THE NEW YORK STATE DEPARTMENT OF STATE

DIVISION OF COASTAL RESOURCES GUIDE TO

ECOLOGICALLY-BASED STREAM RESTORATION IN NEW YORK'S COASTAL WATERSHEDS

George E. Pataki, Governor

Christopher L. Jacobs, Secretary of State

THE NEW YORK STATE DEPARTMENT OF STATE
DIVISION OF COASTAL RESOURCES GUIDE TO

ECOLOGICALLY-BASED STREAM RESTORATION IN NEW YORK'S COASTAL WATERSHEDS

Prepared by:

Amy B. Filipowicz

for the

New York State Department of State
Division of Coastal Resources
41 State Street
Albany, New York 12231

July 2006

The Guide to Ecologically-Based Stream Restoration in New York's Coastal Watersheds was prepared through the National Oceanic and Atmospheric Administration Coastal Services Center's Coastal Management Fellowship Program, which places recent graduates in coastal management and related fields with state coastal programs to conduct special two-year projects. The Coastal Management Fellowship Program is administered by NOAA Coastal Services Center, 2234 South Hobson Avenue, Charleston, South Carolina 29405.

Additional financial assistance was provided through a federal grant from the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of Ocean and Coastal Resource Management, under the Coastal Zone Management Act of 1972, as amended,

The views expressed herein are those of the authors and do not necessarily reflect the views of NOAA or any of its subagencies.

The New York State Coastal Management Program is administered by the New York State Department of State Division of Coastal Resources, 41 State Street, Albany, New York 12231.

July 2006

TABLE OF CONTENTS

Page

LIST OF FIGURES 3

LIST OF TABLES 4

PREFACE 5

CHAPTER 1. INTRODUCTION 7
New York's Coastal Watersheds 7
Diversity of Stream Types 8
Status of New York's Streams 8
Traditional Land Management and Stream Restoration 12
Ecologically-Based Land Management and Stream Restoration 13
Components of Ecologically-Based Stream Management 14

CHAPTER 2: PRIMER ON STREAM ECOSYSTEMS 15
Characteristics of the Stream Corridor 15
Linkages Within the Stream Corridor 17
Stream Channel Evolution 19
Five Areas of Stream Ecosystem Function 20
Hydrology 20
Physical Habitat Conditions 24
Water and Sediment Quality 24
Energy Sources 27
Biotic Characteristics 27

CHAPTER 3. STREAM AND WATERSHED ASSESSMENT 29
Conditions and Causes of Stream Instability and Impairment 30
Natural Causes of Instability and Impairment 30
Human-Induced Causes of Instability and Impairment 31
Watershed-Scale Assessment 32
A. General Watershed Characteristics 33
Reach-Scale Assessment 40
A. General Reach Characteristics 41
B. Natural Reach Characteristics 42
C. Human-Influenced Reach Characteristics 45
Analysis of Ecosystem Function 46

CHAPTER 4. PLANNING FOR STREAM RESTORATION AND PROTECTION 51
The Importance of Protection 51
Definition of Terms 51

Set Vision and Goals 52
Build Community Support 53
Identify Funding Sources 54
Important Considerations for Stream Restoration 54

CHAPTER 5. TOOLS AND TECHNIQUES FOR STREAM CORRIDOR MANAGEMENT 57
I. Land Use Planning 58
II. Resource-Based Laws and Ordinances 63
III. Open Space Protection and Acquisition 65
IV. Municipal Operations 67
V. Stewardship and Education 67

CHAPTER 6. STREAM RESTORATION TECHNIQUES 70
1. Riparian Revegetation 72
2. Barrier Mitigation 75
3. Habitat Construction and Enhancement 80
4. Streambank Stabilization 83
5. Grade Control 91
6. Natural Channel Design 93

CHAPTER 7. RESTORATION MONITORING 98
Designing a Monitoring Program 101
Implementing a Monitoring Program 102
Communicating Monitoring Program Results 103
Common Measures Used in Restoration Monitoring 104
Selected Resources for Restoration Monitoring 105

REFERENCES 107

APPENDIX A 116

APPENDIX B 127

APPENDIX C 133

LIST OF FIGURES

Page

1. New York's coastal watersheds…….....7
2. Percentage of streams and rivers in New York that are impaired…….....10
3. Top ten sources of water quality impairments to streams and rivers in New York……..11
4. Width of riparian buffer correlates to functions……...16
5. River continuum concept (Vannote *et al.*, 1980)……..18
6. Channel evolution model……..20
7. Water cycle……...22
8. Impervious cover relates to increased surface water runoff…….……....23
9. Flooding is a natural occurrence……...31
10. Strahler (1952) stream order…….……....34
11. Hydrophysiographic regions of New York……...56
12(a&b). Riparian revegetation: planting of dormant posts and live stakes……73
13. Planting to re-establish functional riparian buffer……74
14. Culvert……..76
15. Fort Covington Dam, Salmon River, Fort Covington, New York……78
16(a&b). Habitat enhancement projects: boulder clusters and LUNKERS…….....81
17. Bank reshaping……..84
18. Vegetative solutions to streambank instability: live fascines and brush mattresses…….85
19. Bioengineering techniques: joint planting and coconut fiber rolls……...86
20. Flow re-direction structures……..87
21. Hard armoring techniques: rock riprap…….88
22. Grade control structures……....91
23. Natural channel design……..93

LIST OF TABLES

Page

1. Rosgen (1996) stream classification…….36
2. Macroinvertebrates as biological indicators…….45

PREFACE

Ecologically-based stream restoration uses a mosaic of in-stream, riparian and watershed management and restoration techniques to reduce or eliminate stress on streams and improve ecosystem functions. The purpose of this guide is to outline an ecologically-based approach to stream restoration that combines stream corridor and watershed management techniques with environmentally-friendly in-stream restoration techniques. Basic information is provided on the physical processes that shape stream channels and the functions that streams perform. An understanding of these physical and ecological processes is necessary for ecologically-based stream management and restoration. This document serves as a guide for stream restoration project planning by reviewing the tools and techniques of stream corridor management, stream restoration and monitoring. Perhaps most importantly, this guide compiles information and resources from the plethora of stream restoration guides already in existence in a way that is suitable to New York's coastal watersheds. Detailed guidance on the design or implementation of land management or stream restoration practices is beyond the scope of this guidebook; however, resources for more information are provided.

The guidelines have been developed as part of the State's overall policy "to conserve, improve, and protect its natural resources and environment…", as stated in Title 1, section 0101 of the New York State Environmental Conservation Law (ECL). This policy is echoed and expanded upon in several other sections of the ECL and in the State's Coastal Management Program with several specific charges to restore degraded habitat for the purposes of maintaining the health and viability of fish and wildlife populations (ECL Title 3, §0301.1(n); Title 11, §0303.2(b)(1), Title 13 §0105.1, Executive Law Article 42, §913).

The federal Coastal Zone Management Act and the New York State Waterfront Revitalization of Coastal Areas and Inland Waterways Act established direction for the appropriate use and protection of the nation's and the State's coasts and waterways. The New York State Coastal Policies are the articulation of that direction and promote the protection and restoration of streams (http://nyswaterfronts.com/downloads/pdfs/State_Coastal_Policies.pdf). Examples of regulations that are relevant to streams and rivers include: the use of non-structural measures to minimize damage from flooding and erosion; the preservation and protection of freshwater wetlands; and the protection and restoration of significant coastal fish and wildlife

habitats (http://nyswaterfronts.com/waterfront_natural_narratives.asp). New York State coastal policies are applicable to the defined coastal area and selected inland waterways. Although these regulations are not enforceable throughout coastal watersheds (also called the Coastal Nonpoint Pollution Control Program Area), adherence to them is strongly encouraged.

These guidelines are intended to direct future stream restoration projects undertaken in New York's coastal watersheds and funded by the NYS Department of State Division of Coastal Resources. These guidelines will assist coastal managers in reviewing potential projects for funding and consistency with state coastal policies. Additional groups could also benefit from this information, including environmental managers, local decision makers, practitioners of stream restoration, local watershed groups and citizens of coastal watersheds.

CHAPTER 1. INTRODUCTION

New York's Coastal Watersheds

New York State is rich in aquatic resources and has many diverse coastlines, including lakes Erie and Ontario, the Saint Lawrence River, the Hudson River, Long Island Sound and the Atlantic Ocean. New York's coastal watersheds (also defined as the coastal nonpoint pollution control program area), which are the lands that drains into these waterbodies, encompasses over sixty percent of the State's area (Figure 1). There are over 52,000 miles of streams and rivers in New York most of which are small, wadeable streams. Streams and riparian corridors are important components of the coastal ecosystem as they transport water, sediment and nutrients; provide essential habitat for many species; and afford many recreational opportunities. The quality of New York's coastal ecosystem is dependent on the health of its tributary streams.

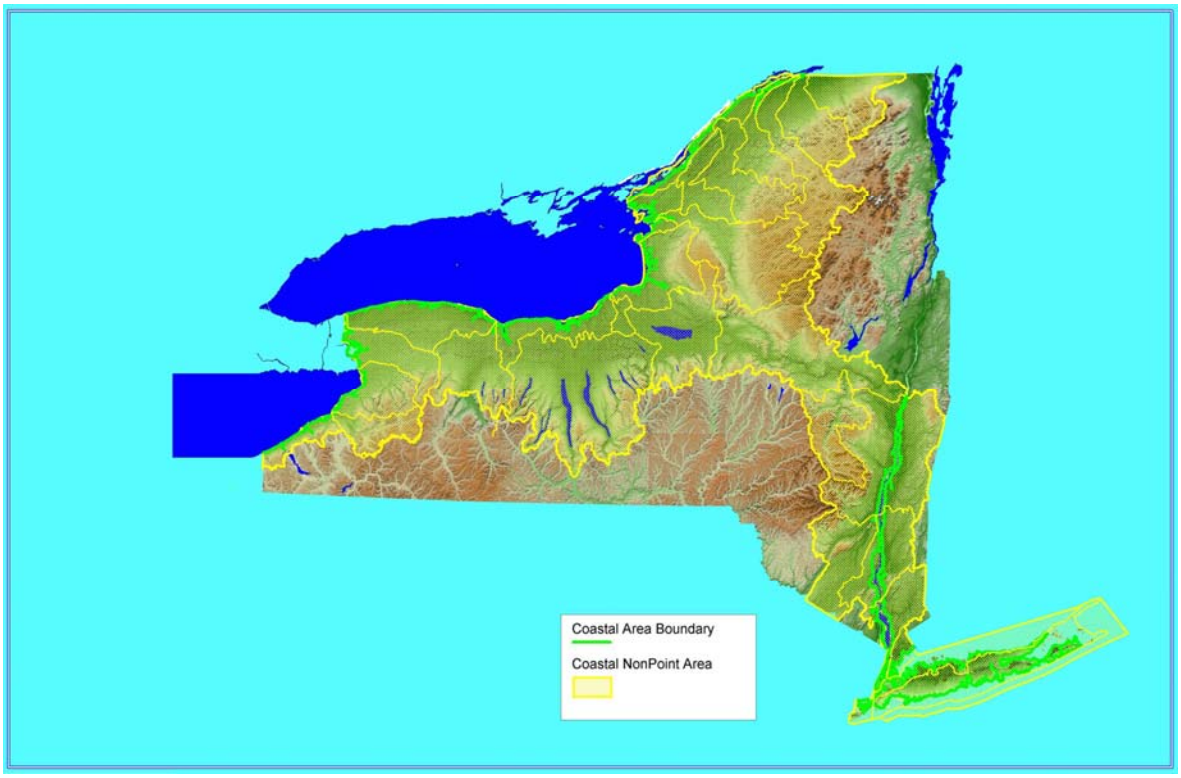


Figure 1. New York's Coastal Watersheds, outlined in yellow, encompass over sixty percent of the State's area and drains to the Great Lakes and Atlantic coasts.

There is a high degree of connectivity between the land, streams and coasts. Human actions that impact one part of the ecosystem inevitably affect the entire system and often have unintended consequences that adversely affect humans in some way, be it through economic loss or increased health risks. By understanding the components of the coastal ecosystem and how they function, we can better manage and preserve the ecological value of streams and coastal ecosystems while maximizing their social and economic benefits. There are measures that citizens, scientists, managers and decision makers can take to protect and restore the aquatic ecosystem.

Diversity of Stream Types

Some aquatic habitats, such as salt marshes, have a high degree of uniformity in composition of vegetation and function among regions. Streams, by comparison, especially those in New York, where underlying geology, soils, topography, vegetation, precipitation and flow differs from one region to the next, are highly diverse. The position of stream reaches within a variety of landscapes, including mountains, forests, farms, suburban neighborhoods and major cities, adds to their diversity and to the complexity of management responses needed. Streams are used by people to meet multiple objectives, whether for navigation, drinking water, irrigation, hydropower, manufacturing, and many forms of recreation not the least of which is sport fishing.

Given all of these variables it is difficult to develop guidelines and establish recommendations that are comprehensive yet specific to the diversity of stream types throughout all of New York. No single approach or single set of tools can be broadly applied to fit all circumstances. However, despite their differences, all stream types are formed and continue to evolve based on the same physical processes and they perform similar ecological functions. It is based on the similarities in processes and functions that the restoration guidelines in this manual are presented. It is essential to tailor general recommendations to specific stream systems based upon its unique characteristics.

Status of New York's Streams

While many streams in New York are of high quality, a number have been adversely affected by human influence. The character of New York's landscape and waterways has been

significantly altered in the last 200 years. Forests, grasslands and wetlands that once kept streams and rivers healthy by stabilizing banks and maintaining water quality have been drastically reduced, especially in coastal watersheds. Over time, agricultural, industrial and urban activities have increased and have had a significant impact on aquatic ecosystems. People have altered watersheds and streams with little concern or understanding of the natural equilibrium of the system as a whole. In agricultural regions, crops were frequently planted up to the stream's edge, which left little to no room for forested streamside buffers. During the industrial era, factories discharged waste products into surrounding waterways. Despite the passing of the Clean Water Act in 1972, streams today are still adversely impacted. Urbanization and sprawl of today's era has yielded increased impervious cover (e.g., streets, roofs and roads), which has increased the amount of runoff and pollution that streams receive.

The NYS Department of Environmental Conservation (NYSDEC) monitors water chemistry and benthic macroinvertebrates to assess stream condition. In 2004, New York State's section 305(b) report identified over 6,000 miles of streams that have some degree of water quality impairment (Figure 2; NYSDEC, 2004). However, more than half of the waterways in New York have yet to be assessed and their water quality condition is unknown. The macroinvertebrate data corroborates the water chemistry results. From 1993 to 2002 the NYSDEC Stream Biomonitoring Unit sampled macroinvertebrates at 1,532 sites on 917 streams. The results indicated that 45% of the sites were non-impacted, 41% were slightly impacted, 13% were moderately impacted, and 1% were severely impacted. With regard to water quality trends, the macroinvertebrate data indicated that 20% of the sites improved since 1992, 19% declined, and 61% showed no change.

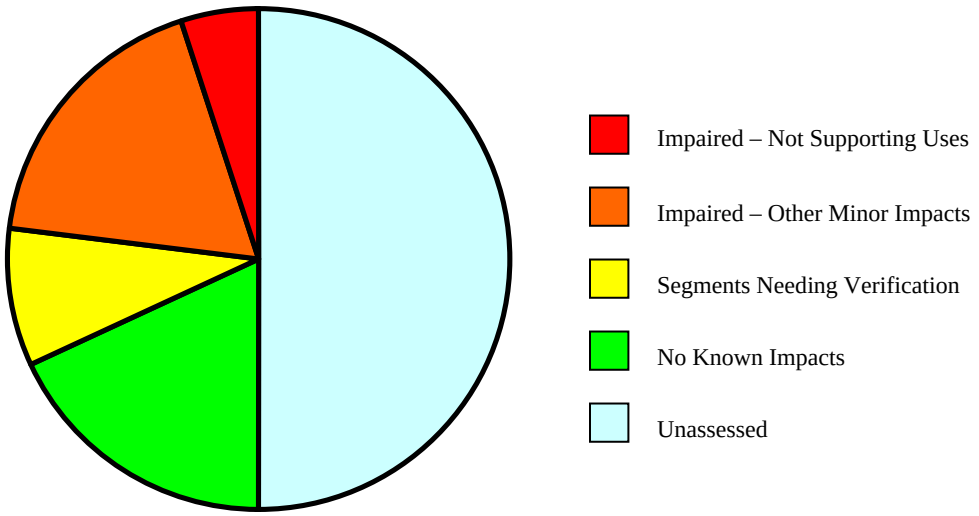


Figure 2. This pie chart shows the percentage of streams and rivers in NY that are impaired, have no known impairments and are unassessed. Over 6,000 miles of streams and rivers in NY were determined to have some degree of water quality impairment in 2004 (shown in red and orange). Over half of NY's waterways have yet to be assessed (shown in blue; adapted from NYSDEC, 2004).

Stream impairment is caused by both point and nonpoint source pollution. A majority of point sources have been controlled since the Clean Water Act was passed in 1972, which is the likely reason for the improvement documented in New York State streams in the last ten years (Bode, Novak, Abele, Heitzman and Smith, 2004). Nonpoint sources of pollution persist and accounted for nine of the top ten causes of stream impairment identified in the 305(b) report (NYSDEC, 2004; Figure 3). Streambank erosion was the most frequently cited source of water quality impairment in streams and rivers. In addition, the macroinvertebrate data indicated that 52% of the impacted sites were impaired by nonpoint source nutrient enrichment (Bode, Novak, Abele, Heitzman and Smith, 2004).

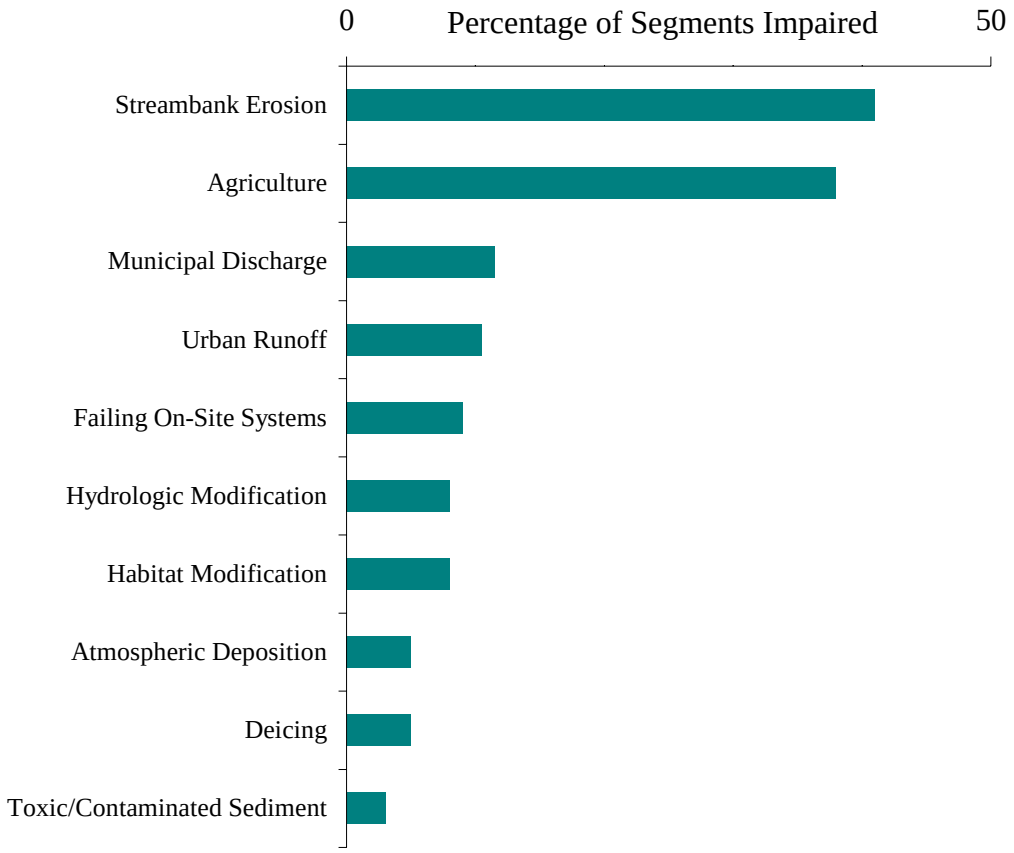


Figure 3. Top ten sources of water quality impairments to streams and rivers in NY (adapted from NYSDEC, 2004).

In addition to the proximate causes of stream impairment, the underlying causes of stream impairment need to be considered. Streambank erosion and other types of nonpoint source pollution are typically caused by larger problems, such as modifications of channel shape, removal of riparian vegetation and changes in watershed land use. In the densely populated and rapidly developing regions of New York's coastal watersheds (Crossett, Culliton, Wiley and Goodspeed, 2004), land use changes contribute significantly to the deterioration of streams and other aquatic ecosystems. In rapidly developing regions, the primary cause of altered stream hydrology is the vast expanse of impervious cover. Impervious cover is defined as "any material that prevents the infiltration of water into the soil" (Schueler, 1994). Examples of typical impervious surfaces include roads, driveways, roofs and parking lots (Schueler, 1994; Arnold and Gibbons, 1996). These surfaces prevent precipitation from percolating into the groundwater table, resulting in decreased groundwater replenishment, and an increased volume of freshwater

runoff, which often transports land-derived pollutants and contaminants into waterways (Schueler, 1994; Arnold and Gibbons, 1996).

Stormwater runoff impacts virtually all suburban and urban streams in New York. Greater expanses of impervious cover combined with traditional stormwater conveyance systems increase the magnitude and frequency of runoff delivered to waterways. An increased total volume of stormwater runoff and flashy delivery of runoff to streams often results in channel instability, streambank erosion, increased turbidity and an overall decline in water quality. Additionally, any physical modification made to the stream channel, floodplain or watershed can change hydrology, which can result in channel instability and loss of habitat structure especially if natural channel processes are not considered in the modification.

Efforts to enhance and restore streams and rivers have increased in recent years. The growth of restoration is due, in part, to an increased commitment of federal and state governments to improve water quality and aquatic resources. Federal initiatives call for the restoration of 25,000 miles of stream corridor and the re-establishment of 2,000,000 miles of buffers (USEPA, 2000). New York State initiatives include efforts to restore designated best uses to 25% of segments that are currently not meeting their use standards and protect or restore 750 miles of tributary buffers in the Hudson River Estuary by 2015 (Hudson River Estuary Program, 2007).

Traditional Land Management and Stream Restoration

Streams in New York have historically been and continue to be adversely affected by the cumulative impacts of direct physical disturbances, point and nonpoint source pollution and increasing watershed development, particularly encroachment into the stream corridor. As a home rule state, local governments in New York play a large role in the control and regulation of land development patterns (i.e., the type, intensity and distribution of land uses) and as such, influence the ultimate condition of aquatic ecosystems. In the past, land development has been highly consumptive and stream health generally has not weighed heavily into land use decisions. Other than for transportation and the generation of power, streams were viewed more as obstacles than opportunities.

Stream restoration techniques have been used for decades to remedy bank instability. Traditional restoration strategies rely on hard armoring, such as rock riprap, which often causes

more harm than good by transferring rather than reducing erosive forces (Fischenich, 2003). For example, it was long believed that flooding and erosion problems could be relieved by straightening a channel, removing gravel bars, placing riprap along the streambed and banks and removing large woody material. Although these practices may initially be seen as beneficial by limiting the frequency of over-bank flooding, eliminating a stream's access to its floodplain results in a greater volume of water in the stream channel and faster flows that have powerful erosive forces. Traditional restoration approaches tend not to be successful because they:

- force streams to conform to a pre-conceived, highly engineered shape, which is not natural or self-sustaining for every region.
- are only applied to short reaches to meet very specific needs (e.g., flood protection, erosion control) without considering the stream network, particularly watershed-based causes and cumulative impacts on downstream portions.
- only treat the symptoms not the underlying causes of stream impairment, and as such require continual maintenance.

Ecologically-Based Land Management and Stream Restoration

Ecologically-based management and restoration balances multiple objectives and seeks to achieve several ecologic, economic and human health and safety benefits. Ecologically-based management involves the coupling of sustainable land management practices in the stream corridor and watershed with environmentally-sensitive restoration techniques. Management and restoration of streams and rivers is not only important to improving the integrity of individual segments, but it is also important to maintaining drinking water supplies, fisheries, wildlife habitat, quality of life and community character.

Ecologically-based in-stream restoration assists in the establishment of improved hydrologic, geomorphic and ecological processes in a degraded watershed system and replaces lost, damaged or compromised elements of the natural system.

Components of Ecologically-Based Stream Management

Ecologically-based stream management is comprised of four main components; watershed and stream assessment, stream corridor and watershed management, in-stream restoration practices and monitoring and evaluation. A chapter of this guidebook is dedicated to each of these topics.

Watershed and Stream Assessment

In order to implement protection or restoration practices it is important to understand the characteristics of the stream and its watershed. An overview of important assessments can be found in Chapter 3.

Land Management within the Stream Corridor and Beyond

In addition to in-stream restoration activities, land management strategies in the stream corridor and the larger watershed can eliminate or mitigate stressors that contribute to the degradation of streams and other waterbodies. An overview of stream corridor and watershed management techniques can be found in Chapter 5.

Stream Restoration Techniques

Ideally, degradation of waterways should be prevented, as it is less expensive and more sensible to protect existing natural resources rather than make attempts to restore them. Unfortunately, many streams and other waterbodies have not been adequately protected and are in need of proactive management and restoration. Stream restoration techniques and recommendations can be found in Chapter 6.

Monitoring and Evaluation

Stream restoration projects must be accompanied by some form of evaluation to determine if the approach was successful in addressing the established vision and goals. A monitoring program should be established before implementation of the restoration project begins so that baseline data can be collected if necessary. Monitoring and evaluation techniques can be found in Chapter 7.

CHAPTER 2: PRIMER ON STREAM ECOSYSTEMS

This chapter is intended for those who do not have a background in stream hydrology, geomorphology or ecology. It provides an overview of the important structural components and functional processes of streams that must be considered when undertaking stream restoration projects, including:

- ***Characteristics of the stream corridor***
- ***Linkages within the stream corridor***
- ***Stream channel evolution***
- ***Five areas of stream ecosystem function***

A general understanding of the structure and function of streams and watersheds is essential for ecologically-based restoration. Restoration projects that work with the natural hydrologic, geomorphic and ecological processes of the stream have an increased likelihood of long-term project success. This chapter provides an overview of important physical, chemical, and biological components of stream ecosystems and processes.

Characteristics of the Stream Corridor

The stream corridor is defined as the stream channel and its immediate shoreland environment, or riparian area including the floodplain. It is an area of critical environmental significance because it includes the stream and the natural and cultural resources that are closely associated with it. The stream corridor is the most important zone for concentrating waterway conservation and management efforts (NYSDEC, 1986).

Stream Channel

Stream channel are comprised of important habitat units; pools, riffles, runs and glides. Increased variety of in-stream habitat types typically results in higher species diversity (Allan, 1995). Pools are deeper areas of slower velocity and finer substrate. They provide refuge and cover for many species of fish, especially trout, as water temperatures tend to be cooler in pools. Riffles are shallow areas of higher velocity and relatively coarse substrate. Riffles are formed by the longitudinal sorting of material that occurs between areas of different stream power (i.e., straight reach vs. meander bend). Riffles serve to aerate water and are good habitat for many species of macroinvertebrates. Pool-riffle sequences are the result of particle sorting and require a range of sediment sizes to develop. As a result, regular riffle-pool alterations may not be

apparent in sandy bottom streams (Allan, 1995). Runs are deeper than riffles but have fast moving water with no turbulence. Runs are transition areas between pools and riffles and as a result provide habitat for a diversity of species. Glides are located immediately downstream of pools. They are zones where the flow is slow and laminar (similar to pools), but become shallower leading up to the next riffle.

Riparian Area

Riparian areas, also known as riparian corridors or buffers, are the transition zones between waterbodies and upland areas. These areas serve as floodplains and may become part of the active channel during periods of high flow. Depending upon the region, the riparian area can be comprised of forests, shrubs, grassy meadows or wetlands. Regardless of their vegetative composition, all riparian areas perform similar functions; they slow runoff and filter nutrients and other pollutants; stabilize streambanks and floodplains; contribute woody debris and other organic matter; and provide shade to maintain cool water temperatures (Wenger, 1999). The width of a buffer correlates to the number of functions it serves. Wider riparian areas perform more functions (Figure 4). In addition, leaves, branches and fallen logs provide energy to fuel the aquatic food web and also provide in-stream habitat for many organisms. Riparian areas also provide essential habitat for wildlife.

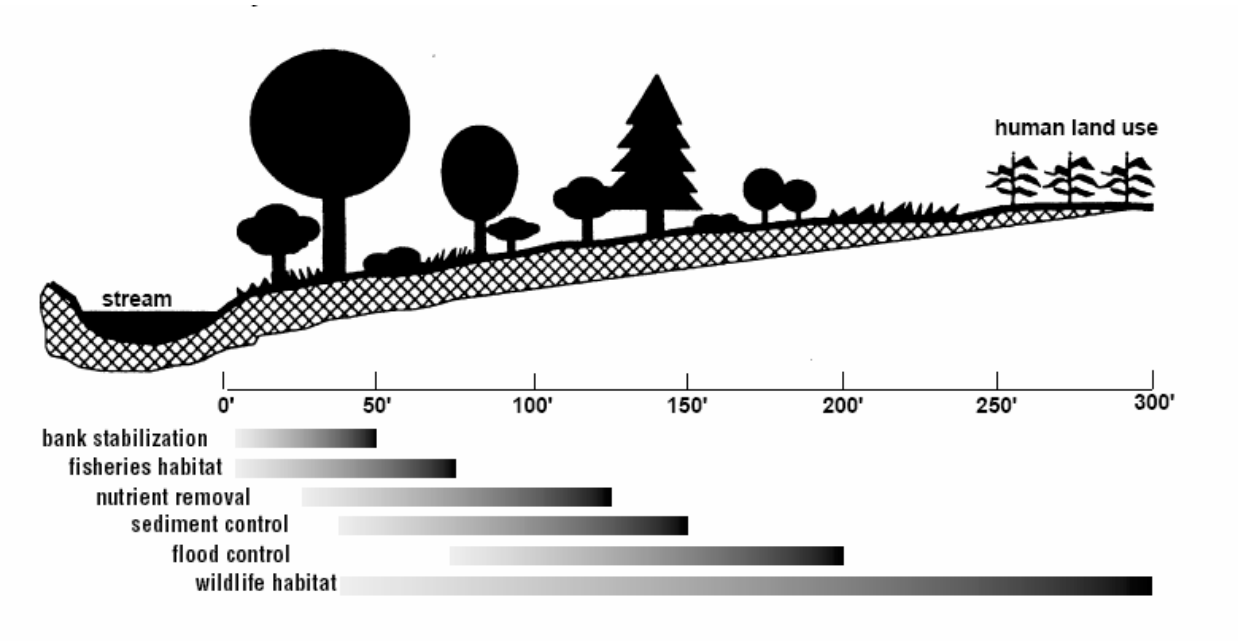


Figure 4. The width of a buffer correlates to the number of functions it serves. Wider riparian areas perform more functions.

Linkages Within the Stream Corridor

Streams are not isolated segments of water but are integrated into the landscape. These linkages should be considered as management and restoration decisions are made.

- *Longitudinal Connections.* Streams are connected in an upstream to downstream fashion. There are distinct physical and ecological differences along this gradient from headwater streams to the mouths of large rivers, as depicted by the river continuum concept (Vannote, Minshall, Cummings, Sedell and Cushing, 1980; Figure 5). Almost everything about a stream or river varies with position along its length. Most streams exhibit a downstream decrease in gradient as slopes are steep in the headwaters and become less steep downstream. Particle size of bed material usually shifts from an abundance of coarser material upstream to predominantly fine-grained sediments in downstream areas. In addition to the differences in channel dimensions and other physical features, a host of biological variables are correlated with stream size and distance downstream; including, sources of energy, food web dynamics and the composition of biological communities. Biological communities downstream are dependent upon the energy and nutrients exported from headwater areas (Allan, 1995). The connection is not unidirectional, however; as migratory fish and other aquatic and semi-aquatic animals represent a flow of energy from downstream to upstream areas.

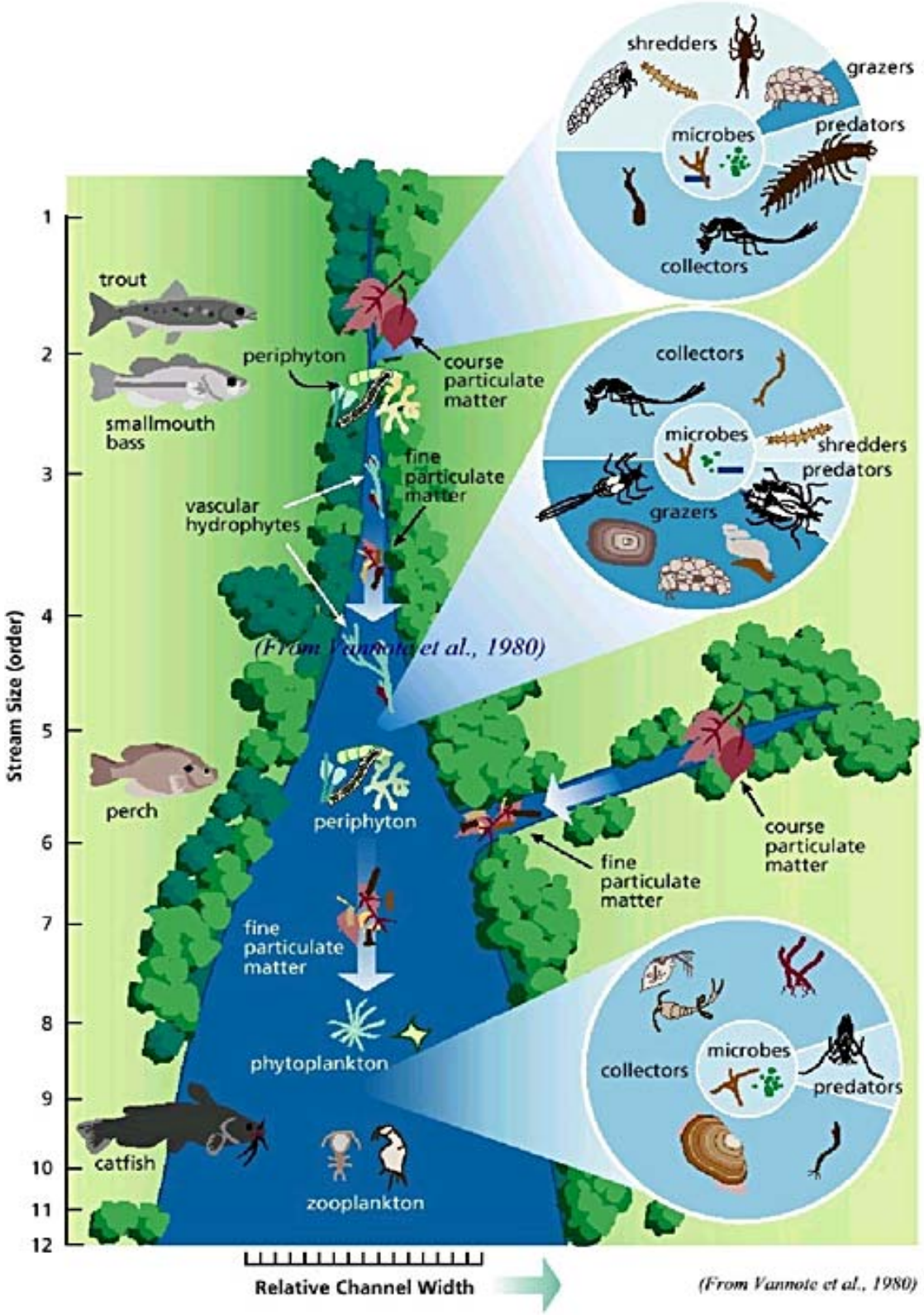


Figure 5. As depicted by Vannote *et al.*'s (1980) River Continuum Concept, a stream's biological and chemical attributes correspond to its physical attributes. The nature of chemical processes and biological communities changes in a downstream direction just as the physical stream itself does.

- *Lateral Connections.* *S*treams are connected across lateral gradients where floodplains and upland areas are linked with waterways. Floodplains and upland areas contribute water, sediment and nutrients to streams. In addition, during floods streams deposit sediment and other nutrients on floodplains. Such connections between streams and floodplains should be maintained or re-established in situations where the ties have been severed.

- *Vertical Connections.* Vertical connections exist between surface water and groundwater. Surface water and groundwater influence the quality and quantity of one another (Winter, Harvey, Franke and Alley, 1998). Streams interact with groundwater in two ways: they gain water from inflow of groundwater though the streambed; they lose water to groundwater by outflow though the streambed; or they do both, gaining in some reaches and losing in other reaches.

Stream Channel Evolution

Stream channels are not static and constantly change shape over time while seeking a state of equilibrium. There is a general sequence of channel adjustments following natural or anthropogenic disturbances that cause streams to have more energy and erode more sediment. Stable stream reaches go through gradual transitions whereas unstable reaches change drastically. The channel evolution sequence is well documented and is often repeated (Figure 6). First, in response to a natural or anthropogenic physical stress (e.g., heavy rains, channelized banks or altered land use), the streambed erodes and the channel becomes over-deepened. As a result the banks become steep and substantially less stable. Eventually, the banks fail and erode and the channel becomes wide and shallow. The shallower channel has less energy and accumulates sediment. In the process it fills in and forms a narrower channel and a new floodplain within the previous channel.

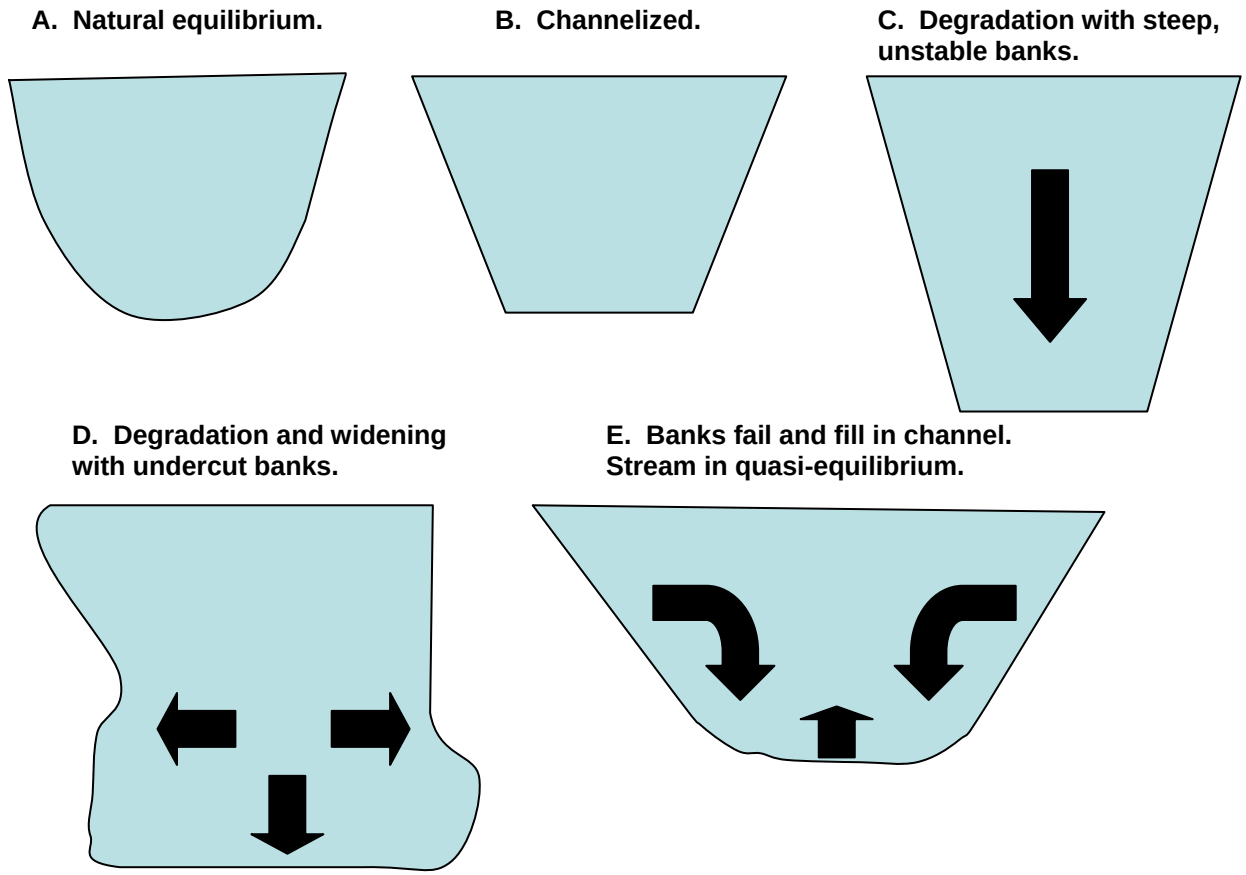


Figure 6. Channel evolution model sequence whereby natural or anthropogenic disturbances initiate a series of morphological changes to the stream channel as it seeks a new state of equilibrium.

Five Areas of Stream Ecosystem Function

Streams are not only landscape features they also serve important purposes. Understanding how streams function is critical to the implementation of successful restoration and protection strategies. A function is defined as a physical, chemical or biological process. There are five areas of ecosystem function: hydrology, physical habitat conditions, water and sediment quality, energy sources and biotic characteristics (adapted from Karr, Fausch, Angermeier, Yant and Schlosser, 1986). These five areas of stream ecosystem function should be considered during the planning, design, implementation and monitoring phases of restoration projects.

Hydrology

Hydrology is the study of the movement and storage of water as it cycles through the atmosphere, surface water and groundwater. As the defining feature of aquatic systems, the

amount, distribution, movement and timing of water are critical factors in shaping stream channels and structuring biological communities. Many organisms life cycles or reproductive periods are timed to take advantage of or avoid specific hydrological conditions. Seasonal changes in stream discharge provide predictable periods of high and low flow affecting a range of other habitat conditions (velocity, turbulence, turbidity, temperature, oxygen levels, and the spatial distribution of riffles, runs and pools). Periodic flood events provide riverine species with access to floodplains and pools for breeding, feeding or refuge from unfavorable conditions in the main channel. Important processes that drive the water cycle and affect hydrology are evaporation, condensation, transpiration, precipitation, runoff and infiltration (Figure 7). A change in the rate of any of these processes alters the balance of the entire system.

One of the greatest threats to natural hydrology is increased development and increased impervious cover (e.g., roads, parking lots, roofs and driveways). These changes result in an increased rate and volume of surface water runoff and a decreased rate of groundwater infiltration (Figure 8). During rain events, waterways in urbanized areas receive large quantities of fast moving stormwater. Conversely, during dry events, low flows are typically lower than usual because the groundwater contribution has been reduced. Depending on the degree of imperviousness, the annual volume of stormwater runoff can increase by two to 16 times its predevelopment rate, with corresponding reductions in groundwater recharge (Schueler, 1994).

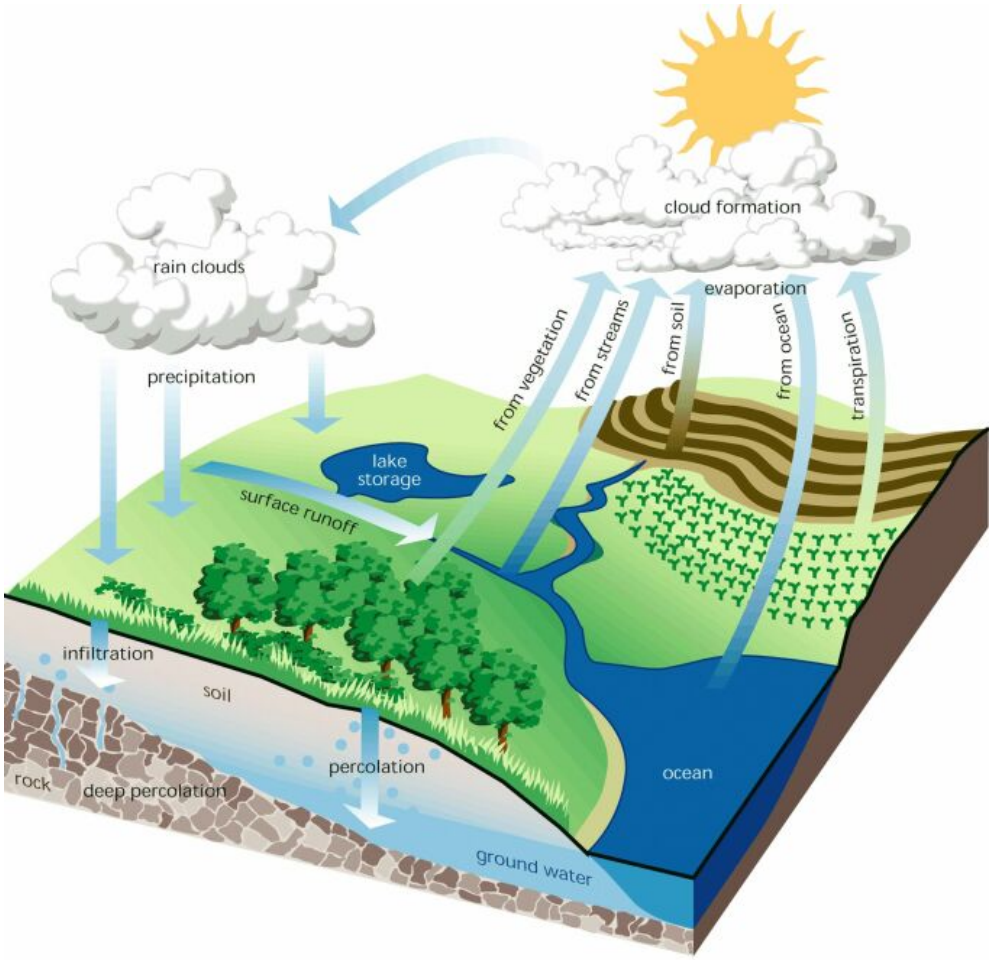


Figure 7. Diagram of the water cycle illustrating the linkages between watersheds and waterbodies and important hydrologic processes (e.g., precipitation, evaporation, runoff and infiltration; Federal Interagency Stream Restoration Working Group, 1998).

Increased impervious cover has also been correlated with decreased water quality. As water flows off impervious surfaces, without an opportunity to be filtered by soil and vegetation, it carries an array of pollutants (e.g., salts, oil and grease, metals, nutrients, pesticides, etc.) directly into waterbodies. In addition to altered water quantity and quality, researchers have documented many other key physical and ecological changes to streams in urbanized areas due to increased impervious cover (Caraco, Claytor, Hinkle, Kwon, Schueler, Swann, Vysotsky and Zielinski, 1998), including:

- Floods increase in magnitude and frequency
- Channels enlarge
- Increased channel erosion and sediment transport
- Dry weather flows decline
- In-stream habitat structure degrades
- Large woody material is reduced

- Stream crossings and potential fish barriers increase
- Riparian forests become fragmented, narrower and less diverse
- Summer stream temperatures increase
- Aquatic diversity is reduced

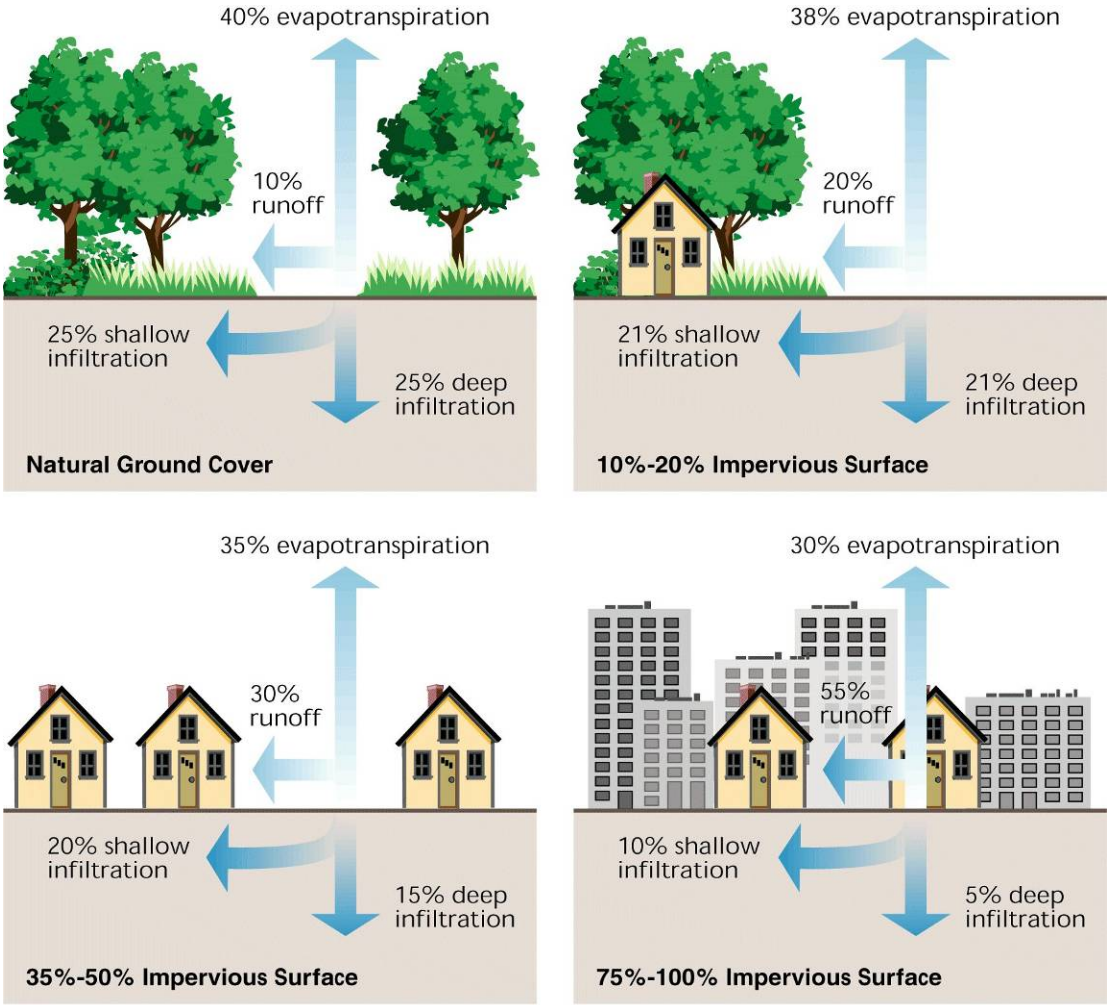


Figure 8. Impervious cover (e.g., roads, rooftops, parking lots) in a watershed results in increased surface water runoff. Studies have shown that as little as 10 percent impervious cover can result in stream degradation (Federal Interagency Stream Restoration Working Group, 1998).

Using various indicators (including macroinvertebrates, fish and measures of water quality), researchers have demonstrated that the health of waterbodies declines when imperviousness reaches 10-20% in the watershed. These studies have been conducted in both freshwater and estuarine waterways (Schueler, 1994; Holland, Sanger, Gawle, Lerberg, Santiago, Riekerk, Zimmerman and Scott, 2004). Watershed imperviousness has emerged as a key environmental indicator as it is directly linked to many environmental variables. The amount

and location of impervious cover can be controlled and monitored by local land use planners and decision makers (e.g., town board, planning board, zoning board of appeals) and natural resource managers. Ultimately, the management of impervious cover benefits all facets of the aquatic ecosystem, including channel stability, water quality and biological communities.

Physical Habitat Conditions

The physical environment provides the foundation of all other structural characteristics (e.g., chemical, biological). Understanding the physical habitat of an area allows for better assessments of the stream ecosystem. Some common physical attributes of streams are described below.

- *Substrate composition.* Substrate composition is determined, in part, by the velocity of water moving through the channel and influences the distribution of organisms.
- *Current.* Water velocity, or current, and the associated physical forces represent the most important environmental factor affecting streams. The speed of current influences the size of particles of the substrate, the delivery and removal of nutrients and food items, and is a direct physical force that affects organisms.
- *Channel morphology.* The size and shape of stream channels is determined by the velocity of water flowing through the stream, local geology and the composition of soils. Common measures of channel morphology include: cross-sectional width, depth and area; slope; and habitat composition (e.g., pool/riffle ratio).
- *Riparian vegetation.* The roots of riparian vegetation are a critical component of streambank structure and serve to strengthen banks and provide resistance to erosion. Additionally, branch and root overhang serve as great habitat and provide cover and shade. Woody debris that enters the stream changes the physical structure of the channel and creates habitat. Debris temporarily pools water, which retains organic matter for processing by macroinvertebrates.

Water and Sediment Quality

The quality of water and sediment are important considerations in stream restoration. Restoration projects that seek to re-establish appropriate flow regimes and channel geomorphology may do little to ensure stream health if water and sediment quality are

chemically impaired. It is important to remember that chemical parameters can be highly variable under natural conditions.

- *Dissolved oxygen.* An adequate level of dissolved oxygen is an essential requirement for a healthy stream ecosystem. Fish and aquatic insects require certain levels of oxygen in the water column to survive (typically > 5 mg/L). While depletion of dissolved oxygen in streams can be natural in some cases, it can also be attributed to oxygen-depleting pollutants such as discharges from wastewater treatment facilities, leaks from septic tanks, and stormwater runoff from agricultural and urbanized areas. In addition, low dissolved oxygen events are more likely to occur during summer months and in low flow locations, such as impoundments behind dams. Some organisms are adapted to low oxygen conditions (called hypoxia) whereas other species, such as trout, suffer detrimental effects if dissolved oxygen concentrations fall below 3 or 4 mg/L. Larvae and juvenile fish are more sensitive than adults and require even higher concentrations of dissolved oxygen. Many fish and aquatic organisms can recover quickly from short periods of low dissolved oxygen. However, prolonged periods of low dissolved oxygen can cause lasting adverse effects, including reduced biodiversity, altered food webs and depressed rates of reproduction.
- *pH.* pH is a measure of the acidity of water and its hydrogen ion concentration. pH is an important characteristic of water that affects its suitability for aquatic organisms and influences chemical reactions. The pH value of streams and other waterbodies is lowered by (1) acid rain and other forms of precipitation in systems that are poorly buffered (e.g., a frequent problem in streams of the Adirondacks and Catskills) and (2) many other anthropogenic activities (e.g., acid mine drainage and industrial effluents).
- *Water temperature.* Water temperature is a critical factor to consider in stream management due to its influence on aquatic organisms and biological processes. To a large degree, water temperature is determined by the source of water in a stream and whether it is derived from cooler groundwater or warmer surface water. Additionally, the amount of riparian cover and shade can keep water temperatures cool.
- *Suspended sediment/turbidity.* Sediment transport is one of the primary functions of streams and rivers. It is important to note that crystal clear water is not natural in all streams and should not be the goal of restoration activities in all cases. Nevertheless,

excess sediment can degrade water quality, clog fish gills and fill in the interstitial spaces between cobbles and gravels where fish deposit eggs thereby suffocating the eggs. Sediment also binds to and transports nutrients and other pollutants into waterbodies.

- *Fecal coliform bacteria.* Fecal coliform bacteria inhabit the intestinal tracts of all warm-blooded and some cold-blooded animals and are used as indicators of fecal pollution. Fecal coliform bacteria are relatively harmless themselves, but they suggest that water may also be contaminated by other pathogens, such as disease causing bacteria or viruses. Elevated concentrations of fecal coliform bacteria may occur as the result of domestic sewage overflow or other nonpoint sources of human or animal waste.
- *Nutrients.* Algae and aquatic plants require nutrients, such as nitrogen and phosphorus, as well as several minor nutrients to sustain growth and metabolism. When these chemicals are limited, plant growth may also be limited. Conversely, nutrient enrichment accelerates plant growth and leads to eutrophication during the decomposition process. Excessive growth of algae and other plants creates nuisance conditions and degrades water quality by depleting dissolved oxygen. Nitrogen and phosphorus levels in streams are elevated by point and nonpoint sources of pollution, such as discharge from wastewater treatment facilities and on-site septic systems, as well as agricultural and residential runoff.
- *Toxic contaminants.* Toxic contaminants are chemicals that can harm the health of humans and aquatic organisms. These chemicals can exist in the water column, but they also tend to adsorb to sediments. Common toxins found in aquatic ecosystems include metals, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), pesticides, and a suite of “emerging contaminants” such as pharmaceutical drugs and flame retardants. Many contaminants are resistant to breakdown and tend to be passed through the food web and accumulate in top predators. Human health advisories for fish consumption are one result of the increased level of contaminants in waterways. The primary contaminants of concern in New York State fish are mercury and PCBs (NYS Department of Health, 2006). Common sources of toxic contaminants include oil, grease, and gasoline from roadways and chemicals used in homes, gardens, yards and agriculture.

Energy Sources

The energy that fuels food webs in streams and rivers is derived from (a) sunlight that drives in-stream primary production and (b) non-living organic matter that originates from within the stream (e.g., dying macrophytes, animal feces) or is transported from outside sources (e.g., leaf litter). While primary production from aquatic plants and algae can be substantial, much of the energy that supports stream food webs is derived from detritus, or non-living sources of organic matter. There are three main categories of non-living organic mater: plant litter, fine particulates and dissolved organic matter (Allan, 1995).

Biotic Characteristics

The composition of living organisms can reveal information about the physical and chemical condition of the habitat. The composition of biological communities is frequently used as an indicator of ecosystem health. An indicator is an organism, species, community or some characteristic of these that indicates the presence of certain environmental conditions. The primary uses of an indicator are to characterize current status and to track or predict significant change.

- *Macrophytes (aquatic plants).* Macrophytes are aquatic plants that grow in or near the water. Macrophytes are typically used as indicators of stream health in areas where they would normally be found because they respond to nutrients, light, toxic contaminants (e.g., metals and herbicides), turbidity and water level changes. They are also easily sampled through the use of transects and do not require laboratory analysis.
- *Periphyton (aquatic algae).* Periphyton are benthic algae that grow attached to surfaces such as rocks or larger plants. Periphyton are useful indicators of environmental condition because they respond rapidly to a number of anthropogenic disturbances, including habitat degradation, contamination by nutrients, metals, herbicides, hydrocarbons and acidification.
- *Aquatic macroinvertebrates.* Macroinvertebrates live in and on the bottom of streams and other bodies of water and include species of crustaceans, insects, worms, snails and mussels. Benthic macroinvertebrates are integral to the aquatic food web, as they provide an important source of food for many species of fish. Macroinvertebrate community composition is used in a variety of aquatic ecosystems as an indicator of habitat condition

and quality. Macroinvertebrate organisms are largely sedentary and are not able to escape environmental or anthropogenic stresses. It is for this reason that the analysis of macroinvertebrate community structure provides an integrated, long-term assessment of overall ecosystem quality. For additional information consult the EPA's website on invertebrates as biological indicators (http://www.epa.gov/bioindicators/html/invertebrate.html) and DEC's website for the stream biomonitoring unit (http://www.dec.state.ny.us/website/dow/stream/orderpageone.htm).

- *Fishes*. Fish are ecologically, recreationally and economically important. Many recreationally important fish are found in New York's streams, including several species of trout, pike, bass, and perch (see DEC Freshwater Fish Brochure - http://www.dec.state.ny.us/website/dpae/pubs/commonfish.pdf). Fish are also good indicators of stream condition. The presence of brook trout, for example, indicates that water quality of headwater streams is usually excellent. Declining brook trout populations can provide an early warning that the health of an entire stream is at risk. Brook trout populations have been eliminated or greatly reduced throughout more than fifty percent of their historical range in New York (Conservation Strategy Workgroup Eastern Brook Trout Joint Venture, 2005). Fish generally have long life histories and integrate pollution effects over longer time periods and larger spatial scales than macroinvertebrates. In addition, because fish are more recognized by the public they provide a more understandable indicator of environmental degradation. Some species of fish, collectively known as diadramous fish, migrate between freshwater and marine waters to live out different parts of their life cycle. There are two types of diadramous fish, those that spend their adult lives in salt water and then move to freshwater to reproduce, such as alewife and striped bass, are called anadromous fish. In contrast, those that spend their adult lives in freshwater and then migrate to salt water to reproduce, such as the American eel, are called catadromous.
- *Riparian vegetation and wildlife*. Healthy riparian areas support a diverse vegetative community as well as many species of resident and migratory mammals, reptiles, amphibians, insects and birds. Species of riparian plants and animals can be used as indicators of stream condition.

CHAPTER 3. STREAM AND WATERSHED ASSESSMENT

This chapter will assist those conducting or reviewing restoration projects in exploring possible causes of stream impairments and assessing the physical, chemical, biological and human-influenced characteristics of the stream and watershed. A critical investigation of this nature is essential to the success of restoration projects. The components of watershed and stream-reach assessment addressed here are similar to the information contained in NYSDOS and NYSDEC's "Watershed Planning in Your Community" guidebook. It would behoove anyone conducting a stream restoration project to fully assess watershed conditions. At the very least, one should know the size and land cover composition of the watershed.

Before implementation of stream restoration projects can begin it is necessary to determine the causes of stream instability and impairment. Such an investigation should reference any existing information and collect new data if needed at watershed and local scales. Sometimes the causes of stream instability and impairment are straightforward and obvious; however, it is more likely that some detective work is needed. In addition to investigating the causes of impairment on a spatial scale (e.g., watershed and local areas), assessments should also include a temporal component. Streams respond to stress over varying time scales and historical information (including aerial photographs) may provide insight about current problems.

The collection and analysis of baseline data pertaining to streams and watersheds is essential in the decision making process. In order to advance the diagnosis and treatment of stream instability and other related problems this chapter will provide an overview of watershed and in-stream assessment techniques. At this point, groups should consider completing a watershed management plan prior to or in conjunction with a stream restoration project (NYSDOS and NYSDEC, 2006). There are numerous techniques to assess the physical, chemical and biological condition of streams, riparian corridors and watersheds. The selection of parameters to assess should be linked to the goals and objectives of the restoration strategy.

Steps for Stream and Watershed Assessment

- Survey existing information.
- Assess gaps in existing information and collect new data where needed.
- Perform desktop assessments of maps and aerial photographs.
- Conduct field surveys.
- Identify potential solutions including stream corridor/watershed management techniques and/or in-stream restoration techniques.

Conditions and Causes of Stream Instability and Impairment

Conditions that provide the impetus for stream restoration activities include impaired stream channel conditions, degraded habitat and threatened infrastructure. A thorough analysis of the causes of these conditions is fundamental to identifying management opportunities and reasonable restoration solutions. For every stream corridor structural attribute that is visually observed to be altered or impaired, there is likely a series of events responsible for the cause of impairment. When conducting a problem analysis it is useful to consider natural and human-induced factors that occur at both the landscape and stream reach scale. Examples of stream instability and impairment that are often visually observed include (adapted from Federal Interagency Stream Restoration Working Group, 1998):

- Stream aggradation (rise in bed elevation over time)
- Stream degradation (drop in bed elevation over time)
- Streambank erosion
- Impaired aquatic habitat
- Impaired riparian habitat
- Loss of native species
- Decrease in species diversity
- Introduction of invasive species
- Increased peak flood elevation
- Lower water table levels
- Increase in fine sediment
- Impaired water quality
- Altered hydrology

There are no simple analytical methods for analyzing relationships between observed impairments and causal events. An investigative approach should be taken that involves an interdisciplinary team and gathers as much evidence as possible. Both natural and human-induced causes of instability and impairment should be considered.

Natural Causes of Instability and Impairment

Despite all evidence to the contrary, the perception persists that ecologically healthy streams and riparian areas are stable. In truth, dynamic processes such as erosion, deposition, flooding and drought frequently occur in healthy streams and are critical for maintaining processes and establishing new habitats. The extent and rates of streambank erosion in pristine systems varies with geological, topographic, climatic and natural land cover conditions; little is known about natural rates of streambank erosion in New York State. However, eliminating all

erosion and flooding can lead to more destruction and instability than letting these processes occur naturally.

Human-Induced Causes of Instability and Impairment

Human-induced factors affect the ecological condition of the stream corridor at landscape and reach scales. Altered land use and increased impervious cover in the watershed can cause a series of hydrologic, geomorphic and ecological impairments (e.g., flashier flows, increased erosion and decreased water quality). Additionally, it is important to consider disturbances at the stream reach scale, such as removal of riparian vegetation, channelization, gravel mining, stream crossings, dams and bank riprap.

Figure 9. Flooding is a natural occurrence that is typical of healthy stream ecosystems. Floodwaters should be allowed to access the floodplain, which should be kept free of buildings and other infrastructure.

Survey of Existing Information

Before beginning a stream and watershed assessment, it is helpful to research what is already known about the area. Historical information, such as aerial photographs, should be obtained. Federal, state, county or local entities may be able to provide information that will save time and effort in the assessment process. Consult the NYS Department of Environmental Conservation's Clean Water Act section 305(b) and 303(d) reports for relevant information about water quality conditions and impairments.

Potential Sources of Existing Information*

County and Local Agencies

- Soil and Water Conservation Districts
- Planning Agencies
- City, Town, Village Officials

Other Groups

- Local and National Non-Profit Groups
- Universities/Schools
- Local Watershed Groups
- Homeowner Associations

State Agencies

- NYS Department of Environmental Conservation
- NYS Department of Agriculture and Markets
- NYS Department of State
- NYS Department of Health
- NYS Department of Transportation

Federal Agencies

- US Department of Agriculture Natural Resources Conservation Service
- US Fish and Wildlife Service
- US Geological Survey
- US Environmental Protection Agency
- National Oceanic and Atmospheric Administration

* *Contact information for these entities can be found in Appendix A.*

Watershed-Scale Assessment

A watershed-scale assessment consists of a landscape level characterization of the natural and human-influenced features of the ecosystem. Much of the necessary information can be obtained from maps and aerial photographs. These data are readily available as geographic information system (GIS) layers. Many GIS data layers can be obtained through the New York State GIS clearinghouse (http://www.nysgis.state.ny.us) or directly from federal, state or local agencies.

Watershed characterization is used to evaluate the human, ecological and physical components within a drainage basin and assess how these factors cumulatively influence habitat and stream condition. In addition to investigating current watershed conditions, characterizations should also examine changes over time. Streams respond to stressors on different time scales. Historical records or photographs can be helpful in identifying causes of stream instability or degradation that occurred in the past, to which the stream may still be responding.

Components of a Watershed-Scale Characterization

A. General Watershed Characteristics
- Watershed and subwatershed delineation
- Stream classification

B. Natural Watershed Characteristics
- Topography
- Soils and geology
- Precipitation
- Wetlands and floodplains
- Surface and groundwater
- Riparian buffers

C. Human-Influenced Watershed Characteristics
- Political boundaries (counties, cities, towns, etc.)
- Land use/Land Cover
- Population
- Zoning and build out potential
- Impervious cover

A. General Watershed Characteristics

- *Watershed and Subwatershed Delineation.* The first step in any stream assessment is to delineate, or map, the watershed. The characteristics and composition of a watershed strongly influence the physical, chemical and biological character of waterways. There are two ways in which watershed boundaries can be delineated. Where applicable the U.S. Geological Survey has developed several layers of watershed boundaries across the country called hydrologic unit codes (HUCs; http://water.usgs.gov/GIS/huc.html). At the broadest level of classification, the country is divided up into 2,150 HUCs or watersheds. These watersheds may be too large for some purposes as they typically encompass multiple waterbodies. If more narrowly defined boundaries are needed they can also be delineated by hand using elevation contours on topographic maps. The Natural Resources Conservation Service has published a helpful fact sheet for delineating watersheds (http://www.nh.nrcs.usda.gov/technical/Publications/Topowatershed.pdf). Once watershed boundaries have been determined, watershed area can be calculated. There is a direct relationship between the size of the watershed and the size of the stream channel. The Center for Watershed Protection (Caraco, Claytor, Hinkle, Kwon, Schueler, Swann,

Vysotsky and Zielinski, 1998) recommends that watersheds larger than 10 mi^2 be broken up into sub-watersheds for assessment and management purposes.

Source: Topographic maps and HUC boundaries can be obtained from the U.S. Geological Survey (USGS).

- *Stream Classification.* Classification is a means of grouping streams and reaches within streams into labeled groups based on common characteristics so that comparisons can be made. Once characteristics (e.g., physical, chemical or biological) of representative streams and stream reaches are known, they can be extrapolated to other streams of the same class. This information can be useful for assessing baseline conditions, estimating probable stream form, monitoring or predicting the changes streams may undergo over time, developing sound management objectives and planning restoration projects. In addition to the two classification methodologies listed below, there are several others available which can be equally as effective in assessing problems and developing appropriate corrective measures (see Bain and Stevenson, 1999)
    - *Stream Order*. Stream order is a method of classification that categorizes streams with respect to their position in the watershed network. A widely-used and easy method is Strahler's (1952) stream ordering system (Figure 10).

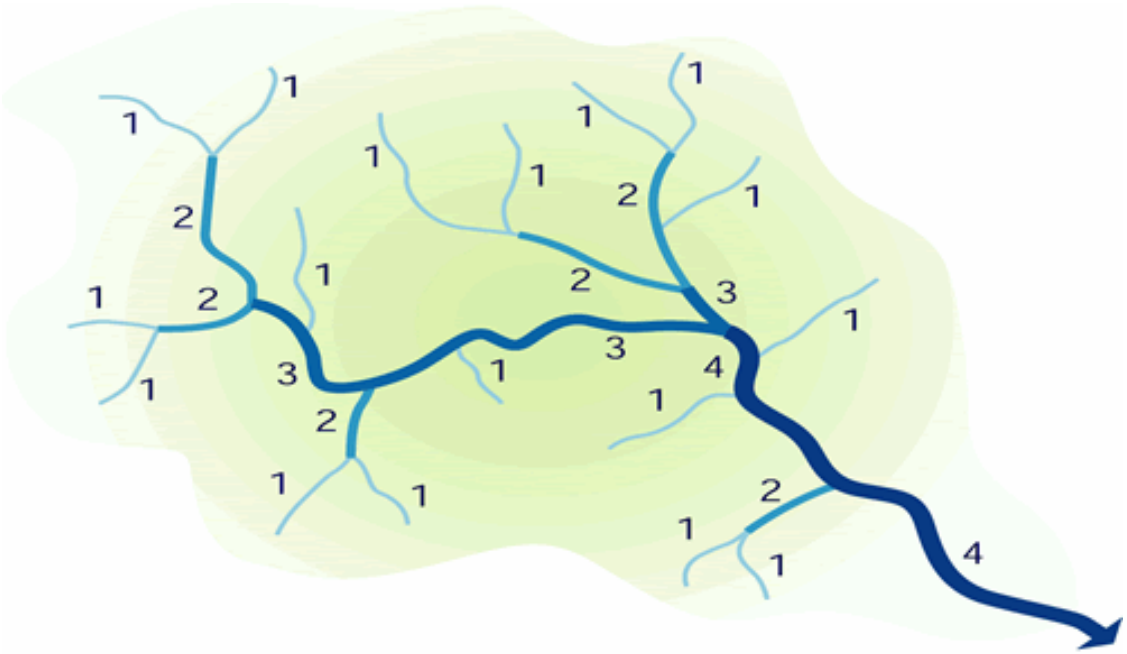


Figure 10. Strahler (1952) stream order classification for a typical watershed.

This system classifies stream segments based upon the number of tributaries upstream and has been found to correlate well with important watershed and stream properties. Stream order is useful in understanding how a stream and its watershed should function, and to some extent what they should look like. Not all streams are the same and this is due, in part, to their position in the larger stream network. A stream with no tributaries, also called a headwater stream, is defined as a first-order stream. A segment downstream of the confluence of two first-order streams is a second-order stream. Only the confluence of two like-order streams results in increased stream order. Streams that are ranked the same order are more similar to one another than streams that are of two different orders.

- *Rosgen Method.* The Rosgen classification system is a widely used method for classifying streams and rivers based on valley and reach-level channel morphology. The U.S. Environmental Protection Agency offers a web-based module to explain the basics of the Rosgen method (http://www.epa.gov/watertrain/stream_class/). There are four levels in Rosgen's classification scheme (Table 1). The Level I characterization uses remote sensing tools and GIS in a watershed-level assessment (Rosgen, 1996). Subsequent levels require field investigations.

Table 1. Rosgen (1996) stream classification.

Rosgen Level	Description
Level I	Broad geomorphic characterization of watershed and valley morphology. Requires topographic maps and aerial photographs. Yields stream types A through G.
Level II	Description of channel characteristics including width-to-depth ratio, entrenchment ratio, channel slope, and substrate composition. Measures of channel dimensions are made with respect to bankfull elevation. Bankfull elevation is defined as the height on the streambank where water begins to overflow onto the floodplain. This step requires field investigation. Yields additional descriptions of stream type [e.g., A(1-6) through G(1-6)].
Level III	Further assessment of stream conditions and the degree of departure from an optimal state. Includes field assessments of riparian vegetation, flow regime, bank erosion potential and aggradation/degradation trends. These parameters relate to the channel evolution sequence
Level IV	Models and empirical relationships are used to validate the extent and magnitude of stream channel adjustment. Examples of empirical analyses include: disturbed vs. reference; pre- vs. post-disturbance; above vs. below disturbance.

B. Natural Watershed Characteristics

- *Topography*. Topography is the geographic representation of the surface features of a region, including elevation and slope. Elevation influences the climatic conditions of an area, size and shape of the watershed, slope, water velocity and composition of in-stream habitats.

  Sources: U. S. Geological Survey topographic maps and digital elevation maps (DEMs).
- *Soils and geology*. The soils and geologic composition of a watershed influence its natural ability to store and transport water and sediment. Certain areas are prone to erosion due to geologic and soil characteristics. Such information is helpful in assessing stream impairments and in the restoration decision-making process.

  Sources: U.S. Department of Agriculture Natural Resources Conservation Service (http://soildatamart.nrcs.usda.gov) provides soils data and information on surficial and bedrock geology can be obtained from the New York State Museum (http://www.nysm.nysed.gov/gis/).
- *Precipitation.* The amount of annual precipitation that a region receives influences the volume of water that passes through the stream channel.

Sources: U.S. Department of Agriculture Natural Resources Conservation Service (http://www.ncgc.nrcs.usda.gov/products/datasets/climate/data/precipitation-state/ny.html).

- *Wetlands and floodplains.* Wetlands and floodplains are important features to consider when planning for watershed and stream restoration. These features provide storage capacity for floodwaters and important habitat for many species. Stream instability may occur in areas where wetlands have been lost or the stream has been cut off from its floodplain.

  Sources: The NYS Department of Environmental Conservation Freshwater Wetlands Program has a lot of background information on freshwater wetlands and mapping information (http://www.dec.state.ny.us/website/dfwmr/habitat/fwwprog.htm). The U.S. Fish and Wildlife Service (USFWS) provides data on federally designated wetlands (http://wetlands.fws.gov). Floodplain maps can be obtained from the Federal Emergency Management Agency (FEMA). Currently only hard copies of maps are available as FEMA is in the process of digitizing its floodplain maps. Paper copies of maps can be obtained locally from county soil and water conservation districts. Caution should be exercised when interpreting floodplain maps, as some maps are outdated and may be inaccurate.

- *Surface and groundwater*. The storage and transport of water are among the primary functions of a watershed. A watershed's ability to store water is determined, in part, by the area of surface waters in the drainage basin, including natural and man-made wetlands, lakes and ponds. The area of surface waterbodies can be calculated using aerial photographs. In addition, the quantity and quality of groundwater is an important consideration when assessing surface water streams. Surface water and groundwater are not two separate entities; rather they are directly linked and are part of a single resource (Winter, Harvey, Franke and Alley, 1998). If reduced stream flow is a concern, it may be helpful to assess groundwater quantity. For additional background information on groundwater, visit The Groundwater Foundation (www.groundwater.org).

  Source: Aerial photographs can be obtained from the NYS GIS Clearinghouse (http://www.nysgis.state.ny.us/gisdata/inventories/results.cfm?themeIDs=18).

Information on groundwater quality and quantity and be obtained from the U. S. Geological Survey.

- *Riparian buffers*. The width and continuity of riparian buffers are important considerations for water quality, and aquatic and terrestrial habitat. There are no New York State or Federal regulations that mandate how wide or continuous buffers should be. The location of the stream and its inherent characteristics, such as slope and vegetative cover, as well as the intent of the buffer dictates how wide it should be. Nationally, minimum buffer width criteria range from 20 to 300 ft, with a median width of 100 ft (Schueler, 1995). In New York, the NYS Nonpoint Source Coordinating Committee recommends that riparian forest buffers be comprised of three zones and have a minimum width ranging from 85 to 110 feet (Boekeloo, 2002). Reduction or removal of riparian buffers is a common cause of stream instability.
  Source: Buffer width and continuity can be measured from aerial photographs (digital orthoimagery), which can be obtained from the NYS GIS Clearinghouse (http://www.nysgis.state.ny.us/gisdata/inventories/results.cfm?themeIDs=18).

C. Human-Influenced Watershed Characteristics

- *Political boundaries.* Many watersheds encompass several political jurisdictions including states, counties, cities, towns and villages. It is important to account for all jurisdictions and involve them in stream restoration and watershed management.
  Source: Municipal, county and state boundaries can be located on topographic maps from the NYS GIS Clearinghouse (http://www.nysgis.state.ny.us/gisdata/).
- *Land use/land cover*. Analysis of land cover and land use patterns provides quantifiable information on how the landscape has been altered. Certain categories of land cover and land use, such as the percentage of urban land cover or the percentage of riparian forest cover, have been shown to be directly linked to stream health. Aerial photographs and satellite imagery can be used to classify land cover and land use. It is possible to determine changes in land cover and land use over time by using historical aerial photographs. Some aerial photography dates back to the 1930's.
  Sources: Aerial photography (digital orthoimagery) can be obtained from the NYS GIS Clearinghouse (http://www.nysgis.state.ny.us/) and from County Soil and Water

Conservation Districts. The National Oceanic and Atmospheric Administration is building a Coastal Change Analysis Program (C-CAP; http://www.csc.noaa.gov/crs/lca/ccap.html), which is a nationally standardized database of land cover and change information developed using remotely sensed imagery for the coastal regions of the U.S. As of 2006, C-CAP information is available for New York's Great Lakes watersheds and data is being developed for the rest of the state's coastal area.

- *Population density*. Increased population density is often the root cause of impairment of waterbodies, especially streams in coastal watersheds. In 2003 it was estimated that 153 million people, or 53 percent of the nation's population, lived in coastal counties (Crossett, Culliton, Wiley and Goodspeed, 2004). Population density can be used as a measure to assess how the landscape has been altered and is typically correlated with land cover/land use and impervious cover.

  Source: The U.S. Census Bureau provides datasets in census blocks on their website that can be downloaded to a GIS software program (http://www.census.gov/geo/www/tiger/). Block data can then be clipped to fit the boundaries of a specific watershed, so that population density corresponds to a specific watershed area.
- *Impervious cover*. Impervious surfaces are those that do not allow water to penetrate into the ground, such as roads, parking lots, driveways, roofs and compacted soil. The percentage of impervious cover within a watershed is the best quantitative indicator of the effect of anthropogenic alterations on aquatic ecosystems. Many studies have documented a strong relationship between increased impervious cover and decreased health and stability of freshwater and estuarine streams and rivers (Limburg and Schmidt, 1990; Booth, 1991; Arnold and Gibbons, 1996; Hicks and Larson, 1997; Schueler, 2003; Holland, Sanger, Gawle, Lerberg, Santiago, Riekerk, Zimmerman and Scott, 2004). Impervious cover is arguably the most difficult and time consuming of the human-influenced characteristics to measure, but there is no doubt that it is the most informative. Framing the issue of nonpoint source pollution in terms of impervious surface can be an effective way of enabling local decision makers to understand and take action. Nonpoint Education for Municipal Officials (NEMO) provides an overview of methods for

measuring and estimating impervious cover (http://nemo.uconn.edu/publications/tech_papers/tech_paper_3.pdf).

Source: Aerial photography can be obtained from the NYS GIS Clearinghouse (http://www.nysgis.state.ny.us/) or from local entities.

Effects of Increased Impervious Cover

- Floods increase in magnitude and frequency
- Hydrologic balance disrupted and channel dimensions enlarge
- Dry weather flows in the stream decline
- Streambank erosion increases and contributes greater sediment loads
- Water quality declines
- Summer stream temperatures increase
- In-stream habitat structure degrades
- Aquatic diversity is reduced
- Abundance of sensitive species decline

- *Barriers and Other Structures.* The presence of barriers (e.g., dams and culverts) and other stream crossing structures (e.g., bridges, railroads and pipelines) throughout the watershed should be noted and assessed for their potential to alter the physical condition of the stream, impede fish passage and disrupt ecological continuity.

  Source: Aerial photographs are helpful for locating barriers, such as large dams. Some of these data may exist in digital format from state and federal agencies (e.g., roads and bridges from NYS Department of Transportation). However, where data are outdated or unavailable field inventories should be conducted to inventory structures (see reach-scale assessment for additional information).

Recommended Publications for Watershed Assessments

- Center for Watershed Protection's Unified Subwatershed and Site Reconnaissance: A User's Manual (Wright, Swann, Cappiella and Schueler, 2004). Describes a “windshield survey” that is useful in urban watersheds to identify specific sites causing stream and watershed degradation.

Reach-Scale Assessment

A reach-scale assessment is used to analyze the physical, ecological and human components of the stream corridor. Reach-scale assessments yield additional information about

the causes and extent of stream stability and impairment at a local scale. This information should complement watershed-scale assessments when determining causes of problems and planning for restorative solutions.

Information needed to complete reach-level assessments is predominately based on field collected data. Many groups recruit volunteers for organized stream walks to collect data. Fieldwork to obtain this information can and should involve community volunteers, although certain components may require the involvement of professionals or specialized equipment. To keep costs down, some groups request the volunteer services of experts. The U.S. Environmental Protection Agency provides guidance on organizing and conducting a volunteer streamwalk (USEPA, 1997; http://www.epa.gov/owow/monitoring/volunteer/stream/vms41.html). Highlighted below are some of the more commonly assessed stream reach characteristics. These characteristics have been divided into three categories; general, natural and human-influenced.

Components of Reach-Scale Characterization

A. General Reach Characteristics
- Stream classification

B. Natural Reach Characteristics
- Channel morphology
- In-stream habitat (e.g., pools, riffles, cover)
- Streambank condition
- Substrate
- Flow and discharge
- Water chemistry
- Riparian vegetation
- Aquatic vegetation
- Macroinvertebrate community
- Fish community

C. Human-Influenced Reach Characteristics
- Barriers and structures (e.g., bridges, culverts)
- Point and nonpoint sources of pollution

A. General Reach Characteristics

- *Stream classification.* The Rosgen classification system is a widely used method for classifying streams and rivers based on valley and reach-level channel morphology. The

Rosgen level I classification was previously mentioned as being applicable for watershed-scale assessments. The Rosgen levels II and III assessments are applicable to reach-scale characterizations (Table 1; Rosgen, 1996). Such a universal classification system makes communicating results of stream assessment and monitoring programs easier among practioners.

B. Natural Reach Characteristics

- *Channel morphology***.** Channel dimensions are closely related to the hydrology, local geology and the condition of the watershed. Parameters include bankfull width, bankfull depth, cross sectional area and slope. Bankfull elevation is defined as the point at which water escapes the stream channel and flows out onto the floodplain. This event occurs every one to two years and is the flow that does the most work on the stream channel over time and moves the most sediment. The most effective way to assess channel morphology is to establish permanent transects across and along a stream reach. Such quantative information can confirm visual observation of areas that are unstable and are changing dimensions. Permanent transect lines can be reevaluated over time and are useful to reassess channel morphology following restoration or channel reconstruction.
- *In-stream habitat***.** An inventory of in-stream habitat is a way to assess a stream's ability to support living resources. Stream reaches can be delineated into habitat types (e.g., pools, riffles, runs) on a map and the percent area of each habitat type can be approximated or calculated. Note the presence of any large boulders, riparian vegetation cover, woody debris and suitable gravel beds for fish spawning.

The Makings of Good Fish Habitat

Many stream restoration efforts are focused, at least in part, on improving habitat for recreationally important fish, like trout. During the reach assessment phase, the presence of good trout habitat can be evaluated.

- Good riparian vegetation
- Stable, undercut banks
- Cold water streams that flow year round
- Boulders and woody debris for cover
- Balance of pool, riffle, and run habitats
- Clear water
- Gravel/cobble substrate for foraging and spawning

- *Streambank condition.* Identify problem areas along the stream where the banks are undergoing significant erosion, scour or slumping. Remember that some erosion is natural and beneficial for the system. Map areas that have been armored by hard structures. Also indicate the location of stable overhanging banks, as they provide shelter and habitat for fish.
- *Substrate.* The size of particles that comprise the streambed is one of the most important aspects of fisheries habitat and is one of the most sensitive measures of change. The most common method to assess substrate composition is the Wolman pebble count (Wolman, 1954). In addition to substrate composition, another important measure of substrate suitability is embeddedness. Embeddedness is the degree to which coarse substrate is buried in fine sediments. The U.S. Army Corps of Engineers has published a compendium of techniques for measuring substrate embeddedness (Sylte and Fischenich, 2002; http://el.erdc.usace.army.mil/elpubs/pdf/sr36.pdf).
- *Stream flow/discharge.* Stream flow, or discharge, is the quantity of water passing through a cross-sectional area of a stream channel per unit time. Water velocity, or current speed, is a component of discharge and is recorded as a rate (ft/s or m/s) at a point in a stream. Water velocity and discharge can be influenced by natural events and anthropogenic activities. Historical and/or current data are available for streams where the U.S. Geological Survey has installed gaging stations (http://waterdata.usgs.gov/ny/nwis/). Measurements can also be made in streams where permanent gages do not exist.
- *Water chemistry.* Measures of water chemistry are important considerations in situations where human health and living resources are a concern. In some instances, water quality information may be available from the NYS Department of Environmental Conservation (http://www.dec.state.ny.us/website/dow/index.html) or local groups. Important water quality parameters include temperature, pH, conductivity, alkalinity, turbidity and dissolved oxygen. In some instances, the measurement of additional parameters such as salinity, concentrations of nutrients and chemical contaminants may also be warranted. Parameters can be assessed automatically at regular intervals with deployed water quality instruments or manually at a single point in time with a grab sample. Continuous

measures collected by an automated sensor provide more accurate information about the average value and variability of the parameters that they measure.

- *Riparian vegetation.* The presence/absence of riparian buffers is equally important at the reach scale as it is at the watershed scale. During field surveys, note the composition of the riparian community and areas where no riparian buffer exists (e.g., presence of infrastructure in the riparian area, lawns mowed to the stream's edge). Also take note of invasive species such as Japanese knotweed, giant hogweed and common reed.
- *Aquatic vegetation.* Aquatic plants and algae (periphyton) are essential components of the aquatic ecosystem. However, excessive plant growth can be indicative of eutrophication. There are many species of aquatic invasive plants to be on the look-out for; such as, Brazilian elodea, Eurasian watermilfoil, hydrilla and water chestnut.
- *Macroinvertebrate community.* A survey of macroinvertebrates (the tiny aquatic insects, worms, and other organisms that live on the stream substrate) can be a valuable component of a stream assessment. In some instances, macroinvertebrate data may be available from the NYS Department of Environmental Conservation's biomonitoring unit (http://www.dec.state.ny.us/website/dow/bwam/sbu.html). Macroinvertebrates are good biological indicators of water quality conditions and are important sources of food for many species of fish. Different species vary in their tolerance of pollutants and other stressors (Table 2). Healthy streams have a wide diversity of macroinvertebrates and a large percentage of stress/pollution sensitive species. Macroinvertebrate communities in impaired streams are not as diverse and are predominantly composed of stress/pollution tolerant species with few to no moderately sensitive or sensitive species. The most common method to sample for macroinvertebrates in streams with gravel or cobble substrate is the kick seine method. Appropriate scientific collection permits are required.

Table 2. Macroinvertebrates used as biological indicators of water quality conditions.

Macroinvertebrates as Biological Indicators		
Stress/Pollution Sensitive	**Moderately Stress/Pollution Tolerant**	**Highly Stress/Pollution Tolerant**
Mayfly larvae Stonefly larvae Caddisfly larvae Mussels	Dragonfly larvae Damselfly larvae Crayfish Sowbugs Beetle larvae Scuds	Aquatic worms Blacy fly larvae Midge larvae Leeches Snails

- *Fish community*. Fish surveys can account for the presence of recreationally important, ecologically important, and threatened or endangered species. Knowledge of what types of fishes exist in an area can help to build community interest and support for stream protection or restoration efforts. Similar to surveys of macroinvertebrates, surveys of fish populations can also provide insight on the biological effects of water quality conditions and the suitability of local habitats. The recommended sampling method for surveying fish populations in wadeable streams is electrofishing. Electrofishing requires specialized equipment that can only be operated by trained professionals. The fish community can also be assessed by surveying the catch of local anglers. Appropriate scientific collection permits are required.

C. Human-Influenced Reach Characteristics

- *Barriers and structures.* Dams and culverts are examples of barriers that block the continuity of stream ecosystems and impede fish passage. In addition, man-made structures like bridges and retaining walls can alter the physical properties of stream channels and hinder their abilities to accommodate higher flows. Some groups, like Massachusetts Riverways in cooperation with the University of Massachusetts, have compiled information about the location of barriers and road-stream crossings on a watershed scale (http://www.streamcontinuity.org/index.htm). These maps help to educate the public about the fragmentation of waterways and assist governments in prioritizing problem areas for restoration.

- *Observable point and nonpoint sources of pollution.* Note any obvious sources of sediment or other pollutants entering the stream.

Recommended Publications for Reach-Scale Assessments

- U.S. Department of Agriculture Natural Resources Conservation Service. Stream Visual Assessment Protocol (Newton, Pringle and Bjorkland, 1998; http://www.nrcs.usda.gov/technical/ECS/aquatic/svapfnl.pdf).
- Center for Watershed Protection's Unified Stream Assessment (Kitchell and Schueler, 2004; http://www.cwp.org/PublicationStore/USRM.htm#usrm10).
- U.S. EPA's Rapid Bioassessment Protocols for use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish (Barbour, Gerritsen, Snyder and Stribling, 1999; http://www.epa.gov/owow/monitoring/rbp/).
- U.S. EPA's Volunteer Stream Monitoring Manual (USEPA, 1997; http://www.epa.gov/owow/monitoring/volunteer/stream/).
- U.S. EPA's DRAFT Wadeable Stream Assessment (USEPA, 2006; http://www.epa.gov/owow/monitoring/wsa/). National report that provides a good example of how assessment data can be used and presented. There is a field operations manual that accompanies the full report (http://www.epa.gov/owow/monitoring/wsa/wsa_fulldocument.pdf).

Analysis of Ecosystem Function

After assessments have been completed, the information should be analyzed to determine the relative extent of impairment of the five general areas of stream ecosystem function: hydrology, physical habitat conditions, water quality, energy sources and biotic characteristics (Karr, Fausch, Angermeier, Yant and Schlosser, 1986).

Restoration of one degraded ecosystem function (e.g., physical habitat) may not produce significant or sustainable effects if another function (e.g., hydrology or water quality) is the limiting factor on ecosystem health. Ranking impairments will help define the benefits versus the costs of various protection and restoration actions, including the no-action alternative. Establishing the relative importance of each type of impairment should be used to set the goals of

the restoration plan and guide the development of a monitoring program to evaluate the success of the plan.

Restoring ecological integrity may be only one objective of a multi-objective stream restoration project. Frequently, property or public infrastructure is the driving objective and ecological considerations must compete for consideration in the restoration strategy. Even in these circumstances; however, the impact of the project on ecological functions should be considered in order to minimize negative impacts.

CASE STUDY 1

Community volunteers conduct a reach-scale assessment of Fishkill Creek

The Fishkill Creek Watershed, located in Dutchess and Putnam counties, encompasses 193 mi² in fourteen municipalities. The watershed is located less than 90 miles from New York City and like many regions in the Hudson River Valley, has experienced rapid growth in the last several decades. The Fishkill Creek Watershed Committee, sponsored by Dutchess County Environmental Management Council was formed in 2002 and completed a watershed management plan in 2004. In 2004 (May-August) a streamwalk was conducted along the mainstem of Fishkill Creek using Natural Resources Conservation Service protocols (http://www.nrcs.usda.gov/technical/ECS/aquatic/svapfnl.pdf) to: (1) evaluate the condition of aquatic resources in Fishkill Creek; and (2) educate and involve the community.

Through a training program, streamwalk volunteers received a basic course in stream ecology, morphology, water quality, non-point source pollution and the relationship between the community and the Creek. These trainings increased volunteers' awareness and understanding of potential impairments to the health of Fishkill Creek. What volunteers learned in the training sessions was reinforced when they were in the field conducting the survey.

Fishkill Creek was divided into 26 segments, of which 16 one-mile segments were selected for assessment during the streamwalk. Data were collected for each segment and for each impaired site that was encountered on the streamwalk. Volunteers logged 477 hours of work, took over 700 digital photographs and captured over 90 global positioning system (GPS) locations. Fifty-five sites were deemed to be impaired and a total of 104 individual impairments were documented. Some of the most commonly observed impairments include: streambank erosion (49% of impaired sites); diminished riparian vegetation (44% of impaired sites); litter and pipe discharges (27% of impaired sites); impoundments, including dams (25% of impaired sites); channel or bank manipulations (18% of impaired sites); and excess algae and high water temperatures (2% of impaired sites). The Dutchess County Environmental Management Council maintains a website for the Fishkill Creek Watershed Committee (www.dcemc.org/fishkill) where all of the streamwalk data are available.

CASE STUDY 2

Watershed and Reach Scale Assessments of the Bronx River Watershed Westchester County, NY

The Bronx River begins in Valhalla, NY at the Kensico Reservoir and flows south, emptying into the East River, which is a part of the Long Island Sound and Hudson River Estuary systems. The Bronx River has long been part of a popular transportation corridor, home to industry and many residents. By the end of the 19th century the Bronx River had degenerated into what one official commission called an "open sewer." The history of the river since the 1880s has been one of efforts to reclaim and protect it from the escalating forces of urbanization. The Bronx River watershed drains 56 square miles of what is currently suburban and urban land area in Westchester County and New York City. The fourteen municipalities in Westchester County in the upper watershed and New York City in the lower watershed joined together to form the Bronx River Watershed Coalition in 2005. The Coalition is developing an intermunicipal watershed management plan for the Bronx River that will address the watershed-wide problems and impairments due to urbanization and propose solutions. The overall vision for the project is to make the Bronx River swimmable and fishable.

To begin this process, Westchester County has characterized the watershed and stream reaches of the Bronx River and its major tributaries within the upper portion of the watershed. The Coalition used the Center for Watershed Protection's Unified Subwatershed and Site Reconnaissance and Unified Stream Assessment protocols to collect information. A combination of desktop analyses and field investigations were used to collect information on four major topic areas: baseline watershed assessment, hot spot investigation, neighborhood source assessment and stream assessment. Westchester County Department of Planning conducted the baseline assessment themselves and hired consulting firms to complete the remainder of the assessments, the results of which are discussed below.

Results of Baseline Watershed Assessment:

Area in Westchester County	**48.3 mi²**
Stream length	**Approx. 53.5 miles**
Land use	**Residential (44.9%)** **Open Space (12.6%)** **Non-residential (21.5%)** **Undeveloped (3.3%)** **Water (16.2%)** **Mixed (1.5%)**
Subwatersheds	**15 subwatersheds**
Jurisdictions	**14 cities, towns and villages; 1 county**
Water Quality	**2004 303(d) list for high DO demand and pathogens**
Current Impervious Cover	**20.3%**
Major transportation routes	**Bronx River Parkway, Sprain Brook Parkway, Cross County Parkways, Cross Westchester Expressway (I-287), and New York State Thruway (I-87)**
Significant natural and historic features	**Kensico Reservoir** **White Plains Reservoirs** **Bronx River Parkway Reservation**

Results of Hot Spot Investigation:

Hot spot sites are those that have the potential to contribute higher levels of stormwater pollutants into waterways, such as municipal maintenance facilities, salt and sand storage areas, private businesses and reported sewage overflows. Over 40 upland hot spot sites were assessed within the upper Bronx River watershed. The investigation confirmed 6 severe hot spots, 11 additional hot spots and18 potential hot spots.

Results of Neighborhood Source Assessment:

Twenty-five neighborhoods were evaluated for possible upland restoration opportunities. Several opportunities were considered, including on-site retrofits, better lawn and landscaping practices, better open space management and parking lot retrofits. Six neighborhoods were identified to have high restoration potential.

Results of Stream Assessment:

Stream reaches were visually evaluated for impairments. In total 20.1 stream miles, or 70 stream reaches, in 7 subwatersheds were evaluated. Reaches were assessed for presence of stormwater outfalls, indicators of stream erosion, areas of encroachment into the stream buffer, utility crossings, stream crossings (e.g., bridges), channel modifications, fish barriers and trash/debris. Of the 70 reaches, 4% were in excellent condition, 23% were in good condition, 33% were in fair condition, 24% were in poor condition and 16% were in very poor condition.

In the next phase of the project, the same watershed and stream assessments will be conducted by New York City in the lower portion of the Bronx River watershed. Once all investigations and assessments are completed the Coalition will develop watershed-wide and site-specific recommendations that this group of 15 municipalities can implement to make the Bronx River fishable and swimmable.

CHAPTER 4. PLANNING FOR STREAM RESTORATION AND PROTECTION

This chapter provides a definition of what ecologically-based stream restoration is, as well as a brief introduction to the components that need to be aligned and people that need to be assembled in order for a stream restoration project to be successful. The best stream restoration projects will identify and address the cause of impairments and seek to achieve multiple objectives. Some essential components include:

- ***Setting a vision and associated goals***
- ***Building local community support***
- ***Funding***
- ***Permits***

Once the problems and opportunities associated with the stream corridor and watershed have been assessed, possibilities for restoration and protection should be explored. The methods selected for a given restoration or protection project greatly influence the cost, expertise needed, labor, time to complete, level of maintenance required and potential for success. It is essential to research past experiences and contribute new scientific knowledge to a publicly accessible arena for a discipline as relatively new as ecologically-based restoration. Lessons learned from past successes and failures with similar projects will help guide the development of future projects. Goals and objectives for each restoration project must be articulated early in the planning process. Once goals and objectives have been determined, monitoring parameters may be selected and an assessment program developed.

The Importance of Protection

It is more cost-effective to protect streams that remain in good condition rather than restore them after they have been allowed to degrade. In the past, funding has seldom been allocated to streams in good condition because it was believed that the most pressing needs were streams where damage was more visible. However, it is now widely accepted that healthy streams and rivers require proactive protection to ensure that they remain in good condition.

Definition of Terms

Restoration ecology is a scientific discipline and requires a consistent use of terms. The terms defined below are those key terms commonly used by restoration practitioners.

- *Ecological restoration.* The process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed. It is an intentional activity that

initiates or accelerates ecosystem recovery with respect to its health (functional processes), integrity (species composition and community structure) and sustainability (resistance to disturbance and resilience) [adapted from the Society for Ecological Restoration].

- *Stream restoration.* The process of converting an unstable, altered or degraded stream corridor (including adjacent riparian zone and floodprone areas) to a natural or stable condition considering the recent and future watershed characteristics. This process addresses multiple objectives and can include the restoration of geomorphic dimension and biological and chemical integrity to achieve dynamic equilibrium.

There are several terms that should not be confused with restoration, including streambank stabilization and enhancement. These single-purpose techniques rarely consider watershed characteristics.

- *Streambank stabilization.* Streambank stabilization is a single-objective activity that seeks to secure a severely eroding streambank. Stream stabilization measures that consist primarily of "hard" engineering, such as concrete lined channels, riprap or rock-filled gabions will not be considered restoration in most cases.
- *Enhancement.* Stream enhancement is the process of implementing certain stream rehabilitation practices in order to improve water quality and/or ecological function. A common example of stream enhancement is the placement of in-stream habitat structures.

Set Vision and Goals

In order to set goals for stream restoration, a desired outcome or vision of future stream conditions is needed. Protection and restoration can seek to address any combination of objectives that pertain to water quality, biological quality, hydrological regime, quality of physical habitat, or human health and other community concerns. If the desired outcome is to protect drinking water, goals might be to protect and improve the health of every stream in a particular watershed, to preserve a certain level of flow in every stream, or to protect the quality of recharging groundwater. If the desired outcome is to promote tourism and recreation on

healthy streams, the goals may include enhancing the economic value of the stream by improving access.

In addition to project specific goals, there are established statewide goals for habitat restoration in New York that all projects should strive to achieve (Niedowski, 2000).

1. To the greatest extent practical, achieve functional, community, and/or ecosystem equivalence with reference sites when undertaking restoration.
2. Restore priority habitats for fish, wildlife and plant species, including those listed as threatened, endangered, and of special concern by Federal and State governments, and species of historical or current commercial and/or recreational importance in New York State.
3. Plan and implement restoration initiatives using an ecologically-based regional perspective to integrate and prioritize individual restoration projects and programs.

Gather a Diverse Team

Streams and aquatic ecosystems are ecologically complex. No single discipline can fully address the needs of the ecosystem or the project. Every stage of the project, from planning to implementation and monitoring would benefit from the expertise of a multi-disciplinary team, which could include:

- Hydrologists
- Geologists
- Fluvial geomorphologists
- Fisheries biologists
- Aquatic ecologists
- Botanists/plant ecologists
- Wildlife biologists
- Engineers
- Regulatory officials
- Local leaders

Build Community Support

In addition to the ecological value, the societal value of restoring streams should also be considered in restoration planning. Potential values derived from stream restoration activities may include educational, recreational and commercial benefits. The recreational and aesthetic values of a restored stream may be more influential in garnering public and political support for a projected than the degree of ecological function achieved.

There are several ways to build community support including public events and outreach activities. A watershed forum builds awareness of issues that the community should understand, such as water supply, stormwater pollution, zoning and low impact development. Outreach activities that bring people to the water, such as community clean-up days or adopt-a-stream programs, are a great way to get people in touch with the aquatic resources in their community.

Identify Funding Sources

There are several sources of funding available from private entities and local, state and federal governments for projects involving watershed management and stream restoration. Different sources of funding can be obtained for the planning, design and implementation phases of a project. A comprehensive list of funding sources is provided in Appendix B.

Review Permit Requirements

Depending on the type of restoration project proposed, various permits will be required. An overview of the state and federal laws and regulations that are pertinent to stream restoration and management projects can be found in Appendix C.

Important Considerations for Stream Restoration

1. Do nothing. Aquatic ecosystems are resilient, meaning that they have the ability to recover from disturbances. When thinking about a stream restoration project, the no action alternative must be the first consideration. What would happen if nothing was done at all? Without human intervention streams would adjust and reach a steady state over time, however this process may take decades. Restoration activities can help to expediate the process of natural recovery.

2. Use a reference site. When deciding that a stream is in need of restoration, it is useful to identify reaches within the same stream or other streams in the area that share characteristics with the stream of interest and are in stable condition (Harrelson, Rawlins and Potyondy, 1994). Reference sites can be used as models to identify conditions that are representative of a natural, stable state and are essential in the selection and design of appropriate restoration practices. In addition to helping generate restoration ideas, a reference site is useful for setting goals for the project site and for monitoring purposes. Some practitioners choose to use two reference sites,

one that is stable and in good condition and the other that is degraded. Such a two reference site system assists in developing a trajectory of restoration objectives, where the degraded site is the situation to move away from and the stable site is the one to move toward.

3. Address on-going causes of degradation. Restoration efforts are likely to fail if the root causes of impairment or instability are not adequately identified or addressed. It is not possible to eliminate the cause of degradation in all situations, however it is essential to know these causes exist and it may be possible to mitigate them if they cannot be directly addressed. Depending upon the stressors involved, stream corridor and watershed management techniques, in-stream restoration techniques, or a combination of both may be appropriate solutions.

4. Natural ecosystems are variable. Natural ecosystems are not static and vary on spatial and temporal scales. This, in part, contributes to the complexity of aquatic ecosystems and their great diversity of life. Restoration efforts that are flexible and allow for variability are preferred, such as vegetative solutions to instability. Restoration projects that are static and are designed to harden streambanks, such as the placement of riprap and other structures, are not encouraged as they can contribute to additional problems (e.g., increased downstream erosion).

A Stream Restoration Essential

Development of Regional Curve Models for New York

The US Geological Survey in New York is working to create regional curve models for each of the hydrophysiographic regions in New York (Figure 11; http://ny.cf.er.usgs.gov/nyprojectsearch/projects/2457-A29-1.html). These models are based on bankfull discharge, which is primary force responsible for structuring the size and shape of the stream channel (e.g., creating bankfull elevation) and the size of the drainage area. Regional curves are used in natural stream channel design to verify field determinations of bankfull discharge and stream channel characteristics. Using these curves, the width and depth of the bankfull channel can be approximated, even on streams without gages, once the drainage area of a watershed is known.

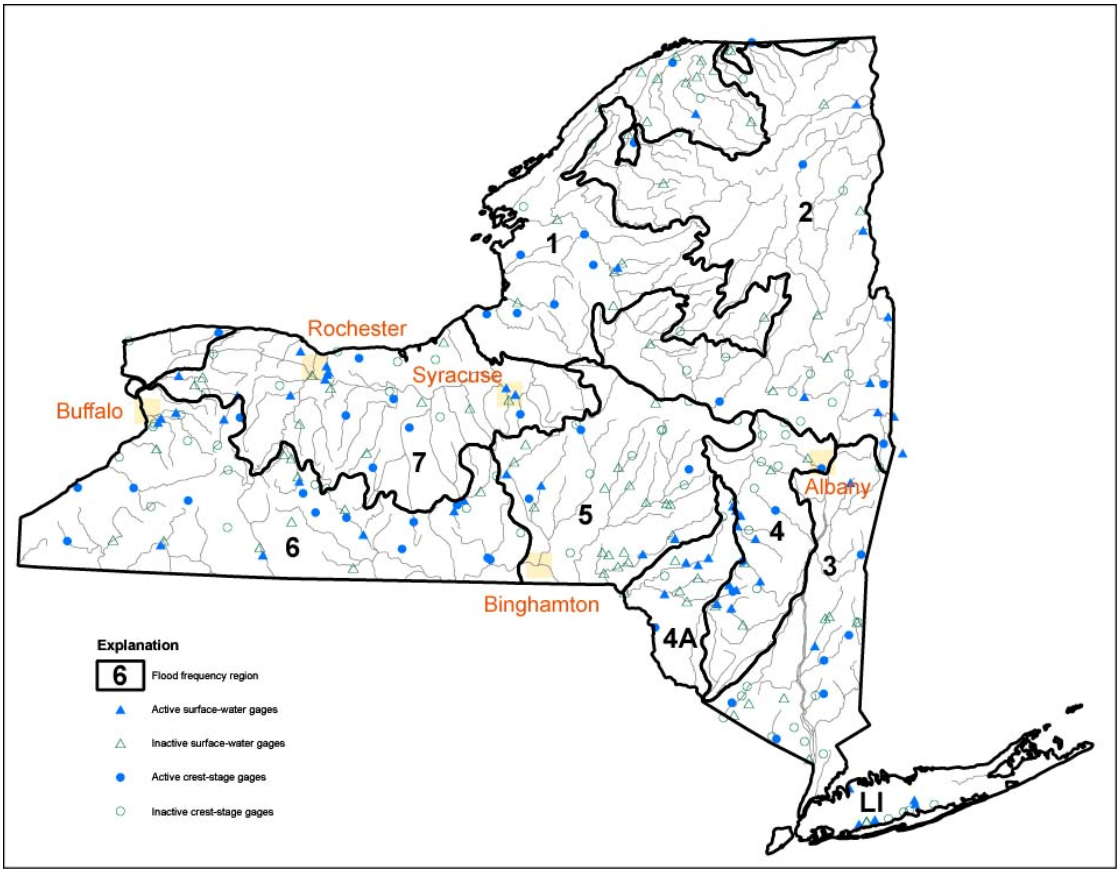


Figure 11. Hydrophysiographic regions of New York used by the U.S. Geological Survey for development of regional curve models. Long Island was excluded from the study and regions 1 and 2 have been combined.

CHAPTER 5. TOOLS AND TECHNIQUES FOR STREAM CORRIDOR MANAGEMENT

This chapter contains information about what can be done along the stream corridor and in upland areas to protect and/or improve in-stream conditions. The tools and techniques presented here will engage local land use planners and municipal officials in stream restoration and protection efforts. Major topics include:

- ***Land use planning***
- ***Resource-based laws and ordinances***
- ***Open space protection and acquisition***
- ***Municipal operations***
- ***Stewardship and education***

There are a number of tools and techniques that local governments and land owners can use to protect and restore the ecological integrity and functioning of stream corridors. The overall goals of these stream corridor management tools and techniques are to minimize physical disturbances, control the input of nonpoint sources of pollution, maintain the natural hydrology of the system and restore impaired stream segments. Stream corridor management tools and techniques include land use planning, resource-based laws and ordinances, open space conservation and acquisition, municipal operations and stewardship and education. In most communities, a variety of stream corridor management techniques will be employed as part of a comprehensive stream corridor and watershed protection program to protect water quality and aquatic habitats.

Forested and vegetated stream corridors can significantly minimize adverse impacts on water quality from land use practices and development pressures. Vegetated land cover protects water quality by filtering pollutants before they reach streams and groundwater. Converting vegetated areas to paved surfaces increases the amount and velocity of water runoff, resulting in stream channel instability, erosion and sedimentation. It also reduces the amount of water available to recharge groundwater aquifers.

Inappropriate development along stream corridors can impair water quality, lead to costly flooding problems and contributes to the degradation of aquatic and terrestrial habitats. Vegetated buffers, also known as riparian areas, along stream corridors can help protect the ecological values of streams as well as provide recreational opportunities for walking and biking. Establishing an adequate buffer area for protection of stream hydrology and ecology requires

analysis of a number of factors including soil type, slope and vegetated cover. A more detailed study may be needed to find the appropriate protection buffer for a specific stream or river. Protecting riparian corridors has multiple benefits, including:

- Reducing velocity and volume of runoff into streams, which helps to stabilize streambanks and beds.
- Providing habitat for plants and animals that require the narrow band of land along rivers to survive.
- Improving water quality through shading/cooling the water, filtering excess nutrients, sediment and other harmful pollutants, and adding important woody debris to the aquatic environment.

I. Land Use Planning

The primary responsibility for regulating land use and development in New York State rests with local municipalities. Local governments can protect water quality and aquatic habitats through a variety of land use tools including: comprehensive plans, zoning, subdivision review and site plan review. The discussion in this section is intended to provide a brief introduction to the tools and techniques that a community can use to protect stream corridors. For more information about local land use planning, contact the NYS Department of State Division of Local Governments and the New York Planning Federation.

1. Comprehensive Plans

A comprehensive plan is used by a community to establish a vision for its future growth and development and to develop policies, goals and recommendations for implementing that vision. Guidelines for preparing a comprehensive plan are contained in New York State General City Law §28-a, Town Law §272-a, and Village Law §7-722. The State statutes define a comprehensive plan as "the materials, written and/or graphic, including but not limited to maps, charts, studies, resolutions, reports and other descriptive material that identify the goals, objectives, principles, guidelines, policies, standards, devices and instruments for the immediate and long-range protection, enhancement, growth and development" of the municipality.

The contents of comprehensive plans vary among communities, but most contain components that address public infrastructure, public services, resource protection and economic

development (Church and Traub, 2000; Damsky and Coon, 2005). Typical contents of a comprehensive plan include:

- General statements of goals, objectives, principles and policies.
- Consideration of regional needs and the official plans of other government units.
- Existing and proposed location and intensity of land uses.
- Existing and proposed educational, historical, cultural, agricultural, recreational, coastal and natural resources.
- Demographic and socio-economic trends and projections.
- Existing or proposed location of transportation facilities, public and private utilities and infrastructure.
- Housing resources and future housing needs, including affordable housing.
- Measures, programs, devices, and instruments intended to implement the goals and objectives of the various topics within the comprehensive plan.

The comprehensive plan can be used to highlight the need to protect natural resources, including stream corridors, and to recommend specific programs to implement protection strategies. The comprehensive plan can also recommend working with adjoining communities to establish intermunicipal, watershed-based or ecosystem-based approaches to natural resource management. New York's zoning enabling statutes require that zoning laws be adopted in accordance with a comprehensive plan. The comprehensive plan should be thought of as a blueprint on which zoning and other land use regulations are based.

2. Zoning

Zoning regulates the use, density and siting of development on individual parcels of land (Damsky and Coon, 2005). Zoning can be used to help implement a municipality's comprehensive plan and may be used to direct growth and development to areas appropriate for that purpose and away from areas intended for protection or preservation, such as stream corridors and wetlands

Zoning commonly consists of two components: a zoning map and a set of zoning regulations. The zoning map divides a municipality into various land use districts, such as residential, commercial and industrial. The zoning regulations describe the permissible land uses

in each of the various zoning districts identified on the zoning map. They also include dimensional standards for each district, such as the height of buildings, minimum distances (setbacks) from buildings to property lines and the density of development.

Many communities want to promote development patterns which traditional zoning can only partially achieve. The desired development patterns may include focusing new development in traditional hamlets and protecting agricultural land and natural resources, including stream corridors and wetlands. Among the innovative zoning techniques available are special use permits, overlay zoning, incentive zoning, performance zoning, planned unit developments, cluster developments and official maps.

a. Special Use Permits

The special use permit is a zoning technique that allows a municipality to require special review and conditions for proposed uses that could have adverse impacts. The special use permit is granted only if the proposal meets the special use permit standards found in the zoning regulations. The special use permit standards established by a municipality should depend upon its planning objectives. For example, special use permit criteria can require development proposals to provide buffer areas and best management practices for control of non-point source pollution adjacent to stream corridors or wetlands. They can also require that a percentage of land be left as open or green space. Special use permits are authorized under New York State General City Law §27-b, Town Law §274-b, and Village Law §7-725-b.

b. Overlay Zoning

Overlay zoning allows a community to apply a common set of standards to a designated area that cuts across different underlying zoning districts. An overlay is a mapped district of supplementary regulations which is superimposed, or overlaid, upon existing zoning districts and regulations in a community (Heritage Task Force for the Hudson River Valley, 1990; Damsky and Coon, 2005). The standards of the overlay zone apply in addition to those of the underlying zoning district. Overlay zoning is frequently used to protect stream corridors and floodplains. The standards for the overlay district can be structured to address riparian buffer protection, flooding dynamics, stormwater management, habitat protection or the amount of impervious cover.

c. Incentive Zoning

Incentive zoning allows developers to exceed the dimensional, density or other limitations of zoning regulations in return for providing certain benefits or amenities to the municipality. Communities can use incentive zoning to provide various public amenities such as affordable housing, public access to a waterbody and public park improvements. Incentive zoning can also be effective in encouraging desired types of development in targeted locations. Incentive zoning is authorized under New York State General City Law §81-d, Town Law § 261-b, and Village Law § 7-703.

d. Performance Zoning

Performance zoning regulates development based on the permissible effects or impacts of a proposed use, rather than by the traditional zoning parameters of use, area and density. Under performance standard zoning, proposed uses whose impacts would exceed specified standards are prohibited unless the impacts can be mitigated. Performance zoning can be used by communities to regulate environmental impacts, such as stormwater runoff, scenic and visual quality impacts, and defined impacts on municipal character.

e. Planned Unit Developments (PUDs)

Planned unit developments allow for more flexible development practices than traditional zoning. A planned unit development can be permitted for a mix of residential densities or a mix of residential and non-residential uses. A community can allow development within the unit to be clustered, such that the individual lots are smaller but more open spaces are preserved than would otherwise occur though traditional zoning.

f. Cluster Developments

Cluster developments allow for flexibility in design of subdivisions in order to concentrate development on the most appropriate portion of a site, thereby preserving important resources and limiting encroachment into environmentally sensitive areas. Cluster subdivisions can be used to preserve open space, scenic views, and agricultural lands and to protect streams, riparian areas, wetlands, steep slopes and wildlife habitats. Cluster subdivisions are authorized under New York State General City Law §37, Town Law §278, and Village Law §7-738.

g. Official Maps

An official map may be used by a municipality to develop logical, efficient and economical street and drainage systems and protect the future rights of way needed to implement these systems. Under the statutes, the governing body of the municipality may establish an official map of its area, showing the streets, highways, parks and drainage systems established by law. It may add future requirements for facilities to the official map and the land so reserved may not be used for other purposes without the consent of the municipality. The official map is authorized under New York State General City Law §26, §29, §35, §35-A, & §36, Town Law §270, §273, §280, §280-A, & §281, Village Law §7-724, §7-734, & §7-736, and General Municipal Law §239-e & §239-f.

3. Subdivision Review

Subdivision regulations control the process by which land is divided into smaller tracts of land. Subdivision is defined in the State enabling statutes as "the division of any parcel of land into a number of lots, blocks or sites as specified in a local ordinance, law, rule or regulation, with or without streets or highways, for the purpose of sale, transfer of ownership, or development." These regulations typically include provisions and procedures related to maximum grades, street widths, cul-de-sac dimensions, minimum lot frontage and infrastructure (e.g., sewers, street lights and sidewalks). Subdivision review is also important to ensure that future development on a site adequately protects riparian areas from physical disturbances, hydrological modifications and pollutant loading. Subdivision review is authorized under New York State General City Law § 32 & §33, Town Law §276 & §277, and Village Law §7-728 & §7-730.

4. Site Plan Review

Site plan review is a land use technique used to evaluate the arrangement, layout and design of a proposed use on a parcel of land. Site plan review allows communities to address a wide range of issues by implementing standards for stormwater management, traffic flow, parking, landscaping and buffering, drainage facilities, and any other elements specified in the local site plan law or ordinance. Site plan review can be a valuable tool for minimizing impacts associated with projects which occur in environmentally sensitive areas.

A local site plan review requirement may be incorporated into the zoning law or ordinance, or may be passed as a separate local law or ordinance. The local site plan review regulations or local zoning regulations determine what uses require site plan approval. The site plan review requirement may be triggered by location of a proposed use within a specified zoning district; type or size of a proposed use; or location within specified overlay zones, such as a flood zone or historic preservation district. Site plan review is authorized under New York State General City Law §27-a, Town Law §274-a, and Village Law §7-725-a.

II. Resource-Based Laws and Ordinances

Laws and ordinances can address a variety of issues that are relevant to streams, including; erosion and sedimentation, stormwater, floodplains, wetlands and groundwater (NYSDEC, 1996). Prior to drafting new regulations, the suitability of existing regulations, codes and ordinances should be evaluated (Genesee Finger Lakes Regional Planning Council, 2006).

1. Erosion and Sedimentation Control / Stormwater Management

Stormwater runoff can result in flooding and erosion, as well as significant pollution of streams and other waterbodies. Communities can manage construction site and post-construction stormwater runoff to protect natural resources and quality of life. The most effective way to manage stormwater is to adopt a stormwater management local law that amends existing subdivision, site plan and/or zoning laws or ordinances. The local law should include the requirement that developers prepare a Stormwater Pollution Prevention Plan (SWPPP) and sanctions for non-compliance. The goal of the local law is to retain stormwater on developed sites wherever possible, with the quantity, rate and quality of runoff remaining as they were before the sites were developed.

One technique for managing stormwater is the incorporation of low impact development (LID), or better site design, into site plans for new development. LID is focused on managing stormwater at its source on a parcel by parcel basis and can be a cost-effective, more attractive type of development that offers both ecological and economic benefits. To accomplish this, creative construction designs direct water off or away from paved surfaces and onto permeable surfaces such as vegetated rooftops, rain gardens, permeable pavement and vegetated swales. More information can be obtained from the U.S. Environmental Protection Agency

(http://www.epa.gov/owow/nps/lid/lid.pdf), Nonpoint Education for Municipal Officials (http://nemo.uconn.edu/reducing_runoff/index.htm) and Low Impact Development Center's (http://www.lid-stormwater.net/intro/homedesign.htm) websites.

2. Floodplain Management

Floodplain regulations are land use controls that govern the amount, type and location of development within defined floodprone areas. In order to participate in the National Flood Insurance Program municipalities are required to adopt and enforce ordinances restricting development in the 100-year floodplain. The restrictions include a requirement that buildings be elevated above flood elevations or be flood-proofed, and also include prohibitions on the filling of land within a floodplain. Enforcement of these local floodplain ordinances, usually under the authority of the local building inspector, is one of the most effective protections that municipalities can provide for the stream corridor. Often, however, building inspectors are unaware that they have this responsibility.

Municipalities can adopt their own floodplain regulations which may be more stringent than the federal standards. Local floodplain regulations are usually more accurate and can identify a larger hazard area (such as a 500-year floodplain), and may also prohibit certain types of construction within flood hazard areas. In this way, local floodplain regulations can tailor flood hazard protection to local needs.

3. Wetlands Protection

Wetlands provide a number of benefits to a community, including protecting water quality; providing flood protection; providing wildlife habitat, providing opportunities for recreation, tourism and education; and enhancing open space and property values.

In coastal communities, they also serve as a buffer against shoreline erosion. State wetland regulations protect freshwater wetlands greater than 12.4 acres (1 acre in the Adirondack Park), freshwater wetlands of unusual local importance and tidal wetlands. The State has established adjacent wetland buffer zones, prohibited certain activities within such areas and has established standards for permit issuance. The U.S. Army Corps of Engineers also regulates federally-defined wetlands. Local regulation of wetlands is an important tool for protecting wetlands and wetland functions in a comprehensive and consistent manner that supports local

planning objectives. Protection of smaller, locally significant wetlands is an integral component of the protection of riparian habitats and functions. Local wetlands regulations often include protection of both watercourses and wetlands.

4. Water Resource Protection

Municipalities can adopt laws to protect groundwater recharge areas, watersheds and surface waters. Local sanitary codes can be adopted to regulate land use practices that have the potential to contaminate water supplies and address the location of drinking water wells and the design and placement of on-site sanitary waste disposal systems. Water resources can be further protected through the adoption of land use laws that prohibit certain potentially polluting land uses in recharge areas, watersheds and near surface waters. These laws may be in the form of an overlay district based on waterbodies or recharge areas or may be watershed based. Site plan review laws and subdivision regulations may also be used to minimize the amount of impervious surfaces, and to require that stormwater systems be designed to protect water supplies.

III. Open Space Protection and Acquisition

Open space provides many benefits to the community including; habitat protection and biodiversity, protection of water quality, providing opportunities for recreation and environmental education, tourism and tourism-related economic development, aesthetics and community character. Open space can be publicly or privately owned and can include recreational sites, parks, greenways, trail networks, cemeteries, forests and woodlands, wetlands and stream corridors, agricultural land and historic properties (NYSDEC, NYSDOS and NYSOPRHP, 2005).

A good way for a municipality to assess the importance of its open space resources is to develop an Open Space Plan or to include an assessment of open space resources as part of its comprehensive plan. Once a community has identified its open space resources, it can develop policies to protect them. Those policies should be expressed in the open space plan and in the community's comprehensive plan, along with maps showing their location. It is important to ensure that the open space policies of the comprehensive plan are implemented through the municipality’s land use controls. The General Municipal Law (GML) establishes open land preservation as a public purpose. Section 247 of the GML authorizes local governments to

expend public funds to acquire interests or rights in real property to preserve open space (NYSDEC and NYSDOS, 2004).

There are two types of land acquisition techniques: fee simple acquisition and acquisition of partial interests or rights by easement. Fee simple acquisition is the purchase of the fee title interest in a parcel of land. Acquisition of partial interests can involve the purchase of development rights (PDR), where the rights to develop the land are voluntarily offered for sale by the owner, who retains all other rights of ownership and a conservation easement is placed on the land and recorded on the title. A conservation easement is a legal agreement between a landowner and the municipality or a qualified conservation organization that permanently limits the use of land to protect its natural resource value. Easements are used to protect property and preserve land by excluding certain activities, such as commercial development or residential subdivisions. Landowners receive a tax break as an incentive. Additional information can be found on the Land Trust Alliance (http://www.lta.org/conserve/options.htm) and the Nature Conservancy's websites (http://nature.org/aboutus/howwework/conservationmethods/privatelands/conservationeasements/).

Local governments in New York can use a variety of approaches to raise revenue to protect open space, including a permanent or time-limited revenue stream derived from existing or new taxes or fees and local general revenue bonds issued for the purpose of obtaining funds to acquire open space resources.

An innovative technique for protecting a community's open space resources is the Transfer of Development Rights (TDR). TDRs are authorized under New York State General City Law §20-f, Town Law §261-a, and Village Law §7-701. Under the State zoning enabling statutes, areas of the municipality which have been identified through the planning process as in need of preservation (e.g., agricultural land) or in which development should be avoided (e.g., municipal drinking water supply protection areas) are established as "sending districts". Owners of land in these designated areas may sell the rights to develop their lands, and those development rights may be transferred to lands located in "receiving districts". Receiving districts are those areas which the municipality has determined are appropriate for increased density based upon a study of the effects of increased density in such areas. For example, a town may determine that it is appropriate to preserve prime agricultural land, which it designates as a

sending district, and that its unincorporated hamlet area may be developed at a higher density and designated as a district where development rights can be used to increase density above what is allowed by right.

IV. Municipal Operations

Municipal operations can impact stream corridors through physical disturbances associated with road and bridge construction, and water quality impacts associated with stormwater discharges and road maintenance activities. Activities to reduce the inputs of sediment and chemicals from roadways into waterbodies, such as street sweeping and regular maintenance of catch basins, are encouraged. In addition, the seeding of roadside ditches is one of the easiest most effective ways to stabilize soil and combat erosion. Several local and county agencies have invested in hydroseeders. Local governments can also take steps to reduce the input of road salt and other deicing chemicals into streams, such as adjusting the rate and timing of applications and constructing proper storage facilities.

V. Stewardship and Education

Local governments can also foster stream corridor management by sponsoring community education and stewardship activities such as stream clean-ups and volunteer monitoring programs that involve businesses, land owners and interested citizens in stream corridor management.

Public education initiatives can build awareness and support for watershed and stream related efforts. Examples of activities include: storm drain stenciling; water bill brochure inserts; road signs that note entrance to specific drainage basins; website for facts and information pertaining to the local watershed; listserve to distribute information about the watershed; press releases for local newspapers and television and radio stations; and watershed education module for local schools.

Volunteer stream clean-ups are great ways to provide citizens with a hands-on experience with waterways in their community and are also great ways to improve the health of streams. The Adopt-A-Stream-Foundation provides some good tips for organizing stream clean-ups (http://www.streamkeeper.org/tools/tips.htm).

Volunteer monitoring programs engage citizens in environmental protection efforts and augment existing monitoring programs that are often limited by shrinking state budgets. There are several resources available for those interested in establishing a volunteer monitoring program. Westchester County's website provides a great example of how volunteer monitoring data can be used to educate the community and to provide decision makers with the information they need (http://cvmp.westchestergov.com/cvmp/). Other useful links include:

- U.S. Environmental Protection Agency (http://www.epa.gov/owow/monitoring/volunteer/stream/);
- Maryland Department of Natural Resources (http://www.dnr.state.md.us/streams/mbss/mbss_volun.html); and
- Connecticut Department of Environmental Protection (http://dep.state.ct.us/wtr/volunmon/volopp.htm).

CASE STUDY 3

Upland Restoration Techniques Used to Improve Conditions in Ketcham's Creek Babylon, NY

The Town of Babylon, NY is the westernmost town in Suffolk County and is located on the South Shore of Long Island. Babylon is heavily urbanized due to its close proximity to New York City. Land use in the Town is predominantly intermediate density residential with 5-10 dwelling units/acre.

Area: 32,664 acres
Population: 216,890 (2004)
Population Density: 6.64 persons/acre (2004)

Ketcham's Creek is a tributary to Great South Bay whose watershed lies within the Town of Babylon. There is a high level of impervious cover in the watershed, which generates significant quantities of stormwater runoff. There are a number of roadways that dead end at the Creek and directly contribute overland runoff. The existing stormwater infrastructure in Babylon was developed prior to the enactment of current environmental and stormwater legislation. The sole function of stormwater systems prior to modern environmental regulations was to convey runoff from the roadways as quickly as possible. These old stormwater systems were simple and extremely efficient. Street drains were designed to collect road runoff, which was directed through a series of underground pipes and eventually discharged directly to Ketcham's Creek and other surface waters. Ketcham's Creek and Great South Bay had impaired water quality due to high concentrations of several pollutants including, pathogens, nutrients, metals and organic compounds. Shellfish beds and bathing beaches are frequently closed due to human health concerns.

The Town of Babylon utilized several upland management techniques in the stream corridor and in the watershed to restore water quality in Ketchum's Creek with the goal of re-opening shellfish beds and bathing beaches. This approach illustrates the steps a community can take to restore streams in heavily urbanized watersheds.

- Stormwater wetlands were created in 2003 to capture runoff and provide some treatment to reduce the contribution of pollutants directly to Ketcham's Creek.
- Grassy swales were constructed at the end of the dead end roadways along the stream corridor to reduce overland runoff.
- Leaching chambers have been installed in the stormwater infrastructure. These leaching chambers withhold runoff and allow suspended sediment to settle in the chambers. The withheld stormwater slowly leaches into the ground as opposed to directly discharging into Ketchum's Creek and Great South Bay, thereby reducing chemical, sediment and thermal pollution.
- Signs were installed to educate the community about the Town's efforts to restore Ketchum's Creek and to discourage illegal dumping, and promote good watershed management practices and adherence to the pooper scooper law.

CHAPTER 6. STREAM RESTORATION TECHNIQUES

This chapter provides an overview of six common categories of stream restoration techniques:

- ***Riparian revegetation***
- ***Barrier mitigation***
- ***Habitat construction and enhancement***
- ***Streambank stabilization***
- ***Grade control***
- ***Natural channel design***

Within each category are a series of questions to consider when planning, reviewing or implementing a stream restoration project. In addition, general guidance and recommendations are provided. References and knowledgeable contacts are listed for each category. Proposed restoration projects should be critically examined and should be justified and supported by stream and watershed assessments (Chapter 3) and include plans for monitoring (Chapter 7).

Ecologically based stream restoration uses techniques throughout the watershed to reduce stress and reverse the loss of ecosystem function. While fully restoring watershed hydrology and removing all anthropogenic stresses might be the preferred approach to stream restoration, constraints of time, cost, legality and existing uses often preclude such comprehensive methodologies. In-stream restoration projects are generally implemented at the reach-scale. A reach is a uniform stream segment and is distinguished from other reaches by natural changes (e.g., substrate composition) or artificial breaks (e.g., bridges, property lines). If approached in an ecological fashion, reach-scale stream restoration is a viable way to achieve restoration objectives in a localized and manageable area that benefits the entire watershed.

It is important to recognize that reach-scale restoration efforts cannot solve watershed-scale problems. Assessments should be conducted and problems identified as outlined in Chapter 3 prior to implementing any reach-scale activity. This will likely prevent efforts from being limited to addressing symptoms and ignoring underlying causes. The most effective way to achieve the greatest ecological success is to pair corridor and watershed-scale land management techniques with reach-scale stream restoration efforts.

Over the last decade, stream restoration practices have evolved from being highly engineered and focused on single objectives (e.g., rock riprap to prevent banks from eroding) to incorporating natural protective features and seeking to achieve multiple objectives (e.g., bioengineering practices that reduce bank erosion and enhance habitat). Despite the fundamental role of engineering, stream restoration as a practice is becoming more holistic. Practitioners are

recognizing that to restore streams to a healthy condition with in-tact ecological functions multiple objectives must be met. Recent advances in stream restoration include attempts to design and re-build stream channels with sufficient structural complexity and variability such that a stable, ecologically functional aquatic ecosystem is regained.

The NYS Department of State Division of Coastal Resources promotes the rehabilitation of streams and rivers through ecologically-based restoration techniques with a preference for "soft" engineering practices. Local governments should encourage and, where appropriate, initiate and participate in stream restoration activities.

General Guidelines

- Passive restoration, where human disturbances are reduced or removed and the ecosystem is allowed to recover naturally should be considered first. Streams are dynamic and resilient ecosystems and are sometimes able to recover once stressors are removed and natural processes resume.
- Restoration, even at the reach-scale, should take a watershed perspective.
- Local reference reaches should be consulted to obtain restoration design parameters.
- Restoration practitioners should seek to achieve multiple objectives, some of which may include: drinking water protection, streambank stabilization, water quality protection, habitat enhancement, aesthetic value, fish passage, stream continuity, appropriate public access, and increased recreational opportunities.
- If active restoration is used, then techniques and materials should be selected that are ecologically-based and mimic the natural environment.
- All restoration projects should be monitored to determine if they meet the goals that they were designed to achieve. A monitoring program should be developed before restoration activities begin.

1. Riparian Revegetation

Activity Description

The restoration of riparian buffers is one of the easiest and most beneficial activities to improve stream ecosystems (Figures 12 a&b, 13). Reforesting lands surrounding rivers and streams has become a key element in improving water quality and habitat. Revegetation efforts should be accompanied by regulations for protection. Municipalities can create their own riparian buffer regulations that are tailored to local conditions and meet the needs of the community. Riparian planting projects generally present a low risk of negative impact and can accelerate the recovery of riparian functions such as temperature control, bank stability, fine sediment control and large woody debris recruitment. Local governments and landowners should be aware that channels migrate within valleys over time and riparian revegetation projects can buffer the effects of erosion and reduce long-term channel migration. However, vegetation alone is not adequate in all situations, in which case bioengineering techniques that combine vegetation with hard structures should be considered.

Considerations

1. Is the vegetation suitable for the site and is it indigenous to the area?
2. Have the causes of vegetation removal or loss been identified and addressed?
3. What types of vegetation will be used (i.e., live stakes, cuttings, potted materials)?
4. Is there a long-term agreement to manage/maintain the buffer with the landowner?

Guidance

- Use only native species that would naturally be found in similar conditions.
- Late fall or early spring are the preferred times for planting.
- Don't be overly neat with planting area. Leave the surface rough with larger rocks and boulders, which will discourage mowing.
- Seed the area around plantings with a hydroseeder or other means to stabilize loose soils. Laying down annual grass provides temporary stability until larger vegetation takes root.
- If planting during the growing season (e.g., summer months) periodic watering may be necessary to ensure plant survival.
- Monitor vegetation during summer months after one growing season.

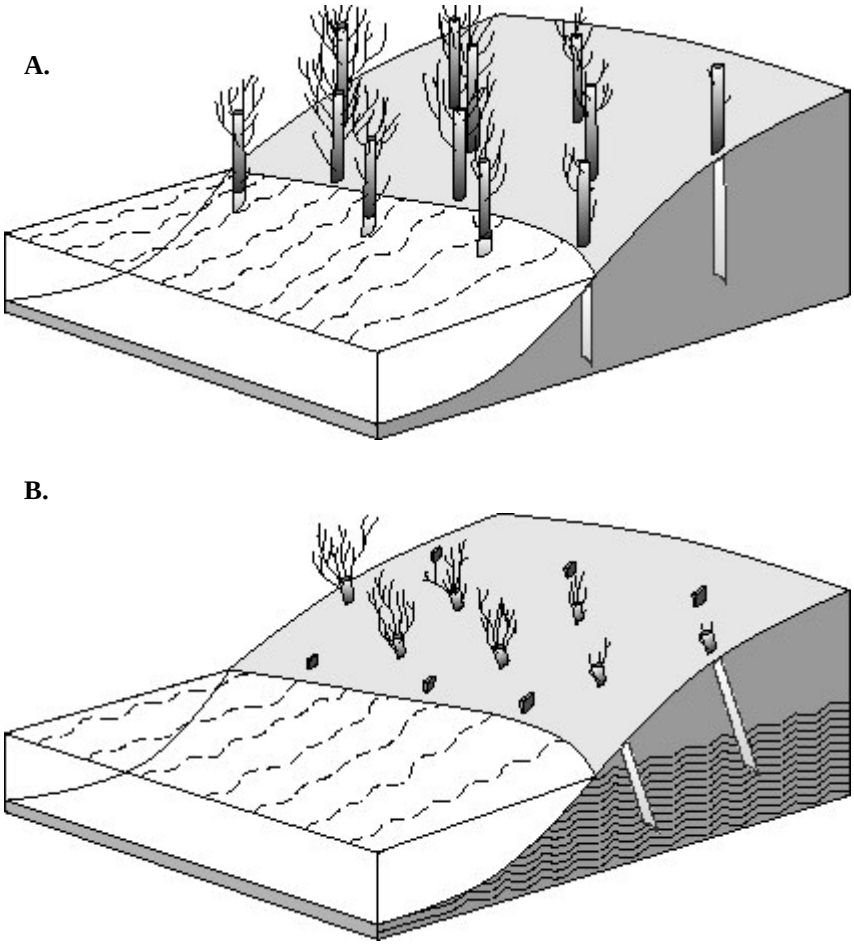


Figure 12 (a & b). In addition to potted plants and grasses, dormant posts (a) and live stakes (b) can be used to re-establish riparian buffers. These plantings also can help to stabilize streambanks (Federal Interagency Stream Restoration Working Group, 1998).

Technical Assistance

Publications:

- Berkshire Regional Planning Commission. 2003. The Massachusetts Buffer Manual. Prepared for the Massachusetts Department of Environmental Protection. (http://www.berkshireplanning.org/download/).
- The Federal Interagency Stream Restoration Working Group. Stream Corridor Restoration: Principles, Processes and Practices. 1998. (http://www.nrcs.usda.gov/technical/stream_restoration/).

Agencies/Groups:

- NYS Department of Environmental Conservation [including the Saratoga Tree Nursery, Saratoga Springs, NY. (518) 587-1120].
- U.S. Department of Agriculture Natural Resources Conservation Service
- NYS Department of State Division of Coastal Resources

Figure 13. Planting potted vegetation in the floodplain aids in the establishment of a functional riparian buffer.

Riparian Buffers

The protection and restoration of riparian buffers is one of the easiest and most beneficial activities to restore streams. Reforesting lands surrounding rivers and streams has become a key element in improving water quality and habitat. In New York there are no statewide regulations for riparian buffer width. However, a group of state agencies comprising the State Nonpoint Source Coordinating Committee recommends a three zone buffer with a minimum width ranging from 85 to 110 feet (Boekeloo, 2002). Local governments have the ability to create their own riparian buffer regulations that can be tailored to fit the conditions and to meet the needs of the community. For more information about the benefits of buffers:

- Cayuga County - Cornell Cooperative Extension (http://www.co.cayuga.ny.us/wqma/greenthumbs/buffers.htm).
- Connecticut River Joint Commission (http://www.crjc.org/buffers/Backyard%20buffers.pdf).
- Massachusetts Buffer Manual (http://berkshireplanning.org/4/1/#buf).
- U.S. Department of Agriculture Natural Resources Conservation Service - Buffer Strips (http://www.nrcs.usda.gov/feature/buffers/).
- National Oceanic and Atmospheric Administration Coastal Services Center - Vegetated Buffers (http://www.csc.noaa.gov/alternatives/buffer.html).

2. Barrier Mitigation

Activity Description

Numerous streams throughout New York contain small dams, perched culverts, or other artificial barriers installed over the last century that disrupt stream continuity, impede the passage of fish and other wildlife, impair water quality and pose risks of injury. Options for barrier mitigation include full or partial dam removal, culvert replacement or installation of fish passage structures.

Considerations

1. Who owns the dam? Is the dam owner actively involved in dam management and maintenance?
2. Is there the potential that contaminated sediments have collected behind the dam?
3. What species of fish are present in the stream? If non-native fish species are present, removal of barriers may introduce invasive species to new areas.
4. Is removal of the barrier and re-establishment of stream continuity and fish passage a priority in the watershed? Are there other watershed or stream issues that should be addressed first to make the barrier removal most cost-effective and successful? For example, if the goal of barrier mitigation is to reintroduce anadramous fish and the area has degraded water quality, then treatment of point and nonpoint sources of pollution should be addressed first to provide suitable habitat for fish before barrier mitigation is considered.
5. Who has a stake in the decision about the future of the dam? Have all the stakeholders' interests been identified?

Guidance

- Full removal of dams, culverts and other barriers that impede fish and wildlife passage and disrupt stream continuity is the best solution for the restoration of streams and diadramous fish habitat and wildlife corridors. Full removal permanently restores the waterway, is self-sustaining and does not require on-going maintenance.

- Where full dam removal is not possible, structures to pass fish and other organisms should be considered. There are several different designs for fishways, including; steeppass, denil and pool-and-weir.
- Poorly designed or failing culverts should be replaced with bridges or open bottom arch culverts.
- New culverts should be embedded into the channel, have a natural bottom substrate, span the channel width and provide water depths and velocities that are comparable to nearby natural stream segments (Figure 14). New culverts should be large enough to pass floodwaters.

Figure 14. It is recommended that culverts be embedded into the channel and have a natural bottom substrate.

Technical Assistance

Publications:

- River and Stream Continuity Partnership. 2006. Massachusetts River and Stream Crossing Standards (http://www.streamcontinuity.org/pdf_files/MA_Crossing_Stds_3-1-06.pdf).
- American Rivers and Trout Unlimited. Exploring Dam Removal: A Decision-Making Guide. (Bowman, Higgs, Maclin, McClain, Sicchio, Souers, Johnson and

Graber, 2002; http://www.americanrivers.org/site/PageServer?pagename=AMR_content_efba).

- River Alliance of Wisconsin and Trout Unlimited. 2000. Dam Removal: A Citizen's Guide to Restoring Rivers (To order: http://www.wisconsinrivers.org/index.php?page=content&mode=view&id=39).
- American Rivers. Paying for Dam Removal: A Guide to Selected Funding Sources (Otto, 2000; http://www.americanrivers.org/site/DocServer/pdr-color.pdf?docID=727).
- American Rivers. Dam Removal Success Stories. (Maclin and Sicchio (eds.), 1999).
- World Commission on Dams. Dams, Ecosystem Functions and Environmental Restoration (Bergkamp, McCartney, Dugan, McNeely and Acreman, 2000).

For additional resources check the American Rivers website (http://www.americanrivers.org/site/PageServer?pagename=AMR_content_8cf8).

Agencies/Groups:

- NYS Department of Environmental Conservation
- NYS Department of Transportation
- NYS Department of State Division of Coastal Resources
- U.S. Army Corps of Engineers
- U.S. Fish and Wildlife Service
- National Oceanic and Atmospheric Administration Restoration Center
- The Nature Conservancy
- American Rivers

CASE STUDY 4

Dam Removal on the Salmon River…a Work in Progress
Fort Covington, NY

The Salmon River in Franklin County, New York is a tributary to the St. Lawrence River. The Fort Covington Dam (Figure 15) is the first barrier on the Salmon River and is located five miles upstream of the confluence with the St. Lawrence River. The Fort Covington Dam is a concrete structure built in 1913 for hydroelectric power but currently serves no purpose. It has a total length of 240 feet with a 90 foot long spillway and impounds approximately 12 acres of water in a linear pond upstream.

Figure 15. The Fort Covington Dam on the Salmon River, tributary to the St. Lawrence River. Work to remove the dam began in 2001 and is expected to be completed by 2007.

Work to remove the Fort Covington Dam began in 2001 when the Town of Fort Covington received an award from the Department of State Division of Coastal Resources through the National Oceanic and Atmospheric Administration's Great Lakes Coastal Restoration Program. In addition to the Town of Fort Covington, project partners include representatives from private consulting firms, non-profit groups, universities, and federal and state agencies. Removal of the dam would open over 15 miles of the main stem of the Salmon River and over 20 miles of tributary streams to migratory and resident fishes. American eel, lake sturgeon and the eastern sand darter are the primary species of interest due to their threatened status and declining populations. Recreationally important species of fish, such as walleye, northern pike and muskellunge will benefit from the removal of the dam as well. Dam removal has not been an easy undertaking in New York State and the Fort Covington Dam would be only the second dam in New York State to be removed for environmental reasons.

Studies completed for the proposed removal evaluated many components of the ecosystem, including: watershed characteristics, fish passage and habitat, macroinvertebrates,

sediment quantity and quality, water levels, flooding and bank stability. During these investigations it was discovered that the Town waterline, which was located on the riverbed behind the Fort Covington dam, would continue to block fish passage if it was left in place and the dam was removed. Therefore, it was determined that the waterline had to be rerouted over a downstream bridge and removed from the riverbed. The costs associated with the design and re-location of the water line added significant cost to the total project budget.

Four removal alternatives were evaluated for the Fort Covington dam site: full removal, spillway removal, full depth partial width removal, and partial depth spillway removal. Each alternative was assessed based on its potential to improve public safety, alleviate flooding and benefit the ecosystem. It was determined that full removal of the dam, including the abutments, would best achieve these goals. Monitoring the ecological effects of dam removal on the Salmon River was also a primary goal of the project. Scientists from the State University of New York College of Environmental Science and Forestry (SUNY–ESF) conducted a baseline assessment to evaluate pre-dam removal environmental conditions. The study design included the Salmon River and a nearby river, the Little Salmon River, which does not have any barriers along its lower reach and served as a reference condition. Post-dam removal surveys will be conducted to complement the data that were collected during the baseline study. The dam is anticipated to be removed during 2007.

Several grants were secured to complete work on this project, including: NYSDOS Division of Coastal Resources/NOAA Great Lakes Coastal Restoration Program, NYS Senate, NOAA/American Rivers, USEPA Great Lakes National Program Office and the Great Lakes Protection Fund.

3. Habitat Construction and Enhancement

Activity Description

Habitat construction and enhancement projects include activities to create habitat in the short term by directly altering the bed and banks of a stream as well as those that add habitat structures within the stream channel. General caution should be applied before proceeding with habitat construction projects. Materials used to construct or enhance habitat should be native to the stream. Additionally, those projects that are designed to be rigid and unchanging over time may interfere with the stream's natural recovery process. Anchoring habitat structures prevents them from drifting and interacting with the stream channel and floodplain at different flow levels.

Examples of habitat construction and enhancement projects include:

- In-stream placement of logs, rootwads and boulders (Figure 16a)
- Pool and riffle construction
- Alcove and side channel excavation
- LUNKERS (which stands for Little Underwater Neighborhood Keepers Encompassing Rheotactic Salmonids). Rheotactic refers to fish that prefer to face into the current. LUNKERS were first developed and used in Wisconsin and serve as an engineered, overhanging bank structure that provides habitat for fish and increases bank stability (Figure 16b).

Considerations

1. Is the lack of habitat to be constructed a limiting factor in the diversity or abundance of fish populations in the stream reach? Sometimes other factors such as high water temperature or barriers to fish passage may be the leading cause of decline in local fish populations. A habitat construction project alone would be of little value in these situations.
2. Is the proposed habitat construction or enhancement project the optimal way to address degraded habitat conditions, or would alternative projects like riparian planting be suitable?
3. Is the habitat construction project designed to mimic habitat elements that would naturally occur in the stream reach? Projects that do not mimic natural habitat

characteristics may provide temporary benefits but often do not provide long-term benefits. Consult a local reference reach to determine what is natural for the area.

4. Do the benefits of the habitat construction project outweigh the risks the project poses? For streams that are in relatively good condition, does the construction project actually risk degrading habitat if it fails?

5. Will this project be self-maintaining through time? High flood flows and sediment loads often modify or destroy projects which are not designed to mimic naturally occurring habitat elements. If the project is not self-maintaining, is there a maintenance plan?

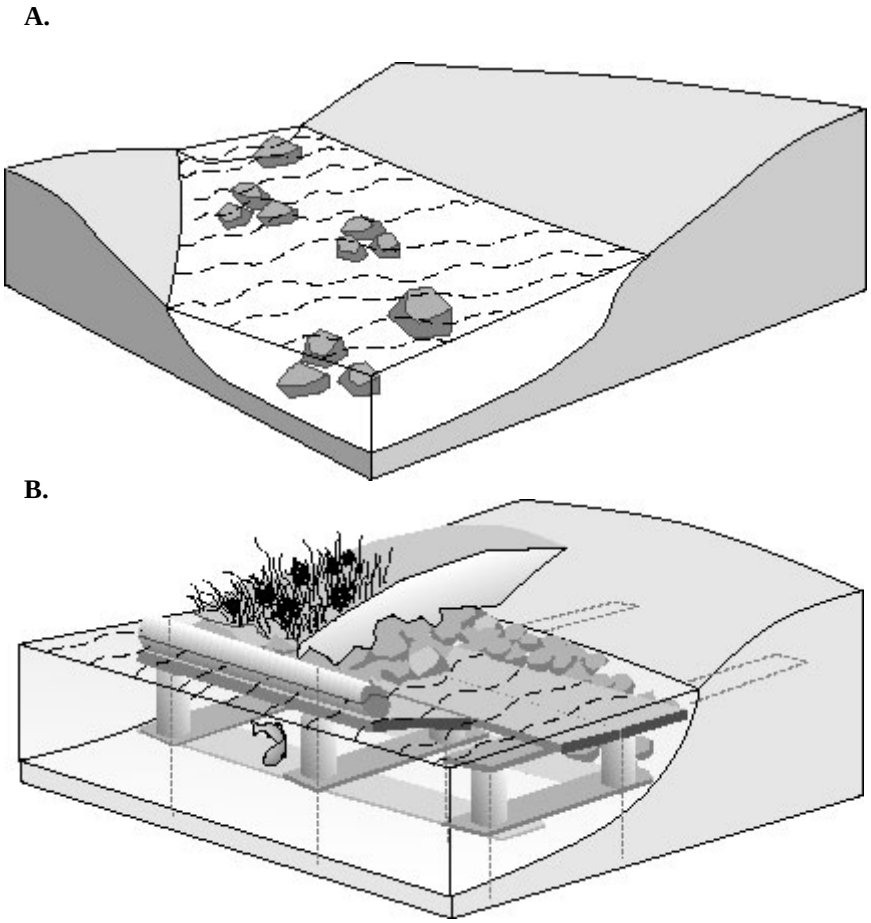


Figure 16 (a&b). Examples of habitat enhancement projects. The placement of boulder clusters in the stream channel (a) creates eddies and small pools. LUNKERS (Little Underwater Neighborhood Keepers Encompassing Rheotactic Salmonids) (b) simulate over-hanging streambanks and provide cover for fish (Federal Interagency Stream Restoration Working Group, 1998).

Guidance

- Design habitat elements to be functional at baseflow conditions. Habitat enhancements for fish and other aquatic organisms that are constructed high in the stream channel serve no purpose during periods of low flow when they are out of water.
- Wood and/or bounder placement projects that rely on the size of the material for stability, rather than anchoring with cables or rebar are preferable because they more closely resemble natural conditions. However, artificially anchoring structures is sometimes necessary.
- In-stream habitat structures alone do not substitute for good riparian and upland management. However, in-stream structures can provide shelter and breeding areas that encourage aquatic insects and fish to thrive. Restoring habitat complexity by including a diversity of habitat types often results in greater species diversity and abundance.

Technical Assistance

Publications:

- King County Department of Public Works. Guidelines for Bank Stabilization Projects (Johnson and Stypula, 1993; http://dnr.metrokc.gov/wlr/biostabl/).
- Federal Interagency Stream Restoration Working Group. Stream Corridor Restoration: Principles, Processes and Practices. (1998; http://www.nrcs.usda.gov/technical/stream_restoration/).

Agencies/Groups:

- NYS Department of Environmental Conservation
- NYS Department of State Division of Coastal Resources
- U.S. Fish and Wildlife Service
- Trout Unlimited

4. Streambank Stabilization

Activity Description

For hundreds of years structures have been placed at the land-water interface to stabilize streambanks and prevent erosion. A variety of materials have been used to stabilize streambanks, including vegetation, timber, rocks, concrete, metal sheet piling, tires and even household junk. Recently, the use of "softer" engineering techniques than those traditionally used has emerged. Bank stabilization projects that primarily use vegetation or integrate vegetation with other materials have proven effective in stabilizing streambanks. As vegetation becomes established, the bank becomes naturally stronger and resistant to erosion, reducing the need for continual maintenance. Vegetated streambanks are more economical, aesthetically pleasing, absorb energy, reduce erosion, provide habitat and improve water quality by trapping and retaining nutrients and pollutants contained in upland runoff. The Division of Coastal Resources encourages the use of bioengineering or hybrid practices in streams in New York's coastal watersheds.

Hard structures, like rock riprap or revetments, are sometimes necessary for streambank stabilization especially in areas where infrastructure is at risk. These structures, however, cause abrupt transitions in ecological zones and can diminish habitat value. Specifically, they decrease the diversity and quality of habitats and impede natural processes that are necessary and beneficial for healthy aquatic ecosystems. They limit the natural ability of streambanks to absorb energy and adjust in response to shifting flows. Hard structures often exacerbate downstream erosion and generally have a short life span.

In agricultural areas, livestock exclusion fencing is recommended to keep animals out of waterways and maintain in-tact streambanks.

Techniques used for bank stabilization include vegetation, bioengineering, bank reshaping, flow redirection and hard armoring and are briefly described below. Many bank stabilization projects combine several of these methods.

- Bank reshaping involves regrading the streambank to reduce the slope and stress on the bank. It is generally recommended that banks be sloped at a ratio of 2:1 (horizontal:vertical; Figure 17).

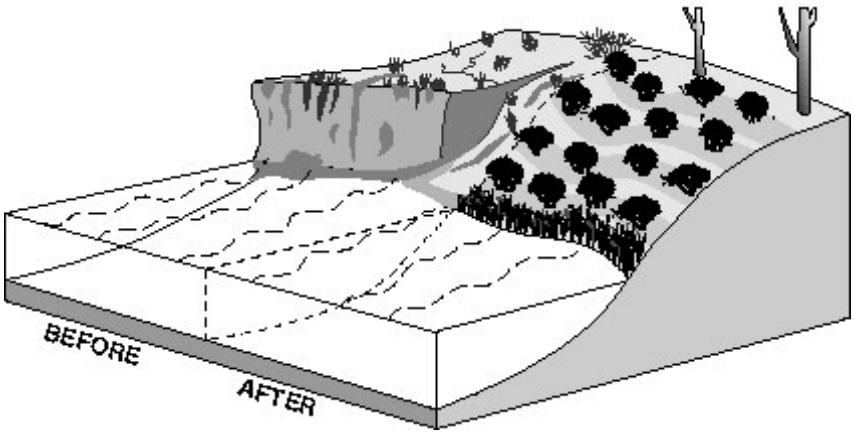


Figure 17. Bank reshaping involves the re-grading of streambanks to produce a more stable slope. Reshaping should be considered prior to planting or use of bioengineering techniques (Federal Interagency Stream Restoration Working Group, 1998).

- Vegetation includes live fascines, brush mattresses, live stakes or branch layering (Figure 18 a&b).
- Bioengineering relies on a combination of structural components and plant materials to produce a dense stand of vegetation that serves as a "living system" to protect streambanks and shorelines. This technique works to stabilize many but not all erosion problems. The major challenge with bioengineering is protecting the bank from erosion until vegetation becomes established. Some projects have used coconut fiber rolls or erosion control blankets that eventually break down and biodegrade to address this issue (Figure 19 a&b).
- Flow redirection structures are constructed at specific angles to direct flow away from streambanks and into the center of the channel and allow for slower moving currents to deposit sediment near the streambank (Figure 20).
- Hard armoring includes a variety of techniques such as rock riprap, revetments and gabion baskets (Figure 21a). If done properly these techniques reduce localized erosion and work in more severe situations where bioengineering practices will not suffice. If hard armoring is required, structures should only be placed at the toe of the bank where erosive forces are most concentrated (Figure 21b). These techniques alone are generally not considered restoration; however, they are necessary in certain situations. Hard armoring techniques can be relatively expensive and require professional assistance and heavy machinery. Hard armoring methods are frequently over-used and are often used in

situations where less expensive, more environmentally friendly and aesthetically pleasing alternatives would have been successful.

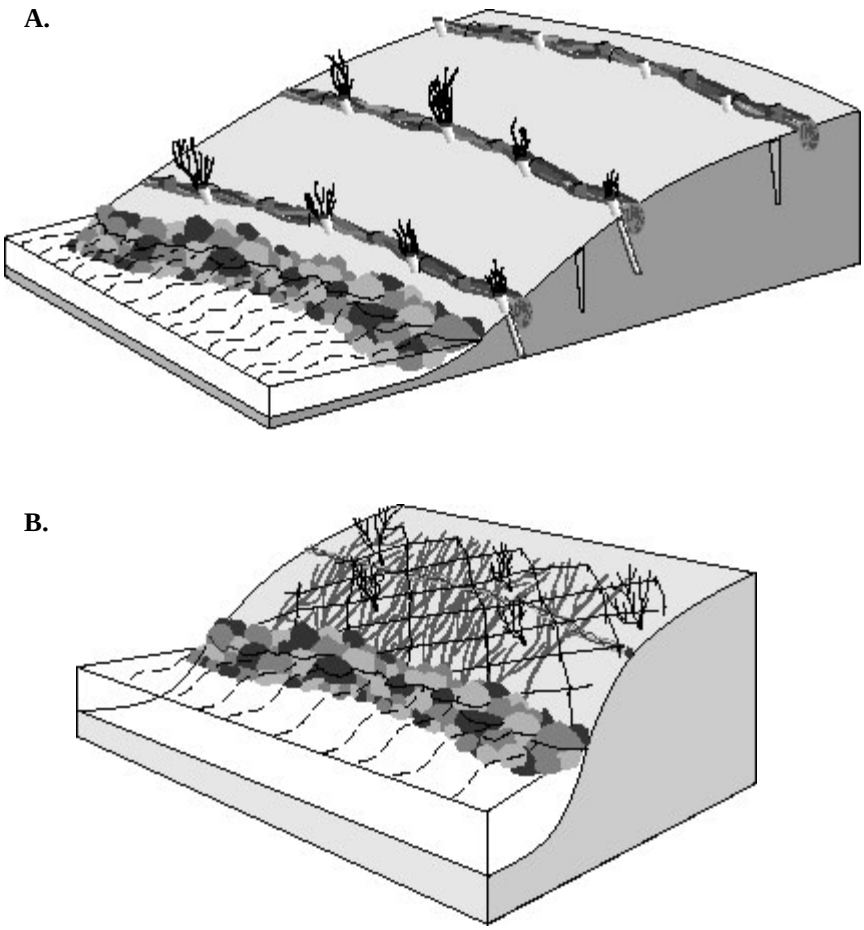


Figure 18 (a&b). Vegetative solutions to streambank instability are preferred. Examples include live fascines (a) and brush mattresses (b) (Federal Interagency Stream Restoration Working Group, 1998).

Considerations

1. Is the proposed bank stabilization method the optimal way to address bank erosion or would alternative projects like riparian planting or upland management techniques (e.g., stormwater management) work well to address bank instability.
2. Are the materials used for bank stabilization similar to materials naturally found in the stream reach?
3. Is the project self maintaining through time? If not, has a maintenance plan been developed?

4. Do the benefits of the bank stabilization project outweigh the ecological risks that the project poses? The degree of risk for bank stabilization is high because these projects impede natural processes, and if the project fails it may actually degrade habitat.

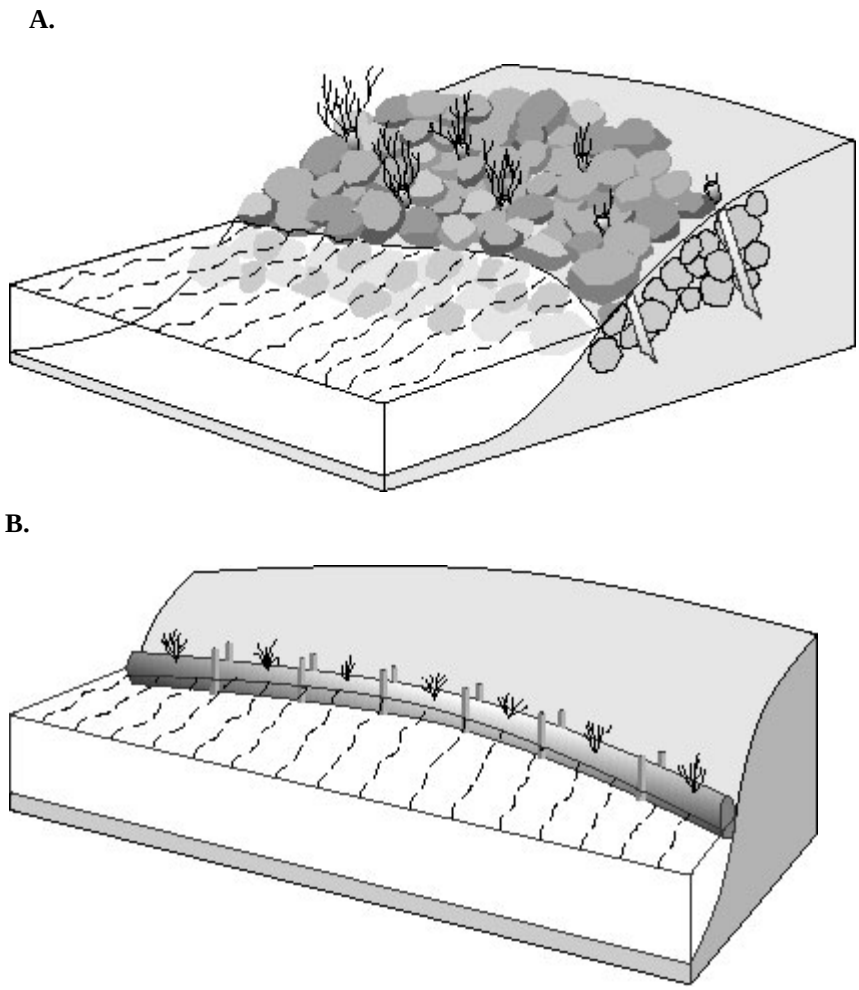


Figure 19 (a&b). Bioengineering solutions to bank instability combine structural elements and vegetation. Examples include joint plantings (a) and coconut fiber rolls (b) (Federal Interagency Stream Restoration Working Group, 1998).

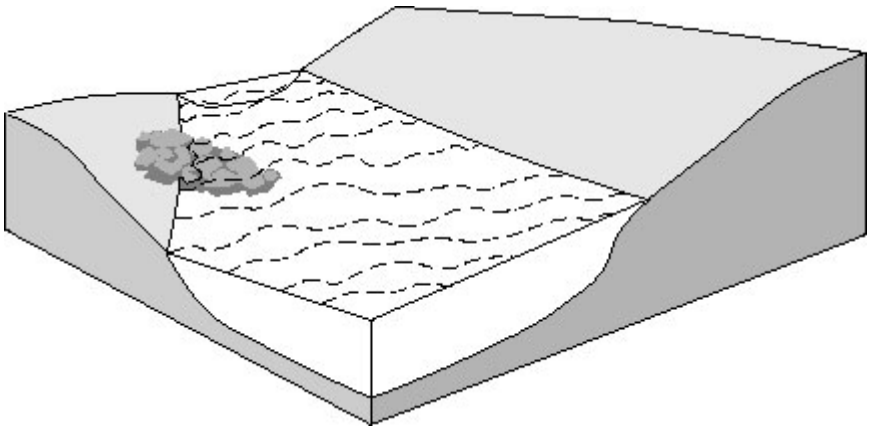


Figure 20. Flow redirection structures, such as this wing deflector, are constructed at specific angles to direct flow away from sensitive streambanks and into the center of the channel (Federal Interagency Stream Restoration Working Group, 1998).

Guidance

- Non-structural methods including bank re-shaping and vegetation should be the primary methods by which streambanks are stabilized. Next, bioengineering practices should be considered that combine vegetation with a minimal amount of structures.
- If non-structural methods are not appropriate (e.g., urbanized areas) then techniques should be used that create the least amount of physical disturbance, provide habitat and are self-sustaining.
- Rock riprap and other hard, structural methods should only be used sparingly and in situations where they are absolutely necessary.

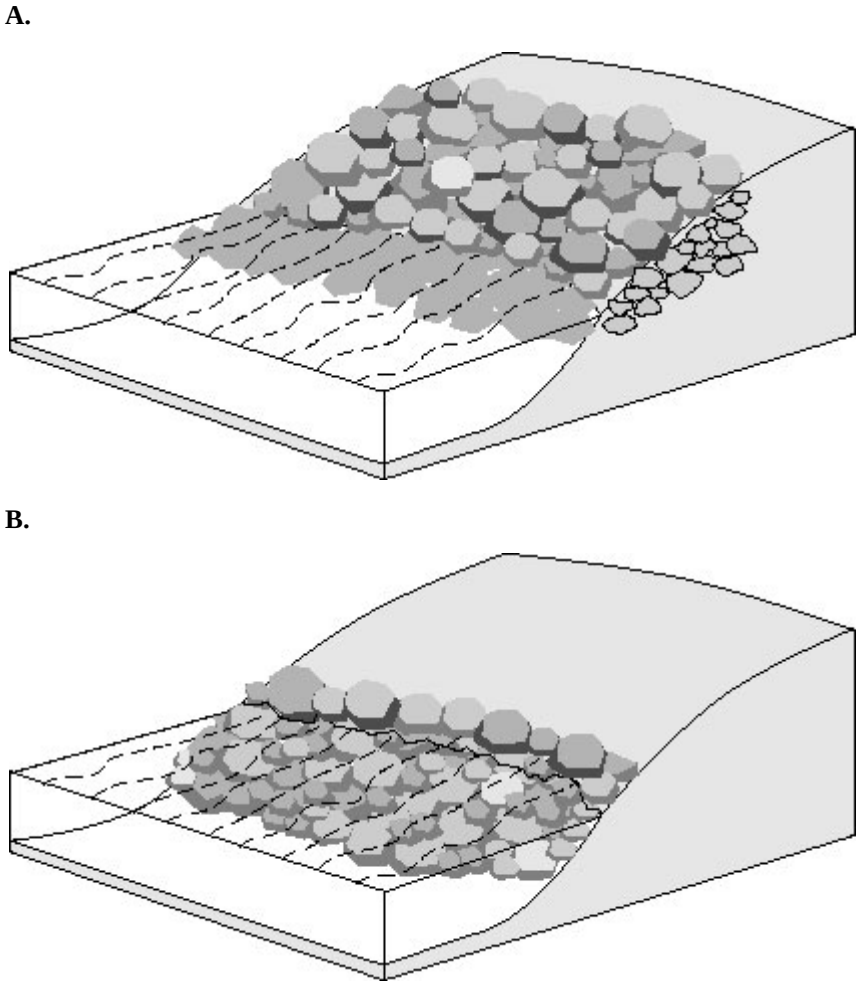


Figure 21 (a&b). Hard armoring techniques, such as rock riprap (a), may be required to stabilize streambanks in areas where sensitive infrastructure is at risk. If rocks or other hard structures are used, it is best if they are only used sparingly and placed at the toe of the bank (b) where erosive forces are most concentrated (Federal Interagency Stream Restoration Working Group, 1998).

Technical Assistance

Publications:

- Virginia Department of Conservation and Recreation. The Virginia Stream Restoration and Stabilization Best Management Practices Guide (Franks, Hill, Siegfried and Sweet, 2004; http://www.aces.edu/waterquality/streams/Fact%20Sheets/vastreamguide.pdf).
- King County Department of Public Works. Guidelines for Bank Stabilization Projects (Johnson and Stypula, 1993; http://dnr.metrokc.gov/wlr/biostabl/).
- Maryland Department of the Environment. Maryland's Waterway Construction Guidelines (Johnson and Brown, 1999; http://www.mde.state.md.us/assets/document/wetlandswaterways/mgwc.pdf).

These guidelines identify the effective uses, limitations, and provide specifications for a wide variety of bioengineering and traditional engineering practices.

- Washington Department of Fish and Wildlife. Integrated Streambank Protection Guidelines (Cramer, Bates, Miller, Boyd, Fotherby, Skidmore and Hoitsma, 2003; http://www.wdfw.wa.gov/hab/ahg/ispgdoc.htm).
- Federal Interagency Stream Restoration Working Group. Stream Corridor Restoration: Principles, Processes and Practices. (1998; http://www.nrcs.usda.gov/technical/stream_restoration/).
- U.S. Army Corps of Engineers. Effects of Riprap on Riverine and Riparian Ecosystems. (Fischenich, 2003; http://el.erdc.usace.army.mil/wrap/pdf/trel03-4.pdf).
- NOAA's Office of Ocean and Coastal Resource Management. Shoreline Management Toolkit: Alternatives to Hardening the Shore (2006; http://www.coastalmanagement.noaa.gov/shoreline.html).
- Lake County Stormwater Management Commission (IL). Streambank and Shoreline Protection Manual (2002; http://www.co.lake.il.us/elibrary/publications/smc/strmmanual.pdf). Reviews designs of bioengineering and structural techniques.
- Greater Detroit American Heritage River Initiative. Best Management Practices for Soft Engineering of Shorelines (Caulk, Gannon, Shaw and Hartig, 2000; http://www.tellusnews.com/ahr/report_cover.html).
- United States Geological Survey. Regionalized equations for bankfull discharge and channel characteristics of streams in New York State -- Hydrologic region 6 in the southern tier of New York (Mulvihill, Ernst and Baldigo, 2005; http://ny.water.usgs.gov/pubs/wri/sir055100/).
- United States Geological Survey. Regionalized equations for bankfull-discharge and channel characteristics of streams in New York State: Hydrologic Region 5 in Central New York (Westergard, Mulvihill, Ernst and Baldigo, 2005; http://ny.water.usgs.gov/pubs/wri/sir045247/).

Agencies/Groups:

- NYS Department of Environmental Conservation
- NYS Department of State Division of Coastal Resources
- U.S. Geological Survey
- U.S. Department of Agriculture Natural Resources Conservation Service
- U.S. Army Corps of Engineers
- National Oceanic and Atmospheric Administration (NOAA)'s Restoration Center

5. Grade Control

Activity Description

In addition to lateral erosion (i.e., streambank erosion) streams can also erode vertically (i.e., streambed erosion). Grade control structures are installed to maintain a desired streambed elevation and to prevent channel incision (Figure 22). Cross vanes, w-weirs and step pools are examples of commonly used grade control structures.

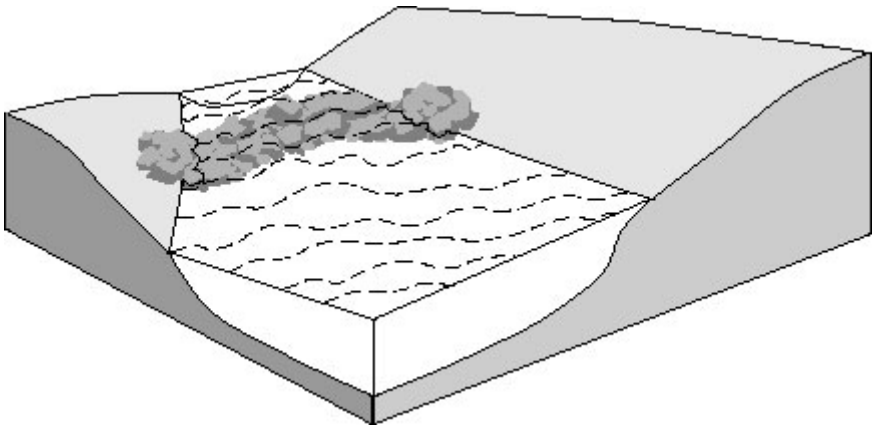


Figure 22. Grade control structures (such as this cross vane) prevent the streambed from eroding, which usually occurs in a downstream to upstream direction (also called a head-cut) (Federal Interagency Stream Restoration Working Group, 1998),

Considerations

1. Are the materials used for grade control similar to materials naturally found in the reach?
2. Is the project self maintaining through time? If not, has a maintenance plan been developed?

Guidance

- Grade control structures that reduce vertical erosion and enhance aquatic habitat are preferred.
- Step pools are only appropriate for high gradient streams.
- Grade control structures should not impede the passage of fish or other wildlife or disrupt natural stream continuity.

Technical Assistance

Publications:

- Virginia Department of Conservation and Recreation. The Virginia Stream Restoration and Stabilization Best Management Practices Guide (Franks, Hill, Siegfried and Sweet, 2004; http://www.aces.edu/waterquality/streams/Fact%20Sheets/vastreamguide.pdf).

Agencies/Groups:

- NYS Department of Environmental Conservation
- NYS Department of State Division of Coastal Resources
- U.S. Geological Survey
- U.S. Department of Agriculture Natural Resources Conservation Service
- U.S. Army Corps of Engineers

6. Natural Channel Design

Activity Description

Natural channel design uses fluvial geomorphic principles to construct a naturally stable stream channel that will maintain its form over time. Examples of practices include moving or relocating stream channels, restoring meanders, re-sculpting channel dimensions and restoring connections to floodplains (Figure 23). In addition, natural channel design may incorporate many of the other activities discussed in this chapter such as bank stabilization and habitat construction. While beneficial, natural channel design projects pose significant environmental risk, require expert involvement and heavy machinery, and necessitate careful consideration and regulatory scrutiny.

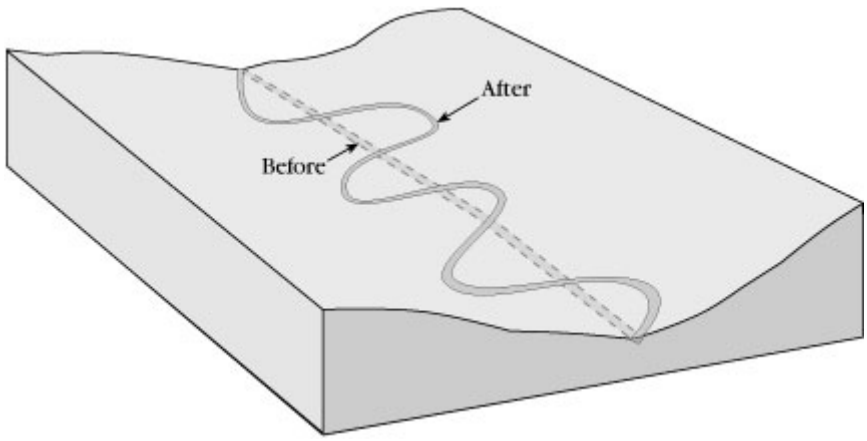


Figure 23. Natural channel design principles can be used to restore meanders in a stream that has been straightened. The installation of meander bends lengthens the stream channel, which serves to slow down stream flow and reduce erosion and flooding (Federal Interagency Stream Restoration Working Group, 1998).

Considerations

1. Is the targeted stream reach too altered or degraded to recover naturally without the use of natural channel design techniques? Will the targeted stream reach recover with the aid of other techniques described in this guide?
2. Have the historical causes for the current condition of the stream channel been explored?
3. Has an adequate watershed assessment been completed indicating that whole channel changes are appropriate? Have other problems identified in the watershed assessment (e.g., water quality, fish passage, etc.) been addressed prior to, or in concurrence with, the natural channel design project?

4. Are the participants involved in the proposed project qualified to analyze and reconstruct the geomorphological dynamics of the stream?

Guidance

- Natural channel design involves more than adjusting the channel's physical dimensions. An interdisciplinary team should be involved from the start of project planning, as an understanding of channel geomorphology; hydrology; riparian; aquatic macroinvertebrate and fish communities; wildlife habitat; and land use issues are needed.
- A reference reach is necessary in order to determine morphological variables for the target condition.
- Natural channel design projects will be among the most expensive and challenging stream restoration projects undertaken.
- Each natural channel design project should be considered an experiment and will require adaptive management. A well-documented plan to monitor impacts on the channel, biological communities, riparian vegetation and the floodplain should be included in any project proposal.
- Include habitat enhancement elements upon project completion. Consider placing large woody debris in the project site, as these items will likely cleared during project construction.

Technical Assistance

Publications:

- Rosgen, D. 1996. Applied River Morphology. Wildland Hydrology.
- North Carolina Stream Restoration Institute and North Carolina Sea Grant. Stream Restoration Guidebook - A Natural Channel Design Handbook (Doll, Grabow, Hall, Halley, Harman, Jennings and Wise, 2003; http://www.bae.ncsu.edu/programs/extension/wqg/sri/stream_rest_guidebook/sr_guidebook.pdf).
- Pennsylvania Department of Environmental Protection. Guidelines for Natural Stream Channel Design for Pennsylvania Waterways (Alliance for Chesapeake

Bay, 2002; http://www.alliancechesbay.org/pubs/projects/deliverables-157-1-2003.pdf).

Agencies/Groups:

- NYS Department of Environmental Conservation
- NYS Department of State Division of Coastal Resources
- Greene County Soil and Water Conservation District
- New York City Department of Environmental Protection
- U.S. Department of Agriculture Natural Resources Conservation Service
- U.S. Geological Survey

CASE STUDY 5

Multi-Objective Stream Restoration with a Drinking Water Focus
Grout Brook, tributary to Skaneateles Lake

Grout Brook is a primary tributary to Skaneateles Lake. Skaneateles Lake is the fourth largest of the Finger Lakes and has been the primary drinking water supply for the City of Syracuse since 1894. Since 1994, the City of Syracuse has been pursuing a policy of "filtration avoidance" to assure a healthy drinking water supply from Skaneateles Lake. Modeled after New York City's program to spend up to $37 million in the Catskill Mountain watershed to avoid an $8 billion filtration plant, Syracuse hopes to avoid spending between $45 and $60 million for filtration.

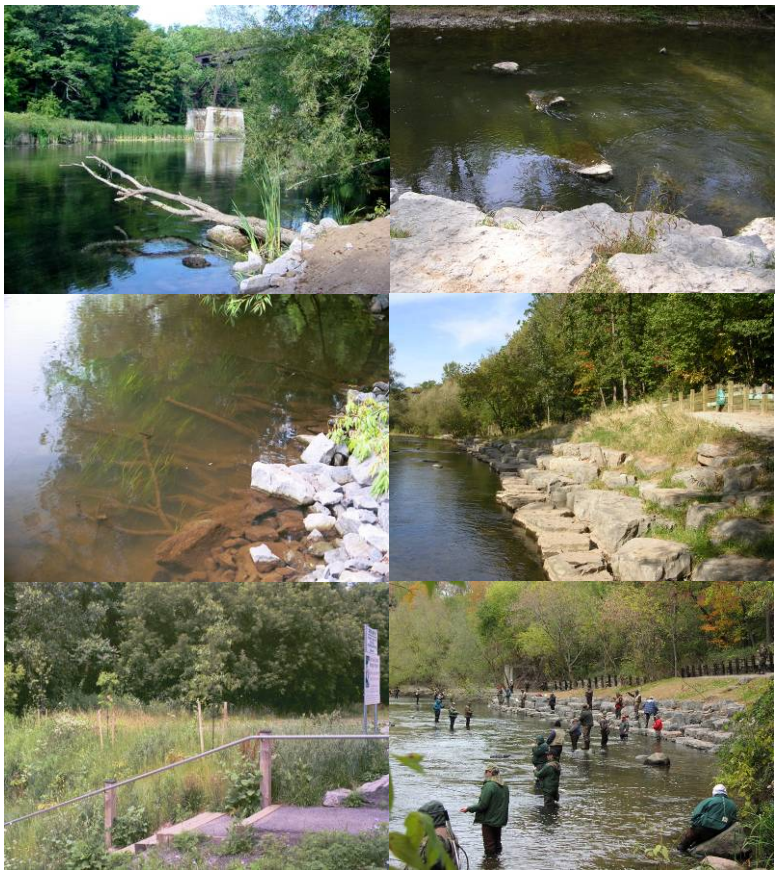
In 2001, the City of Syracuse received a $100,000 award from the Department of State Division of Coastal Resources through the National Oceanic and Atmospheric Administration's Great Lakes Coastal Restoration Program for an erosion control project on Grout Brook. Grout Brook is the largest subwatershed of Skaneateles Lake and is a key trout spawning area. There are about two miles of public fishing rights along Grout Brook, which is best known for rainbow trout and landlocked salmon. It was estimated that the erosion project would prevent 48 tons of silt a year from reaching Skaneateles Lake. The major goals of the project were to reduce erosion and sediment loads to protect the City of Syracuse's drinking water supply; restore wild trout habitat, including spawning areas; provide angler access; and enhance the environmental and recreational value of Grout Brook and Skaneateles Lake.

The project used a combination of traditional streambank stabilization practices (top row of pictures) and innovative bioengineering techniques (bottom row of pictures). These innovative bioengineering techniques (such as grade control, flow redirection and habitat enhancement) have not been employed very frequently in this region of the New York. This project tested these new methods and reduced risk by coupling them with practices that were more familiar to project partners. The result is a section of Grout Brook with stable streambanks, abundant fish habitat, which is easily accessible to anglers and is aesthetically pleasing to surrounding homeowners.

CASE STUDY 6

Multi-Objective Stream Restoration with a Habitat and Recreation/Public Access Focus
Eighteenmile Creek, tributary to Lake Ontario

Eighteenmile Creek is a tributary of Lake Ontario and is located in Niagara County. The U.S. Environmental Protection Agency and the International Joint Commission have identified Eighteenmile Creek as an Area of Concern. The Eighteenmile Creek Habitat Restoration Project began in 2001 with funding from the Department of State Division of Coastal Resources through the National Oceanic and Atmospheric Administration's Great Lakes Coastal Restoration Program. Project partners included the Niagara County Department of Planning and the U.S. Army Corps of Engineers. Niagara County received grant funds to improve habitat for coldwater fisheries and improve angler access. The project area extended from the base of Burt Dam (a barrier to fish passage) to a park that provides public access to the Creek approximately one quarter-mile downstream. Eighteenmile Creek is well-known among anglers for strong runs of trout and salmon that originate in Lake Ontario. The restoration measures targeted in-stream habitat and riparian areas, to enhance streambank stabilization and improve the safety and integrity of the existing hiking trail and fishing access areas. In-stream techniques for habitat enhancement included: locked limbs/locked logs, instant shade, LUNKERS (Little Underwater Neighborhood Keeper Encompassing Rheotactic Salmonids) and hydraulic cover stones. Riparian restoration techniques included vegetated plantings, riprap, a stepped wall and improvements to the hiking trail.



CHAPTER 7. RESTORATION MONITORING

This chapter provides recommendations for the inclusion of a monitoring program for all stream restoration projects. References are provided for additional information on specific physical, chemical and biological parameters. Social and economic parameters could also be considered. The goals of the restoration project should guide which parameters are selected for monitoring. Ideally, monitoring should coincide with stream and watershed assessments (Chapter 3) and begin before a project is implemented and continue after it is built.

Restoration monitoring contributes to the understanding of complex ecological systems and is essential in documenting restoration performance and adapting project approaches. Determining whether the goals of a restoration project are being achieved can only be accomplished by a well-designed monitoring program that evaluates, with an acceptable degree of certainty, whether restoration has caused a significant improvement. Restoration monitoring can provide resource managers with valuable feedback, an opportunity for adaptive management based on results, and ultimately improve the science of restoration ecology.

Federal agencies in the United States are spending well over $1 billion annually to restore rivers and streams, yet only a small number of projects are monitored to determine if restoration efforts are successful (Palmer and Allan, 2006). In the National River Restoration Science Synthesis database, only 10% of projects included any mention of assessment or evaluation (Bernhardt, Palmer, Allan, Alexander, Barnas, Brooks, Carr, Clayton, Dahm, Follstad-Shah, Galat, Gloss, Goodwin, Hart, Hassett, Jenkinson, Katz, Kondolf, Lake, Lave, Meyer, O'Donnell, Pagano, Powell and Sudduth, 2005). Most professionals realize that monitoring is a critical component of restoration and that without it there is no way to evaluate project success. However due to limited funds, monitoring programs are typically among the first items to be cut.

In New York several State and Federal agencies contribute funds to various stream restoration projects. Despite the amount of money, time and effort that is expended for these projects, monitoring and evaluation of restoration projects cannot be enforced and thus it rarely occurs. Discussions among agencies about regulations or incentives for restoration monitoring are necessary. At the very least, funding agencies should favor restoration projects that place a high priority on monitoring.

Palmer and Allan (2006) suggest that there are two types of restoration monitoring, implementation monitoring and effectiveness monitoring. Ideally, projects should be monitored for both how well they were implemented as well as their degree of effectiveness.

Implementation monitoring is an evaluation of how a project met basic goals, such as was it built as designed, is it in compliance with permit requirements, and was it implemented using proven techniques? Effectiveness monitoring is more intensive and involves an in-depth evaluation of physical and ecological parameters. Implementation monitoring should be required of all restoration projects. Effectiveness monitoring should be encouraged, but because it is more time-consuming and expensive it is unrealistic to make it a requirement of all funded projects. However, the benefits of data obtained from restoration projects cannot be overstated. This type of monitoring should be required when unproven restoration techniques are implemented or when the ecological risks of a project are considered high. Monitoring should become a regular part of restoration projects in the future, and standard, accepted methodologies should be followed. Failure to adequately monitor may mean that problems are not identified in time for correction.

The availability of restoration information and monitoring data must be improved. Good records for all projects must be kept, including budgets, workplans, site plans, survey data, monitoring programs, photographs and post-restoration project monitoring data and analysis. Project information and monitoring data should be made publicly available and disseminated to restoration practitioners and other interested parties through conferences, workshops and web-based databases. Restoration practitioners are encouraged to use available on-line restoration directories, including the National Estuary Restoration Inventory (www.neri.noaa.gov), the U.S. Environmental Protection Agency's restoration project directory (http://yosemite.epa.gov/water/restorat.nsf/rpd-2a.htm?OpenPage), or the National River Restoration Science Synthesis (http://nrrss.nbii.gov) to share project information.

General Guidance

These guidelines are adapted from the restoration monitoring protocols developed by the National Oceanic and Atmospheric Administration as directed by Estuary Restoration Act of 2000.

1. Monitoring parameters must be directly linked to the goals established for the project. A monitoring program should be developed early in the restoration process and in conjunction with project planning and design. A monitoring program should:
    - always include a photomonitoring component.

- include at least one *structural* parameter to be monitored from the initiation of the project.
- include at least one *functional* parameter to be monitored no later than one year from the initiation of the restoration project.
- continue until results indicate a trend in whether the project is successfully meeting its goals.

2. Methods for evaluating results must be established, such as statistical tests, trend analysis or other quantitative or qualitative approaches that are directly related to the goals of the project. Restoration projects must include provisions or contingency plans for adaptive management.

3. Baseline conditions for each parameter to be measured must be established. Historical databases and other existing information about the restoration site or the surrounding area can be used to determine baseline conditions.

4. Restoration project sites must be compared to reference sites or historical data that represents a reference condition in order to evaluate progress toward reaching goals. Ideally, reference sites are monitored according to the same plan as used for the restoration project site, so that natural variability and other regional trends can be detected. In some situations, two reference sites would be useful – one that represents a stable condition and the other that represents a degraded condition.

5. Monitoring must be conducted in a timely fashion with a frequency and length of time suitable for each parameter. The length of time over which monitoring should be conducted is driven by project goals, success criteria and monitoring parameters. Five years should be considered a minimum for monitoring projects with physical goals, such as streambank stabilization. Any project including goals for species, biological communities or ecological function should consider a longer monitoring period. Additionally, the monitoring schedule should be designed to measure each parameter at the most appropriate time of day, month and/or year.

Designing a Monitoring Program

A restoration monitoring plan should be developed during the project planning phase and well before construction begins. Restoration monitoring is closely tied to and directly derived from restoration project goals. Monitoring can address physical, chemical, biological and social characteristics and can target the stream, riparian corridor or watershed. It is important that a restoration monitoring plan establish testable hypotheses for each restoration goal (Thayer, McTigue, Bellmer, Burrows, Merkey, Nickens, Lozano, Gayaldo, Polmateer, and Print, 2003; Thayer, McTigue, Salz, Merkey, Burrows and Gayaldo, 2005).

It is recommended that monitoring programs be designed to follow the before/after, control/impact (BACI) approach to analyze the effects of restoration while accounting for temporal and spatial variability. Using this approach, baseline data are collected before restoration is implemented and compared to post-restoration data to evaluate changes over time. In addition, data are collected from the restored stream and from a nearby reference site. Some monitoring programs have further elaborated on this by monitoring two reference sites - a reference (or positive) control and a degraded (or negative) control.

Timing of sampling should also be considered. Structural characteristics of the restored area should be monitored frequently for several years immediately following restoration. Functional characteristics, however, should be monitored later, as the system matures and the function in question has had time to become adequately established. For accuracy and consistency, it is best to monitor the same site year after year and at the same time of year (e.g., in the spring, or more specifically in the same month). Depending on the specific variables of interest and the intensity, frequency and duration of sampling designs a good monitoring program may cost about 10-15% of the total restoration project.

Structural vs. Functional Parameters

Structural characteristics define the physical composition of the habitat.

- Physiographic setting (topography and bathymetry)
- Hydrology
- Sediment grain size
- Habitat created by plants

Functional characteristics describe what ecological service a habitat provides.

- Provides transport/deposition of suspended and dissolved materials
- Provides temporary floodwater storage
- Supports nutrient cycling
- Contributes to primary productivity
- Habitat (feeding and breeding grounds) for fish, invertebrates, birds and mammals
- Supports a complex trophic structure

Implementing a Monitoring Program

The ideal monitoring program has three phases: pre-construction monitoring, monitoring during construction and post-construction monitoring. Photomonitoring should be conducted during all phases. Photomonitoring is the photographing of a site from fixed locations at specific times of year for the duration of the monitoring program. The purpose is to visually document changes in a landscape over a period of time. Several photomonitoring stations should be established at a site and should be permanently marked so that they can be easily relocated. Photomonitoring should capture the phases of restoration. During post-restoration monitoring, stations should be monitored quarterly. Special care should be taken with respect to camera orientation, angle and magnification so as to replicate shots with a high degree of accuracy.

Pre-construction monitoring. It is important to begin monitoring both the project area and reference site(s) well before project construction begins. A pre-construction sampling period of at least a year is recommended. This monitoring should be conducted according to the restoration monitoring plan and the data should be collected and analyzed in a statistically valid manner. Pre-construction data and results should be made available to project managers to help in the design and implementation of the restoration project.

Monitoring during construction. Monitoring during construction should be conducted to ensure that proper design specifications are met.

Post-construction monitoring. Post-construction monitoring should be conducted according to the restoration monitoring plan, including the collection and analysis of data in a statistically valid manner. Data should be compared to pre-construction data and made available to project managers to assist in adaptive management decisions.

Communicating Monitoring Program Results

If the restoration of aquatic ecosystems is to be effective, practitioners must be able to learn from past efforts. To be useful, monitoring data, results and "lessons learned" need to be shared. Local project partners, state and federal agencies, and managers of other restoration projects would all benefit from such information. At present, there is no statewide or national coordinated tracking system of stream restoration projects. Existing federal databases are highly fragmented and rely on volunteer entry. The state and federal agencies and other groups involved in stream restoration in New York State should consider a statewide stream restoration database that houses monitoring data as well as general project information. Additionally, peer-reviewed literature is also a good way to distribute results and involve the academic community.

Volunteer Monitoring Programs

Volunteer monitoring programs can be an effective and beneficial way to evaluate the success of restoration and protection efforts. Many rivers and streams throughout New York are monitored by volunteers from local watershed groups. Volunteer monitoring programs are less costly than hiring private consultants and many societal benefits are gained in the process. Quantative studies have demonstrated that volunteer monitors are capable of producing scientifically credible data (Penningroth, DeBoer and Gallagher, 2003).

The use of volunteers to monitor waterbodies is supported and encouraged by many state and federal agencies, including the U.S. Environmental Protection Agency, which provides resources for volunteer stream monitoring (http://www.epa.gov/owow/monitoring/volunteer/epasvmp.html).

Common Measures Used in Restoration Monitoring

An asterisk (*) denotes minimum measures that should be considered in monitoring the effectiveness of stream restoration projects. Parameters without an asterisk may also be relevant depending on the specific goals of the project. This list is not exhaustive but represents those elements most commonly assessed in restoration monitoring.

Physical Characteristics

- Pool/riffle ratio*
- Channel dimensions*
- Streambank stability (e.g., bank erodibility hazard index)
- Stream flow
- Topography/bathymetry
- Turbidity/Total suspended solids*
- Substrate composition
- Temperature*

Chemical Characteristics

- Nutrients (nitrogen, phosphorus)
- Dissolved oxygen*
- Salinity
- pH*
- Total organic carbon
- Pathogens
- Contaminants (e.g., metals, PAHs, PCBs)

Biological Characteristics

- Width, continuity of vegetated riparian area*
- Stem density
- Canopy cover
- Diversity and abundance of aquatic and riparian vegetation, aquatic macroinvertebrates, fish, amphibians, reptiles, birds and/or mammals as per goals of the project

Selected Resources for Restoration Monitoring

Physical Characteristics

- U.S. Geological Survey. Guidelines for surveying bankfull channel geometry and developing regional hydraulic-geometry relations for streams of New York State. (Powell, Miller, Westergard, Mulvihill, Baldigo, Gallagher and Starr, 2004; http://ny.water.usgs.gov/pubs/of/of03092/of03-092.pdf).
- U.S. Department of Agriculture Natural Resources Conservation Service. Stream Visual Assessment Protocol. (Newton, Pringle and Bjorkland, 1998; http://www.nrcs.usda.gov/technical/ECS/aquatic/svapfnl.pdf).
- U.S. Department of Agriculture Forest Service. Stream channel reference sites: An illustrated guide to field technique. (Harrelson, Rawlins and Potyondy, 1994; http://www.stream.fs.fed.us/publications/PDFs/RM245E.PDF).
- Vermont Agency of Natural Resources. Survey Assessment: Field and Data Analysis Protocols. (Kline, Jaquith, Springston, Cahoon and Becker, 2003; http://www.anr.state.vt.us/dec/waterq/rivers/docs/assessmenthandbooks/rv_phase3handbook.pdf).
- Bain and Stevenson (eds.), 1999. Aquatic habitat assessment: Common methods. American Fisheries Society. Bethesda, MD.
- Wolman, 1954. A method of sampling coarse riverbed material. Transactions of the American Geophysical Union.
- The U.S. Geological Survey operates a series of gaging stations on rivers and streams throughout New York. Historical and real-time hydrologic data (e.g., flow, discharge) for many of these sites are available (http://water.usgs.gov/waterwatch/).

Chemical Characteristics

Water quality parameters can be assessed manually at specific points in time or continuously. Automatic sensors and probes can be deployed for weeks at a time to continuously collect data at specified intervals.

- Bain and Stevenson (eds) 1999. Aquatic habitat assessment: common methods. American Fisheries Society. Bethesda, MD.

Biological Characteristics

- U.S. Environmental Protection Agency. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish. (Barbour, Gerritsen, Snyder and Stribling, 1999; http://www.epa.gov/owow/monitoring/rbp/).
- Bain and Stevenson (eds), 1999. Aquatic habitat assessment: common methods. American Fisheries Society. Bethesda, MD.
- NYS DEC Aquatic Macroinvertebrate Key (http://www.dec.state.ny.us/website/dow/stream/orderpageone.htm).

REFERENCES

Allan, J.D. 1995. Stream Ecology. Structure and Function of Running Waters. Kluwer Academic Publishers. Netherlands. p. 388.

Alliance for Chesapeake Bay. 2002. Guidelines for Natural Channel Design for Pennsylvania Waterways. Pennsylvania Department of Environmental Protection. 82 p.

Arnold, C.L. and C. J. Gibbons. 1996. Impervious Surface: The Emergence of a Key Urban Environmental Indicator. American Planning Association Journal. 62: 243-258.

Bain, M.B. and N.J. Stevenson (eds.). 1999. Aquatic Habitat Assessment: Common Methods. American Fisheries Society. Bethesda, MD.

Barbour, M.T., J. Gerritsen, B.D. Snyder and J.B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, DC.

Bergkamp, G., M. McCartney, P. Dugan, J. McNeely and M Acreman. 2000. Dams, Ecosystem Functions and Environmental Restoration. World Commission on Dams. 115 p.

Berkshire Regional Planning Commission. 2003. The Massachusetts Buffer Manual. Prepared for the Massachusetts Department of Environmental Protection.

Bernhardt, E.S., M.A. Palmer, J. D. Allan, G. Alexander, K. Barnas, S. Brooks, J. Carr, S. Clayton, C. Dahm, J. Follstad-Shah, D. Galat, S. Gloss, P. Goodwin, D. Hart, B. Hassett, R. Jenkinson, S. Katz, G.M. Kondolf, P. S. Lake, R. Lave, J.L. Meyer, T. K. O'Donnell, L. Pagano, B. Powell and E. Sudduth. 2005. Synthesizing U.S. River Restoration Efforts. Science. 308:636-637.

Bode, R.W., M.A. Novak, L.E. Abele, D.L. Heitzman and A.J. Smith. 2004. Thirty-year trends in water quality of rivers and streams in New York State, based on macroinvertebrate data 1972-2002. New York State Department of Environmental Conservation. Albany, NY.

Boekeloo, T (ed). 2002. Hydrologic and Habitat Modification Management Practices Catalogue for Nonpoint Source Pollution Prevention and Water Quality Protection in New York State. NYS Department of Environmental Conservation. Albany, NY. 79 p.

Booth, D. 1991. Urbanization and the natural drainage system: impacts, solutions and prognoses. Northwest Environmental Journal. 7(1): 93-118.

Bowman, M., S. Higgs, E. Maclin, S. McClain, M. Sicchio, A. Souers, S. Johnson and B. Graber. 2002. Exploring Dam Removal: A Decision-Making Guide. American Rivers and Trout Unlimited.

Caraco, D., R. Claytor, P. Hinkle, H.Y. Kwon, T. Schueler, C. Swan, S. Vysotsky and J. Zielinski. 1998. Rapid Watershed Planning Handbook. A Comprehensive Guide for Managing Urbanizing Watersheds. The Center for Watershed Protection. Ellicott City, MD.

Caulk, A.D., J.E. Gannon, J.R. Shaw and J.H. Hartig (eds.). 2000. Best Management Practices for Soft Engineering of Shorelines. Greater Detroit American Heritage River Initiative. Detroit, MI. 78 p.

Church, D. and C.F. Traub. 2000. A Practical Guide to Comprehensive Planning. The New York Planning Federation.

Conservation Strategy Workgroup Eastern Brook Trout Joint Venture. 2005. Conserving the Eastern Brook Trout: An Overview of Status, Threats and Trends. 14 p.

Cramer, M., K. Bates, D. Miller, K.Boyd, L. Fotherby, P. Skidmore and T. Hoitsma. 2003. Integrated Streambank Protection Guidelines. Washington State Aquatic Habitat Guidelines Program. Washington Department of Fish and Wildlife.

Crossett, K.M., T.J. Culliton, P.C. Wiley and T.R. Goodspeed. 2004. Population Trends along the Coastal United States: 1980-2008. Coastal Trends Report Series. NOAA National Ocean Service. 47 p.

Damsky, S.W. and J.A. Coon. 2005. All You Ever Wanted to Know About Zoning. 4th Edition. James Hotaling, editor. New York Planning Federation. Troy, NY.

Doll, B.A., G.L. Grabow, K.R. Hall, J. Halley, W.A. Harman, G.D. Jennings and D.E. Wise. 2003. Stream Restoration: A Natural Channel Design Handbook. North Carolina Stream Restoration Institute and North Carolina Sea Grant.

Federal Interagency Stream Restoration Working Group. 1998. Stream Corridor Restoration. Principles, Processes, and Practices. Washington, DC.

Fischenich, J.C. 2003. Effects of riprap on riverine and riparian ecosystems. ERDC/EL TR-03-4. U.S. Army Corps of Engineers Research and Development Center. Vicksburg, MS. 62 p.

Franks, E., L. Hill, R. Siegfried and D. Sweet. 2004. The Virginia Stream Restoration and Stabilization Best Management Practices Guide. Virginia Departments of Environmental Quality and Conservation and Recreation. 210 p.

Genesee Finger Lakes Regional Planning Council. 2006. Protecting Water Resources through Local Controls and Practices: An Assessment Manual for New York Communities.

Harrelson, C.C., C.L. Rawlins and J.P. Potyondy. 1994. Stream Channel Reference Sites: An Illustrated Guide to Field Technique. U.S. Department of Agriculture Forest Service. General Technical Report. RM-245. Fort Collins, CO. 61 p.

Heritage Task Force for the Hudson River Valley. 1990. The Lower Hudson Basin Tributary Study.

Hicks, A.L. and J.S. Larson. 1997. The Impact of Urban Stormwater Runoff on Freshwater Wetlands and the Role of Aquatic Invertebrate Bioassessment. The Environment Institute. University of Massachusetts. Amherst, MA.

Holland, A.F., D.M. Sanger, C.P. Gawle, S.B. Lerberg, M.S. Santiago, G.H.M. Riekerk, L.E. Zimmerman and G.I. Scott. 2004. Linkages between tidal creek ecosystems and the landscape and demographic attributes of their watersheds. Journal of Experimental Marine Biology and Ecology. 298: 151-178.

Hudson River Estuary Program. 2007. Hudson River Estuary Action Agenda 2005-2009. NYS Department of Environmental Conservation. 79 p.

Johnson, A.W. and J.M. Stypula (eds). 1993. Guidelines for Bank Stabilization Projects in the Riverine Environments of King County. King County Department of Public Works, Surface Water Management Division. Seattle, WA.

Johnson, P.A. and E. Brown. 1999. Maryland's Waterway Construction Guidelines. Maryland Department of the Environment, Water Management Administration. 127 p.

Karr, J.R., K.D. Fausch, P.L. Angermeier, P.R. Yant and I.J. Schlosser. 1986. Assessment of Biological Integrity of Running Waters: A Method and its Rationale. Illinois Natural History Survey, Special Publication No. 5.

Kitchell, A and T. Schueler. 2004. Unified Stream Assessment: A User's Manual. Center for Watershed Protection. Ellicott City, MD. 102 p.

Kling, M., S. Jaquith, G. Springston, B. Cahoon and L. Becker. 2003. Survey Assessment: Field and Data Analysis Protocols. Vermont Stream Geomorphic Assessment Phase 3 Handbook. Vermont Agency of Natural Resources. 65 p.

Lake County Stormwater Management Commission. 2002. Streambank and Shoreline Protection Manual. 23 p.

Limburg, K. and R. Schimdt. 1990. Patterns of Fish Spawning in Hudson River Tributaries – Response to an Urban Gradient. Ecology. 71(4): 1231-1245.

Maclin, E. and M. Sicchio (eds). 1999. Dam Removal Success Stories. American Rivers. 113 p. 114.

Mulvihill, C.I., A.G. Ernst and B.P. Baldigo. 2005. Regionalized Equations for Bankfull Discharge and Channel Characteristics of Streams in New York State: Hydrologic Region 6 in the Southern Tier of New York. U.S. Geological Survey Scientific Investigations Report 2005-5100. Troy, NY. 14 p.

NYSDEC. 1986. Stream Corridor Management: A Basic Reference Manual. NYS Department of Environmental Conservation. Division of Water. Albany, NY. 111 p.

NYSDEC. 1996. Survey and compendium of local laws for protecting water quality from nonpoint source pollution. Division of Water. Albany, NY. 66 p.

NYSDEC. 2004. New York State Water Quality Section 305(b) Report. Division of Water. Albany, NY. 515 p.

NYSDEC and NYSDOS. 2004. Stormwater management guidance manual for local officials. 41 p.

NYSDEC, NYSDOS and NYSOPRHP. 2005. NYS Open Space Conservation Plan.

NYSDOH. 2006. 2006-2007 Health Advisories: Chemicals in Sportfish and Game. New York State Department of Health, Division of Environmental Health Assessment. 30 p.

NYSDOS and NYSDEC. 2006. Watershed Planning in Your Community. Protecting and Improving Local Water Resources.

Newton, B., C. Pringle and R. Bjorkland. 1998. Stream Visual Assessment Protocol. National Water and Climate Center Technical Note 99-1. U.S. Department of Agriculture Natural Resources Conservation Service. 42 p.

Niedowski, N. 2000. New York State Salt Marsh Restoration and Monitoring Guidelines. Prepared for New York State Department of State Division of Coastal Resources and New York State Department of Environmental Conservation Division of Fish, Wildlife, and Marine Resources. 136 p.

Nolon, J.R. 2003. Open ground: Effective local strategies for protecting natural resources. The Environmental Law Institute. Washington, DC. 606 p.

Otto, B. 2000. Paying for Dam Removal: A Guide to Selected Funding Sources. American Rivers. 110 p.

Palmer, M.A. and J.D. Allan. 2006. Restoring rivers. Issues in Science and Technology. 22: 40-48.

Penningroth, S., H. Clark, Y. deBoer and A. Gallagher. 2003. Evaluation of the New York City Watershed and Hudson Basin River Watch volunteer monitoring pilot project. Community Science Institute, Inc. Trumansburg, NY. 234 p.

Powell, R.O., S.J. Miller, B.E. Westergard, C.I. Mulvihill, B.P. Baldigo, A.S. Gallagher and R.R. Starr. 2004. Guidelines for Surveying Bankfull Channel Geometry and Developing Regional Hydraulic-Geometry Relations for Streams of New York State. U.S. Geological Survey. Open-File Report 03-92. Troy, NY. 26 p.

River and Stream Continuity Partnership. 2006. Massachusetts River and Stream Crossing Standards. University of Massachusetts Amherst. 18 p.

Rosgen, D. 1996. Applied River Morphology. Wildland Hydrology. Pagosa Springs, CO.

Schueler, T.R. 1994. The importance of imperviousness. Water Protection Techniques. 1:100-111.

Schueler, T.R. 1995. Site Planning for Urban Stream Protection. Center for Watershed Protection. Ellicott City, MD.

Schueler, T.R. 2003. Impacts of impervious cover on aquatic systems. Center for Watershed Protection. Ellicott City, MD.

Strahler, A.N. 1952. Dynamic basis of geomorphology. Geological Society of America Bulletin. 63: 923-938.

Sylte, T.L. and J.C. Fischenich. 2002. Techniques for Measuring Substrate Embeddedness. EMRRP Technical Notes Collection (ERDC TN-EMRRP SR-36). U.S. Army Corps of Engineers Research and Development Center. Vicksburg, MS. 25 p.

Thayer, G.W., T.A. McTigue, R.J. Bellmer, F.M. Burrows, D.H. Merkey, A.D. Nickens, S.J. Lozano, P.F. Gayaldo, P.J. Polmateer and P.T. Pinit. 2003. Science-Based Restoration Monitoring of Coastal Habitats. Volume One: A Framework for Monitoring Plans under the Estuaries and Clean Waters Act of 2000 (Public Law 160-457). NOAA Coastal Ocean Program Decision Analysis Series No. 23, Volume 1. NOAA National Centers for Coastal Ocean Science. Silver Spring, MD. 35 p.

Thayer, G.W., T.A. McTigue, R.J. Salz, D.H. Merkey, F.M. Burrows and P.F. Gayaldo (eds). 2005. Science-Based Restoration Monitoring of Coastal Habitats. Volume Two: Tools for Monitoring Coastal Habitats. NOAA Coastal Ocean Program Decision Analysis Series No. 23. NOAA National Centers for Coastal Ocean Science. Silver Spring, MD. 628 p.

USEPA. 1997. Volunteer Stream Monitoring: A Methods Manual. Office of Water. EPA-841-B-97-003. Washington, DC. 227 p.

USEPA. 2000. Principles for the Ecological Restoration of Aquatic Resources. EPA841-F-00-003. Office of Water (4501F). United States Environmental Protection Agency. Washington, DC. 4 pp.

USEPA. 2006. *DRAFT* Wadeable Streams Assessment. A Collaborative Survey of the Nation's Streams. Washington, DC.

Vannote, R.L., G.W. Minshall, K.W. Cummings, J.R. Sedell and C.E. Cushing. 1980. The River Continuum Concept. Canadian Journal of Fisheries and Aquatic Sciences. 37: 130-137.

Wenger, S. 1999. A Review of the Scientific Literature on Riparian Buffer Width, Extent and Vegetation. University of Georgia Institute of Ecology. Athens, Georgia. 59 p.

Westergard, B.E., C.I. Mulvihill, A.G. Ernst and B.P. Baldigo. 2005. Regionalized Equations for Bankfull-Discharge and Channel Characteristics of Streams in New York State: Hydrologic Region 5 in Central New York. U.S. Geological Survey Scientific Investigations Report 2004-5247. Troy, NY. 16 p.

Winter, T.C., J.W. Harvey, O.L. Franke and W.M. Alley. 1998. Groundwater and surface water: A single resource. U.S. Geological Survey. Circular 1139. Denver, Colorado. 87 p.

Wolman, M.G. 1954. A Method of Sampling Coarse Riverbed Material. Transactions of the American Geophysical Union. 35(6): 951-956.

Wright, T., C. Swann, K. Cappiella and T. Schueler. 2004. Unified Subwatershed and Site Reconnaissance: A User's Manual. Center for Watershed Protection. Ellicott City, MD. 74 p.

APPENDIX A
KNOWLEDGEABLE CONTACTS

NEW YORK STATE AGENCIES

Department of State

Division of Coastal Resources
New York State Department of State
41 State Street, 8th Floor
Albany, NY 12231
telephone: 518-474-6000
internet: www.nyswaterfronts.com

South Shore Estuary Reserve
Division of Coastal Resources
New York State Department of State
300 Woodcleft Avenue
Freeport, NY 11520
telephone: 516-470-BAYS
internet: http://www.estuary.cog.ny.us/

Division of Local Governments
New York State Department of State
41 State Street, 9th Floor
Albany, NY 12231
telephone: 518-473-3355
internet: http://www.dos.state.ny.us/lgss/index.htm

Department of Environmental Conservation

Division of Water – Headquarters
New York State Department of Environmental Conservation
625 Broadway, 4th Floor
Albany, NY 12233-3500
telephone: 518-402-8233
internet: http://www.dec.state.ny.us/

Division of Fish, Wildlife and Marine Resources – Headquarters
New York State Department of Environmental Conservation
625 Broadway, 5th Floor
Albany, NY 12233-4750
telephone: 518-402-8924
internet: http://www.dec.state.ny.us/

Division of Environmental Permits – Headquarters
New York State Department of Environmental Conservation
625 Broadway, 4th Floor
Albany, NY 12233-1750
telephone: 518-402-9182
internet: http://www.dec.state.ny.us/

Hudson River Estuary Program
New York State Department of Environmental Conservation, Region 3
21 South Putt Corners
New Paltz, NY 12561
telephone: 845-256-3016
internet: http://www.dec.state.ny.us/website/hudson/hrep.html

Hudson River National Estuarine Research Reserve
New York State Department of Environmental Conservation and National Oceanic and Atmospheric Administration
c/o Bard College Field Station
Annandale, NY 12504
telephone: 914-758-5193
internet: http://nerrs.noaa.gov/HudsonRiver/

Region One – Nassau and Suffolk Counties
New York State Department of Environmental Conservation
SUNY at Stony Brook Campus
Loop Road
Building 40
Stony Brook, NY 11790
telephone: 631-444-0204
internet: http://www.dec.state.ny.us/website/reg1/

Region Two – Bronx, Kings, New York, Queens and Richmond Counties
New York State Department of Environmental Conservation
One Hunter's Point Plaza
47-40 21st Street
Long Island City, NY 11101
telephone: 718-482-4900
internet: http://www.dec.state.ny.us/website/reg2/

Region Three - Sullivan, Ulster, Orange, Dutchess, Putnam, Rockland and Westchester Counties
New York State Department of Environmental Conservation
21 South Putt Corners
New Paltz, NY 12561
telephone: 845-256-3000
internet: http://www.dec.state.ny.us/website/reg3/

Region Four - Montgomery, Otsego, Delaware, Schoharie, Schenectady, Albany, Greene, Rensselaer and Columbia Counties
New York State Department of Environmental Conservation
1150 North Westcott Road
Schenectady, NY 12306
telephone: 518-357-2234
internet: http://www.dec.state.ny.us/website/reg4/

Region Five - Franklin, Clinton, Essex, Hamilton, Warren, Fulton, Saratoga and Washington Counties
New York State Department of Environmental Conservation
P.O. Box 296
1115 NYS Route 86
Ray Brook, NY 12977
telephone: 518-897-1200
internet: http://www.dec.state.ny.us/website/reg5/

Region Six - Jefferson, St. Lawrence, Lewis, Oneida and Herkimer Counties
New York State Department of Environmental Conservation
317 Washington Street
Watertown, NY 13601
telephone: 315-785-2239
internet: http://www.dec.state.ny.us/website/reg6/

Region Seven - Oswego, Cayuga, Onondaga, Madison, Tompkins, Cortland, Chenango, Tioga and Broome Counties
New York State Department of Environmental Conservation
615 Erie Boulevard West
Syracuse, NY 13204
telephone: 315-426-7403
internet: http://www.dec.state.ny.us/website/reg7/

Region Eight - Orleans, Monroe, Wayne, Genesee, Livingston, Ontario, Yates, Seneca, Steuben, Schuyler and Chemung Counties
New York State Department of Environmental Conservation
6274 East Avon-Lima Road
Avon, NY 14414
telephone: 585-226-2466
internet: http://www.dec.state.ny.us/website/reg8/

Region Nine - Niagara, Erie, Wyoming, Chautauqua, Cattaraugus and Allegany Counties
New York State Department of Environmental Conservation
270 Michigan Avenue
Buffalo, NY 14203
telephone: 716-851-7000
internet: http://www.dec.state.ny.us/website/reg9/

Department of Agriculture and Markets

Headquarters
Department of Agriculture and Markets
10B Airline Drive
Albany, NY 12235
telephone: 518-457-3880
internet: http://www.agmkt.state.ny.us/

Department of Transportation

Environmental Analysis Bureau
Department of Transportation
50 Wolf Road
Albany, NY 12232
telephone: 518-457-2600
internet: http://dot.state.ny.us/

COUNTY AND REGIONAL AGENCIES

County Soil and Water Conservation Districts

Contacts vary by county.
internet: http://www.agmkt.state.ny.us/soilwater/home.html

County Departments of Planning

Contacts vary by county.

Regional Planning Councils

internet: http://www.dos.state.ny.us/lists/rgcoplan.html

FEDERAL AGENCIES

United States Fish and Wildlife Service

Southern New England - New York Bight Coastal Ecosystems Program
United States Fish and Wildlife Service
Shoreline Plaza Route 1A, P.O. Box 307
3769 Old Post Road
Charlestown, RI 02813
telephone: 401-364-9124
internet: http://www.fws.gov/r5snep/snep1.htm

New York Field Office
United States Fish and Wildlife Service
3817 Luker Road
Cortland, NY 13045
telephone: 607-753-9334
internet: http://www.fws.gov/northeast/nyfo/info/introduction.htm

Long Island Field Office
United States Fish and Wildlife Service
500 St. Mark's Lane
Islip, NY 11751
telephone: 631-581-2941
internet: http://www.fws.gov/northeast/nyfo/info/introduction.htm

Northeast Regional Office, Region 5
U.S. Fish and Wildlife Service
300 Westgate Center Drive
Hadley, MA 01035
telephone: 413-253-8200
internet: http://www.fws.gov/northeast/

National Oceanic and Atmospheric Administration

Office of Ocean and Coastal Resource Management
N/ORM 10th Floor SSMC4
1305 East-West Highway
Silver Spring, MD 20910
telephone: 301 713-3155
internet: http://coastalmanagement.noaa.gov/

NOAA Restoration Center, Headquarters
NOAA Fisheries
F/HC3 1315 East-West Highway
Silver Spring, MD 20910
telephone: 301-713-0174
internet: http://www.nmfs.noaa.gov/habitat/restoration/

NOAA Restoration Center, Northeast Regional Office
NOAA Fisheries
One Blackburn Drive
Gloucester, MA 01930
telephone: 978-281-9300
internet: http://www.nero.noaa.gov/nero/

NOAA Coastal Services Center
2234 South Hobson Avenue
Charleston, SC 29405
telephone: 843-740-1200
internet: http://www.csc.noaa.gov/

United States Environmental Protection Agency

Region Two – New York, New Jersey, Puerto Rico, U.S. Virgin Islands
United States Environmental Protection Agency
290 Broadway
New York, NY 10007
telephone: 212-637-3000
internet: http://www.epa.gov/region02/

United States Geological Survey

New York Water Science Center
United States Geological Survey
425 Jordan Road
Troy, NY 12180
telephone: 518-285-5600
internet: http://ny.water.usgs.gov/

Unites States Department of Agriculture

Natural Resources Conservation Service
United States Department of Agriculture
441 South Salina Street, Suite 354
The Galleries of Syracuse
Syracuse, NY 13202
telephone: 315-477-6524
internet: http://www.ny.nrcs.usda.gov/

United States Army Corps of Engineers

New York District
United States Army Corps of Engineers
Jacob K. Javits Federal Building
26 Federal Plaza, Room 2109
New York, NY 10278
telephone: 917-790-8799
internet: http://www.nan.usace.army.mil/

Buffalo District
United States Army Corps of Engineers
1776 Niagara Street
Buffalo, NY 14207
telephone: 716-879-4104
internet: http://www.lrb.usace.army.mil/

United States Department of Homeland Security

Federal Emergency Management Agency
United States Department of Homeland Security
500 C Street, SW
Washington, DC 20472
telephone: 1-800-621-FEMA
internet: http://www.fema.gov/

NON-PROFIT GROUPS

American Rivers

Headquarters
American Rivers
1101 14th Street NW, Suite 1400
Washington, DC 20005
telephone: 202-347-7550
internet: http://www.americanrivers.org/

Mid-Atlantic/New York Field Office
American Rivers
One Danker Avenue
Albany NY 12206
telephone: 518-482-2631
internet: http://www.americanrivers.org/

River Network

National Headquarters
River Network
520 SW 6th Avenue #1130
Portland, OR 97204
telephone: 503-241-3506
internet: www.rivernetwork.org

Regional Office
River Network
153 State Street
Montpelier, VT 05602
telephone: 802-223-3840
internet: www.rivernetwork.org

Center for Watershed Protection

8390 Main Street, 2nd Floor
Ellicott City, MD 21043
telephone: 410-461-8323
internet: www.cwp.org

The Nature Conservancy

New York State Office
The Nature Conservancy
415 River Street, 4th Floor
Troy, NY 12180
telephone: 518-273-9408
internet: http://www.nature.org/wherewework/northamerica/states/newyork/

New York City Office
The Nature Conservancy
322 8th Avenue, 16th Floor
New York, NY 10001
telephone: 212-997-1880
internet: http://www.nature.org/wherewework/northamerica/states/newyork/

New York Rivers United

PO Box 1460
Rome, NY 13442
telephone: 315-339-2097
internet: http://www.newyorkriversunited.org/

Upper Susquehanna Coalition

56 Main Street
Owego, NY 13827
telephone: 607-687-3553
internet: http://www.u-s-c.org/

Trout Unlimited

internet: http://www.nysctu.org/index.html

New York Planning Federation

279 River Street, Suite 302
Troy, NY 12180
telephone: 518-270-9855
internet: http://www.nypf.org/

Other Contacts

New York City Department of Environmental Protection

Stream Management Program
New York City Department of Environmental Protection
71 Smith Avenue
Kingston, NY 12401
telephone:
internet: http://nyc.gov/html/dep/watershed/home.html

Cornell Cooperative Extension

Contacts vary by county.
internet: http://www.cce.cornell.edu/

New York Sea Grant

New York Sea Grant
SUNY at Stony Brook
121 Discovery Hall
Stony Brook, NY 11794
telephone: 631-632-6905
internet: http://www.seagrant.sunysb.edu/

New York Sea Grant, Extension Offices
SUNY at Stony Brook
146 Suffolk Hall
Stony Brook, NY 11794
telephone: 631-632-8730
internet: http://www.seagrant.sunysb.edu/

New York Sea Grant
Cornell University
112 Rice Hall
Ithaca, NY 14853
telephone: 607-255-2832
internet: http://www.seagrant.sunysb.edu/

New York Sea Grant
10 Westbrook Lane
Kingston, NY 12401
telephone: 845-340-3983
internet: http://www.seagrant.sunysb.edu/

New York Sea Grant
Cornell University Research and Extension Center
3059 Sound Avenue
Riverhead, NY 11901
telephone: 631-727-3910
internet: http://www.seagrant.sunysb.edu/

New York Sea Grant
SUNY College at Brockport
Morgan II, 2nd Floor
Brockport, NY 14420
telephone: 585-395-2638
internet: http://www.seagrant.sunysb.edu/

New York Sea Grant
SUNY at Buffalo
229 Jarvis Hall
Buffalo, NY 14260
telephone: 716-645-3610
internet: http://www.seagrant.sunysb.edu/

New York Sea Grant
SUNY College at Oswego
62B Mackin Hall
Oswego, NY 13126
telephone: 315-312-3042
internet: http://www.seagrant.sunysb.edu/

APPENDIX B
FUNDING OPPORTUNITIES

NEW YORK STATE GRANT PROGRAMS

Environmental Protection Fund

Local Waterfront Revitalization Program
New York State Department of State
Division of Coastal Resources

Who can apply: municipalities
Match requirements: 50/50
Due: End of May
Eligible activities: watershed planning and implementation, of which stream restoration projects can be a component.

Hudson River Estuary Grant Program
Department of Environmental Conservation
Hudson River Estuary Program

Who can apply: municipalities and not-for-profits in the Hudson River Estuary Watershed
Match requirements: 75/25
Due: End of May
Eligible activities: open space planning, inventory and acquisition; community-based conservation and stewardship; watershed planning and implementation

FEDERAL GRANT PROGRAMS

www.grants.gov

National Oceanic and Atmospheric Administration (NOAA)

Community-Based Habitat Restoration Program
http://www.nmfs.noaa.gov/habitat/restoration/projects_programs/crp/partners_funding/callforprojects.html

Who can apply: institutions of higher education, hospitals, other non-profits, commercial (for profit) organizations, organizations under the jurisdiction of foreign governments, international organizations, and state, local, and tribal governments whose projects have the potential to benefit NOAA trust resources.
Match requirements: 50/50
Due: see website
Eligible activities: reestablishment of hydrology, dam or berm removal, improvement or reestablishment of fish passage, habitat creation, establishment of riparian buffer zones, improvement of freshwater habitat features in watersheds that support anadramous fish, exclusionary fencing and planting, invasive species removal, planting of native coastal

wetland vegetation, and enhancement of feeding, spawning and growth areas essential to marine or anadramous fish.

Open Rivers Initiative
http://www.nmfs.noaa.gov/habitat/restoration/projects_programs/crp/partners_funding/callforprojects3.html

Who can apply: institutions of higher education, other non-profits, industry and commercial (for profit) organizations, organizations under the jurisdiction of foreign governments, international organizations, and state, local, and tribal governments whose projects have the potential to benefit NOAA trust resources.
Match requirements: 50/50
Due: see website
Eligible activities: full and partial barrier removal to benefit diadromous fish

NOAA and American Rivers Partnership Grant
Community-Based Restoration Program River Grants
http://www.americanrivers.org/site/PageServer?pagename=AMR_content_63c9

Who can apply:
Match requirements:
Due: April 1st and November 1st of each calendar year
Eligible activities: dam removal or fish passage projects that improve freshwater habitats important to anadromous fish

NOAA and Fish America Foundation Partnership Grant
http://www.nmfs.noaa.gov/habitat/restoration/projects_programs/crp/partners/fishamerica.html

Who can apply: non-profit organizations (such as local sporting clubs and conservation organizations), educational institutions, state and local governments
Match requirements: 50/50
Due: see website
Eligible activities: On-the-ground habitat restoration that benefits marine, estuarine and andramous fisheries resources, particularly sportfish. Projects must involve community participation through an educational or volunteer component.

NOAA and Trout Unlimited Partnership Grant
Embrace-A-Stream Grant Program
http://www.tu.org/site/pp.asp?c=7dJEKTNuFmG&b=277882

Who can apply: Trout Unlimited chapters or councils
Match requirements: 50/50
Due: see website
Eligible activities: On-the-ground restoration, protection or conservation efforts that benefit trout and salmon fisheries and their habitats; education or outreach projects that increase the awareness and support of coldwater conservation among non-TU members; applied research, and assessment or monitoring that addresses the causes of fisheries or watershed problems and informs the development of management solutions.

NOAA, National Association of Counties (NACo) and National Fish and Wildlife Partnership Grant
Coastal Counties Restoration Initiative
http://www.nfwf.org/programs/ccri.cfm

Who can apply: NACo member counties (visit www.naco.org to determine membership), or public or nonprofit private agencies, institutions, and organizations, educational institutions, and any form of local government (i.e., departments, townships, cities, villages, boroughs, conservation districts, planning districts, utility districts, or other units of local government) working in partnership with a NACo member county
Match requirements: 50/50
Due: see website
Eligible activities: improvement or reestablishment of fish passage; establishment of riparian buffer zones and improvement of freshwater habitat features in watersheds that support diadromous fish; enhancement of feeding, spawning, and growth areas essential to marine or diadromous fish; exclusionary fencing and riparian planting; and invasive species removal and native vegetation planting.

United States Fish and Wildlife Service
http://www.fws.gov/grants/

Coastal Program
Fish and Wildlife Management and Habitat Restoration
http://ecos.fws.gov/coastal/viewContent.do?viewPage=portal

Who can apply: federal, state, interstate and intrastate agencies, local and tribal governments, sponsored organizations, public nonprofit institutes and organizations (such as conservation organizations, watershed councils, land trusts, schools and institutions of higher learning), and private landowners in Great Lakes and Southern New England/New York Bight coastal areas.
Match requirements: 50/50
Due: Prospective applicants should contact the coordinators of the Coastal Program office. Some individual Coastal Programs have specific deadlines.
Eligible activities: restoring stream corridors to provide wildlife habitat and improve water quality, reconstruction of in-stream aquatic habitat through bioengineering techniques, reestablishing fish passage for migratory fish by removing barriers to movement.

Partners for Fish and Wildlife Program
http://ecos.fws.gov/partners/viewContent.do?viewPage=home

Who can apply: Any privately owned land (i.e., not owned by a state or federal government). Most applicants are individual landowners. Tribes, schools, local governments, businesses and organizations are examples of other eligible applicants.
Match requirements: 50/50
Due: Prospective applicants should contact the coordinators of the Coastal Program office. Some individual Coastal Programs have specific deadlines.

Eligible activities: restoring wetland hydrology, planting native vegetation, installing fencing and off-stream livestock watering facilities to allow for restoration of stream and riparian areas, removal of exotic plants and animals, reconstruction of in-stream aquatic habitat through bioengineering techniques, reestablishing fish passage for migratory fish by removing barriers to movement.

United States Environmental Protection Agency

Five Star Restoration Matching Grants Program
Partnership Grant between USEPA, NACo, NFWF and WHC
http://www.epa.gov/owow/wetlands/restore/5star/

Who can apply: Schools or youth organizations, local or tribal governments, universities and local cooperative extension districts, local businesses or corporations, conservation organizations or local citizen groups, state and federal resource management agencies, and foundations or other funders. Projects must involve diverse partnerships of ideally five organizations.
Match requirements: 1:1
Due: Early March
Eligible activities: community-based wetland, riparian, and coastal habitat restoration projects that build diverse partnerships and foster local natural resource stewardship through education, outreach and training activities

Great Lakes National Program Office
United States Environmental Protection Agency
http://www.epa.gov/glnpo/fund/glf.html

Who can apply: state pollution control agencies, interstate agencies, public or nonprofit private agencies, institutions and organizations
Match requirements:
Due: deadline varies check website
Eligible activities: topics may vary check website for more information

United States Department of Agriculture Natural Resources Conservation Service

Agricultural Management Assistance
USDA-NRCS
http://www.nrcs.usda.gov/Programs/ama/index.html

Who can apply: Applicants must own or control the land and agree to implement specific eligible conservation practices. Eligible land includes: cropland, hayland, pasture and rangeland, land used for subsistence purposes.
Match requirements: Federal cost-share is 75% of the total cost of an eligible practice.
Due: Continuous sign-up with periodic ranking cut-off dates as determined by the State Conservationist in consultation with the State Technical Committee.
Eligible activities: The NRCS State Conservationist, in consultation with the State Technical Committee, determines eligible practices using a locally led process.

Environmental Quality Incentives Program
USDA-NRCS
http://www.nrcs.usda.gov/Programs/eqip/

Who can apply: Any producer engaged in livestock or crop production on eligible land. Eligible land includes cropland, pasture, private non-industrial forestland and other farmland as determined by the Secretary of Agriculture.
Match requirements: Federal cost-share is 75% of the total cost of an eligible practice.
Due: Continuous sign-up with periodic ranking cut-off dates as determined by the State Conservationist in consultation with the State Technical Committee.
Eligible activities: reduction in non-point source pollution, reduction in soil loss and emissions and promotion of at-risk species habitat.

Wetlands Reserve Program
USDA-NRCS
http://www.nrcs.usda.gov/Programs/wrp/

Who can apply: Eligible lands include: privately owned land, Federal land where the primary benefit is on private or Tribal land, state and local government land on a limited basis, and Tribal land.
Match requirements: Federal cost-share is 75% of the total cost of an eligible practice.
Due: Continuous sign-up with periodic ranking cut-off dates as determined by the State Conservationist in consultation with the State Technical Committee.
Eligible activities: Restoring and protecting wetland habitat for migratory birds and other wetland-dependent wildlife.

Wildlife Habitat Incentives Program
USDA-NRCS
http://www.nrcs.usda.gov/Programs/whip/

Who can apply: Eligible lands include: privately owned land, Federal land where the primary benefit is on private or Tribal land, state and local government land on a limited basis, and Tribal land.
Match requirements: Federal cost-share is 75% of the total cost of an eligible practice.
Due: Continuous sign-up with periodic ranking cut-off dates as determined by the State Conservationist in consultation with the State Technical Committee.
Eligible activities: reduction in non-point source pollution, reduction in soil loss and emissions and promotion of at-risk species habitat.

NON-PROFIT GRANT PROGRAMS

National Fish and Wildlife Foundation

General Grants Program
http://www.nfwf.org/guidelines.cfm

Who can apply: federal, tribal, state, and local governments, educational institutions, and non-profit conservation organizations.
Match requirements: 2:1

Due: check website.
Eligible activities: priority actions promoting fish and wildlife conservation and the habitats on which they depend

Great Lakes Watershed Restoration Program
http://www.nfwf.org/programs/greatlakes/index.cfm

Who can apply: non-profit 501 (c) organizations, tribes, or state and local governments (i.e., counties, townships, cities, boroughs, conservation districts, planning districts, utility districts, school districts or other units of local government) from the Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, or Wisconsin portions of the Great Lakes watershed
Match requirements: 1:1
Due: check website.
Eligible activities: Restore, enhance, and protect near shore and off shore native fish communities and other living resources, their habitats, and ecological relationships to sustain all fisheries and provide for a balanced ecosystem; preserve, protect, and restore the wetlands that are vital to the survival and diversity of the living resources of the Great Lakes; and preserve, protect, and restore the tributaries and their watersheds that support the living resources of the Great Lakes ecosystem.

APPENDIX C
FEDERAL AND STATE LAWS AND REGULATIONS RELATED TO STREAM RESTORATION AND MANAGEMENT

FEDERAL LAWS AND REGULATIONS

National Environmental Policy Act (NEPA) of 1969
The Act established a program for reviewing the environmental impacts of activities that fall within the jurisdiction of any federal agency. Under NEPA, the review of agency actions can require the drafting of an Environmental Assessment (EA) or an Environmental Impact Statement (EIS). These documents are the tools by which potential environmental effects of actions are identified and alternatives to the proposed actions evaluated. NEPA is administered by the United States Environmental Protection Agency (http://www.epa.gov/compliance/nepa/).

Clean Water Act of 1972, as amended in 1977
The Act established the basic structure for regulating discharges of pollutants into the waters of the United States. The Act's primary objective is to restore and maintain the integrity of the nation's waters, including rivers and streams. The Clean Water Act set water quality standards for all contaminants in surface waters and made it unlawful for any person to discharge any pollutant from a point source into navigable waters, unless a permit was obtained under its provisions. The Clean Water Act is administered by the United States Environmental Protection Agency (http://www.epa.gov/r5water/cwa.htm). Relevant sections of the Clean Water Act include: section 303(d) allows states to identify waters that are not achieving water quality standards, develop a priority ranking of waterbodies, and develop total maximum daily loads for identified pollutants; section 401, which grants the states regulatory authority to regulate water quality within their boarders; section 404 was enacted to control pollution from discharges of dredged or fill material.

Rivers and Harbors Act of 1899
The United States Army Corps of Engineers is authorized to regulate the construction of any structure or work within navigable waters under sections 9 and 10 of the Rivers and Harbors Act. Section 10 of the Act states that the building of any wharfs, piers, jetties and other structures is prohibited without Congressional approval, and excavation or fill within navigable waters requires the approval of the United States Army Corps of Engineers.

Endangered Species Act (ESA) of 1973
The purpose of the ESA is to protect and recover imperiled species and the habitats upon which they depend. It is administered jointly by the United States Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS). The USFWS has primary responsibility for terrestrial and freshwater organisms, while the responsibilities of NMFS are mainly marine species such as salmon and whales. Under the ESA, species may be listed as “endangered” or “threatened”. Section 7 of the ESA requires federal agencies to use their legal authorities to promote the conservation purposes of the law. This section also requires federal agencies to consult with USFWS and NMFS to ensure that actions they authorize, fund or carry out will not jeopardize listed species (http://www.fws.gov/endangered/).

Coastal Zone Management Act (CZMA) of 1972
Congress enacted the CZMA, and its subsequent amendments, to protect the coastal environment from the growing demands associated with residential, recreational, commercial and industrial uses. Through the CZMA, states are encouraged to develop coastal zone management programs to allow economic growth that is compatible with the protection of natural resources, the reduction of coastal hazards, the improvement of water quality, and sensible coastal development. New York State has an approved coastal zone management plan and the Department of State Division of Coastal Resources administers the program through the National Oceanic and Atmospheric Administration (http://coastalmanagement.noaa.gov/czm/czm_act.html; http://nyswaterfronts.com/).

National Flood Insurance Act of 1968
The National Flood Insurance Act and its subsequent amendments have provided an incentive for local governments to adopt floodplain regulations and ordinances. Administered by the Federal Insurance Administration of the Federal Emergency Management Agency (FEMA), participating communities are required to adopt certain minimum floodplain management standards, including restrictions on new development in designated floodways, a requirement that new structures in the 100-year flood zone be elevated to or above the 100-year flood level and a requirement that subdivisions are designed to minimize exposure to flood hazards. Under the National Flood Insurance program (NFIP), federally subsidized flood insurance is made available to owners of flood-prone property in participating communities.

NEW YORK STATE LAWS AND REGULATIONS

New York State Environmental Conservation Law (ECL)

Use and Protection of Waters Program
The use and protection of waters program (6NYCRR Part 608; Article 15 of the ECL), also known as the stream protection program, provides the legislative basis for regulating the construction or repair of water impoundment structures and any disturbance of a stream bed, its banks, or any excavation or fill of navigable waters. This approval applies to most stream restoration projects (http://www.dec.state.ny.us/website/regs/part608.html).

State Environmental Quality Review Act (SEQR)
Through SEQR (6NYCRR Part 617 of the ECL), New York State has established a process to systematically consider environmental factors early in the planning stages of actions that are directly undertaken, funded or approved by local, regional and state agencies. Like many other states, SEQR closely follows the provisions of NEPA. Under SEQR, the review of agency actions can require the drafting of an Environmental Assessment Form (EAF) or an Environmental Impact Statement (EIS). The Legislature has made SEQR self-enforcing; that is, each agency of government is responsible to see that it meets its own obligations to comply. The Department of Environmental Conservation (DEC) is charged with issuing regulations regarding the SEQR process; however, DEC has no authority to review the implementation of SEQR by other agencies (http://www.dec.state.ny.us/website/dcs/seqr/handbook/seqrintro.html).

New York State Historic Preservation Act of 1980
The Act requires state agencies to consult with the State Historic Preservation Office if it appears that any projects being planned may or will cause any change (beneficial or adverse) in the quality of any historic, architectural, archeological or cultural property (http://nysparks.state.ny.us/shpo/environ/preservation.htm).

New York State Waterfront Revitalization of Coastal Areas and Inland Waterways Act
New York State's Coastal Management Program (CMP) is administered by the NYSDOS Division of Coastal Resources. The CMP was developed pursuant to the Coastal Zone Management Act of 1972 and approved in 1982. The NYS Waterfront Revitalization of Coastal Areas and Inland Waterways Act (State Executive Law Article 42) declares that it is public policy of the State within its coastal area to conserve and protect fish and wildlife and their habitats and prevent permanent adverse changes to ecological systems. The Act ensures that all State and federal actions in the coastal area comply with enforceable policies and purposes of the CMP (http://nyswaterfronts.com/consistency.asp).