MEMORANDUM

TO: Anne Capra, Conservation Administrator/Planner
Town of South Hadley

FROM: Julianne Busa, Ph.D.; Rachael Weiter, EIT; Liz Isenstein, EIT
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1550 Main Street, Suite 400
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DATE: June 1, 2021

RE: Town-Wide Road-Stream Crossing Assessment – MVP Action Grant
Road-Stream Crossing Assessment Technical Memorandum

1 Introduction

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 throughout the Town of South Hadley will be at greater risk of failure, which could result in flooding damage to homes and businesses, transportation infrastructure, and utilities; and stream channel erosion.

Fuss & O'Neill assessed road-stream crossings throughout the Town in support of the Climate Resilient South Hadley project, which was funded through the Commonwealth's Municipal Vulnerability Preparedness (MVP) Action Grant program. The goal of the project is to increase resilience to flooding and reduce flood-related impacts. To that end, the project systematically assessed road-stream crossings Town-wide to identify existing and future vulnerabilities and high-priority culvert/bridge replacement projects that would reduce flood vulnerability, increase the climate resilience of the Town's transportation infrastructure, and increase stream continuity for aquatic organism passage.

The assessments consisted of field surveys of individual stream crossings using established road-stream crossing assessment protocols, followed by analysis of the field data to assign vulnerability ratings to each crossing based on multiple factors 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 used to prioritize structures for upgrade or replacement. Conceptual designs for replacement of high-priority crossings were developed based upon the field data and vulnerability ratings.

This report summarizes the methods and results of the road-stream crossing field surveys and vulnerability assessment, as well as recommendations and conceptual designs.

2 Stream Crossing Field Surveys

2.1 Selection of Crossings

Road-stream crossings to be included in the assessment were initially identified based on review of aerial imagery, flood mapping, and other local or state-wide data layers. The project sought to assess all road crossings of mapped streams which could reasonably and safely be assessed, including those along both local and state roads. Some additional locations were added to the list based on the knowledge of staff from South Hadley's DPW and Planning Department.

48 road-stream crossings throughout South Hadley were ultimately assessed via field surveys and desktop vulnerability assessments. The locations of the selected crossings which span three watersheds, are shown on the map in **Figure 1**. Summary information on each crossing is provided in **Appendix B—Table 1**. Nearly all of these crossings occur at naturally flowing streams, which typically pose the greatest potential for flooding impacts. Two crossings were at locations identified by the Town as problem areas, but where no active stream channel could be identified. These locations may be indicative of ill-defined intermittent streams that were dry at the time of assessment, or they may be wetland areas that collect and hold water in a more dispersed fashion, with the respective culverts serving as hydrologic connections from one side of the road to the other.

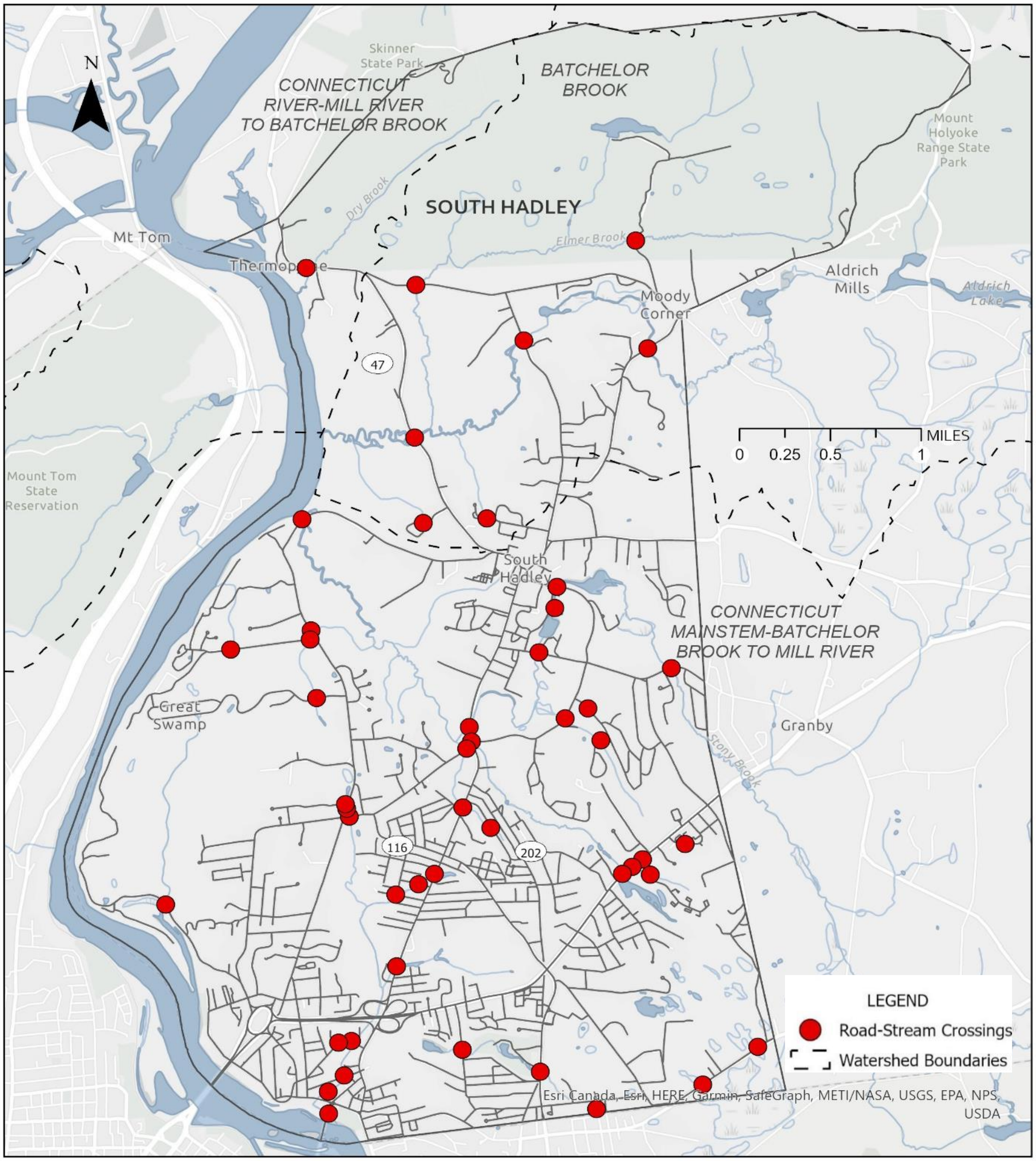


Figure 1. Road-stream crossings selected for assessment in the Town of South Hadley. Watershed boundaries are indicated by dotted lines.

2.2 Field Data Collection

Field surveys of the selected crossings were conducted between November 24th and December 10th, 2020 using road-stream crossing assessment procedures and field data collection forms documented in the RIDOT Road-Stream Crossing Assessment Handbook (available at http://www.dot.ri.gob/about/stormwater.php and developed by Fuss & O'Neill). This method is adapted from methods used by MassDOT in the Deerfield River watershed and stream crossing survey methods developed by the Massachusetts River & Stream Continuity Project/Partnership and by the North Atlantic Aquatic Connectivity Collaborative (NAACC). More specifically, methods for assessing aquatic connectivity and structural condition are consistent with and adapted from the North Atlantic Aquatic Connectivity Collaborative (NAACC). Methods for collection and assessment of other field data for evaluating geomorphic vulnerability, hydraulic capacity, and potential flooding impacts to infrastructure and public services were developed by Fuss & O'Neill and/or adapted from other standardized assessment protocols used in the northeastern U.S. The same methodology has now been used for road-stream crossings in municipalities throughout Massachusetts through several other MVP grant funded projects, which allows comparison of results across communities. Digital photographs were also taken at each crossing. A blank copy of the field data collection form is provided in **Appendix A**.

The crossing surveys were performed by a two-person field crew consisting of water resources and wetland scientists. Both members of the field assessment team were NAACC Certified Lead Observers, one was also a NAACC Level 1 Coordinator. Digital field data collection methods were used to complete the crossing surveys, using a GPS-enabled tablet with a pre-loaded digital version of the field form and aerial imagery for the project locations. Field data for the project are saved and managed using an ArcGIS database and web application (**Figure 2**). Following the stream crossing surveys, field data were checked for quality control purposes.

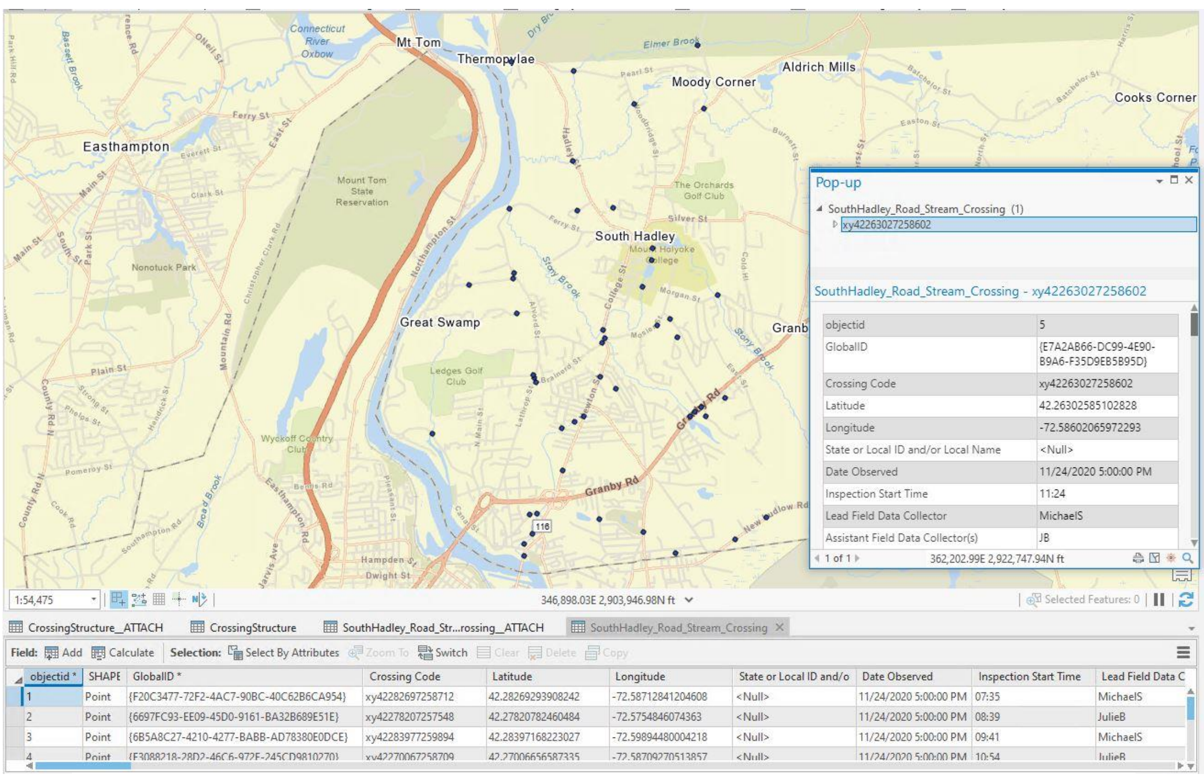


Figure 2. ArcGIS web application for South Hadley stream crossing survey data

2.3 Crossing Survey Findings Summary

Appendix B summarizes key field data and findings of the road-stream crossing surveys for the Town of South Hadley.

The following issues were observed at the surveyed stream crossings:

- **Poor Structural Condition:** Approximately one third of the crossings were observed to be in poor condition and in need of significant repairs or replacement. The most common critical structural deficiency was poor longitudinal alignment of the culvert, sometimes due to shifting of the culvert barrel or installation of another structure along the culvert alignment (this is common, e.g., when an existing culvert has been extended due to the widening of a road). Damage to the joints and seams, structural integrity, embankment piping and loss of armoring was also observed at many of these crossings. See **Figure 3** for examples of crossings in poor structural condition.
- **Flow Constriction**: All but eleven (11) of the assessed crossings are moderate or severe constrictions of the stream. Twenty-five (25, or 52%) of the 48 crossings were rated as severely constricted, indicating that the bankfull width of the stream channel was at least twice as wide as the total width of the structure opening(s). Flow constriction limits the hydraulic capacity of the crossings as well as contributing to erosion and sediment deposition that has occurred near the crossings.
- **Physical Barriers for Aquatic Passage**: Twenty-four (24, or 50%) of the crossings present moderate to severe barriers to aquatic organism passage. Several structures have cascading or freefalling outlets with drops of up to two to four feet. Most structures do not have substrates that match the streambed, creating a discontinuity for organisms trying to pass through the crossing.
- **Channel Erosion:** Varying degrees of stream channel erosion were observed in the reaches immediately upstream and/or downstream of 81% of the 48 assessed crossings.
- **Sediment Deposition:** Varying degrees of sediment deposition were observed in the reaches immediately upstream and/or downstream of 69% of the 48 assessed crossings. Substantial sediment deposition was observed at twelve (12) crossings in various locations and watersheds throughout the Town. At these locations, sediment deposits were noted to have depths at least half the height of the stream banks. Such 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 or affect the quality of in-stream habitat.
- **Buried Streams:** Buried sections of stream are a very common feature in South Hadley (7 of the 48 crossings assessed appeared to be part of or consisted of buried sections of stream) and in some cases the inlet or outlet could not be located. Historically, such buried streams were sometimes created through a single project that places underground a significant portion of a stream, generally to make way for other development. Streams can also be buried gradually section by section as development expands roads, parking lots, and the number and size of structures in areas where road-stream crossings already exist. Buried streams carry an extra risk associated with changes in size, shape, and/or material within the structure (with potential consequences to structural integrity or hydraulic capacity), may have other structures (e.g. catch basins) incorporated into the structure that limit hydraulic capacity and increase the risk of blockages, and are more difficult to maintain. Several of the crossings were observed to intersect

with drainage catch basins or similar structures. All 7 buried stream sections observed were in the southern, more developed portion of the town.

Figure 3. Examples of crossing structures in poor structural condition observed at various locations during field assessments.

3 Vulnerability Assessment and Prioritization

Using data from the stream crossing surveys and available GIS data, each of the assessed crossings was assessed for vulnerability to flooding and associated impacts relative to hydraulic capacity, structural condition, geomorphic conditions, aquatic organism passage, transportation services, land use, and climate change considerations The vulnerability and impact ratings were then combined to generate an overall rating, which was used to assign a priority to each crossing for potential upgrade or replacement. Methods and equations are provided in **Appendix C**.

3.1 Assessment Method

The following individual assessments were performed for each stream crossing:

- **Existing and Projected Future Streamflow:** Existing and future (climate change scenario) peak discharge was estimated for common recurrence intervals using regional regression equations developed by USGS for estimating peak flows at ungaged locations (i.e., StreamStats) or drainage area ratios for crossing locations where regional regression equations are unreliable. Flood flows under future climate change were estimated using a design flow multiplier of 1.2, representing a 20% increase in rainfall intensity and peak flows above current conditions to account for anticipated increases in design rainfall intensities and peak riverine discharge associated with future climate change projections. The recommended 20% increase in design rainfall intensity is consistent with climate change projections for extreme precipitation under a medium to high emissions scenario and a 50- to 100-year planning horizon, based on the typical design life (50 years) of most culvert and bridge infrastructure, and the useful life, which is typically 50-100 years for such infrastructure. It should be noted that design life is different from useful life, which is typically longer than the design life and more accurately represents the extended service life of infrastructure, assuming regular maintenance. The 20% increase is also generally consistent with the recommended percent increase values in extreme precipitation storm depth and intensity for common design storms, as outlined in the Resilient MA Action Team (RMAT) Climate Resilience Design Standards and Guidelines (April 2021).

- **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, which employs HDS-5 methods, was used for the analysis. Hydraulic capacity was determined for a selected headwater depth, which represents that depth at which the crossing is at risk of structural failure or the roadway is at risk of overtopping, depending on crossing type and material. Manning's Equation for uniform open channel flow was used to estimate the crossing hydraulic capacity for lager structures (bridges) or where the cross-sectional area could not be approximated with CulvertMaster. 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 for both existing and projected future peak streamflow.
- **Structural Condition:** Condition ratings and scores were assigned based on visual observation of the structural condition of the crossing inlet, outlet, and barrel 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.
- **Geomorphic Impacts:** Fluvial geomorphic impacts were considered by assessing the potential for crossing structures to impact geomorphic processes that might, in turn, threaten the structure itself and other adjacent 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 and the type and severity of impacts that have already occurred. Factors that were considered include stream alignment, bankfull width, degree of constriction, significant breaks in valley slope, bank erosion, sediment deposition, structure and channel slope, stream bed material, and other geomorphic parameters.
- **Aquatic Organism Passage (AOP):** Aquatic passability was assessed using the latest NAACC protocols and rating system for 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.
- **Ecological Integrity:** The habitat quality of the river reaches made accessible by removing an existing barrier to aquatic passage is also an important consideration in the crossing prioritization process. Ecological integrity scores were assigned to each crossing based on the concept of Index of Ecological Integrity (IEI). IEI scores were obtained from the Critical Linkages dataset for Massachusetts developed by the Landscape Ecology Lab at UMass Amherst as part of the Conservation Assessment and Prioritization System (CAPS) program.
- **Impacts to Transportation Services:** Potential disruption of transportation services resulting from single crossing failures was evaluated by considering the federal functional classification of the roadway (i.e., level of travel mobility and access to property that it provides). 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.

- **Other Potential Flooding Impacts:** The potential impacts to existing development, infrastructure, and land use upstream and downstream of each stream crossing were assessed in the event of failure of the crossing. A potential impact area was approximated for each crossing, having a width defined by buffering the stream centerline by a distance equal to two times the bankfull width, and a length defined as 0.5 miles upstream and downstream of the crossing. Flooding vulnerability was quantified based on the percentage of developed land cover, using 1.0 meter resolution data from the Massachusetts statewide 2016 Land Cover/Land Use dataset (https://docs.digital.mass.gov/dataset/massgis-data-2016-land-coverland-use) , and the presence of upstream or downstream crossings within the impact area, as well as any utility infrastructure (gas, sewer, water, etc.) observed to be attached to or located within the crossing structure.

3.2 Prioritization Method

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 as well as the ecological benefit of crossing removal.

Failure risk is defined as the product of the probability of failure of a crossing, as determined through assessment of the crossing's hydraulic, geomorphic, and structural condition (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. Risk scores were calculated for hydraulic risk, geomorphic risk, and structural risk according to equations provided in **Appendix C**. An overall priority score was calculated based on the combined hydraulic risk (existing and future climate change), geomorphic risk, structural risk, and aquatic organism passability of each crossing. See details of the prioritization method in **Appendix C**.

The overall failure risk for a crossing (represented by the *Crossing Risk Score*), which is dictated by the highest (i.e., worst-case) level of risk, was then calculated as the maximum of the hydraulic risk and future hydraulic risk scores, geomorphic risk score, and structural risk score.

The potential ecological benefit of removing an existing barrier to aquatic passage is also an important consideration in the crossing prioritization process. The additional 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. Aquatic passage benefit scores were assigned to each crossing based on the concept of Index of Ecological Integrity (IEI). The *Aquatic Passage Benefit Score* was calculated by combining the aquatic passability score with the ecological integrity score.

A *Crossing Priority Score* was calculated for each crossing by combining the *Crossing Risk Score* with the *Aquatic Passage Benefit Score*. The two scores are combined by summing the maximum of the two scores with the average of the two scores. This approach prioritizes those crossings that rate highly for both factors, while simultaneously ensuring that a very high score for either factor will be preserved. The *Crossing Priority Score* was then re-scaled 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, and not as an absolute measure of any physical or other aspect of the crossings.

3.3 Assessment and Prioritization Results

Table 1 summarizes the hydraulic risk (existing and future), geomorphic risk, structural risk, and aquatic organism passability scores, as well as the Scaled Crossing Priority Score (normalized on a scale of 0 to 1) for each of the highest priority crossings located in the Town of South Hadley. The detailed road-stream crossing assessment and prioritization worksheets and scores are provided in **Appendix B**.

Table 1. Top-ranked high priority crossings: road-stream crossing vulnerability assessment and prioritization results summary.

Road Name	Stream Name	HUC 12 Watershed Name	Impact Score	Hydraulic Risk Score	Future Hydraulic Risk Score	Geomorphic Risk Score	Structural Risk Score	AOP Benefit Score	Crossing Risk Score	Crossing Priority Score	Scaled Crossing Priority	Binned Prioritization Score
School Street	Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	5	20	25	20	15	12	25	43.5	0.87	High
Main Street	Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	12	12	16	12	20	16	38	0.76	High
Granby Road	Leaping Well Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	16	20	15	20	37.5	0.75	High
Newton Street	Newton Smith Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	16	20	15	20	37.5	0.75	High
Hillside Avenue	Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	4	8	16	20	15	20	37.5	0.75	High
Hadley Village Rd	Unnamed Tributary to Leaping Well Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	4	4	16	20	15	20	37.5	0.75	High
Rte 47/Hadley Street	Dry Brook	Connecticut River-Mill River to Batchelor Brook	4	20	20	16	12	15	20	37.5	0.75	High
Brainerd Street	Unnamed Tributary to Stony Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	20	20	12	20	36	0.72	High
Granby Road	Unnamed Tributary to Leaping Well Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	16	20	9	20	34.5	0.69	High
Newton Street	Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	12	20	9	20	34.5	0.69	High
Granby Road	Unnamed Tributary to Leaping Well Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	4	8	12	20	9	20	34.5	0.69	High
Pine Grove Drive	Unnamed Tributary to Leaping Well Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	12	8	9	20	34.5	0.69	High

Hydraulic Risk

Sixteen of the 48 crossings assessed (33%) are hydraulically undersized under existing precipitation conditions, having insufficient capacity to convey the 10-year peak flow (**Figure 4**). Additionally, two crossings (4%) are hydraulically undersized relative to the 25-year return interval peak flow (**Figure 4**). Twenty-one crossings, (44%) were found to be sized such that they could pass the 100-year return interval peak flow under existing conditions; these include larger bridges, as well as some smaller structures where peak flows are also low as a result of a smaller watershed area feeding into the crossing. Under future climate conditions, assuming an increase in peak flows of 20% for all return intervals evaluated, the number of crossings expected to be undersized for the 10-year peak flow rises to 18 (38%), with two crossings (4%) expected to be undersized for the 25-year return interval flow. Only 17 crossings (35%) are expected to be able to pass the future 100-year return interval peak flow.

These percentages are for all crossings taken together, but hydraulic capacity ratings differ by structure type. Bridges, due to their larger openings, are generally sized to accommodate larger flows. Round and elliptical culverts tend to have the most variation in size; the majority of the culverts in South Hadley are round, and approximately half were undersized for the 25-year flood.

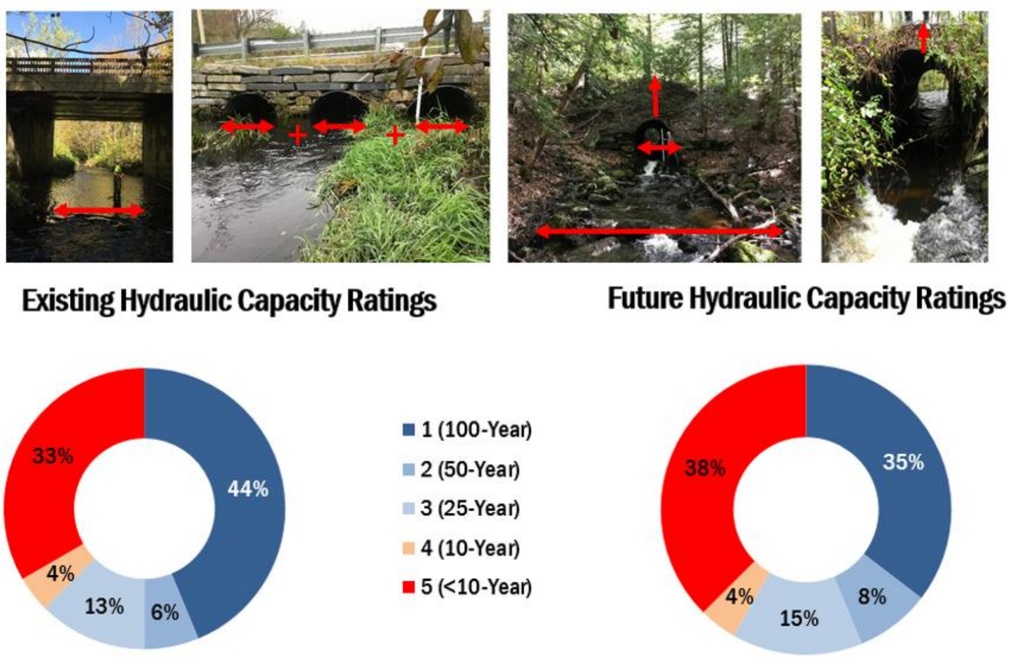


Figure 4. Top: Illustration of various factors that determine hydraulic capacity ratings. Left and far left: structure width or combined width of multiple structures; Center right: Structure width relative to expected peak stream flows; Center right and far right: height of road fill over structure determines when water will overtop road.
Bottom: Distribution of hydraulic capacity ratings across all assessed crossings, for both existing conditions and expected future precipitation conditions under a climate change scenario.

Hydraulic risk scores take into account the capacity of the culvert and the associated flooding impacts. Geographically, road-stream crossings with higher hydraulic risks are concentrated in the southern portion of the town due to the greater road density and urbanization of that area (**Figures 5 and 6**).

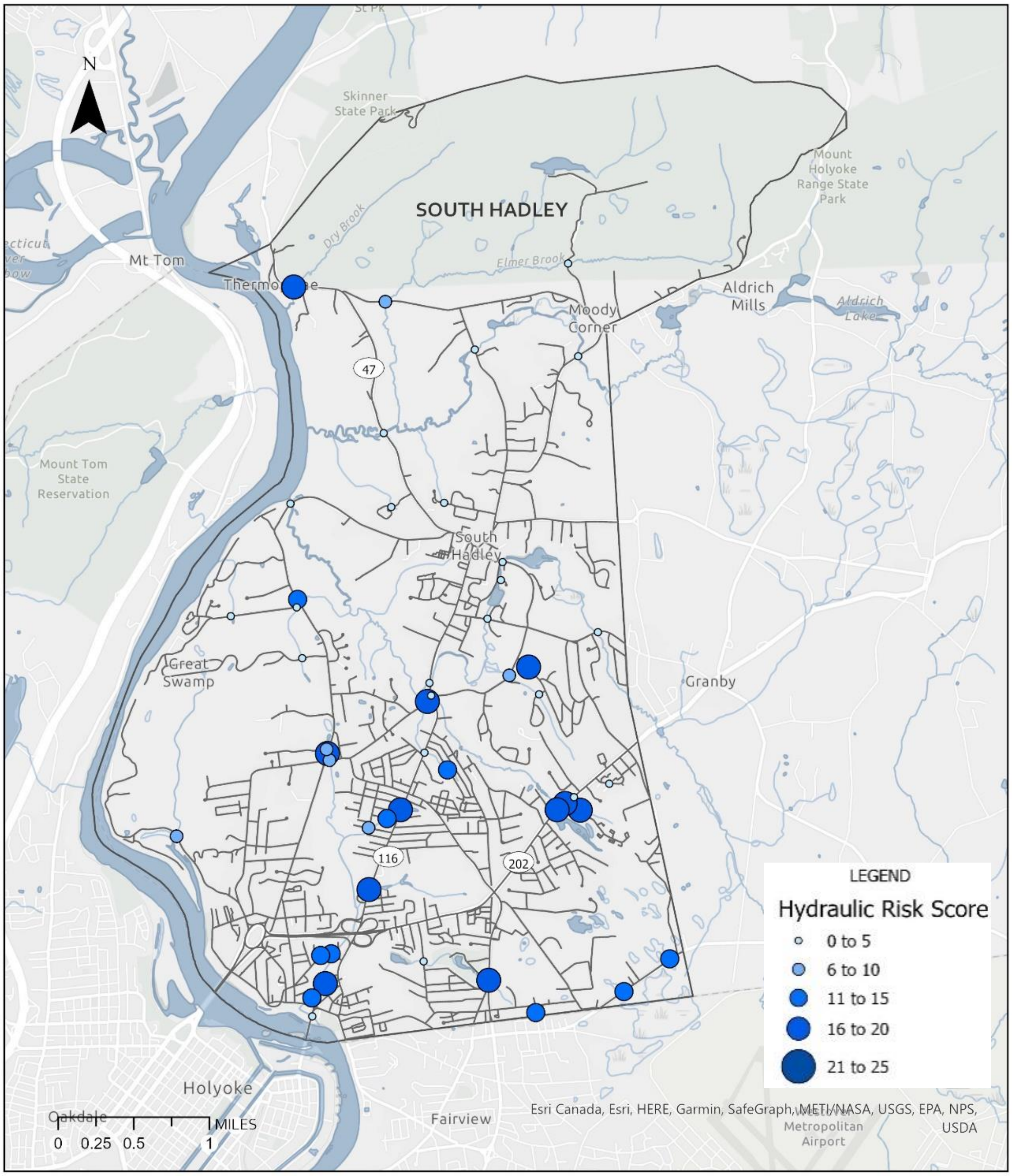


Figure 5. Spatial distribution of hydraulic risk scores for all assessed crossings under existing climate (precipitation and peak flow) conditions.

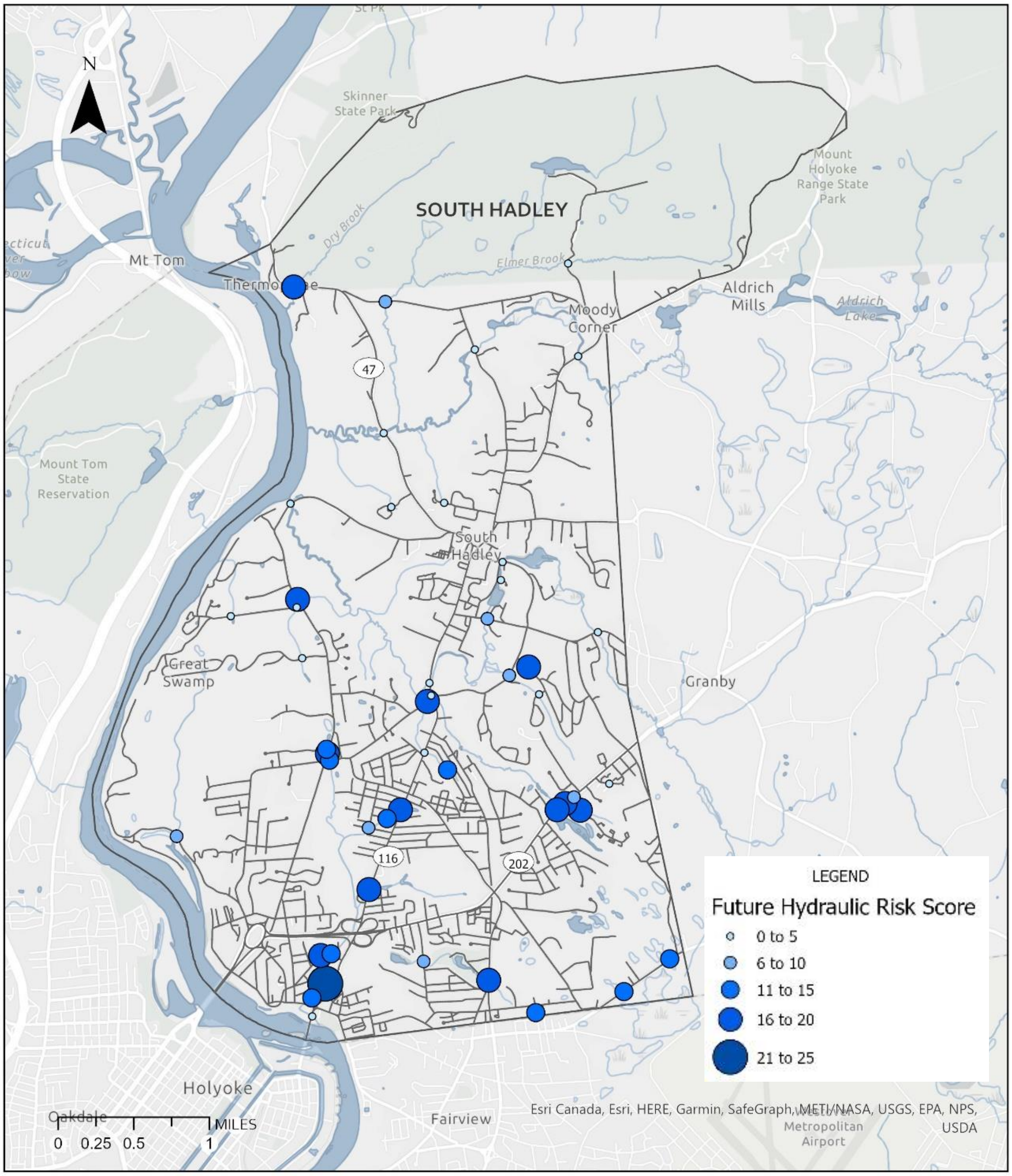
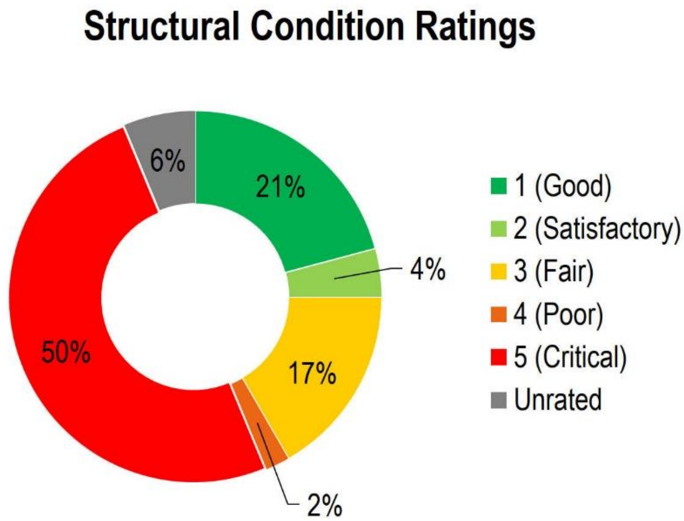
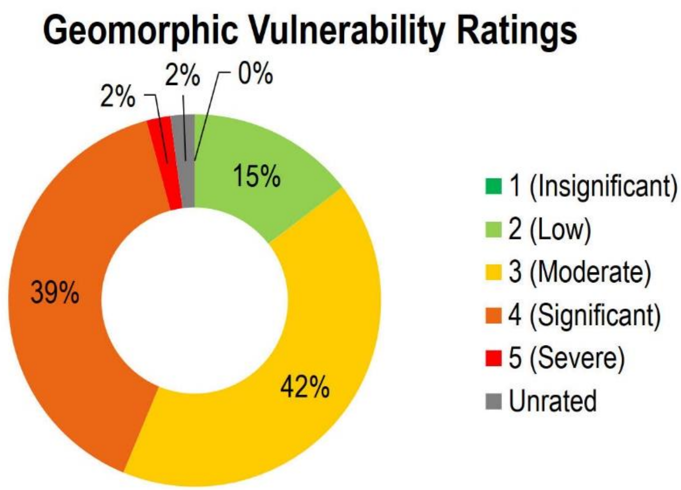


Figure 6. Spatial distribution of hydraulic risk scores for projected future climate (precipitation and peak flow) conditions.





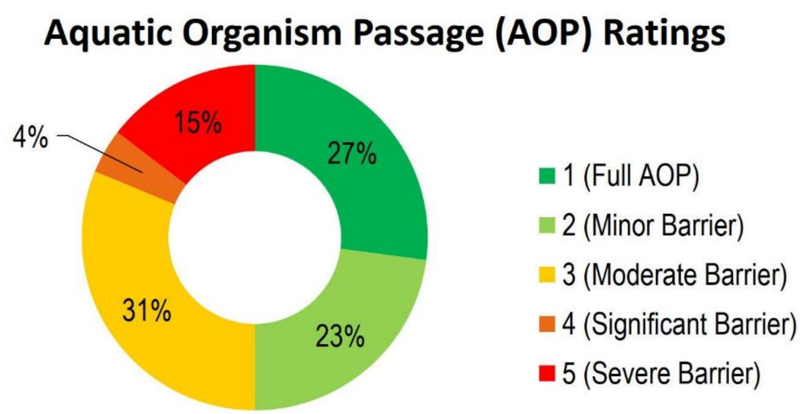


Figure 7. Top to Bottom: Distribution of structural condition, geomorphic vulnerability, and aquatic organism passage ratings across all assessed crossings.

Geomorphic Risk

Twenty crossings (42%) received significant or severe geomorphic vulnerability ratings (**Figure 7**), taking into account both observed geomorphic impacts and potential geomorphic impacts, and an additional 21 crossings (42%) received moderate geomorphic vulnerability ratings. The high number of crossings with moderate to severe geomorphic vulnerability ratings is largely due to the constrictions formed by these crossings, and the large number of crossings with sandy streambeds and/or high erosion. See **Figure 8** for images demonstrating factors contributing to higher geomorphic vulnerability ratings. The crossings with the highest geomorphic risk were located on School Street and Brainerd Street (**Figure 9**).

Figure 8. Geomorphic Vulnerability Ratings/Scores consider factors such as outlet drops which contribute to scour, the bankfull width of the stream, and alignment of the stream with the structure. The Main Street crossing over Buttery Brook (top) received a Geomorphic Vulnerability Score of 4 due to the free fall at the outlet as well as flow constriction and alignment factors. The Pearl Street crossing over Elmer Brook (middle) has a very wide tailwater scour pool at the outlet. The Willimansett Street crossing over Buttery Brook (bottom), where the stream bends immediately after leaving the outlet, demonstrates poor alignment of the crossing structure with the stream.

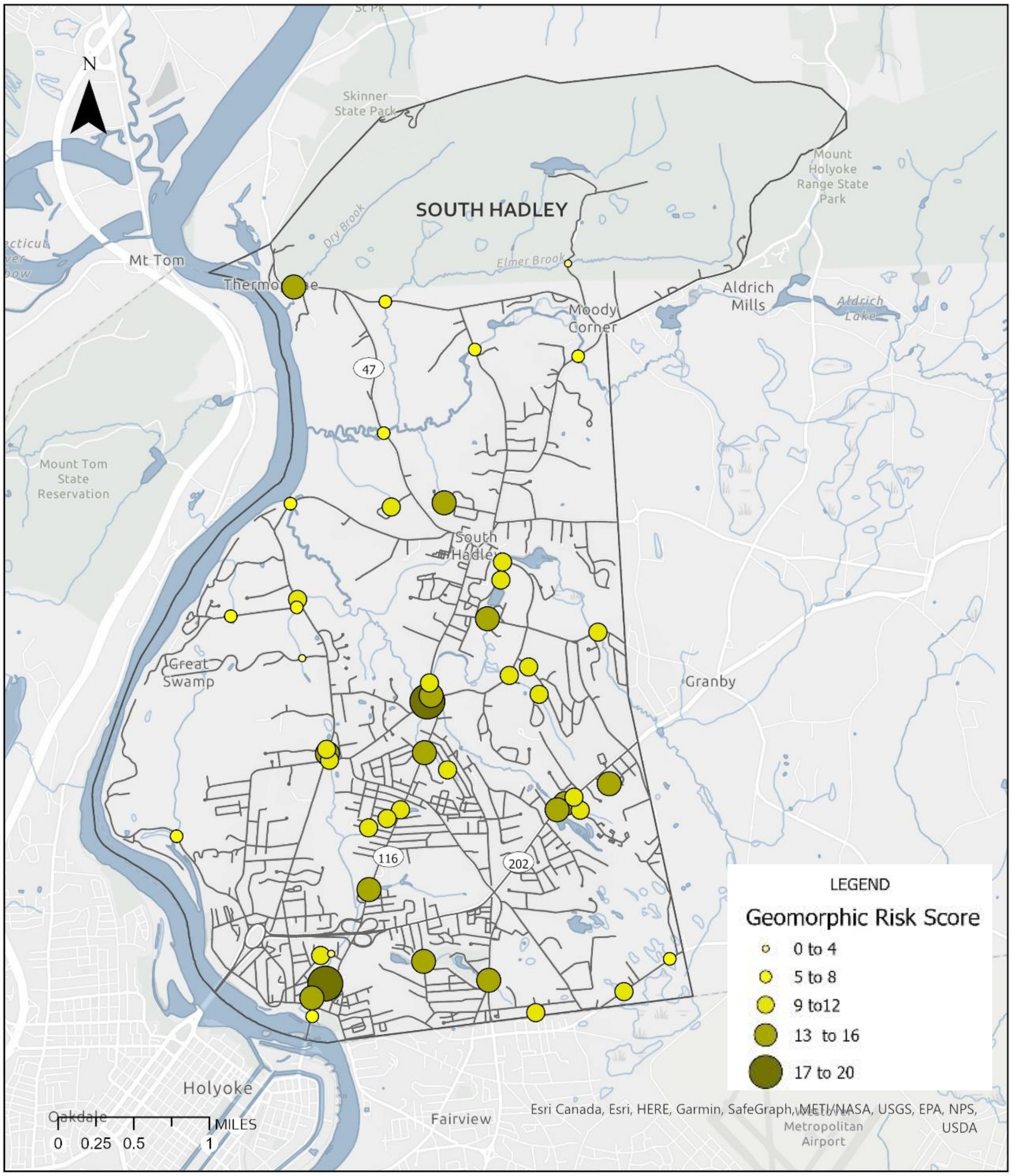


Figure 9. Spatial distribution of geomorphic risk scores for all assessed crossings.

Structural Risk

Twenty-four (50%) of the 48 assessed crossings were rated as critical relative to structural condition, and only twelve crossings (25%) were rated as either good or satisfactory (**Figure 7**). Multiple crossings with high structural risk are located on US 202/Granby Road and Route 116/Newton Street (**Figure 10**). Common structural deficiencies included embankment piping (and associated subsidence), damage to culvert joints and seams, loss of structural integrity, and disruption of the structure's longitudinal alignment. Note that these deficiencies can be related, as loss of structural integrity or damage to joints and seams can lead to or worsen embankment piping by providing new flow paths for water and soil. Note that at three crossings which are part of buried stream sections, structural condition could not be assessed due to lack of access.

Aquatic Organism Passage

Twenty-four of the assessed crossings (50%) are considered at least moderate barriers to aquatic organism passage (**Figure 7**), but only seven of these were rated as severe barriers. 18% are considered to provide full aquatic passage. Among the ten crossings with the highest potential AOP benefit scores—that is, crossings which are barriers to aquatic organism passage but which are also at locations where improved passage would have the greatest benefit—eight were also scored as high priority overall. Although most of the 48 assessed crossings are located within the southern portion of the Town, the results for AOP benefit scores were more broadly distributed across the Town than the other risk and benefit factors **(Figure 11)**, which makes sense since AOP benefit is partially linked to having intact/higher value habitat nearby.

Potential Impacts

Because impacts to transportation services were calculated as a function of road classification, the crossings with the highest potential for transportation disruption were found to occur on state roadways, rather than Town-owned roads. Some of the sites with high potential for flooding impacts were also located on state roads (Route 116 and US 202). However, high impact scores related to potential flooding were also seen on municipal roads throughout Town. The highest ranked crossings for potential flooding impacts were the Morgan Street crossing of Stony Brook and the Gaylord Street and School Street crossings of Buttery Brook (**Figure 12**). The Morgan Street crossing is located at the south end of the Mount Holyoke College campus; the Gaylord Street and School Street crossings are located in the densely developed South Hadley Falls area.

Prioritization

The School Street and Main Street crossings of Buttery Brook were the highest priority crossings overall, with the highest potential for impacts due to flooding or service disruptions and high risks associated with both current and future hydraulic capacity or a high benefit to providing AOP. It should be noted that both of these crossings consist of longer, buried sections of stream, making them significantly more difficult to improve with replacement structures (both physically and in terms of community acceptance, since there would need to be significant changes to the surface landscape around the culverts). Several additional crossings along Buttery Brook (at crossings with Hillside Avenue and Route 116/Newton Street) and along Stony Brook or its tributaries (at crossings with Brainerd Street, US 202/Granby Road, Hadley Village Road, and Pine Grove Drive) are also included among the top priorities (**Table 1, Figure 13**).

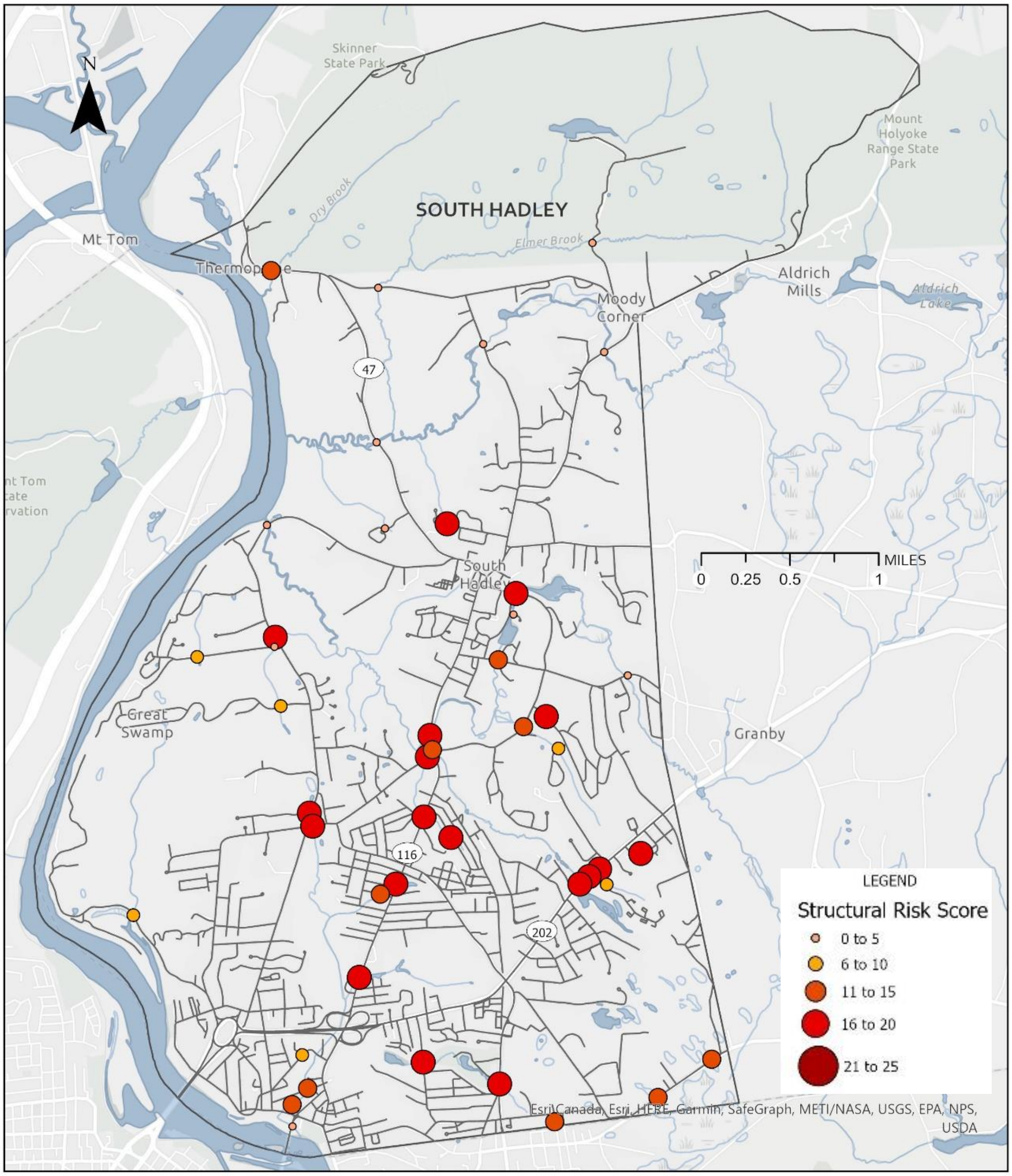


Figure 10. Spatial distribution of structural risk scores for all assessed crossings.

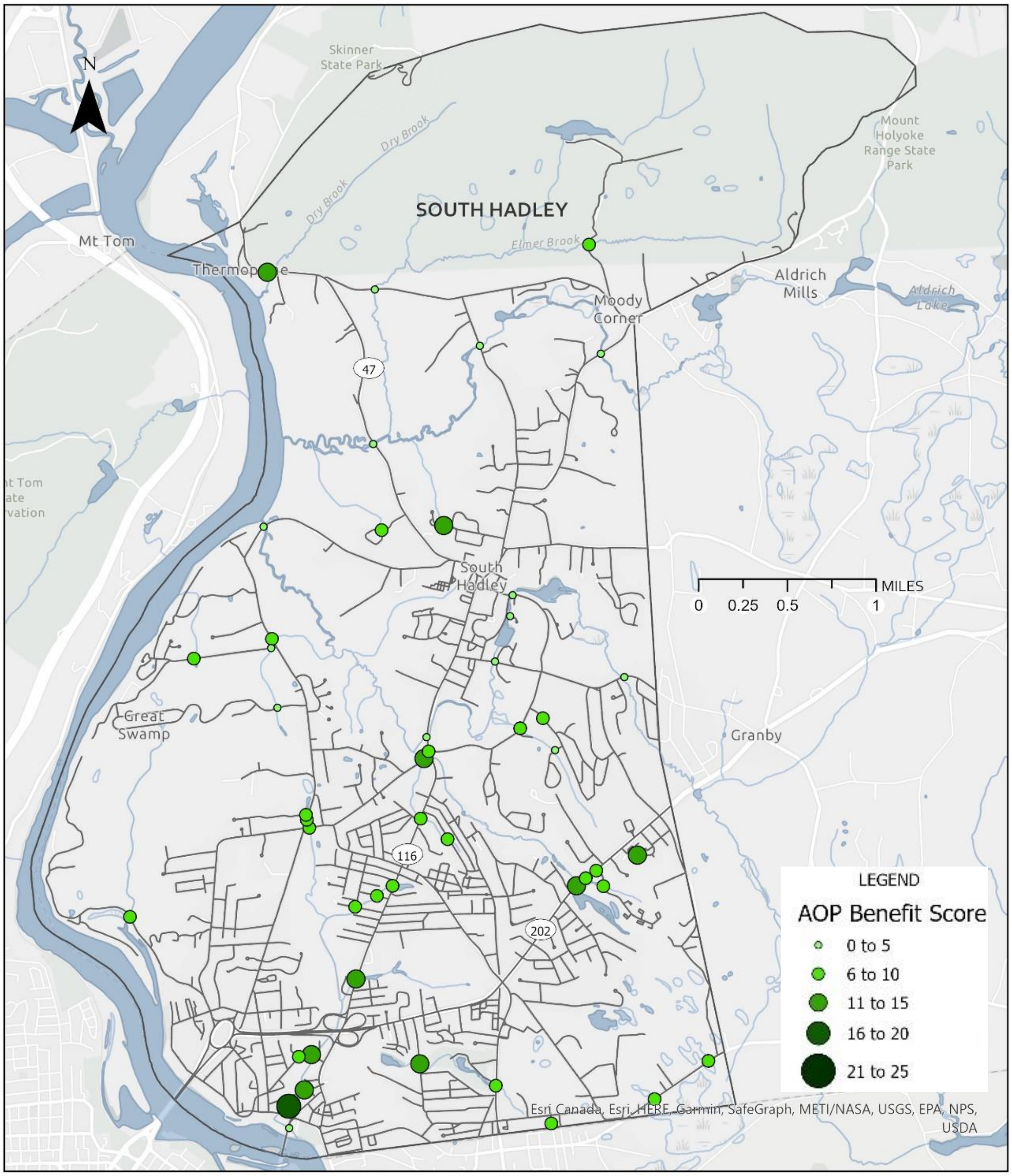


Figure 11. Spatial distribution of aquatic organism passage benefit scores for all assessed crossings.

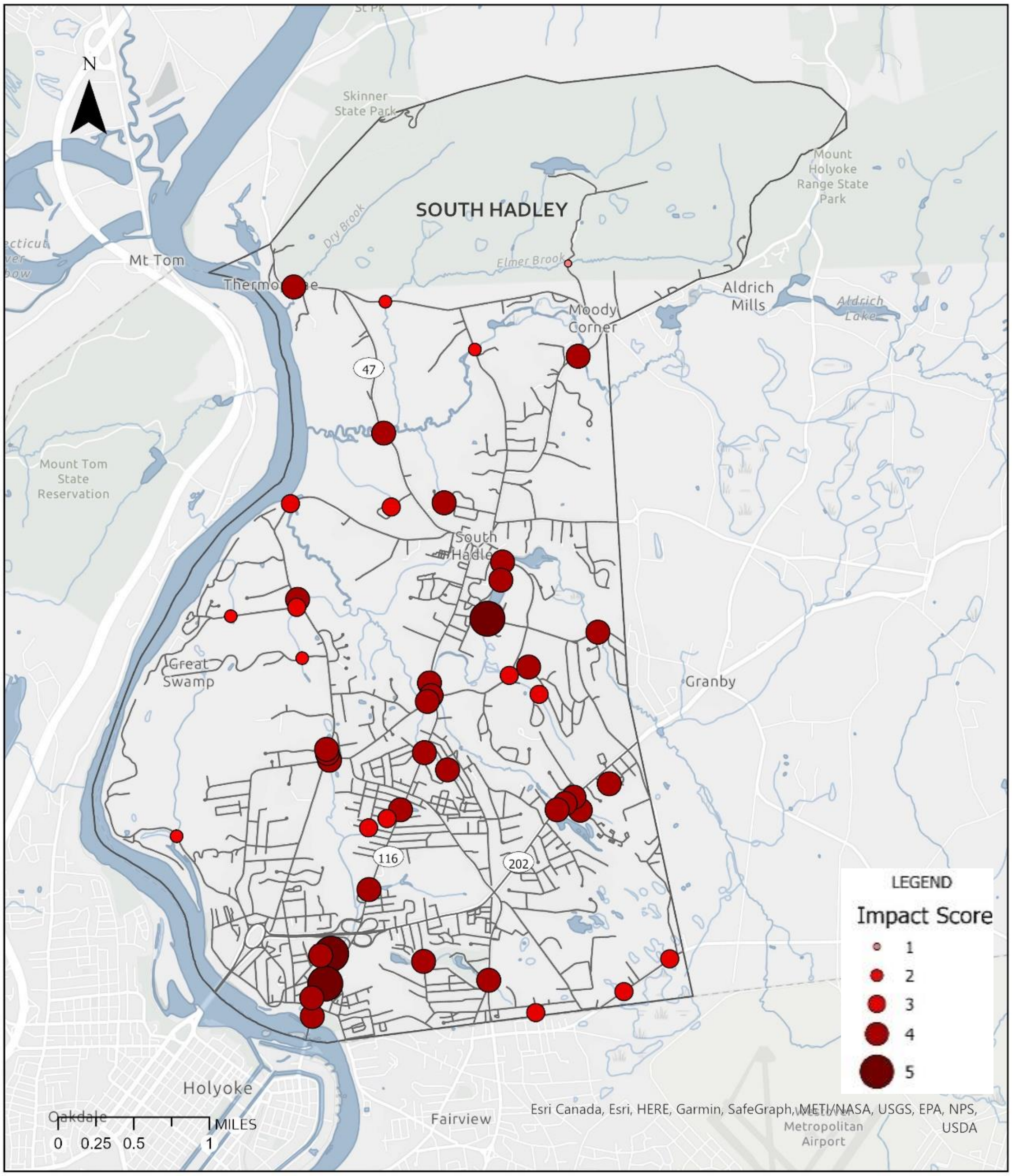


Figure 12. Spatial distribution of impact scores for all assessed crossings.

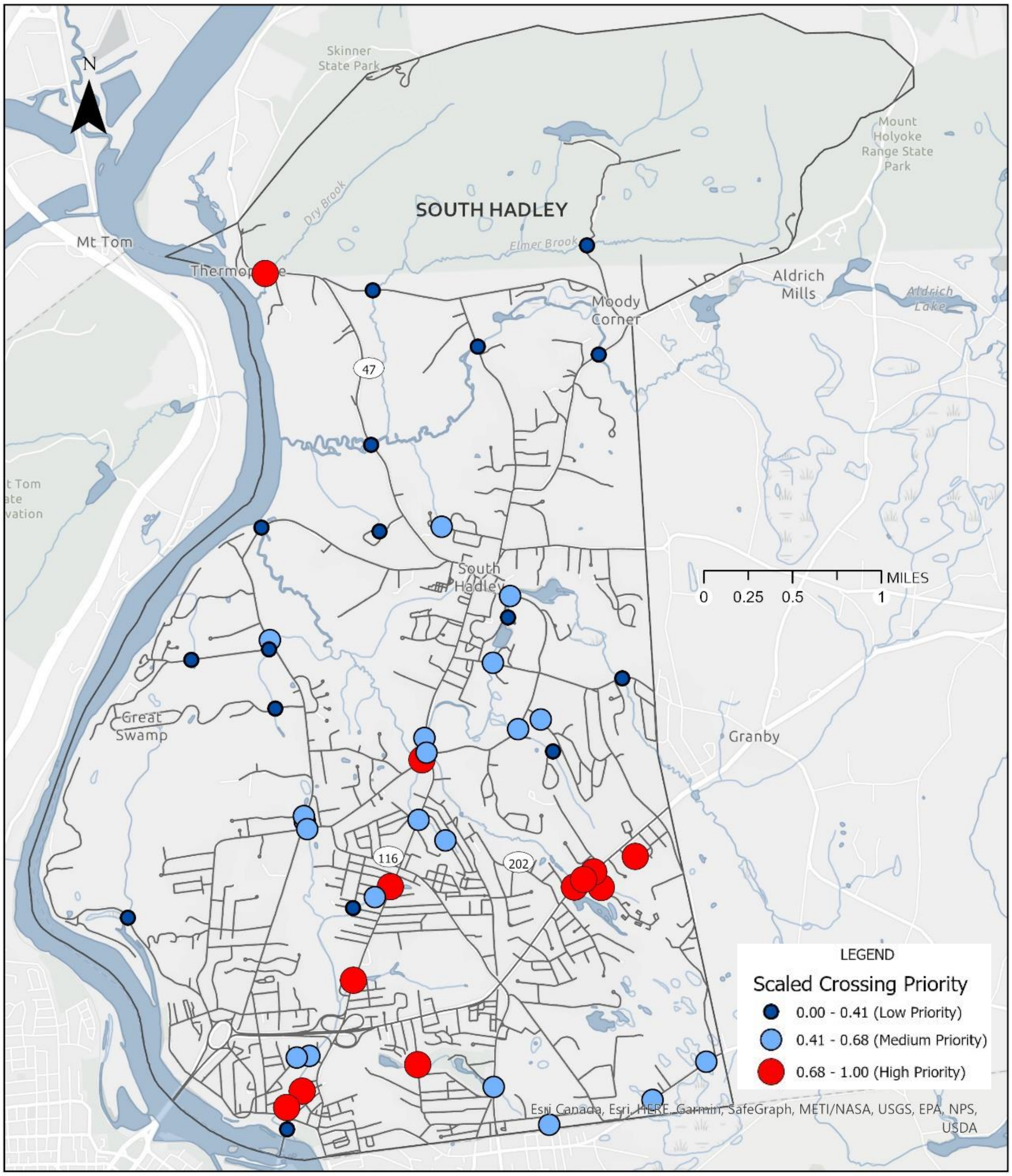


Figure 13. Spatial distribution of scaled crossing priority scores for all assessed crossings, Town-wide. Red dots indicate high priority crossings; light blue dots indicate medium priority crossings, and dark blue dots indicate low priority crossings.

4 Concept Designs

Specific recommendations for crossing upgrades or replacements (i.e., replacing the existing crossings with larger structures) were developed for ten stream crossings on Town roads that were evaluated as part of this assessment **(Figure 14)**. These crossings were selected on the basis of high or medium priority rankings. Privately-owned crossings were not considered for concepts at this stage, nor were crossings associated with larger, buried sections of stream due to the additional challenges and need for longer-term planning that would be associated with such replacement projects. Two additional crossings that received lower overall rankings but still exhibited significant vulnerabilities were included in the list of concepts based on input from the Town, as these crossings are in areas of known flooding.

These planning-level recommendations and design concepts are intended to enhance the resilience of the stream crossings and river system by replacing the existing crossings with ones that will withstand extreme flood events, provide for the passage of debris during floods, and provide for passage of aquatic organisms under normal flow conditions. At several of the crossings, we also recommend channel or floodplain restoration in upstream or downstream areas along with the proposed crossing upgrades to enhance flood resilience, water quality, and aquatic habitat using a combination of natural and infrastructure-based approaches.

Conceptual-level opinions of probable costs are provided for each of the concepts in **Appendix D**. These costs include estimates of the anticipated design, permitting, and construction costs, which are based on costs of recent similar stream crossing replacement projects in the northeastern U.S.

The following concept designs sheets provide a summary of the existing issues, recommendations, and projected cost ranges for each of the ten priority stream crossings (note that one concept includes three crossings that are presented for simultaneous replacement, due to their close proximity to one another). Each two-page concept includes a description and photographs of existing conditions, key data and findings from the field assessment, a description of the proposed design concept, and a plan view drawing of the site conditions and proposed replacement crossing.

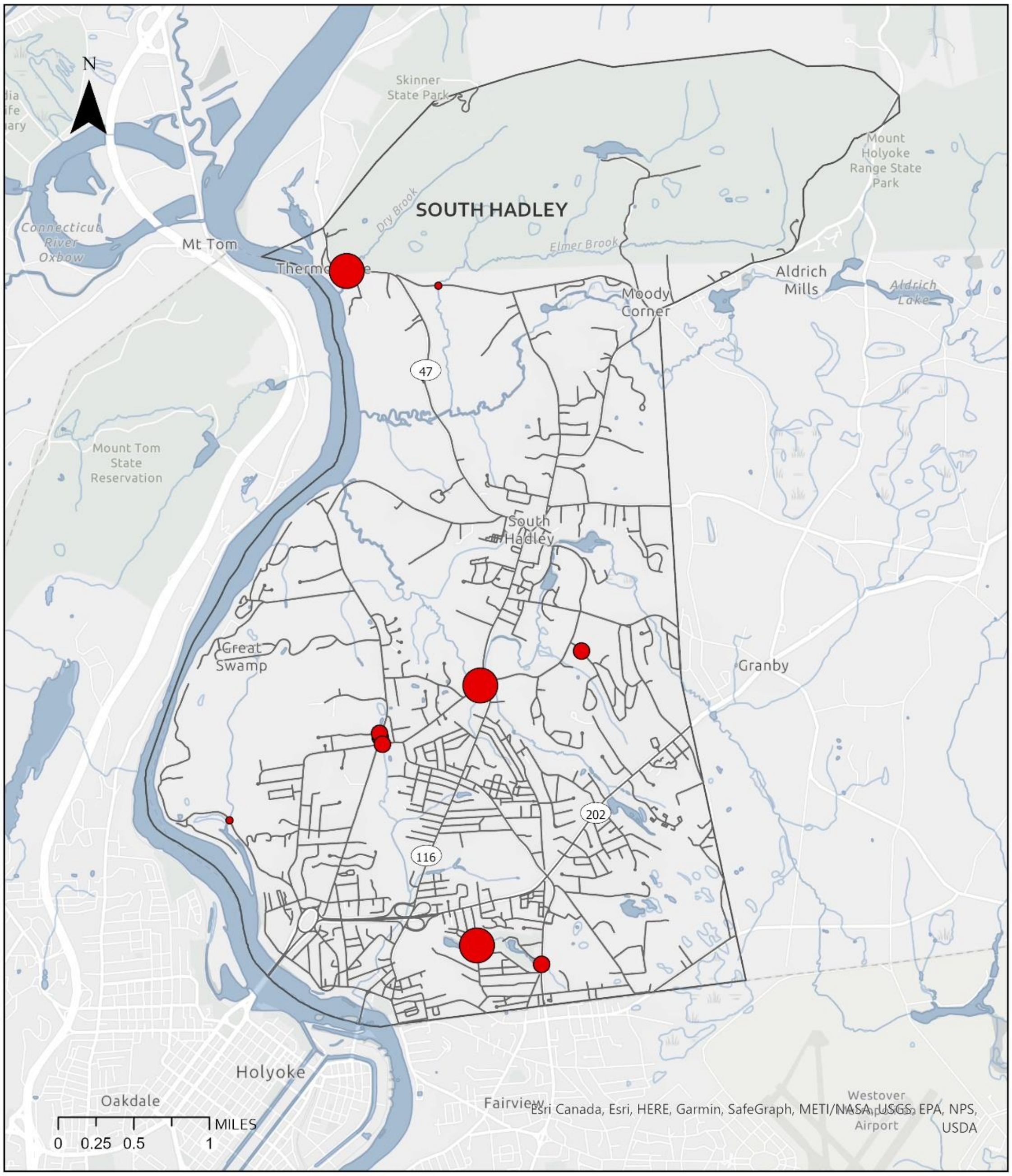


Figure 14. Locations of crossings for which concept designs were developed. Larger dots indicate higher priority scores. Two crossings with lower priority scores were included based on known history of flooding.

Rt. 47/Hadley Street and Titan Pier Road at Dry Brook
Culvert Replacement Concept
South Hadley, MA

Site Description

Rt. 47/Hadley Street and Titan Pier Road cross Dry Brook approximately 300 feet west of the intersection of Rt. 47/Hadley Street and Sullivan Lane. The existing structure is a round pipe constructed of concrete at the inlet and corrugated metal at the outlet, and there appears to be a larger chamber in the structure between the inlet and outlet pipes. The culvert appears to change direction under South Hadley Road or Titan Pier Road. The culvert diameter is 4 feet at the inlet, resulting in a severe constriction of the stream's approximately 16-foot bankfull width. The crossing is undersized for all peak flows assessed under existing and future climate conditions. Noted structural deficiencies include embankment piping and damage to the culvert joints, headwalls and wingwalls, and armor.

Proposed Concept

- Replace the existing metal pipe culvert with an open-bottom arch with a span of approximately 22 feet to accommodate a future estimated bankfull width of approximately 17.4 feet associated with an estimated 20% increase in bankfull flows due to climate change,
  - ➢ This will result in a crossing that meets the Massachusetts River and Stream Crossing Standards, which require a span of 1.2 times the stream's bankfull width.
- The proposed culvert replacement design concept will:
  - ➢ Provide increased hydraulic capacity to reduce flooding risk and to allow water and debris associated with larger storms to pass.
  - ➢ Decrease potential for road overtopping during heavy precipitation.
  - ➢ Reduce geomorphic risk by realigning the culvert and eliminating changes in structure material and dimensions.
  - ➢ Improve the passability of the structure

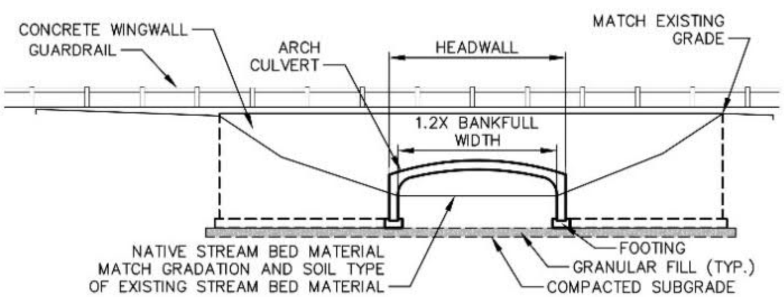


Image 3: Typical detail of an open arch culvert designed to meet MA Stream Crossing Standards

Image 1: Existing structure inlet during field visit on November 24, 2020.

Image 2: Existing structure outlet during field visit on November 24, 2020. Note the large scour pool, eroded banks, and perched outlet. Also note the change from concrete at the inlet to corrugated metal at the outlet.

Image 4: Interior of the existing culvert during November 24, 2020 field visit. Note the change in culvert alignment at the chamber in the background.

Site Prioritization Summary

Scaled Crossing Priority Score (0-1): 0.75
Impact Score (1-5): 4
Hydraulic Risk Score (1-25) (Existing/Future): 20/20
Geomorphic Risk Score (1-25): 16
Structural Risk Score (1-25): 12
AOP Benefit Score (1-25): 15

Existing Crossing Characteristics

Material: Corrugated metal pipe, concrete
Structure Width: 4 feet (inlet), 5 feet (outlet)
Structure Height: 4 feet (inlet), 5 feet (outlet)
Structure Length: Approximately 107 feet
Bankfull Width: Approximately 16 feet

Hydraulic Capacity Summary

Total Drainage Area: 0.71 miles^2
Existing Structure Capacity: 87.5 cfs
Estimated Peak Flows:

Recurrence Interval	Existing	Future
10-year	88.4 cfs	106 cfs
25-year	121 cfs	145 cfs
50-year	149 cfs	179 cfs
100-year	178 cfs	214 cfs

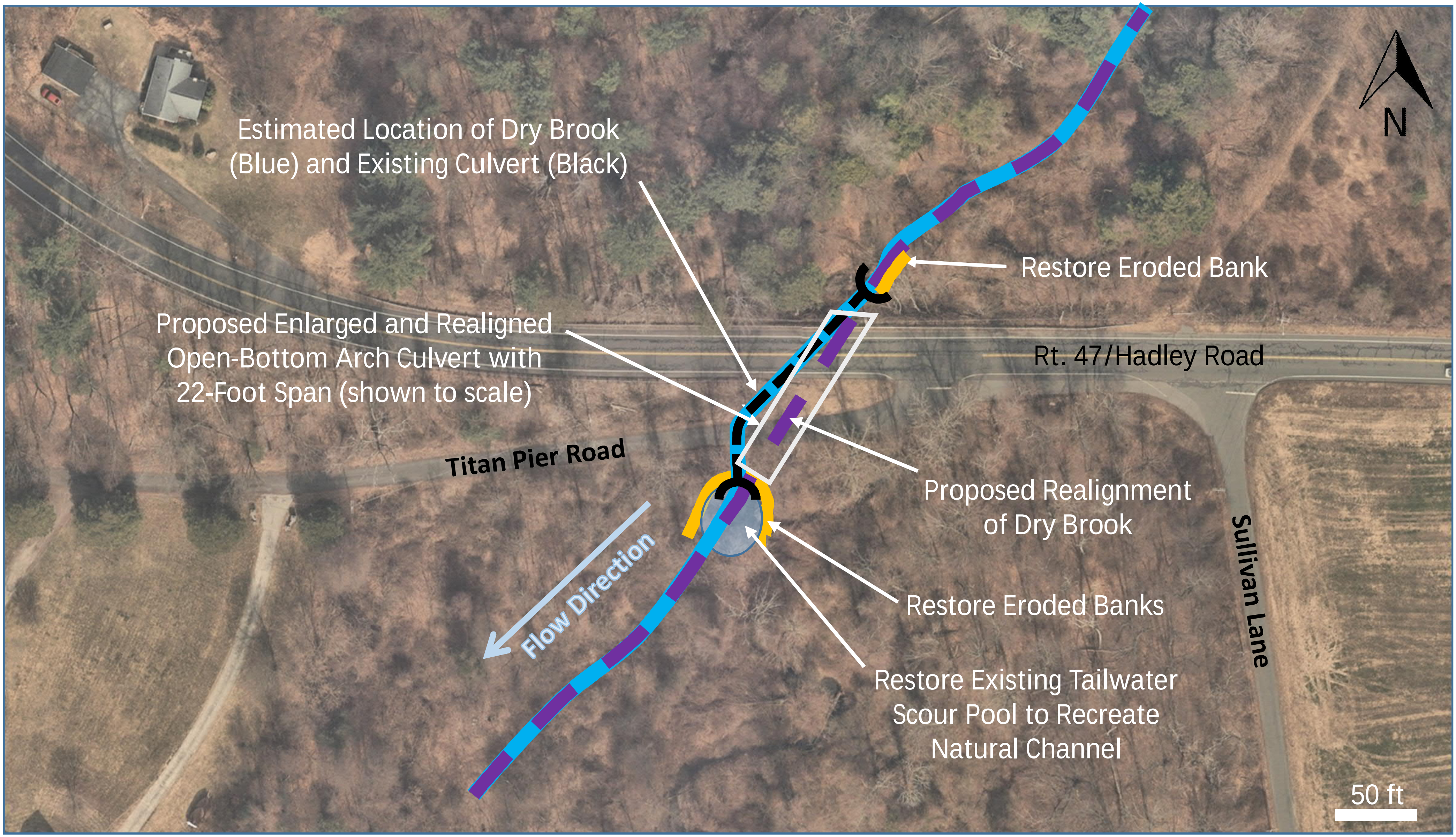
Notable Assessment Findings

- High potential for transportation disruption and flood impact potential
- Severe constriction
- Structure changes material, size, and direction between inlet and outlet

Preliminary Opinion of Cost[1]

Total project cost: $1,600,000

[1]Actual project cost may range from -30% to +50% of the quoted cost.



Rt. 47/Hadley Road and Titan Pier Road

Culvert Replacement Concepts, South Hadley, MA

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Hillside Avenue at Buttery Brook
Culvert Replacement Concept
South Hadley, MA

Site Description

Hillside Avenue crosses Buttery Brook approximately 0.25 miles south of the intersection of Rt. 202/Granby Road and Hillside Avenue. The existing structure is a 3-foot round pipe constructed of concrete set in concrete headwalls at the inlet and outlet. A Contech manhole was observed near the crossing on the road surface and a created basin that appears to be associated with stormwater management is located in the woods adjacent to the inlet. The crossing has adequate capacity to pass most or all peak flows under existing and future climate conditions, however, the site is subject to elevated structural and geomorphic risk. Severe constriction of the stream's approximately 11-foot bankfull width has caused extensive scour at the outlet that has undermined the structure and an asphalt scour protection pad that was previously poured at the outlet. This asphalt now remains as a floating shelf over the scour hole. Sinkholes are also forming behind the headwall at the outlet.

Proposed Concept

- Realign the crossing and replace the existing culvert with an open-bottom arch or three-sided box culvert with a span of approximately 16 feet to accommodate a future estimated bankfull width of approximately 12.2 feet associated with an estimated 20% increase in bankfull flows due to climate change.
  - ➢ This will result in a crossing that meets the Massachusetts River and Stream Crossing Standards, which require a span of 1.2 times the stream's bankfull width.
- The proposed culvert replacement design concept will:
  - ➢ Relieve constriction and reduce potential for scour and erosion
  - ➢ Reduce geomorphic risk by realigning the culvert
  - ➢ Improve the passability of the structure

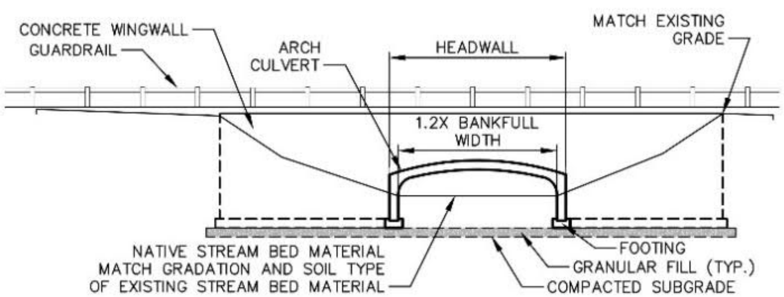


Image 3: Typical detail of an open arch culvert designed to meet MA Stream Crossing Standards


Image 1: Existing structure inlet during field visit on November 25, 2020. Note the inlet drop and misalignment of the stream with the inlet.


Image 2: Existing structure outlet during field visit on November 25, 2020. Note the large scour pool, severely eroded banks and undermined endwall, and perched outlet. Also note the two perched stormwater pipes (to the right of the outlet in this photo).


Image 4: View downstream of the culvert outlet during the November 25, 2020 field visit. Note the severe bank erosion.

Site Prioritization Summary

Scaled Crossing Priority Score (0-1): 0.75
Impact Score (1-5): 4
Hydraulic Risk Score (1-25) (Existing/Future): 4/8
Geomorphic Risk Score (1-25): 16
Structural Risk Score (1-25): 20
AOP Benefit Score (1-25): 15

Existing Crossing Characteristics

Material: Concrete
Structure Diameter: 3 feet
Structure Length: 166 feet
Bankfull Width: Approximately 11.3 feet

Hydraulic Capacity Summary

Total Drainage Area: 0.74 $miles^2$
Existing Structure Capacity: 170 cfs
Estimated Peak Flows:

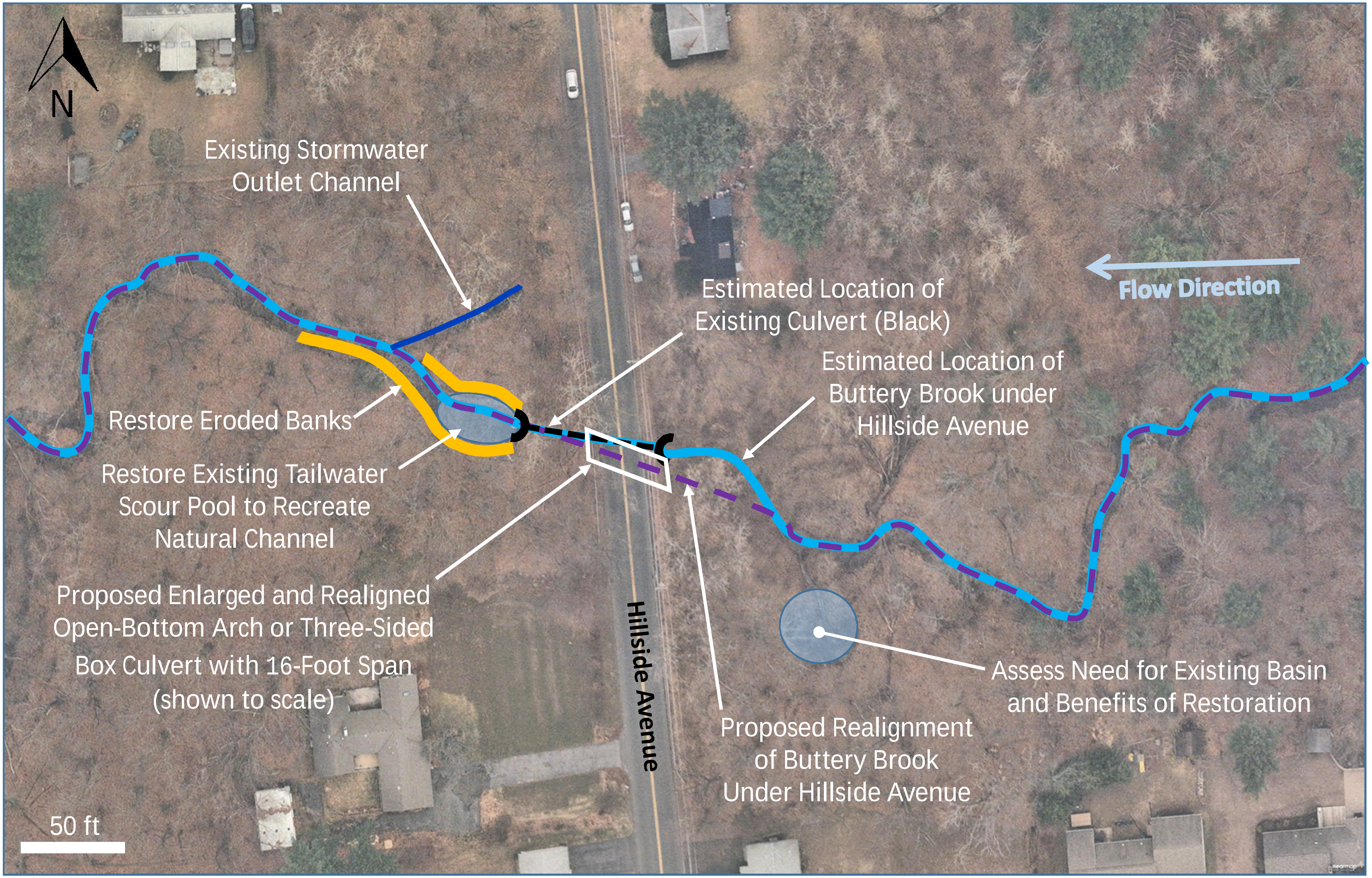
Recurrence Interval	Existing	Future
10-year	78.0 cfs	93.6 cfs
25-year	106 cfs	127 cfs
50-year	129 cfs	155 cfs
100-year	154 cfs	185 cfs

Notable Assessment Findings

- Severe scour at the outlet has undermined the endwall and caused the formation of sinkholes and a large scour pool
- High flood impact potential
- Critical structural deficiencies include culvert blockage, embankment piping, and poor structural integrity and alignment

Preliminary Opinion of Cost[1]
Total project cost: $900,000

[1]Actual project cost may range from -30% to +50% of the quoted cost.



Hillside Avenue

Culvert Replacement Concepts, South Hadley, MA

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Brainerd Street at Unnamed Tributary to Stony Brook
Culvert Replacement Concept
South Hadley, MA

Site Description

Brainerd Street crosses an unnamed tributary to Stony Brook approximately 275 feet west of the intersection of Newton Street, College Street, and Brainerd Street and immediately to the east of a utility corridor. The existing structure is a round corrugated metal pipe that is partially buried in sediment at the inlet and perched at the outlet. This is partially due to the severe constriction formed by the 3-foot diameter of the culvert. The pipe also appears be poorly aligned and has a partial internal blockage near the outlet. The crossing is undersized for all peak flows assessed under existing and future climate conditions. Critical structural deficiencies include embankment piping, poor structure alignment, the blockage, deterioration of the invert, poor structural integrity of the barrel, and damaged or missing stone armor. The severe constriction and the placement of the culvert inlet at a sharp bend in the stream contribute to the high geomorphic risk associated with the crossing.

Proposed Concept

- Realign the crossing and replace the existing culvert with a three-sided box culvert with a span of approximately 12 feet to accommodate a future estimated bankfull width of approximately 9 feet associated with a 20% increase in bankfull flows due to climate change
  - ➢ This will result in a crossing that meets the Massachusetts River and Stream Crossing Standards, which require a span of 1.2 times the stream's bankfull width.
- The proposed culvert replacement design concept will:
  - ➢ Provide increased hydraulic capacity to reduce flooding risk and to allow water and debris associated with larger storms to pass.
  - ➢ Decrease potential for road overtopping during heavy precipitation.
  - ➢ Reduce geomorphic risk by realigning the culvert
  - ➢ Improve the passability of the structure

Image 3: Example of embedded box culvert (Maine Audubon).

Image 1: Existing structure inlet during field visit on December 4, 2020, showing a blockage causing a drop into the inlet and erosion on the bank above the pipe.

Image 2: Existing structure outlet during field visit on December 4, 2020. Note the large scour pool, eroded banks, and perched outlet.

Image 4: Interior of the existing culvert during December 4, 2020 field visit. The culvert is poorly aligned and rusted through, and a blockage has formed inside the barrel.

Site Prioritization Summary

Scaled Crossing Priority Score (0-1): 0.72

Impact Score (1-5): 4

Hydraulic Risk Score (1-25) (Existing/Future): 20/20

Geomorphic Risk Score (1-25): 20

Structural Risk Score (1-25): 20

AOP Benefit Score (1-25): 12

Existing Crossing Characteristics

Material: Corrugated metal pipe

Structure Diameter: 3 feet

Structure Length: Approximately 100 feet

Bankfull Width: Approximately 8.3 feet

Hydraulic Capacity Summary

Total Drainage Area: 0.32 $miles^2$

Existing Structure Capacity: 32.8 cfs

Estimated Peak Flows:

Recurrence Interval	Existing	Future
10-year	41.5 cfs	49.8 cfs
25-year	56.6 cfs	67.9 cfs
50-year	69.3 cfs	83.2 cfs
100-year	82.9 cfs	99.5 cfs

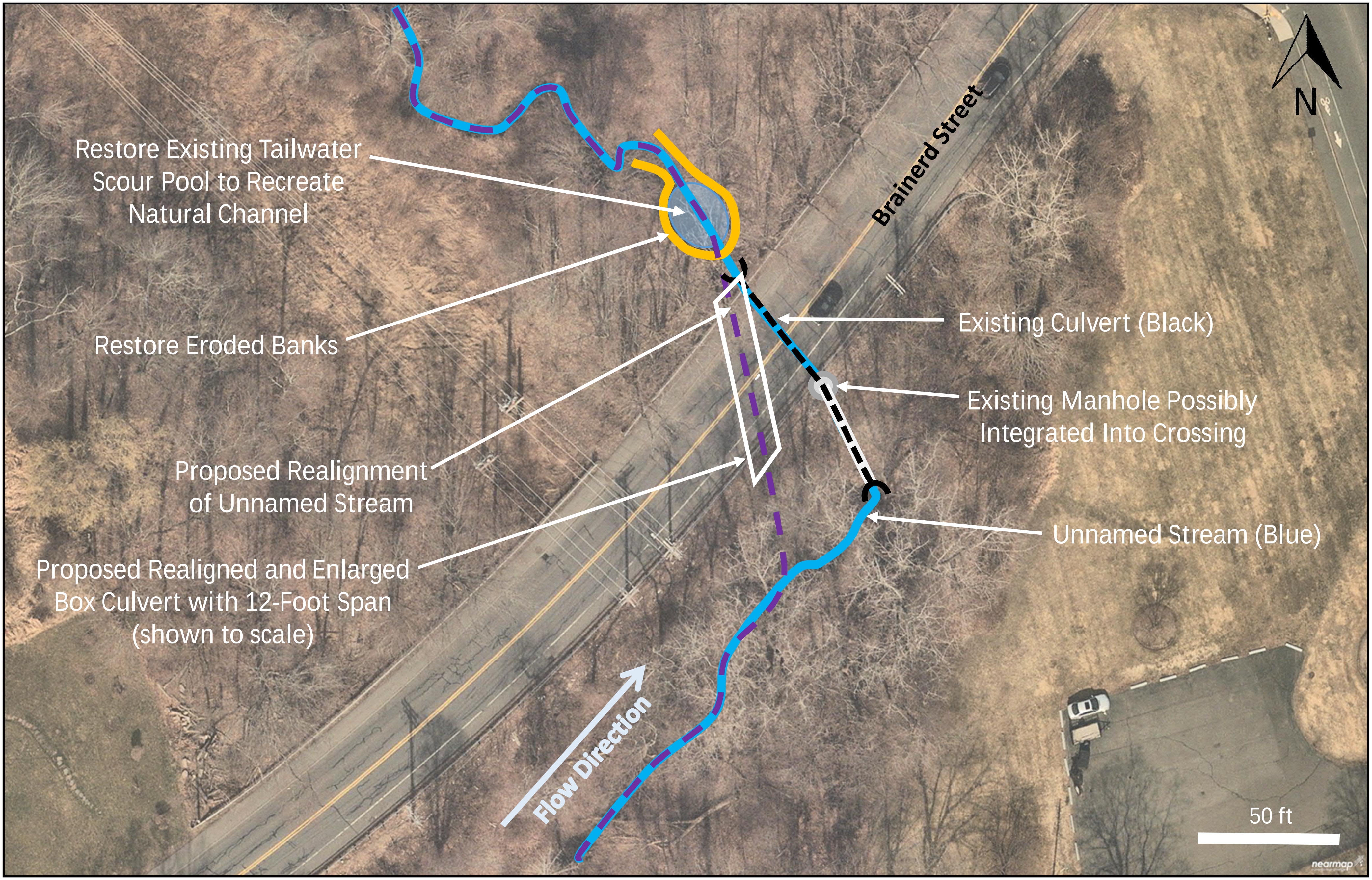
Notable Assessment Findings

- High flood impact potential
- Severe constriction
- Critical structural deficiencies include culvert blockage, embankment piping, and poor structural integrity and alignment

Preliminary Opinion of Cost[1]

Total project cost: $890,000

[1]Actual project cost may range from -30% to +50% of the quoted cost.



Brainerd Street

Culvert Replacement Concepts, South Hadley, MA

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Cedar Ridge, Lathrop Street, and Brainerd Street at Unnamed Tributary to Buttery Brook Culvert Replacement Concept

South Hadley, MA

Site Description

Cedar Ridge, Lathrop Street, and Brainerd Street cross an unnamed tributary to Buttery Brook approximately 0.8 miles west of the intersection of Brainerd Street and Rt. 116. The existing structures are all round concrete or corrugated metal pipes that are partially buried in sediment at the inlet. This is partially due to the severe constriction of the stream caused by each culvert. The Lathrop Street crossing is undersized for all peak flows assessed under existing and future climate conditions and the stream enters the inlet at a right angle, increasing geomorphic risk. Due to their close proximity to one another, the replacement of any one of these culverts may result in impacts that would impact the other two, and the crossings are very similar in scale and construction.

Proposed Concept

- Replace the existing culverts with three-sided box culverts with spans of approximately 9 feet to accommodate a future estimated bankfull width of approximately 6.9-7.5 feet associated with an estimated 20% increase in bankfull flows due to climate change,
  - This will result in crossings that meet the Massachusetts River and Stream Crossing Standards, which require a span of 1.2 times the stream's bankfull width.
- Realign the Lathrop Street crossing to the north of the existing crossing to eliminate the sharp bend in the stream at the inlet
- The proposed culvert replacement design concept will:
  - Provide increased hydraulic capacity to reduce flooding risk and to allow water and debris associated with larger storms to pass.
  - Decrease potential for road overtopping during heavy precipitation.
  - Reduce geomorphic risk by realigning the Lathrop Street culvert
  - Provide an economy of scale when designing, permitting, and constructing the culvert replacements, reducing overall costs.

Image 3: Example of a box culvert (Maine Audubon).

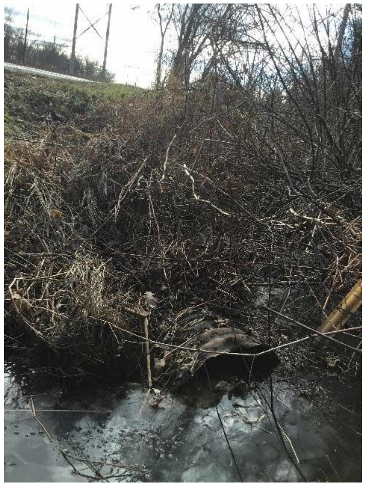


Image 1: Existing structure inlet during field visit on December 10, 2020. Note the sediment deposition blocking the projecting inlet.

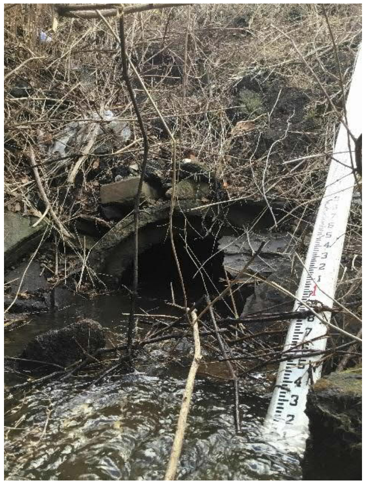


Image 2: Existing Brainerd Street culvert inlet during field visit on December 10, 2020.

Site Prioritization Summary (Cedar, Lathrop, Brainerd)

Scaled Crossing Priority Score (0-1): 0.66, 0.66, 0.54
Impact Score (1-5): 4, 4, 4
Hydraulic Risk Score (1-25) (Existing/Future): 8/12, 20/20, 8/12
Geomorphic Risk Score (1-25): 12, 16, 12
Structural Risk Score (1-25): 20, 0 (insufficient data), 16
AOP Benefit Score (1-25): 6, 6, 6

Existing Crossing Characteristics

Material: Concrete, Corrugated metal, Concrete
Structure Diameter: Unknown, 2 feet, 2 feet
Structure Length: Unknown, 88 feet, 54 feet
Bankfull Width: Approximately 6.5-6.9 feet

Hydraulic Capacity Summary

Total Drainage Area: 0.15 miles^2, 0.16 miles^2, 0.17 miles^2
Existing Structure Capacity: 43.6 cfs, 12.9 cfs, 45.0 cfs
Estimated Peak Flows (Brainerd Street):

Recurrence Interval	Existing	Future
10-year	24.8 cfs	29.8 cfs
25-year	34.1 cfs	40.9 cfs
50-year	41.8 cfs	50.2 cfs
100-year	50.2 cfs	60.2 cfs

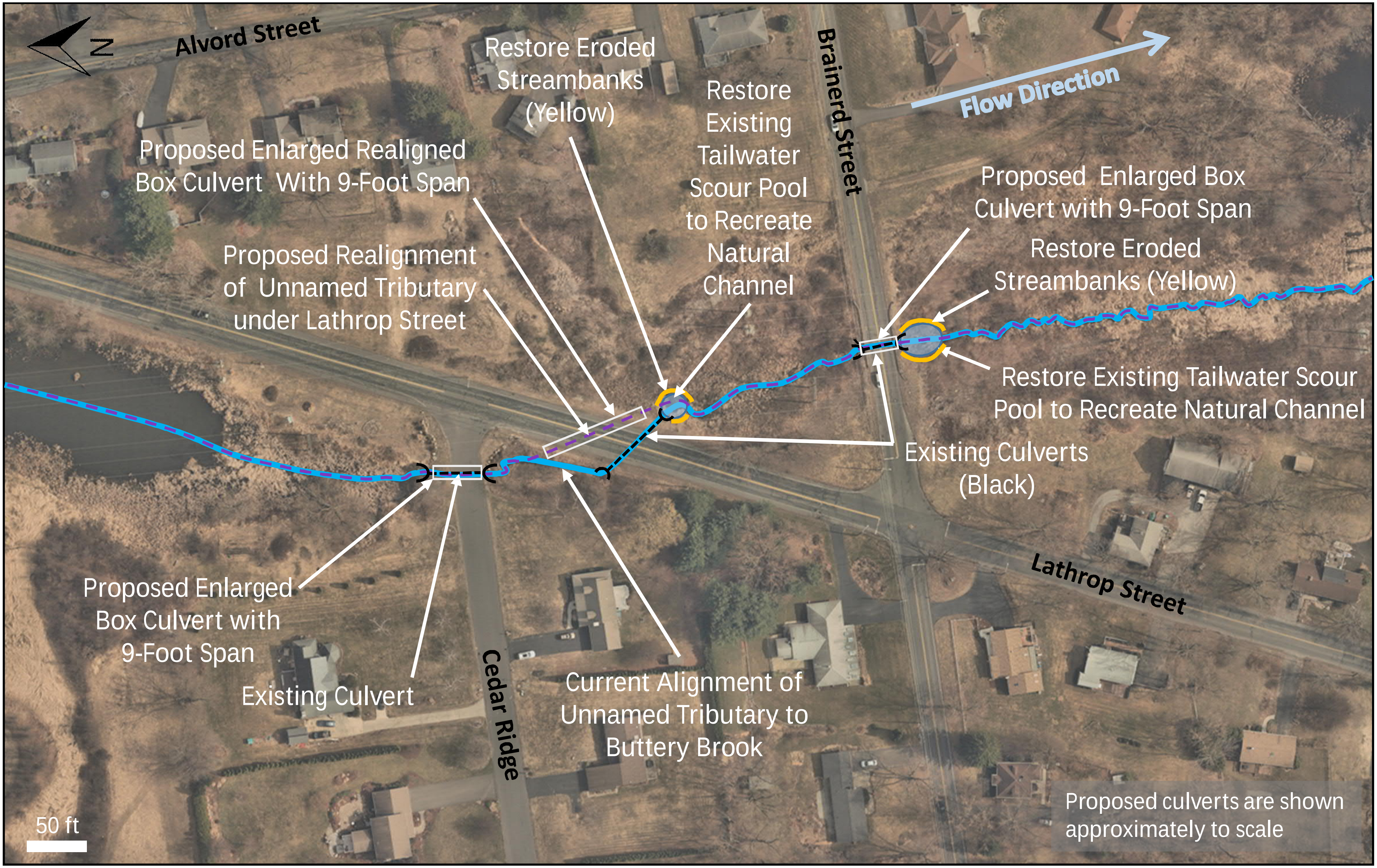
Notable Assessment Findings

- High flood impact potential
- High hydraulic and geomorphic risk at Lathrop Street culvert due to small diameter and angle of culvert to stream
- Cedar Ridge culvert integrated with stormwater drainage
- Sinkhole forming and outlet submerged at Brainerd St.

Preliminary Opinion of Cost[1]

Total project cost: $1,900,000

[1]Actual project cost may range from -30% to +50% of the quoted cost.



Cedar Ridge, Lathrop Street, and Brainerd Street

Culvert Replacement Concepts, South Hadley, MA

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Willimansett Street at Buttery Brook
Culvert Replacement Concept
South Hadley, MA

Site Description

Willimansett Street crosses Buttery Brook approximately 240 feet north of its intersection with Hollywood Street and Memorial Drive. The existing structure is a round pipe constructed of concrete at the inlet and corrugated metal at the outlet with brick near the middle of the structure. The culvert diameter is approximately 3 feet at the inlet, resulting in a severe constriction of the stream's approximately 20-foot bankfull width. The crossing is undersized for all peak flows assessed under existing and future climate conditions. Noted structural deficiencies include embankment piping, poor structure alignment, loss of structural integrity, spreading of culvert joints, and damage flared end section.

Proposed Concept

- Realign the crossing to the north of the existing crossing to create a straight structure that avoids the manhole and the three wells at the structure outlet and eliminates the bends in the stream channel at the culvert inlet and outlet.
- Replace the existing culvert with a bridge, open-bottom arch, or three-sided box culvert with a span of approximately 26 feet, to accommodate a future estimated bankfull width of approximately 21.5 feet associated with a 20% increase in bankfull flows due to climate change
  - ➢ This will result in a crossing that meets the Massachusetts River and Stream Crossing Standards, which require a span of 1.2 times the stream's bankfull width.
- The proposed culvert replacement design concept will:
  - ➢ Provide increased hydraulic capacity to reduce flooding risk and to allow water and debris associated with larger storms to pass.
  - ➢ Decrease potential for road overtopping during heavy precipitation.
  - ➢ Reduce geomorphic risk by realigning the culvert and eliminating changes in structure material and dimensions.

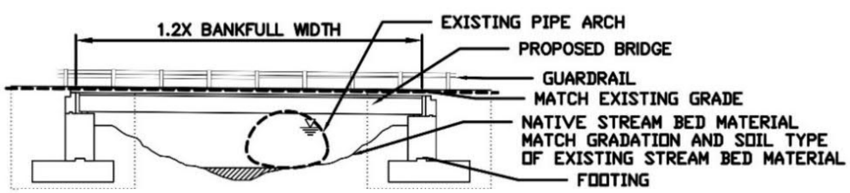


Image 3: Typical detail of a bridge designed to meet the MA River and Stream Crossing Standards.

Image 1: Existing structure inlet during field visit on November 25, 2020, showing a blockage causing a drop into the inlet and erosion of the banks to either side.

Image 2: Existing structure outlet during field visit on November 25, 2020. Note the gaps on either side of the culvert where erosion and piping may be occurring and the damage to the flared end section.

Image 4: Interior of the existing culvert during November 25, 2020 field visit. The culvert is poorly aligned and constructed of three different types of structural material.

Site Prioritization Summary

Scaled Crossing Priority Score (0-1): 0.66
Impact Score (1-5): 4
Hydraulic Risk Score (1-25) (Existing/Future): 20/20
Geomorphic Risk Score (1-25): 16
Structural Risk Score (1-25): 20
AOP Benefit Score (1-25): 6

Existing Crossing Characteristics

Material: Corrugated metal pipe, concrete, brick
Structure Diameter: 3 feet (inlet); 3.5-4 feet (outlet)
Structure Length: Approximately 156 feet
Bankfull Width: Approximately 20 feet

Hydraulic Capacity Summary

Total Drainage Area: 0.54 miles^2
Existing Structure Capacity: 35.2 cfs
Estimated Peak Flows:

Recurrence Interval	Existing	Future
10-year	59.8 cfs	71.8 cfs
25-year	84.5 cfs	97.8 cfs
50-year	99.7 cfs	120 cfs
100-year	119 cfs	143 cfs

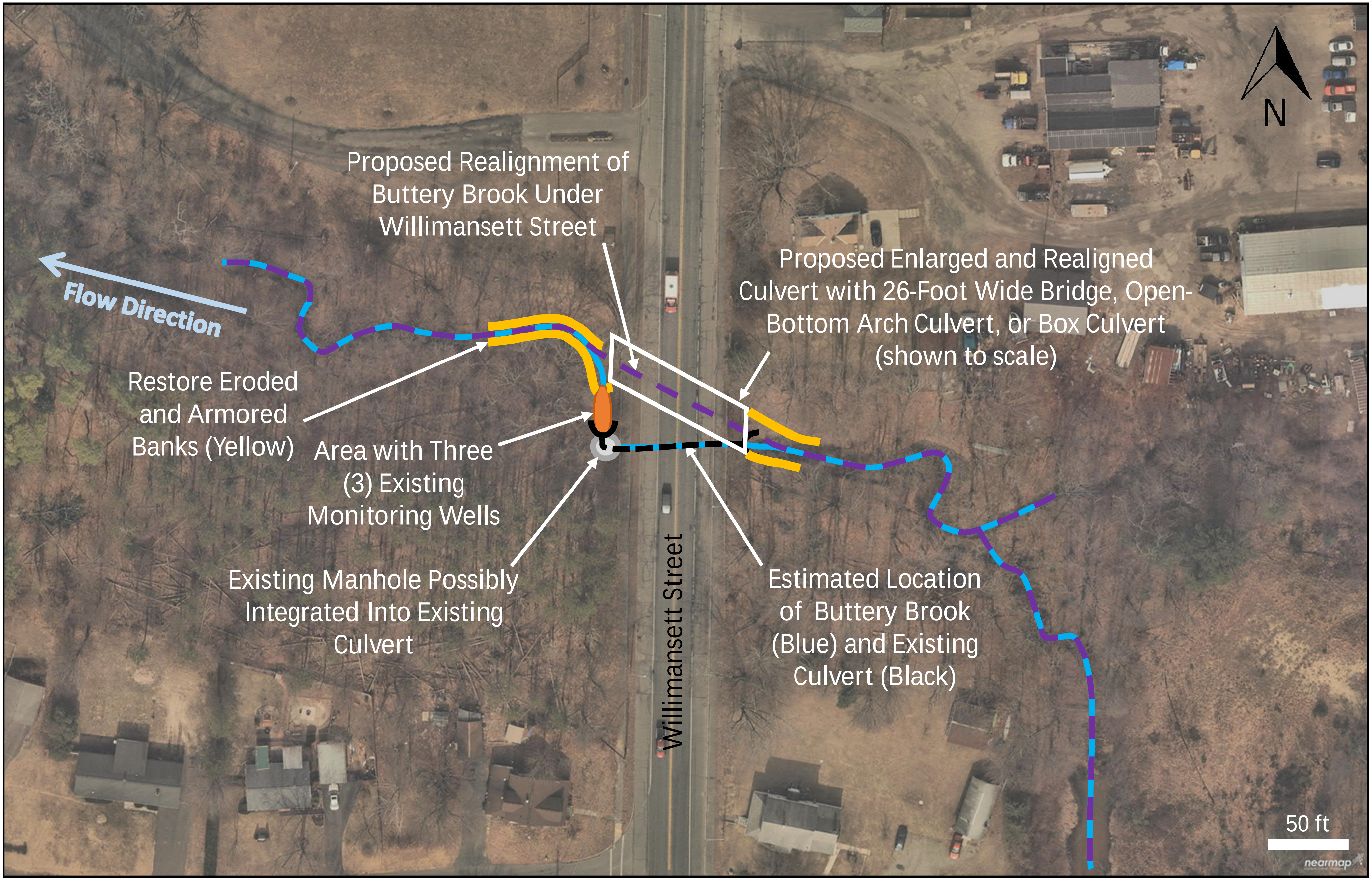
Notable Assessment Findings

- High flood impact potential and potential for transportation disruption and
- Structure changes material, size, and direction between inlet and outlet
- The structure outlet is located near three wells whose purpose is unknown

Preliminary Opinion of Cost[1]

Total project cost: $1,300,000

[1]Actual project cost may range from -30% to +50% of the quoted cost.



Willimansett Street

Culvert Replacement Concepts, South Hadley, MA

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Westbrook Road at Unnamed Tributary to Stony Brook
Culvert Replacement Concept
South Hadley, MA

Site Description

Westbrook Road crosses an unnamed tributary to Stony Brook approximately 475 feet east of the intersection of Mosier Street and Westbrook Road. The existing structure is a round corrugated metal pipe that is mostly buried in sediment at the inlet and buried to about half the culvert diameter at the outlet. This is partially due to the severe constriction formed by the 2-foot diameter of the culvert. The crossing is undersized for all peak flows assessed under existing and future climate conditions. Critical structural deficiencies include embankment piping, poor structural integrity, and severe blockage of the barrel. The embankment piping has resulted in the collapse of the road embankment above the inlet.

Proposed Concept

- Realign the crossing and replace the existing culvert with an open-bottom arch with a span of approximately 8 feet to accommodate a future estimated bankfull width of approximately 6.5 feet associated with an estimated 20% increase in bankfull flows due to climate change,
  - This will result in a crossing that meets the Massachusetts River and Stream Crossing Standards, which require a span of 1.2 times the stream's bankfull width.
- The proposed culvert replacement design concept will:
  - Provide increased hydraulic capacity to reduce flooding risk and to allow water and debris associated with larger storms to pass.
  - Decrease potential for road overtopping during heavy precipitation.
  - Reduce geomorphic risk by alleviating the constriction.
  - Improve the passability of the structure.

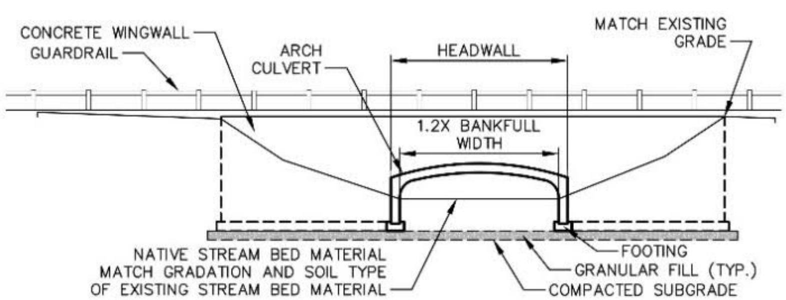


Image 3: Typical detail of an open arch culvert designed to meet MA Stream Crossing Standards

Image 1: Existing structure inlet during field visit on December 9, 2020, showing a blockage at the inlet and the collapsed bank above the pipe.

Image 2: Existing structure outlet during field visit on December 9, 2020. Note the severely eroded banks.

Image 4: The upstream channel during the December 9, 2020 field visit. A sediment bar has formed and split the channel upstream of the inlet.

Site Prioritization Summary

Scaled Crossing Priority Score (0-1): 0.66
Impact Score (1-5): 4
Hydraulic Risk Score (1-25) (Existing/Future): 20/20
Geomorphic Risk Score (1-25): 12
Structural Risk Score (1-25): 20
AOP Benefit Score (1-25): 6

Existing Crossing Characteristics

Material: Corrugated metal pipe
Structure Diameter: 2 feet
Structure Length: Approximately 107 feet
Bankfull Width: Approximately 6.1 feet

Hydraulic Capacity Summary

Total Drainage Area: 0.1 miles^2
Existing Structure Capacity: 0.71 cfs
Estimated Peak Flows:

Recurrence Interval	Existing	Future
10-year	17.1 cfs	20.5 cfs
25-year	23.6 cfs	28.3 cfs
50-year	29.1 cfs	34.9 cfs
100-year	34.9 cfs	41.9 cfs

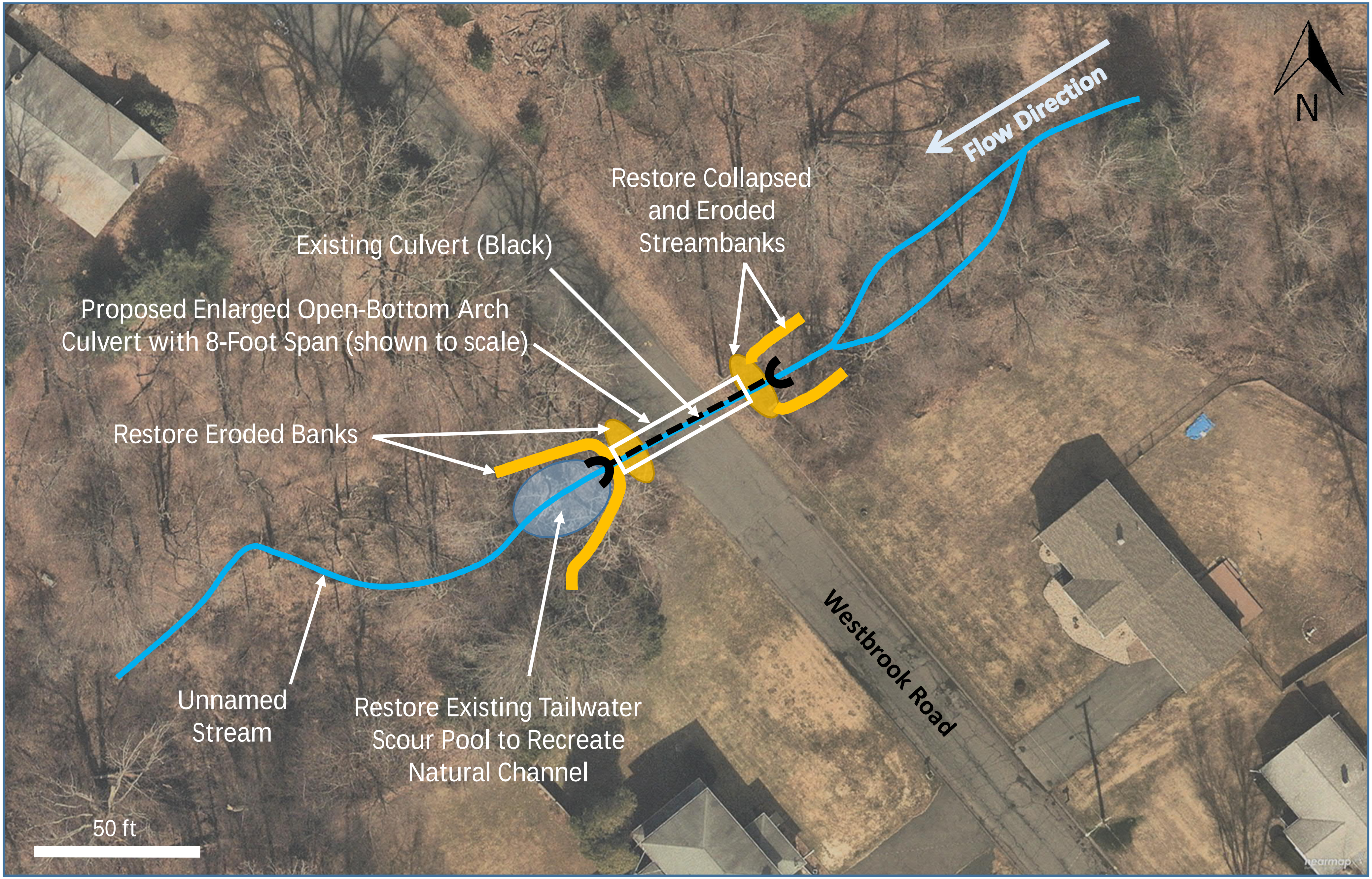
Notable Assessment Findings

- High flood impact potential
- Severe constriction
- Severe bank erosion and collapse at the inlet and outlet

Preliminary Opinion of Cost[1]

Total project cost: $560,000

[1]Actual project cost may range from -30% to +50% of the quoted cost.



Westbrook Road

Culvert Replacement Concepts, South Hadley, MA

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River Road at White Brook
Culvert Replacement Concept
South Hadley, MA

Site Description

River Road crosses White Brook approximately 1000 feet northeast of the intersection with Bayon Street. The location is known to have experienced flooding in the past. The existing structure is a round corrugated metal pipe that is almost fully buried in sediment and debris at the inlet and partially filled with sediment at the outlet. This is partially due to the severe constriction formed by the 5-foot diameter of the culvert. Due to the blockage, the crossing is undersized for all peak flows assessed under existing and future climate conditions. Sediment deposition at the culvert may be exacerbated by the presence of a beaver dam approximately 130 feet downstream of the culvert. At the time of assessment, water impounded by the beaver dam was backed up through the culvert.

Proposed Concept

- Replace the existing culvert with a bridge, open-bottom arch, or three-sided box culvert with a span of approximately 18 feet to accommodate an estimated future bankfull width of approximately 14 feet associated with an estimated 20% increase in bankfull flows due to climate change,
  - This will result in a crossing that meets the Massachusetts River and Stream Crossing Standards, which require a span of 1.2 times the stream's bankfull width.
- The proposed culvert replacement design concept will:
  - Provide increased hydraulic capacity to reduce flooding risk and to allow water and debris associated with larger storms to pass.
  - Decrease the potential for road overtopping during heavy precipitation.
  - Decrease the potential for blockage of the culvert
  - Improve the passability of the structure
  - Decrease sensory cues such as the sound of flowing water that trigger dam building behavior in beavers
- Install a flow-control device through the beaver dam to regulate the height of the impoundment of water at the culvert. Flow-control devices have been shown to be a cost-effective long-term solution to mitigating the impacts of beaver activity.

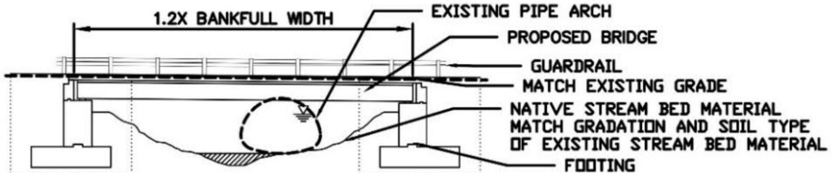


Image 3: Typical detail of a bridge designed to meet the MA River and Stream Crossing Standards.

Image 1: Existing structure inlet during field visit on December 10, 2020, showing only the top of the pipe. The rest of the inlet is buried under sediment and debris.

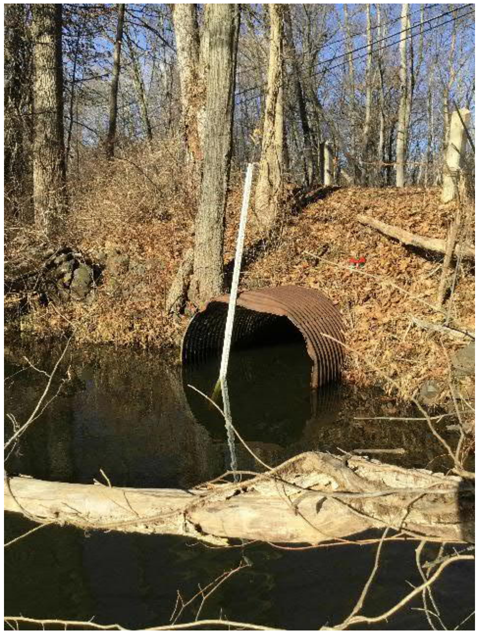


Image 2: Existing structure outlet during field visit on December 10, 2020.

Site Prioritization Summary

Scaled Crossing Priority Score (0-1): 0.39
Impact Score (1-5): 2
Hydraulic Risk Score (1-25) (Existing/Future): 10/10
Geomorphic Risk Score (1-25): 6
Structural Risk Score (1-25): 10
AOP Benefit Score (1-25): 9

Existing Crossing Characteristics

Material: Corrugated metal pipe
Structure Diameter: 5 feet
Structure Length: Approximately 47 feet
Bankfull Width: Approximately 13.1 feet

Hydraulic Capacity Summary

Total Drainage Area: 0.79 miles^2
Existing Structure Capacity: 3.74 cfs (due to blockage)
Estimated Peak Flows:

Recurrence Interval	Existing	Future
10-year	83.7 cfs	100 cfs
25-year	114 cfs	137 cfs
50-year	138 cfs	166 cfs
100-year	165 cfs	198 cfs

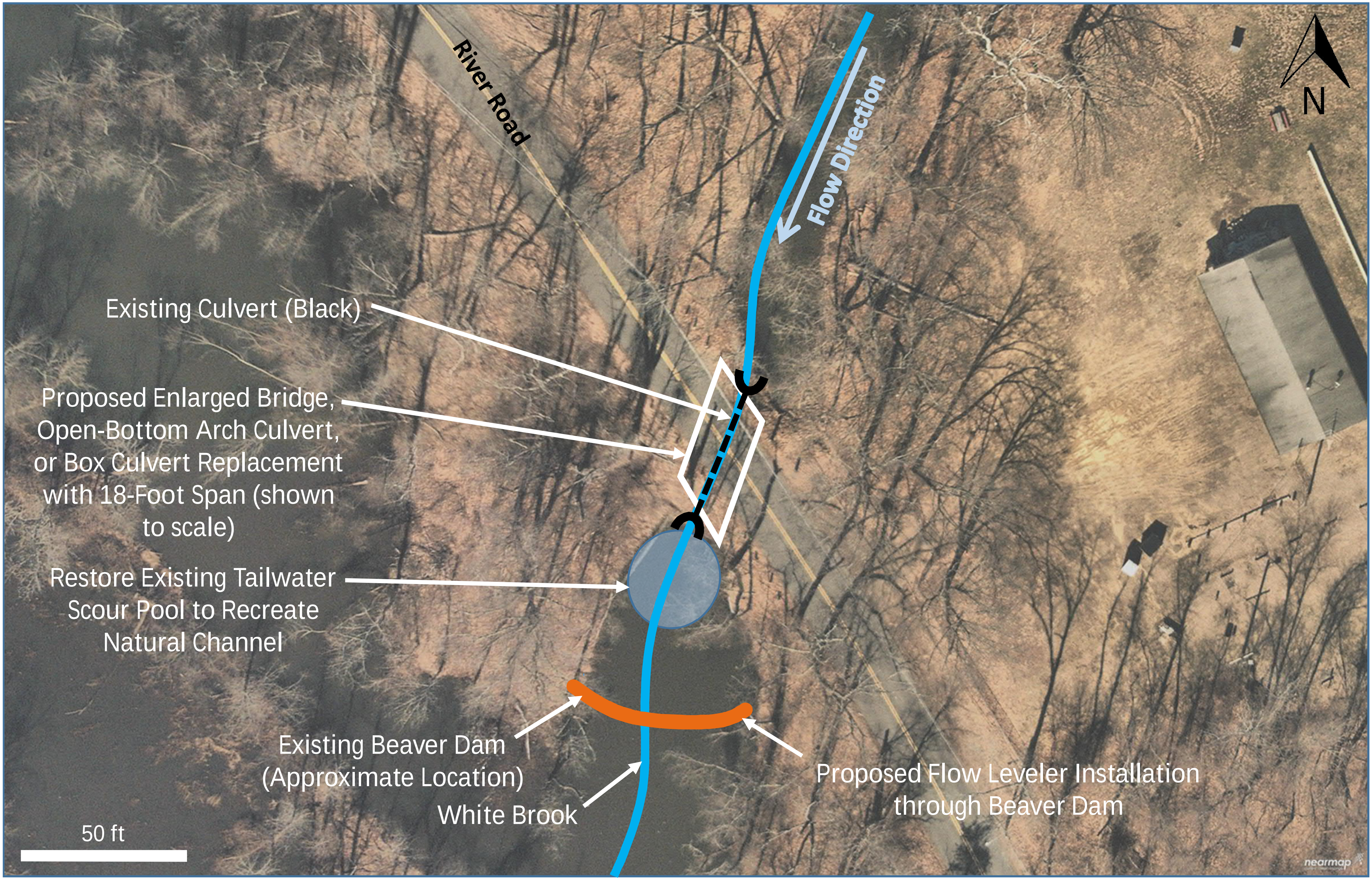
Notable Assessment Findings

- Severe constriction
- Severe blockage
- Severe lack of hydraulic capacity

Preliminary Opinion of Cost[1]

Total project cost: $950,000

[1]Actual project cost may range from -30% to +50% of the quoted cost



River Road

Culvert Replacement Concepts, South Hadley, MA

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Springfield, MA 01103
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Pearl Street at Elmer Brook
Culvert Replacement Concept
South Hadley, MA

Site Description

Pearl Street crosses Elmer Brook approximately 0.3 miles east of the intersection of Rt. 47/Hadley Street and Pearl Street. The location is known to have experienced flooding in the past. The existing structure is a round corrugated metal pipe perched at the outlet. This is partially due to the severe constriction formed by the 6-foot diameter of the culvert. The crossing is undersized for all peak flows assessed under existing and future climate conditions. A large tailwater scour pool has formed as a result of the constriction and the streambanks downstream of the crossing appear to be eroding toward farm fields. Based on aerial imagery it appears that severe erosion may also be occurring upstream of the crossing. The erosion that has occurred has resulted in mobilization of sediment that has been deposited as large sandbars farther downstream.

Proposed Concept

- Realign the crossing and replace the existing culvert with a bridge, open-bottom arch, or three-sided box culvert with a span of approximately 24 feet to accommodate an estimated future bankfull width of associated with a 20% increase in bankfull flows due to climate change
  - ➢ This will result in a crossing that meets the Massachusetts River and Stream Crossing Standards, which require a span of 1.2 times the stream's bankfull width.
- The proposed culvert replacement design concept will:
  - ➢ Provide increased hydraulic capacity to reduce flooding risk and to allow water and debris associated with larger storms to pass.
  - ➢ Decrease potential for road overtopping during heavy precipitation.
  - ➢ Improve the passability of the structure
- Contact landowners upstream and downstream of the crossing to discuss implementation of nature-based bank stabilization solutions for bank erosion, including native riparian plantings:
  - ➢ Bank stabilization will limit the loss of existing farmland
  - ➢ Nature-based solutions are low cost and require little maintenance.
  - ➢ Nature-based solutions provide additional benefits, including improved in-stream and riparian habitat and improved water quality.

Image 1: Existing structure inlet during field visit on November 24, 2020.

Image 2: Existing structure outlet during field visit on November 24, 2020. Note the large scour pool, eroded banks, and perched outlet.

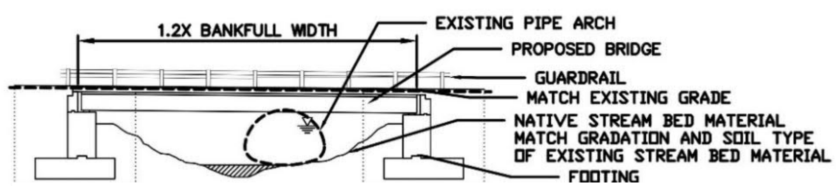


Image 3: Typical detail of a bridge designed to meet the MA River and Stream Crossing Standards.

Site Prioritization Summary

Scaled Crossing Priority Score (0-1): 0.35
Impact Score (1-5): 2
Hydraulic Risk Score (1-25) (Existing/Future): 10/10
Geomorphic Risk Score (1-25): 8
Structural Risk Score (1-25): 2
AOP Benefit Score (1-25): 5

Existing Crossing Characteristics

Material: Corrugated metal pipe
Structure Diameter: 6 feet
Structure Length: Approximately 45 feet
Bankfull Width: Approximately 19 feet

Hydraulic Capacity Summary

Total Drainage Area: 3.61 miles^2
Existing Structure Capacity: 231 cfs
Estimated Peak Flows:

Recurrence Interval	Existing	Future
10-year	296 cfs	355 cfs
25-year	400 cfs	480 cfs
50-year	486 cfs	583 cfs
100-year	578 cfs	694 cfs

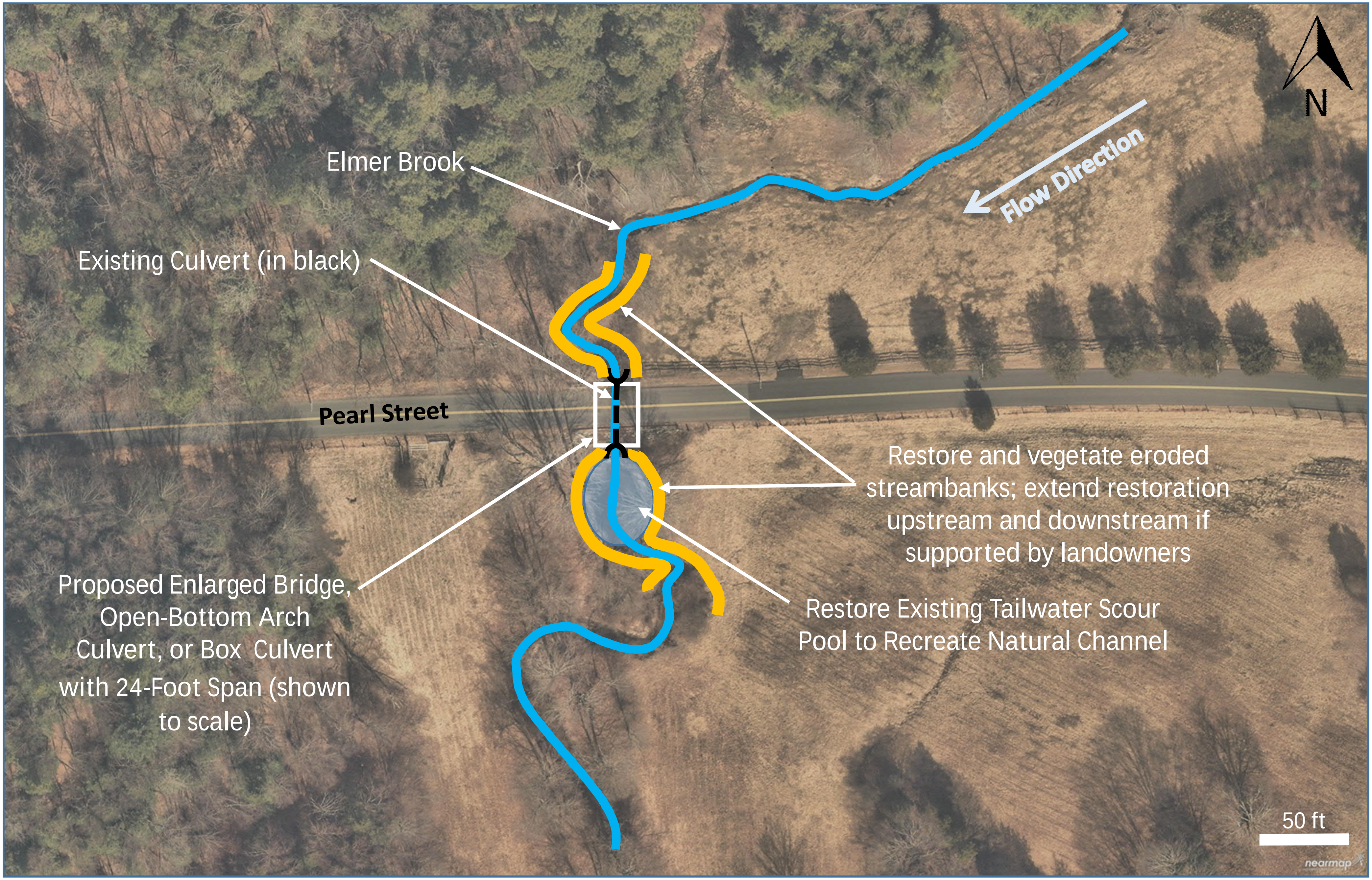
Notable Assessment Findings

- Severe constriction
- Severe erosion downstream of the crossing, potentially threatening existing farmland
- Potential severe erosion upstream of the crossing
- Deposition of eroded sediment downstream of the crossing

Preliminary Opinion of Cost[1]

Total project cost: $900,000

[1]Actual project cost may range from -30% to +50% of the quoted cost.



Pearl Street

Culvert Replacement Concepts, South Hadley, MA

Disclaimer: This map is not the product of a Professional Land Survey. It was created by Fuss & O'Neill, Inc. for General Reference and is not a legally authoritative source. Fuss & O'Neill, Inc. makes no warrantee, express or implied, related to the spatial accuracy, reliability, completeness, or currentness of this map. Data Source: Bureau of Geographic information (MassGIS), Commonwealth of Massachusetts, Executive Office of Technology and Security Services. Imagery © Google.

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5 Project Phasing

In general, projects should be phased in the following order:

- It is recommended that high priority crossings and crossings that are known flooding locations be replaced before lower priority crossings. The priority rankings documented here attempt to capture the worst risks in terms of likelihood of occurrence and magnitude of the impacts. Although these results represent a screening-level analysis, in general it is expected that the replacement or repair of high priority crossings will provide the best value in terms of risk reduction.
- Crossing replacements, particularly replacements that increase crossing capacity, should be constructed starting with the downstream-most crossing and proceeding upstream. This will reduce the risk that increasing the capacity of a crossing will result in the failure of an undersized crossing downstream on the same waterbody.
- Crossings that are physically integrated or located very close together should be repaired or replaced as part of the same project or in phased projects to avoid repeating work such as excavation or paving and to maximize cost efficiencies associated with permitting, bidding, construction mobilization and demobilization, and materials purchasing.

It may be beneficial to prioritize crossing replacement or repair projects that can proceed quickly due to:

- Significant public/stakeholder/adjacent landowner support due to known flooding or other safety problems (or lack of public opposition).
- Simpler permitting requirements (permitting requirements may vary based on site characteristics and the size of the project).
- Availability of grant funding that is highly specific to a known risk or benefit factor at a crossing site (e.g. funding for improving removing barriers to aquatic connectivity).
- Anticipated or planned capital improvements that will occur at or near the crossing site. Road repaving or utility installation projects may provide an opportunity during which the site would already be disturbed and the road closed. Coordinating a crossing replacement project with these or other infrastructure projects may save time and money in the long run.

The replacement of multiple medium and low priority crossings on a short timescale may provide as much risk reduction and ecological benefit as the replacement of one high priority crossing that takes longer to implement due to an extended permitting process, lack of stakeholder support, potential impacts to other infrastructure, or other factors that could not be captured in this analysis.

6 Funding Sources

Potential funding sources for road-stream crossing upgrades are listed below. Note that this list is not exhaustive and the availability of these funding sources may vary over time.

Federal Funding Sources

- 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
  - Building Resilient Infrastructure and Communities (BRIC)
  - 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).

State Funding Sources

- Municipal Vulnerability Preparedness (MVP) Action Grants (such as the one that funded this project)
- Massachusetts Division of Ecological Restoration (DER) Funding Programs
  - Culvert Replacement Municipal Assistance (CRMA) Grant Program
  - Restoration Priority Project funding and technical assistance
- Natural Resource Damages (NRD) Program Restoration Funds
- Massachusetts Department of Transportation (MassDOT) Municipal Small Bridge Program
- Massachusetts Department of Transportation (MassDOT) Chapter 90 Program

Appendix A

Stream Crossing Survey Field Data Form (blank)

FUSS & O'NEILL

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. 5-7

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 Wildlife ________ or None

Visible Utilities ☐ OVERHEAD WIRES ☐ WATER/SEWER PIPES ☐ GAS LINE ☐ NONE ☐ OTHER ________

pp. 9-12

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, 13-15

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

Stream Substrate ☐ MUCK/SILT ☐ SAND ☐ GRAVEL ☐ COBBLE ☐ BOULDER ☐ BEDROCK ☐ UNKNOWN

GEO.

pp. 13

Bank Erosion ☐ HIGH ☐ LOW ☐ ESTIMATED ☐ NONE

Significant Break in Valley Slope ☐ YES ☐ NO ☐ UNKNOWN

Sediment Deposition ☐ UPSTREAM ☐ DOWNSTREAM ☐ WITHIN STRUCTURE ☐ NONE

Elevation of Sediment Deposits >= 1/2 Bankfull Height ☐ YES ☐ NO

TIDAL

pp. 16-18

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 ________

Tide Gate Severity ☐ NONE ☐ MINOR ☐ MODERATE ☐ SEVERE ☐ NO AQUATIC PASSAGE

CROSSING COMMENTS

pp. 5

____

FORM PUBLISHED: OCTOBER 18, 2018

FORM ADAPTED BY FUSS & O'NEILL, INC. (WITH PERMISSION) FROM THE NAACC AQUATIC CONNECTIVITY STREAM CROSSING SURVEY DATA FORM

STRUCTURE 1

OUTLET

pp. 19-35

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 Armoring ☐ 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)______.____

INLET

pp. 35-43

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

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 ☐ NONE

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

Inlet Dimensions A. Width______.____ B. Height______.____ C. Substrate/Water Width______.____ D. Water Depth______.____

ADDITIONAL CONDITIONS

pp. 43-56

Slope % ________ Slope Confidence ☐ HIGH ☐ LOW   Internal Structures ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER________

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

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

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

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

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

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

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

Dry Passage through Structure? ☐ YES ☐ NO ☐ UNKNOWN   Height above Dry Passage________

STRUCTURAL CONDITION ASSESSMENT

pp. 57-70

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

STRUCTURE COMMENTS

pp. 44

FORM PUBLISHED: OCTOBER 18, 2018

STRUCTURE 2

OUTLET

pp. 19-35

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 Armoring ☐ 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)_________.____

INLET

pp. 35-43

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

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 ☐ NONE

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

Inlet Dimensions A. Width_________.____ B. Height_________.____ C. Substrate/Water Width_________.____ D. Water Depth_________.____

ADDITIONAL CONDITIONS

pp. 43-56

Slope % _____________ Slope Confidence ☐ HIGH ☐ LOW

Internal Structures ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER_________

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

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

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

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

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

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

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

Dry Passage through Structure? ☐ YES ☐ NO ☐ UNKNOWN

Height above Dry Passage_____________

STRUCTURAL CONDITION ASSESSMENT

pp. 57-70

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

STRUCTURE COMMENTS

pp. 44

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FORM PUBLISHED: OCTOBER 18, 2018

STRUCTURE 3

OUTLET

pp. 19-35

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 Armoring ☐ 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)_____._____

INLET

pp. 35-43

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

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 ☐ NONE

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

Inlet Dimensions A. Width_____._____ B. Height_____._____ C. Substrate/Water Width_____._____ D. Water Depth_____._____

ADDITIONAL CONDITIONS

pp. 43-56

Slope % _____ Slope Confidence ☐ HIGH ☐ LOW

Internal Structures ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER_____

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

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

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

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

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

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

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

Dry Passage through Structure? ☐ YES ☐ NO ☐ UNKNOWN

Height above Dry Passage_____

STRUCTURAL CONDITION ASSESSMENT

pp. 57-70

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

STRUCTURE COMMENTS

pp. 44

_____

FORM PUBLISHED: OCTOBER 18, 2018

STRUCTURE 4

OUTLET

pp. 19-35

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 Armoring ☐ 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)_________._____

INLET

pp. 35-43

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

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 ☐ NONE

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

Inlet Dimensions A. Width_________._____ B. Height_________._____ C. Substrate/Water Width_________._____ D. Water Depth_________._____

ADDITIONAL CONDITIONS

pp. 43-56

Slope % ____________ Slope Confidence ☐ HIGH ☐ LOW

Internal Structures ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER________

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

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

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

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

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

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

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

Dry Passage through Structure? ☐ YES ☐ NO ☐ UNKNOWN

Height above Dry Passage____________

STRUCTURAL CONDITION ASSESSMENT

pp. 57-70

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

STRUCTURE COMMENTS

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STRUCTURE 5

OUTLET

pp. 19-35

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 Armoring ☐ 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)_________.____

INLET

pp. 35-43

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

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 ☐ NONE

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

Inlet Dimensions A. Width_________.____ B. Height_________.____ C. Substrate/Water Width_________.____ D. Water Depth_________.____

ADDITIONAL CONDITIONS

pp. 43-56

Slope % __________ Slope Confidence ☐ HIGH ☐ LOW

Internal Structures ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER__________

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

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

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

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

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

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

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

Dry Passage through Structure? ☐ YES ☐ NO ☐ UNKNOWN Height above Dry Passage__________

STRUCTURAL CONDITION ASSESSMENT

pp. 57-70

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

STRUCTURE COMMENTS

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STRUCTURE 6

OUTLET

pp. 19-35

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 Armoring ☐ 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)__________.____

INLET

pp. 35-43

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

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 ☐ NONE

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

Inlet Dimensions A. Width__________.____ B. Height__________.____ C. Substrate/Water Width__________.____ D. Water Depth__________.____

ADDITIONAL CONDITIONS

pp. 43-56

Slope % __________ Slope Confidence ☐ HIGH ☐ LOW

Internal Structures ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER__________

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

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

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

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

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

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

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

Dry Passage through Structure? ☐ YES ☐ NO ☐ UNKNOWN

Height above Dry Passage__________

STRUCTURAL CONDITION ASSESSMENT

pp. 57-70

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

STRUCTURE COMMENTS

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STRUCTURE 7

pp. 19-35

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 Armoring ☐ 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)_________._____

pp. 35-43

INLET

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

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 ☐ NONE

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

Inlet Dimensions A. Width_________._____ B. Height_________._____ C. Substrate/Water Width_________._____ D. Water Depth_________._____

pp. 43-56

ADDITIONAL CONDITIONS

Slope % _________ Slope Confidence ☐ HIGH ☐ LOW   Internal Structures ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER_________

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

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

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

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

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

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

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

Dry Passage through Structure? ☐ YES ☐ NO ☐ UNKNOWN   Height above Dry Passage_________

pp. 57-70

STRUCTURAL CONDITION ASSESSMENT

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

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STRUCTURE COMMENTS

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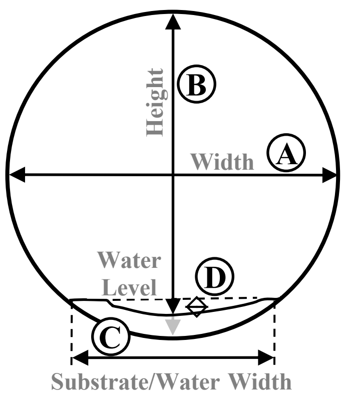
Structure Shape & Dimensions

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.

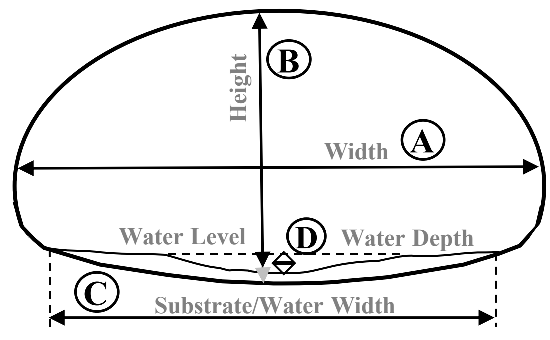
NOTE: Culverts 1, 2 & 4 may or may not have substrate in them, so height measurements (B) are taken from the level of the "stream bed", whether that bed is composed of substrate or just the inside bottom surface of a culvert (grey arrows below show measuring to bottom, black arrows show measuring to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

1



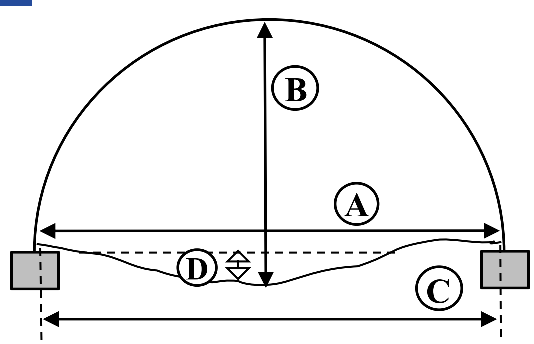
Round Culvert

2



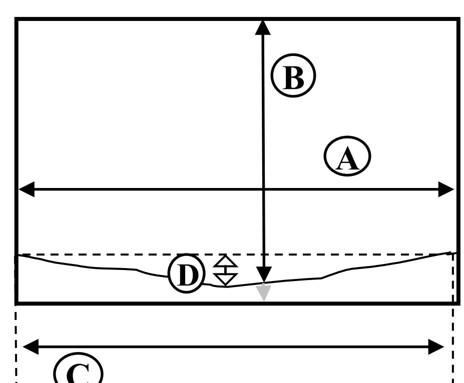
Pipe Arch/Elliptical Culvert

3



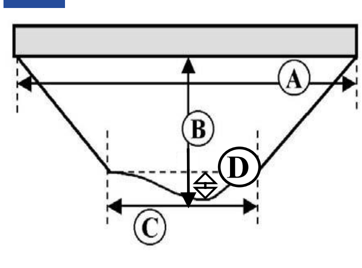
Open Bottom Arch Bridge/Culvert

4



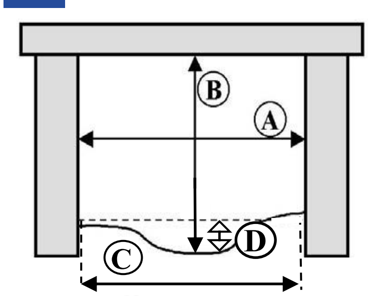
Box Culvert

5



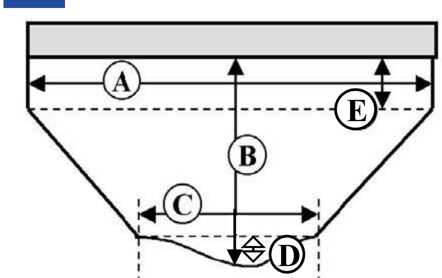
Bridge with Side Slopes

6



Box/Bridge with Abutments

7



Bridge with Abutments and Side Slopes

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Appendix B

Road-Stream Crossing Scoring and Prioritization Results

objectid	XY Code	Road Name	Stream Name	HUC 12 Watershed Name	HUC 12 Watershed Code	Existing Hydraulic Capacity Score-Binned	Future Hydraulic Capacity Score-Binned	Geomorphic Vulnerability Score	Structural Condition Score	Transportation Disruption Score	Flood Impact Potential Score	AOP Score	Ecological Benefit Score	Impact Score	Hydraulic Risk Score	Future Hydraulic Risk Score	Geomorphic Risk Score	Structural Risk Score	AOP Benefit Score	Crossing Risk Score	Crossing Priority Score	Scaled Crossing Priority	Binned Prioritization Score
1	xy42282697258712	PEARL STREET	Elmer Brook	Batchelor Brook	010802010701	5	5	4	1	1	2	5	1	2	10	10	8	2	5	10	17.5	0.35	Low
2	xy42278207257548	WOODBRIDGE STREET	BACHELOR BROOK	Batchelor Brook	010802010701	1	1	3	1	1	2	1	3	2	2	2	6	2	3	6	10.5	0.21	Low
3	xy42283977259894	Rte 47/HADLEY STREET	Dry Brook	Connecticut River-Mill Rive	010802010610	5	5	4	3	4	3	5	3	4	20	20	16	12	15	20	37.5	0.75	High
4	xy42270067258709	Rte 47/Hadley Street	Batchelor Brook	Batchelor Brook	010802010701	1	1	2	1	4	4	1	5	4	4	4	8	4	5	8	14.5	0.29	Low
5	xy42263027258602	PRIESTLY FARMS ROAD	Unnamed	Batchelor Brook	010802010701	1	1	3	1	1	3	3	3	3	3	3	9	3	9	9	18	0.36	Low
6	xy42263477257920	Sycamore Park	Unnamed	Batchelor Brook	010802010701	1	1	4	5	1	2	4	3	2	2	2	8	10	12	10	23	0.46	Medium
7	xy42263197259903	Ferry Street	Stony Brook	Connecticut mainstem-Bat	010802010702	1	1	2	1	1	3	1	4	3	3	3	6	3	4	6	11	0.22	Low
8	xy42254027259794	ALVORD STREET	Unnamed	Connecticut mainstem-Bat	010802010702	3	4	3	5	1	4	2	3	4	12	16	12	20	6	20	33	0.66	Medium
9	xy42253267259802	RIVER LODGE ROAD	unnamed	Connecticut mainstem-Bat	010802010702	1	1	2	1	1	3	1	3	3	3	3	6	3	3	6	10.5	0.21	Low
10	xy42252337260652	RIVER LODGE ROAD	Unnamed	Connecticut mainstem-Bat	010802010702	1	1	4	5	1	2	2	3	2	2	2	8	10	6	10	18	0.36	Low
11	xy42216847255524	New Ludlow road	Unknown	Connecticut mainstem-Bat	010802010702	5	5	4	5	3	3	3	3	3	15	15	12	15	9	15	27	0.54	Medium
12	xy42220017254940	New ludlow rd	Unnamed, non-channel	Connecticut mainstem-Bat	010802010702	5	5	2	5	3	2	2	3	3	15	15	6	15	6	15	25.5	0.51	Medium
13	xy42217767257269	WILLIMANSETT STREET	Buttery Brook	Connecticut mainstem-Bat	010802010702	5	5	4	5	4	4	2	3	4	20	20	16	20	6	20	33	0.66	Medium
14	xy42214737256658	Ann street	Unnamed	Connecticut mainstem-Bat	010802010702	5	5	4	5	1	3	2	3	3	15	15	12	15	6	15	25.5	0.51	Medium
15	xy42219487258108	HILLSIDE AVENUE	Buttery Brook	Connecticut mainstem-Bat	010802010702	1	2	4	5	2	4	5	3	4	4	8	16	20	15	20	37.5	0.75	High
16	xy42286577256362	LITHIA SPRINGS ROAD	Elmer brook	Batchelor Brook	010802010701	4	5	3	3	1	1	3	3	1	4	5	3	3	9	5	16	0.32	Low
17	xy42257867257156	PARK STREET	Stony Brook	Connecticut mainstem-Bat	010802010702	1	1	3	5	1	4	1	5	4	4	4	12	20	5	20	32.5	0.65	Medium
18	xy42256127257178	PROSPECT HALL ROAD	Stony brook	Connecticut mainstem-Bat	010802010702	1	1	3	1	1	4	1	5	4	4	4	12	4	5	12	20.5	0.41	Medium
19	xy42252417257340	MORGAN STREET	Stony Brook	Connecticut mainstem-Bat	010802010702	1	2	3	3	2	5	1	5	5	5	10	15	15	5	15	25	0.5	Medium
20	xy42251277255916	MORGAN STREET	Stony Brook	Connecticut mainstem-Bat	010802010702	1	1	3	1	2	4	1	4	4	4	4	12	4	4	12	20	0.4	Low
21	xy42245227256666	RED BRIDGE LANE	Unnamed tributary to Ston	Connecticut mainstem-Bat	010802010702	1	1	3	3	1	3	1	3	3	3	3	9	9	3	9	15	0.3	Low
22	xy42246997257050	MOSIER STREET	Unnamed tributary to Ston	Connecticut mainstem-Bat	010802010702	2	3	4	5	1	3	3	3	3	6	9	12	15	9	15	27	0.54	Medium
23	xy42246187258080	COLLEGE STREET/Rte 116	Stony Brook	Connecticut mainstem-Bat	010802010702	1	1	3	5	4	4	1	5	4	4	4	12	20	5	20	32.5	0.65	Medium
24	xy42244997258054	BRAINERD STREET and Newto	Leaping Well Brook	Connecticut mainstem-Bat	010802010702	1	1	4	3	4	4	3	3	4	4	4	16	12	9	16	28.5	0.57	Medium
25	xy42244417258104	BRAINERD STREET	Unnamed tributary to Ston	Connecticut mainstem-Bat	010802010702	5	5	5	5	2	4	4	3	4	20	20	20	20	12	20	36	0.72	High
26	xy42237867257834	HILDRETH AVENUE	Unnamed tributary to Ston	Connecticut mainstem-Bat	010802010702	3	3	3	5	1	4	2	3	4	12	12	12	20	6	20	33	0.66	Medium
27	xy42232237258843	JOFFRE AVENUE	Buttery Brook	Connecticut mainstem-Bat	010802010702	3	3	3		1	3	3	3	3	9	9	9	0	9	9	18	0.36	Low
28	xy42248427259724	STONEGATE DRIVE	Unnamed	Connecticut mainstem-Bat	010802010702	1	2	2	3	1	2	1	3	2	2	4	4	6	3	6	10.5	0.21	Low
29	xy42247837256806	Westbrook Road	Unnamed	Connecticut mainstem-Bat	010802010702	5	5	3	5	1	4	2	3	4	20	20	12	20	6	20	33	0.66	Medium
30	xy42236747255747	Hadley Village Rd	Unnamed tributary to Leap	Connecticut mainstem-Bat	010802010702	1	1	4	5	1	4	5	3	4	4	4	16	20	15	20	37.5	0.75	High
31	xy42234167256116	PINE GROVE DRIVE	Unnamed tributary to Leap	Connecticut mainstem-Bat	010802010702	5	5	3	2	1	4	3	3	4	20	20	12	8	9	20	34.5	0.69	High
32	xy42235437256200	GRANBY ROAD	Unnamed tributary to Leap	Connecticut mainstem-Bat	010802010702	1	2	3	5	4	4	3	3	4	4	8	12	20	9	20	34.5	0.69	High
33	xy42234807256312	GRANBY ROAD	Unnamed tributary to Leap	Connecticut mainstem-Bat	010802010702	5	5	4	5	4	4	3	3	4	20	20	16	20	9	20	34.5	0.69	High
34	xy42234187256414	GRANBY ROAD	Leaping Well Brook	Connecticut mainstem-Bat	010802010702	5	5	4	5	4	4	5	3	4	20	20	16	20	15	20	37.5	0.75	High
35	xy42239507258135	NEWTON STREET	Unnamed tributary to Ston	Connecticut mainstem-Bat	010802010702	1	1	4	5	4	4	2	3	4	4	4	16	20	6	20	33	0.66	Medium
36	xy42234007258433	NEWTON STREET	Buttery Brook	Connecticut mainstem-Bat	010802010702	5	5	3	5	4	4	3	3	4	20	20	12	20	9	20	34.5	0.69	High
37	xy42233147258602	MOUNTAIN AVENUE	Buttery Brook	Connecticut mainstem-Bat	010802010702	5	5	4	5	1	3	3	3	3	15	15	12	15	9	15	27	0.54	Medium
38	xy42226327258824	NEWTON STREET	Newton Smith Brook	Connecticut mainstem-Bat	010802010702	5	5	4	5	4	4	5	3	4	20	20	16	20	15	20	37.5	0.75	High
39	xy42220107259300	GAYLORD STREET	Buttery Brook	Connecticut mainstem-Bat	010802010702	3	3			2	5	3	4	5	15	15	0	0	12	15	28.5	0.57	Medium
40	xy42217237259373	SCHOOL STREET	Buttery Brook	Connecticut mainstem-Bat	010802010702	4	5	4	3	1	5	3	4	5	20	25	20	15	12	25	43.5	0.87	High
41	xy42277677256216	Amherst	Batchelor Brook	Batchelor Brook	010802010701	1	1	2	1	4	2	1	4	4	4	4	8	4	4	8	14	0.28	Low
42	xy42238647259355	BRAINERD STREET	Unnamed tributary to Butt	Connecticut mainstem-Bat	010802010702	2	3	3	4	2	4	2	3	4	8	12	12	16	6	16	27	0.54	Medium
43	xy42239287259384	LATHROP STREET	Unnamed tributary to Butt	Connecticut mainstem-Bat	010802010702	5	5	4		1	4	2	3	4	20	20	16	0	6	20	33	0.66	Medium
44	xy42239687259396	Cedar Ridge	Unnamed tributary to Butt	Connecticut mainstem-Bat	010802010702	2	3	3	5	1	4	2	3	4	8	12	12	20	6	20	33	0.66	Medium
45	xy42231187261314	RIVER ROAD	White Brook	Connecticut mainstem-Bat	010802010702	5	5	3	5	1	2	3	3	2	10	10	6	10	9	10	19.5	0.39	Low
46	xy42219947259437	Gaylord Street	Unnamed tributary to Butt	Connecticut mainstem-Bat	010802010702	3	4	3	2	2	4	3	3	4	12	16	12	8	9	16	28.5	0.57	Medium
47	xy42214097259533	BRIDGE STREET	Buttery brook	Connecticut mainstem-Bat	010802010702	1	1	2	1	4	4	1	4	4	4	4	8	4	4	8	14	0.28	Low
48	xy42215877259543	MAIN STREET	Buttery Brook	Connecticut mainstem-Bat	010802010702	3	3	4	3	3	4	5	4	4	12	12	16	12	20	16	38	0.76	High

Table 2: Top Ranked Crossings Based on Existing Hydraulic Risk Score

XY Code	Road Name	Stream Name	HUC 12 Watershed Name	Impact Score	Hydraulic Risk Score	Future Hydraulic Risk Score	Geomorphic Risk Score	Structural Risk Score	AOP Benefit Score	Crossing Risk Score	Crossing Priority Score	Scaled Crossing Priority	Binned Prioritization Score
xy42283977259894	Rte 47/Hadley Street	Dry Brook	Connecticut River-Mill River to Batchelor Brook	4	20	20	16	12	15	20	37.5	0.75	High
xy42234187256414	Granby Road	Leaping Well Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	16	20	15	20	37.5	0.75	High
xy42226327258824	Newton Street	Newton Smith Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	16	20	15	20	37.5	0.75	High
xy42244417258104	Brainerd Street	Unnamed Tributary to Stony Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	20	20	12	20	36	0.72	High
xy42234167256116	Pine Grove Drive	Unnamed Tributary to Leaping Well Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	12	8	9	20	34.5	0.69	High
xy42234807256312	Granby Road	Unnamed Tributary to Leaping Well Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	16	20	9	20	34.5	0.69	High
xy42234007258433	Newton Street	Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	12	20	9	20	34.5	0.69	High
xy42217767257269	Willimansett Street	Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	16	20	6	20	33	0.66	Medium
xy42247837256806	Westbrook Road	Unnamed	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	12	20	6	20	33	0.66	Medium
xy42239287259384	Lathrop Street	Unnamed Tributary to Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	16		6	20	33	0.66	Medium
xy42217237259373	School Street	Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	5	20	25	20	15	12	25	43.5	0.87	High
xy42216847255524	New Ludlow Road	Unknown	Connecticut mainstem-Batchelor Brook to Mill River	3	15	15	12	15	9	15	27	0.54	Medium
xy42233147258602	Mountain Avenue	Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	3	15	15	12	15	9	15	27	0.54	Medium
xy42220017254940	New Ludlow Rd	Unnamed, Non-Channel	Connecticut mainstem-Batchelor Brook to Mill River	3	15	15	6	15	6	15	25.5	0.51	Medium
xy42214737256658	Ann Street	Unnamed	Connecticut mainstem-Batchelor Brook to Mill River	3	15	15	12	15	6	15	25.5	0.51	Medium
xy42220107259300	Gaylord Street	Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	5	15	15			12	15	28.5	0.57	Medium

Table 3: Top Ranked Crossings Based on Future Hydraulic Risk Score

XY Code	Road Name	Stream Name	HUC 12 Watershed Name	Impact Score	Hydraulic Risk Score	Future Hydraulic Risk Score	Geomorphic Risk Score	Structural Risk Score	AOP Benefit Score	Crossing Risk Score	Crossing Priority Score	Scaled Crossing Priority	Binned Prioritization Score
xy42217237259373	School Street	Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	5	20	25	20	15	12	25	43.5	0.87	High
xy42283977259894	Rte 47/Hadley Street	Dry Brook	Connecticut River-Mill River to Batchelor Brook	4	20	20	16	12	15	20	37.5	0.75	High
xy42234187256414	Granby Road	Leaping Well Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	16	20	15	20	37.5	0.75	High
xy42226327258824	Newton Street	Newton Smith Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	16	20	15	20	37.5	0.75	High
xy42244417258104	Brainerd Street	Unnamed Tributary to Stony Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	20	20	12	20	36	0.72	High
xy42234167256116	Pine Grove Drive	Unnamed Tributary to Leaping Well Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	12	8	9	20	34.5	0.69	High
xy42234807256312	Granby Road	Unnamed Tributary to Leaping Well Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	16	20	9	20	34.5	0.69	High
xy42234007258433	Newton Street	Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	12	20	9	20	34.5	0.69	High
xy42217767257269	Willimansett Street	Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	16	20	6	20	33	0.66	Medium
xy42247837256806	Westbrook Road	Unnamed	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	12	20	6	20	33	0.66	Medium
xy42239287259384	Lathrop Street	Unnamed Tributary to Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	16		6	20	33	0.66	Medium
xy42254027259794	Alvord Street	Unnamed	Connecticut mainstem-Batchelor Brook to Mill River	4	12	16	12	20	6	20	33	0.66	Medium
xy42219947259437	Gaylord Street	Unnamed Tributary to Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	12	16	12	8	9	16	28.5	0.57	Medium
xy42216847255524	New Ludlow Road	Unknown	Connecticut mainstem-Batchelor Brook to Mill River	3	15	15	12	15	9	15	27	0.54	Medium
xy42233147258602	Mountain Avenue	Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	3	15	15	12	15	9	15	27	0.54	Medium
xy42220017254940	New Ludlow Rd	Unnamed, Non-Channel	Connecticut mainstem-Batchelor Brook to Mill River	3	15	15	6	15	6	15	25.5	0.51	Medium
xy42214737256658	Ann Street	Unnamed	Connecticut mainstem-Batchelor Brook to Mill River	3	15	15	12	15	6	15	25.5	0.51	Medium
xy42220107259300	Gaylord Street	Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	5	15	15			12	15	28.5	0.57	Medium

Table 4: Top Ranked Crossings Based on Geomorphic Risk Score

XY Code	Road Name	Stream Name	HUC 12 Watershed Name	Impact Score	Hydraulic Risk Score	Future Hydraulic Risk Score	Geomorphic Risk Score	Structural Risk Score	AOP Benefit Score	Crossing Risk Score	Crossing Priority Score	Scaled Crossing Priority	Binned Prioritization Score
xy42217237259373	School Street	Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	5	20	25	20	15	12	25	43.5	0.87	High
xy42244417258104	Brainerd Street	Unnamed Tributary to Stony Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	20	20	12	20	36	0.72	High
xy42283977259894	Rte 47/Hadley Street	Dry Brook	Connecticut River-Mill River to Batchelor Brook	4	20	20	16	12	15	20	37.5	0.75	High
xy42234187256414	Granby Road	Leaping Well Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	16	20	15	20	37.5	0.75	High
xy42226327258824	Newton Street	Newton Smith Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	16	20	15	20	37.5	0.75	High
xy42234807256312	Granby Road	Unnamed Tributary to Leaping Well Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	16	20	9	20	34.5	0.69	High
xy42217767257269	Willimansett Street	Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	16	20	6	20	33	0.66	Medium
xy42239287259384	Lathrop Street	Unnamed Tributary to Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	16		6	20	33	0.66	Medium
xy42215877259543	Main Street	Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	12	12	16	12	20	16	38	0.76	High
xy42219487258108	Hillside Avenue	Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	4	8	16	20	15	20	37.5	0.75	High
xy42236747255747	Hadley Village Rd	Unnamed Tributary to Leaping Well Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	4	4	16	20	15	20	37.5	0.75	High
xy42263477257920	Sycamore Park	Unnamed	Batchelor Brook	4	4	4	16	20	12	10	23	0.46	Medium
xy42239507258135	Newton Street	Unnamed Tributary to Stony Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	4	4	16	20	6	20	33	0.66	Medium
xy42244997258054	Brainerd Street And Newton Street	Leaping Well Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	4	4	16	12	9	16	28.5	0.57	Medium
xy42252417257340	Morgan Street	Stony Brook	Connecticut mainstem-Batchelor Brook to Mill River	5	5	10	15	15	5	15	25	0.5	Medium

Table 5: Top Ranked Crossings Based on Structural Risk Score

XY Code	Road Name	Stream Name	HUC 12 Watershed Name	Impact Score	Hydraulic Risk Score	Future Hydraulic Risk Score	Geomorphic Risk Score	Structural Risk Score	AOP Benefit Score	Crossing Risk Score	Crossing Priority Score	Scaled Crossing Priority	Binned Prioritization Score
xy42244417258104	Brainerd Street	Unnamed Tributary to Stony Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	20	20	12	20	36	0.72	High
xy42234187256414	Granby Road	Leaping Well Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	16	20	15	20	37.5	0.75	High
xy42226327258824	Newton Street	Newton Smith Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	16	20	15	20	37.5	0.75	High
xy42234807256312	Granby Road	Unnamed Tributary to Leaping Well Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	16	20	9	20	34.5	0.69	High
xy42217767257269	Willimansett Street	Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	16	20	6	20	33	0.66	Medium
xy42219487258108	Hillside Avenue	Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	4	8	16	20	15	20	37.5	0.75	High
xy42236747255747	Hadley Village Rd	Unnamed Tributary to Leaping Well Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	4	4	16	20	15	20	37.5	0.75	High
xy42263477257920	Sycamore Park	Unnamed	Batchelor Brook	4	4	4	16	20	12	10	23	0.46	Medium
xy42239507258135	Newton Street	Unnamed Tributary to Stony Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	4	4	16	20	6	20	33	0.66	Medium
xy42234007258433	Newton Street	Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	12	20	9	20	34.5	0.69	High
xy42247837256806	Westbrook Road	Unnamed	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	12	20	6	20	33	0.66	Medium
xy42254027259794	Alvord Street	Unnamed	Connecticut mainstem-Batchelor Brook to Mill River	4	12	16	12	20	6	20	33	0.66	Medium
xy42237867257834	Hildreth Avenue	Unnamed Tributary to Stony Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	12	12	12	20	6	20	33	0.66	Medium
xy42239687259396	Cedar Ridge	Unnamed Tributary to Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	8	12	12	20	6	20	33	0.66	Medium
xy42235437256200	Granby Road	Unnamed Tributary to Leaping Well Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	4	8	12	20	9	20	34.5	0.69	High
xy42257867257156	Park Street	Stony Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	4	4	12	20	5	20	32.5	0.65	Medium
xy42246187258080	College Street/Rte 116	Stony Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	4	4	12	20	5	20	32.5	0.65	Medium

Table 6: Top Ranked Crossings Based on Aquatic Organism Passage (AOP) Benefit Score

XY Code	Road Name	Stream Name	HUC 12 Watershed Name	Impact Score	Hydraulic Risk Score	Future Hydraulic Risk Score	Geomorphic Risk Score	Structural Risk Score	AOP Benefit Score	Crossing Risk Score	Crossing Priority Score	Scaled Crossing Priority	Binned Prioritization Score
xy42215877259543	Main Street	Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	12	12	16	12	20	16	38	0.76	High
xy42234187256414	Granby Road	Leaping Well Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	16	20	15	20	37.5	0.75	High
xy42226327258824	Newton Street	Newton Smith Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	16	20	15	20	37.5	0.75	High
xy42219487258108	Hillside Avenue	Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	4	8	16	20	15	20	37.5	0.75	High
xy42236747255747	Hadley Village Rd	Unnamed Tributary to Leaping Well Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	4	4	16	20	15	20	37.5	0.75	High
xy42283977259894	Rte 47/Hadley Street	Dry Brook	Connecticut River-Mill River to Batchelor Brook	4	20	20	16	12	15	20	37.5	0.75	High
xy42244417258104	Brainerd Street	Unnamed Tributary to Stony Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	20	20	12	20	36	0.72	High
xy42263477257920	Sycamore Park	Unnamed	Batchelor Brook	4	4	4	16	20	12	10	23	0.46	Medium
xy42217237259373	School Street	Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	5	20	25	20	15	12	25	43.5	0.87	High
xy42220107259300	Gaylord Street	Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	5	15	15			12	15	28.5	0.57	Medium

Table 7: Top Ranked Crossings Based on Impact Score

XY Code	Road Name	Stream Name	HUC 12 Watershed Name	Impact Score	Hydraulic Risk Score	Future Hydraulic Risk Score	Geomorphic Risk Score	Structural Risk Score	AOP Benefit Score	Crossing Risk Score	Crossing Priority Score	Scaled Crossing Priority	Binned Prioritization Score
xy42217237259373	School Street	Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	5	20	25	20	15	12	25	43.5	0.87	High
xy42220107259300	Gaylord Street	Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	5	15	15			12	15	28.5	0.57	Medium
xy42252417257340	Morgan Street	Stony Brook	Connecticut mainstem-Batchelor Brook to Mill River	5	5	10	15	15	5	15	25	0.5	Medium
xy42215877259543	Main Street	Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	12	12	16	12	20	16	38	0.76	High
xy42234187256414	Granby Road	Leaping Well Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	16	20	15	20	37.5	0.75	High
xy42226327258824	Newton Street	Newton Smith Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	16	20	15	20	37.5	0.75	High
xy42219487258108	Hillside Avenue	Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	4	8	16	20	15	20	37.5	0.75	High
xy42236747255747	Hadley Village Rd	Unnamed Tributary to Leaping Well Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	4	4	16	20	15	20	37.5	0.75	High
xy42283977259894	Rte 47/Hadley Street	Dry Brook	Connecticut River-Mill River to Batchelor Brook	4	20	20	16	12	15	20	37.5	0.75	High
xy42244417258104	Brainerd Street	Unnamed Tributary to Stony Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	20	20	12	20	36	0.72	High
xy42263477257920	Sycamore Park	Unnamed	Batchelor Brook	4	4	4	16	20	12	10	23	0.46	Medium
xy42234807256312	Granby Road	Unnamed Tributary to Leaping Well Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	16	20	9	20	34.5	0.69	High
xy42234007258433	Newton Street	Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	12	20	9	20	34.5	0.69	High
xy42235437256200	Granby Road	Unnamed Tributary to Leaping Well Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	4	8	12	20	9	20	34.5	0.69	High
xy42244997258054	Brainerd Street And Newton Street	Leaping Well Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	4	4	16	12	9	16	28.5	0.57	Medium
xy42234167256116	Pine Grove Drive	Unnamed Tributary to Leaping Well Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	12	8	9	20	34.5	0.69	High
xy42219947259437	Gaylord Street	Unnamed Tributary to Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	12	16	12	8	9	16	28.5	0.57	Medium
xy42217767257269	Willimansett Street	Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	16	20	6	20	33	0.66	Medium
xy42239507258135	Newton Street	Unnamed Tributary to Stony Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	4	4	16	20	6	20	33	0.66	Medium
xy42247837256806	Westbrook Road	Unnamed	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	12	20	6	20	33	0.66	Medium
xy42254027259794	Alvord Street	Unnamed	Connecticut mainstem-Batchelor Brook to Mill River	4	12	16	12	20	6	20	33	0.66	Medium
xy42237867257834	Hildreth Avenue	Unnamed Tributary to Stony Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	12	12	12	20	6	20	33	0.66	Medium
xy42239687259396	Cedar Ridge	Unnamed Tributary to Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	8	12	12	20	6	20	33	0.66	Medium
xy42238647259355	Brainerd Street	Unnamed Tributary to Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	8	12	12	16	6	16	27	0.54	Medium
xy42239287259384	Lathrop Street	Unnamed Tributary to Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	20	20	16		6	20	33	0.66	Medium
xy42257867257156	Park Street	Stony Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	4	4	12	20	5	20	32.5	0.65	Medium
xy42246187258080	College Street/Rte 116	Stony Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	4	4	12	20	5	20	32.5	0.65	Medium
xy42256127257178	Prospect Hall Road	Stony brook	Connecticut mainstem-Batchelor Brook to Mill River	4	4	4	12	4	5	12	20.5	0.41	Medium
xy42270067258709	Rte 47/Hadley Street	Batchelor Brook	Batchelor Brook	4	4	4	8	4	5	8	14.5	0.29	Low
xy42251277255916	Morgan Street	Stony Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	4	4	12	4	4	12	20	0.4	Low
xy42277677256216	Amherst	Batchelor Brook	Batchelor Brook	4	4	4	8	4	4	8	14	0.28	Low
xy42214097259533	Bridge Street	Buttery Brook	Connecticut mainstem-Batchelor Brook to Mill River	4	4	4	8	4	4	8	14	0.28	Low

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Appendix C

Road-Stream Crossing Scoring and Prioritization Methods

Hydraulic Capacity Worksheet
Massachusetts Road-Stream Crossing Assessment
Town-Wide Road-Stream Crossing Assessments – Town of South Hadley
May 2021

Table 1: Headwater Depth at $Q_{failure}$

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

Table 2: Tailwater Depth used in Calculating Hydraulic Capacity ($Q_{failure}$)

Crossing Type	Crossing Structure Slope	Tailwater Depth
Non-Tidal Crossings	> 2%	TW = 0.75 x D
	< 2%	TW = 0.75 x D when HW/D < 1.3 TW = 1.0 x D when HW/D ≥ 1.3
Tidal Crossings	Not Applicable	TW = 1.0 x D
Crossings discharging directly into a lake, pond, or wetland[1]	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] 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.

Table 3: Hydraulic Capacity Score

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

Equation 1: Hydraulic Capacity Ratio

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

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

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

Geomorphic Vulnerability Worksheet
Massachusetts Road-Stream Crossing Assessment
Town-Wide Road-Stream Crossing Assessments – Town of South Hadley
May 2021

Table 1: Crossing Alignment Impact Potential Ratings

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

Table 2: Bankfull Width Impact Potential Ratings When Confident Width Measurements are Available

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

Table 3: Bankfull Width Impact Potential Ratings When No Confident Width Measurements are Available

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

Table 4: Channel and Crossing Structure Slope Impact Potential Ratings

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

Table 5: Sediment Continuity Impact Ratings

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

Table 6: Bank Erosion and Outlet Armoring Impact Ratings

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

Table 7: Inlet and Outlet Grade Impact Ratings

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

Table 8: Combined Geomorphic Potential Impact Ratings

Combined Potential Impact Rating	Likelihood for Geomorphic Impacts
3	Very unlikely
4-6	Unlikely
7-9	Possible
10-12	Likely
13-15	Very likely

Table 9: Combined Observed Geomorphic Impact Ratings

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

Table 10: Overall Geomorphic Impact Score

Sum of Geomorphic Potential Impact Ratings and Observed Geomorphic Impact Ratings	Geomorphic Impact score
6	1
7-12	2
13-18	3
19-24	4
25-30	5

Structural Condition Worksheet
Massachusetts Road-Stream Crossing Assessment
Town-Wide Road-Stream Crossing Assessments – Town of South Hadley
May 2021

Table 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 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 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 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 4: Structural Condition Binned Score

Lowest Score Resulting from Level 1, Level 2, and Level 3 Variable Assessment	Structural Condition Binned Score
0.81 - 1.00	1
0.61 - 0.80	2
0.11 - 0.60	3
0.01-0.10	4
0.0	5

Equation 1: Level 3 Condition Score

$$Score = 1.0 - (0.1 \times N)$$
$$N = number\ of\ variables\ from\ Table\ 3\ marked\ "Poor"$$

Aquatic Organism Passage Worksheet
Massachusetts Road-Stream Crossing Assessment
Town-Wide Road-Stream Crossing Assessments – Town of South Hadley
May 2021

Table 1: Component Scores for AOP Field Variables

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

Equation 1: Openness Measurement (feet)

$$Openness\ Measurement = \frac{Structure\ Cross\ Sectional\ Area}{Structure\ Length}$$

Equation 2: Openness Score (S_o), for openness measurement (x) in feet

$$S_o = (1 - e^{-5.7x})^{2.6316}$$

Equation 3: Height Score (S_h) for height measurement (x) in feet

$$S_h = min\left(\frac{1.1x^2}{4.84 + x^2}\right), 1)$$

Table 2: Weights associated with each variable in the component scoring algorithm

Parameter	Weight
Outlet Drop	0.161
Physical Barriers	0.135
Constriction	0.090
Inlet Grade	0.088
Water Depth	0.082
Water Velocity	0.080
Scour Pool	0.071
Substrate Matches Stream	0.070
Substrate Coverage	0.057
Openness	0.052
Height	0.045
Outlet Apron	0.037
Internal Structures	0.032

Table 3: Binned Aquatic Passability Score

Aquatic Passability Score	Descriptor	Binned Aquatic Passability Score
1.00	No Barrier	1
0.80 - 0.99	Insignificant Barrier	1
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

Table 4: Binned Ecological Integrity Score

Aquatic Index of Ecological Integrity (IEI) Value	Binned Ecological Integrity Score
0.0-0.3	1
0.31-0.5	2
0.51-0.7	3
0.71-0.9	4
0.91-1.0	5

Equation 4: Outlet Drop Score (S_{od}) for outlet drop measurement (x) in feet

$$S_{od} = 1 - \frac{1.029412x^2}{0.26470588 + x^2}$$

Equation 5: Aquatic Passability Score

$$Aquatic\ Passability\ Score = Minimum\ [Composite\ Score,\ Outlet\ Drop\ score]$$

Transportation Services Disruption Worksheet
Massachusetts Road-Stream Crossing Assessment
Town-Wide Road-Stream Crossing Assessments – Town of South Hadley
May 2021

Table 1: Transportation Disruption Component Scores

Disruption Rating	Road Classification (Highway Functional Classification)
1	Local Roads, Trails, Driveways
2	Major and Minor Collectors
3	Minor Arterials
4	Other Principal Arterials
5	Interstates, Freeways, and Expressways

Flood Impact Potential Worksheet
Massachusetts Road-Stream Crossing Assessment
Town-Wide Road-Stream Crossing Assessments – Town of South Hadley
May 2021

Equation 1: Stream Buffer Distance as a Function of Bankfull Width (for use where bankfull width available)

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

Table 1: Stream Buffer Distance as a Function of Crossing Structure Width and Degree of Constriction

(for use where bankfull width not available)

Crossing Structure Constriction Rating	Stream Buffer Distance (Substitute for Equation 8-1)
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

Table 2: Flood Impact Rating – Developed Area

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

Table 3: Flood Impact Rating – Upstream and Downstream Crossings

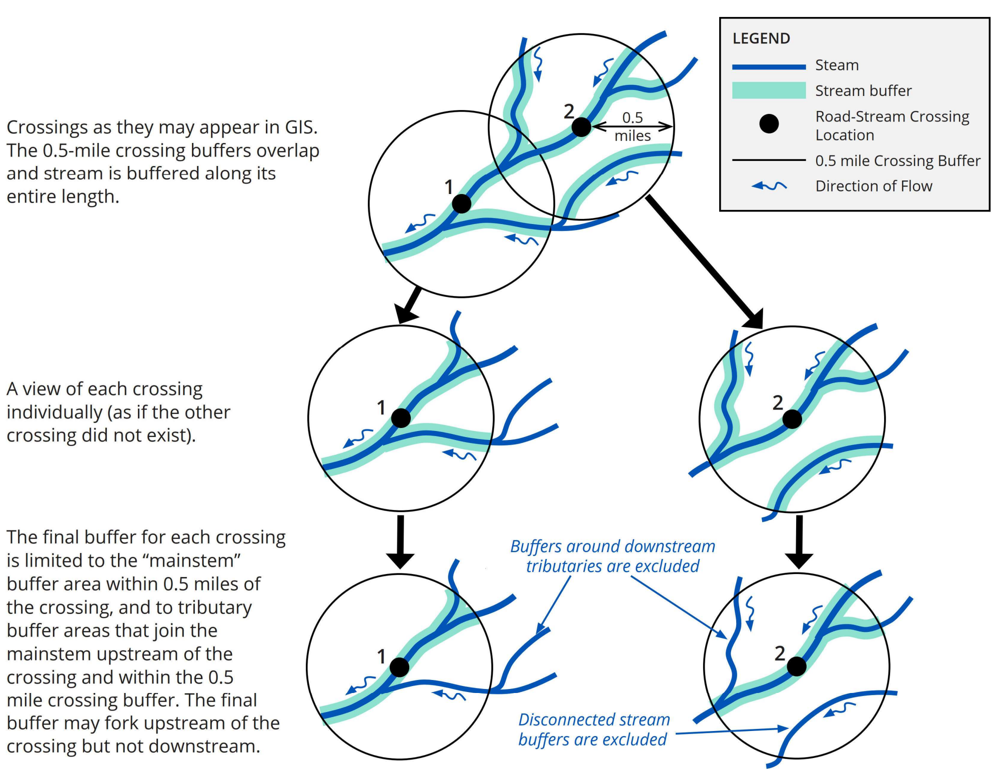
Flood Impact Rating	Number of Upstream and Downstream Crossings within Potential Flood Impact Area Buffer Polygon
1	0
2	--
3	1
4	--
5	>1

Note: -- indicates category not used

Table 4: Binned Flood Impact Potential Scores

Binned Flood Impact Potential Score	Sum of Component Flood Impact Ratings
1	1 – 2
2	3 – 4
3	5 – 6
4	7 – 8
5	9 – 10

Figure 1: Stream Crossing Buffer Diagram



Prioritization Worksheet
Massachusetts Road-Stream Crossing Assessment
Town-Wide Road-Stream Crossing Assessments – Town of South Hadley
May 2021

Equation 1: Crossing Failure Risk

$$Failure\ Risk = Probability\ of\ Failure\ \times\ Magnitude\ of\ the\ Impact\ of\ Failure$$

Equation 2: Impact Score

$$Impact\ Score\ = Maximum\begin{bmatrix} Binned\ Transportation\ Disruption\ Score, \\ Binned\ Flood\ Impact\ Potential\ Score \end{bmatrix}$$

Equation 3: Existing Hydraulic Risk Score

$$Existing\ Hydraulic\ Risk\ Score = Binned\ Existing\ Hydraulic\ Capacity\ Score\ \times\ Impact\ Score$$

Equation 4: Future Hydraulic Risk Score

$$Future\ Hydraulic\ Risk\ Score = Binned\ Future\ Hydraulic\ Capacity\ Score\ \times\ Impact\ Score$$

Equation 5: Geomorphic Risk Score

$$Geomorphic\ Risk\ Score = Binned\ Geomorphic\ Vulnerability\ Score\ \times\ Impact\ Score$$

Equation 6: Structural Risk Score

$$Structural\ Risk\ Score = Binned\ Structural\ Condition\ Score\ \times\ Impact\ Score$$

Equation 7: Crossing Risk Score

$$Crossing\ Risk\ Score = Maximum\begin{bmatrix} Existing\ Hydraulic\ Risk\ Score, \\ Climate\ Change\ Risk\ Score, \\ Geomorphic\ Risk\ Score, \\ Structural\ Risk\ Score \end{bmatrix}$$

Equation 8: Aquatic Passage Benefit Score

$$Aquatic\ Passage\ Benefit\ Score = Binned\ Aquatic\ Passability\ Score\ \times\ Binned\ Ecological\ Integrity\ Score$$

Equation 9: Crossing Priority Score

$$Crossing\ Priority\ Score = Maximum[Aquatic\ Passage\ Benefit\ Score, Crossing\ Risk\ Score] + Average[Aquatic\ Passage\ Benefit\ Score, Crossing\ Risk\ Score]$$

Table 1: Relative Priority Ratings

Crossing Priority Score (normalized)	Priority Rating
0.66 – 1.00	High
0.33 - 0.65	Medium
0.00 - 0.32	Low

Appendix D

Opinions of Probable Cost

ORDER OF MAGNITUDE OPINION OF CONSTRUCTION COST	DATE PREPARED:	4/14/2021	
PROJECT: Rt. 47/Hadley Street and Titan Pier Road Culvert Replacement	BASIS:		
LOCATION: South Hadley, MA	ESTIMATOR:	RLW	CHECKED BY: DD
DESCRIPTION: Road-Stream Crossing Replacement	JOB NO.	20170390.V20	

This is an order of magnitude cost estimate, as defined by the American Association of Cost Engineers, that is expected to be within -30 to +50 percent of the actual project cost. Fuss & O'Neill has no control over the cost of labor, materials, equipment or services furnished by others or market conditions. Fuss & O'Neill's opinion of probable Total Project Costs and Construction Cost are made on the basis of Fuss & O'Neill's experience and qualifications and represent Fuss & O'Neill's best judgment as an experienced and qualified professional engineer, familiar with the construction industry. Fuss & O'Neill cannot and does not guarantee that proposals, bids or actual Total Project or Construction Costs will not vary from opinions of probable cost prepared by Fuss & O'Neill.

ITEM DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL
EROSION AND SEDIMENT CONTROL	LS	1	$10,000.00	$10,000.00
REMOVE & DISPOSE OF ASPHALT PAVEMENT (assume 3") and base (assume 12")	SY	648	$20.00	$12,955.56
EARTH EXCAVATION (18 ft high embankment)	CY	2332	$32.00	$74,624.00
PAVING (AGGREGATE BASE, HOT MIX ASPHALT, AND TACK COAT	SY	648	$45.00	$29,150.00
PRECAST CONCRETE 3-SIDED STRUCTURE AND FOOTINGS (22 FT SPAN)	LF	125	$7,000.00	$875,000.00
CONCRETE FOOTINGS	CY	0	$1,200.00	$0.00
TEMPORARY SHORING AND EXCAVATION	LS	1	$125,000.00	$125,000.00
BRIDGE RAIL AND GUARDRAIL	LF	300	$40.00	$12,000.00
WATER CONTROL	LS	1	$75,000.00	$75,000.00
EXCAVATE AND REGRADE CHANNEL	SY	811	$10.00	$8,111.11
GRADING OF STREAMBANK	SY	378	$10.00	$3,777.78
STREAMBANK STABILIZATION AND RESTORATION	SY	378	$7.00	$2,644.44
		SUBTOTAL		$1,228,262.89
CONTRACTOR MOBILIZATION AND DEMOBILIZATION, TESTING, BONDS/INSURANCE	LS	10%	1	$122,826.29
		CONSTRUCTION SUBTOTAL		$1,351,089.18
DESIGN	LS		$100,000.00	$100,000.00
PERMITTING	LS		$50,000.00	$50,000.00
CONSTRUCTION ADMINISTRATION	LS		$75,000.00	$75,000.00
		SUBTOTAL		$1,576,089.18
		20% Contingency		$315,217.84
		TOTAL		$1,576,089.18
		(-30%)		$1,103,262.42
		(+50%)		$2,364,133.77

ORDER OF MAGNITUDE OPINION OF CONSTRUCTION COST	DATE PREPARED:	4/14/2021	
PROJECT: Hillside Avenue Culvert Replacement	BASIS:		
LOCATION: South Hadley, MA	ESTIMATOR:	RLW	CHECKED BY: DD
DESCRIPTION: Road-Stream Crossing Replacement	JOB NO.	20170390.V20	

This is an order of magnitude cost estimate, as defined by the American Association of Cost Engineers, that is expected to be within -30 to +50 percent of the actual project cost. Fuss & O'Neill has no control over the cost of labor, materials, equipment or services furnished by others or market conditions. Fuss & O'Neill's opinion of probable Total Project Costs and Construction Cost are made on the basis of Fuss & O'Neill's experience and qualifications and represent Fuss & O'Neill's best judgment as an experienced and qualified professional engineer, familiar with the construction industry. Fuss & O'Neill cannot and does not guarantee that proposals, bids or actual Total Project or Construction Costs will not vary from opinions of probable cost prepared by Fuss & O'Neill.

ITEM DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL
EROSION AND SEDIMENT CONTROL	LS	1	$20,000.00	$20,000.00
REMOVE & DISPOSE OF ASPHALT PAVEMENT (assume 3") and base (assume 12")	SY	336	$20.00	$6,711.11
EARTH EXCAVATION (22 ft high embankment)	CY	1230	$32.00	$39,371.85
PAVING (AGGREGATE BASE, HOT MIX ASPHALT, AND TACK COAT	SY	336	$45.00	$15,100.00
PRECAST CONCRETE 3-SIDED STRUCTURE (16 FT SPAN)	LF	60	$7,000.00	$420,000.00
CONCRETE FOOTINGS	CY	23	$1,200.00	$28,000.00
TEMPORARY SHORING AND EXCAVATION	LS	1	$50,000.00	$50,000.00
BRIDGE RAIL AND GUARDRAIL	LF	230	$40.00	$9,200.00
WATER CONTROL	LS	1	$50,000.00	$50,000.00
EXCAVATE AND REGRADE CHANNEL	SY	813	$10.00	$8,133.33
GRADING OF STREAMBANK	SY	1111	$10.00	$11,111.11
STREAMBANK STABILIZATION AND RESTORATION	SY	1111	$7.00	$7,777.78
		SUBTOTAL		$665,405.19
CONTRACTOR MOBILIZATION AND DEMOBILIZATION, TESTING, BONDS/INSURANCE	LS	10%	1	$66,540.52
		CONSTRUCTION SUBTOTAL		$731,945.70
DESIGN	LS		$70,000.00	$70,000.00
PERMITTING	LS		$50,000.00	$50,000.00
CONSTRUCTION ADMINISTRATION	LS		$50,000.00	$50,000.00
		SUBTOTAL		$901,945.70
		20% Contingency		$180,389.14
		TOTAL		$901,945.70
		(-30%)		$631,361.99
		(+50%)		$1,352,918.56

ORDER OF MAGNITUDE OPINION OF CONSTRUCTION COST	DATE PREPARED:	4/14/2021	
PROJECT: Brainerd Street Culvert Replacement	BASIS:		
LOCATION: South Hadley, MA	ESTIMATOR:	RLW	CHECKED BY: DD
DESCRIPTION: Road-Stream Crossing Replacement	JOB NO.	20170390.V20	

This is an order of magnitude cost estimate, as defined by the American Association of Cost Engineers, that is expected to be within -30 to +50 percent of the actual project cost. Fuss & O'Neill has no control over the cost of labor, materials, equipment or services furnished by others or market conditions. Fuss & O'Neill's opinion of probable Total Project Costs and Construction Cost are made on the basis of Fuss & O'Neill's experience and qualifications and represent Fuss & O'Neill's best judgment as an experienced and qualified professional engineer, familiar with the construction industry. Fuss & O'Neill cannot and does not guarantee that proposals, bids or actual Total Project or Construction Costs will not vary from opinions of probable cost prepared by Fuss & O'Neill.

ITEM DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL
EROSION AND SEDIMENT CONTROL	LS	1	$10,000.00	$10,000.00
REMOVE & DISPOSE OF ASPHALT PAVEMENT (assume 3") and base (assume 12")	SY	500	$20.00	$10,000.00
EARTH EXCAVATION (10 ft high embankment)	CY	1126	$32.00	$36,029.63
PAVING (AGGREGATE BASE, HOT MIX ASPHALT, AND TACK COAT	SY	500	$45.00	$22,500.00
PRECAST CONCRETE 3-SIDED STRUCTURE (12 FT SPAN)	LF	95	$4,000.00	$380,000.00
CONCRETE FOOTINGS	CY	37	$1,200.00	$44,333.33
TEMPORARY SHORING AND EXCAVATION	LS	1	$100,000.00	$100,000.00
BRIDGE RAIL AND GUARDRAIL	LF	275	$40.00	$11,000.00
WATER CONTROL	LS	1	$25,000.00	$25,000.00
EXCAVATE AND REGRADE CHANNEL	SY	556	$10.00	$5,555.56
GRADING OF STREAMBANK	SY	667	$10.00	$6,666.67
STREAMBANK STABILIZATION AND RESTORATION	SY	667	$7.00	$4,666.67
		SUBTOTAL		$655,751.85
CONTRACTOR MOBILIZATION AND DEMOBILIZATION, TESTING, BONDS/INSURANCE	LS	10%	1	$65,575.19
		CONSTRUCTION SUBTOTAL		$721,327.04
DESIGN	LS		$70,000.00	$70,000.00
PERMITTING	LS		$50,000.00	$50,000.00
CONSTRUCTION ADMINISTRATION	LS		$50,000.00	$50,000.00
		SUBTOTAL		$891,327.04
		20% Contingency		$178,265.41
		TOTAL		$891,327.04
		(-30%)		$623,928.93
		(+50%)		$1,336,990.56

ORDER OF MAGNITUDE OPINION OF CONSTRUCTION COST	DATE PREPARED:	4/14/2021	
PROJECT: Cedar Ridge, Lathrop Street, and Brainerd Street Culvert Replacements	BASIS:		
LOCATION: South Hadley, MA	ESTIMATOR:	RLW	CHECKED BY: DD
DESCRIPTION: Road-Stream Crossing Replacement	JOB NO.	20170390.V20	

This is an order of magnitude cost estimate, as defined by the American Association of Cost Engineers, that is expected to be within -30 to +50 percent of the actual project cost. Fuss & O'Neill has no control over the cost of labor, materials, equipment or services furnished by others or market conditions. Fuss & O'Neill's opinion of probable Total Project Costs and Construction Cost are made on the basis of Fuss & O'Neill's experience and qualifications and represent Fuss & O'Neill's best judgment as an experienced and qualified professional engineer, familiar with the construction industry. Fuss & O'Neill cannot and does not guarantee that proposals, bids or actual Total Project or Construction Costs will not vary from opinions of probable cost prepared by Fuss & O'Neill.

ITEM DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL
EROSION AND SEDIMENT CONTROL	LS	1	$10,000.00	$10,000.00
REMOVE & DISPOSE OF ASPHALT PAVEMENT (assume 3") and base (assume 12")	SY	1276	$20.00	$25,511.11
EARTH EXCAVATION (4 ft high embankment on average)	CY	1701	$32.00	$54,423.70
PAVING (AGGREGATE BASE, HOT MIX ASPHALT, AND TACK COAT	SY	1276	$45.00	$57,400.00
PRECAST CONCRETE 3-SIDED STRUCTURE (9 FT SPANS)	LF	200	$3,000.00	$600,000.00
CONCRETE FOOTINGS	CY	78	$600.00	$46,666.67
TEMPORARY SHORING AND EXCAVATION	LS	1	$75,000.00	$75,000.00
BRIDGE RAIL AND GUARDRAIL	LF	375	$40.00	$15,000.00
WATER CONTROL	LS	1	$50,000.00	$50,000.00
EXCAVATE AND REGRADE CHANNEL	SY	797	$10.00	$7,966.67
GRADING OF STREAMBANK	SY	1644	$10.00	$16,444.44
STREAMBANK STABILIZATION AND RESTORATION	SY	1644	$7.00	$11,511.11
		SUBTOTAL		$969,923.70
CONTRACTOR MOBILIZATION AND DEMOBILIZATION, TESTING, BONDS/INSURANCE	LS	10%	1	$96,992.37
		CONSTRUCTION SUBTOTAL		$1,066,916.07
DESIGN	LS		$50,000.00	$50,000.00
PERMITTING	LS		$50,000.00	$50,000.00
CONSTRUCTION ADMINISTRATION	LS		$75,000.00	$75,000.00
		SUBTOTAL		$1,241,916.07
		20% Contingency		$248,383.21
		TOTAL		$1,241,916.07
		(-30%)		$869,341.25
		(+50%)		$1,862,874.11

ORDER OF MAGNITUDE OPINION OF CONSTRUCTION COST	DATE PREPARED:	4/14/2021	
PROJECT: Willimansett Street Culvert Replacement	BASIS:		
LOCATION: South Hadley, MA	ESTIMATOR:	RLW	CHECKED BY: DD
DESCRIPTION: Road-Stream Crossing Replacement	JOB NO.	20170390.V20	

This is an order of magnitude cost estimate, as defined by the American Association of Cost Engineers, that is expected to be within -30 to +50 percent of the actual project cost. Fuss & O'Neill has no control over the cost of labor, materials, equipment or services furnished by others or market conditions. Fuss & O'Neill's opinion of probable Total Project Costs and Construction Cost are made on the basis of Fuss & O'Neill's experience and qualifications and represent Fuss & O'Neill's best judgment as an experienced and qualified professional engineer, familiar with the construction industry. Fuss & O'Neill cannot and does not guarantee that proposals, bids or actual Total Project or Construction Costs will not vary from opinions of probable cost prepared by Fuss & O'Neill.

ITEM DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL
EROSION AND SEDIMENT CONTROL	LS	1	$20,000.00	$20,000.00
REMOVE & DISPOSE OF ASPHALT PAVEMENT (assume 3") and base (assume 12")	SY	959	$20.00	$19,177.78
EARTH EXCAVATION (12 ft high embankment)	CY	1918	$32.00	$61,368.89
PAVING (AGGREGATE BASE, HOT MIX ASPHALT, AND TACK COAT	SY	959	$45.00	$43,150.00
PRECAST CONCRETE 3-SIDED STRUCTURE AND FOOTINGS (26 FT SPAN)	LF	80	$8,000.00	$640,000.00
CONCRETE FOOTINGS	CY	0	$1,200.00	$0.00
TEMPORARY SHORING AND EXCAVATION	LS	1	$100,000.00	$100,000.00
BRIDGE RAIL AND GUARDRAIL	LF	190	$40.00	$7,600.00
WATER CONTROL	LS	1	$100,000.00	$100,000.00
EXCAVATE AND REGRADE CHANNEL	SY	833	$10.00	$8,333.33
GRADING OF STREAMBANK	SY	822	$10.00	$8,222.22
STREAMBANK STABILIZATION AND RESTORATION	SY	822	$7.00	$5,755.56
		SUBTOTAL		$1,013,607.78
CONTRACTOR MOBILIZATION AND DEMOBILIZATION, TESTING, BONDS/INSURANCE	LS	10%	1	$101,360.78
		CONSTRUCTION SUBTOTAL		$1,114,968.56
DESIGN	LS		$100,000.00	$100,000.00
PERMITTING	LS		$50,000.00	$50,000.00
CONSTRUCTION ADMINISTRATION	LS		$75,000.00	$75,000.00
		SUBTOTAL		$1,339,968.56
		20% Contingency		$267,993.71
		TOTAL		$1,339,968.56
		(-30%)		$937,977.99
		(+50%)		$2,009,952.83

ORDER OF MAGNITUDE OPINION OF CONSTRUCTION COST	DATE PREPARED:	4/14/2021	
PROJECT: Westbrook Road Culvert Replacement	BASIS:		
LOCATION: South Hadley, MA	ESTIMATOR:	RLW	CHECKED BY: DD
DESCRIPTION: Road-Stream Crossing Replacement	JOB NO.	20170390.V20	

This is an order of magnitude cost estimate, as defined by the American Association of Cost Engineers, that is expected to be within -30 to +50 percent of the actual project cost. Fuss & O'Neill has no control over the cost of labor, materials, equipment or services furnished by others or market conditions. Fuss & O'Neill's opinion of probable Total Project Costs and Construction Cost are made on the basis of Fuss & O'Neill's experience and qualifications and represent Fuss & O'Neill's best judgment as an experienced and qualified professional engineer, familiar with the construction industry. Fuss & O'Neill cannot and does not guarantee that proposals, bids or actual Total Project or Construction Costs will not vary from opinions of probable cost prepared by Fuss & O'Neill.

ITEM DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL
EROSION AND SEDIMENT CONTROL	LS	1	$10,000.00	$10,000.00
REMOVE & DISPOSE OF ASPHALT PAVEMENT (assume 3") and base (assume 12")	SY	296	$20.00	$5,911.11
EARTH EXCAVATION (18 ft high embankment)	CY	887	$32.00	$28,373.33
PAVING (AGGREGATE BASE, HOT MIX ASPHALT, AND TACK COAT	SY	296	$45.00	$13,300.00
PRECAST CONCRETE 3-SIDED STRUCTURE (8 FT SPAN)	LF	45	$4,000.00	$180,000.00
CONCRETE FOOTINGS	CY	18	$1,200.00	$21,000.00
TEMPORARY SHORING AND EXCAVATION	LS	1	$50,000.00	$50,000.00
BRIDGE RAIL AND GUARDRAIL	LF	100	$40.00	$4,000.00
WATER CONTROL	LS	1	$50,000.00	$50,000.00
EXCAVATE AND REGRADE CHANNEL	SY	208	$10.00	$2,077.78
GRADING OF STREAMBANK	SY	422	$10.00	$4,222.22
STREAMBANK STABILIZATION AND RESTORATION	SY	422	$7.00	$2,955.56
		SUBTOTAL		$371,840.00
CONTRACTOR MOBILIZATION AND DEMOBILIZATION, TESTING, BONDS/INSURANCE	LS	10%	1	$37,184.00
		CONSTRUCTION SUBTOTAL		$409,024.00
DESIGN	LS		$50,000.00	$50,000.00
PERMITTING	LS		$50,000.00	$50,000.00
CONSTRUCTION ADMINISTRATION	LS		$50,000.00	$50,000.00
		SUBTOTAL		$559,024.00
		20% Contingency		$111,804.80
		TOTAL		$559,024.00
		(-30%)		$391,316.80
		(+50%)		$838,536.00

ORDER OF MAGNITUDE OPINION OF CONSTRUCTION COST	DATE PREPARED:	4/14/2021		
PROJECT: River Road Culvert Replacement	BASIS:			
LOCATION: South Hadley, MA	ESTIMATOR:	RLW	CHECKED BY: DD	
DESCRIPTION: Road-Stream Crossing Replacement	JOB NO.	20170390.V20		

This is an order of magnitude cost estimate, as defined by the American Association of Cost Engineers, that is expected to be within -30 to +50 percent of the actual project cost. Fuss & O'Neill has no control over the cost of labor, materials, equipment or services furnished by others or market conditions. Fuss & O'Neill's opinion of probable Total Project Costs and Construction Cost are made on the basis of Fuss & O'Neill's experience and qualifications and represent Fuss & O'Neill's best judgment as an experienced and qualified professional engineer, familiar with the construction industry. Fuss & O'Neill cannot and does not guarantee that proposals, bids or actual Total Project or Construction Costs will not vary from opinions of probable cost prepared by Fuss & O'Neill.

ITEM DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL
EROSION AND SEDIMENT CONTROL	LS	1	$10,000.00	$10,000.00
REMOVE & DISPOSE OF ASPHALT PAVEMENT (assume 3") and base (assume 12")	SY	289	$20.00	$5,777.78
EARTH EXCAVATION (6 ft high embankment)	CY	289	$32.00	$9,244.44
PAVING (AGGREGATE BASE, HOT MIX ASPHALT, AND TACK COAT	SY	289	$45.00	$13,000.00
PRECAST CONCRETE 3-SIDED STRUCTURE (18 FT SPAN)	LF	53	$8,000.00	$424,000.00
CONCRETE FOOTINGS	CY	21	$1,200.00	$24,733.33
TEMPORARY SHORING AND EXCAVATION	LS	1	$100,000.00	$100,000.00
BRIDGE RAIL AND GUARDRAIL	LF	190	$40.00	$7,600.00
WATER CONTROL	LS	1	$100,000.00	$100,000.00
EXCAVATE AND REGRADE CHANNEL	SY	492	$10.00	$4,922.22
GRADING OF STREAMBANK	SY	444	$10.00	$4,444.44
STREAMBANK STABILIZATION AND RESTORATION	SY	444	$7.00	$3,111.11
		SUBTOTAL		$706,833.33
CONTRACTOR MOBILIZATION AND DEMOBILIZATION, TESTING, BONDS/INSURANCE	LS	10%	1	$70,683.33
		CONSTRUCTION SUBTOTAL		$777,516.67
DESIGN	LS		$75,000.00	$75,000.00
PERMITTING	LS		$50,000.00	$50,000.00
CONSTRUCTION ADMINISTRATION	LS		$50,000.00	$50,000.00
		SUBTOTAL		$952,516.67
		20% Contingency		$190,503.33
		TOTAL		$952,516.67
		(-30%)		$666,761.67
		(+50%)		$1,428,775.00

ORDER OF MAGNITUDE OPINION OF CONSTRUCTION COST	DATE PREPARED:	4/14/2021	
PROJECT: Pearl Street Culvert Replacement	BASIS:		
LOCATION: South Hadley, MA	ESTIMATOR:	RLW	CHECKED BY: DD
DESCRIPTION: Road-Stream Crossing Replacement	JOB NO.	20170390.V20	

This is an order of magnitude cost estimate, as defined by the American Association of Cost Engineers, that is expected to be within -30 to +50 percent of the actual project cost. Fuss & O'Neill has no control over the cost of labor, materials, equipment or services furnished by others or market conditions. Fuss & O'Neill's opinion of probable Total Project Costs and Construction Cost are made on the basis of Fuss & O'Neill's experience and qualifications and represent Fuss & O'Neill's best judgment as an experienced and qualified professional engineer, familiar with the construction industry. Fuss & O'Neill cannot and does not guarantee that proposals, bids or actual Total Project or Construction Costs will not vary from opinions of probable cost prepared by Fuss & O'Neill.

ITEM DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL
EROSION AND SEDIMENT CONTROL	LS	1	$20,000.00	$20,000.00
REMOVE & DISPOSE OF ASPHALT PAVEMENT (assume 3") and base (assume 12")	SY	339	$20.00	$6,777.78
EARTH EXCAVATION (9 ft high embankment)	CY	508	$32.00	$16,266.67
PAVING (AGGREGATE BASE, HOT MIX ASPHALT, AND TACK COAT	SY	339	$45.00	$15,250.00
PRECAST CONCRETE 3-SIDED STRUCTURE (24 FT SPAN) AND FOOTINGS	LF	30	$11,000.00	$330,000.00
CONCRETE FOOTINGS	CY	0	$1,200.00	$0.00
TEMPORARY SHORING AND EXCAVATION	LS	1	$100,000.00	$100,000.00
BRIDGE RAIL AND GUARDRAIL	LF	104	$40.00	$4,160.00
WATER CONTROL	LS	1	$100,000.00	$100,000.00
EXCAVATE AND REGRADE CHANNEL	SY	667	$10.00	$6,666.67
GRADING OF STREAMBANK	SY	1011	$10.00	$10,111.11
STREAMBANK STABILIZATION AND RESTORATION	SY	1011	$7.00	$7,077.78
		SUBTOTAL		$616,310.00
CONTRACTOR MOBILIZATION AND DEMOBILIZATION, TESTING, BONDS/INSURANCE	LS	10%	1	$61,631.00
		CONSTRUCTION SUBTOTAL		$677,941.00
DESIGN	LS		$100,000.00	$100,000.00
PERMITTING	LS		$50,000.00	$50,000.00
CONSTRUCTION ADMINISTRATION	LS		$75,000.00	$75,000.00
		SUBTOTAL		$902,941.00
		20% Contingency		$180,588.20
		TOTAL		$902,941.00
		(-30%)		$632,058.70
		(+50%)		$1,354,411.50