




# Stream Restoration

## A Natural Channel Design Handbook

**Prepared by the North Carolina Stream Restoration Institute and North Carolina Sea Grant**

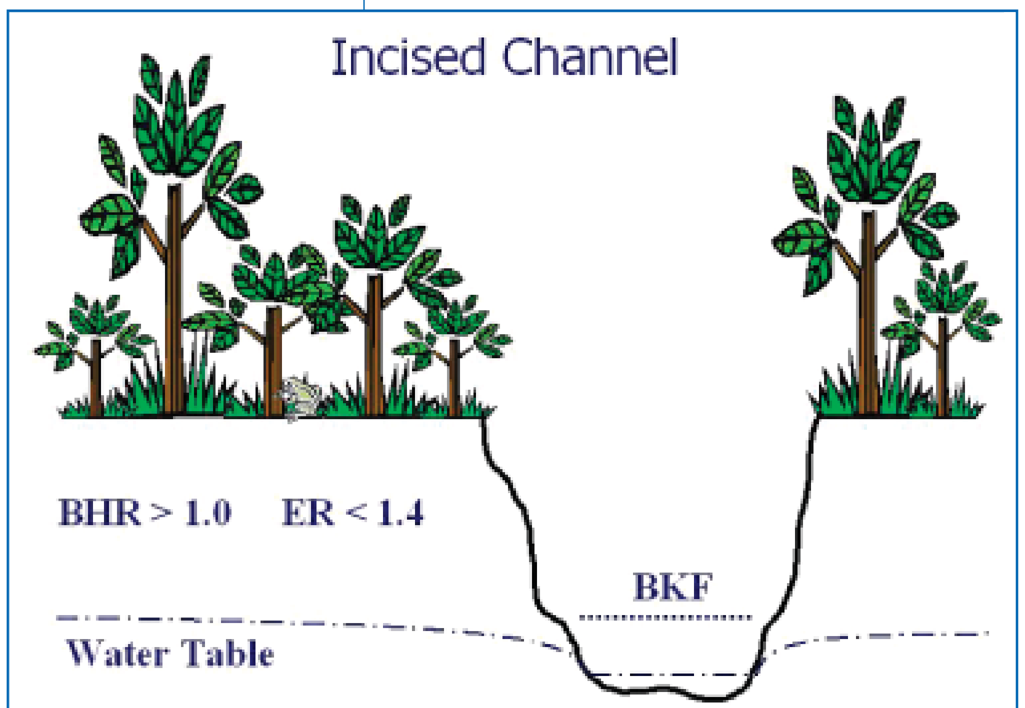
# Chapter 5: **Priority Options for Restoring Incised Streams**

Incision of stream channels is caused by straightening of channels, loss of riparian buffers, changes in watershed land-use or changes in sediment supply. Because incised streams typically are unstable and function poorly, they are good candidates for stream-restoration projects. Rosgen (1997) presents four priority options for restoring incised channels. This chapter describes those four options—with the first priority being the most preferred and the last being the least optimal.

An incised stream has a bank height ratio greater than 1.0 ft/ft, meaning that the bankfull stage is at a lower elevation than the top of either streambank (*Figure 5.1*). Severely incised streams with bank height ratios greater than 1.8 ft/ft are usually classified as Rosgen stream types G or F. Shear stress at high flows in these streams may become very high, increasing the potential for streambank erosion and/or streambed down-cutting. Moderately incised streams with bank height ratios between 1.4 and 1.8 ft/ft may be classified as Rosgen stream types E, C or B, but they are at increased risk of instability. Slightly incised streams with bank height ratios between 1.1 and 1.3 ft/ft are often stable; however, they may become unstable if land use in the watershed changes or riparian buffers disappear.

*Figure 5.1*

Cross section of an incised channel




Designers should consider each restoration option in priority order before settling on a final design. The options are described in the following sections and compared in Table 5.1. This chapter also discusses several recent North Carolina case studies that illustrate the application of these restoration approaches.

### 5.1 Priority 1:
### Establish Bankfull Stage at the Historical Floodplain Elevation.

The objective of a Priority 1 project is to replace the incised channel with a new, stable stream at a higher elevation. This is accomplished by excavating a new channel with the appropriate dimension, pattern and profile (based on reference-reach data) to fit the watershed and valley type (*Figure 5.2*). The new channel is typically an E or C stream with bankfull stage located at the ground surface of the original floodplain. The increase in streambed elevation also will raise the water table, in many cases restoring or enhancing wetland conditions in the floodplain.

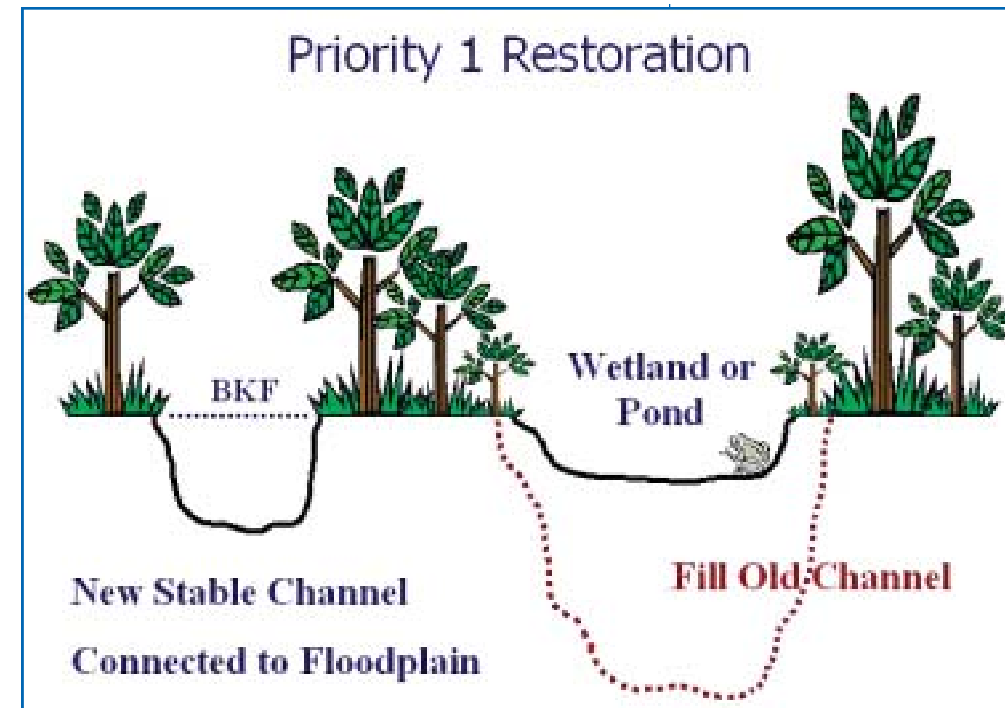



*Figure 5.2*

Cross section of a Priority 1 restoration project

If designed and constructed properly, a Priority 1 project produces the most long-term stable stream system. It may also be the least expensive and simplest to construct depending on surrounding land-use constraints. Priority 1 projects usually can be constructed in dry conditions while stream flow continues in its original incised channel. The new channel can be stabilized with structures and bank vegetation before water is directed into the new stream. A special consideration with Priority 1 projects is the unbalanced cut/fill requirements. Typically, the amount of soil excavated in constructing the new channel will be much less than that required to completely fill the existing incised channel. The designer has the option of bringing additional fill to the site or creating floodplain ponds and/or wetlands to support habitat and recreation.

Surrounding land uses can limit the use of a Priority 1 approach if there are concerns about increased flooding or widening of the stream corridor. Most Priority 1 projects will result in higher flood stages above bankfull discharge in the immediate vicinity of the project and possibly downstream. The Priority 1 approach also requires sufficient land area on one or both sides of the existing incised stream to construct the new meandering channel on the floodplain. It also may be necessary to raise the existing channel at the beginning of the project reach and/or lower the new channel at the end of the project reach to connect with the existing channel.

### 5.2 Priority 2:
### Create a New Floodplain and Stream Pattern with the Stream Bed Remaining at the Present Elevation.

The objective of a Priority 2 project is to create a new, stable stream and floodplain at the existing channel-bed elevation. This is accomplished by excavating a new floodplain and stream channel at the elevation of the existing incised stream (*Figure 5.3*). The new channel is designed with the appropriate dimension, pattern and profile (based on reference-reach data) to fit the

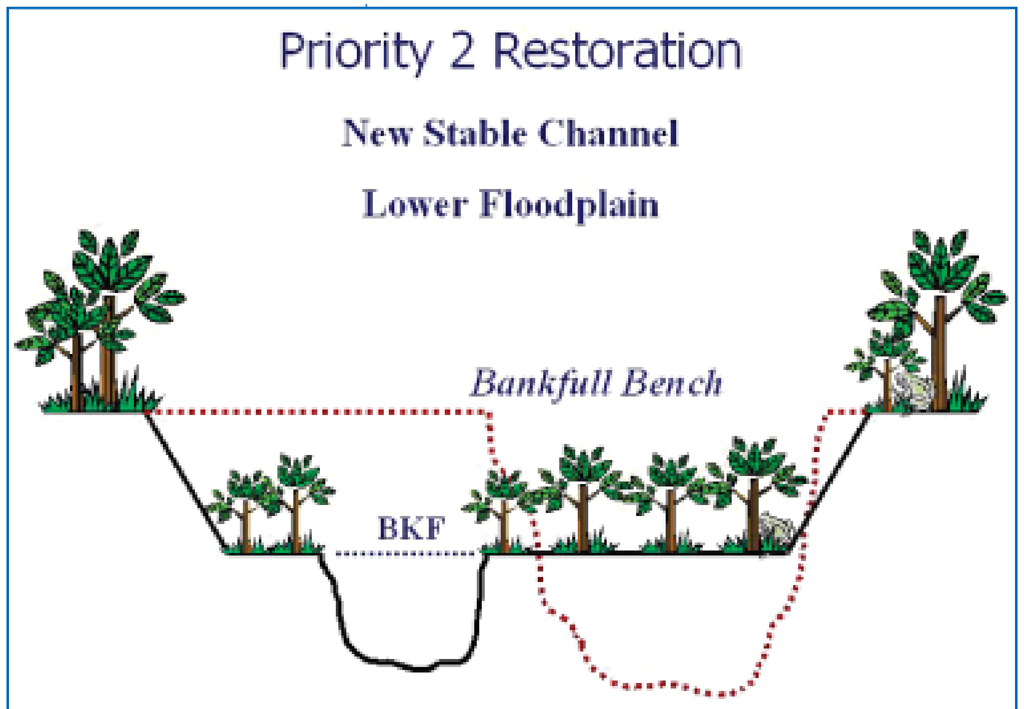



*Figure 5.3*

Cross section of a Priority 2 restoration project

watershed. The new channel is typically an E or C stream with bankfull stage located at the elevation of the newly excavated floodplain.

A Priority 2 project can produce a stream system with long-term stability if designed and constructed properly. It may be more expensive and complex to construct than a Priority 1 project, depending on valley conditions. Priority 2 projects usually can be constructed in dry conditions while stream flow continues in its original channel or is diverted around the construction site. Typically, water is diverted into the new channel as soon as all or part of it is constructed and stabilized with structures and temporary bank-protection measures. Because the new floodplain is excavated at a lower elevation, Priority 2 projects do not increase—and may decrease—the potential for flooding. Also, the stream corridor created by the excavated floodplain may enhance riparian wetlands.

Unlike Priority 1 projects, which are normally short on material to fill the old channel, Priority 2 projects typically produce a surplus of cut material. Designers must consider the expense and logistics of managing extra soil material excavated from the


*Figure 5.4*

Cross section of a Priority 3 restoration project



floodplain. The designer may elect to raise the bed of the stream slightly in an attempt to balance cut and fill. Further, surrounding land uses can limit the use of a Priority 2 approach if there are concerns about widening of the stream corridor. This approach requires sufficient land area on one or both sides of the existing incised stream to construct the new floodplain and meandering channel.

### 5.3 Priority 3: Widen the Floodplain at the Existing Bankfull Elevation.

Priority 3 is similar to Priority 2 in its objective to widen the floodplain at the existing channel elevation to reduce shear stress. This is accomplished by excavating a floodplain bench on one or both sides of the existing stream channel at the elevation of the existing bankfull stage *(Figure 5.4).* The existing channel may be modified to enhance its dimension and profile based on reference-reach data. The resulting channel is typically a B or Bc (low slope) stream with bankfull stage located at the elevation of the newly widened floodplain. Priority 3 projects typically do not increase sinuosity to a large extent because of land constraints.

A Priority 3 project can produce a stream system with long-term stability if it is designed and constructed properly. But it may require more structural measures and maintenance than Priority 1 or 2 projects. It may be more expensive and complex to construct, depending on valley conditions and structure requirements. Priority 3 projects are constructed in wet conditions unless stream flow is diverted around the construction site. These projects typically have little impact on flooding potential unless there are large changes in channel dimension. Priority 3 projects typically do not produce large quantities of extra cut material or require extensive changes to surrounding land uses. They also do not typically affect riparian wetlands or elevation of the water table.

In-stream structures are important to the success of Priority 3 projects. In many projects, a channelized stream must remain in its current location because of surrounding land uses or utilities. The resulting stream may be classified as a B or Bc channel even though the valley conditions support a more meandering E or C channel. In this case, boulder cross-vane structures should be used to protect streambanks, provide grade control and support scour pools for habitat *(see Chapter 8).*

### Section 5.4 Priority 4: Stabilize Existing Streambanks in Place.

Priority 4 projects use various stabilization techniques to armor the bank in place. These projects do not attempt to correct problems with dimension, pattern or profile. Priority 4 projects often use typical engineering practices to harden (armor) one or more streambanks. Projects may use riprap, concrete, gabions, bioengineering or combinations of structures to protect streambanks. Both the upstream and downstream impacts of the project should be carefully evaluated. Because these projects do not correct dimension, pattern and profile, they are likely to continue being susceptible to extreme shear stress, which can erode streambanks in spite of armoring.

A Priority 4 project can stabilize streambanks if designed and constructed properly, but inspection and maintenance may be necessary to ensure long-term success. For these reasons, the long-term cost may be more. Priority 4 projects are constructed in wet conditions unless stream flow is diverted around the construction site. These projects typically have no impact on flooding potential and do not require changes to surrounding land uses. They also do not typically affect riparian wetlands or elevation of the water table.

| Option | Advantages | Disadvantages |
|---|---|---|
| 1 | Results in long-term stable stream<br>Restores optimal habitat values<br>Enhances wetlands by raising water table<br>Minimal excavation required | Increases flooding potential<br>Requires wide stream corridor<br>Unbalanced cut/fill<br>May disturb existing vegetation |
| 2 | Results in long-term stable stream<br>Improves habitat values<br>Enhances wetlands in stream corridor.<br>May decrease flooding potential | Requires wide stream corridor<br>Requires extensive excavation<br>May disturb existing vegetation<br>Possible imbalance in cut/fill |
| 3 | Results in moderately stable stream<br>Improves habitat values<br>May decrease flooding potential<br>Maintains narrow stream corridor | May disturb existing vegetation<br>Does not enhance riparian wetlands<br>Requires structural stabilization measures<br>May require maintenance |
| 4 | May stabilize streambanks<br>Maintains narrow stream corridor<br>May not disturb existing vegetation | Does not reduce shear stress<br>May not improve habitat values<br>May require costly structural measures<br>May require maintenance |

*Table 5.1* Advantages and disadvantages of restoration options for incised streams

## 5.5 Priority 1 Case Study: Yates Mill Pond Tributary

The Yates Mill Pond Tributary project is located in a rural watershed in Wake County just south of Raleigh. The existing intermittent stream was incised due to historic straightening and removal of riparian vegetation. The upstream end of the project reach was not incised, meaning that the new channel could be connected with the existing channel at its current elevation. At the downstream end of the first phase of construction in 2000, the existing channel was six feet below the new streambed elevation. A temporary boulder-drop-structure connected the new and old channels until the second phase of construction was completed in 2002.

Table 5.2 lists physical parameters for the existing and new stream channels. A cross-section survey depicting the existing and as-built stream channels is shown in Figure 5.5. Before and after photos of the project are shown in Figures 5.6 and 5.7. The project design called for constructing a new, stable C5 stream on the floodplain west of the existing channel. All of the construction was completed in dry conditions before water was turned into the new channel. Because the excavated soil didn't completely fill the existing incised channel, several small ponds were created to provide habitat. To help stabilize the new channel, several log vanes and log weirs were installed along the streambank in addition to root wads, transplants and erosion matting.

| Parameter | Existing | Design |
|---|---|---|
| Watershed Area (sq mi) | 0.12 | 0.12 |
| Stream Classification | E6-G5 | C5 |
| Bankfull Cross-Sec Area (sq ft) | 8 | 8 |
| Width/Depth Ratio (ft/ft) | 5-12 | 14 |
| Entrenchment Ratio (ft/ft) | 0.6-4.0 | 15 |
| Bank Height Ratio (ft/ft) | 1.0-3.7 | 1.0 |
| Length (ft) | 750 | 800 |
| Sinuosity (ft/ft) | 1.1 | 1.2 |
| Riparian Buffer Width (ft) | 5-10 | 50-80 |

*Table 5.2.* Parameters of Yates Mill Pond tributary-restoration project



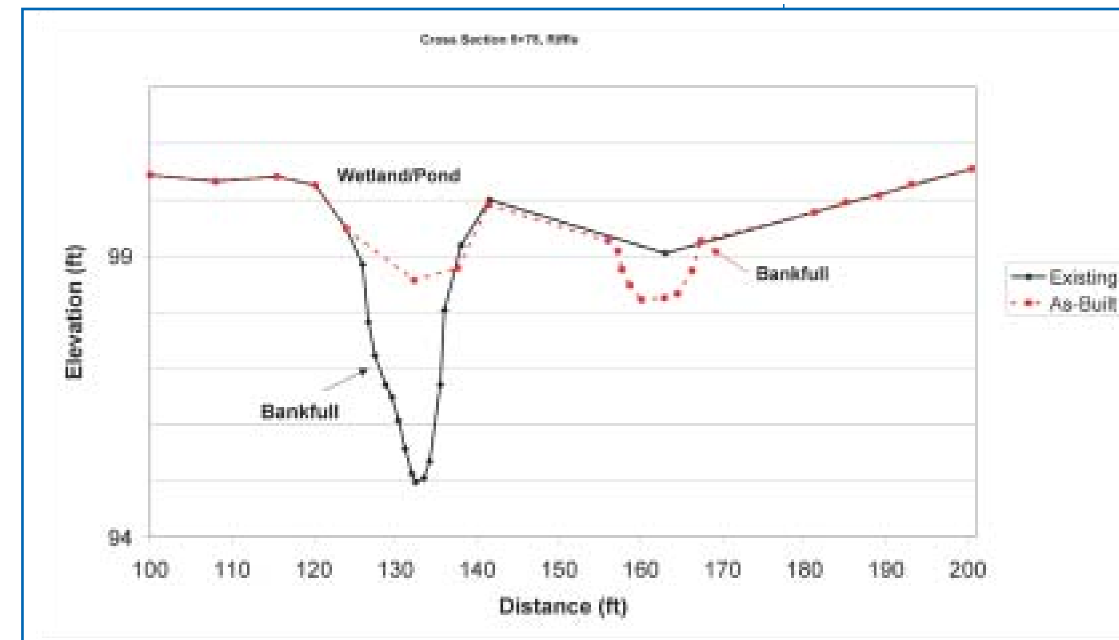



*Figure 5.5*

Cross-section survey of Yates Mill Pond tributary-restoration project

*Figure 5.6*

Yates Mill Pond tributary-restoration project before construction

*Figure 5.7*

Yates Mill Pond tributary-restoration project after construction

## 5.6 Priority 2 Case Study: Pine Valley Golf Course Tributary

The Pine Valley Golf Course tributary project is located in an urban watershed in New Hanover County in Wilmington. The existing perennial stream was incised due to historic ditching and draining for construction of the golf course and surrounding residential community. The upstream end of the project reach was a drainage culvert that prevented a Priority 1 approach. Project constraints included a sewer line along the left streambank, two permanent golf-cart bridges, two irrigation-line crossings and vegetation concerns at three golf holes crossing the stream reach.

| Parameter | Existing | Design |
|---|---|---|
| Watershed Area (sq mi) | 0.5 | 0.5 |
| Stream Classification | F | E |
| Bankfull Cross-Sec Area (sq ft) | 10 | 10 |
| Width/Depth Ratio (ft/ft) | 15 | 10 |
| Entrenchment Ratio (ft/ft) | 1.5 | 5 |
| Bank Height Ratio (ft/ft) | 2 | 1 |
| Length (ft) | 789 | 906 |
| Sinuosity (ft/ft) | 1.04 | 1.2 |
| Riparian Buffer Width (ft) | 10 | 50 |

*Table 5.3* Parameters of Pine Valley Golf Course restoration project

Table 5.3 lists physical parameters for the existing and design stream channels. A cross-section survey depicting the existing and as-built stream channels is shown in Figure 5.8. Before and after photos of the project are shown in figures 5.9 and 5.10. The project design called for constructing a new, stable E5 stream and floodplain at the elevation of the existing channel. Stream flow was diverted through a pump during construction, after which water was turned into the new channel. Because the excavated soil exceeded the amount needed to fill the existing channel, excess soil was hauled to a stockpile area on the golf course property. To help stabilize the new channel, several log cross-vanes and log weirs were installed along the streambank in addition to root wads, transplants and erosion mats.

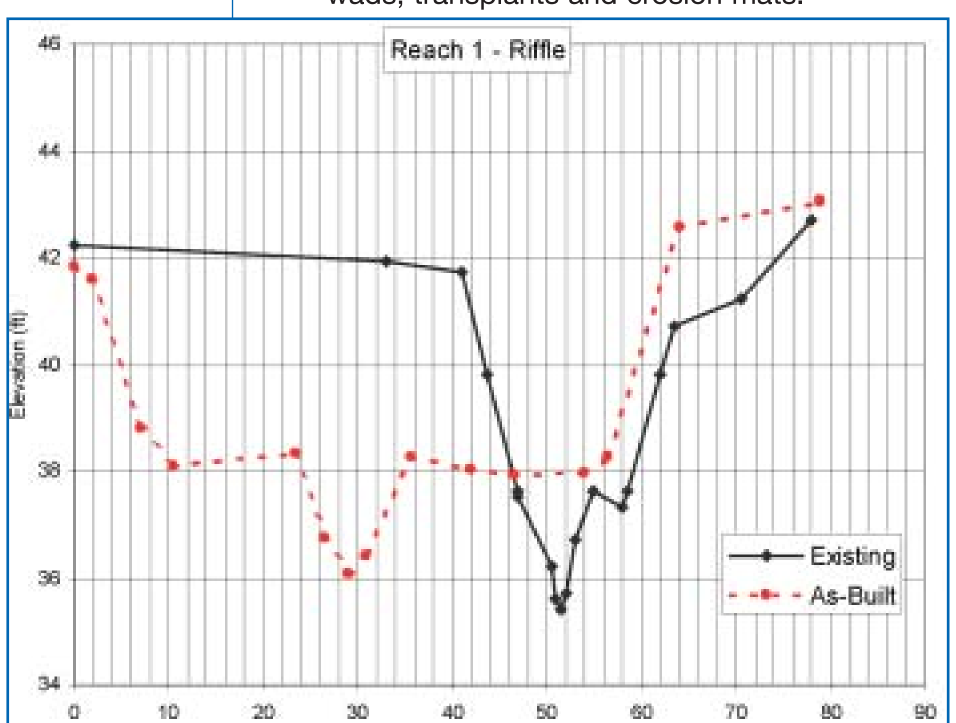



*Figure 5.8*

Cross-section survey of Pine Valley Golf Course restoration project

*Figure 5.9*

Pine Valley Golf Course restoration project before construction

*Figure 5.10*

Pine Valley Golf Course restoration project after construction

## 5.7 Priority 3 Case Study: Cove Creek

The Cove Creek project is located in a rural watershed in Watauga County, west of Boone. The existing perennial stream was incised due to a head-cut advancing from a downstream mill dam that was removed in 1989. The upstream end of the project reach was a bridge that prevented a Priority 1 approach. Adjacent landowners were not able to provide sufficient property to construct a new meandering stream, which ruled out a Priority 2 approach. The resulting project goals were to change stream types from F4 to B4c by excavating floodplain benches and to enhance habitat using in-stream structures.

Table 5.4 lists physical parameters for the existing and design stream channels. A cross-section survey depicting the existing and as-built stream channels is shown in Figure 5.11. Before and after photos of the project are shown in figures 5.12 and 5.13. The project design called for constructing floodplain benches at the bankfull elevation of the existing channel and installing boulder cross-vanes. Construction was completed during low flow. Cross vanes, root wads, transplants and erosion mats were used along the streambank to help stabilize the channel and floodplain.

| Parameter | Existing | Design |
|---|---|---|
| Watershed Area (sq mi) | 15 | 15 |
| Stream Classification | F4 | B4c |
| Bankfull Cross-Sec Area (sq ft) | 175 | 164 |
| Width/Depth Ratio (ft/ft) | 16 | 15 |
| Entrenchment Ratio (ft/ft) | 1.1 | 1.7 |
| Bank Height Ratio (ft/ft) | 2.0-2.2 | 1.0 |
| Length (ft) | 1200 | 1200 |
| Sinuosity (ft/ft) | 1.1 | 1.1 |
| Riparian Buffer Width (ft) | 5-10 | 25-40 |

*Table 5.4.* Parameters of Cove Creek restoration project

## 5.8 Priority 4 Examples

Examples of Priority 4 stabilization and armoring projects are shown in figures 5.14-5.17.

*Figure 5.11*

Cross-section survey of Cove Creek restoration project

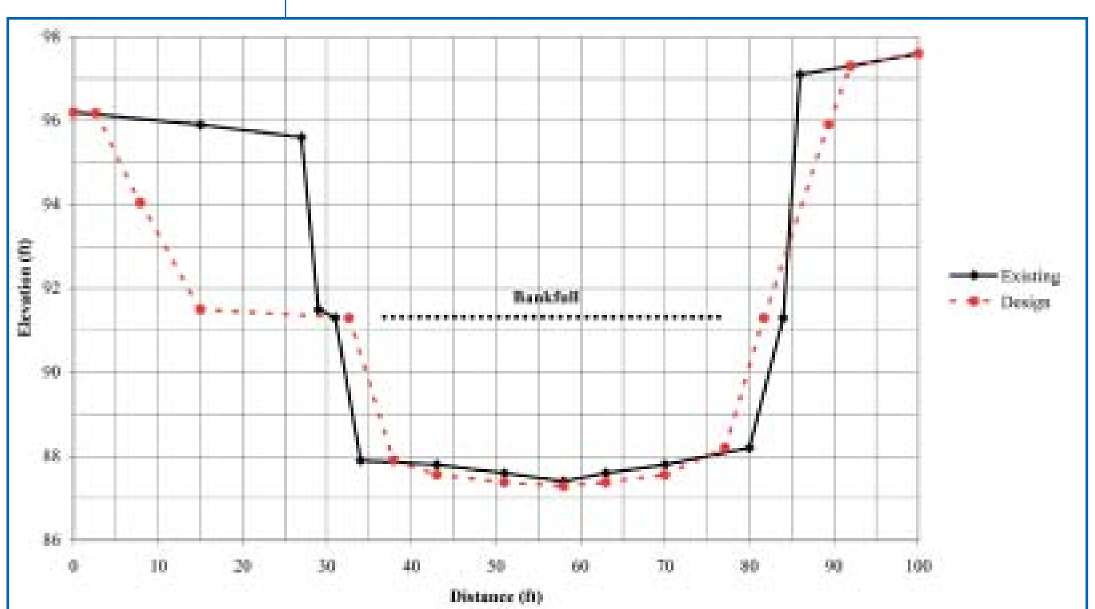





*Figure 5.12*

Cove Creek restoration project before construction

*Figure 5.13*

Cove Creek restoration project at bankfull flow after construction

*Figure 5.14*

Streambank stabilization using riprap at the toe of the bank and bioengineering on the slopes

*Figure 5.15*

Channel armoring using riprap at the toe of the streambank

*Figure 5.16*

Streambank armoring using gabion baskets

*Figure 5.17*

Armoring of streambank using log-crib wall

NC STATE UNIVERSITY