Addressing Water Quality through Stormwater Retrofits in the Reedy River Watershed, Greenville, South Carolina

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ABSTRACT. The Reedy River is situated in one of the most rapidly urbanizing areas in the country. Changes in historic and modern land use have adversely affected hydrology and water quality in the watershed. While the Reedy River has exhibited the capacity for long-term recovery, water quality in urban areas remains poor and hydrology is altered due to increases in impervious area. The Friends of the Reedy River (FoRR) have identified stormwater as a major threat to the river. Along with various partners, they have developed plans for a stormwater retrofit project along a highly utilized recreational corridor to serve as a demonstration for improved stormwater management for an existing development in a highly urbanized area. The project will be funded through grants and participation in the local stormwater utility fee credit program.

New developments are subject to local stormwater ordinance requirements that address quantity and quality control to varying degrees. Many older developments predate existing stormwater requirements and lack adequate stormwater controls. A combination of effective policy and incentive-based land management tools are needed for long-term watershed protection. As urban and suburban areas continue to expand, creative stormwater management solutions are needed particularly for existing developed areas to help protect, sustain, and improve the quantity and quality of surface waters. Public-private partnerships can capitalize on effective use of resources to achieve common watershed protection goals in these challenging areas.

INTRODUCTION

Past and present land use practices influence watershed hydrology and impact water quality. This was demonstrated on a landscape level in the southeast Piedmont following European settlement and clearing of forests for agriculture, and is evident today in rapidly developing areas of the region. Innovative solutions are often needed to address the current and legacy impacts of urban stormwater runoff and pollution.

Historic Land Use

Throughout the 1800s and early 1900s, the availability of inexpensive land and labor facilitated the widespread conversion of forestland throughout the southeast Piedmont for cultivation of row crops. Rapid land clearing and nonconservative agricultural practices combined with the cumulative effects of intense rainfall, steep slopes, and highly erosive soils resulted in significant topsoil loss and accelerated erosion and sedimentation across the region during this time (Trimble, 2008). In the South Carolina Piedmont, erosive land use peaked around 1920. The average depth of total erosion from 1700 to 1970 was estimated between 7 and 12 inches for most areas in this region (Trimble, 2008). Over time, streams, rivers, and floodplains became choked with sediment. Formerly cultivated bottomlands became covered with thick deposits of unfertile erosional debris and were subject to increased frequency of flooding due to the decreased capacity of stream channels to convey floodwaters (Trimble, 2008).

In 1931, Bennett reported that over half of the formerly cultivated alluvial land in the southeast Piedmont region was covered by erosional material from a few inches to more than six feet. Approximately 60 percent of South Carolina Piedmont bottomlands became unsuitable for cultivation due to the effects of accelerated sedimentation (Happ, 1945).

The 1930s brought the Great Depression, which led to the creation of various federal jobs programs for soil conservation, flood control and drainage. Many streams and rivers throughout the southeast were channelized (straightened and dredged) during this time and wetland areas drained to reclaim flooded alluvial lands. In the decades that followed and with the decline of cotton, many row crop areas were converted to pasture or reverted back to forested land. Erosion and sediment delivery rates also began to decline (Trimble, 2008). At the same time there was an economic shift away from farms and towards urbanizing areas where factories and mills offered new opportunities. Urban and suburban land uses increased. Rivers and streams were used for hydropower, municipal and industrial water supply and waste discharge. Water quality was at an all-time low. Untreated discharges of domestic and industrial wastes were common. Later, with the passage of the Clean Water Act in 1972, waste treatment methods developed, discharges were regulated, and significant water quality improvements ensued.

Development of urban and suburban areas increased markedly during the late 20th and early 21st centuries across the southeast Piedmont. Streams and rivers responded to the replacement of natural lands with impervious infrastructure by cutting through valley deposits, expanding to accommodate increased stormflows, and leaving behind eroded channels with unstable streambanks of poorly developed and highly erodible legacy sediments. In the Georgia Piedmont, channel erosion created streams and rivers with larger than historic channel capacities and higher recurrence intervals for overbank flooding, especially in upper watershed reaches (Ruhlman and Nutter, 1999).

Modern Land Use

Growth continues across many areas of the region today. Watershed hydrology, groundwater recharge, stream geomorphology, climate, biogeochemistry, and stream ecology have been affected by urbanization and the resulting increase in impervious area throughout many southeastern watersheds (O'Driscoll et al., 2010).

In undeveloped areas, rainfall is intercepted by vegetation, infiltrates into the ground, is stored in surface depressions or soil, and slowly percolates through soils. This process recharges deeper groundwater and helps sustain surface water baseflow.

In urban watersheds, the consequences of vegetation removal, land grading, replacement of permeable soils with impervious surfaces, and installation of stormwater conveyance systems combine to decrease natural watershed subsurface storage and increase stormwater runoff. As a result, urban streams rise more quickly during storms (i.e., exhibit a shorter lag time to peak flow), have greater stormwater volumes and higher peak flows, and experience increased frequency of flooding compared to rural streams (Konrad, 2003).

Urban streams respond to changes in watershed hydrology by becoming enlarged (incised and widened) to accommodate increased stormwater flows. The effects of channel expansion and floodplain conversion have caused many streams and rivers to become hydrologically detached from their adjacent floodplains. This detachment significantly decreases the natural capacity of these dynamic systems to slow and detain floodwaters and filter pollutants. Replacement of natural floodplain lands with urban and suburban development has also affected the recharge capacity of these important areas. The decrease in floodplain-surface water interaction and functioning is exacerbated in formerly channelized streams and rivers that effectively funnel stormwater and pollutants downstream.

Water quality is degraded in urbanized watersheds as a result of increased stormwater runoff from impervious surfaces through conveyance and collection systems that concentrate and deliver sediment, oil, grease, toxic chemicals, pesticides, nutrients, pathogens, heavy metals, and thermal pollution directly to surface waters. In-stream habitat quality is often low in urban areas due to impaired water quality, riparian canopy loss, and erosive stormwater flows that scour stream channels and deposit heavy sediment loads.

The effects of urban development often are greatest in small watersheds (Konrad, 2003) like the Reedy River near Greenville. Studies have indicated that the single most effective tool for protecting water quality in rapid growth areas is improved stormwater management to prevent flooding, stream channel erosion and water quality degradation (Ruhlman and Wenger, 2001).

Stormwater Management

Stormwater management has evolved from conveyance systems designed to efficiently remove stormwater runoff from developed properties to the inclusion of detention systems designed to reduce the effects of downstream flooding through control of peak flow. However, conventional detention basins often fail to protect water resources, as they typically rely on rate-based instead of volume-based stormwater control, which can further alter watershed hydrology, downstream channel integrity and water quality (Roseen et. al., 2001).

Stormwater detention basins have traditionally been designed to control peak flow rate for specific design storms such as the 2-, 10-, 25-, and 100-year events. However, it is the smaller more frequent storm events that deliver the majority of stormwater pollutants in a given year (Hunt et al., 2006), and which have the greatest ability to alter channel geomorphology and aquatic habitat (Roseen et al., 2001). Channel degradation can result from longer duration peak flows and an increase in the frequency of channel forming flows. Water quality and stream channel stability have, therefore, been degraded as a result of the cumulative effect across the urban landscape of concentrating and passing runoff from these smaller storms. Furthermore, conventional detention basins often fail to protect water resources because of poor design, construction, installation, and/or lack of maintenance.

The need exists to move beyond conventional detention as primary solution and to control quantity and quality near the source. Low impact development (LID) practices and technologies have the potential to help offset adverse impacts to hydrology and water quality caused by development and urbanization. However, the greatest reductions in impacts are typically most feasible for small, relatively frequent rainfall events and more pervious soil textures. Measures for management of larger, more intense and less frequent storm events are often still needed (Holman-Dodds, 2003).

Federal, state, and local governments have recognized the significance of urban stormwater pollution and the need for improved stormwater management. They have responded with the development of stormwater programs that include best management practices aimed at protecting water quality. As such, development sites are subject to new stormwater requirements that include both quantity and quality control. However, water quality volume is not consistently defined, and provisions to prevent downstream channel erosion are often absent or lacking. Municipal stormwater programs are encouraging the use of LID practices to more effectively replicate predevelopment hydrology. These practices reduce runoff, provide better water quality, flood control, and can minimize or eliminate the need for some types of conventional stormwater infrastructure.

Retrofitting existing developments has been identified as one of the major challenges for the future of stormwater management planning in South Carolina (Tomes, 2008). Many older existing urban areas were developed without adequate stormwater controls, or with controls that are undersized for modern stormflows. Some municipal stormwater programs have requirements or offer incentives for stormwater retrofits. While regional hardscape infrastructure (end of pipe) solutions are often needed for effective control in these difficult areas, feasible opportunities often exist to implement creative stormwater retrofits to provide water quality and channel protection benefits.

The Friends of the Reedy River (FoRR) is a volunteer-based non-profit organization whose mission is to support, enrich and improve the Reedy River through conservation efforts. For over 20 years, FoRR has worked to bring attention to the stresses on the river, and in 2013 they turned their attention to urban stormwater runoff. The following sections characterize the Reedy River watershed and highlight a case study that addresses stormwater quality through a cooperative stormwater retrofit project.

REEDY RIVER WATERSHED

The Reedy River watershed encompasses 260 square miles and is situated in the Piedmont of South Carolina in the Saluda River Basin (Figure 1). The upper watershed lies entirely in Greenville County, is heavily urbanized, and includes all or parts of the Cities of Travelers Rest, Greenville, Simpsonville, Mauldin, and Fountain Inn.

Figure 1. Location of Reedy River Watershed.

Lake Conestee is one of two major impoundments on the Reedy River and is the de facto regional detention structure for the upstream (urbanized) watershed. Boyd Mill Pond is located downstream of Lake Conestee in Laurens County. The lower Reedy watershed is largely rural and terminates at Lake Greenwood.

Growth and Development

Population growth rate has increased in urban areas and decreased slightly in rural areas of the Reedy watershed in recent years (Table 1).

Table 1. Population growth.

	Change in Population	
	Greenville Co.	*Laurens Co.*
1990-2000[a]	19%	20%
2000-2013[a]	24%	-0.5%
2000-2030[b]	38%	33%

[a] U.S. Census data
[b] (Campbell and Allen, 2007)

A 2007 growth study (Campbell and Allen, 2007) indicated a future growth ratio of 5:1 (rate of development/rate of population growth, signifying a high rate of per capita land consumption) for an eight-county region of Upstate South Carolina. Water quality and quantity impacts are higher for such sprawling growth patterns (Privette et al., 2014). Other recent studies have shown that growth in the Greenville area is occurring in a sprawling pattern. The Greenville/Mauldin/Easley metro area was ranked as the 3rd most sprawling metro area in the U.S. in 2010 (Smart Growth America, 2014). Greenville was ranked as the 7th most sprawled city in 2010 (Hamidi and Ewing, 2014).

Land cover data for the watershed area above Lake Conestee indicate a significant change in developed land from 1985 to 2000 (36 and 69 percent, respectively) (North Wind, 2007a). Over the same period, percent impervious cover increased from an estimated 10-18 percent in 1985 to 25-33 percent in 2000 in the upper Reedy watershed; impervious cover in the lower watershed increased from an estimated 3-10 percent to 15-20 percent (Allen et al., 2007).

Using National Land Cover Database data (NLCD, 2014), we determined the change in impervious area in the Upper Reedy watershed between 2001 and 2011 (Table 2). Increases occurred across all impervious classes, with the exception of the smallest class, which decreased. The greatest increase in impervious area over this period (58%) occurred in the highest impervious class (2,371 acres, or an average of 237 acres/year).

Table 2. Impervious Area Change in the Upper Reedy Watershed, 2001-2011.

Impervious Class*	*2001*	*2011*	*Change*	*% Change*
		(acres)		
0-19.9	71,031	68,022	-3,279	-5
20-39.9	123,76	13,015	639	5
40-59.9	5,308	5,370	62	1
60-79.9	3,544	3,751	207	6
80-100	4,101	6,472	2,371	58

* Impervious surface percentage per 0.3 acres.

Studies have shown that drainage area and impervious surface are the most significant variables affecting the magnitude and frequency of flooding in urban areas in the southeast Piedmont region (Feaster et al., 2012). These data show a continued increasing trend in growth and development in the watershed.

Watershed Hydrology

Urbanization has significantly impacted watershed hydrology in the Upper Reedy watershed. Analysis of climatic, streamflow, and flood frequency data clearly show an impact on streamflow patterns that are linked to deforestation, development and urbanization (North Wind, 2007a and b).
Evaluation of streamflow data from 1942-2006 for the Reedy River near Mauldin revealed a significantly increasing trend in peak flow and a corresponding significantly decreasing trend in baseflow over the same period, both attributable to the effects of urbanization (2007a). Figure 2 shows the increasing trend of annual peak flow over time in the Reedy River near Mauldin. In urbanized parts of the watershed, high flows are dominated by stormwater. During low flow periods, the Reedy River becomes an effluent-dominated river downstream of municipal wastewater discharge points.

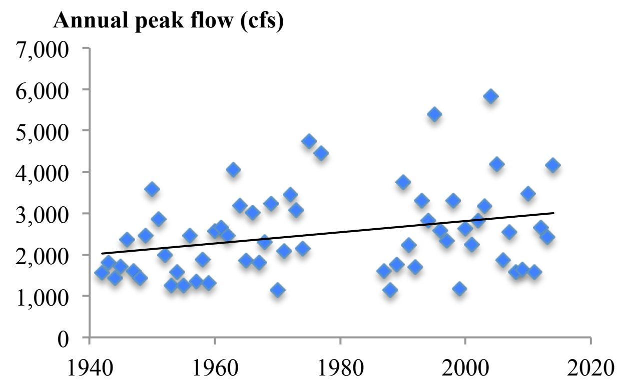

Figure 2. Annual peak flow, Reedy River at Mauldin.

Another study in the Saluda-Reedy Watershed (SRW) showed an inverse correlation between forest cover and peak flow. Watersheds with more forest cover had lower per area peak flow values compared with urban and agricultural watersheds. The most heavily urbanized watershed (upper portion of the Upper Reedy River) had the highest per area peak flows (North Wind, 2007b).

Water Quality

In the SRW, better water quality is found in watersheds with more forest cover. Not surprisingly, urban/suburban watersheds such as the Upper (urban) Reedy River revealed the poorest water quality (North Wind, 2007b). An analysis of historic local surface water quality data showed generally improving water quality trends across the SRW over time, with some declining trends in heavily developed and urbanizing watersheds. It should be noted that there are many areas of the Reedy River watershed for which water historic and modern quality is unknown.

Many water quality improvements can be correlated with the implementation of the Clean Water Act in 1972. However, water quality improvements from decreased point source pollutant loadings (i.e. due to reductions in textiles and improved waste treatment technologies) may be somewhat masked due to the increase of nonpoint source pollutant loadings caused by the conversion and development of forested and other undeveloped areas (Pinnacle Consulting Group, 2005).

Sediment quality is also essential to understanding the quality of the watershed system as a whole.

Assessments have confirmed the presence of a wide variety of contaminants associated with sediment, particularly behind impoundments such as Lake Conestee (North Wind, 2006). Sediment quality is a reflection of historic (legacy) releases of contaminants from a variety of sources.

Use Support

Use support data collected by the South Carolina Department of Health and Environmental Control (SCDHEC) was analyzed for ambient stream and river monitoring sites in the Reedy River watershed from 1988 to 2012.

Figure 3 shows that for aquatic life use support, which integrates chemical and biological data, the percentage of sites classified as:

- Good (fully supports) has remained relatively low,
- Fair (partially supports) has increased, and
- Poor (does not support) has decreased.

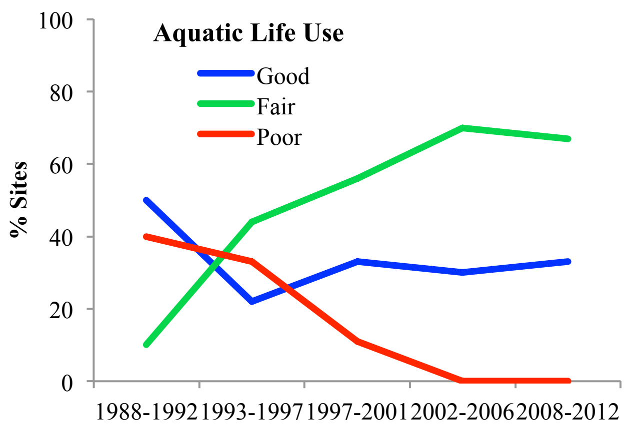

Figure 3. Aquatic life use support, Reedy watershed.

An analysis of recreational use support data (bacterial) collected by SCDHEC also revealed similar trends. The Reedy River also supports municipal, industrial, and agricultural uses.

STORMWATER RETROFIT PROJECT

The City of Greenville has undergone a renaissance over the past 30 years with a surge in urban redevelopment and revitalization. Central to this revitalization has been the improvement and expansion of parklands and greenways as zones of environmental preservation and cultural assets for active and passive recreation. Additionally, greenways have become important additions as alternative multi-modal transportation routes for pedestrians and bicyclists. The Swamp Rabbit Trail (SRT) extends 17 miles from Travelers Rest to Conestee Village. The SRT has proven to be a recreational resource and significant economic development engine, leading to dramatic increases in the quality of life and business development opportunities for many communities.

Between Woodland Way and East Faris Road in Greenville's Cleveland Park, the SRT parallels the Reedy River along a 3,500-feet corridor. A number of public and private properties adjoin the trail and river along this reach, including older developments characterized by significant impervious surfaces and a lack of stormwater treatment facilities, a result of their construction prior to existing stormwater regulations. Stormwater runoff from these older developments largely flows unabated through ditches, culverts, open channels and buried pipes that discharge directly into the river. Standing water in this corridor has adversely affected the SRT itself causing structural failures of the trail. The riparian habitat is generally of low quality with a prevalence of non-native, nuisance, and invasive plant species.

Within this corridor, existing development, coupled with open land adjacent to the river and the SRT, provides the opportunity for a variety of stormwater retrofits to improve the water quality of stormwater discharging to the river. The proximity of the SRT offers community education opportunities to highlight water stewardship through development of demonstration projects.

The First Baptist Church (FBC) property in Greenville is FoRR's first project site within this corridor restoration initiative. The FBC was constructed in the early 1970s before existing detention requirements. The impervious footprint of the 24-acre site is approximately 9 acres. Most of the stormwater runoff from this area is captured through stormwater infrastructure and directed to a buried 24-inch pipe that flows directly to the Reedy River without any flow attenuation or water quality treatment. The remainder of the campus includes landscaped and open areas.

FoRR, in collaboration with the FBC, and the Greenfields Consortium, LLC, is working with a number of partners on a stormwater retrofit project that includes: 1) a stormwater wetland detention basin to capture, detain, and treat first flush stormwater runoff from the primary stormwater outfall pipe, 2) enhancement of existing stormwater conveyance swales, and 3) a separate small stormwater wetland/rain garden. The larger stormwater wetland basin demonstrates a retrofit for an existing developed site with higher relative impervious surface. The smaller rain garden demonstrates a retrofit for smaller areas commonly found in suburban situations.

Collectively, these innovative retrofits will simulate the function of natural systems by using physical, chemical, and biological processes that increase infiltration, decrease direct runoff to the river from the more frequent smaller storms, and provide biodegradation and phytoremediation of stormwater pollutants. Other components of the project include riparian restoration, and installation of passive recreational amenities and educational signage.

The proposed stormwater management improvements are designed in accordance with the City's new Stormwater Management Utility Fee Credit Policy, which was created to encourage enhancing/retrofitting existing stormwater systems or creating new ones where none previously existed. Generally, this program provides storm water utility fee credits to commercial, industrial, institutional or multi-family residential property for implementation of water quantity and quality control measures, K-12 water resources education programs, and inspection certification. The FoRR/FBC project will be one of the first retrofit-construction projects under this program. The maximum annual fee credit is 40%, with a 100% single year credit for detention on an existing property that lacks detention.

Using preliminary cost estimates typical for design, permitting and construction of this retrofit project, it would take over 25 years to offset the direct financial costs with savings from the voluntary fee credit program. Moreover, one cannot determine whether or not the fee credit will be approved without first paying for design and permitting, which typically can range from 10 to 15 percent of the project construction budget. This initial financial burden should not be overlooked as it devalues the program's financial incentive goals.

The FoRR, the Greenfields Consortium, and the FBC are working to fill the gap for financial requirements to design and implement the project. The team has developed a collaborative partnership strategy to seek grant funding to complete the project in phases. Without this additional funding and partnership, the project would be unlikely to commence or succeed. We are working with a number of partners and supporters including Greenville County Soil and Water Conservation District and the City of Greenville on design and permitting, as well as riparian and stormwater management education that stresses the importance of protecting our waterways. It is through this partnership that we are able to leverage resources to move the project forward.

DISCUSSION

A 2011 survey of southeast (EPA Region IV) stormwater utilities revealed that less than 0.1 percent of storm water account holders received credits through such incentive programs, and that the average percent fee reduction was only 27 percent (SeSwA 2011). Financial barriers may drive this low level of participation. In the context of such incentive programs across the southeast region, solving this financial shortfall scenario is key to addressing widespread problems associated with stormwater runoff from developed urban areas. Substantive improvements to storm water management through such fee credit programs require greater financial incentives to encourage significant participation. These will likely need to be coupled with other incentives for stormwater retrofit such as the Greenville County Stormwater Banking Program. The County's program offers density bonuses for developers who use LID practices in lieu of detention and who pay a fee that is applied to a stormwater banking fund for strategic stormwater retrofit projects.

A combination of policy and incentive-based land management tools are needed for long-term watershed protection. Effective provisions and performance standards for stormwater quantity and quality control and downstream channel and flood protection are a prerequisite. Regional solutions such as the adoption of Unified Sizing Criteria (USC), which has been adopted in neighboring states to South Carolina for well over a decade, can be beneficial (Lamb, 2012). Incentives that truly incentivize are also essential.

Developers are successfully incorporating stronger stormwater controls to meet strict volume reduction and water quality standards in both redevelopment and greenfield projects. Complying with stormwater regulations is one factor among many that influences a project's costs but is rarely the driving factor (ECONorthwest, 2011).

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