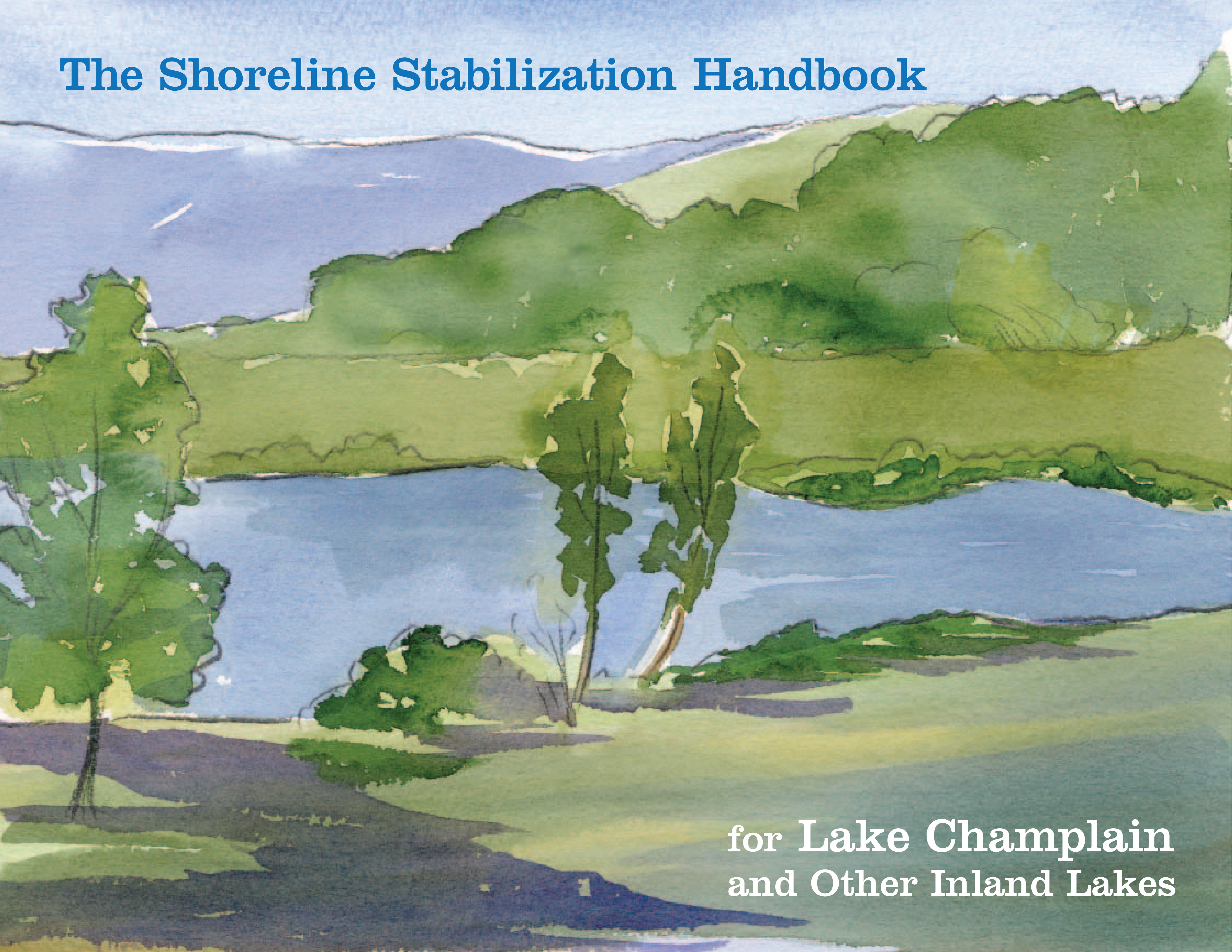
The Shoreline Stabilization Handbook



for Lake Champlain and Other Inland Lakes

Additional copies of this handbook can be obtained from the:

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Acknowledgments

This handbook is for area residents and government officials who are working to create and maintain a landscape that complements Lake Champlain's setting and ecology, while enhancing opportunities for the enjoyment of its natural and recreational features.

While some of the introductory information is specific to Lake Champlain, many of the erosion control and stabilization techniques are applicable to smaller lakes as well.

The idea for this project began after the ice storm of January 1998, which resulted in an immediate and significant loss of trees in the Champlain Valley. The temporary loss of vegetation has accelerated existing shoreline destabilization and created new areas of destabilization. Discussions with representatives from state and federal agencies, local municipalities, and regional organizations around the lake identified the need for a comprehensive approach to shoreline stabilization that considered a range of environmentally sensitive options tailored to site conditions, costs, and effectiveness.

Much of the information used for this handbook is not new. Section 2 was adapted from the poster, "Protect Your Shore," published by the New England River Basin Commission in the mid-1970's as part of the Lake Champlain Basin study. The Shoreline Stabilization Handbook built upon this poster's basic content and incorporated information on stabilization that has been developed during the past 30 years. Section 6 provides references for the resources used.

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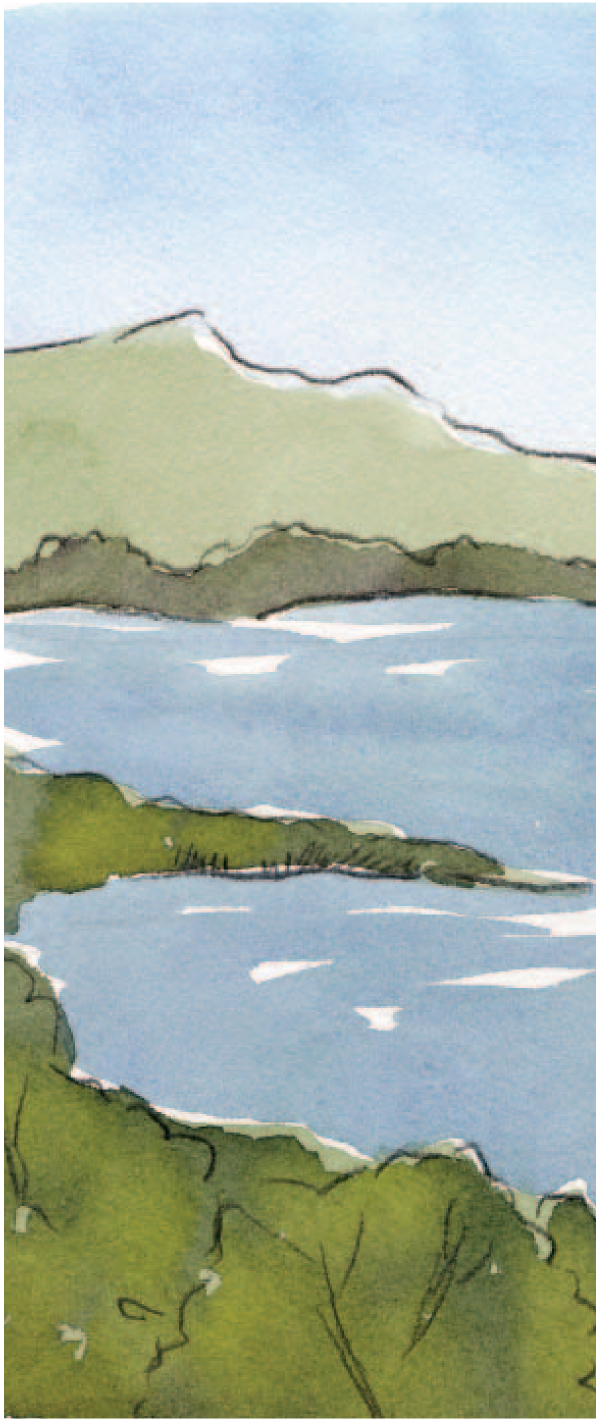
Introduction

Shoreline erosion around bodies of water is a natural process that brings both benefits and damages. Some of the benefits include the creation and resupply of natural beaches, and the creation of habitat for fish and wildlife. When erosion is severe or too close to structures, it can result in property loss, structural damage to roadways and/or houses, and poor water quality. Sometimes erosion becomes a problem when roads or structures are built unknowingly in erosion prone areas. Learning to recognize where erosion may interfere with structures or infrastructure can help you avoid this problem. Shoreline erosion can be modified by human activity.

This handbook is a result of a growing interest to manage the process of shoreline erosion to prevent loss of property and structures in the Lake Champlain Basin. It is intended for use by landowners and their consultants, municipalities, and state and local authorities. You will find information regarding the characteristics of Lake Champlain and the potential causes of erosion. The handbook provides specific shoreline stabilization options, including hard structural methods and bioengineered methods. Guidance is provided on how to plan stabilization activities and obtain required permits. You will also find a list of additional resources and a glossary of terms used in the handbook.

Traditional shoreline protection methods, such as seawalls and embankments of large stones, can be very effective; however, many such methods are expensive and can have detrimental, unintended environmental consequences. In the Lake Champlain Basin, there has been a significant effort to find natural, cost effective processes, such as bioengineering, that use live plantings, as well as other methods such as land-use planning, to modify the processes of shoreline erosion.



Contents

Lake Champlain Basin

Topographic map courtesy of the Lake Champlain Basin Program

General Characteristics

Lake Champlain is about 120 miles long and is oriented almost due north-south. The shoreline touches New York State, Vermont, and Quebec, Canada. The lake flows north into the Richelieu River and is joined to the Hudson River drainage by the Champlain Canal. There are 570 miles of shoreline, and the Lake Champlain Basin encompasses 8,234 square miles.

The lake is bounded by the Adirondack Mountains to the west and the Green Mountains to the east. The mountains dictate prevailing westerly winds and create strong northerly and southerly winds as well. Due to the mountains and occasional strong storms with heavy winds, the mean annual wind speed over the lake varies significantly. Wind speeds as high as 72 mph have been recorded in the Lake Champlain Basin.

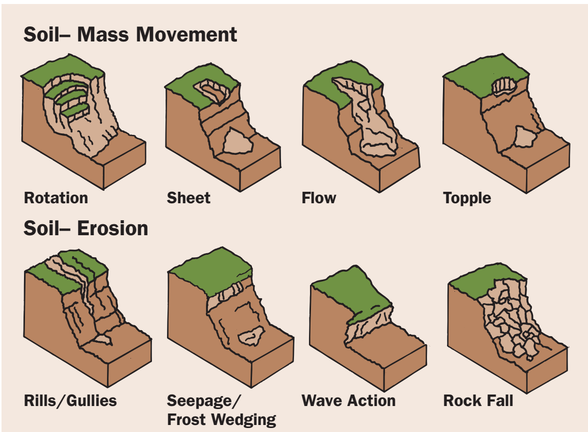
The lake's water level fluctuates due to precipitation, evaporation, runoff, and groundwater yield. The mean water level of Lake Champlain is 95.5 feet. The record high water level in the lake was 101.89 at Rouses Point in 1993, and the record low water level was 92.4 in 1908. The average annual water level peak usually occurs in April or May after snow and ice have melted. The annual low usually occurs in October or November.

The Lake Champlain Basin generally receives a significant amount of annual rainfall, ranging from about 30 inches on the northwest shore to 60 inches in the mountains.

Economic development and population growth are increasing in the Basin. Residential and commercial developments on the shores of the lake have the potential to increase the natural rate of erosion and damage the long-term integrity of the lake's shoreline.

Causes Of Erosion

Shoreline erosion can generally be grouped into two types. The first is the severe downward movement of slope materials such as rock, soils, artificial fills, or a combination of all these materials in landslides. The second is soil erosion, which is the wearing away of individual soil particles by the natural forces of wind, water, ice, or gravity.



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How erosion affects a lake shoreline is determined by location, configuration, orientation, and water depth. The material that makes up a shoreline and its degree of exposure help determine whether wind, waves, and precipitation will affect the shoreline property. Shoreline materials are defined in two categories: *unconsolidated* and *consolidated*. Unconsolidated materials include gravel, sands, and clays. Unconsolidated materials are not tightly compacted and are vulnerable to erosion. Consolidated materials are areas of bedrock and usually experience little or no erosion. Beaches develop on shorelines composed of unconsolidated material.

Causes of erosion can be grouped into the following categories:

- **terrestrial forces**
- **aquatic forces**
- **human activities**

Terrestrial and aquatic forces generally work together, and each can cause specific types of shoreline erosion.

Terrestrial Forces

Terrestrial forces erode shorelines and carry material to beaches. They include slumping, sliding, soil creep, frost action, and wind action. Erosion caused by these forces is a natural process although human activities can be a contributing cause. Generally these types of erosion occur on banks and unconsolidated shorelines with no vegetation.

Slumping This downward movement of a mass of unconsolidated material moving as a unit is commonly caused by groundwater that exerts outward pressure on soil particles, causes the formation of a drainage area, and creates a landslide.

Sliding This movement of soil or rock is similar to slumping and is caused mainly by groundwater, but occurs less frequently.

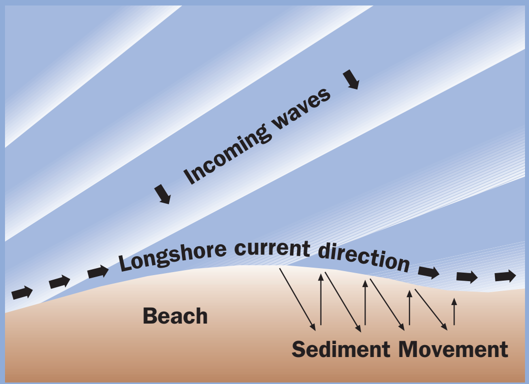
Soil Creep This gradual downhill movement of soil and loose rock material on a slope only involves soil erosion, not landslides. Gravity, combined with an aquatic force, is a usual cause.

Frost action Frost action generally occurs in poorly drained soils such as clay, and often results in the development of heaves or depressions.

Wind erosion Banks and shorelines that are composed of fine, dry soil are prone to wind erosion; banks and shorelines made of saturated, wet soil are less prone. The amount of rainfall an area receives has a direct effect on wind erosion. Wind breaks such as trees, shrubs, sedges, and grasses will slow down the rate at which wind erosion occurs.

Natural Shoreline Processes

The Lake Champlain shoreline is not static. Wave and wind action, changing water levels, currents, and sediments carried in by rivers all work together to exert constant pressure on the lakeshore. These forces both erode *and* build the shoreline. It is important to consider the natural forces along a particular stretch of shoreline in order to avoid interfering with a beneficial natural process.



One such process is *longshore drift.* When waves come at the shore at even a slight angle, sediment is moved along the shore. This sediment results in the creation and maintenance of beaches on the shore. Stabilizing such a critical bank would likely result in erosion of that beach or other stretches of shoreline if its sediment supply is cut off.

Aquatic Forces

Aquatic forces include raindrop splash, sheet erosion, rilling, gullying, wave action, longshore drift, and ice push. Aquatic forces remove material from the beach as well as the bank during high lake levels and often remove material from one area and deposit it elsewhere.

Raindrop splash Soil erosion occurs when raindrops hit directly on exposed soil. In heavy storms a significant amount of soil can be splashed up in the air. This occurs on both level and steep banks but has more severe results on steeper slopes.

Sheet erosion Storm water flow that occurs in sheets removes thin layers of soil from sloping land. Sheet erosion tends to be less severe than raindrop splash. The extent of erosion resulting from sheet flow is dependent on depth and velocity of runoff and the given size and shape of a slope.

Rilling Soil is removed in very small but well-defined channels or streamlets where there is a concentration of overland water flow. Rilling is the most common process of rainfall erosion losses. Rilling is most severe at sites that have a combination of steep slopes and loose unconsolidated materials.

Gullying This is the removal of soil by intermittent larger diameter stream channels. The total amount of soil eroded due to gullies is not necessarily as great as that removed from rilling. However, gullies are more difficult to fix and prevent.

Wave action This is the impact of waves hitting directly on exposed soil. Lake Champlain waves vary with wind speeds and duration, water depth, and the continuous length of water over which

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Paved roadways built along the shores of a lake increase the velocity of stormwater runoff that accelerates bank erosion.

winds blow in one direction. Wave heights can be calculated when these properties are known. Choosing and designing a shoreline stabilization method requires knowing the maximum height of waves affecting the property. Each shoreline along the lake is different. Waves on Lake Champlain can also be created by heavy boat traffic near shorelines.

The extent of soil erosion from wave action depends greatly on the bank slope, vegetation, and bank composition. Natural beaches serve as buffers for the bank and absorb some of the wave action before it hits the bank. Erosion due to wave action is greatly reduced when there is a gently sloped beach or a beach composed of pebble or boulders that break up the waves before they hit. Soil erosion caused by wave action commonly occurs during high water, when beaches are completely submerged in water and the bank is exposed.

Longshore drift This occurs when waves strike the shoreline at an angle. Longshore drift moves shoreline material from one location to another and is an essential natural process in beach formation and resupply. The effects of longshore drift are often made worse by deflectors or structures which redirect wave energy, causing erosion elsewhere. Structures perpendicular to the shore, such as groins, cut off sediment movement and cause erosion elsewhere.

Ice push The lake is usually partially frozen from December to March. When the ice begins to melt in the spring, it may push, destroy, or lift objects, particularly if it is aided by wind and rising water levels. Often the ice is pushed ashore in blocks or sheets that pile up and erode the shoreline. Ice also moves in response to water level changes during the winter months. Ice push on larger lakes, such as Lake Champlain, is caused by wind and not necessarily ice expansion. In small bays, ice expansion can create erosion.

Storms Storms accelerate the loss of soil due to aquatic and terrestrial forces such as wind, wave action, and ice damage. A great amount of natural vegetation along the Lake Champlain shoreline was lost in the 1998 ice storm. Shoreline vegetation is lost each year due to heavy storms that occur in the Lake Champlain region.

Human Activities

Activities such as clear-cutting of forests and shorelines, increasing and concentrating stormwater runoff, agriculture, urbanization, and construction cause or increase soil erosion. Erosion is a natural process, however, human influences can contribute significantly to increases in sedimentation and runoff.

Clearing of natural vegetation This procedure, done by many landowners to expand their view or increase recreational area, removes live natural vegetation and wildlife habitat and destroys the roots of the plants that provide significant stabilization to a bank or shoreline.

Stormwater runoff Impervious structures such as pavement on driveways, buildings, roofs, drainage ditches, berms, and common stormwater collection methods increase the velocity and energy of stormwater, which, if directed down a slope or bank, can cause rilling or gullying.

Agriculture Agricultural practices like plowing, irrigation, drainage ditches, and grazing all can modify the rate of erosion. Water runoff from agricultural land is the greatest in the spring months when snow is melting and the soil is saturated.

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Construction of an erosion stabilization project may result in a stretch of shoreline becoming covered with unsightly stone riprap and causing erosion elsewhere.

Urbanization Beaches that are modified for personal use or land that is cleared for housing or roadways increase the opportunity for soil erosion. Urbanization has lead to a huge loss of natural vegetation along the Lake Champlain shoreline increasing the rate of erosion. Development of housing uphill of a bank can result in increased stormwater runoff over the bank.

Construction of Shoreline Projects Shorelines and beaches erode naturally and stopping the natural process is not always the best choice. Human influence is often overlooked as a cause of erosion.

Shoreline stabilization projects such as sea walls commonly affect property elsewhere due to the redirection of waves away from the area in which the wall was constructed onto adjacent properties, with possible adverse impacts on the natural longshore drift of sediment. Structures developed along a lakeshore (including houses) may create erosion problems or simply transfer them elsewhere.

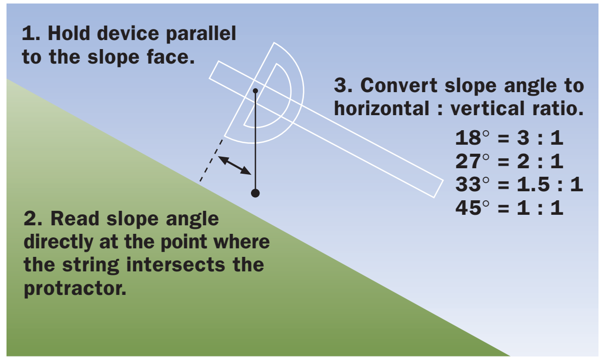
Planning Your Erosion Control Installation

The siting and installation of the erosion control method to be used is much easier when you develop a thorough plan that includes the details of what needs to be done, materials, and how, when, and by whom the installation will be done. This section provides a general guide to creating your plan.

Identify Your Surroundings (Site Evaluation)

A site evaluation is the essential first step to determine what, if any, shoreline stabilization method is most appropriate. Conferring with your neighbors can be helpful. Ideally, an entire section of shoreline should be evaluated for erosion causes and natural processes before a stabilization plan is developed.

Determining the slope angle and height of the shoreline bank, the type of soil present, drainage characteristics, the type of vegetation growing, and the extent of shoreline erosion are key elements of the site evaluation. The information developed during the evaluation will help you determine the most appropriate erosion control solution.



Measure the Slope Angle

The angle of a slope can be determined by using a protractor and a yardstick as shown. The protractor is fastened tightly to a yardstick with a string and weight. The slope angle can be determined by holding the yardstick up and aligning it to what appears to be the average slope of the land and reading the angle on the protractor. The slope angle can then be converted to the appropriate horizontal to vertical ratio. The slope height can be estimated by visually comparing the height of the slope to any nearby structure such as a tree. An inclinometer can also be used to determine both slope angle and height; however, this instrument is not easily obtained.

Determine Soil Characteristics

Determining the type of soil present on the subject property is very important for choosing plant species and planting techniques that may need to be used. In most cases, it will require outside assistance and/or research to properly determine the soil type. County soil surveys are very helpful and can be obtained at any library, town office, or the Natural Resources Conservation Service (NRCS) office. University cooperative extension agents and town offices are also good sources of information. *See Section 6 for resources.*

Observe Drainage Patterns

A visual observation of the drainage characteristics on the property should be conducted to determine the extent of surface water runoff. The best time to do this is during periods of heavy rainfall. Any observations on the direction and speed of runoff should be noted. Any catch basins, ditches, gullies, or general areas of concentrated water flow should also be noted.

Identify Existing Vegetation

Determining what types of vegetation are growing on a particular shoreline will confirm previous observations on soil type and drainage characteristics. Other references can be used to find out what range of conditions the plant species need to grow and survive. If bioengineering will be a part of erosion control, using native vegetation is strongly recommended and will blend the control into the rest of your property.

Characterize Shoreline Erosion

The type of erosion occurring will help determine what options should be considered to stabilize the site. Referring to Section 2 of the handbook will help. It is possible that more than one type of erosion may be occurring on your site. This can also be done on a property that does not yet have significant shoreline erosion by identifying potential causes of erosion, particularly if the site or neighboring sites are modified. The checklist on the following page (from Ohio State University) provides areas to review when performing a site evaluation and will help you identify actual and potential erosion problems.

Shoreline Checklist

1. On what shore type is your property located?

- ☐ high erodible bluff (greater than 30 feet high)
- ☐ low erodible bluff (10 to 30 feet high)
- ☐ low erodible plain (less than 10 feet high)
- ☐ sand dunes
- ☐ wetlands or marsh

2. Describe your shoreline property. (Measure the distance with a tape and answer below)

How high above the water level is your house?

____

How close to the edge of a bluff is your house?

____

How close are the other structures to the edge of a bluff?

____

What is the angle of slope of the bluff, sand dune or beach? (see previous page on how to determine)

____

How wide is the beach from the waterline to the base of the bluff?

____

3. What kind of materials make up the bluff?

- ☐ sand
- ☐ one layer of clay or unstratified material
- ☐ one layer of sand or silt
- ☐ bedrock
- ☐ mixed layers of sand, silt, clay or till

4. What kind of materials make up the beach?

- ☐ sand
- ☐ sand and gravel
- ☐ gravel and rock
- ☐ other (specify) ______________________________

5. What are the problems along your shoreline? (Check all appropriate answers)

Wave action

Y☐ N☐ Are waves eroding the beach?

Y☐ N☐ Are waves eroding the base of the bluff during storms?

Y☐ N☐ Are there presently any shore protection structures on your property?

Y☐ N☐ Are there presently any shore protection structures on your neighbor's property?

Y☐ N☐ Are shore protection structures, if present, in good repair

Groundwater

Y☐ N☐ Does groundwater flow out of the face of your bluff?

Y☐ N☐ Is active slumping (landslides) occurring?

In what ways do you add water to the groundwater supply on the top of the bluff?

- ☐ septic tank
- ☐ sprinkler or irrigation
- ☐ drain pipes
- ☐ swimming pool

Surface runoff and wind erosion

Y☐ N☐ Are the effects of the following visible on your property?

- ☐ raindrop impact
- ☐ rill (small ruts)
- ☐ gullies

Y☐ N☐ Are you contributing to surface runoff?

- ☐ drain pipes from home or garage
- ☐ sprinkler or irrigation
- ☐ other (specify) ______________________________

Y☐ N☐ Is sand being blown off the beach or are dunes shifting?

Y☐ N☐ Is there any vegetation on the bluff top, face or toe?

Y☐ N☐ Was there ever any vegetation on the bluff top, face or toe? (in your memory)

If yes, what happened to it?

____

What vegetation types are (or were) found on the bluff top, face or toe?

- ☐ trees or woods
- ☐ shrubs or brush
- ☐ grass

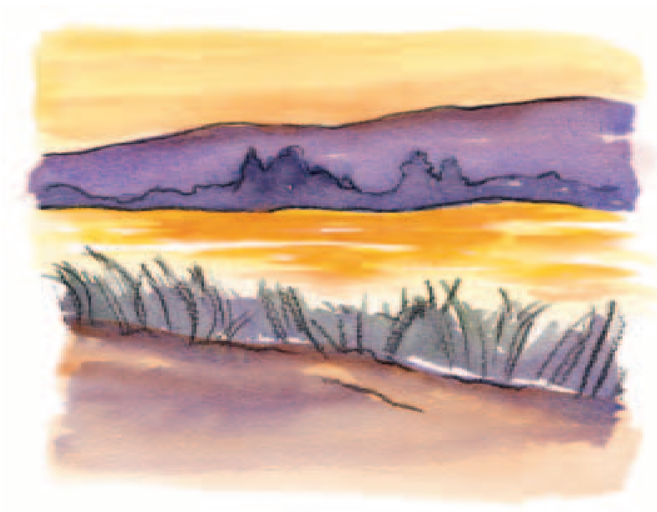
Property Use

How do you use your shoreline property? (Check the appropriate answer)

- ☐ homesite
- ☐ vacation cottage or recreation
- ☐ agriculture or forestry
- ☐ developed for business
- ☐ rental property

How do you use the bluff or backshore area?

- ☐ for access to beach by foot or vehicle
- ☐ as a place to view the lake
- ☐ as a building site
- ☐ for fill
- ☐ other (specify) ______________________________



Draft Your Plan

The next step is to choose a solution for each of the problems identified.

It is important to identify property surroundings before implementing any process of shoreline stabilization. Areas and structures that should be identified and considered in the plan-preparation process are:

- Wetlands
- Natural beaches
- Houses
- Septic structures
- Existing stabilization structures
- Neighboring properties
- Roadways
- Other transportation structures

Who Should be Involved?

The next step in the plan-preparation process is determining who is going to be involved. At this point, it may be necessary to work with neighbors if similar problems have been observed on their property. Shoreline characteristics and erosion problems are not limited by property boundaries.

It is helpful to contact state agencies, town and county governments or regulatory agencies, county extension services, or experienced soil engineers before proceeding. A list of resources and references can be found in Section 6. These resources can help determine if the erosion identified is an individual property issue or has broader ramifications. They will also help you decide what shoreline stabilization method, if any, may be best for the subject property and how to proceed in implementing the chosen method.

It is recommended that, when possible, any method of shoreline stabilization involve neighbors from the very beginning of the plan-preparation process. Trying to solve a shoreline erosion problem without talking to your neighbors can result in failure. It can also worsen impacts to neighboring properties. If similar problems are occurring on adjacent properties, teaming up with the neighbors may well make the erosion control installation more effective. Designing a shoreline protection method that covers a greater distance may result in less cost per linear foot and minimize inadvertent impacts to adjacent shorelines. The permit processes used both in Vermont and New York State call for a period of public consultation and review of proposed activities. Before you begin the permit process, it is good practice and common sense to advise your neighbors of your plan. At this point, you should answer questions, address objections, and obtain their support. This interaction can help you minimize unanticipated costs and may streamline the permit process.

Choosing The Best Method For You

The information gathered from your site evaluation and from any outside professionals should be brought together to determine what, if any, method of shoreline stabilization is needed. The matrix presented in Section 4 will help in the decision process. You should keep in mind all of the options, including doing nothing, before making a final decision.

If your decision results in an erosion control installation, you should make every effort to incorporate preservation of natural vegetation and drainage and the establishment of shoreline buffer zones in planning your control design. Using a comprehensive approach to site planning and development will identify features and conditions as well as opportunities to reduce the need for structural controls. The use of natural vegetation should always be considered before implementing any structural techniques.

The local site development and plan review process is often the mechanism where site selection and site design are closely evaluated for compliance with the criteria used by your local community and state for land use planning and environmental management.

Preparation

Before any land preparation can be performed, the state and/or federal permitting process must be completed. Section 5 of the handbook covers permit requirements and the permitting processes used by the various levels of government and agencies involved.

Land Preparation

Grading and shaping a bank does not always need to be performed and should be avoided if possible. Many banks are naturally graded to the approximate angle and shape needed for a shoreline stabilization structure to be installed.

Preparing a property begins with grading and shaping the slope if it is needed. When grading and shaping the slope, it is important to try to avoid introducing water into or onto the slope because this will likely increase the extent of erosion during construction, and change the slope characteristics.

If the option is available, all existing vegetation should be maintained. If vegetation needs to be removed, the local zoning and planning administrator should be informed. In Vermont, there are some towns with ordinances regarding clear cutting vegetation. The ordinance requirements need to be addressed before doing any cutting.

The following three areas should be equally prepared when grading and shaping a slope: the **slope crest** (the area along the edge of the top of the slope), the **slope face** (the flat surface on the slope), and the **slope toe** (the bottom of the slope face where it flattens out).

These guidelines are recommended when grading and shaping a slope:

- Grade the slope face back to a stable angle and shape
- Protect the toe of the slope against scour and undermining using rocks or boulders
- Protect the slope face against raindrop splash and frost action with erosion matting
- Divert or intercept upland water flow away from the slope crest
- Intercept or prevent seepage from forming at the slope crest
- Any revegetation should be performed above the toe of the bank
- Use erosion control prevention matting

Grading the slope to a stable angle generally means an inclination of no more than 1.5 feet horizontal to 1 foot vertical; however, the angle can be increased depending on the soil type and if bioengineering methods are incorporated into the plan. The appropriate slope angle for each method is mentioned in Section 4 of the handbook. A slope of 2:1 or less is adequate for plant development and growth; however, anything greater than this may not be suitable for plant development.

Slopes may need to be cut or filled to achieve the desired grade and shape. Cut slopes should be rounded at the top and sides to blend with the surroundings, and provide an environment suitable for plant development. Creating terraces on cut slopes will slow upland water runoff and provide a base for seeds and plants. Boulders, stumps, and/or large debris may need to be removed at the top of a slope and overhangs. Loose rocks should be removed, working from top to bottom of the slope. Material removed may be used for the construction of a wall or for backfill.

The slope should be smoothed out to remove any gullies or rills. This may require using backfill. Caution should be used when applying fill because it sometimes creates compaction of the soil.

Funding of Construction Costs

For many public erosion control projects, and some private ones, government funding assistance with construction costs may be available. It is helpful to check with federal and state agencies and regional organizations about grants and loans related to water quality protection, hazard or disaster mitigation, transportation infrastructure, and natural resource protection. Section 6 includes contact information for agencies and organizations that may offer financial or technical assistance for construction activities.

Property Insurance

In most cases, homeowner's property insurance policies do not cover erosion damage. If your property is in a floodplain it may be eligible for federal government funding through the National Flood Insurance Program from the Federal Emergency Management Agency (FEMA). However, this insurance only covers damage to buildings. It does not usually cover construction of, or damage to erosion control methods.

You can determine if your property is located in a floodplain by looking at flood insurance maps. If structures on your property are located at or below the 100-year flood line, your lending agency will likely require you to purchase flood insurance. The 100-year flood line on Lake Champlain is approximately 102 feet above sea level. The National Flood Insurance Program only covers floods due to high water levels. It is recommended that everyone who owns or is considering the purchase of lakeshore property determine what insurance is available for that property.

Sources for additional information on flood insurance can be acquired through local insurance agents, municipalities, and flood insurance maps. Flood insurance maps for Vermont and New York can be viewed at regional planning commissions and town and city offices. Section 6 includes more information regarding flood insurance.

An Introduction to Erosion Control Methods

Today we know more about the potential impacts of development on environmental and water resources. We have learned that impact assessments of proposed shoreline erosion control installations should consider the combined effects that the project may have on a common shoreline, as well as the cause(s) of the erosion. This approach identifies and avoids incremental degradation of a shoreline when short-term solutions are used or when solutions on one property impact neighboring shorelines by displacing the erosion.

Choosing what erosion control method will work best for a particular segment of shoreline is the most difficult step in implementing a stabilization process. It requires an understanding of the causes of erosion and physical characteristics of the shoreline and adjacent land. Erosion is sometimes a problem because previous structures were sited inappropriately, without taking into consideration erosion processes. In order to successfully implement a stabilization method that will work effectively, while creating minimal impacts to adjacent properties and the environment, it is important to consider all available options.

These are methods used for providing shoreline erosion control in the Lake Champlain region:

1. **non-structural and preventative**
2. **structural**
3. **bioengineering**
4. **biotechnical**

Non-structural erosion stabilization options are often the simplest solution and generally work best where erosion is minor and where the land is mostly undisturbed by human activity. They may provide the best long-term benefit, as well as protecting natural habitat values.

Structural installations have traditionally been the first choice to provide shoreline protection, due in part to the greater familiarity of contractors and consultants with these methods. Hard physical structures to secure a shoreline are widely used and promoted throughout the United States. They have proven to be effective, but tend to be expensive, need replacement over time, and can have detrimental environmental impacts if not properly designed and installed.

Bioengineering uses vegetation plantings for shoreline stabilization. Vegetation provides resistance against light to moderate wave action. The plant roots break up the energy of the waves and hold the soil intact while acting as barriers to erosion and mass movement, and assisting in water drainage. The presence of plants on the shore also has multiple scenic and fish and wildlife habitat advantages.

Biotechnical methods of shoreline stabilization combine structural and bioengineering methods to stabilize shorelines. The structural and plant materials work together to provide an improved erosion control in areas of high wave energy or severe erosion, minimizing environmental impacts and providing stability within the system. A biotechnical approach is suitable for a wide range of erosion conditions and commonly used to prevent surface erosion and shallow mass-movement of soil.

All the methods presented help control or slow down a natural, ongoing occurrence; they do not prevent erosion.

Comparison of Stabilization Techniques

When choosing to apply any shoreline stabilization method, there is the chance of failure and of causing neighboring impacts. The charts on the following pages are provided to show a comparison of methods and the advantages and disadvantages for each. More in-depth information on each method is presented on the following pages. You should note that all cost figures are in 2003 US dollars, and should be adjusted in subsequent years for inflation.

	Erosion Control Method	Where It Works	Where It Doesn't Work	Neighboring Impacts	Labor/Preparation	Cost
NON-STRUCTURAL	**Re-Vegetation with Native Species** *page 19*	Along embankments, roadways, and steep slopes	Heavy wave action	None	Moderate	Low
	Relocation *page 20*	Where a structure is threatened by erosion along a shoreline and adequate room on site is available	Structures that cannot be moved due to structural integrity or inadequate space on site	None	High	High
	Drainage *page 20*	On banks that have become eroded from surface runoff Works well along roadways	Banks that are eroding due to other forces than runoff	Moderate to None	Moderate	Moderate
STRUCTURAL	**Stone Riprap Revetment** *page 21*	Embankments or shorelines where the underlying soil is stable	Steep slopes or embankments with significant amount of loose soil	Moderate to High	Moderate	Moderate to High
	Gabion Mattress *page 22*	Along embankments and roadways	Steep slopes Heavy wave action	Moderate to High	Moderate	High
	Concrete Wall *page 23*	Along moderate slopes which receive heavy action	Steep slopes Loose soil	Moderate to High	High	High
	Gabion Wall *page 23*	Along moderate slopes which receive heavy action	Steep slopes Loose soil	Moderate to High	High	High
	Bulkheads *page 24*	Unvegetated high banks with a lot of backfill and little wave action	Steep slopes Heavy wave action	Moderate to High	Moderate	Moderate to High
	Groins *page 25*	Long stretches of sandy beach	Rocky soils Heavy wave action	High	Moderate	Moderate
	Breakwaters *page 25*	Heavy wave action, >4 feet Harbors	Minimal wave action	High	High	High

Monitoring and Maintenance	Permitting	Can be Installed by	Advantages	Disadvantages	
Moderate	Low to None	Skilled Individuals	• Low costs and labor • Aesthetically pleasing • Grows stronger with age • Provides wildlife habitat	• Limited time of year for installation of native species • High failure rate in first two years • Additional re-seeding may be necessary each year	NON-STRUCTURAL
None	Moderate	Design– Engineer Install– Professional Contractor	• Removes future problems • No monitoring and maintenance	• Costs can be high • Improper setback distance may result in future problems • Requires heavy equipment • Requires significant land preparation	
Moderate	Moderate to Intensive	Design– Engineer Install– Professional Contractor	• Re-directs water flow • Drainage structures are barely visible	• Can be expensive • May require significant land preparation • May create problem elsewhere	
Moderate	Moderate	Design– Engineer Install– Professional Contractor	• Proven to be successful • Less expensive than other structural methods	• Not aesthetically pleasing • Costs can be high • Creates barrier for fish and wildlife habitat • Weakens with age	STRUCTURAL
High	Moderate	Design– Engineer Install– Professional Contractor	• Can be built without heavy equipment • Supports vegetation	• Not aesthetically pleasing • Costs can be high • Creates barrier wildlife • High maintenance and repair • Weakens with age	
Moderate	Intensive	Design– Engineer Install– Professional Contractor	• Strong, durable structure • Works well against heavy waves	• Expensive • Not aesthetically pleasing • Creates barrier for wildlife habitat • Does not support vegetation • Weakens with age	
High	Moderate	Design– Engineer Install– Professional Contractor	• Resists heavy waves • Supports vegetation	• Expensive • Not aesthetically pleasing • Creates barrier for wildlife • Weakens with age	
Moderate	Moderate	Design– Engineer Install– Professional Contractor	• Holds eroding soil in place • Can support some vegetation	• Expensive • Not aesthetically pleasing • Weakens with age • Labor intensive	
Moderate	Not Permittable	Design– Engineer Install– Professional Contractor	• Essentially non-moving shoreline	• Not aesthetically pleasing • Need long reaches • Takes up a lot of space	
Moderate	Intensive	Design– Engineer Install– Professional Contractor	• Reduces wave action	• Boat hazard • Environmental hazard	

	Erosion Control Method	Where It Works	Where It Doesn't Work	Neighboring Impacts	Labor/Preparation	Cost
BIO-ENGINEERING	**Live Staking** *page 26*	On slopes where erosion is minimal. Commonly used in conjunction with other methods	Badly eroded areas	Low	Low	Low
	Contour Wattling *page 27*	On slopes where erosion is minimal Top of a slope to provide a buffer zone	Badly eroded areas that receive heavy erosive action	Low	Low	Low
	Brush Layering *page 28*	On badly eroded slopes which need to be restored	Loose soils Heavy wave action	Low	Moderate	Low
	Brush Matting *page 29*	On badly eroded slopes which need to be restored	Loose soils Heavy wave action	Low	Moderate	Low
BIO-TECHNICAL	**Erosion Control Matting** *page 31*	Moderate to steep slopes along roadways or on slopes	Heavy wave action	Low	Moderate	Low
	Vegetated Riprap *page 31*	Waterways or inland lakes where the underlying soil is stable	Steep banks with loose soil	Moderate	High	Moderate to High
	Vegetated Gabion Wall *page 32*	Moderate slopes to resist wave action	Steep slopes Loose soil	Moderate	High	High
	Vegetated Gabion Mattress *page 33*	Moderate slopes to resist wave action, ice, and surface erosion	Steep slopes Loose soil	Moderate	High	High
	Vegetated Cribbing (Live Cribbing) *page 34*	Unvegetated slopes with a lot of backfill and little wave action	Steep slopes Heavy wave action	Moderate	Moderate	Moderate to High

Monitoring and Maintenance	Permitting	Can be Installed by	Advantages	Disadvantages	Category
Moderate	Low	Skilled Individuals	• Grows stronger with age • Provides habitat for wildlife • Low costs and labor • Natural appearance • Does not require skilled labor	• Limited time of year for installation • High failure rate in first two years	BIO-ENGINEERING
High	Low	Skilled Individuals	• Grows stronger with age • Provides habitat for wildlife • Low costs and labor • Natural appearance	• High monitoring and maintenance • Limited time of year for installation • Requires skilled individuals • High failure rate in first two years	BIO-ENGINEERING
High	Low	Skilled Individuals	• Restores banks • Grows stronger with age • Provides habitat for wildlife • Natural appearance • Low costs	• More labor intensive • High monitoring and maintenance • Limited time of year for installation • Requires skilled individuals • High failure rate in first two years	BIO-ENGINEERING
High	Low	Skilled Individuals	• Restores banks • Grows stronger with age • Provides habitat for wildlife • Natural appearance • Low costs	• More labor intensive • High monitoring and maintenance • Limited time of year for installation • Requires skilled individuals • High failure rate in first two years	BIO-ENGINEERING
High	Low	Skilled Individual(s)	• Restores banks, slopes • Grows stronger with age • Provides wildlife habitat • Natural appearance	• High monitoring and maintenance • Limited time of year for installation	BIO-TECHNICAL
High	Moderate	Design– Engineer Install– Professional Contractor	• Increased stability with vegetation • More natural appearance • Provides some wildlife habitat	• Costs can be high • Labor intensive • High failure rate for vegetation in first two years • Increased monitoring and maintenance with vegetation added.	BIO-TECHNICAL
High	Moderate	Design– Engineer Install– Professional Contractor	• Increased stability with vegetation • More natural appearance • Provides some wildlife habitat	• High costs • Labor intensive • High failure rate for vegetation in first two years • High monitoring and maintenance	BIO-TECHNICAL
High	Moderate	Design– Engineer Install– Professional Contractor	• Increased stability with vegetation • More natural appearance • Provides some wildlife habitat	• High costs • Labor intensive • High failure rate for vegetation in first two years	BIO-TECHNICAL
High	Moderate	Design– Engineer Install– Professional Contractor	• Use of timber creates nice, natural appearance • Provides wildlife habitat • Increased stability with vegetation • Holds eroding soil in place	• Expensive • Labor intensive • High failure rate for vegetation	BIO-TECHNICAL

Non-Structural and Preventative Options

As a natural process, erosion is not always a problem. First and foremost, consider the effect of doing nothing. In some instances a “do nothing” or preventative approach may be the appropriate solution. Doing nothing may be the best solution where:

- erosion does not threaten valuable structures
- these structures can be relocated
- erosion is possibly part of a natural process such as supplying sand to a beach
- the erosion is proceeding at a slow rate and may be considered “natural”

Where erosion is minor along the shores of the lake, implementing one or several non-structural or preventative options may be most effective and should always be considered before any other stabilization method is used.

These are the most common non-structural and preventative methods:

Land Use Planning

Using comprehensive site planning and design principles whenever possible helps to preserve and maintain the integrity of natural shorelines. Using site planning and design principles is not limited to municipalities, counties, and developers; individual property owners or several owners working together can use site planning and design to preserve or enhance the integrity of a shoreline. Land use management and planning can prevent inadvertent erosion and can be a very cost effective approach to shoreline stabilization. Land use planning:

- represents a link between shoreline stabilization and protection, and economic development
- accomplishes environmental preservation and enhancement as well as socioeconomic objectives
- identifies areas of shoreline with no erosion or with naturally-progressing erosion that should be maintained
- identifies existing or potential shoreline erosion problems needing attention, and
- defines specific measures for managing shoreline erosion

These goals and measures are often incorporated as objectives within state and local land-use planning programs.

Environmental management is frequently implemented through local plans, ordinances, zoning and site development review criteria. The intensity, type, and general design of planned development projects can be managed to minimize changes to lakeshore properties. For instance, setbacks combined with preservation of a buffer of natural vegetation will protect a shoreline from erosion due to clearing and grading.

Public Education

This cost effective method involves increasing awareness by the general public and specifically local governments, developers, and property owners about what is being done and can be done to:

- preserve the natural shoreline
- mitigate the impact of erosion
- improve the water quality in Lake Champlain

Public interest in shoreline erosion will lead to more widely available information sources regarding erosion and shoreline property management and control at libraries, in brochures and on websites.

Native Plants Available from Regional Nurseries

TREES

- Balsam fir
- Striped maple
- Red maple
- Silver maple
- Sugar maple
- Serviceberry
- Yellow birch
- White birch
- Grey birch
- American hornbeam
- American beech
- White ash
- Larch
- Hop hornbeam
- White spruce
- White pine
- Balsam poplar
- Quaking aspen
- Pin cherry
- Black cherry
- White oak
- Swamp white oak
- Bur oak
- Red oak
- White cedar
- Basswood
- Eastern hemlock

SHRUBS

- Speckled alder
- Bog rosemary
- Bearberry
- Black chokeberry
- Buttonbush
- Sweet fern
- Beaked hazelnut
- Pagoda dogwood
- Red-osier dogwood
- Bush honeysuckle
- Wintergreen
- Witch-hazel
- Winterberry
- Sheep laurel
- Bog laurel
- Canada (wild) plum
- Chokecherry
- Rhodora
- Roseshell azalea
- Staghorn sumac
- Willow
- Elderberry
- Red elderberry
- Mountain ash
- Meadowsweet
- Steeplebush
- American yew
- Lowbush blueberry
- Hobblebush
- Witherod
- Arrowwood
- Nannyberry
- Highbush cranberry

FERNS AND VINES

- Maidenhair
- Ebony spleenwort
- Maidenhair spleenwort
- Lady fern
- American bittersweet
- Bulbet fern
- Hayscented fern
- Goldie's wood fern
- Evergreen wood fern
- Ostrich fern
- Sensitive fern
- Cinnamon fern
- Royal fern
- Virginia creeper
- Christmas fern
- Braun's holly fern
- New York (tapering) fern
- Rusty woodsia

HERBACEOUS PLANTS

- Sweet flag
- Spikenard
- Baneberry
- Common columbine
- Wild ginger
- Water arum
- Marsh marigold
- Harebell
- Turtlehead
- Bunchberry
- Crowberry
- Trailing arbutus
- Joe-pyeweed
- Blue flag iris
- Creeping snowberry
- Soft rush
- Cardinal flower
- Pickerelweed
- Pitcher plant
- False Solomon's seal
- Foamflower
- Red trillium
- White trillium
- Bellwort
- Blue vervain
- Canada violet

Sources of Native Plant Materials in Vermont. Agency of Natural Resources. Department of Environmental Conservation, August 2003

Re-Vegetation with Native Species

In most cases where a bank or slope is disturbed but not severely threatened by erosion, simple re-seeding or re-planting of native species is all it takes to stabilize the shoreline. This may require grasses or sedges, shrubs, and trees. Woody vegetation, in particular, provides excellent natural stabilization due to the deep roots that they produce. The most effective plant-based shoreline stabilization is a multi-layered strip that includes trees, shrubs, and ground covers (no mown areas) to help minimize future loss of land. The highest success rate occurs when transplanting is done in late fall through early spring. In most cases, planting in the fall will be most convenient since that is also the typical seasonal low-water level in the lake; it also gives the plants an opportunity to establish roots under insulating snow cover.

"Native" species from other geographic areas are genetically different from local material and planting non-native genetic material is compromising Lake Champlain's plant communities.
In Vermont, by law, only native species can be used in plantings. The Intervale Foundation in Burlington, VT produces local native species for riparian restoration plantings.
http://www.intervale.org/NNReparian.htm

Slope Crest Planting

The slope crest involves the area along the edge of the top of a bank or slope. This area is a protective layer for the slope face and provides a buffer zone between the slope and any upland residential structures. The slope crest is important where the slope is too steep and shoreline stabilization cannot be attempted. If a dense strip of vegetation is planted in this area it will strengthen the face of the slope and help protect from future slumping or sliding. Any existing vegetation should be left undisturbed on the slope crest. Plants that can be grown in this area if no or very little vegetation is present include grasses and shrubs.

Slope Face Planting

The slope face is the flat steep surface on the slope. A wide variety of plant species can succeed on slope faces. Generally grasses, legumes, willows (shrubs and trees), dogwoods, alders, and poplars are the best plant species for slope face planting. These plants are "pioneer species," meaning they are usually the first native species to grow in an area. They usually grow fast, vigorously, and in abundance.

Trees growing on eroded slopes should be monitored. If the trees fall over due to undermining or slumping slopes, they will disturb a large amount of soil when the root mass is pulled up. If there are existing trees on a slope, they should be examined for signs of undercutting and toppling. Trees can be removed if these signs indicate trees are going to topple over imminently. It should be noted that trees that have fallen into the lake provide valuable fish habitat and do not necessarily need to be removed.

Slope Toe Planting

The slope toe is the area where the slope face flattens out. If the slope toe is subject to frequent wave action, plantings of live vegetation are most likely not going to survive and will not provide the best means of stability. If the toe is not subject to heavy erosion, then trees and woody shrubs provide excellent upland stability.

It is important to use only native vegetation; non-native species are becoming a serious problem in the Lake Champlain Basin. A listing of native and non-native species can be found on the preceding page of this handbook.

Drainage

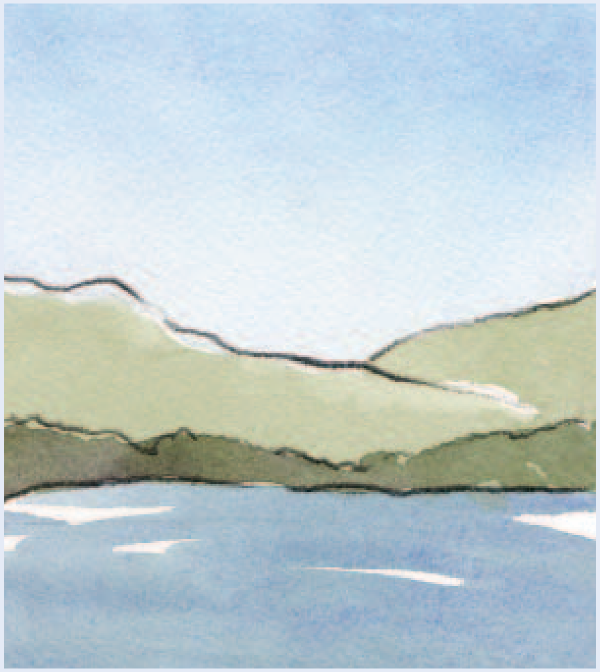
Gullies are commonly seen along the banks of Lake Champlain. Where erosion is caused by runoff, often it can be intercepted and retained, dispersed, or simply better controlled using these drainage structures:

- a berm, or mound of earth placed along the top of a bank to stabilize a slope by intercepting water and sediment from surface runoff. Berms allow vegetation to re-establish in the area in which the gully formed. Caution is needed with this approach, however, to ensure redirected water does not cause erosion in a new location
- dispersion and infiltration of water into vegetated areas before it reaches the shoreline
- a pipe or stabilized ditch down the face of a bank to transport the water
- an interceptor drain, where groundwater is diverted into a discharge pipe to the lake. This is a more difficult option and a permit may be required

Improving drainage is fairly inexpensive. A professional should assist in all drainage work so that the water discharge does not cause future problems.

Relocation

This method relies heavily on the type of structure(s) being threatened by the loss of property from erosion. Structures include buildings, roadways, septic systems, and water lines. Compared with the other non-structural stabilization and prevention options discussed, this is the most expensive due to separate costs for moving and



developing a new structure that may require new utilities and services.

The option of relocation versus constructing shoreline protection must be weighed against the risk of failure. Depending on the type of structure(s) considered for relocation, it might be more cost effective to relocate than to install erosion protection along the shore. It is important to look at the condition of the structure(s) to be moved, any underlying foundation associated with it, any obstructions and overall access to the land, and the distance to be moved. If relocation is chosen, the structure(s) must be moved as far away as possible from the shoreline to make sure that erosion will never threaten the structure(s) again. The local zoning administrator must be contacted to determine the minimum setback distance from the shoreline. A professional mover should be contacted to plan for moving a building.

Structural Installations

A structural installation protects areas against severe soil erosion on steep to moderately steep banks and may be necessary to protect investments that cannot be relocated. They are most common along roadways, lakeshores, and stream banks and are built to resist wave action. Before the selection of a structural method is made, consider methods that will use or incorporate vegetation for their aesthetic, habitat and longevity benefits.

Several types of structural installations have been built along Lake Champlain shorelines. Each addresses specific erosion management requirements and are more suitable for certain areas than others. Structural methods have similar designs and typically require professional assistance and heavy equipment or extensive labor for construction. The following is an overview of structural methods commonly used on the lake to manage shoreline erosion, the materials used in each method, a breakdown of the steps needed for proper installation, and the approximate cost of installation.

Revetments

A revetment uses stone or concrete and is composed of three layers: an *armor layer*, a *filter*, and a *toe*.

The *armor layer* provides the most resistance and stability against wave action and is usually composed of rough, angled stone (riprap). The size of the material used will vary depending on the steepness of the slope and the energy of the waves to be resisted. The thickness of the armor layer around a lake should be at least 27 inches. It is important to mix smaller materials with larger materials to ensure the small cracks in the layer are filled. The determination of what size material to use is usually based on the approximate wave height to which a property is subjected. An engineer should be consulted to determine the appropriate size material to use.

The *filter layer* provides support to the armor layer and allows for movement of water through the structure. It consists of a special filter fabric called a geotextile or six inches of well-graded stone.

The *toe* is located at the lowest point of the revetment. It supports and anchors the structure, minimizing movement.

Revetments are used along waterways or inland lakes to minimize shoreline or bank erosion. They are generally not installed on steep slopes. All revetments should be installed when water levels are at the lowest point, usually during the fall months.

Two types of revetments are used on Lake Champlain:

Stone Riprap

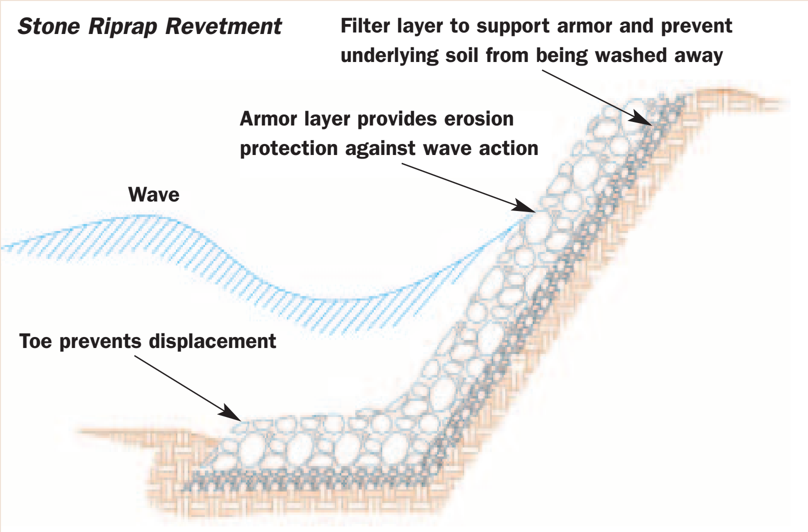
Stone riprap is the most common method used in the United States and one of the most versatile and effective means of bank protection. It involves placing a layer of stones and boulders along a slope face or bank and prevents erosion and mass-movement caused by wave action, ice, and surface erosion.

To begin installation of a stone riprap revetment, the ground should be graded to achieve a slope no steeper than 1.5 feet horizontal to 1 foot vertical rise and no flatter than 2 feet horizontal for every one foot of vertical rise. Clean, well-graded fill material should be added to achieve a uniform grade. Fill should not consist of stones larger than six inches and should be firmly compacted before construction begins.

It is recommended to use a filter fabric, whenever possible. If using a stone mix, it should be composed of stones ranging up to 3 inches in

GRIFFIN INTERNATIONAL, INC.

A stone riprap revetment combines smaller placed rocks on the face of the bank and larger rocks to help stabilize the toe of the bank near the waterline.



diameter with very few fines. If a filter fabric is used, it is helpful to build a small stone layer in between the filter cloth and the armor layer. The revetment can be constructed three different ways: hand placed, end-dumped, or placed by a derrick crane. In most cases, graded rock and stones or concrete are end-dumped on the site and then rearranged in proper size sequence. When constructing a revetment against heavy wave action, a derrick crane is often used to place larger materials. The choice of construction will depend on the size of material being used.

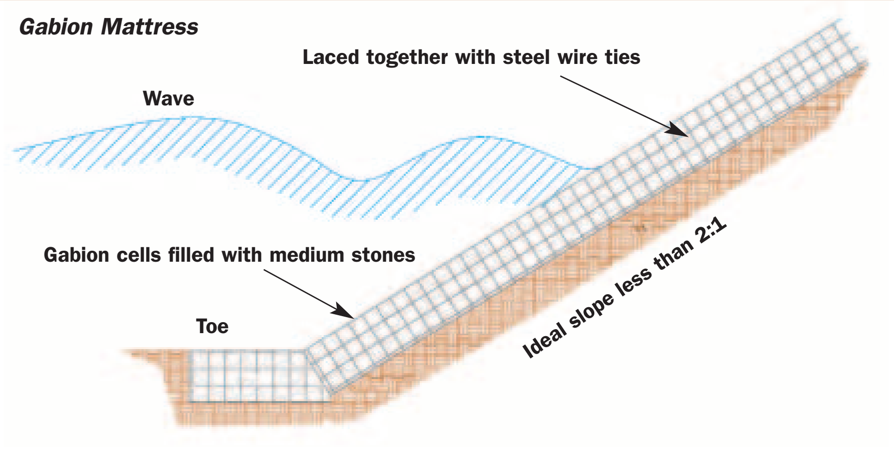
If machinery is needed to build a riprap revetment, the installation cost will most likely fall in the range of $30 to $55 per linear foot for a structure that is approximately 25-50 feet in width.

Gabion Mattress

Gabions are rectangular baskets formed from a triple twisted mesh of galvanized steel, filled with medium size rocks, laid on a slope or bank, and then tied together to form an armor layer. Gabion mattresses are used to protect a bed or bank of a slope against erosion on a variety of sites. Using proper equipment, gabions can be placed in dry or wet conditions. Generally, gabion mattresses are placed along slopes or banks that are moderately steep. They require a firm soil foundation and a solid toe for construction. Gabion mattresses work ideally in clay soils. Installing a filter fabric under/behind the gabions improves the stability of underlying layers. Although not commonly seen along the lake, they are well suited to specific areas that possess a strong clay soil base.

Installing gabion mattresses is done as follows:

(1) The area to be protected by the gabion mattress structure should be graded to the final desired slope. Filter fabric or another gravel filter layer is installed and smoothed out across the slope.



(2) The process of assembling the gabion baskets should proceed according to the instructions provided by the supplier. The gabions usually come folded flat, stacked, and bundled by the supplier. They should be bent into the design form and all the ends and diaphragms should be tied together.

(3) The assembled gabion baskets are then placed in their appropriate spots and tied to one another. It is important that all gabion baskets that are adjacent to one another be tied together. This prevents movement and failure of the structure. Tying the baskets together should proceed according to the manufacturer's recommendations.

(4) Once several gabions are assembled, filling should begin. Filling should be done carefully in the gabions to prevent damage. The fill should be flush with the facing of the gabion baskets. This may require hand smoothing the facing.

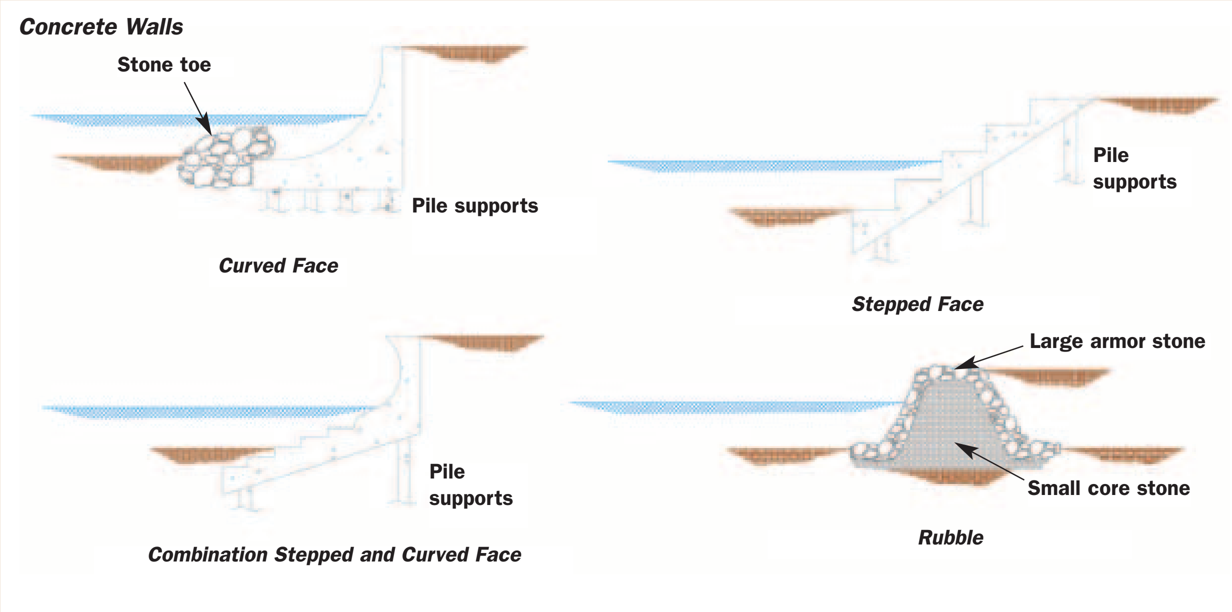
(5) After the fill has been placed, the covers of the gabions are installed and secured with tie wires.

Installation costs associated with gabion projects are considered among the highest for bank stabilization techniques. However, the gabion mattress requires shallower baskets that are generally less expensive than a gabion wall. Costs for these baskets range from $1.10 to $1.75 per square foot. Items needed for closure of the baskets are normally included and prices vary depending on the size of wire you need. Such things as tiebacks, stone, and backfill also add to the overall cost of the structure. Overall costs of the project will be approximately $50 to $100 per lineal foot of area to be protected. This cost includes the baskets, filling of the baskets, stone fill (if needed), and basket closure.

The development of revetment structures requires a lot of labor and in most situations the use of heavy machinery. The filling and closure of the gabion baskets is labor intensive and requires a large crew to complete either a gabion mattress or stone riprap installation in a short amount of time, depending on the size of the area to be protected.

Seawalls

Seawalls can be constructed in a variety of ways but are most commonly built as a sloping wall or stepped wall to resist wave action along shoreline property. They can be built on moderate to steep slopes and should be installed during the low water season to allow for adequate construction of the toe that usually will be covered by water during most of the year. Concrete seawalls are most commonly seen along Lake Champlain.



Concrete Walls

Piled or poured concrete walls are often used with additional rock protection at the toe of a slope. Typically, concrete walls should be used instead of gabion walls for protection against extreme wave action. They are expensive due to extensive design and labor requirements.

Concrete seawalls are constructed in a similar manner as a gabion seawall. Concrete is used instead of gabions and stones. Construction of a concrete seawall requires professional design and a qualified contractor for installation.

The construction of concrete walls is very labor intensive and heavy machinery must be used, making it one of the most expensive methods of lakeshore stabilization. Costs associated with the installation of a concrete seawall will fall in the range of $100 to $300 per linear foot for a wall 25-50 feet high, and vary depending on the location and complexity of the structure.

Gabion Walls

The baskets used to form gabions (see description on preceding page) along a bank or slope, are generally deeper than the baskets used to form a gabion mattress. Gabion walls require the same firm soil foundation needed for the gabion mattress method.

The gabion wall system is installed according to the following steps:

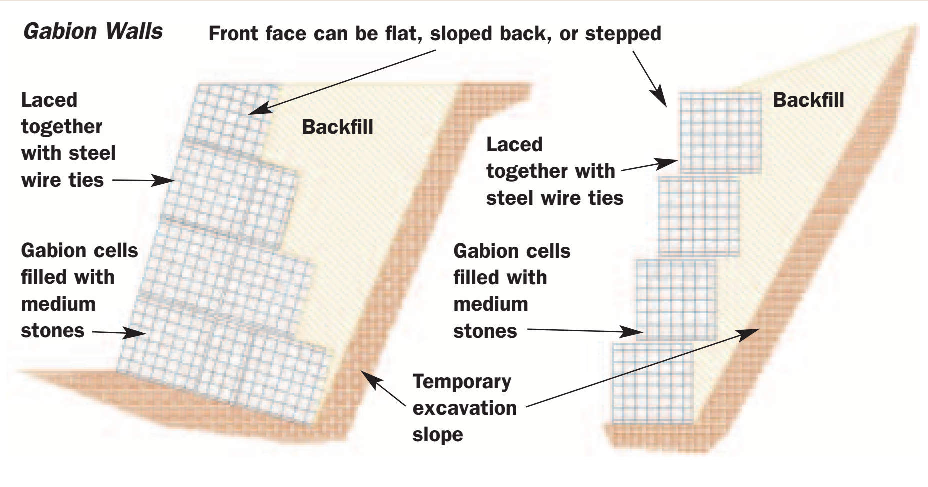
(1) The area to be protected by the gabion wall structure first needs to be graded to the final desired slope. Filter fabric or any other gravel filter layer is then installed and smoothed out across the slope.

(2) The process of assembling the gabion baskets should proceed according to the instructional manual provided by the supplier. The gabions should come folded flat, stacked, and bundled by the supplier. They should be bent into the design form and all the ends and diaphragms should be tied together.

(3) The assembled gabion baskets are then placed in the appropriate location and tied to one another. It is important that all gabion baskets that are adjacent to one another be tied together as this prevents movement and failure of the structure. Tying the baskets together should proceed according to the manufacturer's recommendations.

(4) Once several gabions are assembled, filling should begin. Filling should be done carefully in the gabions to prevent damage. The fill should be flush with the facing of the gabion baskets. This may require the use of your hands to smooth out the facing.

(5) After the fill has been placed, the covers of the gabions are installed and secured with tie wires.



WWW.DMILL.COM/PICS_GABION4.JPG

A close up of gabion wall baskets filled with small to medium size rocks; they are typically placed on moderate slopes with minimal to moderate wave action.

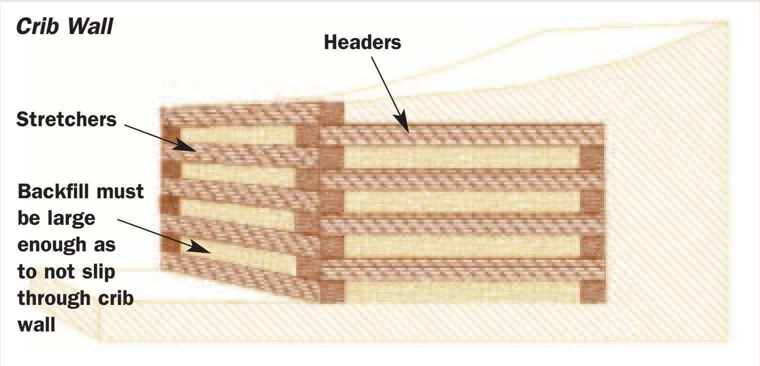
As with the gabion mattress structure, costs associated with gabion seawalls generally are among the highest for bank stabilization and erosion control techniques. The cost of the gabion wall baskets range from $1.50 to $3.20 per square foot for 3 foot deep baskets, $1.25 to $2.00 per square foot for 18 inch deep baskets, and $1.10 to $1.75 per square foot for 12 inch deep baskets. Overall costs of the project will cost approximately $50 to $100 per linear foot of area to be protected. This cost includes the baskets, filling of the baskets, stone fill (if needed), and basket closure.

Bulkheads

These retaining wall structures hold backfill and prevent it from sliding, while providing protection against moderate wave action. They are built where the soil on a slope is eroding and needs to be secured. This method is suitable in areas where a large quantity of backfill is available and the shoreline receives moderate wave action. They do not resist heavy wave action. They will protect un-vegetated, eroding high banks with a moderate slope. They should be installed during the low water season. These are the most commonly used bulkhead structures:

Sheet Piles

These are used instead of seawalls in places where erosion has occurred over very steep slopes with high elevation changes. They are not typically used for erosion control; rather, sheet piles are used as a foundation for structures such as buildings or docks.



Piles can be constructed of wood, concrete, steel, plastic, or a combination of these materials. They are installed adjacent to one another to essentially create a vertical wall adjacent to the water edge. A professional geotechnical engineer must plan the design of a sheet piled system.

Installation of a sheet pile system generally requires heavy construction equipment and materials following this procedure:

(1) The shoreline is excavated and a vertical soil wall is created. Depending on soil conditions, a bank may need to be sloped back and later backfilled.

(2) Prefabricated piles are driven into the soil using a pile-driving hammer. Cast-in-place piles are constructed of concrete poured into auger-drilled holes in the ground.

(3) Backfill is placed behind the piles and topsoil is added, graded, and seeded.

Steel/Timber Cribbing

Cribbing uses steel or timber-walled cells to form a box-like structure filled with rock or soil to add strength. The cells can be formed several different ways, but most commonly are built in a "log cabin" type style in which the steel or timber is stacked on to one another with a block of concrete placed in between. Timber is more commonly used than steel due to its availability and resistance to salt and weathering. Rough-cut, structural-grade Douglas fir is the most commonly used species of timber.

Construction of crib walls follows this procedure:

(1) Starting at the lowest point of the slope, material is excavated 2-3 feet below the ground surface. The excavation should be at an incline of 1:6 (Horizontal:Vertical).

(2) The first course of steel/timber/concrete is placed at the front and back of the excavation, about five feet apart and parallel to the slope contour.

(3) The next course of material is placed perpendicular to the slope (at right angles) on top of the

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Timber crib walls, typically constructed using Douglas fir, are not commonly built on Lake Champlain's shores; they could be adapted as seawalls.

previous course. The materials should overhang the previous layer by 3-6 inches.

(4) The steps are continued until the excavation is full. Each course should be secured to the preceding course by nails or bars. Fill is finally placed between layers.

The installation of bulkheads, whether sheet piling or steel/timber cribbing, costs roughly the same amount and requires heavy machinery. Timber construction will reduce costs slightly for a crib wall. Bulkheads generally fall in the range of $75 to $125 per linear foot of protected area.

Groins

Groins consist of a long narrow wall or mound of rock, built perpendicular to the shoreline to minimize transport of sand down a beachfront. The construction of groins is not permittable in Vermont or New York because of their effect on water flow and sediment movement and the hazard for boating.

No cost and labor breakdown is provided since this installation is not permittable.

Breakwaters

These structures intercept waves before they reach the shore. They must be designed by professional engineers, constructed by qualified contractors, and marked with flags or buoys to avoid boating accidents. The construction of breakwaters in both Vermont and New York waters requires state and federal permits.

Once commonly used, breakwaters are now rarely considered as a means to stabilize a lakeshore, due to the high costs, amount of labor required, and environmental concerns. The cost of a breakwater installation ranges from $150 to $300 per linear foot.

Bioengineering Installations

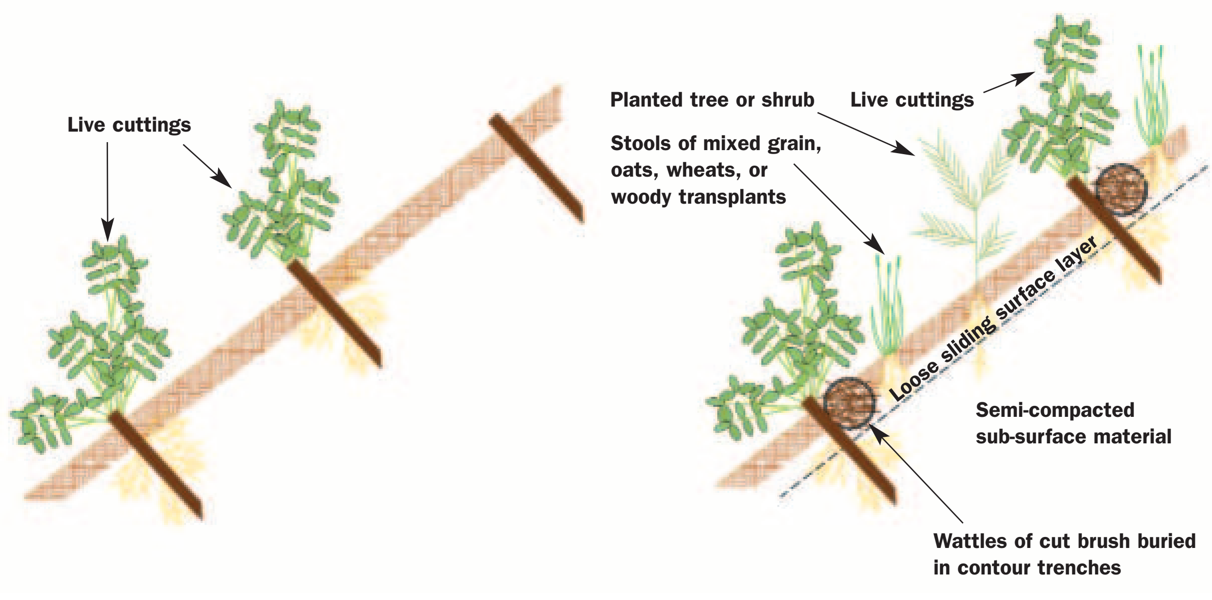
Bioengineering dates back to 12th century China. It has been widely used in Europe for over 150 years and today increasingly throughout the United States. Bioengineering methods are not yet widely used in the Lake Champlain region. However, the aesthetics, lower costs, and longer-term benefits to the shoreline and water quality make these methods well suited to this area.

Bioengineering stabilizes a bank and shoreline while improving fish and wildlife habitat. This method works well in combination with structural methods; the combination is described as a biotechnical installation.

Bioengineering alone is generally not applied on steep slopes and usually requires some shaping of a slope as part of the installation. Typically, private landowners use bioengineering methods in small areas along a lake.

This method is most suitable in areas where site soils have adequate moisture, sufficient light and drainage throughout the growing season so live vegetation can become fully established. A clay or loamy soil is more suitable for root anchorage than rocky, sandy or silt soils. As noted elsewhere in this handbook, bioengineering shoreline erosion controls should be installed at seasonal low water on the lake and during the dormant growing season for the plants being used. The selection of what types of plants and how and when to harvest the plants to be used in your installation is discussed in other areas of Section 4. The most commonly used materials, installation methods and costs for bioengineering include:

Live Staking, and Live Staking with Contour Wattling and Native Species Planting



Live Staking

This is the easiest and least expensive bioengineering erosion control method to install. Live cuttings of certain species inserted into the ground on a slope or shoreline will sprout roots and new branches, eventually forming mature woody plants. This method is limited to small areas with minimal bank erosion damage. It is most effective where shallow erosion has occurred, and when combined with other bioengineering methods, such as live fascine bundling and brush matting (see pages 27 and 29). This method does not require skilled labor to apply. It can be used in a number of different areas including the sides of gullies and across slopes.

The most commonly used plant species is the willow; however, some species of dogwood or alder may be used. (See page 19 for a list of native willow, dogwood or alder species.) The stakes should be 0.25 to 1 inches in diameter and 2 to 3 feet long. A dead blow hammer will be needed to drive the live stakes down into the ground. These hammers are available at any hardware store. A steel bar may be necessary to form pilot holes in tightly compacted soils.

Installation of a live staking system consists of the following steps:

(1) The live stakes should be collected and prepared for installation. The stakes must be cut from dormant, mature stems and used within 8-10 days of being harvested. A supply of fresh cuttings should be collected using a sharp pair of shears. The side branches should be trimmed making sure not to damage the bark. The stake should be cut to the needed length (a minimum of 1 foot) and an angle cut should be made at the bottom. It is important to make sure the angle cut is done at the bottom so that the stake is not planted upside down.

(2) The live stakes should be installed by using a dead blow hammer. It is important to use a dead blow hammer as opposed to using a mallet so that you minimize damage to the live stake. The stake should be driven gently into the ground forming a right angle to the slope. If the soil is tightly compacted, it may be necessary to create a pilot hole by using a steel bar. It is important to make sure that the soil is packed around the live stake if you have used a pilot hole. The live stakes should be driven in so that approximately 70% of the stem is buried and 30% is exposed.

(3) The stakes should be installed 2 to 3 feet apart in a triangular pattern. There should be no more than 2 to 4 stakes per square yard. Soil should be firmly packed around the stakes.

Costs are minimized if the cuttings are collected from free sites and volunteer labor is provided. However, in your planning assume that labor and plant materials will be purchased. Overall costs will range from $1.50 to $3.50 per stake.

Contour Wattling (Live Fascines)

Fascines are stems and branches from live woody plants tied together in bundles. Plants that work best in the Lake Champlain climate are willow, red osier dogwood, and snowberry.

When placed in shallow trenches parallel to a bank or shoreline, live fascines are called contour wattling. These bundles, held in place with wooden stakes, slow runoff and trap sediment. Live fascines are commonly used with other methods to add structural support to the toe of the bank. They are suitable to protect the toe and face of a slope where erosion is primarily caused by stormwater runoff and the depth of erosion is approximately 6 to 8 inches. Riprap is the most commonly used method to provide a stable toe. A live fascine bundle can also be grown on the top of the slope to act as a vegetative buffer zone.

Installing this method system requires skilled, experienced individuals and consists of the following steps:

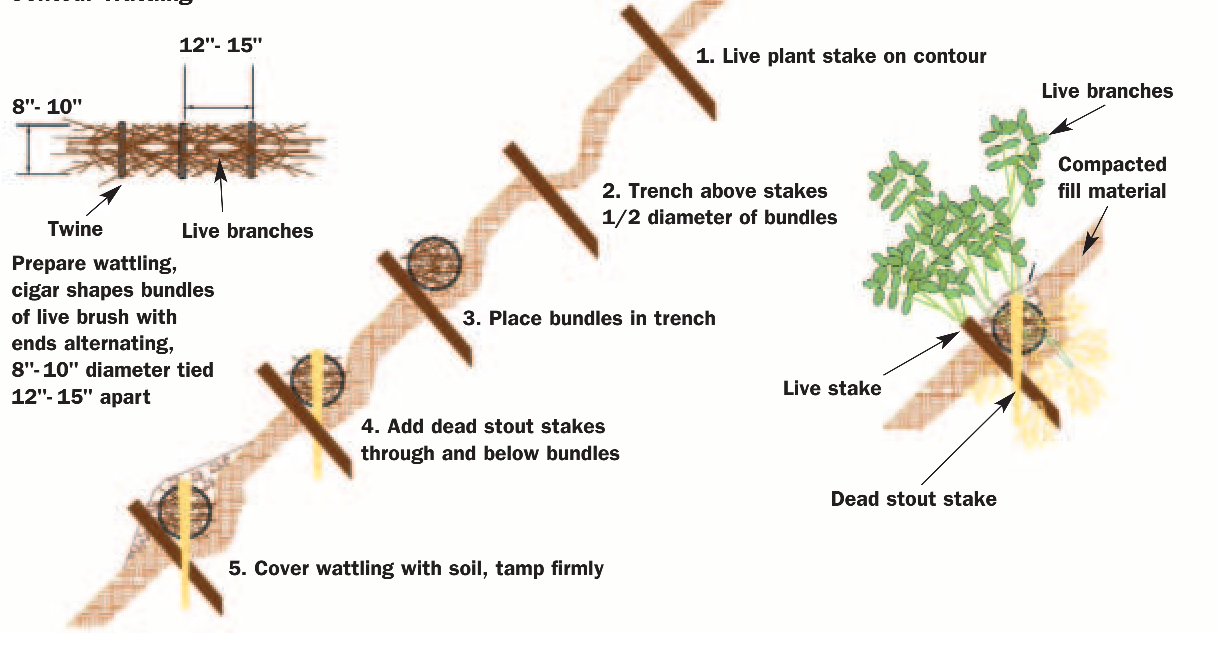
(1) The live fascine bundles must be constructed using fresh, live cut plant material. The cuttings should be straight and range from 0.25 to 1 inch in diameter and 5 to 30 feet in length depending on the site conditions. Age, size and species should be mixed throughout the bundle with the growing tips of the cuttings facing in the same direction. It is okay to keep the side branches when forming a live fascine bundle. The cuttings should be mixed together until the bundle is approximately 6 to 8 inches in diameter when securely tied. The bundles can be tied with hemp binder twine or by wrapping "pigtails." A tie should be placed every foot with a non-slipping knot such as a square knot.

(2) Trenches should be dug at the base of a slope and should be just large enough in width to hold a fascine bundle. The depth should be about half the size of the bundle.

(3) The bundles should be placed in the newly dug trench and secured using a wooden stake approximately 2 to 3 feet long. The stakes, pounded into the bundle and ground using a heavy hammer, should be spaced every 2 to 3 feet along the length of the bundles and driven down so that there are 2 to 3 inches remaining above the top of the bundle.

(4) Moist topsoil should be placed in and along the sides of the bundles. It is important to not fully bury the fascines; a few twigs or leaves

Contour Wattling



should penetrate through the layer of soil.

(5) Additional trenches should be dug up the slope at an appropriate interval. Steps 3 and 4 should be repeated until the slope is covered. A 3-foot spacing interval is recommended between rows.

(6) Straw or mulch should be placed in between the rows on flatter slopes and a jute or coir fabric on steeper slopes. The fabric can be held in place by running the ends of it into the trenches and staking the fascine through the fabric.

Costs associated with the construction of this type of installation are generally minimal. For the typical 6 to 8 inch live fascine bundles, costs range from $10.00 to $30.00 per foot. This price includes twine, securing devices for installation, harvesting, transportation, handling, fabrication, storage, excavation, backfill, and compaction. As with all stabilization techniques, costs will vary depending on design, access to site location, time of year, and labor rates. Installation is relatively simple because heavy equipment is not needed except to prepare the slope of the bank.

Brush Layering

This involves using cut branches from live woody plants and dispersing them between layers of soil along a shoreline or bank to create a series of benches. Long, dormant live branches from willow, alder, and dogwood are most commonly used to provide extra strength and reinforcement for the soil or fill along a slope or bank. This method is most commonly used in replacing new fill, restoring shallow slumps, and repairing narrow gullies. It provides future erosion protection and stabilization to loose soil slopes, can be used on either cut (natural) or filled slopes, and works best when combined with natural "geofabrics" or synthetic "geogrids."

Skilled individuals should install a brush layering system. Beginning at the base of the slope and working upwards:

(1) Long branches should be cut from your chosen plant species. The length of the branches can range up to 12 feet and should be approximately 0.25 to 1 inch in diameter. A supply of fresh, dormant cuttings should be collected and trimmed of almost all branches.

(2) The first bench should be excavated at the bottom of the slope. The face surface of the bench should angle back into the slope approximately 10-25 degrees off horizontal.

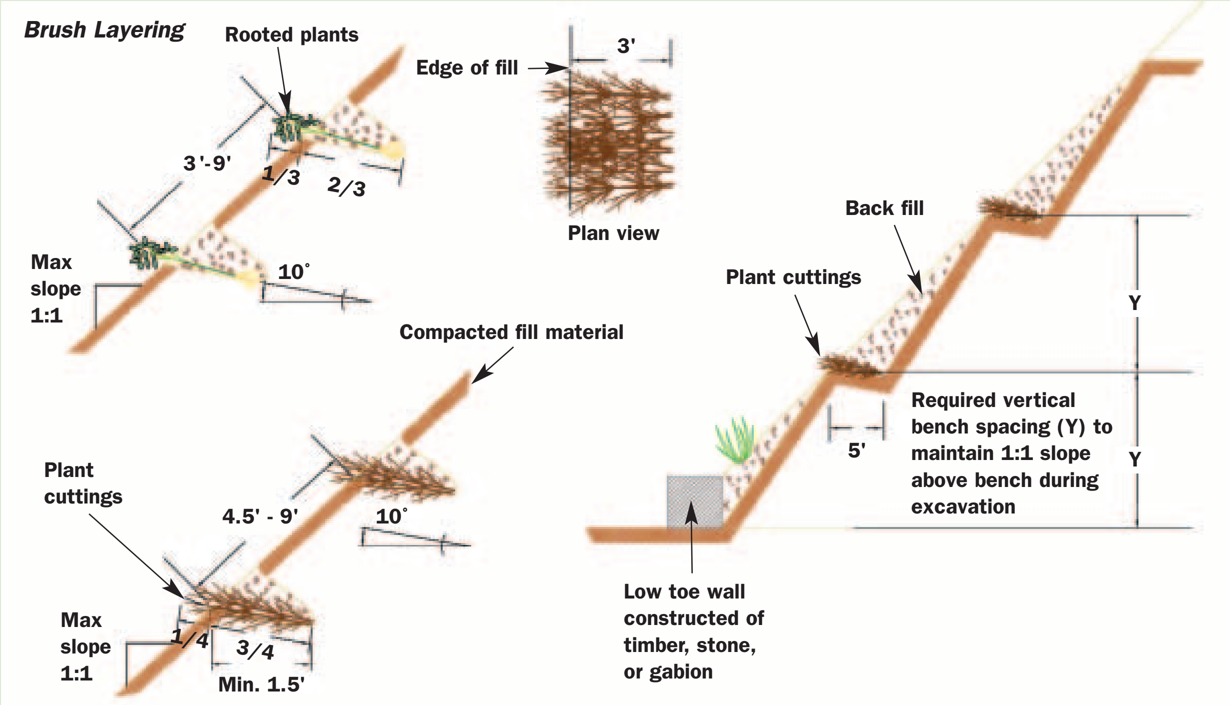
(3) The first layer of cuttings should be placed on the bench making sure all the cut ends are touching the back of the excavated area and the tips of the branches are pointing out of the slope. The cuttings should be crisscrossed with the first layer being approximately 1 inch thick.

(4) Dry, light soil placed on the cuttings should fill any cracks or air voids in the layer. The next layer of cuttings should be placed on top of this layer and the process should be repeated until there are several different layers.

(5) Steps 1 through 4 should be repeated as you move up the slope. It will be helpful to build two benches at once and to move the soil from the upslope bench onto the cuttings on the lower bench.

(6) Mulch or straw should be placed on the soil between benches.

In situations where there has been heavy erosion on a bank, covering soil is usually filled in the bench areas by machinery.

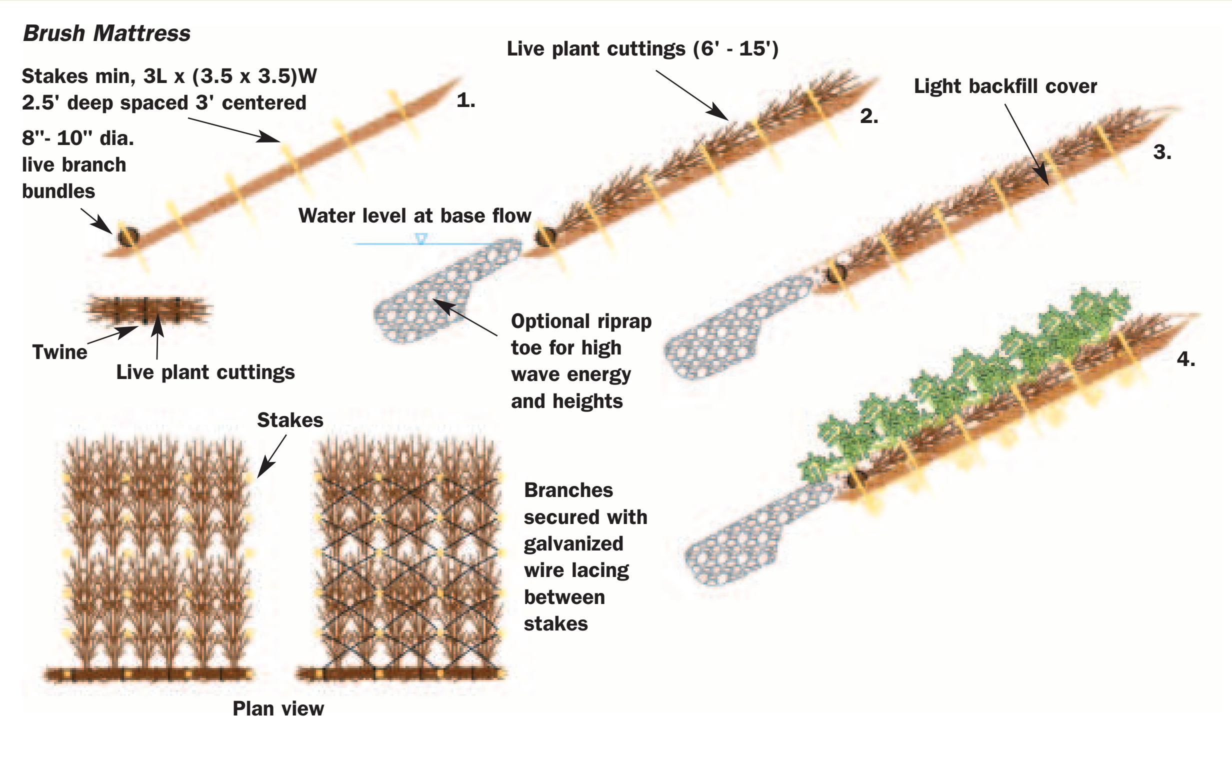


The brush layering method is generally more costly than the other bioengineering methods. Costs can be minimal if the plant material is easily available and volunteer labor is used. Costs are higher when using fill between the brush layers due to the need for significant labor or heavy machinery. On large sites, a geotechnical engineer may need to be hired to assist in the design and construction process. Natural geofabrics tend to be expensive, but add needed stability to the system. Costs of these range from $.50 to $2.00 per yard. Overall costs are difficult to estimate and vary based on design, access to site, time of year, and labor rates. Generally total costs will fall in the area of $12.00 to $30.00 per foot.

Brush Matting

Brush mattresses (mats) are made of interwoven layers of live branches cut from any woody plant that sprouts roots from its stem. The process of layering brush is called "matting." Mats are secured in place over a stream bank or shoreline, with stakes and twine. The most commonly used plant is the willow, however, some species of shrub dogwood and viburnum may be used as well. The plants should be 2 to 3 years old, flexible, and approximately 5 to 10 feet in length. The branches can range from 0.5 to 1.5 inches in diameter.

Mats are used primarily to restore moderately eroded slopes. They are an excellent alternative to using stone or gabion revetments. Brush mattresses do require skilled individuals to apply and can be used on either cut or filled slopes, and usually requires some fill to acquire the proper slope shape. Brush mattresses are commonly used with a live fascine at the toe to provide additional support. Wire or twine, and stakes are needed to hold down the tied layer of branches.



Installation of a brush matting system consists of the following steps:

(1) The bank should be properly graded before installing the brush mattresses. Brush mattresses should be placed on evenly surfaced banks to assure good soil-stem contact throughout. The slope should be between 5 and 18 feet in length. It is important to ensure that soil is not too tightly compacted to allow plants room to grow.

(2) One end of the live branches should be inserted into a trench at the bottom of the slope and laid on the bank, perpendicular to the trench.

(3) Stout stakes approximately 2 to 4 inches thick and 24 to 36 inches long, cut diagonally, are pounded into the slope in rows spaced approximately 18 inches apart.

(4) A layer of branches 2 to 4 inches thick should be laid out and fastened in place using either twine or wire. The most commonly used tie wire is number 12 galvanized annealed. If twine is used, it should be machine spun bristle coir, approximately 0.2 to 0.5 inches thick and have a breaking strength of 70 to 100 pounds.

(5) The twine or wire runs diagonally from stake to stake and is tied in a clove hitch.

If a live fascine bundle is an element in the installation, the twine or wire should be tied down loosely and secured only after the fascine bundles have been integrated in the trench.

A live fascine bundle should be constructed at the base of the slope or shoreline by following the steps presented in the contour wattling method (see page 27). Although not required, they are recommended to achieve maximum strength and stability in a brush matting installation.

Costs associated with brush matting are the highest for any bioengineering method due to the extensive amount of labor. Costs are reduced if the plant material is widely available and volunteer labor is used. For personnel who are familiar with the project and brush matting process, costs range from $12.00 to $24.00 per 10 square feet. If contract labor must be used costs range from $25.00 to $55.00 per 10 square feet.

Plant Selection for Bioengineering and Biotechnical Installations

Plants are used in several different types of shoreline erosion control installations. Bioengineered installations involve using live plant cuttings from a woody plant that sprouts roots from its stems. Biotechnical installations combine bioengineering and structural elements. The choice of a plant species is dependent on the stabilization process chosen and the conditions on site.

In most cases, a mix of plant species provides the best structural support for slope stabilization. The slope crest, face, and toe should be looked at when selecting plant species. Many plant species are suitable for slope stabilization projects including grasses, herbaceous plants, vines, shrubs, and small trees.

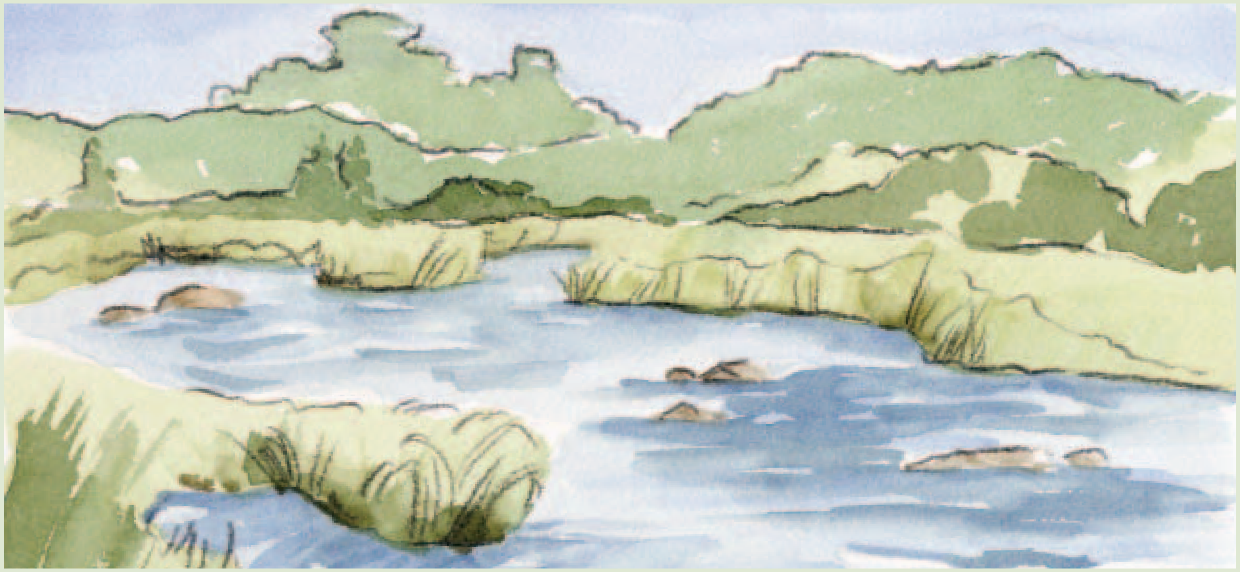
Non-native species should be avoided since they will displace native plants and may have detrimental effects on wildlife habitat. Page 19 provides a list of native plant species available from area nurseries.

A wide range of species that are tolerant to many environmental conditions should be considered. Planting a mixture of species will provide the highest success rate. Local nurseries and plant professionals can be helpful resources when planning and deciding what plant types to use. The plant species can either be purchased or, if they are readily available and abundant, can be harvested from other areas of your property. Nearby shorelines with natural vegetation should be looked at to determine which species grow well in a particular area. Whatever type of plant material is chosen, it should be free of rot, plant disease, and/or insect damage.

Plant Harvesting for Bioengineering and Biotechnical Installations

When you decide on the most effective type and mix of plants to be used for stabilization, harvesting should only be done when plants are dormant. The best indicator of dormancy is when a plant's leaves have turned color and fallen from the twig. This is usually during mid-to-late October. The plant cuttings can be used through the winter until early spring when the buds have begun to break open.

Some of the plant species found in the plant list on page 19 can be harvested by cutting with pruning shears, clearing saws, handsaws, or chain saws. A mechanical saw may work best if a large number of cuttings is needed. A clearing saw works best for cuttings that are up to 3" in diameter and a chainsaw will work best for any cuttings over 3" in diameter. When several cuttings are done together, it is best to tie them in a bundle with the growing ends pointed in the same direction. All of the side branches should be left intact and the bundle tied tightly enough so the cuttings cannot be damaged. The cuts should be made approximately six inches to 1 foot above ground and should be transported with care. They should be covered with a tarp or blanket material to avoid drying out. The cuttings should be kept cool, moist, and shaded at all times before transplanting. The cuttings can be stored in the cold for as long as ten weeks.



Biotechnical

Biotechnical shoreline stabilization methods combine the use of structural-mechanical materials and plants. The structural and biological materials work together to provide improved erosion control in areas of high wave energy or severe erosion while minimizing environmental impacts. Both the structural and biological materials provide stability within the system and are suitable for a wide range of areas. When properly installed, a biotechnical solution provides improved aesthetics over structural methods. It does require a greater amount of planning and is commonly used to prevent both surface erosion and shallow mass-movement of soil.

These methods should only be installed during the dormant plant growing season and low water levels. With the exception of live cribbing, the construction of biotechnical methods can be separated into structural and bioengineering installations. For best development and structural support, it is recommended that they be constructed together. As with bioengineering methods, biotechnical methods are not yet widely used in the Lake Champlain region. However, the longer-term benefits to the shoreline and water quality make these methods well suited to this area and they should become more commonly used as awareness increases of their effectiveness and ability to blend into their surroundings.

The following is an overview of the materials used for each biotechnical installation, the steps needed for proper implementation and an estimate of costs involved. Site conditions for bioengineered installations need to be considered before the structural portions are installed.

Erosion Control Matting

Erosion control matting, made of lightweight, entangled nylon filaments, generally comes in rolls that can be easily shipped, stored, and installed.

There are two options when installing erosion control matting: soil filling or non-soil filling. The matting is rolled out on a bank or slope and grass seeds are spread and planted throughout the matting. Soil filling is usually done to provide topsoil for the seeds to develop. This helps to reinforce the plant roots. As the plant roots grow, they become intertwined with the matting, producing a very stable slope cover.

This method requires no heavy equipment for installation, and generally can be installed by one person. Other biodegradable and photodegradable fabrics and natural products such as coir fabric can also be used. Erosion control matting is commonly placed on banks, slopes, and along the edges of roadways.

Installation of an erosion control matting system is done as follows:

(1) The slope must be properly shaped to design specifications with all rocks and soil clumps removed.

(2) The matting, generally 3-4 feet wide, is rolled down the slope overlapping 3-4 inches with each successive roll. Staples are installed down the center of each mat with 3 to 5 feet separating the staples. For most slopes, 3 or 4 staples should be installed in every square yard.

(3) After the matting is anchored down with metal staples and if the soil filling method is used, .5 to .75 inches of fine soil should be spread into the mat, completely filling the spaces.

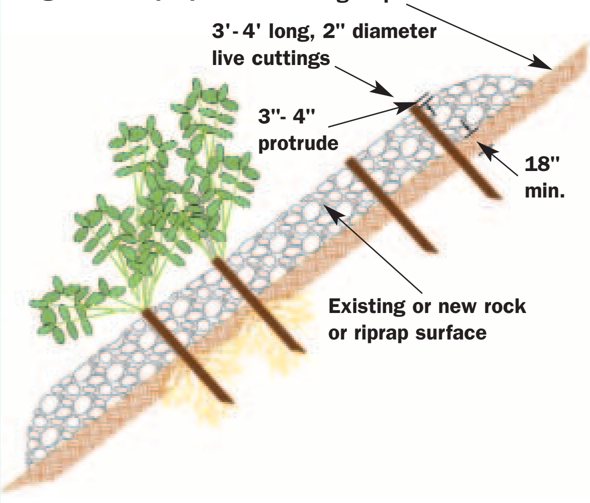
(4) Once the filling is complete, seeding should occur. Seeding may occur before and after filling to increase vegetation.

Costs associated with erosion control matting are similar to the costs to install live staking which is $1.50 to $3.00 per square yard. Costs are minimal due to minimal labor requirements and no need for heavy machinery.

Vegetated Riprap (Joint Planting)

Vegetated riprap, often referred to as joint planting, combines the use of a stone revetment structure and live plants. Live cut stakes approximately 1 to 1.5 inches in diameter are placed in the cracks or openings between the rocks. The stakes need to be long enough to be able to reach through the armor and filter layers into the soil at the base of the riprap. The cuttings from willow trees tend to work best for this method. In a mature installation, the roots of the plants provide additional soil strength and the vegetation hides the rock creating a more scenic look. Vegetated riprap is primarily used along waterways or inland lakes.

Vegetated Riprap



The structural riprap portion should consist of rocks large enough to not be moved or washed away by waves or ice.

The riprap installation should be complete prior to installing the live cuttings using this procedure:

(1) The slope should be worked so that it is no greater than 1.5 to 1 (Horizontal:Vertical) and overlayered with a filter fabric on the slope face. The rock layer should be placed on top of the filter fabric being careful not to damage or puncture it.

(2) Once the cuttings have been prepared to the appropriate length, they should remain moist and installed that same day. Insert the live cuttings into the openings or cracks between the rocks. It may be helpful to use a bar or rod to create a hole to insert the cuttings down into the soil through the filter fabric.

(3) The live cuttings (stakes) should be arranged as perpendicular to the slope as possible and the tips of the cuttings should be a little above the top facing of the armor layer. At this point, it is important to check that the live cuttings fit snugly in the hole and are secure.

(4) The live stakes should be tamped into the ground. The best way to do this is to carefully use a dead-blow hammer making sure not to damage or strip the bark.

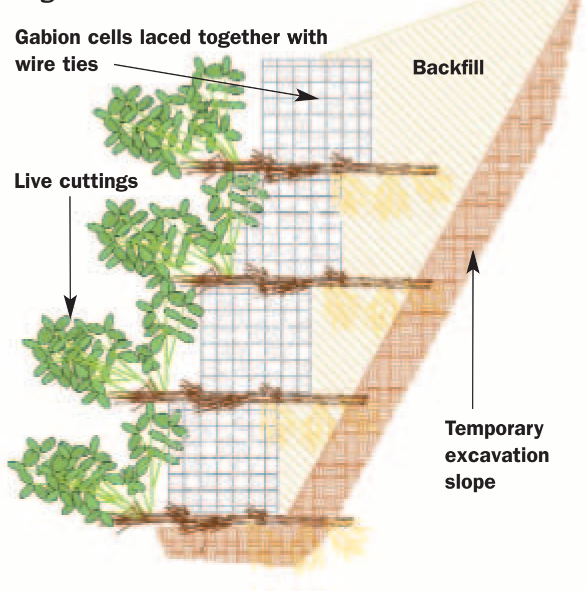
The live cuttings or stakes can be oriented in any direction with a density ranging from two to four stakes per square yard. The orientation chosen will depend on where the openings in the rocks are located.

Costs associated with installing vegetated riprap erosion control using an existing revetment structure are minimal if the live cuttings or stakes are readily available and installed by volunteer labor. If a riprap revetment is not already in place, costs will increase dramatically and range from $75 to $200 per linear foot.

Vegetated Gabion Walls

This combines a gabion wall structure with live plants. Branches or cuttings 0.5 to 1 inch in diameter are placed through the gabion baskets while the wall is being formed. The length of these cuttings should be long enough to reach behind the back of the rock baskets (gabions). Generally, these structures are installed on moderately steep slopes to resist wave action. The structural portion of the system consists of gabion wire baskets, binding wire, gabion rock fill, and backfill capable of supporting plant growth. The addition of vegetation assists in structural support and increases wildlife habitat. A vegetated gabion wall is a nonstandard construction project and its development must be fully coordinated with a contractor, the manufacturer, and the designer in order to modify the type of backfill and vegetation to be used.

Vegetated Gabion Wall



Installing the vegetated gabion wall system consists of the following steps:

(1) At the lowest point, excavate 2 to 3 feet of footing area below the natural grade. A footing is typically constructed of concrete or some hard structural material. This footing area should be inclined into the slope so that the structure will have a inclination of at least 1:6 (Horizontal: Vertical) to add stability to the structure.

(2) The first level of wire baskets should be placed on the footing area and filled with rock. Depending on the height of the wall, two or more baskets placed together may be needed. The minimum width to height ratio for a gabion wall structure is 0.5 for stability. It is important that a qualified geotechnical engineer approve the structural wall design.

(3) A thin layer of backfill should be spread on top of each tier of rock-filled closed wire baskets. It is important to spread backfill behind the gabion baskets to a level that is even with the top of the gabion.

(4) The live cuttings should be placed on the soil and rock-filled gabion baskets forming right angles to the wall with the tips to the front and ends in the backfill behind the wall.

(5) The live cuttings should be covered with another thin layer of soil and the soil or backfill should be compacted to ensure full contact with the live cuttings.

(6) Steps 1 through 5 should be repeated until the proper height is reached.

Costs associated with creating a vegetated gabion wall are minimal if the wall is already built.

If the full structure needs to be installed, costs are generally among the highest for all bank stabilization projects. The cost of the gabion baskets range from $1.50 to $3.20 per square foot for 3-feet deep baskets, $1.25 to $2.00 per square foot for 18 inch deep baskets, and $1.10 to $1.75 per square foot for 12 inch deep baskets. Overall costs of the project will range from approximately $100 to $150 per linear foot of area to be protected. This cost includes the baskets, filling of the baskets, stone fill (if needed), and basket closure.

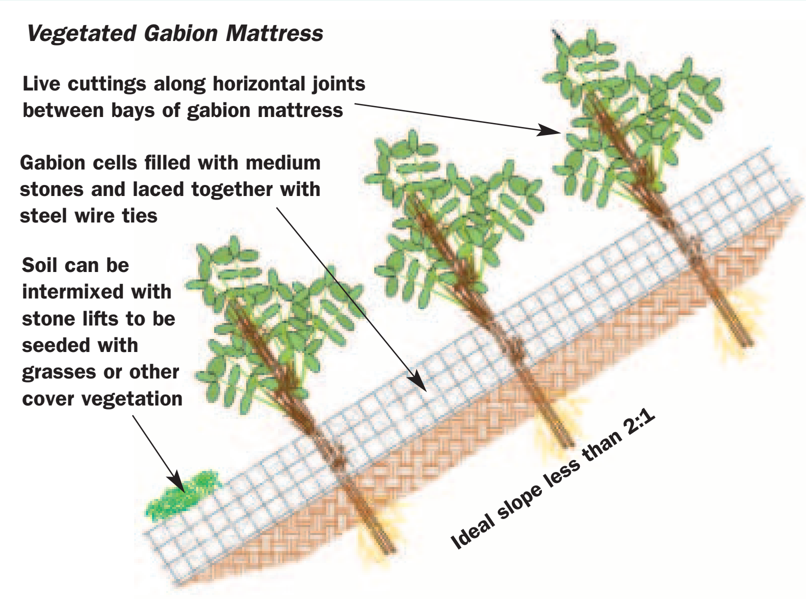
Heavy machinery is not always required for the development of a gabion structure. However, the filling and closure of the baskets is very labor intensive and requires several people. A large crew of skilled individuals is needed to complete this project in a short amount of time.

Vegetated Gabion Mattresses

Live cut stakes, generally 1 to 1.5 inches in diameter, are inserted in the spaces between a gabion mattress to add strength to the structure. These stakes should be long enough to go through to the soil at the back of the rock baskets (gabions). Willow cuttings are the most commonly used material for this method.

Vegetated gabion mattresses are installed on moderately steep slopes to resist soil erosion from wave action, ice, and surface erosion. The structural portion of the system consists of gabion wire baskets, binding wire, and rock fill. The mattresses are usually no thicker than one foot.

Site characteristics described under revetments in the structural section should be followed when applying a vegetated gabion mattress.



Installing this system consists of the following steps:

(1) The bank and slope should be worked so that it is no greater than 1.5:1 (Horizontal:Vertical) and the gabion baskets should be placed on the bank as directed in the manufacturer's installation guide.

(2) All cuttings should remain moist and be used the same day they are cut.

(3) The wire baskets should be filled with rocks and the live cuttings should be inserted through the openings in the rocks. A bar or rod may be needed to help form holes to insert the live cuttings. It is important to make sure the cuttings fit firmly into the openings. If the stakes are loose, they will fail to root, limiting the effectiveness of the system.

(4) The live cuttings should be tamped into the ground using a dead-blow hammer. It is important to not damage the bark during this process.

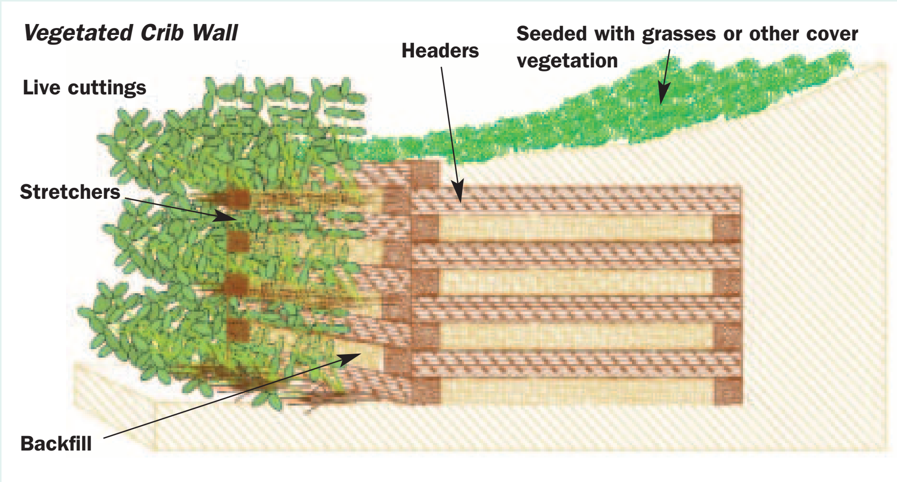
(5) The live cuttings should be arranged to not exceed four cuttings per square yard. The arrangement usually depends on where the openings in the rocks are located.

(6) Sandy soil should be spread over the gabions to fill the openings in between the rocks due to its good drainage characteristics. The soil helps establish the growth of the live cuttings.

Costs associated with creating a vegetated gabion mattress are minimal if the mattress layer is already in place. If a gabion mattress structure needs to be installed, costs increase dramatically. However, costs to create a vegetated gabion mattress are less than the costs of creating a vegetated gabion wall. Costs for the gabion baskets range from $1.10 to $1.75 per square foot. Items needed for closure of the baskets are normally included, and prices vary depending on how heavy a wire you will need. Overall costs of the project will be approximately $100 to $150 per linear foot of area to be protected. This cost includes the baskets, filling of the baskets, stone fill (if needed), and basket closure.

Vegetation Cribbing (Live Cribbing)

Live plant cuttings are placed in the soil or fill in the cells that form the crib wall. The cuttings generally are 1 to 1.5 inches in diameter and should be long enough to be inserted into the crib wall structure for adequate root development. Willow cuttings are the most commonly used plant material for live cribbing.



Using a timber crib wall with live plant material creates a very natural appearance. Live cribbing does not work well on high banks that receive heavy wave action. This method is most commonly used on banks that have very little vegetation or where a lot of backfill is going to be used to restructure the bank slope.

A vegetated crib wall is a non-standard construction project and its development must be fully coordinated with the contractor, the manufacturer, and the designer in order to specify the type of backfill and vegetation to be used.

Installation of a live crib wall is done as follows:

(1) Starting at the lowest point of the slope, material is excavated 2-3 feet below the ground surface. The excavation should be at an incline of 1:6 (Horizontal:Vertical).

(2) The first course of steel/timber/concrete is placed at the front and back of the excavation, about five feet apart and parallel to the slope contour.

(3) The next course of material is placed perpendicular to the slope (at right angles) on top of the previous course. The materials should overhang the previous layer by 3-6 inches.

(4) The steps are continued until the excavation is full. Each course should be secured to the preceding course by nails or bars. Fill is placed between layers.

(5) The live plant cuttings are inserted into the soil or fill, in the spaces or cells, which form the crib wall. A sandy soil or fill should be used to allow for adequate drainage.

Costs associated with the installation of a vegetated crib wall vary depending on the material used. Timber is more cost effective and may require less machinery to install. Vegetated crib walls generally fall in the range of $100 to $150 per linear foot of area to be protected including the construction of both the structural and bioengineering portions. The use of concrete or steel will increase the overall cost significantly.

Guidelines for Success

These guidelines are applicable to all methods and should be completed before installing any structural, bioengineering, or biotechnical erosion control process. Professional assistance is required for proper calculation and design.

Installation

(1) Determine the seasonal range of water level for the property. This can be accomplished by measuring the high and low water levels each year or by consulting with local or state officials.

(2) Determine the approximate wave heights to which the property is subject. Professionals should be contacted to help determine the approximate wave height.

(3) Select a shoreline stabilization technique to be used. Determining what method is best for a particular property is discussed in Section 3 of the handbook.

(4) Before any work is done, a line of silt fencing needs to be installed on the down slope side of the shoreline stabilization to prevent water pollution from sediment laden runoff during construction. This is important because if this is ignored you might be subject to a state or county fine. The fencing should ideally be installed at least 6 inches from the water edge. If the fencing needs to be placed in the water, due to site constraints, a row of sand bags should be placed on the inner or outer base of the fencing to hold it down.

(5) Select a material (plant) to be used for the armor layer which is capable of resisting the calculated design wave height. (see page 30)

(6) Select the size of material to be used. (see page 30)

(7) Determine the proper height at which to set the top of the bank. (see page 11)

(8) Determine if any overtopping is expected for low structures, if so, implement changes to the design to accommodate for overtopping.

(9) Design features if necessary.

(10) Design adequate surface runoff and overtopping runoff management structures and provide any other drainage structures that may be necessary, such as culverts and ditches.

(11) Consider the ends of the structure to prevent flanking and damage to neighboring properties.

(12) Design the toe protection.

(13) Design the filter and underlayers.

(14) Construct the project and,

(15) Provide firm compaction of any fill and backfill materials.

Monitoring and Maintenance

Once an erosion stabilization project is complete, monitoring and maintenance are essential for continuing success. Monitoring and maintaining a shoreline stabilization project identifies the need for repair in a timely manner, provides a basis for designing a repair if needed, and provides information on the performance of the stabilization installation.

Monitoring

Monitoring should be performed on adjacent shorelines up and down from the constructed area to identify any possible neighboring impacts. A simple site inspection performed by someone with knowledge of the original design of the project is the most cost effective, and is generally considered sufficient monitoring. This inspection should include observing the shore, water, structure, vegetation, and overall environmental conditions. Taking pictures along with notes is the best way to document any problems observed. Periodic pictures of the same area will make it easier to identify changing characteristics.

Monitoring is of greatest importance during the first two years after construction. Inspections should be conducted after high-water events or heavy storm action. During periods of low-water levels, visual monitoring should occur on portions of the structure under water the majority of the year.

The type of shoreline erosion protection installed dictates monitoring frequency. As a general guideline, projects should be monitored at least twice per year. Projects using bioengineering methods are most vulnerable during the first months following installation and should be checked frequently to identify potential failures quickly. Special attention should be paid to the toe protection and the upper bank slope where the natural bank material or vegetation occurs. Changes in overall conditions of the lake, such as water level and wave action, should be noted. An evaluation of vegetative growth and any material that has been washed ashore should be part of every inspection. Additional planting may be needed depending on the growth of the plants within the first two years.

The project design engineers should stipulate the monitoring frequency for hard structural projects. For erosion control installations such as constructed walls, a professional may need to inspect the structure.

Maintenance

When maintenance is required, there are two approaches: repair the structure at the first sign of damage, or take no action until major maintenance is required. Repairing minimal damage may not always be cost effective or necessary, particularly with hard structure solutions. Most projects do not have to be flawless and will still provide adequate shoreline protection while having minor damage. Knowing whether damage is severe may not always be obvious and if there is doubt you should consult a professional. Bioengineering projects do require repair as soon as damage is identified if the project is in the first two years of development. After two years, the vegetative roots have taken hold and repair may not be necessary. Waiting until major maintenance is required is, in many cases, the best solution.

Repairing a Failed Project

Failure in a project or installation may not always be easy to identify. The highest failure rate occurs during the first two years after installation of an erosion control project. Bioengineering projects have a higher failure rate in the first two years because the vegetation needs time to develop. Negative impacts to adjacent properties caused by the installation of an erosion control project is called flanking and considered a failure that needs to be addressed accordingly. Slumping, gullying, or bank undermining are signs that the structure is failing and should be repaired immediately through re-vegetation or structural repair. Movement of the structure toward the lake or displacement of a wall generally means the toe of the structure is failing and should be repaired by adding additional toe protection or back filling where necessary.

Erosion occurring behind a structure means it was not built high enough and should be repaired by back filling or increasing the height of the structure. In an installation using large stones and rocks, movement of the stones and exposure of the filter layer is a common sign of failure and can be repaired by placing additional stones on top. As with planning and designing a shoreline stabilization project, it is important to consult with professionals when a failure and needed repairs have been identified. Repairs need to be carefully thought out and properly installed to prevent further damage.

Permit Requirements

How to Make the Permit Process Work for You

As part of the process to create a plan to manage shoreline erosion on your property, you should determine whether the method(s) and structure(s) you will use require a permit. Depending on what type of structure is being installed and where, it is possible that permits may be required from local, state, and federal government agencies. If permits are required, it is very helpful to contact these agencies early in your planning. This enhances full understanding of the permit requirements and the review process involved, giving you the opportunity to include the requirements in the overall design of your installation and avoid costly adjustments after the fact.

The permit process works differently depending on the type of permit requested. The most important step is to contact the permitting agency to discuss the project and complete their application forms. It will save you time to have contacted all the agencies that will be involved in issuing required permits. In most instances, a review of your application cannot proceed until all the agencies that need to be involved have received your application.

Often agency staff will conduct a site visit to observe the area. When an application is received, the permitting agency will typically publish a public notice of the proposed improvements. After the public notice is released, a review is held for public comments regarding the permit application. Waiting periods vary depending on what agency is issuing the permit. Generally once the comment period is over and all environmental concerns have been addressed, a permit can be issued.

Types of Permits and Permit Authority

Municipal/County Regulations

There is no specific permit information standard used by every level of government. Some permits are specific to shoreline modifications; others require approvals for aspects of construction typically related to shoreline stabilization (such as filling, clear-cutting, and land alteration); and others do not have any permitting or notification requirements. You should contact your municipal or county office to determine what permitting requirements apply to your project. Often towns and counties will refer you to federal agencies such as the Army Corps of Engineers for permitting. You should notify the county and/or any municipalities of any shoreline alteration you are planning to do, before starting the work, to identify any regulations with which you need to comply. A listing of county contact information and other resources is located in Section 6 of this handbook.

Vermont State Permits

In Vermont, permits are required when erosion control installations involve construction, filling, or potential hazards that alter the shoreline and/or wetlands. The shoreline is considered the surrounding perimeters of the Lake Champlain Basin and includes canals and slips. Vermont state permitting may also be required for shoreline work on tributaries of the lake. Any project that may alter the area beyond the mean water level of the lake (95.5 feet) will require a Shoreland Encroachment Permit. Encroachments include, but are not limited to, shoreline stabilization projects such as retaining walls and revetments. If the lake's adjacent wetlands are being affected by the project, a Wetland Conditional Use Determination from the Vermont Water Quality Division is required. Also some projects on lakes or within the buffer zone along the shoreline will require an Act 250 permit.

The first step in the Vermont state permitting process is to contact the regional permit specialist at your regional Agency of Natural Resources office. In Grand Isle, Franklin, Chittenden, and Addison Counties, the appropriate regional office is in Essex Junction, Vermont. The regional office in Rutland should be contacted if one is in Rutland County. The permit specialist will provide a project review sheet that identifies what permits are likely required with appropriate contact numbers. The permit specialist can also provide many permit application forms.

When you file your completed application, send it back with the design plans for your project. The application will be reviewed for compliance with all regulations and you may be asked for additional information. A public notice is typically sent out about your proposed project to give town officials, neighbors, and any interested persons the opportunity to comment on or object to your project. In most instances, your application is approved or denied within 30-60 days depending on the regulatory agency. Contact information about Vermont state government permit agencies is located in Section 6 of this handbook.

New York State Permits

New York State requires permits for any construction, excavation, filling, or discharging of fill material into Lake Champlain or onto its banks. The New York State Department of Environmental Conservation (NYSDEC) and the Adirondack Park Agency (APA) are the two permitting agencies involved in shoreline stabilization and erosion control installations.

The first step is to contact the NYSDEC and the APA to discuss your project and obtain a permit application form. When you file your completed application, send it back with the design plans for your project. The application will be reviewed for compliance with all regulations, and you may be asked for additional information. A public notice is typically sent out about your proposed project to give town officials, neighbors, and any interested persons the opportunity to comment on or object to your project. In most instances your application is approved or denied within 30-60 days depending on the regulatory agency. Contact information about the NYSDEC and APA is located in Section 6 of this handbook.

Federal Permits

Any construction, excavation, or discharging of fill material that encroaches beyond the ordinary high water mark of Lake Champlain or the lake's adjacent wetlands and tributaries requires a permit issued by the Army Corps of Engineers. Federal permits are only issued after a state permit has been approved.

You should obtain a permit application from the district offices of the Army Corps of Engineers responsible for the territory where your shoreline erosion control project will be installed. Once your completed application with design plans is received, a public notice will be issued to notify interested people of your proposal. If no objections are received within 30 days, the district engineer will consider issuing a permit based on the project's environmental impacts. Contact information for the Vermont and New York district offices of the Army Corps of Engineers is located in Section 6 of this handbook.

Resources and References

Resources Used in the Development of this Handbook

These resources can provide additional guidance or assistance in the technical areas covered in Sections 4 and 5. The list has been segmented for easier use.

Sources of Information Pertaining to Methods of Erosion Control

A Bioengineering Solution System to Coastal Shoreline Stabilization. December 2000. George Farek and John Lloyd-Reilley. Also go to www.landandwater.com.

Bioengineering for Hillslope, Streambank and Lakeshore Erosion Control. November 1996. Thomas G. Franti. Also go to www.ianr.pubs.unl.edu/Soil/g1307.htm.

Biotechnical and Soil Bioengineering Slope Stabilization, A Practical Guide for Erosion Control. 1996. Donald H. Gray and Robbin B. Sotir. John Wiley & Sons, Inc., New York.

Biotechnical Slope Protection and Erosion Control. 1982. Donald H. Gray and Andrew T. Leiser. Van Nostrand Reinhold Company, New York, New York.

Brush Mattresses for Streambank Erosion Control. May 2001. Hollis H. Allen and Craig Fischencih.

Control of Soil Erosion. January 1996. Robert P. Stone and Neil Moore. Ontario Ministry of Agriculture and Food, Ontario, Canada. Also go to www.gov.on.ca.

Design Recommendations for Riparian Corridors and Vegetated Buffer Strips. April 2000. Richard A. Fischer and J. Craig Fischenich.

Gabions for Streambank Erosion Control. May 2000. Gary E. Freeman and J. Craig Fischenich.

Ice Push Damage on Lake Bomoseen, Vermont. Final Report. May 2001. U.S. Army Corps of Engineers, State of Vermont, and Lawrence W. Gatto, Michael G. Ferrick, and Darryl J. Calkins. Impacts for Stabilization Measures. May 2001. Craig Fischenich.

Lake Champlain Shoreline Erosion Control. New England River Basins Commission and Army Corps of Engineers.

Live and Inert Fascine Streambank Erosion Control. May 2001. Robbin B. Sotir and Craig Fischenich.

Shoreline Erosion and Its Potential Control on Thurmond Lake. Erosion Control Magazine. December 1999. Bruce K. Ferguson. Also go to www.forester.net/ec_9911_shoreline.html.

Shoreline Stabilization Using Wetland Plants and Bioengineering. Volume 46, Number 3. June 2002. Cathy J. Wendt and Hollis H. Allen. Wisconsin Valley Improvement Co., Wausau, Wisconsin.

Soil Bioengineering Measures for Hill and Slope Stabilization Works With Plants. Florin Florineth and Cristopher Gerstgraser, Institute of Soil Bioengineering and Landscape Construction, University of Agriculture, Forestry and Renewable Natural Resources, Vienna, Austria.

Soil Bioengineering. Rick Grillmayer, Nottawasaga Valley Conservation Authority. Also go to http://collections.ic.gc.ca/streams/tech/S-engineering.html.

Streambank Stabilized Using Natural Bioengineering Solutions. November 2000. Murray McHugh. Also go to www.landandwater.com.

The WES Stream Investigation and Streambank Stabilization Handbook. David S. Biedenharn, Charles M. Elliott, and Chester C. Watson. October 1997.

Use of Riprap in Soil Bioengineering Streambank Protection. Robbin B. Sotir and Nelson R. Nunnally. Robbin B. Sotir & Associates Inc., Marietta, Georgia. Also go to www.sotir.com/pubs/publist/riprap/riprap.html.

Sources of Information Pertaining to Plants

Controlling Erosion Using Vegetation. Access Washington. Department of Ecology. Also go to www.ecy.wa.gov.

Buffer Strips for Riparian Zone Management. January 1991. U.S. Army Corps of Engineers, New England Division, Waltham, Massachusetts.

Manual of Vascular Plants of Northeastern United States and Adjacent Canada. 1991. Henry Gleason and Arthur Cronquist. The New York Botanical Garden, Bronx, New York.

Native Shrubs for Landscaping. 1987. Sally L. Taylor, Glenn D. Dreyer, William A. Niering. The Connecticut Arboretum at Connecticut College, New London, Connecticut. 40 pp.

Native Vegetation for Lakeshores, Streamsides and Wetland Buffers: What you need to know to re-establish or enhance a buffer strip along water and wetland in Vermont. 1994. Vermont Department of Environmental Conservation, Water Quality Division, Waterbury, Vermont. 52 pp.

Sources of Native Plant Materials in Vermont. August 2003. Vermont Department of Environmental Conservation, Water Quality Division, Waterbury, Vermont. 19 pp.

Plant Material Selection and Acquisition. May 2001. Craig Fischenich.

Recommended Trees for Vermont Communities, 2001. Vermont Department of Forests, Parks, and Recreation. Also go to www.vtcommunityforestry.org for additional publications and information.

Tree pamphlets: *Benefits of Trees, Tree Selection, New Tree Planting, Mature Tree Care.* 1991. International Society of Arboriculture. 4 pp ea. Available from the Vermont Department of Forests, Parks, and Recreation.

Wetland, Woodland, Wildland: A Guide to the Natural Communities of Vermont, 2000. Elizabeth Thomson and Eric Sorenson. Published by the Vermont Department of Fish and Wildlife and The Nature Conservancy.

FEMA: National Flood Insurance Program. Go to www.fema.gov/.

Who Provides Assistance

These are the phone numbers and contact information for regional, state and federal officials in the Lake Champlain Basin. All of the sources listed can provide assistance and some may be more knowledgeable about the areas covered in the handbook. All published numbers are as of April 2004.

Vermont and New York Cities and Towns

Starting a conversation on shoreline stabilization with your local municipal officials can be highly beneficial. Vermont and New York Cities and Towns can provide assistance and direction regarding permitting, town regulations, shoreline construction, and questions about Lake Champlain and the other bodies of water in their areas of jurisdiction. They may also be able to recommend additional sources of information.

County-Based Planning Organizations

Vermont Regional Planning Commissions and New York County Planning Offices can provide assistance in planning programs related to Lake Champlain, grants and funding, acquiring local and regional maps, and responding to questions about local, state, and federal regulations. New York Planning Offices can provide assistance and direction regarding county regulations and permitting of shoreline construction projects.

Vermont Regional Planning Commissions

Addison County Regional Planning Commission (802) 388-3141, www.acrpc.org.

Chittenden County Regional Planning Commission (802) 846-4490, www.ccrpcvt.org.

Northwest Regional Planning Commission (802) 524-5958, www.nrpcvt.com.

Rutland Regional Planning Commission (802) 775-0871, www.rutlandrpc.org.

New York County Planning Offices

Clinton County Planning Office (518) 565-4711 or (518) 565-4709

Essex County Planning Office (518) 873-3685

Washington County Planning Office (518) 746-2290

Vermont Agency of Natural Resources Regional Offices

Vermont Agency of Natural Resources regional offices can provide assistance in permitting, regulations, shoreline construction projects, and other areas relating to natural resources in Vermont.

Franklin, Chittenden, Grand Isle, and Addison Counties

Agency of Natural Resources Office
(802) 879-5656

Act 250 Information (802) 879-5614

Contacts

- *Permit Specialist*
- *Chittenden County Coordinator*
- *Franklin, Grand Isle and Addison County Coordinator*
- *Regional Engineer*
- *Assistant Regional Engineers*

Address
111 West St.
Essex Junction, Vermont 05452

Rutland County

Permit Specialist (802) 786-5907

Agency of Natural Resources Office
(802) 786-5920

Act 250 Information (802) 786-5920

Contacts

- *Rutland County Coordinator*
- *Regional Engineer*
- *Assistant Regional Engineers*

Address
Asa Bloomer State Office Building
Rutland, Vermont 05701-5903

Vermont Department of Environmental Conservation, Water Quality Division

The Department of Environmental Conservation (Water Quality Division) can provide assistance in lake watershed and shoreland management, plant identification, and native and exotic aquatic plant species. The Department also provides assistance through its wetlands, rivers, dams, and stormwater programs.

www.vtwaterquality.org.

Lakes & Ponds Management/Protection Section
(802) 241-3777

Wetlands Section
(802) 241-3754

Chittenden County
District Wetlands Ecologist, (802) 241-1418

Addison & Rutland Counties
District Wetlands Ecologist, (802) 241-3761

New York State Department of Environmental Conservation and Adirondack Park Agency

The New York State Department of Environmental Conservation and the Adirondack Park Agency can provide assistance in lake watershed management and land use management, plant identification, native and rare aquatic plant species, wildlife habitat, permitting, wetland evaluation and protection, and about the laws and regulations in New York State. The Adirondack Park Agency has authority only within the Adirondack Park.

Division of Environmental Permits, Region 5

Raybrook Office

Contacts
Regional Permit Administrator, (518) 897-1234
Deputy Regional Permit Administrator,
(518) 897-1234

Address
NYS Dept. of Environmental Conservation
Route 86
P.O. Box 296, Raybrook, NY 12885-0296

Division of Environmental Permits, Region 5

Warrensburg Office

Contact
Deputy Regional Permit Administrator,
(518) 623-1281

Address
NYS Dept. of Environmental Conservation
County Route 40
P.O. Box 220, Warrensburg, NY 12885-0220

Adirondack Park Agency

Contact
Division of Regulatory Programs,
(518) 891-4050

www.northnet.org/adirondackparkagency

Address
Division of Regulatory Programs
P.O. Box 99
Ray Brook, New York 12977

U.S. Army Corps of Engineers

The U.S. Army Corps of Engineers issues permits and can answer technical questions regarding shoreline construction projects.

Vermont Project Office

Contact
Senior Project Manager, (802) 872-2893
Project Manager, (802) 872-2893

Address
Vermont Project Office
U.S. Army Corps of Engineers
8 Carmichael Street, Suite 205
Essex Junction, VT 05452

New York District Office

Contact
(212) 264-0185
www.nan.usace.army.mil

Address
U.S. Army Corps of Engineers
Attn: Regulatory Branch—Room 1937
26 Federal Plaza
New York, NY 10278-0090

Soil and Water Conservation Districts

The Soil and Water Conservation Districts provide assistance on issues relating to erosion control, water quality, wildlife habitat, and land use management.

Clinton County

Office (518) 561-4616 ext. 3

Contacts
- *District Manager*
- *District Conservationist*
- *Soil Conservation Technician*

Address
6064 Route 22, Suite 1
Plattsburgh, New York 12901

Essex County

Office (518) 962-8225

Contacts
- *District Field Manager*
- *District Office Manager*
- *Lake Champlain Water Quality Specialist*

Address
Cornell Cooperative Extension Center
P.O. Box 407
Westport, New York 12993

Washington County

Office (518) 692-9940 ext. 3

Contacts
- *District Manager*
- *Office Manager*
- *District Technician*

Address
USDA Service Center
2530 State Route 40
Greenwich, New York 12834-9627

Natural Resources Conservation Service

The Natural Resources Conservation Service provides assistance on issues relating to erosion control, water quality, and land use management. They also may provide assistance relating to project funding.

Vermont Service Centers

St. Albans (802) 527-1296
27 Fisher Road

Williston (802) 879-4785
600 Blair Park Rd., Suite 280

Berlin (802) 828-4493
617 Comstock Rd, Suite 1

Middlebury (802) 388-6748
68 Catamount Park

White River Jct. (802) 295-7942
28 Farm View Dr.

Rutland (802) 775-8034
170 S. Main St.

Vermont Natural Resources Conservation Districts

The Vermont Natural Resources Conservation Districts provide assistance in wetland conservation and restoration, wildlife habitat, aquatic habitat, land management, and other areas related to land conservation.

Franklin County NRCD (802) 524-6505

Grand Isle NRCD (802) 864-0223

Rutland NRCD (802) 775-7192

Winooski NRCD (802) 872-2861

Flood Insurance

FEMA
www.fema.gov
1-877-FEMA-MAP

Flood Insurance Agency
www.floodinsuranceagency.com

Glossary

Armor: The outer layer of material, usually heavy stone, of a control structure exposed to direct wave action.

Bank: The rising ground bordering the sea, river, or lake.

Beach: The zone of unconsolidated material that extends landward from the low water line to the place where there is marked change in material or physiographic form, or the line of permanent vegetation.

Bedrock: A general term for the rock, usually solid, that underlies soil or other unconsolidated, surface material.

Bioengineering: The use of live plants and plant material to reinforce soil, serve as water drains, act as erosion prevention barriers, and promote water drainage in wet soils.

Biotechnical: The use of both live plant material and inert structures to stabilize and reinforce slopes.

Bluff: An unvegetated high bank composed largely of unconsolidated deposits with a near-vertical face overlooking a body of water.

Bluff Crest: Upper edge or margin of a shoreline bluff.

Bluff Face: The sloping portion of a high bank.

Bluff Toe: The base of a bluff where it meets the beach.

Riparian Buffer: A protective strip of vegetated land.

Clear-cut: A timber harvest method that removes all the trees on an area in one operation.

Cliff: A high, very steep to perpendicular or overhanging face of rock rising above the shore.

Downdrift: The direction of predominant movement of coastal materials by currents.

Drainage (soil): The rapidity and extent of the removal of water from the soil by surface runoff and by down-draw flow through the soil.

Erosion: The wearing away of rock or soil and the resulting movement of particles by wind, water, ice, or gravity.

Fetch: A continuous length of water over which winds blow in one direction.

Flow: A mass movement involving rapid flowage of wet soil, rock, and displaced vegetation as a viscous mass down a slope or a channel; including mudflow, debris flow, and earth flow.

Geomorphology: The study of the characteristics, origin, and development of landforms.

Gully: Large intermittent drainage channel developed from the erosion forces of drainages occurring from surface water runoff.

Impermeable: Having a texture that does not permit fluids to move through it freely.

Infiltration: The movement of water or solutions into or through a rock or soil through its cracks or fractures; the flow of rainwater into soil material.

Joint: A crack formed in rock by movements normal to the cracks and without shear movements of the rock on either side of the crack.

Mass Movement: Movement of a portion of land surface down a slope as a slide, a flow, or soil creep in which gravity is the main driving force.

Natural Landscape Elements: The natural watercourses, topography, hydrology, and vegetation that comprise a particular site.

Percent Slope: The direct ratio (multiplied by 100) between the vertical and the horizontal distance for a given slope; e.g., a 3-foot rise in a 10-foot horizontal distance would be a 30 percent slope.

Rill: A tiny drainage channel cut in a slope by the flow of water. Can develop into a gully with continuing erosion.

Runoff: That part of the precipitation that appears in uncontrolled surface streams, drains, or sewers. It is stream flow unaffected by artificial diversion, imports, storage, or other works in or on the stream channels.

Saturated: A condition in which the joints of a material are filled with a liquid, usually water.

Shoreline: The intersection of a specified plane or water with the beach. It migrates with changes of the water level.

Slide: A mass movement resulting from failure of soil or rock along a rotational or planar surface.

Slope: The inclination of the land surface from the horizontal percentage of slope. It is the vertical distance divided by the horizontal distance and multiplied by 100.

Moderate Slope: Considered to be a slope that is 45 degrees (1:1) or less.

Steep Slope: Considered to be a slope that is greater than 45 degrees.

Slump: A slide characterized by a rotary movement of a generally independent mass of rock or earth along a curved slip surface.

Soil: The loose surface material capable of supporting plant growth, and having properties resulting from the integrated effect of climate and living matter on the decomposition of bedrock and surficial surface deposits.

Soil Creep: The gradual and steady downhill movement of soil and loose rock material on a slope.

Till: Poorly sorted and generally unstratified sediments, deposited directly by and underneath a glacier.

Toe of Slope: A break in the slope at the foot of a bank.

Unconsolidated: Sediment where particles are loose and not cemented together.

Upland: A general term for elevated land above the beach that lies above the extreme high water level.

Wetlands: Lands where the water table is near or at the surface most of the year. Aquatic vegetation, such as cattails, is typical. Lands such as marshes and swamps are typical wetlands.

Index

Note: Italicized page locators refer to figures/tables.

F

G

H

I

J

L

M

N

O

P

R

S

Northwest Regional Planning Commission

7 Lake Street, Suite 201
St. Albans, VT 05478

Tel: (802) 524-5958

Email: nrpcvt@nrpcvt.com