OPTIONS FOR GREENING RALEIGH

Low-Density Residential Development Stormwater Management

Raleigh

February 2024

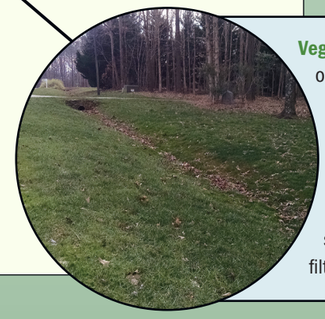
Green roofs reduce runoff volume and rates by intercepting rainfall in a layer of rooftop growing media that is typically six inches (extensive) or deeper (intensive). Green roofs offer an array of benefits, including extended roof lifespan (due to additional sealing, liners, and insulation), improved building insulation and energy use, reduction of urban heat island effects, opportunities for recreation and rooftop gardening, noise attenuation, air quality improvement, bird and insect habitat, and improved aesthetics.

Bioretention areas, or rain gardens, are engineered landscape features that reduce runoff volume and pollution by capturing and temporarily storing or infiltrating runoff through soil, stone, and vegetation. They can also provide bird and insect habitat and improved aesthetics.

Permeable pavement in driveways allows rainwater and runoff from surrounding hard surfaces to filter into the ground. This solution offers a strong, appealing driveway surface and lowers the property's overall impervious area.

Cisterns harvest rainwater from rooftops and temporarily store water for uses such as irrigation, washing vehicles or laundry, and flushing toilets. They reduce the volume and improve the quality of stormwater runoff and delay the peak flow.

Bioretention areas planted with turf grass have been shown to provide similar treatment as those planted with trees and shrubs.



Vegetated swales are shallow, open grass channels that can be an alternative to traditional curbs and gutters. Vegetated swales are designed to convey runoff while providing limited pollutant removal by sedimentation and horizontal filtration through vegetation.

Rooftop downspout disconnection. By directing rooftop runoff onto vegetated areas, you can direct the water to areas where it will be useful rather than being conveyed to the stormwater system where it may cause harm or overload the pipe system.

Green Infrastructure practices use vegetation, soils, and natural processes to manage stormwater runoff by mimicking nature to absorb and store water. Integrating these practices into a site can reduce the area required for conventional stormwater management by incorporating treatment within landscaping features and surfaces that would otherwise be impervious. This can be a cost-effective approach to treating stormwater by making more efficient use of a site with the potential for reduced construction costs, increased property values, and greater revenue generation from the additional space made available.

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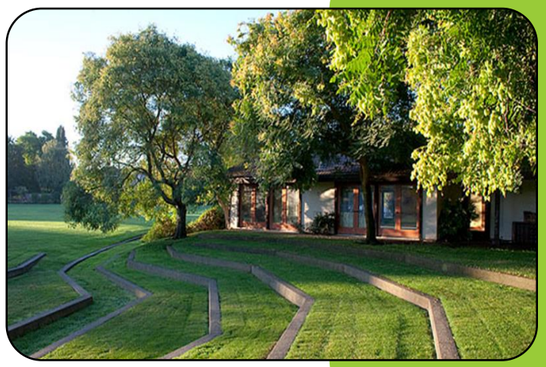
Cost Savings for Low-Density Residential Green Stormwater Management

Boulder Hills Development

- Pelham, NH
- Porous asphalt instead of conventional pavement
- Saved $50,000 (6%) by avoiding curbing, outlet control structures, large stormwater detention ponds



Village Homes Development

- Davis, CA
- Vegetated swales, rain gardens, open space, narrow streets, clustered lots
- Saved $800 per lot, $192,000 for entire neighborhood compared to conventional development

2nd Avenue Neighborhood

- Seattle, WA
- Bioswales, added vegetation, wetlands, reduced impervious area
- Saved $217,255 (25%) compared to conventional retrofits

Gap Creek Subdivision

- Sherwood, AR
- Preserved natural drainage areas, traffic-calming circles, reduced street width
- Saved $4,800 per lot, $678,500 (15%) total compared to conventional development

Auburn Hills Subdivision

- Racine, WI
- 40% of site preserved as open space with wetlands, green space, added open swales, bioretention
- Saved $761,396 compared to conventional development

Downspout Disconnection Program

- Portland, OR
- City offers financial incentives for disconnections ($13-$53 per downspout)
- Estimated reduction = 1 billion gallons of stormwater annually, $250 million reduction in construction for underground pipes citywide (based on 44,000 homeowners participating)

OPTIONS FOR GREENING RALEIGH

Medium-Density Residential Development Stormwater Management

Raleigh

February 2024

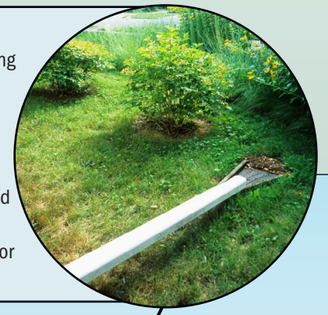
Bioretention areas, or rain gardens, are engineered landscape features that reduce runoff volume and pollution by capturing and temporarily storing or infiltrating runoff through soil, stone, and vegetation.

Rain barrels and cisterns harvest rainwater from rooftops and temporarily store water for uses such as irrigation, washing vehicles or laundry, and flushing toilets. They reduce the volume and improve the quality of stormwater runoff and delay the peak flow.

Bioretention areas located between the curb and sidewalk can treat runoff from the street or adjacent parcel, provide pollinator habitat, and beautify the area.

Permeable pavement in parking lanes helps water from rain and runoff from nearby hard surfaces soak into the ground, which improves water quality and reduces runoff volume. This solution offers a structurally stable and attractive parking surface while decreasing the area's overall imperviousness.

Rooftop downspout disconnection. By directing rooftop runoff onto vegetated areas, you can direct the water to areas where it will be useful rather than being conveyed to the stormwater system where it may cause harm or overload the pipe system.



Permeable pavement sidewalks promote groundwater recharge, reduce stormwater runoff, and improve water quality, all while offering a durable and visually appealing pedestrian walkway.

Bioretention located in the right-of-way can treat runoff from the street or rooftops where pollutants build up and then wash off between rain events. They can also shade the adjacent roadway and beautify the streetscape.

Permeable pavement in driveways allows rainwater and runoff from surrounding hard surfaces to filter into the ground. This solution offers a strong, appealing driveway surface and lowers the property's overall impervious area.

Green Infrastructure practices use vegetation, soils, and natural processes to manage stormwater runoff by mimicking nature to absorb and store water. Integrating these practices into a site can reduce the area required for conventional stormwater management by incorporating treatment within landscaping features and surfaces that would otherwise be impervious. This can be a cost-effective approach to treating stormwater by making more efficient use of a site with the potential for reduced construction costs, increased property values, and greater revenue generation from the additional space made available.

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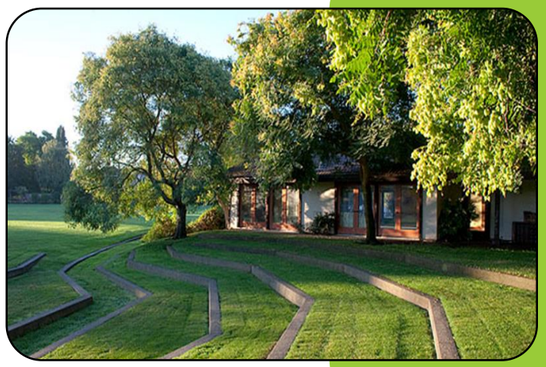

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OPTIONS FOR GREENING RALEIGH

High-Density Residential Development Stormwater Management

Raleigh

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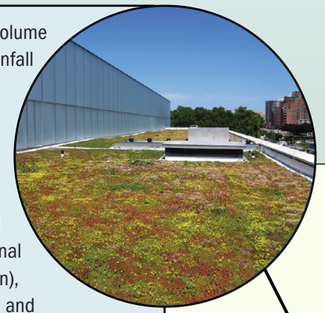
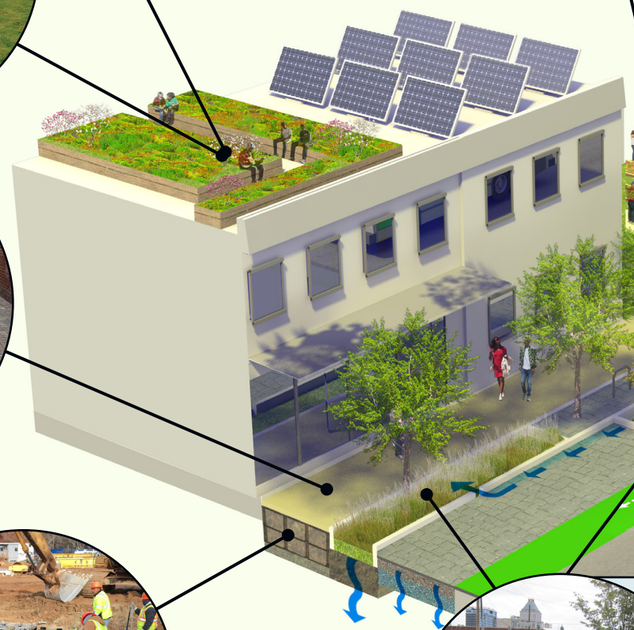
Green roofs reduce runoff volume and rates by intercepting rainfall in a layer of rooftop growing media that is typically six inches (extensive) or deeper (intensive). Green roofs offer an array of benefits, including extended roof lifespan (due to additional sealing, liners, and insulation), improved building insulation and energy use, reduction of urban heat island effects, opportunities for recreation and rooftop gardening, noise attenuation, air quality improvement, bird and insect habitat, and improved aesthetics.



Urban agriculture is the cultivation, processing, marketing, and distribution of food in urbanized areas. Research regarding soil and water interactions with ecologically-based food production systems indicates that large-scale implementation of urban agriculture can help restore urban hydrology and water quality.

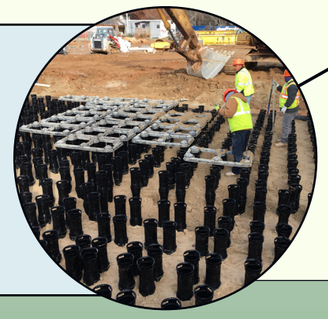


Cisterns harvest rainwater from rooftops and temporarily store water for uses such as irrigation, washing vehicles or laundry, and flushing toilets. They reduce the volume and improve the quality of stormwater runoff and delay the peak flow.

Permeable pavement in parking lanes helps water from rain and runoff from nearby hard surfaces soak into the ground, which improves water quality and reduces runoff volume. This solution offers a structurally stable and attractive parking surface while decreasing the area's overall imperviousness.

Permeable pavement sidewalks promote groundwater recharge, reduce stormwater runoff, and improve water quality, all while offering a durable and visually appealing pedestrian walkway.

Suspended pavement systems prevent compaction of high-quality soil media (often engineered) underneath the surface of a structural surface and reduce runoff volume and pollution. These systems are ideal for trees, which need soil with void space to thrive.



Bioretention areas, or rain gardens, are engineered landscape features that reduce runoff volume and pollution by capturing and temporarily storing or infiltrating runoff through soil, stone, and vegetation. Street trees can be incorporated into bioretention areas to maximize stormwater treatment, mitigate urban heat island effects, and meet landscaping requirements.

Pervious plazas. Incorporating permeable pavement in plazas, sidewalks, or open space area can reduce impervious area and provide additional opportunities for treatment and infiltrating of stormwater runoff in pedestrian areas.

Green Infrastructure practices use vegetation, soils, and natural processes to manage stormwater runoff by mimicking nature to absorb and store water. Integrating these practices into a site can reduce the area required for conventional stormwater management by incorporating treatment within landscaping features and surfaces that would otherwise be impervious. This can be a cost-effective approach to treating stormwater by making more efficient use of a site with the potential for reduced construction costs, increased property values, and greater revenue generation from the additional space made available.

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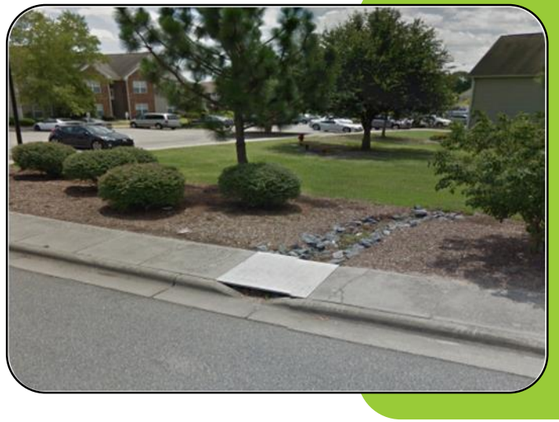
Cost Savings for High-Density Residential Green Stormwater Management

Bronx River Houses

- New York, NY
- Blue and green roofs, rain gardens, perforated pipes, subsurface stormwater chambers
- NYC Green Infrastructure Plan expected to save $2.4 billion in avoided conventional stormwater infrastructure construction

Panther Hollow (Study, not implemented)

- Pittsburgh, PA
- Analysis of green roof cost-saving potential for high-density residential: $260/year/roof saved in conventional stormwater drainage infrastructure



Poplar Street Apartments

- Aberdeen, NC
- 270-unit apartment complex
- Bioretention, channels, swales, stormwater basins
- Saved $175,000 (72%) compared to conventional development

The Natural Resources Defense Council (NRDC) estimates that, using green roofs, strategic tree planting, bioswales, and rain gardens can save $43,500/year for a single building (study assumes 34,000 square feet and 4 stories). This includes: energy cost reduction, tax credits, avoided conventional roof replacement, increased property values, increased rental income, and stormwater fee reduction.

Silver Creek Watershed Area

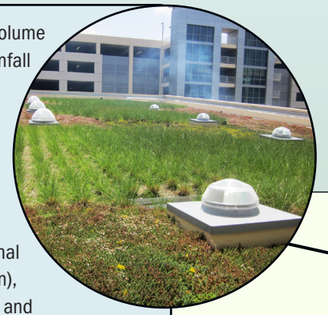
- Toledo, OH
- Highly developed downtown area, subject to flooding
- Blue roofs, bioswales, permeable pavement
- Estimated benefits, including reduced flooding, exceeding $39,500 annually

OPTIONS FOR GREENING RALEIGH

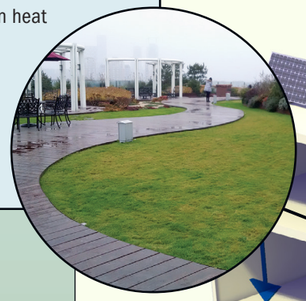
Raleigh

February 2024

Mixed-Use Development Stormwater Management



Green roofs reduce runoff volume and rates by intercepting rainfall in a layer of rooftop growing media that is typically six inches (extensive) or deeper (intensive). Green roofs offer an array of benefits, including extended roof lifespan (due to additional sealing, liners, and insulation), improved building insulation and energy use, reduction of urban heat island effects, opportunities for recreation and rooftop gardening, noise attenuation, air quality improvement, bird and insect habitat, and improved aesthetics.



Urban agriculture is the cultivation, processing, marketing, and distribution of food in urbanized areas. Research regarding soil and water interactions with ecologically-based food production systems indicates that large-scale implementation of urban agriculture can help restore urban hydrology and water quality.

Permeable pavement in parking lanes helps water from rain and runoff from nearby hard surfaces soak into the ground, which improves water quality and reduces runoff volume. This solution offers a structurally stable and attractive parking surface while decreasing the area's overall imperviousness.

Green Infrastructure practices use vegetation, soils, and natural processes to manage stormwater runoff by mimicking nature to absorb and store water. Integrating these practices into a site can reduce the area required for conventional stormwater management by incorporating treatment within landscaping features and surfaces that would otherwise be impervious. This can be a cost-effective approach to treating stormwater by making more efficient use of a site with the potential for reduced construction costs, increased property values, and greater revenue generation from the additional space made available.

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Cisterns harvest rainwater from rooftops and temporarily store water for uses such as irrigation, washing vehicles or laundry, and flushing toilets. Cisterns in highly impervious areas can be installed in parking garages or under buildings and can store a significant amount of water. They reduce the volume and improve the quality of stormwater runoff and delay the peak flow.

Suspended pavement systems prevent compaction of high-quality soil media (often engineered) underneath the surface of a structural surface and reduce runoff volume and pollution. These systems are ideal for trees, which need soil with void space to thrive.

Permeable pavement sidewalks promote groundwater recharge, reduce stormwater runoff, and improve water quality, all while offering a durable and visually appealing pedestrian walkway.

Bioretention areas, or rain gardens, are engineered landscape features that reduce runoff volume and pollution by capturing and temporarily storing or infiltrating runoff through soil, stone, and vegetation. Street trees can be incorporated into bioretention areas to maximize stormwater treatment, mitigate urban heat island effects, and meet landscaping requirements.

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Cost Savings for Mixed-Use Development Green Stormwater Management

Mill Creek

- Kane County, IL
- 1,500 acre mixed-use community with conservation design principles. 45% open space reduces stormwater costs and increases natural beauty.
- Saved $3,411 per lot (27%)

Green Downtown Area

- West Union, IA
- Implementing permeable pavers rather than traditional pavement results in long-term cost savings
- Estimated cumulative savings of a 57-year period of about $2.5 million compared to traditional pavement options with typical maintenance

Capitol Region Watershed District

- St. Paul, MN
- Rain gardens, stormwater planters, infiltration trenches, tree trenches
- Estimated $500,000 saved (20%) compared to conventional stormwater drainage infrastructure

Panther Hollow (Study, not implemented)

- Pittsburgh, PA
- Area is 9.6% commercial, 30% high density residential, 60.4% low density residential
- Estimated $295/year saved in stormwater drainage costs per green roof

City Sidewalks

- Olympia, WA
- City-wide sidewalk analysis determined traditional sidewalks costs $101 per square yard and pervious sidewalks cost $54 per square yard
- Considered construction and long term maintenance costs and the cost for conventional stormwater management required with traditional sidewalks.

OPTIONS FOR GREENING RALEIGH

Commercial Development Stormwater Management

Raleigh

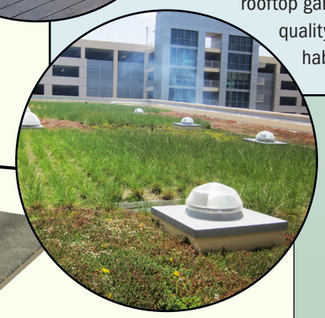
February 2024

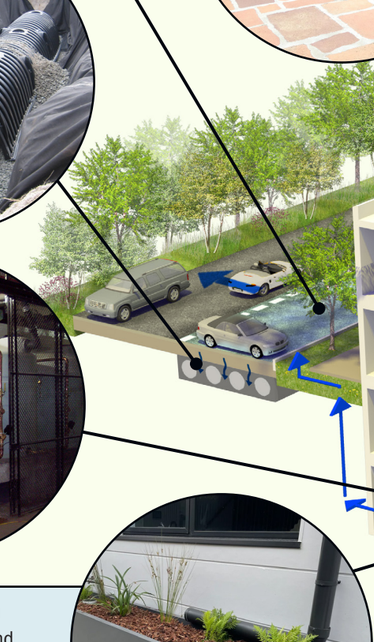
Permeable pavement in parking stalls helps water from rain and runoff from the parking lot, sidewalks, and other nearby hard surfaces to soak into the ground, which improves water quality and reduces runoff volume. This solution offers a structurally stable and attractive surface while decreasing the area's overall imperviousness.

Pervious plazas. Incorporating permeable pavement in plazas, sidewalks, or open space area can reduce impervious area and provide additional opportunities for treatment and infiltrating of stormwater runoff.

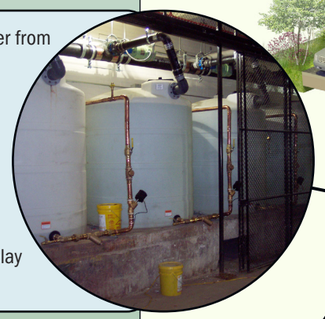
Green roofs reduce runoff volume and rates by intercepting rainfall in a layer of rooftop growing media that is typically six inches (extensive) or deeper (intensive). Green roofs offer an array of benefits, including extended roof lifespan (due to additional sealing, liners, and insulation), improved building insulation and energy use, reduction of urban heat island effects, opportunities for recreation and rooftop gardening, noise attenuation, air quality improvement, bird and insect habitat, and improved aesthetics.

Subsurface storage can be an option on sites where space is a constraint. Below ground systems can be configured to store water for reuse on site or for treatment through infiltration.





Cisterns harvest rainwater from rooftops and temporarily store water for uses such as irrigation, washing vehicles or laundry, and flushing toilets. They reduce the volume and improve the quality of stormwater runoff and delay the peak flow.



Curb bump out bioretention areas can be integrated into traffic calming measures to treat stormwater runoff from the street and meet landscaping requirements.

Planter boxes use bioretention functions, including filtration and plant uptake, to treat runoff directly adjacent to structures and foundations without impacting the structural stability of surrounding infrastructure.

Suspended pavement systems prevent compaction of high-quality soil media (often engineered) underneath the surface of a structural surface and reduce runoff volume and pollution. These systems are ideal for trees, which need soil with void space to thrive.

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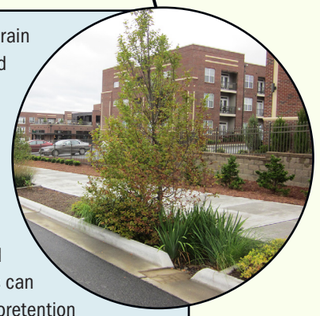

Permeable pavement in parking lanes helps water from rain and runoff from the nearby driving lanes and other hard surfaces to soak into the ground, which improves water quality and reduces runoff volume. This solution offers a structurally stable surface that is visually different than the driving lane while decreasing the area's overall imperviousness.

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Cost Savings for Commercial Development Green Stormwater Management

US EPA Building

- RTP, NC
- Grassy swales, water quality ponds, bioretention, preserved natural areas, 100-ft lake buffer established
- Saved $500,000 by avoiding curb and gutter and oil-grit separators

Greenland Meadows Retail

- Greenland, NH
- 4.5 acres of porous asphalt, catch basins, sand filter, sub-surface crushed stone reservoir
- Saved $930,000 compared to conventional stormwater management

Vancouver Island Tech Park

- Saanich, British Columbia
- Constructed wetlands, grassy swales and open channels, ponds, permeable pavement, native plants
- Saved $530,000 compared to conventional stormwater management

Tellabs Corporate Campus

- Naperville, IL
  - 330,000 sq ft office space
  - Preserved natural wetlands and drainage, bioswales
  - Saved $461,510 (14%) compared to conventional stormwater retrofits

Oregon Museum of Science and Industry

- Portland, OR
- 6-acre parking lot retrofit with vegetation and bioswales
- Saved $78,000 compared to conventional stormwater management

City Hall, Bloedel Donovan Park

- Bellingham, WA
- Parking lot rain garden retrofits. City Hall converted 5% of parking lot, and Park converted 550 square feet to rain gardens
- Saved $22,000 (80%) and $40,000 (76%) respectively