An Economic Analysis of Improved Road-Stream Crossings




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Summary

Road-stream crossings, which include culverts and bridges, are an essential element of our transportation networks, allowing roads to pass over rivers and streams. Our communities and our economies depend on functioning road networks and safe crossings.

We also depend on healthy rivers and streams for clean water, recreation, and a host of other benefits, and we are learning more about the relationships between road-stream crossing designs and their effect on natural areas. Undersized or poorly designed crossings fragment streams and disrupt the natural movement of water, sediment and aquatic organisms, causing erosion and degraded habitat. The most problematic of these crossings prevent aquatic organisms, such as brook trout, from accessing the upstream habitat they need to survive and reproduce.

Yet crossings can be designed to avoid these problems. Improved road-stream crossings deliver social, economic and ecological benefits and are a key element of adapting our infrastructure to a changing climate. Unfortunately, their initial cost can be a significant obstacle for highway departments with limited budgets.

Multiple Benefits of Improved Crossings

Stream crossings that are sized to carry high flows and designed to mimic the natural stream conditions provide a number of benefits, including:

- Healthier rivers and streams: Improved stream crossings lead to healthier rivers and streams and populations of fish and other wildlife dependent upon them. Research shows that people value healthy aquatic systems, even if they don't use them for recreation.

- Enhanced river-related recreation: As "barrier" crossings are replaced with upgraded structures, fish can access the food, cool water and spawning sites they require. Healthier fish populations and improved movement of fish can result in better opportunities for recreation, especially fishing. These activities bring money to local communities.

- Improved safety and mobility: Well-sited and adequately sized stream crossings are more likely to allow water to pass during high flows and are less likely to sustain damage from large storms. When culverts fail, the road is also frequently damaged and in extreme cases, the road can wash out and be closed for many days. This can isolate households and prevent emergency services from reaching people in need of help. Road closures also cause travel delays, loss of tourism revenue, lost income for local businesses on these routes, and lost income for those who cannot access their places of employment.

- Avoided flooding: While crossing design is not the only cause to flooding during extreme weather events, it can be a key factor. Flood damage to private property can be avoided with road-stream crossings capable of withstanding high water flows. Additionally, physical and

mental health impacts associated with flooding and the disruption of everyday life can be substantially reduced through avoided flooding.

- Improved water quality: Right-sized and well-designed stream crossings are less likely to cause erosion and scour in the stream, and they are less likely to fail. Erosion, scour, and culvert failure all degrade water quality.

As the climate changes, well-designed stream crossings will become even more important. With higher temperatures, fish requiring cold water to survive will need access to upstream reaches. With more frequent intense storms, the high flows in rivers will come more often and be more extreme, and our infrastructure will need to be able to handle these flows to avoid flooding, water quality impacts, and costly repairs.

Costs of Improved Crossings
Upgrading culverts to larger and more fish-friendly designs can be expensive in the short term. The initial installation cost for an improved road-stream crossing culvert upgrade can be 50% or even 100% more than a traditional crossing designed to pass water quickly under a road. Yet upgraded crossings require less frequent maintenance, and they last longer. Accordingly, when maintenance and replacement are factored in, the average annual cost of an upgraded crossing can be lower over its lifetime than that of an undersized crossing over the same time frame.

If we include in our considerations of costs the impacts of climate change, in particular the increased frequency of intense storms that scientists predict for the Northeast, undersized stream crossings will become even more costly, since they will require yet more maintenance and replacement. During major storms, undersized crossings fill with water, clog with debris and worsen flood impacts. Over time, water passing through poorly designed culverts scours away surrounding soil and increases the likelihood of sudden failure during large storms, whereas properly sized and designed crossings can withstand these storms without major damage. Improved crossings can therefore help communities to avoid expensive unplanned repairs to their infrastructure resulting from both flooding and stream crossing failure.

Economic and Regulatory Constraints
While we can assign a dollar value to some of the benefits of improved stream crossings, many are difficult to capture in dollar values, and so a clear-cut benefit-cost analysis is not yet possible. Although highway departments are responsible for allocating funds toward the cost of improving culverts, the benefits are shared by a wide and diffuse range of groups, including community members protected from flood impacts, anglers, and nature enthusiasts, who may not recognize the connection between stream crossing improvements, public safety and healthy streams. This can make it difficult for transportation departments with limited budgets to justify the high initial expense of upgrading problematic stream crossings. At present, there are few funding sources to help offset these costs.

In addition to these economic constraints, many states lack adequate incentives, standards and regulations to encourage or require stream crossings that provide this full range of potential benefits both now and under a changing climate. Following major storms that cause the failure of undersized road-stream crossings, the existing federal and state regulations often result in a replacement of the same undersized crossings. Because the regulations governing the allocation of funding for disaster recovery are confusing, many communities are unaware of potential opportunities to improve their stream crossings following major storm events. Consequently, key opportunities to improve these crossings are often missed or lost.

Recommendations

Given the challenge of reconciling the initially high costs of upgraded stream crossings with limited economic data about for ecological, social and economic benefits associated with improved stream crossings, we need to think strategically about how to most effectively further the implementation of ecologically beneficial and flood resilient crossing designs in priority locations. Our recommendations are as follows:

- Improved information*:* We recommend research to prioritize culverts of greatest ecological and social importance and to identify which are most vulnerable to flood impacts. Second, it is imperative that highway departments at all levels improve their tracking of culvert costs and performance over time so that we can better understand the economics of different design options. Finally, we propose further research to better quantify the benefits of improved stream crossings.

- Adequate funding: Sustained and sufficient funding streams to help highway departments are essential. These should include grants and loans and come from both state and federal sources. Of particular importance is the combined use of disaster related funding and environmental funding, since improved stream crossings meet both hazard mitigation and ecological objectives.

- Standards and regulations: Finally, state regulations for the size and design of stream crossings need to be strengthened. Financial incentives should be developed and provided for communities that adopt codes and standards for stream crossings that will carry high flows and allow aquatic organisms to move through the channel. These measures, which can save communities money in the long term, will help better protect our freshwater ecosystems and build flood resilience in our communities.

Background

Since 2007, The Nature Conservancy (the Conservancy), Adirondack Chapter, has been working to identify and prioritize environmentally important road-stream crossings in order to help focus limited transportation maintenance resources in areas of greatest conservation value. In an initial project, undertaken with the New York State Department of Transportation (NYSDOT), the Conservancy developed a computer model to identify environmental priority culverts on NYSDOT-maintained roads across the state based on habitats and species of importance as well as stream conditions. The environmental priority culverts were integrated into NYSDOT's database in 2011 and are now informing state transportation planning and maintenance.

Since NYSDOT owns only about 13% of roads in New York, it was important to apply this model to all classes of roads and at a finer scale. Beginning in 2010, the Conservancy partnered with the Ausable River Association and Plattsburgh State University of New York (SUNY-Plattsburgh) for a stream crossing prioritization effort in the Ausable River watershed of the Adirondacks in New York. The Conservancy downscaled the statewide model to identify priority streams and stream crossing locations in the watershed, and Plattsburgh State scientists conducted on-the-ground site assessments of the environmental priority culverts to ascertain which of the culverts are actually barriers to the movement of fish and wildlife.

As the site inventory neared completion during 2011, Tropical Storm Irene struck the region and caused widespread flooding. Damage to private property and transportation infrastructure, including culverts and roads, was extensive and costly in the Adirondacks and across the northeastern U.S. In the Ausable River watershed the flood impacts were severe: many major roads were destroyed and public and private property sustained millions of dollars of damage (Figure 1).

Figure 1: Tropical Storm Irene Damage in the Ausable River Watershed

Credit: Larry Masters

Overnight, Tropical Storm Irene literally changed the landscape of the Northeast. In the Ausable River watershed, the culvert project team realized the importance of looking at stream crossings from new perspectives, including potential safety and economic liabilities for communities. As a result, the team initiated an outreach effort to local highway departments in the watershed to learn more about their culvert priorities, which were largely unrelated to fish passage. We learned which culverts have been the sites of frequent flooding, which culverts require ongoing maintenance, which culverts are likely to fail in future storms, and the barriers communities face in improving these problem culverts. The end result of this effort was the identification of a select set of culverts that are ecological priorities, barriers to the movement of stream dependent organisms, and community maintenance or safety concerns. We are now working to secure funding to improve these priority road-stream crossings.

Through this work, we learned that cost is the major factor preventing local highway departments from upgrading undersized and barrier road-stream crossings to those that are adequately sized to carry large flows and provide aquatic organism passage. Yet there is little useful data about just how much more costly upgraded culverts are and whether they may be a cost effective option in the long term, especially when a range of benefits is considered. This report begins to fill this information gap.

This report is meant to be a useful resource for highway departments, leaders, planners, and emergency managers from local to federal levels as they make decisions about how to design and install road-stream crossings.

Introduction

Road-Stream Crossings: Aquatic and Human Communities

While transportation networks are vital to our communities and our economy, it is now well understood that infrastructure such as roads have significant impacts on natural ecosystems. Road-stream crossings, which include culverts and bridges, are necessary structures that allow our roads to pass over stream and rivers. Unfortunately, because of their design, many crossings have led to a number of problems for the health of the streams and organisms that live in them.

Stream crossings that are too small, too high above the stream ("perched" crossings), and/or have water depths that are too low all restrict the natural movement of water, sediment, and organisms (Figure 2). Crossings can cause significant ecological problems if they block the movement of fish that depend upon traveling upstream and downstream at different parts of their life cycles. For example, many species of fish can only survive summer heat by taking refuge in cold water, while others may need to travel to breed and spawn. A range of other animals, including amphibians, insects, reptiles, and mammals, also depend upon moving along healthy streams for their survival. Poorly designed stream crossings can also prevent sediment and woody debris from moving naturally through the channel, which can lead to degraded habitat for the organisms dependent upon the stream. Undersized crossings that appear to be sufficient for the movement of organisms when installed can become problematic over time as the stream adjusts to the narrowing caused by the structure. These crossings may contribute to the erosion of stream banks and water quality problems.[1]

Fortunately, stream crossings can be designed to allow streams to function more naturally and provide animals the ability to move along the stream corridor and meet their needs at different stages of their lives (Figure 3). The ecological importance of stream connectivity has become increasingly understood, and many environmental agencies at local, state and federal levels address the issue through adoption of standards and regulations that promote or require better design for crossings.

On the other hand, there has been relatively little attention on the role of stream crossings in helping to keep communities safe, mitigating flood impacts and even saving money in the long term. Poorly designed crossings may erode stream banks and roads, become clogged, and exacerbate flooding. Intense precipitation may lead to the failure of undersized crossings, as culverts and bridges are undermined by high flows. These failures have both localized and larger-scale impacts, since they result in road closures and the need for costly, unplanned repairs by local highway departments. There are also significant costs for ongoing maintenance of clogged culverts, flooding, road repairs, road closures, and culvert repair.

[1] A more detailed discussion of the ecological importance of stream crossings can be found at www.streamcontinuity.org.

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

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

Perched crossings are above the level of the stream bottom at the upstream or 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.

Figure 2. Road-Stream Crossing Problems

Figure and text reproduced from: Singler, A. and B. Graber. 2005. Massachusetts Stream Crossing Handbook. Massachusetts Riverways Program, Commonwealth of Massachusetts Executive Office of Environmental Affairs.

Important characteristics of this crossing include its large size suitable for handling flood flows, water depth and velocity that match upstream and downstream conditions, and a natural channel bottom that creates good conditions for stream dwelling animals.

Figure 3. Example of a Well Designed Road-Stream Crossing

Figure and text reproduced from: Singler, A. and B. Graber. 2005. Massachusetts Stream Crossing Handbook. Massachusetts Riverways Program, Commonwealth of Massachusetts Executive Office of Environmental Affairs.

Stream Crossings and Climate Change Adaptation

As the climate changes, adequately sized and well-designed stream crossings can play an important role both for aquatic ecosystems and human communities. For example, scientists predict that rising temperatures will reduce suitable habitat for cold-water fish such as brook trout (Horton et al. 2013). To survive in these warmer conditions, fish will need to move upstream to cold-water refugia. Adequately designed culverts and bridges allowing unrestricted movement for fish and other aquatic organisms can help ensure access to the full range of their habitat to meet their needs under these new warmer conditions.

Stream crossings are also important for community safety and well being with a changing climate. The frequency of extreme storms and the amount of precipitation falling in these storms have both increased over the past few decades, and scientists predict that these trends will continue as the climate changes (U.S. Global Change Research Program 2009). Over a 50-year period, New England and the Mid-Atlantic experienced 61% and 42% increases in the frequency of extreme precipitation, and New York, Vermont, New Hampshire and Massachusetts all saw over 50% increases in extreme precipitation[2] (Madsen and Figdor 2007).

[2] "Extreme" precipitation events were defined relative to the local climate, based on an analysis of daily precipitation records spanning 59 years for each of 3000 weather stations across the United States. The 59 largest storms at each station were labeled "extreme," and trends in the frequency of these storms over time were studied.

The Northeast experienced a 74% increase in the amount of precipitation in very heavy storms in recent decades, more than any other region of the United States (Horton et al. 2013).

During these major storms, undersized crossings can exacerbate flood impacts and result in costly damage to infrastructure. When these culverts fail, there are safety impacts as roads become unsafe to travel and communities become separated from the emergency services they require. In addition, culvert failure can cause significant water quality problems. In short, stream crossings will be under increasing pressure to carry increasing volumes of water from these more frequent and more extreme precipitation events. Failure to address the problem can cause ecological, safety, and economic impacts in communities.

While many climate-related changes are likely to impact our transportation infrastructure, the increasing frequency of intense rainfall raises significant concerns, and transportation agencies across the United States are recognizing the need to adapt their infrastructure to prepare for these impacts. A study of the Transportation Research Board examined the consequences of climate change for U.S. transportation infrastructure and concluded that weather extremes such as intense precipitation and intense hurricanes will have major impacts. While these impacts will vary based on mode of transportation and region of the country, they will be widespread and very costly. Transportation departments will need to make major changes to their systems of planning, design, construction and maintenance (Committee on Climate Change and U.S. Transportation 2008).

A study for the National Cooperative Highway Research Program (NCHRP) called particular attention to the impacts of increased precipitation, noting: "Risks to the highway system due to … increased precipitation amounts/intensity appear to be the biggest cause for concern and amongst the first priorities for action." Among the report's recommendations was the redesign of culverts to accommodate both fish passage and new patterns of precipitation (Meyer et al. 2011). Similarly, a summary of interviews with numerous state Departments of Transportation found that "maintenance demands from flooding and snow… have increased precipitously in many states" (Venner and Zamurs 2012).

Despite widespread recognition of the major impacts on infrastructure from climate change, there has been little progress beyond assessment of risk and vulnerability to the crucial step of implementing priority actions. Most transportation agencies' work on adaptation has focused on identifying the major climate change concerns and adaptation strategies at a high level, yet little has been done to incorporate adaptation into design of projects and implementation (Meyer et al. 2011).

With widespread climate change impacts and potentially high costs for many adaptation options, decision makers and transportation departments face the challenge of prioritizing how to "climate-proof" their road networks and reduce constituents' risk. Decisions about what measures to undertake will include consideration of the expected risks to be mitigated, the cost of potential measures, and the expected return on investment. A potential starting point is to invest in measures that can help build the resilience of our transportation networks in the face of climate impacts and also bring benefits today. Improving road-stream crossings is an example of one such “low regrets” measure (IPCC 2012), since it offers immediate benefits – healthier streams and improved movement for fish and wildlife – and also prepares our transportation infrastructure to withstand extreme precipitation, which can better protect communities from future floods.

The evidence for the ecological benefits of improved road-stream crossings is clear, and there is ample information supporting the importance of adequately sized crossings for safety and flood mitigation. Yet the initial costs of improving stream crossings are significant. Unfortunately, few studies document these costs. Even fewer quantify the potential benefits. This report begins to fill gaps by presenting a range of quantitative and qualitative information about the social, environmental and economic benefits of improving road-stream crossings as well as information about costs.

<u>Geographic Focus</u>

While the economic information presented here is relevant across the country, the report’s geographic focus is the Adirondack region of New York and the northeastern United States. We present a broad range of economic values – both benefits and costs – and also focus on values that are most relevant to this region.

The primary data related to culvert costs and flood damages are from the 512 square mile Ausable River watershed in New York (Figure 4). The watershed includes 767 river miles and 70

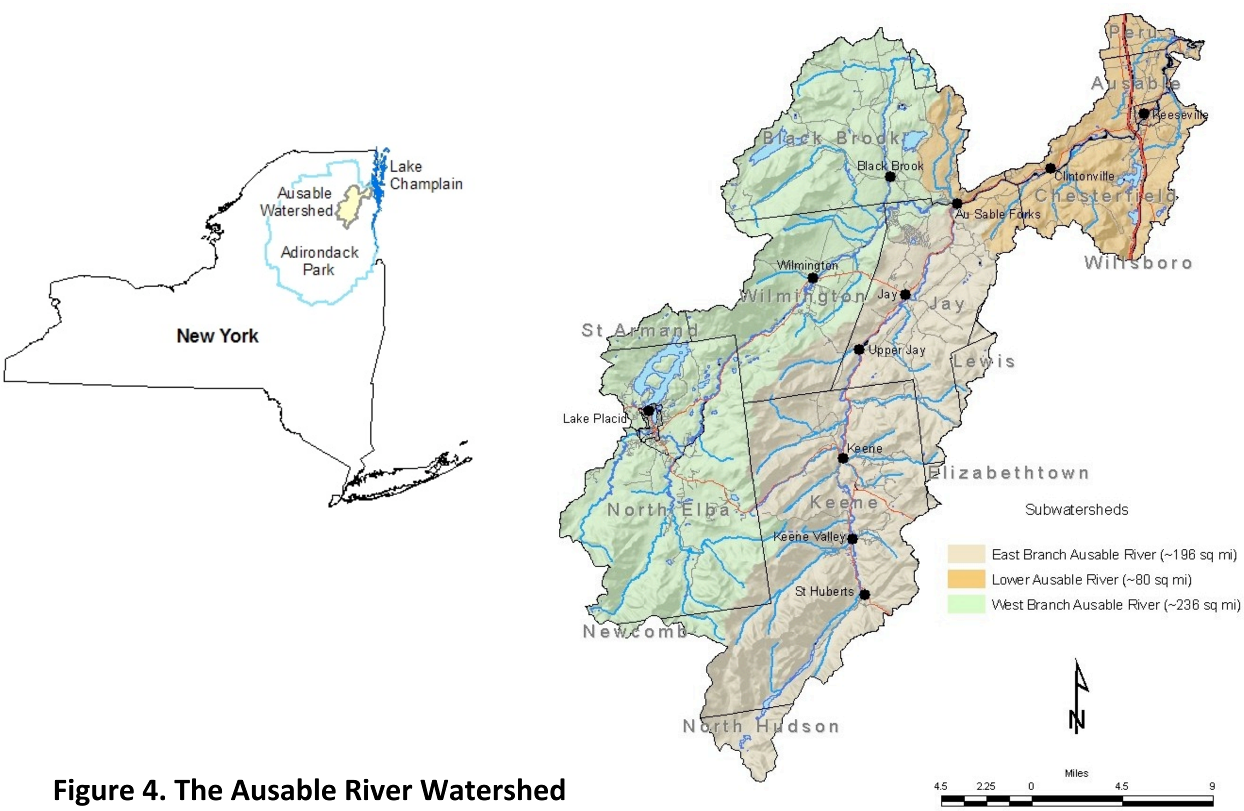

Figure 4. The Ausable River Watershed

tributaries, and the river drains to Lake Champlain. This watershed was severely affected by two flooding events in 2011: a spring flood that resulted in record-breaking water levels in Lake Champlain and the downstream Richelieu River and Topical Storm Irene in August.

On August 27, 2011, intense precipitation from Tropical Storm Irene led to widespread flooding across the eastern U.S., with severe impacts to infrastructure and property in inland communities in Vermont, New York, Massachusetts and New Jersey. The Federal Emergency Management Agency (FEMA) declared a disaster for this event in 13 U.S. states, the District of Columbia, and Puerto Rico. According to the National Hurricane Center, the total damage estimate from the storm was $15.8 billion (Avila and Cangialosi 2011), which made Irene the seventh most costly tropical cyclone in the U.S. since 1900 (Blake et al. 2011).

Overview

This report is organized as follows:

- Section 1 examines the many benefits – social, environmental and economic – of upgraded road-stream crossings.
- Section 2 focuses on the costs of upgrading stream crossings, both in the short term and over longer periods of time.
- Section 3 presents data from a case study culvert in the Ausable River watershed in the Adirondacks.
- Section 4 focuses on the constraints – economic, political, and social – to upgrading stream crossings.
- Section 5 highlights existing opportunities to move this work forward, presents policy and planning recommendations, and discusses some key information needs.

1. Benefits of Improved Road-Stream Crossings

Benefits Overview: Key Points

Improving stream crossings to ensure the movement of aquatic organisms can result in many other social, environmental and economic benefits, ranging from improved water quality to reduced mental health impacts for people and avoided property damage following major storms. Table 1 summarizes the major benefits.

Table 1. Benefits of Upgraded Road-Stream Crossings

Type of Benefit	Outcomes
Social	- Improved safety and mobility - Avoided physical and mental health impacts - Enhanced river-related recreation
Environmental	- Healthier populations of fish and wildlife - Improved river habitat for in-stream and river-dependent species - Decreased erosion of stream banks - Improved water quality - Avoided water quality impacts from storm-related failure

Economic	- Avoided flood repair costs:
	  - Repair of damaged infrastructure
	  - Repair and replacement of damaged property
	  - Travel delays
	  - Lost business income from road closures
	- Local jobs for contractors
	- Avoided costs to repair environmental degradation (e.g., water quality)

A broad range of people benefit from improved crossings. These include nearby property owners who avoid major flood damage, road users, business owners, contractors, recreational anglers and nature enthusiasts.

While it is somewhat straightforward to estimate the costs of work to improve stream crossings, **quantifying the benefits in dollar values presents a major challenge**, for several reasons. Many of the benefits are the result of *avoided* flooding and/or stream crossing failure, yet it is very difficult to predict how often flooding or failure is likely to occur and how severe the avoided impacts would be. These are complex questions for climate scientists and hydrologists and require detailed data, up-to-date climate models, and high resolution hydrologic, topographic, and land use information. Moreover, quantifying social and environmental benefits is a complicated endeavor.

It is important to note that **values for social and environmental benefits are context and location-specific**. For sites where primary data about benefits and values are not available, economists often rely on a technique called "benefits transfer." Using benefits transfer, values obtained from past studies are applied to similar sites lacking primary data to estimate the value of a resource. Despite its frequent use, the reliability of benefits transfer to estimate values is controversial among economists. There are a number of potential challenges associated with use of benefit transfer: for example, the methods used to derive the values, e.g. how questions in surveys are worded and how surveys are implemented, often influence the resulting values. **Since values for social and environmental benefits are context-specific, we cannot indiscriminately apply them to any location. On the other hand, these values *do* provide a useful overview of the overall importance of these benefits to communities**.

The key benefits of upgrading stream crossings are discussed in more detail below, along with some economic values from past studies that have quantified some of these benefits. The following sections also present relevant information – qualitative and quantitative – related to these benefits in our region of focus, the Adirondacks.

Social Benefits

The social benefits associated with improved stream crossings are primarily the result of avoided or reduced flood impacts and/or culvert failure. Many of these benefits are simply avoided costs. While undersized crossings are not the only factor contributing to flooding from extreme storms, and while it is difficult to attribute how much flood damage has resulted from particular undersized crossings, it is clear that they can be a major contributing factor.

Improved Safety and Mobility

Adequately sized and designed stream crossings improve the safety of our roads. When high flows damage or destroy undersized culverts, they can pose a significant safety risk for drivers and passengers in vehicles. The safety of road users may be significantly undermined as a result of damage or loss of a culvert. Similarly, if there is major flooding of the road because the culvert is clogged with debris or filled with water, drivers may find themselves in unsafe situations attempting to navigate their vehicles through water and unable to see the conditions of the road. In the United States, most flood impacts are vehicle-related.

When data is available, mortality impacts can be quantified for specific events and the benefit of avoided mortality may be calculated. The U.S. Environmental Protection Agency recommends using $7.9 million as the "value of statistical life" (VSL) in valuing reduced mortality (US EPA 2010). For example, two people died in the Adirondacks when their car plunged into the river at a site where a bridge had been undermined by floodwaters during Tropical Storm Irene (Clermont 2011). There were multiple other deaths of drivers on flooded roads in other parts of the east coast from this storm. In cases where we can reliably estimate how many deaths could have been avoided as a result of improved stream crossing, we could quantify a safety benefit based on EPA's VSL.

Road flooding and culvert failures typically require closures of the road for repairs, which may impede people's ability to access their jobs, other parts of their communities, and emergency services. Following Tropical Storm Irene, thirteen Vermont towns near the Green Mountain National Forest were isolated from main roadways due to bridge and road failure (Gillespie et al. 2013). In the Adirondacks, the major roads connecting the towns in the Ausable River watershed were damaged to the point that they could not be used; in addition, many residents were unable to access the main roads from their homes. This kind of social disruption has widespread impacts, and it may result in reduced safety if people are unable to access the services they need during and following a disaster. In other cases, roads passing over damaged culverts and bridges may remain open but be less safe to travel.

Avoided Health Impacts

There are also human health impacts resulting from flooding that may be exacerbated by undersized culverts. These impacts include loss of life from drowning and trauma from the event itself, as well as increased mortality in months following a flood. Floods also result in non-fatal injuries, such as cuts and sprains, as people attempt to remove themselves from dangerous situations and when they return to their homes following floods. Although less common in developed countries, illness such as vector-borne and rodent-borne disease can also result following floods (Ahern et al. 2005). When the data is available, the economic value of health impacts may be estimated through a "cost of illness" method, which considers the costs such as treatment, rehabilitation, and the value of lost income due to injury or illness (US EPA 2010).

Mental health impacts can also be significant and may include anxiety, depression, and post-traumatic stress disorder resulting from fear of future floods, disruption of daily life and disconnection of households from one other (Ahern et al. 2005). A literature review about the evidence of mental health impacts on those who have been affected by flooding concluded that flooding is very stressful for people of all ages, and that social and mental health problems can continue for long after the flood event (Stanke et al. 2012). Mental health impacts can be quantified through surveys of those who have been affected by floods; for example, a study of lost productivity due to mental health impacts following Hurricanes Rita and Katrina (which were much more devastating events than Tropical Storm Irene in terms of property damage and loss of life) found that $1,150 was lost per worker per year, with a total economic loss of $462 million across the general population due to missed days of work. The combination of worker absence and the resulting impacts on productivity across the economy resulted in $1.1 billion of lost annual economic value caused by mental health impacts (Zahran et al. 2011). While we don't have an economic estimate for the mental health impacts related to Tropical Storm Irene, we do know that the flooding disrupted many lives. A news article in the Adirondacks (Morris 2012) noted, nine months after the storm: "The physical damage caused by Tropical Storm Irene has started to fade some, but the emotional toll it took on the people it affected still lingers," and a retrospective in Vermont echoed this sentiment.[3]

Economic surveys have shown that residents and non-residents of communities impacted by flooding are willing to pay for the additional flood protection. For example, a study of New Orleans residents and non-residents' willingness to pay for several different measures to protect New Orleans from future floods found that the average U.S. household was willing to pay $449 for upgrading the city's levee infrastructure to withstand a Category 5 tropical storm, $103 for coastal marsh restoration, and $103 for a modernized transportation system to improve residents' ability to evacuate. While Hurricane Katrina was a unique event in the scale and nature of its devastation and in many ways unlike Tropical Storm Irene, these economic data indicate that households both within and outside of areas impacted by flooding are often willing to pay for measures that improve the protection of residents from floods.

Enhanced River-Related Recreation

Upgraded stream crossings result in healthier streams and fish populations, which can improve opportunities for recreation, in particular fishing. The value of these improvements can be measured through surveys of how much people are willing to pay for improved fishing ("stated preferences") and by actually measuring how much anglers spend on their fishing trips ("revealed preferences"). Some of these values are summarized below:

- A recent analysis considered 391 observations from 48 stated preference studies conducted between 1977 and 2001 of people's willingness to pay for improved recreational fishing. For trout outside of the Great Lakes region, people were willing to pay between $4 and $11 for each additional fish caught (Johnston et al. 2006).

- A literature review assessed the economic impacts of aquatic habitat restoration and enhancement projects, including fish passage projects, in the U.S. The report estimated that the value of removal of barriers within river systems is $515,000 per river mile in 2010 dollars (Charbonneau and Caudill 2010); the U.S. Fish and Wildlife Service (USFWS) uses this figure to estimate the economic benefits to anglers associated with removing barriers across a large region. While this is an impressive figure, it is important to note that this value is based on a single study of the economic impact of a dam removal in Maine and the associated restoration of anadromous (sea-run) fish, which migrate from the ocean to spawn in freshwater rivers, in terms of expenditures by anglers (Robbins and Lewis 2008). The improvements in fishing from this type of fish passage restoration project are substantial, and it is unlikely that this economic benefit would be as significant in other places.

In the Adirondacks, the pilot region for our work on stream crossings, fishing generates significant economic activity, and we can expect that healthier streams will boost these values:

[3] See http://www.vpr.net/news/irene/.

- In the eight counties that make up most of New York's Adirondack Park, an estimated $56 million was spent in local communities by anglers while on fishing trips in 2007. Anglers in Essex County, New York, where most of the Ausable River watershed is located, spent about $12.7 million in "at-location expenditures," and about 48% of these fishing trips were primarily for trout fishing (Connelly and Brown 2009).

- In the Ausable River watershed of the Adirondacks, in 2007 there were an estimated 76,000 angler days. An angler day is defined as any part of a day that a person spent fishing.

- Assuming that the expenditure per angler day is about the same across Essex County, we can estimate that $2.3 million was spent in 2007 by anglers on the Ausable River (Connelly and Brown 2009). Stream crossing improvements should lead to healthier streams and fish populations overall and could be expected to improve these numbers.

Tourism revenue data from the Adirondacks highlight the importance of tourism for the region's economy and the role of fishing as a driver of tourism. Tourism is a $1.2 billion industry per year in the Adirondacks, supporting about 20,000 jobs across the region. In Essex County, where the Ausable River watershed is primarily located, travelers spent about $341 million in 2011 (Tourism Economics 2012). About 4% of the total tourism direct spending was related to fishing It is also important to note that these tourists depend upon safe, functioning roads.

Environmental Benefits

Well-designed and adequately sized stream crossings provide a range of important environmental benefits. Replacing undersized and/or perched stream crossings with structures that allow organisms, sediment and debris to pass naturally through the stream can lead to great improvements in aquatic habitat. This habitat improvement benefits fish and other organisms that depend on streams.

Because upgraded crossings are less likely to fail during major storms, the environmental benefits include a number of avoided failure-related impacts. For example, when culverts fail due to large storms, the road is also likely to be damaged, which can result in a massive load of sediment entering the stream. This high concentration of sediment, particularly following a single event, degrades water quality and can negatively impact the ecology of a stream and the ability of organisms, such as trout, to reproduce (Dunne and Leopold 1978). Water quality impacts are experienced both locally, at the site of the failed culvert, and downstream.

While there are multiple environmental benefits related to the improvement of road-stream crossings, most are difficult to quantify and value in dollar terms. As noted earlier, valuation studies are site and context specific and the results are highly sensitive to the particular valuation technique that is used. What is clear from the information below is that people value healthy streams, whether or not they are direct users of the streams for fishing or other recreation. Improving the condition of streams and the organisms that live in them can result in measurable economic benefits through improved fishing and additional tourism revenue.

The following discussion of values related to environmental benefits is by no means exhaustive. Consideration of the values of some important benefits, such as improved water quality, is beyond the scope of this report.

Many studies have quantified the value of improved aquatic habitat and the benefits that people obtain from aquatic ecosystems (also called ecosystem services). These studies provide strong evidence that the benefits of healthy aquatic ecosystems are substantial. Some key values from several comprehensive studies as well as studies pertinent in our geography are highlighted below:

- A major study of the average value of all ecosystem service benefits from freshwater resources (rivers and lakes) estimated that the value of these benefits – which include water supply, sediment retention, recreation, refugia, and food production - is $3,440 per acre per year (Costanza et al. 1997).

- A review of 41 studies of economic values of freshwater resources – both lakes and rivers – for fish and wildlife habitat and recreation found that the average value of freshwater was $48 per acre-foot of water for the U.S., with values ranging widely in different regions of the country. For New England, the average value was $4 per acre-foot, while the value for lower Colorado River was $597 per acre-foot (Frederick et al. 1996). The research team noted that the high values occurred in places with a high demand for water-based recreation and a scarcity of high quality streams for those activities due to natural climate and extensive development of water resources.

- A number of economic studies have focused on "non-use" values of rivers. The basic idea is that individuals may benefit simply by knowing that free flowing rivers and natural fisheries exist, even if they do not make specific use of them (Wilson and Carpenter 1999). Non-use values range greatly by place and river: a review of 14 studies, published between 1978 and 2000 and that estimated the non-use value of specific rivers or combinations of rivers, found that the annual non-user household willingness to pay for "non-use values" ranged from $17 to $262, with an average value of $108 per household in 2003 dollars (Levine 2004).

- A recent survey undertaken by the U.S. Environmental Protection Agency estimated the values that people hold for aquatic ecosystem improvements that are not tied to particular use of the resource for recreation. The survey used a "Bioindicator-Based Stated Preference Valuation method," which was developed to estimate ecological results that people may value even though they don't understand the full ecological science behind the outcome. The preliminary data indicated that households in the northeastern U.S. are willing to pay $9.34 per year for a 1% improvement in "aquatic ecosystem condition" relative to the most natural waters in the region (Helm 2012).

Economic Benefits

Like social benefits, most of the economic benefits of improved road-stream crossings result from avoided flooding. While flood damage costs potentially avoided by upgraded stream crossings are a potential measure of this benefit, it can be very challenging to accurately quantify these damages. A recent literature review noted: "estimating the full range of economic costs from natural disasters is difficult, both conceptually and practically. Complete and systematic data on disaster impacts are lacking, and most data sets are underestimates of all losses" (Kousky 2012).

In addition to this challenge, as noted earlier, undersized crossings are certainly not the sole cause of all flood related damage. Flooding and flood impacts are the result of many factors, such as land use patterns and practices, stream management, location of infrastructure, and the condition of in-stream and riparian habitat. Given these many factors, it may not be possible to attribute a specific percentage of flood-related repair and replacement costs to undersized or poorly designed stream crossings in many locations.

Avoided Flood Damage

When culverts are a problem, among the major costs that may be avoided through upgraded stream crossings are the expenditures for the repair of roads and other infrastructure that are damaged as a result of inadequately sized culverts. Undersized crossings are more likely to fail when there are extreme flows of water in the stream, and they are also more susceptible to being clogged by debris during major storms. The resulting flooding or outright failure undermines the road at the site and can also exacerbate downstream flooding. For example, at a single site in Vermont where a culvert washed out during Tropical Storm Irene, the cost of the road repair alone was $1.1 million (Gillespie et al. 2013).

To understand the scale of costs associated with flood damage and the failure of undersized culverts, we collected data following Tropical Storm Irene in the Ausable River watershed. Among the impacts of Tropical Storm Irene was extensive damage to roads, culverts, and bridges at local, county, and state levels. As of October 2012, FEMA had obligated $217 million in public assistance to communities and $102 million for individuals and households in the counties of New York that were part of the Tropical Storm Irene disaster declaration (Federal Emergency Management Agency 2012).[4] As part of FEMA's Public Assistance process, FEMA staff inventoried Tropical Storm Irene damage to public infrastructure and facilities – including culverts – and estimated repair costs for damaged infrastructure. FEMA assistance provides 75% of the repair costs. The data presented in Table 2 are based on FEMA's damage assessment and repair cost estimates as summarized in post-disaster Project Worksheets for culvert and associated road damage and failure in several towns.

There are some key limitations to using FEMA figures to estimate the cost of undersized stream crossing-related damage and failure. First, FEMA estimates are general approximations based on pre-set formulas; as a result, they do not necessarily reflect the actual cost of repairs at specific sites. For example, at one site in the Ausable watershed, the FEMA estimate of the cost to install a concrete box culvert was $45,000, while the actual cost of the project was $203,000 (C. Garrow, Town of Jay Department of Public Works, pers. comm.). Second, FEMA's Project

[4] See http://www.fema.gov/disaster/4020?page=0%2C0%2C1#tabs-2.

Worksheets are site-specific and not necessarily comprehensive. For example, the cost of culvert repair may be estimated on one worksheet while the cost of removing debris and repairing the road and other structures may be on a separate worksheet. Without viewing all the worksheets, it can be difficult to assess the total cost of repairs. Third, the cost of the damage to private property caused by flooding where a culvert was damaged or failed is not captured on a Project Worksheet; these repair costs are reimbursed through assistance to individuals and households, and we do not have access to these data.

Table 2 summarizes FEMA's estimates of the costs to repair all road and bridge damage on town and county roads in communities in the Ausable River watershed (T. Murphy, Federal Emergency Management Agency, pers. comm.). These figures are not limited to culvert-related damages and they do not include damage on state roads, which was also extensive, or on county roads in Clinton County. They also include damage in parts of Essex County that are outside of the Ausable River watershed.

Table 2. Tropical Storm Irene Road and Bridge Repair Estimates for Local and County Roads in Ausable River Watershed Communities

Jurisdiction	FEMA contribution (75% of estimated repair cost)	State contribution (25% of estimated repair cost)	Total repair cost based on FEMA estimates
Jay	$717,280	$239,093	$956,373
Keene	$346,000	$115,333	$461,333
Keeseville	$7,000	$2,333	$9,333
Black Brook	$59,000	$19,667	$78,667
Essex County	$3,671,000	$1,223,667	$4,894,667
Total			$6,400,373

In the town of Jay, where more detailed data was available, the repair costs related to undersized stream-carrying culverts alone were about $404,000, which was about 55% of total road and bridge damage[5] (C. Garrow, Town of Jay Department of Public Works, pers. comm.). This figure includes the cost of repairing damaged culverts or replacing culverts with extensive damage, repairing road damage caused by culvert failure or flooding, and stabilizing streams with excessive erosion due to undersized culverts.

Extrapolating the 55% figure to the $6.4 million in repair costs from Table 2 results in an estimate of $3 million to repair undersized stream-carrying culverts on town and county roads in the Ausable watershed damaged during Tropical Storm Irene. We can assume that many of these repair costs could have been avoided with larger road-stream crossings. The cost of

[5] Driveway culverts carrying overland flow and damage to roads due to the river overtopping its banks are not included in this 55%.

replacing a single damaged culvert in many of these communities is more than the highway department's entire annual budget for capital projects.

In addition to the costs of repairing infrastructure, other "direct impacts" of flooding, which may be avoided with upgraded culverts, include damage to homes and their contents, businesses and their supplies, evacuation and rescue costs, temporary housing costs, and moving and storage costs (Kousky 2012).

<u>Avoided Road Closures</u>

Undersized culverts are more likely to fail or result in flooding along roadways; this flooding in turn leads to road closures, which can be costly. People who use roads impacted by culvert failures are likely to experience travel delays and may need to travel longer distances due to closures and detours, resulting in lost productivity and direct expenditures on gas. Road closures can lead to lost days of work for businesses located on the road or employees residing on roads that are closed, resulting in lost income. A study of culvert failures across the U.S. found that delay costs to users of the road made up a significant portion of the cost of replacing culverts in an emergency situation, rather than through routine and planned maintenance. In the cases analyzed, the emergency replacement costs ranged from 4 to 140 times greater than planned replacement costs, largely due to user delays. This suggests that waiting until culverts fail through emergencies can be very expensive when the impacts on road users are factored into the cost analysis, yet delay costs often are not considered because they are not borne by the highway department undertaking the work (Perrin and Jhaveri 2004). It can be challenging to estimate these costs, particularly on smaller roads where data about traffic volume and types of vehicles on the road are unavailable.

Road closures can also lead to a more widespread loss of revenue in places with tourism-based economies. For example, road closures resulting from Tropical Storm Irene damage blocked access from a major highway serving the High Peaks region of the Adirondacks for the Labor Day weekend, an important weekend for tourism. Similarly, the state of Vermont noticed that many hotels reported cancellations of room reservations during what is normally a busy season for tourists (Lunderville 2012).

2. Costs of Improved Road-Stream Crossings

Costs Overview: Key Points

There are many different design options for road-stream crossings. Crossings that simulate the natural conditions of the stream channel are almost always more expensive in the short term than traditional pipe culverts designed to meet a hydraulic standard. This initially higher cost is often an impediment for highway departments with limited budgets.

Over time, larger road-stream crossings that mimic the natural stream require less maintenance and typically last longer because they are made with more durable materials. **In many places, the annual cost of an upgraded road-stream crossing over its lifetime may be lower than that of a more traditional culvert simply based on expected maintenance and replacement costs.** This horizon does not factor in predicted increases in intense storms due to climate change.

In addition to their durability and less frequent need for maintenance, road-stream crossings that are sized and designed to simulate the natural stream conditions better withstand large storms and help communities avoid flood damage to roads and private property. **Upgraded stream crossings can be a more cost effective option than traditional designs in 30 to 40 years because of avoided damage such as flood-related maintenance and repair**.

Since climate projections point to an increased intensity of storms which will lead to more frequent flooding, **we expect upgraded road-stream crossings to become even more cost effective as the climate changes**. Also, making repairs in an emergency is more costly than planned maintenance.

This section begins with some basic information about different types of stream crossings. Next, we summarize a number of studies about the initial costs of different types of stream crossings. Then we consider the long-term costs of stream crossing designs. Finally, we discuss long-term costs in the context of climate change.

Road-Stream Crossing Design Choices

The cost of a road-stream crossing depends on its design and material, which is influenced by a variety of factors, including the width and flow in the stream, site topography and geology, the materials available, the volume and type of traffic on the road and potential constraints at the site including nearby landowners. The durability of different materials and designs is also important.

There are numerous types of materials and design options for stream crossings (Figure 5), including culverts and bridges. Types of culverts include pipe culverts, box culverts and bottomless arches. Culverts can be made from concrete, steel, aluminum, and plastic. Culverts can be cylindrical, arch-shaped, elliptical, or rectangular in shape. Their bottoms may be open (mimicking the natural channel) or closed. Bridges are spanning structures with no structural bottom that are attached to two or more abutments. In New York State, a bridge is defined by its width, as any spanning structure with an interior width of 20 feet or more, whereas a culvert is a structure with an interior width of less than 20 feet.[6]

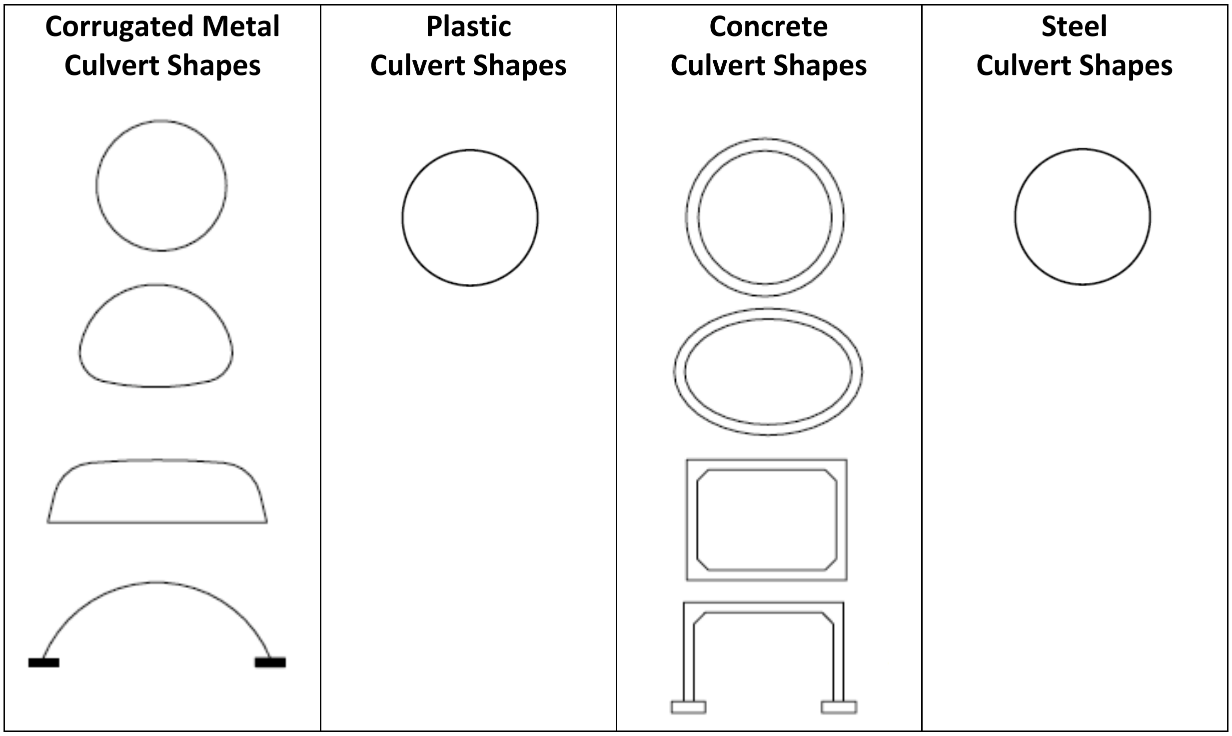

Figure 5. Road-Stream Crossing Materials and Shapes

Figure from Orr, D.P. 2003. Roadway and Roadside Drainage. Cornell Local Roads Program. CLRP 98-5.

The decision about the design and size of stream crossing is typically made by the entity responsible for the road: a town, county, or state highway department. State and federal environmental regulations (primarily from the U.S. Army Corps of Engineers), general permits, and in some cases, town and county codes, can all influence decisions about the size and design for a crossing. Appendix A outlines the range of applicable permits and regulations for culvert projects in the Adirondacks.

Several sources of design guidance are available for transportation departments undertaking work on road-stream crossings. New York's Department of Environmental Conservation provides "recommended" standards on its website that discuss ecological issues related to road-stream crossings.[7] New York's Interagency Aquatic Connections Team (InterACT), which

[6] For more definitions, see http://www.clrp.cornell.edu/techassistance/BC/what_is_a_bridge.pdf.
[7] See http://www.dec.ny.gov/docs/permits_ej_operations_pdf/streamcrossing.pdf.

includes federal, state, and local agencies, has developed extensive engineering guidance to help state, local and private entities plan and design road-stream crossings that minimize stream erosion and degradation and improve aquatic connectivity. The engineering guidance has not been formally issued as of present.[8]

In New York State, there are differing sources of guidance related specifically to culvert sizing (Table 3). The Cornell Local Roads Program serves as New York's Local Technical Assistance Program for county and town road departments and produces guidance documents about road design (Orr 2003). New York State DOT's highway drainage manual provides different and less uniform guidance, leaving more room for individual decisions provided that they are well documented in design approval and drainage reports (NYSDOT 2011).

Table 3. Culvert Sizing Guidance in New York State

Type of road	**NYSDOT design storm recommendation***	**Cornell Local Roads design storm recommendation***
Town road with low traffic	50 years, but 10 or 25 years is acceptable if documented in design reports	10 year storm
Town road with high traffic or county road with low traffic	50 years, but 10 or 25 years is acceptable if documented in design reports	25 year storm
County road with high traffic	50 years, but 10 or 25 years is acceptable if documented in design reports	50 year storm
State roads and arterials	50 year storm	100 year storm

* The design storm recommendation is the type of storm that the culvert should be designed to pass. A design storm is described by the probability of occurrence based on historical weather data. For example, a "10 year" design storm has a probability of occurring once in 10 years.

New York's published culvert design guidance documents suggest that culvert sizing be based primarily on hydraulic standards, i.e., the expected frequency of larger storms as determined by historical records. There are several limitations to this approach. First, information about the expected flow in streams is often out-of-date and does not reflect more recent precipitation trends. For example, New York's official precipitation intensity calculations are based on

[8] The Interagency Aquatic Connections Team (InterACT) document, "Ecological and Engineering Considerations for Constructing New or Replacement Road Crossings in New York State" (2010) has not been formally issued.

datasets from 1961 and 1977 (Technical Paper No. 40 and NOAA Technical Memorandum NWS HYDRO-35, respectively),[9] yet climate records show that extreme storms have been on the rise over the past several decades, and the data in use do not reflect these increases. Efforts are underway to update New York's precipitation data, but for the moment, much of the information available to highway engineers is outdated. Not only is the data based on relatively old records, but it does not account for expected precipitation changes in the future with climate change. Another problem is that culverts designed based strictly on a hydraulic standard do not incorporate ecological considerations such as the natural conditions of the channel.

While a variety of information and regulations can guide highway departments in their decision-making about road-stream crossing design, the cost of a structure – from design to installation and maintenance – is always a crucial factor. Highway departments face shrinking budgets and competing priorities due to aging infrastructure, and unfortunately this often leads to choosing the option that costs the least in the short term.

Installation Costs

The upfront installation costs of larger stream crossings that mimic natural stream channels are almost always higher than the costs of smaller, more traditional pipe culverts designed to meet hydraulic standards. Given the wide variety of culvert materials, designs and sizes, there is considerable disparity in just how much more expensive upgraded culverts are. Cost comparisons vary widely based on what kind of crossing is in place and what kind of crossing is chosen as a replacement, as well as site characteristics and required construction practices. For example, a major cost element in many Adirondacks culvert projects is the requirement that the stream segment be de-watered during the construction project. The overall cost of a project will include materials, labor and equipment.

Table 4 summarizes information from several studies on the installation costs – including materials, labor, and equipment – of upgrading crossings. The table indicates the cost increase for replacing existing culverts with upgraded designs that allow for aquatic organism passage and/or accommodate future flows, rather than replacement with the same design and size (in-kind replacement). The following sections provide more information about these studies.

Green Mountain National Forest, Vermont

The U.S. Forest Service's model approach to culvert design is called stream simulation, defined as "a method of designing crossing structures…with the aim of creating within the structure a channel as similar as possible to the natural channel in both structure and function. The premise is that the simulated channel should present no more of an obstacle to aquatic animals than the adjacent natural channel" (Forest Service Stream-Simulation Working Group 2008).

An engineer with the U.S. Forest Service estimated the construction costs for five culvert replacement projects on rural roads in Vermont's Green Mountain National Forest – both the cost for replacement of the culverts with a stream simulation design, and the cost of

[9] This data can be downloaded from http://www.nws.noaa.gov/oh/hdsc/currentpf.htm.

replacement with a more traditional hydraulic design method. Hydraulic design culverts are sized to pass a particular flood, with estimated flow levels based on equations with high error estimates; the design does not consider the physical dimensions of the natural channel (Gillespie et al. 2013).

The Forest Service initially estimated that the stream simulation culverts would cost an average of 46% more than culverts with a traditional design (with a range of 24% to 61% extra cost). Ultimately, three of these culverts were replaced with the stream simulation culverts, and the construction costs were significantly lower than had been estimated, due to an unexpected decrease in the cost of materials because of an economic downturn. While the engineer had estimated a 46% cost increase for stream simulation culverts, the final cost increase was on average 14% more than the estimated cost of in-kind replacement (Gillespie et al. 2013).

Table 4. Installation Cost Increase of Improved Road-Stream Crossings Compared With In-Kind Replacement Costs

Location	Mean % cost increase for improved crossing (range of values)	Notes
Green Mountain National Forest, Vermont	14% (9% - 22%)	Compares stream simulation culvert costs with cost of replacement based on hydraulic design
Minnesota (statewide)	10% (1% - 33%)	Compares cost of replacing existing culvert with improved "MESBOAC" design; costs considered are those of structures only
Maine (statewide)	Mean not available (80% - 295%)	Improved culvert widths in this study are 200% to 300% that of existing culvert
Tongass National Forest, Alaska	17% (-5% - 38%)	Compares stream simulation culvert cost with hydraulic design cost; stream simulation culverts are 25% - 83% wider than hydraulic design culverts; cost increase insignificant for streams of slope less than 3%
Oyster River Watershed, New Hampshire	42% (24% - 75%)	Compares cost to upgrade undersized culverts for a range of climate change/ precipitation change scenarios and land use scenarios with cost of in-kind replacement

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Minnesota Culvert Cost Analysis

A study of culvert installation practices in Minnesota compared the costs of replacing 11 culverts by the conventional design with the costs of replacement using an alternative design called "MESBOAC" (Match, Extend, Set, Bury, Offset, Align, Consider), defined as a "a stream-simulation technique designed to mimic the natural channel characteristics through the culvert." Use of the MESBOAC design increased the cost of culvert projects by an average of 10% over the conventional design cost for 10 of these culverts. Most of the cost increase was from the larger culvert size required to accommodate the reduction in flow capacity that results from burying the culvert in the channel (Hansen et al. 2009).

Maine Culvert Construction Cost Comparison

A study from Maine analyzed the economic impact of proposed legislation requiring that culverts across the state of Maine be sized at 1.2 times the natural bankfull width of the stream channel. Bankfull width is the width of a stream channel from the top of one bank to the top of the opposite bank; this is also the width at which any additional water in the stream would overflow into the floodplain. The researchers developed cost estimates – including material costs, labor costs, and equipment costs – for seven different culvert replacement scenarios. For each scenario, the cost of in-kind replacement of the undersized culvert was compared with the cost of several alternative culvert designs, all of which were 1.2 times bankfull width. The upgrade scenarios involved doubling or tripling the width of the existing culvert, so costs were significantly higher than in other studies where width increases were more moderate. (For example, the U.S. Forest Service estimates that a 50% increase in culvert width results in a 33% increase in project cost.) The cost increase ranged from 80%-295% more for the upgraded culvert than the in-kind replacement (New England Environmental Finance Center 2010).

Tongass National Forest, Alaska

A Forest Service analysis from Alaska compared the upfront costs of culverts with a hydraulic design with culverts with a stream simulation design (defined above) at ten different sites. The study found that stream simulation culverts cost 20-30% more than hydraulic designs on streams with slopes of or more than 3%. On streams with slopes less than 3%, the cost difference was not very significant (R. Gubernick, United States Forest Service, pers. comm.).

Oyster River Watershed, New Hampshire

A study of the coastal Oyster River watershed in New Hampshire examined the costs of replacing undersized culverts with culverts sized to convey the expected flows resulting from increased development and increased frequency of extreme rainfall events (due to climate change). Across all the different scenarios of precipitation and development, the average cost to upgrade rather than replace in-kind was about $3,300 per culvert, which is about a 42% cost increase per culvert. For the "most likely pessimistic" precipitation scenario and with the most development the study found that the cost of upgrading the undersized culverts was an average of 49% higher than the cost of in-kind replacement (Stack et al. 2010).

Washington State Cost Estimates

Some attention has been given to the cost of repairing and replacing barrier culverts on state roads in Washington, largely as a result of a 2007 lawsuit about Tribes' fishing rights and the role of culverts in blocking the movement of fish to and from Tribes' historical fishing sites. The estimated cost of fixing barrier culverts on state roads ranged from $129,000 to $369,000 per culvert (Blumm and Steadman 2009); a cost of in-kind replacement of these culverts was not provided, and so it is not possible to estimate the percentage cost increase for these culverts.

Long-Term Costs

While the installation costs of larger road-stream crossings that more closely simulate natural channel conditions are higher than those of smaller crossings, improved culverts can be less expensive on an annual basis if we take a longer-term perspective. First, smaller culverts are prone to clog with debris such as sticks, leaves, rocks, and fine sediment, and this results in the need for regular maintenance to keep them clear so that the stream can flow through. On the other hand, larger crossings typically require less maintenance. Second, small pipe culverts have a shorter lifespan than many types of larger stream crossings that are made from more durable materials (more information about lifespan is below). Finally, undersized culverts are more likely to be damaged or destroyed during large storm events, resulting in an even shorter lifespan than expected.

Comprehensive information about the long-term annual costs of different stream crossing designs is quite limited. The few existing analyses are based on assumptions rather than site-specific observations about maintenance requirements and life span of different designs. This reflects a widespread lack of long term record keeping by highway departments, from the local to state level, about stream crossing installation costs, maintenance needs and costs, lifespan, and replacement costs.

A synthesis report on fish-friendly road-stream crossings summarized the situation: "There are insufficient data available that describe the total life cycle costs of culverts. For example, there are only qualitative statements…that state wider-span culvert expenses may be offset by lower maintenance and stream-channel protection costs following construction. Work is required to populate a database with standardized costs for culvert operations on a life cycle basis. This will require State DOTs to cooperate in following consistent procedures for describing all costs, including both design and maintenance of the culvert and the local stream reach" (Hotchkiss and Frei 2007).

Culvert Lifespan

The expected lifespan of a culvert depends upon a variety of factors, including the material used, slope of the site, size of the structure, and acidity of the stream. When asked about how long culverts of different types typically last, highway engineers within the same region provided answers with considerable variation.

According to a NYSDOT manual, a corrugated metal pipe culvert lasts between 25 and 50 years (New York State Department of Transportation 2011); highway supervisors in the Adirondacks estimate that the lifespan of these culverts is between 15 to 30 years. For concrete box culverts, NYSDOT estimates a 70-year lifespan (New York State Department of Transportation 2011), and local highway supervisors in the Adirondacks estimate 50 to 100 years.

Long-Term Culvert Cost Analysis in Maine

Economists with the Natural Resources Conservation Service (NRCS) conducted a study comparing the long-term costs of undersized round culverts with larger arch shaped culverts that restore fish passage and more natural stream conditions at four sites in eastern Maine (Long 2010). In this study, the upgraded culverts were two to four times wider than the undersized round culverts. The study assumed a 10-year lifespan for round culverts and at least a 50-year lifespan for the arch culverts. The analysis included the costs of installation, operation, maintenance (e.g., removing debris, controlling beavers, repairing the road bed due to storms) and replacement but did not assume any premature culvert failure due to high flows.

Over a 50-year time frame, the average annual costs of the arch culverts – including maintenance and replacement – were less than those of the round culverts for two of the four cases considered. The average annual costs of the arch culverts were 22% and 26% less than the round culverts for the sites where the arch culverts were more cost effective; at the other two sites, the estimated average annual costs of the arch culverts were 18% and 35% higher than the costs of the round culverts. Results from this analysis (J. Long, Natural Resources Conservation Service, pers. comm. and Long, 2010) are presented in Table 5.

This study indicates that at certain sites, even without major flood events and without quantifying any of the environmental or safety benefits, improved road-stream crossings can be less expensive than undersized crossings in the long term.

Table 5. Eastern Maine Culvert Cost Estimates (2007 dollars) [10]

Scenario	Description	Average annual cost over 50 year time-frame	
		Arch culvert	Round culvert
Case 1	10' x 4'5" arch replaces two 2.5' round culverts	$1,357	$1,706
Case 2	12' x 5' arch replaces 3.5' round culvert	$1,545	$1,887
Case 3	12' x 5' arch replaces 3' round culvert	$2,265	$1,461
Case 4	12' x 5' arch replaces 4' round culvert	$2,452	$2,000

Stream Crossing Costs and Changing Climate

As the climate changes and extreme precipitation events increase in frequency (impacts we are already experiencing), any cost analysis of stream crossings should consider the costs to repair and replace culverts that are damaged or destroyed because of high flows produced by these storms. The expenditures to repair and replace culverts following major storm events can be considerable. The impacts of climate change, particularly increased intense storms, have not yet

[10] This analysis used a 4.2% discount rate, included a 3% inflation factor for maintenance and replacement cost, and amortized the net present value over 50 years.

been factored into cost analyses for road-stream crossings; once they are, we can expect that undersized crossings will become increasingly more expensive, and improved crossings will become less expensive in comparison.

Undersized crossings are more likely to be dislodged and/or destroyed due to high flows in streams than more durable, larger culverts that mimic the natural stream conditions. Recent evidence from Tropical Storm Irene in Vermont corroborates this. In Vermont, an estimated 1,000 culverts were washed out or damaged from the storm (Lunderville 2012). In just four towns near the Green Mountain National Forest, 70 culverts were damaged or destroyed. Rochester, one of these towns, sustained damage to or completely lost 25 culverts. In the town of Hancock, the repair cost for a single site – where a 12 foot -wide culvert became plugged with debris and floodwater overtopped the road – was estimated at about $1.1 million including road repair (Gillespie et al. 2013). While this example is not representative of all culvert sites that sustained damage, it indicates that the repairs from a single failure can be extremely costly.

In contrast to these costly repairs, three recently completed culvert upgrades in the neighboring Green Mountain National Forest, which were designed and built using the Forest Service's "stream simulation" design, all survived the storm and did not require any maintenance or replacement. These crossings had been replaced because the previous culverts had been barriers to the movement of aquatic organisms and were believed to be likely to plug with debris and fail in large storm events. An analysis of the performance of these stream simulation crossings concluded that that these culverts "function virtually maintenance free with a low risk of catastrophic failure, making them a cost-effective long-term investment and provide greater community flood resilience and strong benefits to aquatic species facing climate change and other periodic stressors" (Gillespie et al. 2013).

Delaware County in the Catskill region of New York has experienced frequent flooding in the last few decades, with 11 federally declared flood related disasters between 1996 and 2011. A single stream crossing in the town of Hancock provides a compelling example of the cost effectiveness of upgrades based on repeated culvert failure. Three flood events between 1996 and 2005 caused damage to an undersized and perched pipe culvert on the Big Hollow Creek, a tributary to Fish Creek, which flows into the East Branch of the Delaware River. In those nine years, Delaware County's Public Works department spent over $70,000 to repair damages to the culvert, road and adjacent ditches. Because of the rural location, travelers on this road had to take an 18-mile detour while the road was closed for these repairs. Late in 2005, with hazard mitigation funding assistance from FEMA, the county replaced the pipe culvert with a three-sided concrete culvert with a natural bottom, designed to convey a 100-year storm, for a cost of $143,000. Given the costly history of damages associated with the undersized culvert, the County Public Works Commissioner called the investment in the upgraded culvert a "no-brainer." Since the culvert was replaced, the county has experienced seven federally declared flood disasters, including Tropical Storm Irene, and the new stream crossing has survived all of these events without significant damage (Reynolds, Delaware County Department of Public Works, pers. comm.).

While upgraded road-stream crossings can be less expensive than their undersized counterparts in the long term, even more so with a changing climate, it can be difficult to determine how quickly this will happen on the basis of storm events. This is because there is still considerable uncertainty about how much more frequent “extreme” weather events will be in the future and how extreme the events will be in terms of their impacts on stream crossings. Detailed climate predictions, flow data, and an improved understanding of stream crossing performance over time are all needed to estimate the long-term maintenance and replacement needs that highway departments can realistically expect for these different types of crossings.

3. Adirondack Culvert Case Study

We collected information about an upgraded culvert in the Adirondacks for a long-term cost comparison. Though a full analysis of the social, environmental and economic benefits of this upgrade project is beyond the scope of this report, some existing benefits information related to the region is presented below.

The Lewis Brook culvert conveys a tributary to the East Branch of the Ausable River and is located on a town road in Jay, New York. The Town of Jay highway department provided information for this analysis, including FEMA Project Worksheets related to damage following Tropical Storm Irene.

The original road-stream crossing structure at the site consisted of two adjacent 5 foot wide by 36 foot long corrugated metal pipes (Figure 6). The culvert had been an ongoing flood and maintenance concerns for the town, with flooding and closure of the road occurring regularly during and after intense storms, including spring floods of 2011. The culvert was also a barrier to the movement of aquatic organisms because it was perched above the channel, meaning that there was a significant difference in height between the outlet of the culvert and the streambed that would impair the movement of fish and other organisms.

Following floods caused by storms in spring 2011, the Town of Jay began seeking funding to replace the culvert. In August 2011, high flows caused by heavy precipitation from Tropical Storm Irene punctured and crushed the culvert, and it failed entirely. Because the site had a

Figure 6: Original Culvert on Lewis Brook
Note that portions of the road have been damaged and lost above the culvert.

Credit: Chris Garrow

history of previous damage, the town was eligible for two sources of funding to upgrade the culvert: FEMA Public Assistance funding and FEMA Hazard Mitigation Funding. (Normally, FEMA funding covers “in-kind replacement” of a damaged structure if the repair cost is less than 50% the cost of the replacement cost.) The U.S. Fish and Wildlife Service contributed $15,000 through the National Fish Passage Program for the upgraded culvert, but the majority of the costs were borne by the town itself.

While the culvert is located on a relatively small town road, the road became an important link in the local transportation network following Tropical Storm Irene, due to major damage and closure of the state road connecting the region’s towns to one another. The team replacing the culvert faced the challenge of conducting the work while also keeping the road open to traffic. The new culvert is a concrete box measuring 10 feet wide, 5 feet tall and 44 feet long (Figure 7). While the new culvert has the same total width as the culvert it replaced, the single culvert is less prone to becoming clogged with debris than the two smaller structures it replaced. In addition, the new culvert was designed to restore movement of fish through the stream: the amount of upstream habitat made accessible to aquatic organisms, including eastern brook trout, by installing the new culvert is about 1 mile.

Figure 7. Upgraded Culvert on Lewis Brook

Credit: Chris Garrow

Installation Costs

For this culvert, the initial cost of a concrete box was more than twice as much as the cost of in-kind replacement of the original double metal pipe culvert. Table 6 summarizes the estimated installation costs for the two culvert options.

Table 6. Lewis Brook Culvert Installation: Estimated and Actual Costs

	FEMA's cost estimate (from Project Worksheets)	Town highway department cost
Replacement of original double metal pipes	$23,632	$91,000 (estimate)
Upgrading crossing to concrete box culvert	$45,424	$218,097
Percentage cost increase for upgraded culvert	92%	140%

The upgraded concrete box culvert is clearly much more expensive – more than twice the cost – than in-kind replacement of the pipe culvert. This percentage cost increase is much higher than the percentage increases from studies elsewhere in the country (Table 4). We do not have adequate information about the previous studies to assess why the estimated percentage cost increase for this culvert upgrade is so much higher.

The costs of the concrete box culvert project were broken down as follows:

- Labor: 26%
- Equipment (including machine operating): 37%
- Materials (including culvert structure(s), rock, fill, pavement): 37%

Table 6 also shows that FEMA's estimate of the costs of for the upgraded culvert was significantly lower than the actual costs. (Estimated costs for in-kind replacement by FEMA were also much less than the highway supervisor's estimates of in-kind replacement costs.) Unfortunately, the FEMA paperwork was not detailed enough to understand this huge disparity, such as what items may be missing. For example, the actual project costs included a number of essential tasks – including debris removal at the site, preparing the streambed, installing a bypass for water to comply with state regulations, repaving the road, and restoring the site – that may not have been included in FEMA's cost estimate. Yet even without these additional tasks, the structure itself (i.e. the concrete box) cost the town $55,000, which is $10,000 more than FEMA's estimated cost for the entire project.

<u>Long-Term Costs</u>

We used the actual costs of the upgraded culvert and the highway department's estimated costs for the in-kind replacement to conduct a long-term cost comparison of the two culvert options at this site. The results of this analysis, summarized in Table 7, show the average annual cost for the concrete box culvert and the average annual cost for double corrugated metal pipe culvert over several time periods.

Table 7. Estimated Average Annual Cost for Lewis Brook Culvert (2012 dollars)

	Annual cost over 15 years	**Annual cost over 35 years**	**Annual cost over 70 years**
Double metal pipe culvert	$6,551	$4,446	$2,726
Concrete box culvert	$13,533	$5,800	$2,900
Percentage additional annual cost for concrete box culvert	107%	30%	6%

This cost comparison is based strictly on installation and maintenance of the two culverts for the expected lifespan, which we assumed to be 30 years for the pipe culvert and 75 years for the concrete box. We assumed that the culverts would be replaced at the end of their expected life cycles and not due to catastrophic failure caused by an extreme storm. We utilized maintenance cost estimates from an NRCS study in Maine (Long 2010), which are fairly conservative and do not reflect more frequent intense storms that require removal of debris and sediment, and we applied a real discount rate of 2.0%, which includes inflation.[11] This analysis only considers the costs that a highway department would incur and does not include any potential benefits such as fish passage and human safety.

The cost estimates show that in the shorter term, the concrete box culvert is clearly much more expensive on an annual basis. Yet if we think about the annual costs in terms of the lifespan of the box culvert, the annual cost difference becomes much lower.

Long-Term Costs and Changing Climate

A major factor excluded from this cost comparison is an estimate of expected frequency of failure of the pipe culvert – and the need for premature replacement – as a result of high flows caused by major storms. While climate scientists are not able to estimate with confidence the expected frequency of very intense storms in the Adirondacks, we know that a greater frequency of failure-causing storms will make the larger, more durable, fish-friendly culverts cost effective more quickly. Table 8 considers the amount of time required for the box culvert to become less expensive on an annual basis, than the pipe culvert, as a result of more frequent intense storms that would lead to the failure of a pipe culvert.

As expected, the more frequently an undersized culvert fails, the more quickly an upgraded culvert, despite its initial high installation cost, becomes the less expensive option. This analysis focuses entirely on the costs to local highway departments and does not take into account any

[11] Discount rate from OMB Circular No. A-94 (2012), online at http://www.whitehouse.gov/sites/default/files/omb/memoranda/2012/m-12-06.pdf.

of the safety risks, lost income, or private flood damages that result from culvert failure. Factoring these costs into the analysis would shorten the time in which the upgraded culvert becomes a less expensive option.

Table 8: Upgraded Culvert Cost Effectiveness With Increased Storm Frequency

Frequency of extreme precipitation event that causes failure of pipe culvert	Number of years in which upgraded culvert annual costs become less than pipe culvert annual costs
Once per 30 years	90
Once per 25 years	69
Once per 20 years	40
Once per 15 years	30
Once per 10 years	20
Once per 5 years	10

Watershed-Wide Culvert Upgrade Cost Estimate

The economic data for this case study was collected as part of a larger stream crossing assessment project in the Ausable River watershed, undertaken by The Nature Conservancy in partnership with the Ausable River Association and Plattsburgh State University of New York. This project included computer modeling of stream crossings to prioritize their environmental importance and extensive field surveys of crossings to assess whether or not their design and size allows for the movement of fish such as brook trout.[12] We can use the data from this project to produce a watershed-wide estimate of the cost of upgrading the most problematic stream crossings.

The computer model produced a set of 207 environmental priority culverts from a total of 537 crossings, and through the fieldwork, we found that 32% of surveyed culverts in the watershed are major barriers to the movement of fish and 21% are moderate barriers (Miller et al. 2012). Based on these results, we can assume that about 174 culverts would need improvement (retrofit or replacement) to restore fish passage in all streams watershed-wide. In total, about 67 culverts in the watershed that are both environmental priorities and barriers to the movement of fish.

We also collected data about road-stream crossings that are town or county highway department priorities for replacement due to flooding and maintenance issues. There are 20 crossings that are community priorities and are known to be major (n = 12) or moderate (n = 8) barriers to the movement of fish. There are also 30 community priority crossings that had not been field surveyed; we will assume that 10 of these (32%) are major barriers to the movement of fish and 6 of these (21%) are moderate barriers. It is important to note that our estimates of

[12] Results of this project can be viewed at http://nyanc-alt.org/gis/ausable/.

community priorities do not include crossings on state roads, since we were not able to gather information about state road priority crossings during this project. As a result, the total number of community priority culverts presented here are likely to be underestimates.

The Lewis Brook culvert was likely more costly than a planned upgrade, since it was unplanned and included the repair of significant damage caused by Tropical Storm Irene. A reasonable estimate for the average cost of an upgraded, fish friendly and flood resilient culvert is about $150,000 per site. This figure is consistent with the costs of culvert upgrades in the Green Mountain National Forest in Vermont (Gillespie et al. 2013).

Table 9 presents the costs to upgrade different types of problematic stream crossings. This table indicates that total costs can vary greatly depending on the choice of the type of crossings to upgrade. Since it is impractical and impossible to upgrade every crossing on every roadway, setting priorities based on environmental and social importance can help communities achieve multiple objectives and see the greatest total benefit relative to their expenditure. In addition, we can expect that highway departments would see significant savings in annual maintenance as a result of upgrading their highest priority crossings.

Table 9. Ausable River Watershed Road-Stream Crossing Upgrade Cost Estimates

Stream crossing type to be upgraded	**Number of crossings in Ausable River Watershed**	**Estimated cost to upgrade these crossings**
All major barriers to fish movement	174	$26.1 million
All major barriers to fish movement and environmental priorities	67	$10.1 million
All major or moderate barriers to fish movement and local priorities due to flooding and maintenance concerns	36	$5.4 million
All major barriers to fish movement and local priorities due to flooding and maintenance concerns	20	$3 million

Estimated Benefits of Culvert Upgrades

While a complete quantification of the benefits we would expect to see from undertaking any set of these upgrades work is beyond the scope of this report, some of the major benefits to be compared with these cost estimates are summarized below:

- Avoided road and culvert damage repair costs following storms: After Tropical Storm Irene, over $3 million was spent by towns and counties (excluding state roads) to repair road and bridge damage related to culverts on local roads. This does not include removal of debris that may have contributed to flooding at undersized culverts or failure of undersized culverts.

- Improved fishing watershed-wide due to improved fish passage: Each year, anglers on the Ausable River spend about $2.3 million at local businesses in the watershed as part of their fishing trips.
- Avoided private property damage caused by flooding at the site of undersized culverts
- Avoided health impacts related to flooding
- Improved safety on local roads
- Avoided travel delays from road closures due to culvert failure
- Improved aquatic habitat and healthier fish populations
- Decreased erosion of stream banks from culvert failures
- Improved water quality

A more detailed assessment and economic valuation of the social, economic and environmental benefits from upgrading stream crossings in the region is a component of future work that The Nature Conservancy will undertake collaboratively with NYSDOT.

4. Road-Stream Crossing Upgrade Constraints

Despite the many potential benefits, the initial cost to upgrade road-stream crossings is considerable. Sufficiently detailed economic information is not yet available to quantify and compare the full set of benefits and costs. While the substantial installation cost of improved crossings is clearly a factor inhibiting more widespread upgrades, there are other factors – social and political – to be overcome. This section explores the major constraints to improving stream crossings, while the final section identifies some important opportunities, including potential funding mechanisms, and proposes a path forward.

Economic Factors

Highway departments at all levels – from towns to states – are increasingly constrained by a lack of resources. For a small town highway department, the cost to upgrade a single stream crossing may be a large percentage of its total annual budget for road improvements. For example, the Adirondack town of Jay, which incurred an estimated $956,000 in road and bridge damages from Tropical Storm Irene, received a total of $92,000 per year between 2008 and 2012 from New York State's Consolidated Local Street and Highway Improvement Program for all of its road, bridge and culvert repair projects.

While many highway department managers recognize the ecological and flood resilience benefits of upgrading stream crossings, the initial cost is often simply prohibitive given their budgets and many competing needs. Similarly, although larger crossings may save money in the long term because they last longer and require less maintenance, highway managers are usually unable to justify an expense based on a cost savings over a 25- to 75-year time period. The result is that culverts are not replaced until they fail and when replaced, the least expensive option becomes the default unless funding is available to help offset the cost of an upgraded design.

Existing economic information about road-stream crossings is limited, as we have shown in earlier sections of this report. At local to state levels, there has been little systematic recordkeeping about the costs of stream crossings. As a result, there is no widespread and economically proven consensus on the potential cost savings over time of upgraded crossings. This is complicated by considerable uncertainty about just how frequent culvert failure-causing extreme precipitation events will be in the future, which makes it is difficult to predict how long it will take for an upgraded culvert to become a less expensive option on an annual basis. Finally, most of the benefits of improved crossings are not easily quantifiable.

Even if our economic information were better, it is not always easy to see the connection between the costs and benefits of improved stream crossings, since those who make decisions about the design of structures are often quite removed from those who benefit. For example, highway departments that pay for crossing repairs and replacements with a combination of local, state and federal dollars have a mandate to keep roads in working order; their success is evaluated based on how effectively they have used their funds to keep the road network functioning safely. On the other hand, the potential beneficiaries of improved crossings are diverse and diffuse, ranging from households who avoid future flooding to travelers on local roads for work and leisure, as well as recreational anglers and nature enthusiasts. While these beneficiaries do pay for the maintenance of road networks through taxes, they may not see the connection between a culvert upgrade and the benefits they experience. This challenge makes it even more difficult for a highway department to justify a more expensive stream crossing design.

Generally, there are limited funding streams that can be used for upgrading stream crossings to provide ecological and community benefits. For selective proactive upgrades, some funds are available through highly competitive grants from agencies such as the Fish and Wildlife Service and the National Oceanic and Atmospheric Administration (NOAA); in these grant competitions, many worthwhile projects are denied funding simply because the available amount is not nearly enough to meet the demand. A local highway supervisor in the Adirondacks noted that the town routinely has to issue bonds to raise funds for its culvert and bridge projects and then spend many years paying back the debt and the interest.

With limited budgets and few sources to help offset the initially high cost of upgrades, the most economically rational option for highway departments with culverts requiring replacement may be to wait until culverts fail in major disasters, and then use FEMA assistance to help with the costs of repair or replacement. Given the limitations on how FEMA public assistance funding may be spent (discussed below), these damaged culverts are very likely to be replaced with structures of the same design and size. This may result in repeated failure and flooding, both of which could have been avoided by simply replacing the undersized culvert with one of adequate size and design.

Climate Change Uncertainty, Lack of Information

In the face of a changing climate, improved road-stream crossings provide both ecological and social benefits, by ensuring that aquatic organisms can access the full range of habitat to meet their life cycle needs and by safeguarding communities from future flood damage. Yet in many places, including parts of northern New York, communities are wary of discussing climate change and may be reluctant to take action.

The uncertainty about very local impacts of climate change also makes it difficult for local decision makers to justify expenditures on infrastructure improvements. While scientists are able to downscale global climate models to better predict local climate change impacts, detailed studies are costly and still include considerable uncertainty, which can be difficult to understand.

Investing in adaptation requires political will. As noted in a study of the costs of natural disasters: “Even when measures have been shown to be cost effective, it has been observed that it is difficult to inspire adoption. For public investments it has been argued that this is because politicians, first, have a limited time in office and are unlikely to be judged on how they address low-risk threats and, second, have many other issues vying for their attention (Posner

2006). That said, the occurrence of a natural disaster can serve as a focusing event, increasing attention to the risk and thus leading to more investments in mitigation" (Kousky 2012).

Even with a commitment to addressing the impacts of climate change, the range of adaptation options can be overwhelming. With a great deal of transportation infrastructure and private property at risk from climate change impacts, culverts may not be seen as the critical priority for adaptation investments. Similarly, from an ecological perspective, a wide range of climate change impacts is expected across all ecosystems, and adaptation options for natural ecosystems also need to be prioritized. Upgrading road-stream crossings are actions that can serve both purposes but may be overlooked by an assessment that narrowly focuses on one type of system.

Limited Standards and Regulations

A lack of strong, clear and consistent standards and regulations for the design of stream crossings has contributed to the perpetuation of undersized culverts that block the movement of aquatic organisms and negatively affect the natural function of streams. Decisions about the design of new or replacement stream crossings are typically influenced by local, state, and/or federal regulations or standards, but these are often poorly defined, confusing, and in many cases not required.

State and Federal Standards and Regulations

State general permits and U.S. Army Corps of Engineers Nationwide or Regional Permits regulate work in streams, including culvert construction. To use these general permits, specific conditions, defined within the permits, must be followed. In many places the permit conditions are weak, poorly understood and minimally enforced. Some regions have taken steps to improve the requirements for culvert design. One example is the New York Army Corps District's new General Regional Conditions, released in 2012. Yet most states use only the Nationwide Permits, which do little to incentivize adequately sized culverts.

There is also an opportunity to adopt standards for stream crossing design at the state level. In the Northeast, several states have taken this important step. For example, Massachusetts developed a set of statewide River and Stream Crossings Standards through a partnership between the state's Division of Ecological Restoration, the University of Massachusetts, The Nature Conservancy and American Rivers. Yet many state environmental agencies, including that in New York, have not adopted standards and only provide recommended practices for stream crossings. In New York, permits are issued based on a determination that a proposed project is reasonable and necessary, does not endanger the health, safety or welfare of New Yorkers, and does not cause "unreasonable, uncontrolled or unnecessary damage to the natural resources of the state." This language provides considerable discretion for state agency personnel in permitting decisions. Still other states do not even have recommended practices.

Even when strong standards have been adopted, they are often not well understood and/or applied properly. Because many stream crossing projects do not require notification of state or federal environmental agencies, they may be completed in violation of existing standards with no consequence. As an example of the complexity of state and federal standards, an overview of the permits and standards that apply in the Adirondacks is provided in Appendix A.

Federal Disaster Assistance

When stream crossings fail as a result of major floods that lead to a federal disaster declaration, communities are eligible for funding toward the costs of replacement from FEMA as well as state emergency management agencies. Unfortunately, there is a great deal of confusion about how FEMA assistance can be used and how communities can better access funding to improve their infrastructure proactively following a disaster. Unless a town, county or state has adopted and consistently applied a set of standards about culvert size and design, FEMA's Public Assistance generally will fund the replacement of a damaged culvert with one of the same design and size. The result is that many communities build back their pre-existing infrastructure rather than building back in a way that improves their flood resilience and the health of their rivers and streams.

The regulations governing FEMA funding offer little opportunity for communities to upgrade their road-stream crossings unless clear, consistent local or state policies are in place prior to a disaster. Recently, the state of Vermont was denied funding to help pay for upgraded culverts because FEMA determined that Vermont's standards had not been uniformly applied. Following this determination by FEMA, in May 2013 the state developed and adopted a new set of standards for stream crossing design in its Stream Alteration General Permit in order to ensure eligibility for funding to improve their stream crossings following future flood events.[13] This underscores the importance of strong standards at the state level. More information about FEMA programs as they relate to culvert repair and replacement is provided in Appendix B.

[13] Vermont's Stream Alteration General Permit is available at http://www.watershedmanagement.vt.gov/rivers/docs/rv_StreamAltGeneralPermit2013.pdf.

5. Opportunities and Path Forward

Despite the range of barriers, there are concrete steps we can take to help work toward improvement in the design of our road-stream crossings. The importance of this work as a climate adaptation strategy is becoming increasingly recognized among decision makers. New York State's 2100 Commission, convened in response to severe weather events including Irene and Superstorm Sandy, recommended actions to be taken to improve the resilience of the state's infrastructure. Among the recommendations in the report were strategic investments in replacement of undersized pipe culverts with concrete box culverts and/or bridges in flood-prone areas (NYS 2100 Commission 2013).

Below we present a series of recommendations and key areas in which to focus. The first recommendation proposes additional information that can help highway departments identify where to focus their efforts. The second recommendation considers different mechanisms for funding culvert upgrades. The final recommendation focuses on policy and planning changes from local to federal level.

Improve the Information Base

Prioritize Stream Crossings of Greatest Ecological and Safety Importance

There are millions of stream crossings across the United States. In New York State alone, there are an estimated 1.2 million culverts on local, county and state roads, and about 50,000 culverts with a width of more than five feet (Long 2008). Since the resources do not exist to upgrade all culverts, it is important to identify those that are the most important from social, economic and environmental perspectives, and the most vulnerable to flooding and failure.

A prioritization of stream crossings would evaluate these factors:

- which road-stream crossings are the most ecologically important in terms of habitat and species dependent upon them,
- which crossings are currently limiting the movement of aquatic organisms based on their size and design,
- which crossings are most important from a community and safety perspective (e.g., located on roads with emergency service facilities such as hospitals or roads that connect communities),
- which crossings have been problematic for flooding and maintenance in the past, and
- which crossings are most vulnerable to expected climate change impacts.

Completing this kind of a prioritization is a complex task that requires a large amount of data, ranging from local highway maintenance records, to species presence and habitat needs, to detailed data about climate change impacts on a local scale, including the expected frequency of major storms and the flows that we can expect to see in our rivers and streams. Fieldwork to assess crossings would be required (for the second factor in the prioritization, as noted above). Despite the effort involved, application of a method of prioritization is needed to ensure that vital resources are directed toward improvements on higher priority streams and at-risk infrastructure, especially given the current fiscal climate.

There are many examples of stream crossing assessments that can serve as models in other regions, and many different tools exist for prioritization of crossings to replace. For example, a statewide connectivity analysis in Massachusetts led to the identification of sites where changes to infrastructure such as culverts would have the greatest impact on wildlife and habitat. The collaborative project involves the state transportation department, the University of Massachusetts Amherst and The Nature Conservancy.[14] The researchers found that improvements at just 10% of the locations analyzed would bring a disproportionately large set of ecological benefits (The Nature Conservancy 2013). In the Ausable River watershed, a set of community priority and fish barrier stream crossings was identified through modeling, fieldwork and outreach to local community highway departments (Miller et al. 2012).

While road-stream crossing assessments and prioritizations are underway or have been completed in many northeastern states, few have explicitly considered the vulnerability of crossings to increasing flows in streams as a result of climate change. It is important that forecasts for climate change be included in this work so that infrastructure is designed not just for the flows of the past but also to anticipate and withstand future flows. Finally, it is essential that transportation departments participate in processes of assessment and prioritization and have access to the results so that they can direct their limited funding to these priority stream sites.

Improve Tracking of Stream Crossing Costs and Performance

Better documentation of the costs to design, install and maintain different road-stream crossings over time, as well as the actual lifespan of these structures, is also essential to improving our understanding of the economics of crossing design types. The performance of upgraded crossings, particularly maintenance requirements and conditions following storms, should be monitored and compared with crossings that have not been upgraded. This needs to be done at all levels, from local town highway departments to state departments of transportation, and the information should be accessible for analysis. We need more case studies from more locations across the country.

Although improved tracking would require extra time from highway department personnel, this investment of time is likely to be outweighed by the benefits. Long-term information about stream crossing performance and cost should help communities to identify priority crossings as they consider upgrades. Better tracking would ensure that information is retained at highway departments even as personnel change. This information should also help improve the efficiency of expenditures by public agencies. For example, we can better understand if regulations that allow reimbursement replacement but not upgrade of culverts make the most efficient use of public tax dollars. Finally, contributing to the very limited information base

[14] More information about this project is available at http://www.umasscaps.org/applications/critical-linkages.html.

about culvert costs over time should help communities receive adequate reimbursement from FEMA for stream crossing replacements following disasters. As we have seen, the estimated replacement costs for our case study culvert were much lower than the project's actual costs.

Refine Economic Data

While tracking of road-stream crossing costs and performance should improve decision-making by transportation departments, additional information is also needed. Highway departments at all levels need to understand the full benefits as well as the full costs of the options they may choose, in both short and long time frames. This information is not readily accessible. Although full benefit and cost analyses are time intensive, a small and focused set of such analyses would be extremely valuable for highway department managers to understand the full range of societal and environmental costs associated with undersized crossings. This information can be used to validate investment in upgraded culverts in priority locations. In addition, complete economic information should help make the case for new sources of funding, beyond the day-to-day budgets of highway departments, to help pay for these improvements.

Establish Sustained Funding Streams

At present, there are limited sources of funding for road-stream crossing upgrades and improvements, leaving the financial burden to constrained highway departments who cannot typically afford to improve their infrastructure. Financial assistance for this work is essential, especially for local highway departments, who operate with very limited resources and maintain a large proportion of roads. In New York State, local jurisdictions maintain 85% of road mileage. Additional funding for upgrades will need to come through new streams of funding. Several funding models are reviewed below.

Cost-Share Programs

Given high costs and constrained budgets at all levels, the most realistic funding model for widespread stream crossing upgrades is a cost-share structure, in which government agencies provide a portion of the funding and the local town or county responsible for the crossing covers the remaining amount. Most existing programs that fund replacement of stream crossings to improve stream continuity require cost sharing. In the Northeast, these programs include the U.S. Fish and Wildlife Service's National Fish Program, the Eastern Brook Trout Joint Venture (for restoration of trout habitat), and grant programs of the National Fish and Wildlife Foundation. The available funding for these programs will need to be substantially increased, and new funding streams need to be developed.

At present, disaster recovery funding from FEMA cannot be used as part of match for funding from other federal agencies such as the U.S. Fish and Wildlife Service. Yet the benefits of upgraded crossings fall within the missions of both agencies, as they reduce vulnerability to flood-related disaster and improve ecosystems for fish. Finding a solution to this barrier should substantially increase the available funding for upgrades in communities rebuilding infrastructure following floods.

Third Party Compensatory Mitigation

Compensatory mitigation may be a viable funding source for stream crossing upgrades in places where there are sufficient impacts on streams that need to be mitigated. There are several types of mitigation programs; mitigation banks and in-lieu fee programs are the best developed and most utilized. In both types of mitigation, those who undertake projects (e.g., transportation departments and private developers) that will adversely affect wetlands or streams may be required to contribute money that is used to protect, restore, establish or enhance wetland or stream sites. While banks and in-lieu fee have mostly focused on wetlands to date, a limited number of stream mitigation projects that improve connectivity through including dam removals and culvert replacements, have been undertaken in different places across the country.

Other models of compensatory mitigation may also provide funding for stream crossing improvements. Conservation banks are being established in some states to help protect and restore species that are listed as endangered or threatened under the Endangered Species Act. In California, a number of state and federal agencies in California are developing an approach called Regional Advance Mitigation Planning (RAMP), in which mitigation funding will be strategically targeted for identified conservation needs at a landscape scale.

Stand Alone Aquatic Resource Improvement Programs

Another funding model for improving stream crossings is a dedicated program for improvements to aquatic habitat. An example of this is the Salmon Habitat Support Fund, a program that is funded by the voluntary donations of renewable energy customers of Portland General Electric (PGE) in Oregon. PGE customers who purchase renewable energy have an option to donate $2.50 per month when paying their electricity bills. This donation is used for habitat restoration projects that benefit salmon populations in Oregon. About 8,000 customers participate in this program, generating $240,000 per year for projects that improve stream habitat. A number of the projects undertaken since the Habitat Support Fund's establisment in 2004 have improved fish passage.[15] This particular program in Oregon was the result of unique circumstances and was specifically designed to address threatened or endangered anadromous fish, yet this model may be viable in other places, such as New York, where freshwater resources are highly valued by the public and residents may be willing to make voluntary contributions toward a fund that protects or improves stream habitat.

Innovative Finance Structures

In the aftermath of several major recent natural disasters, including Tropical Storm Irene and Hurricane Sandy, state and federal governments are increasingly discussing the importance of more resilient infrastructure. As noted earlier, New York State established the 2100 Commission to help identify ways to improve the resilience of the state's infrastructure in the face of natural

[15] More information about this program is available at http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/oregon/howwework/oregon-salmon-habitat-fund-factsheet-2012.pdf.

disasters. In places like New York with widespread aging and vulnerable infrastructure, new funding sources and structures – including grants and loans – will be required to improve resilience to future floods. Ideally, these financing structures will help ease the burden on local governments of the high initial costs of upgrading stream crossings and enable the necessary investments that can save money, improve environmental outcomes, and reduce future damages in the long term.

The NYS 2100 Commission recommended establishment of an "Infrastructure Bank" to improve public infrastructure funding and mobilize additional resources to meet infrastructure needs. As proposed by the Commission, this bank would make use of a diverse range of funding sources and would allocate funds through loads and grants (NYS 2100 2013). This type of financing structure could be a key source of funding for road-stream crossing upgrades that help promote resilience to future floods.

Strengthen Regulations, Standards and Incentives

While sufficient levels of funding are essential, strong codes and regulations must also be in place so that new and replacement crossings provide aquatic organism passage and flood protection. Yet standards and regulations can only go so far if highway departments are unaware of how to apply them or if they are inconsistently required. Closing the loopholes on exceptions and conducting meaningful outreach and training to highway departments are essential steps once standards and regulations are in place.

There are multiple jurisdictional levels at which strong regulations and standards are important. These are highlighted below.

Federal Regulations

At the federal level, strong permit requirements from the U.S. Army Corps of Engineers is a first step for improving the design of future culvert projects. The Regulatory Program of the U.S. Army Corps of Engineers is charged with protecting "waters of the United States," which includes all streams and rivers. The Corps issues Nationwide Permits that "authorize activities that have minimal individual and cumulative adverse environmental effects."

Many culvert projects are covered by Nationwide Permits. To qualify for use of a Nationwide Permit, a number of General Conditions must be met, including the condition that "no activity may substantially disrupt the necessary life cycle movements of those species of aquatic life indigenous to the waterbody, including those species that normally migrate through the area, unless the activity's primary purpose is to impound water," and the condition that "the pre-construction course, condition, capacity, and location of open waters must be maintained for each activity." Appendix B provides more information about Nationwide Permits and General Regional Conditions that apply in New York.

The goal of Nationwide Permits is to minimize the delay and paperwork associated with authorization of activities that are determined to have "minimal adverse effects on the environment." Projects that do not meet the conditions of the Nationwide Permits, General

Conditions, and General Regional Conditions must seek an individual permit. The process for individual permits is extensive and lengthy, including a full review as well as public notice and comment period. Given the incentive to ensure that culvert projects are covered by Nationwide Permits, strong requirements in Army Corps permits are key to promoting adequate design of new and replacement culverts.

State Standards, Regulations and Incentives

For many states, an important first step toward improved stream crossings is the adoption of stream crossing standards.[16] These standards are not regulations, and authorities have discretion in determining how they are adopted or implemented. Yet they are a starting point. A second step is to integrate standards into permitting decisions. Some states, such as Massachusetts, are working to do this, and other states can learn from its example. Establishing strong state-level requirements, or integrating standards into permitting decisions, can help ensure that new and replacement stream crossings are designed to withstand extreme storms and improve environmental outcomes.

One state with a particularly strong set of regulations is Oregon, where a fish passage law requires the owner or operator of an "artificial obstruction" located in waters that currently contain or historically contained native migratory fish to address fish passage requirements prior to certain "trigger events," such as installation or major replacement of the obstruction.[17] It is important to note that these requirements focus entirely on the movement of fish and complying with this law may not result in a full range of flood resilience benefits.

An additional benefit for states that have clear and strong regulations and standards in place is that they are better positioned to receive funding assistance toward upgraded stream crossings following major disasters. As explained in Appendix B, in places where standards exist, FEMA funds toward damaged culverts can be used to upgrade culverts to meet the standard rather than simply to replace a pre-existing undersized culvert.

States can also create incentive programs to encourage towns and counties to adopt codes and standards (see below) related to culvert design and sizing. An example of such a program is in Vermont, where towns that adopt a minimum set of codes and standards receive an additional 10% of state funding from two state road grants programs.[18] While the template of standards is fairly minimal, the incentive program is a noteworthy model, particularly in states where it may be politically difficult to pass regulations or adopt standards for stream crossings.

Local Codes and Planning Opportunities

In the Adirondacks, we learned that a key window of opportunity for upgrading stream crossings occurs following a major flood. Communities – towns and counties – can prepare

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[16] State stream crossing standards and guidelines for Massachusetts, Connecticut, Vermont, and New Hampshire can be viewed at http://streamcontinuity.org/online_docs.htm.

[17] For more information see http://www.dfw.state.or.us/fish/passage/.

[18] For more information, see http://www.aot.state.vt.us/ops/documents/aot-ops_OrangeBook.pdf.

themselves before floods strike so that in the aftermath of a major storm event they are well positioned to improve their infrastructure.

One measure that communities can take is to establish infrastructure codes and standards that specify adequate size and design requirements for stream crossings. Communities that adopt standards become responsible for adhering to them when they install or replace stream crossings regardless of the situation (i.e. whether or not the crossings have been damaged in a flood), and in the event of a federally declared disaster, FEMA Public Assistance funding can be used to upgrade destroyed or heavily damaged crossings to meet those standards. Following a number of federally declared disasters that led to costly flood damage, Delaware County in New York adopted infrastructure standards that have resulted in more flood-resilient and fish-friendly culverts. Following adoption of these standards, FEMA funding has helped to pay for upgraded culverts that meet these standards following federally declared disasters. Delaware County's standards are included in Appendix C.

Ensuring that problematic road-stream crossings are identified as action items in hazard mitigation plans is another concrete step that communities can take. Following flood-related disasters, communities with FEMA-approved hazard mitigation plans in place are eligible to apply for Hazard Mitigation Grant Program funding from FEMA for measures identified in their plans. Stream crossing upgrade priorities need to be included in these plans before floods occur.

Moving Forward

In this report, we have presented a range of information about the many ecological, social, and economic benefits, as well as the associated costs, of improving road-stream crossings. At all levels of government, resources are limited and difficult decisions need to be made regarding environmental protection and infrastructure maintenance. As the climate changes, all communities will be confronted with determining the most effective and appropriate ways of preparing themselves for the impacts. Upgrading road-stream crossings is by no means the only solution to the myriad challenges that communities in the Northeast will encounter in the face of more frequent storms, higher temperatures, and other changes. On the other hand, it is one concrete action that communities can take to prepare themselves and that offers multiple benefits, including better protection from severe flooding and healthier rivers and streams. We hope that this report has provided information to help move this work forward – in manageable pieces if needed – in the Adirondacks and more broadly in the Northeast and other regions of the United States.

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Cover photo credits: Ausable River Association (top left and top right), Dan McKinley, U.S. Forest Service, Green Mountain National Forest (lower right), and Chris Garrow, Town of Jay (lower left).

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Appendices

Appendix A. Applicable Regulations and Permits for Culvert Projects in the Adirondacks

Culvert projects in the state of New York typically require permits from the New York State Department of Environmental Conservation (DEC) as well as the Army Corps of Engineers.

The DEC has different permitting processes in different regions of New York. The information below relates to permits for DEC Region 5, which covers Clinton, Franklin, Essex, Hamilton, Fulton, Saratoga, Warren, and Washington counties. The permits and processes may be different in other regions. For culverts located inside the Adirondack Park, depending on the project impacts, permits from the Adirondack Park Agency (APA) may also be required.

While permits from the Army Corps of Engineers apply to all applicants (i.e., the organization responsible for a particular culvert project), the DEC and APA have different permit processes for culvert projects undertaken by different types of applicants (e.g., counties, towns, the state department of transportation, all others).

New York State Regulations

In New York State, a Protection of Waters Permit is required for any activity that disturbs a protected stream, and three standards are used to evaluate permit decisions. The regulations for this permitting are as follows:

§608.7 Permit application review:

(a) The department will review applications, plans, and other supporting information submitted and may:

(1) grant a permit approving the manner and extent to which alterations are proposed to be made to water resources of the state;
(2) grant a permit with conditions as necessary to protect the health, safety, or welfare of the people of the state, and its natural resources; or
(3) deny a permit.

(b) The department's review will determine if proposed alterations to water resources of the state are consistent with standards contained in section 608.8 of this Part, considering issues such as:

(1) the environmental impacts of a proposal, including effects on:
    (i) aquatic, wetland and terrestrial habitats; unique and significant habitats; rare, threatened and endangered species habitats;
    (ii) water quality, including such criteria as temperature, dissolved oxygen, suspended solids;

(iii) hydrology, including such criteria as water velocity, depth, discharge volume, flooding potential; and
(iv) water course and waterbody integrity, including such criteria as erosion, turbidity, and sedimentation.

(2) the adequacy of design and construction techniques for structures;
(3) operational and maintenance characteristics;
(4) the safe commercial and recreational use of water resources;
(5) the water dependent nature of a use;
(6) the safeguarding of life and property; and
(7) natural resource management objectives and values.

§608.8 Standards: The basis for the issuance or modification of a permit will be a determination that the proposal is in the public interest, in that:
(a) the proposal is reasonable and necessary;
(b) the proposal will not endanger the health, safety or welfare of the people of the State of New York; and
(c) the proposal will not cause unreasonable, uncontrolled or unnecessary damage to the natural resources of the state, including soil, forests, water, fish, shellfish, crustaceans and aquatic and land-related environment.

For more information, see http://www.dec.ny.gov/regs/4438.html/.

New York State General Permits for NYS Department of Transportation

a. In all regions of NY, the DEC General Permit GP-0-11-002, the NYSDOT General Permit, applies to culvert replacement. Relevant text is quoted below:

   Under this general permit, the New York State Department of Transportation is authorized to conduct the following activities within the limits of DEC regulated wetlands and regulated adjacent areas:

   Bank and channel stabilization activities for transportation related construction activities. Bank and channel stabilization activities shall be allowed on embankment slopes, within 200 linear feet of bridge or culvert inlets and outlets, at structure foundations, or at similar locations

   - For these activities, DOT must submit a Request for Authorization Form and a set of project plans to DEC, and written confirmation of authorization must be received prior to any work

   Permanent and temporary placement of earth fill when such fill is related to the rehabilitation or replacement of an existing transportation facility.
   Placement of earth fill is allowed when it is associated with any of the following activities: culvert installation, repair or extension.

- For these activities, DOT must submit a Request for Authorization Form and a set of project plans to DEC, and written confirmation of authorization must be received prior to any work.

Rehabilitation or in-kind and in-place replacement of existing transportation facilities. Authorized activities include rehabilitation or replacement (essentially replicating existing facility in configuration, alignment and dimension) of: drainage culverts; culvert end sections and aprons.

- For these activities, DOT must submit a Notification of Intent Form and a set of project plans to DEC at least 10 days prior to the start of work, and if there are no environmental concerns expressed by DEC during the 10 day review period, DOT is authorized to perform the activity without further approval.

b. If the project does not meet the conditions of the DEC General Permit, the DOT must follow the DEC permitting process for individual culvert replacements.

c. Other permits may be required from DEC, depending upon the project's impacts.

- Additional permits may include Water Quality Certification and Freshwater Wetland impacts.
- The DEC and the Army Corps have a Joint Application Form that covers these permits.

For more information, see https://www.dot.ny.gov/divisions/engineering/environmental-analysis/repository/GP-0-11-002_NYSDOT-GP.pdf.

New York State General Permits for Towns and Counties

a. For culvert replacement, towns and counties in DEC Region 5 (Clinton, Franklin, Essex, Hamilton, Fulton, Saratoga, Warren and Washington counties) can use the Municipal General Permit GP-5-12-00.

   Under this general permit, counties and municipalities are authorized to conduct the following activities on navigable waters, non-navigable waters classified C with a standard of (T) or higher; and/or NYS DEC regulated Freshwater Wetlands (FWW) and their 100 foot wide Adjacent Areas (AA) outside the Adirondack Park: New installation, replacement, repair or maintenance of a single arch, box, elliptical or round culvert and associated headwall protection that involves stream bed/bank disturbance which totals less than seventy (70) lineal feet, provided the replacement or repair does not consist of slip-lining.

   - To use the municipal general permit, counties and towns need to complete a Municipal General Permit Authorization Form and submit it at least three business days prior to commending work. Work may proceed three business days after the DEC receives the authorization form, unless applicants are advised otherwise.

- The permit is not applicable for work on a number of Adirondack streams, including the entire west branch of the Ausable River and the Ausable River from Rainbow Falls to Lake Champlain. For culverts on these streams, applicants need to follow the DEC permitting process for individual culvert replacements.

- For more information, see http://www.dec.ny.gov/docs/regions_pdf/r5draftmunigp.pdf.

b. If a project does not meet the requirements of the Municipal General Permit pertaining to culvert replacement that are included to protect aquatic resources and maintain or restore fish passage, a town or county needs to follow the DEC permitting process for individual culvert replacements.

New York State Individual Permits

a. The DEC requires an Article 15 Protection Of Waters Permit for a range of activities, including placement of structures in or across a stream with a classification and standard of C(T) or higher. A classification of C(T) includes all waters used as a source of drinking water, waters used for swimming and other contact recreation, and waters supporting fisheries and suitable for non-contact activities), and waters that support trout populations).

- A Joint Application for Permit form must be submitted to the DEC.
- A Short Environmental Assessment form is a required part of the application.
- For more information, see http://www.dec.ny.gov/docs/permits_ej_operations_pdf/jointapp.pdf.

b. If the culvert is on a Wild, Scenic or Recreational River on state land, an Application Supplement for Wild, Scenic and Recreational Rivers System Permit must also be submitted to the DEC.
    - For more information, see http://www.dec.ny.gov/docs/permits_ej_operations_pdf/spplmntwsrr1.pdf.

Army Corps of Engineers Nationwide Permits

a. Most culvert projects are covered by the recently reissued Army Corps Nationwide Permits (NWPs). Nationwide Permits are general permits that “authorize activities that have minimal individual and cumulative adverse environmental effects.”

Some NWPs require applicants to notify the Corps engineers prior to beginning the work. These pre-construction notifications (PCNs) allow the Corps to confirm whether or not the activities qualify for NWP authorization. Unless a nationwide permit contains a condition requiring the applicant to notify the Corps prior to undertaking the proposed activity, a written authorization is not necessary, and the Corps does not need to be informed of or approve the project.

The NWPs that are most relevant to work on culverts (installation, replacement and upgrades) include:

- NWP 3: Maintenance: The repair, rehabilitation, or replacement of any previously authorized, currently serviceable structure, or fill.

- NWP 13: Bank Stabilization.

- NWP 14: Linear Transportation Projects: Activities required for the construction, expansion, modification, or improvement of linear transportation projects (e.g., roads, highways, railways, trails, airport runways, and taxiways).

- NWP 18: Minor Discharges: Minor discharges of dredged or fill material into all waters of the United States.

- NWP 27: Aquatic Habitat Restoration, Establishment, and Enhancement Activities.

- NWP 29: Residential Developments.

- NWP 39: Commercial and Institutional Developments.

To qualify for NWP authorization, applicants must comply with a number of General Conditions (GCs). The following General Conditions are most pertinent to culvert work:

- GC 2. Aquatic Life Movements. No activity may substantially disrupt the necessary life cycle movements of those species of aquatic life indigenous to the waterbody, including those species that normally migrate through the area, unless the activity's primary purpose is to impound water. All permanent and temporary crossings of waterbodies shall be suitably culverted, bridged, or otherwise designed and constructed to maintain low flows to sustain the movement of those aquatic species.

- GC 3. Spawning Areas. Activities in spawning areas during spawning seasons must be avoided to the maximum extent practicable. Activities that result in the physical destruction (e.g., through excavation, fill, or downstream smothering by substantial turbidity) of an important spawning area are not authorized.

For more information about Nationwide Permits, see http://www.nan.usace.army.mil/Portals/37/docs/regulatory/geninfo/natp/NWP_FedReg.pdf.

In New York, there are also a number of General Regional Conditions (GRCs) that specify practices that must be followed when using a Nationwide Permit. These General Regional Conditions apply to all NWPs. The GRCs most pertinent to culvert upgrades and replacement are as follows:

- GRC A11. Construction Best Management Practices (BMP's) to ensure compliance with NWP General Condition #2 – Aquatic Life Movement and #9 Management of Water Flows. (A number of BMPs are specified; see document for details.)

- GRC A12. Construction Best Management Projects for Culvert Rehabilitation Projects, not including culvert replacement projects. (A number of BMPs are specified; see document for details.)

For more information, see http://www.nan.usace.army.mil/Portals/37/docs/regulatory/geninfo/natp/NWP_PN_30MAY12.pdf.

PCNs are required for certain kinds of activities under all of the NWPs listed above. The Corps must respond within 45 days of receipt of the PCN. For projects requiring a PCN, a Joint Application for Permit must be submitted to the Army Corps of Engineers along with the Corps Environmental Questionnaire.

If a project is covered under a NWP with no PCN requirement, the Army Corps does not need to be notified.

b. For culvert projects that are not covered by a Nationwide Permit or do not comply with the General Conditions or General Regional Conditions, applicants must submit a Joint Application for Permit to the Army Corps of Engineers (in addition to submitting a copy to the DEC) along with the Corps Environmental Questionnaire in order to receive an Individual Permit.

Adirondack Park Agency Permits

Culvert projects that have impacts to wetlands inside the Adirondack Park require permits from the Adirondack Park Agency.

a. Many culvert replacement projects are covered by APA General Permit 2002G-3AA, General Permit for Certain Minor Regulated Activities in APA-Jurisdictional Freshwater Wetlands. The permit authorizes: culvert repairs, replacements or extensions or new culvert installations with less than 300 square feet of permanent wetland excavation or fill per culvert site and compensatory wetland mitigation is addressed.

    - To use the General Permit, applicants must complete an Application and Certification for Certain Minor Regulated Activities in APA-Jurisdictional Freshwater Wetlands and submit it to the APA. The APA will review the application within 15 days of receipt and will arrange a site visit. If the application is approved, the APA will issue an approval within 10 days.

For more information, see http://apa.ny.gov/Forms/GP2002G-3AAR-GeneralPermit.pdf.

b. If the culvert project will have an impact on wetlands but does not meet the conditions required for use of the General Permit, then an APA wetlands permit is required.

NYS Department of Transportation would need to complete an Application for State Agency Projects General Information Request (GIR) as well as a Supplemental Information Request Application Form for Public Transportation Projects. For more information, see http://apa.ny.gov/Forms/GIR-StateAgencyR%20.pdf.

Towns, counties and individuals must complete two forms for this permit:

- Application for Major Projects: General Information Request: The APA has up to 90 calendar days to review these applications and make a decision. If the project is approved, the APA issues a permit within 90 days. Alternatively, the APA may call for a public hearing, which must be held within 90 days after the application is deemed complete.

  For more information, see http://apa.ny.gov/Forms/GIR-MajorProjects.pdf.

- Supplemental Information Request Application Form for Public Transportation Projects: This form must be submitted with the General Information Request.

Appendix B: Overview of Relevant FEMA Disaster Assistance Programs

The Robert T. Stafford Disaster Relief and Emergency Assistance Act of 1988 comprises the statutory authority for most of FEMA's disaster response activities, including the allocation of Public Assistance funding and Hazard Mitigation funding.

Overview of FEMA Disaster Assistance Programs

FEMA's assistance to individuals and communities falls into two general categories: (1) post-disaster assistance, which becomes available to specific states and counties after a FEMA disaster is declared, and (2) pre-disaster assistance, which is allocated on a competitive basis and is available nationwide. Post-disaster assistance is discussed below, and several pre-disaster assistance programs are summarized in a later section.

Post-disaster assistance includes several different types of financial assistance for individuals and communities. FEMA issues disaster declarations by state and disaster, so each state impacted by the same disaster has its own declaration. The assistance programs are administered by state agencies in close coordination with FEMA. The declaration includes a listing of the counties in the state that are eligible for each type of assistance.

Immediately following a disaster declaration, individuals and communities in the designated counties are eligible for two types of **recovery assistance**:

1. **Individual assistance**: FEMA provides three types of individual assistance:
    a. Individuals & Household Program (IHP), which provides money and services to people in declared disaster areas;
    b. Housing assistance; and
    c. Other needs assistance, for needs, such as "furnishings, transportation, and medical."

2. **Public assistance** is grant assistance for communities to quickly respond to and recover from declared disasters. Public assistance is discussed more thoroughly in the next section.

Six months following a disaster, communities in designated counties are eligible for assistance from the **Hazard Mitigation Grant Program**. This program provides "grants to States and local governments to implement long-term hazard mitigation measures after a major disaster declaration." This pool of funding is also referred to as "Section 404 funding" (because it was authorized under Section 404 of the Stafford Act). Hazard mitigation grants are discussed in a separate section.

FEMA Public Assistance

Public assistance funds are federal disaster grants provided to communities in eligible counties as "supplemental reimbursement for the repair or restoration of the infrastructures and facilities to pre-disaster condition" after a disaster declaration. FEMA allocates the money to the state, and the relevant state agency disburses the funds to applicants with some oversight from FEMA. In New York, the New York State Office of Emergency Management (NYSOEM) works closely with FEMA to manage post-disaster assistance.

Eligible applicants for public assistance funds include State agencies, municipalities, Native American Tribal Organizations, and certain private non-profit organizations that provide essential services of a governmental nature (such as school districts and community centers). According to the NYSOEM Public Assistance Program Handbook of Policies and Guidelines for Applicants for Tropical Storm Irene, "Reimbursement is generally provided on a 75% Federal share, 25% non-Federal share." FEMA notes on its website that the FEMA reimbursement percentage is always at least 75%, so it is possible that FEMA will cover a larger portion in other places and/or for other disasters.

There are seven work categories for which public assistance can be used:

A. Debris removal
B. Emergency protective measures
C. Road systems and bridges
D. Water control facilities
E. Public buildings, contents and equipment
F. Utilities
G. Parks and recreational facilities

Culvert repair falls under category C (road systems and bridges).

<u>Repair or Replacement?</u>
In determining whether a damaged structure (such as a culvert) should be repaired or completely replaced, FEMA has a "50% rule," which states "a facility is eligible for replacement when the repair cost exceeds 50 percent of the replacement cost. The comparison of repair costs with replacement costs results in a fraction that expresses repair as a percentage of replacement." In terms of culverts, FEMA will pay for a new culvert only if the cost of repairing the existing culvert is less than half of the cost of a new culvert.

<u>In-Kind Replacement or Upgrade?</u>
The Stafford Act authorizes FEMA to reimburse the costs of repair and replacement of a facility based on its design prior to the disaster, and "in conformity with current applicable codes, specifications and standards." The Code of Federal Regulations (44 CFR §206.226(d)) specifies that for the costs of Federal, State, and local repair or replacement standards that change the predisaster construction of a facility, such as upgrading a culvert, to be eligible, the standards must:

1. Apply to the type of repair or restoration required (standards may be different for new construction and repair work);
2. Be appropriate to the predisaster use of the facility;

3. Be found reasonable, in writing, and formally adopted and implemented by the State or local government on or before the disaster declaration date, or be a legal Federal requirement applicable to the type of restoration;
4. Apply uniformly to all similar types of facilities within the jurisdiction of the owner of the facility; and
5. For any standard in effect at the time of a disaster, it must have been enforced during the time it was in effect. [19]

In short, unless the five conditions above are met with regard to culvert standards, FEMA money can not be used to reimburse 75% of the cost of an upgraded culvert. Following Tropical Storm Irene, the State of Vermont was refused funding toward upgraded culverts because FEMA had determined that it was not applying its standards uniformly. On the other hand, FEMA did fund several culvert upgrades in New York State to improve fish passage based on the recommendation state's Department of Environmental Conservation.

If the above conditions are not met but a county, town or state wishes to see a larger or different type of culvert replacement, this would be an "improved" project, which is defined by FEMA as a project that for which "damaged facilities are restored to the predisaster condition or function, but improvements are made at the time of restoration or repair." Federal funds (FEMA and other federal agency sources) can only be used to cover 75% of the estimated cost of the non-improved culvert; the additional cost of the upgrade is to be paid from other non-federal sources. While funds for an improved project can be combined with grants, only grants from non-federal agency sources can be used to pay for the other 25%. An improved project must be approved
prior to construction. The additional cost of an improved project – even just 25% - is often prohibitive for communities, particularly in the wake of a disaster that has resulted in major damage.

FEMA Hazard Mitigation Grant Program

Hazard mitigation grant funding is made available to states about six months after the disaster declaration, though the allocation of the funds to communities may take much longer. These funds can be used for hazard mitigation planning as well as implementing long-term hazard mitigation measures following a disaster. Eligible applicants include States, Tribes, and local communities.

The amount of funding for the hazard mitigation grant program (HMGP) for each state is based on the total expected amount of damages to be paid out under the disaster assistance program. For states (like New York) with a FEMA-approved state mitigation plan, the amount available for the HMGP is 15% of the first $2 billion of estimated amount of disaster assistance, and up to 10% for the next $2 billion and $10 billion.

[19] FEMA's Construction Codes and Standards are online at http://www.fema.gov/public-assistance-local-state-tribal-and-non-profit/construction-codes-and-standards.

The HMGP provides both planning grants as well as project grants. The planning grants are for communities that do not already have hazard mitigation plans in place to develop their plans. There is a significant time lag between a disaster and the allocation of the funds, and this may lead to a lost opportunity to build stronger infrastructure, since many damaged facilities – such as culverts on roads that are critical for communities – will need to be repaired quickly.

To be eligible for hazard mitigation grant funding, a community must have a current, FEMA-approved, community-adopted all-hazards mitigation plan in place. Project grants are used for implementing hazard mitigation measures that are included in a community's plan. The FEMA HMGP funds provide 75% of eligible costs, and a 25% non-Federal match is required. For culvert upgrades, the plan needs to reference specific culverts that should be replaced to enhance community safety.

When hazard mitigation funding becomes available to a state, the state emergency management agency first sets priorities for the use of the funds. The state agency then helps with the development of applications and submission of applications to FEMA. The role of FEMA is to ensure that state-recommended projects are eligible under federal regulations.

Appendix C. Delaware County (New York) Bridge and Construction Standards

WHEREAS, the 21st century Bridge Program was established by Resolution number 234 of 1994; and

WHEREAS under the program all Bridges in Delaware County are owned and maintained by the Delaware county DPW; and

WHEREAS the Board recognizes that there will be times that Towns and Villages in the County will want to increase the size of their existing structures to a length that becomes 20 feet in span or longer; and

WHEREAS the Board wants the new structures to be designed and built to the same standard that the county builds its structures;

NOW, THEREFORE BE IT RESOLVED, that the following procedure be followed for all structures that will become the counties after construction is complete:

The proposing municipality shall retain an engineer, licensed to practice Engineering in NYS to perform all the necessary work identified herein.

1. The municipality shall have a hydrologic and hydraulic analysis performed to determine the required structure waterway opening. The analysis shall be summarized in a report. The report shall include all the necessary calculations to determine the waterway opening of the structure. The calculations shall include a USGS quadrangle map clearly delineating the limits of the watershed for the proposed crossing. It shall also include a sketch plan of the proposed structure. The sketch shall include the skew angle of the proposed structure, the bank full width of the stream to be crossed as measured a minimum of 100 feet upstream and downstream of the proposed bridge, the proposed alignment of the approach roadways, and other appropriate information.
    a. The design standards for the hydrology and hydraulics shall be:
        i. The USGS regression equations Methodology dated 1991 shall be used.
        ii. The waterway opening shall be the smaller of the two following conditions
            1. 50 year recurrence interval with 2 feet of freeboard
            2. Pass the 100 year recurrence interval under gravity flow conditions.
            3. The hydraulics shall be modeled manually with reasonable assumptions or by using any generally accepted modeling software package ie HEC RAS.
    b. The report shall be submitted to the DPW for review and written approval prior to any further work being done on the bridge design.

c. DPW is required to review and act on the document within 10 working days of the receipt by the department.
d. If the H&H report does not clearly identify the need for the structure to be a bridge as defined by the New York State Highway Law, then the municipality shall not build a structure with a span length of 20 feet or greater just to have the county take the structure over.

2. Once the H & H report has proven that a structure having a span of 20 feet or greater is required, and the report is accepted, the municipality shall proceed with the design.
3. Design phase shall include a number of sub phases. Each of the sub phases have to be approved in writing by the DPW prior to the advancement to subsequent sub phases. The sub phases shall include:
    a. Type, size, and location study
        i. Under this submission the engineer shall identify the general alignment of the structure and the approach roadways
        ii. The skew of the crossing with respect to the stream shall be clearly shown
        iii. The type of substructure units to be utilized shall be identified
        iv. The type of superstructure to be utilized shall be identified
    b. 50% plans
        i. This submission shall include all of the major components of the structure
        ii. Shall include the angles and lengths of all the wing walls
        iii. Shall show the limits of the approach guide rail
        iv. Shall show the limits of all required stone slope protection
    c. 75% plans
        i. This submission shall include all the necessary details to construct the bridge
        ii. Shall include a listing of all the standard DOT specifications that will be used in the project.
        iii. Shall include a rough draft of the special specifications required.
    d. 100% plans
        i. This submission shall include all the necessary details, specifications and bid documents to put the project out to bid
4. Design Standards. The following design standards shall be used on all county structures:
    a. Substructures
        i. Must be based on a geotechnical report by a Professional Engineer licensed to practice in the state of NY. Must have at least two years of experience in the field of geotechnical engineering
        ii. The preferred substructure shall be steel sheet piling. If sheets can not be driven to the required depths, the walls shall be tied back. If tie backs do not provide the required restraint, concrete abutments shall be allowed. Concrete abutments shall be founded on and

doweled into rock or be on steel piles. Integral abutments may be acceptable to the department based on the projected water velocities of the design storm, slope of the stream and general topography of the valley floor. It is not to be assumed that integral abutments will automatically be acceptable. If they are acceptable, there will be a requirement for scour protection against loss of embankment material from the approaches.

b. Superstructure
    i. Design loading shall be HS 25
    ii. Cross section of roadway shall be in accordance with AASHTO for the appropriate level of service of the roadway on which the bridge will be situated
    iii. NYSDOT bridge design manual and Bridge Design Detail (BDD) sheets shall be used.
    iv. If the type is beam and deck, the deck shall be a 6"X8" nail laminated, pressure treated deck in accordance with standard details provided by the county or approved equal.
    v. The superstructure may also be an adjacent pre-stressed concrete box section, pre-stressed concrete plank, or longitudinal glue laminated structure. On all these types of structures, the design shall be provided and stamped by the manufacturer's licensed PE.
    vi. The guide rail shall conform to the standard drawings provided by the DPW.
    vii. All structural steel used shall be hot dipped galvanized after fabrication.
c. The DPW will provide a copy of the standard details to be used for the construction of all standard county bridges. A copy of the standard sheets will be on file with the Clerk of the Boards office. The DPW will make the details available to Towns and Villages in the county in an electronic format. The Towns and Villages can request of the DPW that the details be provided directly to engineers that they have selected to perform professional services to them. The Municipalities shall ask for a current set of standards for each structure they start to ensure that the most current standards are used.

5. Construction Phase
    a. Construction observation
        i. The municipality shall provide for full time construction inspection by a qualified construction inspector.
        ii. The construction inspector shall ensure that the construction contractor has a Quality Control program adequate to ensure that the project is built in accordance to the contract documents
        iii. The inspector shall implement a Quality Assurance program to document the contractors quality control program and to certify that the project is built in accordance with the contract documents
        iv. The QA plan shall include construction photographs of all significant

features that will ultimately hidden by backfill material.

v. The County shall be given a complete copy of all the construction documents at the completion of the project.

vi. The County shall be notified of the day the structure is opened to the traveling public.

b. Record Drawings

i. The construction inspector shall insure that a set of record drawings be kept current at all times. The Record drawings shall clearly document all deviations of the constructed project from the design plans.

ii. The county shall be provided with two reproducible sets of record drawings upon the project completion. One set will be kept on file in the DPW and the other set will be provided to the NYSDOT for the purposes of the Unified Bridge Inspection Program.

iii. The record drawings shall be provided to the county within 20 working days of the day that the bridge was first opened to the traveling public.

c. Level One Load Rating Calculations

i. A level one load rating calculation shall be provided upon the completion of the project. The level one shall accurately reflect the structural capacity of the project as it was completed. The level one shall be submitted on the forms required by the NYSDOT. The rating shall clearly identify the structural capacity of all the components an also identify the controlling components. The rating shall be signed and stamped by a PE licensed to practice engineering in NY State.

ii. Two original copies of the signed and sealed Load Rating Calculations shall be submitted to the DPW within 14 working days of the opening of the structure to the public.