



Brushy Creek Stream Stabilization

Greenville County, SC

Project Completed: October 2020

Nomination Category: Environment, Projects Less Than \$5 Million

Submitted for Award: April 2, 2021

Project Overview

The Brushy Creek stream stabilization project exemplifies a well-planned and executed public works project. Presented with significant environmental and infrastructural risks, Greenville County led a joint effort amongst multiple stakeholders to not only address the immediate concern, but also to enhance the impacted waterway for increased resident enjoyment and renewed environmental health. The County-led project team accomplished this effort on schedule and within budget, featuring specific project components incorporated to serve as an installation example for future applications—and a “stronger together” mindset.

Brushy Creek drains a highly urbanized 2.65-square-mile watershed in downtown Greenville, SC. Following years of bank erosion and incision along this urban stream, several significant storm events exposed a large sanitary sewer gravity main operated by Renewable Water Resources (ReWa) and sparked a need for intervention. The County-formed project team of the City of Greenville, ReWa, and adjoining property owners Mills Mill Associates and Enigma Corporation recognized an opportunity to implement much-needed stream restoration in addition to stabilizing the exposed sanitary line. To form this coalition, the county relied on interagency relationships formed through a separate ongoing watershed partnership. Greenville County was the lead agency, while both ReWa and the City made financial contributions to the construction costs of the project. To gain buy-in from the adjacent property owners, the County met with them early in the process to present the schematic design and pictures of what the different materials and stabilization techniques would look like upon completion.

Project construction began in June 2020 and was completed in October of the same year. This collaborative effort resulted in the stabilization and restoration of approximately 900 feet of stream in the highly urbanized area of Greenville County between Seth Street and Mills Avenue (Figure 1). However, this was more than just a collaborative effort to protect a sewer line and implement stream restoration. Rather than simply repairing the bank failure, the County seized the opportunity to address multiple issues, and given the visibility and accessibility of this project as well as the availability of continuous water quality monitoring data, to use the effort as a demonstration project. The examples set forth in utilizing an array of both soft and hard stream stabilization techniques serve as an example for private developers as they implement best management practices to achieve the environmental standards required by the County’s Land Development Division.

The stabilization measures used on this project include rock cross vanes and arm vanes, eight types of erosion control and turf reinforcement matting, riparian area improvements, and hard and soft bank toe protection. The design firm, Woolpert, worked with local manufacturers to determine the best products for providing the County with a range of coverages and levels of protection. Hard measures, including stacked boulders and interlocking grid systems were installed to protect exposed or threatened ReWa sewer lines.

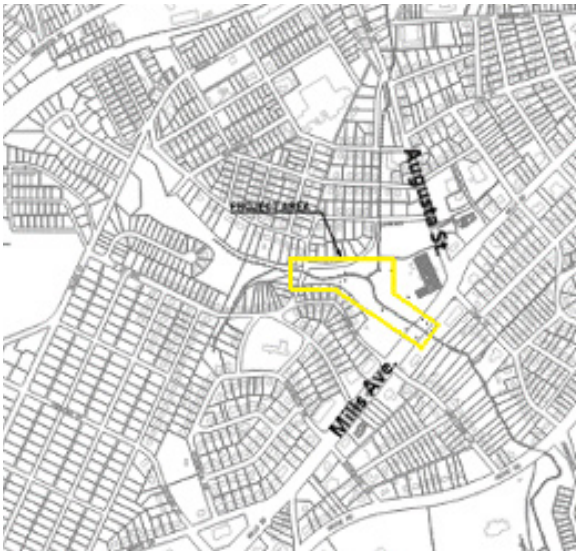


Figure 1. Vicinity map of Brushy Creek stream stabilization.

Woolpert provided additional resources, such as drone footage of the project corridor, to create a short educational video summarizing the project. Further, since 2012 Woolpert has maintained a continuous water quality monitoring station for the county along this stream reach. This provides the county with a unique opportunity to quantify upcoming improvements in water quality once the new native vegetation associated with the stream stabilization is fully established.

By incorporating multiple stabilization techniques, engaging a variety of stakeholders, and leveraging existing water quality monitoring data and equipment, the County devised a project plan within the capital improvement project budget to address the driving issue of an exposed sanitary sewer line and fulfill the following additional purposes:

1. Test multiple bank stabilization and stream restoration techniques, providing guidance to engineers and contractors for future applications
2. Improve water quality in an impaired watershed
3. Strengthen relationships with existing partners in a Section 5(r) planning process
4. Educate the community on water quality issues

Construction Management and Schedule

Since part of the project's goals were founded upon environmental enhancement, the construction management plan and schedule were also formed around the preservation and continuation of the area's ecology. The project was phased such that only small portions of the landscape were left bare simultaneously, limiting increased stormwater runoff and its respective impacts downstream. Further, the total disturbed area was limited relative to the scale of the project. In areas where traditional sediment erosion control practices were not feasible, a creative and temporary approach was employed to mitigate water quality degradation. The area immediately adjacent to the stream was protected by allowing its natural berm to direct runoff away from the stream.

The project was conceived in 2016, the drawings were completed in September 2017, and after it was approved by the partners, 90% of the design was finalized in November 2019 with the necessary approval from property owners and the United States Army Corps of Engineers. Moving forward, challenges arose in obtaining easements and project maintenance agreements from the impacted property owners. Ultimately, the County entered into a long-term maintenance agreement to satisfy landowner concerns. The project was sent to procurement in December 2019.

Several varieties of seeds and plants required germination and establishment at the correct time of year. This provided additional rationale for keeping to a strict construction schedule. The original construction contract duration was 16 weeks and implementation took place from June to October 2020. At the completion of the project, seeding incorporated two rounds of two seasons of grasses—making for a long-term viable, overall thicker stand of grass than previously existed. Also successfully planted in the appropriate seasons were 1,500 live stakes and 38 assorted trees and bushes. Without outstanding construction management, proper revitalization of the land would not have been possible.



Figure 2. Mills Avenue camera.

Safety Performance

Throughout construction of the stabilization techniques, industry safety measures, including workers' constant use of the appropriate protective gear, were closely observed. A live camera feed (Figure 2) used for documenting installation provided an extra layer of accountability to ensure all team members followed appropriate safety protocols.

The side of the stream across from the Lofts at Mills Mill, a sizable condominium complex with an active homeowner's association and a dog park, was prioritized first as adjacent construction was done on an as-needed basis.

To protect the public and residents of the nearby community, staging for all construction activity was done at a location (provided by Enigma Corporation) removed from pedestrian traffic, and the project was phased to limit contact with residents.

In terms of COVID-19 safety precautions, appropriate social distancing measures were taken between members of the crew and when in contact with the surrounding community.

Environmental Considerations

With the development of a nearby residential community and a series of severe storms in recent years, Brushy Creek had lost much of its natural ecosystem to streambank erosion. In addition to stabilizing the streambank around critical infrastructure, a key goal of this project was to protect the local ecology through the restoration of its habitat and tree canopy to their natural, predeveloped state. The physical measures employed in the stream will inhibit further stream degradation and scour. To mimic nature, green infrastructure was chosen over gray wherever possible, making this project a model to encourage similar techniques for the County and area contractors (Figure 3). Compiled into an educational video, drone footage of the area before, during and after construction communicates the importance of these stabilization techniques to the public.

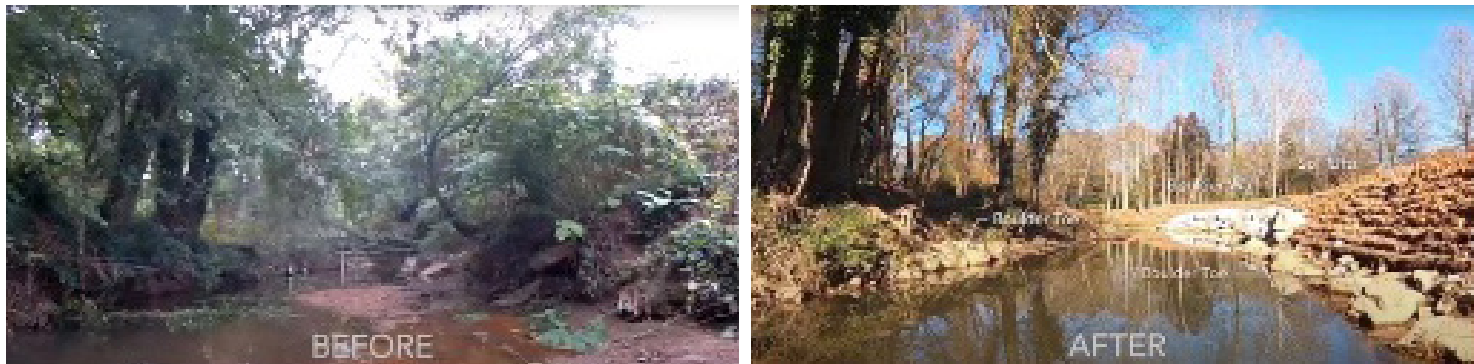


Figure 3. Brushy Creek before and after the implementation of boulder toe walls and soil lifts.

Water quality benefits from stabilized banks inspired the design. As much of the existing mature tree canopy as possible was saved, and additional plantings and vegetation were selected specifically to serve as tools to reduce the sediment load conveyed by the stream. Once fully established, these native plant species and their root structures will shield the banks from erosion while providing a barrier to contaminants and interface for the uptake of nutrients within stormwater runoff. Additionally, the full tree canopy will shade the stream, keeping the water cool and dissolved oxygen content high.

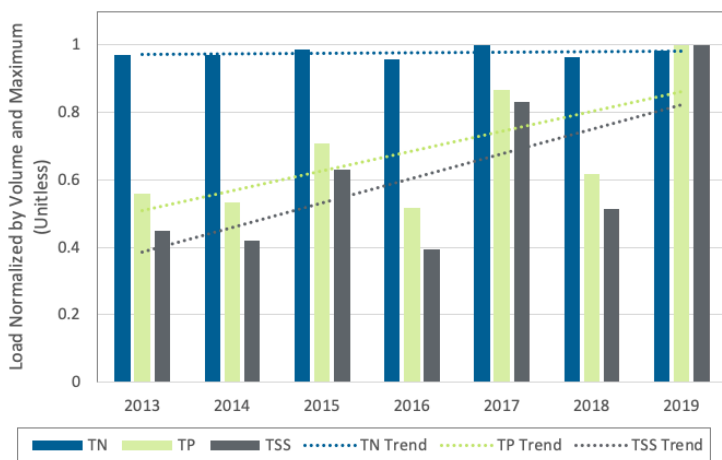


Figure 4. Pollutant loading within Brushy Creek at Mills Avenue since 2013.

Greenville County was able to take environmental protection a step further by quantitatively monitoring the area water quality before and after implementing the chosen stabilization techniques. Figure 4 displays this nutrient data collection. As this site stabilizes and additional monitoring data is recorded, the County will be able to assess the impacts of the project on long-term pollutant loading. For seven years, the County has collected water quality data for pH, turbidity, dissolved oxygen, and specific conductivity coupled with discrete grab samples for bacteria and nutrient concentrations (Figure 5). In the last four years, the stabilized reach of Brushy Creek has displayed increasing concentrations of total nitrogen and total phosphorus, while its concentration of total suspended solids has remained consistently high. These numbers are expected to substantially decrease as the newly planted vegetation establishes. The materials and methods used along Brushy Creek will be monitored for longevity, form and function on a long-term basis.



Figure 5. Greenville County monitoring station at Mills Avenue.

Brushy Creek is a tributary to the Reedy River and, consequently, Boyd Millpond and Lake Greenwood. The Reedy River is impaired for total nitrogen and, as a result, the stakeholders for the Brushy Creek stream stabilization project are also principal stakeholders in the Reedy River Water Quality Group's current efforts to create a Clean Water Act Section 5(r) plan. The Section 5(r) plan is a collaborative approach to addressing nutrient concerns in this watershed. The Brushy Creek stream stabilization project provides a foundational BMP for addressing water quality concerns and will serve as an example for implementation throughout the Reedy River watershed. The county is developing similar projects as a direct result of this project's early success. These additional projects include a regenerative bioswale in the Plano Drive community and installation of multiple low-impact development techniques (e.g., pervious pavers, bioretention cells, rain garden and bank stabilization) at Shoeless Joe Jackson Memorial Park.

Thorough environmental stability requires continual post-construction inspection. Within a few weeks of completion, invasive Japanese knotweed overtook the soil lifts on site (Figure 6). Invasive species such as these decrease the biodiversity of an ecosystem and can increase soil erosion. A certified herbicide applicator was contracted to remove the knotweed under the direction of Woolpert-certified managers of invasive species. The County will inspect the area for invasive species twice in the next year to ensure these species are not inhibiting the design and establishment of native species.



Figure 6. Soil lifts immediately following construction (left) and Japanese knotweed invasion of the soil lifts (right).

Community Relations

Careful consideration was given to mending the impacted portion of Brushy Creek adjacent to the Lofts at Mills Mill. Relations between the County, City, contractor, consultant and surrounding community were prioritized throughout the duration of the design implementation. For this, residents and property owners were encouraged to take a crew-guided tour of the site and the project was phased to limit residential disturbance. As a result, Mills Mill owners, residents and property managers as well as owners from the neighboring Enigma Corporation were extremely courteous toward the project team. In this way, when problems arose at the condominium complex, they were immediately addressed by the crew. For instance, the addition of Shoreblock to the streambank posed security issues to Mills Mill after portions of an existing fence were removed, opening the area to pedestrian traffic through the development. The contractor immediately replaced the open area with boulders found on site and installed supplementary fencing. Additionally, the Mills Mill HOA requested substituting several plant types during the planting phase of the project. Their requests were accommodated by the County to provide residents with a unique green space to enjoy—complete with blueberry bushes and elderberry trees.



Figure 7. Brushy Creek after the implementation of boulder toe walls and soil lifts.

The project team considered the accessibility of this area to the community when choosing stabilization techniques. Strategies selected for the reach of Brushy Creek appear more natural than other forms of bank stabilization once native species populate them (Figure 7). The inclusion of several techniques like these provide the perfect opportunity to educate the public about the importance of soil conservation. Ultimately, property owners were very happy with the final enhanced version of the creek.

“I have to give a great big thank you to Greenville County for the fantastic work they did in restoring the land by our creek,” remarked Bill Kaiser, president of the Lofts at Mills Mill HOA, “This was a huge job, and they did it with minimal disruption to our condo complex. Everyone involved was very polite and sensitive to our needs. I have had many of our residents say how beautiful of a job they did in cleaning up the creek and planting such wonderful new trees. It will be enjoyed by everyone!”

Product, Application, or Task Name: <small>(Place at the confluence between Brushy Creek and small tributary)</small>	Small Cross Vane	Difficulty	Low	High		
How Difficult was it to Bid this Product/Application?		1	2	3	4	5
Comments:						
How Difficult was it to Order Materials for this Product/Application?		1	2	3	4	5
Comments:						
How Difficult was it to Have Materials Delivered to Site?		1	2	3	4	5
Comments:						
How Difficult was it to Install/Perform Product/Application?		1	2	3	4	5
Comments:						
Will Product/Application work for the intended purpose?		YES		NO		
Comments: <small>(Yes/No)</small>						
ESL which product(s) would you recommend/replace?						
Would you recommend using this Product/Application?		YES		NO		
Comments: <small>(Yes/No)</small>						
ESL which product(s) would you recommend/replace?						
Suggested improvement to product/application:						
Overall rank of product:		1	2	3	4	5

Figure 8. Excerpt from the contractor exit survey.

To enhance the public outreach of this project even further, the County maintained a live camera feed of the project site throughout the duration of construction. The live camera was available for the public to view through both the county's website and the Reedy River Water Quality Group's website. This live broadcast allowed the public to watch the installation of various techniques as well as track the overall progression of construction.

Because the County views bank stabilization and stream restoration as a preferred BMP for addressing water quality issues, it was important to learn from this project for application to future projects. Therefore, extensive notes were taken during the construction phase on lessons learned. Furthermore, regular debriefings occurred between the contractor and engineers to determine the ease of installation, practicality of use, and potential maintenance issues with each product and installation process used. A contractor exit survey (Figure 8) was prepared to assist in capturing important details. This documentation will be used by the County not just to specify future products, but also to assist in educating local engineers and contractors regarding bank stabilization and stream restoration projects.

Adverse Conditions

While this project was publicly funded, it was located almost entirely on private land; the Lofts at Mills Mill and Enigma Corporation owned the land on either side of Brushy Creek. An exceptional amount of time and effort was required to overcome multiple, and sometimes conflicting, goals. Plans were ultimately approved by all parties and maintenance agreements were determined to ensure the longevity of the changes made to the stream banks and bed. While the COVID-19 pandemic postponed the commencement of construction due to delays in material shipment, the project was still completed in a timely manner so that vegetation was planted appropriately.

During the summer and fall of 2020, several large storm events and residual hurricane storm systems impacted the project site. The construction team worked through extremely hot, wet conditions to ensure the project was delivered with minimal delays and under budget. This effort often included early mornings, late nights and extra visits to the site to limit potential damage during especially severe storm events.



Figure 9. ReWa sewer pipeline exposed due to stream degradation.

Large rain events, like those which impacted the area throughout construction, have been particularly acute since 2015. The resulting significant bank erosion and consequential exposed gravity sewer line (Figure 9) that solicited need for this stabilization project made the installation of bank protection very difficult. Nonetheless, the excavation and installation of several areas of exposed pipe were performed successfully thanks to a dedicated construction crew.

As previously stated, the abundance of invasive species in the area threatened the longevity of design efficacy at the completion of construction. Maintenance agreements drafted between the County and the contractor addressed this issue, ensuring the site will receive continued inspection. Even further, the prevalent and very active beaver population damaged the initial plantings, requiring additional protection measures such as adding tree cages and acquiring assistance from animal control specialists.

Additional Considerations

Even though the project was intended to provide more than just protection to critical infrastructure, the budget was established principally to protect ReWa sewer lines along Brushy Creek. Maintaining this budget over the duration of the project was prioritized and, as changes arose, adjustments were made accordingly for the betterment of the project and cost. For instance, since the implementation of the design took place almost one year after the finalization of contract drawings, the stream morphology had changed somewhat from the assumed state in the construction plans. The County made cost-saving decisions throughout the course of construction, including removing two single-arm vanes no longer necessary due to natural alterations in the stream. Further, boulder toe walls were constructed to temporarily protect the sanitary sewer using rocks that were already on site, rather than the designed A-Jacks. The unused A-Jacks are being housed in a County storage facility for future project use. Upon completion, the project came in under budget by \$10,000.

Between the time of final design and project bidding, two large storms caused further erosion around the exposed sanitary sewer. To minimize construction change orders, additional field survey data was obtained to better estimate the need for backfill and stabilization materials. This effort resulted in a more accurate bid and contributed to completing the project under budget.

Alternative Materials, Practices and Funding

This project was unique in that funding was secured as a collaboration between three separate public entities: the City of Greenville, Greenville County and ReWa. Each agency recognized the severity of the stream condition and coordinated with the common goal of protecting critical infrastructure while providing for ecological restoration and resilience. Collaboration of this kind can be rare in public works and should be applauded.

Several varieties of stream stabilization techniques were employed throughout the project to encourage their use in other contexts in the area and beyond. The stabilization was designed to be a demonstration so that contractors, property owners, designers and members of the community could visit and assess each method and material for continued use. The Enigma Corporation side of the stream is open to the public, allowing access for interested contractors and designers. The County is excited to offer its lessons learned about each strategy's feasibility, price, effectiveness and other factors. In this way, stream stabilization and restoration will be promoted beyond Brushy Creek and the Reedy River watershed. Perhaps others will be inspired to continue sharing their experiences for a strengthened and united environment and community.



Figure 10. Flexamat.

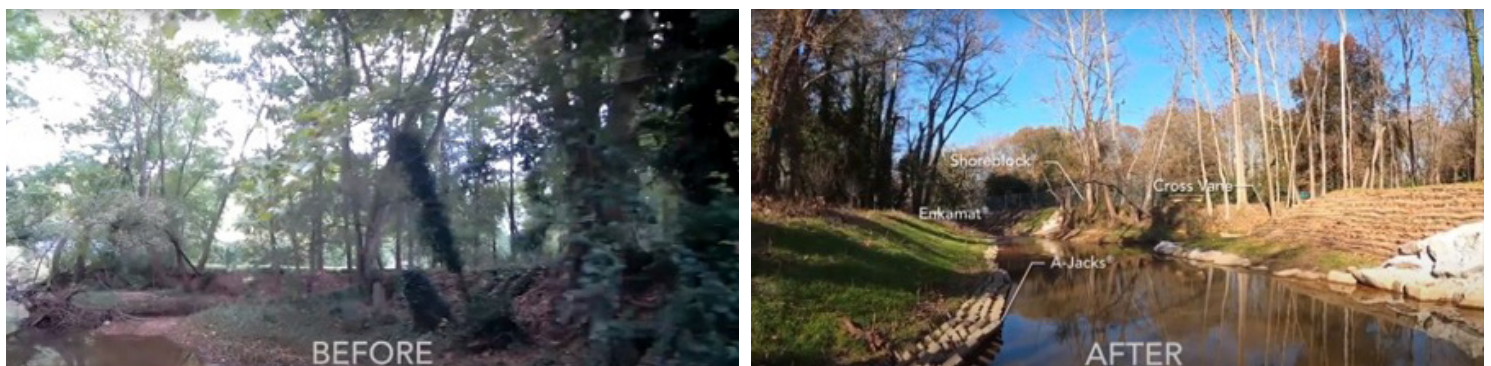


Figure 11. A-jacks.

