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**Case Study 14**

**Streambank Stabilization in the  
Merrimack River Basin,  
New Hampshire**

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**Cover photo:** Completed section of Merrimack River in New Hampshire

### **Advisory Note**

Techniques and approaches contained in this handbook are not all-inclusive, nor universally applicable. Designing stream restorations requires appropriate training and experience, especially to identify conditions where various approaches, tools, and techniques are most applicable, as well as their limitations for design. Note also that product names are included only to show type and availability and do not constitute endorsement for their specific use.

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## Case Study 14

# Streambank Stabilization in the Merrimack River Basin, New Hampshire

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## Problem

The Intervale Country Club (ICC), a 9-hole golf club open to the public, celebrated its 100th anniversary in 2003. The original course was constructed in 1903 by the U.S. Army Corps of Engineers (USACE). Two fairways (6 and 9) abut the river. The course has maintained a cart path along the river bank in the past. Senior club members recall the time when they could have driven the carts on the river side of large pines that now stand at the edge of the bank. Some members of the ICC estimate that 15 to 20 feet of shoreline have been lost over the past 20 years.

The Merrimack River flows 115 miles across central New Hampshire and through eastern Massachusetts where it enters the Atlantic Ocean at Newburyport. The Merrimack River Watershed is more than 5,000 square miles in size.

Over the years, the lake-like section of the river has become both a popular place for building homes and for recreation. Today, boat waves are the main cause for bank destabilization. The waves easily detach exposed soils at the toe of slopes, causing undercutting and mass wasting. The soils are predominately medium to fine sands with very little cohesive strength, once exposed.

Property loss along this reach of the river is due to flooding, ice scouring, and mass wasting of large trees. However, most of the instability problems along this reach are caused by people. Many stabilization methods (concrete walls) have resulted in flows redirected to the downstream neighbor. Many approaches to bank stabilization have been used over the years, as bank erosion has increased due to increased boating activity, as well as development in general.

## Solution

Bank stabilization using concrete walls was common prior to 1980. In the 1970s and 1980s, riprap covering the entire height of the slope was a common practice,

and in the 1990s, a combination of riprap along the bottom half of the slope and vegetative stabilization along the top was used. ICC used a similar riprap and vegetative stabilization in 1997.

Broad support for the project came from the local, state and Federal levels. Securing project permit requirements was actually ahead of schedule until the site had a positive hit for an endangered species—Bald Eagles. Because of the open water generally associated with this section of the river and sections further south on the river, the Bald Eagle has used this area for winter roosting. The project team coordinated site walks with New Hampshire Fish and Game and contracted with New Hampshire Audubon to provide assistance in how best to construct the project and not interfere with the Bald Eagles. The final solution was that New Hampshire Fish and Game had to approve the cutting of any tree more than 6 inches in diameter on the site. In addition, work could not be done from November 15 to April 15 of the following year.

This decision had two effects on the project. First, to the use of dormant cuttings and brush layering was precluded because the site could not be constructed during the dormant season. Secondly, the limitation on tree cutting increased construction time because the contractor would have to walk the excavator back and forth from the bank to place materials.

The site was divided into two phases. Phase I was the 6th fairway, consisting of 1,000 linear feet of shoreline. Phase II, not yet constructed, is the 9th fairway and is approximately 1,400 feet long.

## Design

To preserve the trees on site, a concept of construction from the riverside was evaluated. The riverbed adjacent to the project provided a 12-foot-wide (4 m) shelf before dropping off at a steeper angle. The use of a Portadam<sup>®</sup> system or water dam barrier was investigated. This option was not utilized, however, as the contractor was able to complete the project from the top of the bank with selective tree cutting.

Preliminary design analysis provided three distinct facts for slope stability along this stretch of the river:

- The angle of repose of the natural slopes could be very steep and still be stable. Visual evidence showed slopes of 1H:1V and steeper as being stable provided that the toe of the slope was not undercut. The parameter for the stability analysis was limited to site observation. The native soil used in the analysis was a silty sand.
- The main cause of the toe scour was boat waves. Even at high water elevation, water moved by the site at a fairly slow velocity.

Although ice damage is not a major concern for this section of the river, significant ice has formed along the river in the past.

- The river has a normal flow between 3,000 and 7,000 cubic feet per second. Low flow is less than 1,000 cubic feet per second, while flood stage occurs at greater than 31,000 cubic feet per second. The historic recorded discharge of 150,000 cubic feet per second for the river occurred during a 1936 hurricane.

## Design stability analysis

Analysis was performed to verify the bank's slope stability and erosion resistance. The slope stability analysis was conducted using MacStars 2000™, a software package using the Bishop Simplified Method (Bishop 1955) to determine the global and internal stability. The slope stability analysis determined the impact of the root system after installation and establishment of vegetation.

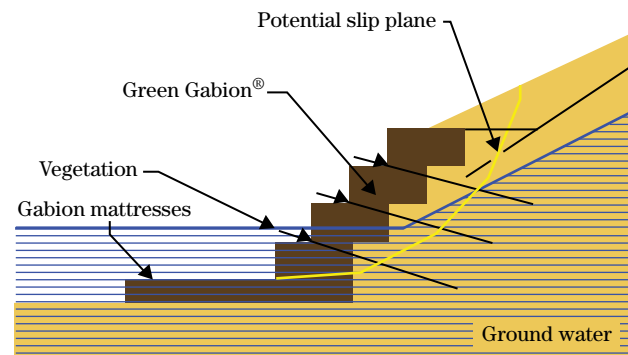
The slope stability analysis, done immediately after installation, resulted in a safety factor of 1.55 for global stability and 4.02 for internal stability (fig. CS14-1). The impact of the vegetation on slope stability was determined based on measured shear resistance of willow roots. The shear resistance of a 3-year-old willow can have an ultimate shear stress of 9.1 kilonewtons per square meter ( $\text{kN/m}^2$ ) ( $191 \text{ lb/ft}^2$ ) (Goldsmith 1996). The reinforcing root length was considered to be 2 meters (6 ft) deep. To represent the root reinforcement in the structure, the density of the vegetation was considered at 30 centimeters (1 ft) spacing between each plant for each row of units.

The analysis of the impact of vegetation on slope stability was performed using the shear resistance of a willow after 3 years of growth. A reduction factor of 3 was applied to the ultimate strength to represent the uncertainties of the growing vegetation. A shear resistance of 3.0 kilonewtons per square meter ( $63 \text{ lb/ft}^2$ ) was used in the calculation. With the contribution of the vegetation, the internal stability of the structure (fig. CS14-1) gave a safety factor of 4.55 and a global safety factor of 1.55. The internal stability of the slope may increase 10 percent after the establishment of the vegetation. This last analysis was considered as information only and not for the design stability analysis. The global stability was not affected because the potential slip plane did not pass through the vegetation.

The material's erosion resistance was verified using MACRA 1™ software by Maccaferri. The analysis was performed to verify the resistance of erosion immediately after installation of the structure and after 3 years of vegetation establishment. The gabion revetment has a shear resistance of 336 newtons per square meter ( $\text{N/m}^2$ ) ( $7.0 \text{ lb/ft}^2$ ) without vegetation and 450 newtons per square meter ( $9.4 \text{ lb/ft}^2$ ) with vegetation established.

The safety factor for erosion was calculated to be 9.9. Wave action from boats and potential ice gouging were not considered due to the limited budget for design analysis. Maccaferri literature shows that a gabion revetment can resist wave action up to 1.7 meters high (5.5 ft) on a slope of 1H:1.5V. Wave height due to boat traffic on the Merrimack River is estimated at 1 meter

**Figure CS14-1** Slope stability analysis of design



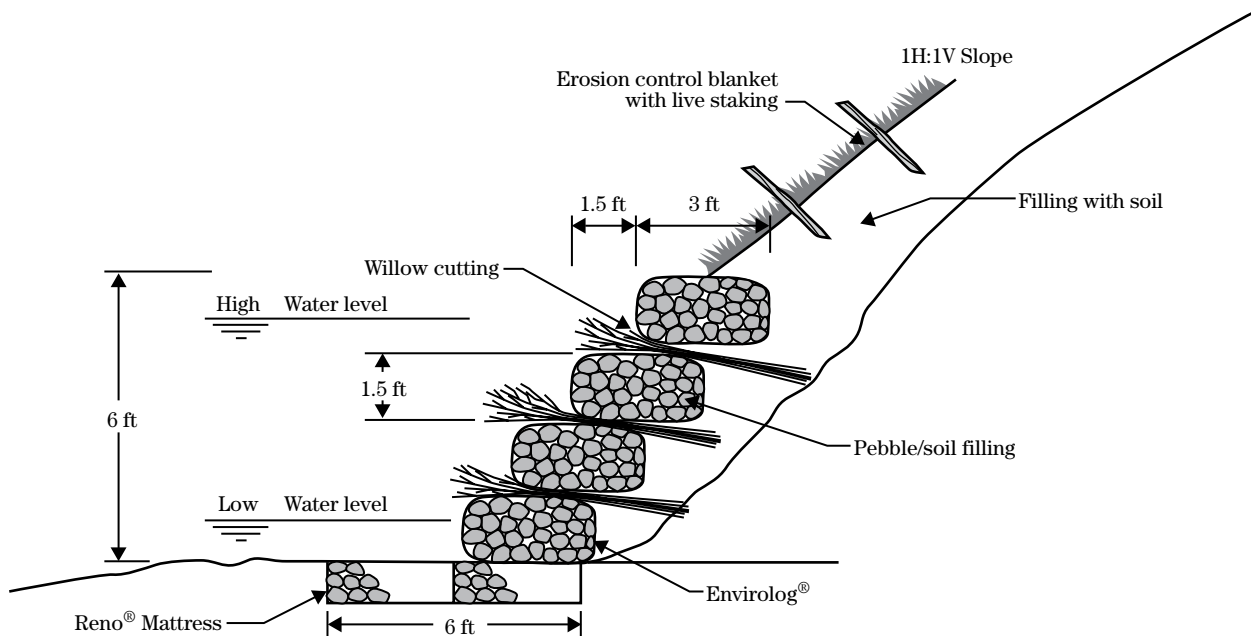
(3 ft), which is less than the maximum wave action allowed for stability.

Ice impacts can be analyzed best using scale models for laboratory testing. It was decided that this type of analysis would be too expensive. Additionally, ice has not been a problem in this reach of the Merrimack River for the past few years. The probability of local damage by ice impact was determined to be very

limited based on the experience of the manufacturer and because of the added protection afforded by the vegetation on the external face of the gabion units.

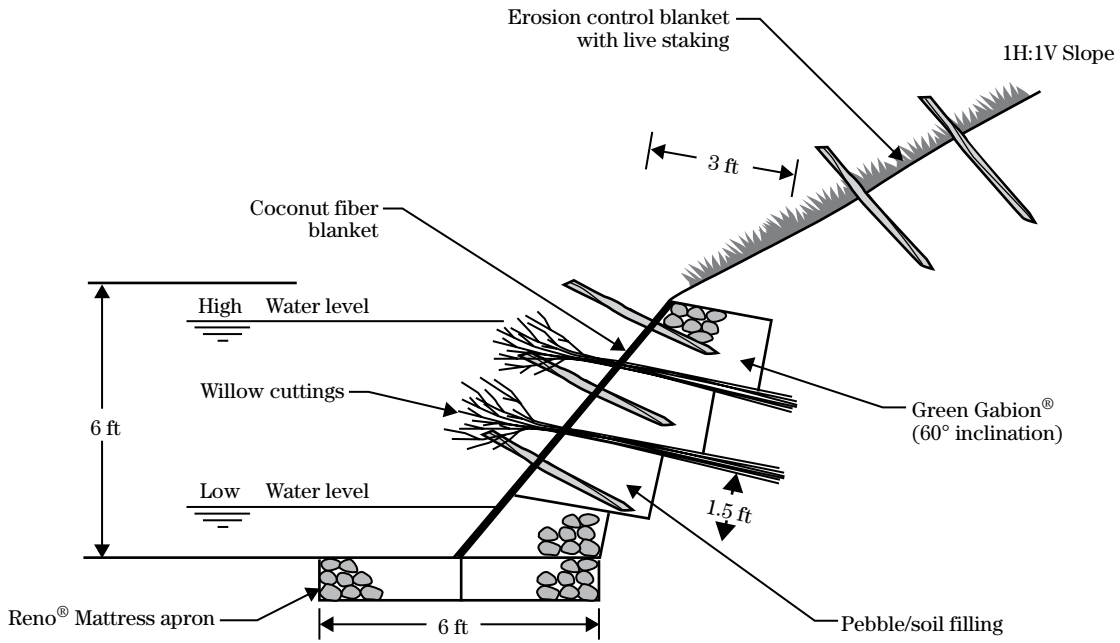
To prevent any potential scour under the structure, a Reno<sup>®</sup> Mattress of 30 centimeters (12 in) by 1.9 meters (6 ft) was installed at the base of the units, with an extension of 1 meter (3 ft) streamward to stop any erosion (figs. CS14-2 and CS14-3).

**Figure CS14-2** Reno<sup>®</sup> Mattress, gabions, and vegetation form a stable streambank design



**Typical cross section**

**Figure CS14-3** Reno<sup>®</sup> Mattress used with vegetation to create a stable slope



## Material selection

The selection of appropriate materials was very important to the environmental aspects of this project so that the final installation would be integrated into the surrounding environment. Two new types of products were selected that offer strength, resistance, and natural integration. Green Gabion<sup>®</sup> (fig. CS14-4) is a trapezoidal-type of gabion with an inclination angle of 60°, lined with 900 grams per square meter (26.5 oz/yd<sup>2</sup>) coconut mat in the facing. The unit is 2 meters (6.5 ft) long, 1 meter (3.25 ft) wide, and 0.5 meter (19 in) high. Envirolog<sup>®</sup> is a cylindrical type of gabion lined with 900 grams per square meter (26.5 oz/yd<sup>2</sup>) coconut mat. Both types of product used in this project are made of PVC-coated woven wire mesh. To ensure durability of the structure, all wire is galvanized and PVC-coated before being transformed in mesh. The flexibility and strength of the double-twisted mesh are very important. The flexibility of the mesh allows the units to adapt to the profile of the bank even after any subsequent settlement.

The voids of a gabion structure (30 to 40%) are filled with topsoil. The topsoil helps to retain the moisture in the structure to promote growth of the vegetation and also acts as a substrate for the propagation of the root

system between the stones. This forms a strong interlocking with stone and wire and roots.

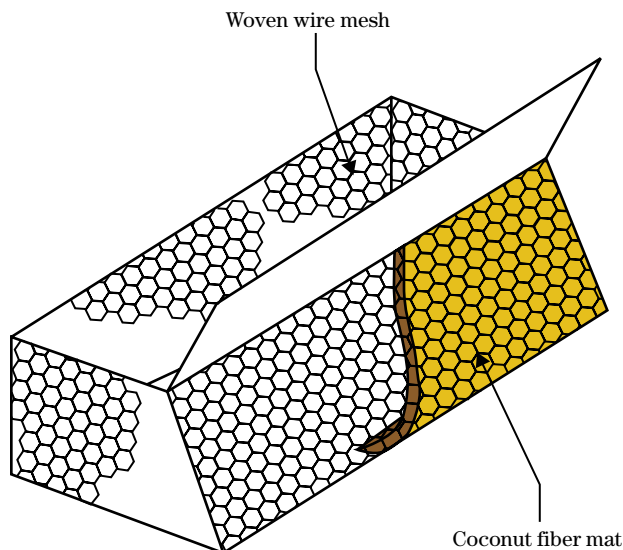
To retain the topsoil in the units for vegetation, a thick layer of coconut mat is lined inside the wire mesh basket (figs. CS14-4 and CS14-5).

The coconut mat, with a durability of 3 to 5 years before its biodegradation, helps to maintain the topsoil's moisture for the vegetation.

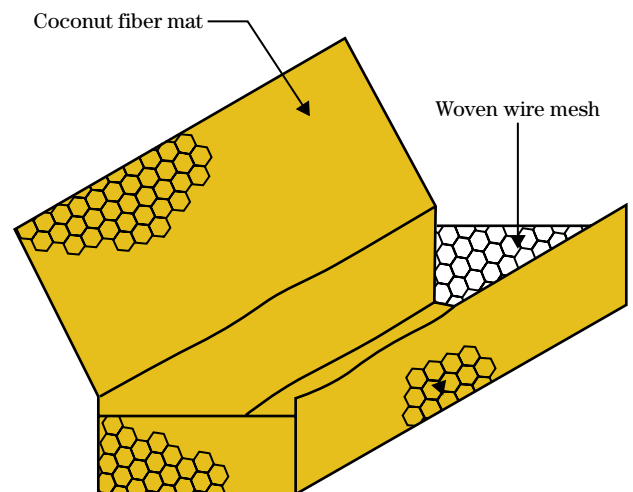
## Assembly and installation

Construction on the site began in June 2002. Don Wheeler Construction of Bedford, New Hampshire, was the contractor. Work began with cutting the approved trees, clearing an upper work area, and creating a temporary tee so the 6th fairway could still be used during the summer. Work was completed in September 2002. The project schedule was extended for numerous reasons including the very tight labor market at the time of construction. Ideally, this type of project works best with a six-person crew; however, there were times when only two workers were available for the project.

**Figure CS14-4** Green Gabion<sup>®</sup> schematic



**Figure CS14-5** Coconut fiber was used to line gabion baskets to retain soil for vegetation growth.



Because of the timing of the project, the original concept of dormant cutting was abandoned in favor of potted willow and dogwood shrubs. The revised specification called for one 1-gallon shrub per linear foot of lift, totaling approximately 4,000 shrubs.

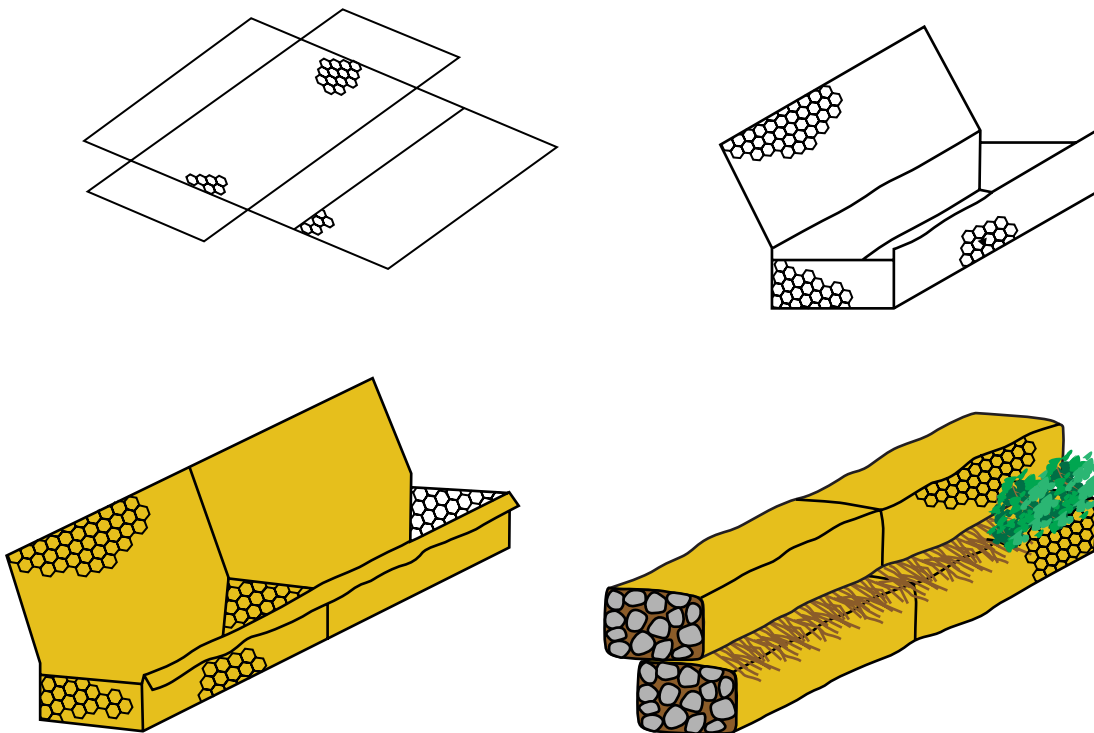
The units were preassembled as a box and lined with the coconut mat before being placed on the site (figs. CS14-6 and CS14-7).

The coconut mat was secured to the wire mesh using lacing wire. The units were placed side by side and connected together with the adjacent units and with

the upper and lower baskets. Between each row, willows and dogwood shrubs were placed at an interval of 30 centimeters (1 ft).

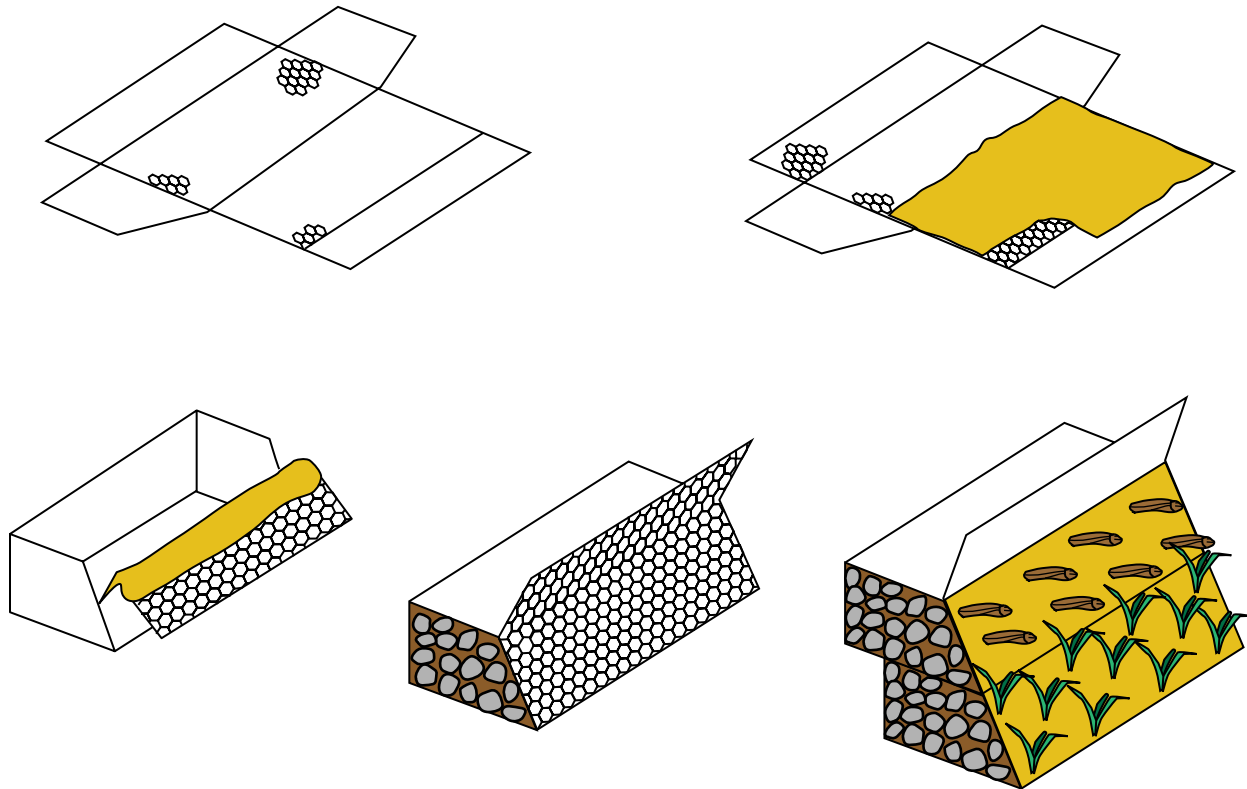
After being placed and secured together, the units were filled with stone and topsoil (fig. CS14-8). The lower sections, which are more exposed to the wave action, first were filled with stone followed by topsoil to fill the voids. Filled in this way, the bottom units were getting a higher percentage of stone to prevent loss of topsoil with time. The upper section was filled with stone and topsoil already mixed together before being placed in the units.

**Figure CS14-6** Green Gabions® preassembled with coir fiber mat





**Figure CS14-7** Green Gabions® preassembled with coir fiber mat



**Figure CS14-8** Installed gabion baskets lined with coconut fiber mat and filled with stone and topsoil



## Conclusion and recommendations

In general, the project work was done as per the specification for the assembly and installation of the units. Because of the limited budget, a full-time inspector on the project was not possible. Some small problems could have been prevented with an inspector on the site, considering that the contractor did not have a lot of experience with gabions. In particular, there was a problem with the size of the stone being too small in the Reno<sup>®</sup> Mattresses used for toe protection. Some stones have already come out of the mattress after 1 year. These mattresses should be opened and refilled with proper sized stone.

After only one growing season, the vegetation is generally well established where it was planted. Some areas

where the plants were too small or not properly placed during the installation have some problems with establishment in the structure. Figures CS14-9 and CS14-10 show the progression of the growth of vegetation. Figure CS14-9 was taken in the spring, and figure CS14-10 in the midsummer of the first growing season. The modified gabions used on this project combined with thick coconut blanket can resist erosion for 3 to 5 years before seeing any degradation of the coconut blanket. Live staking was recommended by the designer to enhance vegetation where it was missing.

In general, the project is a success considering that few repairs or follow up will be necessary. The landowner now has a stabilized bank, and this green solution can certainly be applied elsewhere along the Merrimack River to fix eroding streambanks.

**Figure CS14-9** Project in spring after initial installation



**Figure CS14-10** Completed project in midsummer after installation

