U.S. FISH AND WILDLIFE SERVICE, SOUTHEAST REGION

PARTNERS FOR FISH AND WILDLIFE PROGRAM

GUIDANCE AND RESOURCES FOR STREAM IMPROVEMENT PROJECTS

Figure 1. Head cut on Davis Creek tributary stream in Tennessee.

"RIVERS OF THE SOUTHEASTERN UNITED STATES CONTAIN SOME OF THE WORLD'S MOST DIVERSE AQUATIC COMMUNITIES. THE SOUTHEAST CONTAINS ABOUT 90 PERCENT OF THE NEARLY 600 TAXA OF MUSSELS AND CRAYFISHES (ABOUT 300 OF EACH), APPROXIMATELY 73 PERCENT OF THE AQUATIC SNAILS, AND ABOUT 50 PERCENT OF THE FRESHWATER FISHES KNOWN FROM THE CONTINENTAL UNITED STATES" (*SHUTE ET AL. 1997*).

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INTRODUCTION

Purpose of This Document

This document is intended to provide U.S. Fish and Wildlife Service (Service) field staff a source of readily available information and guidance about how to plan, design, and carry out a stream improvement project. Further, we hope this document will provide useful information to all conservation delivery biologists interested in stream habitat improvement regardless of their affiliation. Our intent is not to duplicate the extensive literature and stream improvement technical guidance manuals that currently exist but to provide the users of this document with relatively straightforward information that will help them through the various steps of carrying out a stream improvement project.

Explanation of Terminology

For this document, we have chosen to use the term stream "improvement" rather than the more popular term stream "restoration." Our use of the term improvement is intended to convey a broader array of activities, which may include any habitat restoration, enhancement, establishment, maintenance, or conservation activities intended to reduce or eliminate the source or sources of stream degradation and increase the suitability of the aquatic habitat for aquatic species. These terms are defined as follows:

Conservation: Any single action or group of actions or decisions that are made to support the aquatic resource values of stream habitat.

Enhancement: The manipulation of physical, chemical, or biological characteristics of the stream habitat to heighten, intensify, or improve specific functions.

Establishment: The manipulation of physical, chemical, or biological characteristics of the stream habitat to create and maintain habitat that did not previously exist. An example is the construction of side-channel spawning and rearing habitat where none previously existed.

Maintenance: Additional work that involves the manipulation of the physical, chemical, or biological characteristics present which are critical for the successful completion of the restoration process. Habitat maintenance activities are conducted by modifying an existing habitat improvement agreement when a particular project requires additional work several years after the original agreement was signed and the work is necessary to complete or maintain the improvement process.

Restoration: The manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning full (natural/historical) functions to lost or degraded native habitat (Service 2003). The National Research Council (1992) defined restoration as the return of an ecosystem to a close approximation of its condition prior to disturbance. This definition assumes that sufficient information is available about the past structure and function of the stream system to enable one to make a rational determination of whether restoration can be achieved. In reality, this assumption can seldom, if ever, be verified. Thus, restoration in a strict sense may not be possible or knowable since researchers may never know all of the details of past stream structure and function (Lewis 1989, Williams et al. 1997). Habitat restoration includes:

1. Practices conducted with the goal of returning a site, to the extent practicable, to the ecological condition that likely existed prior to loss or degradation. Examples include returning meanders and sustainable profiles to straightened streams, reducing or minimizing erosion and sedimentation in a stream in order to improve water quality, and reestablishing native vegetation along degraded streambanks (Figure 2).

2. Practices conducted when the restoration of a site to its original ecological condition is not practicable but will repair one or more of the original habitat functions and involve the use of native vegetation. An example includes the placement of streambank or in-stream habitat diversity structures in streams that cannot be restored to their original condition or profile.

3. Removal of the disturbing/degrading element to enable the native habitat to reestablish or become fully functional. Examples include fencing livestock out of riparian areas and removing constructed barriers to promote the movement of aquatic species.

Figure 2. Stream Restoration, Ochlawaha Bog, NC: Before (left), immediately after (right), and second growing season (below).

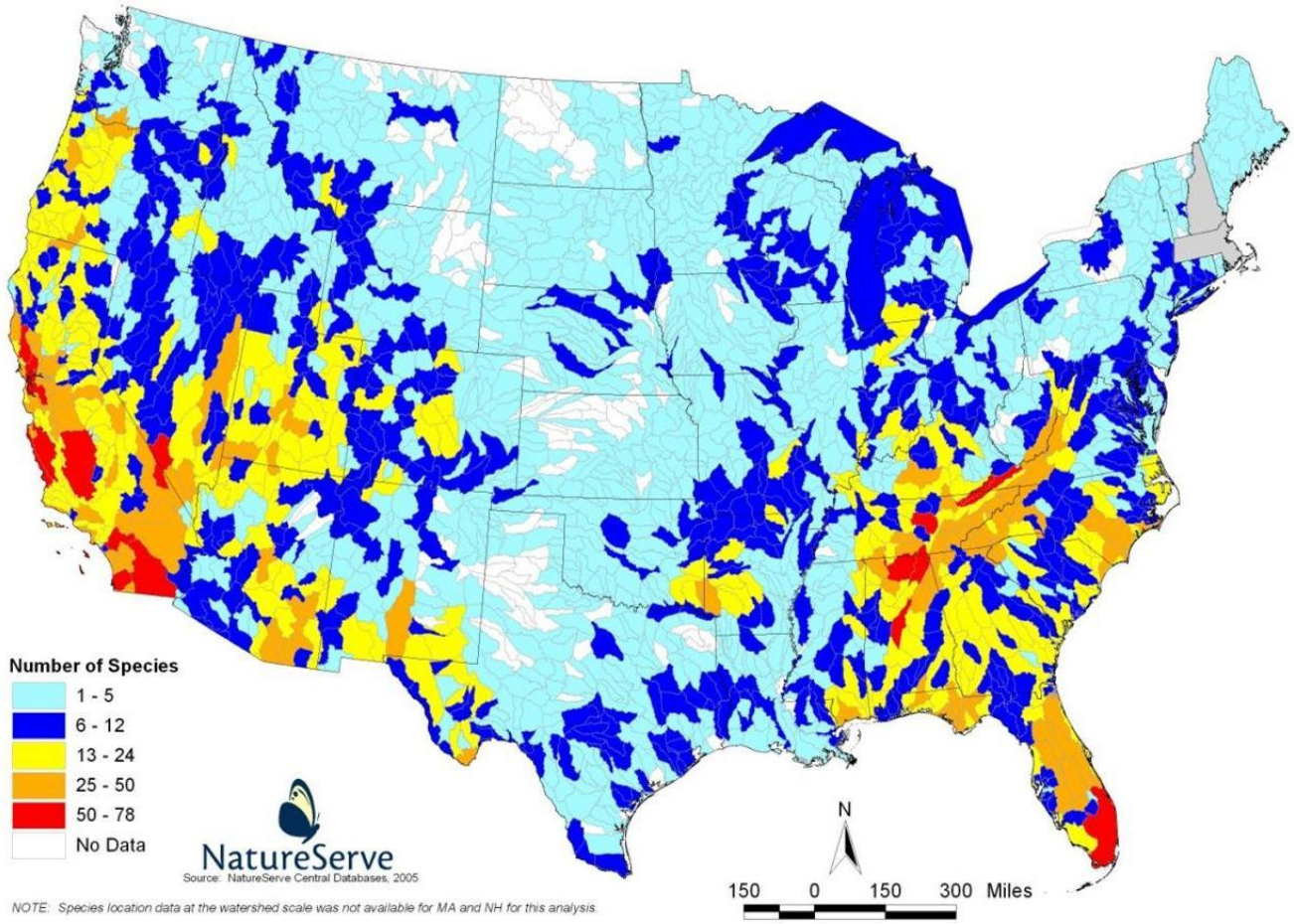
Background

The Partners for Fish and Wildlife (PFW) Program began in 1987, with a small budget and only a few staff to develop and implement the Program. Early on in the Service's Southeast Region, the majority of our PFW Program efforts on private land were focused on wetland improvement activities associated with waterfowl and other migratory birds. However, as the PFW Program became more successful and popular with private landowners and funding from Congress increased, our Regional efforts and initiatives expanded to other priority habitats and related species of conservation concern, including conservation actions designed to improve imperiled streams and watersheds. On October 3, 2006, President Bush signed into law the Partners for Fish and Wildlife Act (U.S. Congress 2006), which provided congressional authorization for the PFW Program within the Service. This Act recognizes the past contributions of the PFW Program and specifically directs the staff to continue to provide technical and financial assistance to private landowners to restore, enhance, and manage private land to improve fish and wildlife habitat.

The Southeast Region established an internal Stream Review Team in 2005 to address the technical challenges and staff training needs within the PFW Program relative to ongoing and future stream habitat improvement activities. This Stream Review Team completed a review of a variety of stream improvement projects in multiple states (Figure 3), and a subgroup of this team has integrated the information gained and lessons learned with other useful guidance available from literature into this document for the PFW Program staff to use as a reference when implementing stream improvement projects.

Figure 3. Members of the Stream Review Team assess a recently restored stream in Kentucky.

Figure 4. Number of U.S. Endangered Species Act listed, proposed, candidate, and G1-G2 species by 8-digit watershed.



Significant Aquatic Resources

Stream habitats in the Southeast Region exhibit an aquatic species diversity and endemism unsurpassed in North America, and many taxa are imperiled (Figure 4) or in decline (Scott 2006). Southeastern rivers have undergone or are at significant risk for degradation from a variety of other anthropogenic activities (Scott and Helfman 2001). The Southeast Region includes more than 70 major river basins with more freshwater aquatic species than any other region (62 percent of the Nation's freshwater fishes and 75 percent of its freshwater mussels). Furthermore, many of the streams in the Southeast are impaired due to a long history of significant erosion and sedimentation, contaminants, impoundments and other fish passage barriers, and other perturbations. About 34 percent of endangered, threatened, and special concern fish species and about 90 percent of the native mussel species that are endangered, threatened, or considered to be of special concern are found in the Southeast.

Figure 5. Freshwater mussel survey on the Little River in North Carolina demonstrates the species diversity found in a small reach.

There are many threats to the aquatic ecosystems of the Southeast Region, including perturbations from agricultural operations; urban expansion and other construction activities; mining operations; and various point-source discharges from cities, private industry and other sources (Benz and Collins 1997, Olsenius 2004). In lotic systems, the following six factors are threats to biological diversity and associated extinctions: habitat loss and degradation, the spread of invasive exotic species, overexploitation, secondary extinctions, chemical and organic pollution, and climate change (Allan and Flecker 1993).

Figure 6. Pearl River (in Louisiana) fish and mussel kill due to a chemical spill at the Bogalusa Paper Mill in August 2011.

Since 1994, the PFW Program has worked with over 1,000 private landowners and other partners in carrying out stream conservation projects on over 1,400 miles of streams in the Southeast. In the beginning, the PFW Program staff pursued aquatic resource conservation projects involving private landowners and other partners wherever we could locate them (a "scattergun" approach). However, we have continually improved our strategic focus to more effectively address the highest-priority watersheds and streams based on our expanding knowledge of priority habitats and those protected species and other species of concern that are associated with the diverse stream ecosystems (Service 2011, Service and U.S. Geological Survey 2006, Olsenius 2004).

Figure 7. Cooperating with private landowners continues to be integral in order to conserve the highest-priority streams and watersheds in the Service's Southeast Region.

See the following web links for additional information:

State Wildlife Action Plans at http://teaming.com/state-wildlife-action-plans-swaps.

National Fish Habitat Initiative and Action Plan at http://www.fishhabitat.org.

Southeast Aquatic Resources Partnership at http://southeastaquatics.net.

PFW Strategic Plan: FY 2012-FY 2016 at http://www.fws.gov/southeast/es/partners/strategicPlan.html.

Our strategic habitat conservation and adaptive management approach has paralleled similar changes in the national watershed improvement strategy, including greater emphasis on strategic planning at the watershed or ecosystem level, focusing conservation actions on a limited number of high-priority watersheds and associated target aquatic species, and identifying and treating key physical and biological processes intended to eliminate or reduce the source or sources of the stressors to the aquatic system (Heller 2004, Federal Interagency Stream Restoration Working Group [FISRWG] 1998, Service 2011, Williams et. al. 1997).

Typically, it is the main stem of stable rivers and larger streams that harbor rare species. However, tributary streams and their headwaters are critical to maintaining the water quality, water quantity, and biodiversity of downstream reaches (Richardson and Hinch 1998; Alexander et al. 2007; Meyer et al. 2007). Detailed information about the distribution and habitat needs of federally protected and candidate species and other rare species can be obtained from several websites:

U.S. Fish and Wildlife Service at http://www.fws.gov/endangered.
NatureServe Explorer at http://www.natureserve.org/explorer.
State Wildlife Action Plans at http://www.wildlifeactionplans.org.

Our Approach for this Document

Any form of habitat improvement involving aquatic ecosystems is a very complex undertaking and requires the integration of a wide range of scientific and technical disciplines. Although there are numerous technical guidance documents and related publications in the scientific literature, the range of scientific disciplines and techniques for stream habitat improvement have been subject to change as new information is obtained through project monitoring efforts and longer-term research studies.

A large number of stream improvement projects have been completed within the PFW Program. There is considerable technical information and valuable lessons to be learned from these projects if the time is taken to strategically follow up and evaluate them using adaptive management techniques. However, most of the limited project funds that have been provided to the PFW Program have been directed to the "on-the-ground" delivery of specific projects. Little finding has been made available for the type of longer-term monitoring needed to evaluate and validate the success or failure of specific habitat improvement practices with regard to any predetermined criteria. A carefully considered monitoring plan for stream improvement projects is critical to documenting the success of our efforts and gaining the information that is needed to carry out an adaptive management approach. Although funding support for monitoring through the PFW Program is limited, staff should collaborate with our partners to leverage available funds and resources to carry out the monitoring of at least selected projects.

Inadequacies associated with stream improvement monitoring activities are not unusual. For example, a report by Bernhardt et al. (2005) noted that, based on their synthesis of information from 37,099 stream projects carried out nationwide by a variety of entities, only 10 percent revealed any form of assessment or monitoring associated with the project (>20 percent of projects in the Southeast exhibited some form of monitoring). Of the tens of thousands of projects reviewed, this study also concluded that most were not adequately tracked and that a

much greater national effort was needed to gather and disseminate data on restoration methods and outcomes. In response to this need, the PFW Program implemented a Project Monitoring Protocol in 2005 (Appendix A).

This document is designed to provide helpful information to staff who anticipate working on a stream improvement project. It is not meant to be a "cookbook" for those who are designing and implementing stream improvement projects. The authors hope that what will be gained through reviewing the information contained within these pages is the fact that stream improvement projects require considerable understanding of the nature of streams, including their past, present, and potential future conditions as well as their physical, chemical, and biological characteristics. Stream improvement projects should be developed with the involvement of interdisciplinary teams to ensure project success. To quote some of our colleagues involved with stream improvement projects: "It's not rocket science, it's harder."

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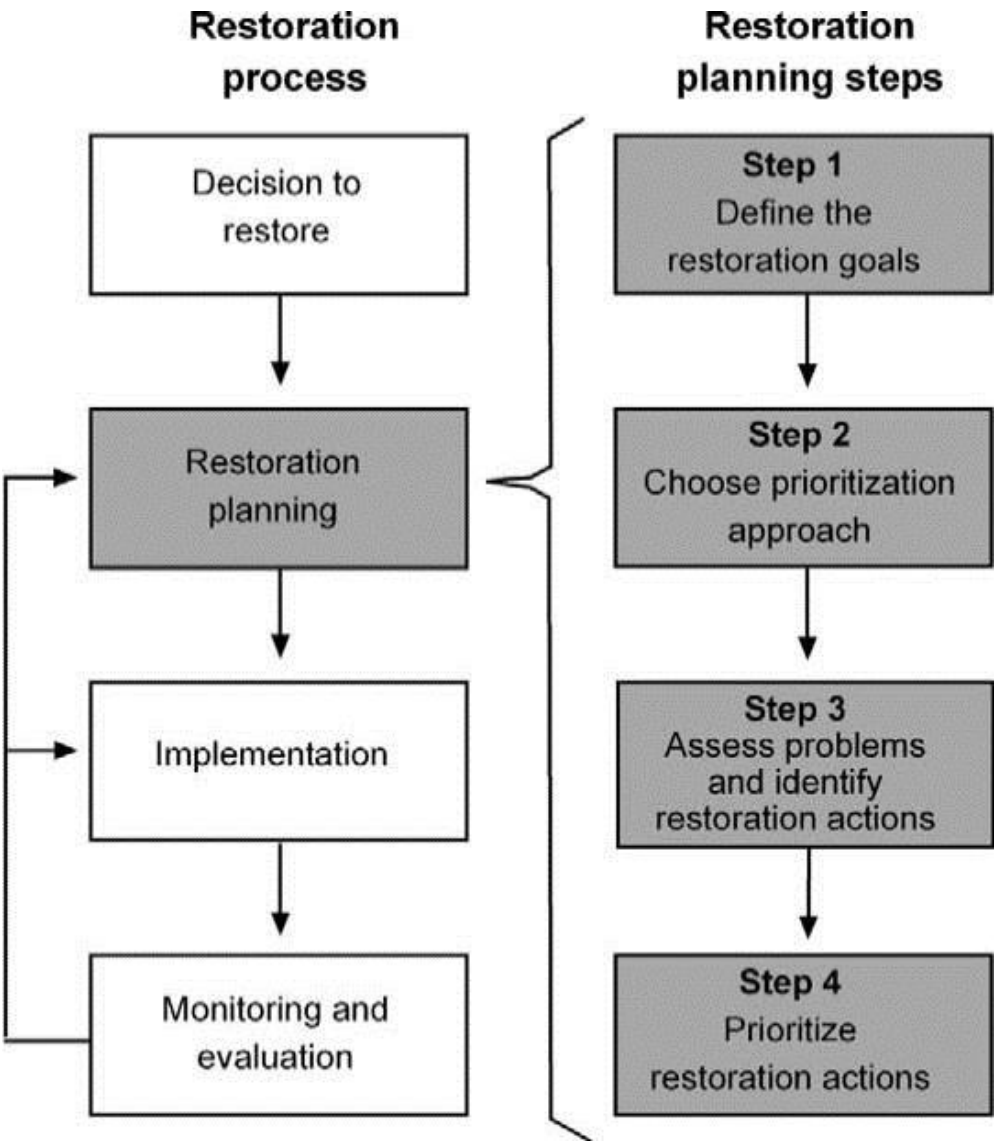
PLANNING A STREAM IMPROVEMENT PROJECT

"A river is the report card for its watershed" (Alan Levere).

Essential to the process of planning a stream improvement project is the identification of goals, development of a priority approach consistent with the goals, completing a watershed assessment to identify needed actions, and prioritization of the list of actions based on evaluation criteria that reflect stakeholder-defined habitat improvement goals (Figure 2, Beechie et al. 2008). Goal statements should include biological objectives; address the causes of impairment; and consider potential social, economic, or land-use constraints (Beechie et al. 2008).

Figure 8. River restoration process and steps for prioritizing actions (from Beechie et al. 2008).



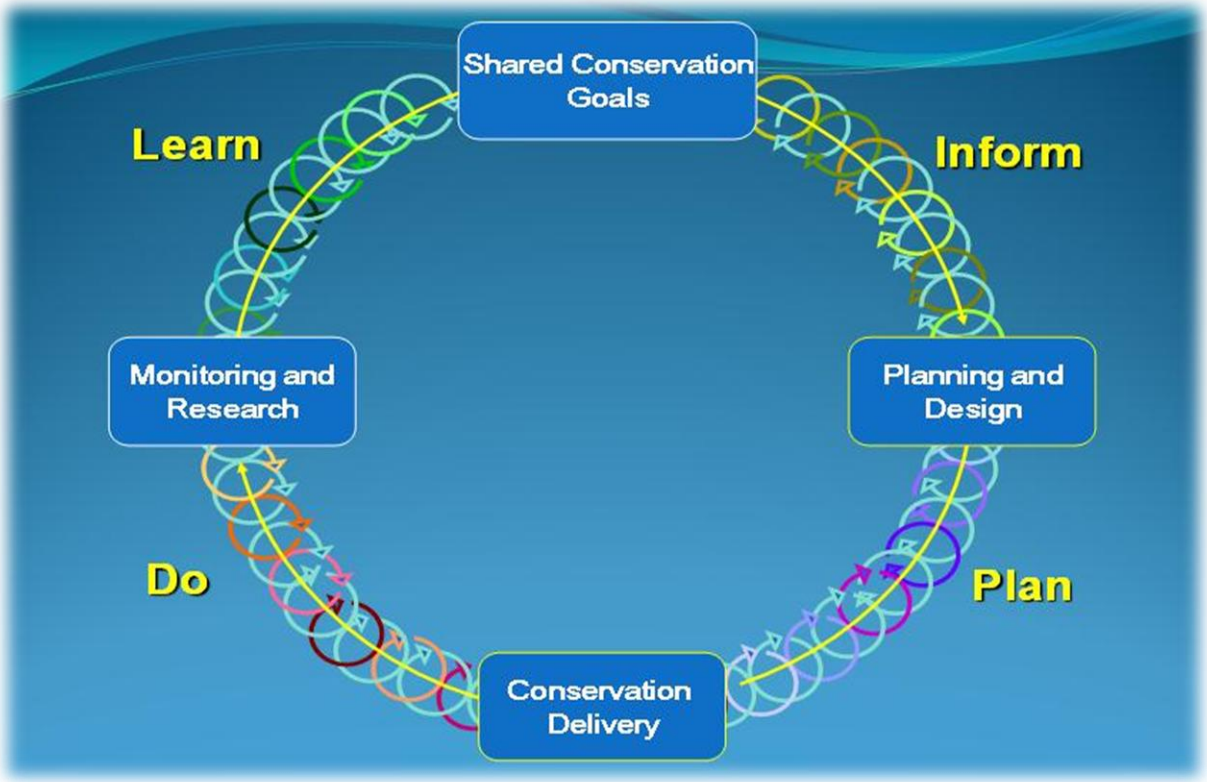
Identifying and Prioritizing Projects

"To provide for rational, adaptive progress in ecosystem management and to reduce the risk of irreversible and unanticipated consequences, managers and scientists must identify catchments and aquatic networks where ecological integrity has been least damaged by prior management, and jointly develop means to ensure their protection as reservoirs of natural biodiversity, keystones for regional restoration, management models, monitoring benchmarks, and resources for ecological research" (Frissell and Bayles 1996).

The Service is committed to a Strategic Habitat Conservation (SHC) approach (Figure 9) that requires consideration of five elements within the adaptive management loop (Service and U.S. Geological Survey 2006). These elements are:

- Biological Planning
- Conservation Design
- Delivery of Conservation Actions
- Monitoring
- Research

Figure 9. Service SHC approach.



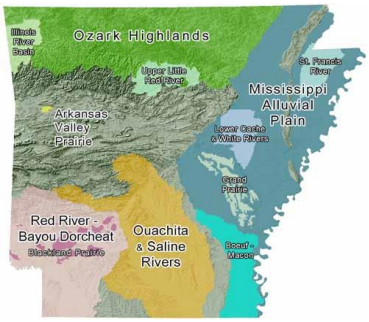
All of these required elements are directed toward the delivery of landscape-level habitat improvement and conservation actions within designated focus areas that address the key life needs of protected species and other at-risk species.

The Service advocates that program coordinators work in focus areas to ensure funding will be used to achieve the maximum resource benefits within a watershed. Due to the high expense associated with certain types of stream improvement projects, it is unlikely that PFW Program funding and landowner in-kind match alone will cover the cost of project design and implementation. Therefore, before beginning a project, it is advisable to identify key partners and stakeholders, form an advisory and technical team, and gain their technical assistance and/or financial support (Federal Interagency Stream Restoration Working Group 1998; Saldi-Caromile et al. 2004; U.S. Environmental Protection Agency [EPA] 2000; Firehock and Doherty 1995). In addition to private landowners, partners may include federal and state agencies, conservation organizations, local governments, tribal governments, universities, private industry, public utilities, and others.

In 2011, the PFW Program, Southeast Region, in collaboration with our many partners, revised and updated its Strategic Plan, which identifies and describes target focus areas within each state and the Commonwealth of Puerto Rico. The Strategic Plan also includes summary information on priority habitats, focal species, threats, and action strategies (Service 2011). Geographic focus areas identified in the Strategic Plan address the following criteria:

- the percent of private land within the focus area (a PFW Program focus area must have some private land);
- the history or knowledge of voluntary private landowner interest in the PFW Program and habitat conservation (landowners must be willing to develop and carry out projects);
- the number of threatened, endangered, and candidate species;
- the number of other federal trust species (e.g., aquatic species or other at-risk species, as identified in other strategic plans);
- the estimated significance of the proposed focus area relative to preventing the listing of a candidate species or the recovery of a protected species (linked to other strategic plans and Service recovery plans for protected species); and
- the perceived importance of the focus area from a landscape perspective (e.g., does the focus area link or connect important habitat types and reduce the fragmentation of habitat).

Figure 10. Arkansas PFW Program focus areas.



Stream Assessment

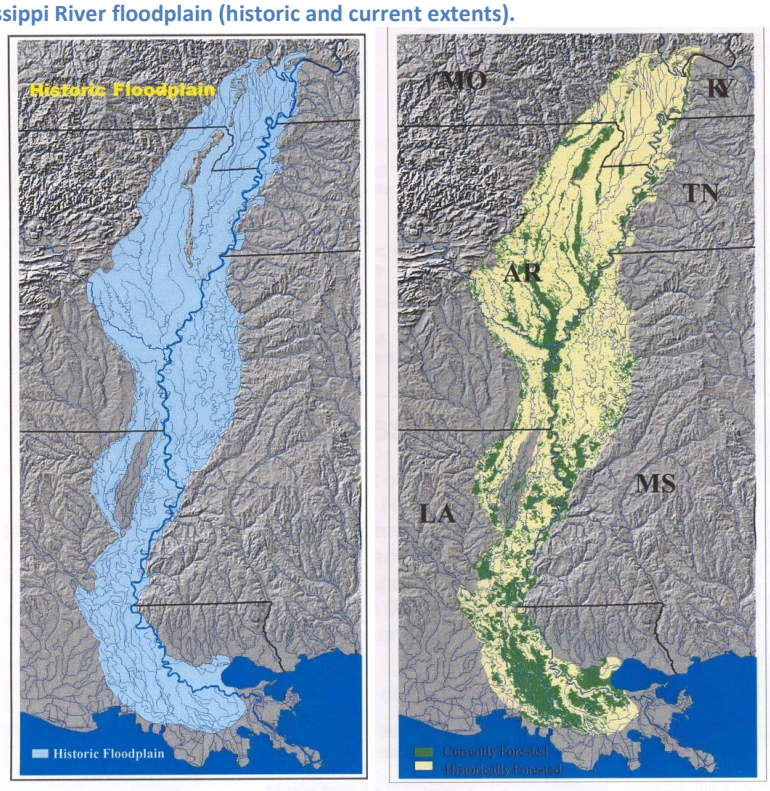
Within the Southeastern United States, physical habitat degradation has been identified as the primary reason for the continuing decline of freshwater mussel and fish populations (Warren et al., 2000; Neves et al., 1997; Allan and Flecker 1993). The EPA reported that the primary causes of water quality impairment in assessed wadable streams were nitrogen, phosphorus, streambed sediment, and riparian disturbance (EPA 2006). Many agencies and organizations oversee various conservation programs that can provide technical and financial assistance to landowners to conduct habitat improvement projects on privately owned land. However, these programs often don't provide funding for the collection of baseline data needed in order to prioritize areas in need of restoration, effectively design projects, and monitor project success.

A stream inventory and assessment is essential to provide the process-based framework to define past and present watershed dynamics, develop integrated solutions, and assess the potential consequences and success of habitat improvement activities (Natural Resource Conservation Service 2007). By conducting a stream assessment within a watershed, resource managers should be able to identify degraded reaches within the system and the sources of impairment. Two levels of assessment can be used to identify channel stability and overall threats to stream systems:

(1) A project-scale assessment for determining improvement potential at site specific locations and

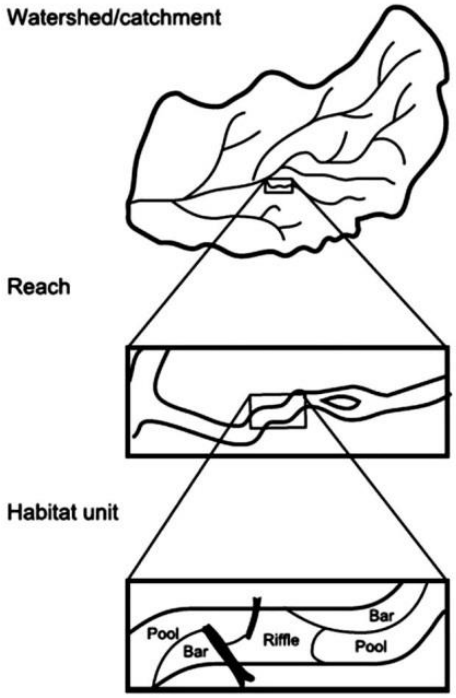
(2) A landscape-scale assessment to determine threats and impacts throughout a watershed.

Figure 11. Lower Mississippi River floodplain (historic and current extents).



While an on-the-ground assessment is essential to provide the practitioner with accurate information about baseline stream conditions at the project scale (or greater), a Geographic Information System can provide a watershed or landscape view of a river basin and the relationships (based on coverage available in your state) between natural resources and threats to those resources. Historical aerial photographs may provide a snapshot of changes in the landscape over time and are useful for planning, outreach, and education. These are often available from university and local libraries, local historical societies, USDA Farm Service Agency offices, state archives, and landowners. Data compiled during this initial project phase are essential for identifying and prioritizing projects for on-the-ground habitat improvement. A comprehensive review of physical stream assessment conditions was conducted by the U.S. Army Corps of Engineers (USACE) and the EPA (Somerville and Pruitt 2004). This review found that subjective visualized assessment protocols, while relatively easy to use, were rarely detailed enough to be used for project design. These may be useful for watershed-scale assessments or coarse-level prioritization. This review further describes objective quantitative assessments (which are much more labor intensive) as most appropriate for project design and should be based on comparison to stable reference conditions. Access to the document is available through this web link:
http://www.epa.gov/owow/wetlands/pdf/PhysicalStreamAssessmentSep2004Final.pdf.

Figure 12. Scale of improvement projects should focus at the watershed level, with projects occurring at the reach and habitat unit level as appropriate (Roni 2005).



While a number of stream assessment protocols are available for use, the "Stream Corridor Inventory and Assessment Techniques: A guide to site, project and landscape approaches suitable for local conservation programs" (USDA, Natural Resources Conservation Service [NRCS], WSSI, Revised 2001) is available to help practitioners determine the appropriate level of stream corridor inventory and assessment techniques useful at the project level (Figure 12).

This reference is available at
ftp://ftp.wcc.nrcs.usda.gov/wntsc/strmRest/StreamCorridorInventoryTechniques.pdf.

Other streambank assessment resources that may be useful include:

- EPA's Watershed Assessment of River Stability and Sediment Supply (WARSS) at http://water.epa.gov/scitech/datait/tools/warsss/index.cfm.

- Stream Channel Reference Sites: An Illustrated Guide to Field Technique (USFS 1994) at http://www.stream.fs.fed.us/publications/PDFs/RM245E.PDF.

Guidance for Prioritizing Stream Improvement Projects

Within the PFW Program, the general types of stream improvement practices that have been most often practiced are listed below:

- Livestock, human foot traffic, and vehicle exclusion fencing and gating.

Figure 13. Example of livestock damage to a stream corridor in Georgia.

Figure 14. Livestock exclusion fencing protects a stream corridor in North Carolina.

- Provision of an alternate water source for livestock in association with restricting access to riparian and stream areas.

Figure 15. Alternate water source (a well) for livestock, situated outside the stream corridor.

- Reestablishment of native vegetation in the riparian zone.

Figure 16. Reestablishment of native vegetation in the riparian zone.

- Elimination or control of invasive exotic species.

Figure 17. Volunteers controlling invasive exotic plants within a stream corridor in North Carolina (Photo credit: Hiwassee River Watershed Coalition).

- Streambank biostabilization to reduce erosion and sedimentation.

Figure 18. Bank sloping, rock vanes, and lives stakes, Old Field Creek in North Carolina.

- Removal of barriers to aquatic organism passage or failing culverts.

Figure 19. Failing culvert before removal, Watauga Creek, in North Carolina.

Figure 20. Culvert replaced by a bridge spanning the stream corridor, Watauga Creek, in North Carolina.

- Reestablishing stream connectivity with its floodplain and associated wetlands.

Figure 21. Mississippi River levee (in Mississippi) being removed.

Figure 22. Post-removal of levee and backwater flooding in Mississippi.

- Restoration of in-stream aquatic habitat (e.g., installation of in-stream habitat structures, such as boulders, gravel beds, logs; artificial habitat structures; reestablishing or creating pools and riffles; control or elimination of aquatic nuisance species; and reestablishment of submerged aquatic vegetation).

Figure 23. Large woody debris provides important habitat for aquatic species (Florida).

- Projects that address the specific habitat needs of at-risk species.

Figure 24. Constructed riffle to benefit rare darters, Raccoon Creek, in Georgia.

- Trash and debris removal from the stream corridor.

Figure 25. Kona trestle in the North Toe River (North Carolina) before and after removal.

- Education and outreach projects.

Figure 26. Bat-wing-shaped kiosk provides information about gray bats and cave habitat along Chickamauga Creek in Georgia (Photo credit: Georgia Department of Natural Resources).

Once a potential project has been identified, there are a number of guiding principles that should be followed (adapted from EPA 2000; Cramer et al. 2002; Montgomery and Buffington 1998; Kauffman et al. 1995; National Research Council 1992). They are:

- Projects should attempt to restore the ecological integrity of the habitat, including the structure, function, composition, and natural processes of the ecosystem.

- Project plans should be envisioned within the relative context of a watershed or ecosystem and with regard to anticipated future changes as other activities throughout the watershed or ecosystem may impact the project (Figure 12).

- Project plans should address the causes of habitat degradation (restoration efforts are likely to fail if the sources of degradation persist).

- Clear, achievable, and measurable goals and objectives should be developed for each project.

- Note that treating large-scale land-use-related problems (including deforestation, accelerated erosion, and altered hydrologic and sediment regimes) with small-scale intervention is ineffective and costly (Frissell and Ralph 1998).

- Projects should be designed to be self-sustainable and will minimize the need for continuous maintenance of the site.

- When appropriate, a passive restoration approach should be used. Before actively altering a site, determine if simply reducing or eliminating the stressors will be enough to allow the site to recover naturally.

- Native plant species adapted to site conditions will be used in restoration treatments.

- Allelopathic and nonnative species will not be used.

- Habitat restoration is a complex undertaking that requires the integration of a wide range of technical disciplines. We should strive to provide trained and knowledgeable staff and to work within interdisciplinary teams during the planning, assessment, design, implementation, and monitoring stages of the SHC approach.

- For comparative purposes, a reference site should be identified. A reference site should be comparable in structure and function to the proposed project site and should serve as a prototype for the project.

- Project plans should use a geomorphological approach (Tompkins and Kondolf 2001) and follow natural channel design principles (Rosgen 1997).

- All projects should be monitored before, during, and after implementation. Based on our monitoring results, we should employ an adaptive management approach in order to achieve project objectives.

When working within focus area watersheds, project identification should ideally involve a stream corridor assessment that will help prioritize and identify reaches in need of improvement (EPA 2000, FISRWG 1998). A comprehensive watershed assessment should show where the needs for conservation and potential for future rehabilitation sites are concentrated and should help to identify specific threats and stressors to target species (Jorde 2002).

The following hierarchical strategic steps should be considered when prioritizing conservation projects within designated focus watersheds (adapted from Roni et al. 2002, 2005):

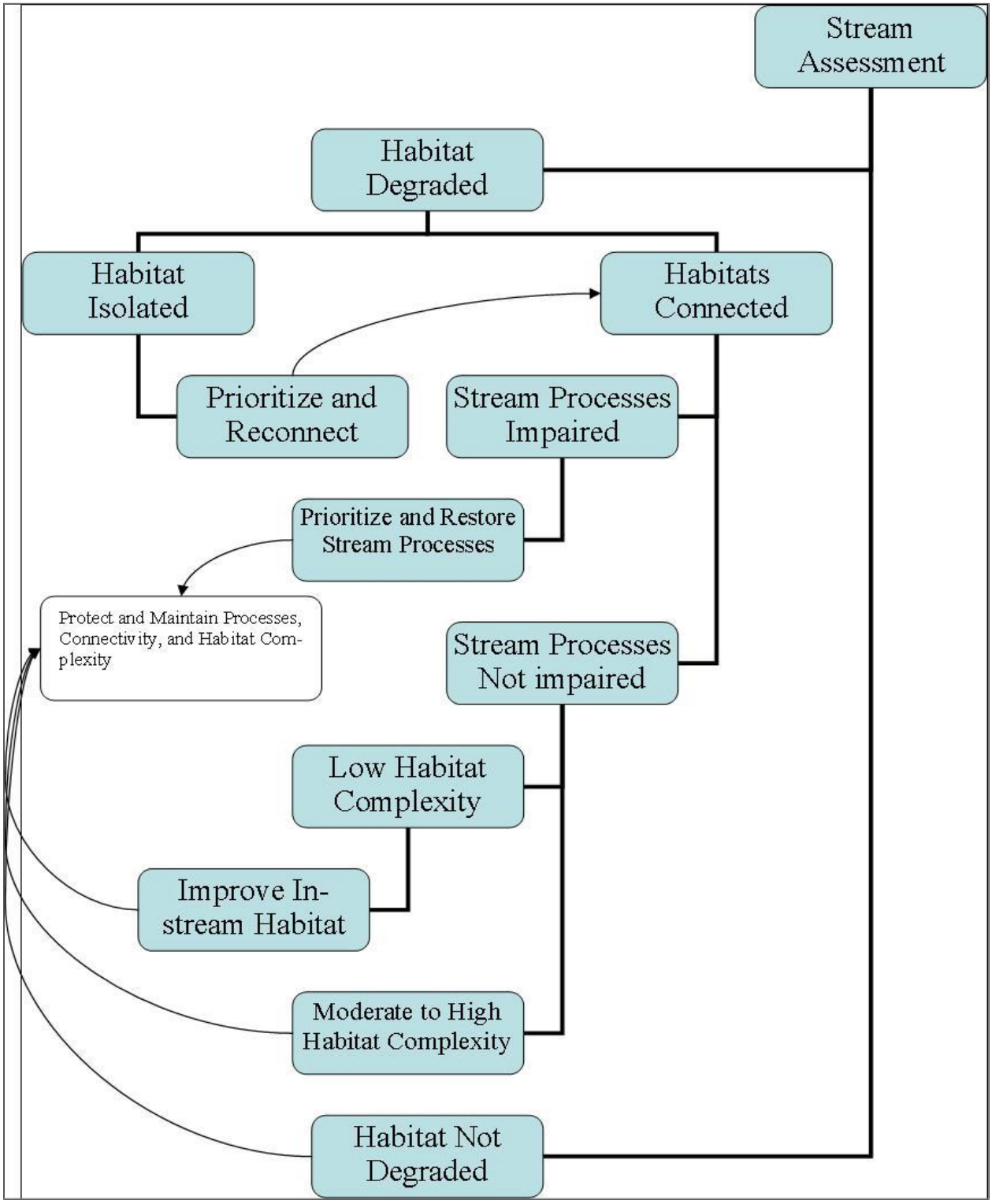
1. Conserve, protect, or enhance existing high-quality habitats to protect water quality and quantity (EPA 2000). The protection of stream corridors and watersheds may avoid the need for costly improvement actions and is usually the least expensive and most ecologically sound approach to conservation (Richardson and Hinch 1998, Harding et al. 1998). Examples include habitat protection through land acquisition, conservation easements, zoning, or other land-use policies and regulations (Saldi-Caromile et al. 2004). It is important to note that PFW Program funds cannot be used to acquire land, easements, or leases, but PFW Program biologists can provide technical assistance during the process of land protection or work with partners to develop land protection proposals that use funding sources that accomplish these goals (e.g., Recovery Land Acquisition/Section 6 grants, North American Wetlands Conservation Act grants).

2. Reconnect high-quality habitats. This includes those projects that restore watershed connectivity, limiting key fish and wildlife populations. Practices may involve the restoration of aquatic organism passage; restoration of riparian and floodplain corridors; and reconnecting the stream main stem with its floodplain and associated side channels, wetlands, tributary streams, and springs. Examples of techniques include livestock exclusion fencing, reestablishing streamside forests, levee removal, reconnection of oxbow or slough lakes, removal of water-control structures, reconnecting a channelized stream with its floodplain, redirecting a channelized stream into its remnant channel, removal of floodplain fill, and barrier removal or replacement with a passage-friendly alternative for aquatic organisms.

3. Once the connectivity of habitats has been restored, restore channel stability and natural riverine processes. This includes projects that restore wetland hydrology, control sediment delivery to stream channels, restore native flora and fauna, eradicate invasive exotic species, remove human-made structures that confine channels, remove roads and control related runoff, improve water quality, reduce water withdrawals, restore riffle/pool habitat, and restore wood in streams.

4. In-stream habitat enhancement (e.g., the addition of wood, submergent vanes) should be employed after restoring natural processes or where short-term improvements in habitat are needed.

Figure 27. Strategy for prioritizing improvement activities in Southeastern streams and watersheds. Note that watershed-scale habitat improvement plans would likely include a combination of hierarchical strategic steps (adapted from Roni et al. 2002).



Examples of Hierarchical Strategic Steps

Figure 28. Seniard Creek, in North Carolina. Example of hierarchical strategy #1 (conserve, protect, or enhance existing high-quality habitats). Habitat Information Tracking System (HabITS) Database Project Number 41814.

The owner of this tract has established permanent conservation easements on this property through both the North Carolina Clean Water Management Trust Fund and the USDA/NRCS's Wetlands Reserve Program. Conservation of this tract occurred because of a partnership initiated by the Service and developed with other partners in the upper French Broad River which focused on the conservation of rare aquatic species using state and federal conservation program funds. This tract is surrounded on three sides by national forest land and contains Seniard Creek, a headwater tributary of the Mills River, which is home to the endangered Appalachian elktoe mussel.

Figure 29. Perdido Creek, in Alabama. Example of hierarchical strategy step #2 (reconnect habitats of high quality with intact processes). HabITS Database Project Number 5367.

Dr. Ronnie Haynes, Regional PFW Coordinator, looks on as Randy Roach, PFW Coordinator, Alabama (now retired), explains the Perdido Creek Stream Improvement Project. The project: (1) redirected a channelized reach of stream to its remnant channel, which increased in-stream aquatic habitat by 2,855 linear feet; (2) restored floodplain wetland hydrology; (3) prevented a head cut from progressing; and (4) rehabilitated the abandoned channelized section to function as flood storage and habitat for aquatic species and other wildlife.

Figure 30. Mitchell River, in North Carolina. Example of hierarchical strategic steps 1-4. HabITS Database Project Number 5322.

Chris Metcalf, North Florida PFW Coordinator, demonstrates pool location below recently installed submergent vane. The Mitchell River Project used a watershed-based strategy to conserve and improve aquatic habitat. Treatment techniques included permanent protection of the riparian corridor through easements and stream buffer restoration. The construction of a series of submergent cross vanes within this reach, coupled with the establishment of native vegetation along its banks, helps reduce bank erosion and hinders nonpoint-source pollution from entering surface waters. Submergent vanes also create in-stream habitat complexity.

Stressors in Streams and Watersheds

Surface water quality and quantity may be impacted by many stressors (both on- and off-site) within a watershed. Following is the EPA's list of the top ten water quality impairments in the United States, acknowledging that surface water and watersheds are usually impacted by a combination of these (EPA 2008):

Table 1. The EPA's top ten 303(d) list of impairments in the United States (August 14, 2007)

General Impairment	Number Reported	Percent Reported	Cumulative Percentage
Pathogens	8,558	13.5	13.5%
Mercury	8,555	13.5	26.9%
Sediment	6,749	10.6	37.5%
Metals (other than mercury)	6,368	10.0	47.5%
Nutrients	5,617	8.8	56.3%
Oxygen depletion	4,540	7.1	63.5%
pH	3,376	5.3	68.8%
Cause unknown - biological integrity	2,867	4.5	73.3%
Temperature	2,852	4.5	77.8%
Habitat alteration	2,246	3.5	81.3%

This EPA website has additional information on national aquatic resource assessments and water quality conditions in streams: http://water.epa.gov/type/rsl/index.cfm. The USDA (NRCS 2007) has developed a summary of common streambank problems, causes, and solutions (Appendix B).

Climate Change

The Intergovernmental Panel on Climate Change (IPCC) has concluded that the earth's climate system is changing at an accelerating rate and attributes many of these changes to human influence (IPCC 2007). Secretarial Order 3226 (Amendment 1) requires that climate change impacts be considered and analyzed when planning or making decisions within the Department of the Interior (U.S. Department of the Interior 2009). This order requires the Service to incorporate climate change impacts into their conservation planning activities under SHC.

Climate change will lead to significant impacts across the United States (Wigley 2004). These may include increasing temperatures, altered rainfall patterns, and sea level rise. The effect of climate change on wildlife and habitats is expected to be variable and species-specific, with a predicted general trend of ranges shifting northward and to higher elevations (Shugart et al. 2003). Nonnative species will likely increase (Walther et al. 2002). Although the annual average precipitation in the United States has increased by about 7 percent over the past 30 years, there has been pronounced drying over the Southeast. Trends in precipitation from 1901 to 2006 show that rainfall in parts of the Southeast has substantially declined since the 1900s (Backlund et al. 2008). At the same time, the U.S. Global Change Research Program reports that extreme precipitation events are on the rise (Kunkel et al. 2008). The result is that some areas will be more prone to flooding rains followed by longer periods of drought. Warmer temperatures will only serve to compound these trends (warmer air can hold more moisture),

increasing the likelihood of heavy downpours. In between these extreme rainfall events, droughtlike conditions will likely increase in frequency, as increasing temperatures will accelerate soil-moisture evaporation rates, reducing the amount of water available to plants. It is expected that water needed to recharge groundwater and surface waters will also diminish. Streams and watersheds may be impacted by climate change in the following ways (Bakke 2009, Hellman et al. 2008, Meyer et al. 1999, Winter 2000):

- Increase in average water temperatures;
- Reduction in habitat for cool-water species of fish and macroinvertebrates;
- Weather extremes (drought and precipitation) accompanied by hydrologic changes (increase and decrease in stream discharge), inducing geomorphic changes (accelerating erosion and sedimentation);
- Reduction in organic matter storage and loss of organisms during more intense flushing events;
- Shorter periods of inundation of riparian wetlands and greater drying of wetland soils;
- Expansion of the range and abundance of invasive exotic species;
- Stream acidification;
- Decreased dissolved oxygen levels;
- Changes in land-use patterns;
- Increase in in-stream habitat fragmentation; and
- Increased abundance of invasive exotic plants, which alters the rate or timing of evapotranspiration or runoff.

Additional resources related to climate change:

EPA: Climate Change Effects on Streams and River Biological Indicators: A Preliminary Analysis (Final Report): http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=190304.

Service: Climate Change Website: http://www.fws.gov/home/climatechange/.

U.S. Geological Survey: National Climate Change and Wildlife Science Center: https://nccwsc.usgs.gov/.

DESIGNING PROJECTS

In order to avoid the failure of stream improvement projects, practitioners should focus on restoring ecosystem processes and functions that form and sustain aquatic habitats rather than on the habitats themselves (Roni et al. 2005). The two main types of failures noted in freshwater improvement projects involve site-prescribed engineering solutions that are overwhelmed by altered watershed processes that are far removed from degraded habitats (e.g., increase in sediment supply from upslope sources can bury in-stream structures and pools) and improvement measures that prevent habitat formation that would otherwise naturally occur (e.g., bank protection prevents the formation of new floodplain habitats) (Roni et al. 2005). Therefore, in selecting projects, it is important to consider the potential impacts of changes in the watershed upstream and downstream of the project area. Remember, due to the dynamic nature of waterways, stream improvement projects have the potential for impacting off-project land in a positive or negative way. The long-term success of a stream improvement project can be determined by variables within the watershed that are beyond the practitioner's control, such as changes in stream hydrology due to an increase in impervious surface, sand and gravel mining, climate disruption, and others. It is critical that practitioners use foresight and caution when designing projects.

As watersheds become urbanized, stream form and natural processes are increasingly altered. Traditional engineering methods for flood control and streambank stabilization employ the use of hard armoring, berms, in-stream structures, and measures that isolate stream channels from their floodplains and otherwise affect natural fluvial processes in an attempt to lock these naturally dynamic systems in place. These stabilization measures impact stream evolution processes, riparian succession, sedimentation processes, habitat, and biological community interactions (Fischenich 2003). As watersheds develop and streams become channelized, aquatic species and their habitats become reduced and eliminated. Traditional engineering methods also may transfer scour and erosion problems to another area of the stream system (Li and Eddleman 2002), often resulting in a domino effect of stream-channel instability downstream. To prevent this from happening, practitioners should employ the natural channel design method for stream improvement (Rosgen 1996, 1997); this method supports the restoration of stream-channel function in impaired systems.

Figure 31. Gabion baskets impair stream function along roadways and are prone to failure.

Natural Channel Design

A stable channel is defined as the ability of a stream, over time and in the present climate, to transport the sediment and flows produced by its watershed in such a manner that the stream maintains its dimension, pattern, and profile without either aggrading or degrading (Rosgen 1996). The natural channel design approach recognizes the connection between stream geomorphology and the surrounding watershed, emphasizing the physical environment responsible for stream-channel formation and necessary to maintain stream function. The essence for this design approach is based on measured morphological relations associated with bank-full flow, geomorphic valley type, and geomorphic stream type (NRCS 2007). Because of the diversity of natural conditions and variety of constraints and objectives at individual project sites, design processes must be customized for each project.

While practitioners may be focusing on the habitat unit scale with individual landowners (Figure 12), this approach requires that a reach or watershed-scale assessment be done to determine the underlying causes of channel instability. This technique uses a combination of hydraulic geometry; analytical calculations; regionalized, validated relationships; and analogy in a precise series of steps (NRCS 2007). This design approach is best applied using an interdisciplinary team and should not be attempted by practitioners unless they have received extensive training in the methods of fluvial hydrogeomorphology. In most cases, this approach will require that the landowner or conservation partner hire a qualified consultant to design and implement their stream improvement project. Major components of natural channel design are covered in detail in the web links listed below.

Natural Channel Design Information

- Natural Channel Design Review Checklist (Baker Engineering and Service 2008): http://www.fws.gov/chesapeakebay/pdf/Final%20NCD%20Review%20Checklist%20Document%201-23-08.pdf.

- Wildland Hydrology Reference Materials (David L. Rosgen website): http://www.wildlandhydrology.com/html/references_.html.

- A Natural Channel Design Handbook, North Carolina Stream Restoration Institute and North Carolina Sea Grant: http://www.bae.ncsu.edu/programs/extension/wqg/sri/stream_rest_guidebook/guidebook.html.

- Guidelines for Natural Stream Channel Design for Pennsylvania Waterways: http://www.keystonestreamteam.org/kst_guidelines2007.htm.

- Hydraulic Analysis for Stream Restoration Design, USACE: http://el.erdc.usace.army.mil/elpubs/pdf/eba08.pdf.

- Stream Habitat Restoration Guidelines, WDFW: http://www.wdfw.wa.gov/hab/ahg/shrg/index.htm.

- Stream Restoration Design, National Engineering Handbook, NRCS. Chapter 11, Rosgen Geomorphic Channel Design: http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/water/quality/?cid=stelprdb1043243

- Virginia Department of Conservation and Recreation, 2004. Virginia Stream Restoration and Stabilization Best Management Practices Guide: http://www.deq.virginia.gov/Portals/0/DEQ/Water/Publications/BMPGuide.pdf.

Links To Regional Curve Information

- Hydraulic Regional Curves for Selected Areas of the U.S: http://water.epa.gov/lawsregs/guidance/wetlands/upload/Appendix-A_Regional_Curves.pdf.

Natural Channel Design Software

- Rivermorph: http://www.rivermorph.com/.

- WinXSPro (a Channel Cross-section Analyzer from USDA, Forest Service): http://www.stream.fs.fed.us/publications/winxspro.html

Bioengineering Streambanks

Traditional engineering practices to armor streambanks that involve the use of "hard armoring," such as riprap and gabions, often transfer bank instability problems to another area of the stream (Li and Eddleman 2002). For this reason, we recommend the use of "soft armoring" when designing bank stabilization projects. Types of "soft armoring" approaches to streambank stabilization include (adapted from Gray and Sotir 1996):

1. Soil Bioengineering: using native plant materials and biodegradable fabrics to stabilize eroding stream banks.

2. Biotechnical Streambank Stabilization: Using a combination of native plant materials, biodegradable fabrics, wood, and rock to stabilize eroding streambanks.

Soil Bioengineering or biotechnical streambank stabilization are appropriate techniques to use in the following circumstances:

- Your stream assessment has revealed that the cause of bank failure is **not** due to an unstable channel bed or systemwide instability and that reduced sedimentation and bank restoration will result in habitat benefits.

- You are using this in combination with methods to stabilize an unstable channel bed.

- You need an emergency or temporary fix while a more comprehensive restoration project is designed.

Figure 32. Bioengineering technique, using soil lifts and brush layers, helps prevent erosion and lateral migration of meander along Holly Creek, in Georgia, during implementation (left) and two growing seasons later (right).

When a biotechnical method is determined environmentally compatible for a site, the stabilization effectiveness factors should include durability, adjustments to scour or subsidence, river depths, channel alignments, impact on flow lines, and impact on erosion upstream and downstream (Biedenharn et al.1997).

Limitations and Cautions

- In situations where the stream bed is unstable (degrading or aggrading) or there is systemwide instability, one should not attempt bioengineering solutions by themselves.
- Make certain to eliminate or greatly reduce human and animal trampling at the site in order to ensure survival of vegetation.
- Know your channel bank-full elevation in order to determine the appropriate elevation at which to begin installing plant materials. Woody vegetation establishment is essential for project success.
- Make sure that shallow or exposed bedrock is considered during design and will not affect your ability to install a biotechnical solution to streambank erosion.
- Transition the bank slope of the project site into nontreated banks both upstream and downstream to prevent end scour.
- Make certain that your project will redirect flows and lead to bank scour on adjacent properties.
- Piping of groundwater through streambank soils and excess surface runoff in the project area can impact the success of bank treatments and needs to be addressed in the design process.

- Consider impacts to native plant establishment from invasive exotic plants. Control invasive exotic plants prior to planting native vegetation.

Steambank Biostabilization Guides

- *Big River Bioengineering and Stabilization Techniques* (Mississippi Watershed Management Organization): http://www.mwmo.org/Riverbank_Practices_draft_May5_2008.pdf.

- *Environmentally sensitive channel- and bank-protection measures* (Transportation Research Board): http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_544.pdf.

- *Biodraw and ESenSS* (Salix Applied Earthcare): http://www.salixaec.com/.

- *National Engineering Handbook. Stream Restoration Design. Treatment Technique Design* (NRCS): http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/water/quality/?cid=stelprdb1044707.

- *Virginia Stream Restoration and Stabilization Best Management Practices Guide* (Virginia Department of Conservation and Recreation): http://www.midatlanticoceanresearchplan.org/virginia-stream-restoration-and-stabilization-best-management-practices-guide.

- *Integrated Streambank Protection Guidelines* (WDFW): http://wdfw.wa.gov/hab/ahg/ispgdoc.htm.

Figure 33. Dormant live cuttings ("live stakes") of willow and silky dogwood are stored in buckets containing water prior to planting.

Plant Materials

Woody plants used for soil bioengineering and biotechnical stream stabilization tend to be pioneer species whose characteristics include the ability to root from cuttings, to grow readily following planting, and to grow under harsh conditions (Polster 2003). Willow (*Salix* spp.) and shrub dogwood (*Cornus* spp.) are among the most commonly used plants. It is critical that **native** plant materials adapted to site conditions are used to ensure successful growth. If possible, collect seeds and cuttings from sites in similar local watersheds in order to preserve the genetic integrity of the local stock and to ensure the highest likelihood of success (Cramer et al. 2002).

Landphair and Li (2001) identify three limitations when using biotechnical methods: (1) the suitability and availability of plants, (2) applicability of biotechnical methods, and (3) construction timing. The survival rate of plant materials used in biostabilization is affected by handling, installation care, and weather. Soil conditions are an important consideration in assuring plant survival success, and it may be necessary to amend site soils with topsoil. It is important to note that plant materials take time to develop root tensile strength, thus leaving biotechnical stream stabilization projects vulnerable immediately after completion.

Biotechnical streambank stabilization should occur during plant dormancy although timing may be extended through the refrigeration of live stakes and seedlings, the use of vegetative mats, and the use of containerized seedlings. Practitioners are beginning to use older tree seedlings in buffer plantings due to a higher mortality of younger and bareroot seedlings. In addition, browsing wildlife can cause significant mortality of plantings; therefore, practitioners should use tree shelters (plastic tubing) or other methods to protect seedlings from predation if beaver, muskrat, deer, or other browsers are present or expected within the recently restored area. If weeds are a potential problem, biodegradable shade fabric (staked around the seedlings) can help reduce competition as does select mowing during the first few years. It may also be necessary to mechanically or chemically treat weeds and invasive grasses until seedlings become established. Mechanical removal should be the preferred management option for weed control in riparian restoration projects. If chemical treatment is the preferred option for weed control, the type, amount, and concentration of the chemicals should be carefully considered, and extreme care should be exercised to prevent chemical runoff to the stream.

Native Plant Material Information and Sources:

- Lady Bird Johnson Wildflower Center: http://www.wildflower.org.
- Natural Resource Conservation Service: http://plants.usda.gov/java/.
- Plant Native: http://www.plantnative.org/.
- North Carolina State University Stream Restoration Program Riparian Vegetation Resources: http://www.bae.ncsu.edu/programs/extension/wqg/srp/riparian.html.

State Native Plant Society websites:

- Alabama Native Plant Society: http://www.alabamawildflower.org/.
- Arkansas Native Plant Society: http://www.anps.org/.
- Florida Native Plant Society: http://www.fnps.org/.

- Georgia Native Plant Society: http://www.gnps.org/.
- Kentucky Native Plant Society: http://www.knps.org/.
- Louisiana Native Plant Society: http://www.lnps.org/.
- Mississippi Native Plant Society: http://www.mississippinativeplantsociety.org/.
- North Carolina Native Plant Society: http://www.ncwildflower.org/.
- Heliconia Society of Puerto Rico: http://www.heliconiasocietypr.org/.
- South Carolina Native Plant Society: http://www.scnps.org/.
- Tennessee Native Plant Society: http://www.tnps.org/.

Figure 34. Silky dogwood live stake, first growing season after planting.

State Forestry Resources Agency Websites:

- Alabama Forestry Commission: http://www.forestry.state.al.us/seedling_search.aspx?bv=5&s=0.
- Arkansas Forestry Commission: http://forestry.arkansas.gov/Seedlings/Pages/default.aspx.
- Caribbean Forestry Commission: http://www.fao.org/forestry/en/.
- Florida Division of Forestry: http://www.fl-dof.com/forest_management/seedling_sales_index.html.
- Georgia Forestry Commission: http://www.gfc.state.ga.us/Seedlings/Reforestation.cfm.
- Kentucky Division of Forestry: http://www.forestry.ky.gov/seedling/.
- Louisiana Department of Agriculture and Forestry: http://www.ldaf.state.la.us/portal/Offices/Forestry/Reforestation/SeedlingInventory/tabid/242/Default.aspx.
- Mississippi Forest Commission : http://www.mfc.state.ms.us/seedlings/index.htm.

- North Carolina Division of Forest Resources: http://www.dfr.state.nc.us/.
- South Carolina Forestry Commission: http://www.state.sc.us/forest/nur.htm.
- Tennessee Division of Forestry: http://www.agriculture.state.tn.us/available.asp.

Handling Plant Materials and Other Technical Information:

- Plant Material Selection and Acquisition (USACE Technical Note): http://el.erdc.usace.army.mil/elpubs/pdf/sr33.pdf.
- USACE Technical Note. Bottomland Hardwood Planting: Example Contract Specifications: http://el.erdc.usace.army.mil/elpubs/pdf/wgrs3-5.pdf.
- National Park Service. Planning a Native Plant Project: http://www.nps.gov/plants/restore/pubs/intronatplant/planning.htm.

Figure 35. Service biologists admiring live stake growth, Mitchell River, in North Carolina.

Resources for Invasive Exotic Plant Control and Eradication:

- Southeast Exotic Pest Plant Council: http://www.se-eppc.org/weeds.cfm/.
- University of Georgia Center for Invasive Species and Ecosystem Health: http://www.bugwood.org/.
- USFS, Nonnative Invasive Plants of Southern Forests: http://www.invasive.org/eastern/srs/.
- Invasive and Exotic Species of North America: http://www.invasive.org/.
- USFS, Fire and Nonnative Invasive Plants in the Southeast Bioregion: http://www.fs.fed.us/rm/pubs/rmrs_gtr042_6/rmrs_gtr042_6_091_112.pdf.
- USFS, A Management Guide for Invasive Plants in Southern Forests: http://www.treesearch.fs.fed.us/pubs/36915.

Geotextile Materials

The geotextile fabric used in streambank improvement projects should be selected based on its ability to biodegrade at a rate that coincides with the development of plant material root tensile strength. The use of a woven coir fabric in projects has advantages over nonwoven coir, jute, or straw erosion-control products, including high tensile strength and increased longevity, while remaining cost-effective and easy to install (Miller et al. 1998). In restoration, do not use any erosion-control blankets that contain netlike mesh made of plastic, polypropylene, nylon, or twine; they all have the ability to entrap or harm fish and wildlife (Barton and Kinkead 2005).

Figure 36. Coir (coconut fiber) blanket, used to create soil lifts--a biostabilization technique for streambanks.

Sources of Geotextile Materials and Information:

- International Erosion Control Association: http://www.ieca.org/.
- Rolanka International: http://www.rolanka.com/.
- FILTREXX: http://www.filtrexx.com/.
- REXIUS Erosion Control Systems: http://www.ecoberm.com/ecoblanket.htm.
- North American Green: http://www.nagreen.com/.

Wood in Streams

Large wood has been used for many reasons and with varying degrees of success throughout the history of stream restoration and habitat enhancement. While not all uses of wood in restoration or enhancement projects can be termed as successful, all can be considered experiments that serve as learning tools.

Figure 37. Large wood (root wads) stabilizes banks, creates habitat for macroinvertebrates, and provides cover for fish in this newly restored stream channel in McDowell County, North Carolina.

It should come as a surprise to no one that wood is a natural component of nearly all streams. What may be surprising is how much wood was historically in rivers and what a significant role it can play in shaping stream morphology and biological communities. A well-documented example is that of the Red River in Louisiana, which was unnavigable due to wood blockages for 300 to 400 years over a distance of approximately 300 miles.

Trees that die because of some type of disturbance and reach the stream mostly intact serve at least three roles in fluvial systems. First, large wood serves a role in controlling stream hydraulics and geomorphology (Thompson 1995, Abbe et al. 2003, Montgomery et al. 2003, Shields and Smith 1992). Second, wood provides substrate and habitat for aquatic biota, including: (1) low-velocity sites that shelter fishes during high-flow events, (2) escape habitat and more complex visual patterns to confuse predators, and (3) a matrix upon which macroinvertebrates can colonize or carry out part of their life cycle (Lehtinen et al. 1997). Third, wood and leaves provide nearly all the organic matter needed by microorganisms that form the base of the food web (Benke and Wallace 2003).

Figure 38. Log vanes aid in reducing scour along streambanks in Mitchell County, North Carolina.

Background Information and Decision Making

One must weigh the risk of incorporating various techniques against the benefits they provide. In any case, the first step should be a survey of the area and collection of information considering the following:

- Is the stream channel periodically "snagged" or cleared of its wood load?
- Are there significant areas of riparian forests upstream or within the project area that can act as a natural source of large wood? If so, what is the migration rate through the project area?
- Is there infrastructure downstream that would be at significant risk in the event that wood is mobilized by high flows?

If the stream is periodically snagged, the most useful action from the aspect of stream health would be to eliminate these practices before undertaking restoration. If snagging cannot be avoided, the project is unlikely to benefit from the use of wood except through employment of the most stable techniques (see Table 2 below). If snagging is not an issue, a second step is to determine if wood will be used for hydraulic reasons, for habitat, or both. A rule to remember is: as gradient decreases, the need to incorporate wood for stream structure and function increases (Benke and Wallace 2003). Stream order--a stream size classification based on the hierarchy of tributaries in a watershed--is a third consideration. In general, the higher the stream order (i.e., the larger the stream), the lower the probability that a wood structure will remain in place during

a high-flow event (Roper et al. 1998, Bisson et al. 2003). Quantifying the risks and success rates to stakeholders and decision makers is an important component of the process.

The best way to minimize risk in projects using large wood is to carry out appropriate engineering design calculations in order to ensure proper stabilization and anchoring of the structure or key pieces. For initial planning of the wood size needed for stability, Saldi-Caromile et al. (2004) provide a dimensionless plot of log length/bank-full width versus log diameter/bank-full depth. This publication also includes an appendix on the engineering design of log structures and is available online at http://wdfw.wa.gov/hab/ahg/shrg/. Fox and Bolton (2007) offer reference conditions for natural channel design that allows for variations in quantity and volume owing to differences in hydraulic geomorphology. Other references integrating large wood, hydraulics, and engineering design include Abbe et al. (2003), Hilderbrand et al. (1998), Mutz (2003), and Morris (2012). An engineering design firm experienced in stream restoration should be consulted if wood is to be incorporated in a design upstream of human infrastructure or if there are site constraints that make avulsions or large logjams unacceptable. Even in remote areas, the incorporation of engineering analyses can serve to ensure that all appropriate steps have been taken and help explain why a particular failure occurred.

Figure 39. Tree revetment installation along Brushy Creek in Kentucky.

Table 2. A comparison of common techniques using large wood for hydraulic and habitat considerations. Techniques and specific designs must be developed to meet site objectives and constraints. For additional information see Saldi-Caromile et al. 2004.

TECHNIQUE	MOBILITY/RISK TO INFRASTRUCTURE	OTHER CONSIDERATIONS	RELATIVE LONGEVITY AT A SITE	HABITAT COMPLEXITY VALUE	HYDRAULIC COMPLEXITY VALUE	BANK PROTECTION VALUE
LOG VANE AND CROSS VANE	LOW	EVENTUAL EROSION OF LOG, POTENTIALLY RESULTING IN FLOW ALTERATIONS	LOW TO MEDIUM	MEDIUM	HIGH	LOW TO MEDIUM
TREE REVETMENT	LOW	POTENTIAL FOR RAPID UNDERCUTTING AND MASS WASTING WHEN REVETMENT REACHES END OF USEFUL LIFE	HIGH	LOW	LOW	HIGH
VORTEX LOG	LOW	SCOUR INTO STREAMBANK, CAUSING BANK FAILURE	HIGH	MEDIUM TO HIGH	HIGH	LOW
ENGINEERED LOGJAMS	LOW TO MEDIUM	AVULSIONS AND SPAN BLOCKAGES CAUSED BY LARGE JAMS	MEDIUM TO HIGH	HIGH	HIGH	HIGH
TRASH RACKS	MEDIUM	AVULSIONS AND SPAN BLOCKAGES CAUSED BY LARGE JAMS	HIGH	HIGH	HIGH	LOW TO HIGH

LARGE WOODY DEBRIS NETS AND FENCING	MEDIUM	POTENTIAL FOR RAPID DECAY OF NET OR FENCE MATERIAL	MEDIUM	HIGH	HIGH	LOW TO HIGH
LOOSE WOOD PLACEMENT	HIGH	CAN SERVE AS HABITAT FOR AMPHIBIANS DURING BASE FLOW	LOW	MEDIUM	LOW	LOW

Additional information on large wood placement, restoration, and management is located at the following websites:

- Streambank Habitat Enhancement with Large Woody Debris: http://el.erdc.usace.army.mil/elpubs/pdf/sr13.pdf.
- Tree Revetment for Streambank Stabilization: http://www.mdc.mo.gov/fish/streams/revetmen/.
- Anchoring and Placement of Large Woody Debris: http://www.wdfw.wa.gov/hab/ahg/ispg_app_i_anchoring.pdf.
- Managing Wood in Streams: http://lwa.gov.au/files/products/river-landscapes/pr030531/pr030531.pdf.
- Woody Debris Management: http://projects.geosyntec.com/NPSManual/Fact%20Sheets/Woody%20Debris%20Management.pdf.
- Large Woody Debris in Streams: http://www.dnr.state.oh.us/water/pubs/fs_st/stfs21/tabid/4176/Default.aspx.
- The Use and Design of Soil Anchors, NRCS: http://www.irrigationtoolbox.com/NEH/Part%20654/TECHNICAL-SUPPLEMENTS/TS14E.pdf.

Aquatic Organism Passage

"Long-term conservation of fish resources will depend not only on passage for both adult and juvenile fish but also on maintenance of healthy stream and river ecosystems. Essential to this approach is a focus on habitat quality and strategies for aquatic organism passage based on communities rather than individual species" (Jackson 2003).

Migratory and resident fish need unimpeded access within rivers and their tributaries for spawning and rearing, to colonize available habitat, and to seek thermal and chemical refuge (Coffman 2005). In addition to blocking the upstream passage of fish, barriers also disrupt the in-stream movements of some aquatic macroinvertebrates (Vaughan 2002), particularly freshwater mussels. Mussels disperse as specialized larvae (or glochidia) attached to the gills or fins of a host fish, upon which they are obligatory parasites. Barriers fragment habitat and populations and disrupt gene flow and recolonization dynamics after local extirpations (Coffman 2005). Physically, barriers tend to disrupt stream flow, sediment transport, and thermal regimes. They also result in channelization, erosion, and sedimentation within the stream corridor.

The focus of this section is on human-caused barriers to aquatic organism movement rather than those that are natural barriers (e.g., waterfalls, cascades, beaver dams). While certain barriers that fragment rivers, such as dams, are well studied, others (including weirs, ramps, culverts, and road bridges) remain poorly documented (Peter 1998). A national database showing the location and description of dams is maintained by the USACE and is available at http://geo.usace.army.mil/pgis/f?p=397:1:0. In addition, the Service's National Fish Passage Program maintains an online application called the Geospatial Fisheries Information Network, which makes available to the public a comprehensive national inventory of stream barriers (e.g., dams, culverts) collected from multiple sources and is available at http://ecos.fws.gov/geofin/.

The following human structures or activities may present a problem to the movement of aquatic organisms, may impact in-stream and riparian habitat, and should be considered for removal or modification (NRCS 2010):

- Low-water crossings (for humans and livestock).
- Culverts and bridges.
- Tide and flood gates.
- Dams.
- Water withdrawal and diversions that dewater channels.
- Utility lines (e.g., water, sewer)

While it is generally documented that most unmodified human-made dams likely constitute barriers to aquatic organism passage, little work has been done to assess and identify other artificial structures (e.g., culverts) that also may constitute a barrier to aquatic organism passage in Southeastern streams. This section will focus on road crossings that impede passage.

Types of Barriers to Aquatic Organism Passage Created by Road Crossings

There are many barriers to aquatic organism passage resulting from road or driveway construction across streams (Figures 40 through 47). The cumulative impact of barriers on aquatic resources can be significant. Barriers to fish movement lower in the watershed generally have greater impacts to migratory fish. Barriers may be considered partial (i.e., impassable to some species or age classes all or most of the time), temporary (i.e., impassable to all or most species age classes during periods of low water), or complete (i.e., impassable to all species at all times) (NRCS 2007).

Figure 40. Examples of crossings with insufficient water depth.

Figure 41. Excessive water velocity due to the culvert being undersized compared to stream bank-full width. Culvert slope can also increase stream velocity.

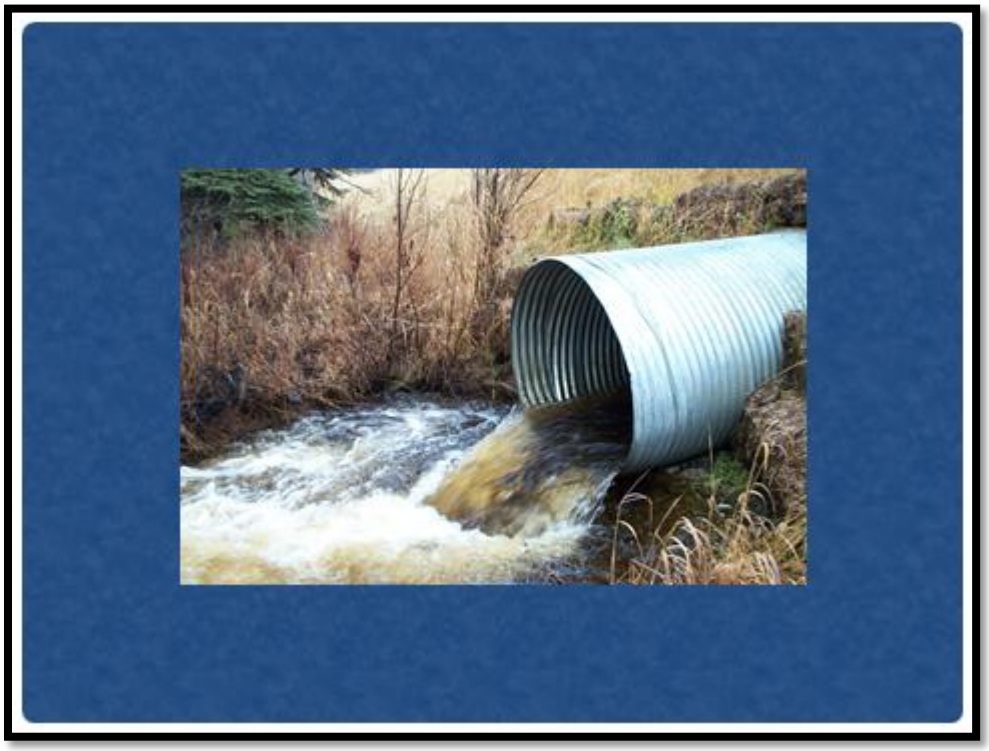


Figure 42. Debris accumulation upstream of culverts presents a barrier to aquatic species.

Figure 43. This crushed culvert is in the process of failing. Failure will result in additional impacts to in-stream habitat caused by the culvert's bedding washing downstream, especially through sedimentation.

Figure 44. A perched culvert outlet (right) and steep inlet drop (left) present passage problems for aquatic animals.

Figure 45. A shallow jump pool presents problems for fish trying to move upstream stream reaches.

Figure 46. Inadequate resting areas and artificial darkness can present a barrier to aquatic species.

Figure47. The lack of a forested buffer results in an increase in stream temperatures, which impacts the movement of certain aquatic species (left); chemicals and nutrients that may be discharged in association with improperly treated wastewater may also present a barrier to the movement of aquatic species (right).

Barrier Inventory and Assessment Guidelines at Road/Stream Crossings

The "National Inventory and Assessment Procedures for Identifying Barriers to Aquatic Organism Passage at Road-Stream Crossings" (USFS 2005), is available at http://www.stream.fs.fed.us/publications/PDFs/NIAP.pdf.

In the Southeastern United States we recommend using the modified upstream predictive models developed by Coffman (2005) to identify barriers to small-bodied fish movement. This information is available at the following websites:

- http://www.fws.gov/southeast/fisheries/SEFishPassage/coffman_exec_summary.pdf.
- http://www.fws.gov/southeast/fisheries/SEFishPassage/USDA_SRS_CATT_culvert_report2005.pdf.

Design Standards for Small Road Crossings - Southeast Region

The degree to which upstream movement is impaired for aquatic species depends on those physical characteristics of a culvert that influence jump, velocity, exhaustion, depth, and behavioral barriers (Coffman 2005). Unfortunately, limited research has been done to determine what limits of those physical characteristics constitute a barrier to the movement of native resident fish and aquatic macroinvertebrates in the Southeastern United States (see the following website at http://www.fws.gov/southeast/fisheries/SEFishPassage/).

Streams are dynamic systems that respond to environmental changes and seek stability through channel adjustment. The impact from road crossings to stream-channel morphology and aquatic resources can be significant. Therefore, the best option for road-crossing design is to avoid or remove the crossing entirely or reduce the number of crossings at a particular site. Properly sized spanning structures (e.g., bridges or bottomless culverts) should provide for the passage of aquatic species and accommodate the movement of debris and bed material. Furthermore, spanning structures usually can be constructed with minimal in-stream impacts, do not require stream channel realignment, retain the natural streambed conditions, and the horizontal and vertical clearances may be designed to allow for human and wildlife passage beneath the structure.

When designing a culverted road crossing, stream simulation is an approach that should ensure the passage of all aquatic organisms while minimizing impacts to the physical characteristics of the stream channel. The USDA, Forest Service, has a manual (*Stream Simulation: An Ecological Approach to Providing Passage for Aquatic Organisms at Road-Stream Crossings)* available at http://stream.fs.fed.us/fishxing/aop_pdfs.html.

The following websites contain guidelines and additional information about stream simulation:

- Service, Athens Field Office, Georgia: http://www.fws.gov/Athens/stream_crossing/.
- Washington Department of Fish and Wildlife: http://wdfw.wa.gov/publications/01501/.
- Federal Highway Administration: http://www.fhwa.dot.gov/engineering/hydraulics/pubs/07033/index.cfm.
- NRCS: http://directives.sc.egov.usda.gov/viewerFS.aspx?id=3491.

Where to go for technical and/or financial assistance:

- Federal Highway Administration: http://www.fhwa.dot.gov/.
- State Transportation Websites: http://www.fhwa.dot.gov/webstate.htm.
- Other Federal Agencies (NRCS, USFS, NPS).
- Local Government/Public Works Departments.

Materials and sources (bridges and culverts):

- Big R Manufacturers, Inc.: http://www.bigrmfg.com/.
- Contech Construction Products, Inc.: http://www.contech-cpi.com/.
- Paragon Railcar Salvage: http://www.prsx.com/index.html.
- Atlantic Industries: http://www.ail.ca/EN/.
- York Prefabricated Timber Bridges: http://www.ybc.com/bridges/timber-prefabricated-bridges/about/.

Road-crossing cautions and considerations (adapted from British Columbia Ministry of Forests 2002):

- There is the potential for large woody debris and other trash to accumulate behind the crossing and cause failure.

- If the culvert rise is higher than the current road elevation, a bridged crossing may be required.

- When considering using a retired railroad car, make sure it will meet state Department of Transportation and the American Association of State Highway and Transportation Officials (AASHTO) standards for the crossing if installation will occur on a public road. Railroad cars are often more appropriate for private drives.

- Consider vehicles (size and tonnage) that will need to use crossing (if private, consider oil or gas delivery, emergency vehicles, or other).

- Concrete abutments may take significant time to cure and result in extended road closings.

- Road closures will impact residents during bridge and abutment construction and culvert installation. Identification of an alternative route may be required for foot or vehicular traffic during project construction.

- Bridged crossings are generally more expensive than culverted crossings.

- Construction monitoring is essential to ensure project success.

- Ensure engineered designs receive engineer approval and meet state standards for road crossings.

- Crossings should be constructed in riffle reaches (where lateral migration of the channel will be minimal) and should cross perpendicular to the stream.

- Heavy equipment should operate from outside the active channel to the maximum extent possible.

- Do not allow side ditches to discharge directly into the stream. Divert ditch water into a constructed sump or, where possible, onto stable vegetated areas that can filter sediments prior to entering the active stream channel.

- Wet concrete should not be allowed to contact the stream or any other water that has the potential to enter the stream. Uncured concrete or grout can kill aquatic organisms by altering the pH of receiving waters. Precast concrete and carefully protected grout should

be used to eliminate the risk to aquatic species. If cast-in-place concrete is required, all work should be done "in the dry," and the site should be effectively isolated from any water that may enter the stream for a minimum of 48 hours.

- Measures to control sediment and erosion should be in place prior to beginning construction.

- Equipment used should be washed and free of pollutants, in good working order, and inspected for leaks prior to construction.

- The removal of vegetation from riparian and floodplain areas should be minimized to the maximum extent possible. Ground-disturbance areas should be revegetated immediately, using native grasses, annual cover crops, vegetative mats, and woody vegetation seedlings.

- If temporary access roads or detours are constructed, they should be returned to their original ground elevations and revegetated immediately upon project completion.

- Construction should be timed to occur during low-water events for a particular channel. Stream-flow data is available online from the USGS at: http://waterdata.usgs.gov/.

- Bottomless culverts should be installed according to the potential maximum depth of scour associated with the natural stream bed in order to prevent the undercutting of footings.

- The barrel of closed-bottom structures should be set to the appropriate depth below the streambed (based on scour potential) and at the same natural stream gradient as shown by the longitudinal profile survey. The culvert foundation, trench walls, and backfill should be free of logs, stumps, limbs, or rocks that could damage or weaken the pipe.

- Temporary stream diversions should always be excavated in isolation from the stream flow, starting from the bottom end of the diversion channel and working upstream in order to minimize sediment production. To prevent the loss of sediment, the bottom end of the diversion channel should be left intact until the trench is almost complete; it should not be opened until all measures have been taken to reduce surface erosion resulting from the channel. After the stream crossing has been completed, the diversion should be closed from the upstream end first and, on completion, actions should be taken to reestablish the prediversion conditions and to stabilize and revegetate the site.

- Where practical, water can also be pumped across the work site and discharged into the stream channel below the site. This technique requires the stream to be dammed above the construction site. This eliminates the need for a diversion channel, greatly reducing the problems of sediment production associated with digging and operating a newly created stream channel. Pump intakes should be screened to prevent the entrainment of fish. On-site backup pumps are highly recommended in all pumping situations.

STREAM HABITAT IMPROVEMENT IMPLEMENTATION

A number of guidelines are available on the web, and some of these provide step-by-step guidance to practitioners about stream improvement projects from planning through project implementation and monitoring:

- Natural Stream Channel Guidelines for Pennsylvania Waterways: http://www.keystonestreamteam.org/kst_guidelines2007.htm.
- Stream Habitat Restoration Guidelines, Washington Department of Fish and Wildlife: http://wdfw.wa.gov/hab/ahg/shrg/index.htm.
- NRCS Stream Restoration Design, National Engineering Handbook: http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/water/quality/?cid=stelprdb1043243.
- The Virginian Stream Restoration and Stabilization Best Management Practices Guide: http://www.deq.virginia.gov/Portals/0/DEQ/Water/Publications/BMPGuide.pdf.

Permits and Compliance

Partners for Fish and Wildlife Program Policy

All Service program projects must comply with all federal laws, regulations, and policies. Program projects must also comply with any applicable state, local, and tribal laws and regulations that do not conflict with, or are not preempted by, federal laws and regulations.

More information and detail about policy and compliance with federal laws and regulations is available through the PFW Program website at http://www.fws.gov/policy/640fw1.html.

The Service website containing the Endangered Species Consultation Handbook is available at http://www.fws.gov/endangered/esa-library/index.html#consultations.

The Service website for the National Environmental Policy Act guidance is available at http://www.fws.gov/habitatconservation/nepa.html.

One critical step in the process of preparing to implement a stream improvement project is identifying and securing the appropriate permits needed before work begins. This process usually occurs once you have a project design or conceptual plan. Be aware that regulations may vary from state to state. Make sure you or your project partners contact state regulatory agencies and check with local governments to determine which permits are required for your project.

Applicable acts, programs, authorities, and permits can include the following (NRCS 2007):

- National Environmental Policy Act.
- Endangered Species Act.
- National Historic Preservation Act.
- Wild and Scenic Rivers Act.
- Fish and Wildlife Coordination Act.
- Federal Insecticide, Fungicide, and Rodenticide Act.
- Clean Water Act.

- Executive Order 13112, 1999: Invasive Species.
- Rivers and Harbors Act of 1899.
- Magnuson-Stevens Fishery Conservation and Management Act.
- Local and state water quality permits.
- Water rights.
- National Flood Insurance Program.
- Local and state flood permits.
- Local zoning permits.

Additional information on permitting stream improvement projects is available through the NRCS at http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17777.wba.

A Stormwater Pollution Prevention Plan (SWPPP) should be developed for each project to help minimize impacts within the stream corridor during and after project construction. A great resource to aid practitioners in the development of the SWPPP is available through the Environmental Protection Agency's website at: http://www.epa.gov/npdes/pubs/sw_swppp_guide.pdf.

Local permits may be required, depending on the county or city in which you are working. Usually these are associated with floodplain ordinances. If projects are located in a Coastal Zone Management (CZM) area, be certain to check with state and local officials to make sure projects are in compliance with their regulations. Additional information on CZM areas is available at: http://www.boemre.gov/eppd/compliance/czma/index.htm.

Appendix D provides additional web links to regulatory information resources by state in the Southeast Region.

Construction

Plans, specifications, and cost estimates:

A set of final construction plans should be prepared that typically includes:

- Title sheet with vicinity map and general notes.
- Construction baseline and geometry.
- Plan and profile sheets.
- Typical cross sections.
- Detailed cross sections.
- Construction details and notes for any specialized structures.
- Utility plans for any pipeline, buried cable, sewers, etc., within the limits of construction disturbance.
- Planting plan, details, and notes.
- Construction sequence.
- Erosion- and sediment-control plan, details, and notes.

Special provisions should be prepared that provide details on materials, construction methods, and tolerances for specialized stream improvement techniques and structures. Cost estimates should be developed for the project, using local pricing.

Construction and post-construction:

1. **Assist with Bidding -** Upon completion of the design plan, the project moves into the construction phase. The sponsor agency can provide assistance to the landowner for the solicitation of a qualified contractor to perform the work. Many Service field offices and state resource agencies maintain a list of contractors qualified in natural channel design methods. For projects that require specialized expertise in stream rehabilitation practices, it is advisable to prequalify contractors.

   As a lead agency, the Service's PFW biologists are responsible for responding to requests for information from potential contractors, showing them the site if requested; for reviewing proposals to ensure that the contractor will be able to implement the project as designed; and for attending preconstruction conferences.

2. **During Construction Inspection -** A stream improvement expert should provide project implementation monitoring oversight and inspection services during construction. Even with the best-designed plans, changes in stream conditions between survey and construction or the natural variability of stream channels may create conditions that require adaptive management. The design engineer or other qualified lead agency personnel should provide guidance as to the construction of specialized structures and provide day-to-day verification that the intent of the stream restoration design is achieved.

3. **Post-Construction Monitoring -** All projects should include post-construction monitoring in order to evaluate how well the stream restoration plan has achieved the design goals. Monitoring can include geomorphic or hydraulic measurements to evaluate the design, surveys to evaluate improvements to habitat (e.g., benthic surveys), and post-construction monitoring of vegetation survival.

Monitoring Projects

The PFW policy has established a requirement that all habitat improvement projects carried out through the PFW Program include a monitoring component to document the success of project implementation. Additionally, monitoring information collected should be included in the PFW Habitat Information Tracking System (HabITS) and in compliance with PFW guidelines and definitions (see Appendix A for details).

Additional monitoring and assessment resources:

- Center for Watershed Protection: http://www.cwp.org/.
- EPA: http://water.epa.gov/type/watersheds/monitoring/index.cfm.
- NRCS: http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17776.wba.
- USFS: http://www.stream.fs.fed.us/publications/PDFs/RM245E.PDF.

- WDFW: http://wdfw.wa.gov/hab/ahg/shrg/29-shrg_monitoring.pdf.
- North Carolina State University: www.bae.ncsu.edu/programs/extension/wqg/sri/stream_rest_guidebook/guidebook.html.
- Wildland Hydrology: http://www.wildlandhydrology.com/html/references_.html.

Estimating Project Costs

One challenge in the development of a stream improvement project is to accurately estimate total project cost. Types of expenses to consider that can be funded with PFW funds include project administration, preconstruction engineering, construction oversight and management, project construction, implementation, monitoring, and maintenance.

Several tools are available to assist in estimating project costs. One excellent resource to help address this issue is the NRCS's state cost-share lists, which may be obtained on the web or through your NRCS State Office. These lists, available for the Environmental Quality Incentives and Wildlife Habitat Incentives Programs, should provide an average cost, broken down by the practice level, for many activities one might encounter. These cost lists should be used as a template, considering most projects vary somewhat based on distance to material, size and type of equipment needed, experience of operator, etc.

Cost-share lists for each state may be located through the following NRCS conservation program web links:

- Alabama: http://www.al.nrcs.usda.gov/programs/.
- Arkansas: http://www.ar.nrcs.usda.gov/programs/.
- Caribbean: http://www.pr.nrcs.usda.gov/programs/.
- Florida: http://www.nrcs.usda.gov/wps/portal/nrcs/main/fl/programs/.
- Georgia: http://www.ga.nrcs.usda.gov/programs/.
- Kentucky: http://www.ky.nrcs.usda.gov/programs/.
- Louisiana: http://www.la.nrcs.usda.gov/programs/.
- Mississippi: http://www.ms.nrcs.usda.gov/programs/.
- North Carolina: http://www.nc.nrcs.usda.gov/programs/.
- South Carolina: http://www.sc.nrcs.usda.gov/programs/.
- Tennessee: http://www.nrcs.usda.gov/wps/portal/nrcs/main/tn/programs/.

Other state and federal agencies, local conservation organizations, and consulting firms may also provide information on stream improvement project costs. It is important to note that costs for stream improvement activities can vary greatly from state to state.

The North Carolina Ecosystem Enhancement Program (NCEEP) has provided information related to stream restoration costs as they relate to mitigation, and this information may be useful in estimating project costs.

Figure48. Breakdown of expenses for NCEEP stream restoration projects in 2006.

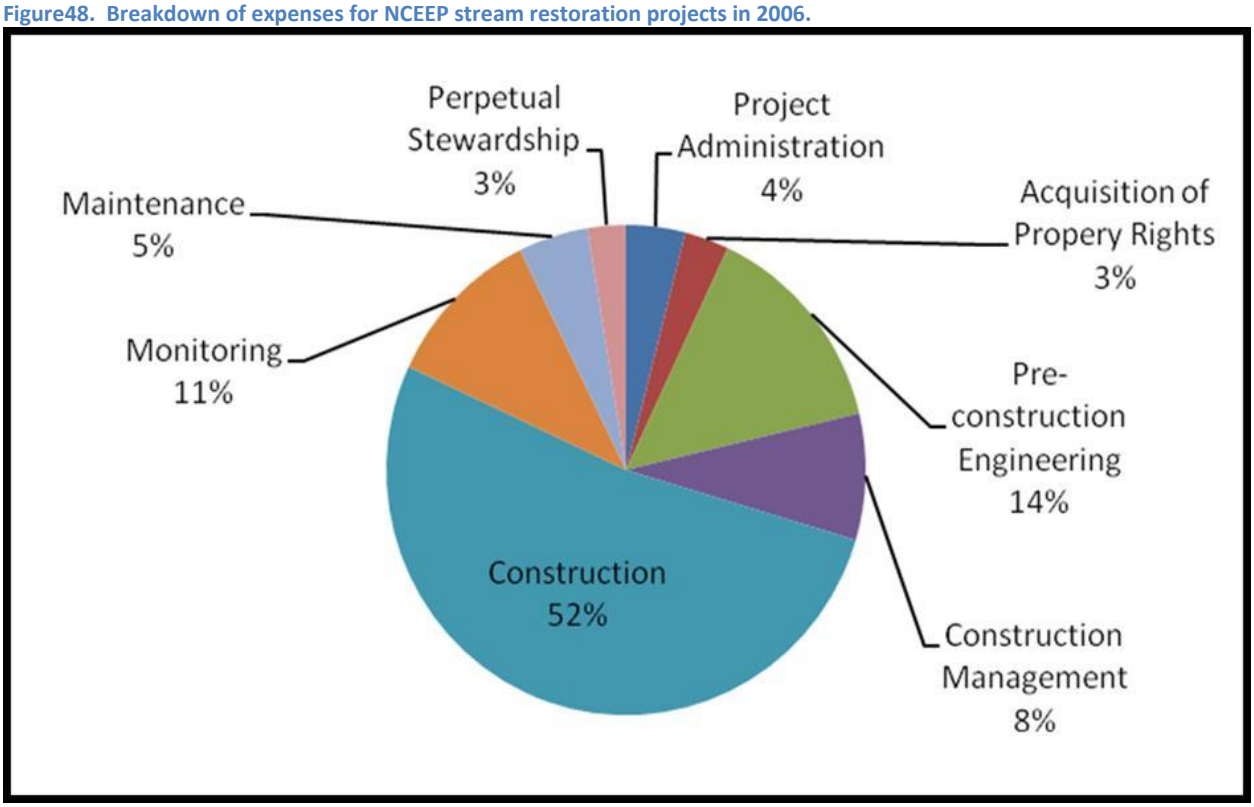


Table 3. NCEEP project total expenses, actual length of modified stream, and expense per linear foot of design-build and design-bid-build projects for stream mitigation by location (Templeton et al. 2008).

Variable	All Projects (n=45)	Urban Projects	Rural Projects
Total Expenses (2006 $)	$46,343,525	18,338,967	28,004,558
Length of Restoration/Enhancement (linear foot)	191,374	64,347	127,027
Expense per linear foot	$242.16	$285.00	$220.46

Construction Costs

Several main factors influence construction costs, including access to a site, excavation and earth-moving requirements, stream size and condition, project length, project constraints (e.g., adjacent development, utilities), bioengineering methods used, mobilization costs, and weather. Recent published data on the cost of stream improvement is sparse. We have included information for practitioners to generally estimate construction costs in Appendix D and the following web links:

- EPA Evaluating the Cost-Effectiveness of Restoration: http://water.epa.gov/type/watersheds/archives/chap5.cfm.
- Inflation Calculator: http://www.bls.gov/data/inflation_calculator.htm.

LEVERAGING FUNDS FOR STREAM IMPROVEMENT PROJECTS

According to PFW Program policy, the goal of the PFW Program is to match at least 50 percent of the project costs, including cash and in-kind services, from non-Service sources. Due to the potentially high costs of stream improvement projects, coupled with PFW Program funding limitations, in most cases PFW Program biologists will need to leverage funding from other sources, such as those provided by state fish and wildlife agencies, conservation districts, and private conservation groups. Various obstacles, including funding cycles, program objectives, and eligibility requirements, are expected to present challenges that should be evaluated carefully in order to ensure compatibility with the PFW Program. It is important to note that sources will vary from state to state. Below are potential sources of matching funds.

Federal Funding

A comprehensive website that lists grant opportunities with the federal government is available at:

www.grants.gov/

The online Catalog of Federal Domestic Assistance provides access to a database of all federal programs available to state and local governments; federally recognized Indian tribal governments; territories (and possessions) of the United States; domestic public, quasi-public, and private profit and nonprofit organizations and institutions; specialized groups; and individuals. This database is available at: https://www.cfda.gov/.

Federal programs that may be a source of leveraged funding for stream improvement projects:

- NRCS Conservation Programs: http://www.nrcs.usda.gov/programs/.
- Farm Service Agency Conservation Programs (e.g., CRP, GRP, CREP): http://www.fsa.usda.gov/FSA/webapp?area=home&subject=copr&topic=landing.
- EPA (Federal Funding Programs): http://www.epa.gov/owow/funding/federal.html.
- EPA (Water Grants and Funding): http://water.epa.gov/grants_funding/.
- Service Programs (e.g., PFW Program, Coastal Program, North American Wetlands Conservation Act, Fish Passage, Cooperative Endangered Species Conservation Fund): http://www.fws.gov/grants/.
- NOAA, Fisheries Restoration Center (Fish America Foundation): http://www.habitat.noaa.gov/funding/southeast.html.
- USACE (e.g., Water Resources Development Act/Programmatic Authority: Section 22, Section 206, Section 1135, Section 204):

http://planning.usace.army.mil/toolbox/guidance.cfm?Option=BL&BL=EcosystemRestoration&Type=None&Sort=Default.

- USFS (Forest Legacy Program): http://www.fs.fed.us/spf/coop/programs/loa/aboutflp.shtml.
- Catalog of Federal Funding for Watershed Protection: http://cfpub.epa.gov/fedfund/.
- Directory of Watershed Resources: http://efc.boisestate.edu/Default.aspx?alias=efc.boisestate.edu/watershed.
- USGS (Water Resources of the United States): http://water.usgs.gov/.

State and local conservation organizations may offer different opportunities for funding stream improvement and conservation projects. Appendices E and F provide examples of state-administered and nonprofit conservation programs and associated websites for each state in the Southeast.

SERVICE STREAM TEAM AND CONTACT INFORMATION

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- Laura Fogo, U.S. Fish and Wildlife Service, Sandhills Suboffice, 140-A Southwest Broad Street, Southern Pines, North Carolina 28388; Phone: 910-695-3323; Email: Laura_Fogo@fws.gov.

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- Robin Goodloe, Ph.D., U.S. Fish and Wildlife Service, Athens Field Office, 105 West Park Drive, Athens, Georgia 30606; Phone: 706/613-9493; Email: Robin_Goodloe@fws.gov.

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- Chris Metcalf, U.S. Fish and Wildlife Service, Panama City Fisheries Resource Office, 1601 Balboa Avenue, Panama City, Florida 32405; Phone: 850/769-0552; Email: Chris_Metcalf@fws.gov.

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APPENDICES

APPENDIX A: Partners for Fish and Wildlife Program Project Monitoring Guidelines, Southeast Region

This policy guidance establishes a requirement that all habitat improvement projects carried out through the Partners Program shall include a monitoring component to be included in our Habitat Information Tracking System (HabITS), and in compliance with the following guidelines and definitions.

Overview

Monitoring of Partners Program habitat improvement projects in the Southeast Region will focus on achieving the following goals:

- Improve Program delivery, customer satisfaction and overall Program accountability;
- Improve project implementation and to assess whether projects were carried out according to the habitat improvement plan;
- Document and demonstrate success of PFW Program projects based on defined habitat factors that have been described as necessary for conservation of focal species;
- Evaluate the effectiveness of specific habitat improvement practices, and enable Program staff to learn from each project relative to implementing changes in future projects; and,
- Identify long-term information and research needs. This monitoring process is designed to meet these goals with minimal staff time and cost. As such, this process focuses on working with our partners to develop and pursue specific monitoring efforts, and using the information found in existing studies and published reports and other literature to help test and support our assumptions that specific habitat improvement efforts provide benefits to targeted fish and wildlife species.

To help us ensure that we are delivering the right conservation actions in the right places on the landscape, we are directed to work closely through our Landscape Conservation Cooperatives (LCCs) and Climate Service Centers (CSCs) as they become operational, as well as our many external partners as we apply the Strategic Habitat Conservation (SHC) process. We must continue to address and strive to improve our project accountability if we expect to continue to receive funding support for our conservation delivery efforts. We must continue to work with all of our partners to document and demonstrate that our conservation delivery efforts are successful in meeting stated species and habitat goals and objectives. We must also strive to document and clarify our shortcomings and information needs through an adaptive management approach, and collaborate and work closely with our partners to help us address these needs.

Most of us that are actively involved with conservation delivery recognize that our current internal capacity to develop and carry out the level of monitoring and research that is needed is lacking. We currently lack the capacity to address and answer many of the specific questions that address future climate change impacts and species and habitat biological information needs and outcomes that are positively affected by our conservation delivery efforts. The future implementation of the LCCs and CSCs, and a comprehensive monitoring strategy for the National Wildlife Refuge System, are intended to help address this shortcoming, and it will be essential that everyone in the PFW Program become actively engaged in an effective and appropriate manner with the establishment and operation of the LCCs, CSCs, and Refuge monitoring protocols.

Developing and implementing a scientifically sound monitoring plan that addresses the biological outcome questions that need to be answered is a challenging and difficult task. You should consider the following information in developing a monitoring plan, realizing that our lack of capacity and other environmental factors that we cannot control must be considered.

You should view the information below from the viewpoint of combining approaches to best meet your needs in the most cost-effective and efficient way possible.

♦ **Species-level monitoring—**seeks to detect changes in the status and/or trend in the presence, abundance, or occupancy of selected priority or focal species linked to our specific on-the-ground conservation actions. Although this type of monitoring may be the most desirable, it may not always be appropriate due to the many environmental factors that cause variability (potential interpretation errors) in species population data, the costs associated with this type of monitoring, and the long periods of study time that are typically needed to address the variation errors in the data.

Species monitoring may be more feasible and cost effective in the following situations:

- Plant species or other species that are rare, but are known to be restricted to just a few sites within the geographic area of interest.
- Conspicuous species that can be easily monitored.
- Species that are not found in the study area, but are intentionally introduced.
- Species that have been or have ongoing monitoring efforts being carried out by one or more of our partners.
- An imperiled species that is determined to be of such a high priority due to pending extinction issues that it must be intensively monitored.

♦ **Habitat-based monitoring---**the focus is on monitoring environmental features that are thought to control the distribution and abundance of the target or focal species. This approach is based on assumptions that are supported by the use of habitat suitability or other habitat models and the existing scientific literature. Thus, habitat-based monitoring assumes that changes in the configuration or quality of habitat relative to the life needs of the designated target or focal species would be reflected in changes in the species. Although specific assumptions may not be validated for specific species, this approach can provide

information that helps us understand the link between our management actions and improvements to the habitat that should benefit certain species or groups of species.

- **Threats-based monitoring---**This approach also depends on assumptions that may use models and are supported by scientific information found in the literature or other sources. Attention is focused on the possible underlying causes of potential decline of species and/or habitat components. For example, the specific threats that are documented in a species recovery plan would be addressed and monitored, with an assumption that if the threat or threats are removed, the species would benefit. Climate change is a type of threat. Species vulnerability assessments that document and provide scientific information regarding the specific vulnerability of species and groups of species to climate change would provide us with useful examples of specific criteria that should be included in a monitoring plan.

- **Ecosystem-based monitoring---**This involves parameters related to the spatial configuration of major community types that are important indicators of changes to the distribution of species. Parameters include land cover and land use types and fragmentation information. Models and GIS data sets at the landscape-scale being developed to address climate change issues and impacts should be helpful in making decisions about what to include in your monitoring plan.

There are numerous factors that must be considered when developing and carrying out a monitoring plan. Further, there is no model or suite of criteria that will meet our needs in every situation. The overarching goal of our monitoring approach and partnerships is to design and carry out monitoring that will detect changes in the status and trend for selected focal species and habitats, and provide us with a documented measure of accountability and success of our habitat improvement conservation delivery practices and will also provide us with scientifically sound information for adaptive management. Development and implementation of monitoring plans will be a work in progress, and we should apply adaptive management in continuing to refine our approach as we move forward.

All Partners Program monitoring plans should include the following information:

- Address the four categories of monitoring (i.e., Baseline, Implementation, Effectiveness, and Validation monitoring).

- For each monitoring category, identify and define the specific tasks to be completed and the estimated time frames for completion of each task.

- Identify and discuss the role of the Service and our partners in developing and implementing the specific tasks identified in the Plan.

- Identify the target or focal species and related population, habitat, or other criteria that will be monitored. Baseline monitoring should include those monitoring criteria that you expect to follow throughout the scope of the monitoring plan. Only monitoring criteria that are feasible to obtain and can be reasonably measured should used.

- Provide rationale as to why the selected species and monitoring criteria were chosen.

- Identify any information gaps or anticipated obstacles that would preclude or limit our ability to carry out the Plan at the desired level.

- Provide ideas or recommendations as to how noted limitations can be effectively reduced or eliminated.

Definitions

The following definitions are applicable to this process:
Monitoring: The collection and assessment of repeated observations and measurements over time to evaluate the effectiveness of specific habitat improvement actions.

Types of Monitoring

- **Baseline:** Characterizes existing conditions before a project begins. Baseline monitoring establishes the benchmark against which the success of a project can be measured and evaluated. (Applicable to all Partners projects)
- **Implementation or Compliance:** Assesses whether project activities were carried out according to the habitat improvement plan. (Applicable to all Partners projects)
- **Effectiveness:** Evaluates whether the project had the desired effect on the selected resource indicators. For example, a post-survey review documents that changes from the baseline condition in the stream pool depth occurred after placement of large, woody debris in the stream.
- **Validation:** Attempts to establish a cause-and-effect relationship between the implementation of the project and specific habitat practices, and the selected biological responses and indicators. For example, did the planting of trees and shrubs lead to an increase in the population of black bears; or, did a specific mussel population increase following specific in-stream restoration actions?

Validation monitoring can be the most costly and involved, as it tends to move into the realm of "research," and may require long periods of data collection and analysis to address cause-and-effect relationships. Also, such validation efforts often result in additional questions and the need for additional studies. For the Partners Program, validation monitoring that would involve extensive and long-term data collection and analysis will not be conducted in most situations.

To fully address our monitoring needs, we will need to work closely with our partners, but will also rely on site-visit observations and references to other published scientific studies and reports to support our assumptions regarding cause-and-effect relationships and biological responses related to the success and benefits of projects to specific species or groups of species. In some situations, the Service and our partners may collectively agree to share funding and technical assistance resources to evaluate the benefits of specific habitat improvement practices or groups of similar projects and practices within a specific watershed (e.g., specific populations of protected mussels and fishes within a specific watershed). To monitor and scientifically evaluate/validate such information would require data collections, analyses and evaluations on

both the study sites and designated reference areas, and would require data from multiple years to address any real changes in biological responses and population status.
The Partners Program may choose to be a partner in a limited number of such efforts, thereby providing technical assistance and/or financial assistance to the effort. However, it is important for us to weigh the costs and benefits to be obtained from such efforts with our goals of assisting private landowners in carrying out on-the-ground habitat improvement practices that are typically recognized as being beneficial to fish and wildlife resources.
The information that may be gained from these partnership approaches to validation monitoring, or from the published results of other studies not directly supported by the Service, should be used in our adaptive management approach (i.e., revise our practices as new information becomes available to us), and to support or modify our assumptions regarding the fish and wildlife benefits of our projects and specific habitat improvement practices.

General Monitoring Schedule (record dates for all visits):

Over the duration of a Partners project agreement, staff should visit each project site a minimum of five times according to the general monitoring schedule listed below, and prepare a narrative monitoring report for that project following each site visit.

- Pre-project visit
- Mid-project visit
- Post-project visit
- Mid-agreement visit
- End of agreement visit

Effective monitoring requires thinking ahead with a clear identification of the goals and objectives of each project. Project goals should focus on the desired habitat and ecological changes, and benefits for Federal trust and other species of concern.

- **Pre-project:** This site visit and narrative report should scope out any specific baseline project information that has not already been included in the HabITS project narrative, and is identified as being needed to evaluate the project during later visits. It is during this visit that the Partners biologist should formulate the specific variables that will be monitored during future visits; for example, any success criteria, weather conditions such as drought that may affect the survival of planted vegetation, soil types, the number of gopher tortoise burrows on site prior to the projects, and/or the documentation of the presence or absence of target species, etc. Specific information to be documented is dependent upon the determination of those pertinent factors that can be reasonably measured and are needed to address the project goals and objectives found in the HabITS project narrative.

Photographic Documentation (to be completed for all monitoring visits):

- Establish permanent photographic locations at the project site and take appropriate photographs during each site visit.
- Take sufficient photographs to document and highlight the before and after habitat conditions, and any other unique or special features of the project.

- Electronically scan the best photographs and transfer into the HabITS Monitoring Module.

■**Mid-project:** This visit and narrative report should address primarily project implementation issues.

- Check and document the status (e.g., active, on schedule, complete, of all project activities described in the scope of work in project agreement.
- Have the landowner and other partners carried out their responsibilities (technical or financial) as stated in the agreement? Describe.
- Do the landowner and/or contractor(s) have technical or other issues that need resolving? Document and track resolution of each.
- Continue photographic documentation.

■**Post-project (immediately following scheduled completion of project activities or shortly thereafter):** Monitoring information collected during this visit and the narrative report should address the following issues:

- Project Implementation: A continuation of mid-project review issues; e.g., were all of the planned habitat improvement activities (e.g., a prescribed burn, three water-control structures installed, etc.) as noted in the project agreement completed as planned? Were all of the planned technical and financial assistance contributions met by all partners as identified in the plan?
- Project Effectiveness and Validation: Collect monitoring information for any specific factors previously selected to help determine the success of a project activity. Address whether or not the desired or expected ecological or biological conditions were achieved, based on the success criteria previously identified? For example, if the agreement plan called for the successful re-establishment of at least 200 trees per acres, and at least five species of trees, begin to collect the information needed to document this accomplishment. Summarize known or expected benefits to target species or other Federal trust resources. Is the project site being used by a target species? Use appropriate references from other published literature as needed. Summarize any research studies and partnerships associated with the project. Begin to document any recognized research needs and information gaps.

- Photographic Documentation: Continue at previously established photographic sites.

- Landowner Satisfaction Survey: Complete a landowner satisfaction survey and report to answer at least the following questions:

  Are the landowner(s) and other partners satisfied with the project results to date?
  Are the landowner(s) and other partners satisfied with the performance of the Service?
  What does the landowner(s) and other partners like or dislike about this project?

Do the landowner(s) and other partners have recommendations for improvement? List and discuss.

- **Mid-agreement:** For a project under the minimum 10-year agreement, the project should be visited approximately half way through the length of the agreement. If the project is of longer duration (e.g., 25 years), we recommend visiting the site at approximately 5-year intervals.

  Monitoring information collected and the narrative reports should continue to evaluate all of the issues identified in the Post-Project visit, above. Also, if the agreement included specific habitat maintenance responsibilities for the landowner and/or the Service, determine if these responsibilities are being carried out as specified in the agreement. Also, evaluate and document your thoughts as to whether the maintenance practices are achieving the desired results, and offer appropriate recommendations.

- **End-Of-Agreement:** Monitoring information collected and the narrative report should continue to evaluate all of the issues identified in the Post-Project and subsequent visits, above. Also, in this final narrative report, the Service biologist should develop project conclusions, based on all of the project information collected and evaluated throughout the life of the project. For example, what went well with this project, and what did not go well, and why? What are the documented benefits of this project to Federal trust resources? Additional data needs? What should be avoided in future projects, and recommendations?

ANNUAL REPORTS:

For each monitoring plan that is developed, an annual monitoring report should be prepared and entered into the HabITS data base by no later than August 15th of each fiscal year. The monitoring report should summarize what was monitored, what was learned from the monitoring relative to the needs of the target or focal species and benefits linked to our conservation delivery actions, any modifications to the monitoring plan, any adaptive management changes, and the prospectus.

APPENDIX B: Matrix of Common Streambank Problems, Causes, and Solutions

Table 4. Matrix of Common Streambank Problems, Causes, and Solutions (NRCS 2007).

PRIMARY GOAL	PROBLEM	IMMEDIATE CAUSE	ROOT CAUSE	SOLUTION
Protect property: cropland, forestland, residential land Infrastructure: roads, bridges, utilities, levees	Lateral migration	Excess energy/ increased velocity	Steepened gradient or increased flow	Reduce energy gradient by reducing slope
		Inadequate riparian vegetation	Clearing and/or removal of mature vegetation	Restore riparian vegetation and buffer area.
		Channel obstruction	Woody material, landslide has reduced channel capacity at site forcing flow around obstruction	Remove obstruction to restore channel Capacity
		Unstable channel planform	Normal lateral migration, channelization or modifications have created small radius bend(s)	Modify channel geometry to conform to natural channel geometry relationships of stable channels. Typically with radius of curvature/bankfull width ratio greater than 2.0

		Excessive bedload deposition	Excessive erosion upstream generating more bed load than channel can transport. May be result of channel incision and widening upstream of problem. May be aggravated by channel widening, resulting in excessive width depth ratios. May also be depositional area created at delta above confluence with larger stream or reservoir	Find and treat sources generating excessive bedload. Channel may then need to have stable cross section and planform reestablished at problem reach. Attempts to modify channel to transport bed load through the problem reach are only successful in moving the problem downstream
	Slope failure	Critical bank height exceeded	Channel incision has created bank height that exceeds soil strength to resist failure	Stabilize bed to prevent additional incision, and raise bed elevation to restore bank heights that are less than critical height. An alternative after halting incision is to slope banks to an angle that is stable for the materials and heights
			Banks are over steepened by lateral erosion at the toe of the bank resulting in slope failure	Stop lateral erosion at the toe. Refer to causes of lateral migration to insure root cause is addressed
		Geotechnical problems	Banks have internal geotechnical problems resulting in bank failure only indirectly effected by streamflow (seeps, springs, weeps, differing soil materials)	Address the geotechnical problem before attempting any other solution. Consult with appropriate technical personnel for assistance

Restore or maintain channel capacity	Bed-load accumulation	Excessive upstream sources	Large bank failures/escarpments or bed degradation contributing excessive bed load	Identify and make appropriate treatment to reduce bed-load contributions
		Reduced velocity in reach resulting in deposition of bed-load material	Change in slope or backwater effects from channel obstruction downstream reservoir or confluence with another stream	May be no effective practical solution without detailed project analysis and major project activity to reduce bed load
	Multiple or frequent log jams	Logjams restrict flow, resulting in loss of channel capacity and increased flooding or bank scour near obstruction	Introduction of woody material from logging, clearing ,or high mortality rate of mature trees upstream of problem, resulting in log jams at site	Locate source, and address problem by removing potential for excessive woody material in channel
	Multiple or frequent logjams	Logjams restrict flow, resulting in loss of channel capacity and increased flooding or bank scour near obstruction	Excessive slope failure upstream causing large woody material from riparian zone to enter channel	Address problem of slope failure upstream of problem. Refer to causes of slope failure to ensure root cause is addressed
	Increased runoff/ flooding	Land use changes in watershed such as urbanization or intensified agricultural use	Change in flow regime resulting in increased peaks or extended durations initiating changes in channel morphology	Make watershed modifications to restore natural flow regime. Alternative is to allow channel morphology to adjust naturally, or make carefully planned adjustments to changes in flow regime

APPENDIX C: Regulatory Web Links for Southeastern States

Alabama:

- U.S. Army Corps of Engineers: http://www.sam.usace.army.mil/Missions/Regulatory.aspx
- Alabama Department of Environmental Management: http://www.adem.state.al.us/permitting/PermittingInfo.htm
- Endangered Species Act Section 7 Compliance: http://www.fws.gov/daphne/
- State Historic Preservation Office: http://www.preserveala.org/
- Floodplain Management: http://www.adeca.alabama.gov/C16/Floodplain/default.aspx

Arkansas:

- U.S. Army Corps of Engineers: http://www.swl.usace.army.mil/Missions/Regulatory/ApplyingforaPermit.aspx
- Arkansas Department of Environmental Quality: http://www.adeq.state.ar.us/water/default.htm
- Endangered Species Act Section 7 Compliance: http://www.fws.gov/arkansas-es/
- State Historic Preservation Office: http://www.arkansaspreservation.com/
- Floodplain Management: http://www.floodplain.ar.gov/

Caribbean:

- U.S. Army Corps of Engineers: http://www.saj.usace.army.mil/Missions/Regulatory/SourceBook.aspx
- Puerto Rico Environmental Quality Board: http://www.ecos.org/section/states/?id=PR
- Puerto Rico Department of Natural Resources and Environment: http://www.drna.gobierno.pr/
- Endangered Species Act Section 7 Compliance: http://www.fws.gov/caribbean/es/
- State Historic Preservation Office:
- Floodplain Management:

Florida:

- U.S. Army Corps of Engineers: http://www.saj.usace.army.mil/Missions/Regulatory.aspx
- Florida Department of Environmental Protection: http://www.dep.state.fl.us/water/wetlands/erp/nwp.htm
- Endangered Species Act Section 7 Compliance: http://www.fws.gov/northflorida/
  http://www.fws.gov/panamacity/
  http://www.fws.gov/verobeach/
- State Historic Preservation Office: http://dhr.dos.state.fl.us/
- Floodplain Management: http://flfloods.org/

Georgia:

- U.S. Army Corps of Engineers: http://www.sas.usace.army.mil/
- Georgia Environmental Protection Division: http://www.georgiaepd.org
- Endangered Species Act Section 7 Compliance: http://www.fws.gov/athens/
- State Historic Preservation Office: http://georgiashpo.org/
- Floodplain Management: http://www.gaepd.org/Documents/techguide_wpb.html

Kentucky:

- U.S. Army Corps of Engineers: http://www.lrl.usace.army.mil/Missions/Regulatory.aspx
- Kentucky Division of Water: http://www.water.ky.gov/permitting/
- Endangered Species Act Section 7 Compliance: http://www.fws.gov/frankfort/
- State Historic Preservation Office: http://heritage.ky.gov/
- Floodplain Management: http://water.ky.gov/floodplain/Pages/default.aspx

Louisiana:

- U.S. Army Corps of Engineers: http://www.mvn.usace.army.mil/
- Louisiana Department of Environmental Quality: http://www.deq.louisiana.gov/portal/tabid/63/Default.aspx
- Endangered Species Act Section 7 Compliance: http://www.fws.gov/lafayette/
- State Historic Preservation Office: http://www.crt.state.la.us/archaeology/index.aspx
- Floodplain Management: http://www8.dotd.la.gov/lafloods/

Mississippi:

- U.S. Army Corps of Engineers: http://www.mvk.usace.army.mil/
- Mississippi Department of Environmental Quality: http://www.deq.state.ms.us/newweb/MDEQRegulations.nsf?OpenDatabase
- Endangered Species Act Section 7 Compliance: http://www.fws.gov/mississippiES/
- State Historic Preservation Office: http://mdah.state.ms.us/
- Floodplain Management: http://www.msema.org/floodplain-management/

North Carolina:

- U.S. Army Corps of Engineers: http://www.saw.usace.army.mil/Missions/RegulatoryPermitProgram.aspx
- North Carolina Division of Water Quality: http://portal.ncdenr.org/web/wq
- Endangered Species Act Section 7 Compliance: http://www.fws.gov/nc-es/
- State Historic Preservation Office: http://www.hpo.ncdcr.gov/
- Floodplain Mapping Program: http://www.ncfloodmaps.com/

South Carolina:

- U.S. Army Corps of Engineers: http://www.sac.usace.army.mil/Missions/Regulatory.aspx
- South Carolina Department of Health and Environmental Control: http://www.scdhec.net/environment/water/401nwpermits.htm
- Endangered Species Act Section 7 Compliance: http://www.fws.gov/charleston/
- State Historic Preservation Office: http://shpo.sc.gov/Pages/default.aspx
- Floodplain Mitigation Program: http://www.dnr.sc.gov/water/flood/mgrsinfo.html

Tennessee:

- U.S. Army Corps of Engineers: http://www.lrn.usace.army.mil/Missions/Regulatory/DistrictBoundaries/Tennessee.aspx
- Tennessee Department of Environment and Conservation: http://www.tennessee.gov/environment/permits/arap.shtml
- Endangered Species Act Section 7 Compliance: http://www.fws.gov/cookeville/

- State Historic Preservation Office: http://www.tn.gov/environment/hist/
- Floodplain Management: http://www.tnafpm.com/

APPENDIX D: Resources for Determining Project Costs

Table 5. Costs for Rural Stream Restoration, from a User's Guide to Watershed Planning in Maryland, 2007.

Practice	*Type*	*Planning Level Construction Costs*	*Units*
Non-Ag BMPs	*Abandoned mine reclamation*	Varies	Acre
	Forest harvesting BMPs	$8 to $30 per acre/year	Acre
	Structural shoreline control	$350 per linear foot	Linear Foot
	Non-structural shoreline control	$125 per linear foot	Linear Foot
	Marina pumpouts	$12,500 per station	Station
Septic Systems	Septic hookups	$20,000 per connection	Per system
	Septic denitrification	$5,500 per system	
	Septic pumpout	$125 to $325 per system	
Crop BMPs	Nutrient Management Plan	$ 6 acre/year	Per Acre of Treatment
	Conservation Tillage	$17 per acre/year	
	Cover Crops	$20 to $30 per acre/year	
	Conservation Plans	$350 per acre	
	Land Retirement	Varies	
	Reforestation (from crop)	$ 500 to $ 1500 per acre	
	Riparian forest buffers	$ 500 to $1000 per acre	
	Riparian grass buffer	$ 100 to $ 500 per acre	
Animal Waste Management Systems	Livestock AWMS	$ 65,000	Per system
	Poultry AWMS	$ 27,000	
	Barnyard runoff controls	$ 7,200	
Pasture BMPs	Stream fencing/off-stream watering/rotational grazing	$ 150 acre/year	Per acre treated
	Fencing/off-stream watering	$ 100 acre/year	
	Off stream watering only	$ 65 acre/year	
Wetland Restoration	Restoration of prior converted wetlands	$ 1000 to $1000 per acre	
Costs derived from *CBP, 2003, DNR, 2002b, CWP, 1998*. Note State and Federal Cost share money may be available for certain practices.			

Table 6. Urban Stream Restoration Costs in Maryland, 2007.

Practice	*Type*	*Planning Level Construction Costs*	*Unit*
Storage Retrofits[1]	Modify existing pond	9.5K (5 to 15 K)	Per impervious acre treated
	Culvert storage	12.5 K (7.5 to 17.5 K)	
	New facility	15.5K (12.5 to 20 K)	
	ROW/conveyance	15.5 (12.5 to 30 K)	
	Parking lot	25K (10 to 40 K)	
On-site Retrofits[1]	Residential	15K (10 to 25 K)	Per impervious acre treated
	Non-Residential	25K (10 to 40 K)	
Stream Cleanup and Repair Practices	Stream cleanup	$100 ($0 to 1000)	Per reach cleaned
	Adopt-a-stream	$500 ($200 to 1000)	Per stream mile per year
	Soft bank stabilization[2]	$50 ($15 to 75)	Per linear foot
	Hard bank stabilization[2]	$100 ($20 to 300)	
	In-stream practices [3]	$45 ($20 to 75)	
	Grade controls[3]	$1,800 each ($1,200 to 3,600)	
	Natural channel design[4]	$250 ($200 to 300)	
	De-channelization[4]	$50 ($100-200)	
	Stream daylighting or parallel pipes[4]	$150 ($50-300)	
	Fish barrier removal	$10,000 ($5,000 to 50,000)	Per barrier
Riparian Reforestation	Soil amendments [5]	$1500 ($500 to 10,000)	Per acre
	Rubble removal	$500 ($200 to 1,000)	
	Invasive plant removal	$250 ($100 to 750)	
	Bare root trees[6]	$1,000 ($575 to 1,500)	
	Container trees[6]	$2,000 ($1,000 to 3,000)	
	Balled & burlapped trees[6]	$5,000 ($2,500 to 7,500)	
Discharge Prevention	Repair illicit connection[7]	$2,500 ($1,000 to 5,000)	Per correction
	Establish citizen hotline[7]	$1,300-$3,300 startup costs $1,500- $4,500 annual cost[8]	Per community
	Discharge inspection	$300 ($220 to 400)	Per facility, see Brown *et al.* (2004)
	Septic inspection	$325 ($250 to 400)	
Pervious Area	Upland reforestation	See Riparian Reforestation	Per acre
	Forest Conservation	$8 to 30 per acre year	
	Conservation Easement	$2500 (500 to 10,000)	
Source Control	Neighborhood stewardship	$15 ($5 to 30)	Per household
	Hotspot prevention plan[8]	$5,000 ($2,500 to 25,000)	Per hotspot
Municipal Operations	Street sweeping	$25 to 45	Curb mile/ year/pass
	Storm drain cleanouts	$250 to 1000	Per catch basin

Costs derived from CBP, 2003, DNR, 2002, Kitchell and Schueler, 2005. Note: State and Federal Cost share money may be available for certain practices.

Notes:

[1] Retrofit costs do not include land acquisition or maintenance

[2] Bank stabilization includes toe protection, bank shaping and establishment of vegetation

[3] Costs for individual in-stream habitat and grade control practices vary, consult Manual 4

[4] Costs for comprehensive stream restoration are highly site specific, depending on materials use and site conditions, and do not include costs for utility relocations, culvert replacement, land acquisition, or permitting

[5] Compost and other soil amendments over 25% of total planting area

[6] Tree planting costs are variable costs and depend on plant species, tree age, planting method, labor source, and tree protection, and maintenance planning

[7] For more detail consult Brown *et al.* (2004)

[8] Cost of preparing and implementing pollution prevention plan, including installation of limited structural storm water management practices at the site

Table 7. Incidental Construction Items.

Item	Costs	Units
Construction Office	$750	Month
Excavation	$3-20	CY
Clearing and Grubbing (Woodland)	$5,000-10,000	Acre
Silt Fence	$2	LF
Blaze Orange Fence	$2	LF
Coir Erosion Control Matting	$5	SY
Temporary Construction Entrance	$1,500-2,000	Each
Temporary Stream Crossing / Ford	$2,000-5,000	Each
Permanent Seeding	$1,000-$2,000	Ac
Temporary Seeding	$100-125	Ac
Herbaceous Plugs	$1.50	Each
Containerized Shrubs (12-24")	$12	Each
Tubling Shrubs	$3	Each
Bare Root Woody	$1.5	Each
Containerized Trees (3-4')	$20	Each
Ball and Burlap Trees	$300	Each
Lime	$200	Ton
2 " Topsoil (salvaged)	$2,500	Ac
6 " Topsoil (Furnished)	$5,000	Ac

Source: Costs of Incidental Items drawn from bid tabulations from a variety of projects by VDOT, MSHA, and NC Wetlands Restoration Program. Construction costs include labor, material, equipment and installation, but excludes design costs.

Table 8. Typical costs for stream restoration in the Northwest (Bair 2000).

Item	High end (cost/river mile)	Low end (cost/river mile)	Reasonable mean (cost/river mile)
Plan, design & NEPA	$110,040	$21,833	$68,880
Materials (trees)	$64,900	$14,747	$20,566
Mobilization	$8,200	$1,333	$2,777
Equipment	$122,000	$17,333	$20,800
Labor	$17,167	$112	$5,000
Riparian planting/ maintenance	$7,646	$3,893	$5,512
Instream structure maintenance	$24,640	$4,760	$5,600
Total	**$354,593**	**$64,011**	**$129,135**

Table 9. Costs for Stream Restoration in the Upper Midwest, 2006.

Table 3. Size and cost of stream restoration projects in the NRRSS database for the Upper Midwest region.

	Total for All Projects with Data	*Extrapolated Total for All Projects*	*Mean for All Projects with Data*	*Median for All Projects with Data*
Project length (miles)	1,842.50[a]	5,763.16	4.28[a]	0.26[a]
Project cost ($)[b]	75,642,874[c]	160,930,214	189,107[c]	12,957[c]

Extrapolated totals were calculated by multiplying average values by the number of projects with missing data.
[a] $n = 430$.
[b] Cost estimates are based on data from the years 1990–2003.
[c] $n = 400$.

Table 10. Stream Restoration costs in California, 2004.

Item	Quantity	Unit	Unit Cost	Cost
Mobilization	1	L.S.	$50,000	$50,000
Rock Groins				
Rock Placement	4,590	ton	$65	$298,350
Earthwork (misc.)	5,000	cu yd	$5	$25,000
			Subtotal	**$323,350**
Planted Groins				
Willow/Cottonwood Pole Placement	880	LF	$35	$30,800
Earthwork (misc.)	2,000	cu yd	$5	$10,000
			Subtotal	**$40,800**
Drop Structures				
Earthwork (per each)	700	cu yd	$5	$3,500
Rock Drops (per each)				
Rock weirs	800	ton	$75	$60,000
Rock groins	200	ton	$55	$11,000
Grading (per each)	150	yds	$5	$750
Planting (per each)	0.1	ac	$20,000	$2,000
Erosion Control (per each)	1	L.S.	$2,000	$2,000
			Subtotal	**$79,250**
Gradient control structures	1	ea	$79,250	$79,250
Rock Riprap				
Earthwork	1600	cu yd	$5	$8,000
Rock Placement	1600	ton	$65	$104,000
			Subtotal	**$112,000**
Gabion repair	(allow)		$50,000	$50,000
Restoration planting	1	ea	$125,000	$125,000
Erosion Control	1	L.S.	$30,000	$30,000
			Subtotal (Construction)	**$760,400**
Contingency			25%	$190,100
Administration			7%	$53,228
			TOTAL	**$1,003,728**

APPENDIX E: State-Administered and Nonprofit Conservation Programs

Alabama:

- Soil and Water Conservation Committee: http://www.swcc.state.al.us/
- Landowner Assistance Programs : http://www.outdooralabama.com/research-mgmt/Landowner/
- Choctawhatchee, Pea, Yellow River Watershed Authority: http://www.cpyrwma.alabama.gov/pages/history_page.htm
- ADCNR, State Wildlife Grants: http://www.outdooralabama.com/research-mgmt/State%20Wildlife%20Grants/
- Cooperative Extension Service: http://www.aces.edu/counties/
- Southeast Watershed Forum, Directory for AL: http://www.southeastwaterforum.org/directory/alabama_sum.asp
- Alabama Agricultural and Conservation Development Commission Program http://swcc.alabama.gov/pages/aacdc.aspx?sm=b_i
- Legacy, Partners in Environmental Education: http://www.legacyenved.org/
- Curtis and Edith Munson Foundation: http://www.munsonfdn.org/guide.htm
- Alabama State Water Program: http://www.aces.edu/waterquality/streams/general.htm
- Cyber-Sierra's Conservation Grants Center: http://www.conservationgrants.com/bystate.htm

Arkansas:

- Association of Conservation Districts: http://www.aracd.org/
- Landowner Incentive Program: http://www.outdooralabama.com/research-mgmt/landowner/lip/
- ADEQ, Proactive Programs: http://www.adeq.state.ar.us/home/progs_proactive.htm
- AGFC, Acres for Wildlife: http://www.agfc.com/species/Pages/SpeciesConservationProgramsAAW.aspx
- Arkansas Watershed Advisory Group: http://www.awag.org/
- Cooperative Extension Service: http://www.uaex.edu/findus/county_offices.htm
- Wetland and Riparian Zones Tax Credit Program: http://anrc.cast.uark.edu/home/programs/conservation/riparian-zone-restoration-and-wetland-creation-tax-credit.html
- Arkansas Conservation Alliance: https://www.facebook.com/pages/Arkansas-Conservation-Alliance/160231854017414
- Arkansas Water.Org: http://arkansaswater.org/index.phpoption=com_content&task=view&id=204&Itemid=84
- Arkansas Wetland Conservation: http://www.mawpt.org/policy/
- Arkansas Department of Environmental Quality http://www.adeq.state.ar.us/
- Arkansas Natural Heritage Program Conservation Partners http://www.naturalheritage.org/about-us/partners.aspx
- Northwest Arkansas Conservation Authority: http://www.nwaconservation.org/

- The Conservation Fund: http://www.conservationfund.org/southeast/arkansas
- Arkansas Watershed Advisory Group: http://www.awag.org/Grant Seekers Tool Kit/index.htm

Caribbean:

- Caribbean Area Conservation Districts: http://www.pr.nrcs.usda.gov/partnerships/consdistricts.html
- Puerto Rico Departmento de Recursos Naturales y Ambientales: http://www.drna.gobierno.pr/
- Official Website of the Government of Puerto Rico: http://www.gobierno.pr/GPRPortal/Transactions/Transactions.aspx?img=imgAgricult&c%09at=14
- Servicio de Extensión Agrícola: http://www.uprm.edu/agricultura/sea/newmap.html
- Avian Knowledge Network: http://www.avianknowledge.net/content/about/partners/fcpr
- Conservation Stewardship Program: http://www.privatelandownernetwork.org/yellowpages/resource.aspx?id=12687
- Conservation Trust of Puerto Rico: http://www.fideicomiso.org/
- Island Resources Foundation: http://www.irf.org/mission/index.php
- Puerto Rice Sea Grant: https://www.facebook.com/pages/Sea-Grant-Puerto-Rico/57622267141
- Puerto Rice Water Resources Center: http://www.ece.uprm.edu/rumhp/prwrri/

Florida:

- Association of Conservation Districts: http://afcd.us/
- Landowner Assistance Program: http://www.myfwc.com/LAP/
- DEP 319 Program: http://www.dep.state.fl.us/water/nonpoint/319h.htm
- DEP Water Management Program: http://www.dep.state.fl.us/secretary/watman/
- Florida Forest Service: http://www.floridaforestservice.com/
- UF/IFAS Cooperative Extension: http://solutionsforyourlife.ufl.edu/map/
- Southeast Watershed Forum, Directory for FL: http://www.southeastwaterforum.org/directory/florida_sum.asp
- State Wildlife Grants Program: http://myfwc.com/conservation/special-initiatives/fwli/grant/
- Conserve Florida Water Clearinghouse: http://www.conservefloridawater.org/
- Conservation Trust for Florida: http://www.conserveflorida.org/
- Florida Fish and Wildlife Research Institute: http://research.myfwc.com/features/view_article.asp?id=25480
- Alachua Conservation Trust: http://alachuaconservationtrust.org/
- Southwest Florida Management District: http://www.swfwmd.state.fl.us/projects/
- Cyber-Sierra's Conservation Grants Center: http://www.conservationgrants.com/bystate.htm

Georgia:

- Soil and Water Conservation Commission: http://gaswcc.georgia.gov/portal/site/SWCC/
- GA Wildlife Resources Division Landowner Programs: http://www.georgiawildlife.com/conservation/landowner-programs?cat=6
- GA EPD Watershed Protection Branch: http://www.gaepd.org/Documents/epdforms_wpb.html

- GA Land Conservation Program: http://glcp.georgia.gov/
- Cooperative Extension Service: http://extension.uga.edu/environment/water/
- Cyber-Sierra's Conservation Grants Center: http://www.conservationgrants.com/bystate.htm
- Upper Chattahoochee Riverkeeper: http://www.chattahoochee.org/
- Georgia River Network: http://www.garivers.org/
- Southeast Watershed Forum, Directory for GA: http://www.southeastwaterforum.org/directory/georgia_sum.asp
- Conserve Water Georgia: http://www.conservewatergeorgia.net/
- Conserve Georgia: http://www.conservegeorgia.org/
- Partnership for a Sustainable Georgia: http://www.energyace.com/Articles/2010/Partnership-for-a-Sustainable-Georgia
- ACCG Water Resources Toolkit: http://www.georgiaplanning.com/watertoolkit/main.asp?PageID=9
- Georgia Dept. of Community Affairs: http://www.dca.state.ga.us/main/quickmenuListing.asp?mnuitem=PROG
- Georgia Environmental Finance Authority: http://www.gefa.org/
- Cyber-Sierra's Conservation Grants Center: http://www.conservationgrants.com/bystate.htm
- Georgia Water Resources Institute: http://www.gwri.gatech.edu/
- Robert W. Woodruff Foundation: http://www.woodruff.org/

Kentucky:

- Soil and Water Conservation Commission: http://conservation.ky.gov/Pages/SoilandWaterConservationCommission.aspx
- KY Division of Water Grants http://water.ky.gov/Funding/Pages/EPASpecialAppropriationGrants.aspx
- Cooperative Extension Service: http://www.ca.uky.edu/county/
- Kentucky Fish and Wildlife Foundation: http://www.kentuckywildlife.com/
- Kentucky Waterways Alliance: http://www.kwalliance.org/
- Kentucky Conservation Coalition: http://kycoalition.org/
- Kentucky Conservation Committee: http://www.kyconservation.org/index.htm
- Watershed Watch in Kentucky: http://www.wwky.org/
- Southeast Watershed Forum, Directory for KY: http://www.southeastwaterforum.org/directory/kentucky_sum.asp
- Wetland and stream mitigation program: http://fw.ky.gov/navigation.aspx?cid=639&navpath=C704
- Habitat Improvement Resources http://fw.ky.gov/navigation.aspx?cid=704
- Kentucky Natural Lands Trust: http://www.knlt.org/
- Cyber-Sierra's Conservation Grants Center: http://www.conservationgrants.com/bystate.htm

Louisiana:

- Soil and Water Conservation Districts: http://www.laconservationdistricts.org/
- DNR, Office of Coastal Management: http://dnr.louisiana.gov/crm/

- Department of Wildlife and Fisheries, State Wildlife Grants: http://www.wlf.louisiana.gov/wildlife/state-wildlife-grant-programs-louisiana
- LSU Ag Center Coast and Wetland Conservation: http://www.lsuagcenter.com/en/environment/conservation/wetlands/
- Louisiana Forestry Association: http://www.laforestry.com/site/
- Louisiana Sea Grant: http://www.laseagrant.org/index.html
- The Conservation Fund: http://www.conservationfund.org/southeast/louisiana
- Cyber-Sierra's Conservation Grants Center: http://www.conservationgrants.com/bystate-il.htm
- Southern Regional Water Program: http://srwqis.tamu.edu/louisiana/program-information/louisiana-target-themes/watershed-management/
- The Teche Project: http://www.techeproject.com/
- Bayou Vermillion District: http://www.bayouvermiliondistrict.org/
- Louisiana Association of Nonprofit Organizations: http://www.lano.org/
- Louisiana Cooperative Extension: http://www.lsuagcenter.com/en/administration/about_us/extension/

Mississippi:

- Soil and Water Conservation Commission: http://www.mswcc.state.ms.us/
- Mississippi Fish and Wildlife Foundation: http://www.wildlifemiss.org/
- Mississippi Land Trust: http://www.mississippilandtrust.org/
- Wildlife Forever Challenge Grants: http://www.wildlifeforever.org/grants/overview.aspx
- The Riley Foundation: http://www.rileyfoundation.org/
- Coastal Conservation Association of Mississippi: http://www.ccamississippi.org/
- Mississippi Wildlife Federation: http://www.mswildlife.org/
- Southeast Watershed Forum, Directory for MS: http://www.southeastwaterforum.org/directory/mississippi_sum.asp
- Cyber-Sierra's Conservation Grants Center: http://www.conservationgrants.com/bystate.htm
- Lower Mississippi River Conservation Commission: http://www.lmrcc.org/

North Carolina:

- Division of Soil and Water Conservation: http://www.ncagr.gov/sw/
- Division of Water Resources Development Project Grant Program: http://www.ncwater.org/Financial_Assistance/
- Association of Soil and Water Conservation Districts: http://www.ncaswcd.org/
- Wildlife Resource Commission Wildlife Landowner Programs: http://www.ncwildlife.org/Conserving/Landowners.aspx
- North Carolina Forest Service, Stream Restoration: http://ncforestservice.gov/water_quality/wq_streamrestoration.htm
- Wildlife Habitat Foundation: http://www.ncwhf.org/
- North Carolina Wildlife Federation: http://www.ncwildlifefederation.org/
- North Carolina Ecosystem Enhancement Program: http://portal.ncdenr.org/web/eep
- Clean Water Management Trust Fund: http://www.cwmtf.net/

- Albemarle-Pamlico National Estuary Program: http://portal.ncdenr.org/web/apnep
- Natural Heritage Trust Fund: http://www.ncnhtf.org/
- Division of Water Quality: http://portal.ncdenr.org/web/wq
- Natural Heritage Program: http://www.ncnhp.org/
- Conservation Trust for North Carolina: http://www.ctnc.org/
- Cooperative Extension Service: http://www.ces.ncsu.edu/
- Toe River Valley Watch: http://toerivervalleywatch.org/
- NC State University Stream Restoration Program: http://www.bae.ncsu.edu/programs/extension/wqg/srp/
- Watershed Association for the Tuckaseegee River: http://watrnc.org/
- Ellerbe Creek Watershed Association: http://www.ellerbecreek.org/
- Hiwassee River Watershed Coalition: http://www.hrwc.net/
- Catawaba River Keeper: http://www.catawbariverkeeper.org/
- Southeast Watershed Forum, Directory for NC: http://www.southeastwaterforum.org/directory/northcarolina_sum.asp
- Cyber-Sierra's Conservation Grants Center: http://www.conservationgrants.com/bystate-n.htm
- North Carolina Conservation Network: http://www.ncconservationnetwork.org/
- Western North Carolina Alliance: http://wnca.org/
- Pamlico Tar River Foundation: http://www.ptrf.org/
- North Carolina CREP: http://www.ncaswcd.org/?page_id=90
- One North Carolina Naturally: http://wfs.enr.state.nc.us/pages/ConservationPlanningTool.html
- North Carolina Land for Tomorrow: http://www.land4tomorrow.org/
- Save Water NC: http://www.savewaternc.org/
- Environmental and Conservation Organization: http://eco-wnc.org/
- NC Muddy Water Watch: http://imrivers.com/ncmuddywaterwatch

South Carolina:

- Soil and Water Conservation Districts: http://www.dnr.sc.gov/conservation/index.html
- South Carolina Conservation Bank: http://sccbank.sc.gov/infoapp.html
- Land and Water Conservation Fund: http://www.scprt.com/our-partners/grants/lwcf.aspx
- South Carolina Wildlife Federation: http://www.scwf.org/
- DNR, Rivers, Watersheds and Stewardship: http://www.dnr.sc.gov/water/envaff/river/index.html
- Cooperative Extension Service: http://www.clemson.edu/extension/county/index.html
- Resource, Conservation and Development Councils: http://scrcd.tripod.com/
- The River Alliance: http://www.riveralliance.org/
- Gaylord and Dorothy Donnelly Foundation: http://www.gddf.org/f.html
- Southeast Watershed Forum, Directory for SC: http://www.southeastwaterforum.org/directory/southcarolina_sum.asp
- South Carolina Conservation Credit Exchange: http://www.conservesc.com/
- Community Open Land Trust: http://communityopenlandtrust.org/
- Harry Hampton Memorial Wildlife Fund: http://www.hamptonwildlifefund.org/
- Palmetto Conservation: http://www.palmettoconservation.org/

- Soil and Water Conservation Society: http://www.swcssc.org/
- South Carolina Aquatic Plant Management Society: http://www.scapms.org/
- Water Environment Association of South Carolina: http://www.weasc.org/index.php
- SC America Water Works Association: http://www.scawwa.org/index.php
- Cyber-Sierra's Conservation Grants Center: http://www.conservationgrants.com/bystate-os.htm
- DHEC Watersheds: http://www.scdhec.gov/environment/water/shed/
- Waccamaw Riverkeeper: http://www.winyahrivers.org/
- The Conservation Fund: http://www.conservationfund.org/southeast/southcarolina
- River Venture: http://www.riverventure.org/

Tennessee:

- Association of Soil and Water Conservation Districts: http://tnacd.org/
- Department of Environment and Conservation:
  http://www.state.tn.us/environment/sitemap.shtml
- Heritage Conservation Trust Fund: http://www.state.tn.us/environment/trustfund/
- Cooperative Extension Service: https://utextension.tennessee.edu/Pages/default.aspx#Beef
- Tennessee Scenic Rivers Association: http://www.paddletsra.org/
- Cumberland River Compact: http://www.cumberlandrivercompact.org/
- Clean Water Network: http://tcwn.org/
- Land Trust for the Tennessee: http://www.landtrusttn.org/
- Southeast Watershed Forum, Directory for TN:
  http://www.southeastwaterforum.org/directory/tennessee_sum.asp
- Tennessee Wildlife Resources Commision Private Lands Conservation Programs:
  http://www.tn.gov/twra/habitatconserv.html
- Cyber-Sierra's Conservation Grants Center:
  http://www.conservationgrants.com/bystate-tu.htm
- Tennessee Environmental Council: http://tectn.org/

APPENDIX F: Regional and National Nonprofit Organizations and Associated Web Links

- Creekbank.com: http://www.creekbank.com
- National Fish and Wildlife Foundation: http://www.nfwf.org/Pages/default.aspx
- Fish America Foundation: http://www.fishamerica.org/
- American Rivers: http://www.americanrivers.org/
- North America Native Fishes Association: http://www.nanfa.org/grants.shtml
- The Conservation Fund: http://www.conservationfund.org/
- Rails to Trails Conservancy: http://www.railtrails.org/index.html
- Izaak Walton League of America: http://www.iwla.org/index.php?id=19
- Turner Foundation: http://www.turnerfoundation.org/
- Charles Stewart Mott Foundation: http://www.mott.org/
- River Network: http://www.rivernetwork.org/
- Local Government Environmental Assistance Network: http://www.lgean.org/
- The Conservation Fund: http://www.conservationfund.org/southeast
- River Management Society: http://www.river-management.org/
- The Nature Conservancy: http://www.nature.org/
- Trout Unlimited: http://www.tu.org/
- Center for Watershed Protection: http://www.cwp.org/
- Erosion Control Technology Council: http://www.ectc.org/
- American Water Resources Association: http://www.awra.org/about/
- Water Environment Federation: http://www.wef.org/
- National Estuarine Research Reserve System: http://nerrs.noaa.gov/
- Aquatic Resources Education Association: http://www.areanet.org/
- River Revival: http://www.internationalrivers.org/en/node/599

APPENDIX G: Coursework/Training

- Wildland Hydrology, Inc.: http://www.wildlandhydrology.com/html/courses.htm

- DOI Learn and National Conservation Training Center:
  http://training.fws.gov/learn/courses.htm
  FIS3210 Applied Fluvial Geomorphology – Level 1
  FIS3310 River Morphology and Applications—Level II
  FIS3105 Introduction to River Science and Management

- National Center of Earth-Surface Dynamics: http://www.nced.umn.edu/

- Canaan Valley Institute Stream Restoration Program:
  http://www.canaanvi.org/canaanvi_web/streamrestoration.aspx

- Narragansett Bay Research Reserve Coastal Training Program:
  http://www.nbwctp.org/programs.html

- Environmental Protection Agency: http://www.epa.gov/warsss/resources/bank.htm

- US Forest Service North America Watershed Links:
  http://www.fs.fed.us/biology/watershed/index.html

- Salix Applied Earthcare (Private Group, California): http://www.salixaec.com/train.htm

- International Erosion Control Association: http://www.ieca.org/RegionOneHomepage.asp

- NC State University Stream Restoration Program:
  http://www.bae.ncsu.edu/programs/extension/wqg/srp/rivercourse.html

- University of Louisville Stream Institute: https://louisville.edu/speed/civil/si.html

- Utah State University: http://cnr.usu.edu/streamrestoration/

- River Restoration Northwest: http://rrnw.org/

- The Resource Institute, Inc.: http://www.resourceinstituteinc.org/RI-education.html

- University of Minnesota: http://www.nced.umn.edu/srcp

- Center for TMDL and Watershed Studies:
  http://www.tmdl.bse.vt.edu/stream_restoration/C111/

APPENDIX H: Equipment List

- Survey Equipment (including rod, laser level, tripod:TOTAL Station)
- Measuring Tapes
- Rebar (1/2 inch)
- 3 foot Grade Stakes
- Mallet
- Nails
- Waders (chest) and boots
- Gloves
- GPS
- Camera
- Rebar Caps
- Batteries
- Calculator
- Clippers/Machete
- Compass
- Field Note Books
- Flagging Tape/Pins
- Maps
- Paint (Florescent)
- Pencils
- Rod and Tape Levels
- Rulers
- Permanent Marking Pen
- Stopwatch
- Safety Rope
- Shovel
- Current Meter