Wake County's population has tripled over the last forty years, and will grow by another half a million residents over the next twenty.

As we've grown, we've paved over large areas to build homes, businesses, public buildings, and roads. Poorly managed stormwater runoff from that developed landscape now threatens the health of our streams and rivers, squanders water we need to meet growing demand, and causes local and downstream flooding.

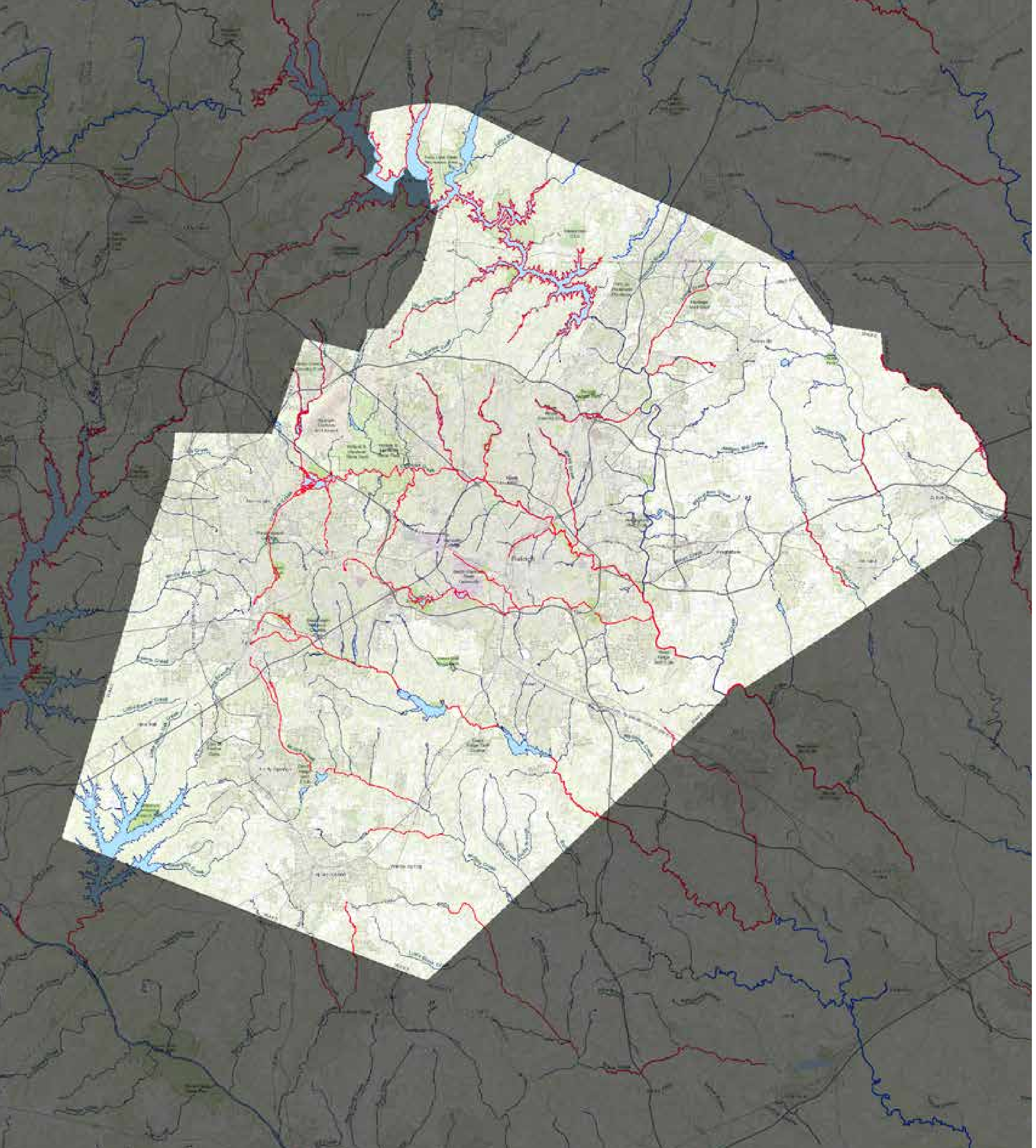
Fortunately, there is a solution.

Green Stormwater Infrastructure (GSI) offers a better, often cheaper way to manage stormwater - from both our existing and future neighborhoods.

This primer explains how.

GREEN STORMWATER INFRASTRUCTURE

A WAKE COUNTY PRIMER



This map of Wake County shows streams and drainages in relation to major roads and municipal territories, a fair proxy for dense impervious surface. Streams in red violate water quality standards and are classed as 'impaired', often by excessive stormwater runoff.

HOW TO USE THIS PRIMER

This primer on 'green stormwater infrastructure' (GSI) is intended as a resource for local elected officials and interested residents of communities in Wake County. As used in this primer, GSI is stormwater management that draws on or mimics natural processes to keep rainwater where it falls, soaking into the ground or evaporating back into the air rather than running into nearby streams. A working goal of GSI is to ensure that, for at least 90% of storms, water runs off the developed landscape at no greater rate and volume than it ran off before development.

GSI meshes with two larger concepts: 'green infrastructure' – conserving natural landscapes that benefit us; and 'integrated water management' – recognizing that stormwater, drinking water, and wastewater are all one resource. The pages below explain why GSI is needed here now, where it is already being used in Wake County, and how it relates to the mission of each department of local government.

Please cite this document as NC Conservation Network. 2017. Green Stormwater Infrastructure, A Wake County Primer. For more information, contact Grady McCallie, NC Conservation Network, grady@ncconservationnetwork.org, or 919-857-4699 x101.

EXECUTIVE SUMMARY: TEN WAYS TO BRING GSI TO YOUR TOWN

When land is developed, hard surfaces – roofs, sidewalks, streets – shed more stormwater than the trees and shrubs they replace. Less rain soaks into the ground or evaporates back into the air, and more runs off into nearby streams, eroding their beds and banks, and degrading water quality. Groundwater supplies shrink and baseflows in streams drop, while increased runoff immediately after storms increases flooding downstream. Stormwater retention basins – required in many towns since 2006 – help slow runoff but still degrade streams and diminish groundwater recharge.

Now there is a better option: Green Stormwater Infrastructure. GSI consists of a toolbox of practices and techniques – rain gardens, bioswales, tree protection, and permeable pavement, among others – that keep stormwater onsite instead of letting it run off. GSI practices protect groundwater supplies and stream health, and can cost much less over time than managing stormwater with large detention basins.

This summary outlines ten ways municipal leaders can bring the benefits of GSI to your community. Four focus on public infrastructure, four on private development, and two on getting the administrative structures right.

PUBLIC INFRASTRUCTURE

1. Use GSI to address neighborhood flooding. When neighborhoods suffer frequent flooding from stormwater runoff, GSI can help – often at a lower cost than such traditional approaches as armoring streambanks and installing larger culverts.

2. Design municipal roads with GSI. When it's time to build or rebuild roads, GSI practices should be part of the design. A new resource from the National Association of City Transportation Agency, the Green Street Stormwater Guide (2017), shows how.

3. Design parks facilities with GSI. New recreation facilities should be designed and built with GSI practices. Parks often include large parking lots that are good candidates for rain garden retrofits.

4. Use public land for GSI retrofits. Tracts belonging to the town – including rights of ways along roads – are often well suited to host GSI practices that benefit the whole community.

PRIVATE DEVELOPMENT

5. Conserve key natural areas. Stream zones, floodplains, wetlands, and forests on original soils all help contain and absorb stormwater runoff. Targeted land conservation can protect the most valuable of these tracts from clearing and development.

6. Revise ordinances to remove barriers to GSI. Changes to development ordinances – for example, simplifying curb cuts, or allowing rain gardens to satisfy both stormwater and vegetation standards – can make it easier for developers to design GSI into their projects.

7. Establish a GSI cost-share program. Providing even modest cost-share support can inspire residents and businesses to install GSI practices in developed neighborhoods.

8. Protect trees, plant trees. Trees can capture and hold the first inch of rain. Hiring an urban forester or simply investing in tree conservation and planting can pay big dividends in runoff reduction, property values, and quality of life for residents.

ALIGN THE LOCAL FRAMEWORK

9. Build GSI into planning documents. As communities update their comprehensive plans, GSI should figure prominently in plan environmental elements. In particular, a modern plan should state that matching pre- and post-development runoff patterns is a core policy for both public investment and private development in the jurisdiction, because it saves money and improves quality of life.

10. Remove budgeting barriers to GSI. While GSI practices have routinely been found to have lower lifecycle costs than traditional stormwater infrastructure, those costs are not distributed the same way between capital and operations – so it is key for budget officers to know how to document those tradeoffs when presenting GSI policies and designs to town decision-makers.

The NC Museum of Art manages runoff with a gorgeous, large-scale system that includes bioswales, cisterns, infiltration, and conserved natural features. Smaller GSI practices, such as rain gardens, can be installed at much lower cost by churches, schools, and individual landowners.

WHAT ARE GSI PRACTICES?

The term 'green stormwater infrastructure' (GSI) embraces a variety of different measures that all work to keep stormwater behaving, as much as possible, the way it did before human activity altered the landscape. GSI practices can range in size from stand-alone, parcel-specific measures to jurisdiction-wide efforts.

PARCEL-SIZED PRACTICES

These practices are the nuts and bolts of GSI.

Rain gardens. Rain gardens are shallow basins, filled with appropriate plants, that receive run-off from nearby surfaces and let it soak into the ground or transpire into the air. A recent study in Cincinnati, Ohio, found that rain gardens, over their lifespans, cost 42% less than traditional detention basins while delivering better downstream protection.[1] *See Figure A.*

Planter boxes. A kind of rain garden designed for urban areas, planter boxes can hold trees and other vegetation, and collect ground-level runoff and add beauty and interest to densely developed areas. *See Figure B.*

Vegetated swales. Better than ditches, vegetated swales slow down stormwater, letting some of it filter into the soil, and letting sediment pollution settle out on the way. *See Figure C.*

Disconnected downspouts. One of the cheapest GSI practices, disconnected downspouts release roof runoff onto grass lawns, letting stormwater soak into the ground, rather than sending it directly onto pavement or into storm sewers. *See Figure D.*

Permeable pavement. In the right locations, permeable pavement can keep standing water off of roads and parking lots while recharging groundwater supplies.

Preserving natural features. Parcels often have natural features – swales, trees, bands of highly porous soils – that slow water and let it soak into the ground. These features should be protected during development.

Tree canopy. Trees intercept significant volumes of stormwater; conservation of existing tree canopies and planting of new trees can be effective GSI practices.

Rainwater capture and use. Cisterns and rain barrels can help catch water for gardens and some indoor uses. Rainwater capture can be more useful as a source of supply than a method of reducing runoff, but it has a role in better water management overall.

Land conservation. Undeveloped land typically does the best job of transpiring water back into the air, promoting infiltration, and slowing runoff – so conserving key parcels can make a big difference on the local level.

Green roofs. With special substrates and plants adapted to exposed conditions, green roofs capture rain and evaporate it back into the air with little or no runoff.

LARGER SCALE COMBINATIONS

Protecting a whole watershed or town requires a large number of practices, often scaled up and bundled together. Green streets and green parking often combine tree planting, permeable pavement, vegetated swales, and planter boxes or other rain gardens. Neighborhood-scale retrofits can include rain gardens, swales, and downspout disconnection across multiple properties at once. Watershed restoration plans can combine all of these with land conservation and streambank and wetland restoration.

PROGRAMMATIC APPROACHES

Policies for municipal facilities design. Local governments can direct staff to incorporate GSI into plans for new facilities – whether that is a new road or a town aquatic center. City planners and designers can systematically apply design standards that minimize stormwater runoff and protect groundwater recharge.

Incentive programs for private retrofits. Some local governments offer cost share programs that shoulder part of the cost of installing GSI practices if the resident or business agrees to maintain them.

Modifications to development ordinances. Some developers would like to deploy GSI approaches, but are deterred by local codes that require structural stormwater controls and discourage alternatives. Fine-tuning development ordinances can clear the way for voluntary private adoption of GSI.

Urban tree canopy protection. Trees can capture significant volumes of rain and evaporate them back into air – with an added bonus that the air is cooler, foiling the heat-island effect and reducing residents' cooling costs. That can be particularly valuable here in Wake County, with our hot, humid summers. Urban trees improve residents' health, reduce rates of absenteeism from school and work, and raise property values.[2] Towns can protect their urban tree canopy through direct investment, public education, or regulation.

Jurisdiction-wide inspection and maintenance of practices. Stormwater control practices work only if they are maintained. For all municipalities in Wake County, ensuring that practices are maintained is a requirement of federal law as well as a good idea.

1 Donald Vinyard, et. al. 2015. Comparing Green and Gray Infrastructure Using Life Cycle Cost and Environmental Impact: A Rain Garden Case Study in Cincinnati, OH. Journal of the American Water Resources Association. 51:5. 1342.

2 US Forest Service and University of Washington. 2016. Green Cities, Good Health: Work & Learning.

Figure A

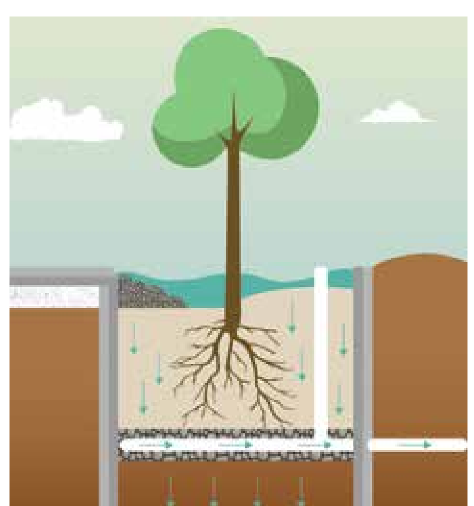


Figure B

Figure C

Figure D

WHY GSI NOW?

Since 1980, Wake County's population has more than tripled.[3] Along with that growth has come a massive increase in impervious surface, areas that were previously forests and fields, but are now covered with pavement, sidewalks, roofs, and hard-packed lawns.

When rain hits those surfaces, it no longer soaks into the grounds or gets caught on leaves and evaporates; instead, it runs off, carrying dirt and pollutants, into the nearest creek. Creeks surge after a rainstorm, widening floodplains and eroding streambanks. Yet because less water soaks into the ground, groundwater fed streams shrink more during dry months. Even away from floodplains, the increase in impervious surface has caused 'urban flooding,' where stormwater has nowhere to go, creating problems for residents who aren't anywhere near a stream or river.

Over the last forty years, the best practices for managing stormwater have changed. Until around 1990, state law and policy encouraged landowners to move stormwater downstream as rapidly as possible. In the 1990s, responding to concerns both about flooding and water pollution, federal and state authorities began to require the construction of large detention basins. Basins were designed to hold peak runoff and release it slowly within 72 hours (to free up pond volume to catch the next rain). While this is better than no control, detention basins are expensive to build and maintain, and take up land that would otherwise be buildable. Also, while basins cut the peak rate of runoff from a storm, they don't reduce the total volume of runoff, so they don't help much to increase recharge of groundwater or prevent downstream bank erosion.

In the early 2000s, scientists and engineers began promoting a new approach: Green Stormwater Infrastructure (GSI), which emphasizes solutions that mimic nature. Managing stormwater this way can reduce or prevent flooding, protect stream flows and water quality, and sustain water supplies for growing communities – all at a lower total cost than trying to solve each of these problems individually by pouring more concrete.

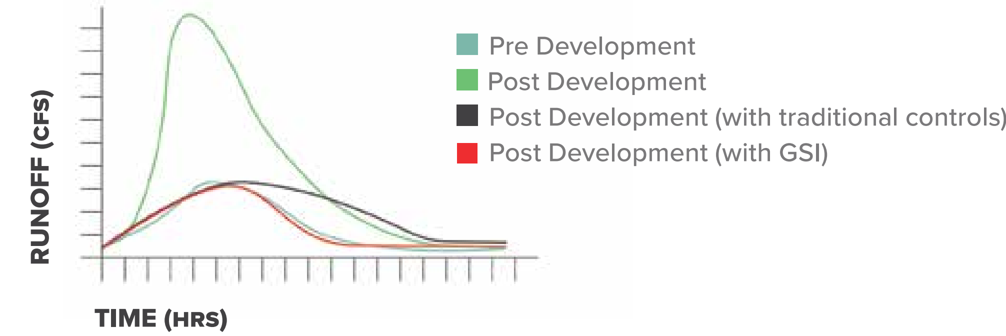
On a practical level, GSI delivers these solutions by, as much as possible, echoing the natural water cycle. *See Figure E.* Stormwater is kept onsite and allowed to soak into the ground and evaporate back into the air, or is captured for use in buildings. With less runoff, potential pollution stays put also, keeping rivers cleaner. Less runoff means fewer major drains and pipes are needed to shunt stormwater away. Use of rainwater for flushing toilets and irrigating lawns reduces strain on drinking water and wastewater infrastructure. GSI does require some new institutional structures, and requires engaged leadership and support from local leaders. This primer describes how.

GSI AND THE 'ONE WATER' FRAMEWORK

Green Stormwater Infrastructure fits well within the 'One Water' framework, a way of looking at water that is increasingly widespread among municipal water managers and elected officials nationwide. At its heart, One Water is the insight that the water in rain, groundwater, rivers, reservoirs, city pipes, and estuaries is all part of one cycle. The stormwater we want to keep out of buildings and off roads is the same water that we need to meet growing demand at other times of year. Managing it wisely can save us a lot of money and a lot of grief.

3 US Census Bureau. Wake County in 1980: 301,327 residents; 2010: 900,993; est. for 2017: 1 million residents.

Figure E **RUNOFF HYDROGRAPH**



Even a modest level of impervious surface in a watershed can significantly increase runoff. By keeping water onsite, GSI practices can match post-development runoff to pre-development patterns, avoiding harms downstream.

Table 1* - Key differences between conventional and integrated 'One Water' approaches to water/stormwater management.

Aspect of Urban Water Management	Conventional Approach	Integrated Approach
Overall approach	Integration is by accident. Water supply, wastewater and stormwater may be managed by the same agency as a matter of historical happenstance but physically the three systems are separated.	Physical and institutional integration is by design. Linkages are made between water supply, wastewater and stormwater, as well as other areas of urban development, through highly coordinated management.
Choice of infrastructure	Infrastructure is made of concrete, metal or plastic.	Infrastructure can also be green including soils, vegetation and other natural systems.
Management of stormwater	Stormwater is a constraint that is conveyed away from urban areas as rapidly as possible.	Stormwater is a resource that can be harvested for water supply and retained to support aquifers, waterways and biodiversity.
Management of water demand	Increased water demand is met through investment in new supply sources and infrastructure.	Options to reduce demand, harvest rainwater and reclaim wastewater are given priority over developing new resources.

* William Cesanek, Vicki Elmer, Jennifer Graeff, 2017. Planners and Water. PAS Report 588, at 23.

GSI AND GROUNDWATER

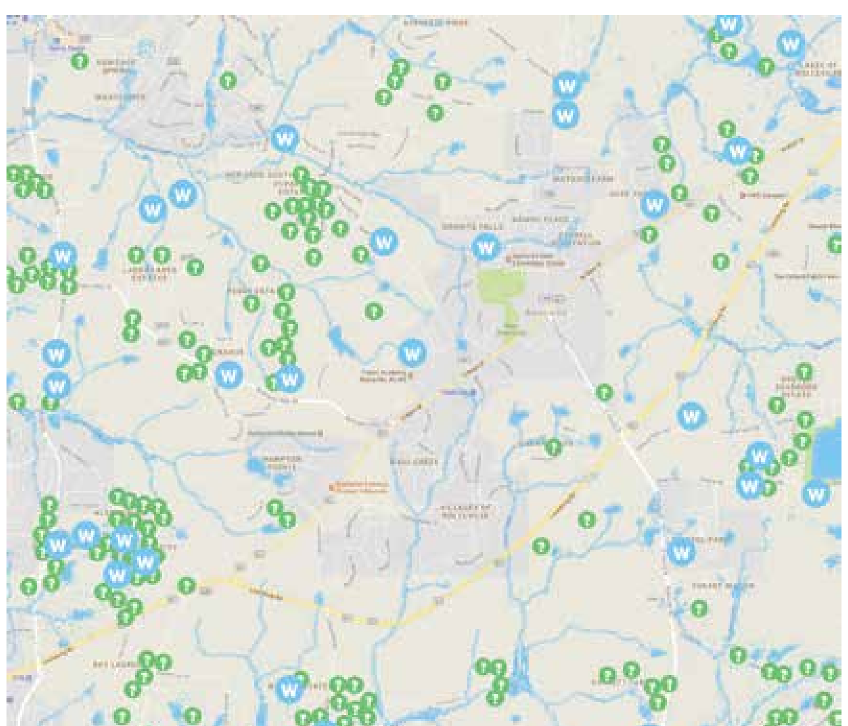
An estimated 140,000 residents in Wake County get their drinking water from private wells; perhaps another 108,000 residents rely on community water systems that pump from wells.[4] All those wells ultimately depend on recharge from rain. In Wake County, groundwater moves through pore spaces in the weathered rock just under the surface, and in smaller quantities through cracks in bedrock.[5] When development paves over the land surface, recharge rates fall, and groundwater dries up. Over time, that threatens the continued viability of drinking water wells.

Beyond drinking wells, groundwater also sustains our streams and rivers between rain events and during the dry months of the year. As stormwater runoff volumes increase, stream channels are incised, with streambeds dropping lower. This can result in less recharge into groundwater in the surrounding floodplain, and a draining of groundwater supplies. Even on rivers where dams impound surface flows, runoff often arrives when surface reservoirs are already full, so the water is allowed to flow on downstream. Then, when the dry months or drought arrives, lower flows from groundwater mean less water is available to replenish reservoirs or feed run-of-river intakes.

By restoring groundwater recharge, GSI practices help protect private drinking wells and also protect flows in our streams in the driest times of year. GSI achieves this result by matching post-development runoff – and infiltration, and evaporation – to pre-development conditions for the 90th percentile storm. In Wake County, that means a GSI practice must be able to absorb up to 1½ inches of rain with no increase in runoff. In Wake County, that covers over 90% of the rain that falls each year.

4 There is no official census of private wells in Wake County. This estimate was derived by subtracting the number of public and private utility residential accounts from the number of occupied residential structures in the county. The estimate of community water system users is from EPA's Safe Drinking Water Information System database.

5 Ralph Heath. 1980. Basic Elements of Ground Water Hydrology With Reference to Conditions in North Carolina. USGS.



This map shows known (W) and probable (?) drinking water wells in the vicinity of Rolesville.

GSI AND FLOODING

Rain that can't evaporate or soak into the ground has to go somewhere: it runs downhill.

Increased runoff damages streams and rivers. In the near term, more runoff causes more frequent flooding downstream. Over decades, runoff eats away at stream beds and banks, destroying fish habitat and leaving stream channels in urbanizing watersheds wider and deeper compared to those in rural watersheds.[6] Where streambanks are rigid from armoring and the channel cannot widen, downstream flooding gets worse and worse. Perhaps because of this, one 2004 study found that practices that keep rainfall onsite improve the values of all properties in the floodplain downstream by 2% to 5% - small for any one property, but large when aggregated across a town or watershed.[7]

Closer to home, increased impervious surface doesn't just widen floodplains downstream. It has also caused completely new flooding – urban flooding – in neighborhoods in Wake County. Also called 'pluvial flooding,' because it happens when it rains, this kind of flooding can be particularly destructive, because it typically happens to residents who don't live anywhere near a floodplain, haven't prepared, and have had no reason to buy flood insurance. The Federal Emergency Management Agency has estimated that 20% - 25% of economic losses from flooding happen outside designated floodplains and reflect urban drainage.[8]

To be clear, GSI cannot prevent all flooding. Even if applied to all future and existing development in Wake County, GSI would only mimic natural processes for the first 1½ inches of rain. Beyond that, stormwater pipes will still convey runoff to streams faster than the pre-development landscape did. So, intense storms in heavily developed watersheds will still cause impacts.

However, when combined with floodplain restoration and urban tree canopy protection, GSI can add a buffer of protection against routine flooding.

Moreover, by limiting total runoff – not just peak flow – GSI protects riverbanks. Excess volume, even when released gradually, causes continual bank erosion. As GSI practices reduce runoff volumes, that erosion tapers off, and the river channel keeps clearer – so not only does the river carry less water immediately after a heavy rain, but the river also has more capacity to hold it.

6 Barbara Doll, et al. 2002. Hydraulic geometry relationships for urban streams throughout the Piedmont of North Carolina. Journal of the American Water Resources Association. Jun 2002. 38:3.

7 John Braden and Douglas Johnston. 2004. Downstream Economic Benefits from Storm-Water Management. J. of Water Resources Planning and Management. 130:6.

8 FEMA. 2008. Floodplain Management — Principles and Current Practices, at 2-12.

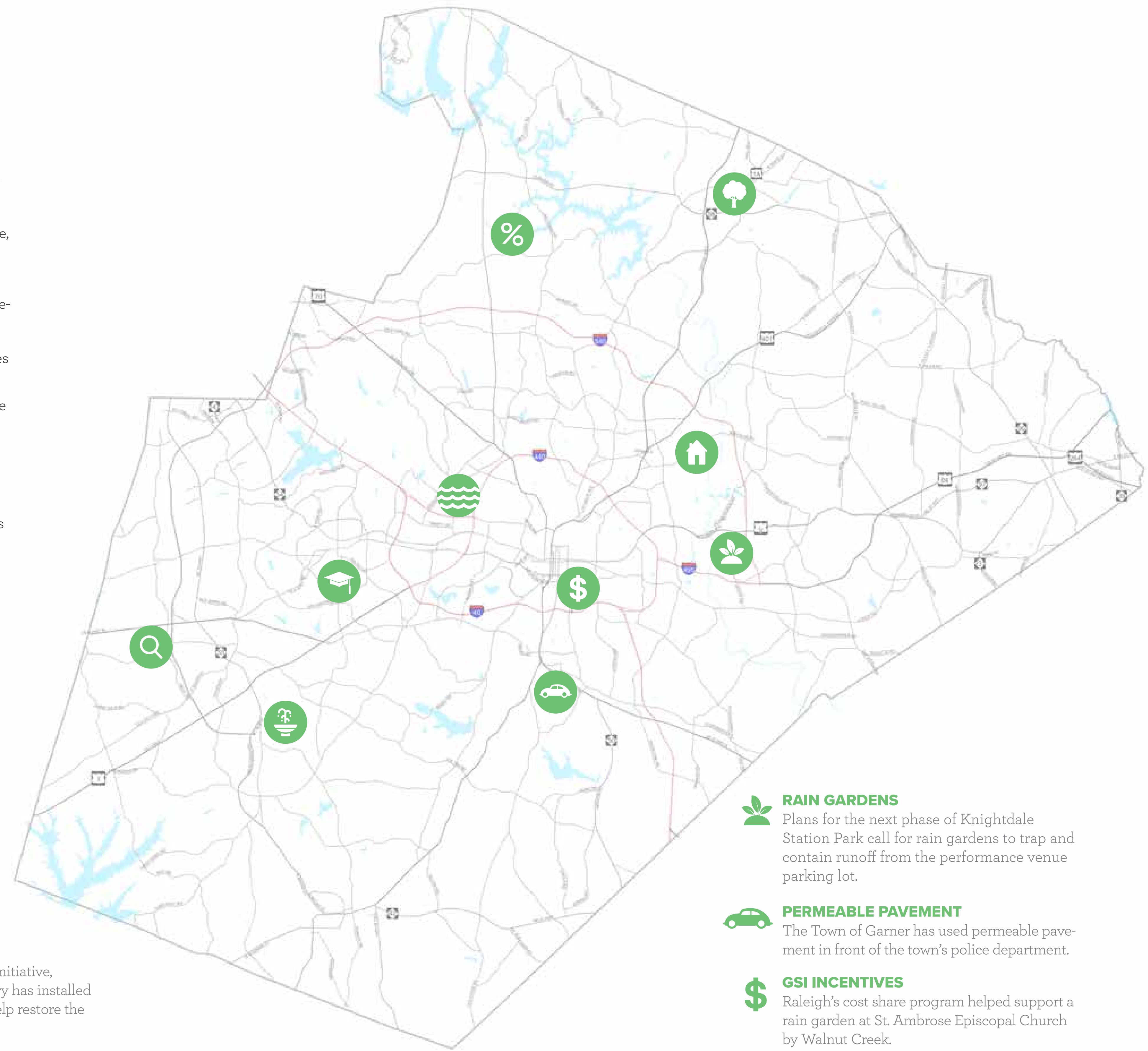
Excess stormwater ravages natural streams, eroding banks, toppling riparian trees, and filling stream bottoms with silt and sediment.

GSI IN WAKE COUNTY TODAY

Good water management involves all parts of local government. Public utilities build and maintain water and sewer infrastructure – and, in some towns and cities, stormwater infrastructure also. Planners guide where private development builds on the landscape, and shape decisions about where to place roads, schools, and water and sewer lines. Municipal transportation departments periodically rebuild roads, a process that can either create new runoff problems or can help solve flooding problems that have plagued neighborhoods for years. Parks and recreation departments can protect key parcels as open space, host retrofit projects, educate town residents, and follow green practices in the construction of their own facilities, which often include extensive roof areas and parking lots.

Because nearly every department of local government has a role to play in good water management, leadership needs to come from the top. Town managers and local elected officials must ask the right questions to help staff escape silos and work together. As best practices for sustainable water management evolve, leaders can help ensure that staff gets access to training and receives support – through the town budget and in local ordinances – to implement best practices consistently.

Wake County already has some great examples of green infrastructure approaches that can and should be widely replicated. Some of these are one-shot projects, advanced by creative staff and bold leaders. The challenge facing local leaders is to take these good examples and make them systematic practices, so our communities can benefit from these new ideas across the board.



MITIGATION REQUIRED
Wake County requires mitigation – such as by GSI – before an owner can exceed the permitted impervious surface levels for a subdivision lot.

BIOSWALE AND INFILTRATION COMPLEX
The NC Museum of Art runs stormwater through bioswales and tiered wetlands to slow and treat it.

INSPECTING PRACTICES
The Town of Apex requires owners of stormwater practices to inspect and report annually, and puts the list online for the public to see.

USE OF PUBLIC PROPERTY
The Town of Holly Springs is co-locating GSI and recreational uses on public land to control the first inch of runoff from the entire upstream watershed.

SCHOOL RETROFIT
As part of a larger watershed initiative, Kingswood Elementary in Cary has installed a rain garden and cistern to help restore the Black Creek watershed.

GREEN ROOF
The Buffaloe Road Aquatic Center uses a green roof to minimize runoff from the swimming pool building.

RAIN GARDENS
Plans for the next phase of Knightdale Station Park call for rain gardens to trap and contain runoff from the performance venue parking lot.

PERMEABLE PAVEMENT
The Town of Garner has used permeable pavement in front of the town's police department.

GSI INCENTIVES
Raleigh's cost share program helped support a rain garden at St. Ambrose Episcopal Church by Walnut Creek.

URBAN FORESTRY
Wake Forest has an urban forester on staff, and impressive programs to inventory and maintain town trees.

GSI AND LAND DEVELOPMENT

As a component of the built environment, green infrastructure is strongly shaped by local plans, ordinances, and the local permitting process. The American Planning Association encourages planners to look for five 'points of engagement' to promote better management of water resources: visioning, plan making, policies, development work, and public investments.[9] For a local elected official or an interested resident, planners are increasingly key allies in getting the ground rules right for GSI.

COMPREHENSIVE PLANS

A community's comprehensive plan sets the tone and vision for public investments and private development activities. Most municipalities in Wake County – even those that have recently adopted comprehensive plans that are cutting-edge in other respects – have not yet folded concepts of integrated water management or GSI into their comp plans.

One example of a strong stormwater policy is this language from a draft revision of Raleigh's 2009 comprehensive plan: "Potential stormwater impacts from new development on adjoining properties should mimic pre-development conditions and control the peak rate of runoff and/or volume of runoff so as to avoid flooding of adjoining and downstream properties, erosion of stream banks, and to allow the recharging of groundwater."[10] The draft revisions also include actions to promote GSI at city facilities, to adjust codes to facilitate low impact development, and to restore local streams.[11]

DEVELOPMENT ORDINANCES

As required by state and federal law, all towns in Wake County have ordinances requiring new developments to be built with measures to manage post-construction runoff. In general, though, state standards are still focused on a gray infrastructure model of stormwater management, so towns need to take a couple more steps to secure the real benefits of GSI:

Removing barriers to GSI. Town ordinances often force developers to use wet ponds, preempting GSI practices that could save developers money while offering better control of runoff. Opening up the spectrum of allowed practices frees developers to deploy GSI to everyone's benefit.

Increasing certainty. Developers may perceive a risk in trying (for them) new techniques. Allowing developers to count tree boxes or bioswales to meet both stormwater and vegetation requirements can encourage adoption of GSI approaches, as can allowing developers to place GSI practices in the town's right of way.

PERMITTING PROCESS

Beyond standards in town ordinances, the permit process for new developments and redevelopments can influence whether applicants try out GSI approaches. For example, Raleigh plans to develop a cost-benefit tool to make it easier for developers to tell up front whether GSI approaches to stormwater management make sense for any given site.[12] The city also plans to create an expedited review process for projects that use GSI. Both of these process changes may seem out of reach for a town with a small staff and budget, but with some creative thinking, it may be possible to repurpose the tools Raleigh is already developing.

9 William Cesanek, Vicki Elmer, Jennifer Graeff, 2017. Planners and Water. PAS Report 588, at 7.
10 Staff draft revisions to Section 5 of the Raleigh 2009 Comprehensive Plan, released June 7, 2017, EP 3.12.
11 Id, EP actions 3.1, 3.2, and 3.12.
12 TetraTech. 2016. Implementation Work Group Report: Advancing Green Infrastructure and Low Impact Development in Raleigh.

A SPECIAL NOTE: TREE PROTECTION

Protection of existing trees is a powerful GSI practice. The US Forest Service notes that, in addition to lowering urban summer temperatures and increasing property values, trees can intercept and transpire significant volumes of rain, take up nitrogen, and protect water quality downstream.[13] Trees are generally most effective where they have been preserved, and relatively less effective when planted after a site has been cleared and had its soils compacted by development activities.

Towns have found multiple ways to protect trees. Ordinances can require new developments to achieve standards for canopy coverage, and can ensure that the stormwater benefits of conserved trees are counted towards developer's obligations to control runoff.

13 US Forest Service. 2010. Urban Watershed Forestry Manual. Part 2, at 4.

NATURAL GROUND COVER

10-20% IMPERVIOUS SURFACE WITHOUT GSI

Even a modest level of impervious surface in a watershed can significantly increase runoff. By keeping water onsite, GSI practices match post-development runoff to pre-development patterns, avoiding harms downstream.

- Evaporation
- Runoff
- Deep Infiltration
- Shallow Infiltration

10-20% IMPERVIOUS SURFACE WITH GSI

GSI AND PUBLIC UTILITIES

Town engineers have a vital role in implementing GSI. Towns whose stormwater programs are an integral part of the engineering department may already have taken steps towards integrated water management, including increased use of GSI practices.

GSI can help sustain both groundwater and surface water supplies for growing communities. GSI recharges the groundwater flows that feed reservoirs in a drought; also, keeping stormwater onsite tends to reduce demand for such seasonal uses as outdoor watering, leaving more of the existing capacity to serve year-round growth.

Public works departments can incorporate GSI in several ways:

Favor GSI solutions to local flooding. When rapid development leads to drainage problems, town engineers often get calls from constituents. The traditional approach of installing wider pipes to move the water away faster just shifts the problem downstream, so it makes sense to check whether GSI practices offer a solution before turning to gray infrastructure approaches. A 2007 EPA study found that 11 out of 12 GSI practices were cheaper than their conventional equivalents, so looking at GSI options first may also save the town money. [14]

Adoption of a GSI 'portfolio standard'. Inspired by renewable energy portfolios, the idea of this approach – applied successfully by the cities of Grand Rapids and Milwaukee – is to gradually increase the percentage of town stormwater assets that use GSI approaches.[15]

Better asset management. Over the last decade, a number of public utilities across North Carolina have established asset management programs to better track their gray infrastructure. Fewer communities have folded stormwater control measures (SCMs) into asset management programs, but there are good reasons to do so. Structural measures, such as detention basins, need regular maintenance and eventual replacement. Many towns have federal Clean Water Act stormwater permits; those permits make maintenance of measures a condition of compliance. Having a system that tracks the status of public and private SCMs is a condition of most municipal stormwater permits.

GSI measures may require tweaking of the tracking system.[16] Some practices may need special metrics, such as the percentage of randomly chosen properties that are keeping their downspouts disconnected. Others may require distinct skills, such as confirming that the correct plants are still growing in a rain garden. Experts recommend that departments responsible for inspection and maintenance of GSI practices take advantage of simple checklists and training for staff or contractors who will be working with GSI practices.[17]

A final aspect of GSI management is the question of who is responsible for maintenance. Municipalities have tried several models; the City of Raleigh has chosen a 'dual responsibility' approach, in which stormwater/public works conduct inspections and identify needed repairs, but parks staff or private contractors conduct the actual maintenance.[18]

14 American Rivers. 2012. Banking on Green, at 9.
15 Center for Neighborhood Technology. 2012. Upgrade Your Infrastructure: A Guide to the Green Portfolio Standard.
16 Caitlin Feehan. 2013. A Survey of Green Infrastructure Maintenance Programs in the United States.
17 American Rivers. 2013. Staying Green: Strategies to Improve Operation and Maintenance of Green Infrastructure in the Chesapeake Bay Watershed.
18 TetraTech. 2016. Implementation Work Group Report: Advancing Green Infrastructure and Low Impact Development in Raleigh, at 9-11.

GSI AND TRANSPORTATION

Every town in Wake County owns and manages a number of municipal roads. Ideally, a town can afford to invest in retrofits to manage stormwater runoff from roads that were built before current design practices. Yet, it will always be more expensive to retrofit a finished road than to build wisely from the start. That's why it makes sense for municipal transportation departments to prioritize three situations for integrating green infrastructure:

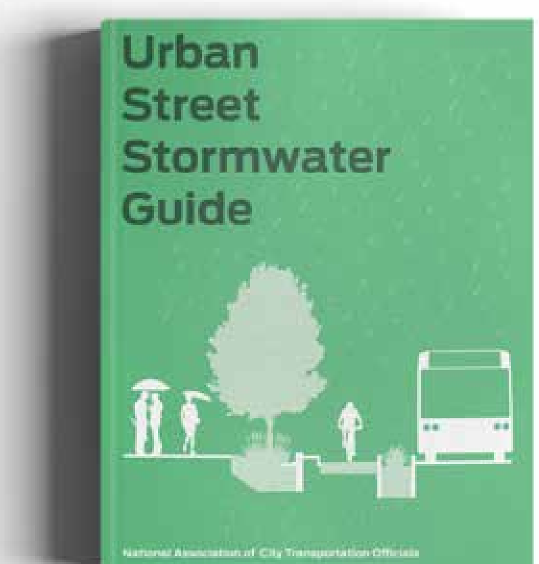
New construction. All new roads should be 'green stormwater streets', with infiltration and other practices designed so that the post-develop runoff will match – as much as possible – the runoff of the corridor before it was paved.

Road widening, traffic calming, new sidewalks. When roads are widened to accommodate more traffic, the additional pavement can create new flooding problems nearby. GSI practices that trap and infiltrate runoff are key to preventing those harms. Road narrowing – often part of a street makeover or 'road diet' to protect neighborhood character and the safety of walkers – offers great opportunities to install rain gardens in curb bumpouts. GSI practices can often be added to traffic calming features without changing their footprint.

Road reconstruction. Every so often, even a well-maintained road reaches the end of its life and needs to be replaced down to the subsurface. Such replacement should always include a review of existing stormwater practices and introduction of GSI. Again, the goal should be to return runoff to the pattern that pre-dated the original construction of the road.

Can this be done? Yes. In the summer of 2017, the National Association of City Transportation Officials published a guidebook with detailed examples of how to fit GSI practices into streets of all sizes and forms, from small residential alleys to major arterials.[19] The guide also offers advice on how to blend GSI practices with 'complete streets' practices that make streets inviting for pedestrians and bikers, and give local businesses a boost as well.

19 National Association of City Transportation Officials. 2017. Urban Street Stormwater Guide.



NACTO's Urban Street Stormwater Guide shows how to fit GSI practices into the design of municipal roads of any size.

GSI AND PARKS

Local parks and recreation departments can support adoption of GSI in a variety of ways. Local elected officials or advisory commission members should work with parks and recreation staff to explore these options.

Land conservation. Most of this primer focuses on GSI practices to catch and manage water on developed landscapes. But protecting certain properties in their natural state, shielding them from clearing and development, is a key GSI tool. Ideally, the town can partner with a land trust or state agency to identify the most valuable and vulnerable properties in the jurisdiction or in a watershed. From a water management perspective, criteria should highlight tracts that are vital recharge zones for groundwater, or that serve as buffers to keep excess volumes of runoff out of streams and other surface waters. Then, both private and public conservation dollars can be targeted to keep those properties in a natural condition.

Use of public lands for retrofits. Some kinds of GSI measures can be scattered across the landscape – but it can also be helpful to have larger, anchor projects on publicly-owned properties. Often, undeveloped parcels that have been donated or purchased by the town are well placed for GSI practices to intercept runoff before it reaches major streams. Also, many parks have concentrations of impervious cover around buildings and parking lots; these can offer good opportunities for GSI.

Education programs. Environmental educators in the parks department can help community residents better understand how GSI works and help them imagine installing GSI measures on their own private parcels.

Town facilities. As Wake County's population grows, towns are expanding recreational facilities – trails, swimming pools, rec centers. Each facility offers a chance to control runoff with GSI measures, and to set good stormwater management as a baseline for the town.

Urban forestry programs. A single tree can intercept up to an inch or two of rainfall at a time before allowing any precipitation to run off. To maximize the benefit of trees, some towns hire urban foresters. Their roles range from inventorying trees in the jurisdiction, to sponsoring plantings, to helping ensure that public and private construction projects keep as many trees alive as possible.

***Table 2* - Municipal tree programs in Wake County.**

The National Arbor Day Foundation recognizes "Tree Cities" that commit to inventory their public trees, adopt ordinances to protect them, and spend at least $2 per capita on trees. Fewer towns have citizen advisory boards. The most effective programs – in Wake Forest and Raleigh – are staffed by urban foresters who work with other town staff and residents to plant and maintain trees.

Town	Tree City?	Board?	Forester?
Apex	Y	Y	N
Cary	Y	Y	N
Fuquay-Varina	N	N	N
Garner	N	N	N
Holly Springs	N	N	N
Knightdale	Y	N	N
Morrisville	N	N	N
Raleigh	Y	Y	Y
Rolesville	Y	N	N
Wake Forest	Y	Y	Y
Wendell	Y	N	N
Zebulon	Y	N	N

FINANCING GSI

Some steps to implement green infrastructure have minimal budgetary impacts. Such actions can include adding elements that support GSI and integrated water management to the comprehensive plan; considering options for GSI in the design of new and reconstructed roads; educating local businesses and the public. Some aspects of GSI may even provide cost savings, including changes that protect town infrastructure, stop bank erosion, stop local flooding, or increase property values and therefore property tax revenues.

Other aspects of GSI can cost money: installing and maintaining retrofits; training municipal staff to recognize opportunities to apply GSI measures.

Local governments have found multiple ways to finance GSI.

General fund. GSI projects, particularly plans and retrofits, may receive their own line item in the town's annual stormwater program budget or in the capital budget. One common factor that can trip up GSI projects is the distribution of costs and benefits between a town's capital and operating budgets. That's because GSI projects can often be a little more expensive on the front end (capital), while providing much longer life and lower operating costs than gray infrastructure alternatives. A budget process that segments the two can overlook GSI opportunities with significant net cost-benefit ratios.[20]

Stormwater utility fee. Increasingly, local governments across North Carolina levy a stormwater utility fee. Such a fee can be useful for the revenue it raises; it also gives towns a way to create incentives for private behavior by giving breaks in the fee to landowners who adopt various GSI approaches on their own.

State and federal 'green reserve' funds. Since 2009, the federal Clean Water State Revolving Fund and Drinking Water State Revolving Fund have required states to set aside a portion of their funds for GSI projects. While most revolving funds are loans and eventually must be repaid in full, the Green Reserve funds can be made available on generous terms, with principal diminishing over time.

Private costs and public benefits. Perhaps the most effective way to promote broad adoption of GSI is for a town to structure the development process to reward applicants that deploy GSI in the context of redevelopment.

ADDITIONAL RESOURCES

Concepts of GSI and integrated water management have penetrated professional disciplines – planning, engineering, water management, and public administration. As a result, there are now excellent resources geared to each set of professionals who carry out the work of local government. We recommend the following resources for more detailed information on GSI and integrated water management.

ALL TOPICS

US EPA. 2016. Green Infrastructure Wizard, at https://cfpub.epa.gov/giwiz/index.cfm. Allows keyword searches as well as pre-set collections of reports on how to use GSI to meet regulatory requirements, where to find design standards for GSI practices, and how to fund GSI.

GSI, PLANNING & DEVELOPMENT

William Cesanek, Vicki Elmer, Jennifer Graeff, 2017. Planners and Water. PAS Report 588. Provides a detailed view of how planners can bring GSI and One Water concepts into planning, infrastructure, and oversight of land development.

TetraTech. 2016. Code Review Work Group Report: Advancing Green Infrastructure and Low Impact Development in Raleigh. Offers detailed analysis of ways development ordinances can create barriers to or open pathways for implementation of GSI.

GSI AND WATER INFRASTRUCTURE

American Rivers. 2013. Staying Green: Strategies to Improve Operation and Maintenance of Green Infrastructure in the Chesapeake Bay Watershed. Appendices include a table of maintenance needs for various GSI practices and links to inspection and maintenance checklists.

American Rivers. 2016. The City Upstream and Down: How Integrated Water Management Can Help Cities Thrive. Discusses integrated water management strategies, including GSI.

National Academies of Science. 2016. Using Graywater and Stormwater to Enhance Local Water Supplies. Discusses options, costs, benefits, and legal mechanisms to use gray water and stormwater as water supplies.

GSI AND TRANSPORTATION

National Association of City Transportation Officials. 2017. Urban Street Stormwater Guide. Describes GSI practices and shows how to incorporate them into a wide variety of street designs.

GSI AND CONSERVATION

NC Cooperative Extension. 2008. Protecting and Retaining Trees: A Guide for Municipalities and Counties in North Carolina. Covers both regulatory and incentive-based options for protecting the urban tree canopy.

Trust for Public Land. 2016. City Parks, Clean Water. Describes ways municipal park managers across the country have deployed GSI to address multiple management goals.

FINANCING GSI

EPA. 2014. Getting to Green: Financing Options for Green Infrastructure. Reviews financing options, with examples from around the country.

Jeff Hughes. 2014. Methods and Strategies for Financing Green Infrastructure. UNC-Environmental Finance Center. Written for Durham County, but with advice applicable to towns in Wake County as well.

Stacey Isaac Berahzer. 2014. Crosswalking between Gray and Green Infrastructure for Budget Officers. UNC-EFC. Contains practical advice on how to fit GSI financing into capital and annual town budgets.

EXCELLENT EXAMPLES FROM ELSEWHERE

NRDC. 2011. Rooftops to Rivers II. Includes detailed case studies of 14 cities.

US EPA. 2016. City Green: Innovative Green Infrastructure Solutions for Downtowns and Infill Locations. Includes 12 case studies from around the country.

GLOSSARY

The 90th percentile storm is, when the historical record of 24-hour rainfall events is ordered from smallest to largest, the size storm that is larger than or equal to 90% of the recorded storms. In Wake County, the 90th percentile storm amounts to about 1½ inches of rainfall.

Baseflow is the year-round flow into a stream from groundwater. It can comprise a small fraction of stream flow in wet weather, but virtually all the flow during dry months or during droughts.

The Clean Water Act, 33 U.S.C. §§ 1251–1387, is the leading federal statute for the protection of surface water quality. It does not regulate groundwater. Since 1993, the U.S. Environmental Protection Agency has interpreted the Clean Water Act to require many local governments to manage stormwater runoff from public and private landscapes within their jurisdictions.

Ecological flows, as defined by NC state law, are the instream flows needed to sustain a resilient, diverse community of native organisms in a stream or river. Baseflows often are the ecological flows during dry months of the year.

Floodplains are relatively flat areas, adjacent to a stream or river, that experience periodic flooding. Many federal and state rules are keyed to the 100-year floodplain, defined as the zone having at least a 1% chance of flooding in any given year.

Gray infrastructure is the set of structures – pipes, concrete, treatment plants – built to manage stormwater, drinking water, and waste water. Green infrastructure and Green Stormwater Infrastructure are both alternatives to aspects of gray infrastructure.

Green infrastructure is the sum of the natural features – trees, forests, streams, wetlands, undeveloped floodplains – that support our communities by removing pollution from water, slowing runoff, reducing flooding, moderating extreme temperatures, and improving air quality.

Green Stormwater Infrastructure (GSI) is the set of practices used to manage stormwater by mimicking natural processes, with the goal of keeping rainfall from running off developed landscapes at a rate and volume greater than pre-development patterns.

Groundwater is water under the surface of the earth. In Wake County, most groundwater moves through unconsolidated sediments between the surface and the bedrock; some water is in fractures in the bedrock. Further east in the coastal plain, significant groundwater resources are found in deep aquifers stacked like a layer cake, but that is not a factor in Wake County.

Hydrographic matching means that rates and volumes of post-development runoff match rates and volumes of runoff from the pre-development landscape. Rules and ordinances requiring matching must pick a standard; the standard used in North Carolina's Storm-EZ tool, and some local ordinances, is hydrographic matching for the 90th percentile storm. Some jurisdictions elsewhere in the county use the 85th, 95th, or 100th percentile storms.

Impervious surfaces are any surfaces in the built environment that shed rather than retaining or absorbing precipitation, including most roofs, sidewalks, and pavement. State laws require control of runoff above various thresholds of impervious surface (12%, 24%). Hard-packed lawns function as impervious surfaces even when they are not counted as such for regulatory purposes.

One Water, as defined by the Water Research Foundation, is 'an integrated planning and implementation approach to managing finite water resources for long-term resilience and reliability, meeting both community and ecosystem needs.' Its chief hallmark is a systems approach that views all water as having potential value.

Storm-EZ is a spreadsheet-based tool developed by the NC Department of Environmental Quality to help land developers easily calculate the degree to which runoff patterns from developed site (with various combinations of stormwater practices) will match pre-development runoff.

Stormwater is water that results from precipitation and melting snow or ice.

Urban (pluvial) flooding is localized flooding outside a floodplain that occurs when, as a result of impervious surfaces in the built landscape, rainwater cannot soak into the ground and cannot run off fast enough to avoid ponding.

Wastewater is water than has been used by people and requires treatment before it can be released back into the environment through infiltration, land application, or discharge into streams or rivers.

A ***water budget*** is an accounting of how water moves through the hydrologic system in any given watershed or jurisdiction: how much falls as rain, soaks into the ground, runs or seeps into surface waters, is withdrawn for human uses, and evaporates back into the air.

Water supply is the sum of surface and groundwater available for use by a community on a sustainable basis.