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National Management Measures to Control Nonpoint Source Pollution from Hydromodification

Chapter 6: Guiding Principles

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Chapter 6: Guiding Principles

Many of the management measures and practices recommended by EPA to reduce the nonpoint source (NPS) pollutant impacts associated with hydromodification activities stress the need to incorporate planning as a tool. States, local governments, or community groups should begin the planning process early when trying to determine how to address a particular NPS issue associated with a new or existing hydromodification project. The planning process should bring key stakeholders together so that a variety of options can be explored to adequately define the problem and potential solutions. Once the issues are identified according to the various perspectives, project goals can be established to solve one or more environmental problems.

One important part of the planning process is the identification of the goals of the different stakeholders. Once these goals, which are sometimes different for the different groups of stakeholders, are identified and defined, the planning team can strive to achieve a balance among the needs of the various stakeholders. Often restoration compromises can be made to meet differing goals of the stakeholders to achieve a balance of the needs of the different groups. For example, changes in hydroelectric dam operation may be possible to produce minimum base flows downstream from the dam to support a variety of aquatic habitats, while still providing energy in a profitable manner. In addition, solutions that only allow for complete removal of the dam and restoration to preexisting stream conditions may not be possible because of other changes in the watershed (e.g., urbanization, other hydromodification projects, or the need for affordable and environmentally friendly electricity). A compromise solution that enables the dam to continue to operate while minimizing environmental impacts and to enhance critical downstream habitats that support a desirable fish population may be the best solution.

Part of the planning process and achievement of balance when evaluating techniques for restoring areas impacted by NPS pollution associated with hydromodification activities can be termed “creating opportunities.” For example, an opportunity may be found by working with stakeholders such as local homeowners who are concerned about the unsightly algae present in a community reservoir. Reducing runoff containing an abundant supply of nitrogen and phosphorous pollutants from lawns surrounding the reservoir may lead to reductions in the algal bloom. Changes in land use that result in increasing the permeability of land adjacent to a channelized stream can reduce the overall volume and velocity of water in the stream. As flooding conditions are reduced, “hard” structures like bulkheads can be replaced with softer, vegetative solutions along the stream channel. The combination of reduced scouring flows associated with the greater stream velocities and vegetated channel banks can lead to improved instream ecological conditions. There are many other possible opportunities waiting to be found and implemented when projects are evaluated at the watershed level.

Project planning and analysis are essential parts of success when trying to reduce the impact of NPS pollution from new or existing hydromodification activities. One example of a planning process is explained in the EPA document *Ecological Restoration: A Tool to Manage Stream Quality* (USEPA, 1995a). This document outlines the key steps in the ecological restoration decision framework as:

- Identification of impaired or threatened watersheds

- Inventory of the watershed
- Identification of the restoration goals
- Selection of candidate restoration techniques
- Implementation of selected restoration techniques
- Monitoring

Other EPA guidance documents offer similar approaches to the restoration planning process, including *Community-Based Environmental Protection: A Resource Book for Protecting Ecosystems and Communities* (USEPA, 1997a). Both guidance documents offer a variety of case studies to provide readers with examples of the frameworks as they are applied to real-world situations. EPA's *Draft Handbook for Developing Watershed Plans to Restore and Protect Our Waters* (USEPA, 2005c) also provides useful planning information related to watershed plans.

The Natural Resources Conservation Service (NRCS) is also a source of information for planning. NRCS provides assistance through their Watershed Protection and Flood Prevention Program, whose purpose is to assist federal, state, local agencies, local government sponsors, tribal governments, and program participants to protect and restore watersheds from damage caused by erosion, floodwater, and sediment; to conserve and develop water and land resources; and to solve natural resource and related economic problems on a watershed basis. The program provides technical and financial assistance to local people or project sponsors, builds partnerships, and requires local and state funding contribution.[1]

NRCS uses locally-led conservation programs, which are an extension of the agency's traditional assistance to individual farmers and ranchers, for planning and installing conservation practices for soil erosion control, water management, and other purposes. Through this effort, local people, generally with the leadership of conservation districts along with NRCS technical assistance, will assess their natural resource conditions and needs, set goals, identify ways to solve resource problems, utilize a broad array of programs to implement solutions, and measure their success.

When planning any new development activities or restoration of already developed or impacted activities, it is important to account for the guiding principles:

- Using a watershed approach
- Smart growth principles
- Project design principles
- Monitoring and maintenance of structures

Each of these principles is discussed in more detail below.

[1] Additional information about this program, as well as contact information is available at http://www.nrcs.usda.gov/programs/watershed.

Using a Watershed Approach

EPA recommends the use of a watershed approach as the key framework for dealing with problems caused by runoff and other sources that impair surface waters (USEPA, 1998). The watershed protection approach is a comprehensive planning process that considers all natural resources in the watershed, as well as social, cultural, and economic factors. Using a watershed approach, multiple stakeholders integrate regional and locally-led activities with local, state, tribal, and federal environmental management programs. EPA works with federal agencies, states, tribes, local communities, and non-governmental sectors to make a watershed approach the key coordinating framework of planning, restoration, and protection efforts to achieve "clean and safe" water and healthy aquatic habitat.

The watershed approach framework can be applied to address impacts caused by hydromodification activities throughout a watershed. Additionally, the watershed approach can help to identify and address problems within a watershed that increase NPS pollution associated with hydromodification activities.

Major elements of successful watershed approaches include:

- Focusing on hydrologically-defined areas—watersheds and aquifers have hydrologic features that converge to a common point of flow; watersheds range in size from very large (e.g., the Mississippi River Basin) to a drainage basin for a small creek.

- Using an integrated set of tools and programs (regulatory and voluntary, federal/state/tribal/local and non-governmental sectors) to address the myriad problems facing the Nation's water resources, including NPS and point source pollution, habitat degradation, invasive species, and air deposition of pollutants (e.g., mercury and nutrients).

- Involving all parties that have a stake or interest in developing collaborative solutions to a watershed's water resource problems.

- Using an iterative planning or adaptive management process of assessment and setting environmental, water quality, and habitat goals (e.g., water quality standards).

- Planning, implementation, and monitoring to ensure that plans and implementation actions are revised to reflect new data.

- Breaking down barriers between plan development and implementation to enhance prospects for success.

A key attribute of the watershed approach is that it can be applied with equal success to large- and small-scale watersheds. Federal agencies, states, interstate commissions, and tribes usually apply the approach on larger scales, such as in watersheds greater than 100 square miles in size.

However, local agencies and urban communities can apply the approach to watersheds as small as several acres in size.

Although specifics may vary from large scale to small scale, the basic goals of the watershed approach remain the same—protecting, maintaining, and restoring water resources, based on the geomorphology, ecology, and other natural characteristics of the waterbody. Local runoff management program officials must be especially conscious of watershed scale when planning and implementing specific management practices. For example, programmatic practices, such as stream protection ordinances and public education campaigns, are usually applied community wide. Consequently, the results benefit many small watersheds. In contrast, structural practices, such as vegetative approaches, usually provide direct benefits to a single stream. Regional structural management practices such as headland breakwater systems for larger watersheds can be used, but they do not protect smaller contributing streams. Given limited resources, program officials must often analyze cost and benefits and choose between large- and small-scale practices. Often, a combination of nonstructural and structural practices implemented across the watershed and at regional and local levels is the most cost effective approach.

An example of the watershed approach being used for hydromodification activities is the South Myrtle Creek Ditch Project. South Myrtle Creek, which flows into the South Umpqua River in Oregon, was historically populated with cutthroat trout (*Oncorhynchus clarki*) and coho salmon (*Oncorhynchus kisutch*). However, since the early 20th century, diversion structures, used primarily to provide water for irrigating agricultural crops, have blocked the passage of fish through creek waters (USEPA, 2002c). One example of the diversion structures was a diversion dam with a concrete apron, which was installed in a portion of South Myrtle Creek to raise the water level in an impoundment to provide irrigation water for adjacent and downstream landowners. During the summer, water levels in the creek would elevate 14 feet above natural levels and were diverted into a 2.5 mile irrigation ditch. Ultimately, hydromodification of this stream caused flow modifications and high stream temperatures, which degraded water quality for the native trout and salmon populations.

9 Elements of Watershed Planning

EPA has identified a minimum of nine elements that are critical for achieving improvements in water quality. EPA requires that these nine elements be addressed for section 319-funded watershed plans and strongly recommends that they be included in all other watershed plans that are intended to remediate water quality impairments. Additional information is available from FY 2004 Guidelines for the Award of Section 319 Nonpoint Source Grants to States and Territories *at http://www.epa.gov/owow/nps/cwact.html. The nine elements are listed below:*

a. Identification of causes of impairment and pollutant sources or groups of similar sources that need to be controlled to achieve needed load reductions, and any other goals identified in the watershed plan. Sources that need to be controlled should be identified at the significant subcategory level along with estimates of the extent to which they are present in the watershed (e.g., X linear miles of eroded streambank needing remediation).

b. An estimate of the load reductions expected from management measures.

c. A description of the nonpoint source management measures that will need to be implemented to achieve load reductions and a description of the critical areas in which those measures will be needed to implement this plan.

d. Estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon to implement this plan.

e. An information and education component used to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the nonpoint source management measures that will be implemented.

f. Schedule for implementing the nonpoint source management measures identified in this plan that is reasonably expeditious.

g. A description of interim measurable milestones for determining whether nonpoint source management measures or other control actions are being implemented.

h. A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made toward attaining water quality standards.

i. A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established under item h immediately above.

In 1998 one of the landowners initiated a project to restore flow and improve water quality in South Myrtle Creek. The project used the guiding principles of the watershed approach to restore the health of the creek.

- *Partnership*. The project was a collaborative effort of landowners, who donated services and supplies. The project received funding and support from government agencies, such as the U.S. Fish and Wildlife Service, the Oregon Water Resources Department, the Oregon Watershed Enhancement Board, the Bureau of Land Management, the Natural Resources Conservation Service, and the Douglas County Watermaster.

- *Geographic focus*. Resource management activities were directed specifically to the creek and the drainage ditch, where flow restoration and improved water quality were desired.

- *Sound management techniques based on strong science and data*. An assessment of South Myrtle Creek identified water quality problems from flow modification and high stream temperatures as the priority problems in the creek. The diversion dam and concrete apron were found to be causing the problems. Landowners, the Water Resources Department, and the Watershed Enhancement Board developed a plan, the goal of which was to restore flow and improve water quality in the creek. The plan was implemented by removing the diversion dam and concrete apron. The irrigation system was switched to a sprinkler type system, which is more efficient than the original ditch irrigation. In addition, the denuded riparian area was revegetated to help lower stream temperatures and new seedlings were protected with fencing to keep away livestock.

With the cooperation of the landowners, the county and state governments, and other interested parties, the South Myrtle Creek Ditch Project was a success. Water temperatures have improved and flows have increased by 2.5 cubic feet per second during the summer. Restoration of the streambed to its historical level has allowed passage of salmon and trout to the 10 miles of stream above the dam (USEPA, 2002c).[2]

Smart Growth

Smart growth practices cover a range of development and conservation strategies that are environmentally sensitive, economically viable, community-oriented, and sustainable. Environmental impacts of development can be reduced with techniques that include compact development, reduced impervious surfaces and improved water detention, safeguarding of environmentally sensitive areas, mixing of land uses (e.g., homes, offices, and shops), transit accessibility, and better pedestrian and bicycle amenities.

Through smart growth approaches that enhance neighborhoods and involve local residents in development decisions, these communities are creating vibrant places to live, work, and play. The high quality of life in these communities makes them economically competitive, creates business opportunities, and improves the local tax base. Smart growth practices have also been shown to help protect water quality by reducing the amount of paved surfaces and allowing natural lands to filter rainwater and runoff before it reaches downstream areas.

Based on the experience of communities around the nation that have used smart growth approaches to create and maintain great neighborhoods, the Smart Growth Network[3] developed a set of ten basic principles:

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[2] Additional information about the project is available at http://www.epa.gov/owow/nps/Section319III/OR.htm.
[3] Smart Growth Network (SGN) is a partnership of government, business, and civic organizations that support smart growth. The SGN Web site, Smart Growth Online (http://www.smartgrowth.org/Default.asp?res=1024), features an extensive array of smart growth-related news, events, information, research, presentations, and publications.

1. Mix land uses
2. Take advantage of compact building design
3. Create a range of housing opportunities and choices
4. Create walkable neighborhoods
5. Foster distinctive, attractive communities with a strong sense of place
6. Preserve open space, farmland, natural beauty, and critical environmental areas
7. Strengthen and direct development towards existing communities
8. Provide a variety of transportation choices
9. Make development decisions predictable, fair, and cost effective
10. Encourage community and stakeholder collaboration in development decisions

EPA offers help to communities through the EPA smart growth program to improve development practices and get the type of development they want. They work with local, state, and national experts to discover and encourage successful, environmentally sensitive development strategies. EPA is engaged in conducting research, publishing reports and other publications,[4] showcasing outstanding communities, working with communities through grants[5] and technical assistance (Smart Growth Implementation Assistance Program),[6] and bringing together diverse interests to encourage better growth and development.[7]

Low Impact Development

Low Impact Development (LID) is an innovative stormwater management approach. The goal of LID is to mimic a site's predevelopment hydrology by using design techniques that infiltrate, filter, store, evaporate, and detain runoff close to its source (Low Impact Development Center, Inc., n.d.).

LID is based on the paradigm that stormwater management should not be viewed as stormwater disposal and that numerous opportunities exist within the developed landscape to control stormwater runoff close to the source. These principles include (NRDC, n.d.):

- Integrate stormwater management early in site planning activities
- Use natural hydrologic functions as the integrating framework
- Focus on prevention rather than mitigation
- Emphasize simple, low-tech, and low cost methods
- Manage as close to the source as possible
- Distribute small-scale practices throughout the landscape
- Rely on natural features and processes
- Create a multifunctional landscape

[4] http://www.epa.gov/piedpage/publications.htm
[5] http://www.epa.gov/piedpage/grants/index.htm
[6] http://www.epa.gov/piedpage/sgia.htm
[7] Links to technical assistance, tools, partnerships and grants and other funding are at "Making Smart Growth Happen" at http://www.epa.gov/piedpage/sg_implementation.htm.

The use of LID practices offers both economic and environmental benefits. LID measures result in less disturbance of the development area and conservation of natural features, and they can be less cost intensive than traditional stormwater control mechanisms. Cost savings for control mechanisms are not only for construction, but also for long-term maintenance and life cycle cost considerations (USEPA, 2000).

Ten common LID practices are the following (NRDC, n.d.):

- Impervious surface reduction and disconnection
- Permeable pavers
- Pollution prevention and good housekeeping
- Rain barrels and cisterns
- Rain gardens and bioretention
- Roof leader disconnection
- Rooftop gardens
- Sidewalk storage
- Soil amendments
- Tree preservation
- Vegetated swales, buffers, and strips

Project Design Considerations

General Design Factors

When designing any type of restoration project, it is important to consider the watershed as a whole as well as the specific site where restoration will occur. A watershed survey, or visual assessment, evaluates an entire watershed and can be used to help identify and verify pollutants, sources, and causes of impairments that lead to changes in streambank erosion. Additional monitoring of chemical, physical, and biological conditions may be necessary to determine if water quality is actually being affected by observed pollutants and sources. Watershed surveys can provide an accurate picture of what is occurring in the watershed. EPA's *Volunteer Stream Monitoring: A Methods Manual*[8] provides a watershed survey visual assessment form that may be used. In addition to EPA's method, a variety of visual assessment protocols have been developed by states and agencies. Designers of watershed restoration plans should look for assessment protocols that are already being used in their state or local area (USEPA, 2005c). Another general resource for planning and implementing restoration projects associated with hydromodification activities is EPA's *National Management Measures to Protect and Restore Wetlands* (USEPA, 2005b).

Photographs may also be a powerful tool that can be incorporated into watershed surveys. Photos serve as a visual reference for the site and provide before and after pictures that may be used to analyze restoration or remediation activities. In addition to taking individual photographs, aerial photographs may also provide important before and after information and can be obtained from

[8] http://www.epa.gov/owow/monitoring/volunteer/stream/vms32.html

USGS (Earth Science Information Center), USDA (Consolidated Farm Service Agencies, Aerial Photography Field Office), and other agencies (USEPA, 2005c). Refer to EPA's draft *Handbook for Developing Watershed Plans to Restore and Protect Our Waters* (USEPA, 2005c) for more information about watershed assessments.

Assessment

Tools to analyze channels on a site-by-site basis may include geomorphic assessments such as the methodology developed by Rosgen. Geomorphic assessments help to determine river and stream characteristics such as channel dimensions, reach slope, and channel enlargement and stability. This information about stream physical characteristics might help the restoration team to understand current stream conditions and may be evaluated over time to describe degradation or improvements in the stream. Geomorphic assessment may also be useful for predicting future stream conditions, which can help in selecting suitable restoration or protection approaches (USEPA, 2005c).

The Rosgen geomorphic assessment approach groups streams into different geomorphic classes, based on a set of criteria that include entrenchment ratio, width/depth ratio, sinuosity, channel slope, and channel materials. Assessment methodologies, such as Rosgen's Stream Classification System, can help identify streams at different levels of impairment, determine the types of hydrologic and physical factors affecting stream morphologic conditions, and choose appropriate management measures to implement if needed.[9] Another common geomorphic assessment method is the Modified Wolman Pebble Count (Harrelson et al., 1994), which characterizes the texture (particle size) in the stream or riverbeds of flowing surface waters. It can be used alone or with Rosgen-type assessments. The composition of the streambed can provide information about the characteristics of the stream, including effects of flooding, sedimentation, and other physical impacts on a stream (USEPA, 2005c). Other assessment methods may be available from state agencies or environmental organizations.

The physical conditions of a site can provide important information about factors affecting overall stream integrity, such as agricultural activities and urban development. Runoff from cropland and feedlots can carry sediment into streams, clog existing habitat, and change geomorphological characteristics. An understanding of stream physical conditions can facilitate identification of sources and pollutants and allow for designing and implementing more effective restoration and protection strategies. Physical characterization should also extend beyond the streambanks or shore and include a look at conditions in riparian areas (USEPA, 2005c).

Before choosing a practice to restore an area impacted by hydromodification activities, it is also important to determine what biological endpoints are desired and to consider other environmental or water quality goals. Biological endpoints may include metrics such as the number of fish surviving, number of offspring produced, impairment of reproductive capability, or morbidity. Biological endpoints can be used to evaluate the effectiveness of treatment schemes and can serve as a design parameter during restoration planning. Water quality goals, such as increasing low dissolved oxygen levels, reducing nitrogen or phosphorous pollutant

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[9] More information about the Rosgen Stream Classification System is available at http://www.epa.gov/watertrain/stream_class/index.htm.

levels, or decreasing turbidity, are also important to consider when planning restoration. For example, if turbidity is a major problem in the waterbody, planners will want to choose a method of restoration that prevents erosion, is efficient at trapping sediment before it enters the waterbody, or one that will help sediment to settle in desired locations of the stream or river. Looking at endpoints and goals before designing the method of restoration can help planners and stakeholders achieve the desired results.

Engineering Considerations

When choosing from the various alternatives of engineering practices for addressing impacts associated with hydromodification, such as protecting and restoring eroding streambanks and shorelines, the following factors should be taken into consideration:

- Foundation conditions
- Level of exposure to erosive forces
- Availability of materials
- Initial and annual costs
- Past performance

Foundation conditions may have a significant influence on the selection of the specific practice or combination of practices to be used for restoring areas impacted by hydromodification, including shoreline or streambank stabilization. Foundation characteristics at the site must be compatible with the structure that is to be installed for erosion control. A structure such as a bulkhead, which must penetrate through the existing substrate for stability, will generally not be suitable for shorelines with a rocky bottom. Where foundation conditions are poor or where little penetration is possible, a gravity-type structure such as a stone revetment may be preferable. However, all vertical protective structures (revetments, seawalls, and bulkheads) built on sites with soft or unconsolidated bottom materials can experience scouring as incoming waves are reflected off the structures. In the absence of additional toe protection in these circumstances, the level of scouring and erosion of bottom sediments at the base of the structure may be severe enough to contribute to structural failure at some point in the lifetime of the installation.

Along streambanks, the erosive force of the current during periods of high streamflow will influence the selection of bank stabilization techniques and details of the design. For shorelines, the levels of wave exposure at the site will also generally influence the selection of shoreline stabilization techniques and details of the design. In areas of severe levels of exposure to erosive forces, such as strong wave action or currents, light structures such as vegetative techniques, timber cribbing, or light riprap revetment may not provide adequate protection. The effects of winter ice along the shoreline or streambank may also need to be considered in the selection and design of erosion control projects.

The availability of materials is another key factor influencing the selection of suitable techniques for protecting and restoring areas affected by hydromodification activities. For a vegetative approach, availability of plant materials of sufficient quantity and quality is an important design consideration. A particular type of bulkhead, seawall, or revetment may not be economically feasible if materials are not readily available near the construction site. Installation methods may also preclude the use of specific structures in certain situations. For instance, the installation of bulkhead pilings in coastal areas near wetlands may not always be permissible due to disruptive impacts in locating pile-driving equipment at the project site.

Costs should also be included in the decision making process for implementing hydromodification practices. The total cost of a project should be viewed as including both the initial costs (materials, labor, and planning) and the annual costs of operation and maintenance. To the extent possible, practices should be compared by their total costs. Although a particular practice may be cheaper initially, it could have operation and maintenance costs that make it more expensive in the long run. For example, in some parts of the country, the initial costs of timber bulkheads may be less than the cost of stone revetments. However, stone structures typically require less maintenance and have a longer life than timber structures. Other types of structures whose installation costs are similar may actually have a wide difference in overall cost when annual maintenance and the anticipated lifetime of the structure are considered (USACE, 1984). Environmental benefits, such as creation of habitat, should also be factored into cost evaluations.

An example of a valuable resource that provides specific cost information for practices to protect or reduce streambank and shoreline erosion is your local USDA Service Center, which makes available services provided by the NRCS.[10]

The engineering designers should also evaluate similar existing projects and practice designs to determine how well they performed compared to design specifications. An important consideration for determining past performance is to compare the physical, water quality, and biological endpoints specified in the design with the corresponding endpoints that were observed in the monitoring results. For example, if an operation and maintenance program for an urban channelization project incorporates establishment of vegetative cover along many of the low energy areas of an urban stream, the long-term performance of the vegetative cover can be evaluated with metrics such as:

- Percent of riparian area with erosion problems
- Number of recreationally important fish species present
- Annual operation and maintenance costs
- Changes in important water quality parameter values (e.g., dissolved oxygen, turbidity)

Incorporating Monitoring and Maintenance of Structures

Generally, the monitoring program will help to determine how well the project is performing with respect to the design goals and the extent of any maintenance activities needed (NRC, 1992). The project monitoring plan should be an integral part of the overall design and will be an important consideration for developing long-term project costs and resource needs. Once the project's goals are established, performance indicators are then matched to the goals to create the

[10] A list of USDA Service Centers is available at http://offices.sc.egov.usda.gov/locator/app. A list of regional and state NRCS offices is available at http://www.nrcs.usda.gov/about/organization/regions.html#state.

monitoring program (NRC, 1992). The monitoring program should also be appropriate to the scope of the project (NRC, 1992) by including considerations such as:

- The area covered by the monitoring compared to the area of the overall project—both should be similar.
- The frequency and intensity of sampling to provide reliable assessments of the performance indicators.
- The cost and resources required for monitoring should reflect the overall cost and resources of the project.
- The performance indicators provide information to enable effective assessments of the project goals and decision-making for project maintenance activities.

Each project will have unique goals and corresponding monitoring needs. Chapter 3 of The National Research Council's document *Restoration of Aquatic Ecosystems* (NRC, 1992) provides detailed advice on considerations for planning a monitoring program for restoration activities such as those associated with hydromodification activities. Some additional monitoring considerations can be found in the USDA Forest Service document *A Soil Bioengineering Guide for Streambank and Lakeshore Stabilization* (USDA-FS, 2002):

- Keeping track of where plants were harvested—is there a correlation between growth rate of certain cuttings and the "mother" plants?
- Is the installation functioning as designed?
- Which areas are maturing more rapidly than others?
- Are seeds sprouting in the newly formed beds?
- Which plants have invaded the site through natural succession?
- What has sprouted in the second season?
- Which areas are experiencing difficulty and why?
- Is the bank stabilizing or washing away and why?
- Is something occurring that is unexpected?
- Which techniques are succeeding?
- Are any of the structures failing?

USDA NRCS' *The Practical Streambank Bioengineering Guide*[11] (Bentrup and Hoag, 1998) provides an example monitoring form. The monitoring sheet is also available in Appendix C of *A Soil Bioengineering Guide for Streambank and Lakeshore Stabilization* (USDA-FS, 2002).[12]

During the first few years after installation, maintenance is necessary until vegetation becomes established and the bank stabilizes. Structures may shift or you may notice something that was left undone. Once vegetation is established, projects should become self-sustaining and require little or no maintenance. Be sure the site is managed to give the treatment every chance to be effective over a long period of time (USDA-FS, 2002).

[11] http://www.engr.colostate.edu/~bbledsoe/CE413/idpmcpustguid.pdf
[12] http://www.fs.fed.us/publications/soil-bio-guide/guide/appendices.pdf

Common maintenance tasks include (USDA-FS, 2002; Bentrup and Hoag, 1998):

- Remove debris and weeds that may shade and compete with cuttings
- Secure stakes, wire, twine, etc.
- Control weeds
- Repair weakened or damaged structures (including fences)
- Replant and reseed as necessary (it is not uncommon for a flood to occur days after installation)

Planting success varies from project to project. Bentrup and Hoag (1998) provide the following potential growth success rates:

Pole Plantings	*70-100%*
Live Fascines	*20-50%*
Brush Layering	*10-70%*
Post Plantings	*50-70%*

It is beneficial to inspect the project every other week for the first 2 months after installation, once a month for the next 6 months, and then every other month for 2 years, at least. One should also inspect the project after heavy precipitation, flooding, snowmelt, drought, or any extraordinary occurrence. Assess damage from flooding, wildlife, grazing, boat wakes, trampling, drought, and high precipitation (USDA-FS, 2002). Additional information about monitoring is available from USDA NRCS' *The Practical Streambank Bioengineering Guide* (Bentrup and Hoag, 1998).

Plan and design all streambank, shoreline, and navigation structures so that they do not transfer erosion energy or otherwise cause visible loss of surrounding streambanks or shorelines.

Maintenance varies with the structural type. For stone revetments, the replacement of stones that have been dislodged is necessary; timber bulkheads need to be backfilled if there has been a loss of upland material, and broken sheet pile should be replaced as necessary. Gabion baskets should be inspected for corrosion failure of the wire, usually caused either by improper handling during construction or by abrasion from the stones inside the baskets. Baskets should be replaced as necessary since waves will rapidly empty failed baskets.

Steel, timber, and aluminum bulkheads should be inspected for sheet pile failure due to active earth pressure or debris impact and for loss of backfill. For all structural types not contiguous to other structures, lengthening of flanking walls may be necessary every few years. Through periodic monitoring and required maintenance, a substantially greater percentage of coastal structures will perform effectively over their design life. Since streambank or shoreline protection projects can transfer energy from one area to another, which causes increased erosion in the adjacent area, the possible effects of erosion control measures on adjacent properties should be routinely monitored.