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Publication Date
2001-09-24

STREAM RESTORATION CASE STUDIES IN NORTH CAROLINA UTILIZING NATURAL CHANNEL DESIGN TECHNIQUES

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Abstract: Many rural North Carolina streams are degraded due to historic channelization, dredging, and loss of riparian vegetation. The resulting incised channels have poor habitat and unstable bed features and streambanks. Stream restoration options for incised channels include constructing a new stable channel at the floodplain elevation, enhancing the floodplain at the existing channel elevation, or stabilizing streambanks in place. This paper describes three North Carolina stream projects completed since 2000 that make use of a variety of techniques to restore incised streams. Components of each project include channel geometry modification, in-stream structures, streambank stabilization, and riparian corridor restoration. Project objectives are to improve water quality and habitat, reduce streambank erosion, and enhance floodplain functions. The Stone Mountain project is a Priority 1 restoration in which an incised stream was relocated at a higher elevation on the adjacent floodplain. The South Fork Mitchell River project is a Priority 2 restoration in which channel geometry was modified at the existing elevation to create a new meandering stream with enhanced floodplain. The Mitchell River project is a Priority 3 restoration in which the floodplain of an incised straightened channel was widened and boulder structures were used to protect streambanks. The planning, design, construction, and monitoring of these projects are described along with lessons learned about effective restoration techniques.

Introduction

Natural stream functions in many areas of North Carolina are threatened by changes in watershed hydrology and land use. Impacts include impaired habitat, fish kills, unsafe water supplies, flooding, and reservoir siltation. Causes of impairment include impoundments, diversions, urbanization, agriculture, forestry, transportation, and loss of riparian vegetation. All of these affect stream stability, which is defined as the ability of a channel to carry the water and sediment delivered by its watershed, such that over time it maintains its dimension, pattern, and profile while neither aggrading nor degrading. Stream restoration is defined as the process of improving the conditions in and around the channel such that natural biological and hydrologic stream functions occur in stable channels. Restoration project components include channel geometry modifications, in-stream structures, streambank stabilization, and riparian corridor management.

Over the past decade, natural resource management organizations in North Carolina have adopted a natural channel design approach to restoring unstable streams. This approach is based on the use of regional relationships for bankfull channel dimension and reference reach geometry. Permitting agencies evaluating the hydrologic, water quality, and wildlife impacts of stream restoration and mitigation projects are now requiring that designers use natural channel design approaches. These requirements have facilitated interest among many government and private organizations in learning what stream restoration techniques are most appropriate for local watershed conditions.

Since 1996, numerous stream restoration projects have been funded by the NC Department of Environment and Natural Resources, NC Department of Transportation, NC Wildlife Resources Commission, USDA-NRCS, US EPA, USGS, US Fish and Wildlife Service, local Soil and Water Conservation Districts, private industries, citizen groups, and local landowners. The purpose of this paper is to describe several restoration projects addressing rural incised streams and lessons learned from stream restoration experiences in North Carolina.

Project Steps

Each stream restoration project requires site-specific management, assessment, and design to adequately address local conditions. The steps leading to successful stream restoration projects are:

1. Establish a multi-disciplinary team with knowledge of local hydrology and landowners;
2. Assess watershed and stream conditions to determine problems, causes, and potential for restoration;
3. Design stream restoration options including various construction and management strategies;
4. Select and implement viable design options working with local landowners and resource managers;
5. Evaluate stream restoration efforts and adjust construction or management as necessary.

Project Team

Successful stream restoration teams include engineers, hydrologists, and biologists with knowledge of local watersheds and familiarity with local landowners. Successful projects typically begin with a few cooperating landowners who have a strong interest in improving stream conditions on their property and who are willing to try innovative approaches. It is not necessary that these landowners have severely impaired streams, but more importantly that they are excellent demonstration sites for other nearby landowners. In the South Fork Mitchell River Watershed, the initial cooperating landowner was a beef cattle farmer who had a strong interest in protecting the trout streams on his property. After four years, more than 20 landowners throughout the watershed have requested assistance for stream restoration.

Before beginning detailed assessment work, the project team must agree on specific objectives for each stream reach under consideration. The general goal of the South Fork Mitchell River Project is to restore quality trout habitat to mountain streams degraded by livestock and eroding streambanks. For each stream reach, we identified specific restoration needs and measures that should be implemented. These include livestock exclusion, riparian vegetation establishment, and natural channel construction. Not all measures are necessary at each site depending on need. The project team works with individual landowners to determine stream restoration components that fit the needs of each site.

The leader of the South Fork Mitchell River Project team is Dick Everhart, USDA-NRCS District Conservationist, who has extensive knowledge of local environmental conditions and good working relationships with many private landowners. The other 15 members of the project team include biologists with expertise in fish habitat and riparian vegetation, hydrologists with expertise in sediment monitoring and geomorphology measurements, and engineers with expertise in livestock best management practices and stream restoration design and construction. The team meets bi-monthly to select new project sites, discuss monitoring results, develop design options, and plan education programs to enhance the project.

Assessment

The goal of assessment is to identify specific problems, their causes, and the restoration potential for each stream reach. Watershed land uses are inventoried to determine pollution sources and changes in hydrology that may affect stream quality. Project teams also measure water quality, habitat, and the channel's departure from stability. The types of water quality and habitat monitoring depend on the specific problems in the watershed. In the Mitchell River Project, sediment is the major water quality problem affecting trout habitat. Therefore, the monitoring program includes sediment transport in addition to fish and macroinvertebrate sampling. In other watersheds, water quality problems include sediment, nutrients, and bacteria resulting from cattle farms and urban development. In some cases, monitoring is more comprehensive with less emphasis on habitat and more on drinking water supply issues. Each project must have a targeted monitoring program to identify critical areas for restoration and to evaluate success.

Departure from stability is measured using physical measurements of channel dimension, pattern, and profile (Knighton 1984; Leopold et al 1992; Newbury and Gaboury 1993; Simons 1992). A naturally stable channel is one that transports the water and sediment delivered by its watershed while maintaining its dimension, pattern, and profile, such that over time it neither aggrades nor degrades. Channel dimension is defined as the width, depth, and cross-section area. Pattern is the plan view, including sinuosity, meander wavelength, and radius of curvature. Channel profile refers to the slopes of riffles, pools, runs, and glides (Leopold 1994). The first step in the stability departure assessment is to classify the stream according to its physical features. The standard stream classification system in North Carolina is that developed by Rosgen (1994), which is valuable in determining the physical stability of the stream and its restoration potential. The most important physical feature in the Rosgen stream classification system is the bankfull (or channel-forming) stage. Physical indicators such as top of bank, top of point bar, scour line, and vegetation changes are used to estimate bankfull stage in the field. Regional relationships for bankfull dimension related to watershed drainage area are used to verify field bankfull indicators (Harman et. al. 1999). Natural channels may vary from the expected values shown by the regression lines depending on channel shape and sediment supply. Narrow and deep channels (Rosgen type E) are more efficient than wide and shallow channels (Rosgen type C), thus resulting in typically smaller cross section areas for the same discharge. These relationships should only be used to verify bankfull stage in the field and not to design new channel cross-sections. Local reference reach measurements should be used for channel design.

Stream potential is a quantitative and qualitative assessment of the stream's current stability condition versus what the stream should be based on the morphological setting. A wide array of morphological monitoring techniques are used to quantify stability including, permanent cross sections, longitudinal profiles, stream bank erosion surveys, substrate sampling, bed scouring, sediment transport, and others (Kellerhals and Bray 1971). Once the cause of the instability is identified, a solution can be formulated and a reference reach can be selected that matches the degraded stream's valley slope and morphology.

Design

Stream restoration design must address specific problems with a system of construction and management measures. The design process should address watershed influences such as agriculture, forestry, or urban stormwater in addition to natural channel relocation or reshaping where necessary. Design information is collected from reference reaches located in the same hydrophysiographic province as the degraded stream. Reference reaches are stable stream segments that represent a stable dimension, pattern, and profile. A reference reach is not always a pristine stream, but it is a naturally stable stream. The following field survey data are collected at a reference reach with the same morphological valley type and slope as the design stream:

- Stream type
- Bankfull cross-section area, width, and mean depth
- Bankfull maximum depth
- Floodprone area width
- Valley slope and stream slope
- Sinuosity
- Channel and point bar materials
- Drainage area
- Bankfull velocity and discharge
- Slopes of riffles, pools, runs, glides
- Widths and depths of riffles, pools, runs, glides
- Spacing of riffles, pools, runs, glides
- Meander length
- Radius of curvature
- Belt width
- Bank height

The variability found in naturally stable reference reaches demonstrates the large differences observed in natural channel morphology. Designers should make use of this variability in creating or reshaping channels within the ranges observed in naturally stable channels. In this way, designers can avoid creating "cookie cutter" restored channels.

For incised stream channels, designers have several restoration options to consider (Rosgen 1997). In a Priority 1 restoration project, the incised channel is replaced by a new meandering channel located at a higher elevation on the floodplain. The new channel is sized such that the bankfull stage is at the land elevation of the existing floodplain. In the Stone Mountain project, a Priority 1 restoration was implemented to replace the F4 channel with a meandering C4 stream. The surrounding land use was agricultural, and the upstream channel was not incised, making this type of restoration relatively straightforward. Soil excavated from the new channel was used to fill the former channel after water was turned into the new stream. Some areas of former channel were left unfilled to serve as floodplain pond habitat.

The South Fork Mitchell River project is an example of a Priority 2 restoration in which it was not feasible to create a new channel at a higher elevation. Instead, the channel geometry was modified at the existing elevation to create a new meandering stream with a widened floodplain. In these projects, streams classified as F4 were changed to C4 channels.

The Mitchell River project is an example of a Priority 3 restoration in which the floodplain of an incised straightened channel was widened and boulder structures were used to protect streambanks. The Mitchell was converted from an incised C4 channel to a C4 with lower bank heights.

In addition to channel geometry, designs must consider bank and bed stabilization, riparian management, and watershed management. Stream channel and bank stabilization practices include rock vanes, log vanes, j-hook vanes, cross vanes, root wads, shrub and sod transplants, willow stakes, and erosion control fabrics. Each restoration project requires a unique set of practices depending on site conditions.

Implementation

Natural channel design is a new concept for most earth moving contractors. Therefore it is essential that a professional familiar with the design be on-site during channel construction for the job. Many projects with technically sound designs fail because they were improperly installed by an unqualified contractor. Much of this work involves placing individual rock boulders and root wads. A trackhoe with a hydraulic thumb and a skilled operator works well for implementing most designs. Because large storms often occur soon after construction, it is important to install devices that provide immediate stability.

Evaluation and Adjustment

The measurements discussed under the assessment section are also made after construction to evaluate the success of stream restoration efforts. Often times adjustments and modifications are required and should be made as soon as possible to prevent further damage.

Summary

Stream restoration using natural channel design procedures is being used throughout North Carolina to improve water quality and aquatic habitat. Many projects are currently being implemented with multi-agency teams of hydrologists, engineers, and biologists with the objectives of improving water quality and aquatic habitat, demonstrating effective stream protection measures, and evaluating the effectiveness of implemented measures. Projects are initiated by landowners and watershed stakeholders who identify unstable stream reaches with potential for restoration. Project teams then assess watershed land uses to determine sources of pollution and hydrologic changes and monitor streams to determine channel stability, aquatic habitat, and pollutant impacts. Restoration design options are developed using relationships for bankfull channel dimension and reference reach geometry. Project teams then work with landowners and local resource agencies to select the preferred restoration option and develop a construction plan. Components of successful projects include constructed stream beds and banks, instream structures such as rock vanes, stabilized banks using vegetation and root wad revetments, and protected stream corridors with livestock exclusion and riparian plantings. The effectiveness of these projects is evaluated using sediment sampling, stream channel measurements, water chemistry, and biological assessment. Educational programs are used to share experiences in order to improve future projects.

Lessons learned from North Carolina projects include:

- Successful stream restoration results when teams of hydrologists, engineers, and biologists begin with clear objectives.
- Cooperative landowners are necessary for innovative approaches and demonstration sites.
- Stable reference reaches must be used to determine appropriate natural channel design parameters.
- Natural channel design must address both hydraulic capacity and sediment transport such that stability is maintained.
- Stream restoration designs must include systems of measures to prevent pollution, establish riparian vegetation, and address channel stability.
- On-site construction management is essential to ensure that earth-moving contractors follow design specifications.
- Monitoring is essential to develop designs, measure success, and determine if follow-up work is needed following initial construction.

Biographical Sketch: Will Harman is Vice President and co-founder of Buck Engineering. Will has 10 years of experience in watershed management, stream geomorphology and hydrology, water quality monitoring and data analyses, and geographic information systems. Will served as Program Leader for the NC Stream Restoration Institute at NC State University from 1998-2000. He has utilized natural stream channel design technologies on over 75 projects in North Carolina and surrounding states. Will developed a series of training workshops and educational materials for private consultants and natural resources management professionals on channel forming flows, morphological assessments, sediment transport, and natural channel design technologies. He provides expertise on stream restoration to agencies, nonprofit organizations, and landowners.

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