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Wetlands Program Guidance

Meeting the Massachusetts Stream Crossing Standards to the Maximum Extent Practicable

2026



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Preface

In September 2020, the Massachusetts Culverts and Small Bridges Working Group issued a report as directed by Section 102 of the 2019 General Appropriations Act for Senator Adam G. Hinds and Massachusetts Legislature titled Recommendations for [Improving the Efficiency of Culvert and Small Bridge Replacement Projects](#). In response to recommendations of the report, MassDEP is working with the United States Geological Survey and UMass Amherst to develop an easy-to-use web-based tool, including a statewide hydraulic model, and a guidance document to streamline the regulatory process and maximize improvement in resiliency, aquatic organism passage, and habitat connectivity without exacerbating downstream flooding, property damage or other impacts. MassDEP's goal in creating such a tool and guidance is to develop a companion regulatory presumption if certain criteria are met to make permitting of river and stream crossing projects easier.

Under the Wetlands Protection Act regulations at 310 CMR 10.53 (8), projects that propose to replace culverts and/or bridges must meet the [Stream Crossing Standards](#) (Crossing Standards) to the maximum extent practicable provided they consider 12 criteria such as the potential for downstream flooding, the potential for erosion and head-cutting, engineering constraints, and cost.

This provision of the regulations is referred to as a “limited project,” which provides the Issuing Authority (conservation commission or MassDEP) discretion in applying the Crossing Standards. This will not change. However, since many stream crossing replacement projects determine their design based on “cost of replacement,” a presumption has been developed to further facilitate permitting of these projects. With certain exceptions that may arise from site specific circumstances, the design alternative is presumed to meet the Crossing Standards to the maximum extent practicable when the projected cost of the project complies with the Guidance document herein and the cost exceedance above the baseline design goes towards improving aquatic organism passage.

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1.0 Summary

In 2006, the River and Stream Continuity Partnership consisting of UMass Amherst, the Massachusetts Division of Ecological Restoration, American Rivers, and The Nature Conservancy developed the [*Massachusetts River and Stream Crossing Standards*](#) (Crossing Standards) to provide guidance on bridge and culvert designs that would facilitate the movement of fish and wildlife beneath roads and railroads. Recognizing that the Crossing Standards were relevant to several of the “Interests” protected by the Massachusetts Wetlands Protection Act (WPA),¹ in 2014 the Massachusetts Department of Environmental Protection (MassDEP) incorporated the standards into the WPA regulations (Regulations). The Crossing Standards are now required for all new, permanent crossings of rivers and streams. It was recognized that, in some cases, it might be impossible or infeasible to fully meet those standards when replacing an existing crossing. As a result, MassDEP included language in the Regulations stating that replacement crossings must meet the Crossing Standards “to the maximum extent practicable.” Bridge replacement projects that are exempt from review under the WPA must still meet Massachusetts Water Quality Standards administered by MassDEP; these standards also require replacement crossings to meet the Crossing Standards to the maximum extent practicable (MEP).

This document provides guidance for conservation commissions, conservation agents, MassDEP staff, potential applicants, and environmental consultants, on to how to apply the concept of maximum extent practicable during the design and permitting of replacement stream crossings. It provides information on evaluating site conditions and considering cost as a factor in determining if meeting the Crossing Standards is practicable and provides conceptual design options for maximizing aquatic organism passage in circumstances where it is not practicable to fully meet the Crossing Standards. Wetlands Protection Act regulations that require replacement crossings to meet the Crossing Standards to the maximum extent practicable help protect the fisheries and wildlife habitat “Interests” of the WPA. In addition, this guidance recommends baseline design criteria (see Section 4.2) for road-stream crossings to enhance the resiliency of transportation infrastructure and ensure that culverts and bridges are designed and constructed in ways that further the flood control and storm damage prevention “Interests” of the WPA. Those criteria are used to define baseline designs against which the costs of full compliance with Crossing Standards are compared to determine whether meeting those standards is practicable. Meeting the flooding and storm damage interests – and thus increased storm resiliency – will increase the likelihood that crossings will withstand future storms and avoid having to employ limited resources for repeat reconstruction projects and mitigation of consequential flooding that could be avoided.

Sometimes it is just not practicable to replace a crossing with one that fully meets the Crossing Standards. Often this is not simply a matter of what is possible but how much it will cost. Section 3.0

¹ The eight interests of the WPA are: 1) protection of public and private water supply, 2) protection of ground water supply, 3) flood control, 4) storm damage prevention, 5) prevention of pollution, 6) protection of land containing shellfish, 7) protection of fisheries, and 8) protection of wildlife habitat.

discusses various physical, legal and regulatory constraints4.04.07 discusses financial considerations, and how the concept of maximum extent practicable accounts for the need to balance costs with ecological benefits.

Recognizing that the cost of meeting the Crossing Standards is a major obstacle for implementing culvert replacement projects, one of the most important considerations for evaluating maximum extent practicable is the balance between cost and ecological benefits. We begin with the assumption that if significant ecological benefits are likely to be achieved by meeting the Crossing Standards, then a substantial increase in replacement costs, beyond what is needed to meet the baseline design can be justified. The question then becomes how much increased cost is justified before that cost is no longer considered “practicable?” In this guidance, we propose that cost thresholds above baseline for defining maximum extent practicable should be based on 1) habitat quality and 2) the increase in aquatic connectivity likely to be achieved by meeting the Crossing Standards (connectivity restoration potential). How crossings and stream segments are classified by habitat quality and connectivity restoration potential is discussed in Section 4.1. Cost thresholds can be found in Section 4.3, Table 2.

Section 5.0 discusses design elements that can be used to maximize aquatic organism passage during crossing replacement when full compliance with the Crossing Standards is not practicable. These include:

- Reducing velocity and ensuring adequate water depths
- Construction of low-flow channels
- Stabilizing the streambed and grade control structures
- Use of log and rock weirs and cross vanes
- Preventing erosion and scour
- Upsizing substrate material
- Protecting upstream wetlands

Section 6.0 provides guidance on Notice of Intent submittals and the review of proposed crossing replacements. When reviewing proposed crossing replacement projects that seek to use maximum extent practical rather than meeting the Crossing Standards, it is important to keep in mind that proposing to replace a crossing with an ‘in-kind’ structure is not sufficient to demonstrate maximum extent practicable. To demonstrate maximum extent practicable, the Notice of Intent should include descriptive information and the estimated cost for 1) a baseline design (see Section 4.2) and 2) a fully developed proposed design that meets the MEP recommendations in this guidance document (see Section 4.3) including the appropriate cost factor from Table 2.

Consistent with other limited projects, in rare cases when a project cannot meet the maximum extent practicable cost factor or the baseline design recommendations, the Issuing Authority (conservation commission or MassDEP) may issue an Order of Conditions and impose such conditions as will contribute to Interests identified in the WPA. Issuing Authorities should take into account an applicant’s

ability to pay based not on the specific finances of the applicant but considering the financial capability reasonably expected for that type of applicant, be it an individual homeowner, home builder, small business owner, large commercial developer, or a municipality. While the Issuing Authority may take into account an applicant's ability to pay, it is recommended that, at a minimum, crossing replacements should meet baseline design criteria (see Section 4.2) and aquatic organism passage should be addressed to the extent that it is practical (see Section 5.0).

Whether a proposed crossing replacement fully meets the Crossing Standards or meets those standards to the maximum extent practicable, appropriate site assessment and engineering are important for ensuring that structures are sized and designed to avoid downstream flooding, achieve desired bed elevations, avoid scour, and provide adequate stability for stream channels, bedforms, footings and abutments. This is especially important for those limited projects that cannot meet the maximum extent practicable cost factor and the baseline design recommendations.

There are an estimated 25,000-30,000 road stream crossings in Massachusetts. Along with legacy dams scattered across the state, stream crossings are fragmenting our river and stream networks in ways that undermine their ecological integrity and ability to support healthy populations of fish, salamanders, turtles, crayfish, and other aquatic or semi-aquatic organisms. Climate change that is threatening populations of cold-water and other aquatic species, also threatens to undermine our transportation infrastructure. Legacy culverts need to be replaced with structures that can better accommodate the extreme storm and flood events that are projected to occur with increasing frequency due to climate change. At a minimum, all crossing replacements should be able to pass design floods for the road classes where they occur (see Table 1). Where there are opportunities to restore aquatic connectivity, especially for high-quality habitat, we need to design and construct new and replacement crossings to meet the Crossing Standards to the maximum extent practicable.

2.0 Introduction

In 2004, the River and Stream Continuity Partnership released its first edition of the *Massachusetts River and Stream Crossing Standards* (Crossing Standards). The Partnership – University of Massachusetts Amherst, MA Division of Ecological Restoration, American Rivers, and The Nature Conservancy – developed the Crossing Standards to provide guidance on bridge and culvert designs that would facilitate the movement of fish and wildlife beneath roads and railroads. The Crossing Standards were revised in March 2011, and a minor error was corrected in 2012.²

² Massachusetts River and Stream Crossing Standards. 2011 (corrected in 2012). River and Stream Continuity Partnership, 27 pp.

Recognizing that the Crossing Standards³ were relevant to several of the “Interests” protected by the Massachusetts Wetlands Protection Act (WPA), the Massachusetts Department of Environmental Protection (MassDEP) in 2014 incorporated the standards into the WPA regulations. The Crossing Standards are now required for all new, permanent crossings of rivers and streams. It was recognized that, in some cases, it might be impossible or infeasible to fully meet those standards when replacing an existing crossing. As a result, MassDEP included language in the Regulations stating that replacement crossings must meet the Crossing Standards “to the maximum extent practicable” (310 CMR 10.53(8)(a)).⁴ The Regulations included a list of stream features and site conditions that should be evaluated when considering whether a crossing replacement must fully comply with the Crossing Standards or only comply to the maximum extent practicable (see Section 6.0). However, it has become clear that additional guidance is needed for both potential applicants and Issuing Authorities as to how to apply the concept of maximum extent practicable during project review and permitting.

This guidance document is based on conclusions from the Culvert and Small Bridge Work Group⁵ and provides information for evaluating site conditions and considering cost as a factor in determining if meeting the Crossing Standards is practicable and provides conceptual design options for maximizing aquatic organism passage in circumstances where it is not practicable to fully meet the Crossing Standards. It is primarily intended for conservation commissions, conservation agents, MassDEP staff, potential applicants for Orders of Conditions under the WPA, and environmental consultants that advise applicants and/or conservation commissions.

Wetlands Protection Act regulations that require replacement crossings to meet the Crossing Standards to the maximum extent practicable help protect the fisheries and wildlife habitat “Interests” of the WPA. In addition, this guidance recommends baseline design criteria (see Section 4.2) for road-stream crossings to enhance the resiliency of transportation infrastructure and ensure that culverts and bridges are designed and constructed in ways that further the flood control and storm damage prevention “Interests” of the WPA. Where cost is the primary factor in considering whether meeting the Crossing Standards is practicable, it is worthwhile to consider that local intense storms have in recent years caused numerous crossing failures in towns across Massachusetts. Given that climate change is expected to produce increasing numbers of intense storms, as well as storms of higher intensity in the future, it is recommended that culvert replacement projects meet the Crossing Standards whenever

³ The Crossing Standards include General Standards, intended to facilitate the passage of fish and other aquatic organisms, and Optimal Standards addressing the needs of both aquatic organisms and terrestrial wildlife. References to the Crossing Standards in WPA regulations relate only to the General Standards.

⁴ References to meeting the Crossing Standards “to the maximum extent practicable” are also included in 310 CMR 10.24(10), 10.35(6)(a), 10.54(4)(6), and 10.56(4)(a).

⁵ Massachusetts Culverts and Small Bridges Working Group issued a report as directed by Section 102 of the 2019 General Appropriations Act for Senator Adam G. Hinds and Massachusetts Legislature titled *Recommendations for Improving the Efficiency of Culvert and Small Bridge Replacement Projects*.

possible to avoid adverse impacts affecting public safety, transportation infrastructure, and the ecological integrity of river and stream ecosystems.

2.1 Applicability & Limited Project Status

This guidance document addresses regulatory requirements for replacing road-stream crossings. Road-stream crossings subject to regulation include culverts and bridges on roads, highways, railroads, driveways, and bike and pedestrian paths that cross jurisdictional streams. A stream, as defined in the WPA regulations, is “...a body of running water, including brooks and creeks, which moves in a definite channel in the ground due to

a hydraulic gradient...”⁶

The Crossing Standards were developed “specifically for freshwater, non-tidal rivers and streams and may not be appropriate for coastal waterways.” They were intended as conceptual performance standards to facilitate fish and wildlife movement and maintain river and stream continuity. In addition to tidally influenced crossings, the standards are also not intended for ditches (unless they are modified streams), storm water management systems, and wetland crossings (where there is no defined stream channel).⁷

This guidance does not apply to:

- Crossings on tidal streams and rivers
- Stormwater conveyances: non-jurisdictional stormwater management systems under the WPA
- Ditches (unless they are modified streams)
- Wetland crossings where no defined stream channel exists
- Culvert extensions, although such projects should avoid the creation of outlet drops and other physical barriers to aquatic organism passage
- Superstructure replacements, where bridge abutments are deemed by a registered professional engineer to not require replacement

⁶ The full definition from 310 CMR 10.04 is “Stream means a body of running water, including brooks and creeks, which moves in a definite channel in the ground due to a hydraulic gradient, and which flows within, into or out of an Area Subject to Protection under M.G.L. c. 131, § 40. A portion of a stream may flow through a culvert or beneath a bridge. Such a body of running water which does not flow throughout the year (*i.e.*, which is intermittent) is a stream except for that portion upgradient of all bogs, swamps, wet meadows and marshes.”

⁷ In some cases, the presence of a wetland and absence of a defined channel upstream of a crossing may be the result of water being impounded by the crossing itself. In these cases, use of the Crossing Standards would be appropriate.

The Crossing Standards may not be appropriate for low-flow, sand-bedded streams found on Cape Cod and other regions. These streams may be tidally influenced (therefore, not covered under this guidance), but some are non-tidal. Many of these streams have a long history of management (e.g., dredging and water controls) and channel widths are, to some degree, artificial. Crossing structures designed to span 1.2 times channel width are at risk of creating sand deltas and areas of shallow water, conditions that can block the movement of fish, including migratory (diadromous) species such as river herring. Applicants who are proposing crossings on these types of streams, and Issuing Authorities that will be reviewing these applications, should consult with the MA Division of Marine Fisheries on appropriate designs for these stream crossings.

Replacement projects that are unable to meet all the recommendations outlined in this guidance may, at the discretion of the Issuing Authority, be approved under the limited project provisions of the Regulations. It is important to note that even low volume roads can have big impacts on the ecological integrity of streams and rivers. If a limited project is unable to meet the recommendations in the guidance for MEP, applicants should still make every practical effort to improve aquatic connectivity.

2.2 The Massachusetts River and Stream Crossing Standards (General Standards)

The Crossing Standards are conceptual performance standards to facilitate fish and wildlife movement and maintain river and stream continuity and are not meant to be a substitute for proper design and engineering to address hydraulic capacity (ability to pass specific storm flows), safety, and stability of structures and embankments.

The Crossing Standards are summarized below. A copy of the Crossing Standards can be downloaded from the [mass.gov website](https://www.mass.gov).

General Standards

1. Spans (bridges, 3-sided box culverts, open-bottom culverts or arches) that preserve the natural stream channel are strongly preferred.
2. Culverts should have open bottoms or be embedded below the stream bed:
 - a minimum of 2 feet for all culverts
 - a minimum of 2 feet and at least 25 percent of the diameter for round pipe culverts
 - When substrate material used to embed a culvert includes components >15 inches in diameter, embedment depths should be at least twice the D84 (particle width larger than 84% of particles) of the substrate material
3. Crossings should span the channel width (a minimum of 1.2 times the bankfull width). Bankfull width is the width of the channel at bankfull elevation, the elevation at which water fills the channel just before it spills out into the floodplain.
4. Substrate within embedded or open bottom structures should have characteristics (size, shape) comparable to the substrate within the natural channel. Comparable in this case means within the range of variability of characteristics found in the natural channel.

5. Crossing structures should be designed with appropriate bed forms and streambed characteristics so that water depths and velocities within the crossing are comparable to those found in the natural channel at a variety of flows.
6. Crossing structures should have an openness greater than or equal to 0.82 feet (0.25 meters). Openness is the cross-sectional area of the structure opening (excluding those portions of the structure occupied by substrate or persistent water) divided by structure length (measured as a straight line from midpoint of the inlet to the midpoint of the outlet).
7. Banks should be present on each side of the stream matching the horizontal cross-sectional profile of the existing stream and banks

Perennial streams and rivers are important as habitat and/or movement corridors for fish and wildlife. Many intermittent streams serve as seasonal habitat for fish (especially brook trout) and stream salamanders (two-lined, dusky and spring salamanders). Therefore, it is not appropriate to dismiss intermittent streams as unimportant for fish and wildlife movement. However, these standards are not intended for channels that lack habitat for fish or wildlife and do not serve as movement corridors needed to access appropriate habitat. That said, it can be difficult to determine whether any particular intermittent stream is important for fish and wildlife passage. Unless compelling evidence indicates otherwise, intermittent streams should be assumed to have value for fish and wildlife passage.⁸

Individuals involved in crossing design and construction, and the permitting of road-stream crossings, are strongly encouraged to read the Crossing Standards document. It contains detailed explanations for each of the crossing standards listed above, as well as a list of important considerations when applying the standards.

2.3 Other benefits of meeting the crossing standards

The Crossing Standards were specifically developed to enhance aquatic connectivity and facilitate the movement of woody debris and substrate, which maintain downstream habitats and stream stability. Their larger openings are more efficient than traditional culverts at passing woody debris (the branches and trunks of trees) and less likely to clog from accumulated debris. Accumulated debris at the inlet can result in water overtopping the road and is a common cause of culvert failure. Overtopping can also occur when culverts are not blocked but are undersized and unable to pass enough water to prevent it from backing up and eventually either flowing over the road surface or piping through the road fill.

Undersized crossings concentrate water during high flows, increasing water velocities and erosive power that can lead to scour. Scour, particularly at the crossing outlet, can undermine footings, aprons, adjacent banks, and other structures. Both scour and overtopping can cause washouts. Washouts and overtopping typically result in road closures and can also cause property damage both upstream and downstream of the crossing. In some rare instances, culvert failures have cost lives. Crossing structures

⁸ Language in this paragraph was adapted from the Massachusetts River and Stream Crossing Standards, River and Stream Continuity Partnership, 2011.

built to Crossing Standards generally are more durable than standard culverts and have longer lifetimes. The shorter lifespan of traditional culverts, increased maintenance, the necessity of replacing failed crossings, and the property damage caused by crossing failures often negate the initial cost savings achieved by constructing undersized crossing structures. In other words, the near-term investment to meet Crossing Standards will decrease long term costs associated with storm damage.

Climate change has already caused rain events to be more severe, and severe storm events more frequent. Forecasts suggest that this will only get worse in the foreseeable future. It is difficult to determine how large structures will need to be to handle future flood events. However, replacing undersized culverts and bridges with crossings that meet the Crossing Standards will improve resiliency and better protect both infrastructure and the environment.

2.4 Fully meeting the crossing standards is not always practicable

Sometimes it is just not practicable to replace a crossing with one that fully meets the Crossing Standards. Often this is not simply a matter of what is possible, but how much it will cost. Sections 3.0 and 4.0 will discuss some of the constraints that can make it impracticable to fully meet the Crossing Standards during culvert or bridge replacement. Section 3.0 discusses various physical, legal and regulatory constraints, such as property ownership, associated utilities, adjacent buildings, other roads and driveways, upstream wetlands, potential for downstream flooding, and potential for stream instability and head cutting. Section 4.0 discusses financial considerations, and how the concept of maximum extent practicable can take into account the need to balance costs with ecological benefits. Section 5.0 discusses design elements that can be used to maximize aquatic organism passage during crossing replacement when full compliance with the Crossing Standards is not practicable.

3.0 Site Constraints

Site conditions can make it difficult or impossible to meet the Crossing Standards. Some of these conditions will be apparent when evaluating a replacement project and others may surface during the design or construction phases. In general, it is best to evaluate site conditions as early as possible during project scoping before progressing with design development. Constraints may result in yes/no scenarios (for example, can land rights be obtained or an adjacent structure demolished to meet Crossing Standards?). More often they result in cost increases that, even when significant, should be evaluated against the ecological benefits of meeting the standards (see Section 4.0). Below are some common examples of physical constraints that may be encountered.

3.1 Utilities

Existing and proposed general utilities, oriented through the culvert or along the existing roadway, could possibly be re-routed, but typically this requires coordination with utility companies, temporary or

permanent relocations, temporary support, and/or temporary connections. However, utilities that are buried or part of a gravity system can introduce significant constraints. Gravity systems, such as sewer or drainage structures require a specific gradient to work properly. Pump stations, siphon systems, or force mains can be included if gradients are affected, but require additional infrastructure, a larger footprint, and equipment. Buried utilities can be difficult to locate and re-route, especially if they have a concrete encasement. The extent of the constraint will vary depending on the project.

3.2 Adjacent structures and right-of-way constraints

Adjacent structures can include buildings, roadways, and miscellaneous foundations. In more urban areas, these may include a building on one side of the culvert and a roadway that cannot be shifted on the other side of the stream. A site may be constrained by limited right-of way such as private property on either side of the culvert that would require eminent domain land costs and time for negotiations. Relocation of smaller structures is sometimes possible, though with related expenses, approvals, and permitting.

3.3 Grade and height to roadway

A change in elevation of the existing roadway may be needed to meet the Crossing Standards. This could be due to the general increase in size needed for the replacement culvert to meet hydraulic and hydrologic (H&H) design, maintain a reasonable culvert cross section to avoid blockages, or to meet the openness standard in the Crossing Standards. In many cases, this can be accommodated in the design, but in some situations a significant roadway elevation change can impose a series of cascading effects.

Given that the stream elevation will be constant, meeting the Crossing Standards may require a change in roadway elevation above the culvert. For instance, realistic grading to change elevation for a 35-mph paved roadway is approximately 1 foot per 20 feet of roadway. Therefore, a roadway elevation change of 5 feet would require roadway re-construction for 100 feet along the roadway on each side of the existing culvert, as well as re-grading transverse to the roadway. This can be accommodated but may significantly increase the project scope and cost. The length of roadway affected by raising the road elevation depends on the speed limit, with impact areas that are much longer for higher speed limits.

Depending on the site, adjacent FEMA defined flood areas, wetlands, or rights of way may be impacted when roadway elevations are raised. This can impose requirements for impacts studies and the need to provide additional compensatory storage mitigation, all of which can increase project scope, cost, and schedule. Driveways, intersections, utilities, or traffic signals may need to be relocated or regraded to align with the new roadway elevations, which may be difficult to accommodate at certain sites and/or require site work on private land. Some structural systems may be able to accommodate openness with less impact to roadway elevation (less cover to the roadway or topping slab requirements), and the Engineer of Record should evaluate a range of possible options, including any possible trade-off in structure durability and maintenance requirements.

Culverts crossing wide roadways, such as multi-lane highways, may not be able to meet the openness standard in the Crossing Standards. This is acknowledged in the Crossing Standards, where it is stated, “However, for some very long structures it may be impractical or impossible to meet this standard.”⁹ The Crossing Standards document also acknowledges the lack of a strong scientific basis for the openness standard.¹⁰ Therefore, although the openness standard should be met whenever possible, it is the criterion in the Crossing Standards where not meeting the standard can be most easily justified so long as the general intent of maximizing aquatic organism passage is accommodated.

3.4 Stability of Underlying Soil

Underlying soils determine the foundation requirements for a new culvert. For a given culvert, this could impact whether footings are a viable option for support, or whether a 4-sided culvert or embedded pipe bearing on the soil would be more feasible. Poor soil may require deep foundations (such as piles). Longer spanning culverts transfer higher loads to foundations and underlying soil. Soils that may have been suitable for shorter spanning culverts may require more costly and intrusive foundations when replaced by longer spans.

3.5 Downstream flooding ¹¹

Undersized culverts should be replaced in ways that satisfy baseline design recommendations (see Section 4.0) and thereby reduce the risk of roadway overtopping or washout. For existing undersized crossings that provide detention storage (i.e., impound water) at their specified design storm, special consideration is needed to ensure that the crossing replacement will not result in increased downstream flooding. When the FEMA flood profile indicates backwater flooding exists on the upstream side of the crossing, an analysis should be conducted to the limit of the next in line downstream hydraulic restriction to demonstrate no downstream flood increase. A proponent whose project would increase the water surface elevation of a floodway is required to contact FEMA regarding application for Letter of Map Amendment (LOMR) or Conditional Letter of Map Amendment (CLOMR). Analysis and discussion of potential downstream flooding should be a part of a Notice of Intent submission when the existing crossing provides detention storage combined with one or both of the following scenarios.

- An additional undersized culvert of the same size or smaller occurs a short distance downstream (i.e., inadequate capacity to absorb a potential increase in flow from the loss of storage associated with the culvert replacement)
- Structures or other infrastructure located between the project site and the next downstream crossing are below the road deck elevation of the downstream crossing

⁹ Page 12 of Massachusetts River and Stream Crossing Standards.

¹⁰ Pages 25-26 of Massachusetts River and Stream Crossing Standards.

¹¹ Upstream flooding is often an important consideration when enlarging crossings on tidal streams and rivers. This guidance document is not intended for tidal stream crossings.

The responsibility to avoid flood impacts lies with the applicant and consulting professional engineer. Demonstration of downstream flooding avoidance should be submitted when the Issuing Authority requires it but should not be requested as a rule of thumb for all projects. When required, acceptable demonstration of downstream flood impact avoidance includes a HEC-RAS or similar FEMA-approved model.

Increased downstream flow does not always cause an increase in downstream water surface elevation. In most cases where there is concern about downstream flooding, the potential for flooding can be accommodated or mitigated through other means of controlling stream flow (see Section 5.0), although the project area may need to include work in the channel upstream or downstream of the immediate culvert site. In some situations, the effects of downstream flooding may require a holistic approach of replacing multiple culverts throughout a system in an order that mitigates flood conditions.

3.6 Head cutting and stream stability

An incised or unstable channel downstream from the crossing can result in the propagation of head cutting (erosion of the stream bed) upstream. An existing culvert can impede the head cutting process but may create an outlet drop and some scour at the culvert location, restrict fish passage, and increase the risk of foundation failures. However, meeting the Crossing Standards and providing natural substrate in the new culvert could remove the obstruction and allow head cutting to propagate through the culvert and upstream. In the case of a low-gradient stream with soft bed material, head cutting of half a mile or more is possible, resulting in serious degradation of stream habitat up-gradient of the crossing. This can be addressed in a design through mitigation measures that stabilize the stream, but it requires additional design work and remediation of the stream beyond the immediate culvert site (see Section 5.0).

3.7 Upstream wetlands and important habitat

The restriction of flow at a culvert can result in an increase in water elevation upstream by the backing up of water. In these backwatered areas small amounts of bordering vegetated wetland (BVW) may develop. The loss of a small amount of BVW can be justified by meeting the Crossing Standards and achieving a significant improvement in aquatic connectivity, and such losses can be allowed by Issuing Authorities when conducted as a limited project.¹² However, in some rare cases, the wetland upstream may be too valuable to lose, such as when it is particularly large, provides an unusual habitat type, or supports a state-listed rare or endangered species. In the case of state-listed species, consultation with the Natural Heritage and Endangered Species Program is always required.

When it is necessary to protect a valuable wetland that formed due to an undersized culvert, it may be possible to maintain the wetland and fully comply with the Crossing Standards. This can sometimes be accommodated through mitigation measures (e.g., rock vanes and weirs) that restrict stream flow and promote backwatering up-gradient of the crossing (see Section 5.0), but this approach often requires

¹² 310 CMR 10.53(3)

work in the stream beyond the immediate culvert site. Yet, it is highly preferred over maintaining an undersized culvert, as the latter will present a more significant barrier to aquatic organisms than a series of low weirs, and the crossing will be at risk of roadway overtopping and washout.

Meeting the Crossing Standards may not be appropriate for low-flow, sand-bedded streams found on Cape Cod and other areas. Because these streams receive most of their flow from groundwater, bankfull width does not have the same relevancy as it would for streams with significant inputs from surface water. Many of these streams have a long history of management (e.g., dredging and water controls) and channel widths are, to some degree, artificial. Use of open-bottom or embedded structures with low-flow channels are preferred for these types of streams. However, crossing structures designed to span 1.2 times channel width may create sand deltas and other areas of shallow water that can block the movement of fish, including migratory (diadromous) species such as river herring. Applicants that are proposing crossings on these types of streams, and issuing authorities that review these applications, should consult with the MA Division of Marine Fisheries on appropriate designs for these stream crossings.

3.8 Archaeological or Historical Significance

A site, or the structure itself, may have archaeological or historical significance that results in limitations or prohibitions on the areas that can be affected or work that can be done at the site. These constraints may take precedent over the Crossing Standards and result in a design and construction that focuses on alternative measures (see Section 5.0) that can mitigate restrictive culvert design considerations. Waivers from archaeological or historical constraints may be possible in some cases but may require time and effort to procure.

3.9 Effects of physical constraints

For most crossing replacement projects, meeting Crossing Standards will not be significantly affected by physical constraints. In some cases, however, physical constraints may make it impossible to meet the Crossing Standards or will result in substantial construction impacts, scheduling delays, and financial costs in order to meet the standards. In almost all cases, these constraints can be quantified as additional costs to the project and addressed via the analysis of costs and benefits discussed later (see Section 4.0). The financial cost of meeting the Crossing Standards is fully justified in many cases. However, there are some constraints that can increase the project cost so significantly that the project would no longer be feasible. The Regulations allow for these situations through the maximum extent practicable language.

4.0 Cost

Recognizing that the cost of meeting the Crossing Standards is a major obstacle for implementing culvert replacement projects, one of the most important considerations for evaluating maximum extent practicable is the balance between cost and ecological benefits. We begin with the assumption that if significant ecological benefits are likely to be achieved by meeting the Crossing Standards, then an increase in replacement costs, beyond what is needed to meet the baseline design recommendations, can be justified. The question then becomes how much increased cost is justified before that cost is no longer considered “practicable?” In this guidance, we propose that cost thresholds above baseline for exceeding maximum extent practicable should be based on 1) habitat quality and 2) the increase in aquatic connectivity likely to be achieved by meeting the Crossing Standards (connectivity restoration potential). Meeting the Crossing Standards to the maximum extent practicable is important for improving habitat for fish and wildlife and addressing the fisheries and wildlife habitat interests of the WPA, as well as providing other benefits, such as less restricted movement of sediment and woody debris.

4.1 Ecological benefits

For habitat quality, we classify stream segments, and the crossings on those segments, into three classes (highest quality, high quality, general quality) based on whether they fall into one or more of the following categories.

- BioMap Aquatic Core (a component layer of BioMap, the State’s prioritization of lands and waters that are most important for conserving biological diversity in Massachusetts)
- Coldwater fisheries resource (streams, rivers, and tributaries identified by the MA Division of Fisheries and Wildlife that support reproducing cold-water fish)
- Diadromous fish run (streams and rivers identified by the MA Division of Marine Fisheries to be important as spawning or migratory habitat for fish that migrate between freshwater and the ocean)
- Area of Critical Environmental Concern (ACEC; places designated by the Massachusetts Secretary of Energy and Environmental Affairs that receive special recognition because of the quality, uniqueness and significance of their natural and cultural resources)
- Wild and Scenic River (rivers in Massachusetts that have been federally designated as Wild and Scenic Rivers)

Classes are assigned to stream segments and associated crossings according to the following.

Highest Quality: two or more of the above categories apply

High Quality: one of the above categories apply

General Quality: All other stream and river segments

This classification is presumed to accurately indicate the habitat quality of stream segments. That presumption may be overcome, to either lower or raise the classification level of a given stream segment, by the presentation of credible evidence from a competent source. Evidence can include local knowledge of biota supported by that stream segment, documentation of environmental degradation sufficient to impair the stream's ability to provide habitat for fish and wildlife (assuming that the degradation was not caused by an existing crossing), high CAPS Index of Ecological Integrity (IEI) scores, or results of habitat suitability models suggesting that the stream segment supports cold-water fish.

To assess connectivity restoration potential, we use the most current [Critical Linkages and Coldwater Critical Linkages](#) analyses from the Designing Sustainable Landscapes project at the University of Massachusetts Amherst.

Highest Restoration Potential: Top 5% of statewide Critical Linkages or top 10% of Coldwater Critical Linkages Effect scores for crossings on streams with a projected mean summer temperature $\leq 16^{\circ}\text{C}$ (61°F)

Very High Restoration Potential: 5-10% of statewide Critical Linkages or top 10-20% of Coldwater Critical Linkages Effect scores for crossings on streams with a projected mean summer temperature $\leq 16^{\circ}\text{C}$ (61°F)

High Restoration Potential: 10--20% of statewide Critical Linkages or top 20-30% of Coldwater Critical Linkages Effect scores for crossings on streams with a projected mean summer temperature $\leq 16^{\circ}\text{C}$ (61°F)

Medium Restoration Potential: 20-25% of statewide Critical Linkages or top 30-40% of Coldwater Critical Linkages Effect scores for crossings on streams with a projected mean summer temperature $\leq 16^{\circ}\text{C}$ (61°F)

Other: All other crossings (below top 25% for Critical Linkages; below top 40% for Coldwater Critical Linkages)

Critical Linkages scores are derived from models and field assessments of how passable road-stream crossings are for aquatic organisms. Field assessments have not been completed for all crossings in Massachusetts and Critical Linkages scores are not available for all crossings.¹³ These classifications are presumed accurate, but the presumption may be overcome, and the classification adjusted to either raise or lower the classification level of a given crossing, by the presentation of credible evidence from a competent source. For example, a road-stream crossing that is classified as having Very High Restoration Potential, but which occurs just above or below an impassable waterfall, may warrant being reclassified as Other. The presence of mapped dams and other stream crossings are already factored into Critical Linkages scores. The potential that a dam may be removed, or another stream crossing upgraded, might warrant increasing the restoration potential classification. Discovery of an unmapped dam or other crossing in the vicinity might warrant decreasing the classification.

4.2 Establishing a baseline for assessing the additional cost of meeting the crossing standards

Maximum extent practicable based on cost should be determined by comparing the cost to fully meet the Crossing Standards against a baseline design cost. Legacy culverts (those installed years ago before modern standards and storms of increasing severity) are often undersized for passing both water and aquatic organisms. Thus, baseline cost should not be determined by replacement-in-kind. To establish a reasonable baseline for assessing maximum extent practicable based on cost, MassDEP recommends baseline designs that include:

- capacity to pass a hydraulic design flood based on road or highway functional class,
- a certain amount of freeboard to facilitate the passage of ice and woody debris, and
- spans large enough to prevent scour and avoid excessive velocities that would inhibit aquatic organism passage.

Recommended hydraulic design floods for various functional road classes and other crossing structures are presented in Table 1.

Table 1. Recommended Hydraulic Design Floods for Various Functional Road Classes and other Crossing Structures
14

Road or Highway Functional Classification	Hydraulic Design Flood
Interstate or Limited Access Highway	100-year flood
Rural Principal Arterial	50-year flood

¹³ Critical Linkages scores are generally unavailable for crossings on small headwater streams (watershed size < 74 acres) or due to unmapped streams or unmapped roads. For crossings that lack Critical Linkages scores it is recommended that best professional judgement be used along with scores from crossings directly upstream and/or downstream. Where no other scored crossings are available as a reference, it is recommended that the crossing in question be assigned to the “Other” category.

¹⁴ Adapted from the MassDOT Bridge Manual Hundredth Anniversary Edition (2024), Table 2.6.3-1

Rural Minor Arterial	50-year flood
Rural Collector, Major	25-year flood
Rural Collector, Minor	10-year flood
Rural Local Road	10-year flood
Urban Principal Arterial	50-year flood
Urban Minor Arterial Street	25-year flood
Urban Collector Street	10-year flood
Urban Local Street	10-year flood
Bike Trail/Shared Use Path	10-year flood
Driveways with stream watersheds greater than 0.5 square miles	10-year flood
Driveways with stream watersheds less than or equal to 0.5 square miles	5-year flood
Railroad Crossings	Functional equivalent of the road classification. At a minimum the 10-year flood.

In addition to accommodating the recommended hydraulic design flood, the baseline design should provide at least one foot of freeboard for crossings with spans < 20 feet, or at least two feet of freeboard for crossings on streams with spans of 20 feet or wider.¹⁵ In some cases, once the proposed crossing opening reaches a certain size water levels at the crossing during flood events will be controlled by water levels downstream of the crossing. In these situations, a crossing with less freeboard may be sufficient if documentation is provided demonstrating that providing a larger opening will not increase freeboard. Natural substrate included within the stream crossing should be included in the hydraulic analysis.

Below are minimum span recommendations for replacement crossing baseline designs.

- 80% of the bankfull channel width for a 10-year hydraulic design flood
- 90% of the bankfull channel width for a 25-year hydraulic design flood
- 100% of the bankfull channel width for 50-year and 100-year hydraulic design floods

These baseline design recommendations are important for addressing two “Interests” of the WPA: flood prevention and storm damage prevention; however, site specific information or constraints may warrant adjustments. It is recommended that designers incorporate climate change predictions based on current state guidance when evaluating hydraulic and hydrologic conditions for crossing replacement.

4.3 Balancing costs and ecological benefits

The proportional cost increases (MEP cost relative to baseline cost) for determining what is practicable based on habitat quality and connectivity restoration potential, are presented in Table 2. To develop these cost factors, we created four simple, but realistic, crossing replacement scenarios and asked three consulting engineers, each with many years of experience, to provide cost estimates for 1) baseline

¹⁵ Freeboard is the height between the hydraulic design flood water surface elevation and the proposed crown of a culvert or low chord of a bridge to allow for the passage of debris and ice.

design with a 10-year flood event, 2) baseline design with a 25-year flood event, and 3) full compliance with the Crossing Standards, for each scenario. These cost estimates gave us an idea of what the potential range would be for costs of meeting the Crossing Standards relative to costs for baseline designs. The cost factor for the highest restoration potential on the highest quality streams was set at a value (150%) that would meet the Crossing Standard under many, but not all conditions. The other cost factors were scaled between 105% and 140% depending on the various combinations of habitat quality and connectivity restoration potential (Table 2).

Cost estimates should cover all the costs of the replacement crossing, even costs that would be the same for both the baseline and full compliance/MEP option (e.g., site assessment costs). Costs in the estimate should include stream survey, geotechnical analysis, design, permitting, materials, and construction (including temporary water control measures, as needed). There are several permitting implications for not fully meeting the Crossing Standards. For example, crossing replacements that meet baseline design recommendations but do not comply with the U.S. Army Corps of Engineers Nationwide Permit requirements, including the Regional Conditions for Stream Crossing Standards are not eligible for the U.S. Army Corps of Engineers' Non-Reporting process under the Clean Water Act; a Pre-Construction Notification (PCN) would be required instead. The additional cost of the PCN process should be included in the baseline design cost estimate. Cost increases up to and including the percentage shown in Table 2, for the appropriate habitat quality and connectivity restoration potential, are considered practicable.

Table 2. Maximum Extent Practicable Cost Factors. Fully meeting the Crossing Standards is considered practicable if the cost to do so is equal to or less than the values presented, based on habitat quality and connectivity restoration potential.

	Highest Quality	High Quality	General Quality
Highest restoration potential	150% of baseline cost	130% of baseline cost	125% of baseline cost
Very high restoration potential	140% of baseline cost	125% of baseline cost	120% of baseline cost
High restoration potential	130% of baseline cost	120% of baseline cost	115% of baseline cost
Medium restoration potential	120% of baseline cost	115% of baseline cost	110% of baseline cost
Other	110% of baseline cost	110% of baseline cost	105% of baseline cost

When, based on this table, the total cost of meeting the Crossing Standards (design, permitting, and construction) would make the replacement project impracticable, the Issuing Authority should consider other design options to maximize aquatic organism passage with resulting crossing replacement costs up to, but not exceeding the cost factors listed above. Section 5.0 of this document describes various design elements that could be used to mitigate the barrier effects of road-stream crossings, even when full compliance with the Crossing Standards is not practicable.

Maximum extent practicable cost factors (Table 2) are guidance; issuing authorities can still work with applicants to incorporate improved aquatic organism passage into crossing designs. For crossing replacements reviewed as limited projects, issuing authorities should take into account an applicant's ability to pay based not on the specific finances of the applicant but considering the financial capability reasonably expected for that type of applicant, be it an individual homeowner, home builder, small business owner, large commercial developer, or a municipality. While the Issuing Authority may take into account an applicant's ability to pay, it is recommended that, at a minimum, crossing replacements should meet baseline design criteria (see Section 4.2) and aquatic organism passage should be addressed to the extent practical.

4.4 Chapter 85 review requirements

The Federal Highway Administration defines a vehicular bridge as a structure spanning more than 20 feet. A bridge structure is part of the National Bridge Inventory (NBI) database and is subject to National Bridge Inspection Standards (NBIS) for regular inspection and appraisal. State departments of transportation are responsible for implementing bridge inspections and load ratings for municipally owned structures in addition to state-owned bridges.

In Massachusetts, smaller structures spanning over 10 feet but less than or equal to 20 feet have a separate designation as small bridges (Massachusetts code: "BRI"). This contrasts with most other states, where the structures would be classified as culverts. These structures are subject to many of the same regulations and requirements as the longer span structures. The "small bridge" designation is

significant, because it invokes several provisions that would otherwise only apply to spans of more than 20 feet. Massachusetts General Law Chapter 85, Section 35 (specifically, *Chapter 85: Regulations and By-laws Relative to Ways and Bridges*) requires that municipal small bridge projects be reviewed and approved by MassDOT. Bridge design standards are described by the MassDOT Bridge Manual Hundredth Anniversary Edition (2024).

Chapter 85 requirements may result in longer review periods, require additional engineering design and reporting requirements, and higher project materials costs to meet MassDOT highway and bridge design standards. The MassDOT review can extend a project timeline, the degree to which will vary depending on the project. If initial project estimates do not account for Chapter 85 review, additional engineering costs may be incurred to account for the design requirements and reporting submittals.

MassDOT bridge standards have been developed over many years and represent the best practice for design and construction of highway/vehicular bridges in the Commonwealth. In some cases, it can be argued that some standards are not all or partially needed for small municipal, lightly travelled roadways. For some crossings on low-volume or low-speed roadways, there may be justification for waivers on some items such as crash-tested highway guardrail.

MassDOT has published guidance on Chapter 85 design considerations specific to bridge superstructure replacement which applies to both small bridges and federal vehicular bridge structures (span of 10 feet up to 20 feet and greater than 20 feet, respectively).¹⁶ Chapter 85 review only applies to public roads and highways and is not applicable for structures with spans of 10 feet or less. Chapter 85 submittals should follow the MassDOT submission format and include the same submittals provided in the MassDOT Bridge Manual - Hundredth Anniversary Edition. Contact MassDOT for guidance on submittal requirements.

5.0 Maximizing ecological benefits when compliance with Crossing Standards is not practicable

One goal of the WPA regulations is that culvert replacements meet the Crossing Standards to maintain the capacity of streams to provide flood control, storm damage prevention, fisheries, and wildlife habitat (“Interests” of the WPA). This is not always possible due to constraints noted in Sections 3.0 and 4.0, and for these cases designing to the maximum extent practicable may be justified. The recommended approach for evaluating the tradeoffs between aquatic connectivity and financial cost when a proposed replacement crossing will not meet the Crossing Standards are discussed in Section 4.0.

Whenever a decision is made to invoke the maximum extent practicable provisions in the Regulations, designers should propose measures to minimize negative effects on aquatic organism passage. Properly designed and constructed mitigation strategies can result in stream properties at the crossing location that effectively mitigate some of the crossing’s impacts on aquatic life in the stream. Discussions with

¹⁶ Municipal Bridge Projects MGL Chapter 85 Section 35 Review Process: Design Requirements and Submittals for New Bridge and Full Bridge Replacement Projects.

engineering consultants that evaluated the culvert replacement scenarios indicated that most mitigation strategies can be implemented with minimal impact to total project cost, though **oversight of construction methods and ensuring adequate performance is critical to a successful project.**

Anyone implementing these strategies should be well versed in successful construction methods as improper implementation can lead to washout of mitigation measures during storms, necessitate ongoing maintenance, or end up providing minimal benefit. Mitigation may require work in the stream outside of the road right-of-way and the need for access to conduct such work can be a significant constraint.

The intent of the Crossing Standards is to ensure stream continuity by placing all culvert structural elements outside of the bankfull width (preferably, outside the 1.2 x bankfull width span). When not fully meeting the Crossing Standards, extra mitigation may need to be taken to maintain conditions that are similar to the natural stream. It is almost always preferable to use an open bottom structure, so that the substrate is continuous and naturally meets the stream at the inlet and outlet. However, an improperly designed or constructed open-bottom culvert can lead to scour at the foundations, and deeper foundations may be warranted to ensure they are below the calculated scour depths.

When using a closed-bottom structure it is essential that it be properly embedded. With closed-bottom culverts there is the risk of substrate washout during a flood event. This can then lead to scour and undercutting of the culvert at the inlet and outlet, which can lead to failures. There are products on the market where the culvert itself is formed to mimic characteristics of stream roughness or surface shape. These are generally less effective than using natural substrate materials, which can be constructed to meet specific site requirements and create a channel that has similar characteristics to the natural streambed.

5.1 Erosion and scour

Erosion and head cutting can be mitigated by hardening the streambed to reduce the risk of failure if they should occur. Structural mitigation includes proper depth and stability of foundations and appropriate use and design of wingwalls, headwalls, and other protective elements. Traditional riprap may succeed in protecting crossing structures, but it does little to facilitate aquatic organism passage and does not meet the natural substrate standard of the Crossing Standards. In some cases, it may be possible to provide riprap scour protection below the substrate with two feet or more of natural streambed material over it. If buried riprap is used for scour protection, it is important that fine soil components (silt and clay) be washed into the voids among the rocks. Otherwise, there is a danger that at low flow, what little water is in the stream might go sub-surface leaving too little water for aquatic organism passage. The strategic placement of appropriately sized stone to form rock cross vanes (see Figure 1, Figure 2, Figure 3, and Figure 4), can provide grade control above, below or within crossing structures that mimic natural conditions in streams where step pools naturally occur, or quasi-natural conditions in other stream types as an acceptable option to avoid erosional head cuts.

Where there is a risk of an outlet drop forming over time due to scour from high velocity water exiting the crossing structure, rock or log weirs placed downstream of the outlet may be able to prevent an outlet drop even if the culvert invert ends up perched above the streambed due to scour. A weir designed to function like natural stream features can create a tailwater pool with a water elevation high enough to allow fish and other aquatic organisms to swim into the structure without needing to leap. Sometimes the height of a weir needed to backwater the culvert would, itself, pose a significant barrier to aquatic organism passage. In these cases, consider the use of a series of weirs to incrementally increase water elevations until the desired elevation at the culvert is reached (see Figure 2).

5.2 Upsizing substrate material

If it is impracticable to construct a crossing that meets the Crossing Standards for width (1.2 x bankfull width), then it will be important to choose substrate materials and a channel design that will resist being washed out of the crossing structure during significant storm events. This will require a shear analysis to adequately size the substrate material and a channel design that retains substrate by controlling driving forces and providing adequate resistance. Crossings that constrict bankfull flows are likely to cause scour; the key is to avoid scour at the inlet, within the structure, or at the outlet. Depending on how much of a constriction is proposed (and the shear forces anticipated), it may be necessary to size material and design the crossing to achieve a static bed within the structure, and potentially for some distance upstream and downstream. Where rocks and boulders are used to construct streambeds associated with crossing, it is important to fill voids with fine sediments by washing them in to ensure that streamflow doesn't go sub-surface. Washing in the fines will also "lock" in the larger substrates making the streambed more stable and less vulnerable to the erosive forces.



Figure 1. Cross vane (A-vane, from Virginia Tech Stream Restoration Series Fact Sheet Number 1)



Figure 2: A series of rock vanes downstream of a crossing after a dam removal (photo credit: Scott Jackson).

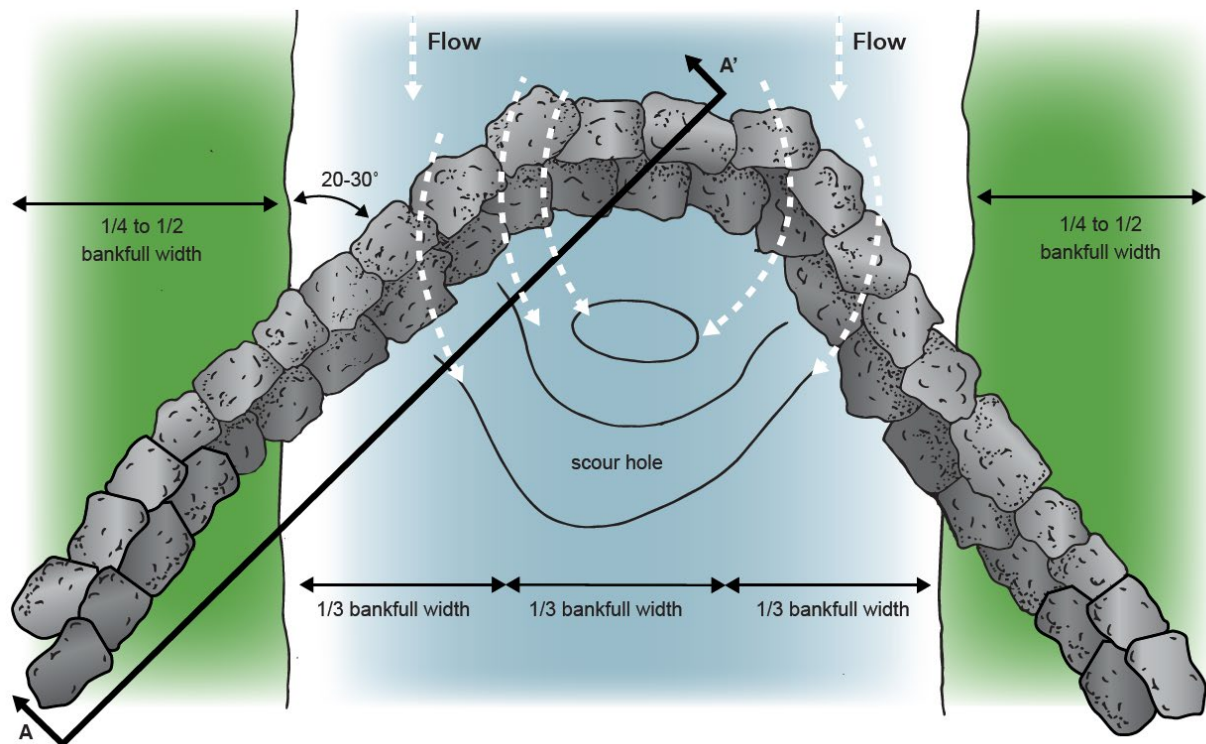
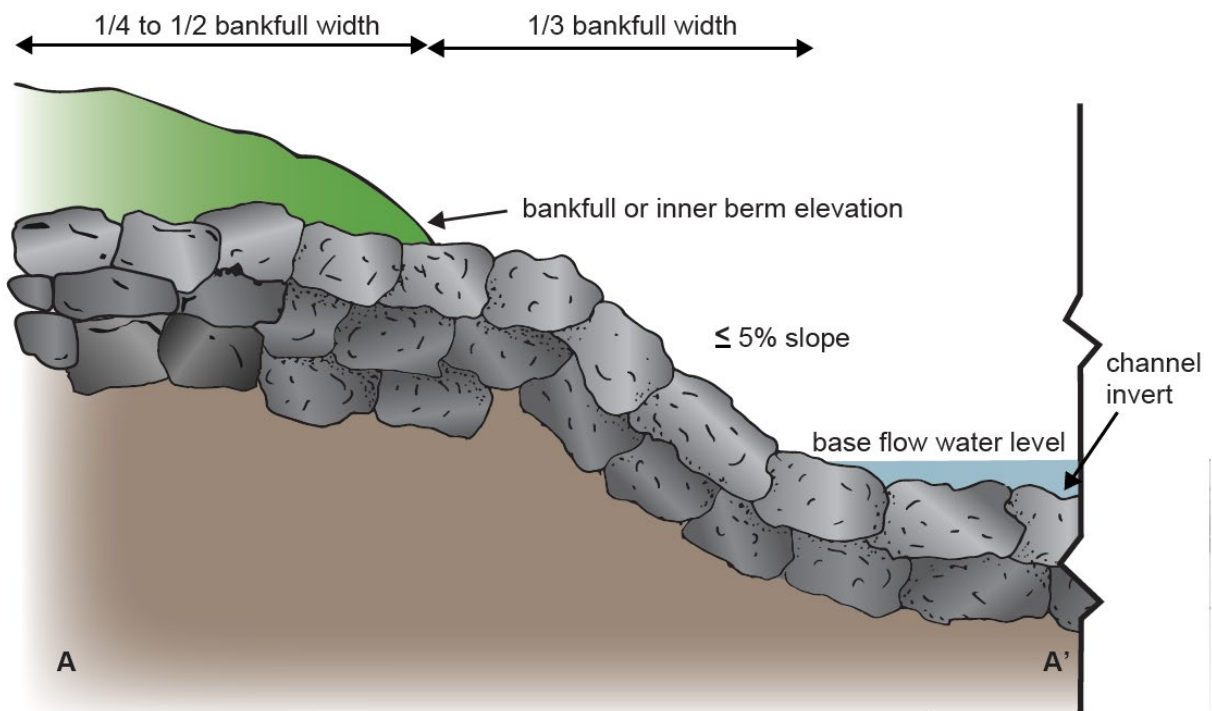


Figure 3. Cross vane plan view (illustration by Sarah Cisneros, from Virginia Tech Stream Restoration Series Fact Sheet



Number 1)

Figure 4. Cross vane profile view (illustration by Sarah Cisneros, from Virginia Tech Stream Restoration Series Fact Sheet Number 1)

Although it is desirable to equip the crossing structure with substrate that matches what is found in the natural stream channel, it may be necessary to upsize the substrate material to ensure streambed and channel stability. It may be possible to use substrate on the surface (on top of a static bed) that falls within the range of variability of the natural channel, even if it is not possible to match average or predominant substrate conditions found in the stream. For crossings on high-gradient streams, it might be feasible to use retention sills to prevent substrate from washing out of a culvert. Care should be taken, however, when using retention sills, because if they prove ineffective at preventing substrate washout, they can themselves act as barriers to aquatic organism passage.

5.2 Protecting upstream wetlands

Replacement of undersized culverts with larger, more resilient structures can result in drainage of upstream areas, which can be harmful to wetlands, important habitat, or cyclical benefits of natural floodplains. Where these valuable habitats occur, mitigation strategies can be used to prevent or reduce the loss of wetlands while also improving aquatic organism passage. A series of low weirs or rock vanes can be used to incrementally raise water elevations upstream of a crossing (see Figure 2 and Figure 5) to prevent the dewatering of wetlands that would otherwise be drained if the crossing was built in compliance with Crossing Standards. The weirs and rock vanes may, themselves, reduce aquatic organism passage to some degree, but they may be useful as a compromise measure to protect wetlands and other valuable upstream habitats while providing some increased aquatic connectivity. These strategies can be implemented upstream, downstream, and/or within the crossing structure. Best practices should be consulted when designing and constructing these features (see Section 5.1).



Figure 5. Rock weirs to enhance fish passage in Northeastern Maine (photo credit: USFWS)

5.3 Reducing velocity and ensuring adequate water depths

To ensure aquatic organism passage, culverts and bridges need to have similar characteristics to the natural channel upstream and downstream during the full range of flow conditions likely to be experienced in a typical year. Low flow channels, necessary for many aquatic organisms, are especially important for migratory (diadromous) fish.

When not fully meeting the Crossing Standards, extra mitigation may be needed to maintain flow during dry conditions and slow the flow during flood events. When crossings are constructed with smaller spans than those recommended in the Crossing Standards, efforts should be made to reduce water velocities using methods that mimic natural features and processes in streams. These can include backwatering above and/or below the crossing as well as the creation of a roughened channel within the structure itself. A roughened channel incorporates features that provide drag and resistance to water flow (see Figure 6 and Figure 7).



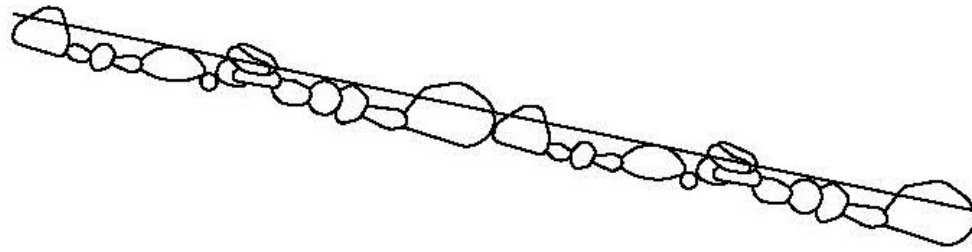
Figure 6. Roughened channel after dam removal on Wagner Creek, Oregon (Rogue River Watershed Council website)



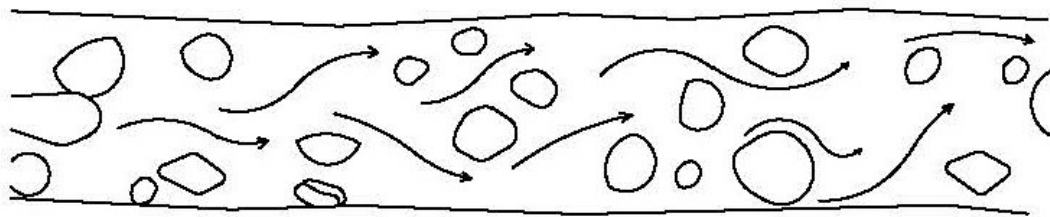
Figure 7. Roughened channel just upstream of crossing inlet to reduce water velocities (photo credit: Scott Jackson).

The following approaches can be used within a structure or in the stream channel upstream or downstream of the crossing to regulate water depths and velocities. These are examples and typical designs would be expected to have some, but not all, of these features.

- Installation of large rocks and boulders to roughen the channel (Figure 6, Figure 7, and Figure 8)
- A sinuous low-flow channel within the structure with habitat boulder placement under the direction of a fluvial geomorphologist
- Banks on both sides of the stream within the structure to provide bank-edge where water velocities are typically lower than in the main part of the channel (Figure 9)
- Rock and log deflectors that are anchored on one bank and extend out into the channel
- Rock cross vanes that extend from bank to bank across the stream channel (Figure 5). V-shaped cross vanes or weirs can also be used to concentrate low flows (Figure 1, Figure 2, Figure 3, and Figure 4)
- Constructed step pools in higher gradient streams (Figure 10)



PROFILE VIEW



PLAN VIEW

Figure 8. Use of large rock embedded in the substrate to create a roughened channel. It is important to use rocks large enough and embed them deep enough to prevent them from being dislodged by seasonal high velocities and storm flows.

5.4 Best practices for instream mitigation

Mitigation measures to enhance aquatic organism passage when crossings cannot be built to achieve Crossing Standards requires expertise and experience so that those measures are adequately designed and properly constructed. The approach is to mimic natural features and flows in the more constricted width and environment of a crossing. **Traditional riprap dumped into a stream or on its banks may achieve some of the objectives discussed in this section, but it is likely to be much less effective, perhaps even harmful, than efforts to mimic natural stream processes with the strategic placement of wood and rock.**

Previous sections have provided context for the importance of controlling stream velocity and associated scour, both to allow for aquatic organism passage and to maintain streambed stability. The following are some general best management practices (BMPs) for implementing strategies described in this section, but designers should keep abreast of available training opportunities and literature for other BMPs. These are general design recommendations and caveats. They are no substitute for proper site assessment and

analysis, and site-specific design and construction oversight by people with the appropriate training and experience.



Figure 9. Banks within the structure provide bank-edge habitat where water velocities are typically lower than in the main part of the channel. In this photo, banks also contribute to the formation of a low-flow channel that provides sufficient water depth for aquatic organism passage at low flows.

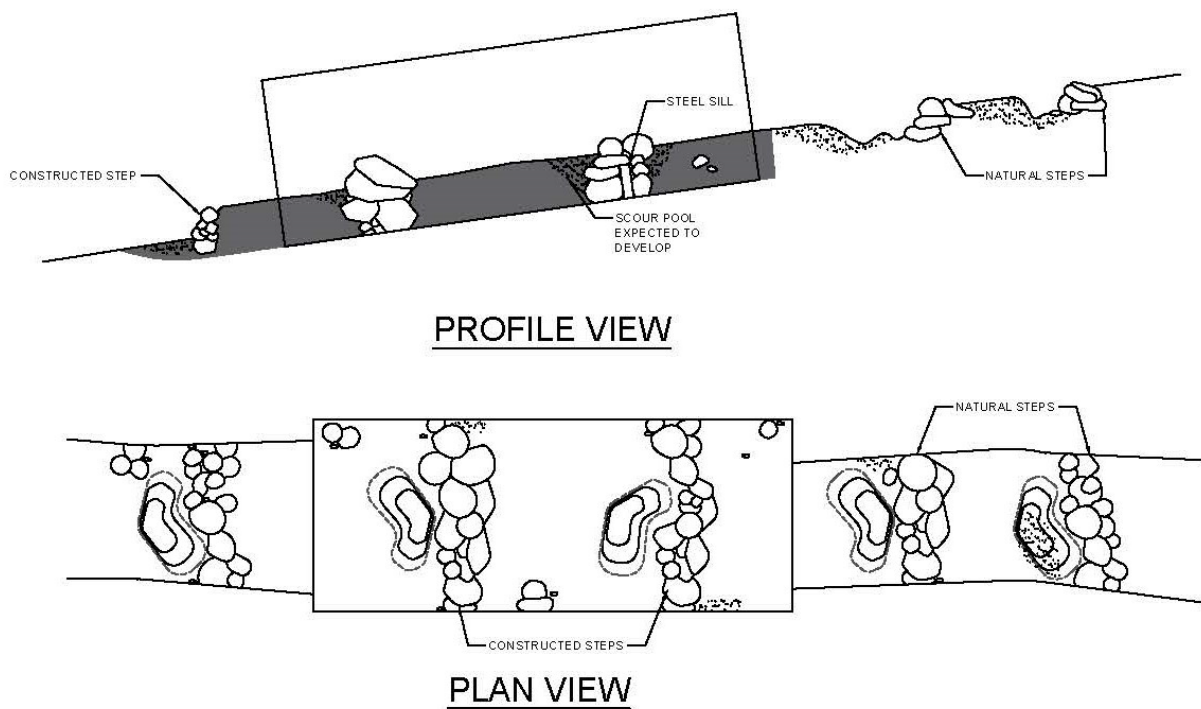


Figure 10. Created step pools can be used within or outside the structure to create instream habitat, reduce stream velocity, and backwater the outlet to prevent the formation of an outlet drop.

5.4.1 Low flow channel maintaining appropriate water depths and velocities

Maintaining appropriate water depths and velocities at a variety of flows generally requires the construction of a low-flow channel to concentrate water during periods of low flow, and with adequate width to avoid velocities at moderate to high flows that exceed those found in the natural stream channel. The bed should be graded to the thalweg (deepest part) of the channel, so it continually concentrates flow as stage drops. The culvert invert slope should be continuous with the streambed (avoid formation of inlet or outlet drops) and the substrate designed and constructed correctly to form a low-flow channel within the crossing structure. The subsurface of the streambed should be sealed and impervious (see next section). The proposed low-flow channel should ideally be based on a stream reference reach located outside the influence of the replacement crossing. Cross section profile should mimic the reference reach, including low-flow channel, channel widths and features, and banks when possible.

5.4.2 Stabilizing the streambed and grade control structures

When designing or constructing a streambed for a crossing, careful attention should be paid to the size, shape and placement of structural components (boulders, rocks, riprap). Designers should perform shear analyses to determine how large those elements should be and how deeply they should be buried. However, it is equally important to focus on the finer components of the substrate (silt and clay). These components are needed to seal the bed and prevent water at low flow from disappearing into the substrate. The substrate recipe should be thoroughly mixed before it is added to the constructed streambed and, after it is in place, the fines should be washed into the voids below using a water hose or other methods. When properly implemented, the subsurface layer should be impervious. For rock weirs and cross vanes, place seal material with fines on the upstream side of the structures to limit permeability.

5.4.3 Log versus rock weirs and cross vanes

Weirs and cross vanes can be constructed of rock/boulders or logs. Rocks and boulders are generally preferred over grade control structures made of logs. Log grade control structures are less durable (shorter life expectancy) and more easily undercut than rock/boulder structures. If used, logs should be at least 8 inches in diameter and keyed into the bank. Log cross vanes should not create a bed elevation change greater than 0.5 foot. For rock weirs and cross vanes, boulders should be somewhat angular so that they can be keyed together. Boulder sizes should be determined based on a shear analysis and calculated scour depth, with a built-in safety margin. The size of boulders needed for weirs and vanes are generally larger than for riprap because boulders within grade control structures are more exposed to flow than riprap. Rock cross vanes should not change the bed elevation by more than 2 feet. Multiple cross vanes may be needed to achieve the desired drop in stream elevation.

5.4.4 Ensuring a proper foundation

Both boulder and log weirs should be buried into the streambed and banks to ensure a proper foundation that can resist displacement during high flow events. Single log weirs are not recommended; in some cases, two logs can be stacked to get sufficient depth of burial to be stable. For rock structures, one layer of rock should be buried as a “footer” for a second layer that sticks up above the water surface during most flows. Structures should slope down toward the center of the channel (the “sill” of a cross vane). Weirs and cross vanes should be buried into stream banks to prevent bank erosion around the ends. U-shaped or V-shaped cross vanes can focus the flow and erosive forces toward the center of the channel and help prevent erosion and “outflanking” at the banks (see Figure 3 and Figure 4). The ability to carefully place and interlock rocks and boulders to create stable grade control structures comes with experience. A good design can be ruined if implemented by an inexperienced construction crew.

5.5 Additional resources for design and construction of grade control structures

- Virginia Tech’s Stream Restoration Series Fact Sheet Number 1 on Cross Vanes
- US Forest Service Stream Simulation Working Group. 2008. Stream Simulation: An Ecological Approach to Providing Passage for Aquatic Organisms at Road-Stream Crossings. San Dimas: US Forest Service Technology and Development Program (specifically Appendix F, but the entire manual is an excellent resource for designing road-stream crossings for aquatic organism passage)
- Grade stabilization techniques. 2007. USDA-NRCS Part 654, Stream Restoration Design, National Engineering Handbook Technical supplement 14G
- Rosgen Geomorphic Channel Design. 2007. USDA-NRCS Part 654, Stream Restoration Design, National Engineering Handbook, Chapter 11.
- Guidance for Stream Restoration by Steven E. Yochum. 2018. USDA Forest Service, National Stream & Aquatic Ecology Center Technical Note TN-102.4
- Assessment, Planning, Design, and Maintenance of Large Wood in Fluvial Ecosystems: Restoring Process, Function, and Structure. 2016. National Large Wood Manual. U.S. Bureau of Reclamation and U.S. Army Corps of Engineers.

6.0 Reviewing crossing replacement proposals that don’t comply with the Crossing Standards

6.1 Demonstrating maximum extent practicable

When reviewing proposed crossing replacement projects that seek to use the MEP standard to avoid fully meeting the Crossing Standards, it is important to keep in mind that proposing to replace a crossing with an ‘in-kind’ structure is not sufficient to demonstrate maximum extent practicable. To demonstrate

maximum extent practicable, the Notice of Intent should include descriptive information and the estimated cost for 1) a baseline design (see Section 4.2) and 2) a fully developed proposed design that meets the MEP recommendations in this guidance document (see Section 4.3) including the appropriate cost factor from Table 2. Both the baseline and proposed designs should be completed by a registered professional engineer based on a thorough site assessment, including a long profile of the stream, documentation of the channel bed adjustment potential, stream bed analyses, and measurements of bankfull width in reference sections of the stream. The baseline design only needs to be as detailed as necessary to create a reasonable estimate of cost unless the baseline design is the proposed design. For projects that will fully meet the Crossing Standards it is not necessary to submit cost information for the proposed design, nor information about baseline designs or cost.

Project proponents replacing stream crossings are expected to fully meet the Crossing Standards unless it is demonstrated to be impracticable, and then the standards must be met to the maximum extent practicable. Cost is an important consideration when deciding if meeting the Crossing Standards for a proposed crossing replacement project is practicable. However, those costs should be balanced against the ecological benefits that could be achieved if the Crossing Standards were fully applied (see Section 4.0). MassDEP recognizes that site constraints may limit design alternatives and in some instances, may make it impossible to meet the Crossing Standards. WPA regulations (310 CMR 10.24(10) and 10.53(8)) list 12 elements that should be evaluated when considering whether it would be practicable for a proposed replacement project to fully meet the Crossing Standards.

- The potential for downstream flooding
- Upstream and downstream habitat (in-stream habitat, wetlands)
- Potential for erosion and head-cutting
- Stream stability
- Habitat fragmentation caused by the crossing
- The amount of stream mileage made accessible by the improvements
- Storm flow conveyance
- Engineering design constraints specific to the crossing
- Hydrologic constraints specific to the crossing
- Impacts to wetlands that would occur by improving the crossing
- Potential to affect property and infrastructure
- Cost of replacement

Some of these elements are related to physical constraints that might make it impossible or prohibitively expensive to meet the Crossing Standards (see Section 3.0). Other elements pertain to the need to balance financial costs with potential ecological benefits (see Section 4.3). We believe that the 12 considerations can be largely addressed by the guidance's approach to cost (physical constraints can often be converted into financial cost) and benefits (less expense is expected for crossings where little ecological benefit is likely to be gained; greater expense can be justified when ecological benefits are

likely to be high). A design alternative is presumed to meet the Crossing Standards to the maximum extent practicable when the projected cost equals or is greater than the relevant cost factor percentage listed in Section 4.3, Table 2, AND the cost exceedance above the baseline design goes towards improving aquatic organism passage (see Section 5.0).

Consistent with other limited projects, in rare cases when a project cannot meet the maximum extent practicable cost factor or the baseline design recommendations, the Issuing Authority may issue an Order of Conditions and impose such conditions as will contribute to Interests identified in the WPA. In determining whether to exercise its discretion to approve the limited project, the Issuing Authority should consider the elements listed above and whether the applicant has adequately addressed them. Issuing Authorities should also take into account an applicant's ability to pay based not on the specific finances of the applicant but considering the financial capability reasonably expected for that type of applicant, be it an individual homeowner, home builder, small business owner, large commercial developer, or a municipality. While the Issuing Authority may take into account an applicant's ability to pay, it is recommended that, at a minimum, crossing replacements should meet baseline design criteria (see Section 4.2) and aquatic organism passage should be addressed to the extent that it is practical.

Whether a proposed crossing replacement fully meets the Crossing Standards or meets those standards to the maximum extent practicable, appropriate site assessment and engineering are needed to ensure that structures are sized and designed to avoid downstream flooding, achieve desired bed elevations, avoid scour, and provide adequate stability for stream channels, bedforms, footings and abutments. This is especially important for those limited projects that cannot meet the maximum extent practicable cost factor and the baseline design recommendations. Many of the elements from the list above are important factors that should be considered in the design of a replacement crossing.

Some "bridge replacement projects" may be exempt from review under the WPA. These projects are still covered by Massachusetts Water Quality Standards administered by MassDEP. The MA Water Quality Standards also require replacement crossings to meet Crossing Standards "...to the maximum extent practicable."

Appendix A is a flow chart for determining whether the proposed design meets regulatory performance standards for crossing replacements. Appendix B is a checklist that can be used by applicants and Issuing Authorities to determine whether a proposed crossing replacement meets the Crossing Standards to the maximum extent practicable.

6.2 Emergency replacements

Occasionally, severe localized storms result in crossing failures (i.e. washouts). When this occurs on public roads, it can cause disruptions that require quick action to reopen the road. These types of replacement projects are often implemented after a request for Emergency Certification is granted by the appropriate conservation commission. This often leaves little time for site assessment, design, and the acquisition of materials necessary to construct a replacement crossing that meets the Crossing

Standards. The result is often pressure on the conservation commission to permit a replacement crossing that does not meet the Crossing Standards to the maximum extent practicable.

One way to avoid approving a sub-standard crossing replacement is for the conservation commission to work with the municipal highway or public works department to assess stream crossings and identify those that are vulnerable to failure, either because they are structurally deficient or undersized, or due to some other vulnerability. Once these vulnerable crossings are identified, action can be taken to replace those crossings before they fail. Communities can seek funding for these replacements from grants including:

- Hazard Mitigation Grants, for projects that will reduce or eliminate risk of damage to people and property caused by natural hazards (MA Emergency Management Agency, MEMA),
- Municipal Vulnerability Preparedness (MVP) Action Grants, for crossings identified as vulnerable due to climate change in the municipality's Municipal Vulnerability Preparedness Plan (MA Executive Office of Energy and Environmental Affairs, EOEEA),
- Culvert Replacement Municipal Assistance Grants, for culverts located in areas of high ecological value (MA Division of Ecological Restoration, MA DER), and
- Municipal Small Bridge Program, for replacements at existing crossings designated as small bridges or bridges; see Section 4.4 for more details on MassDOT bridge categories (MA Department of Transportation, MassDOT).

Each of these funding programs has specific objectives that would have to be met for a successful grant application, and it is important to select the grant opportunity that provides the best possibility of being funded. By cooperating in the assessment of vulnerable crossings, conservation commissions and municipal highway officials can also discuss possible replacement options should an emergency replacement be necessary. If such an emergency materializes, both parties will be in a better position to take quick action to permit and implement a crossing replacement project.

Another option for dealing with emergency washouts is for the conservation commission to approve under Emergency Certification the installation of a temporary crossing with a condition that within a specified amount of time a Notice of Intent shall be filed to replace the temporary crossing with a permanent crossing that meets regulatory performance standards.

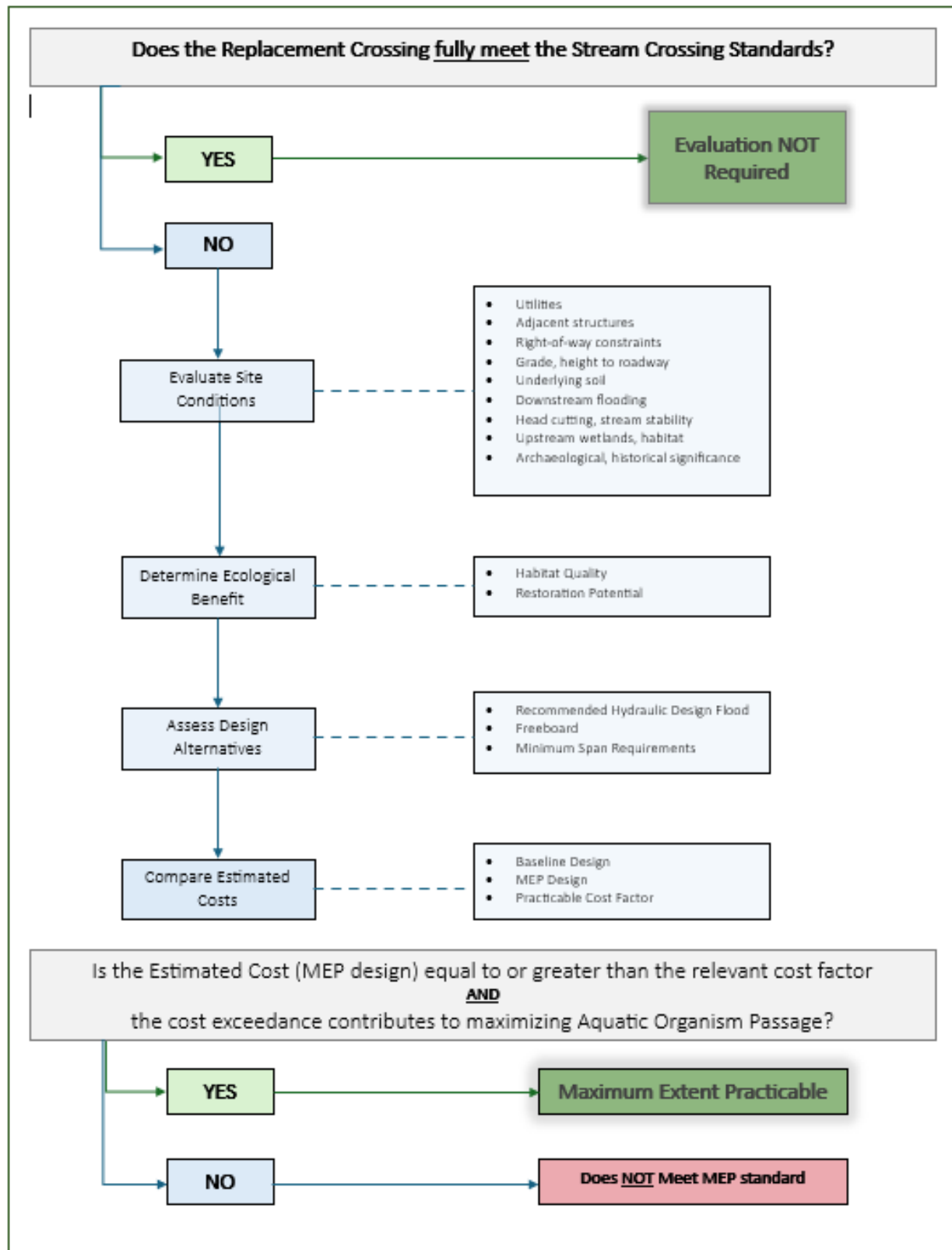
7.0 Conclusion

There are an estimated 25,000-30,000 road stream crossings in Massachusetts. Along with legacy dams scattered across the state, stream crossings are fragmenting our river and stream networks in ways that undermine their ecological integrity and ability to support healthy populations of fish, salamanders, turtles, crayfish and other aquatic or semi-aquatic organisms. Over time, and especially given the projected impacts of climate change on our rivers and streams, we can expect small, isolated populations of fish and wildlife to disappear. Without adequate aquatic connectivity, some of those

vacant habitats will not be colonized by dispersing animals from other populations. With warming air and water temperatures, the discontinuity of future cold-water habitats, and the disruption of aquatic connectivity caused by stream crossings and dams, the risk is especially high for cold-water species.

Climate change that is threatening populations of cold-water and other aquatic species also threatens to undermine our transportation infrastructure. Legacy culverts need to be replaced with structures that can better accommodate the extreme storm and flood events that are projected to occur with increasing frequency due to climate change. At a minimum, all crossing replacements should be able to pass design floods for the road classes where they occur (see Table 1). The upfront costs of designing and constructing crossings to meet the Crossing Standards are likely to result in long-term savings due to their longer life spans compared to traditional culverts, by reducing maintenance costs, and avoiding crossing failures. Where there are opportunities to restore aquatic connectivity, especially for high-quality habitat, we should make every effort to design and construct new and replacement crossings to meet the Massachusetts River and Stream Crossing Standards to the maximum extent practicable.

Appendix A – Flowchart



APPENDIX B - Checklist

In accordance with 310 CMR 10.53(8), applicants must demonstrate that a replacement crossing complies with the Crossing Standards to the Maximum Extent Practicable (MEP). This checklist assists the Conservation Commission in determining if a project has met the burden of complying to the MEP if the replacement stream crossing does not fully meet the Crossing Standards due to **cost** limitations. It is important to note that this checklist does not evaluate the project design, hydraulic capacity, safety, or stability of the proposed structure.

A.1 Notice of Intent (NOI) - Submittal Requirements

- ☐ Written Alternatives Analysis (A.2)
- ☐ Assessment of Physical Constraints (A.3)
- ☐ Estimated Ecological Benefit (A.4)
- ☐ Determination of Practicable Cost using the Relative Cost Factor Ratio (A.5)

A.2 Alternatives Analysis – Crossing Design and Cost Estimates

- ☐ Full Compliance **or** MEP Design Alternative
- ☐ Baseline Design Alternative
- ☐ Written Cost Estimate for each alternative (prepared by PE)

A.3 Assessment of Physical Constraints or Site Considerations

- ☐ Engineering design constraints specific to the crossing such as:
 - existing utilities (sewer pipes, drainage structures)
 - right of way limitations
 - bedrock
- ☐ Potential to affect property and infrastructure (buildings, structures, etc.)
- ☐ Significant/prohibitive roadway elevation requirements
- ☐ Presence of impounded water or wetlands upstream
- ☐ Presence of incised or unstable stream channel

A.4 Assessment of Ecological Benefit

- ☐ Categorization of Stream Segment
- ☐ Assignment of Habitat Quality Class
- ☐ Determination of Connectivity Restoration Potential using [Critical Linkages](#)

A.5 Balancing Crossing Design, Estimated Cost, & Ecological Benefit

Compare the cost of the Full Compliance or MEP Design Alternative with the cost of the Baseline Design Alternative cost and then consider the ecological benefit:

- ☐ Document the relevant Cost Factor Percentage (Table 2)
- ☐ Compare the Estimated Cost from Alternatives Analysis (A.2) and the Cost Factor Percentage
- ☐ Determine if the Design Alternative is **Practicable**

Note: *A design alternative is presumed to meet the Stream Crossing Standards to the MEP when the estimated cost is at least equal to the relevant Cost Factor Percentage AND all costs greater than the baseline cost contribute toward improving aquatic organism passage.*

A.6 Confirm Compliance with MEP

To determine if the proposed replacement stream crossing has been designed to meet the Stream Crossing Standards to the MEP, the Conservation Commission should confirm that the proposed stream crossing has the following:

- ☐ Baseline design criteria (at a minimum) or MEP design
- ☐ Elements to facilitate aquatic organism and wildlife passage
- ☐ Estimated cost that is considered **Practicable**