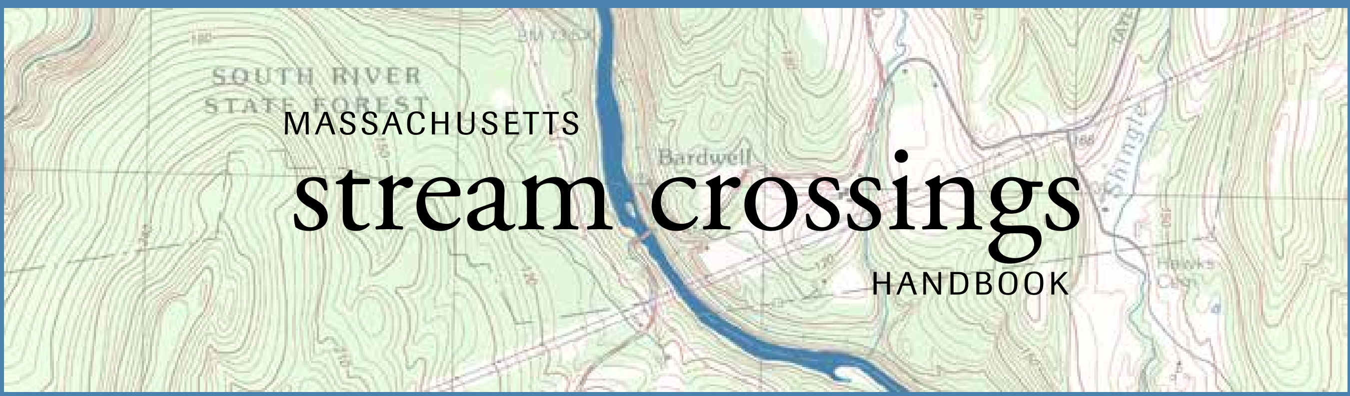
MASSACHUSETTS stream crossings HANDBOOK



DIVISION OF ECOLOGICAL RESTORATION

DEPARTMENT OF FISH AND GAME
Division of Ecological Restoration
Invested in Nature and Community

2nd Edition, June 2012
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COMMONWEALTH OF MASSACHUSETTS
EXECUTIVE OFFICE OF ENERGY AND ENVIRONMENTAL AFFAIRS • DEPARTMENT OF FISH AND GAME

Acknowledgments

The Division of Ecological Restoration, a division of the Department of Fish and Game, restores and protects the Commonwealth's rivers, wetlands and watersheds for the benefit of people and the environment. In 2005, the Massachusetts Riverways Program—now an integrated program of the Division of Ecological Restoration—released the 1st edition of the Massachusetts Stream Crossing Handbook. With funding from the U.S. Environmental Protection Agency's Wetland Program Development Grants provided to the Massachusetts Department of Environmental Protection, this booklet and companion poster are being updated and reprinted to reflect the current Massachusetts Stream Crossing Standards.

The Stream Crossings Handbook is designed to inform local decision makers and advocates about the importance of properly designed and maintained culverts and bridges for fish and wildlife passage. The guidelines presented in this handbook are intended as a supplement, and not as a replacement, to sound engineering design of culverts and bridges. These guidelines describe minimum goals for fish and wildlife passage; additional design considerations are needed to ensure structural stability and effective passage of flood waters.

River continuity is aimed at reducing impediments to movement of fish, wildlife and other aquatic life that require instream passage. The River Continuity Partnership is a collaborative effort with the Division of Ecological Restoration, the University of Massachusetts Extension, The Nature Conservancy, American Rivers, and other nonprofit and agency partners. The Stream Crossing Standards presented in this booklet were developed by the River Continuity Partnership with contributions from state agencies, local and regional nonprofits, and private consultants. The U.S. Army Corps of Engineers' Massachusetts General Permit (April 2018) and the Massachusetts 401 Water Quality Certification (314 CMR 9.00, October 2014) require these or similar standards be met. Further, the Wetlands Protection Act (310 CMR 10.00, June 2014) require all new crossings to meet the Stream Crossing Standards and all replacement crossings to meet the standards to the maximum extent practicable.

Special thanks to those who contributed photographs for this publication and to the partners who helped edit and review it, including local highway personnel, conservation commissioners, and non-profit and state agency personnel. All artwork copyright by Ethan Nedeau (www.biodrawversity.com) and cannot be reproduced without permission. For more information on Stream Continuity, please see www.streamcontinuity.org

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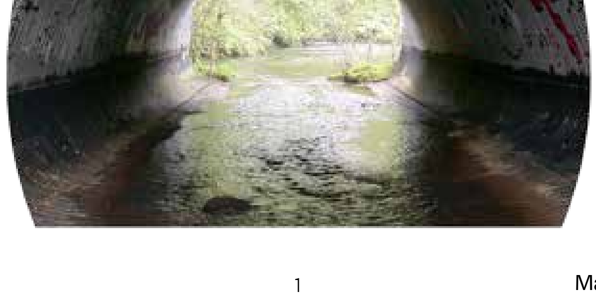
Ethan Nedeau photo

Introduction

Massachusetts' citizens have traditionally been very proud—and protective—of their streams and rivers, recognizing the many benefits of healthy ecosystems. They conduct stream cleanups, set aside conservation land to protect streams, and celebrate the return of anadromous fish each spring. People value streams for different reasons: some enjoy fishing for native trout, others enjoy kayaking, and others simply enjoy sitting quietly on a stream bank. No matter what the reasons, resource managers in Massachusetts are proud to work in a state that demonstrates broad support for stream protection and restoration.

Although public awareness of environmental issues is high in Massachusetts, few people consider the effects of road crossings and other infrastructure on the quality of stream habitat. Stream conditions may be quite different upstream and downstream of a road crossing, and a crossing may look different during low or high water. The design and condition of a stream crossing determine whether a stream behaves naturally and whether animals can migrate along the stream corridor.



Eastern Brook Trout

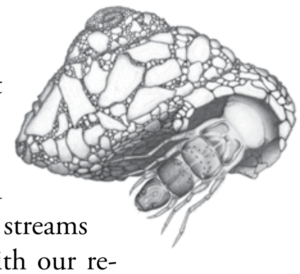
Stream continuity has not often been considered in the design and construction of stream crossings (culverts and bridges). Many crossings are barriers to fish and wildlife. Even crossings that were not barriers when originally constructed may now be barriers because of stream erosion, mechanical breakdown of the crossings, or changes in the upstream or downstream channel shape.

Fortunately, we have learned how to design stream crossings that allow wildlife unrestricted access to a watershed, maintain natural stream conditions, and help protect roads and property from some of the damaging effects of floods. This booklet is meant to communicate the basis for well-designed stream crossings for fish and wildlife and allow people to evaluate existing crossings to decide whether they should be replaced. Town conservation commissions, highway departments, town engineers, and the public should use this booklet to help protect and restore stream continuity throughout Massachusetts.

Stream Continuity and Natural Habitats

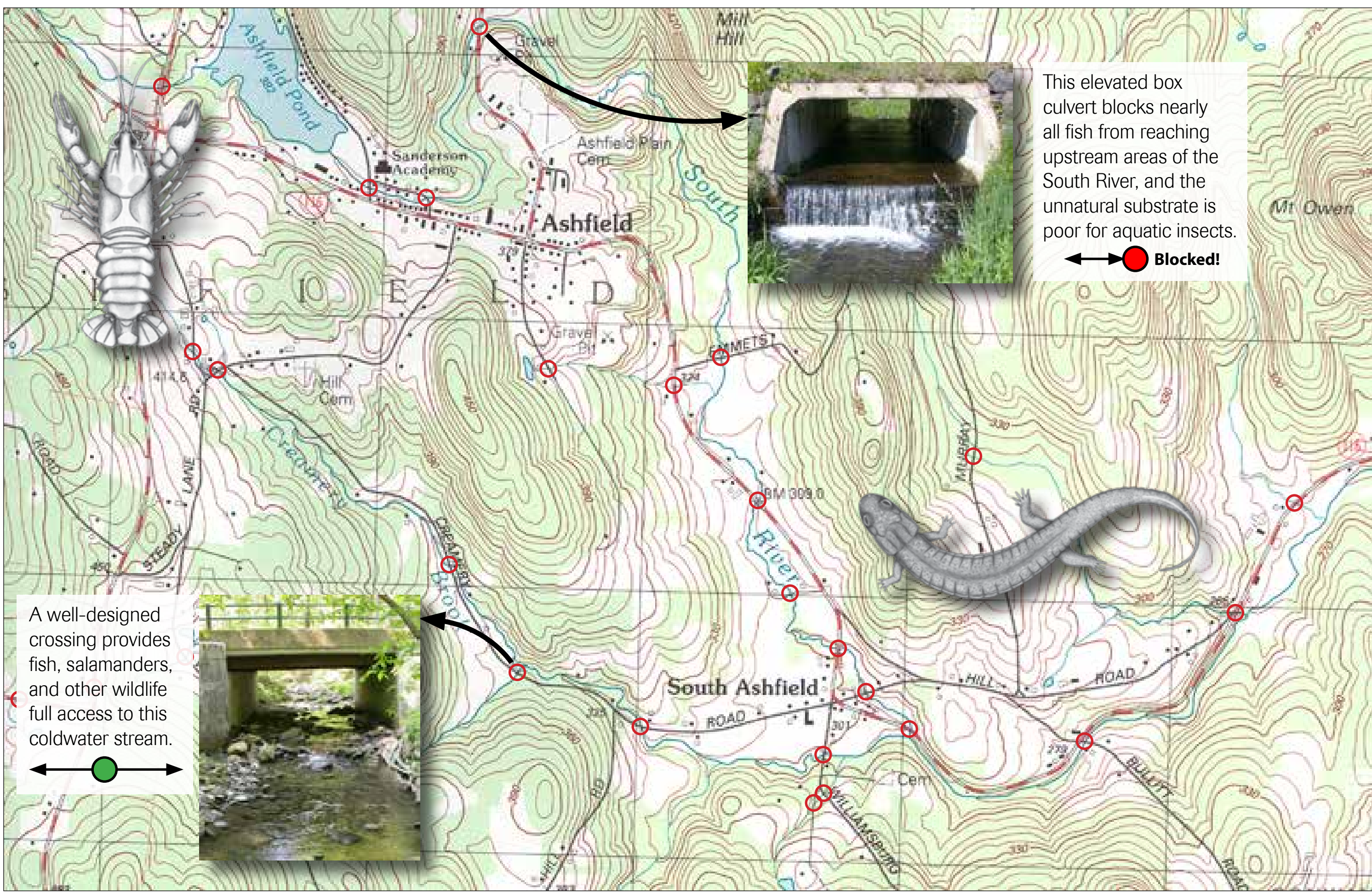
Many species inhabit streams and adjacent forests and wetlands. Effective stream protection requires that we consider the needs of all species including invertebrates such as crayfish and insects, fish such as brook trout and eels, amphibians such as spring salamanders, reptiles such as wood turtles, and mammals such as muskrats and otters. Streams—and the interconnectedness of different parts of a stream or watershed—are essential to these animals. Many riparian animals, such as amphibians and reptiles, are more tolerant of stream discontinuity yet may be affected by road crossings, especially if forced to cross roads where they are vulnerable to traffic and other dangers. For reasons as simple as escaping random disaster or as complex as maintaining genetic diversity, animals living in or along streams need to be able to move unimpeded through the watershed.

Consider the roads you regularly drive to complete your day-to-day tasks. What if the roads you drive on were suddenly permanently blocked so that you could not get to important places? This may sound absurd to us, but this is analogous to what we have done to species that inhabit streams throughout Massachusetts. Through the combined effects of dams and poorly designed bridges and culverts, we have partitioned streams and forced wildlife to cope with our restrictions. Here are a few examples to consider:



snail-case caddisfly

- **Access to coldwater habitats:** Small streams with groundwater seeps and springs provide coldwater refuge during the summer. Species such as brook trout will travel to these areas and congregate there. Fish that can't make it there—perhaps because of barriers we created—may be more susceptible to heat stress and mortality. If barriers restrict the size of a refuge, then animals may be overcrowded and vulnerable to disease, predators, and even anglers.
- **Access to feeding areas:** Different habitats provide different feeding opportunities throughout a day or season, and species regularly travel to exploit these resources. Striped bass and sea-run trout swim up tidal



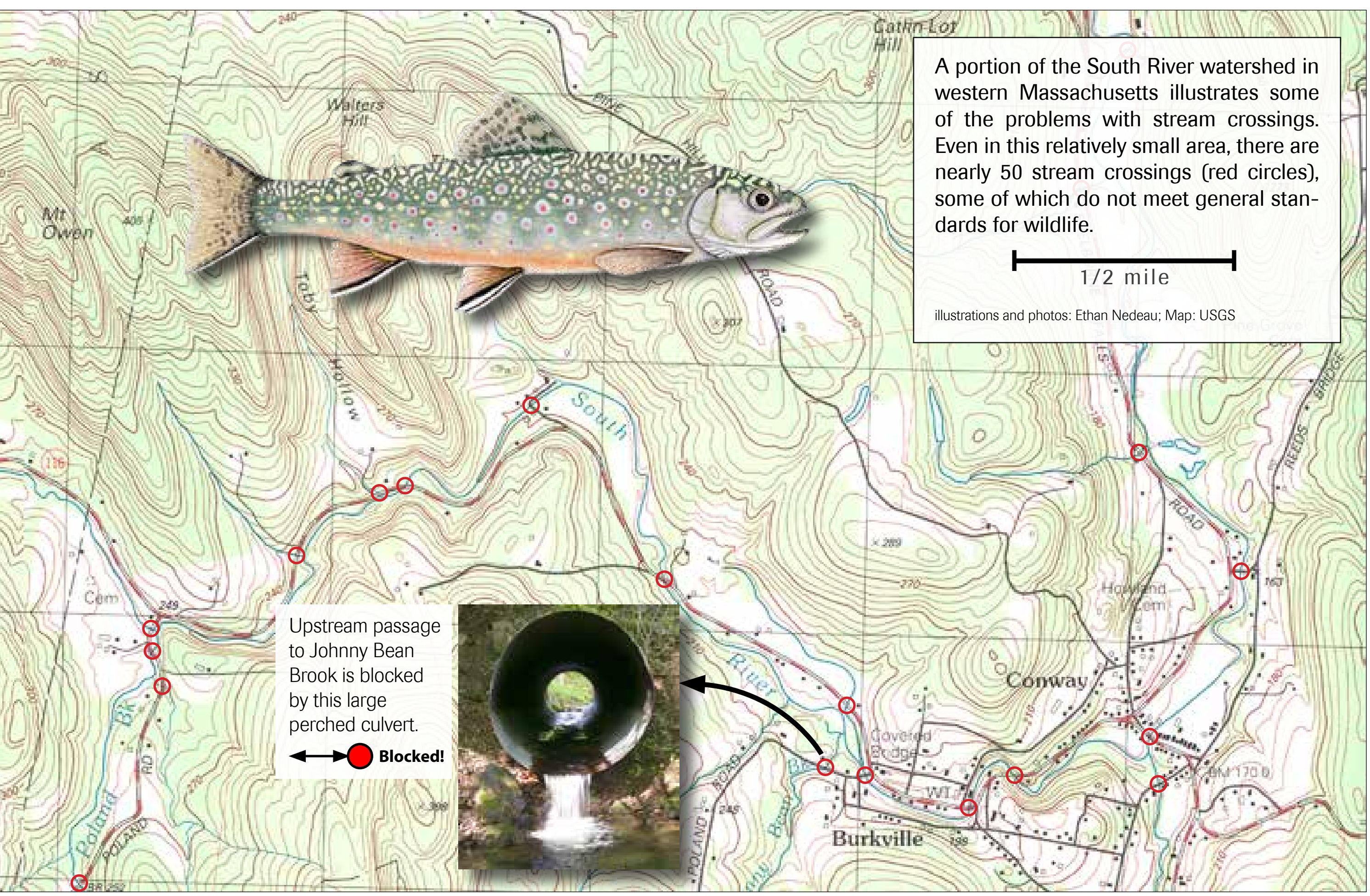
Jane Winn photo

Turtles, salamanders, and other wildlife often must cross roads. Well-designed stream crossings will give them a safer route. This wood turtle can't climb the curb.

creeks to feed during high tide. Insect communities in small ponds and riparian wetlands can be abundant at times, and stream fish will move into these habitats to feed. Restricting access to prime feeding areas will ultimately hurt the fishery.

- **Access to breeding and spawning areas:** Some species need to travel miles to reach spawning areas in streams. The best examples are anadromous species that live in the ocean but spawn in freshwater, such as Atlantic salmon, alewife, shad, lamprey eels, and sea-run trout. Fish may encounter many barriers when adults travel to spawning areas, offspring disperse into juvenile and eventually adult habitat, and juvenile anadromous species swim to the ocean.
- **Natural dispersal:** Some salamanders, turtles and frogs spend most of their lives near streams and travel in and along a stream's length. Poorly designed crossings may force them to climb over an embankment and cross a road, where they are vulnerable to road mortality and predators. Freshwater mussels disperse by having larvae that attach to the fins of a fish, so if a stream crossing blocks fish then it may also prevent upstream dispersal of mussels. If a stream is damaged by a catastrophic event (such as pollution, flooding, or severe drought), then natural dispersal will return the stream to a healthy productive environment.

In addition to effects on wildlife movement, many stream crossings degrade nearby habitat, making conditions inhospitable for some native plants and animals. The effects can be even greater in tidal creeks. By limiting tidal flow, restrictions alter water levels and chemistry, diminish sources of ocean nutrients, and can degrade entire upstream aquatic systems.



A portion of the South River watershed in western Massachusetts illustrates some of the problems with stream crossings. Even in this relatively small area, there are nearly 50 stream crossings (red circles), some of which do not meet general standards for wildlife.

illustrations and photos: Ethan Nedeau; Map: USGS

Recognizing Problems

Three stream crossing problems—undersized crossings, shallow crossings, and crossings that are perched—can be barriers to fish and wildlife and lead to several common consequences. Recognizing poor stream crossings and their consequences is an important step in evaluating whether crossings should be fixed or replaced.

Right: In Washington state, a chum salmon crosses the road because the stream crossing was blocked by floodwaters.
Harley Soltes/The Seattle Times

STREAM CROSSING PROBLEMS

UNDERSIZED CROSSINGS

Undersized crossings restrict natural stream flow, particularly during high flows, causing several problems, including scouring and erosion, high flow velocity, clogging, ponding, and in some cases, washouts. Crossings should be large enough to pass fish, wildlife, and high flows.

SHALLOW CROSSINGS

Shallow crossings have water depths too low for many organisms to move through them and may lack appropriate bed material. Crossings should have an open bottom or should be buried into the streambed to allow for substrate and water depths that are similar to the surrounding stream.

PERCHED CROSSINGS

Perched crossings are above the level of the stream bottom at the downstream end. Perching can result from either improper installation or from years of downstream bed erosion. Crossings should be open-bottomed or sunk in the bed to prevent perching.

COMMON CONSEQUENCES OF POOR STREAM CROSSINGS


Division of Ecological Restoration photo

Low Flow

Low flow is a problem for species movement within the stream. Fish and other aquatic organisms need to have sufficient water depths to move through a stream crossing. Low velocities may lead to stagnant conditions within the crossing.

Causes: shallow crossings, perched crossings


Ethan Nedeau photo

Unnatural Bed Materials

Metal and concrete are not appropriate materials for species that travel along the streambed. The substrate (rocks and other material on the bed of the crossing) should match the natural substrate of the surrounding stream in order to maintain natural conditions and not disrupt the stream continuity.

Causes: shallow crossings, perched crossings


Riverways photo

Scouring and Erosion

In undersized crossings, high water velocities may scour natural substrates in and downstream of the crossing, degrading habitat for fish and other wildlife. High water velocities and related flow alterations may also erode streambanks. Scour pools often develop downstream of perched culverts and may undercut the culvert.

Causes: undersized crossings, perched crossings


Unknown photo

High Flow Velocity

Water velocity is higher in a constricted crossing than it is upstream or downstream. This high flow degrades wildlife habitat and weakens the structural integrity of crossings. During floods, undersized crossings may be filled with fast-moving water. Many of the problems with poorly designed crossings are heightened during high flow events.

Cause: undersized crossings


Unknoiwn photo

Clogging

Some crossings, especially undersized ones, can become clogged by woody debris, leaves, and other material. This may exacerbate the impact of high flows and make a crossing impassable to wildlife. Costly, routine maintenance may be required to prevent this problem.

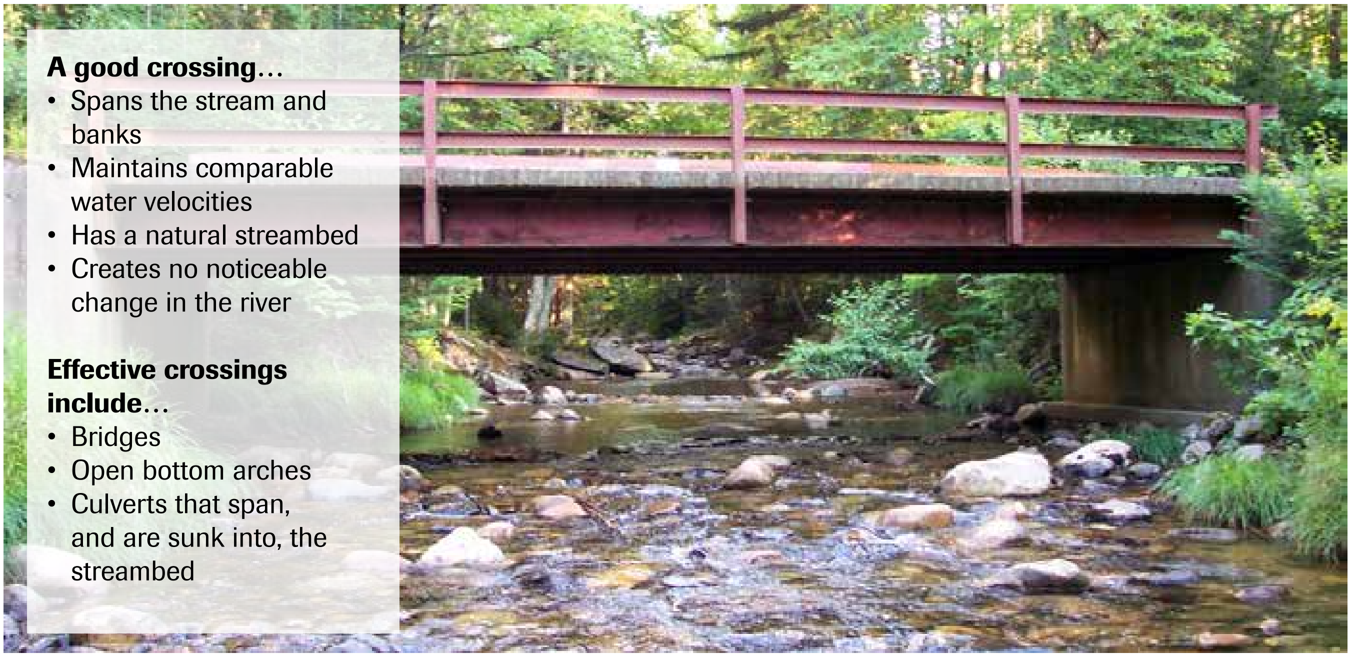
Cause: undersized crossings


Ethan Nedeau photo

Ponding

Ponding is the unnatural backup of water upstream of an undersized crossing. It may occur year-round, during seasonal high water or floods, or when they become clogged. Ponding can lead to property damage, road and bank erosion, and severe changes in upstream habitat. It may also create new wetlands that may not be desirable.

Causes: undersized crossings, perched crossings



A good crossing…
- Spans the stream and banks
- Maintains comparable water velocities
- Has a natural streambed
- Creates no noticeable change in the river

Effective crossings include…
- Bridges
- Open bottom arches
- Culverts that span, and are sunk into, the streambed

Brian Graber photo

Crossing Guidelines

Safe, stable stream crossings can accommodate wildlife and protect stream health while reducing expensive erosion and structural damage. One goal of this booklet is to provide real, easily attainable solutions. **Regulations require that all new and, where feasible, replacement crossings adhere to stream crossing guidelines similar to those presented in this booklet** (See Permits & Regulations under Getting More Information, p. 13).

Crossings should be essentially "invisible" to fish and wildlife—they should maintain appropriate flow and substrate through the crossing and not constrict a stream. At the same time, designs should be efficient and cost-effective. The standards are required for new permanent crossings (e.g., roads, railways, bike paths) on fish-bearing streams and rivers and must be used as guidelines for upgrading existing crossings. These standards were developed specifically for freshwater, non-tidal rivers and streams and may not be appropriate for coastal waterways. Standards are not intended for temporary crossings such as temporary logging roads, or for drainage systems designed to convey storm water or wastewater.

Site constraints may make it difficult to follow these standards. Shallow bedrock can make it impractical to embed culverts, and the road layout and surrounding landscape may make it impossible to attain the recommended standards for height and openness. In those situations, a site assessment will be necessary to determine how to achieve fish and wildlife passage. Site-specific information and good professional judgment should always be used to develop practical and effective crossing designs.

The crossing standards establish minimum criteria that are generally necessary to facilitate fish and wildlife movement and maintain stream continuity. Use of these standards alone will not satisfy the need for proper engineering and design. In particular, appropriate engineering is required to ensure that structures are sized and designed to provide adequate capacity (to pass various flood flows) and stability (bed, bed forms, footings, and abutments).

All crossings should be designed according to one of two sets of standards: General and Optimum. The two standards balance the cost and logistics of crossing designs with the degree of stream protection warranted in sensitive habitats.

Stream Crossing Standards

General standards provide for fish passage, stream continuity, and some wildlife passage. All new permanent crossings and, where feasible, replacement crossings must meet general standards.

Optimum standards provide for fish passage, stream continuity, and wildlife passage. Optimum standards should be used in areas of statewide or regional significance for their contribution to landscape connectedness or in streams that provide critical habitat for rare or endangered species.

STREAM CROSSING STANDARDS

Stream crossing standards are based on six important variables (see page 8 for common measurements). While the specifics of the regulations listed below may change over time, the crossing guidelines presented throughout this handbook remain effective for fish and wildlife.

1. TYPE OF CROSSING

- **General:** Spans (bridges, 3-sided box culverts, open-bottom culverts or arches) are strongly preferred.
- **Optimum:** Use a bridge.

2. EMBEDMENT

- All culverts should be embedded (sunk into stream) a minimum of 2 feet, and round pipe culverts at least 25%.
- If pipe culverts cannot be embedded this deep, then they should not be used.
- When embedment material includes elements >15 inches in diameter, embedment depths should be at least twice the D_{84} (particle width larger than 84% of particles) of the embedment material.

3. CROSSING SPAN

- **General:** Spans channel width (a minimum of 1.2 times the bankfull width of the stream).
- **Optimum:** Spans the streambed and banks (at least 1.2 times bankfull width) with sufficient headroom to provide dry passage for wildlife.

4. OPENNESS

- **General:** Openness ratio (cross-sectional area/crossing length) of at least 0.82 feet (0.25 meters). The crossing should be wide and high relative to its length.
- **Optimum:** Openness ratio of at least 1.64 feet (0.5 meters) and minimum height of 6 feet. If conditions significantly reduce wildlife passage near a crossing (e.g., steep embankments, high traffic volumes, and physical barriers), maintain a minimum height of 8 feet (2.4 meters) and openness ratio of 2.46 feet (0.75 meters).

5. SUBSTRATE

- Natural bottom substrate should be used within the crossing and it should match the upstream and downstream substrates. The substrate and design should resist displacement during floods and maintain an appropriate bottom during normal flows.

6. WATER DEPTH AND VELOCITY

- Water depths and velocities are comparable to those found in the natural channel at a variety of flows.

A Well Designed Crossing

Large size suitable for handling high flows

Open-arch design preserves natural stream channel

Openness ratio greater than 0.5m, suitable for most settings

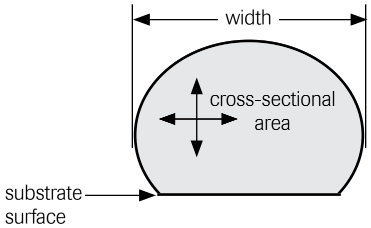
Crossing span helps maintain dry passage for wildlife

Water depth and velocity are comparable to conditions upstream and downstream

Natural substrates create good conditions for stream-dwelling animals

Scott Jackson photo

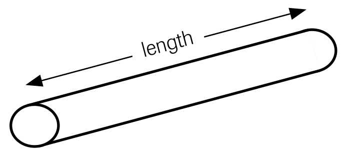
COMMON STREAM CROSSING MEASUREMENTS*



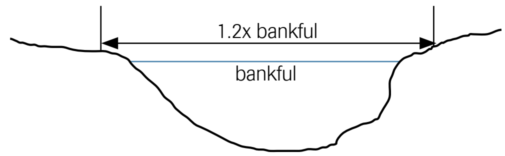
I. Culvert width and cross-sectional area

Openness = $\frac{\text{cross-sectional area}}{\text{crossing length}}$

(all measurements in meters)

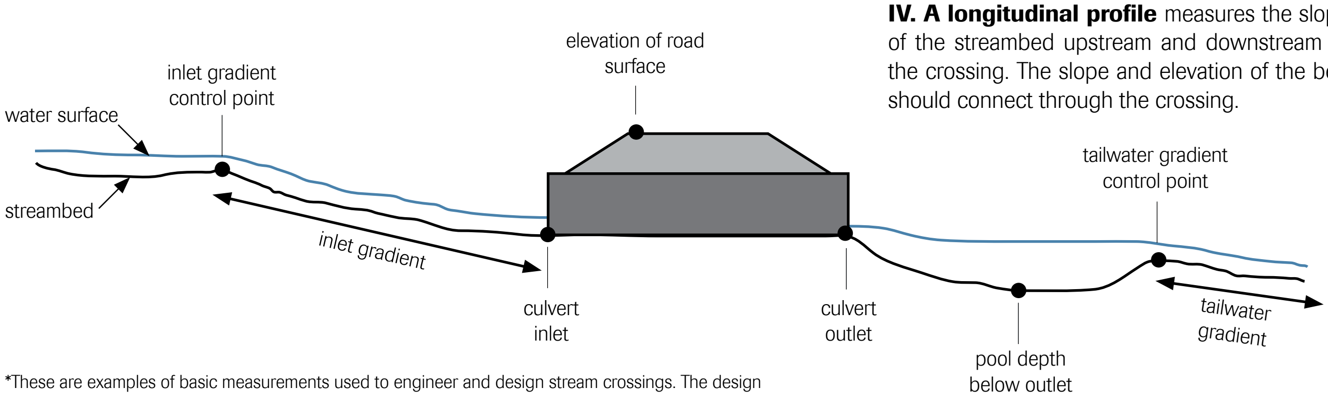


II. Crossing length



III. Stream width

IV. A longitudinal profile measures the slope of the streambed upstream and downstream of the crossing. The slope and elevation of the bed should connect through the crossing.



*These are examples of basic measurements used to engineer and design stream crossings. The design of any structure must consider the channel type and long profile and must account for likely variability of the stream for the life of the structure.

Replacing or Retrofitting Crossings

Most stream crossings in Massachusetts were designed and installed at a time when the environmental impacts of such crossings were not understood. Even effective—but aged—crossings may need to be upgraded or replaced because they have weathered decades of floods and erosion. Periodic upgrading of bridges, culverts, and roads is often required to keep crossings safe and effective.

Repairing or replacing deteriorated culverts is not always as straightforward as installing a larger pipe. Streams may naturally adapt to problems caused by poorly designed or degraded crossings.

Replace...

- If a crossing is structurally poor or degraded
- If a crossing is undersized for high flows
- If a crossing cannot be fixed to allow wildlife passage
- If replacement will not impact critical wetlands

Retrofit...

- If a crossing is structurally sound
- If a crossing is large enough for high flows
- If a retrofit will allow wildlife passage
- If replacement will negatively affect critical wetlands

Replacing or retrofitting an existing crossing should always take into account the existing conditions and potential consequences from changes in flow at the culvert. The benefits of retrofitting or replacing a crossing should be weighed against the costs of the project and the environmental consequences. If feasible, a culvert should be replaced. Careful analysis—drawing on the expertise of engineers, construction professionals, and conservation commissioners—should consider the following:

- Potential for downstream flooding
- Effect on upstream, downstream, and riparian habitat
- Potential for erosion, including headcutting (progressive channel erosion upstream of culvert)
- Overall effect on stream stability

When replacement is desirable, the standards for new crossings should be adhered to as much possible. Crossings should be designed to weather a large flood safely. Otherwise, erosion will occur and the crossing will need to be fixed or replaced again. In a very few cases a retrofit may be more appropriate if the crossing is on an ecologically important stream and the culvert is structurally sound and already large enough for flood flows. In these cases leaving the current culvert in place and adjusting the streambed to eliminate perching, or adding bed material inside the culvert to create a more natural streambed may be possible. Sliplining is strongly discouraged as this practice reduces the openness ratio of the crossing and can exacerbate fish and wildlife passage problems, e.g. increased velocities and perching. A hydraulic analysis may be needed to determine if the retrofit will be able to withstand high flows and function as designed during extreme low flows. Retrofits often require maintenance activities to keep them functioning as designed.

For a replacement culvert, a longitudinal profile of the streambed, both upstream and downstream of the culvert, should be completed to determine how well the up and downstream streambed slopes and elevations match. If there is a significant difference, there is a potential for significant erosion of the streambed, particularly if the new culvert is larger, and additional considerations will have to be taken in the design.

Road Washouts: Bad for Budgets, Bad for Habitat

With an increase in the number and intensity of extreme storm events, local public work departments are reporting an increase in road failures and closures due to overwhelmed culverts. (Unknown photo)

Streams move water, debris, and sediment. Crossings should be designed to accommodate transport of these materials, otherwise they may become clogged or overtop during severe rain events. (Carl Lafreniere photo)

Culvert failures cost communities millions of dollars every year in property and infrastructure damages. The resulting road closures lead to increased costs in terms of limited emergency access, additional commute times, and lost business revenue. When culverts fail, they also send slugs of road fill and sediment into the streams degrading water quality and habitat. Many crossings fail, in some cases repetitively, due to the inability to pass high flows and materials. These crossings require ongoing maintenance and repairs when they become plugged with debris.

Crossings designed with rivers in mind, and that meet the Stream Crossing Standards, have been found to safely pass huge volumes of water, sediment, and debris stirred up by high flows, as well as maintain safe passage for emergency personnel and residents. While initial installation costs for an open arch or bridge span may be more than traditional culvert approaches, long-term costs are significantly reduced as the road crossing survives larger precipitation events and operates with limited maintenance.

Stream Crossing Standards alone do not satisfy the need for proper engineering and design. When sizing a crossing for high flows, communities will need to take into account potential effects of climate change on future storm characteristics (e.g., precipitation events will likely be more intense and occur with greater frequency) and how a stream's hydrology can change due to development in its watershed. The Northeast Regional Climate Center and Natural Resources Conservation Service provide a web tool for extreme precipitation analysis at www.precip.net, which may be useful when considering future flow changes.

Common problems for fish and wildlife passage—outlet drops, scour pools, debris blockages, high velocities and turbulence—are often indicative of undersized crossings which are more vulnerable to overtopping during high flow events. As communities become more aware of how their transportation and ecological infrastructure overlap, they are identifying and prioritizing sites where culvert replacements would benefit environmental, infrastructure and public safety goals.

Following Tropical Storm Irene, the Green Mountain National Forest found that culverts recently replaced using Stream Simulation Design, on which the Stream Crossing Standards are based, suffered little damage and safely passed huge volumes of water, gravel, and debris that clogged and destroyed other traditional culverts in the area. (U.S. Forest Service photo)

CASE STUDY

Reconnecting Bronson Brook

Blacknose dace

Double box culvert at Dingle Road (Inter-Fluve Inc. photo)

Replaced with an Open Bottomless Arch Culvert (Paul Nguyen photo)

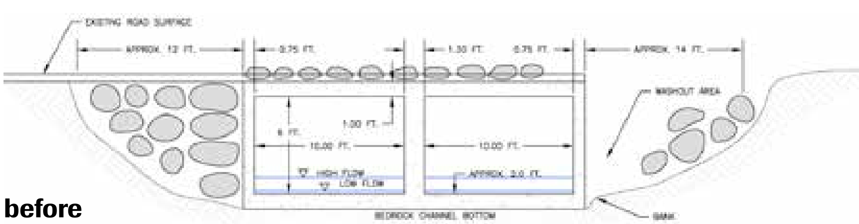
When conservation priorities overlap with the need to replace or upgrade infrastructure, technical and funding support may be available to municipalities, organizations and private landowners. Working with local conservation partners, the Town of Worthington replaced a failed culvert and retrofitted another culvert to restore stream continuity along Bronson Brook. Through a collaborative effort, state and federal grants, private donations and labor were pulled together to make the $380,000 project happen.

Bronson Brook is a high quality coldwater tributary to the East Branch Westfield River, supporting habitat for Atlantic salmon and resident coldwater species such as Eastern brook trout and black nosed dace. The concrete double box culvert on Dingle Road was a barrier to fish due to a perched outlet, shallow water depths and excessive water velocities. A large storm in August 2003 caused the Dingle Road crossing to catastrophically fail when debris clogged and flows overtopped the undersized box culverts, eroding the road fill around the culverts and causing extensive streambank damage downstream. By the end of the storm the channel had flanked the culverts, creating a 14 ft. (4 m) wide rift between the road and the culverts.

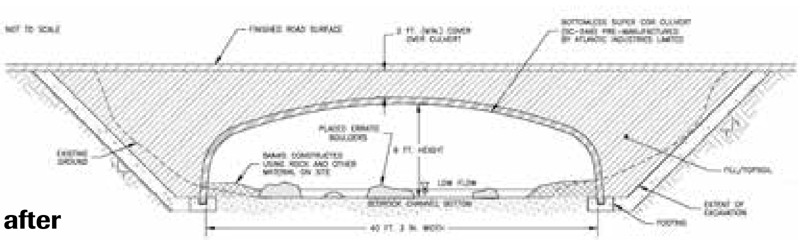
In 2006, the box culverts were replaced with a 40-foot wide open bottomed culvert that spanned the bankfull channel width and allowed for a natural channel streambed throughout. The new arch culvert has prefabricated steel headwalls and is founded on precast concrete footings. The open-bottom arch allows for natural flows through the crossing and reduces the chance of woody material catching and blocking the culvert, thereby reducing the chance of another flood overtopping the culvert.

A nearby crossing at Cummington Road was perched about a foot above the downstream pool. Partners decided to retrofit this crossing because it was already large enough to pass flood flows and it was structurally sound. They built a downstream riffle to raise the water level high enough to reduce perching, and installed retention sills within the crossing to retain natural bed materials.

Fish and salamanders where not the only ones to benefit – the project ultimately reduced maintenance costs for the town, reconnected access for residential and emergency vehicles, and protected municipal and private infrastructure.



The double box culvert at Dingle Road was replaced with a large open-bottom arch with natural bed materials.



Project partners:
Division of Ecological Restoration/Riverways Program, Town of Worthington, Division of Fisheries and Wildlife, Natural Resources Conservation Service (USDA), U.S. Fish & Wildlife Service, National Oceanic & Atmospheric Administration, Westfield River Wild & Scenic Advisory Committee, Westfield River Watershed Association, Connecticut River Watershed Council, The Nature Conservancy, American Rivers, and Inter-Fluve, Inc.

CASE STUDY
Design Challenges Lead to Cooperative and Innovative Efforts


Crossing failure leads to road closure. (Westfield River Wild & Scenic Committee)


This prefabricated bridge design restored passage for vehicles, as well as fish and wildlife. (Westfield River Wild & Scenic Committee)

During a bridge inspection in 2007, the corrugated steel pipe carrying Shaker Mill Brook under McNerney Road was found to be failing. This resulted in the immediate closure of the road—a main thoroughfare for commuting residents and emergency vehicles. A cooperative and innovative effort was needed to reopen this road in a timely manner.

Shaker Mill Brook – a designated National Wild & Scenic River segment—is a coldwater tributary to the West Branch of the Westfield River. MassDOT District 1 reached out to the National Park Service as part of the early environmental and permitting coordination. The project presented many design challenges and considerations. The goal was to use a prefabricated bridge in order to accelerate construction and reopen the road. The change in elevations upstream and downstream of the crossing also needed to be addressed in order to avoid a headcut. In consultation with the Park Service's stream restoration specialist, MassDOT's engineers were able to develop a design that expanded the bankfull flow width of the structure and incorporated natural substrates, riffle and plunge pool features that native cold-water fish need to survive and thrive. Native plantings softened the transition to the banks of the brook.

The National Park Service recognized MassDOT's Engineers with the "Conservation Hero Award" for their cooperative and adaptive approach used to design and replace the culvert with a wildlife-friendly crossing. Animals such as trout, turtles, wood ducks, otter, and mink can now pass freely underneath McNerney Road. The project also reopened the road to its wheeled and two-legged users as well—weeks earlier than planned.

Project Partners: MassDOT, TEC, David G. Roach & Sons, the National Park Service, and the U.S. Army Corps of Engineers.

Conservation Targets

The choice for a crossing design will depend in part on whether a stream has statewide or regional significance for landscape-level connectedness or provides critical habitat for rare or endangered species. The Massachusetts Division of Fisheries and Wildlife's *BioMap2: Conserving the Biodiversity of Massachusetts in a Changing World* identifies areas for biodiversity conservation in Massachusetts and allows local groups to proactively identify conservation targets within their jurisdiction.

The Conservation Assessment and Prioritization System (CAPS), developed by the Landscape Ecology Program at the University of Massachusetts Amherst with funds from MassDEP and EPA, assessed the ecological integrity of lands and waters and subsequently identified and prioritized land for habitat and biodiversity conservation. Results from this assessment include maps for each city and town in Massachusetts depicting Integrated Index of Ecological Integrity (IEI) scores and "Habitat of Potential Regional and Statewide Importance" as defined in MassDEP's "Massachusetts Wildlife Habitat Protection Guidance for Inland Wetlands."

Building upon the CAPS model, Critical Linkages assessed connectivity restoration potential for culvert replacements, dam removals, and construction of wildlife passage structures in Massachusetts. By generating an "Aquatic Connectedness" score, Critical Linkages identifies the best opportunities to improve aquatic connectedness and to restore landscape connectivity in Massachusetts. Using these tools, project managers can ensure that the most critical crossings are replaced to meet the applicable crossing standards. For summary of available datasets, see the Massachusetts Wildlife Climate Action Tool weblink under Getting More Information, Websites, page 13.

Technical Concerns

This document presents minimum needs for fish and wildlife and is not intended to be an engineering design manual. Qualified personnel should carefully consider engineering design and construction techniques for each crossing. Hydraulic analyses are conducted to ensure that a crossing is sufficient for passing floods and will not cause water to scour the streambed or crossing. Structural analyses are necessary to ensure that crossings are safe, particularly for new bridges. For replacement crossings, the slope of the streambed upstream and downstream of the crossing should be compared (known as a longitudinal profile) to ensure that the slope and elevation of the bed connects through the crossing. If it does not connect, excessive streambed erosion can result upstream of the culvert (known as a headcut) or other problems can arise. Qualified consultants can provide technical assistance on all of these issues.

Tim Watts photo

Tidal Restrictions: Different Considerations

A culvert beneath this road restricted full tidal flows from reaching a total of approximately 15 acres of upgradient salt marsh. (Division of Ecological Restoration)

This site has frequent high tides which are wind-driven. The new crossing is sized to accommodate these wind-driven events, which are important to the ecology of the marshes. (Jim Rassman photo)

Crossings of tidal creeks and salt marshes deserve special consideration because of their unique tidal dynamics and effects on upstream habitat. Crossings that are too small to pass the full tidal range are known as tidal restrictions, and their impacts can be severe. By limiting tidal flow like the choke point of an hourglass, restrictions alter water levels and chemistry, diminish sources of ocean nutrients, and can degrade entire upstream aquatic systems. They often block the passage of fish and other aquatic life into important habitats and create favorable conditions for invasive species such as *Phragmites australis* (common reed). Installing a larger culvert or bridge restores the natural tidal flow needed to support healthy marsh habitats.

Special Considerations

The Stream Crossing Standards were developed specifically for freshwater, non-tidal rivers and streams and may not be appropriate for coastal waterways. Tidal crossing projects need to consider:

- Daily fluctuating tides, bidirectional flows, tidal inundation and coastal storm surge
- Flood protection of adjacent and upstream infrastructure
- Saltwater channel morphology and potential impacts due to sea-level rises
- Hydraulic modeling to determine appropriate sizes of structures for desired degree of tidal restoration

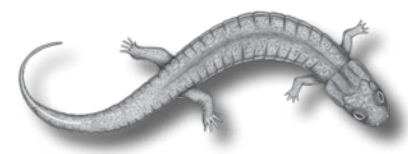
Qualified personnel and consultants should carefully consider engineering design and construction techniques. For guidance specific to tidal and coastal waterways, please contact the Division of Ecological Restoration at 617-626-1540.

Conclusion

Most Massachusetts citizens agree that protecting the environment, while accommodating a growing population and sustaining the economy, is a priority. The transportation infrastructure is essential to our way of life, and because that infrastructure cuts across natural ecosystems, it is imperative that we find ways to minimize adverse effects on habitats and wildlife.

Stream crossing designs have improved in recent years through the collaborative efforts of engineers, construction professionals, and environmental scientists. Safe and stable stream crossings can accommodate wildlife and protect stream health while reducing expensive erosion and structural damage. Further, federal and state regulations for Massachusetts require that all new and upgraded crossings to meet minimum design standards.

This booklet is intended to raise awareness about stream crossings and river continuity, and to highlight the standards for stream crossings. Qualified personnel can provide guidance on technical considerations that this booklet does not address (see Technical Concerns box on previous page). By adhering to the crossing standards in the *Massachusetts Stream Crossings Handbook*, town conservation commissioners, highway departments, and town engineers can play a vital role in protecting and restoring stream continuity in Massachusetts.



Getting More Information

Technical Guidance and Assistance

The Stream Continuity website, maintained by UMass Extension, has up-to-date guidelines and crossing standards and information on crossing problems, the ecological importance of river continuity, and further resources. Staff at the Division of Ecological Restoration are also available to provide suggestions and guidance to improve fish and wildlife movement through stream crossings.

Further Reading

Woolsey, H., A. Finton, J. DeNormandie. 2010. BioMap2: Conserving the Biodiversity of Massachusetts in a Changing World. MA Department of Fish and Game/Natural Heritage & Endangered Species Program and The Nature Conservancy/Massachusetts Program.

Massachusetts Department of Transportation, Highway Division. 2010. Design of Bridges and Culverts for Wildlife Passage at Freshwater Streams (web-based document) http://www.massdot.state.ma.us/Portals/8/docs/environmental/wetlands/WildlifePassagesBridgeDesign122710.pdf

Massachusetts Natural Heritage & Endangered Species Program. 2011. *BioMap2* Technical Report - Building a Better BioMap: A supplement to *BioMap2*: Conserving the Biodiversity of Massachusetts in a Changing World. Natural Heritage & Endangered Species Program, Massachusetts Division of Fisheries and Wildlife, Westborough, MA.

McGarigal, K, B.W. Compton, S.D. Jackson, E. Plunkett, K. Rolih, T. Portante, E. Ene. 2012. Conservation Assessment and Prioritization System (CAPS) Statewide Massachusetts Assessment: November 2011. Landscape Ecology Program, Department of Environmental Conservation, University of Massachusetts, Amherst, MA.

McGarigal, K, B.W. Compton, S.D. Jackson. 2012. Critical Linkages: Assessing Connectivity Restoration Potential for Culvert Replacement, Dam Removal and Construction of Wildlife Passage Structures in Massachusetts. Department of Environmental Conservation, University of Massachusetts, Amherst, MA.

Washington Department of Fish & Wildlife. Design of Road Culverts for Fish Passage (web-based document) https://wdfw.wa.gov/publications/01501/

Websites

Stream Crossing Standards
https://www.streamcontinuity.org/pdf_files/MA%20Crossing%20Stds%203-1-11%20corrected%203-8-12.pdf

Stream Continuity – UMass Extension (North Atlantic Aquatic Connectivity Collaborative)
www.streamcontinuity.org

Division of Ecological Restoration
www.mass.gov/der/

Massachusetts Wildlife Climate Action Tool
https://climateactiontool.org/content/maintain-habitat-connectivity-retrofit-or-replace-culverts

Massachusetts Division of Fisheries and Wildlife
https://www.mass.gov/masswildlife

Northeast Regional Climate Center and the Natural Resources Conservation Service - Extreme Precipitation Analysis in New York and New England
http://precip.eas.cornell.edu/

Permits and Regulations

U.S. Army Corps of Engineers – New England District
http://www.nae.usace.army.mil/Missions/Regulatory.aspx

Massachusetts Department of Environmental Protection – 401 Water Quality Certification and Wetlands Protection Act
https://www.mass.gov/service-details/water-resources-laws-rules

Massachusetts Department of Environmental Protection - Wetland and Waterways Permitting
https://www.mass.gov/wetlands-waterways-permitting-reporting