CONNECTICUT DEPARTMENT OF ENVIRONMENTAL PROTECTION

Inland Fisheries Division
Habitat Conservation and Enhancement Program

Stream Crossing Guidelines

February 26, 2008

I. INTRODUCTION

Inland Fisheries Division (IFD) Habitat Conservation and Enhancement (HCE) staff have been assessing fish passage and instream habitat needs at stream crossings across Connecticut since the late 1980's. The program was created in part to ensure that fish and other aquatic life as well as aquatic habitat needs would be effectively addressed during municipal, State and Federal regulatory permit review processes. These stream crossing guidelines are intended to provide government agencies, non-profit environmental groups and private landowners with the best technical guidance available to ensure unimpeded fish passage for resident and anadromous fishes and to minimize construction related impacts.

Guidelines focus primarily on fish and fish passage, but incorporating the suggested practices will also benefit other wildlife. This document is not intended to be a technical design manual. Readers should consult specific guidance documents provided by municipal, State, or Federal regulatory offices having permitting authority over a stream crossing project. Also, scientific and technical manuals produced by other agencies, including those of the States of Vermont (VDFW 2005), Washington (WDFW 2003), Oregon (Robison et. al. 1999) and California (CFGD 2003) can provide additional guidance on fish passage design and related issues.

Figure 1. Example of small stream in Connecticut that supports a fish community.

Along a stream continuum, stream flow, hydrology, physical habitat and water quality are factors that determine which fish species are present in a watershed and the abundance and diversity of those species. While Connecticut citizens may readily recognize the negative effects of existing dams on fish passage, many may not be aware that stream crossings, particularly culverts, can permanently block or seasonally impede upstream fish passage.

Fish passage needs are often unrecognized on small watercourses. Small streams account for most of the total stream miles within any watershed (Jackson 2003) with an estimated 70% of stream channel in the United States being comprised of small, headwater streams (Leopold et al. 1964). Many small streams in Connecticut support fish populations, often times a single species such as native brook trout (Figure 1). Many “problem” or impassable stream crossings were installed before environmental regulations were in place to review stream crossing designs and before there was a full understanding of the negative impacts to fish passage. Consequently, fish populations can become “fragmented” and unable to reach critical spawning, nursery, feeding, or seasonal refuge habitats that are important to the completion of various life history phases. The fragmentation of stream habitat and fish populations can adversely impact fish community diversity, fish population levels and fish survival. The following section describes common steam crossing problems observed in Connecticut.

II. COMMON STREAM CROSSING PROBLEMS

- **Perched Culverts**

The most common stream crossing problems in Connecticut are perched culverts that are situated above the elevation of the stream bottom at the culvert outlet (downstream end) that present obvious physical barriers to upstream fish passage (Figure 2). Perched culvert conditions are the result of improper installation or are created over time by years of excessive scour and erosion of the streambed at the culvert outlet. Freeze-thaw conditions can also lead to culvert perching.

Figure 2. Example of culverts perched above streambed.

- **Shallow Water Depth**

Another common problem are culverts that create shallow water or sheetflow conditions, especially during seasonal low flow periods (Figure 3). Thus, fish cannot swim through these structures due to insufficient water depths.

- **Excessive Water Velocity**

Excessive water velocities can occur within the main body of a culvert at the inlet/outlet sections. Velocity problems are typically observed within smooth bottom concrete box culverts that do not contain natural streambed substrates and lack channel roughness. Excessive velocities or hydraulic jumps can sometimes occur in culverts placed at improper slopes. Many fish species may not be able to pass through culverts with excessive velocities due to exhaustion (Figure 4).

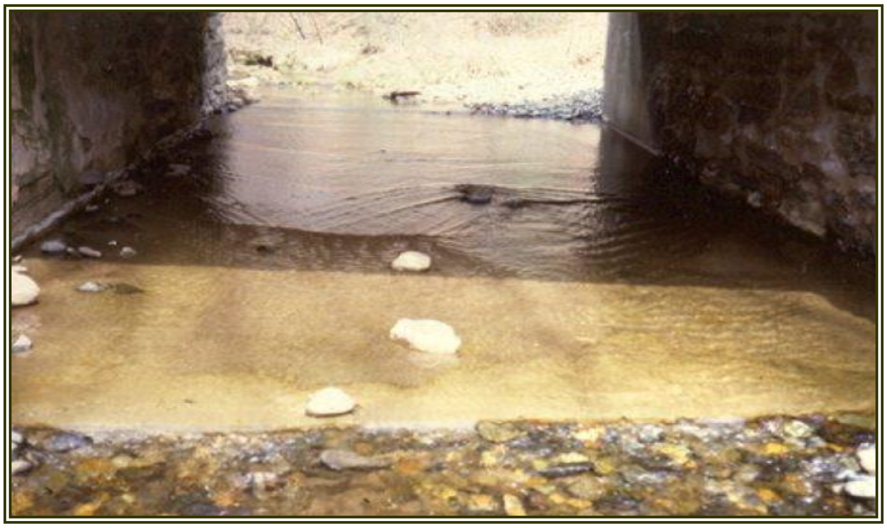

Figure 3. Example of shallow water conditions in a concrete box culvert.

- **Debris accumulation**

Debris accumulation is another condition that can block fish passage. Accumulation of debris most often occurs at undersized culvert or multiple culvert situations, usually at the culvert inlet (Figure 5). Debris blockage can cause damage to the crossing structure or possibly lead to flooding. If debris forms a logjam comprised of large woody debris (LWD), which is defined by biologists as logs with a minimum diameter of 4 inches and a minimum length of 6 feet, it may be possible to remove the logjam and re-introduce portions of LWD downstream of the roadway crossing where it does not present any hazard. Refer to Inland Fisheries Division management guidelines within the LWD Factsheet that can be obtained at the DEP website, http://www.ct.gov/dep/lib/dep/fishing/restoration/largewoodydebrisfactsheet.pdf.

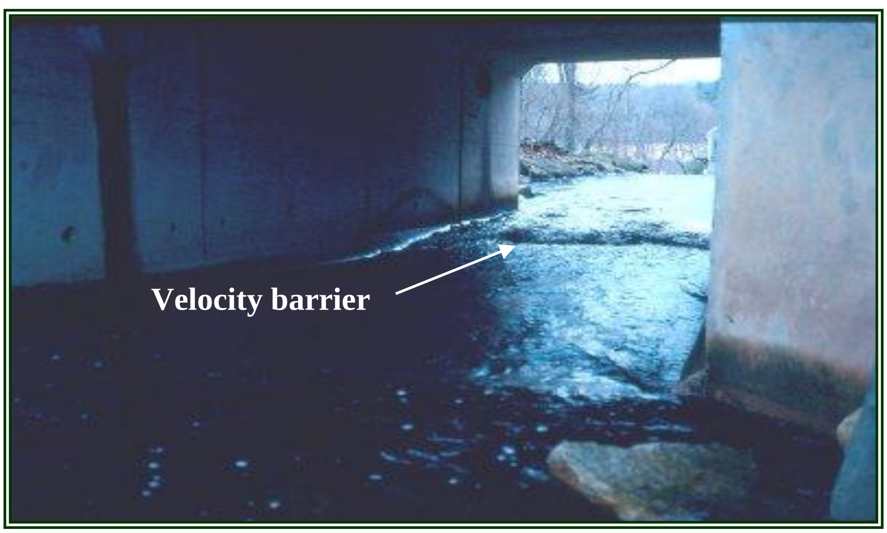

Figure 4. Example of excessive water velocities resulting in a barrier to fish passage.

Figure 5. Debris blockage at culvert inlets that blocks fish passage.

III. STREAM CROSSING GUIDELINES

Fish species in Connecticut streams vary greatly in size, and many adult fishes, e.g., blacknose dace, longnose dace and tessellated darter never exceed 4 inches in length. Thus, when designing fish passage at road crossings, consideration must be given to the entire fish community, not just the larger stream fish such as trout and white sucker.

Many of the standards in these guidelines have been adopted from and are consistent with U.S. Army Corps of Engineers Connecticut Programmatic General Permit guidance. Refer to http://www.nae.usace.army.mil/reg/ctpgp.pdf for more details relative to general permit requirements and also contact the DEP Inland Water Resources Division for permit guidance.

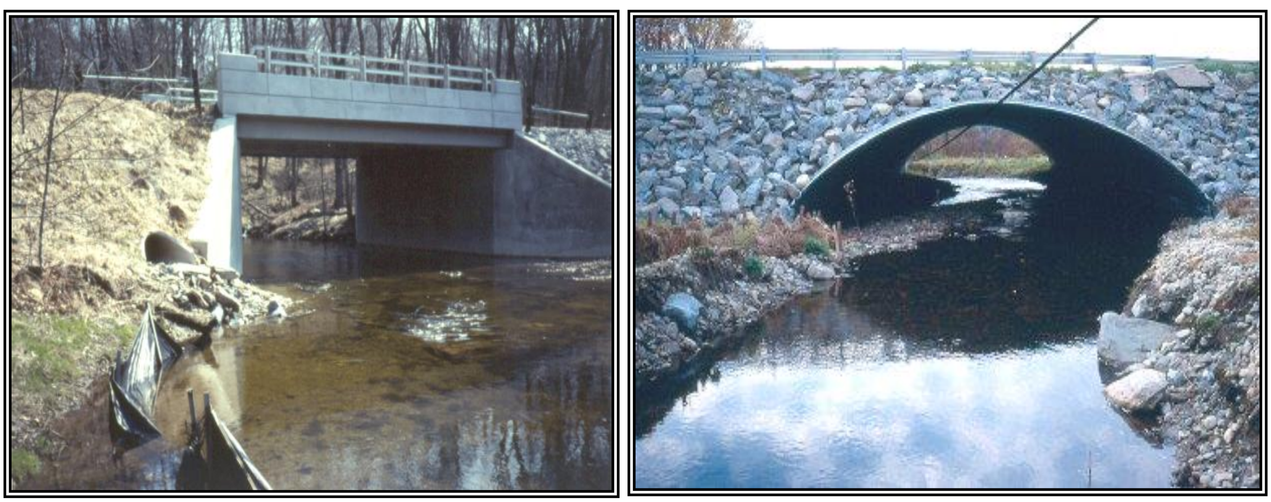

Figure 6. Clear span bridges and bottomless arch culverts are preferred stream crossing structures.

For new or replacement stream crossing projects, the Inland Fisheries Division (IFD) typically recommends the installation of **clear span bridges** or **bottomless arch culverts** for the crossing of perennial watercourses (Figure 6). These structures are "fish passage friendly" since they do not create barriers or impediments to fish migration and they best preserve physical instream habitats. Intermittent watercourses are evaluated for fish passage needs based upon the potential for seasonal utilization of the watercourses by fish.

In certain situations, the IFD has accepted the installation of culverts for stream crossings. However, several modifications to culvert design may be required to ensure fish passage and maintenance of aquatic resource integrity. The modifications recommended are as follows:

- **SINGLE CULVERT**
  The invert of a box culvert should be set no less than 1 foot below the existing streambed elevation. This installation technique is referred to as a sunken or embedded culvert. The invert of a round culvert less than 10 feet in diameter should be set 1 to 2 feet below the existing streambed elevation. For round pipe greater than 10 feet in diameter, the culvert invert should be set a minimum of 20% of the pipe diameter below the streambed elevation.

- **MULTIPLE CULVERTS**
  Multiple culverts are discouraged where design criteria can be met with a single culvert. For multiple culvert situations, one or more of the culverts should be installed as per the guidelines for single culverts (Figure 7). Deflectors may need to be installed in the stream to concentrate low streamflows into and through the recessed culvert. Recessed culvert(s) should be installed in the thalweg or deepest section of the channel and be in alignment with the low flow channel.

Figure 7. Culvert on left is sunken 1 foot below grade. Culvert at right, installed "at grade" accommodates high stream flows.

- **GRADIENT**
  The culvert gradient should be no steeper than the streambed gradient upstream or downstream of the culvert matching the overall stream gradient as closely as possible. Gradient for sunken culverts should not exceed 3%. Bottomless arch culverts or clear span bridges should be utilized in all cases where gradient exceeds 3%.

- **ALIGNMENT**
  Culvert alignment should be similar to that of the stream and not placed at a skew. This will ensure proper water conveyance and will protect against excessive channel erosion or scour.

- **LENGTH**
  Culvert length should be as short as possible. Vertical headwalls rather than fill slopes are recommended at the culvert inlet and outlet to reduce the total culvert length (Figure 8). Narrowing and lowering the roadway along with steepening embankments can also help reduce culvert length.

- **WIDTH**
  The culvert should have a width that spans an area 1.2 times the bankfull width of the stream. In Connecticut streams, bankfull width equates to the channel width wetted at the 1.5 to 2 year storm frequency flow. This standard also applies to arch (bottomless) culverts.

- **CORRUGATED CULVERTS**
  Corrugated culverts are preferred over smooth culverts since the corrugations create a roughness that aids in the retention of streambed material. Metal culverts are least preferred due to longevity concerns with rusting.

Figure 8. Example of vertical headwall that reduces length of culverts.

- **OPENNESS RATIO**

  The culvert should have an Openness Ratio of $\geq$ 0.25. The Openness Ratio (OR) is calculated by dividing a culvert's cross sectional area (height x width) by its length. All measurements are in meters.

  Embedded Culverts: $OR = \frac{[(\text{Cross-sectional culvert area pre-embedded}) - \text{Embedded area}]}{\text{Culvert length}}$

  Arch Culverts (bottomless): $OR = \frac{\text{Height x Width}}{\text{Length}}$

- **PRESERVATION OF STREAMBED SUBSTRATES**

  Native streambed material excavated for culvert placement should be stockpiled and replaced within the culvert following its installation. (Figure 9). Streambed material should be replaced in a manner replicating the original stream cross section with a well-defined low flow channel contiguous with that existing in the stream.

Figure 9. Streambed materials stockpiled for installation within sunken culverts.

IV. OTHER STREAM CROSSING AND HABITAT CONSIDERATIONS

In addition to offering recommendations for structure design, the IFD has developed the following measures to enhance and protect aquatic habitats and resources.

- **SEASONAL CONSTRUCTION WINDOWS**

Stream crossing construction projects can severely degrade stream fish habitat and water quality through the production of excessive turbidity and sedimentation levels. Negative impacts of sedimentation to fisheries resources have been well documented (Cordone and Kelley 1961; Reiser and Bjornn 1979; Ritchie 1972). Also, certain construction activities can prevent or delay the migratory movements of resident riverine and anadromous fishes through a project site. Consequently, seasonal construction windows, defined as "time periods during which construction should occur" are often recommended during times of the year when it is easier to control soil erosion and sedimentation and fewer fish are undergoing migrations.

Appropriate construction windows are typically determined on a case-by-case basis, but the following two windows are most often recommended.

1. INLAND RESIDENT FISH CONSTRUCTION WINDOW

In inland waters, unconfined[1] instream construction activities associated with either bridge/culvert installation and rehabilitation projects should only be **allowed** from the period **June 1 through September 30**, inclusive (Figure 10). Conversely this means a prohibition of unconfined instream construction activities from October 1 through May 30. Cofferdam installation may be allowed outside this window if construction techniques do not involve streambed excavation or sheetpile installation. This construction window pertains to perennial streams only. The use of construction windows to protect intermittent streams will be made on a case-by-case basis and their ability to seasonal support fish populations. Contact HCE fisheries biologists for guidance.

A June 1 through September 30 construction timeframe can be utilized as an effective measure for mitigating construction related disturbances for the following reasons: (1) it protects the spawning, egg incubation, and fry development periods of most resident fishes, (2) it does not interfere with seasonal migratory periods of resident fishes, and (3) it limits construction activities such as dewatering, excavation, trenching, and cofferdam placement to the period of low streamflow which coincides with the historic seasonal low rainfall period in Connecticut. In addition, during the June 1 through September 30 low flow period, erosion control measures are most effective and sediment transport can be more easily confined within the immediate construction area.

2. ANADROMOUS FISH CONSTRUCTION WINDOW

In both the tidal portions of rivers and streams and inland waters, elevated suspended sediment concentrations and sound levels produced by certain construction activities may prevent or delay spawning migrations of anadromous fish. The term anadromous refers to a species that lives in the ocean and returns to freshwater to spawn. Species of concern are alewife and blueback herring (collectively known as river herring), American shad and Atlantic salmon. Activities of particular concern are underwater pile driving, demolition of structures such as bridge piers using hoe rams and unconfined excavation and filing. All of these activities may affect the movement of fish through the project site[2]. Preventing migration would result in a complete failure of fish to spawn upstream of the site. If fish could not spawn anywhere below the site, it would cause the loss of an entire year class of fish that would have been produced in the stream. Delaying migration could reduce spawning stress, resulting in the production of fewer fish than would have been expected.

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[1] Unconfined is defined as work not contained within a cofferdam or similar type water exclusion structure.

[2] Although outside the scope of this document, it should be noted that occasionally a project may require the use of equipment or methods that can generate pressure waves sufficient to injure or kill fish, such as the use of high energy pile drivers to drive large support piles, high energy hoe rams for demolition, and blasting. If a contractor requests to use these during a sensitive period, HCE staff recommend a plan be developed and submitted for review and approval that details how impacts to fish will be avoided or acceptably minimized.

Collectively, spawning migrations of river herring, American shad and Atlantic salmon occur between March 1 and June 30. Therefore to protect all of these migratory species, unconfined instream construction activities associated with either bridge/culvert installation and rehabilitation projects should only be **allowed** from **July 1 to February 28th**, inclusive[3]. Conversely this means a prohibition of unconfined instream construction activities from March 1 through June 30 (Figure 10).

Since the migratory period of each anadromous species is different and may vary from stream to stream and only one or two species occur in some streams, an appropriate construction window should be determined on a case-by-case basis and will depend upon: (1) location of the project, (2) which species are known to migrate through the project area, (3) the timing of migration in the system, and (4) the type of construction activities and manner in which they are conducted. IFD Habitat Conservation and Enhancement staff can be consulted to assist with determining the best construction window to protect anadromous fishes.

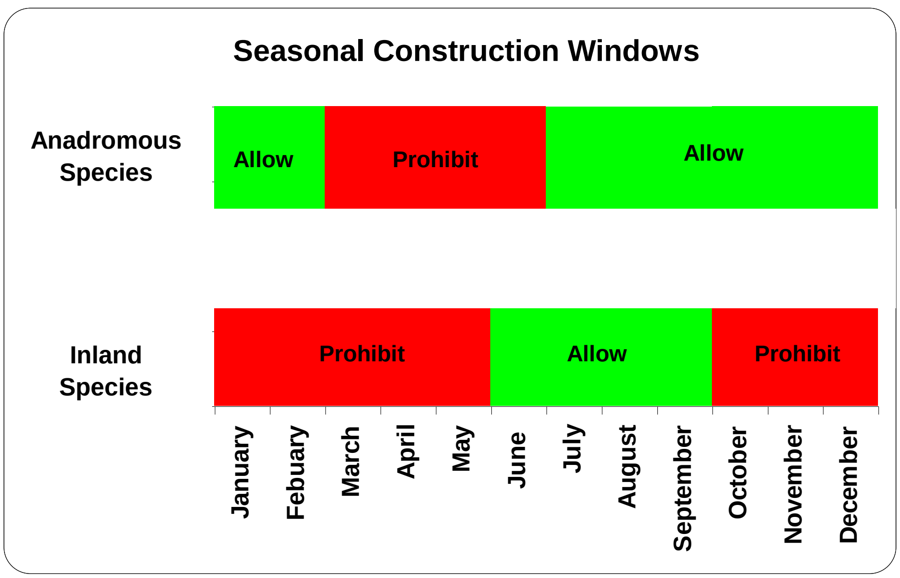

Figure 10. Recommended seasonal construction windows for inland and anadromous fish. *Note that the allowable unconfined work window in streams supporting both anadromous and inland fishes is restricted to the period from July 1 through September 30.*

➢ EROSION AND SEDIMENT CONTROLS

All appropriate erosion and sediment controls should be established prior to and be maintained through all phases of construction. Stream crossing projects should adhere to soil and erosion control best management practices as outlined in the 2002 Connecticut Guidelines for Soil Erosion and Sediment Control Manual (DEP Bulletin 34).

➢ SCOUR PROTECTION

The placement of scour protection measures should be minimized to the fullest extent possible and should match overall stream gradient as closely as possible. The

[3] Note that for projects in the freshwater portions of streams, where the June 1 through September 30 window might be appropriate, a modification of the window might be necessary if the stream supports a spawning run of one or more anadromous species.

placement of riprap in streams for scour protection is discouraged. If scour protection is required within the streambed, it is recommended that the surface layer of natural streambed substrates should be scraped from the existing streambed, saved and then placed back as a top layer over a "sublayer" of riprap. Typically, this top layer of substrates should be no less than 12 inches in depth. This strategy can satisfy both engineering concerns for scour protection as well as fisheries concerns for preserving and maintaining the habitat benefits of natural streambed substrates. In addition, it is recommended that cross sectional and longitudinal profiles of the channel protected for scour should match pre-construction profiles.

- **RIPARIAN ZONE PROTECTION**

Riparian vegetation disturbed during construction should be re-established in a timely manner upon project completion. The species of vegetation selected for reestablishment should be native to the immediate watershed and be non-invasive. Refer to the Connecticut Native Tree and Shrub Availability List for more information. This list is available on the DEP website at http://www.ct.gov/dep/lib/dep/wildlife/pdf_files/habitat/ntvtree.pdf. Where possible, retaining walls should be utilized in lieu of fill slopes along roadway approaches to stream crossing structures to minimize riparian habitat loss.

- **HABITAT MITIGATION**

Instream habitats can often be lost or modified due to culvert placement. For example, placement of a culvert within spawning habitats can directly impact fish population levels. As a consequence, HCE fisheries biologists assess habitat losses and alterations associated with stream crossings and may recommend installation of instream habitat enhancement structures such as rock vanes, rootwads or boulders to offset or minimize instream habitat impacts. Refer to Maryland Waterway Construction Guidelines Manual for a thorough description of some habitat mitigation practices (MDEWA 2000).

- **FISHING ACCESS**

Stream crossing locations can be popular areas for angling, especially on streams stocked with trout. Often times angler parking access is only available through informal pull-off areas along the roadside. Stream crossing replacements that include roadway improvements may also include the installation of guardrails, which will permanently block off these informal parking areas. While the IFD acknowledges the need for roadway and public safety, it is recommended that roadway improvement design plans consider the retention or improvement of public fishing access.

V. CULVERT RETROFITS

Existing culverts that are not scheduled for replacement but which block fish passage can sometimes be modified or retrofitted to provide effective upstream fish passage. There are several retrofit options that can include gradient control weirs, interior baffles/weirs and even the installation of a fishway. Gradient control weirs are usually constructed with large boulders (Figure 11). They are typically placed downstream of the culvert outlet and are used to back-up water through a culvert or reduce an excessive drop at a culvert outlet. Care must be exercised to ensure that gradient control weirs do not block fish passage during low flows. Baffles or weirs can be used to facilitate fish passage by creating a series of pools with drops to increase water depth and decrease water velocities (Figure 12). There are several different baffle configuration designs (Robison et. al. 1999, VDFW 2005). Baffles can increase debris clogging and accumulation and therefore require periodic maintenance. Installation of an engineered fishway can be utilized where the above retrofit options are not viable (Figure 13). Culvert retrofit design can be complicated and will usually require the services of a qualified civil engineer as well as review by HCE fisheries biologists. Culvert retrofits are never a substitute for full replacement and in some cases, full replacement can be more cost effective.

Figure 11. Example of boulder weir installed at outlet to create backwater into a culvert.

Figure 12. Example of concrete weir system.

Figure 13. Example of fishway installed within a culvert.

CONCLUSION
While this publication provides general stream crossing guidance, each stream crossing project may present certain challenges that have not been discussed. This document is not meant to be a technical design manual. Refer to the several design manuals that have been cited for more technical/engineering information, many of which are available on the internet. HCE staff are available to provide technical guidance relative to fish passage requirements for stream crossings; refer to contact information below.

CONTACT INFORMATION

<u>**Technical Guidance**</u>
Bureau of Natural Resources
Inland Fisheries Division
Habitat Conservation and Enhancement Program
Hartford Office: 860-424-3474
Eastern Connecticut: 860-295-9523
Western Connecticut: 860-567-8998
Coastal Connecticut: 860-434-6043

<u>**Regulatory Guidance**</u>
Bureau of Water Protection and Land Reuse
Inland Water Resources Division
Environmental Analysis Section: 860-424-3019

LITERATURE CITED

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