ADVANCING GREEN STORMWATER INFRASTRUCTURE IN RALEIGH

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Presentation Topics

- What GSI is
- Why GSI in Raleigh
- Advancing GSI in Raleigh
- GSI in Raleigh roadway projects
Related Terms

GI  Green Infrastructure
GSI  Green Stormwater Infrastructure
LID  Low Impact Development
SCMs  Stormwater Control Measures
What is GSI?
Increased Development →
More Runoff Volume, Less Infiltration
Increased Development →
More Runoff Volume, Higher Peak Rate, Peaks Faster
Effects of high percent impervious
GSI defined

Practices that **reduce stormwater runoff volume** by promoting infiltration and evapotranspiration, taking advantage of **existing** natural features, and installing **new** features that **mimic nature**

R = runoff
ET = evapotranspiration
I = infiltration

Typical fate of rainfall for urban development
Typical fate of rainfall for natural landscape
GSI looks like...

Bioretention cells, bioswales, permeable pavement, green roofs, street trees, cisterns
GSI looks like…

Bioretention cells, bioswales, permeable pavement, green roofs, street trees, cisterns
Why Raleigh is advancing GSI
Not Raleigh: combined sewers

Older cities:

- Developed earlier (pre-1900)
- Built storm systems earlier
- Dumped in human waste and garbage – **combined sewers**
Raleigh: separate sewers

Younger cities:

- By 1900, society recognized health problems of CSOs
- Raleigh built sanitary sewers separate from stormwater systems
Drivers for advancing GSI in Raleigh

<table>
<thead>
<tr>
<th>Question</th>
<th>Year</th>
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<tbody>
<tr>
<td>NPDES Phase I stormwater permit?</td>
<td>✓ (1994)</td>
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<tr>
<td>Water supply watershed protection?</td>
<td>✓</td>
</tr>
<tr>
<td>Rapid growth and urbanization?</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Want clean water/healthy streams?</strong></td>
<td>✓</td>
</tr>
<tr>
<td>Shellfish waters?</td>
<td>×</td>
</tr>
<tr>
<td>Swimming beaches?</td>
<td>×</td>
</tr>
<tr>
<td>Combined sewer overflows?</td>
<td>×</td>
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<tr>
<td>Consent decree or court order?</td>
<td>×</td>
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Vision for advancing GSI in Raleigh

- Reduce stress and pollution to streams and lakes
- “Manage water where it falls”
- “Raleigh welcomes GSI”
- Put GSI “on the menu”
- Make GSI “business as usual”
How Raleigh is advancing GSI
GSI in Raleigh’s Unified Development Ordinance

Revisions to 25 sections of the UDO

• Amenity areas and urban plazas
• Parking area and drive thru design
• Protective yards
• Streets
• Stormwater and Open Space
GSI for streets

- Revisions to Raleigh Street Design Manual: *July 2018*
- New category, 8 GSI standard detail drawings: *August 2018*
GSI cost evaluation tool

- Online tool for public and private design professionals and developers
- Help understand and evaluate GSI opportunities
- Overcome misconceptions about GSI costs
- Easy to use and maintain, credible results
- Project Advisory Committee of ~15 private designers and City staff
- Beta testing the tool this fall and launch this winter
GSI fact sheets

- Pictorial representations of GSI applied to sites
- 5 site-development scenarios (residential, commercial)
Incentives that encourage GSI

- **Launched Green Raleigh Review October 2018**
  - Offers review fees reimbursement for use of GSI
  - Post-development runoff volume $\leq$ pre-development
  - GSI must be in the stormwater plan

- **Rainwater Rewards is an incentive program**
  (reimburses 75% or 90% of cost)
GSI for Raleigh

• Focus so far has been:
  - Building capacity
  - Engaging stakeholders

• Have begun implementation:
  - City will lead by example
  - Development community is interested, cautious
GSI on Raleigh roadway projects
Example Code Revision: Protective Yards

UDO Section 7.2.4.A & 7.2.4.B  GSI practices shall be allowed in Transitional Protective Yard Types A2, B1, and B2 and in Street Protective Yard Types C1, C2, and C3. In order to accommodate GSI practices the number of shrubs may be reduced in the Protective Yards by ten (10) percent.
CHAPTER 2 STREET ELEMENT OVERVIEW

Within the public right-of-way, the two primary zones are the Streetscape and the Travelway.

Article 2.1 Streetscape

The Streetscape is located on both sides of the Travelway. The Streetscape is the primary pedestrian realm, accommodating people walking, stopping, and sitting, and also functions as the transitional area between moving traffic and land uses. The Streetscape is also the place where transitions between the pedestrian mode and other modes of transportation occur, and thus its design characteristics including landscaping, aesthetics, multimodal accessibility to support desired development patterns. Sidewalks, the planting area, and the maintenance strip behind the sidewalk are conduits to the use of GSI within the Streetscape in certain street typologies. Applicable GSI practices include permeable pavement, curbside bioretention/planters, tree wells/planter boxes, rain barrels, and flow-through stormwater planters.

Article 2.2. Travelway

The Travelway refers to the paved width of a street between curbs that accommodates moving and stationary vehicles in a variety of modes. On wider street cross-sections, additional landscaping such as medians may be present to provide safe havens for pedestrian crossing, traffic separation and calming, restrictions of dangerous turn movements, drainage, and other beneficial functions. The Travelway may include the following elements:

A. General Travel Lane - General travel lanes accommodate vehicles of all types. The design and control for the general travel lane determine the width of the lane(s) and the street, as well as other geometrics such as curb radii. The width of the travel lane directly corresponds with the operating speed of the street and the level of mobility and access.

B. Bicycle Facility - Bicycles may be accommodated in their own space or in a shared lane with other vehicles in the ROW.

C. Transit Facility - Buses, streetcars, taxis, and other mass transit vehicles may be accommodated in their own space or in a shared lane with other vehicles in the ROW.

D. On-Street Parking - Parking within the ROW, typically adjacent to a curb, accommodates automobiles, bicycles or other vehicles. Parallel orientation is most common, though angled (head in and back in) parking may be used to provide additional spaces where sufficient ROW exists and off-street parking capacity is very limited. The presence of on-street parking encourages lower vehicular travel speeds on streets and buffers pedestrians from moving traffic. In certain street typologies, permeable pavement can be incorporated into street parking areas, and bioretention can be incorporated into corner bulb-outs at intersections and curbside extensions/bump-outs.

E. Gutter and/or Shoulder - The choice between gutter and shoulder for transitioning from Travelway to Streetscape depends primarily on area drainage characteristics, environmental sensitivity, land use intensity, and aesthetic intent. For most street typologies, a cross-section supporting more urban development involves the use of curb and gutter. Variations on traditional gutter and/or shoulder designs can be used to incorporate GSI elements. See Section 12.4, Curb and Gutter, for more detail on curb and gutter design. Applicable GSI practices include curb extensions/bump-outs and intersection bulb-outs, which are incorporated into the gutter.
3.2.2 D - Multifamily Street

Multi-Family Local Streets are intended to provide direct lot access and a relatively high level of on-street parking capacity in residential settings (Apartments and Townhomes). Two general travel lanes are present along with the allowance of a row of parking on each side in a parallel, perpendicular or angled configuration. Multi-family streets are to be used exclusively for residential developments built under the apartment or townhouse building types defined in the Unified Development Ordinance. Sidewalks are required on both sides of the street in a public easement. In these sections, the parking is not in the right of way, and the use of permeable pavement can be used in on-street parking areas. Multifamily Streets also are conducive to use of GSI practices including curbside bioretention, bioretention in bulb-outs and/or curb extensions, and permeable pavement sidewalks.
Bioretention Areas
Rights-of-Way
Bioretention

Medians
TYPICAL MEDIAN BIORETENTION SECTION
POSTED SPEED LIMIT HIGHER THAN 30 MPH

NOTES:
1. REFER TO DESIGN PLANS FOR HORIZONTAL CONTROL INFORMATION.
2. BIORETENTION SIZING IS THE RESPONSIBILITY OF THE DESIGN ENGINEER. SIZING CALCULATIONS SHALL BE SUBMITTED TO THE CITY FOR REVIEW.
3. THE INCLUSION OF AN UNDERDRAIN SYSTEM IS DEPENDENT UPON THE RECOMMENDATION OF GEOTECHNICAL INVESTIGATION.
4. IF UNDERDRAIN IS REQUIRED, REFER TO DESIGN PLANS FOR UNDERDRAIN INVERT ELEVATIONS.
5. THE SEASONAL HIGH WATER TABLE SHALL BE 2 FEET BELOW THE BOTTOM OF THE AGGREGATE STORAGE LAYER.
6. REFER TO PLANS FOR UNDERDRAIN CLEANDOUT LOCATIONS AND INSTALLATION DETAILS.
7. GEOTEXTILE MAY BE UTILIZED IN-PLACE OF AGGREGATE CHOKING LAYER IF APPROVED BY ENGINEER.
8. A MAXIMUM OFFSET OF 6 INCHES IS REQUIRED BETWEEN THE INVERT OF THE UNDERDRAIN AND BOTTOM OF STORAGE LAYER.
9. BOTTOM OF STORAGE LAYER SHALL BE SCARIFIED TO PROMOTE INFILTRATION PRIOR TO BACKFILL.
10. ALL UNDERDRAINS, IF REQUIRED, SHALL CONNECT TO STORM DRAIN OR OTHER DRAINAGE FEATURE.
11. VEGETATION MAY BE PLACED ON SIDE SLOPES TO ANCHOR MULCH IF DESIRED.
12. ALL FEATURES, INCLUDING VEGETATION, INTEGRATED INTO MEDIAN BIORETENTION SHALL MEET SIGHT DISTANCE REQUIREMENTS PER STREET DESIGN MANUAL AND RECOMMENDED PLANT SPECIES IN THE NCDOT STORMWATER DESIGN MANUAL.
13. BIORETENTION MEDIA SHALL BE PLACED IN 6" LIFTS THAT ARE WALKED ON OR WATERED TO CONSOLIDATE AND ALLOW SHAPING OF THE MEDIA'S SURFACE. THE MEDIA SHALL NOT BE MECHANICALLY COMPACTED. REFER TO NCDOT STORMWATER DESIGN MANUAL FOR BIORETENTION SOIL MEDIA SPECIFICATIONS.
Typical Median Bioretention Section
Posted Speed Limit of 30 MPH and Lower

Medians
Proprietary Bioretention Devices

- Use proprietary media
- May include pre-filters, screens or other features
- A variety of options available
- Cost starts ~ $6k
Suspended Pavement
Suspended Pavement: post construction

Source: NCSU BAE
Suspended Pavement: post-construction

Source: NCSU BAE
Suspended Pavement: post construction

Source: NCSU BAE
Suspended Pavement: post construction

Source: NCSU BAE
Suspended Pavement:
post construction

Source: NCSU BAE
Suspended Pavement

- Tree box as inlet to suspended pavement system
- Curb cuts to capture runoff flows and infiltration
- Vegetation to prevent erosion
- Open space for runoff storage
- Located to balance pedestrian replaced

[Diagram of suspended pavement system with images of installation and finished product]
Permeable Pavement
Permeable Pavement

- Allows for rainfall infiltration
- Ideal for low traffic surfaces (driveways, parking lots, walkways)
- Provides peak flow mitigation, volume storage, and water quality improvement
Permeable Pavement

Photo Credit: Green Paving Solutions

Photo Credit: US EPA
Permeable Pavement

EXISTING OR PROPOSED 30" CURB AND GUTTER PER T-10.26.1, FLUSH W/TOP OF PICP

2" THICK BEDDING LAYER
NO. 8 WASHED STONE

MIN 4" THICK AGGREGATE BASE
NO. 57 WASHED STONE

30 MIL HDPE IMPERMEABLE LINER,
ALL SIDES,
BOTTOM LINER IF REQUIRED

PERMEABLE INTERLOCKING CONCRETE PAVERS

6"X12" CONCRETE TRANSITION STRIP,
FLUSH WITH TOP OF PICP AND EXISTING PAVEMENT

DRIVING LANE

AGGREGATE SUBBASE
NO. 2 WASHED STONE,
COMPACTED TO BE FIRM AND UNYIELDING
(DESIGN DEPTH PER PLAN)

4" PERFORATED SCHEDULE 40 PVC PIPE, UNLESS OTHERWISE SPECIFIED PER DESIGN PLANS
(PERFORATIONS ANGLED DOWN) SEE DETAIL B

UNCOMPACTED SUBGRADE
(WITHOUT LINER, SEE NOTE 4),
OR 90% COMPACTION
(WITH LINER)

4. BOTH PER PENEtrATIONS AND ATTACHMENT OF 30 MIL HDPE LINER TO CONCRETE CURBS, USE CONCRETE ANCHORS SPACED AT MAXIMUM 12" O.C. AND BALLEST STRIPS SHALL BE DONE IN ACCORDANCE WITH ASTM 6547.
5. ALL AGGREGATE SIZED ACCORDING TO ASTM C148.
6. ASH TO LAYER COEFFICIENTS FOR OPEN-AGRADED BASE AND SUBBASE SHALL RANGE BETWEEN 0.15 AND 0.18.
7. ACASH TO MINIMUM LAYER COEFFICIENT OF 0.3 FOR PAVER AND BEDDING LAYERS IS RECOMMENDED.
8. LOCATE UNDERGROUND AS SHOWN ON THE IMPROVEMENT PLANS. HORIZONTAL LOCATION MAY VARY WITH IMPAVEMENT SECTION AS LONG AS MINIMUM OFFSET DISTANCES AND BOTTOM SLOPES ARE MAINTAINED.
9. DEPTH OF PERFORATED PVC PIPE MAY BE ADJUSTED TO FIT INTO THE BASEMENT DRAINAGE INFRASTRUCTURE AS NEEDED.
Permeable Pavement

Driveways and Alleys
Permeable Pavement

Side Walks and Patios
Permeable Pavement

GRASSED UTILITY STRIP

MIN 4" THICK PERMEABLE CONCRETE, PER DESIGN PLAN

6' MIN'

1/4"/FT

MIN 4" THICK AGGREGATE BASE NO. 57 WASHED STONE, THICKNESS PER DESIGN PLAN

UNCOMPACTED SOIL SUBGRADE (SEE NOTE 4)

VEGETATED CONVEYANCE AND BERM IF PERMEABLE SURFACE DRAINING TO SIDEWALK (SEE NOTE 7)

SECTION VIEW

CITY OF RALEIGH
STANDARD DETAIL

PERMEABLE CONCRETE SIDEWALK

GSI-05
Sandy Forks Road is a 2.5-mile roadway from Six Forks Rd. to Falls of Neuse Rd.
Sandy Forks Road After

Slide Courtesy of: RK&K

Bioretention area #1

Bioretention area #2

Bioretention area #3

Six Forks Rd.

Falls of Neuse
The Sandy Forks Road Widening Project earned Greenroads Silver Certification and received the highest score internationally to date.

<table>
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<tr>
<th>Greenroads® Summary</th>
<th>Sandy Forks – Silver Certified</th>
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<tr>
<td><strong>Total Score</strong></td>
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<td>Project Requirements</td>
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<td>Environment &amp; Water</td>
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<td>Construction Activities</td>
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<td>Access &amp; Livability</td>
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<td>Creativity &amp; Effort</td>
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*Does not include Project Requirements
Sustainability on Sandy Forks Road

Stormwater Management
Sustainability on Sandy Forks Road

Vegetated Medians and Stormwater Management
Sustainability on Sandy Forks Road

Native Plants
Building bioretention areas in small areas like this bump out on Milburnie Road.
Milburnie Traffic Calming Project

Infiltration Testing

Final Product
(Landscaping Pending)
Permeable pavers used on the sidewalks along Hillsborough Street
Silva Cell a modular suspended pavement system were installed on Hillsborough Street.
Constructed stormwater wetlands maximize the removal of pollutants from stormwater runoff through vegetation uptake, retention and settling.
This area on Fox Road will have two biorientation areas designed in-house for stormwater runoff mitigation along the project corridor. Construction is underway.
GSI Lessons Learned, Looking Ahead

- Applied broadly, GSI can reduce both runoff volume and pollutant loads
- GSI can be incorporated into municipal improvement projects, including roadways and parking lots
- Project planners and designers should consider...
- During construction, GSI...