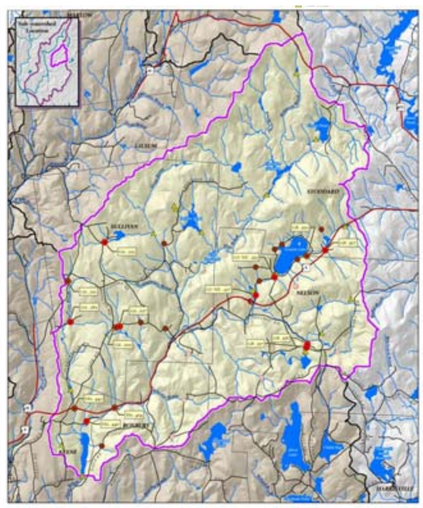
River connectivity restoration priorities in High Quality Sub-watersheds in Southwest New Hampshire

A Final Report to
The New Hampshire Department of Environmental Services
Submitted by
The Nature Conservancy
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NEW HAMPSHIRE DEPARTMENT OF Environmental Services

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The Nature Conservancy
PROTECTING NATURE. PRESERVING LIFE.

SWRPC
Southwest Region Planning Commission

AVEO
Ashuelot Valley Environmental Observatory

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Executive Summary

The year The Nature Conservancy initiated River Continuity Assessment of the Ashuelot River Basin ("Assessment" TNC 2008), was coincidentally immediately after the 100-year floods in Alstead, NH. Alstead was devastated when extreme runoff during a heavy rainstorm overwhelmed a culvert and sent a cascade of water down the river and through the Town. The Conservancy was originally interested in how wildlife, particularly fish, were passing through bridges and culverts to access upstream habitats.

After the completion of the Assessment (TNC 2008), it was apparent that additional work was required to identify restoration priorities. Specifically, the Assessment focused on reporting fragmenting effects of dams, bridges, and culverts, but clear guidance on what to do about them was still needed.

This project focused on identifying priorities to restore stream continuity in three Sub-watersheds in the Ashuelot Basin. These Sub-watersheds were identified by the NH Department of Environmental Services River Management and Protection Program staff as satisfying High Quality Watershed conditions. They all have relatively low development pressure and a high percentage of natural land cover. They are spread across the geography of the Ashuelot Basin. The Hinsdale-Winchester Tributaries Sub-watershed represents the confluence, where the Ashuelot River meets the Connecticut River. The Surry Dam Sub-watershed represents the mid-river reach of the Ashuelot mainstem, and includes headwater streams flowing into the River upstream of Surry Mountain Dam. Otter Brook Reservoir Sub-watershed represents headwaters, with multiple small streams flowing into Otter Brook, on of the River's primary tributaries. This Sub-watershed also includes Granite Lake, which sites within a geographic bowl in Stoddard and Nelson.

Overall, we collected data on 225 of the 239 mapped road-stream crossings in the project area. Using the same road-stream crossing protocol and fragmentation scoring algorithm as we used in the Assessment (UMass 2005), we scored 53 (26%) road-stream crossings as "Severe," that is, those that pose significant barrier to aquatic organism passage, and that may disrupt certain stream functions.

In order to refine restoration priorities, we additionally assessed Severe barriers in two additional ways. First, we calculated total upstream stream miles and focused only on those barriers relatively lower in the watershed whose restoration would open up more aquatic habitat.

Second, we developed a systematic way to determine if a given crossing was adequately sized to withstand a scale-appropriate storm flow. For crossings with upstream watersheds <200 acres, we used crossing dimensions and watershed characteristics to determine if it could pass a volume of water associated with a 25-year flood, or the flood that is likely to occur every 25 years. We similarly determined whether crossings with upstream watersheds >200 acres was adequately sized to pass the 100-year storm event.

We present three Tiers of restoration priority for all Severe barriers. Of the 53 Severe crossings, we selected 20 (or 38% of Severe barriers, and 8% of all crossings) as Tier One restoration priorities. Based on the Sub-watersheds in the project area, this further breaks down to:

- 3 Tier One restoration priorities in the Surry Dam Sub-watershed
- 9 Tier One restoration priorities in the Hinsdale-Winchester Tributaries Sub-watershed
- 8 Tier One restoration priorities in the Otter Brook Reservoir Sub-watershed

We provide preliminary cost categories and outlet perch data for all Severe crossings as well, to add some descriptive information and to allow for comparisons.

Restoration priorities and maps are reported for each Sub-watershed in three different versions of Chapter 2. Chapter 3 summarizes relevant information about outreach, laws and regulations, funding, planning, and additional background. Town officials, Selectmen, Board Members and volunteers can refer to these materials as they consider planning for and budgeting river continuity restoration projects.

CHAPTER 1

INTRODUCTION

Project need

The last several years has seen a remarkable increase in our awareness of river function, flooding risks, and fish and wildlife passage challenges in aquatic ecosystems. Particularly at issue is how well our road infrastructure allows wildlife passage and whether they can withstand storm flow and runoff during extreme floods. Every year since 2005, the northeastern US has experienced at least one 100-year flood[1]. This increase in storm frequency and intensity is likely to continue, especially if climate change predictions come true.

The year The Nature Conservancy initiated River Continuity Assessment of the Ashuelot River Basin ("Assessment" TNC 2008), was coincidentally immediately after the 100-year flood in Alstead, NH. Portions of the Town were devastated when extreme runoff during a heavy rainstorm on October 8, 2005 overwhelmed a culvert and sent a cascade of water down the river. The same flood destroyed roads in the Ashuelot River basin as well. The Conservancy was originally interested in how wildlife, particularly fish, were passing through bridges and culverts to access upstream habitats. Our conservation planning had identified culverts and bridges as potential barriers to wildlife movement[2]. How these human-built structures influenced flooding is inextricably linked to wildlife movement.

Experts in the scientific, regulatory, and conservation fields have recognized that culverts that are unlikely to pass storm flows have a strong correspondence to those that are unlikely to allow upstream passage of fish and other wildlife. This study attempts to combine characteristics of both issues (wildlife passage and storm flow) at the scale of Sub-watersheds. Because river ecosystems operate irrespective of town boundaries, it is important that neighboring towns are aware of how streams and rivers may influence downstream resources.

After the completion of the Assessment (TNC 2008), it was apparent that additional work was required to identify restoration priorities. Specifically, the Assessment focused on reporting fragmenting effects of dams, bridges, and culverts, but clear guidance on what to do about them was still needed. In addition, the large number of road-stream crossings in the 420 square mile Watershed posed too large a scale to set meaningful restoration priorities across the 26 towns overlapping the Ashuelot River Basin. Focusing on Sub-watersheds comprising only 3-4 towns was a more manageable scale on which to focus

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[1] 100-year flood corresponds to the amount of storm runoff expected once for every one-hundred year time-span.

[2] Conervancy staff have completed multiple Conservation Action Plans for both the Ashuelot River and the Connecticut River and their watersheds. Top threats identified in each plan included Altered Flow, River Fragmentation, Invasives Species, and other threats.

restoration planning. This pilot study on Sub-watersheds provides the opportunity to work at a scale most appropriate for local action.

Project area

This project focuses on three Sub-watersheds (HUC12 scale) with relatively high watershed condition and high water quality (See Map 1). Selecting these “High Quality Water” Sub-watersheds focuses on maintaining natural conditions, compared to more developed areas in urban and suburban Sub-watersheds. We hope that Sub-watersheds provided the opportunity to encourage neighboring townships and their respective conservation and land management officials, volunteers, and staff to work together across town-boundaries. This approach seemed more feasible than coordinating restoration priorities among towns separated by as much as 30 miles. In addition, an approach focusing on the river ecosystem provides a unifying theme that not only motivates cross-border collaboration, but also provides enhanced ecological benefits, particularly for river and stream connectivity.

Project goals

We address the issue of aquatic continuity, while also providing focused restoration priorities. Our goals include:

- Through documentation and outreach, provide conservation practitioners, freshwater experts, and local staff and conservation officials with the best information and tools to make aquatic and infrastructure restoration decisions;
- Augment field-based assessments by sampling as many road-stream crossings in the project area as possible, and reporting updated field- and GIS-based results;
- Develop and advance methods for selecting restoration priorities, based on current science and expert judgment;
- Continue the discussion of aquatic fragmentation and restoration of river continuity;
- Focus attention on those human-built river obstructions in each Sub-watershed and/or town, that if corrected and/or restored, would provide both ecological and human benefits in terms of aquatic resources and flood protection.

Fragmentation threat

Bridges and culverts are designed to pass water and protect roadways. During normal conditions, these road-stream crossings may easily pass water, but may pose barriers to upstream fish and wildlife movement. They may also reduce stream function by blocking downstream movement of sediment, nutrients, and coarse woody debris.

Over the last several years, attention on road-stream crossings has increased, both in the science and regulatory realms. Federal and New Hampshire state regulators have recognized the need to require better management and permitting of culverts and bridges to ensure they pass both storm water and aquatic organisms. Conservation planning efforts focused on rivers commonly identify fish and aquatic organism passage as restoration needs.

Flooding threat

During flood conditions, dams provide a benefit by protecting human health and property. Bridges and culverts, on the other hand, if overwhelmed by flood waters, pose a risk of failing and sending a devastating flood downstream, as happened in Alstead in 2005. As road infrastructure ages, this threat increases over time.

Climate patterns appear to demonstrate that flood frequency and magnitude are increasing over time. If climate change predictions hold true, the increase in frequency and magnitude may be even worse, putting even more crossings at risk. In the last several years, the following reports and efforts have addressed the need to address and reduce these risks:

- Ashuelot River Local Advisory Committee (ARLAC) Management Plan
  - http://des.nh.gov/organization/divisions/water/wmb/rivers/ash_river.htm
- NH Climate Action Plan (DES 2009)
  - http://des.nh.gov/organization/divisions/air/tsb/tps/climate/action_plan/nh_climate_action_plan.htm
- NH DES Water Primer
  - http://des.nh.gov/organization/divisions/water/dwgb/wrpp/primer.htm
- USACE & NH DES Wetlands Bureau rules-making
  - http://des.nh.gov/organization/commissioner/legal/rulemaking/index.htm (scroll to Proposed Wetland Rules)
  - http://www.nae.usace.army.mil/reg/index.htm (click on River Continuity)
- Legislative Commissions on flooding & stormwater
  - http://www.nae.usace.army.mil/reg/index.htm
  - http://gencourt.state.nh.us/statstudcomm/reports/1853.pdf
  - http://www.nh.gov/oep/legislation/2008/hb1295/2009/meetings.htm
- Wide-spread town-based hazard mitigation planning, funded in response to recent flooding; funded by FEMA through Homeland Emergency Management; housed at SWRPC offices, Keene, NH.

The case for restoration

The Ashuelot River Basin supports relatively high quality water and habitat compared to similar watersheds across New Hampshire and the Northeast. Its largely intact forest cover and good quality fisheries have attracted conservation attention by both agencies and non-profit conservation organizations. The Watershed includes thousands of acres of conserved land. Its river supports a wide array of native fish and wildlife. The Ashuelot River was designated by the New Hampshire Rivers Management and Protection Program in 1993. Multiple conservation partnerships have identified important habitat areas, including the Conservancy, the Society for the Protection of New Hampshire Forests, the Quabbin to Cardigan Collaborative, The Conte National Fish and Wildlife Refuge, and others.

Restoring ecological integrity will provide the extra benefit of flood prevention. This strategy will help obviate the need to rebuild failed crossings after a flood, and may prevent failure in the first place. We hope this project can serve as a pilot study from which to learn and export best practices at town, state, and regional scales.

Organization of report
This report is organized into sections that both address watershed-wide patterns and needs while also focusing attention on town-scale restoration priorities. Throughout the report we provide guidance and recommendations for other watershed groups or towns who wish to implement road-stream crossing restoration planning.

Chapter 1 presents Introduction, Methods, Results, and Discussion sections for the overall project area. This Chapter is useful for state-wide and regional conservation practitioners interested in the methods and tools of road-stream crossing assessment.

Chapter 2 presents restoration priorities for each Sub-watershed in the project area. Three unique versions of **Chapter 2** are available, depending on which Sub-watershed is addressed. For example, the Hinsdale-Winchester Sub-watershed version (**Chapter 2^{HW}**) focuses on restoration priorities for those towns overlapping that Sub-watershed. Other Chapter names are similarily labled, such as 2^{S} for Surry Dam Sub-watershed and 2^{O} for Otter Brook Reservoir Sub-watershed.

Chapter 3 provides a brief overview of the relevant resources available for towns or watersheds interested in conducting aquatic continuity assessments and /or developing their own restoration plans.

METHODS

Field inventory

Because this project builds on the previous effort to assess crossings, we used the same field assessment protocol as in the Assessment (TNC 2008). Interns and staff from both The Nature Conservancy and Ashuelot Valley Environmental Observatory (AVEO) visited road stream crossings that were not surveyed previously. We attempted to complete, as much as possible, a full sample of all road-stream crossings in our study area.

Field sites were pre-determined, and focused on perennial streams flowing under highways, roads, and railroads (and in some cases, trails). We intersected the NH Hydrography Dataset flowline feature class (i.e. Streams; GRANIT 2006) with NH Department of Transportation Roads data (GRANIT 2005) and NH Railroad data (GRANIT 1992). We used the INTERSECT ArcInfo command to create our point data set for crossings, as in the Assessment (TNC 2008).

Field staff used the same field forms and methodology as employed in the Assessment (see TNC 2008); all new data were incorporated into existing databases; and the same scoring algorithm was employed for all new crossings (See Appendices A-C). "Severe" barriers were the focus of further analysis, as in the Assessment.

Fragmentation scoring algorithm

We used the same fragmentation scoring algorithm as employed in the Assessment (TNC 2008). For sites with incomplete data where we could not return to validate or complete a form, we assigned a fragmentation score if we had enough data (*i.e.* site photographs) to do so. For other sites where we could not assign a score, we labeled the site "Not Assessed."

The fragmentation scoring algorithm combines multiple field-based parameters and assigns relative fragmentation of a crossing on a scale from one to ten, one implying no passage and most fragmenting (Appendix 2). A score of "0" was assigned to barriers for which we had sufficient data to assign a Barrier Class of "Severe" even when certain key field parameters were not available. For example, there were cases where we could not measure all field parameters, but it was clear that some feature or features posed extreme fragmenting challenges. Scores were translated into four Fragmentation Classes, as follows.

Algorithm Score	Barrier Class
0 or 1	Severe
2	Moderate
3 – 5	Minor
6 – 10	Passable[3]

[3] Some of the 6-10 scores may pose challenges for certain species, or may impair certain ecological functions. We intend to assess this nuance in the next iteration of this report.

The algorithm is structured in such a way as to ensure that the most fragmenting features are prioritized. For example, even if a culvert has all the correct features to allow passage, if there is some sort of permanent barrier, such as a screen at one end, the algorithm automatically scores the site a one (1), or Severe barrier. A score of zero (0) reflects our decision that the crossing deserves a Severe rank when data are lacking and/or we could not measure certain key characteristics. This occurred most commonly when we could not safely measure crossing dimensions or could not access the crossing, but did have sufficient data to assign a rank.

GIS analyses
For all barriers scoring Severe, we developed a series of parameters to aid in narrowing our list of restoration priorities.

Stream mileage: In February 2009, we solicited feedback from river ecology experts about the most critical habitat variable to use for prioritizing culvert restoration. We examined the suite of GIS variables used in the Assessment (see TNC 2008), and decided that stream mileage was the best variable to focus restoration decisions. That is, those features whose restoration would restore the most stream habitat for fish passage, and other aquatic ecosystem processes, should be the focus of additional examination. Those crossings with a relatively high number of stream miles provide a relatively higher restoration benefit.

We calculated both the total upstream miles from a given barrier, as well as "restoration mileage," that is, given the removal of a Severe barrier, the number of miles upstream and downstream to the next Severe barrier, that would be re-opened if the barrier was removed.

Stream mileage "exclusions rules": We set a minimum reach length of 0.5 miles as a threshold for determining restoration priorities. That is, any Severe barrier whose total upstream mileage was less than 0.5 miles, we considered lower priority because it restricts a relatively minor portion of the functional stream ecosystem for both flow and fish habitat. While this is not to say headwater stream segments are unimportant, it is a recognition that very short headwater reaches provide less benefit than those barriers lower in the watershed.

To ensure we were not unduly disregarding barriers using the 0.5 mile threshold, we re-included any barrier with an upstream watershed of more than 150 acres. Even small headwater watersheds can collect excessive water volumes during storms and we wanted to ensure we were not unduly disregarding headwater reaches with relatively large upstream catchment basins.

Dams: Because dams are a significant barrier to fish passage and ecosystem processes, we included them in our analysis of restoration mileage. Dams used for water storage, recreation, and flood control generally are managed for the long-term, and in many cases provide a public benefit. For many dams, it may not be feasible nor warranted to engage in restoration or removal strategies. Dams licensed by the Federal Energy Regulatory

Commission (FERC) may face fish passage development requirements under re-licensing agreements. On the other hand, dams that are structurally unsafe and no longer provide any use should be considered for removal. The River Restoration Task Force is a program administered by the NH Dam Bureau that can provide assistance for dam removal. In Appendix 3, dams are listed in order of their upstream mileage.

Storm flow conveyance: Undersized culverts pose significant risks during flood conditions. As culverts are overwhelmed by storm water, the risk of flooding and culvert failure increases. For all Severe and Moderate crossings, we employed a methodology conceived by Dr. Michael Simpson[4] to calculate the volume of each crossing corresponding to the 25- and 100-year storm flows, or the amount of water statistically associated with storms occurring every 25 or 100 years. For crossings whose upstream watershed is less than 200 acres, we calculated the 25-year storm flow. For crossings larger than 200 acres, we calculated the 100-year storm flow. These thresholds were informed by the New Hampshire Stream Rules Stakeholder's work group, a panel of experts who informed the drafting of new state regulations for new and replacement bridges and culverts[5].

Using culvert dimensions, we calculated the ability of each crossing to pass storm flow. If the storm flow water volume exceeded the design capacity of the crossing (which we call "undersized"), we considered that an elevated risk of flooding or failure for that location. Appropriately sized culverts (or "adequate") should pass both normal flows and occasional high flows associated with storm events.

To estimate the ability of a given crossing to pass storm flow, the *Design Charts for Open Channel Flow* (FHWA 1961) methodology was used. We used the following four parameters to complete the estimation.

Step one: Culvert diameter was determined in inches. This value was easily collected from field data forms. In cases where a culvert was not round, the openness ratio of the culvert was used to calculate a culvert diameter.

- Assumption: Openness ratio for non-round culvert diameters is adequate to provide a primary conveyance parameter, that is, the size and shape of the crossing opening.

Step two: Roughness coefficient (n) for each culvert was assumed to be n = 0.015 for each culvert. This corresponds to the approximate coefficient for a rough concrete culvert.

- Assumption: Assigning a standard roughness coefficient for all crossings is similarly adequate as in Step one.

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[4] In Dr. Simpson's work, the ability of stream crossings to pass storm flows were classified similarly: (1) ***Weir*** flow: water volume easily passes through crossing; (2) ***Transitional*** flow: water volume just at the point prior to crossing becoming overwhelmed, and (3) ***Orifice*** flow: water volumes exceeding the capacity of the crossing.

[5] Since the development of our method, the State DRAFT rules on Stream Crossings have increased the minimum design and engineering threshold for small streams to correspond with the 50-year storm event.

Step three: The slope of the pipe in feet per foot was calculated using the USGS 10-85 method (Olson 2008). The 10-85 method calculates slope characteristics in the upstream watershed, but reduces the extremes of the highest headwater reaches (10%) and the lowest approach slope (15%).

- Assumption: The 10-85 method adequately estimates the slope of each crossing. Many of our culverts defined upstream watersheds that were outside (i.e. too small) the recommended ranges for calculating slope.

Step four: The 25- and 100-year flood discharge was determined for each culvert using the *Estimation of Flood Discharge at Selected Recurrence Intervals for Streams in New Hampshire* (Olson 2008). For upstream watersheds less than 200 acres, we applied the volume of storm flow associated with the 25-year flood event; for upstream watersheds larger than 200 acres, we used the 100-flood event flow volume.

- Assumption: We assume that discharge is adequately estimated for each crossing. This required GIS-based calculation both on upstream watershed size and on characteristics of elevation and slope. Many of our culverts defined upstream watersheds that were outside (i.e. too small) the recommended ranges for calculating discharge.

With these four parameters, we determined the normal depth of flow in each crossing structure using the *Design Charts for Open Channel Flow* (FHWA 1961). This allowed for the determination of a culvert's capacity to convey flows under most circumstances at the given storm flow.

Cost categories

Because most problematic stream crossings are under town roads, and in recognition that cost of restoration is a major consideration, we assigned cost categories for all Severe barriers. We used a method developed by the US Fish and Wildlife Service in Maine, that approximated cost based on culvert dimensions (Jed Wright, US Fish and Wildlife Service, Maine Coastal Program, personal communication). This method provided broad ranges of costs, and does not include the cost of fill, nor the cost of engineering, so it should be ***used with caution and as a means of comparison only***, and not as a real restoration estimate.

The cost estimate is based on a regression to determine costs of replacing pipe culverts with bottomless arches, based on their width and the upstream drainage area. The analysis uses a 30 foot long crossing as the standard. Costs are adjusted up by 20% for each additional 10 feet of length and an additional 10% is added for paved roads.

Table 1. Culvert replacement cost guidelines; based on estimates cost of replacing undersized culverts with bottomless arches. The costs below were adjusted up by 20% for each additional 10 feet of length over 30 feet, and 10% additional costs if the road is paved. Costs do not include engineering nor fill estimates, so should be used as initial guidelines rather than field-based estimates[6].

Culvert width (ft)	**Cost (Thousands of dollars)**	**Upstream Drainage Area (sq. mi.)**	**Upstream Drainage Area (Ac)**
<6	10	<0.6	<384
6-10	20	0.6 - 1.7	384 - 1,088
10-13	45	1.7 - 2.8	1,088 - 1,792
13-16	60	2.8 - 4.1	1,792 - 2,624
16-19	100	4.1 - 5.8	2,624 - 3,712
19-22	130	5.8 – 7.6	3,712 - 4,864
22-25	160	7.6 - 9.7	4,964 - 6,208
25-28	190	9.7 - 12.0	6,208 - 7,680
28-31	220	12.0 - 14.6	7,860 - 9,344
31-33	250	14.6 - 16.6	9,344 - 10,624

After applying these guidelines and the adjustments for additional length and paved roads, we summarized the range of costs into seven cost categories (Table 2).

Table 2. Adjusted cost categories (See Table 1 and text for additional information).

Adjusted cost range	Cost Category
< $25,000	1
$25,000 - $50,000	2
$50,000 - $100,000	3
$100,000 - $250,000	4
$250,000 - $500,000	5
$500,000 - $1,000,000	6
> $1,000,000	7

Restoration priorities

Our model for setting priorities for road-stream crossing restoration is based on a series of ever-decreasing number of possible restoration choices. We used (1) field-based fragmentation scores, (2) linear stream mileage; (3) the volume capacity of the crossing during storm-flow; (4) occasionally we lacked data on pipe dimensions, but it was clear from other information that the culvert deserved priority consideration. Cost guidelines may inform a restoration decision when, all else being equal, the restoration benefits attained among two choices are similar.

> Step one: The first layer in setting priority was the field-based identification of Severe road-stream crossings. Fragmentation scores are based on field inventory and the multiple parameters that inform whether wildlife can navigate the crossing as they travel or swim up- or downstream. Fragmentation scores also reflect the crossings ability to support natural flow, sediment transport, and other ecosystem processes.

[6] This method developed by Jed Wright and Alex Abbot at US Fish and Wildlife Service, Falmouth, Maine.

Step two: Once we determined our list of Severe barriers, we then applied stream mileage "exclusion rules" to eliminate from consideration those Severe barriers whose upstream mileage and watershed size were relatively small compared to other choices.

Step three: We ranked the remaining Severe barriers in order of how much stream mileage would be opened given their removal.

Step four: Finally, we **highlighted** those remaining barriers that appear undersized, or inadequate to pass a volume of water associated with storm flows.

Those Severe crossings with the potential to restore high stream mileage *and* those that are undersized are ranked as **Tier 1** priorities for restoration. **Tier 2** priorities are those Severe crossings that would restore relatively high mileage, but adequately pass storm flow. **Tier 3** priorities include those Severe crossings that do not meet the mileage thresholds. For those crossings where we lacked data, we used photographic evidence and other field data to help in our determination.

Outreach to Towns

A key goal of the project was to engage town officials and road managers in the municipalities in the study area. In consultation with Lisa Murphy at Southwest Region Planning Commission (SWRPC), and David Moon at AVEO, we scheduled both group meetings and individual meetings with Conservation Commissioners, road agents, and town public works officials.

Because field volunteers may not have been able to collect all relevant information at each crossing location, and recognizing that local experts had historical information to contribute, we encouraged town officials and volunteers to provide any information they could. At each meeting we introduced the goals of the project, presented our site maps, and requested any information on road-stream crossings. TNC, SWRPC, and AVEO staff recorded information on watershed maps and relevant data was transferred into the master digital database. Results of interviews were incorporated, if relevant, to our road-stream crossing database.

RESULTS

Sub-watershed summary

The three HUC12 Sub-watersheds comprise 73,020 acres across 12 towns, with over 282 perennial stream miles (Table 3). In these three High Quality Waters Sub-watersheds, there are 8.3 crossings per 10 stream miles, compared to 16 crossings / 10 stream miles in the Keene Tributaries HUC12. On average, these three Sub-Watersheds are <3% developed (97% natural land cover), well below the commonly cited 10% threshold where water quality degradation accelerates. By comparison, the Keene Tributaries Sub-watershed is currently 13% developed.

Across the project area, we identified 239 mapped road-stream crossings for assessment and priority ranking. We did not assess 14 crossings, primarily due to access restrictions or safety concerns (9) or mapping errors (4). One additional crossing was not found. We visited 92 new sites to fill in data gaps from the Assessment (TNC 2008). This corresponds to a 94% sample, providing an excellent opportunity to assess watershed fragmentation across the entire project area.

Table 3: Summary statistics for each HUC12 Sub-watershed. Keene Tributaries Sub-watershed added for comparison. # Crossings (Xings) is also presented in # crossings per 10 stream miles in parantheses. # Severes in parantheses is the number of Severe railroad crossings. #Mod = Moderate; #Pass = all passable culverts, including "Minors"; #NA = not assessed; %Develop = % development in Sub-watershed.

HUC12	**Acres**	**Stream Miles**	**# Xings**	**# Dams**	**#Severes (RR)**	**# Mod**	**# Pass**	**# NA**	**% Develop**
Hinsdale-Winchester	23,624	80.6	66 (8.2)	9	14 (3)	29	17	3	3.4
Surry Dam	19,180	81.7	61 (7.4)	8	11	32	15	3	2.8
Otter Brook	30,198	120.0	112 (9.3)	16	25	50	29	8	3.2
TOTAL	73,002	282	239	33	53	111	61	14	NA
Keene Tributaries	*21,637*	*97*	*156 (16.1)*	*24*	-	-	-	-	*13*

Summary statistics for towns

Only portions of each town are sampled in this project, based on Sub-watershed delineations. More than half of the towns of Sullivan and Surry are within the project area. Chesterfield, Walpole, and Keene are all relatively large towns with high populations, but only small proportions of each town's acreage fall within the Sub-watersheds in this study. Chesterfield, in fact, while encompassing 15% of the Hinsdale-Winchester Sub-watershed, had no road-stream crossings, except those associated with Pisgah State Park, which we did not sample[7].

Keene, Hinsdale, and Walpole all have relatively lower forest cover and higher population density. Conversely, Roxbury, Stoddard, Nelson, and Gilsum had at least 90% forest cover each, with relatively low population densities. Overall, the majority of

[7] The DOT GIS-based road coverage we used to identify crossing locations did not include roads nor trails within Pisgah State Park.

acreage in the project area is characterized by relatively intact forests and river ecosystems.

Table 4. Town and Sub-watershed information[8]. Town acres, Forest cover %, Population, and Persons/Mi^2 are for the entire town, *not* the portion of the project area.

Town / Sub-watershed	**Town Acres**	**Acres in Study Area (%)**	**Forest Cover %**	**Population (2008 Est.)**	**Persons / Mi^2**
Hinsdale-Winchester					
Hinsdale	14,497	3,715 (26%)	74	4,264	206
Winchester	35,556	15,442 (43%)	84	4,342	79
Chesterfield	30,427	4,487 (15%)	85	3,754	82
Surry Dam					
Alstead	25,211	7,063 (28%)	85	2,016	52
Surry	10,241	6,952 (67%)	85	736	47
Gilsum	10,682	4,114 (39%)	90	809	48
Walpole	23,469	1,051 (4%)	67	3,663	103
Otter Brook Res.					
Stoddard	33,950	8,614 (25%)	92	1,032	19
Sullivan	11,985	10,037 (84%)	87	788	41
Nelson	14,898	7,356 (49%)	90	662	30
Roxbury	7,845	2,887 (37%)	93	245	20
Keene	23,867	1,302 (5%)	67	22,653	611

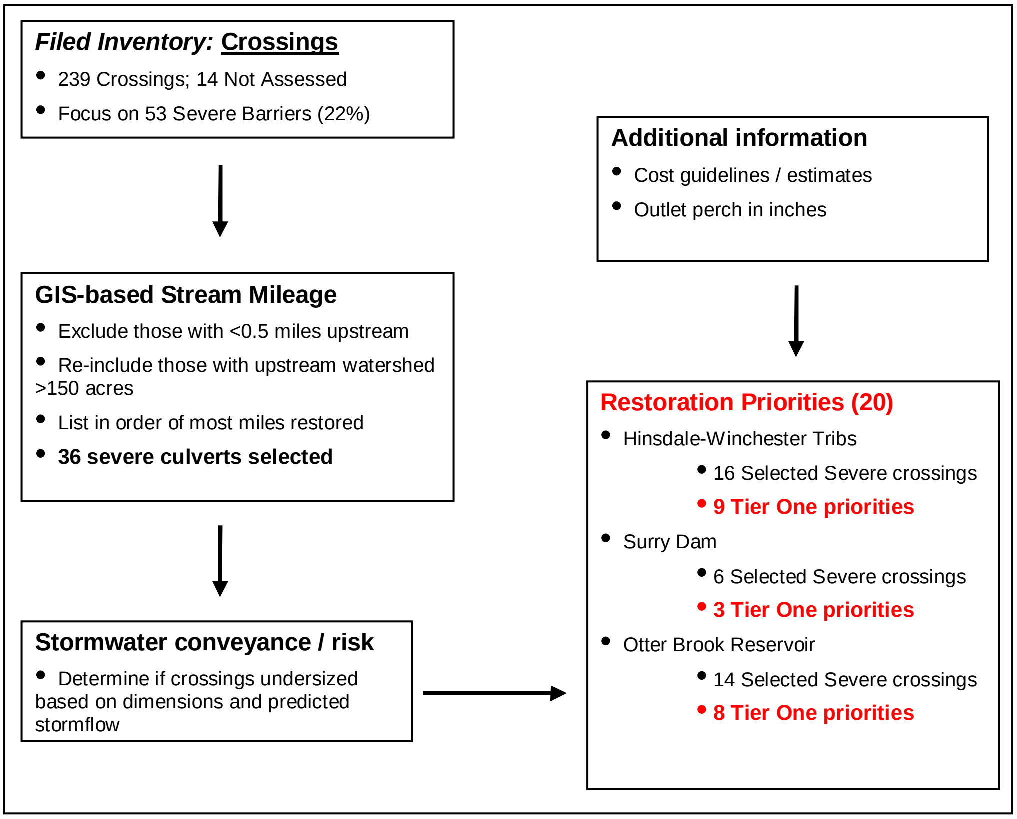
Field assessment

Of the 239 crossings sampled, 53 (26%) rank as Severe (Figure B). This is slightly higher than the 2008 assessment results of 20% Severe (TNC 2008). Adding in the 33 active dams, this corresponds with 63 Severe barriers, or 26% of all human-built features in the river system. For comparison, in the entire Ashuelot Basin, 31% of human-built features are Severe.

In addition across the 239 crossings in our study area, there were fewer Moderate barriers (111 or 54%) and higher proportion of crossings that are passable (26%) than in the previous Assessment (56% and 20%, respectively; see TNC 2008).

[8] Source material at: http://www.spnhf.org/research/research-projects.asp; and http://www.nh.gov/oep/programs/DataCenter/Population/PopulationEstimates.htm

Figure A: Summary of field and GIS sampling and results for road-stream crossings for all three Sub-watersheds.



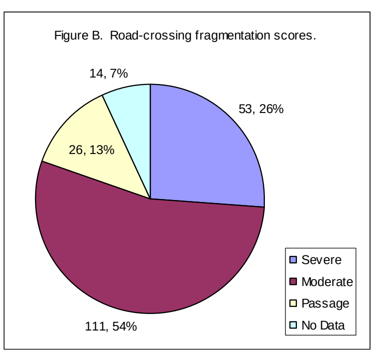


Figure B. Road-crossing fragmentation scores.

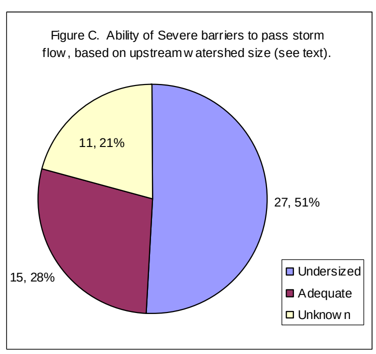


Figure C. Ability of Severe barriers to pass storm flow, based on upstream watershed size (see text).

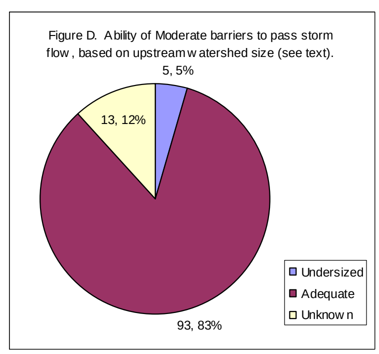
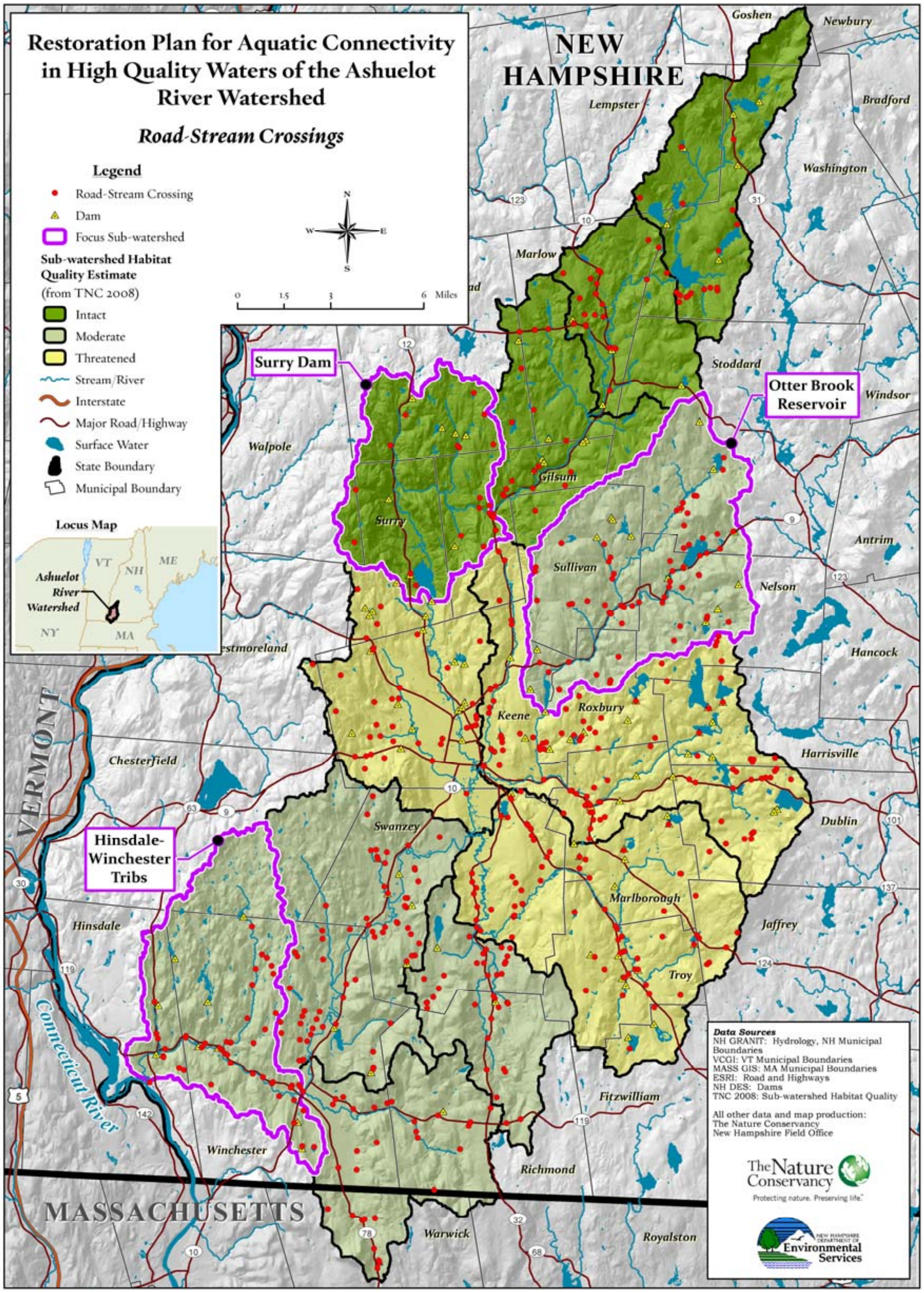


Figure D. Ability of Moderate barriers to pass storm flow, based on upstream watershed size (see text).



Map 1. Ashuelot River Basin with Sub-watersheds highlighted.

Storm flow conveyance
Just over half of all Severe crossings were not adequate to pass storm flow at the 25- or 100-year flood (Figure C). By contrast, most Moderate crossings (83%) were adequate to pass storm flow (Figure D).

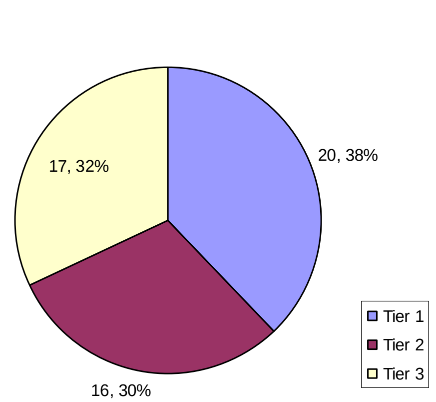
Restoration priorities
Of the 53 crossings assigned a fragmentation score of Zero or One (Severe crossing), 32 were selected based on the mileage exclusions rules. Of those, one crossing was eliminated from consideration because it was associated with a dam. Of the remaining 31 Severe crossings, five were re-included in our priority analysis because they had upstream watersheds larger than 150 acres, for a total of 36. Of these 22 ranked as undersized based on Storm flow conveyance.

Nineteen Severe culverts with substantial upstream mileage and undersized culverts received the highest priority rank of **Tier 1** (Figure E). One additional Severe crossings was assigned a Tier 1 priority rank because it is associated with multiple pipes and channels in downtown Hinsdale (making field data difficult), for a total of 20 **Tier 1** priorities (or 8% of all crossings sampled, and 38% of all Severe Crossings). Based on photographs and field forms this crossing appears to be problematic for a variety of reasons.

There are 13 **Tier 2** priorities, or those Severe crossings that adequately pass storm flow. In addition, we assigned **Tier 2** priority rank to three crossings under the railroad line in Hinsdale and Winchester, even though they are undersized, for a total of 16 **Tier 2** priorities. This was based on the likelihood that restoring these historic stone railroad culverts would require excessive costs and low feasibility of success.

The remaining 17 Severe crossings we assigned **Tier 3** priority rank (see Chapter 2, Map 2[HW,S,O]).

Figure E. Priority Tiers for Severe crossings.



Outreach to towns

Project partners met with town officials nine times over the course of the project period (Table 5). The primary purpose of meetings was to inform town officials, staff, and volunteers about the project and invite comment and input. In addition we consulted river ecologists and conservation experts to hone our approach and methods both at the outset, and throughout the course of the project.

Our primary town-based meeting in Keene in November 2008 included attendees from all but three towns. We scheduled one-on-one meetings for those towns who could not provide representation at the Keene meeting.

We were invited to present our project at a meeting sponsored by the neighboring Sunapee Region Planning Commission. In addition, we met with regional NH Department of Transportation officials late in project to ensure that outreach materials were accurate.

Table 5. Town and partner outreach dates, participants, and purpose.

Date	**Participants**	**Meeting notes**
11/6/08	TNC, SWRPC	Keene Library; introduction and map-based interviews with all towns
12/9/08	SWRPC	Winchester Conservation Commission to complete introductory interviews
1/4/09	SWRPC	Hinsdale Conservation Commission to complete introductory interviews
1/27/09	SWRPC	Chesterfield Conservation Commission to complete introductory interviews
2/18/09	TNC	Aquatic expert interview to refine project approach
4/20/09	TNC	Eric Derleth (USFWS) interview to refine project approach
5/20/09	TNC	Sunapee RPC presentation to introduce neighboring communities to project
6/2/09	SWRPC, TNC	Alstead Conservation Commission to update Commissioners about project
9/10/09	SWRPC, TNC	Regional DOT expert interviews to refine outreach materials

DISCUSSION AND LESSONS LEARNED

Methodology

While focusing on a smaller project area allowed us to visit nearly all mapped crossings, relying on GIS maps still produced occasional errors in crossing locations. The four crossings that simply were not there (representing 1.5% of all mapped crossings) seemed an acceptable error. The additional nine others that could not be found or accessed primarily were caused by private property restrictions. For example, Class 6 roads or private roads without landowner permission will likely always be a challenge for finding and accessing a small percentage of crossings.

- Lesson learned: Future project should expect about 2-3% of mapped culverts will not be sampled either through mapping error or access restrictions, even when there is ample time to visit all sites.

Database management continued to be challenging and time consuming for this project, based on a number of factors. First, managing hundreds of paper field forms, GIS maps, site photographs, and a scoring algorithm required regular attention and quality control. Second, the scoring algorithm required attention to make sure our field data accurately portrayed aquatic fragmentation. Following data entry, but still early in the fragmentation scoring steps, we attempted to find the right balance to ensure “Severe” culverts were correctly identified. There is a subtle balance between “Moderate” and “Severe,” and we wanted to ensure that we were not overemphasizing the fragmentation threat. With additional advances in assessment and scoring methods, this threshold will become clearer.

- Lesson Learned: Field sampling for culvert assessments could take advantage of improvements in hand-held sampling technology that combines data logger functions with GIS maps and GPS units. These units would reduce database quality control substantially.

Finally, there were multiple cases where volunteers or staff could not answer all questions appropriately in the field to provide a fragmentation score. We assigned scores based on other data, such as photo interpretation and expert judgment. There is a wide variety in crossing design, history, and road and stream conditions that regularly challenged our methodology. Fortunately, this topic is demanding the attention of multiple experts and partners, and new tools, regulations, and science for river fragmentation and road-stream crossing restoration are currently under development region-wide.

Setting priorities

Since the Assessment (TNC 2008), we narrowed our list of GIS-based attributes for ranking priorities to stream mileage, and added information about storm flow conveyance and cost categories. Our method combined field data, engineering concepts, storm-flow predictions, and GIS to broadly categorize each crossing’s cost and ability to pass storm flow. In addition, focusing on a Sub-watershed scale allowed both a more complete sampling of road-stream crossings while providing a more realistic geography to advance restoration activities.

For storm flow conveyance, much of the data relied on estimating slope and discharge, using GIS-based slope and upstream watershed characteristics. Slope is included in most other culvert assessment field protocols, but for consistency, we continued to use the same methodology as in the Assessment (TNC 2008), which only requires slope comparisons to the neighboring stream channel (i.e. steeper or similar). We developed our conveyance model after the conclusion of field assessment, so we relied on the 10-85 method (Olson 2008).

- Lesson learned: Storm flow data is critical for future crossing assessments. Field methods that require slope measurements, roughness coefficients, in the field would improve these estimates substantially. However, these parameters require additional field time and training. The need to balance more detailed field work with more sites per unit time will continue to be a critical decision. For HUC12 Sub-watertsheds, it would make sense to increase the field assessment detail; for larger watersheds the protocol used here still seems appropriate.

Relative to the Assessment, where we simply stated that 20% of all crossings and dams were "Severe," our new approach has allowed us to narrow our focus to those 20 crossings (8% of project area's crossings) that are most restrictive for wildlife passage as well as potentially problematic for storm flow.

- Lesson Learned: Adding safety and cost considerations to wildlife passage protocols will help town and regional planners decide how to proceed. A rapid field method to estimate cost would help improve these estimates substantially.

Clearly, dams pose a fragmentation threat. Dam removal requires a different suite of strategies, permitting steps, costs, and dam owner permission. We decided to use dam locations to develop mileage parameters, and to display the location of dams. However, this project focuses primarily on identifying restoration priorities for bridges and culverts.

- Lesson Learned: Dam restoration will remain more complex and costly than culvert restoration. Because most dams are privately owned, the issue of developing relationships and obtaining permission will always be a priority first step.

Town engagement

Because many rural Towns rely on volunteer staff, they have limited capacity to contribute time compared to larger urban towns and cities. We are confident that most towns in our Project Area are aware of our study, but fully engaging any given town in restoration projects will require additional local action.

The issue of cost is critically important to towns. Each restoration project requires more extensive engineering, feasibility, and design to fully estimate costs. Our categories simply provide a relative scale for comparison. As towns develop master plans, zoning ordinances, and town budgets, they will have good information on where

- Lesson Learned: engaging with and influencing town decisions can take years. Over the two years of this project, we succeeded in our Outreach efforts to inform town staff and volunteers about our project. Garnering support, particularly for costly capital improvement projects, requires on-going, long-term and sustained effort.

Future of river continuity

The need to address road-stream crossing infrastructure has been address by local, state and federal agencies. The Federal Emergency Management Agency (FEMA) has provided funding to develop Hazard Mitigation plans in many towns. The US Army Corps of Engineers (USACE) now requires permit review[9] for road-stream crossings that may restrict the passage of aquatic organisms. The NH Department of Environmental Services Wetlands Bureau is drafting rules to regulate the development of new and replacement of current culverts and bridges to ensure crossings maintain stream function and wildlife passage. The New Hampshire Aquatic Resources Mitigation fund has recognized the need to fund projects that protect river ecosystems and will review and fund projects starting in 2010.

To inform these regulatory activities agency, academic, and consulting experts continue to improve methodologies to assess and prioritize restoration. There are currently a wide range of assessment options to choose from (see Chapter 3), depending on need, scale, and expertise.

Conclusion

Over the course of the next year, we intend to engage with both local and regional planning entities to implement river continuity restoration. For example, the SWRPC Natural Resource Advisory Committee and the Ashuelot River Local Advisory Committee are both committed to advancing and promoting restoration activities. Successful implementation of new Wetland Bureau rules for stream crossings will require education and outreach at multiple scales. Funding and increased capacity for restoration projects is growing through the efforts of groups as The Nature Conservancy, Trout Unlimited, American Rivers, and others.

Restoring river continuity is a multi-year effort. This project identified 20 top priorities for restoration. Successfully restoring one crossing per year is ambitious, given the combined challenges of outreach, permitting, and costs. If culverts have a 30-year life expectancy, it is critical that new regulations, designs, and funding, be available as they age and fail.

It is our hope that planning and implementation will continue to provide benefits for both the ecological systems and their constituent biodiversity, while also protecting human health and property. River continuity restoration combines ecosystem restoration with ecosystem services. People are more likely to support this kind of win-win strategy, providing a high likelihood of success over time.

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[9] The USACE State Programmatic General Permit (SPGP) for New Hampshire relies on the DES Wetlands Bureau to determine which projects require a Federal Permit.

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Chapter 2^{HW}

Restoration Priorities for Hinsdale – Winchester Tributaries Sub-watershed

Hinsdale-Winchester Tributaries Sub-watershed Description

The Ashuelot River ends in Hinsdale where it flows into the Connecticut River. This 23,624 acre (37 mi^2) Sub-watershed encompasses three towns, only two of which—Hinsdale and Winchester—have significant stream restoration needs. Nearly the entire northern portion of the Sub-watershed, and all of its acreage in Chesterfield, is protected within Pisgah State Park. The headwaters in Pisgah Park (primarily Broad Brook) flow into Fullam Pond before heading south into Winchester.

Additional major tributaries flowing into the Ashuelot River mainstem include Tufts Brook and Snow Brook in Winchester, and Tongue and Kilburn Brooks in Hinsdale. Numerous additional un-named creeks flow both north and south into the Ashuelot River. Creeks south of the Ashuelot Mainstem are generally shorter and steeper, while northern creeks are longer.

Three large dams and multiple bridges cross the Ashuelot River mainstem in this Sub-watershd. The Ashuelot River Dam and the Winchester Town Dam, both in Winchester, were removed through the efforts of New Hampshire's River Restoration Task Force, restoring hundreds of miles of free-flowing mainstem and tributary aquatic habitat.

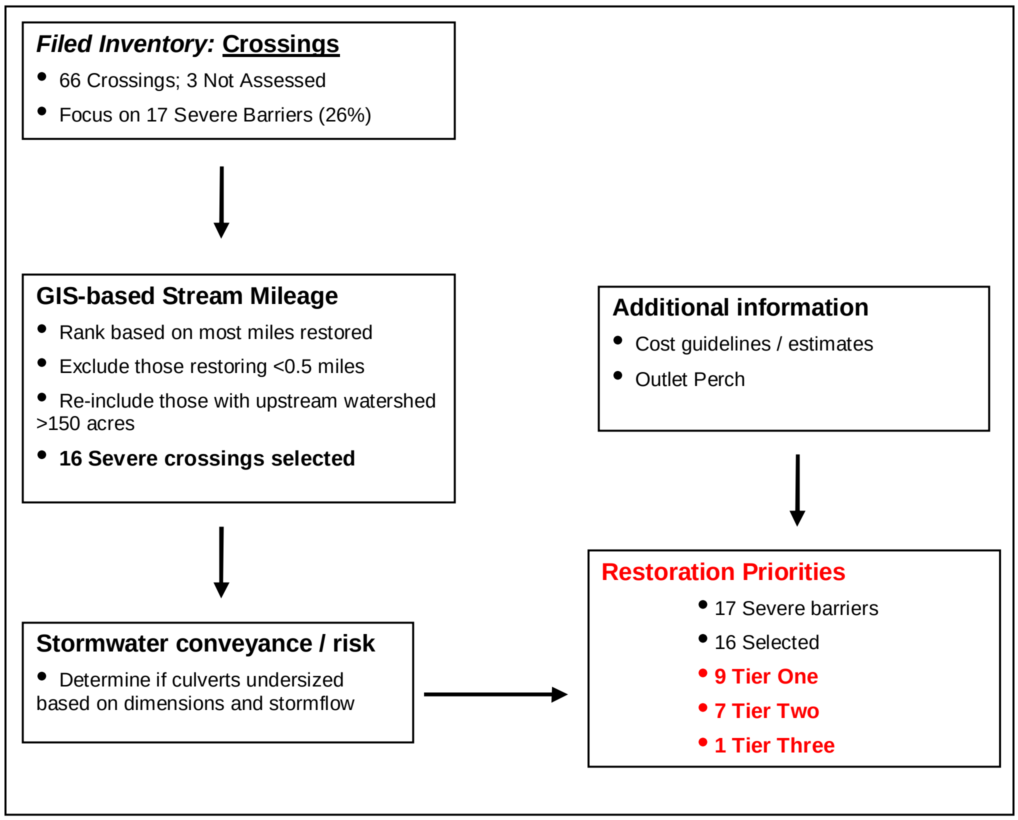
The primary stream fragmentation issues are concentrated near the town centers, along the major roads and railroads that parallel the mainstem of the Ashuelot River. Multiple historic and ageing culverts where the brooks join the River likely restrict fish from moving upstream and away from the mainstem. Some of these likely pose potential risks for flooding as well.

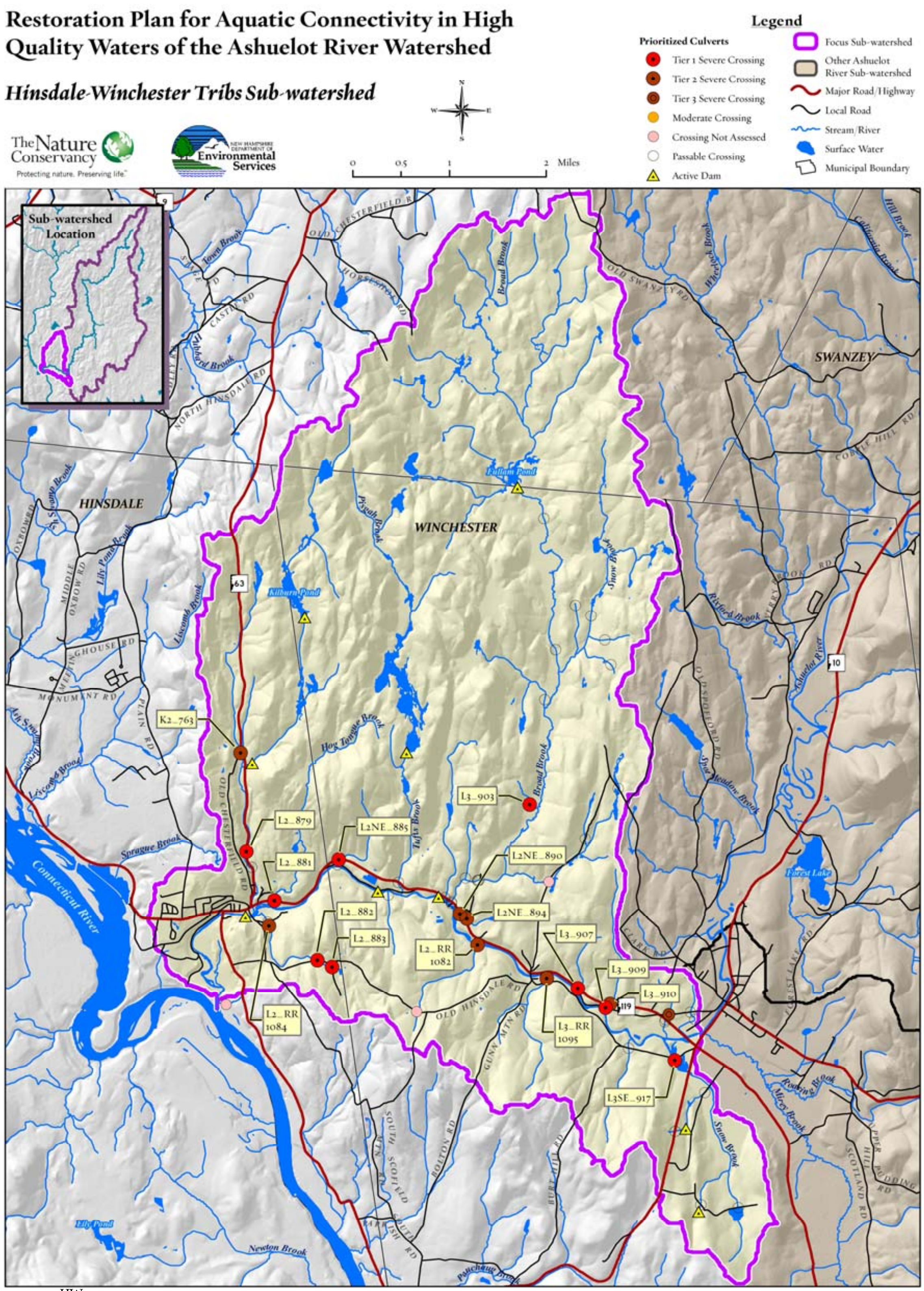
Nearly half of the town of Winchester is within this Sub-Watershed, and it contains the highest number of road-stream crossings. Both Winchester and Chesterfield are heavily forested towns, which provide excellent landscape context for water quality benefits. Unique to this Sub-Watershed is the old railroad line that parallels the Ashuelot River. Old stone culverts and historic railroad bridges now serve recreational purposes, with snowmobiling in the winter, and hiking and mountain biking in the spring, summer, and fall.

About one quarter of the town of Hinsdale is captured in this Sub-watershed. The major tributary, Kilburn Brook, flows steeply down along Route 63 until it winds its way to the Ashuelot River mainstem in the town center. The Ashuelot pours into the Connecticut River after meandering through several agricultural fields and floodplain forests and wetlands. The historic railroad bridge, now maintained by snowmobilers, is the last crossing over the Ashuelot River.

A total of 80.6 miles of stream habitat flow primarily north, south, and west in this Sub-watershed. We mapped sixty-six road stream crossings here, about one quarter of which were ranked as severe barriers. Of the 17 severe crossings flowing under roads or railroads, eight may also restrict storm flow to the point of being overwhelmed by flood waters.

Figure A^{HW}: Summary of field and GIS sampling and results for road-stream crossings for Hinsdale-Winchester Tributaries Sub-watershed.





MAP 2HW: Hinsdale-Winchester Tributaries Sub-watershed with Restoration Priority Tiers highlighted.

Table A^HW: Town and Sub-Watershed information[10] for Hinsdale-Winchester Tributaries Sub-watershed.

Town / Sub-watershed	**Town Acres**	**Acres in Study Area (%)**	**Forest Cover %**	**Population (2008 Est.)**	**Persons / Sq. Mi**
Hinsdale	14,497	3,715 (26%)	74	4,264	206
Winchester	35,556	15,442 (43%)	84	4,342	79
Chesterfield	30,427	4,487 (15%)	85	3,754	82

Table B^HW: Summary statistics Town by Town for Hinsdale-Winchester Tributaries Sub-watershed.

Town	**# Xings**	**#Dams**	**#Severes**	**# Mod**	**#Pass**	**#ND**	
Hinsdale	17	2	6	6	4	1	
Winchester	49	7	11	23	13	2	
Total	**66**	**9**	**17**	**29**	**17**	**3**	

Restoration priorities

Of the 17 Severe crossings in the Hinsdale-Winchester Tributaries Sub-watershed, 16 (including 3 railroad crossings) represent the highest need for restoration based on stream mileage (Table C^HW). Eleven are also undersized. The top **Tier 1** restoration priorities include eight undersized crossings plus one additional series of culverts and bridges in downtown Hinsdale (Crossing L2_881). We could not obtain dimension information on three crossings. Two Severe crossings (one each in Hinsdale and Winchester) were both large enough to convey storm flow and are ranked as Tier 2 priorities. We also assigned Tier 2 priority to the railroad crossings due to high cost and low feasibility.

Restoration of the nine **Tier 1** crossings could restore more than 120 miles of stream habitat. Given that many of these crossings have outlet perches of more than 12 inches, their restoration may also provide upstream fish passage for multiple species, including strong swimming Salmonids and Cyprinids, such as trout, suckers, chubs, as well as weaker swimming species (see Nedeau 2006).

Because this Sub-watershed represents the confluence area between the Ashuelot and the Connecticut River, it is also the focus of restoration for diadromous fish species, such as Atlantic salmon and American shad. Particularly after the restoration of fish passage at Fisk Mill Dam, the first barrier upstream of the confluence, diadromous fish may be able to access tributary habitats and confluence areas in Hinsdale (such as Kilburn and Hog Tongue Brooks).

[10] Source material at: http://www.spnhf.org/research/research-projects.asp; and http://www.nh.gov/oep/programs/DataCenter/Population/PopulationEstimates.htm

Table C^HW: List of restoration priorities for stream crossings in the Hinsdale-Winchester Tributaries Sub-watershed. Bolded text represents **Tier 1** priorities. Red text represents Undersized crossings. US Miles=total stream mileage upstream from crossing; Restoration Miles= miles of stream network restored given the removal or restoration of the crossing; Storm Flow Conveyance=whether crossing is adequate to pass storm flow or is Undersized to pass storm flow at the given statistical "year storm". Crossings with upstream watersheds <200 acres assessed for the 25-year storm; >200 acre upstream watersheds assessed for the 100-year storm. Cost Class and Outlet Perch provided for comparison (see Chapter 1 text).

Priority Tier	Town	Site Code	US Miles	Restoration Miles	Storm Flow Conveyance	Cost Class	Outlet Perch
1	**Hinsdale**	**L2_881**	**2.91**	**5.78**	**Unk.**	**Unk.**	**0-6"**
1	**Hinsdale**	**L2_879**	**9.78**	**5**	**Undersized(?) / 100**	**6**	**>24"**
2	Hinsdale	K2_763	1.99	4	Adequate / 100	5	12-24"
1	**Hinsdale**	**L2_882**	**0.28**	**1.09**	**Undersized / 25**	**4**	**0**
1	**Hinsdale**	**L2_883**	**0.12**	**0.28**	**Undersized / 25**	**5**	**0-6"**
1	**Winchester**	**L3SE_917**	**3.85**	**29**	**Undersized / 100**	**5**	**12-24"**
1	**Winchester**	**L3_907**	**0.69**	**26**	**Undersized / 25**	**5**	**12-24"**
1	**Winchester**	**L3_903**	**0.29**	**25.4**	**Undersized / 25**	**3**	**0-6"**
2	Winchester	L2NE_890	0.55	25.2	Unk.	Unk.	12-24"
1	**Winchester**	**L3_909**	**1.51**	**25**	**Undersized / 25**	**5**	**12-24"**
1	**Winchester**	**L2NE_885**	**1.06**	**4**	**Undersized / 100**	**7**	**0-6"**
2	Winchester	L3_910	1.44	1.5	Adequate / 25	7	>24"
2	Winchester	L2NE_894	0.45	0.55	Unk.	Unk.	Filled
3	Winchester	L3SE_917	0.42	25.5	Undersized / 25	6	0-6"
RR Xings							
2	Hinsdale	L2_RR1084	1.2	3.8	Undersized / 100	6	0
2	Winchester	L3_RR1095	2.0	27.14	Undersized / 100	7	0
2	Winchester	L2_RR1082	1.3	26.2	Undersized / 100	6	12-24"

Figure F^HW: Photos of Tier One restoration priorities. Downstream side of crossing on left; upstream on right.

L2_881

Notes: Hog Tongue Brook's multiple crossings under Howe and Canal Street. Four distinct crossings at this site; all old and eroding; too shallow in some sections, with perches associated with at least two of the crossings. L2_881-1 appears capable of passing storm flow, but others may act as dams during highest flows.

L2 881-1 Canal Street view DS south, old mill spillway

L2 881-1 Canal Street view US north, old mill spillway

L2 881-1 Canal Street close up of cascade into culvert, 1-2 ft. drop

L2 881-2 Sargent Drive view DS south east

L2 881-2 view US north west

L2 881-3 view north, old mill spillway


L2 881-3 Howe Drive, view DS south


L2 881-4 view US north

L2_879

Notes: Kilburn Brook crossing under Route 63 just south of power lines. Significant cascading outlet perch; excessive erosion and scour pool. May pass storm flow, particularly with upstream dams at Kilburm Brook Pumping Station and Kilburn Pond.

L2 879 view US 63 degrees east


L2 879 embankment

L2 879 view DS from inside culvert

L2 879 Kilburn Brook view DS 240 dgrees west

L2_882

Notes: Crossing under Tower Hill Road, just west of Riley Road intersection. Downstream perch; no sediment; ageing corrugated steel.

L2_883

Notes: Crossing under Tower Hill Road, just south of Riley Road intersection. Downstream perch; no sediment; ageing corrugated steel.

L3SE_917

Notes: Snow Brook; outlet of pond under Back Ashuelot Road.   Significant downstream perch, upstream screen and damming.

L3_907

Notes: Tributary under Route 119 just upslope of confluence with Ashuelot mainstem. Significant downstream perch, narrow rapid flow; no sediment.

L3_903

Notes: Tributary of Broad Brook in Pisgah State Park. No sediment; ageing corrugated pipe; slight downstream perch.


L3_909

Notes: Tributary under Ashuelot Street, just upslope of confluence with Ashuelot mainstem. Significant outlet perch; no sediment.

L2NE_885

Notes: Tributary under Route 119 just upslope of confluence with Ashuelot mainstem. No sediment; narrow shallow flow.

L2RR_1084

Notes: Could not access downstream end over 200(?) feet downstream; small stone “tunnel” culvert under extensive fill. May serve as dam during extreme storm flow events.


L3RR_1095

Notes: Double concrete pipes at either end of dam-structure; narrow pipes with limited sediment. Second set of crossings include inlet drop into double concrete box culverts. Structures may act as dam during highest storm flows.



L2RR_1082

Notes: Significant downstream cascade outlet perch; shallow stone bottom; ageing stone structure, but likely very strong. May serve as dam during highest storm flows.

Chapter 2^S

Restoration Priorities for Surry Dam Sub-Watershed

Surry Dam Sub-watershed Description
The Ashuelot River enters Gilsum Gorge and cascades to the west into Gilsum at the upstream end of this Sub-watershed. At 19,180 acres (20 mi^2) and encompassing parts of four towns, this represents the approximate half-way point in the Ashuelot River Basin. The Sub-watershed's southern end is defined by the Surry Mountain Dam, one of eighteen dams in New Hampshire owned and operated by the US Army Corps of Engineers. Completed in 1941, this is one of the oldest Army Corps dams in New England. It protects Keene during extreme flooding events, and its surrounding forests and reservoir are a popular recreation destination for recreation.

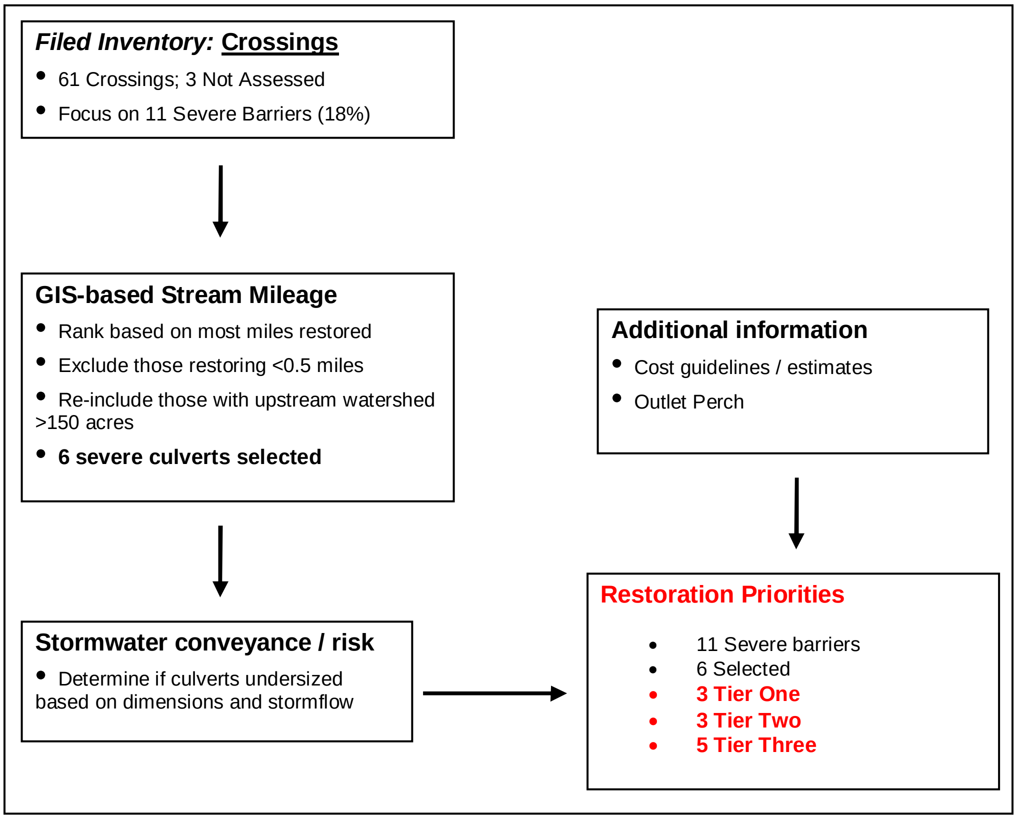
The mainstem of the Ashuelot River in this Sub-watershed flows through gravelly and sandy banks and a heavily forested landscape. The mainstem river and its tributaries attract fly-fishing, kayaking, and canoeing. Its primary tributaries include Thompson and Dart Brook, which flow south from Alstead; Hammond Hollow Brook, flowing north from Gilsum; and Merriam and Fuller Brooks flowing east in Surry. Nearly 82 miles of perennially flowing streams and rivers flow through this heavily forested watershed, characterized by over 97% natural land cover and less than 0.4 river crossings per stream mile (TNC 2008).

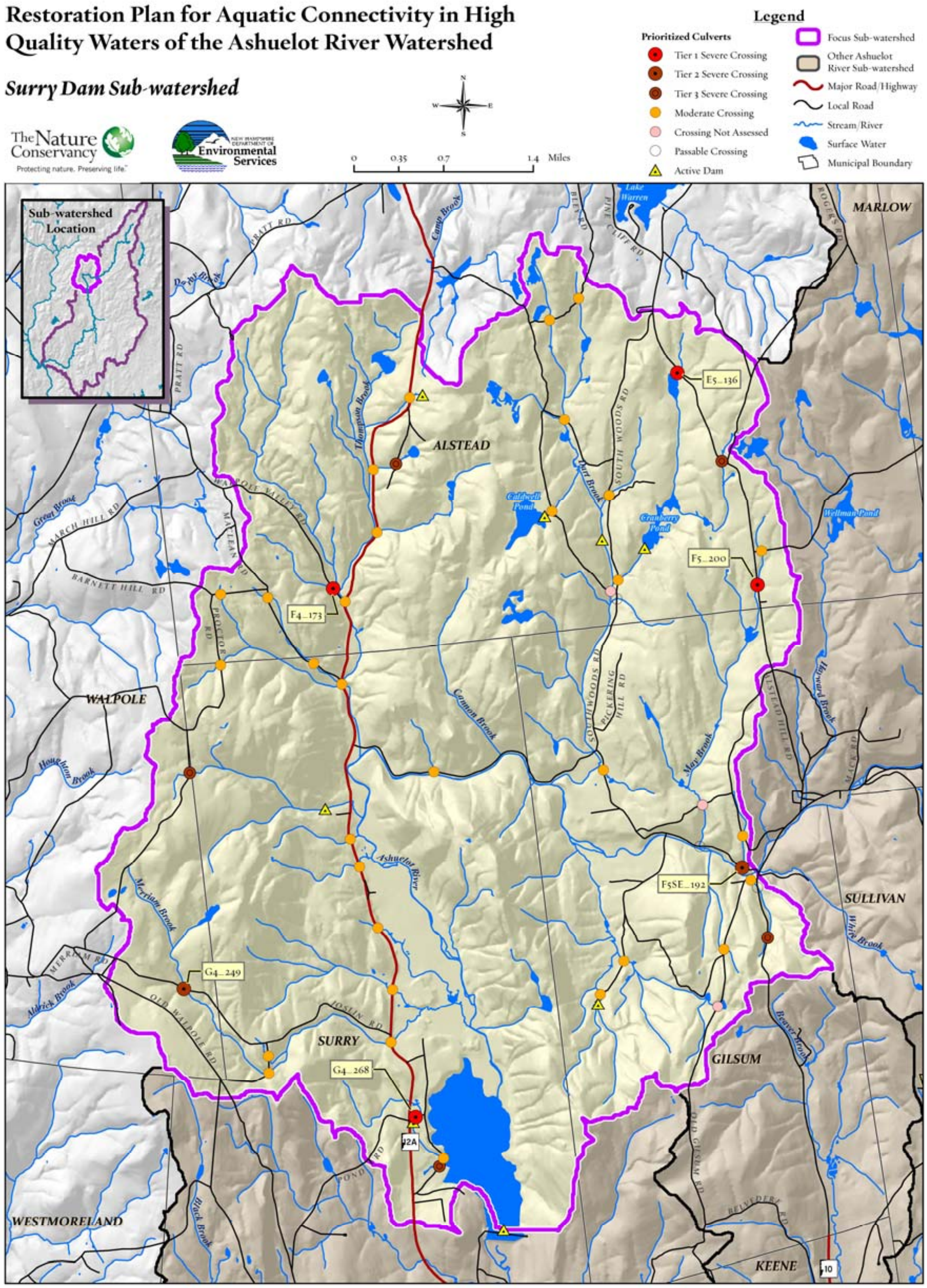
The Ashuelot River mainstem is completely free-flowing through this area until it enters Surry Mountain Reservoir. Many of the dams in this Sub-watershed are high in the headwaters and help maintain high quality ponds.

Four towns share the Surry Dam Sub-Watershed (Table A^S). Alstead encompasses nearly one third of the basin, and its entire northern tier. Nearly 40% of Gilsum's acreage is in Hammond Hollow, that portion of the town within the eastern portion of the Sub-watershed. While nearly two-thirds of the town of Surry drains the Sub-watershed, only four percent of southeastern Walpole overlaps the Sub-Watershed, corresponding to the headwaters of Merriam Brook.

There are relatively few problematic road-stream crossing barriers here as well. In nearly 82 miles of river and stream habitat, only 11 out of 61 road-stream crossings (18%) are ranked as Severe, and nearly half of those are in extreme headwater positions, while six were selected for restoration need (Table B^S). Only three potentially pose a flooding risk during storm runoff as well (Table C^S).

Figure A^{S}: Summary of field and GIS sampling and results for road-stream crossings Surry Dam Sub-watershed.





MAP 2S: Sub-watershed with Restoration Priority severe crossings highlighted.

Table A^{S}: Town and Sub-Watershed information[11] for Surry Dam Sub-watershed.

Town / Sub-watershed	**Town Acres**	**Acres in Study Area (%)**	**Forest Cover %**	**Population (2008 Est.)**	**Persons / Mi^2**
Alstead	25,211	7,063 (28%)	85	2,016	52
Surry	10,241	6,952 (67%)	85	736	47
Gilsum	10,682	4,114 (39%)	90	809	48
Walpole	23,469	1,051 (4%)	67	3,663	103

Table B^{S}: Summary statistics Town by Town for Surry Dam Sub-watershed.

Town	**# Xings**	**#Dams**	**#Severes**	**# Mod**	**#Pass**	**#NA**
Alstead	25	4	5	14	6	1
Surry	19	3	2	12	5	0
Gilsum	14	1	2	6	4	2
Walpole	2	0	2	0	0	0
Total	**61**	**8**	**11**	**32**	**15**	**3**

Restoration priorities

Of the 11 Severe crossings in the Surry Dam Sub-watershed, six represent the highest need for restoration based on stream mileage (Table C^{S}). Three are undersized and represent the top **Tier 1** restoration priorities. One crossing in Surry was washed out and we could not obtain dimension information. Severe crossings in Gilsum and Walpole were both large enough to convey storm flow and are ranked as Tier 2 priorities.

Restoration of the three **Tier 1** crossings could restore more than 65 miles of stream habitat. Given that all three of these crossings have outlet perches of at least 6 inches, their restoration may also provide upstream fish passage for multiple species, including weak swimming Cyprinids, such as dace, shiner, and other minnow species (see Nedeau 2006).

[11] Source material at: http://www.spnhf.org/research/research-projects.asp; and http://www.nh.gov/oep/programs/DataCenter/Population/PopulationEstimates.htm

Table C[S]: List of restoration priorities for stream crossings in the Surry Dam Sub-watershed. Bolded text represents **Tier 1** priorities. Red text represents Undersized crossings. US Miles=total stream mileage upstream from crossing; Restoration Miles= miles of stream network restored given the removal or restoration of the crossing; Storm Flow Conveyance=whether crossing is adequate to pass storm flow or is Undersized to pass storm flow at the given statistical "year storm". Crossings with upstream watersheds <200 acres assessed for the 25-year storm; >200 acre upstream watersheds assessed for the 100-year storm. Cost Class and Outlet Perch provided for comparison (see Chapter 1 text).

Priority Tier	Town	Site Code	US Miles	Restoration Miles	Storm Flow Conveyance	Cost Class	Outlet Perch
1	**Alstead**	**F4_173**	**0.83**	**58**	**Undersized / 25**	**5**	**6-12"**
1	**Alstead**	**F5_200**	**0.57**	**4.7**	**Undersized / 25**	**4**	**6-12"**
1	**Alstead**	**E5_136**	**0.34**	**3.05**	**Undersized / 25**	**4**	**12-24"**
2	Walpole	G4_249	1.50	58.7	Adequate / 100	4	6-12"
2	Surry	G4_268	1.07	1.1	Unk / 100	0	Unk.
2	Gilsum	F5SE_192	0.88	0.7	Adequate / 100	5	12-24"
3	Walpole	F4_165	0.31	2.8	Unkown / 25	3	0-6"
3	Alstead	E5_137	0.22	2.9	Adequate / 25	5	6-12"
3	Alstead	E4_125	0.17	57.4	Collapsed pipe / 25	4	Unk.
3	Gilsum	F5SE_194	0.16	52.5	Adequate / 25	6	0-6"
3	Surry	G4_270	0.10	57.3	Unknown / 25	Unk	Unk.

Figure F[S]: Photos of Tier One restoration priorities. Downstream side of crossing on left; upstream on right.

F4_173

Notes: Thompson Brook culvert under Walpole Valley Road. Outlet perch; no sediment; aging, steep stone abutment.

F5_200

Notes: May Brook culvert under Alstead Hill Road. Very small drainage; no sediment; slight outlet perch.

E5_136

Notes: North of Crane Pond flowing under Gilsum Mine Road. Significant outlet perch; recently repaired(?) but still too small to convey predicted storm flow.

Chapter 2^{O}

Restoration Priorities for Otter Brook Reservoir Sub-watershed

Otter Brook Reservoir Sub-watershed Description

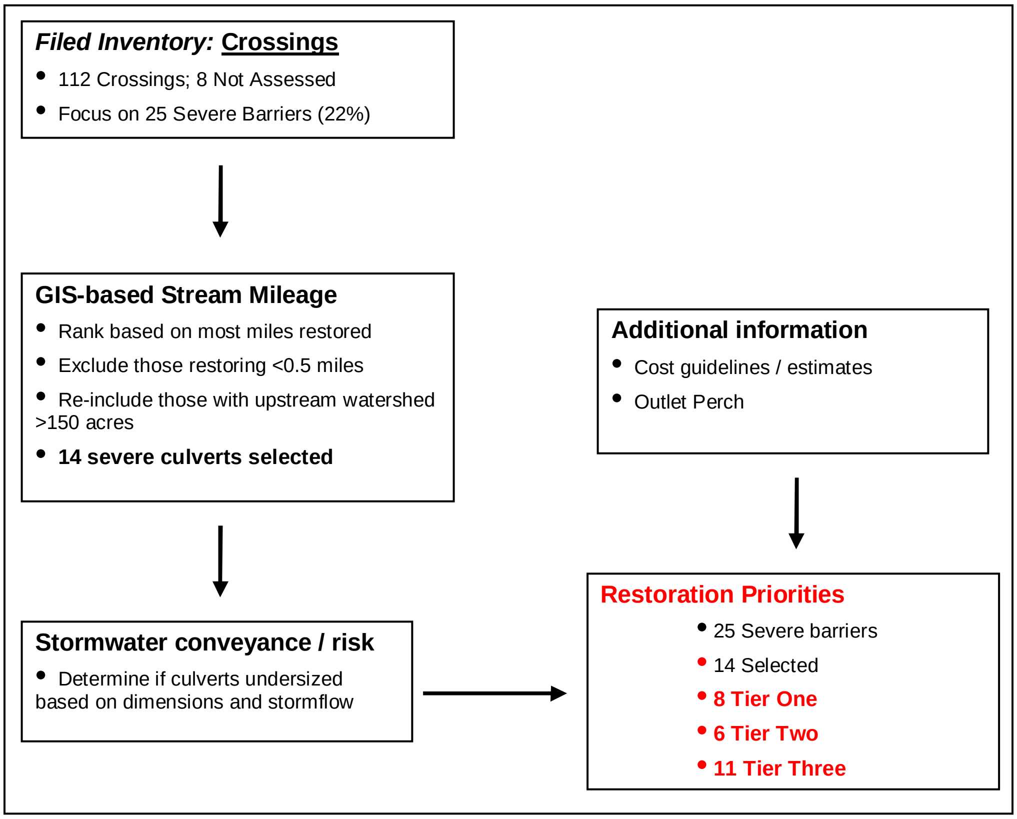
At 30,198 acres (47 mi^2), Otter Brook Reservoir Sub-watershed is one the largest in the Ashuelot River Basin. Otter Brook is the longest tributary in this river system, and with its feeder streams, has over 120 river and stream miles. Otter Brook flows south and west until it enters Otter Brook Reservoir, a recreation and flood control area owned and managed by the US Army Corps of Engineers. Otter Brook Dam was completed in 1958, and with Surry Dam, helps protect the Keene area from flooding while providing recreational benefits to southwestern New Hampshire.

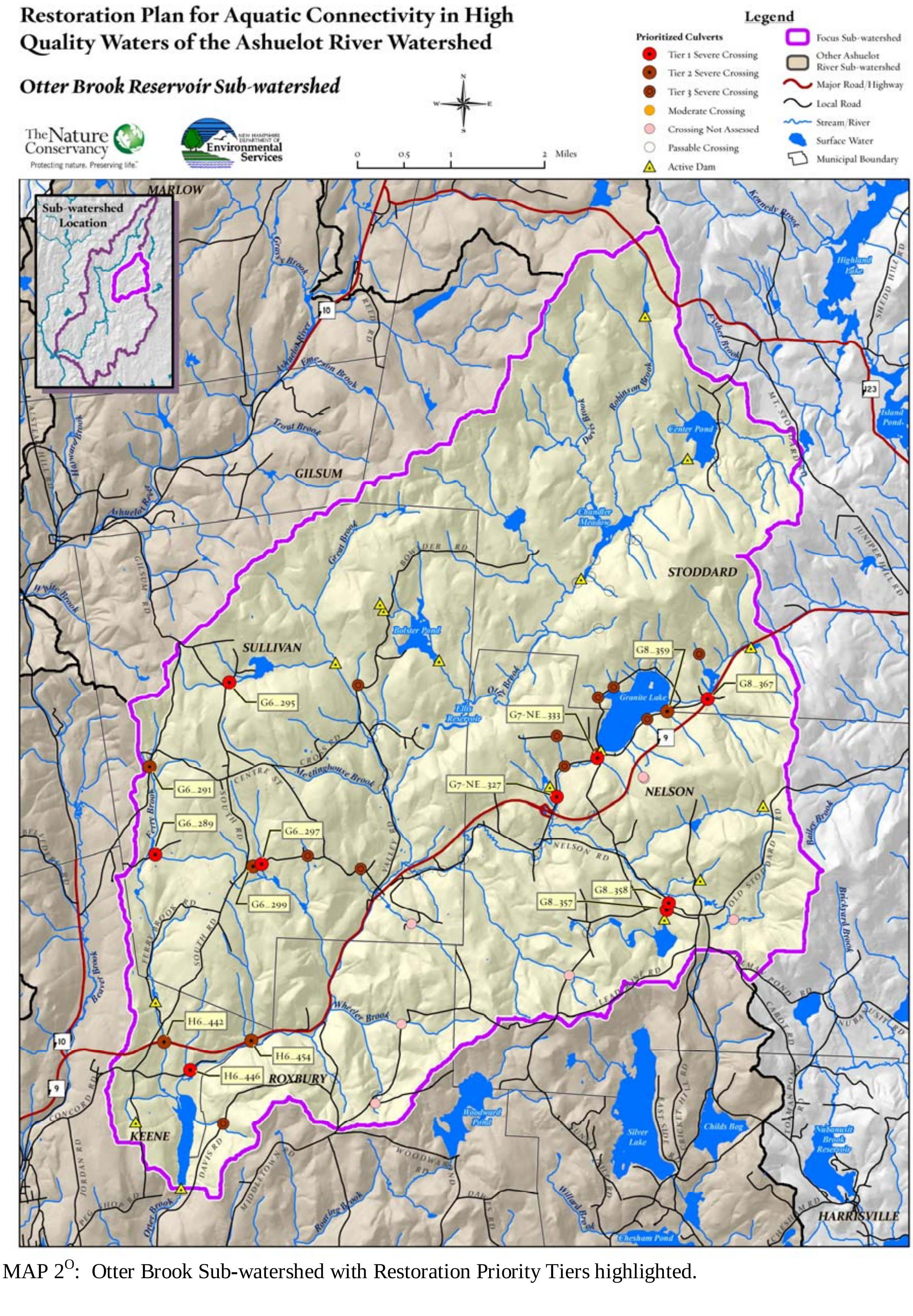
Otter Brook's headwaters in Stoddard collect runoff from over 8,000 acres of forest, wetlands, and ponds, most of which are protected in conservation lands. Headwater streams include Davis, Robinson, and Otter Brook itself. About halfway down, Otter Brook collects water from Bolster, Spaulding and Meetinghouse Brooks, as well as all the water that drains from Granite Lake in Nelson. Hubbard, Wheeler, and Ferry Brook flow into the southern portion of Otter Brook as it enters the Otter Brook Reservoir.

Almost 85% of Sullivan's acres are captured within this Sub-Watershed; all but Sullivan's northwestern tip drains into Otter Brook. The western half of Nelson, and nearly 40% of Roxbury's acreage also drain west and north into Otter Brook. Stoddard and its protected Andorra Forest conservation lands overlap nearly one quarter of the Town's southwestern corner. Finally, a sliver of Keene (5% of its acreage) overlaps the southern tip of the Sub-watershed where Ferry Brook flows south under Route 9 and into Otter Brook Reservoir.

Because it is a relatively large Sub-watershed, this area also has a higher number of road-stream crossings and dams. Of the 112 road-stream crossings, 25 were ranked as severe barriers, while 14 were considered restoration priorities. Sixteen active dams are scattered throughout the Sub-watershed, mostly impounding current or historic water supply and recreational reservoirs and lakes. Granite Lake is the most prominent of these, lying at the center of a large topographic bowl defined by Brooks, Melville, Dakin, Morrison, Fletcher, Felt, and Tolman Hills (clockwise from north to south of Munsonville).

Figure A[O]: Summary of field and GIS sampling and results for road-stream crossings for Otter Brook Reservoir Sub-watershed.





MAP 2^{O}: Otter Brook Sub-watershed with Restoration Priority Tiers highlighted.

Table A^{O}: Town and Sub-Watershed information[12] for Otter Brook Reservoir Sub-watershed.

Town / Sub-watershed	Town Acres	Acres in Study Area (%)	Forest Cover %	Population (2008 Est.)	Persons / Sq. Mi
Stoddard	33,950	8,614 (25%)	92	1,032	19
Sullivan	11,985	10,037 (84%)	87	788	41
Nelson	14,898	7,356 (49%)	90	662	30
Roxbury	7,845	2,887 (37%)	93	245	20
Keene	23,867	1,302 (5%)	67	22,653	611

Table B^{O}: Summary statistics Town by Town for Otter Brook Reservoir Sub-watershed.

Town	# Xings	#Dams	#Severes	# Mod	#Pass	#NA
Stoddard	20	4	5	10	5	0
Sullivan	36	4	8	16	10	1
Nelson	39	5	8	19	7	5
Roxbury	6	1	1	3	1	2
Keene	12	2	3	2	6	0
Otter Total	**112**	**16**	**25**	**50**	**29**	**8**

Restoration priorities

Of the 25 Severe crossings in the Otter Brook Reservoir Sub-watershed, 14 represent the highest need for restoration based on stream mileage (Table C^{O}). Seven are undersized and represent the top **Tier 1** restoration priorities. One additional **Tier 1** crossing in Nelson was collapsed and filled with sediment. Five crossings were large enough to convey storm flow, and one was inaccessible and we could not obtain dimension information, for a total of 6 Tier 2 restoration priorities. Eleven remaining Severe crossings are ranked as Tier 3 priorities.

Restoration of most of the **Tier 1** crossings would represent adding headwater habitat to a fairly intact Otter Brook mainstem. Except for several dams, most of the Severe crossings in this Sub-watershed primarily block headwater reaches. There is a wide diversity of outlet perch heights, with some of the highest perch heights associated with large box culvert under Route 9 in Keene.

[12] Source material at: http://www.spnhf.org/research/research-projects.asp; and http://www.nh.gov/oep/programs/DataCenter/Population/PopulationEstimates.htm

Table C^O: List of restoration priorities for stream crossings in the Otter Brook Reservoir Sub-watershed. Bolded text represents **Tier 1** priorities. Red text represents Undersized crossings. US Miles=total stream mileage upstream from crossing; Restoration Miles= miles of stream network restored given the removal or restoration of the crossing; Storm Flow Conveyance=whether crossing is adequate to pass storm flow or is Undersized to pass storm flow at the given statistical "year storm". Crossings with upstream watersheds <200 acres assessed for the 25-year storm; >200 acre upstream watersheds assessed for the 100-year storm. Cost Class and Outlet Perch provided for comparison (see Chapter 1 text).

Priority Tier	Town	Site Code	US Miles	Restoration Miles	Storm Flow Conveyance	Cost Class	Outlet Perch
2	Stoddard	G8_367	4.68	11.3	Unk. / 100	Unk.	Unk.
2	Stoddard	G8_359	0.64	9.0	Adequate / 25	5	Unk.
1	**Sullivan**	**G6_297**	**1.37**	**54.5**	**Undersized / 100**	**5**	**12-24"**
1	**Sullivan**	**G6_295**	**0.97**	**54.1**	**Undersized / 100**	**4**	**Unk.**
2	Sullivan	G6_299	0.54	53.6	Adequate / 25	4	6-12"
1	**Sullivan**	**G6_289**	**1.13**	**5.3**	**Undersized / 100**	**4**	**6-12"**
2	Sullivan	G6_291	0.76	4.9	Adequate / 100	5	Unk.
1	**Nelson**	**G7NE_333**	**14.51**	**53.2**	**(Undersized?) / 100**	**7**	**0**
1	**Nelson**	**G8_358**	**1.83**	**53.2**	**Undersized / 100**	**5**	**6-12"**
1	**Nelson**	**G7NE_327**	**0.88**	**53.3**	**Filled / 25**	**6**	**Unk.**
1	**Nelson**	**G8_357**	**1.75**	**0.18**	**Undersized / 100**	**5**	**0-6"**
2	Keene	H6_454	2.8	56.0	Adequate / 100	7	>24"
1	**Keene**	**H6_446**	**1.1**	**54.2**	**Undersized / 100**	**4**	**0**
2	Keene	H6_442	6.51	53.6	Adequate / 100	7	>24"
Tier 3							
3	Sullivan	G6_306	0.37	53.5	Adequate / 25	4	>24"
3	Nelson	G7NE_328	0.37	53.5	Filled / 25	6	Unk.
3	Roxbury	H6_450	0.32	53.4	Undersized / 25	4	12-24"
3	Sullivan	G6_301	0.31	53.4	Adequate / 25	4	0-6"
3	Sullivan	G6_304	0.08	53.2	Adequate / 25	6	>24"
3	Stoddard	G7NE_336	0.25	8.6	Undersized / 25	3	12-24"
3	Nelson	G7NE_354	0.23	8.6	Adequate / 25	5	6-12"
3	Stoddard	G7NE_339	0.19	8.5	Undersized / 25	4	>24"
3	Stoddard	F8_244	0.13	3.1	Unk. / 25	Unk.	Unk.
3	Nelson	G7NE_329	0.03	0.37	Adequate / 25	3	6-12"
3	Nelson	G7NE_334	14.5	0.1	Unk. DAM	Dam	Dam

Figure F^{O}: Photos of Tier One restoration priorities. Downstream side of crossing on left; upstream on right.

G6_297

Notes: Hubbard Brook crossing under Hubbard Road. Outlet perch, no sediment, ageing steep stone abutment.


G6_295

Notes: Downstream of Chapman Pond outlet under Gilsum Road. Narrow, fast flow through pipe; scour pool; too small for storm flow.


G6_289

Notes: Tributary of Ferry Brook under Price Road. Significant outlet perch; no sediment; narrow fast flow; aging stone abutments; blockage just upstream of inlet.


G7NE_333

Notes: Granite Lake outlet under Granite Lake Road downstream of dam. Significant inlet drop; shallow and overwidened box culvert. May accommodate storm flows, particularly because this culvert is just downstream of the outlet dam of Granite Lake.

G8_358

Notes: Tributary draining Center Pond under Nelson Road. Significant outlet perch; no sediment; narrow fast flow; aging stone abutments.

G8_357

Notes: Just south of G8_358; tributary draining Center Pond under Nelson Road. Significant outlet perch; no sediment; narrow fast flow; aging stone abutments.

G7NE_327
Notes: Downstream of Bunce Recreation Pond Dam, under Granite Lake Road. NO PHOTOS – SITE FILLED AND COLLAPSED.

H6_446
Notes: Crossing under Concord Road draining tributary flowing into Otter Brook just north of Reservoir. Partially blocked; no sediment; shallow; ageing abutments.


Chapter 3

Methods, Tools, and Resources

Introduction
There are an ever growing list of methods, tools, and resources to assess and prioritize river continuity restoration projects, ranging from volunteer and citizen science field protocols to highly technical methods. Watershed groups, towns, and conservation organizations have a growing list of opportunities to add capacity and grants to address the issue. Federal and state agencies, as well as private foundations, have a growing list of funding options to plan and pay for restoration projects of this kind.

While managing and installing bridges and culverts is a well established process for state and town Public Works Departments and road agents, planning for wildlife passage and storm flow poses new challenges. For one, river ecosystems do not necessarily respect town boundaries. What scale is best for planning? Should towns replace culverts before their engineered life expectancy? How can they pay for it? With towns facing difficult budget constraints and multiple demands, how can town officials expect to justify restoration projects at Town Hall Meetings?

A growing concern is that replacing problematic culverts on a regular basis is more expensive than investing in a more expensive project once. In addition, as storm flows increase, undersized culverts pose a risk to human health and property. Accepting the shared responsibility to restore our infrastructure for both human and ecological reasons will provide benefits for current and future generations.

When a culvert fails during an emergency, clearly the best strategy is to work with local, state, and federal emergency officials and agencies to repair roads quickly and efficiently. The following is most focused on tools to help inform Master Plans, how to planning for future Capital Improvement Projects.

The following sections outline a variety of issues that must be addressed to prepare for restoration projects. Planning for road-stream crossing restoration requires several important steps.

First, becoming informed about the issue is easier than it was just a few years ago. Advancements in the science and assessment methods coincided with development of Outreach materials. **Be informed** and **Consider watershed scale** sections below summarize some of the key issues. **Additional outreach materials and resources** provides a list of both New Hampshire and regional materials, including useful websites.

Identifying problematic crossings and setting priorities requires conducting field assessments as well as GIS and engineering based analyses. Chapters 1 and 2 of this project report demonstrate one approach. See additional information below under **Identify problematic crossings**.

Awareness of the laws and regulations is essential. See list of relevant New Hampshire regulations under **Laws and permits**.

Zoning ordinances are becoming more sophisticated when it comes to protecting property in flood-prone areas. See **Zoning and Ordinances** for a brief review.

Finally, the issue of funding can be the most daunting. However, there is a growing list of agencies and foundations who recognize this issue and have grant programs to support assessments and restoration projects. See **Selected List of Funding Programs** for a selected list.

Be informed

A key step is to introduce all relevant town officials to the issue of River Connectivity. Use outreach materials with Selectmen, Town Staff, and Town Boards (Planning, Zoning, and Conservation Commissions). Staff from Southwest Region Planning Commission compiled the following outreach materials for town staff and volunteers. These resources distill much of the science and guidance into specific questions and issues for Town Boards to consider, and are a good start for introducing the topic.

- *Best Management Practices for Culvert Construction;*
- *Culvert Installation Basics for Planning Boards and Conservation Commissions;*
- *Quick Guide to Culvert Replacements for Fish and Wildlife Passage;*
- See also **Additional outreach materials and resources** later in this Chapter.

Consider watershed scale

Because rivers and streams do not follow political boundaries, it is better to use watershed boundaries as the geography under consideration. A problematic crossing in Town A may pose more concern to Town B depending on and where the stream flows. It is critically important for town officials to be aware of how and where river flows across and through their town boundaries. When considering river continuity restoration projects, be aware of how decisions in your town affect both up- and downstream towns. If you share a watershed with an abutting township, encourage neighboring town volunteers and officials to engage or at least support your project.

Identify problematic crossings

Appendix AA features the updated volunteer-based protocol developed by UMass Cooperative Extension (Jackson 2009). Both the Assessment (TNC 2008) and this project used a modified version of this protocol. It features measurements that are easy to use and understand by volunteers and is designed to be used across a large area in a relatively brief time. It will provide preliminary information on crossings that may require additional field investigation and engineering to determine restoration needs.

Most other field protocols available currently require more technical expertise and equipment. The key difference is that crossing slope and measurements of bankfull or channel width are required at the crossing location. These require a slightly higher investment in staff training, field equipment. In addition, these methods require more field time per crossing, reducing the number of crossings that can be visited in a given field season.

Relevant laws & permits
The following list is adapted from *Guidelines to the Regulatory Requirements for Dam Removal Projects in New Hampshire* (NH Dam Bureau 2007).

- RSA-482-A (Dredge and Fill in Wetlands) grants regulatory authority to the DES Wetlands Bureau for activities conducted within their jurisdiction (e.g., lakes, ponds, streams, wetlands, sand dunes, tidal buffer zone, etc.). Rules promulgated under these laws are found in Env-Wt 100-800 (Wetlands Bureau Administrative Rules). RSA-482-A and the rules promulgated under it require that projects be designed to avoid and minimize impacts to areas under the jurisdiction of the DES Wetlands Bureau. **New Rules (Chapter 900) refer specifically to road-stream crossings; Rules are currently under review and should be implemented in early 2010**.

- RSA-483 (Rivers Management and Protection Program) was established to recognize and designate rivers to be protected for their outstanding natural and cultural resources. The program is administered by DES. After a river is designated to the program, a management plan is developed so that the outstanding qualities of the river may be protected for future generations. The plan is developed and implemented by a volunteer local river advisory committee that also coordinates activities affecting the river on a regional basis. The DES Rivers Management and Protection Program assists with the development and implementation of the management plan and enforces regulations concerning the quality and quantity of flow in protected river segments.

- RSA-483-B (Comprehensive Shoreland Protection Act) established "protected shoreland" adjacent to public water bodies in New Hampshire. The protected shoreland is all land located within 250 feet of a "reference line" of public waters. Within the protected shoreland, certain activities are restricted or prohibited, and others require a permit from the DES. All activities that are regulated by the NHDES must comply with applicable local, state, and federal regulations. Rules promulgated under RSA-483-B are found in Env-Ws 1400.

- RSA-227-C (Historic Preservation) reserves to the State of New Hampshire, acting through the Commissioner of the Department of Cultural Resources, ownership of all historical resources lying on the bottom of navigable waters in the state, great ponds, and three miles seaward from the New Hampshire shore in the territorial tidal waters of the state. The law directs the Division of Historical Resources to cooperate with federal, state, regional, and local government agencies in the planning and conduct of undertakings that affect historic properties and preservation objectives, and directs all other state agencies to cooperate with the Division in the identification and management of historic resources.

Zoning and ordinances

Towns in New Hampshire have started to consider model ordinances focusing on flood hazard areas. The towns of Exeter is working with the Rockingham Region Planning Commission and the New Hampshire Geological Survey to develop an Ordinance based on Fluvial Erosion Hazard areas. Multiple towns have floodplain ordinances that focus on limiting development in floodplain areas. At the federal level, the Department of Homeland Security's Federal Emergency Management Agency (FEMA) developed a Flood Map Modernization Program to help improve flood mapping areas. New Hampshire's Office of Energy and Planning supports and administers this program.
Web: http://www.nh.gov/oep/programs/floodplainmanagement/modernization.htm

In addition, the University of New Hampshire hosts a website focusing on Floodplain Management. It includes training on floodplain management, town profiles, and guidance for towns on joining the National Flood Insurance Program (NFIP). Participating towns must adopt and enforce a floodplain management ordinance in order to receive the benefits of NFIP.
Web: http://www.nhflooded.org/

Finally, through FEMA funding, the Southwest Region Planning Commission (SWRPC) has develop Hazard Mitigation Plans for all the towns in the Project Area. These plans and accompanying maps should be consulted side by side with information presented in this report to see where hazard areas coincide with restoration priorities. Included in each plan are maps identifying potential Hazard areas, including:

- Areas with history or potential for flooding, icing, tornado, washout, and fire ;
- Evacuation Routes;
- Dams, wellhead protection zones, aquifers, floodplains, and public water supplies;
- Bridges and their current condition;
- Elevation and steep slope areas;
- Recreation resources;
- Additional information on roads, town offices, and safety facilities
- Contact: SWRPC; 603-357-0440; http://www.swrpc.org/

Selected List of Field Assessment Protocols

River and Stream Continuity Project: Road-stream crossing Inventory and Instructions (UMass Cooperative Extension, Jackson 2009; See Appendix AA)

- Features volunteer-based protocol requiring minimal training and expense; can be used to assess many sites per field season
- Web Links:
    - http://www.streamcontinuity.org/online_docs.htm

NHFG Culvert Assessment Protocol Instructions: Completing the Field Form (New Hampshire Department of Fish and Game & New Hampshire Department of Environmental Services: River Management and Protection)

- Web Links:
    - http://des.nh.gov/organization/divisions/water/wetlands/streams_crossings.htm
- Contact:
    - John Magee, NH Department of Fish & Game: 603-271-2744
    - Laura Weit or Steve Couture; NH DES Rivers Management and Protection Program: 603-271-8811

Maine Road-Stream Crossing Survey Manual (US Fish and Wildlife, Abbott 2008)

- Features field form, instructions, and helpful guidance; a companion guide on dams and natural barriers also available (Maine Dam and Natural Barrier Survey Manual, Abbott 2008)
- Web Links:
    - http://www.gulfofmaine.org/kb/files/8989/MaineRoad-StreamCrossingSurveyManual2008.pdf
    - http://www.maine.gov/doc/mfs/fpm/water/docs/pdf/MaineDamAndNaturalBarrierSurveyManual2008.pdf

Vermont Stream Geomorphic Assessment Protocols (Vermont Agency of Natural Resources, Water Quality Division

- Features multiple habitat assessment, including road-stream crossings
- Web Links:
    - http://www.anr.state.vt.us/dec/waterq/rivers/htm/rv_geoassess.htm
    - http://www.anr.state.vt.us/dec/waterq/rivers/docs/rv_SGAB&CProtocols.pdf
    - http://www.anr.state.vt.us/dec/waterq/rivers/htm/rv_geoassesspro.htm
- Contact: http://www.anr.state.vt.us/dec/waterq/rivers/htm/rv_geoassess-contact.htm

National Inventory and Assessment Procedure – for identifying barriers to aquatic organism passage at road-stream crossings (US Forest Service, National Technology and Development Program; Clarkin 2005)

- Features full assessment manual with field form, field form instructions, and training materials
- Web links:
    - http://www.streamcontinuity.org/pdf_files/Stream%20Simulation.pdf

Fish Xing: Software and learning Systems for Fish Passage Through Culverts

- A website with software, training, documents, bibliographies, and multi-media, developed by multiple partner agencies
- Web links:
    - http://www.stream.fs.fed.us/fishxing/
    - http://www.stream.fs.fed.us/fishxing/aop_pdfs.html
    - http://www.stream.fs.fed.us/fishxing/biblio.doc
- Contact: http://www.stream.fs.fed.us/fishxing/credits.html

Selected List of Funding Programs

NH State Programs
Watershed Assistance Program
Rivers Management and Protection Program
New Hampshire Department of Environmental Services
Contact: Steve Couture or Laura Weit; 603-271-8811
Web: http://des.nh.gov/organization/divisions/water/wmb/rivers/index.htm

Moose Plate Conservation Grants
New Hampshire State Conservation Committee
PO Box 3907
Concord, NH 03302
Contact: Dea Brickner-Wood; 603-868-6112
Web: http://www.nh.gov/scc/grants/index.htm

Federal Programs
National Oceanic and Atmospheric Administration
NOAA Fisheries: Office Habitat Conservation
Open Rivers Initiative & Restoration Partnerships
National Marine Fisheries Service
Contact: 303-713-0174; 800-518-4726
Web: http://www.nmfs.noaa.gov/habitat/restoration

US Army Corps of Engineers
Regulatory and permitting resources page; scroll to Stream and River Continuity
Web: http://www.nae.usace.army.mil/reg/index.htm

US Federal Highway Administration
Planning and Environmental Linkages
Web: http://www.environment.fhwa.dot.gov/integ/index.asp

Private Organizations and Foundations
FishAmerica Foundation
Marine and Anadromous Fish Habitat Restoration Grants; Conservation Grants; Fisheries Research Grants
Contact: 703-519-9691
Web: http://www.fishamerica.org/grants/

American Rivers
Restoring Rivers: Stream Barrier Removal Grants
Web: http://www.americanrivers.org/our-work/restoring-rivers/dams/noaa-grants-program.html
Contact: Serena McClain; 202-347-7550 x3004

Trout Unlimited
Watershed Restoration-Home Rivers Initiative: Embrace-A-Stream Program
Web: http://www.tu.org/conservation/watershed-restoration-home-rivers-initiative/embrace-a-stream
Contact: John Hunt; 703-522-0200

National Fish and Wildlife Foundation
Freshwater Fish Keystone Program; Eastern Brook Trout Initiative
Web: http://www.nfwf.org/AM/Template.cfm?Section=GrantPrograms; and http://www.nfwf.org/AM/Template.cfm?Section=Fish_&TEMPLATE=/CM/ContentDisplay.cfm&CONTENTID=14089
Contact: 202-857-0166

Additional Outreach Materials and Resources

Outreach & Background

Ecological considerations in the design of river and stream crossings. (Jackson 2003)
Provides overview of ecological information and justification for maintaining and restoring river continuity.
Web: http://www.umass.edu/nrec/pdf_files/ecological_considerations_stream_crossings.pdf

Massachusetts Stream Crossing Handbook & *Poster* (Massachusetts Riverways Program; Nedeau 2005)
Provides a good overview, with photographs and art, of river ecology, the problems presented by undersized stream crossings; and recommended stream crossing guidelines.
Web: http://www.mass.gov/dfwele/river/programs/rivercontinuity/guidancedoc.htm

Fish passage through culverts; an Annotated Bibliography. (Six Rivers National Forest Watershed Interactions Team, Eureka, CA 1999).
Web: http://www.stream.fs.fed.us/fishxing/biblio.pdf
Contact: Michael Furniss, 707-441-3516

Fish passage in the United States; making way for the nation's migrating fish. (National Oceanic and Atmospheric Administration Service; Science, Service and Stewardship Program).
Provides overview of fish passage issues, focusing primarily on dams and NOAA programs for fish passage restoration.
Web: www.nmfs.noaa.gov/habitat

White paper: river restoration and fluvial geomorphology. (NH Dept. of Environmental Services & NH Dept. of Transportation; Schiff et al 2006).
Provides overview on (1) ecological processes and geomorphology of river ecosystems; (2) threats to river ecosystems; and (3) river and streambank restoration, with bibliography.
Web:
http://www.nae.usace.army.mil/reg/River%20Restoration%20and%20Fluvial%20Geomorphology.pdf

Scientific basis of road-stream crossing assessments in the Ashuelot River Watershed. (The Nature Conservancy and NH Dept. of Environmental Services; Nedeau 2006).
Provides good overview of stream crossing impact on fish and other wildlife species.
Web:
http://www.streamcontinuity.org/pdf_files/Stream%20Crossings%20Literature%20Review%20wlogos.pdf

Stream simulation: An ecological approach for providing passage for aquatic organism at road-stream crossings. (US Forest Service Stream-Simulation Working Group 2008).

Provides highly detailed and technical overview of concepts methods, and design of Stream Simulation methods.
Web: ftp://ftp-fc.sc.egov.usda.gov/NHQ/practice-standards/standards/578.pdf

Stream Crossing Engineering and Design Guidelines and Standards

New Hampshire stream crossing guidelines. (University of New Hampshire; Magee & Ballestero 2009),
Provides assisatnace for the design, construction and permitting of stream crossings in New Hampshire.
Web:
http://www.unh.edu/erg/stream_restoration/nh_stream_crossing_guidelines_unh_web_rev_2.pdf

Design for fish passage at roadway-stream crossings: Synthesis report. (US Department of Transportation, Federal Highway Administration; Hotchkiss & Frei 2007)
Provides detailed and comprehensive overview of design methods and standards, with a literature review covering topics about fish passage under roads.
Web:
http://144.171.11.107/Main/Blurbs/Design_for_Fish_Passage_at_RoadwayStream_Crossings_159599.aspx

Best management practicesfor routine roadway maintenance activities in New Hampshire. (New Hampshire Department of Transportation; Nyhan 2001).
Provides comprehensive guidance for road engineers on wide ranging topics including culverts and bridges.
Web:
http://www.nh.gov/dot/org/projectdevelopment/environment/units/technicalservices/documents/BMPManual.pdf

Stream Crossing. (Natural Resource Conservation Service; Conservation Practice Standard DRAFT 2009).
Provides useful definitions and practices for installing and maintaining stream crossings .
Web: ftp://ftp-fc.sc.egov.usda.gov/NHQ/practice-standards/standards/578.pdf