Knapps Creek Demonstration Project

Introduction

The Knapps Creek natural stream restoration project is an ongoing demonstration project in Pocahontas County, West Virginia. Knapps Creek meanders through a rural mountain setting with a fertile floodplain surrounded by Appalachian Mountains reaching up to an elevation of 4477 feet. Site 24, which is the first of many potential sites in the Knapps Creek Watershed, was installed in 2004. Landowners along portions of Knapps Creek have experienced problems with streambank erosion, loss of cropland, sedimentation, and flooding for years. Some of the problems stemmed from recent land use practices and some were caused from harmful land uses dating back to the 1870s. Project partners decided that the problems needed to be corrected to keep the situation from getting worse. The land was and continues to be used for agricultural purposes, primarily livestock grazing and hay production. Partners in this demonstration project want to fix the problems while maintaining the pastoral setting and a viable agricultural economy.

Photo 1, Pre-construction: View is looking upstream at the starting point for Site 24. Note the eroding banks, excessively wide and shallow channel, and deposition of mid-channel bars.

Photo 2, Post-construction (Same area as shown in Photo 1): View is looking upstream at the beginning of the re-constructed channel for Site 24. Natural stream design features include the sloped banks protected by seeding, woody transplants, fence to separate livestock from restored areas, reduced channel width, and a rock vane.

Project Goals and Benefits

The watershed plan identifies natural stream channel restoration methods to stabilize the channel, restore natural meanders, create wetlands, reduce streambank erosion (and loss of cropland), and enhance aquatic and riparian wildlife habitat. There are several examples of natural design techniques used for streambank stabilization in West Virginia. This is the first work to fully restore a stable meander pattern and channel profile with a range of bank stabilizing practices. In the long run, the partners hope their goals will be met with a self-maintaining natural stream system.

A major benefit from this project will be the restoration of the environment to a more natural state. Boulder clusters, constructed pools and riffles, and vegetation transplants will be used to improve the aquatic habitat of the stream to boost the populations of smallmouth bass, darters, minnows, and other fish found in Knapps Creek. Alternative designs using rock rip-rapped bank protection, grouted riprap, or trapezoidal concrete channels would not provide these benefits.

The demonstration project serves as an educational tool to increase public awareness of natural stream channel restoration. Field tours of the completed work have been open to the public to view the results. Site 24 was incorporated into the course curriculum for a class offered by West Virginia University (WVU) during the summer of 2004, providing a “real world” classroom for teaching natural stream channel restoration.

Natural stream restoration projects generally do not include flood reduction as a benefit, but can reduce flood-related damages. At Site 24, flood levels for high frequency events remain essentially unchanged. The stream continues to have access to its floodplain. Maintaining the floodplain is an important and distinctive feature that sets natural stream restoration apart from constructed channels designed to contain floodwaters within a uniform trapezoidal or rectangular channel.

Photo 3, Post-construction: View looking downstream along the beginning of the re-constructed channel. Note the sloped banks with re-established grass, rock vane, and woody transplants to protect the streambank.

Project Partners

It takes many things to make a project successful, but few components are more important than a cooperative partnership. Good communications and cooperation among the partners were critical to the success of this project. Landowners in the Knapps Creek valley organized and formed the *Upper Knapps Creek Watershed Association*, which is the cornerstone for the project. As a landmark project in West Virginia (WV), this project attracted interest from numerous partners. Technical, financial, and administrative assistance came from several sources, including the WV Conservation Agency, Canaan Valley Institute, Greenbrier Valley Conservation District, U.S. Environmental Protection Agency (Region III), WV Division of Natural Resources, USDA Farm Service Agency, WVU, USDA Forest Service, WV Department of Environmental Protection, U.S. Fish and Wildlife Service, USDA Natural Resources Conservation Service (NRCS), Fish America Foundation, consultants, and contractor. Two professional consultants provided invaluable assistance to the project. *Clear Creek Consulting* (Jarrettsville, MD) prepared the base-level planning documents for the entire watershed. *Buck Engineering* (Charlotte, NC) prepared the design documents for Site 24 and provided technical support during construction. The construction contractor, *Smith Brothers* (Lanchester, KY), was recognized as the 2004 WV Conservation Contractor of the Year for their work at Knapps Creek Site 24. Other indirect partners will play a future role in the success of the project by the way they use the land in the watershed. Everyone who lives, works, visits or plays in the watershed can have a positive role in protecting the natural environment.

Watershed and History

Knapps Creek is a tributary to the Greenbrier River located in east-central West Virginia in Pocahontas County, a rural area consisting mostly of forested mountains and farmland. Most of the watershed is in the *Monongahela National Forest*. A wide valley floor provides good agricultural land that is privately owned. Land for Site 24 along the banks of Knapps Creek is used for agricultural purposes, primarily pasture and hay production. Landowners along Knapps Creek have lost some of their usable land due to streambank erosion and sediment deposition during floods.

Photo 4, Pre-construction: View looking downstream through the first channel bend. Note the wide, shallow channel, point bar, gravel deposition, and streambank erosion. The landowner uses the footbridge to cross the stream during high flows to care for cattle.

Knapps Creek starts near Paddy Knob (4477 feet) on the West Virginia - Virginia border at an elevation of 3800 feet. It flows about 18 miles to its confluence with Douthat Creek in Minnehaha Springs (2320 feet). With an average slope of 1.5%, Knapps Creek continues downstream to Marlinton where it enters the Greenbrier River. The Knapps Creek watershed consists of ridges and peaks with steep valley side slopes that are heavily wooded. The local climate produces an annual average rainfall of 47 inches and 34 inches of snowfall. The mean annual stream flow in Marlinton, West Virginia is 149 cubic feet per second (cfs) with a normal flow range of 36 to 318 cfs (there are 7.48 gallons in one cubic foot). Annual peak discharges from 1947 to 1996 ranged from 2,940 cfs to 22,000 cfs.

Photo 5, Post-construction: View looking downstream at the same channel as in Photo 4. Note the restored streambank with vegetation and rock vane to protect the bank from future erosion. A new meander was created just beyond the rock vane where the channel had previously been straightened.

Some of the impacts from past land uses, dating back to the 1870s, are still evident upon the landscape even as nature gradually reestablishes its hold. Timber harvesting removed most of the trees from the mountainsides between 1870 and 1930. This resulted in widespread soil erosion and stream sedimentation. Forest fires, some caused by hot cinders from steam locomotives, also played a part in the destruction of the land cover. When it rained, gullies formed and topsoil washed away. Better-managed logging operations continue to this day, but still have adverse impacts on the watershed. Some tributaries support healthy trout populations, yet others have been impacted by agricultural operations, logging and alteration of the natural stream channels.

Portions of the natural channel were straightened in an attempt to control the creek and preserve farmland. In some areas, livestock grazing has contributed to trampling of streambeds and banks resulting in over widening of the channel and mid-channel bar development. Even with natural stream restoration measures to stabilize the creek, long-term success requires better management of the land in the watershed to prevent excessive erosion. One important management practice needed is the establishment of grazing limitations along established buffer zones of the creek.

Photo 6, Post-construction: View shows a step-pool outlet channel carrying flow from a new wetland area back into the main channel. The step-pool channel was created using rock sills. The new wetland area was created from a portion of the original channel that had been straightened. The meander was reconstructed to bypass the old straightened channel.

Planning

The overall watershed plan identified 25 numbered restoration sites along the main stem and several tributaries of Knapps Creek. Initial funding levels were sufficient to design and construct the first few sites, but not all of them. This meant that someone had to prioritize the sites and establish an implementation plan. The *Upper Knapps Creek Watershed Association* established the priorities considering input from the numerous assisting partners. After several discussions and planning sessions, five sites were selected for early implementation. It was decided that Site 24 would be the first to be designed and constructed.

Project Scope & Natural Design Features

The scope of Site 24 was to re-establish the meander pattern, the cross-sectional area, and the channel bottom profile for 2,643 feet of stream channel using the principles of fluvial geomorphology. Two full meanders, four pools, and two constructed wetlands were installed. Bank protection measures included rock vanes, root wads, woody vegetation transplants, fiber matting, seeding, and mulching. The drainage area specific to Site 24 was 47.35 square miles with a design discharge of 2,164 cfs (stream flow at bankfull depth). The stream type, according to morphological descriptions defined by David Rosgen in *Applied River Morphology* (1996), is a C4. This generally means the stream is a slightly entrenched, meandering, gravel-dominated, riffle/pool channel with a well-developed floodplain. The design gradient (slope) for this portion of the stream was 0.0018 feet/feet (0.18%). The design channel cross-sectional area was 380 square feet with a mean depth of 5.2 feet.

Fencing and livestock watering facilities were installed under the *Conservation Reserve Enhancement Program* administered by the USDA Farm Service Agency. These measures are essential to separate livestock from the restored stream corridor while vegetation is established.

During the restoration of natural meanders, sections of the existing channel were abandoned making a perfect opportunity for the creation of wetlands. Two wetland areas were constructed in these abandoned channel sections. On-site vegetative materials, transplants, and wetland soils were used as seed sources for the new wetlands. Water levels in the wetlands are controlled by log weirs. Both of the wetlands included the construction of outlet channels using a step-pool design. This stable outlet channel allows the wetland to drain excess water back into the main channel of Knapps Creek.

Photo 7, Post Construction: View looking downstream at constructed meander bend. Mature trees were left in place. The riffle-pool sequence was constructed to add diversity in the bottom profile of the stream.

Construction

Construction was undertaken using a competitive bid process via a federal contract. Work was completed during the summer of 2004 over a span of about three months from June to August. Construction was accomplished with conventional equipment and methods. The largest piece of equipment used was a medium sized hydraulic excavator (CAT 325C). The contractor made a special effort to tread lightly upon the landscape only disturbing areas as required. Even though strict construction specifications were used, the contractor did a good job of following the intent of the project and met or exceeded expectations.

Photo 8, Post-construction (same meander bend as in Photo 7): Photo shows reconstructed portion of channel where the meander was restored. Natural design elements shown are the root wads, woody vegetation (willows), rock vane, and preserved mature trees. The rock vane will protect the bank and maintain pool depth for aquatic habitat diversity.

Monitoring

Monitoring is essential to measure the success or failure of any project. Several of the project partners are watching Site 24 to compare expectations with actual results. The NRCS made a thorough attempt to monitor the construction process by site visitation, photography, and meticulous documentation. Other monitoring efforts will include a comparison of pre-construction bank erosion rates to post-construction erosion rates. West Virginia University faculty and students are measuring the aquatic habitat through pre- and post-construction assessments. The WV Division of Natural Resources completed a baseline fish survey and will complete post construction surveys. A detailed site map was prepared to document locations and angles that photos were taken from, which is invaluable in comparing “before” and “after” construction conditions. Monitoring efforts will continue at Site 24 and other future sites in the Knapps Creek demonstration project. Feedback from these monitoring efforts will be used to improve the design and construction of other natural stream-channel restoration projects.

Project Costs

Project costs are always hard to monitor, especially when several entities are involved in the planning, design and construction process. However, one of the secondary objectives for this project was to generate cost data for a natural stream restoration project. The NRCS determined the measurable costs associated with the installation at Site 24, which does not include personnel and other expenses for some of the early planning activities that brought it to fruition. The total cost (2004 dollars) for the Site 24 project was $188 per Linear Foot (LF) with a breakdown of $42/LF for design; $117/LF for construction; and $29/LF for construction administration. This cost is consistent with other data obtained by the author of $200 per LF for natural stream restoration estimates through urban areas in North Carolina.

When looking at these costs one must remember there is a multitude of variables affecting design and construction costs. These costs are not transferable in the same manner as other traditional types of construction (rock riprap, concrete channels, pipe, etc.). However, it provides an order of magnitude for the cost of completing this type of project. As a cost comparison, the estimated cost to armor the same length of streambank (both sides) with rock riprap would be $213 per LF (assuming 24% of construction cost for design and construction administration). Rock riprap would also have some design costs. Of course, rock riprap would only protect the streambank with armoring and would not blend with the natural setting or restore the aquatic habitat. In this case, rock riprap would not have accomplished the other project objectives. Considering that natural stream channel restoration is still a very new technology, the construction costs for Site 24 are very encouraging.

Project Hurdles

Most of the project hurdles such as coordination among the multiple partners and obtaining the necessary environmental permits were overcome during the planning and design stages of the project. Work at Site 24 was simplified because only one landowner was involved, making it easy to obtain site access. Design and construction costs were kept within budget with the dedication of the project partners; conscientious planning and design by the design consultant; and a solid understanding of the principles and practices of natural stream channel restoration. Environmental permitting was simplified by early involvement of the WV Department of Environmental Protection. Project challenges were overcome by involving all of the partners and interested parties throughout the planning, design and construction process.

Factors Influencing Future Success

The restoration of Site 24 was successfully planned, designed, and constructed, but it is too early to judge long-term success. The ultimate success of the project will require it to survive the test of time as the stream channel carries the gamut of storm flows. Some of the factors in determining overall success are dependent upon how nature reacts to our attempt to mimic natural processes of stream flow. Flooding in West Virginia occurs with regular frequency; 2004 was no exception. Within two months of the completed construction, Site 24 endured its first flood. During the heavy rainfalls from the fallout of Hurricane Ivan, Knapps Creek flooded in September 2004. Water flows exceeded bankfull depths overflowing onto the floodplains along the restored stream channel of Site 24. Fortunately, restored areas survived and functioned as intended. Time will tell how Site 24 performs during subsequent storms and larger rainfalls. Periodic maintenance may still be required to repair bank damage after large storms; at least until the restoration work has completely taken hold. Even 100% natural streams experience damage during unusual or infrequent storms.

Some other factors contributing to the success of this project are dependent upon how land uses are managed throughout the watershed, especially the upstream portions. The overall success of Site 24 and other planned sites along Knapps Creek require management and restoration efforts of the upstream watershed and the floodplain corridor along the creek. Individual landowners all along the creek can contribute to the success of the project by using best management practices, such as providing alternate water sources for livestock so they don't have to enter the stream; installing stable constructed crossings for equipment and livestock; using rotational grazing and light grazing on pastures; and isolating riparian areas to restrict grazing. Good management strategies promote stable stream systems and benefit sustained agricultural production.

Lessons Learned and Reinforced

The lessons learned from implementing Site 24 may not be as much new information as they are lessons reinforced. The planning, design and construction went smoothly, but it was not by accident. Good coordination and communications among the various partners greatly benefited the project. There was good buy-in and participation from everyone involved during the planning process, which paid dividends during the design and construction. A multi-disciplinary team is essential to success. Individual partners included civil engineers, biologists, farmers, concerned citizens, environmental scientists, economists, resource conservationists, an archaeologist, planners, and others. The NRCS is committed to this multi-disciplinary approach and employs many of the experts required to complete challenging technical projects such as this one. Everyone involved played an important role in the successful completion of the restoration work at this first site.

The importance of communicating details of natural design elements to the contractor cannot be overemphasized. It is helpful to have thorough detailed drawings and to have the designer on-site during portions of the construction. As an example, it would be invaluable to have the designer present while the contractor builds the first rock vane on a project to ensure it is done correctly. Direct interaction between the contractor and designer is beneficial for both parties. In some cases, it is difficult to show the complete requirements via drawings and specifications. Regarding rock vanes, some of the details to be conveyed include having good rock-to-rock contact; proper construction to prevent flanking; proper depth and embedment of boulders in the channel; good footer rocks to hold the vanes and prevent scour; and attention to detail on the batter and stepping of the boulders to obtain the spillway/splash effects. On Site 24, the consulting engineer made site visits during the construction process and was available to answer questions throughout the process.

Another lesson re-learned is that natural stream channel design, despite outward appearances, is technically more complex and challenging than the traditional methods of channel design. This type of work is "deceptively simple." Viewing the finished product, one would never suspect the complexity of the technology that supports it. After all, we are really trying to emulate Mother Nature, and "she" has been at this for much longer than we have.

Summary

So far, the project has been a success. Site 24 has provided a starting point to build upon and to increase the knowledge base of the natural stream restoration process. This is the first of many potential restoration projects along Knapps Creek and in other locations in West Virginia. Construction of the next Knapps Creek project site is scheduled for the summer of 2005. A third site is in the preliminary design stages. Using thorough documentation of the complete natural stream-channel design process, we are hoping to learn many things from this and future projects. Since natural design techniques are in their infancy compared to traditional structural approaches to stream channel stabilization, we are excited to see how they will perform over time.

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