Stillwater Rd	Unt to Stillwater Pond	A	A	NA	A	A	A	A	A	NA	P	A	A	A	1	1	1	0.9	0.9	1	0
xy41912007159704	Evans Rd	Unamed to Shinscot Brook	A	A	NA	A	A	NA	A	P	NA	A	NA	NA	A	1	1	1	0.9	0.9	1	0
xy41912687150232	Harris Rd	Unt to Harris Brook	A	A	NA	A	A	A	A	A	NA	A	NA	A	A	1	1	1	1	1	1	0
xy41912687150232	Harris Rd	Unt to Harris Brook	A	A	NA	A	P	A	A	A	NA	A	NA	A	A	1	1	1	0.9	0.9	1	0
xy41913457152883	George Washington Highway	Unt to Stillwater Pond	A	A	NA	A	A	A	P	A	NA	P	A	A	A	1	1	0.2	0.9	0.2	5	0
xy41913457152883	George Washington Highway	Unt to Stillwater Pond	A	A	NA	A	A	NA	P	A	NA	A	A	NA	A	1	1	0.2	1	0.2	5	0
xy41913477151701	Douglas Pike	Unt to Stillwater Pond	A	A	A	A	A	NA	A	A	NA	NA	A	A	A	1	1	1	1	1	1	0
xy41914027155460	Log Rd	Woonasquatucket Reservoir	A	A	NA	P	A	A	A	P	NA	P	NA	A	A	1	1	1	0.7	0.7	2	0
xy41914137156217	Burlingame Rd	Unt to Woonasquatucket Reservoir	A	A	A	A	A	NA	A	A	NA	NA	A	NA	A	1	1	1	1	1	1	0
xy41914137156217	Burlingame Rd	Unt to Woonasquatucket Reservoir	A	A	A	A	A	NA	A	A	NA	NA	A	NA	A	1	1	1	1	1	1	0
xy41914227154859	Industrial Rd S.	Unt to Woonasquatucket Reservoir	A	A	A	A	A	NA	A	P	A	NA	NA	NA	A	1	1	1	0.9	0.9	1	0
xy41914627152630	George Washington Highway	Unt to Stillwater Pond	A	A	C	A	A	A	A	A	NA	NA	NA	NA	A	1	0.2	1	1	0.2	5	0
xy41916527154817	Industrial Drive	Unt to Woonasquatucket Reservoir	A	A	NA	A	A	NA	A	A	NA	A	NA	NA	A	1	1	1	1	1	1	0
xy41916957158201	Tarkiln Rd	Unt to Nine Foot Brook	A	P	U	U	A	U	A	A	U	U	U	U	U	1	1	0.2	1	0.2	5	1
xy41918867152209	Douglas Pike	Unt to Stillwater Pond	A	P	A	A	A	NA	A	A	NA	NA	A	NA	A	1	1	0.2	1	0.2	5	0
xy41918867152209	Douglas Pike	Unt to Stillwater Pond	A	P	A	A	A	NA	A	A	NA	NA	A	NA	A	1	1	0.2	1	0.2	5	0
xy41920067155939	Burlingame Rd	Latham Brook	A	A	NA	A	A	NA	A	A	NA	NA	A	NA	A	1	1	1	1	1	1	0
xy41920097155278	Old Forge Rd	Woonasquatucket River	A	A	NA	A	A	NA	A	A	NA	A	A	NA	A	1	1	1	1	1	1	0
xy41920937158733	Tarkiln Rd	Unt to Nine Foot Brook	A	A	NA	A	A	NA	A	A	NA	P	NA	NA	A	1	1	1	0.9	0.9	1	0

Gray boxes indicate missing data. Yellow boxes indicate assumptions that were made to compensate for missing data. See Pilot Study and Digitial Database for details regarding assumptions.

Structural Condition Worksheet

Crossing Code	Road Name	Stream Name	Inlet, Outlet or Barrel Condition A = Adequate P = Poor C = Critical U = Unknown NA = Not Applicable													Scoring						Unknown Structural Variable Flag
			Longitudinal Alignment	Level of Blockage	Flared End Section	Invert Deterioration	Buoyancy or Crushing	Cross-Section Deformation	Structural Integrity of Barrel	Joints & Seams	Footings	Headwalls & Wingwalls	Armoring	Apron/ Scour Protection	Embankment Piping	Level 1 Variables V1 (0.0-1.0)	Level 2 Variables V2 Part 1 (0.0-1.0)	Level 2 Variables V2 Part II (0.0-1.0)	Level 3 Variables V3 (0.0-1.0)	Structural Condition Score (0.0-1.0)	Binned Structural Condition Score (1-5)	
xy41921057155828	Log Rd	Unt to Latham Brook	A	A	NA	A	A	NA	A	A	NA	A	A	NA	A	1	1	1	1	1	1	0
xy41921057155828	Log Rd	Unt to Latham Brook	A	A	NA	A	A	NA	A	A	NA	A	A	NA	A	1	1	1	1	1	1	0
xy41922257156115	Log Rd	Latham Brook	A	A	NA	A	A	NA	P	A	NA	NA	A	NA	A	1	1	0.2	1	0.2	5	0
xy41922257156115	Log Rd	Latham Brook	A	A	NA	P	A	NA	P	A	NA	A	A	NA	A	1	1	0.2	0.9	0.2	5	0
xy41923277152886	Douglas Pike	Unt to Stillwater Reservoir	A	A	NA	A	A	NA	A	P	NA	A	NA	NA	A	1	1	1	0.9	0.9	1	0
xy41923437156751	Bayberry Rd	Latham Brook	A	A	NA	A	A	NA	A	P	NA	NA	NA	NA	A	1	1	1	0.9	0.9	1	0
xy41923797156391	Log Rd	Latham Brook	A	A	A	A	A	NA	A	A	NA	A	A	NA	A	1	1	1	1	1	1	0
xy41924017152999	Douglas Pike	Unt to Stillwater Reservoir	A	P	A	A	A	NA	A	A	NA	NA	NA	A	A	1	1	0.2	1	0.2	5	0
xy41924467152624	Essex St	Unt to Stillwater Pond	A	A	NA	NA	A	A	A	A	A	NA	A	NA	A	1	1	1	1	1	1	0
xy41924627153417	Bryant U. entryway off of Douglas Pike	Unt to Stillwater Pond	A	A	NA	A	A	NA	A	A	NA	A	NA	NA	A	1	1	1	1	1	1	0
xy41926177155080	Farnum Pike	Unt to Woonasquatucket River	A	A	NA	A	A	A	A	A	NA	A	NA	NA	A	1	1	1	1	1	1	0
xy41926517153403	Douglas Pike	Unt to Stillwater Pond	A	A	NA	A	A	NA	A	P	NA	A	A	NA	A	1	1	1	0.9	0.9	1	0
xy41926627152983	Essex St	Unt to Stillwater Pond	A	A	NA	A	A	A	A	A	NA	A	A	NA	A	1	1	1	1	1	1	0
xy41927997155005	Rogler Farm Rd	Unt to Woonasquatucket Reservoir	U	A	U	U	A	NA	P	U	U	U	U	U	A	1	1	0.2	1	0.2	5	1
xy41927997155005	Rogler Farm Rd	Unt to Woonasquatucket Reservoir	U	A	U	U	A	NA	A	U	U	U	U	U	A	1	1	1	1	1	1	1
xy41928037152264	Lydia Ann Rd	Unt to Stillwater Pond	A	A	NA	A	A	NA	A	A	A	A	NA	NA	A	1	1	1	1	1	1	0
xy41928037152264	Lydia Ann Rd	Unt to Stillwater Pond	A	A	NA	A	A	NA	A	A	A	A	NA	NA	A	1	1	1	1	1	1	0
xy41928037152264	Lydia Ann Rd	Unt to Stillwater Pond	A	A	NA	A	A	NA	A	A	A	A	NA	NA	A	1	1	1	1	1	1	0
xy41928267155140	Farnum Pike	Woonasquatucket River	A	A	NA	NA	A	NA	A	A	P	P	NA	NA	A	1	1	0.2	0.9	0.2	5	0
xy41929067155367	Latham Farm Rd	Unt to Woonasquatucket River	A	A	NA	A	A	NA	A	A	NA	A	NA	NA	A	1	1	1	1	1	1	0
xy41929207157455	Log Rd	Unt to Latham Brook	U	P	NA	A	A	NA	A	A	NA	NA	NA	NA	A	1	1	0.2	1	0.2	5	0
xy41929207157455	Log Rd	Unt to Latham Brook	U	A	NA	U	U	NA	U	U	NA	NA	NA	NA	U	1	1	1	1	1	1	1
xy41930757160155	Long Entry Rd	Unnamed Wetland	A	P	NA	A	A	A	A	A	NA	NA	NA	NA	A	1	1	0.2	1	0.2	5	0
xy41931447155286	Farnum Pike	Unt to Woonasquatucket River	A	A	A	A	A	NA	A	P	NA	NA	NA	NA	A	1	1	1	0.9	0.9	1	0
xy41938517155343	Douglas Pike	Woonasquatucket River	A	A	NA	NA	A	NA	A	A	A	P	NA	A	A	1	1	1	0.9	0.9	1	0
xy41939037155601	Farnum Pike	Unt to Woonasquatucket River	P	P	A	A	A	NA	C	A	NA	A	A	A	A	0	1	0.2	0.9	0	5	0
xy41943527156049	Douglas Pike	Unt to Woonasquatucket River	U	U	U	A	A	A	P	U	U	A	U	U	U	1	1	0.2	1	0.2	5	1
xy41943527156049	Douglas Pike	Unt to Woonasquatucket River	U	U	U	P	U	A	P	U	U	A	U	U	U	1	1	0.2	0.9	0.2	5	1
xy41950277156940	Douglas Pike	Unt to Woonasquatucket River	A	A	NA	A	A	A	P	A	NA	A	NA	NA	A	1	1	0.2	1	0.2	5	0
xy41954007157431	Douglas Pike	Unt to Woonasquatucket River	A	A	NA	U	A	A	P	U	NA	P	NA	NA	A	1	1	0.2	0.9	0.2	5	0
xy41954667155188	Greenville Rd	Woonasquatucket River	A	A	NA	A	A	NA	A	A	NA	P	A	NA	A	1	1	1	0.9	0.9	1	0
xy41954667155188	Greenville Rd	Woonasquatucket River	A	A	NA	A	A	NA	A	A	NA	P	A	NA	A	1	1	1	0.9	0.9	1	0
xy41954727157531	Douglas Pike	Unt	A	A	A	A	A	NA	A	A	NA	NA	A	A	A	1	1	1	1	1	1	0
xy41959377156205	Black Plain Rd	Unt to Primrose Pond	A	A	NA	A	A	A	A	A	NA	NA	NA	NA	A	1	1	1	1	1	1	0
xy41959547155800	Pond House Rd	Unt to Primrose Pond	U	A	NA	U	A	A	P	A	NA	A	NA	NA	A	1	1	0.2	1	0.2	5	0
xy41961437156227	Pond House Rd	Unt to Primrose Pond	A	A	NA	NA	A	NA	A	U	A	A	A	NA	A	1	1	1	1	1	1	0
xy41962007156644	Mattity Rd	Unt to Primrose Pond	A	A	NA	A	A	NA	P	A	NA	A	NA	NA	A	1	1	0.2	1	0.2	5	0
xy41962407156390	Black Plain Rd	Unt to Primrose Pond	A	A	NA	NA	A	NA	A	NA	A	A	NA	NA	A	1	1	1	1	1	1	0
xy41964317155322	Providence Pike	Unt to Woonasquatucket River	A	A	A	A	A	NA	A	P	NA	NA	NA	NA	A	1	1	1	0.9	0.9	1	0
xy41972767155740	Providence Pike	Unt to Woonasquatucket River	U	A	A	U	A	NA	A	A	U	NA	A	U	A	1	1	1	1	1	1	1

Gray boxes indicate missing data. Yellow boxes indicate assumptions that were made to compensate for missing data. See Pilot Study and Digitial Database for details regarding assumptions.

Attachment F

Aquatic Organism Passage Assessment Worksheet

Aquatic Organism Passage Worksheet

				Aquatic Organism Passage Component Scores														Scoring					
Crossing Code	Road Name	Stream Name	IEI Value	Constriction	Inlet Grade	Internal Structures	Outlet Armoring	Physical Barriers	Scour Pool	Substrate Coverage	Substrate Matches Stream	Water Depth	Water Velocity	Openness Measurement	Openness Score (So)	Height Score (Sh)	Outlet Drop Score (Sod)	Weighted Composite Passability Score	Aquatic Passability Score	Binned Aquatic Organism Passage Score (1-5)	Binned Ecological Benefit Score (1-5)	Adjacent Crossing Flag	Wildlife CrossingFlag
xy41817227144364	Manton Ave	Woonasquatucket River	0.884	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	7.90	1.00	1.00	1.00	1.000	1.000	1	4	1	0
xy41819437144226	Delaine St	Woonasquatucket River	0.917	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	10.87	1.00	1.00	1.00	1.000	1.000	1	5	1	0
xy41822527143992	Valley St	Woonasquatucket River	0.895	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	6.14	1.00	1.00	1.00	1.000	1.000	1	4	1	0
xy41823467146025	Glenbridge Ave	Woonasquatucket River	0.903	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0				1.00			1	4	0	1
xy41824557143824	Atwells Ave	Woonasquatucket River	0.904	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	5.73	1.00	1.00	1.00	1.000	1.000	1	4	1	0
xy41826547143567	Eagle St	Woonasquatucket River	0.92	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	5.32	1.00	1.00	1.00	1.000	1.000	1	5	1	0
xy41826817141330	N/A: Footbridge	Woonasquatucket River	0	0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	137.69	1.00	1.00	1.00	0.955	0.955	1	3	1	0
xy41826927141044	Steeple St	Woonasquatucket River	0.915	0.5	1.0	1.0	1.0	0.8	1.0	1.0	1.0	1.0	1.0	7.01	1.00	1.00	1.00	0.928	0.928	1	5	1	0
xy41826927141044	Steeple St	Woonasquatucket River	0.915	0.5	1.0	1.0	1.0	0.8	1.0	1.0	1.0	1.0	1.0	7.01	1.00	1.00	1.00	0.928	0.928	1	5	1	0
xy41827107141439	N/A: Footbridge	Woonasquatucket River	0	0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	27.19	1.00	1.00	1.00	0.955	0.955	1	3	1	0
xy41827107141439	N/A: Footbridge	Woonasquatucket River	0	0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	39.15	1.00	1.00	1.00	0.955	0.955	1	3	1	0
xy41827107141439	N/A: Footbridge	Woonasquatucket River	0	0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	30.36	1.00	1.00	1.00	0.955	0.955	1	3	1	0
xy41827117141226	Exchange St	Woonasquatucket River	0.924	0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	38.03	1.00	1.00	1.00	0.955	0.955	1	5	1	0
xy41827207141547	Francis St	Woonasquatucket River	0.863	0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	61.85	1.00		1.00			1	4	1	0
xy41827747141774	Park St	Woonasquatucket River	0.906	0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	12.99	1.00	1.00	1.00	0.955	0.955	1	4	1	0
xy41828647142862	Acorn St	Woonasquatucket River	0.897	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	11.55	1.00	1.00	1.00	1.000	1.000	1	4	1	0
xy41829017142325	Promenade St	Woonasquatucket River	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	19.58	1.00	1.00	1.00	1.000	1.000	1	4	1	0
xy41829077142660	Dean St	Woonasquatucket River	0.884	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	11.54	1.00	1.00	1.00	1.000	1.000	1	4	1	1
xy41829207142410	Promenade St	Woonasquatucket River	0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	19.05	1.00	1.00	1.00	1.000	1.000	1	3	1	0
xy41832947147052	Manson Ave	Dyerville Pond	0.914	0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	7.00	1.00	1.00	1.00	0.955	0.955	1	5	0	0
xy41834977144282	Pleasant Valley Parkway	Unt to Woonasquatucket River	0	0.5	0.0	1.0	0.0	1.0	1.0	0.0	0.0	1.0	1.0	0.25	0.48	0.79	1.00	0.666	0.666	2	3	1	0
xy41835427143915	Pleasant Valley Parkway	Unt to Woonasquatucket River	0	0.9	0.0	1.0	0.0	1.0	1.0	0.0	0.0	1.0	1.0	0.26	0.50	0.83	1.00	0.706	0.706	2	3	1	0
xy41836747144463	Pleasant Valley Parkway	Unt to Woonasquatucket River	0	0.5	1.0	1.0	1.0	1.0	0.8	1.0	1.0	1.0	1.0			0.92	1.00			3	3	1	0
xy41837147148177	Waterman Ave	Unt to Woonasquatucket River	0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.5	0.5	0.16	0.26	0.84	1.00	0.656	0.656	2	3	1	0
xy41837797148021	Di Sarro Ave	Unt to Woonasquatucket River	0	0.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.37	0.71	0.92	0.16	0.396	0.155	5	3	1	0
xy41841257148494	Waterman Ave	Unt to Assapumpset Brook	0.565	0.0	1.0	1.0	1.0	1.0	1.0	0.5	1.0	1.0	1.0			0.75	1.00			3	3	1	1
xy41842197148400	Diaz St	Unt to Assapumpset Brook	0.595	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	1.0	1.0	0.17	0.29	0.72	1.00	0.733	0.733	2	3	1	0
xy41842937148299	Armento St	Assapumpset Brook	0.832	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0			0.84	1.00			3	4	1	0
xy41843377148416	Diaz St	Assapumpset Brook	0.738	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	1.0	1.0	0.09	0.10	0.62	1.00	0.719	0.719	2	4	1	0
xy41843377148416	Diaz St	Assapumpset Brook	0.738	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	1.0	1.0	0.09	0.10	0.62	1.00	0.719	0.719	2	4	1	0
xy41845017150193	Atwood Ave	Unt to Assapumpset Brook	0.609	0.0	1.0	1.0	1.0	1.0	1.0	0.5	0.8	0.5	0.5	0.05	0.02	0.62	1.00	0.715	0.715	2	3	1	1
xy41845257150309	Carpenter Drive	Unt to Assapumpset Brook	0.616	0.0	0.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.04	0.01	0.13	1.00	0.442	0.442	3	3	1	0
xy41845877148670	George Waterman St	Assapumpset Brook	0.726	0.0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.5			0.84	1.00			3	4	1	0
xy41845877148670	George Waterman St	Assapumpset Brook	0.726	0.0	1.0	1.0	1.0	0.5	1.0	0.0	0.0	1.0	1.0			0.35	1.00			3	4	1	0
xy41848417149462	Clemence Ln	Assapumpset Brook	0.7	0.0	1.0	1.0	1.0	0.8	1.0	0.0	0.0	1.0	1.0			0.79	1.00			3	3	1	0
xy41848417149462	Clemence Ln	Assapumpset Brook	0.7	0.0	0.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.5			0.79	0.13			3	3	1	0
xy41848877150503	Pine Hill Ave	Assapumpset Brook	0.563	0.0	1.0	1.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.22	0.42	0.79	0.02	0.288	0.016	5	3	1	0
xy41850727148167	Allendale Ave	Woonasquatucket River	0.907	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0	22.93	1.00	1.00	1.00	0.920	0.920	1	4	1	0
xy41853897155040	Winsor Rd	Unt to Slack Reservoir	0.6	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.00	0.00	0.35	1.00	0.540	0.540	3	3	0	0
xy41853977155807	Winsor Rd	Unt to Slack Reservoir	0.525	0.5	1.0	1.0	1.0	1.0	1.0	0.0	0.0	1.0	1.0	0.20	0.37	0.72	0.03	0.626	0.029	5	3	1	0
xy41855037152232	Greenville Ave	Unt to Assapumpset Brook	0	0.0	1.0	1.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0			0.35	1.00			3	3	1	0
xy41855187155720	Barden Ln	Unt to Slack Reservoir	0.502	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.08	0.07	0.35	0.96	0.537	0.537	3	2	1	0
xy41855907154386	Winsor Rd	Unt to Slack Reservoir	0.575	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.24	0.45	0.72	1.00	0.580	0.580	3	3	1	1
xy41858547156285	Orchard Ave	Unt to Slack Reservoir	0.691	0.0	0.0	1.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.13	0.18	0.72	1.00	0.440	0.440	3	3	1	0
xy41859167148748	Putnam Pike	Woonasquatucket River	0.941	0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	25.13	1.00	1.00	1.00	0.955	0.955	1	5	1	0
xy41859507155898	Roger Williams Drive	Unt to Slack Reservoir	0.646	0.0	0.0	1.0	0.5	0.0	1.0	0.0	0.0	0.0	0.0	0.32	0.63	0.72	0.27	0.230	0.230	4	3	1	1
xy41861407156668	Sheffield Rd	Unt to Slack Reservoir	0.634	0.0	1.0	1.0	0.5	1.0	0.8	0.0	0.0	0.5	0.5			0.50	1.00			3	3	1	0
xy41861407156668	Sheffield Rd	Unt to Slack Reservoir	0.634	0.0	1.0	1.0	0.5	1.0	0.8	0.0	0.0	0.5	0.5	0.05	0.02	0.79	1.00	0.609	0.609	2	3	1	0
xy41861587154159	Greenville Ave	Unt to Slack Reservoir	0	0.0	1.0	1.0	1.0	0.5	1.0	0.5	1.0	1.0	1.0	0.02	0.00	0.35	0.74	0.691	0.691	2	3	1	0
xy41863027154374	Greenville Ave	Unt to Slack Reservoir	0.555	0.5	1.0	1.0	0.5	0.8	1.0	0.0	0.0	0.0	0.0	0.10	0.12	0.72	0.27	0.445	0.272	4	3	1	0
xy41863027154374	Greenville Ave	Unt to Slack Reservoir	0.555	0.5	1.0	1.0	0.5	0.8	1.0	0.0	0.0	0.0	0.0	0.10	0.12	0.72	0.41	0.466	0.407	3	3	1	0
xy41863507153509	Finne Rd	Unt to Slack Reservoir	0	0.5	1.0	1.0	1.0	1.0	1.0	0.0	0.0	1.0	1.0	0.09	0.08	0.62	1.00	0.763	0.763	2	3	1	1
xy41865407149229	Angell Ave	Woonasquatucket River	0.93	0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	16.12	1.00	1.00	1.00	0.955	0.955	1	5	1	0
xy41866427149748	Dean St	Unt to Woonasquatucket River	0	0.0	0.0	1.0	1.0	0.0	1.0	0.0	0.0	1.0	1.0	0.02	0.00	0.28	1.00	0.476	0.476	3	3	1	0
xy41866737155823	Smith Ave Extension	Unt to Slack Reservoir	0	0.0	0.0	1.0	0.5	1.0	1.0	0.0	0.0	0.0	0.0	0.14	0.20	0.50	0.61	0.388	0.388	4	3	1	0
xy41866907149909	Kenton Drive	Unt to Woonasquatucket River	0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	1.0	1.0	0.07	0.05	0.50	0.74	0.669	0.669	2	3	1	0
xy41866937155857	Smith Ave	Unt to Slack Reservoir	0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0	1.0	1.0			0.35	0.86			3	3	1	1
xy41867357150081	Mowry Ave	Unt to Woonasquatucket	0	0.0	1.0	1.0	1.0	1.0	0.8	0.0	0.0	0.0	0.0	0.04	0.02	0.35	1.00	0.526	0.526	3	3	1	1
xy41867357150081	Mowry Ave	Unt to Woonasquatucket	0	0.0	1.0	1.0	1.0	0.5	0.8	0.0	0.0	0.0	0.5	0.02	0.00	0.19	1.00	0.491	0.491	3	3	1	1
xy41867767150198	Susan Drive	Unt to Woonasquatucket River	0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	1.0	1.0	0.03	0.01	0.62	1.00	0.714	0.714	2	3	1	0
xy41867937149613	Riverside Ave	Unt to Woonasquatucket River	0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.04	0.02	0.35	0.74	0.498	0.498	3	3	1	0
xy41867937149613	Riverside Ave	Unt to Woonasquatucket River	0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.04	0.02	0.35	0.33	0.433	0.332	4	3	1	0
xy41867937149613	Riverside Ave	Unt to Woonasquatucket River	0	0.0	0.0	1.0	0.5	0.0	1.0	0.0	0.0	0.0	0.5	0.02	0.00	0.19	1.00	0.331	0.331	4	3	1	0
xy41868517157685	West Greenville Rd	Unt	0	0.0	1.0	1.0	1.0	0.8	1.0	0.0	0.0	1.0	0.0	0.02	0.00	0.19	1.00	0.588	0.588	3	3	1	1
xy41869227150721	Esmond St	Unt to Woonasquatucket River	0	0.0	1.0	1.0	1.0	1.0	0.8	0.5	1.0	0.5	0.5	0.02	0.00	0.50	1.00	0.712	0.712	2	3	1	1
xy41869837155412	Smith Ave	Unt to Slack Reservoir	0	0.0	0.0	1.0	1.0	0.5	1.0	1.0	1.0	0.0	0.0	0.02	0.00	0.35	1.00	0.511	0.511	3	3	1	0
xy41870167152512	Putnam Pike	Unt to Hawkins Brook	0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	1.0	1.0	0.06	0.03	0.62	1.00	0.716	0.716	2	3	1	0
xy41870207153556	Putnam Pike	Reaper Brook	0.666	0.0	1.0	1.0	1.0	1.0	0.8	1.0	0.8	0.5	0.5	0.25	0.49	0.64	1.00	0.755	0.755	2	3	1	0
xy41871207155179	Putnam Pike	Slack Reservoir Outflow	0.701	0.0	0.0	1.0	0.5	0.0	0.8	0.0	0.0	0.0	0.0	0.06	0.03	0.64	0.86	0.277	0.277	4	3	1	0
xy41871637157756	West Greenville Rd	Waterman Reservoir	0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	4.01	1.00	1.00	1.00	0.910	0.910	1	3	1	0
xy41871997158854	Aldrich Rd	Unt to Waterman Reservoir	0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.06	0.04	0.50	0.11	0.405	0.110	5	3	1	0
xy41872697150528	Esmond St	Hawkins Brook	0.652	0.0	1.0	1.0	1.0	0.8	0.8	0.0	0.0	1.0	1.0	0.10	0.10	0.79	1.00	0.686	0.686	2	3	1	1
xy41872697150528	Esmond St	Hawkins Brook	0.652	0.0	1.0	1.0	1.0	1.0	0.8	0.0	0.0	1.0	1.0	0.10	0.10	0.79	1.00	0.713	0.713	2	3	1	1
xy41872937157686	West Greenville Rd	Unt	0.643	0.0	1.0	1.0	1.0	0.0	1.0	0.0	0.0	0.5	0.0	0.04	0.01	0.35	1.00	0.446	0.446	3	3	1	0
xy41873167150365	Julien St	Hawkins Brook	0.633	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.5	0.5	0.42	0.77	0.75	1.00	0.806	0.806	1	3	1	0
xy41873187150300	Dean St	Hawkins Brook	0.621	0.0	1.0	1.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.20	0.35	0.92	0.50	0.466	0.466	3	3	1	0
xy41873187150300	Dean St	Hawkins Brook	0.621	0.0	1.0	1.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.20	0.35	0.92	0.50	0.466	0.466	3	3	1	0
xy41873637149711	Esmond Mill Drive	Woonasquatucket River	0.941	0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	6.55	1.00	0.96	1.00	0.953	0.953	1	5	1	0
xy41874287154980	Pleasant View Circle	Unt to Stillwater River	0.732	0.0	1.0	1.0	1.0	1.0	1.0	0.5	0.8	1.0	1.0	0.26	0.51	0.84	1.00	0.832	0.832	1	4	1	1
xy41874767155492	Austin Ave	Stillwater River	0.811	0.0	1.0	1.0	1.0	1.0	0.8	1.0	1.0	0.5	0.5	0.82	0.98	0.87	1.00	0.808	0.808	1	4	1	0
xy41874767155492	Austin Ave	Stillwater River	0.811	0.0	1.0	1.0	1.0	1.0	0.8	1.0	1.0	0.5	0.0	0.50	0.85	0.91	1.00	0.763	0.763	2	4	1	0
xy41875437157379	West Greenville Ave	Unt to Waterman Reservoir	0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.14	1.00	0.90	1.00	0.905	0.905	1	3	1	0
xy41875777159319	Old Quarry Rd	Unt to Waterman Reservoir	0.529	0.5	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.10	0.11	0.72	0.74	0.494	0.494	3	3	1	0
xy41877147159409	Old Quarry Rd	Unt to Waterman Reservoir	0.547	0.0	1.0	1.0	1.0	1.0	0.8	0.0	0.0	0.0	0.0	0.09	0.09	0.72	0.50	0.466	0.466	3	3	1	0
xy41877287153708	Cedar Swamp Road	Reaper Brook	0.664	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.33	0.64	0.64	1.00	0.875	0.875	1	3	0	0
xy41877397157132	West Greenville Rd	Stillwater River	0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.21	1.00	0.90	1.00	0.905	0.905	1	3	0	0

Gray boxes indicate missing data. Yellow boxes indicate assumptions that were made to compensate for missing data. See Pilot Study and Digitial Database for details regarding assumptions.

Aquatic Organism Passage Worksheet

Crossing Code	Road Name	Stream Name	IEI Value	Aquatic Organism Passage Component Scores: Constriction	Inlet Grade	Internal Structures	Outlet Armoring	Physical Barriers	Scour Pool	Substrate Coverage	Substrate Matches Stream	Water Depth	Water Velocity	Openness Measurement	Openness Score (So)	Height Score (Sh)	Outlet Drop Score (Sod)	Scoring: Weighted Composite Passability Score	Aquatic Passability Score	Binned Aquatic Organism Passage Score (1-5)	Binned Ecological Benefit Score (1-5)	Adjacent Crossing Flag	Wildlife CrossingFlag
xy41877427157059	Putnam Pike	Stillwater Brook	0.766	0.9	1.0	1.0	1.0	1.0	0.8	1.0	1.0	1.0	1.0	1.78	1.00	1.00	1.00	0.977	0.977	1	4	1	1
xy41877557154924	Deerfield Drive	Stillwater River	0.848	0.0	1.0	1.0	1.0	1.0	0.8	0.0	0.0	0.0	0.0	0.34	0.67	0.92	1.00	0.586	0.586	3	4	1	0
xy41877557154924	Deerfield Drive	Stillwater River	0.848	0.0	1.0	1.0	1.0	0.8	0.8	0.0	0.0	0.0	0.0	0.34	0.67	0.92	1.00	0.559	0.559	3	4	0	0
xy41878177153571	Walter Carey Road	Unt to Mountaindale Reservoir	0	0.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	1.0	0.06	0.04	0.35	1.00	0.696	0.696	2	3	0	0
xy41878417150154	Esmond St	Woonasquatucket River	0.926	0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	10.12	1.00	1.00	1.00	0.955	0.955	1	5	0	0
xy41878707160132	Sawmill Rd	Unt to Waterman Reservoir	0.493	0.0	0.0	1.0	1.0	1.0	1.0	0.0	0.0	1.0	1.0	0.07	0.06	0.50	1.00	0.623	0.623	2	2	1	0
xy41878737152022	Mountaindale Rd	Unt to Hawkins Brook	0	0.0	0.0	1.0	1.0	0.5	1.0	1.0	1.0	0.5	0.5	0.03	0.01	0.35	1.00	0.593	0.593	3	3	1	0
xy41880727150256	Farnum Pike	Woonasquatucket River	0.89	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	15.82	1.00	1.00	1.00	0.829	0.829	1	4	0	0
xy41880887157821	Putnam Pike	Waterman Reservoir	0	0.0	1.0	1.0	1.0	0.8	1.0	1.0	1.0	1.0	1.0	0.09	0.08	0.72	1.00	0.823	0.823	1	3	1	1
xy41881987151110	Old Country Rd	Unt to Woonasquatucket River	0.616	0.0	1.0	1.0	1.0	0.5	1.0	1.0	1.0	1.0	1.0	0.14	0.21	0.84	1.00	0.794	0.794	2	3	1	0
xy41883167160369	Melody Hill Ln	Unt to Waterman Reservoir	0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.02	0.00	0.19	0.74	0.548	0.548	3	3	1	0
xy41883167160369	Melody Hill Ln	Unt to Waterman Reservoir	0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.02	0.00	0.19	0.41	0.494	0.407	3	3	1	0
xy41883307160203	Sawmill Rd	Unt to Waterman Reservoir	0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.5	0.5	0.04	0.01	0.50	1.00	0.628	0.628	2	3	1	0
xy41883627158219	Putnam Pike	Nine Foot Brook	0.772	0.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	1.0	1.0	0.32	0.64	0.92	1.00	0.690	0.690	2	4	1	0
xy41883977158247	Austin Ave	Nine Foot Brook	0.772	0.0	1.0	1.0	1.0	1.0	0.8	0.0	0.0	0.0	0.0	0.30	0.59	0.84	1.00	0.578	0.578	3	4	1	1
xy41883977159943	Waterman Lake Drive	Unt to Cutler Brook	0	0.5	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.13	0.18	0.66	0.74	0.566	0.566	3	3	1	0
xy41883977159943	Waterman Lake Drive	Unt to Cutler Brook	0	0.5	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.13	0.18	0.66	0.50	0.527	0.500	3	3	1	0
xy41884477150737	Farnum Pike	Unt to Woonasquatucket River	0.552	0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0			0.50	-0.01			3	3	1	0
xy41884487160015	Sawmill Rd	Cutler Brook	0.609	0.0	1.0	1.0	1.0	1.0	0.8	0.0	0.0	0.0	0.0	0.61	0.92	0.92	1.00	0.599	0.599	3	3	1	1
xy41884547154339	Indian Run Rd	Unt to Stillwater River	0.674	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.25	0.48	0.79	0.74	0.542	0.542	3	3	1	0
xy41884547154339	Indian Run Rd	Unt to Stillwater River	0.674	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.25	0.49	0.79	0.74	0.543	0.543	3	3	1	0
xy41884547154339	Indian Run Rd	Unt to Stillwater River	0.674	0.0	1.0	1.0	1.0	0.8	1.0	0.0	0.0	0.0	0.5	0.19	0.33	0.72	0.96	0.580	0.580	3	3	1	0
xy41884547154339	Indian Run Rd	Unt to Stillwater River	0.674	0.0	0.0	1.0	1.0	1.0	1.0	0.5	0.8	0.0	0.5	0.25	0.48	0.79	1.00	0.617	0.617	2	3	1	0
xy41884807157218	Austin Ave	Unt to Waterman Reservoir	0	0.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	1.0				1.00			3	3	1	1
xy41884937158168	Stone Bridge Rd	Unt to Nine Foot Brook	0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0				1.00			3	3	1	0
xy41885067154130	Pleasant View Ave	Stillwater River	0.873	0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.55	1.00	0.93	1.00	0.952	0.952	1	4	1	0
xy41885087157849	Austin Avenue	Unt to Waterman Reservoir	0	0.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	1.0	0.05	0.03	0.19	1.00	0.688	0.688	2	3	1	0
xy41885967155678	Baldwin Circle	Unt to Stillwater River	0.502	0.0	1.0	1.0	1.0	0.8	1.0	0.0	0.0	0.0	0.0			0.35	1.00			3	2	1	0
xy41886157153645	Mountaindale Road	Reaper Brook	0.776	0.9	0.0	1.0	0.5	0.5	1.0	1.0	0.8	0.5	1.0	2.65	1.00	0.89	1.00	0.753	0.753	2	4	1	0
xy41886477153705	Mountaindale Road	Unnamed Wetland adjacent to Reaper Brook	0	0.5	1.0	1.0	1.0	1.0	1.0	1.0	0.8	1.0	0.0	0.05	0.02	0.25	1.00	0.773	0.773	2	3	1	0
xy41886617150419	Fenwood Ave	Unt to Woonasquatucket River	0.586	0.5	1.0	1.0	1.0	0.8	1.0	0.0	0.0	0.0	1.0	0.07	0.05	0.62	0.96	0.646	0.646	2	3	1	0
xy41886617150419	Fenwood Ave	Unt to Woonasquatucket River	0.586	0.5	1.0	1.0	1.0	0.5	1.0	0.0	0.0	0.0	0.5	0.07	0.05	0.62	0.96	0.566	0.566	3	3	1	0
xy41886617150419	Fenwood Ave	Unt to Woonasquatucket River	0.586	0.5	1.0	1.0	1.0	0.8	1.0	0.0	0.0	0.0	0.5	0.07	0.05	0.62	0.96	0.606	0.606	2	3	1	0
xy41886847150523	Whipple Ave	Woonasquatucket River	0.931	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	12.88	1.00	1.00	1.00	0.991	0.991	1	5	1	0
xy41886917159166	Putnam Pike	Unt to Waterman Reservoir	0.544	0.0	1.0	1.0	0.5	1.0	1.0	0.0	0.0	1.0	1.0	0.05	0.03	0.50	1.00	0.691	0.691	2	3	1	0
xy41887077159144	Valley Rd	Unt to Waterman Reservoir	0.551	0.0	1.0	1.0	1.0	0.8	1.0	0.0	0.0	1.0	1.0	0.25	0.48	0.72	1.00	0.716	0.716	2	3	1	0
xy41888247153923	Mountaindale Road	Stillwater River	0	0.5	1.0	1.0	1.0	0.0	0.8	0.0	0.0	1.0	0.5	0.38	0.73	0.92	1.00	0.621	0.621	2	3	1	0
xy41888247153923	Mountaindale Road	Stillwater River	0	0.5	1.0	1.0	1.0	0.0	0.8	0.0	0.0	1.0	0.5	0.55	0.89	0.97	1.00	0.632	0.632	2	3	1	0
xy41888657151262	Farnum Pike	Unt to Georgiaville Pond	0	0.0	1.0	1.0	1.0	0.5	0.0	1.0	1.0	1.0	0.5	0.06	0.03	0.50	1.00	0.659	0.659	2	3	1	0
xy41888657151262	Farnum Pike	Unt to Georgiaville Pond	0	0.0	1.0	1.0	1.0	0.5	0.0	1.0	1.0	0.0	0.5	0.06	0.03	0.50	1.00	0.577	0.577	3	3	1	0
xy41888837151740	Old County Rd	Unt to Georgiaville Pond	0.445	0.0	0.0	1.0	1.0	1.0	1.0	0.5	1.0	0.5	0.5	0.04	0.01	0.35	1.00	0.632	0.632	2	2	1	0
xy41889357148731	Whipple Rd	Unt to Woonasquatucket River	0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.07	0.06	0.50	1.00	0.549	0.549	3	3	1	1
xy41890377149584	Ridge Rd	Unt to Woonasquatucket River	0.54	0.0	1.0	1.0	1.0	1.0	0.8	0.0	0.0	0.0	0.0	0.06	0.03	0.50	0.13	0.394	0.130	5	3	1	0
xy41890427151403	Sweet Rd	Unt to Georgiaville Pond	0.478	0.0	1.0	1.0	0.0	1.0	1.0	0.0	0.0	1.0	1.0	0.11	0.14	0.50	0.50	0.598	0.500	3	2	1	0
xy41890427151403	Sweet Rd	Unt to Georgiaville Pond	0.478	0.0	0.0	1.0	0.0	0.8	1.0	0.0	0.0	1.0	1.0	0.07	0.05	0.35	0.22	0.428	0.224	4	2	1	0
xy41890897156959	Colwell Rd	Unt to Upper Sprague Reservoir	0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.04	0.02	0.28	1.00	0.538	0.538	3	3	0	0
xy41890917151543	Farnum Pike	Unt to Georgiaville Pond	0.447	0.0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0			0.50	1.00			3	2	1	0
xy41892467149331	Douglas Pike	Unt to Woonasquatucket River	0.641	0.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0	0.5	0.5	0.06	0.03	0.50	1.00	0.621	0.621	2	3	1	0
xy41892467149331	Douglas Pike	Unt to Woonasquatucket River	0.641	0.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0	0.5	0.5	0.06	0.03	0.10	1.00	0.603	0.603	2	3	0	0
xy41892547150396	Crest Drive	Unt to Woonasquatucket River	0	1.0	1.0	1.0	0.0	0.8	1.0	1.0	0.8	1.0	1.0	0.14	0.20	0.52	1.00	0.855	0.855	1	3	1	0
xy41892547150396	Crest Drive	Unt to Woonasquatucket River	0	1.0	1.0	1.0	0.0	0.5	1.0	1.0	0.8	1.0	1.0	0.14	0.20	0.44	1.00	0.811	0.811	1	3	1	0
xy41892547150396	Crest Drive	Unt to Woonasquatucket River	0	1.0	1.0	1.0	0.0	0.0	1.0	1.0	0.8	1.0	1.0	0.14	0.20	0.35	1.00	0.740	0.740	2	3	1	0
xy41893077160835	Route 44	Cutler Brook	0.545	0.5	1.0	1.0	1.0	0.8	1.0	0.0	0.0	0.0	0.0	0.28	0.55	0.92	0.61	0.549	0.549	3	3	1	0
xy41893317160808	Farnum Road	Cutler Brook	0.575	0.5	0.0	1.0	1.0	1.0	1.0	0.0	0.0	1.0	1.0	0.26	0.52	0.86	1.00	0.709	0.709	2	3	1	0
xy41894747150725	Stillwater Rd	Unt to Georgiaville Pond	0.495	0.0	1.0	1.0	1.0	0.5	0.0	0.0	0.0	0.0	0.0	0.12	0.16	0.72	0.41	0.330	0.330	4	2	0	0
xy41894747150725	Stillwater Rd	Unt to Georgiaville Pond	0.495	0.0	1.0	1.0	1.0	0.5	0.0	0.0	0.0	0.0	0.0	0.13	0.18	0.72	0.41	0.331	0.331	4	2	1	0
xy41894887152164	Farnum Pike	Unt to Georgiaville Pond	0.512	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	1.0	1.0			0.84	1.00			3	3	1	0
xy41894887152164	Farnum Pike	Unt to Georgiaville Pond	0.512	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.5			0.84	1.00			3	3	1	0
xy41895577161365	Route 44 Putnam Pike	Unt to Cutler Brook	0	0.0	1.0	1.0	1.0	1.0	0.8	0.0	0.0	0.0	0.0	0.02	0.00	0.35	1.00	0.526	0.526	3	3	1	0
xy41896047161805	Route 44	Unti to Cutler Brook	0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.03	0.01	0.50	1.00	0.547	0.547	3	3	1	0
xy41896637160262	Farnum Rd	Unt to Waterman Reservoir	0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	1.0	1.0	0.06	0.03	0.28	0.50	0.620	0.500	3	3	1	0
xy41896697151958	Old county Rd/Lakeside Drive	Unt to Georgiaville Pond	0.591	0.0	0.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.50	0.27	0.270	0.270	3	3	1	0
xy41897187150342	Ridge Rd	Unt to Georgiaville Pond	0.602	0.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.42	0.78	0.84	1.00	0.531	0.531	3	3	1	0
xy41897827156647	Colwell Rd	Unt to Upper Sprague Reservoir	0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0			0.22	0.61			3	3	1	0
xy41898117157880	Evan's Rd	Nine Foot Brook	0.675	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.23	0.43	0.79	1.00	0.871	0.871	1	3	1	0
xy41898457158358	Burlingame Ln	Unt to Nine Foot Brook	0	0.0	0.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	1.0	0.07	0.05	0.16	1.00	0.600	0.600	3	3	1	0
xy41898477158323	Burlingame Ln	Unt to Nine Foot Brook	0.581	0.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	1.0	0.06	0.04	0.19	1.00	0.688	0.688	2	3	1	0
xy41898517157816	Tarkiln Rd	Unt to Nine Foot Brook	0.43	0.0	0.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	1.0	0.04	0.01	0.35	0.07	0.382	0.067	5	2	1	0
xy41898517157816	Tarkiln Rd	Unt to Nine Foot Brook	0.43	0.0	1.0	1.0	0.5	0.0	1.0	1.0	1.0	1.0	1.0	0.02	0.00	0.05	1.00	0.662	0.662	2	2	1	0
xy41898907154304	Pleasantview Ave	Woonasquatucket Reservoir	0.871	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	7.32	1.00	1.00	1.00	0.748	0.748	2	4	1	0
xy41898957150991	Stillwater Rd	Harris Brook	0.729	0.5	1.0	1.0	1.0	1.0	0.8	1.0	1.0	1.0	1.0	1.44	1.00	1.00	1.00	0.941	0.941	1	4	1	0
xy41899117154630	Log Rd	Woonasquatucket Reservoir	0.679	0.0	1.0	1.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.04	0.02	0.35	1.00	0.406	0.406	3	3	0	1
xy41899147150128	Douglas Pike	Unt to Georgiaville Pond	0.606	0.0	0.0	1.0	1.0	1.0	0.8	0.0	0.0	1.0	1.0	0.37	0.71	0.84	1.00	0.659	0.659	2	3	1	0
xy41899277156654	Colwell Rd	Unt to Upper Sprague Reservoir	0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.04	0.01	0.35	0.08	0.392	0.079	5	3	1	0
xy41900117158371	Evans Rd	Unt to Shinscot Brook	0.512	0.0	1.0	1.0	1.0	0.8	1.0	1.0	1.0	1.0	1.0	0.06	0.04	0.50	1.00	0.811	0.811	1	3	1	0
xy41900437149662	Catherine Rd	Unt to West River	0.515	0.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	1.0	0.0	0.02	0.00	0.62	0.96	0.557	0.557	3	3	1	0
xy41902037159401	Farnum road	Shinscot Brook	0.616	0.0	1.0	1.0	1.0	1.0	0.8	0.0	0.0	0.0	0.0	0.22	0.42	0.72	1.00	0.564	0.564	3	3	1	0
xy41902517157773	Tarkiln Rd	Unt to Nine Foot Brook	0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.02	0.00	0.19	1.00	0.533	0.533	3	3	1	0
xy41902577149498	Maureen Drive	Unt to West River	0.513	0.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	1.0	1.0			0.62	1.00			3	3	1	0
xy41902587151720	Stillwater Rd	Unt to Georgiaville Pond	0	0.9	1.0	1.0	1.0	0.5	1.0	0.0	0.0	0.0	0.0	0.05	0.03	0.72	1.00	0.571	0.571	3	3	1	0
xy41902587151720	Stillwater Rd	Unt to Georgiaville Pond	0	0.9	1.0	1.0	1.0	0.5	1.0	0.0	0.0	0.0	0.0	0.05	0.03	0.72	1.00	0.571	0.571	3	3	1	0
xy41902697157007	Mann School Rd	Unt to Upper Sprague Reservoir	0	0.5	1.0	1.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.07	0.05	0.35	0.96	0.446	0.446	3	3	1	0
xy41902697157007	Mann School Rd	Unt to Upper Sprague Reservoir	0	0.5	1.0	1.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.07	0.05	0.35	1.00	0.452	0.452	3	3	1	0
xy41902757152161	Capron Rd	Capron Pond	0.919	0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	6.55	1.00	1.00	1.00	0.955	0.955	1	5	1	0
xy41902757159093	Farnum Rd	Unt	0.647	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.05	0.02	0.35	0.03	0.386	0.034	5	3	1	0
xy41902877150377	Limerock Rd	Unt to Harris Brook	0.601	0.0	1.0	1.0	1.0	0.0	1.0	0.5	1.0	0.5	0.5	0.07	0.06	0.50	1.00	0.594	0.594	3	3	1	0

Gray boxes indicate missing data. Yellow boxes indicate assumptions that were made to compensate for missing data. See Pilot Study and Digitial Database for details regarding assumptions.

Aquatic Organism Passage Worksheet

Crossing Code	Road Name	Stream Name	IEI Value	Aquatic Organism Passage Component Scores														Scoring				Adjacent Crossing Flag	Wildlife CrossingFlag
				Constriction	Inlet Grade	Internal Structures	Outlet Armoring	Physical Barriers	Scour Pool	Substrate Coverage	Substrate Matches Stream	Water Depth	Water Velocity	Openness Measurement	Openness Score (So)	Height Score (Sh)	Outlet Drop Score (Sod)	Weighted Composite Passability Score	Aquatic Passability Score	Binned Aquatic Organism Passage Score (1-5)	Binned Ecological Benefit Score (1-5)		
xy41902877150377	Limerock Rd	Unt to Harris Brook	0.601	0.0	1.0	1.0	1.0	0.0	1.0	0.5	1.0	0.5	0.5	0.07	0.06	0.50	1.00	0.594	0.594	3	3	1	0
xy41904317158874	Evans road	Unt	0	0.9	1.0	1.0	1.0	0.0	1.0	0.0	0.0	1.0	1.0	0.02	0.00	0.19	1.00	0.641	0.641	2	3	1	0
xy41904937156221	Connors Farm Drive	Unt	0	0.9	1.0	1.0	1.0	0.8	1.0	1.0	0.8	0.0	0.0	0.40	0.75	0.88	1.00	0.766	0.766	2	3	1	0
xy41905587149206	Clark Rd	Unt to West River	0.638	0.5	0.0	1.0	1.0	1.0	0.8	0.0	0.0	0.0	0.0	0.04	0.02	0.35	0.50	0.403	0.403	3	3	1	0
xy41905587149206	Clark Rd	Unt to West River	0.638	0.5	0.0	1.0	1.0	1.0	0.8	0.0	0.0	0.0	0.0	0.04	0.02	0.35	0.74	0.441	0.441	3	3	1	0
xy41906217161244	Cooper Ave	Cutler Brook	0	0.0	1.0	1.0	1.0	0.8	1.0	1.0	0.8	0.0	0.0	0.06	0.04	0.35	1.00	0.624	0.624	2	3	1	0
xy41908317153647	George Washington Highway	Woonasquatucket River	0.921	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0				1.00			1	5	1	0
xy41908677154068	Farnum Pike	Woonasquatucket River	0.898	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0				1.00			1	4	1	0
xy41909167152497	Stillwater Rd	Unt to Stillwater Pond	0.625	0.0	0.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	1.0	0.05	0.03	0.72	1.00	0.550	0.550	3	3	1	0
xy41910887152828	Stillwater Rd	Unt to Stillwater Pond	0.7	0.0	1.0	1.0	0.5	1.0	0.8	0.0	0.0	1.0	1.0	0.47	0.83	0.80	0.03	0.577	0.034	5	3	1	0
xy41910887152828	Stillwater Rd	Unt to Stillwater Pond	0.7	0.0	1.0	1.0	0.5	1.0	0.8	0.0	0.0	1.0	1.0	0.53	0.87	0.76	0.05	0.580	0.048	5	3	0	0
xy41912007159704	Evans Rd	Unamed to Shinscot Brook	0.619	0.5	1.0	1.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.25	0.49	0.72	1.00	0.492	0.492	3	3	1	1
xy41912687150232	Harris Rd	Unt to Harris Brook	0.57	0.5	1.0	1.0	1.0	1.0	0.8	0.0	0.0	1.0	1.0	0.21	0.39	0.68	0.86	0.746	0.746	2	3	1	0
xy41912687150232	Harris Rd	Unt to Harris Brook	0.57	0.5	0.0	1.0	1.0	1.0	0.8	0.0	0.0	1.0	1.0	0.21	0.40	0.68	0.86	0.658	0.658	2	3	1	0
xy41913457152883	George Washington Highway	Unt to Stillwater Pond	0.691	0.0	1.0	1.0	1.0	0.8	0.0	0.0	0.0	0.5	1.0	0.02	0.00	0.50	1.00	0.570	0.570	3	3	1	0
xy41913457152883	George Washington Highway	Unt to Stillwater Pond	0.691	0.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	1.0	0.13	0.19	0.84	1.00	0.581	0.581	3	3	1	0
xy41913477151701	Douglas Pike	Unt to Stillwater Pond	0.522	0.0	1.0	1.0	0.0	0.8	1.0	0.0	0.0	0.0	0.0	0.03	0.01	0.50	0.86	0.461	0.461	3	3	0	0
xy41914027155460	Log Rd	Woonasquatucket Reservoir	0.809	0.0	1.0	1.0	0.5	1.0	1.0	0.0	0.0	0.0	0.0	0.40	0.75	0.72	1.00	0.577	0.577	3	4	1	0
xy41914137156217	Burlingame Rd	Unt to Woonasquatucket Reservoir	0	0.0	1.0	1.0	1.0	0.8	1.0	0.0	0.0	0.0	0.5	0.19	0.33	0.72	1.00	0.586	0.586	3	3	1	0
xy41914137156217	Burlingame Rd	Unt to Woonasquatucket Reservoir	0	0.0	1.0	1.0	1.0	0.8	1.0	0.0	0.0	1.0	1.0	0.19	0.33	0.72	1.00	0.708	0.708	2	3	1	0
xy41914227154859	Industrial Rd S.	Unt to Woonasquatucket Reservoir	0.593	0.0	1.0	1.0	1.0	0.8	1.0	1.0	1.0	1.0	1.0	0.09	0.09	0.72	1.00	0.823	0.823	1	3	1	0
xy41914627152630	George Washington Highway	Unt to Stillwater Pond	0.636	0.0	1.0	1.0	1.0	1.0	0.8	0.0	0.0	0.5	1.0	0.04	0.02	0.50	1.00	0.654	0.654	2	3	0	0
xy41916527154817	Industrial Drive	Unt to Woonasquatucket Reservoir	0.625	0.0	1.0	1.0	1.0	1.0	1.0	0.7	1.0	1.0	1.0	0.11	0.13	0.70	1.00	0.834	0.834	1	3	0	0
xy41916957158201	Tarkiln Rd	Unt to Nine Foot Brook	0.633	0.9	1.0	1.0	1.0	0.8	0.0	0.0	0.0	1.0	0.0	0.02	0.00	0.50	1.00	0.612	0.612	2	3	0	0
xy41918867152209	Douglas Pike	Unt to Stillwater Pond	0	0.0	1.0	1.0	1.0	0.8	1.0	0.0	0.0	0.5	0.5	0.04	0.01	0.50	1.00	0.601	0.601	2	3	0	0
xy41918867152209	Douglas Pike	Unt to Stillwater Pond	0	0.0	1.0	1.0	1.0	0.8	1.0	0.0	0.0	0.5	0.5	0.04	0.01	0.50	1.00	0.601	0.601	2	3	0	0
xy41920067155939	Burlingame Rd	Latham Brook	0.694	0.5	0.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	1.0	0.73	0.96	0.72	0.33	0.535	0.332	4	3	0	0
xy41920097155278	Old Forge Rd	Woonasquatucket River	0.647	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.86	0.98	0.84	0.27	0.496	0.272	4	3	0	0
xy41920937158733	Tarkiln Rd	Unt to Nine Foot Brook	0.553	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.03	0.01	0.28	1.00	0.537	0.537	3	3	0	0
xy41921057155828	Log Rd	Unt to Latham Brook	0.549	0.9	1.0	1.0	1.0	1.0	0.8	0.0	0.0	1.0	1.0	0.04	0.01	0.35	1.00	0.769	0.769	2	3	0	0
xy41921057155828	Log Rd	Unt to Latham Brook	0.549	0.9	1.0	1.0	1.0	1.0	0.8	0.0	0.0	1.0	1.0	0.04	0.01	0.35	1.00	0.769	0.769	2	3	0	0
xy41922257156115	Log Rd	Latham Brook	0.687	0.0	0.0	1.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.16	0.25	0.72	1.00	0.346	0.346	4	3	0	0
xy41922257156115	Log Rd	Latham Brook	0.687	0.0	1.0	1.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.18	0.30	0.73	1.00	0.437	0.437	3	3	0	0
xy41923277152886	Douglas Pike	Unt to Stillwater Reservoir	0.541	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.5	1.0	0.16	0.27	0.72	1.00	0.691	0.691	2	3	0	0
xy41923437156751	Bayberry Rd	Latham Brook	0.619	0.0	1.0	1.0	1.0	1.0	0.8	0.0	0.0	0.0	0.0	0.17	0.28	0.72	0.74	0.515	0.515	3	3	0	0
xy41923797156391	Log Rd	Latham Brook	0.694	0.0	0.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.43	0.79	0.84	1.00	0.515	0.515	3	3	0	0
xy41924017152999	Douglas Pike	Unt to Stillwater Reservoir	0	0.0	1.0	1.0	1.0	0.8	1.0	0.0	0.0	0.5	0.5	0.02	0.00	0.50	1.00	0.601	0.601	2	3	0	0
xy41924467152624	Essex St	Unt to Stillwater Pond	0.56	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	11.13	1.00	1.00	1.00	1.000	1.000	1	3	0	1
xy41924627153417	Bryant U. entryway off of Douglas Pike	Unt to Stillwater Pond	0.597	0.0	0.0	1.0	1.0	0.8	0.8	0.0	0.0	0.0	1.0	0.11	0.13	0.84	1.00	0.519	0.519	3	3	0	0
xy41926177155080	Farnum Pike	Unt to Woonasquatucket River	0	0.0	0.0	1.0	1.0	1.0	1.0	0.0	0.0	1.0	0.0	0.02	0.00	0.19	1.00	0.527	0.527	3	3	0	0
xy41926517153403	Douglas Pike	Unt to Stillwater Pond	0.599	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	1.0	0.0	0.20	0.35	0.72	1.00	0.657	0.657	2	3	0	0
xy41926627152983	Essex St	Unt to Stillwater Pond	0	0.0	0.0	1.0	1.0	1.0	1.0	0.5	1.0	1.0	1.0	0.13	0.18	0.72	1.00	0.738	0.738	2	3	0	0
xy41927997155005	Rogler Farm Rd	Unt to Woonasquatucket Reservoir	0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.05	0.02	0.38	1.00	0.831	0.831	1	3	0	0
xy41927997155005	Rogler Farm Rd	Unt to Woonasquatucket Reservoir	0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.05	0.02	0.35	1.00	0.830	0.830	1	3	0	0
xy41928037152264	Lydia Ann Rd	Unt to Stillwater Pond	0	0.9	1.0	1.0	1.0	0.8	1.0	1.0	0.8	1.0	1.0	1.57	1.00	0.92	1.00	0.943	0.943	1	3	0	0
xy41928037152264	Lydia Ann Rd	Unt to Stillwater Pond	0	0.9	1.0	1.0	1.0	0.8	1.0	1.0	1.0	1.0	1.0	20.08	1.00	1.00	1.00	0.964	0.964	1	3	0	0
xy41928037152264	Lydia Ann Rd	Unt to Stillwater Pond	0	0.9	0.0	1.0	1.0	0.8	1.0	1.0	0.8	1.0	1.0	1.60	1.00	0.93	1.00	0.855	0.855	1	3	0	0
xy41928267155140	Farnum Pike	Woonasquatucket River	0.818	0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.97	1.00	0.91	1.00	0.951	0.951	1	4	0	0
xy41929067155367	Latham Farm Rd	Unt to Woonasquatucket River	0	0.0	1.0	1.0	1.0	1.0	1.0	0.7	1.0	1.0	0.5	0.03	0.01	0.32	1.00	0.770	0.770	2	3	0	0
xy41929207157455	Log Rd	Unt to Latham Brook	0.69	0.0	1.0	1.0	1.0	0.5	1.0	0.0	0.0	0.0	0.5	0.02	0.00	0.19	0.74	0.463	0.463	3	3	0	0
xy41929207157455	Log Rd	Unt to Latham Brook	0.69	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.02	0.00	0.19	1.00	0.822	0.822	1	3	0	0
xy41930757160155	Long Entry Rd	Unnamed Wetland	0	0.0	1.0	1.0	1.0	0.8	1.0	0.0	0.0	0.0	0.0	0.02	0.00	0.19	1.00	0.506	0.506	3	3	0	0
xy41931447155286	Farnum Pike	Unt to Woonasquatucket River	0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	1.0	1.0	0.09	0.09	0.38	1.00	0.708	0.708	2	3	0	0
xy41938517155343	Douglas Pike	Woonasquatucket River	0.838	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.02	0.99	0.90	1.00	0.905	0.905	1	4	0	0
xy41939037155601	Farnum Pike	Unt to Woonasquatucket River	0.539	0.0	1.0	1.0	0.5	0.8	0.8	0.0	0.0	0.0	0.0	0.14	0.20	0.72	0.27	0.390	0.272	4	3	0	0
xy41943527156049	Douglas Pike	Unt to Woonasquatucket River	0	0.5	1.0	1.0	1.0	1.0	1.0	0.0	0.0	1.0	1.0			0.25	1.00			3	3	0	0
xy41943527156049	Douglas Pike	Unt to Woonasquatucket River	0	0.5	1.0	1.0	1.0	1.0	1.0	0.0	0.0	1.0	1.0			0.32	1.00			3	3	0	0
xy41950277156940	Douglas Pike	Unt to Woonasquatucket River	0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.05	0.02	0.28	1.00	0.538	0.538	3	3	0	0
xy41954007157431	Douglas Pike	Unt to Woonasquatucket River	0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.5	0.07	0.05	0.19	1.00	0.784	0.784	2	3	0	0
xy41954667155188	Greenville Rd	Woonasquatucket River	0.681	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.07	0.05	0.50	1.00	0.838	0.838	1	3	0	0
xy41954667155188	Greenville Rd	Woonasquatucket River	0.681	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.07	0.05	0.50	1.00	0.838	0.838	1	3	0	0
xy41954727157531	Douglas Pike	Unt	0	0.0	1.0	1.0	0.5	1.0	1.0	0.0	0.0	0.5	0.5	0.03	0.01	0.35	1.00	0.603	0.603	2	3	0	0
xy41959377156205	Black Plain Rd	Unt to Primrose Pond	0	0.0	1.0	1.0	1.0	0.8	1.0	0.0	0.0	1.0	1.0	0.18	0.30	0.72	1.00	0.707	0.707	2	3	0	0
xy41959547155800	Pond House Rd	Unt to Primrose Pond	0	0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.01	0.00	0.19	0.86	0.845	0.845	1	3	0	0
xy41961437156227	Pond House Rd	Unt to Primrose Pond	0	0.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	1.0	0.50	0.85	0.72	1.00	0.755	0.755	2	3	0	0
xy41962007156644	Mattity Rd	Unt to Primrose Pond	0.656	0.0	1.0	1.0	1.0	0.8	0.8	0.0	0.0	0.0	0.0	0.23	0.43	0.72	1.00	0.537	0.537	3	3	0	0
xy41962407156390	Black Plain Rd	Unt to Primrose Pond	0.644	0.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0	0.0	0.0	0.26	0.50	0.67	1.00	0.572	0.572	3	3	0	0
xy41964317155322	Providence Pike	Unt to Woonasquatucket River	0	0.0	1.0	1.0	1.0	1.0	1.0	0.7	1.0	1.0	1.0	0.07	0.05	0.35	1.00	0.814	0.814	1	3	0	0
xy41972767155740	Providence Pike	Unt to Woonasquatucket River	0	0.9	0.0	1.0	1.0	0.0	1.0	0.0	0.0	1.0	1.0	0.02	0.00	0.50	1.00	0.567	0.567	3	3	0	0

Gray boxes indicate missing data. Yellow boxes indicate assumptions that were made to compensate for missing data. See Pilot Study and Digitial Database for details regarding assumptions.

Attachment G

Flood Impact Potential Assessment Worksheet

Flood Impact Potential Worksheet

Crossing Code	Road Name	Stream Name	Potential Flood Impacts			Scoring				
			Percent Developed Area within Buffer	Number of Stream Crossings Upstream and Downstream of Crossing	Number of Utilities (Gas, Water, Sewer) conveyed by Crossing	Developed Area Score	Upstream/Downstream Crossings Score	Utilities Score	Flood Impact Potential Score (Sum)	Binned Flood Impact Potential Score (1-5)
xy41817227144364	Manton Ave	Woonasquatucket River	77%	2	2	5	5	5	15	5
xy41819437144226	Delaine St	Woonasquatucket River	78%	3	2	5	5	5	15	5
xy41822527143992	Valley St	Woonasquatucket River	85%	4	2	5	5	5	15	5
xy41823467146025	Glenbridge Ave	Woonasquatucket River	43%	0	2	4	1	5	10	3
xy41824557143824	Atwells Ave	Woonasquatucket River	83%	3	1	5	5	3	13	4
xy41826547143567	Eagle St	Woonasquatucket River	82%	4	1	5	5	3	13	4
xy41826817141330	N/A: Footbridge	Woonasquatucket River	51%	6	0	5	5	1	11	4
xy41826927141044	Steeple St	Woonasquatucket River	45%	6	0	4	5	1	10	3
xy41827107141439	N/A: Footbridge	Woonasquatucket River	53%	7	0	5	5	1	11	4
xy41827117141226	Exchange St	Woonasquatucket River	50%	6	1	5	5	3	13	4
xy41827207141547	Francis St	Woonasquatucket River	55%	8	3	5	5	5	15	5
xy41827747141774	Park St	Woonasquatucket River	59%	9	1	5	5	3	13	4
xy41828647142862	Acorn St	Woonasquatucket River	69%	4	2	5	5	5	15	5
xy41829017142325	Promenade St	Woonasquatucket River	45%	6	0	4	5	1	10	3
xy41829077142660	Dean St	Woonasquatucket River	54%	4	0	5	5	1	11	4
xy41829207142410	Promenade St	Woonasquatucket River	44%	5	0	4	5	1	10	3
xy41832947147052	Manson Ave	Dyerville Pond	30%	1	1	4	3	3	10	3
xy41834977144282	Pleasant Valley Parkway	Unt to Woonasquatucket River	85%	6	2	5	5	5	15	5
xy41835427143915	Pleasant Valley Parkway	Unt to Woonasquatucket River	100%	6	1	5	5	3	13	4
xy41836747144463	Pleasant Valley Parkway	Unt to Woonasquatucket River			1	1	1	3	5	3
xy41837147148177	Waterman Ave	Unt to Woonasquatucket River	27%	2	2	4	5	5	14	5
xy41837797148021	Di Sarro Ave	Unt to Woonasquatucket River	50%	6	0	4	5	1	10	3
xy41841257148494	Waterman Ave	Unt to Assapumpset Brook	86%	3	2	5	5	5	15	5
xy41842197148400	Diaz St	Unt to Assapumpset Brook	86%	3	2	5	5	5	15	5
xy41842937148299	Armento St	Assapumpset Brook	70%	3	1	5	5	3	13	4
xy41843377148416	Diaz St	Assapumpset Brook	19%	3	0	3	5	1	9	3
xy41845017150193	Atwood Ave	Unt to Assapumpset Brook	34%	2	0	4	5	1	10	3
xy41845257150309	Carpenter Drive	Unt to Assapumpset Brook	33%	2	0	4	5	1	10	3
xy41845877148670	George Waterman St	Assapumpset Brook	56%	4	0	5	5	1	11	4
xy41848417149462	Clemence Ln	Assapumpset Brook	19%	2	2	3	5	5	13	4
xy41848877150503	Pine Hill Ave	Assapumpset Brook	16%	1	2	3	3	5	11	4
xy41850727148167	Allendale Ave	Woonasquatucket River	17%	2	0	3	5	1	9	3
xy41853897155040	Winsor Rd	Unt to Slack Reservoir	18%	3	0	3	5	1	9	3
xy41853977155807	Winsor Rd	Unt to Slack Reservoir	1%	2	0	1	5	1	7	2
xy41855037152232	Greenville Ave	Unt to Assapumpset Brook	26%	1	0	4	3	1	8	3
xy41855187155720	Barden Ln	Unt to Slack Reservoir	1%	2	0	1	5	1	7	2
xy41855907154386	Winsor Rd	Unt to Slack Reservoir	3%	1	0	1	3	1	5	2
xy41858547156285	Orchard Ave	Unt to Slack Reservoir	13%	3	2	3	5	5	13	4
xy41859167148748	Putnam Pike	Woonasquatucket River	60%	0	1	5	1	3	9	3
xy41859507155898	Roger Williams Drive	Unt to Slack Reservoir	14%	3	2	3	5	5	13	4
xy41861407156668	Sheffield Rd	Unt to Slack Reservoir	22%	3	1	3	5	3	11	4
xy41861587154159	Greenville Ave	Unt to Slack Reservoir	2%	1	0	1	3	1	5	2
xy41863027154374	Greenville Ave	Unt to Slack Reservoir	3%	2	0	1	5	1	7	2
xy41863507153509	Finne Rd	Unt to Slack Reservoir	38%	3	0	4	5	1	10	3

Gray boxes indicate missing data. Yellow boxes indicate assumptions that were made to compensate for missing data. See Pilot Study and Digitial Database for details regarding assumptions.

Flood Impact Potential Worksheet

			Potential Flood Impacts			Scoring				
Crossing Code	Road Name	Stream Name	Percent Developed Area within Buffer	Number of Stream Crossings Upstream and Downstream of Crossing	Number of Utilities (Gas, Water, Sewer) conveyed by Crossing	Developed Area Score	Upstream/Downstream Crossings Score	Utilities Score	Flood Impact Potential Score (Sum)	Binned Flood Impact Potential Score (1-5)
xy41865407149229	Angell Ave	Woonasquatucket River	70%	6	0	5	5	1	11	4
xy41866427149748	Dean St	Unt to Woonasquatucket River	31%	5	2	4	5	5	14	5
xy41866737155823	Smith Ave Extension	Unt to Slack Reservoir	26%	3	0	4	5	1	10	3
xy41866907149909	Kenton Drive	Unt to Woonasquatucket River	28%	6	0	4	5	1	10	3
xy41866937155857	Smith Ave	Unt to Slack Reservoir	23%	2	0	3	5	1	9	3
xy41867357150081	Mowry Ave	Unt to Woonasquatucket	31%	6	2	4	5	5	14	5
xy41867767150198	Susan Drive	Unt to Woonasquatucket River	31%	6	2	4	5	5	14	5
xy41867937149613	Riverside Ave	Unt to Woonasquatucket River	33%	5	1	4	5	3	12	4
xy41868517157685	West Greenville Rd	Unt	62%	2	0	5	5	1	11	4
xy41869227150721	Esmond St	Unt to Woonasquatucket River	16%	4	1	3	5	3	11	4
xy41869837155412	Smith Ave	Unt to Slack Reservoir	22%	3	2	3	5	5	13	4
xy41870167152512	Putnam Pike	Unt to Hawkins Brook	55%	1	2	5	3	5	13	4
xy41870207153556	Putnam Pike	Reaper Brook	13%	3	2	3	5	5	13	4
xy41871207155179	Putnam Pike	Slack Reservoir Outflow	25%	6	2	4	5	5	14	5
xy41871637157756	West Greenville Rd	Waterman Reservoir	64%	2	0	5	5	1	11	4
xy41871997158854	Aldrich Rd	Unt to Waterman Reservoir	3%	1	0	1	3	1	5	2
xy41872697150528	Esmond St	Hawkins Brook	29%	3	2	4	5	5	14	5
xy41872937157686	West Greenville Rd	Unt	9%	4	0	2	5	1	8	3
xy41873167150365	Julien St	Hawkins Brook	23%	3	1	3	5	3	11	4
xy41873187150300	Dean St	Hawkins Brook	26%	3	2	4	5	5	14	5
xy41873637149711	Esmond Mill Drive	Woonasquatucket River	33%	1	0	4	3	1	8	3
xy41874287154980	Pleasant View Circle	Unt to Stillwater River	18%	4	2	3	5	5	13	4
xy41874767155492	Austin Ave	Stillwater River	26%	2	3	4	5	5	14	5
xy41875437157379	West Greenville Ave	Unt to Waterman Reservoir	9%	4	0	2	5	1	8	3
xy41875777159319	Old Quarry Rd	Unt to Waterman Reservoir	10%	1	0	3	3	1	7	2
xy41877147159409	Old Quarry Rd	Unt to Waterman Reservoir	13%	2	0	3	5	1	9	3
xy41877287153708	Cedar Swamp Road	Reaper Brook	890%	0	2	5	1	5	11	4
xy41877397157132	West Greenville Rd	Stillwater River	6%	2	2	2	5	5	12	4
xy41877427157059	Putnam Pike	Stillwater Brook	8%	4	3	2	5	5	12	4
xy41877557154924	Deerfield Drive	Stillwater River	20%	4	0	3	5	1	9	3
xy41878177153571	Walter Carey Road	Unt to Mountaindale Reservoir	790%	0	0	5	1	1	7	2
xy41878417150154	Esmond St	Woonasquatucket River	13%	4	0	3	5	1	9	3
xy41878707160132	Sawmill Rd	Unt to Waterman Reservoir	15%	3	0	3	5	1	9	3
xy41878737152022	Mountaindale Rd	Unt to Hawkins Brook	52%	1	0	5	3	1	9	3
xy41880727150256	Farnum Pike	Woonasquatucket River	18%	5	0	3	5	1	9	3
xy41880887157821	Putnam Pike	Waterman Reservoir	1%	3	0	1	5	1	7	2
xy41881987151110	Old Country Rd	Unt to Woonasquatucket River	23%	3	1	3	5	3	11	4
xy41883167160369	Melody Hill Ln	Unt to Waterman Reservoir	12%	3	0	3	5	1	9	3
xy41883307160203	Sawmill Rd	Unt to Waterman Reservoir	12%	3	0	3	5	1	9	3
xy41883627158219	Putnam Pike	Nine Foot Brook	10%	3	0	2	5	1	8	3
xy41883977158247	Austin Ave	Nine Foot Brook	11%	3	0	3	5	1	9	3
xy41883977159943	Waterman Lake Drive	Unt to Cutler Brook	8%	2	0	2	5	1	8	3
xy41884477150737	Farnum Pike	Unt to Woonasquatucket River			0	1	1	1	3	3
xy41884487160015	Sawmill Rd	Cutler Brook	6%	2	0	2	5	1	8	3

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Flood Impact Potential Worksheet

Crossing Code	Road Name	Stream Name	Potential Flood Impacts: Percent Developed Area within Buffer	Potential Flood Impacts: Number of Stream Crossings Upstream and Downstream of Crossing	Potential Flood Impacts: Number of Utilities (Gas, Water, Sewer) conveyed by Crossing	Scoring: Developed Area Score	Scoring: Upstream/Downstream Crossings Score	Scoring: Utilities Score	Scoring: Flood Impact Potential Score (Sum)	Scoring: Binned Flood Impact Potential Score (1-5)
xy41884547154339	Indian Run Rd	Unt to Stillwater River	16%	2	2	3	5	5	13	4
xy41884807157218	Austin Ave	Unt to Waterman Reservoir			0	1	1	1	3	3
xy41884937158168	Stone Bridge Rd	Unt to Nine Foot Brook			0	1	1	1	3	3
xy41885067154130	Pleasant View Ave	Stillwater River	14%	2	1	3	5	3	11	4
xy41885087157849	Austin Avenue	Unt to Waterman Reservoir	0%	1	0	1	3	1	5	2
xy41885967155678	Baldwin Circle	Unt to Stillwater River			2	1	1	5	7	3
xy41886157153645	Mountaindale Road	Reaper Brook	3%	1	1	1	3	3	7	2
xy41886477153705	Mountaindale Road	Unnamed Wetland adjacent to Reaper Brook	92%	0	0	5	1	1	7	2
xy41886617150419	Fenwood Ave	Unt to Woonasquatucket River	9%	2	0	2	5	1	8	3
xy41886847150523	Whipple Ave	Woonasquatucket River	25%	6	0	3	5	1	9	3
xy41886917159166	Putnam Pike	Unt to Waterman Reservoir	24%	2	2	3	5	5	13	4
xy41887077159144	Valley Rd	Unt to Waterman Reservoir	24%	2	0	3	5	1	9	3
xy41888247153923	Mountaindale Road	Stillwater River	262%	0	2	5	1	5	11	4
xy41888657151262	Farnum Pike	Unt to Georgiaville Pond	33%	2	2	4	5	5	14	5
xy41888837151740	Old County Rd	Unt to Georgiaville Pond	30%	3	0	4	5	1	10	3
xy41889357148731	Whipple Rd	Unt to Woonasquatucket River	0%	3	0	1	5	1	7	2
xy41890377149584	Ridge Rd	Unt to Woonasquatucket River	1%	4	0	1	5	1	7	2
xy41890427151403	Sweet Rd	Unt to Georgiaville Pond	33%	3	1	4	5	3	12	4
xy41890897156959	Colwell Rd	Unt to Upper Sprague Reservoir	5%	1	1	2	3	3	8	3
xy41890917151543	Farnum Pike	Unt to Georgiaville Pond	30%	3	2	4	5	5	14	5
xy41892467149331	Douglas Pike	Unt to Woonasquatucket River	0%	3	0	1	5	1	7	2
xy41892547150396	Crest Drive	Unt to Woonasquatucket River	19%	3	1	3	5	3	11	4
xy41893077160835	Route 44	Cutler Brook	3%	1	0	1	3	1	5	2
xy41893317160808	Farnum Road	Cutler Brook	3%	1	0	1	3	1	5	2
xy41894747150725	Stillwater Rd	Unt to Georgiaville Pond	0%	3	0	1	5	1	7	2
xy41894887152164	Farnum Pike	Unt to Georgiaville Pond	41%	5	1	4	5	3	12	4
xy41895577161365	Route 44 Putnam Pike	Unt to Cutler Brook	13%	1	0	3	3	1	7	2
xy41896047161805	Route 44	Unti to Cutler Brook	0%	1	0	1	3	1	5	2
xy41896637160262	Farnum Rd	Unt to Waterman Reservoir	0%	1	0	1	3	1	5	2
xy41896697151958	Old county Rd/Lakeside Drive	Unt to Georgiaville Pond	41%	5	1	4	5	3	12	4
xy41897187150342	Ridge Rd	Unt to Georgiaville Pond	3%	4	0	1	5	1	7	2
xy41897827156647	Colwell Rd	Unt to Upper Sprague Reservoir	1%	1	2	1	3	5	9	3
xy41898117157880	Evan's Rd	Nine Foot Brook	11%	3	0	3	5	1	9	3
xy41898457158358	Burlingame Ln	Unt to Nine Foot Brook	0%	2	0	1	5	1	7	2
xy41898477158323	Burlingame Ln	Unt to Nine Foot Brook	0%	3	0	1	5	1	7	2
xy41898517157816	Tarkiln Rd	Unt to Nine Foot Brook	13%	3	0	3	5	1	9	3
xy41898907154304	Pleasantview Ave	Woonasquatucket Reservoir	1%	2	1	1	5	3	9	3
xy41898957150991	Stillwater Rd	Harris Brook	19%	1	1	3	3	3	9	3
xy41899117154630	Log Rd	Woonasquatucket Reservoir	16%	1	2	3	3	5	11	4
xy41899147150128	Douglas Pike	Unt to Georgiaville Pond	10%	7	0	2	5	1	8	3
xy41899277156654	Colwell Rd	Unt to Upper Sprague Reservoir	1%	1	0	1	3	1	5	2
xy41900117158371	Evans Rd	Unt to Shinscot Brook	0%	4	0	1	5	1	7	2
xy41900437149662	Catherine Rd	Unt to West River			1	1	1	3	5	3
xy41902037159401	Farnum road	Shinscot Brook	0%	1	0	1	3	1	5	2

Gray boxes indicate missing data. Yellow boxes indicate assumptions that were made to compensate for missing data. See Pilot Study and Digitial Database for details regarding assumptions.

Flood Impact Potential Worksheet

			Potential Flood Impacts			Scoring				
Crossing Code	Road Name	Stream Name	Percent Developed Area within Buffer	Number of Stream Crossings Upstream and Downstream of Crossing	Number of Utilities (Gas, Water, Sewer) conveyed by Crossing	Developed Area Score	Upstream/Downstream Crossings Score	Utilities Score	Flood Impact Potential Score (Sum)	Binned Flood Impact Potential Score (1-5)
xy41902517157773	Tarkiln Rd	Unt to Nine Foot Brook	6%	2	0	2	5	1	8	3
xy41902577149498	Maureen Drive	Unt to West River			1	1	1	3	5	3
xy41902587151720	Stillwater Rd	Unt to Georgiaville Pond	15%	1	0	3	3	1	7	2
xy41902697157007	Mann School Rd	Unt to Upper Sprague Reservoir	13%	1	0	3	3	1	7	2
xy41902757152161	Capron Rd	Capron Pond	10%	2	0	2	5	1	8	3
xy41902757159093	Farnum Rd	Unt	0%	1	0	1	3	1	5	2
xy41902877150377	Limerock Rd	Unt to Harris Brook	3%	3	1	1	5	3	9	3
xy41904317158874	Evans road	Unt			0	1	1	1	3	3
xy41904937156221	Connors Farm Drive	Unt	0%	1	1	1	3	3	7	2
xy41905587149206	Clark Rd	Unt to West River	17%	3	0	3	5	1	9	3
xy41906217161244	Cooper Ave	Cutler Brook	1%	1	0	1	3	1	5	2
xy41908317153647	George Washington Highway	Woonasquatucket River	17%	1	0	3	3	1	7	2
xy41908677154068	Farnum Pike	Woonasquatucket River	0%	1	1	1	3	3	7	2
xy41909167152497	Stillwater Rd	Unt to Stillwater Pond	12%	3	2	3	5	5	13	4
xy41910887152828	Stillwater Rd	Unt to Stillwater Pond	9%	2	2	2	5	5	12	4
xy41912007159704	Evans Rd	Unamed to Shinscot Brook	0%	1	0	1	3	1	5	2
xy41912687150232	Harris Rd	Unt to Harris Brook	40%	1	0	4	3	1	8	3
xy41913457152883	George Washington Highway	Unt to Stillwater Pond	12%	1	1	3	3	3	9	3
xy41913477151701	Douglas Pike	Unt to Stillwater Pond	27%	2	0	4	5	1	10	3
xy41914027155460	Log Rd	Woonasquatucket Reservoir	6%	3	1	2	5	3	10	3
xy41914137156217	Burlingame Rd	Unt to Woonasquatucket Reservoir	1%	1	0	1	3	1	5	2
xy41914227154859	Industrial Rd S.	Unt to Woonasquatucket Reservoir	3%	3	3	1	5	5	11	4
xy41914627152630	George Washington Highway	Unt to Stillwater Pond	1%	1	1	1	3	3	7	2
xy41916527154817	Industrial Drive	Unt to Woonasquatucket Reservoir	11%	3	0	3	5	1	9	3
xy41916957158201	Tarkiln Rd	Unt to Nine Foot Brook			0	1	1	1	3	3
xy41918867152209	Douglas Pike	Unt to Stillwater Pond	0%	1	0	1	3	1	5	2
xy41920067155939	Burlingame Rd	Latham Brook	5%	7	0	2	5	1	8	3
xy41920097155278	Old Forge Rd	Woonasquatucket River	8%	2	1	2	5	3	10	3
xy41920937158733	Tarkiln Rd	Unt to Nine Foot Brook	0%	1	0	1	3	1	5	2
xy41921057155828	Log Rd	Unt to Latham Brook	6%	6	0	2	5	1	8	3
xy41922257156115	Log Rd	Latham Brook	5%	6	0	2	5	1	8	3
xy41923277152886	Douglas Pike	Unt to Stillwater Reservoir	7%	3	0	2	5	1	8	3
xy41923437156751	Bayberry Rd	Latham Brook	6%	2	0	2	5	1	8	3
xy41923797156391	Log Rd	Latham Brook	5%	5	0	1	5	1	7	2
xy41924017152999	Douglas Pike	Unt to Stillwater Reservoir	0%	1	0	1	3	1	5	2
xy41924467152624	Essex St	Unt to Stillwater Pond	6%	2	1	2	5	3	10	3
xy41924627153417	Bryant U. entryway off of Douglas Pike	Unt to Stillwater Pond	0%	2	0	1	5	1	7	2
xy41926177155080	Farnum Pike	Unt to Woonasquatucket River	3%	2	0	1	5	1	7	2
xy41926517153403	Douglas Pike	Unt to Stillwater Pond	7%	2	0	2	5	1	8	3
xy41926627152983	Essex St	Unt to Stillwater Pond	0%	1	1	1	3	3	7	2
xy41927997155005	Rogler Farm Rd	Unt to Woonasquatucket Reservoir	2%	2	0	1	5	1	7	2
xy41928037152264	Lydia Ann Rd	Unt to Stillwater Pond	7%	2	0	2	5	1	8	3
xy41928267155140	Farnum Pike	Woonasquatucket River	4%	3	0	1	5	1	7	2
xy41929067155367	Latham Farm Rd	Unt to Woonasquatucket River	7%	2	2	2	5	5	12	4

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Flood Impact Potential Worksheet

Crossing Code	Road Name	Stream Name	Potential Flood Impacts			Scoring				
			Percent Developed Area within Buffer	Number of Stream Crossings Upstream and Downstream of Crossing	Number of Utilities (Gas, Water, Sewer) conveyed by Crossing	Developed Area Score	Upstream/Downstream Crossings Score	Utilities Score	Flood Impact Potential Score (Sum)	Binned Flood Impact Potential Score (1-5)
xy41929207157455	Log Rd	Unt to Latham Brook	0%	1	0	1	3	1	5	2
xy41930757160155	Long Entry Rd	Unnamed Wetland	4%	1	0	1	3	1	5	2
xy41931447155286	Farnum Pike	Unt to Woonasquatucket River	8%	2	0	2	5	1	8	3
xy41938517155343	Douglas Pike	Woonasquatucket River	3%	1	0	1	3	1	5	2
xy41939037155601	Farnum Pike	Unt to Woonasquatucket River	3%	2	0	1	5	1	7	2
xy41943527156049	Douglas Pike	Unt to Woonasquatucket River	4%	0	0	1	1	1	3	1
xy41950277156940	Douglas Pike	Unt to Woonasquatucket River	2%	1	0	1	3	1	5	2
xy41954007157431	Douglas Pike	Unt to Woonasquatucket River	10%	1	0	3	3	1	7	2
xy41954667155188	Greenville Rd	Woonasquatucket River	4%	1	0	1	3	1	5	2
xy41954727157531	Douglas Pike	Unt	6%	1	0	2	3	1	6	2
xy41959377156205	Black Plain Rd	Unt to Primrose Pond	3%	1	0	1	3	1	5	2
xy41959547155800	Pond House Rd	Unt to Primrose Pond			0	1	1	1	3	3
xy41961437156227	Pond House Rd	Unt to Primrose Pond	6%	3	0	2	5	1	8	3
xy41962007156644	Mattity Rd	Unt to Primrose Pond	8%	3	0	2	5	1	8	3
xy41962407156390	Black Plain Rd	Unt to Primrose Pond	5%	3	0	2	5	1	8	3
xy41964317155322	Providence Pike	Unt to Woonasquatucket River	6%	1	0	2	3	1	6	2
xy41972767155740	Providence Pike	Unt to Woonasquatucket River	8%	0	0	2	1	1	4	1

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Attachment H

Disruption of Transportation Services Assessment Worksheet

Disruption of Transportation Services Worksheet

Crossing Code	Road Name	Stream Name	Located on Hurricane Evacuation Route	Located on E-911 Route	Road Classification (Highway Functional Classification)	Scoring					Local Knowledge Flag
						Hurricane Evacuation Disruption Rating	E-911 Disruption Rating	Road Classification Disruption Rating	Transportation Disruption Score (Sum)	Binned Transportation Disrpution Score (1-5)	
xy41817227144364	Manton Ave	Woonasquatucket River	N	N	4	1	1	3	5	2	0
xy41819437144226	Delaine St	Woonasquatucket River	N	N	5	1	1	2	4	1	0
xy41822527143992	Valley St	Woonasquatucket River	Y	N	4	3	1	3	7	3	0
xy41823467146025	Glenbridge Ave	Woonasquatucket River	Y	N	4	3	1	3	7	3	0
xy41824557143824	Atwells Ave	Woonasquatucket River	Y	N	4	3	1	3	7	3	0
xy41826547143567	Eagle St	Woonasquatucket River	N	N	4	1	1	3	5	2	0
xy41826817141330	N/A: Footbridge	Woonasquatucket River	N	Y	7	1	5	1	7	3	0
xy41826927141044	Steeple St	Woonasquatucket River	N	Y	3	1	5	4	10	4	0
xy41827107141439	N/A: Footbridge	Woonasquatucket River	N	Y	7	1	5	1	7	3	0
xy41827117141226	Exchange St	Woonasquatucket River	N	N	7	1	1	1	3	1	1
xy41827207141547	Francis St	Woonasquatucket River	N	Y	4	1	5	3	9	3	0
xy41827747141774	Park St	Woonasquatucket River	N	N	4	1	1	3	5	2	0
xy41828647142862	Acorn St	Woonasquatucket River	N	N	5	1	1	2	4	1	0
xy41829017142325	Promenade St	Woonasquatucket River	N	N	4	1	1	3	5	2	0
xy41829077142660	Dean St	Woonasquatucket River	N	N	4	1	1	3	5	2	0
xy41829207142410	Promenade St	Woonasquatucket River	N	N	7	1	1	1	3	1	0
xy41832947147052	Manson Ave	Dyerville Pond	N	N	4	1	1	3	5	2	0
xy41834977144282	Pleasant Valley Parkway	Unt to Woonasquatucket River	N	N	5	1	1	2	4	1	0
xy41835427143915	Pleasant Valley Parkway	Unt to Woonasquatucket River	N	N	4	1	1	3	5	2	0
xy41836747144463	Pleasant Valley Parkway	Unt to Woonasquatucket River	N	N	5	1	1	2	4	1	0
xy41837147148177	Waterman Ave	Unt to Woonasquatucket River	N	Y	4	1	5	3	9	3	0
xy41837797148021	Di Sarro Ave	Unt to Woonasquatucket River	N	N	7	1	1	1	3	1	0
xy41841257148494	Waterman Ave	Unt to Assapumpset Brook	N	Y	4	1	5	3	9	3	0
xy41842197148400	Diaz St	Unt to Assapumpset Brook	N	N	7	1	1	1	3	1	0
xy41842937148299	Armento St	Assapumpset Brook	N	N	7	1	1	1	3	1	0
xy41843377148416	Diaz St	Assapumpset Brook	N	N	7	1	1	1	3	1	1
xy41845017150193	Atwood Ave	Unt to Assapumpset Brook	N	Y	3	1	5	4	10	4	0
xy41845257150309	Carpenter Drive	Unt to Assapumpset Brook	N	N	7	1	1	1	3	1	0
xy41845877148670	George Waterman St	Assapumpset Brook	N	Y	4	1	5	3	9	3	0
xy41848417149462	Clemence Ln	Assapumpset Brook	N	N	7	1	1	1	3	1	0
xy41848877150503	Pine Hill Ave	Assapumpset Brook	N	N	7	1	1	1	3	1	0
xy41850727148167	Allendale Ave	Woonasquatucket River	N	N	7	1	1	1	3	1	1
xy41853897155040	Winsor Rd	Unt to Slack Reservoir	N	N	5	1	1	2	4	1	0
xy41853977155807	Winsor Rd	Unt to Slack Reservoir	N	N	5	1	1	2	4	1	1
xy41855037152232	Greenville Ave	Unt to Assapumpset Brook	N	Y	3	1	5	4	10	4	0
xy41855187155720	Barden Ln	Unt to Slack Reservoir	N	N	7	1	1	1	3	1	0
xy41855907154386	Winsor Rd	Unt to Slack Reservoir	N	N	5	1	1	2	4	1	0
xy41858547156285	Orchard Ave	Unt to Slack Reservoir	N	N	5	1	1	2	4	1	0
xy41859167148748	Putnam Pike	Woonasquatucket River	N	Y	3	1	5	4	10	4	0
xy41859507155898	Roger Williams Drive	Unt to Slack Reservoir	N	N	7	1	1	1	3	1	0
xy41861407156668	Sheffield Rd	Unt to Slack Reservoir	N	N	7	1	1	1	3	1	0
xy41861587154159	Greenville Ave	Unt to Slack Reservoir	N	N	5	1	1	2	4	1	0
xy41863027154374	Greenville Ave	Unt to Slack Reservoir	N	N	5	1	1	2	4	1	0
xy41863507153509	Finne Rd	Unt to Slack Reservoir	N	N	7	1	1	1	3	1	1
xy41865407149229	Angell Ave	Woonasquatucket River	N	N	7	1	1	1	3	1	1
xy41866427149748	Dean St	Unt to Woonasquatucket River	N	N	5	1	1	2	4	1	0
xy41866737155823	Smith Ave Extension	Unt to Slack Reservoir	N	N	7	1	1	1	3	1	0
xy41866907149909	Kenton Drive	Unt to Woonasquatucket River	N	N	7	1	1	1	3	1	0
xy41866937155857	Smith Ave	Unt to Slack Reservoir	N	Y	3	1	5	4	10	4	0
xy41867357150081	Mowry Ave	Unt to Woonasquatucket	N	N	7	1	1	1	3	1	1
xy41867767150198	Susan Drive	Unt to Woonasquatucket River	N	N	7	1	1	1	3	1	0
xy41867937149613	Riverside Ave	Unt to Woonasquatucket River	N	N	7	1	1	1	3	1	1
xy41868517157685	West Greenville Rd	Unt	N	Y	5	1	5	2	8	3	0
xy41869227150721	Esmond St	Unt to Woonasquatucket River	N	N	4	1	1	3	5	2	0
xy41869837155412	Smith Ave	Unt to Slack Reservoir	N	N	3	1	1	4	6	2	0

Gray boxes indicate missing data. Yellow boxes indicate assumptions that were made to compensate for missing data. See Pilot Study and Digitial Database for details regarding assumptions.

Disruption of Transportation Services Worksheet

Crossing Code	Road Name	Stream Name	Located on Hurricane Evacuation Route	Located on E-911 Route	Road Classification (Highway Functional Classification)	Scoring: Hurricane Evacuation Disruption Rating	E-911 Disruption Rating	Road Classification Disruption Rating	Transportation Disruption Score (Sum)	Binned Transportation Disrpution Score (1-5)	Local Knowledge Flag
xy41870167152512	Putnam Pike	Unt to Hawkins Brook	N	Y	3	1	5	4	10	4	0
xy41870207153556	Putnam Pike	Reaper Brook	N	Y	3	1	5	4	10	4	0
xy41871207155179	Putnam Pike	Slack Reservoir Outflow	N	Y	3	1	5	4	10	4	0
xy41871637157756	West Greenville Rd	Waterman Reservoir	N	Y	5	1	5	2	8	3	0
xy41871997158854	Aldrich Rd	Unt to Waterman Reservoir	N	N	7	1	1	1	3	1	0
xy41872697150528	Esmond St	Hawkins Brook	N	N	4	1	1	3	5	2	0
xy41872937157686	West Greenville Rd	Unt	N	Y	5	1	5	2	8	3	0
xy41873167150365	Julien St	Hawkins Brook	N	N	7	1	1	1	3	1	0
xy41873187150300	Dean St	Hawkins Brook	N	N	5	1	1	2	4	1	0
xy41873637149711	Esmond Mill Drive	Woonasquatucket River	N	N	7	1	1	1	3	1	0
xy41874287154980	Pleasant View Circle	Unt to Stillwater River	N	N	7	1	1	1	3	1	0
xy41874767155492	Austin Ave	Stillwater River	N	N	5	1	1	2	4	1	0
xy41875437157379	West Greenville Ave	Unt to Waterman Reservoir	N	Y	5	1	5	2	8	3	0
xy41875777159319	Old Quarry Rd	Unt to Waterman Reservoir	N	N	7	1	1	1	3	1	0
xy41877147159409	Old Quarry Rd	Unt to Waterman Reservoir	N	N	7	1	1	1	3	1	0
xy41877287153708	Cedar Swamp Road	Reaper Brook	N	Y	3	1	5	4	10	4	0
xy41877397157132	West Greenville Rd	Stillwater River	N	Y	5	1	5	2	8	3	0
xy41877427157059	Putnam Pike	Stillwater Brook	N	Y	3	1	5	4	10	4	1
xy41877557154924	Deerfield Drive	Stillwater River	N	N	7	1	1	1	3	1	0
xy41878177153571	Walter Carey Road	Unt to Mountaindale Reservoir	N	N	7	1	1	1	3	1	0
xy41878417150154	Esmond St	Woonasquatucket River	N	N	4	1	1	3	5	2	0
xy41878707160132	Sawmill Rd	Unt to Waterman Reservoir	N	N	5	1	1	2	4	1	0
xy41878737152022	Mountaindale Rd	Unt to Hawkins Brook	N	N	7	1	1	1	3	1	0
xy41880727150256	Farnum Pike	Woonasquatucket River	N	Y	4	1	5	3	9	3	0
xy41880887157821	Putnam Pike	Waterman Reservoir	N	Y	3	1	5	4	10	4	0
xy41881987151110	Old Country Rd	Unt to Woonasquatucket River	N	N	5	1	1	2	4	1	0
xy41883167160369	Melody Hill Ln	Unt to Waterman Reservoir	N	N	7	1	1	1	3	1	0
xy41883307160203	Sawmill Rd	Unt to Waterman Reservoir	N	N	5	1	1	2	4	1	0
xy41883627158219	Putnam Pike	Nine Foot Brook	N	Y	3	1	5	4	10	4	0
xy41883977158247	Austin Ave	Nine Foot Brook	N	N	7	1	1	1	3	1	0
xy41883977159943	Waterman Lake Drive	Unt to Cutler Brook	N	N	7	1	1	1	3	1	0
xy41884477150737	Farnum Pike	Unt to Woonasquatucket River	N	Y	4	1	5	3	9	3	1
xy41884487160015	Sawmill Rd	Cutler Brook	N	N	5	1	1	2	4	1	0
xy41884547154339	Indian Run Rd	Unt to Stillwater River	N	N	7	1	1	1	3	1	0
xy41884807157218	Austin Ave	Unt to Waterman Reservoir	N	N	7	1	1	1	3	1	0
xy41884937158168	Stone Bridge Rd	Unt to Nine Foot Brook	N	N	7	1	1	1	3	1	0
xy41885067154130	Pleasant View Ave	Stillwater River	N	Y	3	1	5	4	10	4	0
xy41885087157849	Austin Avenue	Unt to Waterman Reservoir	N	N	7	1	1	1	3	1	0
xy41885967155678	Baldwin Circle	Unt to Stillwater River	N	N	7	1	1	1	3	1	0
xy41886157153645	Mountaindale Road	Reaper Brook	N	N	7	1	1	1	3	1	1
xy41886477153705	Mountaindale Road	Unnamed Wetland adjacent to Reaper Brook	N	N	7	1	1	1	3	1	0
xy41886617150419	Fenwood Ave	Unt to Woonasquatucket River	N	N	5	1	1	2	4	1	0
xy41886847150523	Whipple Ave	Woonasquatucket River	N	N	6	1	1	2	4	1	0
xy41886917159166	Putnam Pike	Unt to Waterman Reservoir	N	Y	3	1	5	4	10	4	0
xy41887077159144	Valley Rd	Unt to Waterman Reservoir	N	N	7	1	1	1	3	1	0
xy41888247153923	Mountaindale Road	Stillwater River	N	N	7	1	1	1	3	1	0
xy41888657151262	Farnum Pike	Unt to Georgiaville Pond	N	Y	4	1	5	3	9	3	0
xy41888837151740	Old County Rd	Unt to Georgiaville Pond	N	N	5	1	1	2	4	1	0
xy41889357148731	Whipple Rd	Unt to Woonasquatucket River	N	N	5	1	1	2	4	1	0
xy41890377149584	Ridge Rd	Unt to Woonasquatucket River	N	N	5	1	1	2	4	1	0
xy41890427151403	Sweet Rd	Unt to Georgiaville Pond	N	N	7	1	1	1	3	1	0
xy41890897156959	Colwell Rd	Unt to Upper Sprague Reservoir	N	N	5	1	1	2	4	1	0
xy41890917151543	Farnum Pike	Unt to Georgiaville Pond	N	Y	4	1	5	3	9	3	0
xy41892467149331	Douglas Pike	Unt to Woonasquatucket River	N	Y	3	1	5	4	10	4	0
xy41892547150396	Crest Drive	Unt to Woonasquatucket River	N	N	7	1	1	1	3	1	0

Gray boxes indicate missing data. Yellow boxes indicate assumptions that were made to compensate for missing data. See Pilot Study and Digitial Database for details regarding assumptions.

Disruption of Transportation Services Worksheet

Crossing Code	Road Name	Stream Name	Located on Hurricane Evacuation Route	Located on E-911 Route	Road Classification (Highway Functional Classification)	Scoring					Local Knowledge Flag
						Hurricane Evacuation Disruption Rating	E-911 Disruption Rating	Road Classification Disruption Rating	Transportation Disruption Score (Sum)	Binned Transportation Disrpution Score (1-5)	
xy41893077160835	Route 44	Cutler Brook	N	Y	3	1	5	4	10	4	0
xy41893317160808	Farnum Road	Cutler Brook	N	N	7	1	1	1	3	1	0
xy41894747150725	Stillwater Rd	Unt to Georgiaville Pond	N	N	5	1	1	2	4	1	0
xy41894887152164	Farnum Pike	Unt to Georgiaville Pond	N	Y	4	1	5	3	9	3	0
xy41895577161365	Route 44 Putnam Pike	Unt to Cutler Brook	N	Y	3	1	5	4	10	4	0
xy41896047161805	Route 44	Unti to Cutler Brook	N	Y	3	1	5	4	10	4	0
xy41896637160262	Farnum Rd	Unt to Waterman Reservoir	N	N	7	1	1	1	3	1	0
xy41896697151958	Old county Rd/Lakeside Drive	Unt to Georgiaville Pond	N	N	7	1	1	1	3	1	0
xy41897187150342	Ridge Rd	Unt to Georgiaville Pond	N	N	5	1	1	2	4	1	1
xy41897827156647	Colwell Rd	Unt to Upper Sprague Reservoir	N	N	5	1	1	2	4	1	0
xy41898117157880	Evan's Rd	Nine Foot Brook	N	N	7	1	1	1	3	1	0
xy41898457158358	Burlingame Ln	Unt to Nine Foot Brook	N	N	7	1	1	1	3	1	0
xy41898477158323	Burlingame Ln	Unt to Nine Foot Brook	N	N	7	1	1	1	3	1	0
xy41898517157816	Tarkiln Rd	Unt to Nine Foot Brook	N	N	7	1	1	1	3	1	0
xy41898907154304	Pleasantview Ave	Woonasquatucket Reservoir	N	Y	3	1	5	4	10	4	0
xy41898957150991	Stillwater Rd	Harris Brook	N	N	5	1	1	2	4	1	0
xy41899117154630	Log Rd	Woonasquatucket Reservoir	N	N	5	1	1	2	4	1	1
xy41899147150128	Douglas Pike	Unt to Georgiaville Pond	N	Y	3	1	5	4	10	4	0
xy41899277156654	Colwell Rd	Unt to Upper Sprague Reservoir	N	N	5	1	1	2	4	1	0
xy41900117158371	Evans Rd	Unt to Shinscot Brook	N	N	7	1	1	1	3	1	0
xy41900437149662	Catherine Rd	Unt to West River	N	N	7	1	1	1	3	1	0
xy41902037159401	Farnum road	Shinscot Brook	N	N	7	1	1	1	3	1	0
xy41902517157773	Tarkiln Rd	Unt to Nine Foot Brook	N	N	7	1	1	1	3	1	1
xy41902577149498	Maureen Drive	Unt to West River	N	N	7	1	1	1	3	1	0
xy41902587151720	Stillwater Rd	Unt to Georgiaville Pond	N	N	5	1	1	2	4	1	0
xy41902697157007	Mann School Rd	Unt to Upper Sprague Reservoir	N	N	7	1	1	1	3	1	0
xy41902757152161	Capron Rd	Capron Pond	N	N	5	1	1	2	4	1	1
xy41902757159093	Farnum Rd	Unt	N	N	7	1	1	1	3	1	0
xy41902877150377	Limerock Rd	Unt to Harris Brook	N	N	5	1	1	2	4	1	0
xy41904317158874	Evans road	Unt	N	N	7	1	1	1	3	1	0
xy41904937156221	Connors Farm Drive	Unt	N	N	7	1	1	1	3	1	0
xy41905587149206	Clark Rd	Unt to West River	N	N	7	1	1	1	3	1	0
xy41906217161244	Cooper Ave	Cutler Brook	N	N	5	1	1	2	4	1	0
xy41908317153647	George Washington Highway	Woonasquatucket River	N	Y	3	1	5	4	10	4	0
xy41908677154068	Farnum Pike	Woonasquatucket River	N	Y	4	1	5	3	9	3	0
xy41909167152497	Stillwater Rd	Unt to Stillwater Pond	N	N	5	1	1	2	4	1	0
xy41910887152828	Stillwater Rd	Unt to Stillwater Pond	N	N	5	1	1	2	4	1	0
xy41912007159704	Evans Rd	Unamed to Shinscot Brook	N	N	7	1	1	1	3	1	0
xy41912687150232	Harris Rd	Unt to Harris Brook	N	N	7	1	1	1	3	1	0
xy41913457152883	George Washington Highway	Unt to Stillwater Pond	N	Y	3	1	5	4	10	4	0
xy41913477151701	Douglas Pike	Unt to Stillwater Pond	N	Y	3	1	5	4	10	4	0
xy41914027155460	Log Rd	Woonasquatucket Reservoir	N	N	5	1	1	2	4	1	0
xy41914137156217	Burlingame Rd	Unt to Woonasquatucket Reservoir	N	N	7	1	1	1	3	1	0
xy41914227154859	Industrial Rd S.	Unt to Woonasquatucket Reservoir	N	N	7	1	1	1	3	1	0
xy41914627152630	George Washington Highway	Unt to Stillwater Pond	N	Y	3	1	5	4	10	4	0
xy41916527154817	Industrial Drive	Unt to Woonasquatucket Reservoir	N	N	7	1	1	1	3	1	0
xy41916957158201	Tarkiln Rd	Unt to Nine Foot Brook	N	N	7	1	1	1	3	1	0
xy41918867152209	Douglas Pike	Unt to Stillwater Pond	N	Y	3	1	5	4	10	4	0
xy41920067155939	Burlingame Rd	Latham Brook	N	N	7	1	1	1	3	1	0
xy41920097155278	Old Forge Rd	Woonasquatucket River	N	N	5	1	1	2	4	1	0
xy41920937158733	Tarkiln Rd	Unt to Nine Foot Brook	N	N	7	1	1	1	3	1	0
xy41921057155828	Log Rd	Unt to Latham Brook	N	N	7	1	1	1	3	1	0
xy41922257156115	Log Rd	Latham Brook	N	N	7	1	1	1	3	1	0
xy41923277152886	Douglas Pike	Unt to Stillwater Reservoir	N	Y	3	1	5	4	10	4	0
xy41923437156751	Bayberry Rd	Latham Brook	N	N	7	1	1	1	3	1	0

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Disruption of Transportation Services Worksheet

Crossing Code	Road Name	Stream Name	Located on Hurricane Evacuation Route	Located on E-911 Route	Road Classification (Highway Functional Classification)	Scoring					Local Knowledge Flag
						Hurricane Evacuation Disruption Rating	E-911 Disruption Rating	Road Classification Disruption Rating	Transportation Disruption Score (Sum)	Binned Transportation Disrpution Score (1-5)	
xy41923797156391	Log Rd	Latham Brook	N	N	7	1	1	1	3	1	0
xy41924017152999	Douglas Pike	Unt to Stillwater Reservoir	N	Y	3	1	5	4	10	4	0
xy41924467152624	Essex St	Unt to Stillwater Pond	N	N	7	1	1	1	3	1	0
xy41924627153417	Bryant U. entryway off of Douglas Pike	Unt to Stillwater Pond	N	Y	7	1	5	1	7	3	0
xy41926177155080	Farnum Pike	Unt to Woonasquatucket River	N	Y	4	1	5	3	9	3	0
xy41926517153403	Douglas Pike	Unt to Stillwater Pond	N	Y	3	1	5	4	10	4	0
xy41926627152983	Essex St	Unt to Stillwater Pond	N	N	7	1	1	1	3	1	0
xy41927997155005	Rogler Farm Rd	Unt to Woonasquatucket Reservoir	N	N	6	1	1	2	4	1	0
xy41928037152264	Lydia Ann Rd	Unt to Stillwater Pond	N	N	7	1	1	1	3	1	0
xy41928267155140	Farnum Pike	Woonasquatucket River	N	Y	4	1	5	3	9	3	0
xy41929067155367	Latham Farm Rd	Unt to Woonasquatucket River	N	N	7	1	1	1	3	1	0
xy41929207157455	Log Rd	Unt to Latham Brook	N	N	7	1	1	1	3	1	0
xy41930757160155	Long Entry Rd	Unnamed Wetland	N	N	7	1	1	1	3	1	0
xy41931447155286	Farnum Pike	Unt to Woonasquatucket River	N	Y	4	1	5	3	9	3	0
xy41938517155343	Douglas Pike	Woonasquatucket River	N	Y	3	1	5	4	10	4	0
xy41939037155601	Farnum Pike	Unt to Woonasquatucket River	N	Y	4	1	5	3	9	3	0
xy41943527156049	Douglas Pike	Unt to Woonasquatucket River	N	Y	3	1	5	4	10	4	0
xy41950277156940	Douglas Pike	Unt to Woonasquatucket River	N	Y	3	1	5	4	10	4	0
xy41954007157431	Douglas Pike	Unt to Woonasquatucket River	N	Y	3	1	5	4	10	4	0
xy41954667155188	Greenville Rd	Woonasquatucket River	N	Y	4	1	5	3	9	3	0
xy41954727157531	Douglas Pike	Unt	N	Y	3	1	5	4	10	4	0
xy41959377156205	Black Plain Rd	Unt to Primrose Pond	N	N	7	1	1	1	3	1	0
xy41959547155800	Pond House Rd	Unt to Primrose Pond	N	N	7	1	1	1	3	1	0
xy41961437156227	Pond House Rd	Unt to Primrose Pond	N	N	7	1	1	1	3	1	0
xy41962007156644	Mattity Rd	Unt to Primrose Pond	N	N	7	1	1	1	3	1	0
xy41962407156390	Black Plain Rd	Unt to Primrose Pond	N	N	7	1	1	1	3	1	0
xy41964317155322	Providence Pike	Unt to Woonasquatucket River	N	Y	4	1	5	3	9	3	0
xy41972767155740	Providence Pike	Unt to Woonasquatucket River	N	Y	4	1	5	3	9	3	0

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FUSS & O'NEILL

Attachment I

Road-Stream Crossing Prioritization Worksheet

Prioritization Worksheet

Crossing Code	Road Name	Stream Name	Municipality	Crossing Type	Impact Score	Hydraulic Risk Score	Future Climate Change Risk Score	Geomorphic Risk Score	Structural Risk Score	AOP Benefit Score	Crossing Risk Score	Scaled Crossing Priority	Binned Prioritization Score	Existing Tidal Influence Flag	Future Tidal Influence Flag	Unknown Structural Condition Flag	Local Knowledge Flag	Adjacent Crossing Flag	Wildlife Crossing or Roadkill Flag
xy41841257148494	Waterman Ave	Unt to Assapumpset Brook	Johnston	Partially Inaccessible	5	25	25	15	25	9	25	0.84	High	0	0	1	0	1	1
xy41866427149748	Dean St	Unt to Woonasquatucket River	Johnston	Culvert	5	25	25	15	5	9	25	0.84	High	0	0	0	0	1	0
xy41834977144282	Pleasant Valley Parkway	Unt to Woonasquatucket River	Providence	Culvert	5	20	25	20	25	6	25	0.81	High	0	0	0	0	1	0
xy41842197148400	Diaz St	Unt to Assapumpset Brook	Johnston	Culvert	5	25	25	10	5	6	25	0.81	High	0	0	0	0	1	0
xy41872697150528	Esmond St	Hawkins Brook	Smithfield	Multiple Culverts	5	5	5	10	25	6	25	0.81	High	0	0	0	0	1	1
xy41888657151262	Farnum Pike	Unt to Georgiaville Pond	Smithfield	Multiple Culverts	5	20	20	15	25	6	25	0.81	High	0	0	0	0	1	0
xy41890917151543	Farnum Pike	Unt to Georgiaville Pond	Smithfield	Partially Inaccessible	5	25	25	15	25	6	25	0.81	High	0	0	1	0	1	0
xy41819437144226	Delaine St	Woonasquatucket River	Providence	Bridge	5	5	25	10	5	5	25	0.8	High	0	1	0	0	1	0
xy41822527143992	Valley St	Woonasquatucket River	Providence	Bridge	5	25	25	10	5	4	25	0.79	High	1	1	1	0	1	0
xy41827207141547	Francis St	Woonasquatucket River	Providence	Bridge	5	5	25	15	5	4	25	0.79	High	1	1	1	0	1	0
xy41828647142862	Acorn St	Woonasquatucket River	Providence	Bridge	5	25	25	10	5	4	25	0.79	High	1	1	1	0	1	0
xy41874767155492	Austin Ave	Stillwater River	Smithfield	Multiple Culverts	5	25	25	15	25	4	25	0.79	High	0	0	0	0	1	0
xy41848877150503	Pine Hill Ave	Assapumpset Brook	Johnston	Culvert	4	16	20	12	20	15	20	0.75	High	0	0	0	0	1	0
xy41842937148299	Armento St	Assapumpset Brook	Johnston	Partially Inaccessible	4	8	12	12	20	12	20	0.72	High	0	0	1	0	1	0
xy41845877148670	George Waterman St	Assapumpset Brook	Johnston	Partially Inaccessible	4	4	4	16	20	12	20	0.72	High	0	0	1	0	1	0
xy41859507155898	Roger Williams Drive	Unt to Slack Reservoir	Johnston	Culvert	4	4	4	12	20	12	20	0.72	High	0	0	0	0	1	1
xy41871207155179	Putnam Pike	Slack Reservoir Outflow	Smithfield	Culvert	5	5	15	20	5	12	20	0.72	High	0	0	0	0	1	0
xy41848417149462	Clemence Ln	Assapumpset Brook	Johnston	Multiple Culverts	4	4	12	12	20	9	20	0.69	High	0	0	0	0	1	0
xy41855037152232	Greenville Ave	Unt to Assapumpset Brook	Johnston	Partially Inaccessible	4	20	20	12	4	9	20	0.69	High	0	0	1	0	1	0
xy41867357150081	Mowry Ave	Unt to Woonasquatucket	Johnston	Multiple Culverts	5	20	20	15	5	9	20	0.69	High	0	0	0	1	1	1
xy41867937149613	Riverside Ave	Unt to Woonasquatucket River	Johnston	Multiple Culverts	4	20	20	16	20	9	20	0.69	High	0	0	0	1	1	0
xy41868517157685	West Greenville Rd	Unt	Glocester	Culvert	4	20	20	8	4	9	20	0.69	High	0	0	0	0	1	1
xy41869837155412	Smith Ave	Unt to Slack Reservoir	Smithfield	Culvert	4	8	12	12	20	9	20	0.69	High	0	0	0	0	1	0
xy41873187150300	Dean St	Hawkins Brook	Smithfield	Multiple Culverts	5	5	5	20	5	9	20	0.69	High	0	0	0	0	1	0
xy41893077160835	Route 44	Cutler Brook	Glocester	Culvert	4	4	4	12	20	9	20	0.69	High	0	0	0	0	1	0
xy41895577161365	Route 44 Putnam Pike	Unt to Cutler Brook	Glocester	Culvert	4	20	20	8	4	9	20	0.69	High	0	0	0	0	1	0
xy41896697151958	Old county Rd/Lakeside Drive	Unt to Georgiaville Pond	Smithfield	Culvert	4	20	20	12	4	9	20	0.69	High	0	0	0	0	1	0
xy41899117154630	Log Rd	Woonasquatucket Reservoir	Smithfield	Culvert	4	20	20	12	20	9	20	0.69	High	0	0	0	1	1	1
xy41913457152883	George Washington Highway	Unt to Stillwater Pond	Smithfield	Multiple Culverts	4	4	4	12	20	9	20	0.69	High	0	0	0	0	1	0
xy41943527156049	Douglas Pike	Unt to Woonasquatucket River	North Smithfield	Culvert	4	4	12	12	20	9	20	0.69	High	0	0	1	0	0	0
xy41950277156940	Douglas Pike	Unt to Woonasquatucket River	North Smithfield	Culvert	4	20	20	8	20	9	20	0.69	High	0	0	0	0	1	0
xy41884477150737	Farnum Pike	Unt to Woonasquatucket River	Smithfield	Partially Inaccessible	3	12	12	9	15	9	15	0.54	High*	0	0	1	1	0	0
xy41835427143915	Pleasant Valley Parkway	Unt to Woonasquatucket River	Providence	Culvert	4	20	20	16	20	6	20	0.66	Medium	0	0	0	0	1	0
xy41861407156668	Sheffield Rd	Unt to Slack Reservoir	Smithfield	Multiple Culverts	4	20	20	16	20	6	20	0.66	Medium	0	0	1	0	1	0
xy41870207153556	Putnam Pike	Reaper Brook	Smithfield	Culvert	4	20	20	8	20	6	20	0.66	Medium	0	0	0	0	1	0
xy41881987151110	Old Country Rd	Unt to Woonasquatucket River	Smithfield	Culvert	4	4	4	8	20	6	20	0.66	Medium	0	0	0	0	1	0
xy41884547154339	Indian Run Rd	Unt to Stillwater River	Smithfield	Multiple Culverts	4	4	4	12	20	6	20	0.66	Medium	0	0	0	0	1	0
xy41886917159166	Putnam Pike	Unt to Waterman Reservoir	Glocester	Culvert	4	20	20	12	4	6	20	0.66	Medium	0	0	0	0	1	0
xy41888247153923	Mountaindale Road	Stillwater River	Smithfield	Multiple Culverts	4	16	16	12	20	6	20	0.66	Medium	0	0	0	0	1	0
xy41890427151403	Sweet Rd	Unt to Georgiaville Pond	Smithfield	Multiple Culverts	4	20	20	12	4	6	20	0.66	Medium	0	0	0	0	1	0
xy41892467149331	Douglas Pike	Unt to Woonasquatucket River	Smithfield	Multiple Culverts	4	20	20	12	20	6	20	0.66	Medium	0	0	1	0	1	0
xy41899147150128	Douglas Pike	Unt to Georgiaville Pond	Smithfield	Culvert	4	20	20	16	20	6	20	0.66	Medium	0	0	0	0	1	0
xy41914627152630	George Washington Highway	Unt to Stillwater Pond	Smithfield	Culvert	4	4	4	12	20	6	20	0.66	Medium	0	0	0	0	1	0
xy41918867152209	Douglas Pike	Unt to Stillwater Pond	Smithfield	Multiple Culverts	4	4	4	12	20	6	20	0.66	Medium	0	0	0	0	1	0
xy41924017152999	Douglas Pike	Unt to Stillwater Reservoir	Smithfield	Culvert	4	4	4	8	20	6	20	0.66	Medium	0	0	0	0	1	0
xy41954007157431	Douglas Pike	Unt to Woonasquatucket River	North Smithfield	Culvert	4	4	4	8	20	6	20	0.66	Medium	0	0	0	0	1	0
xy41954727157531	Douglas Pike	Unt	North Smithfield	Culvert	4	20	20	12	4	6	20	0.66	Medium	0	0	0	0	1	0
xy41826547143567	Eagle St	Woonasquatucket River	Providence	Bridge	4	20	20	8	4	5	20	0.65	Medium	1	1	0	0	1	0
xy41826927141044	Steeple St	Woonasquatucket River	Providence	Bridge	4	4	20	12	4	5	20	0.65	Medium	1	1	0	0	1	0
xy41827117141226	Exchange St	Woonasquatucket River	Providence	Bridge	4	4	20	12	4	5	20	0.65	Medium	1	1	0	1	1	0
xy41824557143824	Atwells Ave	Woonasquatucket River	Providence	Bridge	4	20	20	8	4	4	20	0.64	Medium	1	1	0	0	1	0
xy41827747141774	Park St	Woonasquatucket River	Providence	Bridge	4	4	20	12	4	4	20	0.64	Medium	1	1	0	0	1	0
xy41829077142660	Dean St	Woonasquatucket River	Providence	Bridge	4	4	20	8	4	4	20	0.64	Medium	1	1	0	0	1	1
xy41874287154980	Pleasant View Circle	Unt to Stillwater River	Smithfield	Partially Inaccessible	4	12	16	12	20	4	20	0.64	Medium	0	0	0	0	1	1
xy41885067154130	Pleasant View Ave	Stillwater River	Smithfield	Bridge	4	20	20	12	4	4	20	0.64	Medium	0	0	0	0	1	0
xy41826817141330	N/A: Footbridge	Woonasquatucket River	Providence	Bridge	4	4	20	12	4	3	20	0.63	Medium	1	1	0	0	1	0
xy41827107141439	N/A: Footbridge	Woonasquatucket River	Providence	Bridge	4	4	20	12	4	3	20	0.63	Medium	1	1	0	0	1	0
xy41873167150365	Julien St	Hawkins Brook	Smithfield	Culvert	4	20	20	12	20	3	20	0.63	Medium	0	0	0	0	1	0
xy41877397157132	West Greenville Rd	Stillwater River	Smithfield	Bridge	4	16	20	12	4	3	20	0.63	Medium	0	0	0	0	1	0
xy41880887157821	Putnam Pike	Waterman Reservoir	Smithfield	Culvert	4	20	20	12	20	3	20	0.63	Medium	0	0	1	0	1	1
xy41892547150396	Crest Drive	Unt to Woonasquatucket River	Smithfield	Multiple Culverts	4	4	4	12	20	3	20	0.63	Medium	0	0	0	0	1	0
xy41910887152828	Stillwater Rd	Unt to Stillwater Pond	Smithfield	Multiple Culverts	4	4	12	16	4	15	16	0.63	Medium	0	0	0	0	1	0
xy41914227154859	Industrial Rd S.	Unt to Woonasquatucket Reservoir	Smithfield	Culvert	4	20	20	12	4	3	20	0.63	Medium	0	0	0	0	1	0
xy41837797148021	Di Sarro Ave	Unt to Woonasquatucket River	Johnston	Culvert	3	3	3	12	3	15	12	0.57	Medium	0	0	0	0	1	0
xy41877557154924	Deerfield Drive	Stillwater River	Smithfield	Multiple Culverts	3	12	15	6	15	12	15	0.57	Medium	0	0	0	0	1	0
xy41883977158247	Austin Ave	Nine Foot Brook	Glocester	Culvert	3	15	15	9	3	12	15	0.57	Medium	0	0	0	0	1	1
xy41914027155460	Log Rd	Woonasquatucket Reservoir	Smithfield	Culvert	3	15	15	9	6	12	15	0.57	Medium	0	0	0	0	1	0
xy41939037155601	Farnum Pike	Unt to Woonasquatucket River	North Smithfield	Culvert	3	9	12	9	15	12	15	0.57	Medium	0	0	0	0	1	0
xy41853977155807	Winsor Rd	Unt to Slack Reservoir	Johnston	Culvert	2	8	8	6	10	15	10	0.55	Medium	0	0	0	1	1	0
xy41890377149584	Ridge Rd	Unt to Woonasquatucket River	Smithfield	Culvert	2	10	10	6	2	15	10	0.55	Medium	0	0	0	0	1	0
xy41899277156654	Colwell Rd	Unt to Upper Sprague Reservoir	Smithfield	Culvert	2	10	10	6	2	15	10	0.55	Medium	0	0	0	0	1	0
xy41902757159093	Farnum Rd	Unt	Glocester	Culvert	2	10	10	6	2	15	10	0.55	Medium	0	0	0	0	1	0
xy41845257150309	Carpenter Drive	Unt to Assapumpset Brook	Johnston	Culvert	3	12	15	9	15	9	15	0.54	Medium	0	0	0	0	1	0
xy41853897155040	Winsor Rd	Unt to Slack Reservoir	Johnston	Partially Inaccessible	3	15	15	6	3	9	15	0.54	Medium	0	0	1	0	1	0
xy41878737152022	Mountaindale Rd	Unt to Hawkins Brook	Smithfield	Culvert	3	15	15	6	15	9	15	0.54	Medium	0	0	0	0	1	0
xy41883167160369	Melody Hill Ln	Unt to Waterman Reservoir	Glocester	Multiple Culverts	3	6	9	12	15	9	15	0.54	Medium	0	0	0	0	1	0
xy41884807157218	Austin Ave	Unt to Waterman Reservoir	Smithfield	Partially Inaccessible	3	9	9	6	15	9	15	0.54	Medium	0	0	1	0	0	1
xy41897827156647	Colwell Rd	Unt to Upper Sprague Reservoir	Smithfield	Partially Inaccessible	3	12	15	9	3	9	15	0.54	Medium	0	0	1	0	1	0
xy41902577149498	Maureen Drive	Unt to West River	Smithfield	Partially Inaccessible	3	15	15	9	3	9	15	0.54	Medium	0	0	1	0	0	0
xy41902877150377	Limerock Rd	Unt to Harris Brook	Smithfield	Multiple Culverts	3	15	15	9	15	9	15	0.54	Medium	0	0	0	0	1	0
xy41922257156115	Log Rd	Latham Brook	Smithfield	Multiple Culverts	3	6	9	9	15	9	15	0.54	Medium	0	0	0	0	1	0

*Indicates crossing score was manually assigned. See Pilot Study Section 3.2.10 for additional information.

Prioritization Worksheet

Crossing Code	Road Name	Stream Name	Municipality	Crossing Type	Impact Score	Hydraulic Risk Score	Future Climate Change Risk Score	Geomorphic Risk Score	Structural Risk Score	AOP Benefit Score	Crossing Risk Score	Scaled Crossing Priority	Binned Prioritization Score	Existing Tidal Influence Flag	Future Tidal Influence Flag	Unknown Structural Condition Flag	Local Knowledge Flag	Adjacent Crossing Flag	Wildlife Crossing or Roadkill Flag
xy41923437156751	Bayberry Rd	Latham Brook	Smithfield	Culvert	3	12	15	9	3	9	15	0.54	Medium	0	0	0	0	1	0
xy41962007156644	Mattity Rd	Unt to Primrose Pond	North Smithfield	Culvert	3	15	15	6	15	9	15	0.54	Medium	0	0	0	0	1	0
xy41843377148416	Diaz St	Assapumpset Brook	Johnston	Multiple Culverts	3	12	15	6	3	8	15	0.53	Medium	0	0	0	1	1	0
xy41837147148177	Waterman Ave	Unt to Woonasquatucket River	Johnston	Culvert	5	5	5	15	5	6	15	0.51	Medium	0	0	0	0	1	0
xy41863507153509	Finne Rd	Unt to Slack Reservoir	Johnston	Culvert	3	15	15	6	15	6	15	0.51	Medium	0	0	0	1	1	0
xy41866907149909	Kenton Drive	Unt to Woonasquatucket River	Johnston	Culvert	3	12	15	9	3	6	15	0.51	Medium	0	0	0	0	1	0
xy41867767150198	Susan Drive	Unt to Woonasquatucket River	Johnston	Partially Inaccessible	5	5	15	10	5	6	15	0.51	Medium	0	0	1	0	1	0
xy41871997158854	Aldrich Rd	Unt to Waterman Reservoir	Glocester	Culvert	2	2	2	6	4	15	6	0.51	Medium	0	0	0	0	1	0
xy41883307160203	Sawmill Rd	Unt to Waterman Reservoir	Glocester	Culvert	3	15	15	9	3	6	15	0.51	Medium	0	0	0	0	1	0
xy41885967155678	Baldwin Circle	Unt to Stillwater River	Smithfield	Partially Inaccessible	3	15	15	9	3	6	15	0.51	Medium	0	0	1	0	0	0
xy41887077159144	Valley Rd	Unt to Waterman Reservoir	Glocester	Culvert	3	12	15	9	15	6	15	0.51	Medium	0	0	0	0	1	0
xy41904317158874	Evans road	Unt	Glocester	No Upstream Channel	3	3	3	6	15	6	15	0.51	Medium	0	0	1	0	0	0
xy41916957158201	Tarkiln Rd	Unt to Nine Foot Brook	Smithfield	Partially Inaccessible	3	15	15	6	15	6	15	0.51	Medium	0	0	1	0	0	0
xy41829017142325	Promenade St	Woonasquatucket River	Providence	Bridge	3	3	15	6	15	4	15	0.49	Medium	1	1	0	0	1	0
xy41850727148167	Allendale Ave	Woonasquatucket River	North Providence/Johnston Line	Bridge	3	3	3	6	15	4	15	0.49	Medium	0	0	0	1	1	0
xy41878707160132	Sawmill Rd	Unt to Waterman Reservoir	Glocester	Culvert	3	15	15	6	3	4	15	0.49	Medium	0	0	0	0	1	0
xy41888837151740	Old County Rd	Unt to Georgiaville Pond	Smithfield	Culvert	3	15	15	9	15	4	15	0.49	Medium	0	0	0	0	1	0
xy41898517157816	Tarkiln Rd	Unt to Nine Foot Brook	Smithfield	Culvert	3	9	12	9	15	4	15	0.49	Medium	0	0	0	0	1	0
xy41928267155140	Farnum Pike	Woonasquatucket River	Smithfield	Bridge	3	3	3	6	15	4	15	0.49	Medium	0	0	0	0	1	0
xy41829207142410	Promenade St	Woonasquatucket River	Providence	Bridge	3	3	15	9	3	3	15	0.48	Medium	1	1	0	0	1	0
xy41875437157379	West Greenville Ave	Unt to Waterman Reservoir	Smithfield	Bridge	3	3	3	9	15	3	15	0.48	Medium	0	0	0	0	1	0
xy41898117157880	Evan's Rd	Nine Foot Brook	Smithfield	Culvert	3	15	15	9	3	3	15	0.48	Medium	0	0	0	0	1	0
xy41959547155800	Pond House Rd	Unt to Primrose Pond	North Smithfield	No Upstream Channel	3	15	15	9	15	3	15	0.48	Medium	0	0	0	0	0	0
xy41964317155322	Providence Pike	Unt to Woonasquatucket River	North Smithfield	Culvert	3	15	15	9	3	3	15	0.48	Medium	0	0	0	0	1	0
xy41858547156285	Orchard Ave	Unt to Slack Reservoir	Johnston	Culvert	4	4	4	12	4	9	12	0.45	Medium	0	0	0	0	1	0
xy41866737155823	Smith Ave Extension	Unt to Slack Reservoir	Smithfield	Culvert	3	3	3	9	3	12	9	0.45	Medium	0	0	0	0	1	0
xy41866937155857	Smith Ave	Unt to Slack Reservoir	Smithfield	Partially Inaccessible	4	4	12	8	4	9	12	0.45	Medium	0	0	1	0	1	1
xy41877147159409	Old Quarry Rd	Unt to Waterman Reservoir	Glocester	Culvert	3	9	12	9	3	9	12	0.45	Medium	0	0	0	0	1	0
xy41894887152164	Farnum Pike	Unt to Georgiaville Pond	Smithfield	Partially Inaccessible	4	8	12	8	4	9	12	0.45	Medium	0	0	1	0	1	0
xy41900437149662	Catherine Rd	Unt to West River	Smithfield	Partially Inaccessible	3	6	9	12	3	9	12	0.45	Medium	0	0	1	0	0	0
xy41905587149206	Clark Rd	Unt to West River	Smithfield	Multiple Culverts	3	3	9	12	3	9	12	0.45	Medium	0	0	0	0	1	0
xy41909167152497	Stillwater Rd	Unt to Stillwater Pond	Smithfield	Culvert	4	4	4	12	4	9	12	0.45	Medium	0	0	0	0	1	0
xy41913477151701	Douglas Pike	Unt to Stillwater Pond	Smithfield	Culvert	4	4	4	12	4	9	12	0.45	Medium	0	0	0	0	1	0
xy41920067155939	Burlingame Rd	Latham Brook	Smithfield	Culvert	3	6	9	9	3	12	9	0.45	Medium	0	0	0	0	1	0
xy41920097155278	Old Forge Rd	Woonasquatucket River	Smithfield	Culvert	3	3	9	9	3	12	9	0.45	Medium	0	0	0	0	1	0
xy41972767155740	Providence Pike	Unt to Woonasquatucket River	North Smithfield	Culvert	3	12	12	9	3	9	12	0.45	Medium	0	0	1	0	0	0
xy41883627158219	Putnam Pike	Nine Foot Brook	Glocester	Culvert	4	8	12	12	8	8	12	0.44	Medium	0	0	0	0	1	0
xy41869227150721	Esmond St	Unt to Woonasquatucket River	Smithfield	Culvert	4	4	4	12	4	6	12	0.42	Medium	0	0	1	0	1	1
xy41912687150232	Harris Rd	Unt to Harris Brook	Smithfield	Multiple Culverts	3	3	3	12	3	6	12	0.42	Medium	0	0	0	0	1	0
xy41921057155828	Log Rd	Unt to Latham Brook	Smithfield	Multiple Culverts	3	9	12	6	3	6	12	0.42	Medium	0	0	0	0	1	0
xy41926517153403	Douglas Pike	Unt to Stillwater Pond	Smithfield	Culvert	4	8	12	8	4	6	12	0.42	Medium	0	0	0	0	1	0
xy41929067155367	Latham Farm Rd	Unt to Woonasquatucket River	Smithfield	No Upstream Channel	4	4	4	12	4	6	12	0.42	Medium	0	0	0	0	1	0
xy41931447155286	Farnum Pike	Unt to Woonasquatucket River	Smithfield	Culvert	3	9	12	6	3	6	12	0.42	Medium	0	0	0	0	1	0
xy41865407149229	Angell Ave	Woonasquatucket River	North Providence/Johnston Line	Bridge	4	4	4	12	4	5	12	0.41	Medium	0	0	0	1	1	0
xy41873637149711	Esmond Mill Drive	Woonasquatucket River	Smithfield	Bridge	3	9	12	6	3	5	12	0.41	Medium	0	0	0	0	1	0
xy41877427157059	Putnam Pike	Stillwater Brook	Smithfield	Bridge	4	4	4	12	4	4	12	0.4	Medium	0	0	0	1	1	1
xy41871637157756	West Greenville Rd	Waterman Reservoir	Glocester	Bridge	4	4	4	12	4	3	12	0.39	Medium	0	0	0	0	1	0
xy41877287153708	Cedar Swamp Road	Reaper Brook	Smithfield	Culvert	4	4	12	12	8	3	12	0.39	Medium	0	0	0	0	1	0
xy41889357148731	Whipple Rd	Unt to Woonasquatucket River	Smithfield	Culvert	2	2	2	4	10	9	10	0.39	Medium	0	0	0	0	1	1
xy41897187150342	Ridge Rd	Unt to Georgiaville Pond	Smithfield	Culvert	2	10	10	6	4	9	10	0.39	Medium	0	0	0	1	1	0
xy41898457158358	Burlingame Ln	Unt to Nine Foot Brook	Glocester	Culvert	2	10	10	4	2	9	10	0.39	Medium	0	0	0	0	1	0
xy41902697157007	Mann School Rd	Unt to Upper Sprague Reservoir	Smithfield	Culvert	2	8	10	6	10	9	10	0.39	Medium	0	0	0	0	1	0
xy41920937158733	Tarkiln Rd	Unt to Nine Foot Brook	Smithfield	Culvert	2	10	10	6	2	9	10	0.39	Medium	0	0	0	0	1	0
xy41930757160155	Long Entry Rd	Unnamed Wetland	Glocester	Culvert	2	10	10	4	10	9	10	0.39	Medium	0	0	0	0	1	0
xy41894747150725	Stillwater Rd	Unt to Georgiaville Pond	Smithfield	Multiple Culverts	2	10	10	6	10	8	10	0.38	Medium	0	0	0	0	1	0
xy41836747144463	Pleasant Valley Parkway	Unt to Woonasquatucket River	Providence	Partially Inaccessible	3	9	9	9	3	9	9	0.36	Medium	0	0	1	0	0	0
xy41855187155720	Barden Ln	Unt to Slack Reservoir	Johnston	Culvert	2	10	10	6	10	6	10	0.36	Medium	0	0	0	0	1	0
xy41861587154159	Greenville Ave	Unt to Slack Reservoir	Johnston	Culvert	2	4	6	6	10	6	10	0.36	Medium	0	0	0	0	1	0
xy41883977159943	Waterman Lake Drive	Unt to Cutler Brook	Glocester	Multiple Culverts	3	3	9	9	3	9	9	0.36	Medium	0	0	0	0	1	0
xy41884487160015	Sawmill Rd	Cutler Brook	Glocester	Culvert	3	6	9	9	3	9	9	0.36	Medium	0	0	0	0	1	1
xy41884937158168	Stone Bridge Rd	Unt to Nine Foot Brook	Glocester	Partially Inaccessible	3	9	9	9	3	9	9	0.36	Medium	0	0	1	0	0	0
xy41885087157849	Austin Avenue	Unt to Waterman Reservoir	Smithfield	Partially Inaccessible	2	10	10	6	10	6	10	0.36	Medium	0	0	1	0	1	0
xy41890897156959	Colwell Rd	Unt to Upper Sprague Reservoir	Smithfield	Culvert	3	3	9	9	3	9	9	0.36	Medium	0	0	0	0	1	0
xy41898477158323	Burlingame Ln	Unt to Nine Foot Brook	Glocester	Culvert	2	10	10	4	10	6	10	0.36	Medium	0	0	1	0	1	0
xy41906217161244	Cooper Ave	Cutler Brook	Glocester	Culvert	2	10	10	6	10	6	10	0.36	Medium	0	0	0	0	1	0
xy41924627153417	Bryant U. entryway off of Douglas Pike	Unt to Stillwater Pond	Smithfield	Culvert	3	3	3	9	3	9	9	0.36	Medium	0	0	0	0	1	0
xy41926177155080	Farnum Pike	Unt to Woonasquatucket River	Smithfield	Culvert	3	6	9	6	3	9	9	0.36	Medium	0	0	0	0	1	0
xy41962407156390	Black Plain Rd	Unt to Primrose Pond	North Smithfield	Culvert	3	3	3	9	3	9	9	0.36	Medium	0	0	0	0	1	0
xy41875777159319	Old Quarry Rd	Unt to Waterman Reservoir	Glocester	Culvert	2	8	8	6	2	9	8	0.35	Medium	0	0	0	0	1	0
xy41896047161805	Route 44	Unti to Cutler Brook	Glocester	Culvert	4	4	4	8	4	9	8	0.35	Medium	0	0	0	0	1	0
xy41817227144364	Manton Ave	Woonasquatucket River	Providence	Bridge	5	5	10	10	5	4	10	0.34	Medium	0	1	1	0	1	0
xy41855907154386	Winsor Rd	Unt to Slack Reservoir	Johnston	Culvert	2	2	6	6	4	9	6	0.33	Low	0	0	0	0	1	1
xy41863027154374	Greenville Ave	Unt to Slack Reservoir	Smithfield	Multiple Culverts	2	2	2	6	2	9	6	0.33	Low	0	0	0	0	1	0
xy41872937157686	West Greenville Rd	Unt	Smithfield	Culvert	3	3	3	6	3	9	6	0.33	Low	0	0	0	0	1	0
xy41896637160262	Farnum Rd	Unt to Waterman Reservoir	Glocester	Culvert	2	2	2	6	2	9	6	0.33	Low	0	0	0	0	1	0
xy41902037159401	Farnum road	Shinscot Brook	Glocester	Culvert	2	4	6	6	4	9	6	0.33	Low	0	0	0	0	1	0
xy41902517157773	Tarkiln Rd	Unt to Nine Foot Brook	Smithfield	Culvert	3	3	3	6	3	9	6	0.33	Low	0	0	0	1	1	0
xy41923797156391	Log Rd	Latham Brook	Smithfield	Culvert	2	2	2	6	2	9	6	0.33	Low	0	0	0	0	1	0
xy41927997155005	Rogler Farm Rd	Unt to Woonasquatucket Reservoir	Smithfield	Partially Inaccessible	2	2	2	4	10	3	10	0.33	Low	0	0	1	0	1	0
xy41929207157455	Log Rd	Unt to Latham Brook	Smithfield	Multiple Culverts	2	6	8	6	10	3	10	0.33	Low	0	0	1	0	1	0
xy41961437156227	Pond House Rd	Unt to Primrose Pond	North Smithfield	Culvert	3	3	3	9	3	6	9	0.33	Low	0	0	0	0	1	0

*Indicates crossing score was manually assigned. See Pilot Study Section 3.2.10 for additional information.

Prioritization Worksheet

Crossing Code	Road Name	Stream Name	Municipality	Crossing Type	Impact Score	Hydraulic Risk Score	Future Climate Change Risk Score	Geomorphic Risk Score	Structural Risk Score	AOP Benefit Score	Crossing Risk Score	Scaled Crossing Priority	Binned Prioritization Score	Existing Tidal Influence Flag	Future Tidal Influence Flag	Unknown Structural Condition Flag	Local Knowledge Flag	Adjacent Crossing Flag	Wildlife Crossing or Roadkill Flag
xy41832947147052	Manson Ave	Dyerville Pond	Providence/Johnston Line	Bridge	3	3	3	9	3	5	9	0.32	Low	0	0	0	0	1	0
xy41898907154304	Pleasantview Ave	Woonasquatucket Reservoir	Smithfield	Bridge	4	4	4	8	4	8	8	0.32	Low	0	0	0	0	1	0
xy41823467146025	Glenbridge Ave	Woonasquatucket River	Providence	Bridge Adequate	3	3	3	9	3	4	9	0.31	Low	0	0	0	0	0	1
xy41898957150991	Stillwater Rd	Harris Brook	Smithfield	Bridge	3	3	3	9	3	4	9	0.31	Low	0	0	0	0	1	0
xy41902587151720	Stillwater Rd	Unt to Georgiaville Pond	Smithfield	Multiple Culverts	2	2	2	4	2	9	4	0.31	Low	0	0	0	0	1	0
xy41912007159704	Evans Rd	Unamed to Shinscot Brook	Glocester	Culvert	2	2	2	4	2	9	4	0.31	Low	0	0	0	0	1	1
xy41845017150193	Atwood Ave	Unt to Assapumpset Brook	Johnston	Culvert	4	4	4	8	4	6	8	0.3	Low	0	0	0	0	1	1
xy41870167152512	Putnam Pike	Unt to Hawkins Brook	Smithfield	Culvert	4	4	4	8	4	6	8	0.3	Low	0	0	0	0	1	0
xy41886157153645	Mountaindale Road	Reaper Brook	Smithfield	Bridge	2	2	2	6	2	8	6	0.3	Low	0	0	0	1	1	0
xy41923277152886	Douglas Pike	Unt to Stillwater Reservoir	Smithfield	Culvert	4	4	4	8	4	6	8	0.3	Low	0	0	0	0	1	0
xy41959377156205	Black Plain Rd	Unt to Primrose Pond	North Smithfield	Culvert	2	6	8	4	2	6	8	0.3	Low	0	0	0	0	1	0
xy41859167148748	Putnam Pike	Woonasquatucket River	North Providence/Johnston Line	Bridge	4	4	4	8	4	5	8	0.29	Low	0	0	0	0	0	0
xy41908317153647	George Washington Highway	Woonasquatucket River	Smithfield	Bridge Adequate	4	4	4	8	4	5	8	0.29	Low	0	0	0	0	1	0
xy41938517155343	Douglas Pike	Woonasquatucket River	North Smithfield	Bridge	4	4	4	8	4	4	8	0.28	Low	0	0	0	0	1	0
xy41878177153571	Walter Carey Road	Unt to Mountaindale Reservoir	Smithfield	Culvert	2	2	2	6	2	6	6	0.24	Low	0	0	0	0	1	0
xy41886617150419	Fenwood Ave	Unt to Woonasquatucket River	Smithfield	Multiple Culverts	3	3	3	6	3	6	6	0.24	Low	0	0	0	0	1	0
xy41893317160808	Farnum Road	Cutler Brook	Glocester	Culvert	2	4	6	4	2	6	6	0.24	Low	0	0	0	0	1	0
xy41926627152983	Essex St	Unt to Stillwater Pond	Smithfield	Culvert	2	2	2	6	2	6	6	0.24	Low	0	0	0	0	1	0
xy41878417150154	Esmond St	Woonasquatucket River	Smithfield	Bridge	3	3	3	6	3	5	6	0.23	Low	0	0	0	0	1	0
xy41886847150523	Whipple Ave	Woonasquatucket River	Smithfield	Bridge	3	3	3	6	3	5	6	0.23	Low	0	0	0	0	1	0
xy41902757152161	Capron Rd	Capron Pond	Smithfield	Bridge	3	3	3	6	3	5	6	0.23	Low	0	0	0	1	1	0
xy41880727150256	Farnum Pike	Woonasquatucket River	Smithfield	Bridge	3	3	3	6	3	4	6	0.22	Low	0	0	0	0	1	0
xy41886477153705	Mountaindale Road	Unnamed Wetland adjacent to Reaper Brook	Smithfield	Culvert	2	2	2	4	2	6	4	0.22	Low	0	0	0	0	1	0
xy41904937156221	Connors Farm Drive	Unt	Smithfield	Culvert	2	2	2	4	2	6	4	0.22	Low	0	0	0	0	1	0
xy41908677154068	Farnum Pike	Woonasquatucket River	Smithfield	Bridge	3	3	3	6	3	4	6	0.22	Low	0	0	0	0	1	0
xy41914137156217	Burlingame Rd	Unt to Woonasquatucket Reservoir	Smithfield	Culvert	2	2	2	4	2	6	4	0.22	Low	0	0	0	0	1	0
xy41916527154817	Industrial Drive	Unt to Woonasquatucket Reservoir	Smithfield	Culvert	3	3	3	6	3	3	6	0.21	Low	0	0	0	0	1	0
xy41924467152624	Essex St	Unt to Stillwater Pond	Smithfield	Bridge	3	3	3	6	3	3	6	0.21	Low	0	0	0	0	1	1
xy41928037152264	Lydia Ann Rd	Unt to Stillwater Pond	Smithfield	Bridge	3	3	3	6	3	3	6	0.21	Low	0	0	0	0	1	0
xy41954667155188	Greenville Rd	Woonasquatucket River	North Smithfield	Multiple Culverts	3	3	3	6	3	3	6	0.21	Low	0	0	0	0	1	0
xy41900117158371	Evans Rd	Unt to Shinscot Brook	Glocester	Culvert	2	2	2	4	2	3	4	0.15	Low	0	0	0	0	1	0

*Indicates crossing score was manually assigned. See Pilot Study Section 3.2.10 for additional information.

Attachment J

High Priority Crossings

High Priority Crossings

Crossing Code	Road Name	Stream Name	Municipality	Crossing Type	Impact Score	Hydraulic Risk Score	Future Climate Change Risk Score	Geomorphic Risk Score	Structural Risk Score	AOP Benefit Score	Crossing Risk Score	Scaled Crossing Priority	Binned Prioritization Score	Existing Tidal Influence Flag	Future Tidal Influence Flag	Unknown Structural Condition Flag	Local Knowledge Flag	Adjacent Crossing Flag	Wildlife Crossing or Roadkill Flag
xy41841257148494	Waterman Ave	Unt to Assapumpset Brook	Johnston	Partially Inaccessible	5	25	25	15	25	9	25	0.84	High	0	0	1	0	1	1
xy41866427149748	Dean St	Unt to Woonasquatucket River	Johnston	Culvert	5	25	25	15	5	9	25	0.84	High	0	0	0	0	1	0
xy41834977144282	Pleasant Valley Parkway	Unt to Woonasquatucket River	Providence	Culvert	5	20	25	20	25	6	25	0.81	High	0	0	0	0	1	0
xy41842197148400	Diaz St	Unt to Assapumpset Brook	Johnston	Culvert	5	25	25	10	5	6	25	0.81	High	0	0	0	0	1	0
xy41872697150528	Esmond St	Hawkins Brook	Smithfield	Multiple Culverts	5	5	5	10	25	6	25	0.81	High	0	0	0	0	1	1
xy41888657151262	Farnum Pike	Unt to Georgiaville Pond	Smithfield	Multiple Culverts	5	20	20	15	25	6	25	0.81	High	0	0	0	0	1	0
xy41890917151543	Farnum Pike	Unt to Georgiaville Pond	Smithfield	Partially Inaccessible	5	25	25	15	25	6	25	0.81	High	0	0	1	0	1	0
xy41819437144226	Delaine St	Woonasquatucket River	Providence	Bridge	5	5	25	10	5	5	25	0.8	High	0	1	0	0	1	0
xy41822527143992	Valley St	Woonasquatucket River	Providence	Bridge	5	25	25	10	5	4	25	0.79	High	1	1	1	0	1	0
xy41827207141547	Francis St	Woonasquatucket River	Providence	Bridge	5	5	25	15	5	4	25	0.79	High	1	1	1	0	1	0
xy41828647142862	Acorn St	Woonasquatucket River	Providence	Bridge	5	25	25	10	5	4	25	0.79	High	1	1	1	0	1	0
xy41874767155492	Austin Ave	Stillwater River	Smithfield	Multiple Culverts	5	25	25	15	25	4	25	0.79	High	0	0	0	0	1	0
xy41848877150503	Pine Hill Ave	Assapumpset Brook	Johnston	Culvert	4	16	20	12	20	15	20	0.75	High	0	0	0	0	1	0
xy41842937148299	Armento St	Assapumpset Brook	Johnston	Partially Inaccessible	4	8	12	12	20	12	20	0.72	High	0	0	1	0	1	0
xy41845877148670	George Waterman St	Assapumpset Brook	Johnston	Partially Inaccessible	4	4	4	16	20	12	20	0.72	High	0	0	1	0	1	0
xy41859507155898	Roger Williams Drive	Unt to Slack Reservoir	Johnston	Culvert	4	4	4	12	20	12	20	0.72	High	0	0	0	0	1	1
xy41871207155179	Putnam Pike	Slack Reservoir Outflow	Smithfield	Culvert	5	5	15	20	5	12	20	0.72	High	0	0	0	0	1	0
xy41848417149462	Clemence Ln	Assapumpset Brook	Johnston	Multiple Culverts	4	4	12	12	20	9	20	0.69	High	0	0	0	0	1	0
xy41855037152232	Greenville Ave	Unt to Assapumpset Brook	Johnston	Partially Inaccessible	4	20	20	12	4	9	20	0.69	High	0	0	1	0	1	0
xy41867357150081	Mowry Ave	Unt to Woonasquatucket	Johnston	Multiple Culverts	5	20	20	15	5	9	20	0.69	High	0	0	0	1	1	1
xy41867937149613	Riverside Ave	Unt to Woonasquatucket River	Johnston	Multiple Culverts	4	20	20	16	20	9	20	0.69	High	0	0	0	1	1	0
xy41868517157685	West Greenville Rd	Unt	Glocester	Culvert	4	20	20	8	4	9	20	0.69	High	0	0	0	0	1	1
xy41869837155412	Smith Ave	Unt to Slack Reservoir	Smithfield	Culvert	4	8	12	12	20	9	20	0.69	High	0	0	0	0	1	0
xy41873187150300	Dean St	Hawkins Brook	Smithfield	Multiple Culverts	5	5	5	20	5	9	20	0.69	High	0	0	0	0	1	0
xy41893077160835	Route 44	Cutler Brook	Glocester	Culvert	4	4	4	12	20	9	20	0.69	High	0	0	0	0	1	0
xy41895577161365	Route 44 Putnam Pike	Unt to Cutler Brook	Glocester	Culvert	4	20	20	8	4	9	20	0.69	High	0	0	0	0	1	0
xy41896697151958	Old county Rd/Lakeside Drive	Unt to Georgiaville Pond	Smithfield	Culvert	4	20	20	12	4	9	20	0.69	High	0	0	0	0	1	0
xy41899117154630	Log Rd	Woonasquatucket Reservoir	Smithfield	Culvert	4	20	20	12	20	9	20	0.69	High	0	0	0	1	1	1
xy41913457152883	George Washington Highway	Unt to Stillwater Pond	Smithfield	Multiple Culverts	4	4	4	12	20	9	20	0.69	High	0	0	0	0	1	0
xy41943527156049	Douglas Pike	Unt to Woonasquatucket River	North Smithfield	Culvert	4	4	12	12	20	9	20	0.69	High	0	0	1	0	0	0
xy41950277156940	Douglas Pike	Unt to Woonasquatucket River	North Smithfield	Culvert	4	20	20	8	20	9	20	0.69	High	0	0	0	0	1	0
xy41884477150737	Farnum Pike	Unt to Woonasquatucket River	Smithfield	Partially Inaccessible	3	12	12	9	15	9	15	0.54	High	0	0	1	1	0	0

*Indicates crossing score was manually assigned. See Pilot Study Section 3.2.10 for additional information.

Appendix I: Frequently Asked Questions

This appendix provides answers to frequently asked questions (FAQs) that may come up during project planning, field surveys, or while conducting vulnerability assessments for road-stream crossing assessments conducted in Rhode Island using the methods presented in this Handbook.

I.1 FAQs Regarding the Purpose of This Document

1. **Does this document provide design specifications for replacement crossings?**

   No. This document provides a methodology for assessing and prioritizing road-stream crossings in order to help stakeholders determine where culvert replacement funding may be applied for the greatest possible benefit. This document is not intended as a design manual and contains no design specifications.

2. **What are the regulatory implications of this document?**

   This document is a guideline for assessment and planning **only**. This document contains no design specifications and therefore has no regulatory implications.

3. **Can the assessment methodology be applied to drainage or stormwater culverts?**

   The assessment methodology is intended for use at stream crossings only, as aspects of the methodology assess the potential for and impact of processes that occur in flowing streams but not in drainage ditches or stormwater infrastructure.

I.2 Field Work Preparation FAQs

4. **Where can I find funding for conducting road-stream crossing assessments?**

   Federal and State transportation funding and municipal funding sources are currently limited for road-stream crossing surveys and upgrades/replacements. Available Federal, State, and non-governmental funding sources are listed in in *Section 14.5*. Federal funding opportunities include, among others, several grants from NOAA and FEMA, Southeast New England Program (SNEP) Watershed Grants and Army Corps of Engineers Aquatic Ecosystem Restoration Program funds. State opportunities may be available through the Narragansett Bay and Watersheds Restoration Fund (BWRF) and the CRMC Coastal Habitat Restoration Program. Review *Section 14.5* for additional funding opportunities and recommendations.

5. **How much time does it take to complete the field work and vulnerability assessments?**

   During the pilot study, it took field crews an average of 30 minutes to assess each crossing (not including travel time between crossings). Quality Control (QC) of the data took an average of 20 minutes per crossing. Improvements to the digital field form should reduce the time needed for these tasks by helping to ensure that all data is collected correctly in the field, but field crews may find that more time is needed for initial assessments while learning to use the field form and other tools. Crossings with multiple structures will take more time to assess in the field and to QC, while some structures (e.g., structures assessed as "Bridge Adequate") will take much less time.

Plan for desktop vulnerability assessments to take between 30 minutes and 1 hour per crossing. Crossings at which complete field data was collected and StreamStats data is available will require much less time to assess (approximately 15-30 minutes). Crossings with missing data may take much longer to assess. Using the *Crossing Analysis Spreadsheet* provided in *Appendix F* will speed up the vulnerability assessment considerably (compared to computing and compiling the data from scratch).

I.3 Field Assessment FAQs

6. **Should I assess dry crossings in the same way as other crossings?**

   Yes. Field work and vulnerability assessments should be conducted in the same manner for dry crossings as for crossings that have flow. When a completely dry crossing is encountered, the field crew should verify that the crossings is in fact a culvert and not a drainage pipe (see the following question).

7. **How can I tell the difference between a drainage pipe and a culvert?**

   If a stream is present and clearly flowing from one side of the road to the other, then the structure is easily identifiable as a culvert. Likewise, when a culvert is large enough to look through the structure to see each end, the structure is clearly identifiable as a culvert. When flow is not present at one or both sides of the structure, or when it is not possible to see through the structure due to debris or extended length of the crossing, it may be more difficult to distinguish a culvert from a drainage pipe. In these cases, the following tips can be used to help in the determination:

   To determine whether the structure is a dry culvert or a drainage structure when no flow is present, look for catch basins on the road. A drainage structure will usually be associated with a catch basin on one or both sides of the road. Additionally, a drainage structure may produce scour and sedimentation at the outlet, but there will not be a distinct stream channel or banks present as there would be in the case of a dry culvert. If there is no flow, no visible stream channel or banks on either side of the road, and there are catch basins present on the road above the structure, the structure is most likely a drainage pipe. Also note that drainage channels and culverts are likely to dry up more quickly than stream channels in the absence of rain.

8. **How much data should I collect at a partially accessible crossing? (i.e. the inlet is accessible but the outlet is not, or vice versa)**

   Partially accessible crossings should be assessed to the extent possible by recording all data that it is possible to collect. "Unknown" should be entered or selected in the field form for parameters that cannot be assessed or determined. Numerical parameters should be recorded as "9999" when they cannot be measured. The reason for inaccessibility and the extent of inaccessibility should be recorded in the field form under the crossing comments.

9. **When should "no inlet treatment" and "other" be selected for inlet type/treatment?**

   Refer to *Section 3.5.4*. "No inlet treatment" should be selected when none of the listed inlet treatment types are applicable to the crossing. Selecting "no inlet treatment" does not mean that the crossing does not have an inlet, rather it means that the inlet has not been designed with a treatment that affects the way water flows into the crossing. The inlet type/treatment "other" should be selected when it is clear that the inlet has been designed with a treatment that affects the way water flows into the crossing, but it does not have the characteristics of the listed treatment options.

10. **Clarifying the presence/absence of a headwall on bridges and stone masonry culverts:**

    Headwalls serve two purposes: to retain and support fill on the upstream face of the embankment at the inlet of a culvert, and to direct flow more efficiently into the culvert inlet. Endwalls retain and support fill on the downstream face of the embankment at the outlet of a culvert. Headwalls and endwalls can typically be recognized by the presence of an even, vertical face formed around the culvert inlet and outlet. Headwalls are typically constructed of concrete or stone masonry, but in some cases may be constructed from metal plate or sheeting, or even wood. Headwalls with an even face with no open joints and with beveled or chamfered edges will reduce eddying and facilitate efficient flow into the culvert inlet, increasing culvert capacity.

11. **How should stream alignment of a crossing be assessed when the stream alignment immediately upstream of the crossing is affected by excessive sediment deposition?**

    Alignment of the crossing structure relative to the stream channel should be assessed relative to a high flow scenario, such as the 10-, 50, or 100-year flood. It is common for a stream channel to enter the structure with a mild or sharp bend under low flow conditions due to sediment build-up. If the stream would enter the channel straight-on under high flow conditions by overtopping or displacing the sediment build-up, then the alignment of the crossing should be assessed as "naturally straight" or "channelized straight", as appropriate.

12. **Should I document physical barriers that are upstream or downstream of the structure on my assessment form? (i.e. a dam upstream of the structure)**

    Physical barriers should only be recorded if they are associated with the structure. If a dam is present immediately upstream of a structure and upgrade/replacement of the structure would require modification of the dam, then the dam should be marked as a physical barrier. If a dam is present farther upstream or downstream of the structure but replacement or upgrade of the structure would not require modification of the dam, it can be noted in the crossing comments for consideration in the final prioritization, but it should not be marked in the field form as a physical barrier.

I.4 Vulnerability Assessment FAQs

13. **What Manning's n value should I use for culverts that are corrugated on the outside and smooth on the inside?**

    Bentley CulvertMaster provides a Manning's n value for HDPE pipe with a smooth interior of 0.012 and a Manning's n value for HDPE pipe with a corrugated interior of 0.018-0.020. The majority of corrugated plastic pipes will have smooth interiors.

    Commonly-used Manning's n values may be found in common hydraulic references, including this chart adapted from Chow (1969): http://www.fsl.orst.edu/geowater/FX3/help/8_Hydraulic_Reference/Mannings_n_Tables.htm

14. How do I conduct vulnerability assessments on crossings where I am missing required data due to inaccessibility, inability to find the inlet or outlet, or other legitimate reason?

In general, if any data is able to be collected at a crossing, the vulnerability assessments should be completed and the crossing should be included in the final prioritization. Reasonable assumptions should be made to generate *binned scores* for the crossing when data that is required for an assessment is not available. These assumptions are detailed in each individual vulnerability assessment section of the Handbook.

The assumptions listed above and in the Handbook are meant to serve as a guide for how to handle crossings where data is missing. The professional judgement of the *Assessment Coordinator* should ultimately be used to decide how best to handle crossings with missing data and which assumptions are reasonable to make.

If data is missing for a crossing due to oversight in the field, ideally the crossing should be revisited to collect the missing data. Assumptions should only be made when data cannot be collected because the crossing inlet/outlet is inaccessible, buried, or unable to be found.

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