FINAL REPORT FOR DEMONSTRATION PROJECT
PRIORITIZING STREAM CROSSING IMPROVEMENTS

December 17, 2018

Lisa Rhodes, Alice Smith
MassDEP Wetlands Program
One Winter Street, Boston, MA 02108
Lisa.Rhodes@Mass.gov

Scott Jackson
Dept. of Environmental Conservation
Landscape Ecology Lab
University of Massachusetts
Amherst, MA 01003-9285
sjackson@umext.umass.edu

Funded by a 2011 Wetland Program Development Grant from the U.S. EPA Region 1, under Section 104(b)(3) of the U.S. Clean Water Act

Acknowledgements

This project and report represents a significant effort by various staff at MassDEP, the University of Massachusetts at Amherst, the Department of Ecological Restoration, and many many volunteers.

The primary authors of this report and coordinators of this project are Lisa Rhodes and Alice Smith at MassDEP, and Scott Jackson of the University of Massachusetts at Amherst.

In addition, the following individuals were major contributors to this project, serving as stream continuity coordinators: Pamela Merrill, Christine Odiaga, Mark Stinson and Tim Dexter of MassDOT.

We would also like to acknowledge the following individuals who also participated in this project by providing their expertise, time and/or oversight: Richard Chase, Nancy Lin, Lealdon Langley, Thomas Maguire, Michael McHugh and Michael Stroman of MassDEP; Brad Compton, Ethan Plunkett and Kevin McGarigal of UMass-Amherst; Carrie Banks of the Department of Environmental Restoration and Susan McArthur of MassDOT.

Finally, we would like to acknowledge and thank all of the volunteers, including municipal officials, watershed organizations and others who participated in this project. We also would like to express our gratitude to Beth Alafat, Jackie LeClair and Steve DeMattei of EPA for funding this project and for their continued support of the Wetlands Program.

Table of Contents

Section	Page #
1.0 Abstract	5
2.0 Introduction and Background	5
3.0 Project Purpose and Scope	7
4.0 Methods	8
Location of Targeted Road-Stream Crossings	8
Selection of Subwatersheds for Study	9
Assessments Conducted to Date and Location of Available Staff	9
High Quality Streams	10
Best Case Crossing Points	11
5.0 Quality Control, Training and Data Collection	17
Special Training/Certification	17
Field Forms	17
Quality Control	19
Data Review, Verification, Validation	19
6.0 Access Problems and Sub-Subwatersheds	20
Access Issues	20
Modifications to Subwatersheds	20
7.0 Stream Crossing Data Acquisition	21
Sites Assessed and entered into Stream Continuity Database	21
Summary of Stream Crossing Assessments	27
8.0 CAPS Model Scenario Analysis	28
9.0 Conclusions	31
10.0 Appendices	
Appendix A: Ipswich, Buzzards Bay and Chicopee Subwatersheds with Best Case Crossings and High Quality Streams	A-1
Appendix B: Field Data Form	B-4

Appendix C: MassDEP Assessed CAPS Stream Crossings	C-7
Appendix D: Quality Control Sites	D-39
Appendix E: UMASS Correlation Plots	E-41

Figures	Page #
Figure 4.1: MassDEP Regions with Stream Crossings Assessed as of November 17, 2011	10
Figure 4.2: High Quality Streams in Massachusetts	11
Figure 4.3: Best Case Crossings in Massachusetts	12
Figure 4.4: Selected Watersheds and Subwatersheds	13
Figure 4.5: Ipswich River Subwatershed: Locus and CAPS Crossings	14
Figure 4.6: Buzzards Bay Subwatershed: Locus and CAPS Crossings	15
Figure 4.7: Chicopee River Subwatershed: Locus and CAPS Crossings	16
Figure 5.1: Example of GIS street detail maps with crossing ID's for field use	18
Figure 7.1: Ipswich River Sub-subwatershed: MassDEP Assessed CAPS Crossings	23
Figure 7.2: Buzzards Bay Sub-subwatershed: MassDEP Assessed CAPS Crossings	25
Figure 7.3: Chicopee River Sub-subwatershed: MassDEP Assessed CAPS Crossings	27
Figure 8.1: Five subwatersheds used in the scenario analysis	29
Figure 8.2: Plots of Correlation coefficients for delta aquatic connectedness scores	31
Figure AA-1: Ipswich River Subwatershed-Best Case Crossings and High Quality Streams	A-1
Figure AA-2: Buzzards Bay Subwatershed-Best Case Crossings and High Quality Streams	A-2

Figure AA-3: Chicopee Subwatershed-Best Case Crossings and High Quality Streams	A-3
Figure AC-1: Ipswich River Watershed - MassDEP Assessed Stream Crossings	C-7
Figure AC-2: Buzzards Bay Watershed - MassDEP Assessed Stream Crossings	C-18
Figure AC-3: Chicopee River Watershed - MassDEP Assessed Stream Crossings	C-30
Figure AE-1 to AE-10: Correlation plots for crossings strategically and randomly selected field assessments for comparison to (near) comprehensive crossing assessment in a portion of the five watersheds: a. 20%, b. 30%, c. 40% and d. 50%.	E-41 -50

Tables	Page #
Table 1. Project progress review - September, 2012	20
Table 2. Stream crossing assessments in Ipswich Watershed	21
Table 3. Details of stream crossing assessments in Ipswich Watershed	22
Table 4. Stream crossing assessments in Buzzards Bay Watershed	24
Table 5. Details of stream crossing assessments in Buzzards Bay Watershed	24
Table 6. Stream crossing assessments in Chicopee Watershed	26
Table 7. Details of stream crossing assessments in Chicopee Watershed	26
Table 8. Total Crossing Assessments Completed for All Watersheds	28
Table 9. Correlation coefficients for delta aquatic connectedness scores	30
Table AC-1: Ipswich Stream Crossings Assessed by MassDEP 2012/2013	C-8
Table AC-2: Buzzards Bay Stream Crossings Assessed by MassDEP 2012/2013	C-18
Table AC-3: Chicopee Crossings Assessed by MassDEP 2012/2013	C-30
Table AD-1: MassDEP Audited Sites 2012/2014	D-39

1.0 Abstract

As long linear ecosystems, rivers and streams are particularly vulnerable to habitat fragmentation. Unless designed with ecological considerations in mind, culverts can impact stream ecosystems in many ways, such as interfering with sediment and nutrient transport processes, creating physical barriers to the movement of aquatic organisms, causing excessive stream flow velocities and turbulence during high flows, and providing insufficient water depths at low flow for fish passage. We estimated that there are at least 36,636 road-stream crossings in Massachusetts. This study was conducted to examine the extent of field assessments needed to obtain reliable results from the Conservation Assessment and Prioritization System (CAPS) Critical Linkages model in prioritizing stream crossings for improvement. A second goal is to increase the number of assessments in the North Atlantic Aquatic Connectivity Collaborative Crossings Database ("NAACC Crossings Database") to improve the accuracy of assessing and prioritizing stream crossing improvements.

Field assessments were conducted for over six hundred stream crossings primarily located in three watersheds in Massachusetts: the Buzzards Bay, Chicopee River, and Ipswich River watersheds. An analysis was conducted to see what percentage of crossings would need to be assessed in a subwatershed and still get results similar to a comprehensive assessment of all crossings in that subwatershed. Results of our analysis suggest that it is not necessary to field assess every crossing in a watershed in order to use the Critical Linkages methodology to evaluate the ecological restoration potential for culvert replacements and crossing upgrades. Assessing 50% of the crossings (when selected strategically) yielded results that were very similar to those of the near comprehensive assessments. These results suggest that you might be able to field assess only 30% of crossings in a subwatershed as long as those 30% are selected strategically.

2.0 Introduction and Background

As long linear ecosystems, rivers and streams are particularly vulnerable to habitat fragmentation. A number of human activities can disrupt the continuity of river and stream ecosystems, dams and roads being the most common. Many culverts currently in place were designed primarily for the purpose of moving water under a roadway with little or no consideration given to how that crossing impacts ecological processes. Unless designed with ecological considerations in mind, culverts can impact stream ecosystems in many ways, such as interfering with sediment and nutrient transport processes, creating physical barriers to the movement of aquatic organisms, causing excessive stream flow velocities and turbulence during high flows, and providing insufficient water depths at low flow for fish passage. Undersized culverts not only fragment and disrupt riverine ecosystems, but can also be the source of road and highway vulnerability due to the risk of culvert failure during high flow events. Intersecting roads and streams using GIS, we estimated that there are at least 36,636 road-stream crossings in Massachusetts.

In 2000, UMass-Amherst convened a variety of agencies and organizations to discuss the impact of road-stream crossings on fish and other aquatic organisms. These Agencies and organizations formed the River and Stream Continuity Project (now the "North Atlantic Aquatic Connectivity Collaborative" (NAACC)).[1] The original goals of the River and Stream Continuity Project (Continuity Project) were to: 1) develop technical guidance and standards for river/stream crossings; 2) establish a program to inventory road-stream crossing structures and assess the extent to which they are a barrier to fish and wildlife passage and 3) create a system for prioritizing crossing structures for upgrade or replacement.

In 2005, the Continuity Project developed the first edition of the Massachusetts River and Stream Crossing Standards (Crossing Standards). The Crossing Standards were updated in 2011 and a slightly revised version released in 2012. MassDEP has since incorporated the Crossing Standards into the Wetlands Protection Act regulations at 310 CMR 10.00.[2] The River and Stream Continuity Project also created an assessment protocol, scoring system and database to facilitate the evaluation of barrier effects of road-stream crossings on aquatic connectivity. These assessment protocols served as the basis for the aquatic passability assessment now used by the NAACC in 13 states in the Northeastern U.S.

The "Critical Linkages"[3] project is an extension of the Conservation Assessment and Prioritization System (CAPS) created by UMass Amherst. Critical Linkages assesses the degree to which existing dams and road-stream crossings disrupt the aquatic connectivity of river and stream ecosystems, and to identify crossings where there is high potential for restoring connectivity through culvert replacement. Data collected using Continuity Project/NAACC protocols are an important input into the Critical Linkages assessments. Outputs from Critical Linkages assessments can be used to prioritize road-stream crossings for upgrade or replacement.

Improving river and stream continuity is an important goal of MassDEP, for the following reasons.

1. The benefits of improving a stream crossing can be quantified and prioritized for planning purposes.
2. The NAACC Crossings Database provides field-assessed data on geo-located culverts and bridges that can be used to inform permit review under the Wetlands Protection Act (WPA).
3. Strategic improvements in culverts originally installed for passage of river or stream flow, can increase aquatic connectedness, and improve riverine ecosystem health, which can help a

---

[1] http://www.streamcontinuity.org/
[2] The standards can be accessed on the stream continuity website. See the version dated March 1, 2006, Revised March 1, 2011 and corrected March 8, 2012. Note that the correction is depicted in the footer and not on the front page. http://www.streamcontinuity.org/pdf_files/MA%20Crossing%20Stds%203-1-11%20corrected%203-8-12.pdf
[3] http://www.umasscaps.org/docs_reports/index.html

project meet the WPA performance standards for land under water, bank, and riverfront area resource areas.

4. Larger culvert size can promote passage of flood flows including increases in the frequency and intensity of large rainfall events and in doing so, will help reduce property flooding and storm damage.
5. Prioritization of culvert improvements can assist communities to direct scarce funding to projects that provide the best ecological benefit for the dollar.

3.0 Project Purpose and Scope

This project is a continuation of the goals of the Continuity Project and specifically addresses the use of the Critical Linkages capability of the CAPS models to prioritize culverts needing improvement. Critical Linkages uses two components of the CAPS approach – the aquatic connectedness metric and index of ecological integrity (IEI) – to conduct scenario analyses designed to compare alternative restoration opportunities. Aquatic connectedness is an assessment of landscape connectivity applied to wetland and aquatic ecosystems, and is based on the resistance of the landscape surrounding each cell within aquatic or wetland systems. Where available, the Critical Linkages Project uses data on the passability of road-stream crossings collected by the Continuity Project/NAACC to assign resistance values to each crossing. CAPS IEI scores are used as a measure of habitat quality. Restoration potential is computed as the change in the aquatic connectedness resulting from replacing each existing crossing with a bridge ("delta aquatic connectedness") weighted by habitat quality (IEI).

The Critical Linkages analysis of road-stream crossings uses the scenario testing capabilities of CAPS to evaluate the ecological restoration potential of upgrading crossings to meet MA River and Stream Crossing Standards and thereby accommodate full aquatic organism passage. To do this we need an estimate of aquatic organism passability. Preferably these passability scores ("aquatic scores") would be based on field assessments of road-stream crossings. When field assessments are not available we instead use scores derived from a model.

One objective of this project was to expand the inventory of field-assessed road-stream crossings and evaluated their impact on fish and wildlife passage. We used the Continuity Project protocols to assess more than 600 stream crossing structures for aquatic passability. Assessment watersheds were selected based on the quality of streams in those basins and results from earlier Critical Linkages analyses that were based on modeled, rather than field-assessed data on crossing passability.

A second project objective was to test Critical Linkages by examining the extent to which crossing assessments conducted in the field are needed to obtain reliable results. Where field data are not available, Critical Linkages uses modeled passability scores to determine landscape resistance for its aquatic connectedness metric. The predictions are likely to be substantially improved by using scores based on field assessments in place of the modeled scores. We used extensive data collection in selected subwatershed to evaluate whether we need to assess all crossings in a given area to gain that benefit or whether a more strategic approach (e.g. assess only high-priority sites) would provide satisfactory results.

By providing a better understanding of the CAPS model capability to measure the benefits associated with improvements to stream crossings without full field assessment, we can streamline the process and make better use of resources.

4.0 Methods

Location of Targeted Road-Stream Crossings

In order to survey stream crossings, a map identifying the location of target road-stream crossings was developed. GIS layers for streams were based on centerlines that had been mapped at varying densities across Massachusetts, introducing a source of bias in the CAPS aquatic connectedness metric. To address this issue, stream densities had to be standardized across the state. To accomplish this, stream networks were trimmed to eliminate all streams with watersheds of less than 74 acres. The revised data layer for road-stream crossings was developed by UMass Amherst, starting with the MassGIS networked hydro centerline data layer [4]and the NHD stream centerlines.[5] Those data were then edited in the following manner.

1. The stream network was edited to correct a significant number of breaks in the connectivity of the stream network.
2. Dense networks of channels in cranberry bogs were deleted.
3. Ditches in salt marshes were deleted.
4. Stream mouths were extended all the way to the ocean.
5. Stream centerlines were added in areas that were identified as upland to represent smaller (1st and 2nd order) streams.
6. Stream centerlines were burned into the flow grid.
7. All streams with a watershed of less than 30 ha (74 acres) were deleted. The 30 ha threshold was determined by trial and error until we found the minimum size necessary to produce consistent stream mapping across the state (i.e. eliminate boundary effects in the base hydrography data).

[4] http://www.mass.gov/mgis/watrshed.htm
[5] http://nhd.usgs.gov/data.html

8. The stream data were then overlaid with the MassGIS MassDOT Roads layer and the MassGIS Trains layer. The points where streams data cross roads and/or railroad lines were identified as crossings.

Road-stream crossings that fell on these trimmed streams was a subset of all predicted crossings on untrimmed streams statewide (20,970 of the 36,636 crossings estimated based on GIS); these crossings were referred to as “CAPS crossings.”

Selection of Subwatersheds for Study

The road-stream crossings selected for assessment were located in three subwatersheds, one each from the Ipswich River, Buzzards Bay, and Chicopee River watersheds. The goal was to identify Sub-watersheds that contained approximately 200 stream crossings and in which all (or nearly all) the stream crossings would be field evaluated. This approach was chosen to provide a data set that can be used to conduct the Critical Linkages scenario analyses in areas where most road-stream crossings had been field assessed.

Selection of subwatersheds involved consideration of several parameters including the number and location of road-stream crossings, areas in the state where stream assessments had not previously been conducted, regions where circuit riders and other volunteers were available to conduct the fieldwork, and the occurrence of “high quality streams.”

<u>Assessments Conducted to Date and Location of Available Staff</u>

The next parameters considered in selecting the subwatersheds for this study included mapping locations in the state where stream crossing assessments had been conducted and the location of MassDEP regions where circuit riders were available (i.e. NERO, SERO, and WERO/CERO combined) to help conduct the work. The Continuity Project had already trained cooperating organizations to conduct stream crossing assessments across the state over a period of several years. As of November 17, 2011 when this project began, 1,368 (6.5%) of the 20,970 CAPS crossings in Massachusetts had been assessed by other organizations and individuals. (See Figure 4.1).

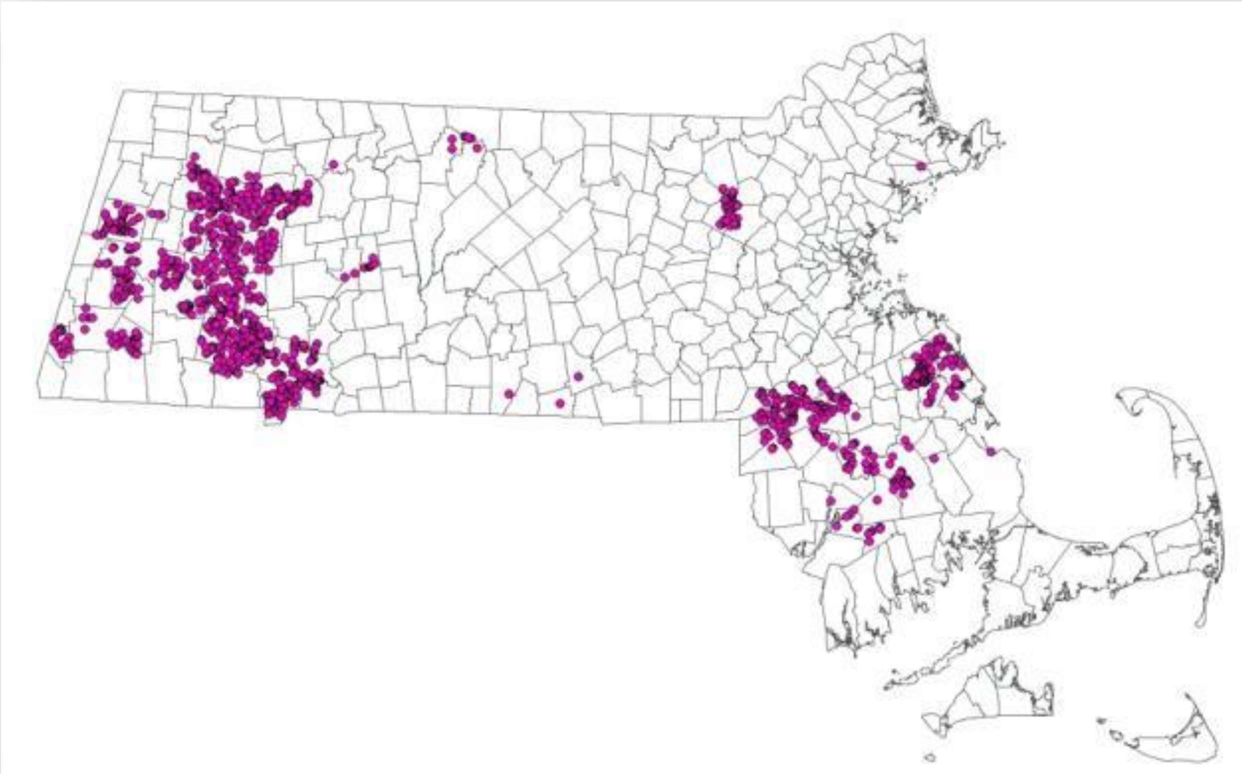

Figure 4.1: MassDEP Regions with Stream Crossings Assessed as of November 17, 2011 (Assessments conducted in the Quabbin Reservoir Watershed are not shown)

High Quality Streams

The “High Quality Streams” data layer was developed by the Continuity Project using the following sources.

- MA Natural Heritage and Endangered Species Program Living Waters Core Habitats (Nov. 2003)
- MA NHESP BioMap Core Habitats (June 2002)
- Areas of Critical Environmental Concern (EOEEA)
- Cold Water Fisheries where Brook Trout populations are “categorized as “intact” and have a contributing watershed of 0.5 sq. mi (approximately 320 acres) or more (Eastern Brook Trout Joint Venture 2006)
- Anadromous Fish Runs from 1997 data provided by the MA Division of Marine Fisheries supplemented with data from the U.S. Fish and Wildlife Service for the Connecticut River Watershed.

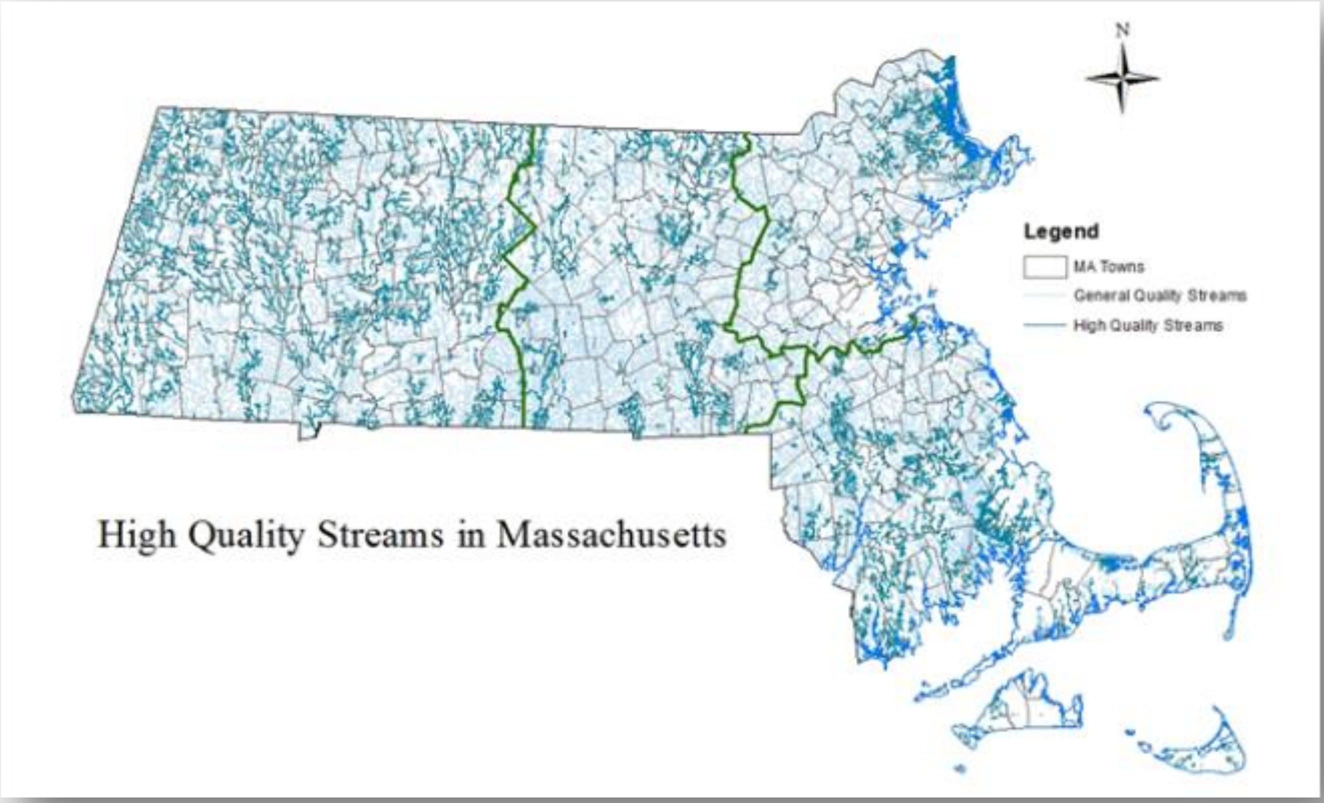

Figure 4.2: High quality streams in Massachusetts

Best Case Crossing Points

The Best Case Crossing Point data layer was developed by UMass Amherst using the Critical Linkages assessment. This data layer identified 2,395 crossings that are the best opportunities to improve aquatic connectedness along the centerline of streams, rivers, water bodies, and wetlands statewide via crossing upgrade or replacement.[6]

[6] Best case points used for this study is based on a GIS datalayer provided by UMass in 2011, and may be different from the current Critical Linkages best case datalayer. See www.umasscaps.org – Documents and Reports link for critical linkages report.

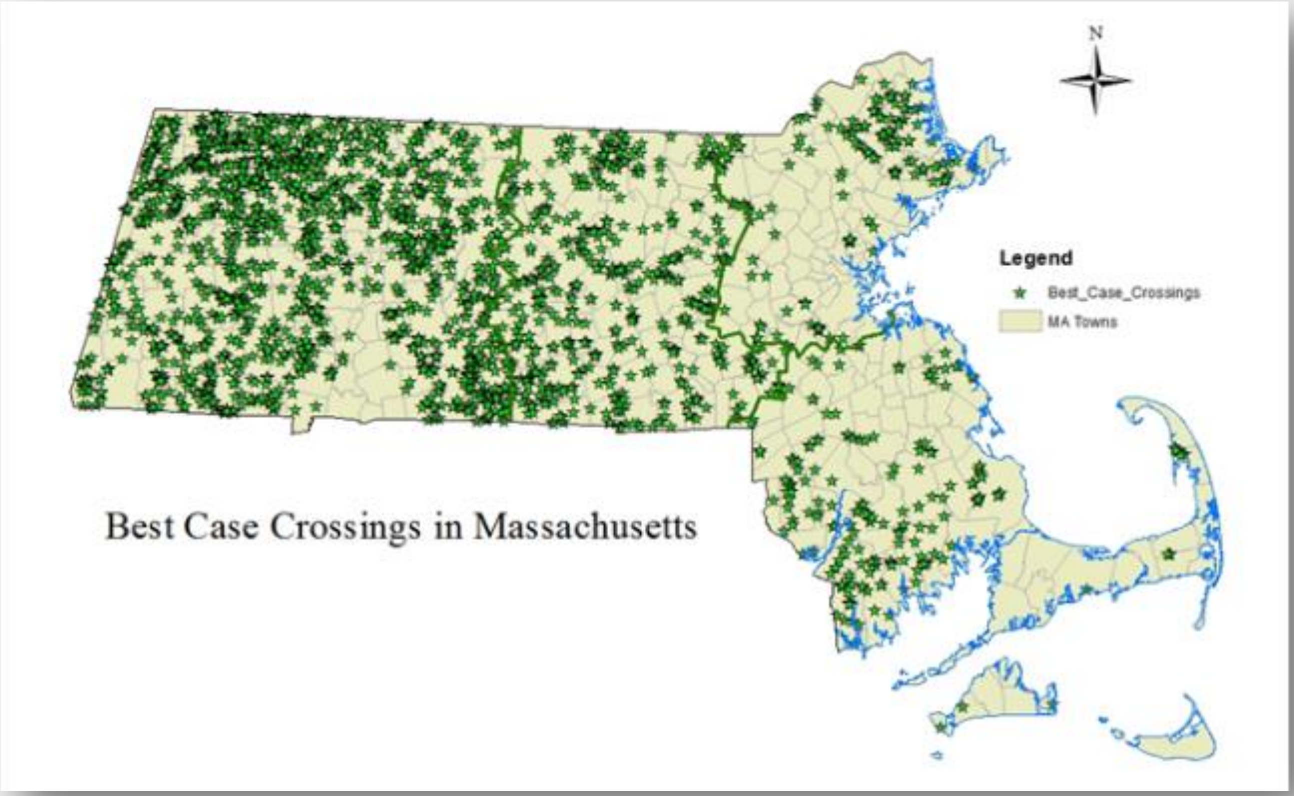

Figure 4.3: Best Case Crossings in Massachusetts

Selected Subwatersheds

By considering all the data above, three subwatersheds were identified that provided the requisite number of culverts for assessment (i.e. 200 per region) while maximizing best case points on the highest quality streams. Locus maps of each subwatershed are depicted in Figures 4.5, 4.6, 4.7 and 4.8. Detailed maps of each subwatershed, along with the best case crossings and high quality streams are in Appendix A.

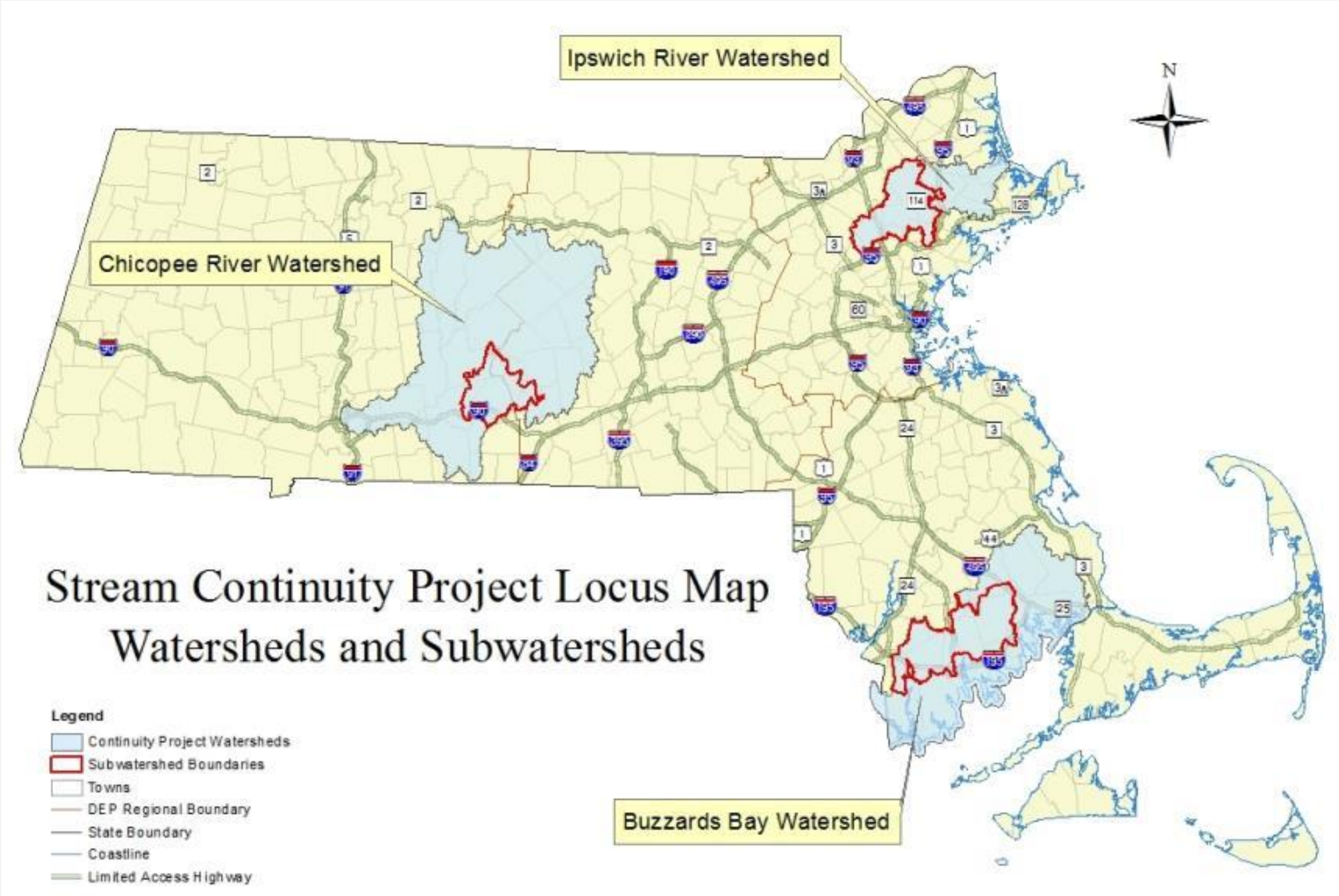

Figure 4.4: Selected Watersheds and Subwatersheds

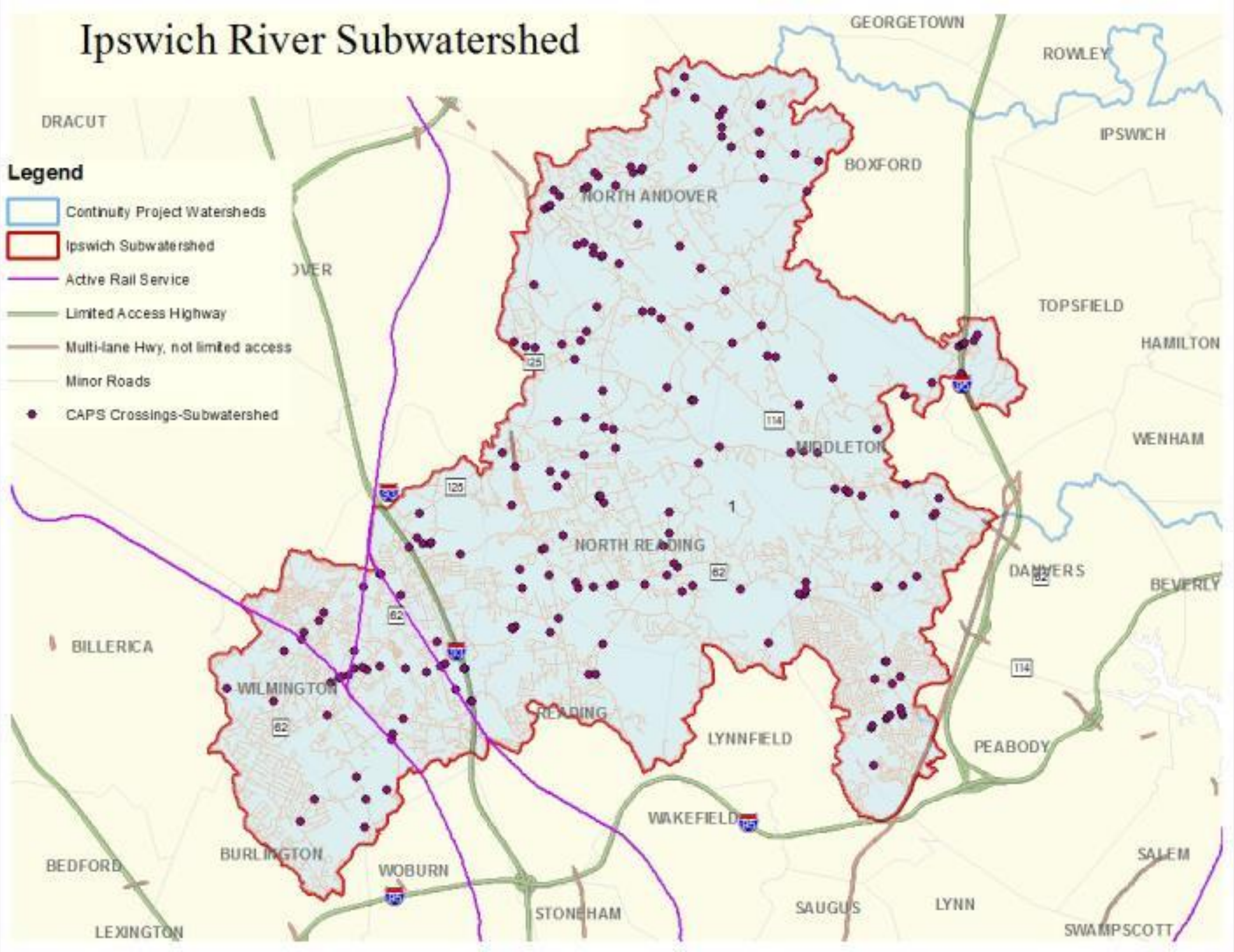

Figure 4.5: Ipswich River Subwatershed: Locus and CAPS Crossings

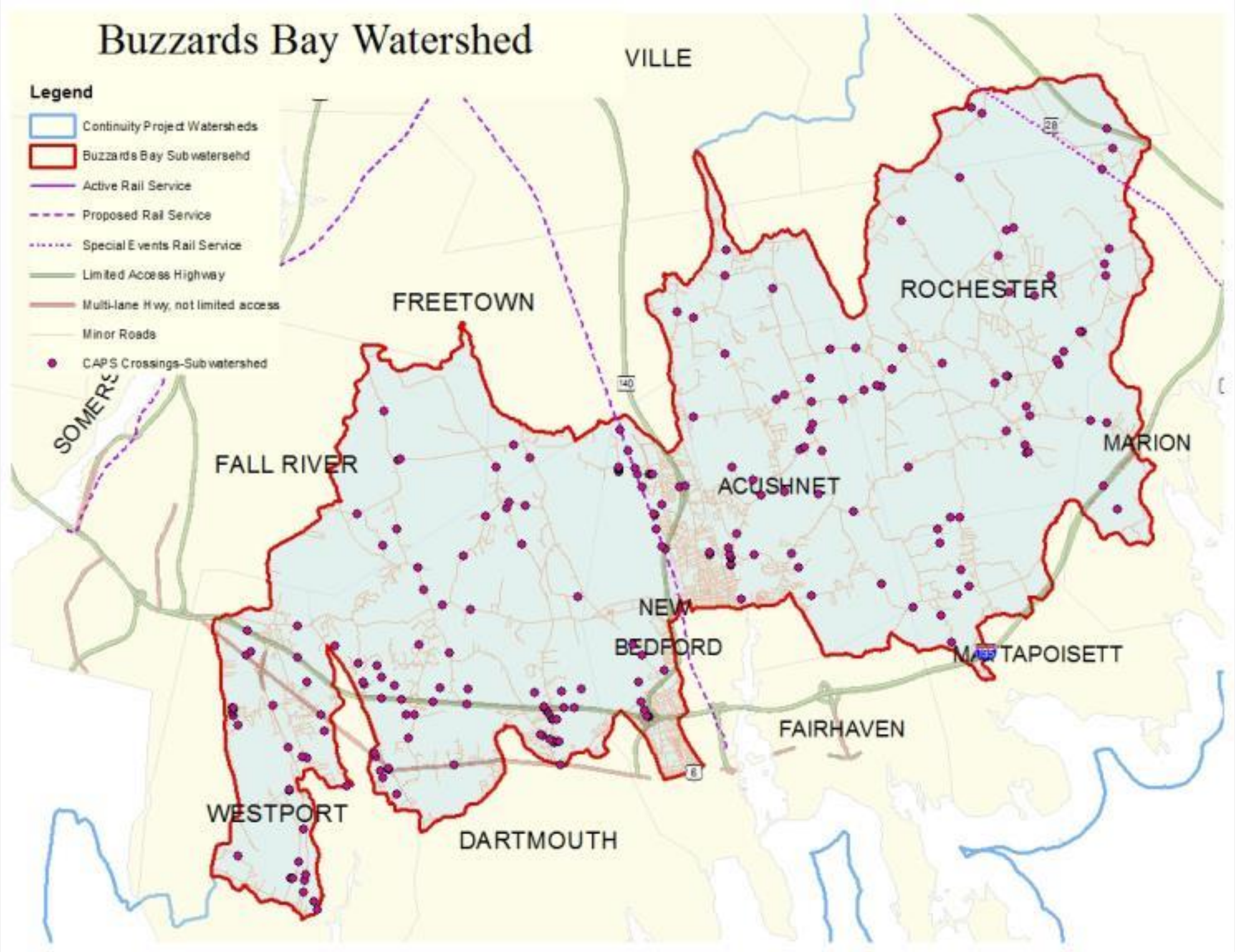

Figure 4.6: Buzzards Bay Subwatershed: Locus and CAPS Crossings

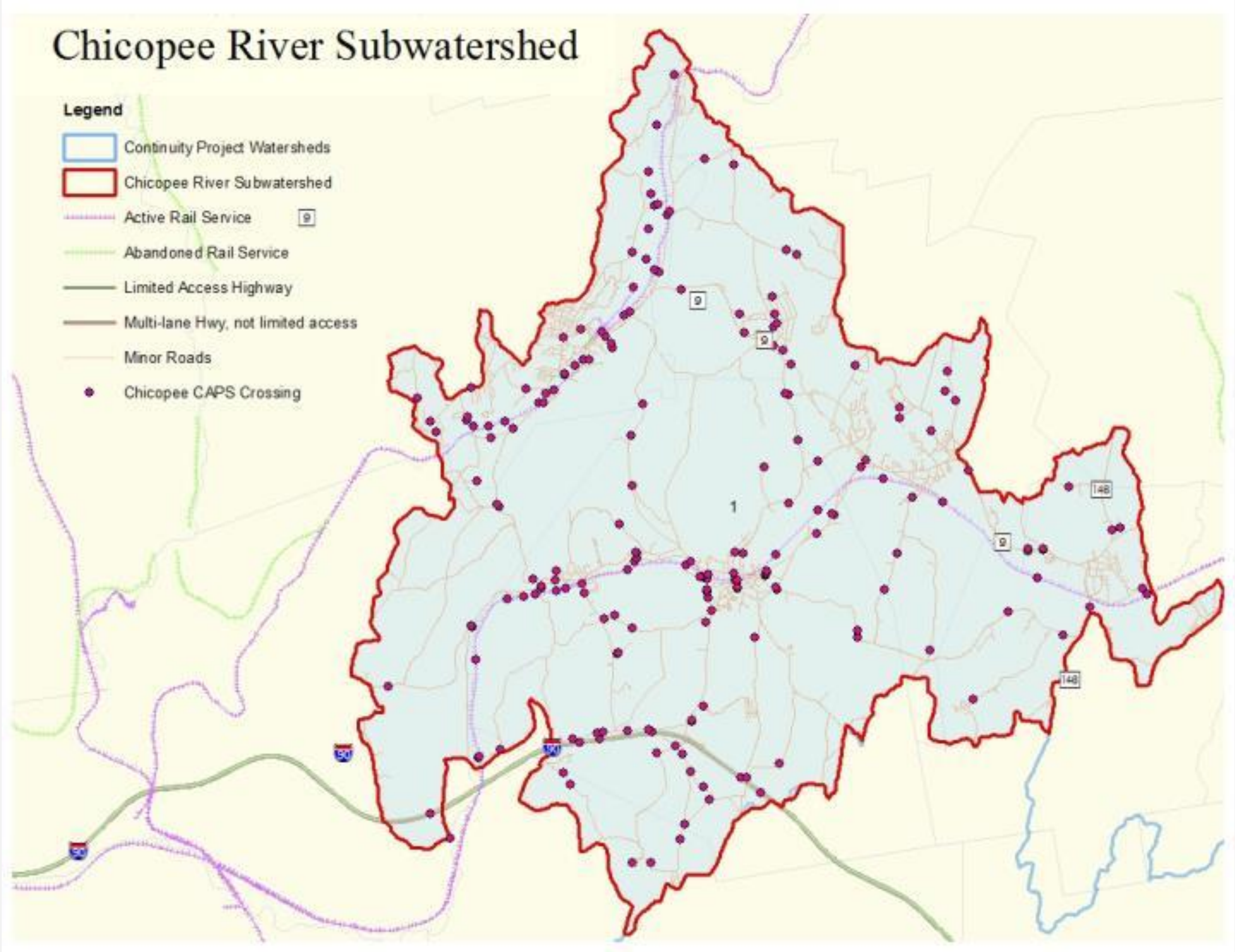

Figure 4.7: Chicopee River Subwatershed: Locus and CAPS Crossings

5.0 Quality Control, Training and Data Collection

Quality Assurance (QA)/Quality Control (QC) was described in the Quality Assurance Project Plan (QAPP) finalized and approved by EPA in April of 2012. The QAPP is available for review at: http://www.mass.gov/eea/agencies/massdep/water/watersheds/quality-assurance-project-plans-qapps.html

Special Training/Certification

All MassDEP staff serving as Survey Coordinators, Survey Team Leaders or Technicians underwent training conducted by the Department of Ecological Restoration (DER) Stream Continuity Project Coordinator. Additional training was conducted as needed by the MassDEP Project Manager, the UMass Project and QA Manager and/or the MassDEP Wetland Program Quality Assurance Advisor. Training included classroom study of assessment protocols and field training which included practice in actual measurement methodology, GPS operation, proper decontamination procedure (to prevent the spread of invasive species), and safety protocols. MassDEP Circuit Riders, as Survey Coordinators, were then able to train additional volunteer Survey Team Leaders or Technicians as they were identified. Survey Team members were each provided with a copy of the approved data collection protocols and quality standards.

Field Forms

Field assessments consisted of paper data forms that were filled out in the field by the survey team. The *Instruction Guide for Field Data Form* provides a detailed description of the methodologies to conduct the measurements outlined above.[7] The *Field Data Form* is the data form for recording the information (See Appendix B). The assessments consisted of collecting the following information:

- GPS coordinates(lat/long, decimal degrees) of the actual crossing using the GPS provided;
- Documenting the road surface and road type (paved/unpaved; single lane/multilane);
- The crossing type (Ford, bridge, open bottom arch, single culvert, multiple culverts);
- The condition of the crossing (excellent/fair/poor);
- Whether or not the stream appears to support fish;
- The height of the crossing structure (from water surface level to the roof inside the structure);
- The height (in inches) of any inlet drop;
- The height in inches of any outlet drop, as well as the outlet type (freefall/cascade);
- The presence of armoring (i.e. rip rap) at the outlet;
- Determining whether the crossing is embedded and if yes, the substrate;
- The presence of any physical barriers to fish;
- The degree to which the crossing span constricts the flow of water;

[7] http://www.mass.gov/eea/agencies/massdep/water/watersheds/quality-assurance-project-plans-qapps.html

- How the crossing impacts water velocity and depth;
- The comparative slope of the crossing (visually, with respect to upstream and downstream slopes);
- The shape of the crossing (round, elliptical, or box);
- The dimensions of culverts/bridge cells

Each stream crossing in the CAPS data layer was assigned a unique crossing ID from the XYCodes_MA_DRAFT_010612 data layer (containing ALL 36,360 crossings in MA) provided by the Stream Continuity project. A stream crossing ID consists of a prefix "xy" followed by the 16 digit geospatial coordinates (latitude and longitude) of the crossing. For example, a crossing with ID xy4173817670881720 refers to a stream crossing on Robinson Road in Acushnet, MA with latitude 41.738176 and Longitude -70.881720. Locus and detailed GIS maps of CAPS crossings with crossing IDs were created to help stream teams locate sites in the field. See sample in images below.

Figure 5.1: Example of GIS street detail maps with crossing IDs for field use.

A single CAPS point crossing on a map can correspond to different stream crossings types in the field. Smaller streams were typically found to consist of a single culvert to be evaluated, but many larger streams or rivers involved measurement of multiple culverts to complete the crossing assessment. Where a crossing involved multiple culverts, data were gathered for each culvert individually. Photographs were taken of each inlet and each outlet for every culvert assessed. At each inlet and outlet, one photo was taken of the crossing with a whiteboard/paper/blackboard prop containing the crossing code ID #, date, and inlet/outlet to document the crossing location. A second photo was taken without this information. For this discussion, the term "crossing assessment" refers to a CAPS point with a unique crossing ID (i.e. xy_code) and the term "culvert assessment" refers to an individual field evaluated pipe or bridge cell. So, there may be multiple culvert assessments within one crossing assessment. To facilitate culvert and stream measurements, increase safety and allow for the evaluation of passage in low flow conditions the field work was conducted during the months of June through September that are typically considered low flow season in Massachusetts. Measurements were taken according to the protocols described in the QAPP and field data forms were completed for each stream crossing.

The paper forms and electronic pictures of the inlet and outlet sides of the crossings were collected by the survey coordinators in each region and entered/downloaded into the NAACC Crossings Database. The NAACC Crossings Database that houses the field assessment data are maintained by the University of Massachusetts Amherst and is available for review at: http://www.naacc.org. The database contains the data gathered in the field, including site photographs. The assessments conducted for this project are listed in Appendix C and also can be viewed by searching the following coordinators: Christine Odiaga, Mark Stinson, Pam Merrill, Alice Smith, and Tim Dexter.

Quality Control

Survey Coordinators were responsible for quality control of the data received from the Survey Team Leaders and Technicians and performing quality control checks on data entered into the NAACC Crossings database. Survey Team Leaders approved for data entry were responsible for quality control of the data they entered into the NAACC Crossings Database.

In addition, Survey Coordinators independently field verified 10% of all surveys in each subwatershed to ensure data were gathered in compliance with this QAPP and accurately reflected the actual onsite conditions. Since each subwatershed consists of approximately 200 sites, Survey Coordinators were required to verify approximately 20 sites to confirm that that the data recorded on the field form accurately reflected the onsite conditions within their assigned Subwatershed. Because there were three Subwatersheds chosen for assessment, this resulted in approximately 60 total sites undergoing the QC procedure. See Appendix D for a detailed list of Quality Control sites.

Data Review, Verification, Validation

The Wetland Program QA Advisor and the Project Manager conducted the final QA/QC check on all data that were entered to the NAACC Crossings Database to ensure completeness and consistency with existing protocols.

6.0 Access Problems and Sub-Subwatersheds

Access Issues

The stream assessments were originally scheduled to be completed during the summer of 2012. However, during the summer of 2012, survey teams encountered numerous crossing sites for which there was no safe access, sites where no crossings could be located, and sites where culvert measurements could not be taken for various reasons.

An end of summer project review indicated that there were 185 unassessed crossings that could not be completed primarily due to access issues. They included 66 Railroad crossings and 97 Interstate Highway crossings that were determined to be inaccessible and could not be field assessed without additional equipment or personnel. Permission to access the Railroad property and assistance to evaluate the crossings was requested but was not received. Over 20 additional stream crossings were not assessed because safe access was not available, no crossing was found in the field, or they were located on private or posted property for which landowner permission could not be obtained.

Table 1. Project progress review - September, 2012

Subwatershed	# Crossings Assessed	# Crossings Not Assessed	# Interstate or Divided Highway Crossings Not Assessed	# Railroad Crossings Not Assessed	# Other Crossings Not Assessed (e.g. inaccessible, unsafe, no trespassing, not found)
Ipswich	167	33	13	9	11
Buzzards Bay	103	97	66	21	10
Chicopee	145	55	18	36	1
Total	415	185	97	66	22

Modifications to Subwatersheds

The access issues in the original subwatersheds required that alternate methods be sought to obtain comprehensive field assessments for the scenario analysis. The chosen strategy was to identify a reduced portion of each subwatershed (hereafter referred to as the “Sub-subwatershed”) where comprehensive field assessments could be accomplished for the scenario analysis and then to complete the remaining assessments at crossings that were within the larger watershed, but easier to access to complete the 600 assessments.

Due to the difficulty in avoiding highways and railroads even when using this strategy, we opted to complete all crossings in two out of three sub-subwatersheds focusing on the Buzzards Bay and Ipswich basins and eliminating the Chicopee Sub-subwatershed from the full field evaluation effort (but assessments were still counted toward the 600 total). To achieve the Critical Linkages scenario analysis, each sub-subwatershed a) contained more than 75 crossings, b) minimized the number of Interstate, US Highways, and Railroad CAPS crossings to insure that all assessments could be completed and c) maximized best case crossings and high quality streams. MassDOT agreed to assist with the project by assessing many of the Interstate and numbered highway crossings.

7.0 Stream Crossing Data Acquisition

Sites Assessed and entered into Stream Continuity Database

<u>Ipswich River Watershed Data</u>

The number of crossings and culverts assessed in the Ipswich watershed, subwatershed and sub-sub watershed are depicted in Table 2. Where crossings had more than one culvert, each culvert was assessed separately and is reflected in the database as a separate record with the same crossing ID.

Table 2. Stream crossing assessments in Ipswich Watershed

Watershed Type	# CAPS Crossings	# Crossings Assessed	# Crossings with Multiple Culverts	# Culverts Assessed	% CAPS Crossings Assessed
Ipswich Watershed	417	228	10	238	54.7
Ipswich Subwatershed	214	172	8	180	80.4
Ipswich Sub-subwatershed	100	92	4	96	92.0

Of the 100 CAPS crossings in the Ipswich Sub-subwatershed, eight (8) crossings were not assessed. Three (3) crossings could not be located in the field and five (5) additional sites were on private property and not accessible (See Table 3 Below).

Table 3. Details of stream crossing assessments in Ipswich Watershed

Watershed Type	# Crossings Assessed	# Crossings Not Assessed	# Highway Crossings Not Assessed	# Railroad Crossings Not Assessed	No Crossing Found at Site	Other Crossings Not Assessed (Inaccessible, Dangerous, No Permission)
Ipswich Watershed	228	-	-	-	-	-
Ipswich Subwatershed	172	42	8	8	4	22
Ipswich Sub-subwatershed	92	8	0	0	3	5

Ten percent of the total crossing assessments were selected for quality assurance review. There were a few errors in the accuracy of measurements, particularly measuring the diameter of the culvert. A couple of culverts were measured using the wrong structure type. Errors of this type occurred with culverts for which elliptical culvert dimensions were mistakenly used instead of the dimensions for a round culvert embedded or with persistent water or for an elliptical culvert embedded or with persistent water. One crossing was in the wrong location, but the correct crossing was found when QA assessments were completed. Some of the photographs were retaken because the original pictures did not clearly represent the crossing.

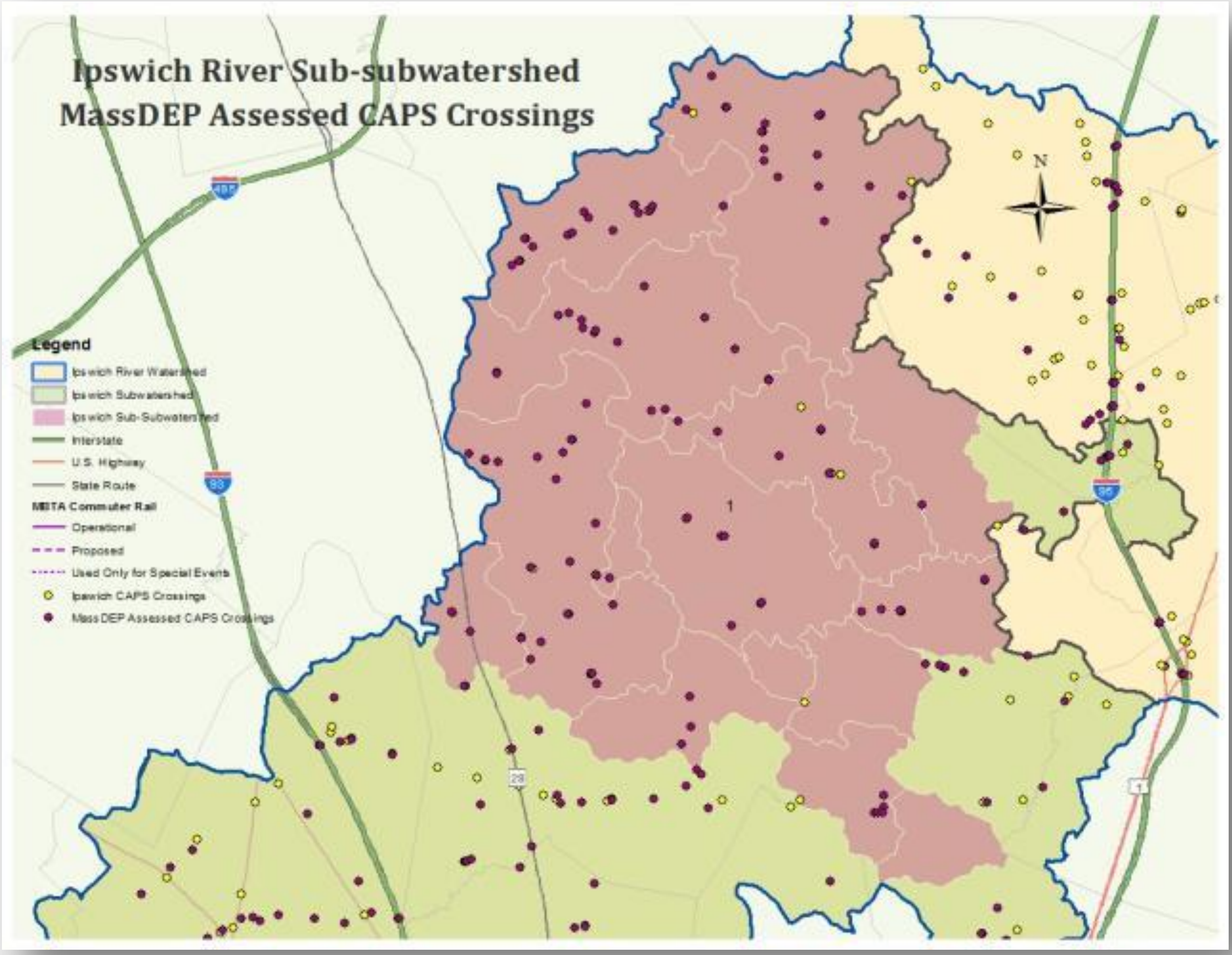

Figure 7.1: Ipswich River Sub-subwatershed: MassDEP Assessed CAPS Crossings

<u>Buzzards Bay Watershed Data</u>

The number of crossings and culverts assessed in the Buzzards Bay watershed, subwatershed and sub-sub watershed are depicted in Table 4. Where crossings had more than one culvert, each culvert was assessed separately and is reflected in the database as a separate record with the same crossing ID.

Table 4. Stream crossing assessments for Buzzards Bay Watershed

Watershed Type	# CAPS Crossings	# Crossings Assessed	# Crossings with Multiple Culverts	# Culverts Assessed	% CAPS Crossings Assessed
Buzzards Bay Watershed	728	275	40	315	37.7
Buzzards Bay Subwatershed	227	170	33	203	74.2
Buzzards Bay Sub-subwatershed	94	80	18	98	85.1

Fourteen CAPS crossings in the Sub-subwatershed were not field assessed for the scenario analysis. There were many sites where no stream crossing could be located, or that were inaccessible, or where other reasons prevented full field assessment (See Table 5 below).

Table 5. Details of stream crossing assessments in Buzzards Bay Watershed

Watershed Type	# Crossings Assessed	#Crossings Not Assessed (Sum of Next 4)	# Highway Crossings	# Railroad Crossings	No Crossing Found at Site	Other Crossings Not Assessed (Inaccessible, Dangerous, QA, No Permission)
Buzzards Bay Watershed	275	-	-	-	-	-
Buzzards Bay Subwatershed	170	57	5	5	14	33
Buzzards Bay Sub-subwatershed	80	14	0	1	9	4

Thirty one additional assessments were conducted for quality assurance. Two of the sites selected for QA had information in the record that did not match the inlet and outlet photos. QA review revealed that these two were in a clump of five crossing sites in close proximity to each other on the same road and the forms had mixed up the crossing IDs. A second inconsistency was the differing ideas about what constitutes a physical barrier that showed up in the collected data. For example, beaver dams in the western region are not considered a physical barrier. It is expected that with the steep stream gradients, beaver dams are gone in a few years. However, in the southeast region, streams tend to have very shallow gradients that allow a beaver dam to remain in place for long periods of time. Some measurement inaccuracies were encountered initially due to survey teams using tapes/sticks with markings in inches and others in 1/10 of a foot. Some field stone culverts were identified as box culverts in the “structure type” field on the form when the structure type should be “bridge with abutments". The corrections were made, some based on photos. Another point of confusion on a few crossings was the determination as to whether a crossing consisted of multiple culverts versus a single cell or culvert with internal support midway through the crossing.

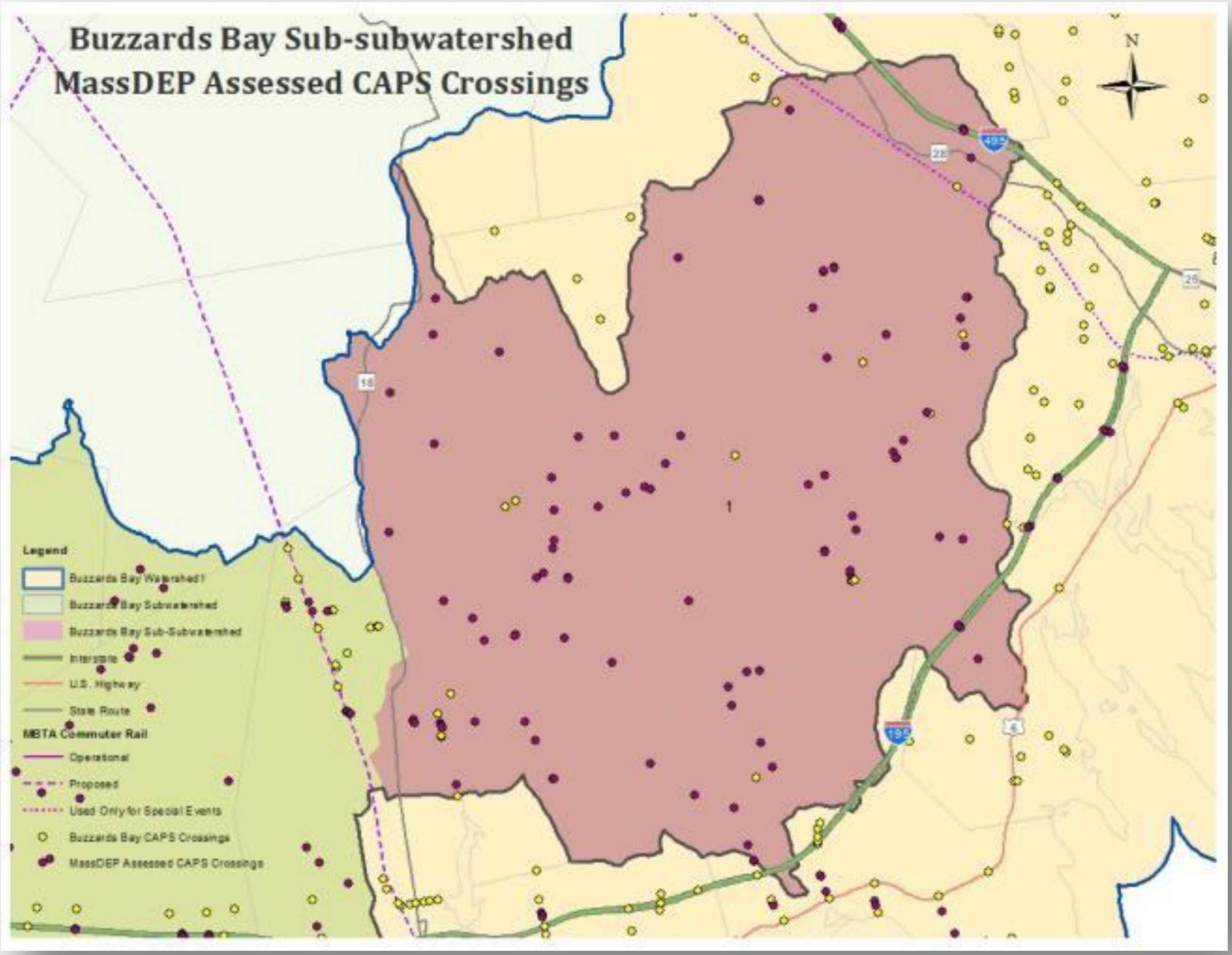

Figure 7.2: Buzzards Bay Sub-subwatershed: MassDEP Assessed CAPS Crossings

<u>Chicopee River Watershed Data</u>

The number of crossings and culverts assessed in the Chicopee watershed, subwatershed and sub-sub watershed are depicted in Table 6. Where crossings had more than one culvert, each culvert was assessed separately and is reflected in the database as a separate record with the same crossing ID.

Table 6. Stream crossing assessments in Chicopee Watershed

Watershed Type	# CAPS Crossings	# Crossings Assessed	# Crossings Assessed with Multiple Culverts	# Culverts Assessed (Same as # Database Logs)	% CAPS Crossings Assessed
Chicopee Watershed	1681	200	0	200	11.9
Chicopee Subwatershed	198	151	0	151	76.3
Chicopee Sub-subwatershed	96	85	0	88	88.5

Of the 96 CAPS crossings in the Chicopee Sub-subwatershed, 11 crossings were not assessed due to presence of highways and railroads (See Table 7 Below).

Table 7. Details of stream crossing assessments in Chicopee Watershed

Watershed Type	# CAPS Crossings Assessed	Crossings Not Assessed	# Highway Crossings	# Railroad Crossings	No Crossing Found	Other Crossings Not Assessed Inaccessible, Dangerous, No Permission
Chicopee Subwatershed	151	47	20	17	0	10
Chicopee Sub-subwatershed	85	11	5	6	0	0

Ten percent of the total crossing assessments (20 stream crossings) were chosen and reassessed for Quality Assurance (QA) purposes. One quality assurance audit found that the survey team had selected an incorrect culvert shape. A round culvert was chosen when it was actually an embedded round culvert with water flowing. The data sheet was corrected for the culvert shape and the added dimensions were documented. Another issue identified was a survey team used a cell phone to take the GPS readings at two crossing sites. This remedy required that the culvert GPS readings be redone for those assessments to insure geospatial location accuracy. All corrections were made on the field data form prior to entering the data into the continuity database so additional data records were not entered.

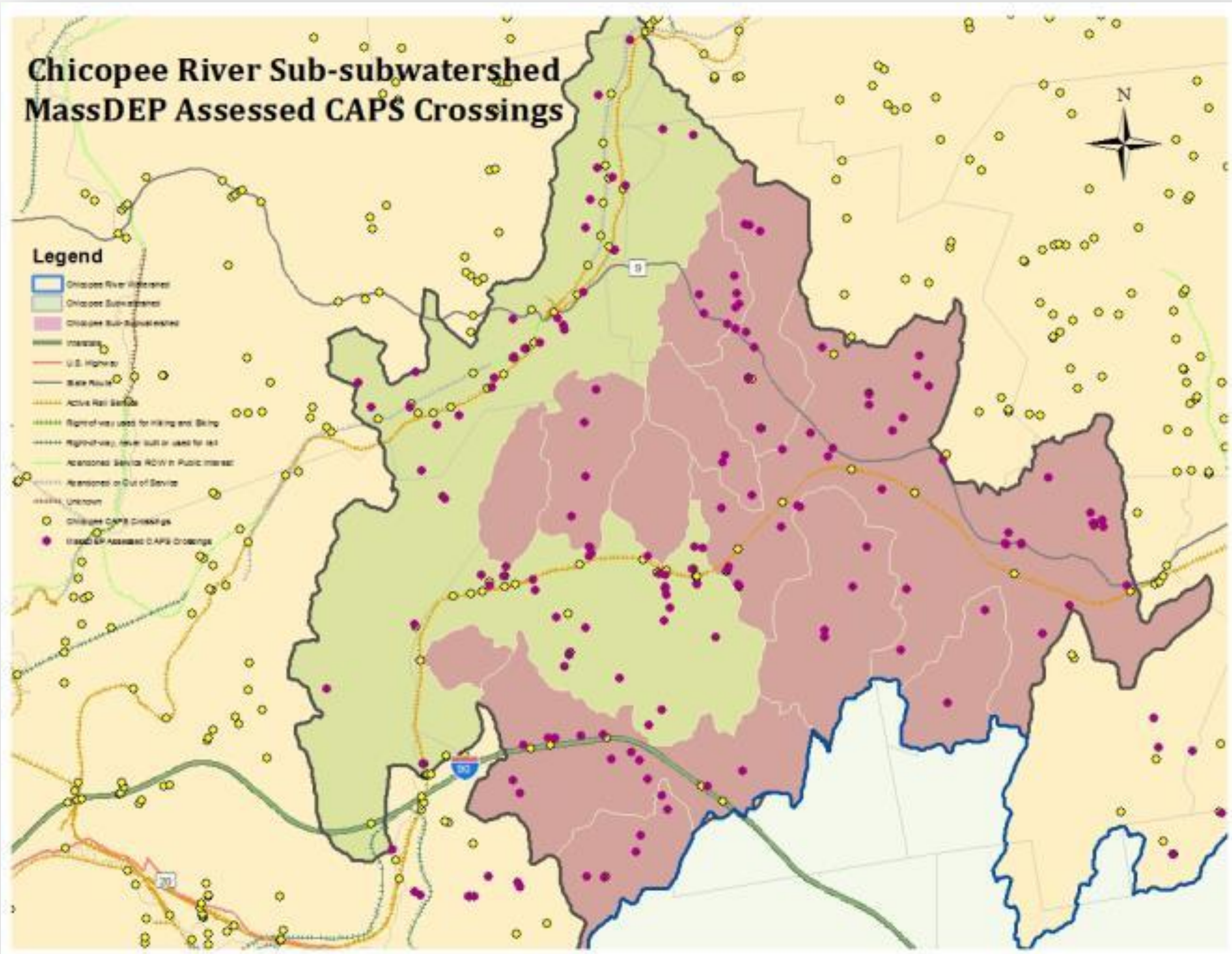

Figure 7.3: Chicopee River Sub-subwatershed: MassDEP Assessed CAPS Crossings

Summary of Stream Crossing Assessments

Seven hundred and six (706) stream crossings were assessed within the three watersheds for the project in its entirety. This exceeds the grant proposal to conduct 600 stream crossing assessments to improve the NAACC Crossings Database. The goal to acquire 100 percent field evaluated crossings in a confined Subwatershed could not be fully met due to field constraints. The strategy used to modify the originally defined Subwatershed and still meet the CAPS model scenario analysis requirements moved the percent completion closer to 100 percent and allowed MassDEP to approach meeting the goal of full field assessment in two of the three sub-Subwatersheds.

Table 8 Total crossing assessments completed for all Watersheds.

Watershed Type	# CAPS Crossings	# Crossings Assessed
Ipswich Watershed	417	228
Buzzards Bay Watershed	728	278
Chicopee Watershed	1681	200
Extra Crossing Assessments in WERO		11
Total		717

8.0 CAPS Model Scenario Analyses

One of the objectives of the MassDEP Stream Continuity Project was to evaluate whether it is necessary to assess all crossings in a watershed in order to get reliable Critical Linkages results. Toward this end MassDEP conducted field assessments of road-stream crossings at all (or nearly all) crossings in particular watersheds (portions of the Buzzards Bay and Ipswich River watersheds). The MassDEP crossing data combined with previously assessed crossings from the Continuity database allowed UMass to run several variations of the Critical Linkages Analysis using combinations of modeled scores and scores based on field assessments.

An analysis was conducted to see what percentage of crossings would need to be assessed in a subwatershed and still get results similar to a comprehensive assessment of all crossings in that subwatershed. To conduct this analysis, UMass focused on five subwatersheds where something close to comprehensive coverage had been obtained, the two subwatersheds assessed by MassDEP (i.e. sub-subwatersheds) and three subwatersheds that had been assessed by others. These included portions of the Buzzards Bay, Farmington, Housatonic, Ipswich and Westfield River watersheds (Figure 8.1). UMass used slightly different boundaries for the Ipswich and Buzzards Bay subwatersheds by delineating actual stream networks than originally identified by MassDEP using GIS watershed boundaries. The percentage of crossings assessed in these UMass delineated subwatersheds were different than those calculated by MassDEP.

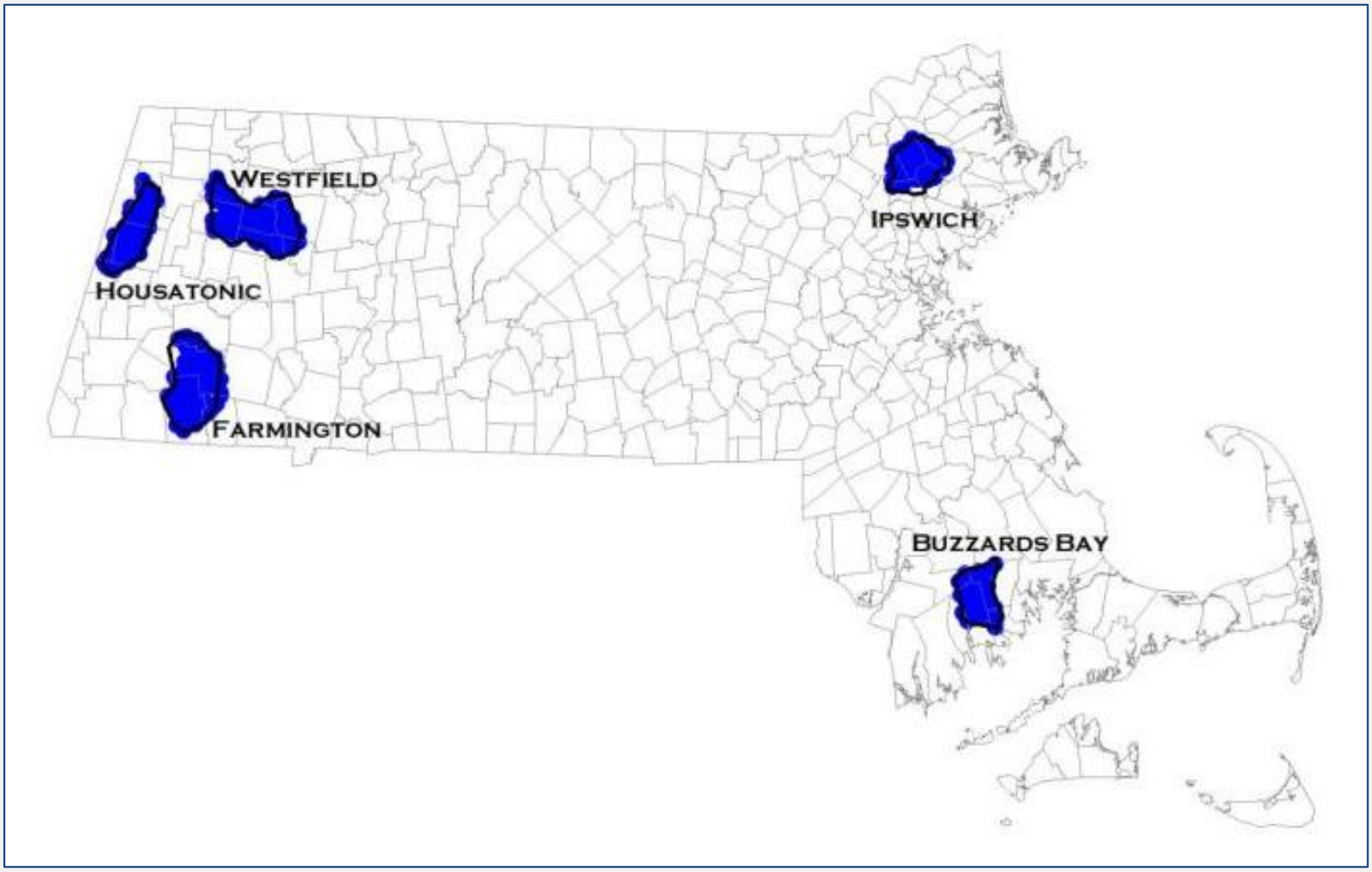

Figure 8.1 Five Subwatersheds used in the scenario analysis

Three baseline scenario runs were conducted using the Critical Linkages methodology.

1) (Near) Comprehensive. This was a run based on near comprehensive assessment (69-80% assessed); all other runs were evaluated in comparison with these results.
2) 0% assessed. This was a Critical Linkages run where all aquatic passability scores were generated by a model rather than field assessments. This is the default option used in Critical Linkages analyses for areas where field assessments have not yet been completed.
3) Null. This is a control, where all aquatic passability scores are randomly generated.

Next, some of the field assessments in each subwatershed were used to simulate situations where 20, 30, 40 and 50% of the crossings were assessed (scores from the model were used for the other crossings). Two versions of each of these runs were conducted: one where the crossings were selected at random and another where the selection was done strategically based on best case 'impact' scores from the 0% assessed run. Starting with the crossings with the highest “impact” scores, those crossings were chosen and the crossings directly upstream and downstream of those crossings, moving down the list in descending order of "impact" until the designated percentage threshold (20%, 30%, 40%, or 50%) was reached. Only crossings that were assessed in the field were chosen for inclusion.

The analyses looked at delta aquatic connectedness scores from the Critical Linkages analyses of road-stream crossings for the five subwatersheds where most crossings had been assessed. The Delta aquatic connectedness is the change in the aquatic connectedness metric score resulting from replacing each crossing with a bridge. In conducting the scenario analysis, where multiple culverts existed at the same crossing, the database evaluated each structure at each crossing and assigned to the crossing the score for the best structure. In cases where there were two records for the same culvert (i.e. if a QA assessment was entered), critical linkages always used the most recent assessment for each crossing. The results of these analyses are presented in Table 9 and Figure 8.2 (plots for all comparisons are included in Appendix E).

Table 9 Correlation coefficients for delta aquatic connectedness scores derived by Critical Linkages analyses for various percentages of assessed crossings chosen at random or via a strategic process compared with results for (near) comprehensive assessments along with a "null" assessment where all passability scores were randomly generated.

	Buzzards Bay	Farmington	Housatonic	Ipswich	Westfield	mean	SE
Null	0.454	0.351	0.091	0.198	0.134	0.246	0.068
0% assessed	0.335	0.308	0.709	0.576	0.687	0.523	0.085
20% random	0.682	0.316	0.789	0.71	0.701	0.640	0.083
30% random	0.512	0.407	0.806	0.743	0.744	0.642	0.077
40% random	0.889	0.368	0.926	0.853	0.812	0.770	0.102
50% random	0.939	0.984	0.888	0.858	0.821	0.898	0.029
20% strategic	0.796	0.987	0.928	0.899	0.954	0.913	0.033
30% strategic	0.945	0.991	0.965	0.95	0.974	0.965	0.008
40% strategic	0.977	0.995	0.978	0.969	0.986	0.981	0.004
50% strategic	0.998	0.998	0.994	0.971	0.991	0.991	0.005
% Assessed	68.7	80.5	75.2	77.4	76.2		

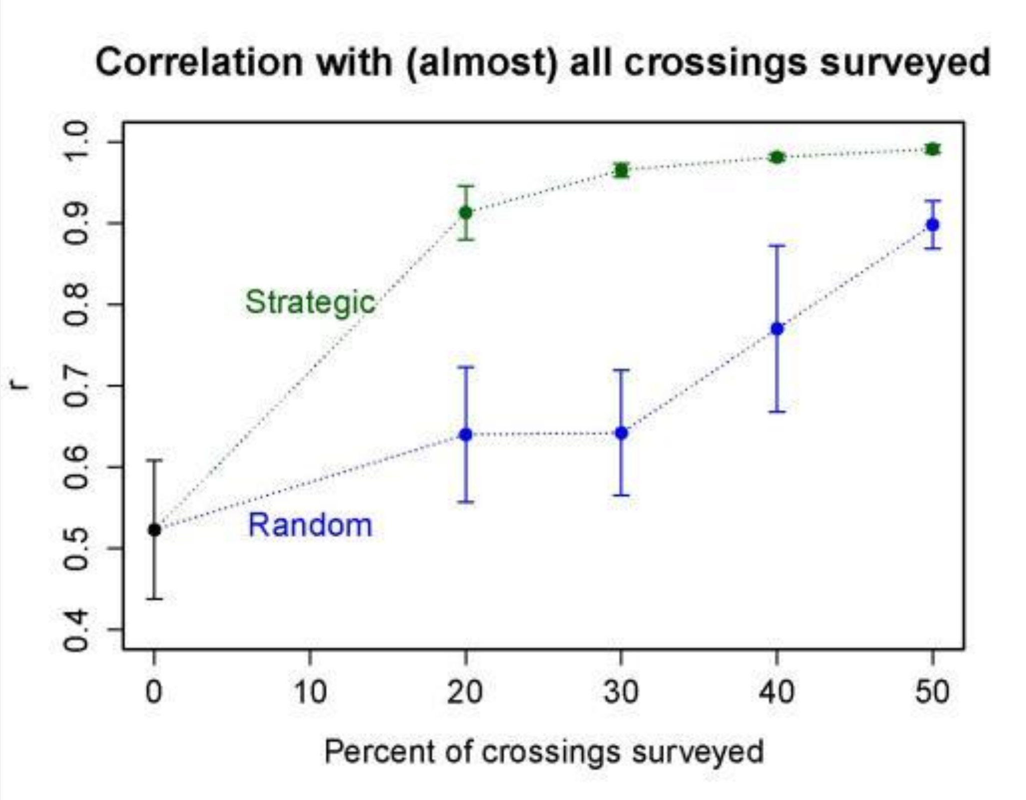

Figure 8.2. Plots of correlation coefficients for delta aquatic connectedness scores derived by Critical Linkages analyses for various percentages of assessed crossings chosen at random or via a strategic process compared with results for (near) comprehensive assessments.

The mean correlation for the null analysis was 0.25. This gives us an estimate of how much crossing scores matter. It suggests that about 94% ($1 – 0.246^2$) of the variation in the delta scores comes from the crossing scores; the rest comes from the relative position of crossings. The mean correlation for the 0% assessed analysis was 0.52. This means that the estimated passability scores from the model are an improvement over the random results (null analysis), but fall far short of what we'd see if all crossings were surveyed.

9.0 Conclusions

The results of this assessment suggest that it may not be necessary to assess every crossing in a watershed to get reasonable results from the Critical Linkages analyses. Using a random selection, an assessment of 50% of the crossings yielded results that were similar to near comprehensive assessments (correlation coefficient of 0.90). Using a strategic approach for selecting crossings yields substantially better results. A correlation coefficient of 0.91 was obtained with the assessment of only 20% of the crossings in the subwatersheds used for the analyses. Strategically selecting 30% of the crossings yielded a correlation coefficient of 0.96; selecting 50% of crossings raised the correlation to 0.99.

These results provide strong evidence that it is not necessary to assess all the crossings in a watershed in order to use the Critical Linkages methodology to evaluate the ecological restoration potential for culvert replacements and crossing upgrades. Assessing 50% of the crossings (when selected strategically) yielded results that were very similar to those of the near comprehensive assessments. These results suggest that you might be able to field assess only 30% of crossings in a subwatershed as long as those 30% are selected strategically.

Barrier Effects of Stream Crossings Assessed

A total of 717 stream crossing assessments were conducted for this study. Of the stream crossings assessed, 78 (11%) were creating a severe or significant barrier to the movement of aquatic organisms. Another 32% of crossings are creating a moderate barrier. Combined, this suggests that nearly half of all road-stream crossings in Massachusetts are disrupting aquatic connectivity and adversely affecting the ecology of the river and stream ecosystems. The Critical Linkages Project provides a system for prioritizing structures for upgrade or replacement that utilizes the Continuity Project/NAACC protocols for assessing and scoring road-stream crossings. This combination of on-the-ground data collection and landscape-scale modeling allows municipalities, agencies and conservation organizations to prioritize culvert improvements and direct scarce funding to projects that provide the best ecological benefit for the dollar. Improvements in strategically targeted culverts can improve connectivity for fish/wildlife and improve riverine ecosystem health, while also facilitating passage of flood flows (including increases in the frequency and intensity of large rainfall events) and help reduce property damage due to flooding and storm damage.

10.0 APPENDICES

Appendix A: Ipswich, Buzzards Bay and Chicopee Subwatersheds with Best Case Crossings and High Quality Streams

Appendix B: Field Data Form

Appendix C: MassDEP Assessed CAPS Stream Crossings

Appendix D: Quality Control Sites

Appendix E: UMASS Correlation Plots